A

THESIS

entitled

A PALYNOLOGICAL INVESTIGATION OF
UPPER JURASSIC - BASAL CRETACEOUS
SEDIMENTS FROM ENGLAND, FRANCE
AND IBERIA

presented

for the degree of

DOCTOR OF PHILOSOPHY

in the

FACULTY OF SCIENCE OF THE OPEN UNIVERSITY

by

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CONTAINS

PULLOUTS
ABSTRACT

A broad palynological study has been made of field samples of Kimmeridgian to Berriasian age from a number of localities in Western Europe:-

1) Southern England - Dorset; Kimmeridgian - Berriasian.
2) Eastern England - Norfolk; Portlandian - Berriasian.
3) Northern England - Yorkshire; Kimmeridgian.
4) Northwest France - the Boulonnais; Kimmeridgian - Portlandian.
5) North Spain - Ribadesella; ?Kimmeridgian.
6) Portugal - Cabo Espichel; Kimmeridgian.

An account of the origins, distribution and occurrence of various sedimentary organic materials (kerogens) is presented and the results obtained are discussed in the light of earlier accounts of the sedimentology, mineralogy, biostratigraphy and palaeogeography.

Two applications of this data are demonstrated:-

1) Palynofacies types can be recognized which can be related to environmental parameters such as distance from shore-line, water depth and turbulence.

2) The kerogen types present and their degree of maturation allow some comment to be made on the potential of the sediments for sourcing hydrocarbons.

In particular it is demonstrated that the highly bituminous Kimmeridgian sediments from Dorset and Yorkshire have considerable potential for sourcing oil.
Microplankton assemblages (dinoflagellate cysts and acritarchs) are recorded and described from the English and French sections which are well dated upon independent palaeontological evidence.

The various taxa constituting the microplankton assemblages are described and in part illustrated in a systematic section. 195 taxa and taxonomic groupings are recorded; 10 new genera, 19 new species and 1 new subspecies are proposed; in addition the diagnosis of 4 genera and 5 species are emended, 5 genera and 8 species are treated as junior synonyms and rejected, and 20 new taxonomic combinations are proposed.

The recorded taxa have been tabulated qualitatively for each of the sections and a series of informal microplankton zones and associations of local stratigraphic value have been established.

The data from these charts has been used to compile a range chart which incorporates 52 selected "key-species" for the Upper Oxfordian - Berriasian interval. Earlier studies concerning Upper Jurassic and Lower Cretaceous microplankton are reviewed in light of the present study.

Although the above biostratigraphic units are mainly of local stratigraphic value only, the observations and results presented here have been substantiated and enlarged upon by work currently being undertaken by the writer. It is concluded that the use of palynological assemblages will provide a useful tool for correlation purposes and the elucidation of the depositional histories of marine basins. Furthermore it is considered that the use of microplankton will provide a reliable time - stratigraphical control in marine sediments of Late Jurassic - Early Cretaceous age.
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3.  Microplankton distribution in the samples analysed from Norfolk.

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1.  Survey of the stratigraphical distribution of dinoflagellates, acritarchs and tasmanitids in the Jurassic.

2.  Causes of unreliability in microfossil samples.
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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTORY REMARKS AND APPROACH TO THE STUDY

The initial aim of the writer's doctoral research was to have been a biostratigraphic and systematic study of organic-walled microplankton (dinoflagellate cysts and acritarchs) from the Upper Jurassic of the Lusitanian Basin, Portugal. This was later extended to include a study of the presumed Kimmeridgian sequence of Ribadesella, Northern Spain. Unfortunately, for reasons discussed elsewhere in this thesis, organic-walled microplankton are effectively absent in the sediments examined from these two regions.

Following these initial setbacks the emphasis of the writer's research became directed towards the Upper Jurassic and basal Cretaceous of England and France, from these two countries the following sediments have been studied.


D. The "Kimmeridge Clay", "Portland Beds" and "Purbeck Beds" of the Boulonnais, France.

The main aim of the study has been a biostratigraphic and systematic study (albeit qualitatively rather than quantitatively) of the microplankton assemblages. It has not been the intention of the writer to produce a detailed...
Upper Kimmeridgian palaeogeography showing the locations of the regions studied. (From Dunn 1972). Spain has been rotated by $30^\circ$ about a polar axis situated near Paris.

**Key**

1 - Dorset

2 - Marton, Yorkshire

3 - the Boulonnais

4 - Norfolk

5 - Cabo Espichel, Portugal

6 - Ribadesella, N. Spain.
monographic study of the microplankton assemblages. Consequently, for the sake of brevity, descriptions of previously described taxa are omitted and only abbreviated synonymy lists are given for each species. Illustrations of taxa have been kept to a minimum, but it is considered that they adequately illustrate a representative selection of the components of the assemblages recovered in this study and their characteristic preservation.

Part of this thesis is also devoted to a general account of the sedimentary organic materials encountered in this study. These include dinoflagellate cysts, acritarchs, miospores, foraminiferal test-linings, wood and plant tissue fragments, sapropels and bitumens. The origins, distribution and palaeoecological significance of each of these materials are discussed in turn and palynological facies types are recognised which can be related to the depositional histories of the regions and sediments studied.

During the course of this work the writer has also presented three papers for publication, these are as follows:

1. Survey of the stratigraphical distribution of dinoflagellates, acritarchs and tasmanitids in the Jurassic (with W. A. S. Sarjeant).
2. Causes of unreliability in microfossil samples (with A. J. King).
3. Upper Jurassic miospores from Cabo Espichel, Portugal.

Papers 1 and 2 have already been published and are presented as supplements; the third paper is at present in press and is reproduced, in a somewhat abbreviated form, in the text.

1.2 PREVIOUS PALYNOLOGICAL STUDIES

Previous palynological research, relevant to the present study, is discussed below in alphabetical order of regions.
A. England: A short paper by Downie (1957) constitutes the first record of British Upper Jurassic dinoflagellate cysts and acritarchs. In this paper Downie describes and illustrates a small number of forms from the Kimmeridge Clay of Dorset and Norfolk.

Lantz (1958) briefly describes and illustrates some Upper Jurassic (including Kimmeridgian) microplankton and miospores.

Oxfordian microplankton assemblages have been described by Sarjeant (1962a) from the Upper Jurassic (Callovian - Oxfordian) of Dorset. Sarjeant (1959, 1961, 1962b) has also described assemblages from the Callovian - Oxfordian of Yorkshire.

In 1963 Norris, presented a thesis describing miospores and microplankton from the Upper Kimmeridge Clay - Purbeck Beds of Southern England although he rather neglected the microplankton. This work gave rise to his 1965 publication in which he described three new dinoflagellate cyst species and a new mode of archaeopyle formation.

The first detailed study of the Kimmeridge Clay was by Gitmez (1969) who presented a thesis in which she described dinoflagellate cysts and acritarchs from the Kimmeridge Clay of Southern England (including Dorset) and parts of Scotland. This thesis gave rise to the subsequent publications by Gitmez (1970) and Gitmez & Sarjeant (1972). These two papers are mainly concerned with systematic descriptions with the emphasis placed on the lower part of the Kimmeridge Clay, there are also several taxonomic errors and few stratigraphic conclusions were drawn.

British Upper Jurassic miospore assemblages are well known through the studies of Couper (1958) and Norris (1969). The latter includes a concise study of miospore assemblages from the Upper Kimmeridge Clay, Portland and Purbeck Beds of Dorset.
"Wealden" miospore assemblages from Southern England have, for a number of years, been studied in the "Cambridge School" supervised by N. F. Hughes.

B. France: Pioneer studies on French Upper Jurassic (Callovian - Kimmeridgian) microplankton assemblages were carried out by Deflandre (1938a, 1938b, 1947). Subsequently Sarjeant (1965, 1968a) has described assemblages from the Callovian - Oxfordian of Normandy.

Gitmez (1970) and Gitmez & Sarjeant (1972) described Kimmeridgian microplankton from various localities in France, including the Boulonnais. There are, however, a number of taxonomic errors in these two papers and major errors in their stratigraphy. In the Gitmez (1970) paper the Argile du Moulin Wibert - Argile de la Crèche section of the Boulonnais is wrongly assigned to the baylei zone of the Kimmeridgian. Furthermore, in the Gitmez & Sarjeant (1972) paper, the Argile de la Crèche, without reference to the earlier paper, is assigned to the scitulus zone.

Herngreen (1971) gave an account of miospores from the "Wealden" of the Boulonnais.

C. Spain and Portugal: As far as the writer is aware, no relevant palynological studies have been carried out in these two countries.

D. North West Europe: The writer, over the last year, whilst in employment with Robertson Research International Limited, has examined microplankton assemblages from the Liassic - Lower Cretaceous of Britain, France, Norway, Denmark, Greenland and the North Sea, from both surface and subsurface sections. Although, for company and trade reasons, the results and implications of these investigations cannot be discussed in this thesis,
they have given the writer a valuable insight into the stratigraphic, geographic and taxonomic significance of a considerable number of microplankton species. Indirectly, if not directly, the knowledge thus gained has been invaluable to the writer during the drafting of this thesis.

1.3 PREPARATION OF SAMPLES

Samples were processed following the method described by Wilson (1971) with the following modifications:

1) Samples rich in bituminous substances were a major problem and required extra care and effort in processing. Some degree of success was achieved by the use of an ultra-sonic tank. Aggregated clots of debris could not, however, be broken down completely without damage to the microfossils, particularly to the larger proximate cysts. The use of Darvan (a Canadian commercial detergent) was suggested to the writer by Dr. G. Norris (University of Toronto, Canada) and found to be very successful. A 4% solution of Darvan in distilled water was added to each residue, brief ultra-sonic treatment (5-10 seconds) was followed by short centrifuging until the supernatant liquid was colourless, (Darvan solution is dark brown). For several samples this treatment with Darvan, followed by filtration, was sufficient to clean the residues for study, and for the remainder, subsequent oxidation time was cut down enormously.

2) A few samples needed very little oxidation, washing with a 10% solution of potassium carbonate was often sufficient. Potassium hydroxide solution, in varying strengths, was experimented with and was considered to be too damaging to the microfossils.

3) All samples were filtered, prior to mounting, through a sinter funnel of porosity grade 3.
All type and figured material, except where indicated otherwise, is
held in the writer's personal collection.

1.4 ACKNOWLEDGEMENTS

A large number of people and institutions have offered advice, assistance,
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CHAPTER 2

STRATIGRAPHY AND LOCATION OF SAMPLES

2.1 UPPER JURASSIC FAUNAL PROVINCES AND STAGE NOMENCLATURE

By late Jurassic times, certain groups of invertebrates, in particular the ammonites, had become segregated in the Northern Hemisphere into two main geographical realms (Arkell 1956; Hallam 1969, 1971; Casey 1971). A Southern or Tethyan Realm was centred on the circum-global "Tethys" with a Boreal Realm occupying the northern part of the hemisphere. The boundary between the two realms was gradational and oscillated somewhat with time, but generally corresponded quite closely in Europe with what is now the Alpine fold belt (Fig. 2). Numerous local provinces were developed, especially in the Boreal Realm, where the prevalence of shallow epicontinental seas and a less stable environmental regime appears to have stimulated faunal differentiation (Casey 1971).

Unfortunately the present state of knowledge, does not allow for any acceptable scheme of integration of the various provinces and it is still necessary to use several different schemes of nomenclature for the terminal Jurassic stages.

1) A shortened Kimmeridgian Stage followed by the Tithonian in the Tethyan Realm.

2) A shortened Kimmeridgian Stage followed by the Volgian in the Boreal Realm.

3) A shortened Kimmeridgian Stage followed by the Portlandian is generally accepted by many continental geologists who accept the Portlandian as being equivalent to the Volgian.

4) A longer Kimmeridgian Stage followed by a shorter Portlandian is generally accepted by British geologists.
FIG. 2.
Ammonite realms in the Northern hemisphere.
Present-day distribution of Tithonian, Volgian and Portlandian faunas. From Casey (1971).
The position is much the same for the basal Cretaceous, there being no satisfactory correlation between the Boreal Ryazanian stage and the Tethyan Tithonian. Since Britain and Northern France lie wholly in the Boreal Realm (Casey 1971), the problem here should centre on the delimitation and interrelationship of Kimmeridgian, Portlandian/Volgian and Ryazanian. The British usage of Kimmeridgian, Portlandian and Berriasian in southern England, which in terms of ammonite provinces is strictly incorrect (Casey op. cit) is, however, maintained here.

Salfield (1913, 1914) introduced a partial zonal scheme for the Kimmeridge Clay and recognised for the first time the occurrence of species of the ammonite genus *Gravesia* in the middle of the formation. D'Orbigny quoted these ammonites as characterising his Portlandian stage, in contradiction to his statement that "Kimmeridgian" equalled the Kimmeridge Clay (and Weymouth Beds) of Fitton (1836) and "Portlandian" equalled the Portland Sand and Portland Stone of Fitton (op. cit.). A dual meaning of the term "Kimmeridgian" has thus arisen. British usage of the term includes all of the beds up to the base of the Portland Sand (albani zone), whereas continental usage only includes horizons up to the beds with *Gravesia*. Species of this genus have, however, now been abandoned as zonal indices in Britain because of their wide vertical range and rare occurrence (Cope 1967).

There is also a long history of debate concerning the age-relationships of the Volgian and Portlandian, which in the past has been made more obscure by varying definitions of the two stages and varying interpretations of the ammonite faunas. The Russians, in recent years, have extended the Volgian down to the level of the *Gravesia* horizon in the Kimmeridgian (sensu anglico) (the *Pectinatus elegans* Zone of Cope 1967) and by introducing a tripartite division of the Volgian,
the old Lower Volgian becomes the Middle Volgian. Continental usage fixes the base of the Portlandian at the same level.

Dissimilarities in the ammonite faunas recorded from the Portlandian and Volgian has been held in the past to reflect differences in age between the two stages, but in recent years the discovery of the ammonite Paracraspedites in the English Portland Stone and the top of the Russian Middle Volgian has considerably strengthened the links between the two stages (Casey 1968).

In spite of Gerasimov and Mikhailov (1966), it nevertheless still appears that certain ammonite genera typical of the British Portland Beds, such as Crendonites, Kerberites and Titanites, have yet to be recorded from the Russian Volgian (Casey 1967). Similarly the Russian Volgian virgatitid ammonite genera (Virgatites, Zaraskites and Michalskia) have no strictly congeneric representatives in the British Kimmeridge Clay - Portland Beds sequence. The occurrence of a prominent band of phosphatic nodules with rolled virgatitids below the Paracraspedites level in the stratotype Volgian suggests that the giganteus and gorei faunas of the Portland Beds existed during an interval of non-deposition and that the type Volgian succession is highly condensed and incomplete (Casey 1971).

Despite the lack of good continuous sections of outcrop, recognition of an ammonite sequence indicative of the Boreal Volgian (Middle and Upper) and Ryazanian presents no problems in the Sandringham Sands. The establishment of the ammonite sequence is largely due to a series of temporary exposures excavated during the Fen Relief Drainage Scheme and North Sea gas pipe-line operations. Paracraspedites occurs near the base of the Sands affording a link with the upper part of the Dorset Portland Beds and the top of the type Russian Middle Volgian. Higher in the Sands, "Garniericeras" is indicative
<table>
<thead>
<tr>
<th>JURASSIC</th>
<th>CRETACEOUS</th>
<th>SYSTEM</th>
<th>STAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIMMERIDGIAN</td>
<td>LOWER VOLGIAN</td>
<td>KIMMERIDGIAN</td>
<td>CASEY 1971</td>
</tr>
<tr>
<td></td>
<td>MIDDLE VOLGIAN</td>
<td>PORTLANDIAN</td>
<td>Sensu anglico</td>
</tr>
<tr>
<td></td>
<td>UPPER VOLGIAN</td>
<td>KIMMERIDGIAN</td>
<td>Sensu gallico</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PORTLANDIAN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RYAZANIAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VALANGINIAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HAUTERIVIAN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 3**

**Correlation Chart of Strata at the Jurassic-Cretaceous Boundary**

- **JURASSIC**
  - KIMMERIDGIAN Clay
  - PHOSPHORITE NODULES
  - KIMMERIDGE CLAY

- **CRETACEOUS**
  - PURBECK BEDS
  - LULWORTH BEDS
  - DURLESTON BEDS
  - WEALDEN BEDS

- **Other Noted Locations**
  - CALCAIRE DE BRECQUEBOURG TO ARGILES DE CHATILLON
  - ASSISES DE OIES TO GRES DE LA CRECHE
  - "WEALDEN BEDS"
FIG. 4.

Geological sketch map of part of Dorset, Southern England, showing the location of the type section of the Kimmeridge Clay (from Dunn 1972).
FIG. 4

Brandy Bay
Broad Bench
KIMMERIDGE BAY
Hen Cliff
Clavell's Hard
Rope Lake Head
Freshwater Steps
Hounstout Cliff
Chapman's Pool
St. Alban's Head

Cretaceous
Portland and Purbeck Beds
Kimmeridge Clay

1 km.
Figure 5. Locality map of Kimmeridgian, Portlandian and Purbeck sections examined in Southern England. (from Norris 1969)
**Kimmeridge Clay**

The Kimmeridge Clay is exposed at various localities along the Dorset coast over a distance of some 30 kilometres from Weymouth to St. Alban's Head. The most complete section is exposed in the cliffs on either side of the village of Kimmeridge, where a continuous outcrop extends for a distance of over 9 kilometres from Brandy Bay eastwards to Chapman's Pool (Fig. 4). The lower part of the succession is not exposed here, but is seen further to the west at Ringstead Bay near Osmington Mills. At its type locality around Kimmeridge Bay, the Kimmeridge Clay attains a maximum thickness of 494 metres. Towards the west, in the Weymouth district, the thickness is nearly halved and inland it reduces to 90 metres.

The majority of ammonites in the Kimmeridge Clay are crushed, but recent work by Ziegler (1962), Cope (1967, 1968) and Casey (1967) has helped to elucidate the ammonite sequence in many parts of the succession. The zonation of the topmost Kimmeridgian is at present being revised and a modified zonal scheme may be presented in the near future (Cope et al. 1969, p. A49).

The following section is that based on descriptions by Arkell (1947), Ziegler (1962) and Cope (1967 and unpublished) as presented by Cope et al. (1969). The number of samples examined is indicated.

**Portland Sand**

Massive Bed above "ZONE OF EPIPALLASICERAS SP."

**HOUNSTOUT MARL.** Blue silty marl with thin cementstones. 18 metres: 3 samples.

**HOUNSTOUT CLAY.** Dark grey silty clays. 8 metres: 2 samples.

**RHYNCHIONELLA MARLS.** Dark grey silty clays. 10 metres: 3 samples.

**LINGULA SHALES.** Dark to medium grey shales. 15 metres:
ROTUNDA ZONE
Grey shales. 16 metres: 2 samples.
Rotunda Nodule Bed. Clays with two main horizons of calcareous nodules. 0.5 metres.
Shales and clays. 4.0 metres. 2 samples.
Hard Bituminous shale. 0.35 metres.

PALLASIOIDES ZONE
Shales and clays. 10.9 metres. 4 samples.

"ZONE OF PAVLOVIA SP."
Dark shales and clays. 19.1 metres. 3 samples.

PECTINATUS ZONE
Grey clays with occasional bands of calcareous nodules. 8 metres. 2 samples.
Hard shale. 0.5 metres.
Shales. 6.0 metres. 3 samples.
Freshwater Steps Stone Band. 0.35 metres.
Shales. 8.8 metres. 1 sample.
Middle White Stone Band. 0.45 metres.
Shales and mudstones. 8.9 metres. 2 samples.
White Stone Band (Main Coccolith Limestone). 0.95 metres. 9 samples.

HUDLESTONI ZONE
Shales with mudstones and hard dicey bands. 15.5 metres. 2 samples.
Basalt Stone Band. 1.2 metres.
Dicey Mudstones. 16.5 metres. 1 sample.
Shales with a thin cementstone. 6.2 metres. 1 sample.
Rope Lake Head Stone Band. 0.45 metres.
WHEATLEYENSIS ZONE

Shales. 4.5 metres.
The Blackstone. 0.90 metres.
Shales. 4.1 metres.
Shales and dicey mudstones. 14.9 metres. 1 sample.
Grey Ledge Stone Band. 0.7 metres.

SCITULUS ZONE

Upper Cattle Ledge Shales. 10.8 metres. 1 sample.
Cattle Ledge Stone Band. 0.5 metres.
Lower Cattle Ledge Shales. 15.4 metres. 1 sample.
Yellow Ledge Stone Band. 0.45 metres.

ELEGANS ZONE

Hen Cliff Shales. 21.5 metres. 2 samples.
Double Band of cementstone with a shale intercalation. 1.1 metres.

AUTISIODORENSIS ZONE

Maple Ledge Shales. 22.5 metres. 3 samples.
Maple Ledge Stone Band. 0.3 metres.
Gaulters Gap Shales (Thickness includes estimated throw of fault).
32.0 metres. 1 sample.
Washing Ledge Stone Band. 0.35 metres.
Washing Ledge Shales (Upper Part). 8.0 metres.

EUDEOXUS ZONE

Washing Ledge Shales (Lower Part). 5.0 metres. 1 sample.
The Flats Stone Band. 0.5 metres.
Shales. 3.0 metres.
Nannocardioceras Bed. 0.02 metres.

Shales. Seen to 16 metres.

The lower parts of the succession which cannot be seen in Kimmeridge Bay are exposed at Ringstead Bay, some 15 km. to the west. The succession is from Cope et al. (1969); based largely on Arkell (1947), and Ziegler (1962).

EUDOXUS ZONE

Shales. Seen to 8.0 metres.

MUTABILIS ZONE

Clays with a thin hard marl bed at the top. 2.5 metres.

Astarte Bed: shaley clay. 0.3 metres.

Black clay (with unexposed portion below). Estimated C. 3.0 metres.

Black clay, with fragile, but well preserved ammonites and bivalves.

6.3 metres. 1 sample.

Bed of flattened septarian nodules. 0.15 metres.

Unexposed portion, CYMODOCE and ?Upper BAYLEI ZONES, estimated 5.0 metres.

BAYLEI ZONE

Shales with abundant Liostrea delta. 5.0 metres.

Exogyra nana Bed. Marl. 0.3 metres.

Rhactorhynchia inconstans Bed. Marly clay, locally indurated.

0.6 metres.

The underlying Ringstead Coral Bed and Ringstead Waxy Clay are Oxfordian in age (Cope et al. 1969) although Gitmez (1970) and Gitmez and Sarjeant (1972) included them in the basal part of the Kimmeridgian.
The Kimmeridge Clay is clearly seen to be a far from uniform formation. It includes a wide variety of sediment types, including several which are repeated in rapid succession. In the lower part of the formation, there is in general, a simple alternation of clay and bituminous shale, in the middle, oil-shales, marls and limestones appear, making a more complex pattern. The uppermost 150 feet of the Kimmeridge Clay consists of clay, silty-clays, sandstones and fine-grained, calcareous sandstones, forming a transitional deposit to the overlying Portland Sand. This is indicative of increasing detrital influence and a gradual shallowing, transitional to the higher-energy, shallow water environment of the Portland Sand. The Rotunda Nodule Bed is indicative of a period of non-deposition and erosion.

Downie and Wilson (unpublished) have recognised a number of cyclic and rhythmic sedimentary units within the Kimmeridge Clay. These are discussed elsewhere in this thesis.

**Portland Beds**

The Portland Beds derive their name from the Isle of Portland from where the famous Portland Building Stone has been quarried since at least Roman times. The beds are exposed on the Isle of Portland and the Isle of Purbeck and consist of a Lower Portland Sand series overlain by the Portland Stone.

A marked shallowing of the sea took place towards the end of Kimmeridge Clay times. The sediments show a gradual passage from clay, through siltstones, to a series of sandstones and marly beds known as the Portland Sand; accordingly the boundary between the two formations has been a matter of opinion (see Arkell 1933). The boundary is now generally accepted as the base of a conspicuous stone-band, the Massive Bed, exposed on Hounstout.
A complete succession is exposed in the face of Ilountout, St. Alban's Head and the surrounding cliffs. The generalised succession (after Cope et al. 1969) is given below. Detailed descriptions of the successions are given by Arkell (1933) and Downie & Wilson (unpublished). Numbers of samples examined is indicated.

PORTLAND STONE

GIgANTEUS ZONE

Portland Freestone Series. 15.0 metres: 1 sample.

Portland Cherty Series. 20.0 metres: 2 samples.

PORTLAND SAND

GOREI ZONE

Black Sandstones and Parallel Bands. 14.0 metres: 1 sample.

St. Alban's Head Marls. 11.0 metres: 3 samples.

(White Cementstone. 0.7 cm: 1 sample).

ALBANI ZONE

Emmit Hill Marls. 9.0 metres: 1 sample.

Massive Bed. 2.0 metres: 1 sample.

The Massive Bed is a hard, brown calcareous sandstone which yields abundant oysters (*Exogyra nana*) and ammonites.

A series of silts, shaly marls and occasional bituminous horizons constitute the overlying Emmit Hill Marls. The top of the Emmit Hill Marls is defined by a thin (0.7 cm) white cementstone band which yields abundant bivalves.

The St. Alban's Head Marls is a series of grey marls with horizons of limestone bands and calcareous nodules. Some of the nodules yield abundant
moulds of bivalves and occasional ammonites.

The Parallel Bands are three thick calcareous sandstones, the upper one overlain by two further sandstone bands which contain intercalated thinner bedded shales. Together with the Black Sandstones they form a marked feature in the cliffs. Some horizons abound with ammonites. Limestones containing nodules and beds of chert constitute the Cherty Series. Giant ammonites of the Titanites group occur at various levels and certain beds are rich in serpulids.

The Freestone Series includes several horizons of Freestones and yield specimens of Titanites, the top of the series is defined by a white porcellaneous limestone yielding remains of crustacea, and fragmentary bivalves. This top bed, known as the Shrimp Bed is overlain by the Purbeck Beds.

Differences between the successions of the Isle of Purbeck and the Isle of Portland are illustrated by Arkell (1933) and Downie & Wilson (unpublished).

The Purbeck Beds

The Purbeck Beds overlie the Portland Beds, generally with an abrupt junction, and consist predominantly of non-marine sediments that represent a wide variety of facies types. At Durlston Bay, the type locality, the Purbeck Beds attain a maximum thickness of 120 metres. The Purbeck Beds are terminated by the incoming of the Wealden Beds, a series of non-marine sands and clays (Allen 1955). Arkell (1947, 1956) used "Purbeckian" as the terminal stage of the Jurassic. The Jurassic - Cretaceous boundary was for a long time conventionally drawn at the junction between the Purbeck and Wealden Beds - a line of lithological change, but within a largely non-marine sequence. However, the Purbeckian is now considered to be a predominantly freshwater and continental facies developed at the top of the Jurassic and the base of the

Some sections of the Purbeck Beds in Southern England have been zoned using ostracods, the history of the zonal classification has been given by Anderson (1958, 1962). References to palaeontological and sedimentological studies are given in Cope et al. (1969).

The lower part of the Durlston Bay succession is discontinuously exposed, and there are several faults. The relationship between the outcrop of the basal beds with that of the main part of the succession is not completely clear and in addition, the junction with the overlying Wealden Beds is not exposed. In spite of these disadvantages, this remains the finest section of these beds in Britain.

The generalised Durlston Bay section is as follows (after Bristow 1857, Arkell 1953, Casey 1963). Number of samples examined is indicated.

<table>
<thead>
<tr>
<th>DURLSTON BEDS</th>
<th>LULWORTH BEDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Cypris Shales and Clays</td>
<td>1 sample</td>
</tr>
<tr>
<td>Unio Beds</td>
<td></td>
</tr>
<tr>
<td>Broken Shell Beds</td>
<td>1 sample</td>
</tr>
<tr>
<td>Chief Beef Beds</td>
<td>1 sample</td>
</tr>
<tr>
<td>Corbula Beds</td>
<td>1 sample</td>
</tr>
<tr>
<td>Intermarine Beds or Upper Building Stones</td>
<td>1 sample</td>
</tr>
<tr>
<td>Cinder Bed</td>
<td>2 samples</td>
</tr>
<tr>
<td>Cherty Freshwater Beds</td>
<td>1 sample</td>
</tr>
<tr>
<td>Marly Freshwater Beds</td>
<td>1 sample</td>
</tr>
<tr>
<td>Soft Cockle Beds</td>
<td>3 samples</td>
</tr>
<tr>
<td>Hard Cockle Bed</td>
<td>1 sample</td>
</tr>
<tr>
<td>Cypris Freestones</td>
<td>1 sample</td>
</tr>
<tr>
<td>Broken Beds</td>
<td>1 sample</td>
</tr>
<tr>
<td>Caps and Dirt Beds</td>
<td></td>
</tr>
</tbody>
</table>

- 30 -
Starting from the base of the Purbeck Beds, the Dirt Beds are generally black, carbonaceous beds up to 0.3 metres thick often containing limestone fragments. The Dirt Beds are usually considered to be fossil soils, rooted in them are abundant tree stumps and occasional fallen trunks. These tree remains are especially common between Lulworth Cove and Bacon Hole where the famous "Fossil Forest" occurs. The Caps overlying the soil beds are limestones, in places consisting of thick algal mats (Brown 1963, Pugh 1969).

A series of brecciated limestones constitute the Broken Beds. Norris (1963) recorded a dinoflagellate cyst assemblage from an horizon 3 feet below the top of these beds which suggests marine conditions of deposition. This was also independently suggested by Brown (1964) using petrological criteria.

The remainder of the Lower Purbeck Series consists of pale grey micrites, calcareous shales and clays, with a considerable amount of gypsum that occasionally occurs in large masses. Insect remains, consisting of beetle elytra and wings of various "flies" occur in part of the soft Cockle Beds (the Insect Bed of Arkell (1933)).

A carbonaceous horizon with a rich fauna of ostracods and gastropods occurs within the Marly Freshwater Bed. Many species of mammal have been recorded from this horizon which constitutes the Mammal Bed of Arkell.

The upper part of the Cherty Freshwater Beds includes the Lower Building Stone of Arkell (op. cit.), a series of workable building stone; charophyte plants are abundant and the macrofauna, chiefly gastropods and bivalves, suggests a low salinity level.

Above the Cherty Freshwater Beds is the quasi-marine Cinder Bed which is taken to mark the Jurassic - Cretaceous boundary (Casey 1963). Its base marks the base of the Durlston Beds and the top of the Lulworth Beds of Casey.
It is predominantly a limestone packed with *Liostrea distorta*; other macrofossils include *Trigonia*, *Protocardia*, *Serpula coacervata* and *Hemicidaris purbeckensis*. Limestones with shale partings constitute the overlying Upper Building Stones. The fauna includes turtles, fish and molluscs with "brackish water affinities".

The Corbula Beds are a series of limestones, shales and marls with beds of fibrous calcite ("beef") and selenite; the overlying Chief Beef Beds are predominantly more argillaceous with more "beef".

The Broken Shell Bed is a hard, massive bed, consisting of fragments of molluscs (including *Unio*), indicative of low salinity conditions, and fish and turtle remains.

Two beds of a very distinctive limestone, the "Purbeck Marble" are present within the Upper Cypris Beds. These contain innumerable *Viviparbus*, indicative of freshwater conditions of deposition. The top part of the formation consists of clays with abundant *Viviparbus*.

### 2.3 YORKSHIRE

Samples were collected only from the Kimmeridge Clay.

In the Yorkshire Basin the Kimmeridge Clay floors the Vale of Pickering and is thickly covered by drift deposits so that exposures are scarce (Fig. 6).

The middle and lower parts of the clay have at times been exposed inland in small brickyards around the western end of the Vale of Pickering. Since the old records, when accepted without revision are often misleading, little can be said regarding the representation of the various zones (Arkell 1933). The lower parts of the Kimmeridge Clay are, however, usually characterised, as in other parts of England, by shales containing large numbers of *Ostrea*. 
Fig. 6. Map showing the distribution of the Jurassic Rocks in Yorkshire.
Near Marton in South Yorkshire, the Kimmeridge Clay is exposed in two clay pits. Fragmentary ammonites have been collected from the Marton Pits by Cope (1972 pers. comm), which, according to Callomon (in Cope op. cit.) are *Pectinatites* of the Gravesia Zone (=Elegans Zone) from the southern pit, and *Hoplocardioceras* of the Eudoxus Zone from the northern pit.

Two samples were obtained for palynological analysis, both from the southern clay pit at Marton (Grid reference SE732824), one sample from near the top of a limestone band exposed in the pit face, the second from immediately above this band.

### 2.4 NORFOLK

Samples were collected only from the Sandringham Sands.

The Sandringham Sands rest on an eroded surface of Kimmeridge Clay and consist predominantly of current-bedded, light coloured silvery sands. The estimated maximum thickness in Eastern England is 50 metres (Casey & Gallois 1973). In the upper part they are often iron-stained, orange-brown, fine quartz, sands with scattered pebbles and in places cemented into flaggy stone bands.

The Sands rise from the fringing margins of the Wash near Heacham and form a narrow, but continuous outcrop from there to West Dereham, some 37 kilometres to the south (Fig. 7).

The base of the Sandringham Sands is seldom naturally exposed, but many temporary excavations have cut through the junction of the sands with the Kimmeridge Clay. A coarse, glauconitic, pebbly, quartz sand incorporating many small phosphatised fragments of Kimmeridgian ammonites and internal moulds of lamellibranchs and small, white-weathering, phosphatic nodules typically constitutes the basal bed. The basal nodules contain large fragments of carbonised wood, bored by marine lamellibranchs and plant fragments in addition to
Figure 8. Subdivisions of the Sandringham Sands seen at outcrop with their ages and relationships to the successions in Lincolnshire and Southern England.
(from Casey & Gallois 1973)
phosphatised shells.

Schwarzacher (1953) concluded that in Sandringham Sands times a north-south coastline had apparently lain near The Wash, between Norfolk and Lincolnshire, and that the occurrence of contiguous beds in the Sandringham Sands with opposing current-bedding dips probably suggests "a more or less horizontal floor in the middle of the basin".

Most of the Sandringham Sands are unfossiliferous and for a long time their precise age was unknown. The Sandringham Sands are overlain by the Snettisham Clay (30 feet thick) and the Carstone (40 feet thick) and for a long time the three units were collectively termed the Lower Greensand and considered to be of Neocomian age.

Studies by Casey (1961-1974) on ammonites from the richly fossiliferous basal nodular beds led him to re-examine specimens collected earlier from the Sandringham Sands and to compare them with the ammonite faunas from the Upper Jurassic and Lower Cretaceous of Russia. He has shown that the English ammonites previously regarded as of Lower Cretaceous (Valanginian) age had been mis-identified and that they are conspecific with forms occurring in the highest Jurassic of Russia. The Sandringham Sands are therefore to be correlated with the Portland, Purbeck and Wealden Beds of Southern England and accordingly span the Jurassic - Cretaceous boundary. A detailed discussion on the stratigraphy and ammonite succession of these beds is given by Casey (1974).

The proposed subdivisions of the Sandringham Sands (Casey & Gallois 1973) are shown in Fig. 8, together with their ages and their relationship to the successions in Dorset and Lincolnshire.

Details of the samples examined are given in Appendix 1.
2.5 **THE BOULONNAIS**

Upper Jurassic sediments, the lateral equivalents of the Kimmeridge Clay, Portland Beds and Purbeck Beds of Dorset, were sampled along the northwest coast of France in a series of cliff sections. The outcrop stretches from just north of Boulogne to the Pointe de la Pochette, a distance of 5 kilometres (Fig. 9).

The first detailed account of the succession was given by Rignax (1892), although general accounts were presented earlier by d'Orbigny (1842-1851). Pruvost (1924), Pruvost & Pringle (1924), Dutertre (1925, 1926), Arkell (1956), Bonte (1969) and Agar & Wallace (1966a, b, 1970) have since contributed important works on the succession.

The following lithological divisions can be recognised:

<table>
<thead>
<tr>
<th>Category</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Purbeckian&quot;</td>
<td>2 samples</td>
</tr>
<tr>
<td>Portlandian</td>
<td></td>
</tr>
<tr>
<td>Grès a <em>Trigonia</em> gibbosa</td>
<td>3 samples</td>
</tr>
<tr>
<td>Assises de Croi</td>
<td>2 samples</td>
</tr>
<tr>
<td>Kimmeridgian</td>
<td></td>
</tr>
<tr>
<td>Argiles des Wimereux</td>
<td>9 samples</td>
</tr>
<tr>
<td>Argiles de la Créche</td>
<td>2 samples</td>
</tr>
<tr>
<td>Grès de la Créche</td>
<td>3 samples</td>
</tr>
<tr>
<td>Argiles de Châtillon</td>
<td>5 samples</td>
</tr>
<tr>
<td>Grès de Châtillon</td>
<td></td>
</tr>
<tr>
<td>Calcaire du Moulin Wibert</td>
<td>4 samples</td>
</tr>
<tr>
<td>Argiles du Moulin Wibert</td>
<td>3 samples</td>
</tr>
<tr>
<td>Calcaire de Brecquerecque</td>
<td></td>
</tr>
</tbody>
</table>

The above succession is exhibited in a number of coastal sections where
FIG. 9.

Geological sketch map of the Boulonnais, Northern France.

(From Dunn 1972).
FIG. 9 THE BOULONNAIS

Calais

Cap Gris-Nez

Wimereux

Boulogne

Section studied

Quaternary
Tertiary
Upper Cretaceous
Lower Cretaceous
Upper Jurassic
Mid-Jurassic
Palaeozoic

5 km
considerable overlap and marked lateral variations in lithology and thickness is evident.

The Calcaire de Brecquereque is the only division not exposed in the cliff sections of the Boulonnais. It consists of thin bands of cementstone with a shallow water fauna, mainly burrowing lamellibranchs.

The lowest division exposed along the coast is the Argiles du Moulin Wibert, consisting of dark clays with a fauna dominated by ammonites. A soft sea-floor, with an abundant benthos, without much evidence of transport or reworking is suggested.

A series of shaly clays, alternating with layers of calcareous nodules and calcilutites, constitutes the succeeding Calcaire du Moulin Wibert. They display frequent mechanical reworking with transported benthos, mainly in the forms of broken lamellibranch shells (Trigonia and Gervillia).

The Grès de Châtillon is a thin division which records the climax of the shallowing as suggested by the underlying Calcaire du Moulin Wibert (Ager & Wallace 1966a). It consists predominantly of uncemented yellow sands and cross-bedded and ripple-marked sandstones. Trace fossils are abundant (Ager & Wallace 1970), the indigenous macrofauna resembles that typical of a close inshore environment.

Evidently the sea deepened after the deposition of the Grès de Châtillon and the bottom waters became muddy and stagnant, since the overlying Argiles de Châtillon are bituminous and highly pyritous and the abundant benthos and trace fossils disappear. Throughout the greater part of this division scattered ammonites are the only macrofauna. Oysters, in particular Exogyra virgula, occasionally established themselves on the muddy floor, building up oyster conquinoids (bands consisting entirely of whole shells).
The Gres de la Creche is taken by the French as the lowest formation of the Portlandian (sensu gallico), but is usually recorded by British workers as Kimmeridgian. Since the lower part of the Gres de la Creche yields ammonites attributable to the genus Gravesia, it may also be regarded as the basal formation of the Volgian (= Tithonian), if that is accepted as the terminal Jurassic stage (Ager 1964).

Lithologically the Gres de la Creche is a complex succession of cross-bedded sands, shelly limestones and clays with abundant trace fossils; life-orientated lamellibranchs occur at various levels. The formation represents a shallow water, high-energy environment. It appears to be comparable to the Gres de Chatillon (although much thicker) and seems to represent a second episode of shallowing and possible emergence. In the lower part of the formation at Cap Gris Nez there appears to be at least three periods of local uplift (marked by phosphatic nodules, scattered pebbles and prominent burrowed horizons). The macrofauna consists of large lamellibranchs of a shallow water type (Perna, Lima, Ostrea, Trigonia) together with drift wood.

The Argiles de la Creche consists of a series of shales and thin sandstones. Bedding planes covered with small, disarticulated lamellibranchs commonly occur.

A triple limestone band marks the base of the overlying Argiles de Wimereux. Phosphatic nodule beds (the La Rochette Nodule Bed) are associated with these limestones; the bed marks an important change in fauna though not in lithology (Ager & Wallace 1966a). The macrofauna consists essentially of large articulated lamellibranchs, although ammonites, vertebrate remains and large pieces of wood are also fairly common. The upper part of the Argiles de Wimereux is similar to the lower part, but perhaps more nodular. Gaping, but still articulate lamellibranchs are common and imply sedimentation in quiet,
comparatively deep water.

The Assises de Croi and the "Argiles a Perna bourchardi" of French authors, consist of an alternation of nodular limestones with sandy glauconitic clay. Its basal unit is the Tour de Croi Nodule Bed which marks a distinct change in lithology (to much darker clays) and an unconformity in which the equivalent of the uppermost Kimmeridge Clay and lower Portland Sand of Dorset are missing. Ager & Wallace (1966a) consider that the equivalent of nearly 40 metres of the Dorset succession is missing. Ammonites recorded from the nodule bed include *Pavlovia rotunda* and other species characteristic of the *P. .. wset Upper Kimmeridgian*. The Assises de Croi are accordingly considered to be the lowest Portlandian (sensu anglico) formation. Giant ammonites of the *Titanites* group and large lamellibranchs occur amongst the macrofauna.

A series of buff or khaki calcareous sands interbedded with bioturbated sands and calcilutites constitutes the Grès a *Trigonia gibbosa*, the "Portlandian superieur" of French authors. Towards the top of this formation the sediments are very variable and exhibit marked lateral variation. The macrofauna is similar to that of the Dorset Portland Stone.

Ager & Wallace (1966a) refer to the Grès a *Trigonia gibbosa* and part of the overlying algal limestones as the Grès des Oies and restrict their "Purbeckian" (the Calcaire des Oies) to a unit, just over 1 metre thick, of predominantly concretionary limestones. In this thesis the "Purbeckian" of the French authors (i.e. Pruvost & Pringle 1924) is maintained here. In this usage it includes the clays and calcareous algal masses that Ager & Wallace (1966a) assign to the upper part of their Grès des Oies.

The "Purbeckian" is similar to the Lower Purbeck Beds of the Dorset coast and is succeeded by "Wealden Beds" of Neocomian age.
2.6 RIBADESELLA, NORTHERN SPAIN

Sediments of Jurassic age are exposed along the northern coast of Spain in the province of Oviedo (Fig. 10), where they rest unconformably on Carboniferous and Devonian limestones, against which, at Ribadesella, they are folded and faulted.

The Upper Jurassic sediments in Northern Spain form part of a thick detrital series which have been attributed to the Lias (Schulz 1858), the Kimmeridgian (Dubar 1925) and even to the Wealden (Karneberg 1934). Dubar & Mouterde (1957) described the macrofauna in some detail and recognised many typical Kimmeridgian forms. Similarly, Pozo (1972) considered them to be Kimmeridgian on the basis of their contained ostracods. Dunn (1972), in his study of the geochemistry of the sediments, accepted the views of Dubar (1925) and Dubar & Mouterde (1957) and thought it safe to assume that at least part of the sequence is Kimmeridgian, probably all of it at Ribadesella.

Detailed accounts of these sediments are few; Dubar & Mouterde (1957) gave a general account of the entire coastal sequence, Cadavieco et al. (1966) presented the results of a morphometric study of the basal conglomerate, and Virgile et al. (1968) gave a description of an algal limestone from an inland exposure.

The sequence of Ribadesella consists of at least 500 metres of a wide variety of detrital sediments. Continental deposition took place on an eroded surface of Lower Jurassic sediments. This was followed by a brief period of fluvial sedimentation before the onset of marine conditions and deposition in a shallow basin. Current bedding directions suggest that the source area lay to the south (Dunn 1972), but northern limits are not known. The Bay of Biscay would have been closed during the Upper Jurassic; accordingly the depositional basin could
have extended across to the Aquitaine Basin (South-West France), or it could have linked up with the Dorset-Boulonnais Basin to the north.

The Ribadesella sequence has not yet been described in any great detail, although Dunn (1972) gives a fairly detailed account of the succession and describes in brief the main sediment types.

16 marine horizons were sampled from the Ribadesella sequence; sample locations were based on measured sections and other unpublished field data kindly provided by Dr. R. C. L. Wilson (Open University).

All of the samples proved to be devoid of recognisable palynomorphs and accordingly, for the sake of brevity, the sequence is not tabulated here.

2.7 CABO ESPICHEL, PORTUGAL

Kimmeridgian sediments are well exposed in magnificent cliff exposures 1 kilometre north of Cabo Espichel, approximately 30 kilometres south of Lisbon. The location and the stratigraphy of the succession showing the locations of the samples analysed is shown in Figs. 11 and 12.

The sediments are locally termed Pterocerian, which in the original classification of Arkell would be considered to be Upper Kimmeridgian or equivalent to the bottom of the extended Portlandian favoured by many European geologists.

The succession consists predominantly of calcareous sediments. Nodular limestones and shales dominate the lower part giving way to algal limestones and marls towards the top. Silts, shales and sandstones, the latter often cross-bedded are also developed within the succession. A rough cyclicity based on alternations of calcareous, argillaceous and clastic sediments occurs throughout the succession.
FIG. 11.

Cabo Espichel, Portugal.

Sketch map showing the sample locality and the generalised regional stratigraphy.

FIG. 12.

Detailed lithostratigraphy of part of the Cabo Espichel succession showing the position of the samples.

Both figs. 11 & 12 are from Riley (in press).
Thick series of nodular limestones. Banded algal limestones alternating with marls.

Red to dark green silts and sandstones.

Limestones alternating with marls. Algal limestones near top and bottom.

Sample CP6.

Dark grey and red shales, Coarse sandstone at base.

Nodular limestones.

Red and grey shales.

Nodular limestone.

Red and grey shales.

Orange sandstone, Cross bedded.

Nodular limestone.

Conglomeratic sandstone.

Nodular limestone.

Red and green shales and sandstones, Cross bedded.

Red and grey shales.

Nodular limestone.

Conglomeratic sandstone.

Nodular limestone.

Grey shales, red silts and cornstone passing down to sands.

Nodular limestone and shales.

Sample CP10.

Orange sandstone with burrows.

Limestones.

Coarse sandstone. Cross bedded.

Red and green, sandy shales.

Nodular limestone.

Conglomeratic sandstone. Cross bedded.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.

Shale.

Green to buff sandstone. Cross bedded.

Shale.

Nodular limestone.
Accounts of the Portuguese Upper Jurassic are given by Choffat (1908), Ruget - Perrot (1961), Franca et al. (1963) and Seifert (1963). More recent accounts are given by Wilson (1968, 1969), at present unpublished, who provided the writer with the samples and the field data summarised in Fig. 12.

An account of the palynology of the samples from Cabo Espichel was presented earlier by the writer (Riley, in press).
CHAPTER 3

THE DISTRIBUTION, OCCURRENCE AND ORIGINS
OF THE SEDIMENTARY ORGANIC MATTER

3.1 INTRODUCTION

Organic matter occurs, in varying degrees of abundance, in all of the sediments examined. Primary organic materials consist of miospores, dinoflagellate cysts, acritarchs, simple "algal cells" and plant tissue fragments, including wood, tracheids and cuticles. These dispersed materials may be termed palynomorphs. Literature concerning the distribution of these materials, in both recent and fossil sedimentary environments, has been recently reviewed by Cross et al. (1966), Stanley (1969), Sarjeant (1970a), Sarjeant & Williams (1967) and Davey (1971).

The abundance of palynomorphs is recognised to be dependent on several factors: (1) the number of palynomorphs originally available; (2) the sedimentary environment; (3) the amount of post-depositional oxidation and destruction; (4) the nature of the processing techniques used to isolate the palynomorphs.

Other dispersed organic materials include sapropelic organic "mush" and reworked palynomorphs, which can be termed secondary or modified organic materials. In addition to these dispersed materials, accumulated organic matter, in the form of bituminous substances, is an important constituent of some of the sediments examined.

The distribution, origins and occurrence of the various sedimentary organic materials encountered in this study is discussed in the following sections.
3.2 DISPERSED PRIMARY ORGANIC MATERIALS

A. Miospores:

Miospores differ in a number of significant respects from all other groups of microfossils. All land vascular plants produce reproductive bodies, collectively termed miospores, which includes both spores and the pollen produced by seed plants. Until the appearance of insect-pollinated flowering plants in the Cretaceous, land plants must have relied primarily on air currents for the distribution of their spores. The vast majority of miospores would have been transported by wind and in many cases subsequently by water currents to the eventual site of deposition. Of the miospores which became fossilised, the majority would be incorporated in sediments accumulating in environments remote from their parent plant. It is this remarkable indifference to, or complete independence from, the environment of ultimate deposition and fossilisation which gives miospores their unique value as stratigraphic markers.

Although miospores have this theoretical ubiquity, there are, however, many complications in reality. A whole series of factors control the relative proportion and the absolute abundances in which the differing constituents of the regional flora come to be represented in the miospore population accumulating at a given site within the depositional basin.

In depositional sites adjacent to the source area the miospore population is typically over-represented by miospores from the local vegetation, miospores from more distant sources being considerably diluted by forms from the adjacent in situ vegetation. An added complication is that, in addition to being distributed by wind, once deposited in a marine environment they may subsequently be transported by marine currents. Miospores are generally of coarse silt size, but since they have a low effective density, they tend to act as
particles of medium silt size and even finer and are generally deposited with other sedimentary particles of this size. The size, density and flotation properties of individual miospores therefore influence to a considerable extent the final place of deposition. Sedimentary settling of the miospores is also controlled by the degree of water turbulence; sedimentary sorting in high-energy environments can considerably modify the potential miospore assemblage.

In order to examine more closely the products of the presumed homogeneous regional flora, certain miospores which occur irregularly and sometimes in great abundance in the sediments examined are omitted. The groups examined, which are discussed separately below, are *Classopollis* species, *Inaperturopollenites* species and bisaccates.

The remainder of the forms consist mainly of pteridophytes of which the majority appear to be ferns (*Cvathodites*, *Gleicheniidites*, *Dictyophyllidites* and some sculptured forms) with some coniferophyta (*Araucariacites*, *Cerebopollenites* and *Tsugaepollenites* etc.). This main part of the miospore flora is taken to have been distributed directly by water and deposited with mineral grains at a distance from source varying with grain size and determined by the effective settling rate.

Near-shore fine grain sediments were found to contain only a few miospore species. These are considered to have been derived from the restricted local flora growing along the coastal margins adjacent to the depositional site, or even in the shallow coastal waters, i.e. as with present day mangrove swamps. This low specific diversity (usually 10-15 species) may also have been accentuated by sedimentary sorting by both wind and water. In sediments from quiet, more open marine environments (i.e. seawards from the landmass) over-representation by local source material becomes less apparent.
and a more diverse miospore assemblage occurs. The absolute abundance of the total miospores does however fall progressively off-shore.

Species of *Classopollis* are most abundant in fine-grain sediments and are frequently the dominant form in assemblages from fine-grain, near-shore sediments. Hughes & Moody-Stuart (1967) have suggested a coastal swamp habitat for the *Classopollis* producing plant, comparable with Tertiary and Recent mangroves; there is, however, no macrofossil evidence as yet of such a habitat for coniferophytes except for the stratigraphically distant *Cordaites - Amyelon* described by Cridland (1964).

Pocock (1972, p. 144) considers that *Classopollis* was almost certainly produced by *Cheirolepsis*. The known vegetative parts of *Cheirolepsis* and related over-lapping leaf conifers in general do not suggest the mangrove swamp habitat suggested by Hughes & Moody-Stuart (1967). Pocock (1972) compared *Cheirolepsis* with the recent *Juniperus*, a plant morphologically similar although not closely related botanically, and suggested that like *Juniperus*, it was possibly adapted to a relatively dry environment.

It is not entirely impossible, however, when set in the context of the limited total of leaf patterns existing at the time, that the *Classopollis* producing plant lived in a swamp environment. Stilt roots, once pioneered in the Carboniferous, are not likely to have disappeared entirely during the Mesozoic (Hughes & Moody-Stuart, 1967).

Allen (1959) refers to rootlet beds of larger plants of unknown origin associated with his remarkable discoveries of *Equisetites* fringe-beds to his pebble beaches in the basal Ashdown and Tunbridge Wells sandstones, possibly there is "room" for the *Classopollis* - producing plant there. It seems probable however, that these *Equisetites* beds only represented very special short lived
conditions and that the plants were only first colonisers.

A further complication is that Hughes & Moody-Stuart (1967) have recorded abundant Classopollis in the Wealden of Southern England where conditions were never very saline. On the other hand Classopollis maxima were important in the type Purbeck (Norris 1963, and herein) which was at times saline enough to support echinoderms, and they continue in southern England through the Wealden Beds at intervals up to the beginning of the Aptian (Hughes & Moody-Stuart 1967). Classopollis also occurs abundantly in the present material from the base of the Sandringham Sands, but according to Hughes & Moody-Stuart (1967) it is rare further out in the definitely marine Spilsby Sandstone of Yorkshire. It has also been observed in abundance in near-shore sediments (tidal–lagoonal) from the Upper Jurassic of Portugal (Riley in press). Portugal probably experienced a sub-humid (Bahamas–Galveston–Florida type) climate (Wilson 1974, pers. comm.); accordingly a coastal swamp origin for the Classopollis producing plant is possible from the sedimentological viewpoint.

Fluctuations in the relative abundance of Classopollis and Inaperturopollenites, previously noted by Norris (1963, 1969), were observed throughout the Upper Kimmeridgian–Portlandian of Dorset and the Kimmeridgian–Portlandian of the Boulonnais; alternations of Classopollis and Inaperturopollenites occur throughout the two successions. When abundant, small inaperturate miospores, however, are very difficult to record definitely owing to the paucity of characters and folding. Some difficulty was experienced in differentiating them from Spheripollenites and Monosulcites species and at times, when highly folded and/or poorly preserved, from the dinoflagellate cyst species Chytroeisphaeridia chytroides (Sarjeant).

Norris (1963) accepted a coastal habitat for the Classopollis producing
plant and equated increasing distance of the depositional site from the land mass
with an increase in abundance of *Inaperturopollenites* and suggested that
*Inaperturopollenites* is a form characteristic of inland/upland vegetation. He
concluded that variations in abundance of the two genera were probably a
consequence of changes in the depositional environment. A rise to abundance
of *Classopollis* through a succession was considered to be indicative of deposition
taking place in a more near-shore environment with the consequent relative
approach of the vegetational area to the site of deposition. The periodic
replacement of *Classopollis* by *Inaperturopollenites* and vice versa is taken herein
to reflect fluctuations in base level resulting in a series of transgressions and
regressions of the sea.

Miospores accumulating in the near-shore sediments would largely be
derived from the adjacent coastal site vegetation, i.e. from the *Classopollis*
producing plants. Miospores borne by the wind from more inland sources (i.e.
*Inaperturopollenites*) would form a much lower proportion of the accumulating
miospore assemblage than *Classopollis* due to the numerical abundance of the
latter. With the obliteration of the coastal vegetation, or its restriction to a
narrow marginal belt, caused by a change in base level resulting in a marine
incursion, the majority of spores would have come from a more inland source,
i.e. the *Inaperturopollenites* producing plant. Under these circumstances, with
the coastal swamp *Classopollis* vegetation both at its minimum extent and its
maximum distance from the site of deposition under consideration, the miospore
rain from other plant communities would have its greatest chance to show up in
the accumulating miospore assemblages.

The converse is also possible, with the *Classopollis* producing vegetation
occurring in the more inland drier sites (Pocock 1972) and the *Inaperturopollenites*
producing vegetation occupying the swampy coastal sites (Hughes & Moody-Stuart 1967, p. 264). Regardless, however, of the spatial distribution of the 

**Classopollis** and **Inaperturopollenites** producing vegetation fluctuations in base level most readily explains the periodic alternations of the two genera.

Bisaccate pollen at this stratigraphic level consists principally of species of **Alisporites** and to a lesser extent **Parvisaccites** and **Undulatasporites**. **Vitreisporites** is excluded here because it occurs in very small numbers in the majority of samples examined. These bisaccate grains appear to be quite uniformly distributed in near-shore sediments but appear to be numerically more important seawards. The suggested explanation is that their accumulation in sediments is entirely modified by their unusually long flotation in water compared with other miozspores. The saccus device of these grains appears to be connected with water flotation and not with wind dispersal when the grain is dry, so that inflation of the saccae and long flotation result from their immersion in water as demonstrated by Federova (1952).

B. **Wood and Cuticle Material:**

Both black and brown wood occurs in the sediments examined. This consists of fragments of structured (i.e. fibrous, in the botanical sense; tracheids and cuticles) and unstructured, amorphous material.

The black wood fragments are generally angular and platey with sharply defined edges, but, if thin, they are sometimes splintered and translucent (brownish black to various lighter shades of reddish brown). Brown wood includes various shades of brown, reddish brown and yellow-orange fragments. Distinction from black wood in transmitted light is difficult when the fragments are thick and therefore opaque.

A relative greater abundance of wood and cuticle material was observed
in sediments from inshore, low-energy, shallow water sediments than sediments from more offshore environments. The greatest abundance of these materials occurs in non-marine sediments from the Purbeck Beds. An increase in particle size of the fragments was similarly noticed landwards. The distribution of these materials is a natural consequence of the nearness of the source area to the site of deposition.

C. Planktonic Freshwater Algae:

Forms probably related to Botryoccus are locally important in the Purbeck Beds, reflecting the non-marine origin of some of the sediments.

D. ? Mineral Charcoal:

A considerable proportion of the smaller wood fragments resemble recent charcoal in appearance. This generally consists of unidentifiable minute opaque black fragments that may be classified as micrinite. Small fragments of fusinite occur with the micrinite fragments, in these translucency is lacking, but organised cellular structure can at times be recognised.

Fusinite, because of its very high carbon content, resistance to breakdown and similarity to true charcoal, has been considered by some authors to be a product of fire. A more probable origin, as suggested by Schopf (1948) and Semasheva & Sofiyer (1963), is by the chemical alteration of woody tissue under wet, more or less aerobic conditions. Fusinite forms today along the southern Florida coast and other coastal regions where marine erosion is exposing woody peats, and is dispersed as black fragments in the accumulating marine sediments (Staplin 1969).

Micrinite appears to be a product of a water-rich environment (van Krevelen 1961). When plant debris is humified under very wet conditions, the bulk of the woody tissue, including cellulose, is broken down into a structureless
black mass that will later be modified to micrinite. The decomposition of the woody tissue is probably a result, at least in part, of in situ microbial (Reese 1959) and fungal activity, perhaps in a coastal swamp or lagoonal environment.

Fragments of micrinite and fusinite, were in general observed to be abundant in the more shallow water, near-shore marine sediments examined. This is perhaps due firstly, to the proximity of "peaty deposits" undergoing marine erosion and the subsequent alteration of the eroded materials to fusinite and micrinite, and secondly to the ability of charcoal to absorb mineral matter and act like a mineral sediment.

E. Dinoflagellate Cysts:

Although fresh-water dinoflagellate cysts are known, there is no evidence for such forms in the sediments examined here, they are all considered to be marine forms.

It is realised by the writer that the distribution of dinoflagellate cysts is probably completely unrelated to the distribution of the living, motile dinoflagellates which produced them. Once discarded by the motile dinoflagellate the cyst behaves as a sedimentary particle and accordingly must be treated as such. As with miospores, the size, density and flotation properties of each individual cyst influences its final place of deposition.

A relationship between the cyst morphology/ornamentation and the environment of deposition is indicated by the present study. Sediments indicative of an offshore marine environment generally contain a diverse cyst assemblage, whereas those indicative of a relatively near-shore, higher energy environment contain a much less diverse assemblage. Associated with this decrease in diversity there is a reduction in absolute abundance (estimated, not counted in this study) and a loss in elaborate ornamentation (i.e. spines and long complex
processes). These reductions might possibly be due to the relatively unfavourable conditions that prevailed in a near-shore environment; perhaps more specifically to environmental parameters such as decrease in water depth and salinity, together with a general lack of environmental stability. A decreasing number of species through a vertical sequence is typically indicative of the approach of near-shore sedimentation. This is clearly seen to occur through the sequences from Dorset and the Boulonnais (discussed elsewhere in this thesis). Consequently, if the number of cyst species are counted and trends in specific diversity noted, marine transgressions and regressions can be inferred.

In general, dinoflagellate cysts were found to be more abundant in sediments containing a high percentage of clay - silt size particles. Reid (1973), in a study of present day intertidal sediments around the British Isles, has demonstrated that even in these sediments, cysts are often abundant if the sediment is very fine-grained and if sedimentation took place in a sheltered area. He reported that, even in certain intertidal sediments away from river mouths, dinoflagellate cysts are more abundant than miospores. This was not found to be the case in the present study, as all assemblages from possible intertidal sediments are dominated by miospores.

In general, the longer-spined cysts and cysts with elaborate processes such as *Systematophora*, *Oligosphaeridium*, and to a lesser extent *Cleistosphaeridium* and *Hystrichodinium*, were found to be more abundant in sediments from an offshore, open marine low-energy environment. Accordingly, it appears possible that these cysts (corresponding to the chorate and proximo-chorate morphological types of Sarjeant (1966)) are "oceanic" (Reid 1973). The processes and spines can possibly be considered to be buoyancy controls which increase the flotation properties of the cysts in a relatively low energy
environment. Cysts with short, stout processes (i.e. Cyclonephelium and Tenua) and cavate and proximate cysts (see Sarjeant 1966, for definitions), particularly those with thickened cyst walls, are the dominant forms in the more inshore, higher energy sediments. The effects of water turbulence and differences in buoyancy of recent motile dinoflagellates and their cysts is discussed at length by Fogg (1965).

The gonyaulacacean ratio has been used by some workers as a palaeoenvironmental index (e.g. Harland 1973). This ratio is simply the number of species that have a gonyaulacacean affinity divided by the number of species having a peridiniacean affinity. If we assume that conditions have not radically altered from today, then it appears that in an open marine environment the number of gonyaulacacean dinoflagellate species is relatively higher than the number of peridiniacean species (Schiller 1937). We must assume that this is reflected in the cyst populations. The calculated gonyaulacacean ratio for cysts collected from deep sea cores in the Caribbean is 18.0 (Wall 1967); while Wall & Dale (1968) gave a ratio of 0.44 for a near-shore cyst population off Wood's Hole, Massachusetts. Fresh water assemblages have high proportions of peridiniacean dinoflagellates (Eddy 1930; Thompson 1947, 1950). The gonyaulacacean ratio has not been calculated for all of the samples studied here because of the generally poorly preserved and fragmentary nature of most of the available material, which makes identification and recognition of the total cyst assemblage per sample impossible. Any results based on an unrepresentative assemblage would of course be meaningless. A decrease in the gonyaulacacean ratio is, however, clearly apparent through the Kimmeridge Clay succession of Dorset. Three ratios were calculated (1) 8.36, from the Main Coccolith Limestone Band at the base of the pectinatus zone; (2) 4.29, from the base of the pallasioloides zone; and (3) 3.92, from
the base of the rotunda zone. This decreasing trend, which indicates the approach of near-shore, shallow water conditions of sedimentation, parallels the known sedimentary evidence.

Peridiniacean cysts occur in varying abundance throughout the sediments sampled, the genera Chytroeisphaeridia, Fromea, Pareodinia and Imbatodium being of particular importance. Although in general they are subordinate to gonyaulacacean cysts, the gonyaulacacean ratio nowhere approaches the value of 15.0 given by Wall (1967) for deep sea assemblages. The maximum value is tentatively considered to be no higher than 10.0, which in itself suggests that none of the sediments examined are of a deep sea origin.

It is also highly probable that the morphology of a cyst produced by a motile dinoflagellate may be controlled by environmental factors such as temperature, salinity and turbulence (Davey 1971, Reid 1973). In other words, one motile dinoflagellate species may produce several dinoflagellate cyst types of varying morphology under different environment conditions.

The distribution of different types of cysts in the sediments examined might therefore be a primary phenomena, or more probably a combination of primary distribution subsequently modified by physical agencies such as water turbulence and sea currents. The distribution of cyst-types and their relative and absolute abundance appears to be of considerable use in delineating certain environmental regimes, open marine, near-shore, lagoonal etc. The writer has no justification, however, in setting definite limits on these environments in terms of temperature, salinity etc. Open marine conditions for some of the Kimmeridgian sediments as suggested by the dinoflagellate cyst assemblages, may be indicative of periods of maximum extent of the Kimmeridge sea. It might, however, indicate periods when the nutrient content was optimum for dinoflagellate productivity.
F. Acritarchs:

The acritarchs include a wide variety of forms of uncertain origins and affinities. Some acritarchs may be dinoflagellate cysts, others may have affinities with miospores, and some may even be the egg cases of small aquatic organisms. The distribution of these forms appears to be clearly related to environmental factors. Differing assemblages of acritarchs have been found to be indicative of distinct palaeoenvironments; each of the assemblages, although generally characterised by certain species, is typified by morphological features such as overall size, and length and thickness of spines/processes.

The distribution of acanthomorph acritarchs in the sediments examined here, strongly demonstrates that they are much more abundant in near-shore, shallow-water environments. In such environments they constitute at times over 90% of the total dinoflagellate cyst and acritarch population. In deeper water, more open sea, lower energy environments they are typically very infrequent to absent. From the present study it is clearly apparent that the acritarch: dinoflagellate cyst ratio decreases seawards away from the shore-line. The distribution of Micrhystridia in the English and French Cenomanian (Davey 1970) and the Permo-Triassic of Pakistan (Sarjeant 1970b, 1973) is comparable.

Near-shore sediments are dominated by species of the acanthomorph genera Micrhystridum and Solisphaeridium, their importance decreasing seawards in more open sea sediments. A richer, more diverse assemblage characterises the offshore sediments, although it is associated with a decrease in the numerical abundance of acritarchs.

Staplin (1961) demonstrated that acritarchs in the Devonian of Canada had a distribution pattern related to reef-masses within the sediments. Sphaeromorphs occurred at all depths, although they increased numerically
seawards. Thin-spined acanthomorphs occurred only rarely within a mile of the reefs, again being more abundant seawards; while the thicker-spined acanthomorphs, together with the herkomorphs and polygonomorphs, only occurred at distances greater than four miles from the reefs.

The Lower Jurassic studies by Wall (1965) demonstrate that inshore basinal environments which tend to be characterised by acanthomorph acritarchs can be subdivided into three: (1) turbulent high-energy conditions characterised by short-spined acanthomorphs; (2) more tranquil, lower-energy conditions characterised by longer-spined acanthomorphs; (3) offshore basinal conditions characterised by a more diverse assemblage.

In general the results of the present study are in close agreement with Wall’s observations. Assemblages from high-energy, near-shore sediments are characterised by short-spined acanthomorphs. In the sample from the base of the Cherty Series (Dorset) forms comparable with *Micrhystridium deflandrei* and *M. inconspicuum* together constitute over 55% of the total acritarch and dinoflagellate cyst assemblage. In the Portland Sand (Dorset), *M. inconspicuum* constitutes over 80% of the total assemblage from one horizon. In lower-energy, near-shore sediments, short-spined forms are still of considerable importance, but longer spined forms (i.e. *M. fragile* and *Solisphaeridium stimuliferum*) are the dominant forms.

Local abundances of two other forms have been observed. *Pterospermopsis australiensis* constitutes over 26% of the total acritarch - dinoflagellate assemblage from near the base of the Cherty Series (Dorset). *Leiofusa jurassica*, a very distinctive netromorph, attains considerable importance in sample S2 from the Sandringham Sands. These two occurrences are somewhat anomalous and cannot readily be explained although they are probably due to some
local environmental control. In the case of the Cherty Series, the abundance of *Pterospermopsis* may be related to the high sponge spicule content of the rock. No published records giving details of comparable abundances of these two forms are, however, known to the writer.

G. Microforaminiferal "test-linings":

These are considered by the writer to be either, the organic (?chitinous) linings of the proloculus of adult foraminifera, or the larval stages of foraminifera. This group of microfossils varies considerably in distribution and abundance in the sediments examined. In general they are more abundant in sediments from inshore, shallow water environments.

H. Incertae sedis algal cells and fungal spores:

These are more abundant in sediments from low-energy, shallow water, near-shore and non-marine environments, elsewhere their distribution is erratic; in the majority of offshore sediments they are typically absent.

I. Arthropod remains:

Fragments of chitinous material, probably attributable to some marine dwelling arthropod occur very infrequently in some of the sediments from low-energy shallow water, near-shore environments. Arthropod remains, algal cells and fungal spores are more abundant in the Portuguese material.

3.3 **DISPERSED SECONDARY ORGANIC MATERIALS**

A. "Mush":

Unorganised, fluffy, semi-coherent organic masses associated with colloidal organic matter occur in many of the samples, particularly from the Kimmeridge Clay. The bituminous sediment samples yield little in the way of structured organic materials, except for a few palynomorphs. The bulk of
their residues consists of homogenised and coagulated masses of indeterminable palynomorphs, wood fragments, bituminous substances, colloidal organic matter, structureless flimsy tissue and finely divided organic and inorganic (pyrite) debris which together constitute a "mush". This type of material appears to represent relatively anaerobic sapropelic conditions of deposition and may be termed a "sapropel". The term sapropel was introduced by Potonie (1908a, b) for products produced anaerobically in the presence of water and enriched in hydrogen, nitrogen and fat-rich substances.

Similar sapropelic indicators form the bulk of the organic residues of the bituminous sediments examined here.

An "organic mush" characterises residues from some of the Portland and Purbeck Bed samples. In these residues, bituminous substances are lacking and pyrite is effectively absent, the bulk of the residues consist of flimsy plant tissue debris and colloidal materials. This type of "mush" is considered to be the result of faulty processing techniques.

Separation of palynomorphs from the "mush" was very difficult and in many instances impossible; the apparently meagre microplankton records from many of the samples is a result of this.

B. Modified Cuticular Remains and Palynomorphs:

These are reworked materials. They are generally differentiated from contemporaneous material by differences in appearance, sheen, body-colour and reaction to stain. Due to the close proximity of older sediments undergoing marine erosion, they are found to be more abundant in sediments from near-shore environments and in sediments immediately above unconformities and breaks in deposition.
3.4 ACCUMULATED ORGANIC MATERIAL - BITUMINOUS SHALES AND OIL SHALES

The distinction between clays, bituminous shales and oil shales is determined by the quantity of contained organic material as outlined below (after Downie and Wilson, unpublished):

<table>
<thead>
<tr>
<th>Name</th>
<th>Content of Organic Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>0 - 10%</td>
</tr>
<tr>
<td>Poor Bituminous Shales</td>
<td>10 - 20%</td>
</tr>
<tr>
<td>Rich Bituminous Shales</td>
<td>20 - 40%</td>
</tr>
<tr>
<td>Oil Shale</td>
<td>&gt; 40%</td>
</tr>
</tbody>
</table>

Bituminous shales are developed in the central part of the Dorset Kimmeridge Clay succession from the *eudoxus* zone to the base of the *wheatleyensis* zone, where they form thin bands up to 2 feet in thickness occurring sporadically through about 850 feet of sediment. Oil shales are developed in the *wheatleyensis* zone, above the bituminous sediments, and in the lower part of the *hudlestoni* zone, forming the Oil Shale Group of Downie & Wilson (unpublished). The bituminous content of the sediments then decreases markedly upwards, except for increases in the "oil-bands" within the *pectinatus* zone where they form part of the Coccolith Limestone Group of Downie and Wilson (unpublished). Within the Coccolith Limestone Group the oil shales are developed as thin, but persistent seams up to 3 inches thick. They are better developed in the Oil Shale Group where several seams over one foot in thickness are developed.

Several of these bands, the Blackstone, the Bubbicum and the Short Joint Coal, have been exploited in the past for the oil and gas that they yield on distillation (Green 1886). Some of the richer seams with an organic content of
over 70%, have yielded over 40 gallons of "oil" per ton of processed sediment. Sediments such as these, which yield oil from their contained organic matter, have been termed "marine kerogen shales" by Takahaski (1922), the term kerogen having been applied earlier by Brown (1912) to distillable organic matter. Many sedimentary geochemists have, however, created confusion by applying the term incorrectly to all sedimentary organic material, whether distillable or not (Staplin 1969).

Thin oil laminae also occur within the limestone band in the Kimmeridge Clay exposure at Marton in Yorkshire. Bituminous sediments are also developed in the lower part of the Portland Sand of Dorset.

Unlike the Dorset sediments, bituminous shales are rather restricted in the Boulonnais, occurring only within the Argiles de Chatillon (roughly equivalent to the Kimmeridge Clay).

The resistant organic materials that occur dispersed throughout the sediments obviously contribute to the formation of the bituminous material, but the mode of origin of the material is open to debate.

The bituminous sediments have a high bromine and iodine content (Cosgrove 1970) suggesting an abundance of marine plant debris, since iodine is an important element in many marine plants (Recent sea-weeds have in fact been used as a commercial source of iodine). Phytoplankton (in particular organic-walled forms such as dinoflagellates) may also have been an important source of the bituminous material. This particular mode of origin appears to be valid for the thin bituminous laminae developed within the primary carbonate bands developed in the Kimmeridge Clay of Dorset and Yorkshire.

A second possibility is that the bituminous matter was formed within coastal swamps and lagoons by the decay and degradation of accumulated plant
material and subsequently redistributed.

It must be borne in mind, however, that the original distribution of the bituminous material, regardless of its origin, may well have been subsequently altered by migration during compaction and diagenesis of the sediments. The bituminous laminae developed in the primary limestone bands are, however, almost certainly unaltered.

Depositional Site:

Conditions at the site of deposition are crucial for the preservation of accumulated organic matter. Conditions must be such so as to prevent, partially at least, the normal degradation of organic material to simple, less resistant organic compounds and carbon dioxide. At the same time the environment must not be conducive for the accumulation of peat and subsequent coal formation.

Staplin (1969) recognises three basic, but obviously inter-related types of organic depositional sites:-

1. Confined basins. In these basins, the most effective accumulations of organic matter are depressions that are more or less enclosed by lowland, with influxes of organic matter of both marine and terrestrial matter. This type of model does not agree, however, with what is known of the palaeogeography of the region.

2. Epicontinental or relatively broad basins. Transgressions and regressions of the sea on the flanks of a subsiding basin result in a series of superimposed fine to coarse deposits that vary considerably in the type and amount of organic material. However, in this model, the organic matter is more diluted by sediment than in the other two main types and the sediment-water interface may never become really anaerobic, the benthos is typically rich and varied and burial may be rapid.
3. The lower shelf and continental slope of open marginal areas. Deposits of extensive epicontinental seas perhaps afford the greatest potential for accumulation of organic materials. In this type of model, which appears to be in accord with the known palaeogeographical and sedimentological data (Berry 1974, pers. comm.) of the region studied here, organic matter is preserved in protected environments that are generally enclosed by sediments which were deposited under more aerobic and higher energy conditions. Fluctuations in water depth, changing erosional patterns; together with variable uplift, standstill and subsidence in various parts of the basin would form a wide variety of potential sites for the accumulation and preservation of organic matter.

It therefore seems probable that the bituminous sediments formed in an extensive, epicontinental marine basin(s). Somewhat restricted circulation within the basin(s) is suggested by the lack of sedimentary structures and the fine-grain nature of the sediments suggests that sedimentation was rather slow. There are, however, certain drawbacks to this model, wave energy must have been dissipated some distance from the shore-line and significant storm action must be precluded over a considerable period of time. The dearth of terrigenous material in the coccolith limestones and associated sediments would, however, in the context of this model, suggest a very broad epicontinental sea with the depositional site lying some considerable distance from the shore-line. This hypothesis would certainly mean, however, that there would have been much less of a contrast in water depths during the deposition of the Kimmeridgian - Portlandian of the Dorset region, possibly a range of only supratidal to 50-100 feet.

Deposition of the sediments of the Boulonnais appears to have been in a site marginal to the Dorset basin. Palaeogeographic evidence tentatively implies that the Kimmeridge Clay of Yorkshire was deposited in a separate "basin".
3.5 **DIAGENESIS OF ORGANIC MATTER**

Near-shore marine sediments contain sorted organic debris, both terrestrial and marine in origin. Various mechanisms during transport alter the constitution and composition of the organic matter. These include chemical transformations, solution, sedimentary sorting, ingestion and subsequent modification by marine organisms, and precipitating and coagulating mechanisms. Depending upon the availability of dissolved oxygen, organic debris which reaches the sea-floor is reworked, modified and augmented by either aerobic or anaerobic organisms.

In an anaerobic, stagnant environment (i.e. during the deposition of the Kimmeridgian bituminous-rich sediments and primary carbonates), much of the available organic matter is preserved where it is buried by the sediment and is found in an unaltered or only partly altered state. In much higher energy, more aerobic environments (i.e. during the deposition of the Dorset Portlandian carbonates and the Norfolk Sandringham Sands) organic material is far less abundant. Much of the organic matter has been lost, by solution, by winnowing and/or by oxidation. The remaining organic matter consists predominantly of resistant cuticle material, particulate fusain or micrinite, some miospores and organic-walled microplankton and reworked material (the latter recognised by its reaction to staining, its body colour and preservation).

It was observed that much of the organic debris is very similar to that occurring in younger, and even Recent, argillaceous sediments. Diagenetic processes affecting organic matter thus appear to be very slow in fine-grained sediments after initial burial and compaction.

The altered remains of algae and fungi (represented by algal cells and fungal spores) appear to have been of some considerable importance in
contributing to the amorphous organic debris preserved in the sapropelic sediments.

In depositional sites where the bottom of a water body is undisturbed by current activity, a living "algal mat" may rest on several buried algal mat and sediment layers (Parker and Leo 1955). In such an instance the algal mat, or a layer of "organic ooze", which is developed may separate a relatively oxygenated water body from the reducing conditions of the bottom sediment (Butkevich 1938). Even if only a thin layer is developed it would be sufficient to form a distinct and sharp division between the diagenetic (the sediment) and active (the water body) regimes, so shielding the sediment from the oxygenated water and its flora and fauna. During the course of time, the layers may, however, be frequently disturbed by storms, currents and tidal activity. Most microbial and biochemical activity takes place near the water-algal/organic ooze-sediment interface (Kuznetsov et al. 1939). Below the ooze-sediment interface, however, the situation becomes anaerobic. The juxtaposition of slightly anaerobic, stagnant conditions just above the ooze-sediment interface (Beauchamp 1964, Bradley 1966) and the essentially anaerobic conditions below it, accordingly appears to be essential for the formation and preservation of that organic matter that is the precursor of kerogens and petroleum.

It is therefore possible to envisage highly organic argillaceous sediments being built up lamina by lamina, as increments of organic detritus and sediment are bound together, utilised and augmented by the dense micro-organism population at the water-sediment interface. This might possibly account for the formation of some of the organic-rich sediments in the English and French Kimmeridgian and the layering that they exhibit.

Relatively rapid burial and isolation of organic matter from biogenetic
processes seems to be essential for its preservation. For the present day anaerobic Santa Barbara Basin (just off southern California), Kaplin et al. (1963) estimated that sulphate reduction by sulphur-fixing bacteria is responsible for the decomposition of 16 per cent of the initially available organic matter at the sediment-water interface. This may provide a clue to the origin of some of the Kimmeridgian organic-rich sediments that have a high sulphur content. Downie & Wilson (unpublished) have recorded sulphur in excess of 8 per cent in some of the bituminous sediments. Where sedimentation into an anaerobic basin is extremely light (the fine-grain nature of the Kimmeridgian sediments does in fact imply a slow rate of deposition); sulphate-reducing bacteria perhaps convert many organic compounds to water and carbon dioxide, leaving a residue of carbon and sulphide rich substances.

The Kimmeridgian material examined during the course of this study strongly suggests that environmental processes, as well as the nature of the primary organic debris, are responsible for the formation of the amorphous debris in sapropelic sediments. A similar conclusion was reached earlier by Staplin (1969) for certain Lower Cretaceous strata in western Canada. Two lines of evidence are available to substantiate this. An environmental profile sequence occurs in some sediments, ranging from structured, (unfusainised cuticles, miospores, dinoflagellate cysts, acritarchs, and recognisable algal and other tissues) to completely unstructured, amorphous organic debris (Plates 1 - 8). It is possible that the organised and structured material was preserved under somewhat antiseptic conditions in sediments accumulating in a slightly oxidising environment (certain present day accumulations of organic matter, such as peaty deposits, do in fact inhibit biogenic degradation by the presence of phenol compounds). In contrast, the unstructured and amorphous
debris has been subject to the essentially biochemical degradation processes mentioned above. The other line of evidence is that of apparent chemical differences in cuticle, organised and unorganised material and other particulate organic matter between different samples. In many of the samples examined, much of the amorphous debris could be removed by the use of oxidising agents (either Schulz solution or fuming nitric acid) followed by bases (potassium hydroxide or potassium carbonate solution) it may even in fact be acid-soluble. The same was found to be true for many identifiable elements of the organic matter. In other samples, however, little effect was noted unless the treatment was prolonged and intense. To account for this, a real difference may exist in the chemistry of what are essentially usually similar materials, as Spackman & Thompson (1963) have demonstrated for some coal macerals, or some catalytic component may be present in some, but not in others. Merely to disregard these differences as being due to the state of oxidation of the sediment is not considered to be completely satisfactory.

3.6 THERMAL METAMORPHISM OF ORGANIC MATTER

Progressive organic metamorphism, eometamorphism or carbonisation (Landes 1966) is the next stage beyond diagenesis; it brings about changes, both physically and chemically, in particulate organic matter and precedes mineral metamorphism. Readily identifiable and easily visible changes include, darkening of the organic matter, decrease in light transmissibility, increase in index of refraction, reflectance and lustre and loss of fine structural detail.

The degree of organic metamorphism is somewhat arbitrarily determined by observing the body colour of the organic debris, especially miospores, non-woody cuticle material and amorphous sapropelic debris, disregarding all
reworked material. These materials seem to be the organic components most sensitive to heat and their alteration in an argillaceous matrix progresses at roughly the same rate. Phytoplankton (i.e. dinoflagellate cysts) appear to be more variable in their response to heat and accordingly are considered to be less useful "thermometers" (Staplin 1969).

In order to estimate the degree of thermal metamorphism, standard palynological techniques were utilised to isolate and concentrate the organic matter from each sample. No oxidising agents on bases were used since they result in a selective loss of the organic constituents and alter their appearance. The progressive severity of organic thermal metamorphism has been subdivided by Staplin (1969) into five degrees, or thermal alteration indices, which are determinable by eye:-

<table>
<thead>
<tr>
<th>Thermal Alteration Index</th>
<th>Organic Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. None</td>
<td>Fresh, yellow.</td>
</tr>
<tr>
<td>2. Slight</td>
<td>Brownish yellow.</td>
</tr>
<tr>
<td>4. Strong</td>
<td>Black.</td>
</tr>
<tr>
<td>5. Severe</td>
<td>Black, with additional evidence of rock mineralisation.</td>
</tr>
</tbody>
</table>

The bulk of the sediments examined contain abundant organic matter, which is generally fresh to only moderately altered (thermal indices being much less than 3). The fresher organic material, with a thermal index of around 1, is present in the less consolidated sediments, in particular the Sandringham Sands and some of the sediments from the Boulonnais. The slightly to moderately
altered material present in the majority of samples is probably due to a relatively higher thermal gradient brought about by stronger compaction and much deeper burial of the sediments.

The ?Kimmeridgian sediments from Northern Spain contain strongly altered organic matter (thermal index around 4) which is generally black in colour, although some brown tints remain together with a few poorly preserved miospores. This alteration is considered to be related to the disturbed and strongly faulted nature of the sediments, and the subsequent increase in temperatures.
PLATE 1.

Upper Purbeck Beds: X 300

Organic residue dominated by well-preserved cellular plant matter. Miospores are common, microplankton are effectively absent. The associated organic matter is predominantly lignitic. The organic residue, dominated by plant and lignitic material has some hydrocarbon potential for dry gas.
PLATE 2

Purbeck Beds : X 300

Organic residue dominated by lignitic matter. Well preserved cellular plant matter is present together with abundant miospores; microplankton are effectively absent, represented by infrequent acanthomorph acritarchs.

The miospores, consisting predominantly of Classopollis, constitute over 40% of the total assemblage. The hydrocarbon potential for dry gas is good; the abundance of sporopollenin indicates, however, that it may have some potential for paraffinic oils.
Organic residue dominated by lignitic materials. These are typically unstructured and degraded, although some pitted tracheids are present. Miospores are moderately common, microplankton rare, represented mainly by acanthomorph acritarchs. Vitrinitic materials dominate over sporopollenin, the residue accordingly has a low hydrocarbon potential for dry gas.
PLATE 4

Purbeck Beds: X 300

Organic residue consisting predominantly of lignitic matter. Tracheidal material with bordered pits is present, together with common miospores. Microplankton are poorly represented, mainly by acanthomorph acritarchs.

This residue is similar to that illustrated in Plate 3, but contains more abundant miospores. It possesses a low hydrocarbon potential for dry gas, but by comparison with plate 3, perhaps a better potential due to the increase in sporopollenin.
Organic residue consisting almost entirely of divided and degraded lignitic matter. Microplankton are represented by abundant acanthomorph acritarchs. Some degraded plant material and sapropel is present.

The hydrocarbon potential is low, perhaps comparable to the example illustrated on plate 4.
Organic residue dominated by fine organic matter consisting of finely divided degraded lignitic matter and bituminous sapropel. Miospores and microplankton are poorly preserved and structurely degraded.

The residue has a high hydrocarbon potential for oil or wet gas.
Organic residue dominated by bituminous sapropel and fine organic matter which appears to be a mixture of sapropel and lignitic matter. Some cellular plant matter is present, showing advanced degradation (sapropel precursors) possibly due to bacterial/algal agencies.

The residue has a high hydrocarbon potential for ? heavy oil.
Assemblage dominated by sapropelic matter with subordinate lignitic matter. Structured material infrequent, palynomorph recovery poor.

Dinoflagellate cysts from this particular type of assemblage, although infrequent, are generally dominated by chorate morpho-types. Acritarchs are generally insignificant.

Preservation is consistently poor and many of the palynomorphs bear mineral (pyrite) grain impressions.

The large amorphous "particles" of sapropel are probably secondary due to migration and coagulation of colloidal sapropel during diagenesis.

The organic residue has a very good potential for liquid hydrocarbons and at this stage is producing heavy immature oil.
CHAPTER 4

SOME APPLICATIONS OF THE PALYNOLOGICAL DATA

4.1 PALYNOLOGICAL FACIES

It is accepted by the writer that the full microflora of a given sedimentary sequence can only be seen through a series of filters:-

(i) Exposure, collecting and preparation of samples
(ii) The sample assemblage of palynomorphs (one palynological facies)
(iii) The sum of all available palynological facies
(iv) The parent community

It is perhaps at present, only possible to reach (iii), but speculations can be made about (iv), which in the case of miospores can possibly be tested by macrofossil work.

This attempt to recognised palynological facies has had four main objectives:-

1. To identify types of sedimentary environments in which any selected palynomorph species, or morpho-type, either should be expected or could not be expected to occur.

2. To estimate, by adding together the results from all the facies present, in any given sequence of sediments, the total palynologic and thus palaeobotanic environments available at the time and place considered.

3. To develop a model relating the palynological characters of a given sediment sample to its depositional environment, which hopefully, can then be applied to sediments of uncertain depositional history.

4. To compare and contrast the facies control of a given palynomorph species against its time control, i.e. to ascertain whether the "top occurrence"
of a given species in a given sedimentary succession is due to "evolutionary extinction" or adverse local environmental conditions.

The term "palynological facies" is used here in the same general sense as "palynofacies" of Combaz (1964), to include all organic elements. In this thesis there is no attempt, however, to utilise all of the possible characters presented by the available palynomorphs, only to present a model for use in the environmental situation examined here. Hopefully, however, this model can be applied to other areas and situations.

My view of the pattern of palynological facies encountered in this study is expressed diagrammatically on Fig. 13. The environmental profile sequence recognised in the sediments is illustrated by a series of photographs (Plates 1-8) of macerated samples taken from the regressive Kimmeridgian - Portlandian sequence of Dorset. The distribution of the various organic elements in terrestrial to marine environments is discussed in Chapter 3. Certain aspects are, however, discussed here.

A. "Fern" spores are taken to have been deposited primarily by water. The fern-spore assemblage is progressively modified by reduction in diversity and grain size with increasing distance from source (D1, D2, D3 etc.).

B. There are some additional qualitative indications in some of the coarser sediment samples of relative proximity to the landmass.

i) presence of extreme size variants of miospores and wood fragments.

ii) presence of spore masses and tetrads.

iii) presence of "exotic" specimens with strongly developed or extreme characters.

iv) presence of megaspores (or fragments) which presumably mostly originated in interfluvial standing-water areas (Batten 1974, pers. comm.)
FIGURE 13

Diagrammatic representation of Upper Jurassic - Basal Cretaceous palynological facies.
PHOTOGRAPHS

**FLORA**
- **Bisaccates**
- **Inaperturates**
- **"Fern" Spores**
- **Megaspores**

**TERRESTRIAL**
- "Botryococcus"

**MARINE PHYTOPLANKTON**
- **Classopollis**
- **Occasional Varied Plankton**
- **Decrease in cyst ornamentation**
- **Decrease in diversity**

**Inversdy**

**Increase in miospore:microplankton ratio**

**Increase in peridiniacean:gonyaulacacean**

**Increase in acritarch: dinoflagellate cyst ratio**

**Acanthomorph acritarchs dominant**

**ABUNDANT STRUCTURED WOOD**
(Fusain and Vitrain) Tracheids and cuticles

**ABUNDANT MICRINITE**
Decrease in size and abundance of wood fragments

**BITUMINOUS KEROGENS IN RESTRICTED BASINS**

**TRANSITIONAL**
- Freshwater
- Brackish

**MARINE INSHORE SHALLOW**
- Marine (Marginal)

**OPEN MARINE**
C. In quiet water, transitional environments, microforaminiferal test-linings, fungal spores and fragments of insect/arthropod carapaces may be numerically significant.

D. No definite limits are set on the term "open marine". Open marine conditions, as suggested by an abundance of dinoflagellate cysts, may be indicative of periods of maximum extent of the sea or merely periods when the nutrient content was optimum for dinoflagellate productivity.

E. The two environments most easily recognised by optical analysis are sapropelic and ligno-humic (sensu Combaz) although a much finer division may be recognised if chemical analyses are carried out on the organic materials.

The Kimmeridgian bituminous sediments examined from Dorset, Yorkshire and the Boulonnais are examples of sapropelic environments. The majority of the remaining samples, with the possible exception of some of the Purbeck Bed material examined from Dorset, is assigned to the ligno-humic environment (i.e. characterised by an abundance of wood and plant material).

4.2 SOURCE ROCK POTENTIAL

A. Recent sediments, by comparison with their ancient counterparts, have low hydrocarbon contents and many of the hydrocarbons which are present in both ancient sediments and crude oils are absent. Recent sediments cannot therefore yield compounds which they do not contain and therefore they cannot source oil (Erdman 1961). With increasing burial, the missing hydrocarbons are formed and the total hydrocarbon abundance increases. This process is termed maturation. The hydrocarbons can be generated either from kerogen (insoluble
organic matter) or from the non-hydrocarbons already present (Tissot et al. 1971).

Hence, in response to the greater temperatures generated by increasing depth of burial, a negligible source potential is gradually replaced by a realisable potential for hydrocarbons.

As the temperatures increase, the sediments develop some, but still limited, potential for dry gas. At this level of maturation they are described as immature.

At higher temperatures, light liquid hydrocarbons are formed by the thermal cracking of larger molecules. The sediments are now mature and can yield oil. As thermal maturation proceeds, more and more of the lighter hydrocarbons are cracked off the heavier compounds and the source rocks yield lighter crudes which ultimately are replaced by light condensates (Durand & Espitalie 1972).

Organic metamorphism occurs at advanced levels of thermal alteration and destroys not only the ability of source rocks to yield liquid hydrocarbons but also any liquids which had previously accumulated in reservoirs. Only dry gas, which may be sour and contain significant amounts of H₂S and CO₂ can now be generated.

By definition, kerogen is that fraction of the total organic matter (commonly over 90%) which is insoluble in organic solvents. It consists of the organic matter which was deposited and survived diagenesis, modified by the products of fungal and bacterial metabolism. Kerogen varies in character as a function of the proximity of the basin of deposition to sources of land plant and algal (freshwater or marine) debris. Although source rocks are laid down subaqueously rather than subaerially, their organic matter may originate either
within the water body or from land (Rodionova & Maximov 1970).

This in turn affects the types of hydrocarbons which the sediment will yield:

(i) woody organic matter tends to be gas prone regardless of its level of maturation (Staplin, Bailey et al. 1973); (ii) epicuticular plant waxes are a rich source of paraffinic base crudes (Biederman 1969) and the associated plant material is a more prolific source of gas than algal debris, which is primarily a rich source of more normal crudes.

The best sources of oil are generally shales and siltstones, although carbonates, particularly argillaceous carbonates, can source. Sandstones are seldom significant as their organic content is not only low but has been oxidised during deposition, thus largely destroying its hydrocarbon potential.

B. Applications of this Study:

The sandstones and high energy limestones analysed in this study, from the Boulonnais, Norfolk (Sandringham Sands) and Dorset (Portland Stone and Sand) have, in general, a low organic content and thermal alteration index and are not considered to be viable source rocks. Certain of the samples are exceptional in the quality of their organic matter, but they are still very lean.

The majority of the shale and siltstone samples have thermal alteration indices of much less than 3. This implies that they are predominantly immature to submature sediments and suggests that they have the potential only for sourcing dry gas in limited quantities or where maturation is higher, heavy gas condensates and "young oils".

The bituminous rocks and oil shales of the Kimmeridgian of Dorset, Yorkshire and the Boulonnais are potentially very good source rocks, should these sediments be subjected to suitable temperatures. It may be noted, however, that
where the organic content is very high (>20% of the sediment volume) migration of liquid hydrocarbons may be prevented by their absorption upon the abundant organic matter. In this way, some very rich rocks may not realise their potential for oil (Kimmeridgian oil shales may contain more than 40% organic matter).

The least likely source rocks are present in the ?Kimmeridgian succession at Ribadesella. This material is very mature and has probably lost all its potential for liquid hydrocarbons. Several of the samples are organically rich, up to 7% (Dunn 1972), and could possibly source gas accumulations in associated reservoirs. The organic matter in these samples is woody or fusinitic, characteristic of a high level of thermal alteration; implying that the sediments would be gas rather than oil prone.

The Portuguese samples, rich in woody material, at present immature-submature, offer some potential as a possible gas source. Should these sediments be subjected to suitable temperatures the abundance of plant tissues and cuticles (rich in plant waxes) might, however, source oil. Reworking and oxidation in a relatively high energy, shallow water environment has, however, probably reduced their hydrocarbon potential.
CHAPTER 5

PALYNOCLOGICAL CHARACTERISTICS OF THE REGIONS AND THEIR DEPOSITIONAL ENVIRONMENTS

5.1 DORSET

The gradual shallowing of the Upper Jurassic sea in the Dorset area is clearly reflected by changes in the palynological character of the sediments. Marine conditions prevailing during Kimmeridge times gradually gave way, with minor fluctuations in base level, to the higher energy, probably tidally influenced, and supratidal environments of the Portland carbonates, culminating in the deposition of the Purbeck Beds over a range of environments from quasi-marine to non-marine (fluviatile and terrestrial).

Maximum depth of the sea is considered to have been attained during the deposition of the bituminous sediments within the middle part of the Kimmeridge Clay succession. An abundance of sapropelic organic matter, a relatively high diversity exhibited by dinoflagellate cysts, and to a less extent by miospores, a high proportion of chorate cysts (in particular species of Systematophora) and a general dearth of acritarchs indicates that these sediments accumulated in a low-energy marine environment with anaerobic bottom conditions. The microplankton species yielded from these sediments are at times poor, due to the obscuring nature of the bituminous, often coagulated debris.

Above the lower part of the pectinatus zone, bitumen-rich sediments and associated sapropelic organic matter decrease rapidly in importance, indicating deposition under more aerobic bottom and higher energy conditions. At about this level there are significant changes in the composition of the dinoflagellate cyst assemblages which may be equated with changes in the sediment geochemistry (Dunn 1972) and ostracod populations (Kilenyi 1969). These changes which are
FIG. 14.


A. Relative abundances of the planktonic elements (dinoflagellates and acritarchs) of the microflora.

(1) proximate dinoflagellate cysts.

(2) cavate dinoflagellate cysts.

(3) chorate dinoflagellate cysts.

B. Relative abundances of (5) planktonic (dinoflagellate cysts and acritarchs) and (4) terrestrial (spores and pollen) elements.
discussed elsewhere (p. 96), are clearly related to a major environmental change apparently resulting in increased water circulation.

Towards the top of the Kimmeridge Clay, miospores increase in importance over microplankton. Amongst the microplankton, chorate cysts become less important, peridiniacean cysts increase at the expense of gonyaulacacean cysts, the specific diversity of the assemblages decreases and acritarchs attain considerable concentrations (Fig. 14). These changes are associated with a progressive increase in importance of zirconium (Dunn 1972). In addition, there is a gradual increase in the quantity of quartz particles of silt-size grade. This is particularly evident through the zone of *Epipallaceras* sp. Furthermore, current bedding is locally developed in the silty clays within the Rhynchonella Marls and Hounstout Clay. Overall, the evidence clearly indicated that deposition took place in a shallow water, high-energy environment. A break in deposition and possibly, even emergence, is indicated by an horizon of phosphatised, rolled nodules (The Rotunda Nodule Bed).

The uppermost Kimmeridge Clay and the overlying Portland Beds are characterised by very restricted miospore assemblages, most consisting of 10-15 species, this is indicative of sedimentary sorting and winnowing, a characteristic of high-energy, shallow water environments. Local abundances of micrinite fragments and reworked palynomorphs (particularly miospores) within the uppermost Kimmeridge Clay and parts of the Portland Sand is indicative of the relative nearness of the shore-line. *Inaperturopollenites dubius* (Potonie & Ventz) is the most common miospore species from the rotunda zone to the gorei zone at Hounstout; although it does exhibit a decline near to the Kimmeridgian-Portlandian boundary. During this decline there is a gradual increase in importance of *Clas30polis turosus* (Rossinger) which reaches a maximum at the
top of the Hounstout Marl, in the Massive Bed, in the lower part of the Portland Sand and in the Emmit Hill Marls. These Classopollis maxima are associated with the diminished ratio of dinoflagellate cysts to acritarchs. The dominant acritarchs associated with these Classopollis maxima, are spinose acanthomorphs (Solisphaeridium and Micryhystridium), which constitute at times, over 80% of the total microplankton assemblage. Relatively long-spined forms are dominant towards the top of the Kimmeridge Clay (M. fragile Deflandre and S. stimulifera (Deflandre)) giving way to shorter spined forms (M. inconspicuum (Deflandre) and M. deflandrei Valensi) in the higher energy sediments of the Portland Beds. These assemblages, characterised by an abundance of Classopollis and acanthomorph acritarchs, also exhibit a low diversity of dinoflagellate cyst species; being typical of near-shore, relatively unstable environmental conditions.

Samples from the overlying Portland Stone typically yielded meagre palynomorph assemblages. The paucity of microplankton may be a reflection of the environment (high-energy, very shallow water) or a result of dilution by the sediment, requiring the processing of large quantities of sediment in order to concentrate a useful and meaningful assemblage. The preservation of both microplankton and miospores, is however, generally poor, which may in certain samples be indicative of post-depositional oxidation and subsequent destruction during diagenesis. The samples from the Cherty Series and the Freestones are effectively barren; Norris (1963, 1969) similarly recorded these sediments as barren.

The majority of the Portland Stone samples yield abundant and often large plant tissue fragments, including well preserved cuticles and tracheids. In addition, small simple algal cells are locally abundant, together with microforaminifera.
*Classopollis* is typically the dominant miospore; chorate cysts, when present, are poorly preserved or fragmented. Acritarchs, particularly short spined acanthomorphs are the dominant plankton. At the base of the Cherty Series micrhystridia constitute 54% of the total microplankton recovered, with the pteromorph species *Pterospermopsis australiensis* constituting a further 26.5%.

In general, samples from the Portland Stone contain only infrequent and poorly preserved microplankton, additional material is needed in order to obtain more representative yields.

Infrequent microplankton have been recorded from certain horizons within the Purbeck Beds by Norris (1963, 1969) thus suggesting marine conditions of deposition. Norris (1963) recorded cysts and acritarchs from the Chief Beef Beds and later (1969) from an horizon 3 feet below the top of the Broken Beds in Durlston. Brown (1964) had earlier suggested a marine origin for the Broken Beds on petrologic criteria. Originally they were thought to be supratidal evaporites.

The majority of palynomorph assemblages from the Purbeck Beds are, however, characterised by the fresh water chloropycean algae *Botryoccocus*. Together with abundant miospores and well preserved tracheids and cuticles this presumably reflects the dominantly non-marine origin of the sediments.

The bulk of the Purbeck sediments samples, with the exception of some possible dinoflagellate cysts and very rare acanthomorph acritarchs, are devoid of microplankton. Very poor assemblages dominated by acritarchs and peridiniacean cysts were obtained from the Chief Beef Beds and the Cinder Bed, Norris (1969) had earlier stated that the Cinder Bed was barren.
5.2 THE BOULONNAIS

The distribution of acritarchs and the major morphological groups of dinoflagellate cysts in the upper part of the succession is shown in fig. 15. A higher energy environment than that of the Dorset succession is well evidenced by the much greater abundance of acritarchs (dominantly acanthomorphs) and the reduced importance of chorate dinoflagellate cysts. Furthermore, the miospore *Classopollis* is numerically dominant throughout much of the succession. Palynological evidence, thus parallels the known sedimentological evidence as to the higher energy environment of the Boulonnais in comparison to that of Dorset.

Unlike the Dorset succession, bituminous sediments are very restricted in their distribution, occurring only within the Argiles de Chatillon. Even here, the organic content only rarely exceeds 10% of the whole sediment and has not been found to exceed 20% (Dunn 1972). Their occurrence here, by analogy with the Dorset succession, is taken to be indicative of conditions where the sea attained its maximum depth.

The shallowing of the sea from the Argile de la Creche through to the Calcaire des Oies is clearly reflected by changes in the palynological characters of the sediments (Fig. 15) and parallels that shown by the Dorset succession. The palynology also agrees in general with the depositional environments postulated by Ager & Wallace (1971).

Mineralogical evidence (Dunn 1972) indicates that the physico-chemical environment during deposition was more oxidising than that of the Dorset area, since glauconite and siderite are present and pyrite is nowhere well developed.
Relative abundances of the major groups of organic-walled microfossils in part of the Kimmeridgian - Portlandian sequence of the Boulonnais.

A. Relative abundances of the planktonic elements (dinoflagellate cysts and acritarchs) of the microflora.
   1. proximate dinoflagellate cysts.
   2. cavate dinoflagellate cysts.
   3. chorate dinoflagellate cysts.

B. Relative abundances of (5) planktonic (dinoflagellate cysts and acritarchs) and (4) terrestrial (spores and pollen) elements.

The environments of deposition are from Ager & Wallace (1970).
Figure 15

A

- Freshwater
- Low energy intertidal
- Low energy infralittoral
- High energy infralittoral
- Low energy deep infralittoral
- Low energy, deep infralittoral or circalittoral
- Low energy, fairly deep infralittoral

B

- Microplankton
- Species
- 50%
This is substantiated by the palynological residues. Bituminous and colloidal organic material is effectively absent in the majority of samples (except for the Argile de la Crèche). Hence, in contrast to the Dorset and Yorkshire samples, "clean palynological strew mounts" are the rule rather than the exception and palynomorphs are free from pyrite infillings and pyrite - grain pressure marks. A consequence of the higher-energy depositional conditions, however, is that palynomorphs are frequently fragmented.

From a study of the sediment types, substantiated to a certain extent by their palynological characters, it is clearly apparent that the Boulonnais succession was, in the main, deposited in a shallow water marine environment which lay in a marginal position to the Dorset depositional area. A gradual shallowing of the sea is readily indicated by the sediment types giving way to the non-marine Calcaire des Oies and overlying "Wealden Beds". Sea-level oscillations may have been effected by Cimmerian orogenic movements. This would readily account for the periodic influxes of sandstone within a predominantly argillaceous sequence.

5.3 YORKSHIRE

Dinoflagellate cysts are an important constituent of the two Kimmeridgian samples analysed from Yorkshire. Chorate cysts are the dominant morphotypes and acritarchs are relatively insignificant elements. The miospore Classopollis is numerically not very significant and bituminous and colloidal matter is abundant. Palynological evidence clearly suggests a relatively
low energy depositional environment under anaerobic bottom conditions, comparable to that in which the Dorset primary limestones were deposited.

5.4 NORFOLK

All of the Sandringham Sands samples contain dinoflagellate cysts, acritarchs and miospores, in varying degrees of abundance. Structured wood, tracheids and cuticles and fragments of black and brown wood are abundant throughout. The palynomorphs are typically well preserved and sapropelic organic material is lacking, being indicative of aerobic marine conditions of deposition. Close proximity to the shoreline is indicated by the abundance of wood fragments and in the lower samples by an abundance of Classopollis, micrinite, acanthomorph acritarchs and evidence of reworking. A low gonyaulaccean ratio is evidenced by an abundance of Pareodinia ceratophora, Muderongia simplex and species of Imbatodinium.

In the higher samples, chorate cysts (Oligosphaeridium pulcherrimum, O. complex and O. sp.) increase in importance, possibly indicative of more "open marine conditions"; although wood fragments still occur in abundance.

5.5 PORTUGAL

Both the assemblages are dominated by the genera Classopollis and Exesipollenites which together constitute approximately 70% of the total microflora of each sample. Wood tissue (cuticles and tracheids) is abundant, together with
frequent fungal spores, reworked miospores and microforaminifera. Fragments of possible insect cuticle are present and microplankton are effectively absent; a single acanthomorph acritarch was observed in the lower sample (CP6).

The restricted nature of the miospore assemblages, only 14 species and forms were recorded, is indicative of an inshore environment of deposition. A lagoonal environment is tentatively suggested by the overall palynological characters of the two samples.

The miospores and all the other organic elements are well preserved, accordingly the absence of microplankton (the sole acritarch is considered to be reworked) is believed to be a primary phenomena. This could be due to unfavourable environmental parameters such as changes in salinity or perhaps an inadequate nutrient supply.

5.6 NORTHERN SPAIN

All the samples proved to be devoid of organic-walled microplankton, the organic residues consisting of poorly preserved and darkened miospores, never numerically very abundant, and finely divided carbonised wood fragments. The thermal alteration index of the contained organic matter is accordingly very high (c. 4.0). This is believed to be due to increases in temperature and pressure brought about by stresses involved in the extensive folding and faulting of the sediments.

Three possibilities can be worked to account for the absence of microplankton:-

1. Adverse environmental conditions.

2. Post-diagenetic alteration and oxidation of the sediments.
3. Destruction by the metamorphic processes brought about by the folding and faulting.

5.7 ORIGIN OF THE SEDIMENTARY CYCLES

Cyclic deposition was first recognised by Downie & Wilson (unpublished) in the Kimmeridgian Clay of Dorset. The following cycles or rhythms have been recognised herein:-

1) 74 alternations of clay and bituminous shale are developed spanning the eudoxus to the base of the wheatleyensis zones. These are interrupted by 12 bands of sporadically occurring carbonate.

2) A rough cyclicity based on the sequence, clay - bituminous shale - oil shale - marl - oil shale - bituminous shale - clay, is repeated 9 times, with minor fluctuations, through the wheatleyensis and lower few feet of the hudlestoni zone.

3) 23 cycles based, on the sequence clay - bituminous shale - bituminous marl - limestone - bituminous marl - bituminous shale - clay, are developed partly of hudlestoni age and partly of pectinatus age.

4) Alternations of clay and bituminous shale are repeated 9 times in the sequence from the Freshwater Steps Stone Band to the base of the Hounstout Clay.

5) To some extent, clays and shales alternate within the uppermost 150 feet of the Kimmeridge Clay (Hounstout Clay and Marls of Arkell).

These cyclic and rhythmic units of deposition appear to extend over a wide area. Similar alterations of sediment types are developed within the Kimmeridge Clay of the Warlingham Borehole in Surrey, Yorkshire and Lincolnshire.

Rhythms based on what are essentially alternations of shales and sandstones are developed within the Kimmeridgian - Portlandian of the Boulonnais.
The cycles of deposition are considered to represent the following changes in the depositional environment:

Clays: Aerobic bottom conditions, abundant benthos, moderate diversity. Dispersed organic matter. Influxes of terrigenous material, distributed by gentle currents.

Bituminous Shale: Slightly aerobic bottom conditions, benthos generally abundant but erratically distributed. Sapropelic organic matter and colloidal organic matter accumulating at the expense of terrigenous material. Weaker and more sporadic bottom currents.


Bituminous Marl: Anaerobic bottom conditions. Calcareous nannoplankton and colloidal and sapropelic organic matter abundant, ?seasonal alterations. No bottom currents, negligible body fossils and terrigenous material, but trace fossils (burrows) are present.

Coccolith Limestone: Anaerobic bottom conditions. Calcareous nannoplankton appear to alternate seasonally with dinoflagellates, the latter associated with colloidal, bituminous and sapropelic matter. No bottom currents, no body fossils, but trace fossils (burrows) are present. Negligible terrestrial influences.

If the main source of the bituminous and colloidal organic matter was planktonic, the rhythmic sedimentation and the replacement of oil shales by coccolith limestones would have to be attributed to changes in the surface waters of the sea body over a wide area and would be indicative of a climatic cause.

Although plankton are considered to have contributed much to the organic matter,
it is not believed to be the prime source. A probable mode of origin is that the bituminous matter accumulated in coastal swamps and lagoons and was subsequently redistributed.

When examined in thin section the highly bituminous sediments are seen to contain lenticular masses of reddish brown organic matter. The form and apparent homogeneous composition of the "globules" suggests that it most probably formed in the flocculation of a dopplerite gel. It is tentatively suggested that they are the products of the decay and degradation of wood cellulose tissue, but only a chemical analysis could confirm this.

It thus appears that the organic matter formed in coastal swamp. Its subsequent redistribution could be therefore ascribed to periodic earth movements. If this is the case, the clays represent periods of regression, the oil shales and coccolith limestones periods of transgression.

Evidences for periodic earth movements are three fold:-

1) The alternations of Classopollis and Inaperturopollenites dominated miospore populations within the Kimmeridgian - Portlandian.

2) Fluctuations in organic-walled microplankton populations, in particular the relative abundances of chorate dinoflagellate cysts and acanthomorph acritarchs.

3) The Kimmeridgian - Portlandian of the Boulonnais, which is marginal to the Dorset depositional basin, consists of a predominantly shallow water argillaceous sequence interrupted by influxes of coarse detrital sediments (sandstones), which can be readily explained by base level oscillations. The sandstones accordingly may be possibly considered to represent migrating sandbanks lying across to the shoreline and maximum terrigenous influence (Ager & Wallace 1966). Terrigenous influence waning towards the centre of the
basin with the deposition of the shales, being virtually absent during the deposition of the coccolith limestones.

5.8 **ORIGIN OF THE PRIMARY LAMINATED CARBONATE BANDS**

Primary laminated carbonate bands are only developed within the Kimmeridge Clay of Dorset and Yorkshire. In the field their appearance varies according to the carbonate content and the degree of weathering. Bands with a high carbonate content are cream to chalky white in colour and distinctively laminated; bands relatively poor in carbonate are generally grey and generally unlaminated.

When developed, the laminations consist of layers of carbonate alternating with layers of organic material. The carbonate bands are composed of calcite, the bulk of which is contributed by coccolithophorids. The organic layers are composed of structureless and colloidal organic matter and organic walled microplankton. Rafted wood and plant tissue fragments and miospores are present in both type of layers.

The laminations can be traced laterally over a considerable distance. Clearly, they are an original sedimentary feature and appear to be due to the periodic replacement of one phytoplankton group (coccolithophorids) by another (dinoflagellates).

Dinoflagellates could have flourished in the cooler waters of late summer and spring (in general recent marine forms favour such conditions), with coccolithophorids replacing them in the warmer summer waters. Rodhe (1933) has, however, found indications of increased productivity of present day calcareous nannoplankton (i.e. coccolithophorids and related forms), during the winter months under circumstances in which virtually no light could have been
available. He concluded that chemetrophic, rather than phototrophic growth was taking place at the expense of dissolved organic matter. Such a mechanism during the formation of the carbonate bands would readily account for the very low organic content of the coccolith layers. Similar chemetrophic growth has been observed by Bernard (1963) who reported that calcareous nannoplankton are often as abundant at depths below the photic zone as they are within it. Either way, seasonal changes in phytoplankton populations most readily explain the alternation of calcitic and organic layers.

Work by Krumbien and Garrel (1952) on sedimentary mineral associations with respect to pH and Eh suggested to Dunn (1972) that the Dorset Kimmeridge Clay accumulated in a slightly alkaline environment of negative pH. During the formation of the bituminous sediments Dunn concluded that the Eh may have dropped to less than -0.3 volts with the pH remaining constant between 7.0 and 7.8. An increase in the pH of the Kimmeridgian sea would have resulted in the precipitation of calcium carbonate (and its availability for coccolithophorid skeletal formation); since the carbonate bands are bituminous, the Eh must have remained constant at about -0.3 volts. Intense phytoplankton productivity (photosynthesis) within the photic zone would have brought about a rise in pH of the water mass to around 9.4 (Baas Becking et al. 1960, Fogg 1965); accordingly the periodic appearance of the primary carbonate bands are considered to represent periods of intense phytoplankton productivity. The laminations are very similar in size and appearance to annual varve deposits forming at the present time in the Black Sea. The Black Sea carbonates are, however, formed totally by direct precipitation from the sea water (Archangelsky 1927, Evans 1971). If, however, an analogy can be drawn between the two, then during the formation of the Kimmeridgian carbonates, sediment accumulated at the rate of
FIGS. 16, 17.

Geochemical and palynological characteristics of the Main Coccolith Limestone (base of *pectinatus* zone), Dorset.

Fig. 16. is from Dunn (1972) and reproduced with the authors permission.

Fig. 17. Relative abundances of the major groups of organic-walled microfossils.

A. Relative abundances of the planktonic elements of the microflora.

1. proximate dinoflagellate cysts.
2. cavate dinoflagellate cysts.
3. chorate dinoflagellate cysts.
4. acritarchs.

B. Relative abundances of the planktonic and the terrestrial elements.

5. spores and pullen.
6. dinoflagellate cysts and acritarchs.
7. microforaminifera.
Fig. 48  Trace Element Variation Across the Main Coccolith Limestone (base of Pectinatus Zone)
about 0.4 mm per year.

Cyclic fluctuations can be recognised within the laminated bands. Within the Main Coccolith Limestone (=White Limestone Band or White Band of various authors), developed at the base of the pectinatus zone, fluctuations can be seen between pairs of laminae with a thick carbonate layer and pairs with a thick organic layer. These fluctuations culminate at intervals of 8 or 16 laminae and as suggested by Downie and Wilson (unpublished) may possibly be related to the 11 year cycles recognised in solar radiation.

Dunn (1972) carried out an investigation of the trace element geochemistry of the Main Coccolith Limestone and demonstrated that the primary carbonate bands show a pronounced dearth of all trace-elements, the Main Coccolith Limestone consisting of 96% calcium carbonate. He also demonstrated a decreasing concentration of trace-elements from the underlying shale into the overlying shale (Fig. 16). These changes, he concluded, are simply a function of the clay mineralogy which in itself is affected by environmental changes.

Splits of the samples analysed by Dunn from the Main Coccolith Limestone were examined during the present study (Fig. 17). Miospores dominate the palynomorph assemblages, constituting between 78 and 99% of the total organic-walled microflora. Among the organic-walled microplankton, chorate cysts are the dominant forms; acritarchs are relatively unimportant, constituting less than 5% of the total population. The Oil Shale Band within the limestone is virtually devoid of microplankton, its organic residue consists predominantly of wood tissue fragments, colloidal and structureless organic matter; miospores are moderately abundant with dinoflagellate cysts and acritarchs constituting less than 1% of the total organic-walled microflora. This suggests, that for this thin unit, the bituminous matter is predominantly derived from the breakdown of plant
Miospore assemblages from the limestone band are fairly well diversified, bisaccate grains are common and Inaperturopollenites is numerically dominant over Classopollis.

Inorganic material contributes very little to the total composition of these limestone bands, accordingly the abundance of palynomorphs and other organic material is possibly more apparent than real, as they are not diluted to any great extent by terrigenous matter.

Overall, these facts, together with the available sedimentological evidence, appear to indicate that the Main Coccolith Limestone was deposited in a low energy environment some distance from land. Water depth is difficult to determine, it may have been a fairly deep water basinal environment or more probably an extensive shelf sea environment.

Regardless of the depth of formation of these carbonates, they were clearly formed under anaerobic bottom conditions. This is evidenced by the dearth of benthos, the preservation of the bituminous matter and the presence of pyrite in the acid insoluble residues. Many of the palynomorphs possess mineral impressions and ornamentation due to the pressure of pyrite mineral grains during compaction of the sediment.

At the top of the Main Coccolith Limestone Band, Dunn (1972) recorded a strong increase in Cr which continues for a short way into the overlying shales. Krejci-Graf (1964) has suggested that high concentrations of Cr might be indicative of marine gyttja sediments (dark pyrite free shales lacking in organic matter). The shales do in fact lack pyrite, palynomorphs accordingly lack mineral grain impressions and organic material is somewhat lacking.

Immediately below the limestone and within its lower few centimetres,
Microforaminiferal test-linings are a fairly common constituent of the total palynomorph assemblage (up to 6%). These are considered to represent larval stages of foraminifera. Their sudden increase in importance at this level cannot be readily explained, although it must be related to some environmental control. Throughout the rest of the Dorset Kimmeridge Clay succession they are rare to absent and irregularly distributed.

Passing from the Main Limestone Band into the shales, both above and below, there is an increase in the relative abundance of chorale dinoflagellate cysts (forms with long processes of varying nature and elaboration) and a decrease in the sporomorph to organic-walled microplankton ratio. This is taken to be due to an environmental control most readily explained by a change in water depth, possibly with a decreased distance from the landmass, and an increase in water circulation bringing in terrigenous inorganic material. This would be most readily explained by a change in base level.
CHAPTER 6

PALAEOGEOGRAPHY AND TECTONICS

6.1 GENERAL DISCUSSION

Considerable similarities are evident between the Kimmeridgian microplankton assemblages recorded from Dorset, Yorkshire and the Boulonnais. These similarities are so great as to make it virtually certain that these areas were all part of one plankton province in one water body. This does in fact agree with what is known of Kimmeridgian palaeogeography (Fig. 18). The assemblages from the Boulonnais reflect its position marginal to the depositional basin; Dorset and Yorkshire appear to have been more central, in deeper water away from the landmass.

North Spain clearly lay on the northern margin of a southern landmass. Continental deposition took place on an eroded surface of Lower Jurassic sediments, followed by a brief period of freshwater sedimentation before the onset of marine conditions. The Bay of Biscay would have closed at this time; accordingly the depositional basin could have extended across to the Aquitaine Basin, or it could have linked up with the Dorset - Boulonnais Basin to the north.

The Upper Jurassic sediments exposed at Cabo Espichel are considered to be probably lagoonal, being deposited on the eastern margin of the Lusitanian Basin. This basin is considered to have been clearly divorced from the northern basin(s). It is tentatively believed to have been a shallow-marine embayment, closed to the north, but with limited southerly communication to the Proto-Atlantic across a barrier reef.

Fig. 19 is a series of cartographic impressions of Britain during the closing stages of the Jurassic.
FIG. 18

Sketch map of the relationship between land and water masses in Upper Kimmeridgian times. (hachured areas are land).

From Dunn (1972).
The open seaway across England disappeared towards the end of Kimmeridge Clay times when the Upper Kimmeridgian uplift, part of the so-called Cimmerian orogenic movements, resulted in the formation of two basins of contrasting facies.

Early less pronounced, but related earth movements possibly resulting in fluctuations of base-level appear to have been responsible for the cyclic/rhythmic sedimentation characteristic of the English and French Kimmeridgian.

The southern basin was essentially non-marine consisting of swamps and lagoons in which the Purbeck and Wealden Beds were deposited. The northern basin, in which the Sandringham Sands, Spilsby Sandstone and Speeton Clay were deposited, was an area of marine deposition. The marine regression in the south brought about by the uplift is clearly reflected in the changing palynological characters through the Upper Jurassic successions of Dorset and the Boulonnais.

There is an apparent absence of the Portland Sand fauna in the northern basin (Casey 1971) although it is not yet possible to say whether this is indicative of drastic shrinkage and isolation of the basin during the Portlandian. The biostatigraphic record may well be incomplete in the basal nodular horizons of the Sandringham Sands and Spilsby Sandstone. There was, however, probably limited or intermittent communication between the two basins (Wills 1951, Casey 1971).

Casey and Bristow (1964) suggest that an isthmus across Bedfordshire in early "Purbeck" times barred access to the northern sea from the southern basin. That this barrier was breached, albeit temporarily, may be inferred...
FIG. 19

a. Cartographic impression of England during the early Kimmeridgian stage of the upper Jurassic.

b. Cartographic impression of England during the late Kimmeridgian and early Portlandian (Volgian) stages of the upper Jurassic.

c. Cartographic impression of England during the late Volgian (early Purbeck) stage of the upper Jurassic.

From Casey (1971).
from the infrequent occurrence of microplankton at certain horizons in the Dorset Purbeck Beds (pers. obs.) and Wealden Beds (Batten 1974, pers. comm.). The microplankton assemblages are, however, at their best only indicative of quasi-marine conditions. A more pronounced breaching of the barrier is evidenced by the Cinder Bed at the presumed base of the Cretaceous. If this horizon is traced northwards the increasing marine aspect of the molluscan fauna clearly indicates that the sea breached the isthmus and entered the southern basin from the north, (Casey 1963, Casey & Bristow 1964). Normal marine communication between the two basins was not, however, established until the Aptian.

The uplift responsible for delinating the two depositional basins in England is considered by Casey (1971) to be essentially a movement within the Caledonian Belt. Casey further considers that subsequent movements of re-adjustment along the Hercynian front, such as the Osterwald phase of Saxonian folding, may have contributed to the emergence of the isthmus across Bedfordshire in Late Portlandian times leading to the elevation and reworking of Upper Portlandian sediments in the northern basin. The nodule horizons between the Roxham and Runcton Beds (Sandringham Sands) may well be due to these subsidiary movements. The occurrence of reworked Kimmeridgian palynomorphs in the basal Runcton Beds also implies that in some areas Kimmeridgian sediments were exposed by uplift and erosion and subsequently reworked.

These late Jurassic movements also gave rise to terrestrial conditions in the southern basin (albeit temporarily) as indicated by the soil horizons in the Purbeck Beds.
Fig. 20 illustrates the tectonic framework of northern Europe and the deep-seated geological structures mentioned above. From this it can be clearly seen that the northern basin is tectonically part of the Russian Platform. Its affinities with the Russian platform are also clearly shown in the nature of its shelf-like sediments and its marine macrofauna and microflora. The clastic deposits of the Sandringham Sands and the Spilsby Sandstone, rich in glauconite and phosphorite nodules, are clearly reflected in the condensed Volgian and Ryazanian sediments of the Moscow Region (Casey 1971). Their ammonite faunas can be matched nowhere else but on the Russian Platform. The strong similarities between the microplankton assemblages of these two regions, rich in numbers of *Imbatodinium* and *Gonyaulocysta*, also indicates very clearly that they were both essentially part of the same water body within the Boreal Realm.

The affinities of the southern Dorset - Boulonnais Basin are clearly with the Tethyan Realm although it is part of the Boreal Realm. The sediments are in fact examples of Hallam's (1969) "intermediate facies association". In Late Jurassic times the Hercynian troughs lying south of the Russian Platform were the site of active subsidence and the deposition of predominantly calcareous sediments. These sediments are examples of Hallam's (1969) "calcareous facies association", the typical Tithonian. The Portland carbonates and Lower Purbeck Beds of southern England and the "Purbeckian" algal limestones of the Boulonnais can accordingly be interpreted as the northern limits of this calcareous or Tethyan province (Hallam 1969, 1971; Casey 1971).

The late Jurassic movements responsible for the delimitation of the two contrasting basins of deposition are perhaps "the nearest approach to mountain
FIG. 20 Tectonic framework of northern Europe (from Casey 1971.)
building in the whole of the so-called Cimmerian Orogeny" (Casey 1971). They appear to be coincident in time with the Nevadan Orogeny of North America, and it is interesting that the movements lay within the mobile belt (Late Precambrian) along which Sutton (1968) considers the Atlantic Ocean to have been formed.

6.2 THE UPPER KIMMERIDGIAN UNCONFORMITY

A conspicuous break in sedimentation is evident at the top of the Kimmeridge Clay in some parts of Britain. Typically developed in the Southern Midlands, the break is represented there by the Upper Lydite Bed which forms a persistent basal unit to the Portland Beds from Swindon to Aylesbury (Arkell 1933, Casey 1971).

Casey (1963) considers the bed to constitute a "basal conglomerate" of the Portland Beds in that area. He interpretates it as a local expression of a more widespread interval of inhibited deposition that widens northwards to embrace the basal beds of the Sandringham Sands and the Spilsby Sandstone and eventually becomes incorporated in the much larger gap denoted by the "Coprolite Bed" at the base of the Speeton Clay in Yorkshire. Throughout its outcrop from Wiltshire to the Yorkshire Coast (Arkell 1933) the bed is characterised by an abundance of black chert pebbles ("lydites") and rolled and phosphatized macrofossils (particularly ammonites) derived from the underlying Kimmeridge Clay. As a result of the recent re-interpretation of the ammonite zones at the top of the Kimmeridge Clay it is now possible to interpret the rotunda nodules of the Dorset succession and the Tour de Croi Nodule Bed of the Boulonnais as the southernmost representatives of this important stratigraphical horizon in the British Mesozoic.
At Chapman's Pool in Dorset, the Rotunda Nodules are only slightly phosphatic indicating that the centre of the depositional basin experienced only a slight pause in deposition in contrast to the more protracted period of phosphatization and reworking experienced in the more marginal areas (Lloyd 1959). Already as noted by Arkell (1947) the condensed rotunda succession resembles the Upper Lydite Bed at Swindon. The former wide distribution of this horizon is evidenced by the phosphatized rotunda fauna found derived in the Lower Cretaceous deposits of the Weald, (Casey 1967)

The Tour de Croi Nodule Bed, in the Boulonnais, marks a distinct change in lithology (to much darker clays) and an unconformity in which the presumed equivalent of nearly 40m of the Portland sands of Dorset are missing (Ager and Wallace 1966), forming a basal conglomerate to the Assises de Croi. This more significant break in deposition is a consequence of its position, marginal to the centre of the Anglo - Paris depositional basin.

In the North Sea Basin this non-sequence includes the uppermost Kimmeridgian, Portlandian and a large part of the Neocomian.

On the reasonable assumption that the Pavlovia zones of the Dorset Kimmeridge Clay are homotaxial with the Pavlovia pavolva zone at the base of the Middle Volgian of the Russian Platform, this regional unconformity, in terms of Boreal stage nomenclature may be dated as Middle Volgian.

With regard to the provenance of the chert pebbles, Neaverson (1925) noted how they tail out southwards from Buckinghamshire and he thereby infers a northerly source. Palaeocurrent directions obtained from the geometry of cross-bedding exhibited by sands within the Boulonnais succession similarly suggest that the source area lay to the north or north-west.
Within the Upper Kimmeridgian of Dorset a number of important palynological, micropalaeontological and geochemical changes take place.

Immediately after *hudlestoni* times a marked change in the overall geochemistry of the sediments is evident (Dunn 1972). Limestones appear at the expense of dolomites and the organic matter content of the sediments (and its associated trace elements) drops sharply. This can be equated with changes in dinoflagellate cyst and ostracod assemblages. A marked floral break is evident in the dinoflagellate cyst populations. From the *pectinatus - rotunda* zones upwards; they acquire a Lower Cretaceous character and there are several well marked appearances and the genera *Hystrichodinium*, *Imbatodinium* and *Muderongia* attain some considerable importance. Although these assemblages retain an Upper Jurassic aspect, they are readily distinguished from earlier Kimmeridgian assemblages. A major faunal break in ostracod populations similarly takes place (Kilenyi 1969). The *pectinatus* to *rotunda* zones contain ostracods in large numbers in the form of a completely new assemblage, far less rich in terms of both species and individuals than the fauna of the lower horizons of the Kimmeridgian. The Lower and Upper Kimmeridgian (*sensu anglico*) have 36 and 21 species of ostracod respectively, with only 1 species common to both.

These changes also correlate with the important change in the macrofauna which takes place at the base of the Argile de Wimereux in the Boulonnais succession (Ager & Wallace 1966a, p405); the La Rochette Nodule Bed, which defines the base of the Argile de Wimereux, is at approximately the same stratigraphical level as the Dorset Coccolith Limestone.
Clearly, these changes are a reflection of a major environmental change, which would be most readily explained by changes in the pattern of water circulation. Casey (1971) has suggested that the North Atlantic began to open in the Upper Jurassic, using as his argument the distribution of Mesozoic phosphatic nodules (discussed below). Accordingly, these changes may be related to changes in oceanic currents brought about by the rifting of the North Atlantic.

Kazakov (1937) and Sheldon (1964) have demonstrated that present day phosphate deposits are found in warm climatic regimes and chiefly in areas of oceanic upwelling brought about by divergence of oceanic currents. Deposition of phosphates occurs mainly along the west coast of continents or in large mediterranean-seas developed along the equatorial side of the depositional basin. Lesser concentrations form in areas of dynamic upwelling along the eastern coasts of continents (McKelvey 1967).

A large circulating gyral in each hemisphere constitutes the main elements of McKelvey's (1967) analysis of an idealised oceanic circulation system. Cool water from the polar regions moves along the east side of the ocean towards the equator, with warmer water from the equatorial zone moving polewards along the west side. Phosphate and nutrient-rich cold waters, aided by the seawards movements of coastal surface waters resulting from the combined effects of the trade winds and Coriolis Force, wells up along the western margins of the continents. The subsequent rise in temperature and pH of the upwelling water mass saturates it with respect to calcium phosphate which is precipitated onto the sea-floor by organic and/or inorganic agencies. Similar phosphatisation processes also take place along the equatorial zone and other situations where two oceanic currents diverge (fig. 21).
FIG. 21. Surface circulation in an idealized ocean, showing areas of ascending nutrient-rich water (from Mckelvey 1967)
Fossil phosphate deposits have a wide geographic distribution, whereas modern deposition takes place between the 40th parallels. This apparent anomaly (some fossil phosphates occur in geographical positions where the producing processes could not operate today) is however, readily explained by allowing for continental drift. A fairly close correspondence between the latitudes of modern phosphates and the palaeolatitudes of fossil phosphates is clearly evident when this is allowed for (Casey 1971).

There is abundant evidence of local pauses and breaks in sedimentation in the British Jurassic and Cretaceous. In the Lower Cretaceous and the base of the Upper Cretaceous beds of phosphorite nodules, frequently accompanied by glauconite, are the normal expression of depositional pauses. Higher in the Cretaceous succession, hard grounds developed within the chalk, maintain the link between interrupted sedimentation and phosphatization (Bromley 1967). In the main part of the Jurassic there is, however, a conspicuous absence of phosphatic nodules. They are absent in the Oxford Clay and increase in importance in the Kimmeridge Clay, but it is not until the Upper Kimmeridgian break that phosphatization is developed on a large scale in the British and French Mesozoic. In this respect these sequences are typical for north-west Europe, where pre - Upper Kimmeridgian phosphatization is very insignificant in comparison to the extensive developments characteristic of offshore deposition in the Cretaceous (Casey 1971).

This relatively sudden introduction of phosphatization into the sedimentary pattern of the north-west European Mesozoic towards the end of the Jurassic, can be explained by (1) a northward shift of climatic belts relative to the continents, or (2) a change in the oceanic circulation system.
Little is known of Mesozoic climates, but the available evidence does not lend support to any ideas of a strong shift of late Jurassic climate belts (Bowen 1961; Casey 1971, 1973). A change in the oceanic currents seems therefore to be more likely.

The phosphate deposits in the Upper Jurassic - Lower Cretaceous of north-west Europe are commonly nodular, containing phosphatized shells and typically occur in an arenaceous or argillaceous matrix seldom more than a few feet thick (e.g. the Rotunda Nodules of the Dorset Kimmeridgian and the Tour de Croi Nodule Bed of the Boulonnais Kimmeridgian). It therefore appears to be typical of phosphate deposition on the stable-areas or platforms adjacent to regions of cold-water upwelling associated with the divergence of oceanic currents (McKelvey 1967, pp. 10-11).

Recent work on the problems of continental displacement during the Mesozoic have generally favoured a Cretaceous age for the opening of the North Atlantic, (Sutton 1968, Allen 1969). On geophysical grounds, however, there is evidence to support an Upper Jurassic opening for the southern North Atlantic (Vogt et al. 1971). Casey (1969) considers, however, that the data concerning the formation and distribution of phosphates may be deemed to favour a Late Jurassic age and comments that this would fit in with the presence of Upper Jurassic rocks on the sea floor off the Canary Islands. By Middle Volgian times, Casey suggests that the North Atlantic rift had opened sufficiently to allow for the development of a typical oceanic circulation system. The shallow epicontinental seas leading off from the European side of the early North Atlantic would then come under the influence of the cold phosphate-rich waters welling up along the western side of the new continent.
The overall evidence, palaeontological, geochemical and sedimentological, therefore strongly suggests that the North Atlantic began to open in Upper Kimmeridgian times. Whether or not the Upper Kimmeridgian of Britain and France marked the final rupture of the North Atlantic Rift is debatable, but it appears to represent some deep-seated structural change, of which diversification of faunal provinces in north-west Europe was a superficial by product (Casey 1971).
CHAPTER 7

THE GENERAL NATURE OF THE MIOCSPORE AND
MICROPLANKTON ASSEMBLAGES AND THEIR
STRATIGRAPHIC SIGNIFICANCE

7.1 GENERAL NATURE OF THE PALYNOMORPH ASSEMBLAGES

The quality of preservation of the organic-walled microplankton and miospores varies considerably. A large proportion of the microplankton is unidentifiable, but in many instances they are abundant enough for good recognisable specimens to be found. In general only 60-80% of the total microplankton assemblage from a given sample could be identified to specific level, in several instances the recovery was much lower. Accordingly a qualitative rather than quantitative approach has been used in this study.

Preservation is poorest in those sediments which have undergone recrystallisation, which has apparently rendered most of the organic material unrecognisable. Bituminous sediments have also yielded little in the way of recognisable elements. Many of the organic-walled microfossils recovered from these sediments have a strong ornament imprinted on them due to compaction among pyrite mineral grains and, in some of the limestones, possible coccoliths.

Specimens from high energy environments are typically fragmentary and damaged; apparently a function of the environment of deposition, due to abrasion with inorganic sedimentary particles.

The Spanish material is consistently carbonised and therefore unrecognisable.

In general, the better preserved residues, mainly from low-energy, lagoonal and non-marine environments are, unfortunately, from the point of view of this study, effectively devoid of organic-walled microplankton.
Miospore assemblages from the Kimmeridge Clay, Portland Beds and Purbeck Beds of Dorset have been adequately described by Norris (1968, 1969) and, to a lesser extent, by Couper (1958) and Lantz (1958). Many of the dispersed miospore species recorded from these beds can be assigned to natural plant orders and families. By doing so (see Norris 1969, p. 207) it is evident that miospore assemblages spanning the Jurassic - Cretaceous boundary represent predominantly pteridophyte/gymnosperm associations. Lycopsids appear to be less important than filicalean elements, although some spores of possible pteridophyte affinity may belong to this group.

Many of the samples examined in this study are dominated either by Classopollis torosus (Reissinger) or Inaperturopollenites dubius (Potonie & Venitz). Together the two species usually constitute at least 70% and occasionally more than 90% of the total miospore flora. Relative abundances of the two species are of little use for stratigraphic purposes, but some palaeoecological significance may be attached to them.

From studies on samples collected in sequence from the marine Upper Jurassic, Norris (1969) recognised three distinctive miospore suites. These he considered to delimit broadly similar miospore assemblages, presumably derived from the same vegetational source. The composition of these suites is illustrated in Fig. 22.

The Kimmeridge Clay, Portland Beds and the basal Purbeck Beds of Durlston Bay are characterised by Suite A. At Hounstout Cliff Norris reported Suite A as occurring from the highest 20 feet of the Crushed Ammonoid Shale to immediately below the Lower Parallel Band. At Durlston Bay he recorded it from the Lower Purbeck Beds, almost to the top of the Broken Beds. All of the
FIG. 22.

Composition of Norris' (1969) microfloral suites showing persistent species (unbroken lines) and spasmodic species (broken lines).

From Norris (op. cit.).
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constituent species occur in the overlying Purbeck Beds and many of them have been reported from the Lower to Upper Jurassic by Couper (1958), Lantz (1958) and Wall (1965). Norris was unable to extend the Suite into lower strata, owing to his lack of material from lower horizons. The writer, however, has observed nearly all of the constituent species of Suite A throughout the Kimmeridge Clay. Although the miospores were not studied in detail the writer is of the opinion that the Suite can be recognised throughout the Kimmeridge Clay. Many of the assemblages from the Lower and Middle parts of the Kimmeridge Clay, however, are much more diverse in terms of specific composition than those of the uppermost Kimmeridge Clay, Portland Beds and Lower Purbeck Beds.

The restricted nature of the miospore assemblages in the Upper Kimmeridge Clay to Lower Purbeck Beds succession (most assemblages consist of 10-15 species) is probably the result of the combination of several factors. The Upper Kimmeridge Clay and Portland Beds comprise marine sediments deposited in an offshore environment (the Lower Purbeck Beds of Durlston Bay are also marine or brackish). Considerable sedimentary sorting of the miospores by both wind and water is likely and quite possibly may have resulted in only a fraction of the total available miospores from the adjacent land reaching the depositional site. The relative impoverishment may also have been accentuated by an extremely limited flora occupying the coastal margins at the time.

Suite A consists predominantly of coniferalean elements, with a few filicalean, lycopsid and other pteridophyte species. Its characters and affinities are those typical of the Upper Jurassic.

Coniferalean elements remain as important constituents of Suite B, but pteridophytes begin to diversity and bryophytes appear as rare elements. Suite B characterises most of the Lower Purbeck and the lower part of the Middle
Purbeck Beds. At Durlston Bay the Suite occurs from the base of the Marls with Gypsum and Insect Beds up to Bristow's (1857) Bed 53 in the Upper Building Stone.

Pteridophytes show a greater increase in diversity in Suite C, although coniferalean elements remain the most diverse persistent constituents. Bryophytes, although still rare, are more common than in Suite B. Suite C occupies the remainder of the Upper Building Stone to the top of the Marble Beds and Ostracod Shales. This Suite has a strong Cretaceous aspect evidenced by the persistent occurrence of species of *Cicatriconisporites*, although it still retains some typically Jurassic characters.

Cycadophytes are rare elements in all of the three Suites. *Classopollis torosus* and *Inaperturopollenites dubius*, the numerical dominants in all of the suites, are both coniferalean species, although some of the inaperturate grains could be derived from equisetalean plants (Batten 1968).

The three Suites accordingly represent a progressive diversification of the miospore assemblages. Each of the Suites is characterised by the appearance of new species. No well marked extinctions are evident, although Norris (1969) reported that local ranges may be restricted in some sections in southern England. Most of the characteristic species of each Suite are rare types, which makes the assigning of individual samples to Suites very difficult. For this reason, no attempt was made to delimit the extent of the three samples in the other successions examined in this study.

The characteristic species of each Suite were observed in the Boulonnais material, but in general the assemblages are much more restricted in terms of specific composition than those from equivalent strata in Dorset. This is considered to be a function of the higher-energy, shallow water conditions of the Boulonnais Kimmeridgian - Portlandian, with consequent sorting and winnowing.
as outlined above.

Miospore assemblages from the Yorkshire Kimmeridgian appear to have close affinities with Suite A.

The Portuguese assemblages (Riley in press) do not correspond directly to Norris' Suites; they appear to represent a mixing of forms typical of Suites B and C.

The Sandringham Sands assemblages are at present being examined in conjunction with Dr. D. J. Batten (B. P., Aberdeen) and Mr. M. J. Fisher (Robertson Research, North Wales) and will be the subject of a future publication. For the present it is perhaps sufficient to comment that species characteristic of the three Suites have been recognised and that Cicatricosisporites and Trilobosporites (indicative of Suite C) are particularly abundant in the upper assemblages.

Progressive diversification of the Suites may be a result of evolution, local phytogeography or changing sedimentary environments. Local palaeogeographic control appears to be severe and does not allow for the use of individual species as "index" forms or key species for fine correlation.

7.3 MICROPLANKTON

Although the writer believes that dinoflagellate cysts will ultimately provide a method of stratigraphic correlation equally as accurate and more widely applicable than do the ammonites, it is felt that there is no need at present to produce a scheme of formal microplankton zones comparable to that produced, for example, for the Upper Cretaceous by Clarke & Verdier (1967).

In the accompanying charts the data is therefore presented where possible in terms of ammonite zones or of stages that are by definition groups of zones.
The presentation of the charts is arranged in such a way as to be especially useful to palynologists, generally working for oil companies, whose sample material sometimes consists of ditch cuttings and who work down-well.

The Dorset and the Boulonnais sections are interpreted as containing a number of local informal microplankton zones. In Dorset six zones are recognised, these are labelled D1 to D6 on Enclosures 1a - c. Five zones are recognised in the Boulonnais, these are labelled B1 to B5 on Enclosures 2a - b.

Microplankton zones have not been recognised in Yorkshire or Norfolk due to the lack of samples collected in sequence. The two assemblages examined from Yorkshire are, however, interpreted as being to the same microplankton association, termed here Y1. Three distinct microplankton associations are recognised in the Norfolk material, labelled N1 to N3 on Enclosure 3.

Inter-regional variation is considered to be due to a combination of phytoplankton evolution and local environmental control which makes correlation between the local zones and associations difficult.

The distribution and ranges of particular species is not constant between the sections examined, which suggests that factors other than phylogenetic evolution and extinction are important in determining individual ranges. The gradual shallowing of the Upper Jurassic sea in the Dorset and the Boulonnais regions and the consequent changing environmental parameters and inter-regional variation in the ranges of certain species is an example of Sylvester-Bradley's (1971) "ecological succession". Species disappear and may perhaps reappear later as conditions change. In those instances where species do not recur, however, it is sometimes difficult to determine whether these "extinctions" are phylogenetic or simply a response to a change in environment.

It can be seen that these informal zones and associations are not a complete
answer to the problem of zonation of these successions. Rather, the zonation and associations here presented must be considered as a tool to be used in conjunction with zonation schemes based on other fossils.

It is certainly not unsettling to discover that the ranges of dinoflagellate cysts and acritarchs do not coincide with those of other fossil types. Having been planktonic forms, dinoflagellates and acritarchs occupied completely different environments from those occupied by benthonic organisms such as the agglutinated foraminifera and ostracodes which are found in the Upper Jurassic and Lower Cretaceous. Even ammonites, which were planktonic or nektonic, were undoubtedly affected by environmental stresses different from those which affected the dinoflagellates and acritarchs. Because of these differences, whatever they may have been, one would expect the character of populations of different kinds of organisms to change at different rates and at different times, and that this would lead to an overlap of stratigraphic units which are based on different kinds of organisms.

Although there is some controversy over the definition of the term "zone" the usage of this term in an informal sense in this thesis does not violate the usage prescribed by the 1972 Subcommission on Stratigraphic Classification where zones are considered as biostratigraphic units quite apart from chronostratigraphic units such as stages. As such they can be considered to be biozones (op. cit., p. 307). Since the informal zones proposed here are meant to convey some time significance, they would be considered to be Concurrent-Range Zones in the sense of the Subcommission (p. 308). They are certainly defined in a similar manner as are Concurrent-Range Zones, with some species beginning in a zone, some ending there, and others confined to it.

The informal zones and associations have been proposed to systematically
organise the sediments examined in this thesis into units based on content and
distribution of dinoflagellate cysts and acritarchs. They may have significance
not only simply as distinctive features of the sediments, but also as indicators
of the depositional environment and, particularly, as guides to the age and
time-correlation of the sediments.

The informal zones and associations are described below by regions. It
must be borne in mind that the boundary lines between the zones are not sharp
and that there is some overlap of species.

DORSET (Enclosures 1a - c)

1. Informal Zone D1

Base of Zone

First appearance of *Ectenodinium egemenii*, *Polystephanephorus sarjeantii*,
*Hystrichosphaeridium petilum*.

Top of Zone

Last appearance of *Stephanelytron scarburghense* and the base of *Gonyaulacysta
longicornis*.

*Dingodinium tuberosus, Barbaraea jurassica, Imbatodinium antennatum* make
their first appearance within this zone. *Scriniodinium dictyotum* subspp. *pyrum,*
*osmingtonense* and *papillatum* are restricted to this zone. *Gonyaulacysta
jurassica* and *Hystrichosphaeridium petilum* are locally abundant. *Nannoceratopsis
pellucida, Taeniophora iunctispina* and *Sarjeantia eisenacki* make their last
appearance within this zone.

2. Zone D2

Base of Zone

First appearance of *Gonyaulacysta longicornis*, last appearance of *Stephanelytron*
scarburghense.

Top of Zone

Immediately below the first appearance of *Imbatodinium mutabilis*, *Gonyaulacysta cristata*, *Pareodinia nuda*.

Assemblages from this informal zone are consistently characterised by a low specific diversity, although this may be a result of the obscuring nature of the very abundant bituminous sapropel. *Cryptarchaeodinium calcaratum*, *Heslertonia pellucida*, *Hystrichodinium pulchrum*, *Gonyaulacysta globata*, *Egmontodinium polyplacophorum* and *Leptodinium acerat* make their first appearance within this zone.

3. Zone D3

Base of Zone

First appearance of *Imbatodinium mutabilis*, *Gonyaulacysta cristata*, *Pareodinia nuda*, *Hystrichodinium telaspinosum*, *Systematophora ovata*.

Top of Zone

The last appearance of *Gonyaulacysta granulata*, *Gonyaulacysta granuligera*, *Cryptarchaeodinium calcaratum*, *Systematophora ovata*, *Leptodinium callere*, *Muderongia simplex*, *Fibraeosphaeridium insignitum*, *Ctenidodinium panncum*, *Chlamydophorella nyei* and *Cyclonephelium distinctum* make their first appearance within this zone. *Muderongia simplex* occurs in abundance towards the top of the zone. *Leptodinium danutae*, *Gonyaulacysta deflandrei*, *Lanterna bulgarica*, *Gonyaulacysta fuscina* and *Imbatodinium longifilum* are restricted to this zone.

The long-ranging Jurassic species *Gonyaulacysta jurassica* and *Gonyaulacysta cladophora* are among the species which make their last appearance within this zone.

Assemblages from the top of this zone are very facies controlled and dominated by acanthomorph acritarchs.
4. Zone D4

Base of Zone

Immediately above the last appearance of *Gonyaulacysta granulata*, *Gonyaulacysta granuligera*, *Cryptarchaeodinium calcaratum* and associated forms which define the top of Zone D3.

Top of Zone

Last appearance of *Fibraeosphaeridium insignitum*, *Tubotuberella apatela*, *Dingodinium alberti* and *Systematophora areolata*.

Assemblages from this informal zone are characterised by a low specific diversity. The dominance of acanthomorph acritarchs indicates that the assemblages are controlled by local facies. There are no apparent first appearances. This informal zone is perhaps best defined by the absence of forms that occur in abundance in the older informal zones from the Kimmeridgian.

5. Zone D5

Base of Zone

Immediately above the last appearance of *Fibraeosphaeridium insignitum* and associated forms which define the top of Zone D4.

Top of Zone

Immediately below the first appearance of *Occisucysta tenuiceras*.

Assemblages from this informal zone are very restricted and characterised by an abundance of acanthomorph acritarchs, and a low specific diversity. Species of *Ctenidodinium* occur infrequently within this zone. *Ctenidodinium schizoblatum* is restricted to this zone.

6. Zone D6

Base of Zone

First appearance of *Occisucysta tenuiceras*. 
Top of Zone

Uncertain.

Assemblages from this informal zone are again very restricted and acanthomorph acritarchs are the dominant palynotypes. Dinoflagellate cysts are very infrequent, consisting predominantly of forms with peridineacean affinities.

THE BOULONNAIS (Enclosures 2a, b)

1. Zone B1

Base of Zone

Uncertain.

Top of Zone

Immediately below the first appearance of *Hystrichodinium pulchrum*, *Scriniodinium inritibilum*. The full vertical extent of this informal zone cannot be ascertained due to the restricted nature of the assemblages recovered from the Argiles du Moulin Wibert and a lack of material from the Grès de Questrecques.

The microplankton assemblages are comparable with those recovered from Zone D1 of Dorset.

2. Zone B2

Base of Zone

First appearance of *Gonyaulacysta serrata*, *Oligosphaeridium pulcherrimum*.

Last appearance of *Hystrichosphaeridium costatum*.

Top of Zone

Immediately below first appearance of *Gonyaulacysta perforans*, *Gonyaulacysta pennata* and associated taxa.

*Meiourogonyaulax dicryptos*, *Imbatodinium antennatum*, *Cryptarchaeodinium calcaratum* and *Hystrichosphaeridium petilum* make their first appearance, and *Gonyaulacysta cladophora* and *Gonyaulacysta jurassica* their last appearance.
within this zone. **Coalitapoma unica** and **Meiourogonyaulax staffinensis** are two distinctive species which are restricted to this zone.

3. **Zone B3**

   **Base of Zone**

   First appearance of **Gonyaulacysta perforans**, **Gonyaulacysta pennata**, **Fromea amphora**, **Tenua hystix**, **Leptodinium callere**.

   **Top of Zone**

   Immediately below the first appearance of **Imbatodinium mutabilis**, **Sirmiodinium grossi**, **Chlamydophorella nyei**, **Leptodinium aceras** and **Hystrichodinium telaspinosum** make their first appearance within this zone. **Scriniodinium dictyotum**, **Cleistosphaeridium tribuliferum** and **Occisucysta balios** make their last appearance within this zone.

4. **Zone B4**

   **Base of Zone**

   First appearance of **Imbatodinium mutabilis**, **Sirmiodinium grossi**, **Cryptarchaeodinium sp.**, **Chlamydophorella nyei**, **Pterospermopsis aureolata**.

   **Top of Zone**

   Taken as the Tour de Croi Nodule Bed.

   **Systematophora** sp. nov., **Gonyaulacysta deflandrei**, **Fibraeosphaeridium insignitum** and **Ctenidodinium panneum** make their first appearance within this zone. Species restricted to this informal zone include **Hexagonidium asperatum**, **Coronifera oceanica** and **Leptodinium danutae**.

   **Cryptarchaeodinium calcaratus**, **Leptodinium callere**, **Egmontodinium polyplacophorum** and **Leptodinium subtile** make their last appearance within this zone.

   Correlation, at least in part, between this zone and Zone D3 recognised in Dorset is evidenced by the mutual occurrence of a number of significant taxa.
5. Zone B5

Base of Zone

Taken as the Tour de Croi Nodule Bed.

Top of Zone

Last appearance of Membraniaulax harryi, Dingodinium tuberosus, Imbatodinium mutabilis, Gonyaulacysta deflandrei, Scriniodinium inritibilum, Fibraeosphaeridium insignitum, Muderongia simplex, Leptodinium aceras and Dingodinium alberti makes their last appearance within this zone.

The three samples examined from the top of the Gres des Oies and the “Purbeck Beds” cannot be assigned to an informal microplankton zone. Two samples are totally devoid of microplankton. The third sample yielded infrequent acanthomorph acritarchs and isolated specimens of Systematophora orbifera and Chytroeisphaeridia chytroeides which are not considered to be of stratigraphic importance.

YORKSHIRE

The two Kimmeridgian samples examined from Marton yielded near identical microplankton assemblage which are designated here as Association Y1. The microplankton recovered from these two samples are listed below in alphabetical order.

Apteodinium granulatum
Barbaraea jurassica
Chlamydophorella nyei
Chytroeisphaeridia chytroeides
Chytroeisphaeridia pococki
Ctenidodinium cf. panneum
Cyclonephelium distinctum

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Cyclonephelium cf. vannophorum
Egmontodinium polyplacophorum
Epipolosphaera reticulospinosa
Fromea amphora
Gonyaulacysta attenuaris
Gonyaulacysta cladophora
gonyaulacysta deflandrei
Gonyaulacysta globata
Gonyaulacysta granulata
Gonyaulacysta granuligera
Gonyaulacysta hyaloderma
Gonyaulacysta jurassica
Gonyaulacysta cf. jurassica
Gonyaulacysta longicornis
Gonyaulacysta nuciformis
Gonyaulacysta perforans
Gonyaulacysta serrata
Herendeenia pisciformis
Hystrichodinium telaspinosum
Hystrichodinium sp.
Meiourogonyaulax staffinensis
Meiourogonyaulax sp. GITMEZ & SARJEANT
Membraniaulax harrii
Occisucysta balios
Oligosphaeridium anthophorum
Oligosphaeridium pulcherrimum
Pareodinia ceratophora
Prolixosphaeridium granulosum
Scriniodinium irritibilum
Sirmiodinium grossi
Systematophora areolata
Systematophora orbifera
Systematophora ovata
Tenua echinata
Tenua hystrix
The two assemblages are characterised by an abundance of specimens attributable to the genus *Gonyaulacysta*. Chorate cysts, attributable to the genera *Oligosphaeridium* and *Systematophora* are also well represented. An Upper Kimmeridgian age is proposed for these two assemblages on the occurrence of *Chlamydophorella nyei*, *Hystrichodinium telaspinosum* and *Cyclonephelium distinctum* and the absence of any Lower Kimmeridgian restricted taxa. The close similarity between these assemblages and those recorded from the lower *pectinatus* zone of Dorset supports the view of Wilson (1971, pers. comm.) that, on sedimentological criteria, the limestone band exposed in the Marton pit is the lateral equivalent of the Dorset Coccolith Limestone band.

**NORFOLK**

Three distinct microplankton associations are recognised in the Sandringham Sands material from Norfolk. They are here informally designated N1 to N3.

Association N1 is recognised in the Jurassic interval of the Sandringham Sands and is characterised by a large number of specimens attributable to *Gonyaulacysta*, associated with abundant acanthomorph acritarchs. The affinities of this association are characteristically Upper Jurassic as evidenced by the occurrence of *Sarjeantia eisenacki*, *Eodinia pachytheca*, *Systematophora arcolata*, *Polystephanophorus sarjeantii*, *Gonyaulacysta longicornis* and *Meiourogonyaulax pila*. Cretaceous influences are, however, reflected by the occurrence of *Trichodinium castanea*, *Gonyaulacysta aichmetes*, *Gonyaulacysta episoma* and cf. *Gardodinium eisenacki*. The occurrence of *Ctenidodinium planneum* and *Ctenidodinium schizoblatum*, although associated with a much more diverse planktonic microflora, indicates correlation in part with Zone D5 recognised in Dorset.
Associations N2 and N3 are recognised in the Cretaceous interval of the Sandringham Sands. Association N2 is characterised by a marked reduction in the numerical importance of the genus Gonyaulacysta but, as in Association N1 acanthomorph acritarchs are still abundant. Chorate cysts, represented by Oligosphaeridium anthophorum, O. complex, O. pulcherrimum and considerable indeterminate material are perhaps the dominant morphotype. Occisucysta tenuiceras is a distinctive constituent of this Association and its occurrence indicates correlation with Zone D6 recognised in Dorset, although it is associated with a much more diverse planktonic microflora than in Dorset. The occurrence of such "typical Jurassic species" as Tenua pilosa, Tenua capitata, Systematophora orbifera and Gonyaulacysta jurassica within this Association may represent extensions in their stratigraphical ranges, or equally, reworking from older sediments.

Association N2 includes the top two samples examined from the Sandringham Sands which are considered by Casey to be of Upper Ryazanian age (Upper Berriasian in this thesis).

This association is characterised by moderately abundant specimens attributable to Spiniferites cingulatus and Spiniferites ramosus. Other distinctive species occurring within this association include Imbatodinium villosum, Imbatodinium verrucosum, Scriniodinium campanula and Cordosphaeridium fasciatum and indeterminable specimens attributable to Hexagonifera and Pseudoceratum.

7.4 STRATIGRAPHIC DISCUSSION

The stratigraphic distribution of 52 selected dinoflagellate cyst taxa chosen for their distinctive morphology and ease of recognition is given in Enclosure 4.
1. The Oxfordian-Kimmeridgian Boundary

In Dorset, the Oxfordian-Kimmeridgian boundary is conventionally taken as the top of the Riptead Coral Bed (Cope et al. 1969), the latter being assigned to the pseudocordata zone of the Upper Oxfordian. The commencement of black "Kimmeridge type clays", which occurs below the Coral Bed does, however, make a more reasonable boundary than the discontinuous bed of worm-casts unjustly labelled the Coral Bed. Since neither the clays nor the Coral Bed yield zonal ammonites this is perhaps, however, a purely arbitrary judgement. The occurrence within the clays below the Coral Bed of such typical Kimmeridgian species such as Ectenodinium egemenii, Polystephanophorus sarjeantii and common Hystrichosphaeridium petilum (Gitmez 1970) does, however, support an early Kimmeridgian rather than a late Oxfordian age for these clays.

2. Lower Kimmeridgian Assemblages

The Lower Kimmeridgian assemblages retain a characteristically Upper Oxfordian aspect as evidenced by the co-occurrence of Gonyaulacysta granuligera, Gonyaulacysta granulata, Systematophora orbifera, Systematophora areolata, Taeniophora iunctispina, Acanthaulax venusta and Scriniodinium crystallinum. Gonyaulacysta jurassica is often a common constituent of the assemblages together with infrequent Stephanelytron and rare Hystrichosphaeridium costatum, Nannoceratopsis pellucida and Ctenidodinium ornatum. Lower Kimmeridgian assemblages are, however, distinguished from Upper Oxfordian assemblages by the incoming of several new taxa, i.e. Dingodinium tuberosus, Ectenodinium egemenii, Polystephanophorus sarjeantii, Hystrichosphaeridium petilum, Barbarae jurassica, Imbatodinium antennatum and certain subspecies of Scriniodinium dictyotum.
3. Middle Kimmeridgian Assemblages

A number of forms which occur in Lower Kimmeridgian assemblages persist into the Middle Kimmeridgian. Species such as *Hystrichosphaeridium costatum*, *Ctenidodinium ornatum*, *Nannoceratopsis pellucida* and species of *Stephanelytron* are, however, typically absent. Species such as *Gonyaulacysta jurassica* and *Tenua pilosa* are numerically less important than in the Lower Kimmeridgian whilst *Gonyaulacysta longicornis*, *Hystrichodinium pulchrum*, *Pareodinia nuda* and *Egmontodinium polyplacophorum* make their first appearance.

4. Upper Kimmeridgian Assemblages

Upper Kimmeridgian assemblages are characterised by the gradual acquisition of Lower Cretaceous characters though still retaining a dominantly Upper Jurassic aspect. Characteristic forms include *Muderongia simplex* (locally of considerable numerical significance), *Ctenidodinium panneum*, *Lanterna bulgarica*, *Imbatodinium mutabilis*, *Leptodinium callere*, *Gonyaulacysta deflandrei*, *Cyclonephelium distinctum* and *Fibracosphaeridium insignitum*, associated with long-ranging Jurassic species of *Gonyaulacysta* and *Systematophora*. Many species which occur in the Lower and/or Middle Kimmeridgian are rarely or infrequently represented in the Upper Kimmeridgian. These include, *Gonyaulacysta jurassica*, *Scriniodinium subtile*, *Leptodinium arcuatum* and *Acanthaulax venusta*.

The incoming towards the top of the Upper Kimmeridgian of the miospores *Cicatricosisporites* and *Classopollis echinatus* is also of some considerable stratigraphic significance.

5. The Kimmeridgian - Portlandian Boundary

The Kimmeridgian - Portlandian boundary was only examined in Dorset, and here the boundary is somewhat arbitrarily taken as the base of the Massive
Bed. In the Boulonnais the boundary is within the non-sequence represented by the Tour de Croi Nodule Bed (see earlier chapters).

Facies control around the boundary in Dorset is very marked, hence palynological criteria for recognising the boundary are somewhat limited. The boundary in Dorset coincides approximately with the boundary between Zones D4 and D5. As such, it appears to be defined by the last appearance of a number of taxa which include *Gonyaulacysta granulata*, *Gonyaulacysta granuligera*, *Cryptarchaeodinium calcaratum*, *Barbaraea jurassica* and *Systematophora ovata*.

Several of the taxa which make their last appearance below the boundary in Dorset, do, however, occur in the Portlandian of the Boulonnais and Norfolk. The stratigraphic significance of the taxa which disappear near to the Kimmeridgian – Portlandian boundary in Dorset must accordingly be treated with caution pending the availability of data from good marine, Lower Portlandian sediments.

6. Portlandian Assemblages

Little can be said regarding the stratigraphical significance of basal Portlandian assemblages due to the local facies control in Dorset and the Boulonnais. There does, however, appear to be a significant reduction in the number of thick-walled, densely granular specimens of *Gonyaulacysta* that characterise the Kimmeridgian.

A number of species, i.e. *Ctenidodinium panneum*, *Systematophora areolata*, *Systematophora orbifera*, *Meiourogonyaulax pila*, *Meiourogonyaulax staffinensis* and *Imbatodinium antennatum*, which occur in the Kimmeridgian persist into the Portlandian.

Characteristic taxa making their first appearance towards the top of the Lower Portlandian include *Imbatodinium villosum*, *Tanyosphaeridium cf.*
variecalamum, Oligosphaeridium complex, Gonyaulacysta aichmetes, Trichodinium castanea and possibly, Gardodinium eisenacki. Chlamydophorella membraniodea, Belodinium dysculum, Ctenidodinium schizoblatum, Ctenidodinium culmulum are distinctive forms which appear to be restricted to the Portlandian (upper Lower - Upper Portlandian).

Sarjeantia eisenacki and Gonyaulacysta jurassica appear to persist through to the top of the Portlandian, although this might be due to reworking.

7. The Jurassic - Cretaceous Boundary

Little can be said regarding the Jurassic - Cretaceous boundary due to local facies control in Dorset and the Boulonnais and the lack of sequential samples in Norfolk.

In Dorset, the boundary does, however, appear to coincide with the boundary between Norris' (1969) miospore suites B and C and in Dorset and Norfolk with the first appearance of Occisucysta tenuiceras.

The disappearance of Belodinium dysculum, Systematophora areolata, Ctenidodinium pannenum, Ctenidodinium schizoblatum and Pareodonia nuda within the uppermost Portlandian may also be of significance as they are not known from the Berriasian (See Riley, in prep.).

8. Berriasian Assemblages

Lower Berriasian assemblages from Dorset are too restricted to be of any real stratigraphic value. In Dorset and Norfolk the first appearance of Occisucysta tenuiceras in the basal Berriasian is, however, significant.

The Lower Berriasian assemblages from Norfolk are characterised by an abundance of specimens attributable to Oligosphaeridium (O. anthophorum, O. complex, O. pulcherrimum and O. spp.), although this may be due to a local
environmental control. *Cyclonephelium distinctum*, *Imbatodinium villosum* and *Muderongia simplex* are also well represented. The presence of the typically Jurassic species, *Gonyaulacysta jurassica*, *Tenua pilosa*, *Tenua capitata* and *Systematophora orbifera* in the Lower Berriasian from Norfolk is most probably due to reworking, although Warren (1967) has reported *Systematophora orbifera* from the Lower Cretaceous.

Upper Berriasian assemblages (Norfolk only) appear to be characterised by the incoming in large numbers of *Spiniferites ramosus* and *Spiniferites cingulatus*. Other distinctive first appearances include *Scriniodinium campanula*, *Cordosphaeridium fasciatum*, *Imbatodinium verrucosum* and species of *Pseudoceratium*.

### 7.5 COMPARISONS WITH PREVIOUS MICROPLANKTON INVESTIGATIONS

From investigations mentioning Upper Jurassic and basal Cretaceous microplankton, I have selected several whose contents warrant discussion and comparison with the present results. These are here dealt with in alphabetical order of authors.

**BEJU 1972**: In this paper the author describes four microplankton zones from the subsurface Jurassic of Roumania. Beju's original age determinations for these zones are as follows:

- **Zone J4**: Oxfordian - Kimmeridgian
- **Zone J3**: Callovian - Oxfordian
- **Zone J2**: Bajocian - Bathonian
- **Zone J1**: Toarcian - Aalenian

Many of the species reported by Beju occur in well-dated European sections (herein and various authors) and allow some comments to be made on the original
ages assigned to the Roumanian material.

Zone J4: An Oxfordian age is proposed to this zone on the occurrence of Gonyaulacysta cladophora, Nannoceratopsis pellucida, Hystrichosphaeridium costatum, Adnatosphaeridium aemulum, Scrinioidinium subvallare, Scrinioidinium crystallinum and Leptodinium subtile.

The occurrence within this zone of Nannoceratopsis gracilis and Scriniocassis weberi is, however, very surprising. Nannoceratopsis gracilis is characteristically an Upper Liassic - Lower Bathonian form and although Beju’s illustrations (pl. IV, figs. 10-14) support his identification, its occurrence is considered to be due to either reworking or mud-recycling from older sediments.

Prior to Beju’s record, Scriniocassis weberi was only known from the Dogger Alpha (Lower Bajocian). Beju’s illustrations (pl. VIII, figs. 7-8) unfortunately do not allow much in the way of comparison with Gocht’s (1964) type material.

Zone J3: A Bathonian - Lower Callovian age is proposed for this zone on the occurrence of Ctenidodinium ornatum (frequent), Cetnidodinium tenellum, Gonyaulacysta jurassica and species of Scrinioidinium, Tenua and Melourogonavulax. A very marked degree of similarity is evident between the microflora of this zone and the German Bathonian assemblages described by Gocht (1970).

Zone J2: A Carixian - Lower Bajocian age is proposed for this zone on the frequent occurrence of Nannoceratopsis gracilis associated with acanthomorph acritarchs and tasmanitids.

Zone J1: A Lower Jurassic (pre-Carixian) age is proposed for this zone on its stratigraphic position below Zone J1 and the absence of any significant microplankton in the microflora; in particular on the absence of Nannoceratopsis gracilis.
COOKSON & EISENACK (1958, 1960b): In these two papers the authors describe dinoflagellate cyst assemblages from the Upper Jurassic (considered by Cookson & Eisenack to be Oxfordian to possible Tithonian) of Australia and New Guinea. A number of the species reported in these publications occur in the English and French sections, thus showing that considerable similarity existed between Europe and Australasia at that time. Some of the species, as shown in this study have stratigraphically significant ranges in the Upper Jurassic and allow us to make some comments on the original ages assigned to the Australasian material.

1. A Middle - Upper Kimmeridgian (i.e. Lower Tithonian) age is proposed for the following samples. The species used for this assignment are listed in each case.

- Broome No. 3 Bore, 1001' - 1211' (Cookson & Eisenack 1960b):
  Belodinium dysculum and Scriniodinium luridum.

- Broome No. 1 Bore, 963' - 977' (Cookson & Eisenack 1960b):
  Belodinium dysculum, Gonyaulacysta serrata and Scriniodinium luridum.

- Roebuck Bay Well No. 1, 972' - 982' (Cookson & Eisenack 1960b):
  Belodinium dysculum, Leptodinium clathratum and Scriniodinium playfordi.

2. A Lower Kimmeridgian age is proposed for the following samples.

- Wapet's Wallal Core, 305' - 350' (Cookson & Eisenack 1960b):
  Nannoceratopsis pellucida and Scriniodinium luridum.

3. An Upper Callovian - Lower Oxfordian age is proposed for the following samples.

- Broome No. 3 Bore, 1405' - 1427' (Cookson & Eisenack 1958, 1960b):
  Wanaea digitata, Adnatosphaeridium aemulum and Nannoceratopsis pellucida.
Cape Range Well No. 1, 3825' - 3840' (Cookson & Eisenack 1958):
same assemblage as above, plus Wanaea clathrata.

Wapet's Wallal Core, 560' - 575' (Cookson & Eisenack 1960b):
Adnatosphaeridium aemulum, Wanaea clathrata and Nannoceratopsis pellucida.

Rough Range Well No. 1, 4376' - 4379' (Cookson & Eisenack 1958):
Adnatosphaeridium filamentosum and Wanaea digitata.

Cape Range Well No. 2, 3970' - 3991' (Cookson & Eisenack 1958):
Wanaea clathrata, Adnatosphaeridium aemulum, Adnatosphaeridium filamentosa and Nannoceratopsis pellucida.

Omatia Well No. 1, samples 36-42 (Cookson & Eisenack 1958):
Gonyaulacysta ambigua, Adnatosphaeridium aemulum, Adnatosphaeridium mirabilis and Wanaea clathrata.

4. A Callovian age (possibly Lower - Middle Callovian) is tentatively proposed for the following samples.

- Cape Range Well No. 1, 6032' - 6060' (Cookson & Eisenack 1958):
Wanaea spectabilis, Adnatosphaeridium aemulum.

- Cape Range Well No. 2, 6365' - 6383' (Cookson & Eisenack 1958):
same assemblage as above.

- Omatia Well No. 1, samples 36-42 (Cookson & Eisenack 1958):
Wanaea spectabilis.

DEFLANDRE 1939, 1941: Several different species are recorded from the Kimmeridgian shales of d'Orbagnoux, France. Although a number of distinctive species are described, several of them have not been recorded in the present study, e.g. Palaeostomocystis punctulosa, Pterocystidiopsis angulosa,
Gonyaulacysta mamillifera (as Gonyaulax mamillifera) and Leptodinium nannotrix (as Gonyaulax nannotrix). These differences make direct comparisons difficult. Similarity between the Kimmeridgian assemblages described herein and Deflandre's material is, however, evidenced by the occurrence of a number of species, e.g. Cryptarchaeodinium calcaratum, Gonyaulacysta ambigua (as Gonyaulax ambigua), Gonyaulacysta hyalodermum (as Palaeoperidinium hyalodermum) and Leptodinium amabilis (as Gonyaulax amabilis).

DODEKova 1967, 1969, 1971: In these three publications dinoflagellate cyst and acritarch assemblages are described from the subsurface Oxfordian - Tithonian of Bulgaria.

The assemblages from the Oxfordian - Kimmeridgian (sensu gallico) are very similar to those described by Klement (1960) from the German Malm. The Roumanian assemblages are also very similar to those described by Deflandre (1939, 1941), Sarjeant (1959-1968) from the Upper Oxfordian of England and France. Only two species, Systematophora areolata and Endoscrinium galeritum were recorded by Dodekova from the Kimmeridgian, both of which were recorded in the present study.

Twenty-five species and one variety were reported from the Tithonian (Dodekova 1969, 1971); fourteen of which have been recorded in the present study. Similarity with the Upper Kimmeridgian of Dorset and the Boulonnais is indicated by the occurrence of Lanterna bulgarica, Amphorula metaelliptica, Dingodinium alberti, Gonyaulacysta helicoidea and Chlamydophorella nyel.

HABIB 1972: In this recent paper Habib describes dinoflagellate cyst assemblages recovered from North Atlantic Mesozoic and Cainozoic sections cored during Leg 11 of the Deep Sea Drilling Project. Unfortunately Habib did not describe in
full the assemblages that he recovered so direct comparisons with the present study are not possible. A number of comments can, however, be made with regard to the dating of some of his microplankton associations.

Association F: Eight species are described from this association which Habib considers to be diagnostic of an Early Cretaceous or Late Jurassic age. Two of these species, *Wallodinium krutzschi* and *Scriniodinium dictyotum* have been recorded from the Late Jurassic in the present study. *Microdinium deflandrei* and *Cometodinium* sp. A may also be represented in the present study by forms included within *Microdinium* spp. and *Cleistosphaeridium* sp. respectively.

A Late Jurassic (Upper Kimmeridgian - Portlandian) age is proposed on the occurrence of *Scriniodinium dictyotum*, *Wallodinium krutzschi* and *Chlamydophorella wallala*.

Association G: Nine diagnostic species are listed from this association which is considered by Habib to be of Early Cretaceous or Late Jurassic age. *Heslertonia pellucida*, *Prolixosphaeridium granulosum*, *Chytroeisphaeridia pococki* and possibly *Cometodinium* sp. A have been recorded in the present study.

A Late Jurassic (Kimmeridgian) age is proposed on the occurrence of *Systematophora fasciculigera*, *Heslertonia pellucida* and *Prolixosphaeridium mixtispinosum*.

HABIB & WARREN 1973: Eleven species of dinoflagellate cysts are recorded by the authors from the Berriasian - Valanginian of the North Atlantic (Site 105 of the Deep Sea Drilling Project), the Tithonian - Valanginian of California and the Berriasian stratotype.

Two species, *Occisucysta?* sp. and *Belodinium dyscolum*, are reported from the Tithonian. *Belodinium dyscolum* has been recorded in the present study.
from the Upper Portlandian. It has also been observed by the writer in
Upper Kimmeridgian – Portlandian assemblages from North Sea wells. Cookson
& Eisenack (1960) originally described Belodinium dysculum from the Tithonian
of Australasia, it accordingly proves to be a very useful index form for the
Late Jurassic. With regard to Occisucysta ? sp., no description or illustration
is given so no comment can be made about its significance.

Nine species are reported from the Berriasian. Four of these species,
Scriniodinium attadalense, Cyclonephelium distinctum, Oligosphaeridium complex
and Scriniodinium campanula, have been recorded in the present study.
Scriniodinium campanula, Cyclonephelium distinctum and Oligosphaeridium
complex have been observed in both Late Jurassic and Berriasian assemblages.
Scriniodinium attadalense has only been observed (albeit only an isolated
specimen) in the Upper Jurassic.

Dingodinium cerviculum and Belodinium dysculum are considered to be
very useful stratigraphic indices, but the importance of the remaining seven
species as valuable guide fossils for demarcating the Jurassic - Cretaceous
boundary. as suggested by Habib & Warren is considered to be of dubious value.

HOROWITZ (1970): In this paper Horowitz describes a number of dinoflagellate
cysts and acritarchs from the Upper Jurassic and Lower Cretaceous of Israel.
The occurrence in the Jurassic of a number of species which he lists is so
surprising as to suggest an error either in identification or in the dating of the
samples. Batten (1973 pers. comm.) has also pointed out to the writer that
certain of his Jurassic miospores are in fact misidentified Cretaceous forms.
Among the species that he illustrates only three appear to be indigenous Upper
Jurassic forms, these are Adnatosphaeridium caulleryi (as Cannosphaeropsis
cauleryi), Spiniferites ramosus ramosus and Hystrichosphaeridium sp. (this
latter form is from his illustration a possible *Hystrichosphaeridium petilum*).

His Jurassic records of *Gonyaulacysta gongylos*, and *Doidyx anaphrissa* are considered to be of doubtful attribution; furthermore, his Jurassic record of *Hystrichosphaeridium mantelli* is considered to be highly doubtful as it is typically a Cenomanian form.

Horowitz's material was obtained from a subsurface well section and, although he does not comment on the type of samples examined, caving or mud contamination from higher horizons would readily account for the occurrence of a predominantly Cretaceous microflora in his Jurassic assemblages.

**KLEMENT 1960:** In this paper the author describes microplankton assemblages from the Lower and Middle Malm of southwest Germany. Twenty-two dinoflagellate cyst species are described from the Malm Gamma, of which sixteen occur in the Lower Kimmeridgian of England and France. Of the thirteen species described from the Malm Delta, eight are known from England and France. Although the assemblages show that considerable similarity existed between England, France and Germany in Lower Kimmeridgian times, the differences suggest that the German assemblages were drawn from a different plankton province and hence a different water body.

**MILLIoud 1967:** In this paper the author describes some dinoflagellate cysts and acritarchs from the western European type localities of the Berriasian, Valanginian, Hauterivian and Barremian stages.

The following dinoflagellate cysts were recorded from the type Berriasian: *Canningia hirtella, Cyclonephelium distinctum, Gonyaulacysta aptiana, Muderongia tomaszowensis, Pareodinia ceratophora* and *Phoberocysta neoeconica*. Of these, only two, *Cyclonephelium distinctum* and *Pareodinia ceratophora*, have been
recorded in the present study, both from the Kimmeridgian - Berriasian. The
differences between the stratotype and the present material may be due to local
environmental controls, especially as the Berriasian material examined in this
study is from shallow water, nearshore environments.

POCOCK 1972: In this paper the author describes microplankton assemblages
from the Jurassic of Western Canada and erects a series of palynological zones.
The stratigraphical significance of two of his zones is discussed below. Some of
the species, as shown in the present study, have stratigraphically significant
ranges and allow us to reconsider some of the original ages assigned to the
Canadian material.

1. Zone J33. Eight microplankton taxa were recorded from this zone which
Pocock considers to be of late Jurassic age. Three of these are acritarchs which
are considered by the writer to be of dubious stratigraphic value; four of the five
dinoflagellate cyst taxa have been recorded in the present study, the exception
being Pocockia waltonii (recorded as Evittia waltonii). The remaining species,
Scriniodinium luridum, Gonyaulacysta jurassica, Gonyaulacysta jurassica var.
longicornis and Pareodinia ceratophora are too long-ranging to be of any precise
stratigraphic value, but the association does suggest a pre-Upper Kimmeridgian
age determination. This is not supported, however, by the occurrence of species
of Cicatricosisporites which Pocock comments "have been recorded from isolated
samples". These samples containing Cicatricosisporites are probably Upper
Kimmeridgian or somewhat younger in age, unfortunately he does not comment on
the microplankton recovered from these "isolated samples" so this cannot be
confirmed.

ii. Zone J32. Pocock listed nineteen microplankton taxa from this zone and
considered the palynomorph assemblage to be closely similar to assemblages described from the Oxfordian and Kimmeridgian of Europe. Five of these are acritarch taxa of little stratigraphic value, two are invalidly published without description or illustration (\textit{Palaeoperidium carlycnse} and \textit{P. ornatum}), so no comments can be made on these, and his proposed new species \textit{Gonyaulax canadenensis} and \textit{G. downei} (transferred to \textit{Gonyaulacysta} by Lentin \& Williams 1973) are treated herein as junior synonyms of \textit{Gonyaulacysta cladophora}. Of the ten remaining taxa, four have been recorded in the present material. The occurrence of \textit{Adnatosphaeridium caulleryi} (as \textit{Cannosphaeropsis caulleryi}), \textit{Scriniodinium subvallare}, \textit{Surculosphaeridium vestitum} (as \textit{Multiplicisphaeridium vestitum}, \textit{Gonyaulacysta cladophora} and \textit{Gonyaulacysta crassicornuta} is indicative of an Upper Oxfordian - ?basal Kimmeridgian age.

RILEY (in press, \textit{In BATTEN et al.}): The writer has recently described a number of microplankton assemblages from the Kimmeridgian - Portlandian of East Greenland. The Lower Kimmeridgian assemblages are comparable with those described herein from Britain and France. Dinoflagellate cyst species are, however, infrequent and consistently poorly preserved; the following, however, are worthy of note: \textit{Endoscrinium oxfordianum}, \textit{Nannoceratopsis pellucida}, \textit{Meiourogonvaulax staffinensis}, \textit{Gonyaulacysta attenuaris}, \textit{Adnatosphaeridium caulleryi}, \textit{Gonyaulacysta ambiguа}, \textit{Gonyaulacysta jurassica}, \textit{Spiniferites ramosus ramosus}, \textit{Pareodinia nuda} and \textit{Gonyaulacysta longicornis}. No good Middle - Upper Kimmeridgian assemblages were recovered and only three species are recorded from the Upper Kimmeridgian - Portlandian. These are \textit{Pareodinia ceratophora}, \textit{Ctenidodinium panneum} and \textit{Systematophora orbifera}, all of which have been recorded in the present study. \textit{Ctenidodinium panneum} accordingly proves to be useful Upper Kimmeridgian - Portlandian index.
RILEY (unpublished): The writer has recently examined a number of assemblages from the *cymodoce* to *?hudlestoni* zones of the Brora area of the Moray Firth. All of the assemblages are dominated by acanthomorph acritarchs, in several instances dinoflagellate cysts are very infrequent to absent. Twenty-eight cyst species were recognised, twenty-seven of which occur in the Kimmeridgian assemblages from Dorset and the Boulonnais. The rare occurrence of *Surculosphaeridium vestitum* (Deflandre) in two of the basal samples is of significance in that it represents the first definite Kimmeridgian record of this species. Of the remaining twenty-seven species, four are Kimmeridgian restricted, these are *Systematophora ovata* Gitmez & Sarjeant, *Meiourogonyaulax staffinensis*, *Gonyaulacysta cauda* and *Gonyaulacysta* sp. A Gitmez.

SARJEANT 1959, 1960, 1961, 1962, 1968: In these papers Sarjeant describes microplankton assemblages from the Oxfordian of England (Dorset and Yorkshire) and France (Normandy). Assemblages from the Upper Oxfordian are similar to those recorded in the present study from the Lower Kimmeridgian. Distinction from the Upper Oxfordian is made possible, however, by the incoming of new taxa in the Kimmeridgian. Furthermore, a number of distinctive species, recorded by Sarjeant from the Upper Oxfordian, are not known to occur in the Kimmeridgian. These include *Acanthaulax palliros*, *Acanthaulax acanthosphaera*, *Pluriavalium osmingtonense*, *Scriniodinium subvallare*, *Surculosphaeridium cribrotubiferum* and *Systematophora fasciculigera* (as *Systematophora valensii*).

Lower Oxfordian assemblages are more markedly dissimilar being characterised by certain species of *Wanaea* and *Tenua* which are not known from higher horizons.

VOZZENNIKOVA 1967: The author describes dinoflagellate cyst assemblages
from the Jurassic, Cretaceous and Palaeogene. Dinoflagellate cysts are reported to be infrequent in the Callovian, absent in the Oxfordian - Kimmeridgian and moderately abundant in the Volgian.

Twelve of the eighteen species reported from the Upper Volgian of Chulkova and thirteen of the twenty species reported from the Upper Volgian of Kuntsevo have been recorded in the present study from the Upper Kimmeridgian - Portlandian. The occurrence of *Imbatodinium villosum* in the Kuntsevo material, by analogy with the present study, suggests that the Kuntsevo assemblage is stratigraphically younger than that from Chulkova.

A considerable number of the species reported by Vozzhennikova from the Upper Volgian are restricted to the Lower Portlandian and/or older sediments in the Boulonnais and Dorset, although they do occur in the Upper Portlandian of Norfolk. Considerable similarity between Vozzhennikova's Upper Volgian material and the present material from the Portlandian of Norfolk is evidenced by the mutual occurrence of a number of taxa including the co-occurrence of *Gonyaulacysta jurassica, Sarjeantia eisenacki, Trichodinium castanea, Gardodinium eisenacki, Chlamydophorella membraniodea* and species of *Imbatodinium*.

The absence in the Russian Volgian of *Systematophora* and *Ctenidodinium* is surprising and may be of biogeographical significance.

WARREN (1967): In this unpublished thesis the author describes dinoflagellate cysts from the Upper Jurassic and Lower Cretaceous of the Sacramento Valley, California. 38 species are recorded from the Upper Tithonian, many of which are new species not yet validly proposed. There are also a number of taxonomic proposals which the present writer considers to be unacceptable. Ten of Warren's recorded species have been observed in the Uppermost Jurassic in the present
study. Mutual occurrences of stratigraphic significance include Diplotesta krutzschi (reported herein as Wallodinium sp.) and Belodinium dsyculum.
CHAPTER 8

SYSTEMATIC SECTION

This section is divided into three parts. The first part deals with the microplankton species recovered during the present study. The second part lists in alphabetical order the species that have been recorded in earlier studies from the Kimmeridgian - Portlandian of Dorset and the Boulonnais, but which were not recovered during the present study. The following published works were consulted in order to present as full an account as possible of the microplankton assemblages in the sections examined in the present study: Downie (1958), Norris (1965), Gitmez (1970) and Gitmez & Sarjeant (1972). The third part, Taxonomic Notes, is concerned with a discussion of the affinities of Antrosphaera Sarjeant 1961 and Spheripollenites Couper 1958. In addition the Cretaceous genus Galeatadinium comb. nov. is proposed.

The taxa are treated according to the International Code of Botanical Nomenclature. Geological ranges given for the species are after Riley & Sarjeant (1972), modified by reference to more recent publications, i.e. Davey & Verdier (1973). Affinities of forms, where stated are after, or based on, Wall & Dale (1968).

PART 1

The classification of dinoflagellate cysts above generic level is, at present, in a state of flux. The procedure used here is a simple and practical one, which may be followed advantageously until a more comprehensive scheme is formulated. Dinoflagellate cyst genera are tentatively placed in alphabetical order in three groups. The Gonyaulacacean and the Peridiniacean groups have more or less well known characteristics (Wall & Dale 1968). The third group "Unknown Affinities Group" contains the remainder of the genera that
cannot be assigned to the two major groups.

Acritarchs are classified following the morphological supra-generic classification of Downie et al. (1963).

Class DINOPHYCEAE Pascher

Order PERIDINIALES Lindman

GONYAULACACEAN GROUP

Genus ACANTHAULAX Sarjeant 1968b

REMARKS: Species attributed to the genus Acanthaulax are closely comparable to species of Gonyaulacysta being differentiated solely by the possession of a dense cover of surface spines. Forms of Gonyaulacysta with a coarsely tubercular surface and infrequent surface spines (i.e. Gonyaulacysta sp. A Gitmez) may represent a transitional stage to Acanthaulax. Future studies may well prove that Gonyaulacysta and Acanthaulax are part of a continuously varying plexus and so make Acanthaulax superfluous. For the present, however, as the known distribution of species attributed to Acanthaulax appears to have some stratigraphic significance, the genus is retained.

Acanthaulax venusta (Klement) Sarjeant 1968


1966 Acanthogonyaulax venusta (Klement); Sarjeant: nomen nudum, 132.

1968b Acanthaulax venusta (Klement); Sarjeant: 227.

1969 Gonyaulacysta venusta (Klement); Beju: nomen nudum, 10, pl. 2, fig. 3.

1971 Gonyaulacysta venusta (Klement); Dodekova: 11, pl. 2, figs.3-4.

KNOWN RANGE: Upper Oxfordian - Tithonian.

Genus ADNATOSPHAERIDIUM Williams & Downie 1966
Adnatosphaeridium caulleryi (Deflandre) Williams & Downie 1969.

1938d Hystrichosphaeridium caulleryi Deflandre: 189, pl. 11, figs. 2-3.

1947a Cannosphaeropsis caulleryi (Deflandre); Deflandre: 1575.

1969 Adnatosphaeridium caulleryi (Deflandre); Williams & Downie: 17.

REMARKS: Many Tertiary forms attributed to this species have been transferred to Cyclonephelium retintextum by Cookson (1956).

The specimen figured by Downie (1957, pl. xx, Fig. 1) from the Kimmeridgian appears to be a Systematophora orbifera Klement.

REPORTED RANGE: Lower Callovian to Eocene.

Adnatosphaeridium sp.

Plate 17, fig. 13.

DESCRIPTION: The central body is subspherical in shape and moderately thick-walled. The processes vary somewhat in length and thickness on an individual specimen; distally they branch and coalesce to form a loose network. Some of the main branches are flattened and rather broad. Shorter branches bearing slender spines occur at or near some of the points of branching. The archaeopyle is apical in position.

DIMENSIONS: Central body 42 x 49, process length, up to 26. One specimen measured.

REMARKS: The Upper Cretaceous species A. filiferum (Cookson & Eisenack) is a similar species in terms of overall morphology. The specimens recorded here, however, are considerably smaller than the quoted size ranges for A. filiferum; a more precise comparison is impossible owing to their poor preservation.
**Genus **AMPHORULA Dodekova 1969

**Amphorula metaelliptica** Dodekova 1969

Plate 12, Fig. 11.

1969 **Amphorula metaelliptica** Dodekova: 20-21, pl. 4, figs. 1-6.

**REMARKS:** The present material two specimens is comparable in size and overall morphology with the type material; the tabulation as described by Dodekova could readily be determined. Its occurrence reported here represents an extension in its geographical range from Bulgaria to England.

**RANGE:** Tithonian.

**Genus **APTEODINUM Eisenack 1958

**REMARKS:** In some instances traces of a reflected tabulation are weakly indicated, this places Apteodinium morphologically very close to Gonyaulacysta.

**Apteodinium granulatum** Eisenack 1958c

Plate 16, Fig. 14.

1958c **Apteodinium granulatum** Eisenack: 386, pl. 23, figs. 8-14; text. fig. 1.

**REMARKS:** A discussion on the possible relationship between **A. granulatum** and Palaeoperidinium ventriosum as illustrated by Deflandre (1935-36) is given by Davey (1969, p.130) and Davey & Verdier (1971, p. 12).

**REPORTED RANGE:** Lower Kimmeridgian - Cenomanian.

**Apteodinium maculatum** Eisenack & Cookson 1960

Plate 16, fig. 6.

1960 **Apteodinium maculatum** Eisenack & Cookson: 4, pl. 2, figs. 1-3.
REMARKS: The observed specimens are somewhat smaller than the type Lower Cretaceous material from Australia but very similar in all other respects. Faint indications of a cingulum are evident on some of the specimens and the "hoof-shaped" pylome is well displayed by two specimens. The "small thickened areas with circular outlines" mentioned by Cookson & Eisenback are, however, completely lacking. In this respect they are similar to the English Barremian specimens described by Sarjeant (1966).

Gitmez (1970) and Gitmez & Sarjeant (1972) recorded similar specimens from the English and French Kimmeridgian as A. cf. maculatum. They were differentiated from the type material solely on the lack of the circular thickened areas, accordingly they are referred here to A. maculatum.

KNOWN RANGE: Kimmeridgian to Albian.

Genus BARBARAEA gen. nov.

DERIVATION OF NAME: After St. Barbara, patron saint of geologists.


Kimmeridgian, England.

REMARKS: Barbaraea differs from all previously described genera by the combination of a polygonal, apical archaeopyle, indication of tabulation and cavate morphology. Hexagonifera differs by possessing a flimsy, looser fitting outer membrane and by lacking any indication of tabulation or cingulum.
Barbaraea jurassica (Gitmez & Sarjeant) comb. nov. and emend.

Plate 9, fig. 13.


REMARKS: The diagnosis is emended to remove reference to the genus Hexagonifera and the ambiguous statement "periblast has a blunt hollow apical projection formed from the periphragm alone".

Although the tabulation is generally indeterminable, the dorsal tabulation could be distinguished with difficulty on some specimens: two apical, three precingular, three postcingular and one antapical plate were observed.

REPORTED RANGE: Lower - Upper Kimmeridgian.

Genus BELODINIUM Cookson & Eisenack 1960b

REMARKS: In the absence of a full knowledge of the tabulation, distinction of this genus depends on the circular nature of the cingulum the presence of an antapical pericoel and an apical archaeopyle. The authors state that their interpretation of the genus is "provisional" and "incomplete": a fuller study of the genus and a revision of the diagnosis are clearly needed before its
status can be validly assessed.

Belodinium dysculum Cookson & Eisenack 1960b

1960b Belodinium dysculum Cookson & Eisenack: 250, pl. 37, fig. 14.

REMARKS: A single specimen, observed in the Portlandian of Norfolk (sample S1) is, although poorly preserved, closely similar to B. dysculum. This species has been reported from the Tithonian of Western Australia (Cookson & Eisenack 1960b), California (Habib & Warren 1973; Warren 1967) and the North Sea (pers. obs.). The specimen described as B. dysculum from the Lower Kimmeridgian of Dorset by Gitmez (1970) is described elsewhere as Carpodinium sp.

REPORTED RANGE: Tithonian.

Genus CANNINGIA Cookson & Eisenack 1960

Canningia sp.

Plate 12, fig. 9.

DESCRIPTION: The cyst is spherical with a short, blunt apical horn and a densely granular wall of moderate thickness (1-2μ). An apical archaeopyle is indicated by partial detachment of the apex along an irregular line of breakage.

DIMENSIONS: Overall length 61μ, apical horn length 6μ, breadth 55μ. One specimen measured.

REMARKS: The two specimens recorded here conform partly with the original diagnosis of the Cretaceous species C. minor Cookson & Hughes, but differ slightly by the possession of a more pronounced apical horn.

They differ from the Australian Cretaceous species C. rotundata Cookson & Eisenack in being smaller, thinner-walled and by lacking a smooth
margin to the archaeopyle.

The most comparable species appears to be C. cf. minor of Beju (1972 p. 290, pl. 3, figs. 5-6) from the ?Bajocian to ?Oxfordian of Roumania. Beju's specimens differ slightly from the present material by their smaller range of dimensions (38-52 µ x 30-50 µ), but are comparable in overall morphology, wall ornamentation and form of the apical horn.

Genus CARPODINUM Cookson & Eisenack 1962

REMARKS: Carpodinium bears a superficial resemblance to Belodinium Cookson & Eisenack. The two genera differ, however, in the mode of archaeopyle formation (Belodinium possesses an apical archaeopyle) and the development in Belodinium of an antapical expansion of the hypotract.

Carpodinium sp.

Plate 12, figs. 3, 8

1970 Belodinium dysculum Cookson & Eisenack; Gitmez: 275, pl. 7, fig. 3.

DESCRIPTION: The cyst is elongate-ovoidal in shape with rounded poles. Relatively high membraneous crests with smooth distal edges demarcate a gonyaulaccean tabulation; a forward extension of the crests forms a distinct, broad blunt apical horn. An equatorial cingulum is indicated. The archaeopyle is precingular in position. The cyst surface is finely granular.

DIMENSIONS: Overall length 75-98 µ, overall breadth 40-65 µ (5 specimens measured).

REMARKS: Carpodinium is typically a Cretaceous genus. C. granulatum Cookson & Eisenack, originally described from the Australian Lower Cretaceous, is similar to the present material in terms of size and general morphology, but possesses sutural crests that are distally serrate or denticulate.

- The single specimen recorded by Gitmez (1970) from the Lower
Kimmeridgian of Dorset as *Belodinium dysculum* lacks the antapical expansion of the hypotrack and the short supporting spines for the sutural crests characteristic of *B. dysculum*, and is considered to be conspecific with the present material.

REPORTED RANGE: Lower Kimmeridgian. (As *Belodinium dysculum*).

**Genus CLEISTOSPHAERIDIDIUM** Davey *et al.* 1966

*Cleistosphaeridium ehrenbergi* (Deflandre) Davey *et al.* 1969

1938a *Hystrichosphaeridium* cf. *hirsutum* Deflandre: pl. 10, fig. 9.
1947 *Hystrichosphaeridium ehrenbergi* Deflandre: fig. 1, no. 5.
1963 *Baltisphaeridium ehrenbergi* (Deflandre); Sarjeant: 486-487, pl. 70, fig. 1, text-fig. 6a.
1969 *Cleistosphaeridium ehrenbergi* (Deflandre); Davey *et al.*: 16.

**REMARKS:** The distinctions between *C. polycanthum* and *C. ehrenbergi* proposed by Gitmez (1970) and maintained by Gitmez & Sarjeant (1972), are considered to be of dubious value, as a slight distortion would readily modify the shape of the central body. Variations in the number of processes may be of intraspecific value only. Accordingly, the two species are here tentatively grouped together with *C. ehrenbergi* having priority.

REPORTED RANGE: *C. ehrenbergi*, Upper Bathonian to Upper Kimmeridgian.

*C. polycanthum*, Upper Oxfordian - Middle Kimmeridgian.

*Cleistosphaeridium polytrichum* (Valensi) Davey *et al.* 1969

1947 *Hystrichosphaeridium polytrichum* Valensi: fig. 4.
1962b *Baltisphaeridium polytrichum* (Valensi); Sarjeant: 487, pl. 70, fig. 2, text-fig. 66.
1969 *Cleistosphaeridium polytrichum* (Valensi); Davey *et al.*: 16.
REMARKS: The taxonomic status of this species is open to doubt. It may form part of a continuously varying plexus with C. ehrenbergi (and forms previously attributed to C. polycanthum), but pending future study it is retained here.

REPORTED RANGE: Bathonian - Upper Cretaceous.

Cleistosphaeridium tribuliferum (Sarjeant) Davey et al. 1969.

Plate 18, Fig. 7.

1962b Baltisphaeridium tribuliferum Sarjeant: 487-488, pl. 70, fig. 4; text-figs. 6c, 7.

1969 Cleistosphaeridium tribuliferum (Sarjeant); Davey et al.: 16.

REMARKS: C. tribuliferum is comparable in general appearance and form of its processes with some species of Hystrichosphaeridium, particularly H. recurvatum (White) and H. petilum Gitmez; C. tribuliferum, however, possesses processes in larger numbers, which are distally closed and irregularly arranged, without any indications of tabulation. The possibility that C. tribuliferum and Hystrichosphaeridium petilum Gitmez are end members of a continuously varying plexus cannot, however, be overlooked.

REPORTED RANGE: Callovian - Upper Kimmeridgian.

Cleistosphaeridium spinosum sp. nov.

Plate 17, fig. 1.

1970 Cleistosphaeridium sp. Gitmez 288, pl. 1, fig. 7.

DERIVATION OF NAME: Latin, spinosum, thorny - with reference to the shape of the processes.

DIAGNOSIS: A species of Cleistosphaeridium having a subspherical to ovoidal
central body bearing numerous processes (c. 70-80). Processes simple, broad-based, tapering distally to a point and short (c. 1/5 of the central body breadth). Cyst wall thin, finely granular. Archaeopyle, apical.

HOLOTYPE: Slide D. 16 (9).

DIMENSIONS: Holotype: length (apex lacking) 48 μ, breadth 55 μ, process length 11 μ. Range: length (apex lacking) 30-50 μ, breadth 30-55 μ, process length 5-11 μ. (8 specimens measured).

DESCRIPTION: The short, broad-based, "thorn-like" nature of the processes is very distinctive. They are hollow, closed distally and proximally, without communication to the endocoel. The surface of the cyst is finely granular. An apical archaeopyle is consistently present, no entire cysts were recorded.

REMARKS: C. spinosum differs from all previously described species of Cleistosphaeridium in the form of its processes. It has previously been recorded, as Cleistosphaeridium sp., by Gitmez (1970) and Gitmez & Sarjeant (1972) from the Kimmeridgian of England, Scotland and France.

? Cleistosphaeridium sp.

Plate 11, fig. 12. Plate 17, figs 4-5, 7.

DESCRIPTION: The central body is spherical to subspherical with a densely granular wall of moderate thickness. The processes are numerous, finely to broadly acuminate, flexous and of variable length, but generally less than 1/3 of the central body diameter. Archaeopyle, ? apical.

DIMENSIONS: Central body diameter 30-50 μ, maximum length of processes
REMARKS: The specimens resemble species of *Cleistosphaeridium* in general appearance, but definite allocation to the genus is not possible due to lack of knowledge of the mode of archaeopyle formation.

The most similar species is perhaps *Cleistosphaeridium aciculare* Davey from the Cretaceous. Davey's species does, however, possess relatively longer processes that are more variable in width and density with occasional small spines developed at their distal extremities.

A superficial similarity is seen with *Cleistosphaeridium multispinosum* (Singh) from the Albian of Canada, which is comparable in terms of size and general form of the processes, but differs in that some processes bifurcate at their tips.

Genus **COALITAPOMA** gen. nov.

DERIVATION OF NAME: Latin, coalitus, fused, united; poma, lid, cover, operculum - with reference to the compound archaeopyle.

DIAGNOSIS: Proximate dinoflagellate cysts, broadly ovoidal to subsphaerical, bearing two reduced antapical horns, apex rounded. Gonyaulacacean reflected tabulation; 4', ?a, ?c, 6'''', 1''''. Archaeopyle compound, by detachment of all apical plates and one precingular plate. Operculum typically remaining attached.

TYPE SPECIES: *Coalitapoma unica* sp. nov. Upper Kimmeridgian, England.

REMARKS: *Coalitapoma* differs from all previously described dinoflagellate cyst genera in its overall shape and mode of archaeopyle formation. No other
proximate cysts have previously been recorded with compound archaeopyles.

**Coalitapoma unica** sp. nov.

Plate 14, fig. 7.


**DERIVATION OF NAME:** Latin, *unicus*, unique.

**DIAGNOSIS:** A species of *Coalitapoma* with two very short, blunt antapical horns. Reflected tabulation 4', 6'', ?c, 6''', 1'''', faintly indicated by very low ridges. Cyst wall densely granular with occasional verrucae.

**HOLOTYPE:** Slide D. 15 (1).

**DIMENSIONS:** Holotype: length 81\(\mu\), breadth 62\(\mu\), Range: length 66–83\(\mu\), breadth 60–65\(\mu\) (7 specimens measured).

**DESCRIPTION:** The reflected tabulation is only recognisable with difficulty. The cingulum is typically indicated by a faint cingular trace across the surface of the cyst and lateral indentations. The epitract appears to be longer than the hypotract. A sulcus has not yet been observed. The position of the archaeopyle is indicated by an incipient line of breakage along the posterior sutures of the apical plates and the lateral and posterior sutures of plate 3''.

**REMARKS:** *C. unica* is an infrequent species in the Kimmeridgian and its reflected tabulation is not fully known, nevertheless it is a very distinctive form and as such is considered to merit the erection of a new taxon.

Gitmez & Sarjeant (1972) recorded this species, as Proximate cyst sp. indet, from the Upper Kimmeridgian of England.
Genus **CORDOSPHAERIDIUM** Eisenack 1963b emend Davey 1969

? **Cordosphaeridium fasciatum** Davey & Williams 1966

1966 ? **Cordosphaeridium fasciatum** Davey & Williams: 90-91, pl. 7, figs. 5-6.
1969 ? **C. fasciatum** Davey & Williams; Millioud: pl. 1, figs. 1-3.

REMARKS: An isolated specimen attributable to this species was recorded from the Berriasian of Norfolk (sample S7).

REPORTED RANGE: Lower Barremian.

Genus **CORONIFERA** Cookson & Eisenack 1958 emend Davey 1969

**Coronifera oceanica** Cookson & Eisenack 1958

1958 **Coronifera oceanica** Cookson & Eisenack: 45, pl. 12, figs. 5-6.

REMARKS: **Coronifera oceanica** is characterized by the possession of numerous, flaccid spines, which are linked proximally by low crests, and by a large, tubular, antapical process. The precise position of the archaeopyle is difficult to discern and it may in fact be variable. In the present material (two poorly preserved specimens) the archaeopyle appears to be apical. Definite apical archaeopyles have been reported by Cookson & Eisenack (1968) and Davey (1969). However, some specimens reported by Davey & Verdier (1973) and Bradfield (1973) appear to possess a pre-cingular archaeopyle and others (Davey & Verdier op. cit.) a combination of apical and precingular. It is possible, however, that these latter two types of opening may result from cysts damage and distortion.

REPORTED RANGE: Upper Hauterivian - Santonian/Lowest Campanian.
Genus **CRIBROPERIDINIUM** Neale & Sarjeant 1962

emend. Davey 1969

**Cribroperidinium edwardsi** (Cookson & Eisenack) Davey 1969

1958 *Gonyaulax edwardsi* Cookston & Eisenack: 32-33, pl. 3, figs. 5-6.

1958 *Gonyaulax orthoceras* Eisenack: 355, pl. 21, figs. 3-11, p. 24, fig. 1, text. figs. 2, 3.

1966 *Gonyaulacysta orthoceras* (Eisenack); Sarjeant: 121, pl. 14, figs. 5-6.

1967 *Gonyaulacysta edwardsi* (Cookston & Eisenack); Clarke & Verdier: 31, pl. 5, fig. 1.

1969 *Cribroperidinium edwardsi* (Cookson & Eisenack); Davey: 125, 128.

1969 *Cribroperidinium orthoceras* (Eisenack); Davey: 128, figs. 13A, B.

REMARKS: I here group together *C. edwardsi* and *C. orthoceras*, considering their morphological differences to be within the limits of variation of a species. The slight differences between the two, (i.e. *C. orthoceras* possesses somewhat lower crests and a more elongate body than *C. edwardsi*) as commented on by Singh (1971), p. 304, are not considered sufficient for taxonomic separation at specific level.

A number of poorly preserved forms were encountered, these are attributed to *C. edwardsi* on the basis of their overall morphology, the possession of a complex reflected tabulation and a thick, two-layer cyst wall.

REPORTED RANGE: *C. edwardsi* Barremian - Campanian. *C. orthoceras* Tithonian - Middle Oligocene.

**Cribroperidinium muderongensis** (Cookston & Eisenack) Davey 1969

1958 *Gonyaulax muderongensis* Cookson & Eisenack: 32, pl. 3, figs. 3-4;

- 148 -
1969 *Gonyaulacysta muderongensis* (Cookson & Eisenack); Sarjeant:

1969 *Cribroperidinium muderongensis* (Cookson & Eisenack; Davey: 128–129

**REMARKS:** Infrequent poorly preserved specimens attributable to *C. muderongensis* were observed in the uppermost Jurassic and basal Cretaceous.

The species is at present, poorly diagnosed and a re-study of the type material is called for. Although it agrees with the diagnosis of *Cribroperidium*, its tabulation is still undescribed. In their original description Cookson & Eisenack referred to the plates simply as being "numerous".

**REPORTED RANGE:** Lower Cretaceous (Aptian).

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**Genus CRYPTARCHAEODINIUM** Deflandre 1939

*Cryptarchaeodinium calcaratum* Deflandre 1939

Plate 16, Fig. 4.

1939 *Cryptarchaeodinium calcaratum* Deflandre: 145, pl. 6, fig. 6.

**REMARKS:** The specimens attributed here to *C. calcaratum* vary somewhat in shape, from spherical to broadly ovoidal, although this may be a function of preservation. The tabulation as described by Gitmez (1970) in her emended diagnosis could be recognised, with difficulty, on a few specimens. In their overall morphology they are, however, very similar to the type material which the author, by courtesy of the late Professor Deflandre, was permitted to examine.
A variation in the height of the sutural crests is evident in some of the present material and several specimens possess briefly bifurcate spines developed on the crests. In all other respects they are very similar to the type material, accordingly taxonomic separation of the specimens is not considered to be justifiable.

Gorka (1965) recorded specimens from the Polish Oxfordian which are much larger than all other described specimens (including the present material) and possess longer sutural spines and possibly a second antapical plate (2''). The attribution of these forms to \textit{C. calcaratum} is accordingly considered to be very doubtful.

Downie (1958, p. 420, pl. 20, fig. 4; text-figs. 2c–d), described and illustrated a single specimen from the Kimmeridgian of Norfolk, stated by Gitmez (1970) as being from Dorset, which is similar in its size and general appearance to \textit{C. calcaratum}. Downie did, however, figure the specimen in an inverted manner and accordingly his interpretation of the reflected tabulation is wrong. This error was maintained by Gitmez (1970) in her discussion on this specimen. When correctly orientated, differences in tabulation are clearly evident between Downie's specimen and \textit{C. calcaratum}. It appears to represent a new species, but pending a re-examination of Downie's specimen and the availability of additional material, no new name is proposed.

\textbf{REPORTED RANGE:} ? Oxfordian - Upper Kimmeridgian.

\textit{Cryptarchaeodinium sp.}

1972 \textit{Cryptarchaeodinium cf. calcaratum} Deflandre; Gitmez & Sarjeant:
192-193, pl. 2, fig. 3; text-fig. 3.
DESCRIPTION: This species is very similar to C. calcaratum Deflandre except for its possession of a small, blunt, apical horn, possible possession of a posterior ventral plate (lpv), and in having sutural crests of an irregularly spinose character. Some of the sutural spines are briefly bifurcate. The cyst surface is minutely granular. The specimens are consistently poorly preserved, folded, or obscured by debris rendering description of the tabulation difficult.

DIMENSIONS: Overall length 45-50 , breadth 37-48 , apical horn length 3-5 , sutural spine-length 5-6 , (8 specimens measured).

REMARKS: Infrequent specimens were recorded which are comparable, in size and overall morphology, with the two specimens illustrated and described as C. cf. calcaratum by Gitmez & Sarjeant (1972) from the cymodoce Zone of Scotland and the pectinatus Zone of the Dorset Kimmeridgian. It is impossible to describe the tabulation with the material available here, but Gitmez & Sarjeant describe and figure it as 4', 6", 6c, 7", ?1pv and 1""'. They represented a new species of Cryptarchaeodinium, as emended by Gitmez (1970), but pending better preserved material no new name is proposed.

Genus CTENIDODINIUM Deflandre 1938 emend.


1966 Dichadogonyaulax Sarjeant, 153.

EMENDED DIAGNOSIS: Spheroidal, ovoidal, ellipsoidal or polyhedral dinoflagellate cysts, having the reflected tabulation, 3-5', 0-1a, 6", 0-6c, 5-6", 1p, 0-1pv, 1""': cingulum divided into plates or undivided, ventral region
may show division into additional small plates. Sutures in the form of low ridges bearing crests of varied form and height (smooth, denticulate or spinous; perforate or imperforate); or marked by lines of spines. Apical horn may be present, median and antapical horns lacking. Cingulum strongly or weakly spiral, laevorotatory. Archaeopyle, epitractal, by schism of the cyst immediately anterior to the cingulum, or along its anterior margin.

TYPE SPECIES: Ctenidodinium ornatum (Eisenack) Deflandre 1938 = Lithodinia jurassica var. ornata Eisenack 1935. Middle Jurassic (Callovian) France.

REMARKS: The diagnosis is emended to allow for more variation in reflected tabulation and sutural ornamentation, primarily to include forms previously attributed to Dichadogonyaulax Sarjeant. A close morphological similarity between Ctenidodinium and Dichadogonyaulax is readily apparent, the only criteria used to differentiate them were slight differences in the reflected tabulation, the form of sutural ornamentation and the absence of ornamentation along the anterior cingular margin of Ctenidodinium. These minor differences are not considered sufficient to justify taxonomic differentiation at generic level and Dichadogonyaulax is accordingly treated here as a junior synonym of Ctenidodinium.

Grouping together the two genera also serves the purpose of considerably reducing the large stratigraphic hiatus (Lower Kimmeridgian - Upper Hauterivian) that previously existed between known occurrences of species of Ctenidodinium; Dichadogonyaulax having a known range of Upper Kimmeridgian - Lower Berriasian.
cf. *Ctenidodinium ornatum* (Eisenack) Deflandre 1938

1935 *Lithodinia jurassica* var *ornata* Eisenack: 175, pl. 4, figs. 9-10; text-figs. 1-4.

1938 *Ctenidodinium ornatum* (Eisenack); Deflandre: 181, pl. 9, figs. 1-7.

1960 *Gonyaulax ornata* (Eisenack); Klement: 30, pl. 2, figs. 11-15, text-fig. 7-10.

REMARKS: A single specimen was recorded from the Boulonnais Kimmeridgian which is comparable with *C. ornatum* in its general appearance and form of its sutural crests, but a more precise comparison cannot be made due to its very poor preservation.

The attribution of Pocock's (1972) specimens from the Canadian Jurassic to this species is considered to be very doubtful. From his description and illustration they appear to be similar to *C. ornatum*, but differ in possessing a precingular archaeopyle.

REPORTED RANGE: Bathonian - Upper Oxfordian, possibly Lower Kimmeridgian.

*Ctenidodinium panneum* (Norris) Lentin & Williams 1973

Plate 14, fig. 10.


1969 *Dichadogonyaulax pannea* (Norris); Sarjeant: 14.

1973 *Ctenidodinium panneum* (Norris); Lentin & Williams: 36

REMARKS: *C. ornatum* is similar to *C. panneum*, but is readily distinguished from it by the non-oblate nature of the cyst, by its possession of six post-cingular plates, lack of division of the median ventral area and by the clear delimitation
of the anterior end of the ventral area from the first apical plate.


Ctenidodinium schizoblatum (Norris) Lentin & Williams 1973

1965 Leptodinium schizoblatum Norris: 798-800, figs. 4-5, 14-17.
1966 Dichadogonyaulax schizobleta (Norris); Sarjeant: nomen nudum, 211.
1969 Dichadogonyaulax schizobleta (Norris); Sarjeant: 14.
1973 Ctenidodinium schizoblatum (Norris); Lentin & Williams: 36.

REMARKS: C. schizoblatum was originally described from the Lower Purbeck Beds of Dorset by Norris (1965). Although it has not been recovered in the present re-study of the Dorset Purbeck Beds it has been recovered from sediments of comparable age in Norfolk (Samples S1 and S3). Although the Norfolk specimens are rare and somewhat distorted, the characteristic sutural ornamentation and the mode of archaeopyle formation are clearly evident.

REPORTED RANGE: Upper Portlandian.

OTHER SPECIES

The following species are retained within the genus:


Ctenidodinium *pachydermum* (Deflandre 1938b, 176, pl. 7, figs. 6-10; text. figs. 7-10). Gocht 1970, 142-143, Oxfordian, France.

*Ctenidodinium tenellum* Deflandre 1938b, 101, pl. 23, fig. 10. Callovian, France.

The following species is transferred to this genus:

*Ctenidodinium norrisium* (Pocock) comb. nov. - *Leptodinium norrisii* Pocock 1972, p. 92-93, pl. 24, fig. 1; text-fig. 9. Upper Jurassic, Canada.


*Cyclonephelium areolatum* Cookson & Eisenack 1960b

1960b *Cyclonephelium areolatum* Cookson & Eisenack: 253, pl. 38, figs. 7-8.

REMARKS: *Cyclonephelium areolatum* was originally described from the ? Tithonian of Australasia, its record here represents a considerable extension to its geographical range. Although infrequent in the writer's assemblages its occurrence indicates that is a useful stratigraphic in index.

REPORTED RANGE: ? Tithonian.

*Cyclonephelium distinctum* Deflandre & Cookson 1955

Plate 12, fig. 7.


1961 *Circulodinium deflandrei* Alberti: 29, pl. 4, figs. 7-13.

REMARKS: Most of the observed specimens bear numerous, rather short processes, especially developed around the periphery; none of the specimens possess antapical horns. Millioud (1967) attributed forms bearing very short processes (< 2 μ) to *C. distinctum* var. brevispinatum. Although variation in spine length was noted, this varietal differentiation is not maintained here. *C. distinctum* is morphologically very similar to *Tenua hystrix* Eisenack and it is quite possible that some reported pre-Aptian records of *T. hystrix* include mid-identified specimens of *C. distinctum*. Gitmez (1970) and Gitmez & Sarjeant (1972) for example, recorded *T. hystrix* as a commonly occurring Kimmeridgian form, yet they did not record a single specimen of *C. distinctum*.

REPORTED RANGE: Berriasian - Lower Tertiary.

*Cyclonephelium* cf. *vannophorum* Davey 1969a

Plate 10, fig. 5.

REMARKS: Very infrequent specimens were observed which are comparable with *C. vannophorum*, but a more precise comparison cannot be made due to their consistent poor preservation.

Bradfield (1973) has recently extended the known stratigraphic range of this species from the Cenomanian to the Aptian.

REPORTED RANGE: Aptian - Cenomanian.
Genus *DICTYOPYXIDIA* Eisenack 1961

*Dictyopyxis* Cookson & Eisenack, 1960b, p. 255, non *Dictyopyxis* Ehrenberg - (a diatom).

*Dictyopyxidia areolata* (Cookson & Eisenack) Eisenack 1961

1955 *Membranilarnax ovalum* Valensi: 590, pl. 2, fig. 4, pl. 5, fig. 6.

1960b *Dictyopyxis areolata* Cookson & Eisenack: 255-56, pl. 39, fig. s 12-14.

1961 *Dictyopyxidia areolata* (Cookson & Eisenack); Eisenack: 316.

1966b *Ellipsoidictyum areolata* (Cookson & Eisenack); G & M. Deflandre, fiches 3318-9.

1970 *Dictyopyxis* sp. Gitmez; 275-276, pl. 1, fig. 1.

1973 *Dictyopyxidia areolata* (Cookson & Eisenack); Eisenack ex Lentin & Williams: 47.

REMARKS: Gitmez (1970) recorded a number of specimens from the English and French Kimmeridgian as *Dictyopyxis* sp. She comments (p. 276) that "they differ from previously known species of *Dictyopyxis* and probably represent a new species, but better specimens are needed before this can be confirmed". Her illustration of (pl. 11, fig. 3), is, however, used by Gitmez & Sarjeant (1972, pl. 7, fig. 9) as an example of *Dictyopyxis areolata*. The writer, however, has recently re-examined some of Gitmez's material and considers them to be conspecific with *D. areolata*.

REPORTED RANGE: Bathonian - Middle Kimmeridgian.

Genus *DINGODINIUM* Cookson & Eisenack 1958

1970 *Parvocavatus* Gitmez; 306.
REMARKS: The genera Dingodinium and Parvocavatus Gitmez are here grouped together with Dingodinium having priority. Gitmez (1970) did not compare her genus with Dingodinium, only with Gurdodinium Alberti, which differs in possessing connecting processes between the two wall layers. In all respects, however, Parvocavatus accords with the diagnosis of Dingodinium. The sole distinguishing feature, is perhaps the hole at the tip of the apical horn in Parvocavatus. This is not, however, a constant feature in the present material and is considered to be possibly preservational. The same conclusion, regarding the status of the genus Parvocavatus, has been reached independently by Davey (1972, pers. comm.).

Dingodinium alberti Sarjeant 1966.

Plate 13, fig. 4.

1966 Dingodinium alberti Sarjeant: 210-211, pl. 21, fig. 3, pl. 23, fig. 1.

REMARKS: The specimens described and illustrated by Norris (1963), as Dingodinium braceatum (never validly published) from the Upper Kimmeridgian-Portlandian of Dorset, England are considered to be conspecific with D. alberti.

REPORTED RANGE: Upper Kimmeridgian - Upper Barremian.

Dingodinium tuberosus (Gitmez) comb. nov.

Plate 9, fig. 8. Plate 13, fig. 8.

1970 Parvocavatus tuberosus Gitmez: 307-308, pl. 16, fig. 9; text.fig. 31.

REMARKS: Some variation in surface ornamentation is evident in the present material. The innerbody wall varies between individual specimens from coarsely tuberculate to almost spinose; the tubercles in the latter being
developed into very short spinelets. When poorly preserved, or adversely orientated, differentiation from D. alberti Sarjeant is only possible with difficulty.

The tabulation as described by Gitmez (1970) could not be verified. In spite of her comment; "archaeopyle apical, the operculum remaining attached" (p. 306), which in itself is contradictory to "there is a split between the apical and precingular plates, which suggests incipient archaeopyle formation" (p. 307), numerous specimens were recovered in the present study with completely detached operculae (illustrated specimen).

REPORTED RANGE: Lower - Upper Kimmeridgian.

Dingodinium sp.

Plate 9, fig. 14.

DESCRIPTION: The inner body is ovoidal in shape, its maximum dimension being in the equatorial region; smooth, thin-walled and bears numerous randomly distributed coarse granules and short spines. The outer membrane is thin and close fitting, except at the antapex where it is extended to form two short, blunt protuberences. This outer membrane is frequently folded and lacks any definite indication of a reflected tabulation. A fold in the equatorial region does, however, appear to be associated with a narrow cingulum.

DIMENSIONS: Overall length 37 μ, breadth 41 μ, innerbody length 32 μ, breadth 39 μ, (1 specimen measured).

REMARKS: This form differs from all previously described species of Dingodinium in its overall morphology, but insufficient material prevents the
erection of a new taxon.

Genus **ECTENODINIUM** gen. nov.

**DERIVATION OF NAME:** Greek, ecteno, stretched out - with reference to the antapical pericoel formed by a extension of the periphragmon.

**DIAGNOSIS:** Elongate cysts, ovoidal to polygonal in outline with the tabulation $4', 6'', 6c, 6''', 1-2p, 1'''$. Processes, apical, antapical and lateral horns lacking Endophragm and periphragm in contact at the apices: a pronounced antapical pericoel is present, but the degree of separation at the apex is very small. Archaeopyle, precingular formed by loss of plate $3''$.


**REMARKS:** Ectenodinium is characterised by its *Gonyaulax*-type tabulation, lack of apical horn and pronounced antapical pericoel.

*Ectenodinium egemenii* (Gitmez) comb. nov.

**Fig. 27A.**

1970 *Leptodinium egemenii* Gitmez: 272-274, pl. 10, figs. 5-6; text. fig. 18.

**REPORTED RANGE:** Lower - Upper Kimmeridgian.

Genus **EGMONTODINIUM** Gitmez & Sarjeant 1972.

**REMARKS:** This genus is distinguished from all other known genera by its tabulation ($4', 5-6ac, 6'', 6c, 6''', 0p, 2pv, 6pc, 1''''$); definitions of the "ac" and "pc" series of plates are given by Gitmez & Sarjeent (1972, p. 228).
Additional very small plates may also be developed at crest nodes and the posterior tabulation is subject to some variation.

The presence of an apical archaeopyle and the overall morphology of this genus places it very close to *Ellipsoidictyum* Klement 1960. The complex tabulation of *Ellipsoidistyum* (described by Gocht 1970, pp. 150-152) is, however, markedly disimilar from that of *Egmontodinium*.

A second species attributable to this genus, as yet undescribed, has recently been observed by the writer in Upper Oxfordian assemblages from the North Sea.

*Egmontodinium polyplacophorum* Gitmez & Sarjeant 1972.

Plate 12, figs. 6, 10.

1972 *Egmontodinium polyplacophorum* Gitmez & Sarjeant: 229-230, pl. 8, figs. 1-4; pl. 9, fig. 3, pl. 11, figs. 5-6, text. figs. 24.

REPORTED RANGE: Upper Kimmeridgian.

Genus *ENDOSCRINIUM* Klement 1960 emend. Vozzhennikova 1967

*Endoscrinium companula* (Gocht) Vozzhennikova 1967

1959 *Scriniodinium campanula* Gocht: 61-62, pl. 4, fig. 6, pl. 5, fig. 1.

1967 *Endoscrinium campanula* (Gocht); Vozzhennikova: 175.

REMARKS: An isolated specimen attributable to this species was recorded from the Sandringham Sands (sample S7).

The specimens described from the Kimmeridgian by Gitmez (1970) and Gitmez & Sarjeant (1972) as *E. cf. campanula* are comparable with this species in their general morphology, but differ in the following points: the surface of the
cyst is granular, the sutural crests are preforate, the apex is rounded and the apical horn is formed from the periphragm only.

REPORTED RANGE: Valanginian - Turonian.

Endoscrinium oxfordianum (Sarjeant) Vozzhennikova 1967.

1962a Scriniodinium (? Endoscrinium) oxfordianum Sarjeant: 263, pl. 1, fig. 15.

1967b Endoscrinium oxfordianum (Sarjeant): Vozzhennikova: 175.

REPORTED RANGE: Oxfordian - Upper Kimmeridgian.

Genus EODINIA Eisenack 1936

Eodinia pachytherea Eisenack 1936

Plate 13, fig. 12.

1936 Eodinia pachytherea Eisenack: 73, figs. 1-6.

REMARKS: The specimens recorded here are comparable with the specimens recorded by Vozzhennikova (1967) from the Volgian of the Moscow Region of the U.S.S.R. Eodinia pachytherea was originally described from the Callovian of the Baltic Region by Eisenack 1936. It has also been recorded by Dodekova (1971) from the Volgian of Bulgaria.

REPORTED RANGE: Callovian - Volgian/Tithonian.

Genus EPIPLOSPHAERA Klement 1960

Epiplosphaera reticulospinosa Klement 1960

Plate 12, fig. 12.
1960  *Epiplosphaera reticulospinosa* Klement: 75-76, pl. 8, figs. 10-12.

REMARKS: *E. reticulospinosa* differs from *E. areolata* Klement in lacking a regular quadrilateral surface structure and from *E. bireticulata* in the absence of a second reticulation superimposed on the first.

REPORTED RANGE: Lower - Upper Kimmeridgian.

*Genus Fibraeosphaeridium* gen. nov.

DERIVATION OF NAME: Latin:—With reference to the fibrous nature of the periphragm and the spheroidal central body.

DIAGNOSIS: Central body sphaeroidal to broadly ovoidal with a two-layer wall. Processes, few, regularly arranged and reflecting a gonyaulacacean tabulation, arise from a thin micro-reticulate fibrilar periphragm and consist of solid bundles of anastomising fibres. Endophragm of moderate thickness, homogenous in structure. Tabulation 4', 6'', 6c, 6''', 1'''. Archaeopyle, precingular, formed by the loss of plate 3''.


REMARKS: The combination of fibrilar periphragm, solid fibrous processes and precingular archaeopyle distinguish this genus from all previously described ones.

*The most comparable genus is Cordosphaeridium* Eisenack emend. Davey & Williams 1966 which differs in possessing some considerable variation in the fibrosity of the processes and the structure of the periphragm.
Fibraeosphaeridium insignitum sp. nov.

Plate 18, fig. 4.

DERIVATION: Latin, insignitum, distinctive - with reference to the distinctive, easily recognisable characteristics of the species.

DIAGNOSIS: As for the genus.

HOLOTYPE: Slide D. 35 (5).

DIMENSIONS: Holotype: dimensions of central body 41 x 36 \( \mu \), process length, up to 18 \( \mu \). Range: central body 40-50 \( \mu \) x 36-45 \( \mu \), process length 17-20 \( \mu \) maximum. (7 specimens measured).

DESCRIPTION: The distribution of the processes clearly reflects a gonyaulacacean tabulation. This was difficult to determine, however, due to a combination of preservation and obscuring organic debris.

The processes vary somewhat in length on individual specimens. Distally, they are markedly flared with an irregular termination due to the irregularly anastomising fibres. A large archaeopyle occupies almost all of the dorsal epitract.

REMARKS: The species and genus are subject to future emendations pending the availability of additional material. It is, however, a very distinctive and easily recognisable form which, in the opinion of the writer merits the erection of a new taxon.

Norris (1963) recorded this form (never validly published) from the Upper Kimmeridgian - Portlandian of Southern England.

Cordosphaeridium inodes (Klumpp), typically a Tertiary species, is similar in that it possesses a fibrous wall and processes. The fibres of C. inodes are, however, short and arranged perpendicular to the surface; in F. insignitum the fibres anastomise over the surface.

It would appear, however, that many 'hystrichospheric' genera, as
evidenced by S.E.M. studies are basically fibrous in structure. Only in certain species, however, is it possible to see the fibres with an optical microscope.

Genus **GARDODINIUM** Alberti 1961

cf. **Gardodinium eisenacki**

1961 **Gardodinium eisenacki** Alberti: 18, pl. 3, fig. 8-13.

**REMARKS:** Two specimens, similar in overall appearance to **G. eisenacki** were recorded from the Sandringham Sands, due to poor preservation, they cannot, however, be attributed with certainty to this species.

The only previous Jurassic record of this species is the isolated specimen reported by Vozzhennikova (1967b) from the Russian Volgian.

**REPORTED RANGE:** Volgian – Albian.

Genus **GONYAULACYSTA** Deflandre ex Norris & Sarjeant 1965 emend.

1964 **Gonyaulacysta** gen. nov. Deflandre: 5. (Type species not validly proposed I.C.B.N. Art. 33, para. 4).

1965 **Gonyaulacysta** Deflandre; Norris & Sarjeant: 65. (Type species validly proposed).

1966 **Gonyaulacysta** Deflandre; Loeblich & Loeblich: 33.

1966b **Gonyaulacysta** Deflandre; emend. Sarjeant 111.

1967 **Gonyaulacysta** Deflandre; Wall: 98. (discussion only no diagnosis given).


**EMENDED DIAGNOSIS:** Proximate dinoflagellate cysts, spherical, ovoidal, ellipsoidal, or polyhedral, with the reflected tabulation 3-4', 0-1a, 6", 6-7"", 1-2p. 0-1pv, 1"". Apical horn constantly present, median and antapical horns lacking. Sutures in form of low ridges; bearing crests of varied form (smooth), denticulate or spinose; perforate or imperforate), or marked by lines of spines of varied form. Height of spines or crests always less than \( \frac{1}{4} \) of cyst breadth. Cingulum strongly or weakly helicoid; cingular plates well or poorly marked.
sulcus generally, but not constantly extending on to the epitract; undivided or divided into a variable number of small plates. Apical horn typically formed from the periphragm only, less frequently both wall layers; the two layers being otherwise in continous contact. Archaeopyle, formed by loss of plate 3". Surface, smooth, granular, nodose, punctate or reticulate.

**TYPE SPECIES:** *Gonyaulacysta jurassica* (Deflandre; Deflandre ex Norris & Sarjeant 1965. Oxfordian, France.

**REMARKS:** The diagnosis is emended to allow for more variation in the reflected tabulation and to exclude forms characterised by either an apical or an antapical pericoel. Forms with an apical pericoel are attributed to *Calcata* gen. nov., those with an antapical pericoel to *Sarjeantia* gen. nov. The genus *Psalgonyaulax* Sarjeant is retained for forms with both apical and antapical pericoels.

Forms according to this diagnosis, but with a general spine cover are, for the present, retained in *Acanthaulax* Sarjeant.

The distinction between other genera that are similar to *Gonyaulacysta* has been tabulated by Sarjeant (1966, table 4).

**Gonyaulacysta achmetes** Sarjeant 1966

1966 *Gonyaulacysta achmetes* Sarjeant: 123–124, pl. 13, figs. 5–6; text-fig. 30.

**REMARKS:** A single specimen attributable to this species was observed in the sample S1 from the Sandringham Sands. Although it is somewhat poorly preserved the characteristic shape of the apical horn and the reduced ornamentation on the sulcus is clearly evident.

Sarjeant originally described *G. achmetes* from the Upper Barremian,
subsequently Dodekova (1971) reported its occurrence in the Tithonian of Bulgaria and Bradfield (1973) from the Upper Aptian of France.

REPORTED RANGE: Tithonian - Upper Aptian.

Gonyaulacysta ambiguа (Deflandre) Sarjeant 1969

Plate 14, fig. 6.

1939 Gonyaulax ambiguа Deflandre: 144, pl. 6, fig. 2.

REPORTED RANGE: Callovian - Upper Kimmeridgian.

Gonyaulacysta angulosa Gitmez 1970

Fig. 23A

1970 Gonyaulacysta angulosa Gitmez: 252, pl. 2, figs. 4-5.

REMARKS: Gonyaulacysta angulosa is similar in general morphology to Gonyaulacysta granuligera (Klement). Unfortunately the illustrations of the type material of these two species do not allow much in the way of comparison. G. angulosa may well prove to be a junior synonym of Klement's species, but pending a re-examination of the types the species G. angulosa is retained.

REPORTED RANGE: Lower - Upper Kimmeridgian.

Gonyaulacysta attenuaris sp. nov.

Plate 15, fig. 3. Fig. 24.

DERIVATION OF NAME: Latin, attenuare, reduce, to make small - with reference to the very reduced apical form.

1972 *G. cf. mamillifera* (Deflandre); Gitmez & Sarjeant: 199-201, pl. 4, fig. 7; text. fig. 7.

**DIAGNOSIS:** Cyst globular, broadly ovoidal to subspherical, apex bearing a small mamelon form, antapex rounded. Reflected tabulation 4', 6', 6c, 6'', 1p, 1'''. Plate boundaries indicated by low membraneous crests. Cingulum slightly helicoid, dividing the cyst equally. Sulcus long, extending further on the epitract than on the hypotract; broadening posteriorly. Cyst wall thin, densely granular and punctate. Precingular archaeopyle formed by loss of plate 3''.

**HOLOTYPE:** Institute of Geological Science slide no. PK 130. H. M. Geological Survey Borehole, Warlingham, Surrey, England, at 2285 ft. 7in. depth. Upper Kimmeridgian (Rotunda Zone). Gitmez & Sarjeant (1972, pl. 4, fig. 7; text. fig. 7).

**DIMENSIONS:** Holotype: overall length 92\(\mu\), breadth 80\(\mu\). Range: overall length 67-92\(\mu\), breadth 58-80\(\mu\). (6 specimens measured).

**DESCRIPTION:** The apical structure varies from a well-developed mamelon form to a feebly developed apical prominence. The reflected tabulation can only be determined with some difficulty. Of the apical plates, plate 1' is long and narrow occupying the anterior of the sulcus; plates 3' and 4' are the largest with plate 2' being reduced in size. Plate 3'', lost in archaeopyle formation, is the largest of the precingular plates, the others are smaller with plate 6'' being the smallest and rather elongate. Of the post-cingular plates,
plate 3"" is the largest; plates 1"", 5"" and 6"" are considerably smaller, plate 1"" being reduced to accommodate the posterior plate 1p. A large plate, 1""", occupies the antapex.

REMARKS: This species has previously been described as *G. cf. mamillifera* and Gitmez & Sarjeant (1972), from the Lower Kimmeridgian of France and the Upper Kimmeridgian of England respectively. It has also been observed by the writer in the Lower Kimmeridgian of Greenland.

A re-examination of the holotype of *G. mamillifera* by the writer revealed several important differences between the two species. The crests of *G. mamillifera* are distinctly spinose and its apical mamelon appears to be more pronounced. In addition, differences can be seen in the tabulation; in the shape and arrangement of several plates (in particular, plates 1"", 2"" and 1p), and an additional plate (1p1) is present in *G. mamillifera*. A comparison between the apical plates of the two species was impossible, the apical region of the holotype of *G. mamillifera* being obscured by organic debris.

**Gonyaulacysta cauda** Gitmez & Sarjeant 1972

1970 *Gonyaulacysta* sp. B. Gitmez: 264-265, pl. 6, fig. 3; text. fig. 14.


REMARKS: *G. cauda* is a rare, but distinctive species characterised by long sutural spines distributed about the antapex and a poorly developed horn.

REPORTED RANGE: Lower - Upper Kimmeridgian.

**Gonyaulacysta cladophora** (Deflandre) Dodekova 1967.

1938b *Gonyaulax cladophora* Deflandre: 173-176, pl. 7, figs. 1-5; text. figs. 5-6.

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1967 *Gonyaulacysta* *cladophora* (Deflandre); Dodekova: 17-18, figs. 2-8.

1972 *Gonyaulacysta downiei* Pocock: 87, pl. 22, figs. 1-3; text-fig. 2.

1972 *Gonyaulacysts canadenensis* Pocock: 89, pl. 24, figs. 1-2, text-fig. 4.

**REMARKS:** Specimens attributed to this species have been recorded to date from the Bajocian to Kimmeridgian (Sarjeant 1972, gives a full list of references) and possibly from the Albian (Davey & Verdier 1973) and over this stratigraphic range they exhibit a considerable amount of morphological variation.

A re-examination of the type material by the writer demonstrated that considerable variation exists between the type specimens. In particular, the shape of the apical horn and the nature of the sutural ornamentation varies considerably between individual specimens.

The most detailed study of *G. cladophora* was by Klement (1960) who differentiated four subspecies on morphological criteria. These have never been maintained by later workers, perhaps, as is the case here, because the available material has never been sufficient or well preserved enough in order to form a meaningful judgement on his proposals. In this respect, Deflandre's original comment that "Although plentiful............ this species is most often in a bad state of preservation" (transl.) is considered to be entirely valid.

In view of the wide range in variation, the species, as it stands at present, is considered to be dubious taxonomic significance and of little stratigraphic use.

The taxonomic situation is further complicated in that certain Lower Cretaceous forms could be considered to fall within the accepted morphological
ranges of *G. cladophora* and also *G. serrata* (Cookson & Eisenack). The possibility that *G. cladophora* and *G. serrata* are conspecific cannot in fact be overlooked (Verdier 1973, pers. comm.).

*Gonyaulacysta downiei* Pocock and *Gonyaulacysta canadenensis* Pocock are considered to be junior synonyms of *G. cladophora*. The distinctions between these species and *G. cladophora* proposed by Pocock (1972) are considered to be of very dubious taxonomic value.

**REPORTED RANGE:** Bajocian - Upper Kimmeridgian and ? Albian.

The Albian record of this species (Davey & Verdier 1973) is probably due to reworking.

*Gonyaulacysta cristata* sp. nov.

**Plate 16, fig. 8. Fig. 25.**

**DERIVATION OF NAME:** Latin, *crista*, crests - with reference to the distinct sutural crests.

1972 *Gonyaulacysta* sp. G. Gitmez & Sarjeant: 212-213, pl. 6, figs. 7-8; text-fig. 15.

**DIAGNOSIS:** A species of *Gonyaulacysta*, broadly ovoidal with a strong, slender apical horn. Reflected tabulation 4', 6'', 6c, 6''', 1p, ?1pv, 1'''. Plate boundaries indicated by high, delicate, irregularly perforate crests with smooth distal edges. Cingulum narrow, helicoid, laevorotatory; epittract smaller than hypotract. Sulcus short, confined mainly to the hypotract, broadening posteriorly. Cyst wall thick, densely granular.

**HOLOTYPE:** Slide D. 41 (1).
DIMENSIONS: Holotype: overall length 68μ, breadth 42μ, apical horn length 9μ, height of sutural crests, up to 5-6μ. Range: overall length 65-78μ, breadth 40-45μ, apical horn length 9-10μ. (6 specimens measured).

DESCRIPTION: The reflected tabulation is difficult to determine due to the obscuring nature of the surface granulation and high sutural crests.

Plate 1' is long and narrow and occupies the anterior of the sulcus.
Plate 4' is of similar shape, plates 2' and 3' are smaller and more rounded in shape. Precingular plates 2' - 5' are moderately large; plates 1'' and 6'' being reduced in size. The postcingular plates 3'' and 4'' are large and occupy almost all of the hypotract; plates 1''', 5''' and 6''' are rather small.
Plate 1p is small and somewhat elongate, the single antapical plate (1''') is large and convex. A posterior ventral plate is faintly indicated, possibly subdivided into small plates.

REMARKS: This new species of Gonyaulacysta is superficially similar to G. perforans (Cookson & Eisenack), differing from it in detail of reflected tabulation and the form of its sutural crests.

G. cristata has previously been described, as G. sp. G., from the Upper Kimmeridgian (pectinatus Zone) of Dorset England by Gitmez & Sarjeant (1972).

Gonyaulacysta deflandrei sp. nov.

Plate 15, fig. 5, fig. 26B.

1972 Gonyaulacysta sp. F. Gitmez & Sarjeant: 211-212, pl. 6, figs. 3, 6; text-fig. 14.

DERIVATION: In honour of the late Professor Georges Deflandre.
DIAGNOSIS: A species of Gonyaulacysta, cyst elongate with a long tapering apical horn. Cyst wall composed of two distinct layers, a fairly thin endophragm and a thicker periphragm. The endophragm bulges into the lower half of the apical horn, its anterior being formed from the periphragm only. Tabulation 4', 1a, 6'', 6c, 6'''', 1p, 1pv, 1''''. Plate boundaries indicated by low, thick membranous crests from which arise short spiny outgrowths, irregularly distributed and isolated, or more often distally confluent forming a loosely constructed sutural network. Cingulum helicoid, laevorotatory, dividing the cyst unequally, the epitracx being longer than the hypotract. Sulcus broad, largely confined to the hypotract. Surface of the cyst densely granular, Archaeopyle precingular, formed by loss of plate 3''.

HOLOTYPE: Slide D. 39 (2).

DIMENSIONS: Holotype: overall length 89μ, breadth 45μ, apical horn length 16μ, Range: overall length 89-98μ, breadth 45-53μ, length of apical horn 16-26μ. (5 specimens measured).

DESCRIPTION: The apical horn is very characteristic, the anterior of the horn being formed by the periphragm only so that there is a distinctive cavity between the wall layers at the horns anterior. Four apical plates combine to form the horn, plate 1' being elongate and extending down for two-thirds of the epitracx. The anterior intercalary plate (1a) is quite large, accordingly the sixth precingular plate (6'') is reduced in size. The other five precingular plates are relatively large. Postcingular plates 1'' and 6''' are reduced in size, the other plates are moderately large. The posterior intercalary plate (1p) is narrow and elongate; a small posterior ventral plate (1pv) occupies the
posterior region of the sulcus. A single, small plate (1") occupies the antapex. A precingular archaeopyle forms by the loss of plate 3"; the holotype exhibits an operculum that has partially slipped inside the cysts central cavity.

REMARKS: In its overall morphology G. deflandrei is markedly different from all previously described species. A comparison may be drawn with G. perforans (Cookson & Eisenack), since both have a similarly elongate theca with a long apical horn, and a comparable reflected tabulation, but the form of the apical horns and sutural crests are completely different; G. perforans possesses an apical horn composed of both wall layers (although the individual layers are not readily recognisable) and well developed, porate, membraneous crests.

Gonyaulacysta ehrenbergii Gitmez 1970

Plate 15, fig. 4.

1970 Gonyaulacysta ehrenbergii Gitmez: 252-254, pl. 2, figs. 8-9, text-fig. 8.

REMARKS: G. ehrenbergii is characterized by its overall ovoidal shape, thick cyst wall and the possession of a seventh post-cingular plate. With a seventh post-cingular plate it is similar to the Lower Cretaceous species G. fetchamensis Sarjeant and G. palla Sarjeant, but it is readily distinguished from these species in details of tabulation, general aspect and size.

REPORTED RANGE: Lower - Middle Kimmeridgian.

Gonyaulacysta episoma Sarjeant 1968

1966 Gonyaulacysta episoma Sarjeant: 118-119, pl. 13, figs. 9-10, text-fig. 27.

REMARKS: A specimen figured as Gonyaulax tenuiceras by Alberti (1961, pl. 11,
fig. 7) from the Upper Barremian of Germany is considered by Sarjeant (1966) to be possibly attributable to this species.

REPORTED RANGE: Lower Cretaceous.

Gonyaulacysta fuscina sp. nov.

Plate 16, fig. 12.

DERIVATION OF NAME: Latin, fuscina, trident; a three pronged fork - with reference to the distinctive distal termination of the apical horn.

DIAGNOSIS: A species of Gonyaulacysta, broadly ovoidal to subspherical, with a strong, well developed apical horn which trifurcates distally. Plate boundaries marked by very low ridges from which arise spines, either simple and isolate or more often irregularly branches and laterally confluent forming a strong, irregular net-like structure. Cyst wall thick, smooth to minutely granular with occasional irregularly distributed small, blunt spines.

HOLOTYPE: Slide D. 43 (3).

DIMENSIONS: Holotype: overall length 82\(\mu\), breadth 60\(\mu\), horn length 10\(\mu\), height of sutural ornamentation 2-5\(\mu\), height of surface spines 1-2\(\mu\). Range: overall length 70-82\(\mu\), breadth 48-65\(\mu\), horn length 14-16\(\mu\). (3 specimens measured).

DESCRIPTION: The tabulation was not readily determinable due to the obscuring nature of the sutural ornamentation and the frequently distorted and somewhat folded appearance of the specimens. The cingulum is of moderate width (3-4\(\mu\)). The cyst wall measured between 1-1.5\(\mu\) in thickness and
consists of two distinct layers. The apical horn, formed from both wall layers, is moderately broad-based and tapers distally before branching into 3 distinct spine-like structures up to 3µ in height.

REMARKS: Seven specimens of this very distinctive species were recorded. It is readily differentiated from all previously described species of Gonyaulacysta in the form of its apical horn and accordingly in spite of the poor preservation of the available material, a new specific name is considered to be justifiable.

_Gonyaulacysta globata_ Gitmez & Sarjeant 1972

Plate 15, figs. 1-2.

1957 *Palaeoperidium* cf. _nuciforme_ Deflandre; Downie: 423, text. fig. 3F.

1972 _Gonyaulacysta globata_ Gitmez & Sarjeant: 195-197, pl. 3, figs. 1-2, text. fig. 5A-B.

REMARKS: _G. globata_ is a very distinctive species; globular in shape, thin-walled and possessing a slender apical horn. The specimens recorded as *Palaeoperidium* cf. _nuciforme_ by Downie (1957) from the English Kimmeridgian appear to be attributable to this species. Unfortunately only an outline text-figure was given by Downie, which, together with his very brief description, does not allow for a more precise comparison.

REPORTED RANGE: Lower - Upper Kimmeridgian.

_Gonyaulacysta granulata_ (Klement) Sarjeant 1969

1960 _Gonyaulax granulata_ Klement: 39-41, pl. 4, figs. 10-13; text.-figs. 18-20.

1969 _Gonyaulacysta granulata_ (Klement); Sarjeant: 9.
REMARKS: *G. granulata* is very similar to *G. granuligera* Klement and a number of authors (i.e. Warren 1967) have grouped them together. Pending a re-examination of Klement's type material the two species are retained. *G. granulata* is retained for forms possessing a short apical horn and moderately low sutures. Forms with a long apical horn and spinose sutures are referred to *G. granuligera*.

REPORTED RANGE: Bajocian - Upper Kimmeridgian and Tithonian.

*Gonyaulacysta granuligera* (Klement) Sarjeant 1969

1960 *Gonyaulax granuligera* Klement: 41-42, pl. 5, figs. 4-5.

1969 *Gonyaulax granuligera* (Klement); Sarjeant: 10.

REMARKS: The observed specimens are very close to the type material, but more spherical in shape with slightly shorter apical horns. See also remarks for *G. granulata*.

REPORTED RANGE: Bajocian - Upper Kimmeridgian.

*Gonyaulacysta helicoidea* (Eisenack & Cookson)

Sarjeant 1966 emend.

Plate 14, fig. 5. Plate 16, fig. 2.


1960 *Gonyaulax helicoidea* Eisenack & Cookson: 2-3, pl. 1, figs. 4-5.

? 1964 *Gonyaulax* sp. B Vardova: 97, pl. 3, figs. 2-4, text-figs. 2a-b.

1962 *Gonyaulax cretacea* Neale & Sarjeant: 441, pl. 19, figs. 1-2; text-fig. 2.

1966a *Gonyaulacysta helicoidea* (Eisenack & Cookson); Sarjeant: 116-117, pl. 13, figs. 7-8; pl. 15, figs. 8-9; text-fig. 26.
1967 *Gonyaulacysta helicoidea* var. *tuberculata* Vozzhennikova; 83, pl. 4, figs. 3a-b.

1970 *Gonyaulacysta* cf. *helicoidea* (Eisenack & Cookson); Gitmez: 258-259, pl. 2, figs. 1-2; text-fig. 11.

**EMENDED DIAGNOSIS:** *Gonyaulacysta* having a spheroidal, ovoidal or polygonal cyst bearing an apical horn of varying length. Epitract longer than hypotrait; antapex flattened. Reflected tabulation 4', 6", 6c, 6", 1p, 1pv, 1'"; plates bordered by denticulate crests, varying considerably in both height and character of denticulation. Cingulum strongly spiral, laevorotatory. Sulcus sigmoidal. Cyst surface smooth, or bearing irregular scatter of tubercles; number, situation and density of tubercles varying greatly between individuals.

**HOLOTYPE:** Cookson & Eisenack 1960, pl. 1, fig. 4. I.C. Cookson Collection, University of Melbourne. Lower Cretaceous, Australia.

**REMARKS:** The differentiation between *G. helicoidea* and *G. cretacea* proposed by Sarjeant (1966a, p. 117) appears to be of dubious value, as a slight distortion would modify the shape of the cyst. Furthermore, the development of tubercles is a variable feature which is considered herein to be of intraspecific value only.

The diagnosis of *G. helicoidea* is emended to allow for the inclusion of *G. cretacea*.

Contrary to the comment by Gitmez (1970, p. 259) that the known range of *G. helicoidea*, at the time of writing, was Barremian to Aptian, previous records included the Tithonian of the U.S.A. (Warren 1967, unpublished), the Russian Upper Jurassic (Vozzhennikova 1967) and the Australian Albian (Eisenack...

*Gonyaulacysta hyaloderma* (Deflandre) Sarjeant 1967

1939 *Palaeoperidium hyalodermum* Deflandre: 144, pl. 6, fig. 3-4.

1967a *Gonyaulacysta hyaloderma* (Deflandre); Sarjeant: 10.

REMARKS: Gitmez (1970) emended the diagnosis of this species to include reference to the reflected tabulation which Deflandre (1939) was unable to determine. A re-examination of the holotype by the writer similarly proved unsuccessful. A tabulation is indicated by the present material, but owing to the delicate, frequently folded nature of the cyst wall and the high obscuring sutural crests, it could not be determined in detail. Accordingly, the reflected tabulation, as described by Gitmez (1970) on the basis of a single specimen, must be treated with caution.

*G. hyalodermopsis* (Cookson & Eisenack 1955, pl. 3, figs. 11-12) from the Australian Lower Cretaceous and *Palaeoperidium* cf. *hyaloderma* of Downie (1957, text. fig. 3d) from the English Kimmeridgian might possibly be conspecific with this species. Variations in overall size and the length of the apical horn may be of infraspecific value only. Sarjeant's suggestion (1967a, p. 252) that Downie's specimen might be a variant of *Gonyaulacysta jurassica* (Deflandre) is considered to be very unlikely.

Tertiary records of this species (de Coninck 1965) are considered to be anomalous, probably representing reworked material.

**Gonyaulacysta jurassica** (Deflandre) Norris & Sarjeant 1965.

Plate 16, fig. 3.

1938b  *Gonyaulax jurassica* Deflandre: 168–170, pl. 6, figs. 2-5; 1-2.

1965  *Gonyaulacysta jurassica* (Deflandre); ex Norris & Sarjeant: G5.

**REMARKS:** The specimens described and illustrated as *G. cf. jurassica* by Singh (1964) and Vagvolgyi & Hills (1969) from the Lower Cretaceous of Canada are considered to be completely unrelated to this species.

The inclusion within this species of Sarjeant's (1972, pl. 1, figs. 2, 4) illustrated specimens from the Middle Jurassic of Greenland is considered to be somewhat doubtful. The presence of an inflated apical pericoel suggests affinities with *Psaligonaulax*.

The single occurrence of this species in the Cretaceous (Sandringham Sands) is considered to be due to reworking.

**REPORTED RANGE:** Bathonian to Upper Kimmeridgian and Tithonian/Volgian.

*Gonyaulacysta jurassica var. longicornis* Deflandre

1938a  *Gonyaulax jurassica var. longicornis* Deflandre: 171, pl. 6, fig. 6.

1964  *Gonyaulacysta jurassica var. longicornis* Deflandre; Deflandre: 5.

**REMARKS:** *G. jurassica var. longicornis* is considered to represent an extreme in the dimensional spread of *G. jurassica* and cannot be considered to be of great taxonomic stratigraphic significance.

*Gonyaulacysta longicornis* (Downie) Sarjeant 1969

emend Gitmes & Sarjeant 1972

Plate 16, fig. 13.

1957  *Gonyaulax longicornis* Downie: 420, pl. 20, fig. 8, text.-figs. 2a-b.
1969 Gonyaulacysta longicornis (Downie); Sarjeant: 10.

1972 G. longicornis (Downie); Gitmez & Sarjeant: 197-199, pl. 2, fig. 6, pl. 4, fig. 1, text-fig. 6.

REMARKS: Gitmez & Sarjeant (1972) emended the diagnosis to include detail of the reflected tabulation.

REPORTED RANGE: Lower - Upper Kimmeridgian and Upper Volgian

Gonyaulacysta nuciformis (Deflandre) Sarjeant 1969
Plate 16, figs. 9-10.

1938 Palaeoperidium nuciforme Deflandre: 180, pl. 8, figs. 4-6.

1962b Gonyaulax nuciformis (Deflandre); Sarjeant: pl. 1, fig. 8, tables 3-4.

1965 Palaeoperidium nuciformis Gorka: 300-301, pl. 2, figs. 1-2.

REMARKS: Specimens attributed to G. nuciformis by previous authors (see Gitmez & Sarjeant 1972 for full synonymy and references) include forms which vary considerably in morphology. The species, as it now stands, is considered to be a "balloon taxon", due to a lack of nomenclatural distinction in publications between the original description of the species and each of the various subsequent attributions to it. Specimens attributed here to G. nuciformis are very similar to the holotype, which the writer was recently able to re-examine, although some variation in the overall size of the cyst and the relative length of the apical horn has been allowed.

The sutural spines and form of the apical horn (typically distally trifurcate) of the holotype is very distinctive, a cingulum is evident, but only a trace of the reflected tabulation is visible, accordingly it could not be determined. Sarjeant (1962b) illustrates a specimen from the English Oxfordian
as *G. nuciformis* and gives the reflected tabulation as \( ?4', 1a, 6'', 6'''', 1p, 1'''' \). His figured specimen does, however, bear the distinctive sutural spines and apical horn characteristic of this species. In contrast, without references to the earlier paper, Gitmez & Sarjeant (1972 pl. 3, fig. 5, text-fig. 8) illustrate and figure a specimen from the Lower Kimmeridgian and give the reflected tabulation as \( 4', 1a, 6'', 6c, 6'''', 1p, 1pv, 1'''' \). Furthermore, the specimen bears very few sutural spines and a simple apical horn.

Clearly, in view of these discrepancies, a re-study of specimens attributed to *G. nuciformis* is needed, in order to reassess the true taxonomic and stratigraphic significance of the species.

REPORTED RANGE: Callovian - Upper Kimmeridgian.

*Gonyaulacysta pennata* sp. nov.

Plate 16, fig. 7.

DERIVATION OF NAME: Latin, *pennatus*, feathered, referring to the featherlike extension at the distal end of the apical horn.

DIAGNOSIS: A species of *Gonyaulacysta* with an elongate-ovoidal to broadly ovoidal cyst. Epitract tapers to form a strong abruptly rounded apical horn of varying length, hypotract dome-shaped, antapex rounded. Cyst wall thick and composed of two layers, the outer periphragm forms the sutural ornamentation and a feather-like extension at the distal end of the apical horn. Plate boundaries indicated by low ridges formed from the periphragm from which arise spines, either simple and isolated or confluent, particularly in the antapical region, to form a loosely constructed net-like structure up to 5 μm in height.
Surface of the cyst densely, but finely granular and irregularly perforate.

HOLOTYPE: Slide B. 26 (5)

DIMENSIONS: Holotype: overall length 84\(\mu\), overall breadth 47\(\mu\), length of apical horn 5\(\mu\), length of apical projection 12\(\mu\), height of sutural crests, up to 5\(\mu\). Range: overall length 75-93\(\mu\), overall length 47-68\(\mu\). (5 specimens measured).

DESCRIPTION: The cingulum is relatively narrow and divides the cyst unequally, the epitrack being longer than the hypotrack. The sulcus is long and narrow extending on to both epitrack and hypotrack. Detail of tabulation could not be determined due to the obscuring nature of the wall granulation and sutural ornamentation.

REMARKS: Five specimens of this distinctive species were observed. In overall morphology they are similar to \textit{G. perforans} (Cookson & Eisenack) but are readily differentiated by the characteristic form of the apical structure.

\textit{Gonyaulaxysta perforans} (Cookson & Eisenack) Sarjeant 1969

Plate 16, fig. 11.

1958 \textit{Gonyaulax perforans} Cookson & Eisenack: 30, pl. 2, figs. 1-4.

1969 \textit{Gonyaulaxysta perforans} (Cookson & Eisenack); Sarjeant: 10.

REMARKS: Several of the specimens attributed by Gitmez (1969, thesis) to \textit{G. perforans} possess long apical horns up to 40\(\mu\) in length, which, from her illustrations (pl. 10, figs. 2-5; pl. 11, figs. 1-2) appear to be of very doubtful attribution. Since this thesis formed the basis of the Gitmez & Sarjeant...
(1972) publication, the distribution of G. perforans in the English and French Kimmeridgian presented by the authors must be treated with caution.

REPORTED RANGE: Middle Kimmeridgian - Albian.

Gonyaulacysta cf. scotti (Cookson & Eisenack) Sarjeant 1969

1958 Gonyaulax scotti Cookson & Eisenack: 30, pl. 2, figs. 4-5.
1969 Gonyaulacysta scotti (Cookson & Eisenack); Sarjeant: 11.

REMARKS: Infrequent specimens were observed that appear to be very similar in overall appearance to G. scotti, but somewhat smaller. In view of their poor preservation and the inadequate diagnosis given for G. scotti, a more precise comparison cannot be made.

To date, G. scotti has only been reported from Australia.

REPORTED RANGE: Upper Jurassic (possibly Upper Callovian - Lower Oxfordian).

Gonyaulacysta serrata (Cookson & Eisenack) Sarjeant 1969

1958 Gonyaulax serrata Cookson & Eisenack: 34, pl. 3, fig. 2; text-figs. 12-14.
1969 Gonyaulacysta serrata (Cookson & Eisenack); Sarjeant: 10.
1970 G. serrata (Cookson & Eisenack); Gitmez 262-263.

REPORTED RANGE: Lower Kimmeridgian - Neocomian.

Gonyaulacysta sp. A. Gitmez 1970

Fig. 23 B

1970 Gonyaulacysta sp. A. Gitmez: 263-265, pl. 3, fig. 3; text-fig. 13.
1972 G. sp. A. Gitmez; Gitmez & Sarjeant: 205-206, pl. 9, figs. 1-2.
REMARKS: This form is a very infrequent species in the Kimmeridgian and is typically poorly preserved. It is characterised by its overall ovoidal shape, thick cyst wall and sparsely spinose surface.

REPORTED RANGE: Lower - Upper Kimmeridgian.

_Gonyaulacysta_ sp. B

Plate 15, fig. 10.

DESCRIPTION: A _Gonyaulacysta_ with a broadly ovoidal cyst bearing a strong, blunt apical horn. Reflected tabulation not determinable due to poor preservation. Plate boundaries indicated by low rather fibrous crests, giving rise to occasional small spines up to 4µ in length. Cyst wall thick, with a densely granular surface.

DIMENSIONS: overall length 80µ, breadth 67µ, length of apical horn c16µ.

(1 specimen measured).

REMARKS: Three poorly preserved specimens were observed, only one being capable of measurement. In its general appearance it appears to be similar to a number of Cretaceous species, but a more precise comparison cannot be made.

_Gonyaulacysta_ sp. H. Gitmez & Sarjeant 1972

Fig. 26A

1972 _Gonyaulacysta_ sp. H. Gitmez & Sarjeant: 213–214, pl. 13, fig. 1; text-fig. 16.

REMARKS: Very infrequent, poorly preserved specimens were observed which are very similar to the specimen described and illustrated by Gitmez & Sarjeant.
Missing pages are unavailable
(1972) from the Middle Kimmeridgian.

Gonyaulacysta spp.

Plate 16, fig. 15.

REMARKS: A considerable number of specimens were recovered from the Kimmeridgian - Portlandian of Dorset and the Boulonnais and, to a lesser extent from the Sandringham Sands, which from their general appearance are attributable to Gonyaulacysta. Sub-division of the specimens was not possible due to a number of factors: dense surface ornamentation, poor preservation, obscuring organic debris and adverse orientation.

OTHER SPECIES

The following species are here transferred to the genus Gonyaulacysta.

Gonyaulacysta punctata (Baltes), comb. nov. = Leptodinium punctatum Baltes, 1970; 3, pl. 1, figs. 2-3, 6-7. Lower Pliocene, Roumania.

Gonyaulacysta bacculata (Baltes), comb. nov. = Leptodinium bacculatum Baltes, 1970, 3, pl. 1, figs. 4-5. Lower Pliocene, Roumania.

Gonyaulacysta aptiana (Deflandre) comb. nov. = Rhynchodiniopsis aptiana Deflandre, 1935; pl. 5, fig. 10, pl. 8, figs. 7-10. Lower Cretaceous, France. (Invalidly transferred to Gonyaulacysta by Sarjeant, 1966, 140).

Genus HERENDEENIA Wiggins 1969

Herendeenia pisciformis (Cookson & Eisenack) Wiggins 1969

1958 Omatia pisciformis Cookson & Eisenack: 61, pl. 8, fig. 6.

1969 Herendeenia pisciformis (Cookson & Eisenack); Wiggins: 146-148,
pl. 1, figs. 1-7; text-figs. 3a-b.

REMARKS: Two specimens, partly obscured by debris, were observed. They are considerably smaller than the type material from the Upper Jurassic of Papua, but comparable in size with the material described from the Lower Cretaceous of Alaska (Wiggins 1969).

REPORTED RANGE: Callovian - Lower Cretaceous.

Genus **HESLERTONIA** Sarjeant 1966

**Heslertonia heslertonensis** (Neale & Sarjeant) Sarjeant 1966

1962 Gonyaulax heslertonense Neale & Sarjeant: 440, pl. 19, fig. 5; pl. 20, fig. 5, text-fig. 1.

1966 **Heslertonia heslertonensis** (Neale & Sarjeant); Sarjeant: 133.

REMARKS: Forms closely comparable with this species were observed in Portlandian assemblages from the Boulonnais. Both forms have in common high, striate crests and similar tabulations. Accordingly the observed material represents an extension in both the stratigraphical and geographical ranges of **H. heslertonensis**.

REPORTED RANGE: Hauterivian.

**Heslertonia pellucida** Gitmez 1970

Plate 11, fig. 9.

1970 **Heslertonia pellucida** Gitmez: 297-299, pl. 4, fig. 12, pl. 14, fig. 2, text-fig. 26.

REMARKS: **H. pellucida** is distinguished from **H. heslertonensis** by the
non-striate nature of its crests and detail of tabulation.

REPORTED RANGE: Lower - Upper Kimmeridgian.

Genus HYSTRICHODINIUM Deflandre 1935 emend.

Clarke & Verdier 1967


REMARKS: The genus Hystrichodinium Deflandre was originally diagnosed as having a helicoid girdle, hollow processes, a sculpture or areolate punctuations and without tabulation. From an examination of a great number of specimens, including a re-examination of Deflandre’s type material, it cannot any longer be stated that the genus is non-tabulate, although this feature is not always clearly displayed. It is also evident that Hystrichodinium possesses a precingular archaeopyle.

Accepting that Hystrichodinium possesses tabulation and a precingular archaeopyle, its morphological similarity with Heliodinium Alberti is readily apparent. In fact, the only useful criterion Alberti uses to distinguish the two genera is the presence of tabulation in Heliodinium.

Heliodinium is accordingly a junior synonym of Hystrichodinium Deflandre emend. Clarke & Verdier.

Clarke & Verdier similarly considered Heliodinium to be a junior synonym of Hystrichodinium, but they did not validify the transfer of the type out of Heliodinium, hence it remained a valid genus.

Hystrichodinium pulchrum Deflandre 1935

Plate 11, fig. 1.

1935 Hystrichodinium pulchrum Deflandre: 229-230, pl. 5, fig. 1. text-figs.
REMARKS: The distinctive surface ornamentation as described by Deflandre (1935) is totally lacking on the majority of specimens; its absence is presumed to be a preservational phenomena or a result of chemical treatment during processing. Similar forms lacking the surface ornamentation have been described from the English Cenomanian by Clarke & Verdier (1967).

Deflandre (1936a) proposed a division of this species into three varieties based on overall size and relative deposition of the processes. Although some degree of variation is apparent in the present material, particularly in the length of the processes, it is impossible to maintain his varieties. It is possible that they merely represent normal specific morphological variability coupled with differential preservation.

H. pulchrum has previously only been recorded from the Cretaceous, its occurrence reported here (in considerable abundance) therefore represents a downward extension of its known stratigraphic range. The poorly preserved specimens by Gitmez & Sarjeant (1972) from the Kimmeridgian as Cleistosphaeridium sp. may however be attributable, at least in part, to this species.

REPORTED RANGE: Valanginian - Senonian.

_Hystrichodinium telaspinosum_ sp. nov.

_Plate 11, fig. 8._

DERIVATION OF NAME: Latin, _tela_, web; _spina_, spine - with reference to the spinose sutural processes and the thin web-like connecting membrane between adjacent processes.
DIAGNOSIS: Broadly ovoidal to subspherical cysts. Wall composed of two layers, a moderately thick, fibrous endophragm and a thin smooth periphragm. Processes long, slender, hollow and spinose, formed from both wall layers. Processes isolate, or more usually a few adjacent processes, along the same sutural line, are connected laterally by a thin, delicate, web-like extension of the periphragm. Cingulum, broad (c. 3-5\(\mu\)), equatorial. Archaeopyle precingular, formed by the loss of a large "hoof-shaped" precingular plate.

HOLOTYPE: Slide D. 27 (2).

DIMENSIONS: Holotype: length of central body 58\(\mu\), breadth 48\(\mu\), length of processes, up to 15\(\mu\). Range: length of central body 40-58\(\mu\), breadth 30-49\(\mu\), length of processes 8-15\(\mu\). (24 specimens measured).

DESCRIPTION: The spinose processes are typically simple and distally pointed, although distally blunt or very briefly bifurcate processes may be present on an individual specimen.

REMARKS: This new species differs from all previously described species in the form of its processes and the fibrous nature of the endophragm.

\textit{Hystrichodinium voigti} (Alberti) comb. nov.

Plate 11, fig. 2.

1961 \textit{Heliodinium voigti} Alberti: 33, pl. 8, figs. 1-5.

1966 \textit{H. voigti} Alberti; Sarjeant: 142-144, pl. 6, fig. 2, text-fig. 6.

1967 \textit{Hystrichodinium voigti} (Alberti); Clarke & Verdier: \textit{nomen nudum}, 38

REMARKS: \textit{H. voigti} is distinguished from \textit{H. pulchrum} Deflandre by the
subpolygonal shape of its central body and more readily discernible tabulation.

REPORTED RANGE: Barremian - Lower Conomanian.

_Hystrichodinium_ sp.

Plate 11, fig. 6.

DESCRIPTION: The central body is broadly ovoidal with rounded apices and bears numerous processes. The processes are of approximately equal length on an individual specimen, but vary somewhat in width. The majority of processes are slender, of uniform width (c. 1 µ) and distally bifurcate or flaired. Occasional processes are present which are wider (c. 3 µ) and branch at about half their length before terminating in a similar manner to the more slender processes. The cingulum is helicoid and equatorial. A precingular archaeopyle is developed by the loss of a somewhat rounded, arch-shaped plate. The cyst wall is thin and finely granular.

DIMENSIONS: central body length 47-52 µ, breadth 40-44 µ, process length 8-10 µ. (4 specimens measured).

REMARKS: This form clearly represents a new species of _Hystrichodinium_. Only four specimens were observed, all crushed and poorly preserved, accordingly no new specific name is proposed.

OTHER SPECIES

_Hystrichodinium patriciae_ (Neale & Sarjeant) comb. nov. = _Heliodinium patriciae_ Neale & Sarjeant 1962, p. 451-452, pl. 19, fig. 3; text-fig. 7.

Hauterivian
Genus HYSTRICHIOSPHAERIDIUM Deflandre 1937
emend. Davey & Williams 1966

*Hystrichosphaeridium costatum* Davey & Williams 1969

? 1938 *Hystrichosphaeridium salpingophorum* (Deflandre); Deflandre: 186, pl. 10, figs. 1-3.

? 1947 *H. salpingophorum* (Deflandre); Deflandre: text-fig. 1, no. 6.

? 1952 *H. salpingophorum* (Deflandre); Deflandre: text-fig. 10.

1960 *H. salpingophorum* (Deflandre); Klement: 55, pl. 7, figs. 3-5; text-fig. 31.

1960 *H. salpingophorum* (Deflandre); Sarjeant: pl. 13, fig. 7.

1961 *H. salpingophorum* (Deflandre); Sarjeant: 99, pl. 15, fig. 7.


1966 *Hystrichosphaeridium costatum* Davey & Williams: 62-63, pl. 10, fig. 4.

? 1971 *Hystrichosphaeridium polonicum* Gorka; Beju: 292, pl. 5, fig. 3.

REMARKS: Davey & Williams (1966) separated this species by restricting the diagnosis of *H. salpingophorum* Deflandre. It is possible, however, that in falls in synonymy with *H. polonica* Gorka which has priority.

REPORTED RANGE: Oxfordian - Lower Kimmeridgian.

*Hystrichosphaeridium petilum* Gitmez 1970

1970 *Hystrichosphaeridium petilum* Gitmez: 289-290, pl. 9, figs. 1, 6; text-fig. 24.

REMARKS: See remarks for Cleistosphaeridium tribuliferum.

REPORTED RANGE: Lower - Upper Kimmeridgian.
**Hystrichosphaeridium sp. A**

Plate 18, fig. 1.

DESCRIPTION: The central body is ovoidal with rounded apices. The processes are short and tubular, opening distally with serrate margin that occasionally bears very short spines. Reflected tabulation not determinable due to poor preservation. The cyst wall is thin, smooth and folded.

DIMENSIONS: length of central body 30-31\mu, breadth 19-20\mu, process length 5-7\mu, process width 2-2.5\mu, (2 specimens measured).

REMARKS: *Hystrichosphaeridium tubiferum* var. *brevispinosum* Davey & Williams from the Lower Tertiary of England is a similar species, but is readily distinguished by its more spheroidal central body and longer and much wider processes.

? *Hystrichosphaeridium arundum* (Eisenack & Cookson) processes a more spheroidal central body, ornamented with the granules, and processes of variable width with delicate, but entire distal margins.

**Hystrichosphaeridium sp. B**

Plate 11, fig. 3.

DESCRIPTION: The central body is speroidal with a thick (1-3\mu), densely granular wall. Processes are of moderate length, tubular, hollow and open distally with a smooth margin. They are slender, simple and distally flaired.

DIMENSIONS: central body diameter 40-44\mu, process length, up to 12\mu, (2 specimens measured).
REMARKS: Two specimens were observed which possibly represent a new species of *Hystriochosphaeridium*. Due to poor preservation and insufficient material, however, a new name is not considered to be justifiable.

**Genus LANTERNA** Dodekova 1969

REMARKS: Species attributed to the genus *Lantern* are characterised by their overall "Lantern-like" shape, the presence of an apical archaeopyle and the absence of ornamentation along plate boundaries.

*L. spinosa* Dodekova appears to possess sutural crests and as such does not accord with the generic diagnosis. Unfortunately, the available illustrations (Dodekova 1969) do not help very much in the way of comparison.

**Lantern** bulgaria Dodekova 1969

Plate 14, fig. 4.

1969 *Lantern** bulgaria** Dodekova: 16-17, pl. 2, fig. 3-6; pl. 3, fig. 1; text-figs. B & Db.

REMARKS: The single specimen observed is very similar to the Bulgarian type-material. It's surface spines are, however, shorter (2-3µ against 4-6µ) but this is not considered to justify any taxonomic differentiation.

REPORTED RANGE: Tithonian.

**Genus LEPTODINIUM** Klement 1960 emend.

*Leptodinium aceras* (Eisenack) Sarjeant 1969 emend

Fig. 29 B.

1966  ? Gonyaulacysta aceras (Eisenack); Sarjeant: nomen nudum. 131

1969  Leptodinium aceras (Eisenack); Sarjeant: 12.

1972  L. aceras (Eisenack); Gitmez & Sarjeant: 215-216, pl. 5, figs. 1-3; text. fig. 17.

REMARKS: Specimens corresponding exactly in morphology and detail of tabulation (when determinable) with the Kimmeridgian material described by Gitmez & Sarjeant (1972) were observed in moderately low number. Gitmez & Sarjeant (op. cit) emended the diagnosis to include reference to the tabulation which was not described by Eisenack.

REPORTED RANGE: Kimmeridgian - Aptian

Leptodinium amabilis (Deflandre) Sarjeant 1969

Plate 16, fig. 5.

1939  Gonyaulax amabilis Deflandre: 141-145, pl. 6, fig. 8.

1966  Gonyaulacysta amabilis (Deflandre); Sarjeant: nomen nudum. 130

1969  Leptodinium amabilis (Deflandre); Sarjeant: 12.

REMARKS: The preservation of the observed specimens is not good enough to permit a full study of this species. In their general appearance and overall size they do, however, correspond closely to the type material which, by courtesy of the late Professor George Deflandre, the writer was recently permitted to examine.

REPORTED RANGE: Lower to Upper Kimmeridgian and Tithonian.

Leptodinium arcuatum Klement 1960 emend Gitmez 1970

Plate 14, fig. 3.

1960  Leptodinium arcuatum Klement: 48, pl. 6, figs. 5-6.

1970  L. arcuatum Klement; Gitmez: 270-271, pl. 7, figs. 1-2, text. fig. 17.

REMARKS: The observed specimens are very similar to the type material
from the Upper Oxfordian of Germany, differing slightly in being somewhat smaller and more elongate. One of the specimens possesses an hypotract in the form of an abruptly truncated cone with a flattened antapex. In all other respects it is similar to other specimens of the species and possesses a tabulation in accord with the specimens described by Gitmez (1970) in her emended diagnosis. Accordingly, taxonomic separation of this single specimen is not considered to be justifiable.

REPORTED RANGE: Upper Oxfordian - Upper Kimmeridgian.

*Leptodinium callere* sp. nov.

Plate 14, figs. 8-9, 13. figs. 28B.

1972 *Leptodinium* cf. *crassinervum* (Deflandre); Gitmez & Sarjeant: 218-219, pl. 3, fig. 8; pl. 5, figs. 3-6; text. fig. 19.

DERIVATION OF NAME: Latin *callere*; thick-skinned - with reference to the thick cyst wall.

DIAGNOSIS: A species of *Leptodinium* with a broadly ovoidal to subpolygonal cyst. Reflected tabulation $4'$, $1a$, $6''$, $6c$, $6'''$, $1p$, $1pv$, $1''''$, $2s$. Plate boundaries indicated by low membraneous crests, which arise from slight thickenings of the periphragm, bearing occasional very short spines. Cingulum relatively narrow, slightly spiral and laevorotatory, dividing the cyst unequally. Epitract approximately twice the length of the hypotract. Sulcus short and board. Cyst wall thick (1-2.5$\mu$), densely granular.


DIMENSIONS: Holotype: length 78$\mu$, breadth 65$\mu$. Range: length 61-80$\mu$, breadth 50-68$\mu$. (14 specimens measured).

DESCRIPTION: Plate 1' is elongate, extending down for almost two thirds of
the epitract. Plates 2', 3p. and 4' are of approximately equal size. The precingular plates are relatively large, except for plate 6'' which is reduced to accommodate the rather large intercalary plate (1a). The postcingular plates vary in size and shape, plate 4'''' is the largest, plate 1''' is comparatively small. Plate 1pv, the posterior plate, is crescent shaped and separates the two unequally developed sulcal plates from the single antapical plate (1''''').

Cingular plates 1c-5c are of equal size, plate 6c being reduced in size. A large precingular archaeopyle, formed by the loss of plate 3'', is typically present.

REMARKS: This new species of Leptodinium is readily distinguished from all other species by its overall shape, thick wall and large epitract. L. crassinervum (Deflandre) is a similar species in terms of overall size and general shape, but differs in detail of tabulation and by the possession of a thick cyst wall with a relatively smooth, unornamental surface.

The combination of a thick cyst and a dense surface ornamentation makes determinations of the tabulation different. For this reason, and also on account of its excellent preservation and orientation, the specimen illustrated by Gitmez & Sarjeant (1972 pl. 5, figs. 4-5), is designated as the holotype.

This species has previously been recorded, by Gitmez & Sarjeant (op. cit.) from the Upper Kimmeridgian of England.

Leptodinium crassinervum (Deflandre) Sarjeant 1969 emend.

Fig. 28A.

1939b Palaeoperidium crassinervum Deflandre: 144, pl. 6, fig. 5.
1967a Gonyaulacysta crassinervum (Deflandre); Sarjeant: 248-249.
1969 ? Leptodinium crassinervum (Deflandre); Sarjeant: 12.

EMENDED DIAGNOSIS: A species of Leptodinium, polygonal in outline,
divided unequally by a narrow, slightly helicoid, cingulum. Epitract approximately twice the length of the hypotract. Tabulation 4', 1a, 6", 6c, 6''', 1p, 1pv, 1''''. Plate boundaries in the form of low membranous crests. Cyst wall moderately thick with a relatively smooth, unornamented surface.

HOLOTYPE: Slide AP25, Deflandres Collection, Laboratoire de Micropalaeontogie, Paris. Kimmeridgian; Orbangnoux, France. Illustrated by Deflandre (1939b, pl. 6, fig. 5) and herein Fig. 28A.

DIMENSIONS: Holotype: length 82μ, breadth 69μ. (length of epitract 56μ, hypotract 26μ).

DESCRIPTION: The apical region of the holotype is obscured by debris, hence it is impossible to determine in detail the structure of the apex. A rounded apex is, however, clearly indicated and four, relatively large apical plates appear to be present. Precingular plates 1"-5" are elongate and relatively large, 6" being reduced to accommodate the large anterior intercalary plate (1a). The narrow cingulum is divided into six plates of approximately equal size. Six post cingular plates, of varied size and shape are present; plate 1"" is the smallest, being reduced to accommodate the intercalary plate (1p). A small oblong posterior ventral plate (1pv) separates the sulcus from the single antapical plate. The sulcus is relatively long and narrows posteriorly. An archaeopyle was not observed, but by analogy with other species of the genus Leptodinium it is considered to result by the loss of plate 3".

REMARKS: This species is based on a single specimen from the French Kimmeridgian. The diagnosis is emended to include reference to the tabulation, which was not described by Deflandre, being based on a re-examination of the holotype by the writer.
Leptodinium cf. crassinervum (Deflandre) Sarjeant 1969

REMARKS: A single specimen, comparable in its general morphology with L. crassinervum, was observed. It is, however, smaller (approximately 55 x 44 μ), thicker walled (c. 2 μ) and possesses a more conical epitract. Preservation is poor and the tabulation indeterminable, accordingly it cannot be attributed with confidence to Deflandres species.

Leptodinium clathratum (Cookson & Eisenack) Sarjeant 1969

1960b Gonyaulax clathrata Cookson & Eisenack: 246–247, pl. 37, fig. 5, text-figs. 2a-b.

1969 Leptodinium clathratum (Cookson & Eisenack); Sarjeant: 12.

1970 L. clathratum (Cookson & Eisenack); Gitmez 271-271, pl. 11, fig. 8.

1971 Gonyaulacysta clathrata (Cookson & Eisenack); Dodckova: 10, pl. 2, fig. 1.

REMARKS: Four specimens of this distinctive species were observed, none of them being well preserved. In this latter respect they are similar to the specimen described by Gitmez (1970) from the Kimmeridgian of France.

REPORTED RANGE: Lower Kimmeridgian - Tithonian.

Leptodinium danutae sp. nov.

Plate 14, fig. 2. Fig. 29A.

1972 Leptodinium sp. Gitmez & Sarjeant: 219-220, pl. 3, fig. 9; fig-text. 20.

DERIVATION OF NAME: After my wife Danuta.

DIAGNOSIS: A spherical to subspherical species of Leptodinium with the tabulation 4', 1a, 6", 6c, 6'', 1p, 1'''. Plate boundaries indicated by relatively
high, delicate, distally denticulate crests. Cingulum strongly helicoid, laevototatory. Sulcus sigmoidal in shape, extending from apex to antapex, narrowing towards the apices. Cyst wall smooth, transparent.

HOLOTYPE: British Museum (Natural History) slide V. 56352. Kimmeridge Clay, from 140ft. below the Massive Bed, Upper Kimmeridgian (rotunda Zone). Hounstout Cliff, Dorset, England. Illustrated by Gitmez & Sarjeant (1972, pl. 3, fig. 9) as Leptodinium sp.

DIMENSIONS: Holotype: overall length 40µ, breadth 40µ. Range: overall length 40-60µ, breadth 30-53µ, (16 specimens measured).

DESCRIPTION: An appearance of polygonality is imparted to the cyst by the sutural crests. The majority of specimens are somewhat crushed, folded and in a poor orientation. Determination of the tabulation is made even more difficult by the small size of the cyst and the transparent nature of its wall.

The four apical plates vary in size and shape, plate 4' is the largest plates 2' and 3' are somewhat smaller, plate 1' is long and narrow, occupying the anterior of the sulcus. Precingular plates 1", 2" and 3" are of comparable size, plates 5" and 6" being somewhat smaller. Plate 6" is much narrower than the other precingular plates. An anterior intercalary plate (1p) lies above plate 6", it is triangular in shape and lies between plate 4' and 1'. The precingular plates 2", 3"", 4"" and 5"" are the largest in the series; plates 6"" and 1"" are reduced in size, the latter to accommodate the posterior intercalary plate (1p). A large convex plate (1""') occupies the antapex.

The strongly helicoid cingulum and the sigmoidal sulcus are very distinctive.
REMARKS: The most comparable species is Leptodinium amabilis (Deflandre), which is readily differentiated by the nature of its sutural crests and detail of tabulation. Cryptarchaeodinium calcarenatum Deflandre is superficially very similar, but considerable differences are evident in the tabulation.

Due to the poor preservation and poor orientation of the specimens encountered in the present study, the specimen illustrated by Gitmez & Sarjeant (1972, pl. 3, fig. 9) is designated as the holotype.

This form has previously been recorded by Gitmez & Sarjeant (op. cit.) from the Upper Kimmeridgian of England.

Leptodinium eumorphum (Cookson & Eisenack) Sarjeant 1969

1960 Gonyaulax eumorpha Cookson & Eisenack: 246, pl. 37, figs. 1-3, text-fig. 3.

1969 Leptodinium eumorphum (Cookson & Eisenack); Sarjeant: 12.

REMARKS: A single, poorly preserved specimen was observed in the French Kimmeridgian which is similar to the type material in its overall shape and form of its sutural crests, differing slightly in being somewhat smaller than the dimensions quoted by Cookson & Eisenack (1960).

REPORTED RANGE: Oxfordian - Tithonian.

Leptodinium subtile Klement 1960

Fig. 27B.

1960 Leptodinium subtile Klement: 46, pl. 6, figs. 1-4.

1970 L. cf. subtile Klement; Gitmez: 274-275, pl. 11, fig. 2.

REMARKS: The slight differences in the tabulation of the Kimmeridgian
specimens described by Gitmez (1970) are not considered sufficient to merit taxonomic differentiation.

REPORTED RANGE: Upper Oxfordian - Tithonian.

**Leptodinium sp.**

Plate 14, fig. 1.

DESCRIPTION: A species of *Leptodinium*, ovoid to elongate in shape with rounded apices. The tabulation is indeterminate due to the poor preservation of the specimens. Plate boundaries are indicated by high sutural crests with distal edges of varied form; smooth, denticulate or deeply denticulate with short, slender spines, distally pointed or furcate. The sutural crests are particularly well developed in the cingular region. The cingulum is narrow and equatorial, the sulcus is long and narrow. Cyst wall thin and smooth.

DIMENSIONS: length 65-71 µ, breadth 45-68 µ, height of sutural crests 4-10 µ, length of sutural spines, up to 3 µ. (2 specimens measured).

REMARKS: Two specimens of this very distinctive form were observed in sample B. It is clearly very different from all previous described species of *Leptodinium*, but in the absence of knowledge of the tabulation and the poor preservation of the available material, no new specific name is proposed.

OTHER SPECIES

The following species is transferred to the genus *Leptodinium*:

*Leptodinium nanotrix* (Deflandre 1939) comb. nov. = *Gonyaulax nanotrix*

Deflandre 1939, p. 143, pl. 6, fig. 7. Kimmeridgian, France. (Transferred to *Gonyaulacysta* by Sarjeant 1969, p. 10).
Genus **MEIOUROGONYAULAX** Sarjeant 1966

**Meiourogonyaulax dicryptos** Gitmez & Sarjeant 1972

1972 *Meiourogonyaulax dicryptos* Gitmez & Sarjeant: 225-226, pl. 7, fig. 6, text-fig. 22.

REMARKS: Although Gitmez & Sarjeant (1972) comment in their diagnosis that *M. dicryptos* possesses a hollow, apical horn, they do not illustrate this; the single specimen that they illustrate is incomplete with a detached operculum. No complete specimens were recovered during this study and furthermore the presence of a seventh postcingular plate could not be confirmed.

**Meiourogonyaulax pila** Gitmez & Sarjeant 1972

Plate 12, fig. 5, Plate 15, figs. 7, 13.

1972 *Meiourogonyaulax pila* Gitmez & Sarjeant: 226-227, pl. 4, fig. 5; pl. 7, fig. 3; text-fig. 23.

REMARKS: In its general appearance *M. pila* is similar to members of the genus *Canningia* Cookson & Eisenack; however, since *Canningia* exhibits no tabulation (except for a weakly indicated cingulum), Gitmez & Sarjeant (1972) consider that there is no possibility of confusion with *M. pila*.

Considerable variation in the surface granulation and wall thickness is evidenced in the present material attributed to this species; furthermore the tabulation is not always readily discernable. In the latter case, differentiation from *Meiourogonyaulax* sp. Gitmez & Sarjeant is very difficult. For the present *Meiourogonyaulax* sp. is differentiated from *M. pila* by the rather dubious criteria of a thicker cyst wall and very vague indications of tabulation. Future studies may well prove that *M. pila* and *M. sp.* are members of a
morphological plexus intermediate between *Meiourogonyaulax* and *Camningia*; and accordingly, a re-assessment of the taxonomic limits of these two genera and the status of the morphologically intermediate forms may well be required.

**REPORTED RANGE:** Middle - Upper Kimmeridgian.


Plate 15, fig. 9.

1970 *Meiourogonyaulax staffinensis* Gitmez: 276-278, pl. 3, fig. 1. text-fig. text-fig. 20a, b.

1972 *M. staffinensis* Gitmez; Gitmez & Sarjeant: 224-225, pl. 9, fig. 4.

**EMENDED DIAGNOSIS:** A species of *Meiourogonyaulax* with a subspherical to elongate cyst and a blunt apical horn of moderate length. Endophragm forms a blunt apical structure bulging into the base of the apical horn, so that the horn contains a cavity between the wall-layers. Tabulation 4', ?0a, 6'', 6c, 6''', 2p, 1pv, 1'''. Sutural crests moderately high, slightly granulate with smooth distal edges, Cingulum slightly helicoid, laevorotatory; sulcus long broadening towards the antapex. Cyst wall densely granular, sometimes tuberculate.

**HOLOTYPE:** Gitmez 1970, pl. 3, fig. 1. British Museum (Natural History) slide v. 53620(1). Upper Jurassic (Lower Kimmeridgian), Staffin Bay, Skye.

**REMARKS:** The diagnosis is emended to include reference to the apical horn.

*Meiourogonyaulax staffinensis* typically occurs minus its apex; in her original diagnosis Gitmez (1970) states "lacking the apex in all specimens seen". One entire specimen has, however, been recovered, during the course of this study, from the Upper Kimmeridgian of Dorset. Unfortunately, the specimen is
obscured in part by organic debris and although the form of the apical horn is recognisable, the shape and arrangement of the apical plates are not clear.

_Meiourogonyaulax stoveri_ Millioud 1969 from the Lower Cretaceous is similar to _M. staffinensis_ when the latter lacks its apex, it differs, however, in having only five post-cingular plates, a thick vacuolar wall and a strongly helicoidal cingulum.

REPORTED RANGE: Lower - Upper Kimmeridgian.

_? Meiourogonyaulax pannosa_ sp. nov.

Plate 15, fig. 12.

DERIVATION OF NAME: Latin, _pannosum_, ragged.

DIAGNOSIS: Cyst subspherical with a rounded antapex, the apex being typically lost in archaeopyle formation. Deep slits extend posteriorly from the archaeopyle margin along reflected sutures, producing a ragged appearance. Tabulation very weakly indicated, indistinct. Cingulum feebly indicated markedly laevorotatory and helicoid. Cyst wall of moderate thickness, surface densely but finely granular.

HOLOTYPE: Slide B. 19 (1)

DESCRIPTION: The cyst appears to be divided equally by the cingulum although no entire specimens have been observed. The tabulation is not readily determinable, but six precingular plates can be recognised. The two ends of the cingulum on the ventral surface are separated by a distance of approximately twice the cingulum width. The sulcus is indicated by a long slit.
DIMENSIONS: Holotype: Length (apex lacking) $47 \mu$, breadth $52 \mu$. Range: (apex lacking) $43-47 \mu$, breadth $49.5 \mu$ (8 specimens measured).

REMARKS: In the mode of archaeopyle formation and a weak indication of tabulation this species is tentatively allocated to the genus *Meiourogonyaulax*. It does, however, bear a superficial resemblance to *Chytroesphaeridia mantelli* Gitmez & Sarjeant and accordingly may represent a form morphologically intermediate between the genera *Chytroesphaeridia* and *Meiourogonyaulax*.

*Meiourogonyaulax* sp. Gitmez & Sarjeant differs by the possession of a dense surface granulation and less distinct indications of tabulation.

*Meiourogonyaulax* sp. Gitmez & Sarjeant 1972

Plate 15, fig. 8.

1972 *Meiourogonyaulax* sp. Gitmez & Sarjeant: 227-228, pl. 4, fig. 4; pl. 7, fig. 12.

REMARKS: The generic allocation of this form is debatable. In its overall appearance it is somewhat similar to the genus *Canningia* Cookson & Eisenack but differs in possessing faint lines indicative of tabulation.

This form is apparently morphologically intermediate between the genera *Meiourogonyaulax* and *Canningia*. With a progressive loss in tabulation, the morphological distinction between the two genera becomes rather vague.

REPORTED RANGE: Middle - Upper Kimmeridgian.

*Meiourogonyaulax* sp. A

Plate 15, fig. 11.

DESCRIPTION: The cyst is elongate with convex sides and a rounded antapex;
the apex is lost in archaeopyle formation. Plate boundaries are indicated by moderately high crests with smooth distal edges. The cingulum is of moderate width and divides the cyst unequally, the epitract is slightly smaller that the hypotract. The cyst wall is thin and transparent; this together with the high sutural crests renders determination of the tabulation very difficult.

DIMENSIONS: length (apex lacking) 53 µ, breadth 43 µ, height of sutural crests 3–4 µ. (1 specimen measured).

REMARKS: The available material is consistently poorly preserved.

Attribution to the genus Meiourogonyaulax is on the basis of overall shape, tabulate nature and mode of archaeopyle formation.

? Meiourogonyaulax sp. B
Plate 15, fig. 6.

DESCRIPTION: The cyst is subspherical in shape, some degree of angularity being imparted by the sutural crests. The apex and antapex are rounded, an apical archaeopyle is incipiently developed. Plate boundaries are indicated by moderately high sutural crests, thin and smooth with a smooth distal edge. The complete tabulation could not be determined, but six precingular and six post cingular plates can be recognised with difficulty. The cingulum is wide (5 µ) and divides the cyst unequally, the epitract being somewhat smaller than the hypotract. No division of the cingulum into plates is evident. The cyst wall is thin and finely granular.

DIMENSIONS: Length 35 µ, breadth 35 µ, height of crests, up to 4 µ, width of cingulum 5 µ.
REMARKS: A single specimen was recorded from the Upper Kimmeridgian of Dorset. It is tentatively attributed to the genus *Mesourogonyaulax* on the basis of its overall shape, tabulate nature and mode of archaeopyle formation. It is, however, considerably smaller than previously described species of this genus.

**Genus MEMBRANIAULAX** gen. nov.

**DERIVATION OF NAME:** With reference to the membraneous nature of the periphragm and the high sutural crests which indicate a *Gonyaulax*-type tabulation.

**DIAGNOSIS:** Broadly ovoidal cysts, almost equidimensional in outline. Periphragm than and membraneous, in contact with the endophragm except at the apex where it is extended to form a blunt, hollow apical horn. Tabulation 4', 1a, 6", ? 6c, 5"", 1p, 1pv, 1'". Plate boundaries indicated by high, hyaline crests, formed from the periphragm, which extended posteriorly to form a number of antapical processes. Cingulum, narrow, circular and equatorial. Archaeopyle precingular, formed by loss of plate 3".

**TYPE SPECIES:** *Membraniaulax harryi* sp. nov. Upper Jurassic (Kimmeridgian) Dorset, England.

**REMARKS:** *Membraniaulax* is clearly differentiated from all other described genera in its overall morphology. *Belodinium* Cookson & Eisenack is perhaps the most similar genus, particularly in the nature of its sutural crests. It differs, however, in possessing a distinct, separatable inner body, a well developed antapical periocoeal and in lacking a distinct tabulation.

Davey (1972 pers. comm.) considers *Membraniaulax* to be similar to
Xiphophoridium Sarjeant on the basis of its overall size, wall thickness and high sutural crests. This is considered to be highly doubtful, species attributed to Xiphophoridium lack apical and antapical projections and are characterised by sutural crests bearing long, dagger-like spines.

Membraniaulax harryi sp. nov.

Plate 13, figs. 5, 9, 11-12.

DERIVATION OF NAME: After my late father Mr. Harry Riley.

1957 Palaeoperidium bicuneatum Deflandre; Downie: i22, pl. 10, fig. 2.
1970 Sciniodinium bicuneatum (Deflandre); Gitmez: 308, pl. 5, fig. 5.
? 1971 Dinopterygium cladooides Deflandre; Davey & Verdier: pl. 3, fig. 4.
1972 Scriniodinium bicuneatum (Deflandre); Gitmez & Sarjeant: 242-243, pl. 15, fig. 4.

DIAGNOSIS: As for the genus with the following remarks. The periphragm is thin and finely granular. Sutural crests high, extending posteriorly to form relatively long, fine-like antapical processes of variable length. The endophragm extends slightly into the apical horn, its antapex is rounded.

HOLOTYPE: Slide D. 35(5).

DIMENSIONS: Holotype: overall length 103μ, breadth 82μ, length of apical horn 15μ, length of antapical processes, up to 23μ. Range: overall length 85-113μ, breadth 65-110μ, length of apical horn 12-15μ, length of antapical processes 15-26μ (47 specimens measured).

DESCRIPTION: The thin, frequently folded nature of the cyst and the high crests render determination of the tabulation difficult. It can only be determined, with
considerable difficulty under phase contrast.

The apical horn is formed from all the apical plates. Plate 1' is elongate, relatively narrow and occupies the anterior of the sulcus; the other apical plates are much larger and more equidimensional. Of the postcingular plates, plate 1'", is very small, plates 3'", 4'" and 5'" are much larger with plate 6'": rather elongate and narrow. The posterior intercalary plate 1p, is quite large; plate 1pv is elongate and narrow. The sulcus is relatively narrow and circular.

The antapical fine-like processes are typically well developed - usually only two or three separate fins can be seen, the others being edge on. This "antapical bundle of fins" is frequently of centre and oblique to the long axis of the cyst.

Being almost equidimensional, equatorial, polar and oblique views are all common.

REMARKS: This species was recorded as Belodinium (?) hypopinnatum by Norris (1963, unpublished) from the rotunda to okusensis zones of the Kimmeridgian - Portlandian of Dorset, England. Comparable forms have also been obtained in Portlandian assemblages from the North Sea Basin (Davey 1972 pers. comm.) and the Upper Oxfordian of France (pers. obs.).

M. harryi is similar to Scriniodinium bicunneatum (Deflandre) in terms of its general appearance, differing from it in the nature of its sutural crests, tabulation and antapical processes. The specimens illustrated by Downie (1955, pl. 20, fig. 2), Gitmez (1970, pl. 5, fig. 5) and Gitmez & Sarjeant (1972, pl. 15, fig. 4) as S. bicunneatum from the English, Scottish and French Kimmeridgian are considered to be referable to this species. In contrast to the author's
statement (p. 243) the specimen illustrated by Gitmez & Sarjeant is in an inverse orientation.

The specimen illustrated by Davey & Verdier (1972) as *Dinopertygium cladoides* appears to be referable to this species.

? *Membraniaulax* sp.

Plate 13, fig. 10.

**DESCRIPTION:** The cyst is broadly ovoidal with rounded apex and antapex, an apical horn is lacking. The cyst-wall is two-layered, the periphragm is thin and membraneous and gives rise to membraneous, hyaline crests which indicate the reflected tabulation. Tabulation indeterminable with the material available, but accords with the basic gonyaulacacean - type. Six precingular, six postcingular and one antapical plate can, however be recognised. The periphragm extends posteriorly to form short, bluntly rounded antapical projections.

The sulcus is long and narrow, broadening antapically. The cingulum is of moderate width and divides the cyst unequally, the epitract being slightly longer than the hypotract. An archaeopyle has not yet been found.

**DIMENSIONS:** Overall length 50\(\mu\), overall breadth 45\(\mu\), length of antapical processes, up to 6\(\mu\). (1 specimen measured).

**REMARKS:** Only one specimen of this very distinctive form has been observed. It clearly represents a new species, but pending the availability of additional material, no new name is proposed.

This form is tentatively attributed to the genus *Membraniaulax* on its
overall morphology, in particular the nature of its thin, membraneous periphram. It is, however, clearly different from the type species of Membraniaulax; being very much smaller, broadly - ovoidal rather than rhomboidal in outline and lacking an apical horn.

Genus MICRODINIUM Cookson & Eisenack 1960

Microdinium spp.

REMARKS: A number of forms attributable to the genus Microdinium were observed. They are small, less than 40 µ, in length, and possess a broad cingulum, tabulation indicated by low crests and an apical archaeopyle formed by the loss of the apical plate(s). Preservation is very poor, accordingly more adequate descriptions and illustrations are not possible. Subdivisions of the specimens is not possible, but two, possibly three, species appear to be represented. Allocation of the forms to previously described species, or the designation of new taxa is not considered to be practical.

The genus Microdinium is characteristically a Cretaceous form although Schulz & Mai (1965; doubtful attribution) have recorded it from the German Middle Jurassic and Vozzhennikova (1967) from the Upper Volgian of the U.S.S.R.

Genus OCCISUCYSTA Gitmez 1970 emend.


1972 Diacanthum Habib: 376.

EMENDED DIAGNOSIS: Spherical, subspherical or broadly ovoidal proximate cysts, with the tabulation 4', 0-1a, 5-6", 6c, 6-7'', 1p, 0-1pv, 1'''. Apical
horn present or absent, medium and antapical horns lacking. Ornamen
tation variable, in the form of grana, spines, alveolae or tuber
cks. Archaeopyle, precingular, formed by the loss of two precingular plates (2" and 3").


REMARKS: The distinction between Diacanthum and Occisucysta proposed by Habib (1970, p. 276) is considered to be of dubious value. The generic
diagnosis of Occisucysta is accordingly emended to allow for the inclusion of the monotypic genus Diacanthum.

Genus OCCISUCYSTA Gitmez 1970

Occisucysta balios Gitmez 1970

Fig. 30A.

1970 Occisucysta balios Gitmez: 267-268, pl. 5, figs. 1-2, text-fig. 16.

REPORTED RANGE: Lower - Upper Kimmeridgian.

Occisucysta aculeata (Klement) comb. nov.

Fig. 30B.

1960 Gonyaulax aculeata Klement: 42, pl. 5, fig. 6-7, text-fig. 21.

REMARKS: This species possesses a 2 plate precingular archaeopyle and is accordingly transferred to the genus Occisucysta (see also Davey & Verider 1971, p. 21).

REPORTED RANGE: Upper Oxfordian to Lower Kimmeridgian.

- 214 -
Occisucysta tenuiceras (Eisenack) Sarjeant 1969 comb. nov.

1958c Gonyaulax tenuiceras Eisenack: 389-391, pl. 21, fig. 15.

1969 ? Gonyaulacysta tenuiceras (Eisenack); Sarjeant: 10.

REMARKS: G. tenuiceras possesses a 2-plate precingular archaeopyle and is accordingly transferred to the genus Occisucysta.

REPORTED RANGE: Berriasian – Cenomanian. (The specimens listed by Habib & Warren (1973), from the Tithonian of California and the Berriasian – Valanginian of a J.O.I.D.E.S. North Atlantic core, as Occisucysta ? sp. might well prove to be conspecific.)

OTHER SPECIES

The following species are retained within the genus Occisucysta:


Occisucysta monoheuriskos Gitmez & Sarjeant 1972, p.221-222, pl. 7, figs. 10-11; text-fig. 21. Lower Kimmeridgian, France.

The following species is transferred to the genus Occisucysta:

Occisucysta hollisteri (Habib) comb. nov. = Diacanthum hollisteri habib 1972, p. 376-377, pl. 9, figs. 1,3; pl.10, fig. 1; text-fig. 2. Late Jurassic/Early Cretaceous to probably Valanginian. North Atlantic.

Genus OLIGOSPHAERIDIUM Davey & Williams 1966

Plate 18, fig. 6.
**Oligosphaeridium anthophorum** (Cookson & Eisenack)

Eisenack & Kjellström 1971 emend.

Plate 18, fig. 6

1958 *Hystrichosphaeridium anthophorum* Cookson & Eisenack: 43, pl. 11, figs. 12-13; text-figs. 16-18.

1958 *Hystrichosphaeridium dictyophorum* Cookson & Eisenack: 44, pl. 11, fig. 14.

1971 *Oligosphaeridium anthophorum* (Cookson & Eisenack): Eisenack & Kjellström: 837.

**EMENDED DIAGNOSIS:** A species of *Oligosphaeridium* with a spherical central body. Wall composed of two layers, a thin endophragm and periphragm, the latter forming the processes. Processes, tubiform, expanded distally into deep broad terminal expansions with completely and irregularly reticulate walls and smooth or finely serrate margins. Reflected tabulation 4', 6", 6"", 1p, 1"". Apical archaeopyle usually present having zig-zag margin.

**HOLOTYPE:** Cookson & Eisenack 1958, pl. 11, fig. 12. National Museum of Victoria, Palaeobotanical Collection. Slide P17471. Upper Jurassic, Papua.

**REMARKS:** I here group together *O*. *anthophorum* and *O*. *dictyophorum*, considering their morphological differences to be within the limits of variation of a species.

*O*. *anthophorum* differs from *O*. *pulcherrimum* (Deflandre & Cookson) in the more extensive reticulation of the processes and the entire edge of the terminal expansion.

**REPORTED RANGE:** *O*. *anthophorum* Upper Jurassic - Lower Cretaceous.
O. dictyophorum Upper Jurassic.

Oligosphaeridium complex (White) Davey & Williams 1966

1842 Xanthidium tubiferum complex White: 39, pl. 4, fig. 11.
1946 Hystrichosphaeridium complex (White); Deflandre: 11.
1966b Oligosphaeridium complex (White); Davey & Williams: 71-74, pl. 7, figs. 1-2, pl. 10, fig. 3, text-fig. 14.

REMARKS: Hystrichosphaeridium elegantulum Lejeune - Carpentier 1940, p. 22, text-figs. 11-12 is considered by Deflandre (1946b) and Davey & Williams (1966b) to be a junior synonym of this species.

REPORTED RANGE: Lower Cretaceous (at least Valanginian) - Lower Tertiary.

Oligosphaeridium pulcherrimum (Deflandre & Cookson)

Davey & Williams 1966

Plate 18, figs. 2-3, 5.

1955 Hystrichosphaeridium pulcherrimum Deflandre & Cookson: 270, pl. 1, fig. 8, text-fig. 21.
1966 Oligosphaeridium pulcherrimum (Deflandre & Cookson); Davey & Williams: 75-76, pl. 10, fig. 9, pl. 11, fig. 5.

REMARKS: The specimen illustrated by Gitmez (1970) from the Lower Kimmeridgian of England is not considered to belong to this species.

The processes of the observed specimens indicate a reflected tabulation of 4', 6", 6"", 1p, 1"". The apical processes are relatively small and an apical archaeopyle is usually present. The fenestrate appearance of the processes in this species are extremely distinctive.

Genus POLYSTEPHIANEPHORUS Sarjeant 1961b
ex Downie & Sarjeant 1964

1960 Polystephanosphaera Sarjeant : 140

REMARKS: The genus Polystephanosphaera was rejected by Sarjeant (1961b, pp. 1095-96) and the type species P. valensis invalidly transferred to Systematophora. The transfer was subsequently validated by Downie & Sarjeant (1964, p. 146). Polystephanophorus was created by Sarjeant to include the rest of the species formerly allocated to Polystephanophorus. Although none of the species were correctly transferred, the transfers were later validated by Downie & Sarjeant (1964).

Polystephanophorus sarjeantii Gitmez 1970

1970 Polystephanophorus sarjeantii Gitmez: 291-292, pl. 11, fig. 4; text-fig. 25.

REMARKS: P. sarjeantii is morphologically very similar to Systematophora orbifera Klement; Re-examination of the type material of these two species is called for as no distinct differences can be seen between the illustrations of the two types as given by Klement (1960) and Gitmez (1970). Verdier (1973 pers. comm.) does in fact consider them to be synonomous.

REPORTED RANGE: Lower - Upper Kimmeridgian.

Prolixosphaeridium granulosum (Deflandre)

Plate 17, fig. 10.

1935  **Hystrichosphaera xantiopyxides** Deflandre: pl. 9, fig. 7.

1937  **Hystrichosphaeridium xantiopyxides** var. granulosum (Deflandre);
Deflandre 29, pl. 16, fig. 4.

1960  **Baltisphaeridium xantiopyxides** var. granulosum (Deflandre); Klement:
59.

1962a  **Baltisphaeridium granulosum** (Deflandre); Sarjeant: 264, pl. 2, fig. 14;
text-fig. 8c.

1966  **Prolixosphaeridium granulosum** (Deflandre); Davey et al.: 172-173.

1970  **Prolixosphaeridium cf. deirense** Davey et al.; Gitmez: 292, pl. 13,
fig. 9.

REMARKS: The specimens described and illustrated as **P. cf. deirense** by
Gitmez (1970), from the Lower Kimmeridgian of Dorset, England, are referred
here to **P. granulosum** on the basis of their overall morphology. In lacking a
dense cover of short spinelets (not mentioned by Gitmez, but evidenced by her
illustration), they are clearly different from **P. deirense**.

REPORTED RANGE: Callovian - Turonian/Senonian.

*Prolixosphaeridium torynum* (Cookson & Eisenack)

Eisenack & Kjellström 1971a

1960b  **Hystrichosphaeridium torynum** Cookson & Eisenack: 252, pl. 38, fig. 6,
15.

1971a  **Prolixosphaeridium torynum** (Cookson & Eisenack); Eisenack &
Kjellström: 951.
REMARKS: A single specimen obscured in part by debris, observed in the Portlandian of Norfolk (sample Sl), appears to be attributable to this species. The observed specimen possesses an apical archaeopyle hence allocation to the genus Prolixosphaeridium is justified. The archaeopyle was originally described as "The opening of the shell appears to have been terminal". This, together with the arrangement of the processes (in rows encircling the cyst) resulted in the provisional transfer of this species to Prolixosphaeridium by Eisenack & Kjellström (1971a).

P. torynum was hitherto only known from the ?Tithonian - Neocomian of Western Australia.


Prolixosphaeridium sp. (Gitmez) stat. nov.

1970 Prolixosphaeridium parvispinum (Deflandre); Gitmez: 293-294, pl. 2, fig. 3.

1972 P. parvispinum (Deflandre); Gitmez in Gitmez & Sarjeant: tables 3-4, 6.

REMARKS: The type specimens of P. parvispinum (Deflandre), recently re-examined by the writer, possess numerous short, simple processes and a surface cover of very short spinelets. The latter are lacking in the specimen illustrated by Gitmez (1970) from the basal Kimmeridgian of Dorset, England; her allocation of the specimens to P. parvispinum is accordingly rejected. Pending the availability of additional and the much needed revision of the genus Prolixosphaeridium no new specific name is proposed.

REPORTED RANGE: Lower - Upper Kimmeridgian.
Genus **SARJEANTIA** gen. nov.

**DERIVATION OF NAME:** After W.A.S. Sarjeant, palynologist.

**DIAGNOSIS:** Elongate cysts, ovoidal to ellipsoidal, with the reflected tabulation 4', 0-1a, 6", 6c, 6'"; 1p, 0-1pv, 1"'. Apical horn constantly present, median and antapical horns lacking. Endophragm and periphragm generally in contact; the periphragm is detached at the apex, forming an hollow apical horn, and at the antapex, forming a well developed pericoel. Archaeopyle, precingular formed by loss of plate 3".

**TYPE SPECIES:** *Gonyaulacysta dangeardi* Sarjeant 1968. Lower Oxfordian, France.

**REMARKS:** *Sarjeantia* is distinguished from *Gonyaulacysta* by the presence of an antapical pericoel, from *Ectenodinium* gen. nov. by the possession of an apical horn.

The stratigraphic range of this genus is Bathonian to Upper Kimmeridgian. It is considered to have gonyaulacacean affinities with gonyaulacoid lineage.

*Sarjeantia eisenacki* (Deflandre) comb. nov.

1938a **Gonyaulax eisenacki** Deflandre; 171-173, pl. 6, fig. 7.

1969 **Gonyaulacysta eisenacki** (Deflandre); Sarjeant: 9.

1970 **Endoscrinium eisenacki** (Deflandre); Gocht: 146-147.

**REMARKS:** *S. eisenacki* is a very distinctive species characterised by the form of its high, denticulate crests and the character of its apex and antapex.
REPORTED RANGE: Bathonian - Volgian.

Genus SCRINIODINUM Klement 1957

Plate 11, fig. 10.

Scriniodinium cf. attadelense (Cookson & Eisenack) Eisenack 1967

1958 Gymnodinium attadelense Cookson & Eisenack: 25, pl. 1, fig. 7.
1967 Scriniodinium attadelense (Cookson & Eisenack); Eisenack: 193.

REMARKS: A single specimen considered to be comparable to this species was observed. In its overall morphology it is similar to the type material from the Australian Aptian, but somewhat smaller (59 x 58μ; holotype 81 x 81μ).

REPORTED RANGE: Berriasian - Aptian.

Scriniodinium crystallinum (Deflandre) Klement 1957

1938a Gymnodinium crystallinum Deflandre: 165, pl. 5, figs. 1-3.
1960 Scriniodinium crystallinum (Deflandre); Klement: 18, pl. 1, fig. 1; text-fig. 1.

REMARKS: Although Gitmez (1970) recorded S. crystallinum in moderate abundance in the basal Kimmeridgian of the Dorset and the Boulonnais sections it was only rarely encountered in the present study. Endoscrinium oxfordianum (Sarjeant) is morphologically similar to S. crystallinum and some difficulty can be experienced in separating the two species. S. crystallinum differs, however, in possessing a distinct indentation in the outer membrane in the cingular region, a smooth rather than granular innerbody, and a less readily discernable tabulation.

The observed specimens are consistently poorly preserved and folded.
REPORTED RANGE: Lower Oxfordian - Upper Kimmeridgian.

Scriniodinium dictyotum Cookson & Eisenack 1960a

1960a Scriniodinium dictyotum Cookson & Eisenack: 248-249, pl. 37, figs. 8-9.

1970 S. dictyotum subsp. dictyotum Cookson & Eisenack; Gitmez: 310.

1970 S. dictyotum subsp. osmingtonensis Gitmez: 310-311, pl. 1, fig. 3; pl. 8, fig. 12.

1970 S. dictyotum subsp. papillatum Gitmez: 311, pl. 9, fig. 11.

1970 S. dictyotum subsp. pyrum Gitmez: 311-312, pl. 13, figs. 1-2; pl. 10, figs. 1; text-figs. 33a-b.

1972 Scriniodinium reticulatum Pocock: 91-92, pl. 23, fig. 3.

REMARKS: A text-figure clarifying the differences between the four subspecies distinguished by Gitmez (1970) is given by Gitmez & Sarjeant (1972, text-fig. 27).

Only the subspecies dictyotum and osmingtonense were encountered in this study (albeit very infrequently).

Scriniodinium reticulatum Pocock from the Callovian of Canada is considered to be a junior synonym of S. dictyotum subsp osmingtonense.

REPORTED RANGE: Callovian - Upper Kimmeridgian and possibly Valanginian

Scriniodinium irritabilum sp. nov.

Plate 11, figs. 5, 7. Plate 13, fig. 3.

DERIVATION OF NAME: Latin, irritabilis, thin-skinned - with reference to the thin outer membrane.

DIAGNOSIS: Outer membrane thin, close fitting, separating at the apex to form a
blunt and hollow apical horn. Apex of innerbody conical to subrounded, antapex rounded to somewhat flattened. Plate boundaries feebly indicated. Cingulum weakly developed and approximately equatorial, or the hypotract is slightly larger than the epitract. Innerbody wall finely granular, thin; outer membrane finely granular and/or perforate. Archaeopyle relatively large, precingular.

**HOLOTYPE:** Slide Y.2(1).

**DIMENSIONS:** Holotype: overall length 73 µ, breadth 62 µ; inner body length 64 µ, breadth 58 µ. Range: overall length 65-87 µ, breadth 54-80 µ; inner body length 62-76 µ, breadth 54-76 µ. (19 specimens measured).

**DESCRIPTION:** The cyst is thin-walled and frequently folded, consequently the overall shape is a variable feature. The apex of the inner body varies from conical, with a slight mamelon form, to subrounded. Tabulation is very weakly indicated, but a few plate boundaries may be recognised with difficulty.

**REMARKS:** *Scriniodinium playfordi* Cookson & Eisenack is a similar species, it differs in being consistently much larger and possessing a surface ornamentation in the form of a small meshed reticulum and a wide, smooth, hyaline, outer membrane.

The specimens recorded by Gitmez (1970) from the Kimmeridgian of England and France as *S. playfordi* are considered to be of very dubious attribution. They are similar to *S. inritibilum* in size and overall morphology, but differ in being smooth-walled, completely devoid of surface ornamentation.
Genus **SIRMIODINIJUM** Alberti 1961 emend. Warren 1973

**Sirmiodinium grossi** Alberti 1961 emend. Warren 1973

Plate 13, figs. 1-2.

1961 **Sirmiodinium grossi** Alberti: 22, pl. 7, figs. 5-7, pl. 12, fig. 5.

? 1965 **Scriniodinium crystallinum** (Deflandre); Gorka: 294, pl. 1, fig. 2.

? 1967 **S. crystallinum** (Deflandre); Dodekova: pl. 1, fig. 2.

1967 **Sirmiodinium sp.** Evitt: pl. 8, figs. 6-11.


**REMARKS:** **Scriniodinium pseudocrystallinum** Beju is considered to fall within the range of variation of **Sirmiodinium grossi** as described by Warren (1973) and is accordingly treated here as a subjective junior synonym of Alberti's species.

The specimens illustrated by Dodekova (1967), from the Oxfordian of Bulgaria and Gorka (1955) from the Upper Jurassic of Poland, as **Scriniodinium crystallinum** are tentatively considered to be more attributable to **S. grossi**. Gorka (p. 294) does in fact mention that her specimen does not possess a precingular archaeopyle, and an incepient combination archaeopyle is suggested by Dodekova's illustration.

Specimens attributable to this species have recently been recorded by the writer, in addition to this study, from the Oxfordian of France and the Bathonian - Callovian of Greenland.

**REPORTED RANGE:** Bathonian - Barremian.
Genus **SPINIFERITES** Mantell 1850 emend. Sarjeant 1970

**Spiniferites ramosus** (Ehrenberg) Loeblich & Loeblich 1966

Plate 11, fig. 4.

1838 *Xanthidium ramosum* Ehrenberg: pl. 1, figs. 1, 2, 5,

1938 *Xanthidium furcatum* Ehrenberg: pl. 1, figs. 12-14.

1932 *Hystrichosphaera furcata* (Ehrenberg); O. wetzel: 136.

1932 *Hystrichosphaera ramosa* (Ehrenberg); O. Wetzel: 144.

1966 *Spiniferites ramosus* (Ehrenberg); Loeblich & Loeblich: 56-57.

REMARKS: A number of intergrading forms, showing considerable variation and assignable to this species, were identified particularly in the Sandringham Sands material. Subdivision of the forms present was not attempted pending future study and the availability of additional material. The specimen illustrated, (from the Portland Sand of Dorset) possesses a distinctly granular wall, but in all other respects appears to be referable to the typical subspecies.

*Hystrichosphaera paradox* Cookson & Eisenack 1968 and

*Hystrichostrogylon membraniphorum* Agelopoulos 1964 were proposed to accommodate identical specimens. It is considered by Davey & Verdier (1973), however, that these forms do not need any special taxonomic treatment.

REPORTED RANGE: Oxfordian - Recent.

Genus **SYSTEMATOPHORA** Klement 1960

**Systematophora areolata** Klement 1960.

Plate 17, figs. 8-9.

- 226 -
1960 Systematophora areolata Klement: 62-64, pl. 9, figs. 1-8; text. fig. 32.
Plate 17, Figs. 8, 9.

REMARKS: In addition to the published stratigraphic range of this species, Norris (1963) recorded it from the Portlandian of England and Warren (1967) from the Lower Cretaceous of California.

REPORTED RANGE: Callovian – Portlandian.

Systematophora complicata Neale & Sarjeant 1962

Plate 17, fig. 12.

1962 Systematophora complicata Neale & Sarjeant: 455-456, pl. 19, figs. 7-8, text-fig. 9.

REMARKS: The arrangement of the process clusters as described by Neale & Sarjeant are not readily determinable due to poor preservation; the structure of the clusters is however, very close to that described. The type material differs slightly from the specimens recorded here, in that they possess a much thicker cyst-wall in contrast to the relatively thin-walled forms observed in this study.

REPORTED RANGE: Barremian.

Systematophora orbifera Klement 1960

Plate 17, figs. 6-11.

1960 Systematophora orbifera Klement: 66-67, pl. 9, figs. 9-10, pl. 10, fig. 7.

REPORTED RANGE: Callovian – Lower Cretaceous.

Systematophora ovata Gitmez & Sarjeant 1972

- 227 -
1970  Systematophora sp. Gitmez: 296, pl. 8, fig. 5.


REPORTED RANGE: Lower - Upper Kimmeridgian.

Systematophora sp.

REMARKS: Infrequent and poorly preserved specimens were observed, which, although being incapable of accurate measurement, description and adequate illustration are considered to represent a new species of Systematophora. In size and general appearance they closely resemble S. orbifera Klement, but differ in lacking the circular basal thickenings to the processes which characterise Klement's species. The processes are very similar to those of S. orbifera in their general appearance and structure, but arise from horse-shoe shaped ridges rather than a circular ridge.

Genus TAENIOPHORA Klement 1960

REMARKS: The genus Taeniophora is similar in many morphological respects to the genera Systematophora Klement and Surculosphaeridium Davey et al. A close similarity is evident between Taeniophora iunctispina Klement, Systematophora areolata Klement and Surculosphaeridium vestitum (Deflandre); in addition, specimens occur which are morphologically very close to these species, but which cannot be speciated with certainty. A re-study of the type material of these species is needed or order to re-asses their taxonomic status; for the present, however, they are retained as separate species.

Taeniophora iunctispina Klement 1960

1960  Taeniophora iunctispina Klement: 68, pl. 10, figs. 1-6.
REPORTED RANGE: Upper Oxfordian - Lower Kimmeridgian.

Genus **TANYOSPHERIDIIUM** Davey & Williams 1966b

**Tanyospheridium cf. variacalamum** Davey & Williams 1966b

Plate 17, figs. 2-3.

REMARKS: The specimens examined are comparable to **T. variacalamum** in overall morphology and general appearance. They are, however, consistently poorly preserved and slightly smaller than the type material (length of 3 specimens 26-29μ, breadth 14-22μ, length of processes 11-12μ).


REMARKS: The emendation of this genus by Pocock (1972) is herein rejected as the inclusion of smooth forms within **Tenua** would create a junior synonym of **Canningia** Cookson & Eisenack.

The inclusion of **Doidyx anaphrissa** Sarjeant in this genus by Benedek (1972), as accepted by the writer, renders the genus **Doidyx** a junior synonym of **Tenua** and hence superfluous.

**Tenua capitata** (Cookson & Eisenack) Gitmez & Sarjeant 1972.

1960 **Hystrichosphaeridium captitatum** Cookson & Eisenack: 252, pl. 39, fig. 9.

1964 **Epiplosphaera ? capitata** (Cookson & Eisenack); Schulz & Mai: Table 1, nomen nudum.

1970 **Tenua cf. capitata** (Cookson & Eisenack); Gitmez: 243-244, pl. 10.
fig. 4. nom. nud.

1971 Prolixosphaeridium capitatum (Cookson & Eisenack); Singh: 242-243, pl. 57, fig. 3.

1972 Tenua capitata (Cookson & Eisenack); Gitmez & Sarjeant: 189, pl. 1, figs. 11-12.

REMARKS: This species is retained in the genus Tenua on the basis of cyst shape, form and number of processes and mode of archaeopyle formation.

The specimens illustrated by Singh (1971) from the Albian of Canada are considered to be of dubious attribution. His generic re- allocation to Prolixosphaeridium is considered to be undesirable as is the combination proposed earlier by Schulz & Mai (1964), which also failed to satisfy the requirements of the I.C.B.N.

REPORTED RANGE: Oxfordian - Middle Kimmeridgian and ? Albian.

Tenua echinata Gitmez & Sarjeant 1972

1972 Tenua echinata Gitmez & Sarjeant: 190, pl. 1, figs. 1, 9.

REMARKS: Tenua echinata is characterised by a dense cover of very short, conical spines. There are, however, marked differences between the two specimens illustrated by Gitmez & Sarjeant (1972, pl. 1, figs. 1 & 9). The paratype (pl. 1, fig. 9) differs from the holotype (pl. 1, fig. 1) in possessing less distinct spines and from the illustration it appears to possess a trilete mark although this can only be confirmed by a re-examination of the specimen.

REPORTED RANGE: Lower - Upper Kimmeridgian.
**Tenua hystrix** Eisenack 1958

1958 *Tenua hystrix* Eisenack: 410, pl. 23, figs. 1-4, text-fig. 10.

REMARKS: See remarks for *Cyclonephelium distinctum*.

REPORTED RANGE: Lower Kimmeridgian - Aptian.

**Tenua pilosa** (Ehrenberg) Sarjeant 1968

1843 *Xanthidium pilosum* Ehrenberg: 61-68.

1904 *Ovum hispidium* (*Xanthidium*) pilosum (Ehrenberg); Lohman: 24-25.

1937 *Hystrichosphaeridium pilosum* (Ehrenberg); Deflandre: 31.

1966a *Cleistosphaeridium pilosum* (Ehrenberg); Davey et al.: nom. nud. 170.

1968 *Tenua pilosa* (Ehrenberg); Sarjeant: 231, pl. 2, fig. 7.

REPORTED RANGE: Middle Callovian - Upper Kimmeridgian.

Genus **TRICHODINIUM** Eisenack & Cookson 1960

emend Clarke & Verdier 1967.

REMARKS: *Trichodinium* as emended by Clarke & Verdier (1967) differs from

*Apteodinium* Eisenack in the horn formation and type of sculpture, from

*Cametodinium* Deflandre & Courteville in the presence of an apical horn and

absence of tabulation and from *Xenicodinium* Klement in the presence of a
cingulum and small apical horn.

**Trichodinium castanea** (Deflandre) Clarke & Verdier 1967

1935 *Palaeopercidinium castanea* Deflandre: 229, pl. 6, fig. 8.

1957 *Dinoflagellaten* gen. and sp. ind., Gocht: 171, pl. 20, figs. 9-10.

1959 *Apteodinium ciliatum* Gocht: 65, pl. 8, figs. 5-6.
1964  *Trichodinium ciliatum* (Gocht); Eisenack & Klement: 811.

1967  *Trichodinium castanea* (Deflandre); Clarke & Verdier: 19, pl. 1, figs. 1-2.

REMARKS: The reasons for treating *T. ciliatum* as a junior synonym of *T. castanea* are discussed by Clarke & Verdier (1967, p. 19).

*Trichodinium castanea* is typically a Cretaceous species, it has, however, previously been reported from the Volgian of the U.S.S.R. (Vozzhennikova 1967).

A single specimen attributable to this species was recorded from the Sandringham Sands (Upper Portlandian, Sample S1).

REPORTED RANGE: Upper Jurassic (Volgian) - Senonian.

Genus *TUBOTUBERELLA* Vozzhennikova 1967

REMARKS: The type species of this genus, *Tubotuberella rhombiformis* is very close in size and overall morphology to *Psaligonyaulax apatela* (Cookson & Eisenack) Sarjeant and may well prove to be conspecific. Pending a re-study of Vozzhennikova’s material both species are provisionally retained herein and the new combination *Tubotuberella apatela* comb. nov. is proposed.

*Tubotuberella apatela* (Cookson & Eisenack) comb. nov.

1960b  *Scriniiodinium apatelum* Cookson & Eisenack: 249, pl. 37, figs. 12-13.

1964  *S. apatelum* Cookson & Eisenack; Manum & Cookson: 20, pl. 4, fig. 4.

1967b  *Endoscrinium apatelum* (Cookson & Eisenack); Vozzhennikova: 174.

1969  *Psaligonyaulax apatela* (Cookson & Eisenack); Sarjeant: 15.

1970  *P. apaleta* (pars) (Cookson & Eisenack); Gitmez: 303-304, pl. 6, fig. 8; text-fig. 29.
1972  *P. apatela* (pars) (Cookson & Eisenack); Gitmez & Sarjeant; tables 3-6.

REMARKS: This species, as mentioned above, is possibly synonomous with *T. rhombiformis* Vozhennikova.

Gitmez (1969, thesis) recorded this species from the Kimmeridgian of England and France and commented (p. 330) that some of her specimens lack an apical prominence on the innerbody. These forms do not conform with the diagnosis of the species as given by Cookson & Eisenack and are attributed herein to the subspecies *T. apatela* subsp. *rotunda* nov. Her work formed the basis of later publications by Gitmez (1970) and Gitmez & Sarjeant (1972); accordingly the specimens recorded as *Psaligonyaulax apatela* by these authors, must be considered to include both *T. apatela* and *T. apatela* subsp. *rotunda*.

*Tubotuberella* is easily distinguished from *Psaligonyaulax* Sarjeant by the absence of well developed tabulation and the presence of an antapical opening.

REPORTED RANGE: Oxfordian - Upper Cretaceous.

*Tubotuberella apatela* subsp. *rotunda* nov.

Plate 9, fig. 5.

1970  *Psaligonyaulax apatela* (pars) (Cookson & Eisenack); Gitmez: 303-304.

1972  *P. apatela* (pars) (Cookson & Eisenack); Gitmez & Sarjeant: tables 3-6.


DIAGNOSIS: A subspecies of *Tubotuberella apatela* lacking an apical protuberence on the innerbody.
HOLOTYPE: Slide D. 27 (6)

DIMENSIONS: Holotype: overall length 88\(\mu\), breadth 50\(\mu\), length of innerbody 56\(\mu\), breadth 49\(\mu\).

DESCRIPTION: This new subspecies is very similar to the typical subspecies as described by Cookson & Eisenack, the sole distinguishing criteria is the absence of an apical protuberence on the innerbody.

REPORTED RANGE: Kimmeridgian, and possibly older.

**Tubotuberella sphaerocephalus** Vozzhennikova 1967

Plate 9, fig. 6.

1967 **Tubotuberella sphaerocephalus** Vozzhennikova: 181, pl. 103, figs. 1-3; pl. 104, figs. 4, 5ab.

REMARKS: This species differs from *T. rhombiformis* and *T. apatela* in having deeply serrate/denticulate crests developed along presumed plate boundaries and the cingulum.

Cooksons & Eisenack (1960b), in their diagnosis of the species apatela comment that the outer membrane of some of their specimens may be serrate at the sides of the cyst, but in the absence of any adequate description or illustration, no comparisons can be made with *T. sphaerocephalus*.

*T. sphaerocephalus* was originally described by Vozzhennikova from the Upper Jurassic of the U.S.S.R. its record herein therefore represents an extension in its geographical range.

Two specimens of this very distinctive species were recorded, but only one was capable of measurement (overall dimensions 86\(\mu\) x 46\(\mu\)).
REPORTED RANGE: Upper Jurassic (probably Volgian).

_Tubotuberella_ teriostia sp. nov.

Plate 9, fig. 7.

DERIVATION OF NAME: Latin _teres_, circular; _ostium_, opening - with reference to the circular opening developed at the antapex.

DIAGNOSIS: A species of _Tubotuberella_, elongate to broadly ovoidal with a small, blunt, apical horn; the hypotract narrowing distally towards a circular, antapical opening with a smooth margin. Outer membrane thin, smooth.

Innerbody broadly - ovoidal to subspherical, thin-walled, smooth, except for a dense cover of fine granules around the antapex. No indication of tabulation, cingulum or sulcus.

HOLOTYPE: Slide D.45(7).

DIMENSIONS: Holotype: overall length 75 \( \mu \) , breadth 45 \( \mu \); length of innerbody 50 \( \mu \), breadth 44 \( \mu \). Range: overall length 75-85 \( \mu \), breadth 45-47 \( \mu \); length of innerbody 48-50 \( \mu \), breadth 44-49 \( \mu \). (3 specimens measured).

DESCRIPTION: Due to the thin nature of its walls, the cyst is typically folded. To some extent the folds simulate plate boundaries, but no definite indications of a tabulation were observed. The apical horns of the observed specimens are abruptly truncated; a small, circular hole is typically present at the anterior end of the horns. The significance of this opening is not fully understood, it may be a primary morphological feature, or preservational.
A small, precingular archaeopyle is indicated by faint lines on the outer membrane of the holotype, the operculum remaining in place.

REMARKS: *T. teriostia* is a very rare species, only 3 specimens were observed, but its distinctive morphology is considered to merit the erection of a new taxon. It is attributed to the genus *Tubotuberella* on the basis of its bicavate morphology, lack of readily determinable tabulation, and antapical aperture.

Genus **XENICODINIUM** Klement 1960

REMARKS: The genus *Xenicodinium* has a known stratigraphic range of Kimmeridgian–Pliocene. The Tertiary–Recent genus *Tectatodinium* Wall 1967, is very similar in morphology to Klement's genus and may in fact be a junior synonym. Sarjeant (1974 pers. comm.) is, however, very doubtful about there being any genetic relationship between the two forms.

**Xenicodinium** sp.

Plate 14, fig. 11.

DESCRIPTION: The cyst is broadly ovoidal with rounded apices, a feebly indicated cingulum divides the cyst equally. A large hoof-shaped precingular archaeopyle is well-developed. The cyst wall is very thin, minutely granular, with a very small-meshed reticulation developed in places. The latter is only visible under a high-power phase contrast objective and may represent a very thin periphragm partially destroyed by adverse preservation and/or extraction techniques.

DIMENSIONS: length 68μ, breadth 56μ. (1 specimen measured).
REMARKS: A number of fragmentary and one entire, but poorly preserved specimen of this form were observed in Upper Kimmeridgian assemblages from the Boulonnais (sample B.19).

OTHER SPECIES

Xenicodinium scabratum (Pocock) comb. nov. = Chytroeisphaeridia scabra Pocock 1972, p. 100, pl. 27, figs. 23-25. Callovian, Canada.

Genus and Species Indet. A.

Plate 10, fig. 11.

DESCRIPTION: The cyst is elongate ovoidal in outline, with a rounded antapex, the apex is lost in archaeopyle formation along an irregular, deeply indented line of breakage. The cyst wall is of moderate thickness, finely granular and bears numerous short processes. The processes are slender, taper slightly from their bases and distally are slightly hairy or capitate. A cingulum and plate boundaries are weakly indicated by alignment of some of the processes by the sutural slits along the archaeopyle margin, and slight cingular indentations at the edges of the cyst.

DIMENSIONS: Length apex lacking 36, breadth 27, process length 2-3. (1 specimen measured).

REMARKS: This form differs from all previously described dinoflagellate cysts in its overall morphology and arrangement of spines. In its overall shape it is perhaps similar to species of the genus Prolixosphaeridium Davey et al. 1966; it differs however in possessing indications of a tabulation and in
the form and arrangement of its processes.

The genus *Microdinium* Cookson & Eisenack emend. Sarjeant 1966 similarly includes species of similar overall shape. This genus does however possess a well developed and distinctive tabulation and bears sutural spines only.

**PERIDINACEAN GROUP**


*Ascodinium sp.* sensu Norris 1963

Plate 9, fig. 12.

**DESCRIPTION:** The innerbody is ovoidal in shape with a rounded apex and antapex, the outer membrane is extended posteriorly to form two blunt antapical protuberances. An apical archaeopyle is formed by the loss of the entire apical region along an irregular line of breakage. A circular cingulum divides the cyst equally and faint lines appear to be indicative of a tabulation. The outer membrane is thin and folded with occasional perforations; the innerbody is thicker-walled and finely granular.

**DIMENSIONS:** Overall length (apex lacking) 65 , breadth 77 , innerbody length 59 , breadth 61 , (1 specimen measured).

**REMARKS:** This form was described by Norris (1963) as *Ascodinium sp.* from the Upper Kimmeridgian (rotunda Zone) to "Purbeckian" of Dorset. The most similar described species is *Ascodinium lordi* Cookson & Eisenack from the Australian Upper Cretaceous, which differs however in being considerably
larger and in possessing a different form of surface ornamentation.

The genus *Ascodinium* was emended by Cookson & Eisenack (1968) to include *A. lori* which is markedly different from all other previously described species, particularly in the form of the apical archaeopyle. *A. lori* and *A. sp.* do in fact appear to be similar in morphology to species of the Cretaceous genus *Senoniasphaera* Clark & Verdier; in particular to *Senoniasphaera* sp. illustrated by Davey & Verdier (1971, pl. 6, fig. 9) from the French Albian.

Genus **CHLAMYDOPHORELLA** Cookson & Eisenack 1958

emend Davey 1969

**Chlamydophorella membraniodea** Vozzhennikova 1967

1967 **Chlamydophorella membraniodea** Vozzhennikova: 114-115, pl. 48, figs. 1-10.

**REMARKS:** *Chlamydophorella membraniodea*, hitherto only known from the Upper Jurassic of the U.S.S.R., differs from other species of the genus in the absence of any apical processes and the presence of tabulation (albeit indeterminable) and a cingulum.

**REPORTED RANGE:** Upper Volgian.

**Chlamydophorella nyei** Cookson & Eisenack 1958

Plate 13, figs. 6-7.

1958 **Chlamydophorella nyei** Cookson & Eisenack: 56, pl. 11, figs. 1-3.

**REMARKS:** Several of the specimens possess supporting processes of small length (c. 1μ) and appear to lack indications of a cingulum. As such they are similar to the Upper Cretaceous species *C. discreta* Clarke & Verdier,
but as they possess processes which are distally bifurcate (albeit only slightly) 
they are attributed to \textit{C. nyei}. In their overall morphology they appear to be 
intermediate to some extent between the two species. \textit{C. nyei} as reported by 
Cookson & Hughes (1964) from the Albian-Cenomanian is considered to be more 
attributable to \textit{Cleistosphaeridium hugonioti} (Valensi).

REPORTED RANGE: Tithonian-Lower Turonian.


REMARKS: Sarjeant (1962) states "In text-figure 11, an arbitrary apical 
orientation has been given .... " So although an apical archaeopyle is 
inferrred and in the original diagnosis, it is by no means certain that the 
archaeopyle is apical. Harland (1974 \textit{pers. comm.}) considers it to be very 
likely that the type species of the genus, \textit{C. chytroeides} (Sarjeant) does in fact 
possess an intercalary and/or precingular archaeopyle. Specimens possessing 
precingular and intercalary archaeopyles have in fact been attributed to this 
genus; \textit{i.e. Chytroeisphaeridia simplicia} Wall 1965 and \textit{C. cariacoensis} and 
\textit{P. avellana}. The cyst of \textit{P. conicoides} certainly has a large intercalary 
archaeopyle which when seen in certain orientations can appear to be apical and/or 
precingular (Harland \textit{pers. comm.}). Davey (1974 \textit{pers. comm.}) similarly 
considers that \textit{C. chytroeides} posses a precingular archaeopyle. Sarjeant 
(1974 \textit{pers. comm.}) states "Chytroeisphaeridia definitely has an apical 
archaeopyle; quite certainly Wall's species - as he has himself stated in a 
recent paper, though without proposing their reallocation - do not belong to 
that genus".
The genus *Chytroeisphaeridia* is maintained in this thesis, following Sarjeant's comments, for forms with an apical archaeopyle. The writer is unfamiliar with Quaternary dinoflagellates and accordingly no re-allocation of Wall's species is proposed here.

Pocock's species *C. scrabata* is characterised by a precingular archaeopyle formed by the loss of a single plate. Accordingly, its allocation to the genus *Chytroeisphaeridia* must be rejected. This species is discussed elsewhere in this thesis as *Xenicodinium scabrata* (Pocock) comb. nov.

The genus *Chytroeisphaeridia* by the combination of apical archaeopyle, non-tabular structure and surface ornamentation typically, in the form of granules, is considered to have, at least in part, peridiniacean affinities.

*Chytroeisphaeridia chytroeides* (Sarjeant) Downie & Sarjeant 1963.

1962b *Leiosphaeridia (Chytroeides) chytroeides* Sarjeant 492, pl. 70, figs. 13-16; text-figs. 11-12.

1963 *Chytroeisphaeridia chytroeides* (Sarjeant); Downie et al: 9.

1964a *Leiosphaeridia wenlocki* Downie; Dupin: pl. 3A, no. 3.


REMARKS: The specimen figured by Dupin (1965) as *Leiosphaeridium wenlocki* from the Upper Jurassic of Aquitaine appears to be attributable to this species.

The German Bathonian specimens illustrated by Gocht (1970, pl. 34, figs. 20-24) possess densely granular walls and are correctly attributable to *C. pococki* Sarjeant. His mention of smooth-walled forms (p. 152) does, however, suggest that *C. chytroeides* is present in his material.

? Chytroeisphaeridia mantelli Gitmez & Sarjeant 1972

Plate 12, fig. 2.

1972 Chytroeisphaeridia mantelli Gitmez & Sarjeant: 186-187, pl. 1, figs. 1-4, pl. 12, fig. 3.

REMARKS: ?C. mantelli is a very distinctive, but infrequent species. It is characterised by a thick cyst wall, which is coarsely granular, bearing an irregular scatter of tubercles, giving it a somewhat warty appearance, and an apical archaeopyle with a "ragged-margin". In its overall morphology it shows a broad accord with the diagnosis of the genus Tenua as emended by Sarjeant (1968). Attribution of the species to the genus Chytroeisphaeridia by Gitmez & Sarjeant was based on its lack of surface spines. This attribution is considered to be somewhat questionable, as it appears to the writer to be morphologically intermediate between the two genera. The possession of a readily discernable two-layer wall also differentiates this species from other described species of Chytroeisphaeridia.

REPORTED RANGE: Lower-Upper Kimmeridgian.

Chytroeisphaeridia pococki Sarjeant 1968

1956 Chytroeisphaeridia sp. Sarjeant: 182, pl. 1, fig. 13.

1968 Chytroeisphaeridia pococki Sarjeant 230: pl. 9, figs. 7-8, pl. 10, fig. 3.

? 1970 Chytroeisphaeridia chytroeides (Sarjeant); Gocht: 152, pl. 34, figs. 20-24.

REMARKS: This species typically occurs in association with C. chytroeides.
The two species have comparable stratigraphic ranges and are very similar in terms of size and general morphology. Accordingly, the differentiation between *C. pococki* and *C. chytroeides* proposed by Sarjeant is considered to be of dubious value. *C. pococki* is diagnosed as possessing a granular wall and *C. chytroeides* a smooth wall; the development of granules appear to be a variable and gradational feature and may be of intraspecific value only.

REPORTED RANGE: Bathonian-Upper Kimmeridgian.

**Genus CONCINNIODINIUM nov.**

DERIVATION OF NAME: Latin, *concinnus*, symmetrical - with reference to the bilateral symmetry exhibited by the cyst.

DIAGNOSIS: Bicavate cysts, spindle-shaped with well-developed bluntly rounded apical and antapical pericoels. Pericoels formed by extensions of the outer membrane separated by a broad median zone of contract with the innerbody. A plane of bilateral symmetry runs from the apex to antapex. Cingulum weakly indicated, tabulation indistinct. Archaeopyle apical.

TYPE SPECIES: *Concinniodinium wilsonii* sp. nov. Kimmeridgian, Dorset, England.

REMARKS: *Concinniodinium* differs from all other described genera on the basis of its overall shape and symmetry. Its affinities are considered to be Periniacean within the pseudoceratioid lineage of Wall & Dale (1968). The most comparable genus is perhaps *Muderongia*.
Concinniodinium wilsonii sp. nov.

Plate 9, figs. 1-2.

DERIVATION OF NAME: Named after Dr. R. C. L. Wilson of the Open University in recognition of his help and supervision during the course of this work.

DIAGNOSIS: As for the genus with the following remarks. The innerbody closely follows the shape of the outer membrane with well-developed bluntly rounded apical and antapical projections extending into the pericoel. Innerbody wall and outer membrane thin and smooth or minutely granular.

HOLOTYPE: Slide D.41(2).

DIMENSIONS: Holotype: overall length 108μ, breadth 52μ, length of innerbody 78μ, breadth 51μ. Range: overall length 79-108μ, breadth 48-52μ. (3 specimens measured).

DESCRIPTION: The tabulation is very weakly indicated. The cingulum is circular and equatorial, the sulcus is long and narrow, extending from apex to antapex.

REMARKS: C. wilsonii is a rare species, in all only three specimens were recorded. Its distinctive nature does, however, merit the erection of a new species. Its distribution suggests that it might have some stratigraphic importance.
Genus FROMEA Cookson & Eisenack 1958 emend.

EMENDED DIAGNOSIS: Proximate dinoflagellate cysts, elongate to broadly ovoidal or subspherical in shape. Archaeopyle apical, with a smooth, rounded margin. Cingulum strongly or weakly indicated, or totally lacking. Cyst wall of variable thickness, smooth or granular, lacking spines or processes.


REMARKS: The genus Fromea was originally defined as "shell elongated, smooth with an equatorial girdle and a wide aperture at one end". The authors also stated that the cingulum is "strongly indicated in the type, less so in other examples". Subsequently, Sarjeant (1966) and Gitmez & Sarjeant (1972) have recorded specimens with little indication of a cingulum. Davey (1969) and the writer (herein) have recorded specimens completely lacking any indication of a cingulum. Forms with varying degrees of surface ornamentation, from completely smooth-walled to densely granular have similarly been recorded by the above authors and herein.

The diagnosis is accordingly emended to include these variations and to allow for more variation in overall shape.

The affinities of this genus are considered to be peridiniacean with the ?pseudoceratoid lineage.

Fromea amphora Cookson & Eisenack 1958 emend.

Plate 12, figs. 1, 4, 11.

1958 Fromea amphora Cooksons & Eisenack: 56, pl. 5, figs. 10-12.
1972 Fromea warlinghamensis Gitmez & Sarjeant: 188-189, pl. 1, figs. 6-8, figs. 5-6.

EMENDED DIAGNOSIS: As for the genus.

DIMENSIONS: Holotype: length (apex lacking) 81\(\mu\), breadth 62\(\mu\), Range of observed specimens: length (apex lacking) 50-93\(\mu\), breadth 48-87\(\mu\). (16 specimens measured).

DESCRIPTION: The cyst varies considerably in overall shape, wall thickness (1-3\(\mu\)) and surface ornamentation (smooth to densely granular). A well developed cingulum, as exhibited by the holotype, was not observed, forms were observed with a faint cingular trace, with cingular indentations at the margins and totally lacking any indication of a cingulum.

REMARKS: A complete gradation was observed between specimens attributable to the Cretaceous species F. amphora and specimens attributable to the Jurassic species F. warlinghamensis. Accordingly, the two species are grouped together, their morphological differences are considered to be within the limits of variation of a single specie, F. amphora having priority.

The two species, as originally defined are considered to be end members of a continuously varying plexus involving the gradual loss of surface granulation and the development of a distinct, well-defined cingulum.

REPORTED RANGE: F. amphora Upper Barremian - Upper Cretaceous (at least Maastrichtian).

F. warlinghamensis. Middle - Upper Kimmeridgian.
Genus **HEXAGONIDUM** nov.

DERIVATION OF NAME: Hexagon, six-sided - with reference to the hexagonal shape of the archaeopyle.

DIAGNOSIS: Broadly ovoidal to elongate proximate cysts possessing an apical horn. Antapex rounded, median and antapical horns lacking. Tabulation, cingulum and sulcus lacking. Archaeopyle, hexagonal in shape, intercalary, formed by the loss of a single plate.

TYPE SPECIES: *Hexagonidium asperatum* sp. nov. Kimmeridgian, France.

REMARKS: *Apteodontium* Eisenack differs in possessing a precingular archaeopyle; *Pareodinia* is again of comparable overall appearance, but differs of comparable overall appearance, but differs in possessing an intercalary archaeopyle formed by the loss of two intercalcary plates.

**Hexagonidium asperatum** sp. nov.

Plate 10, fig. 2.

DERIVATION OF NAME: Latin, asperatus, roughened, irregular - with reference to the surface ornamentation.

DIAGNOSIS: Cyst pear-shaped, expitract tapering to form a strong, but blunt horn of moderate length; antapex rounded. Cyst wall thick, densely granular and coarsely tuberculate; occasional tubercules developed into very short, stout, irregularly shaped processes. Archaeopyle intercalary, hexagonal in shape, formed by the loss of a single plate. No indication of tabulation, cingulum or sulcus.
HOLOTYPE: Slide B. 22 (4).

DIMENSIONS: Holotype: Overall length 51\(\mu\), breadth 35\(\mu\), length of apical horn 6\(\mu\), maximum length of surface processes. 1.5\(\mu\). Range overall length 50-62\(\mu\), breadth 33-35\(\mu\), length of apical horn 5-6\(\mu\) (3 specimens measured).

DESCRIPTION: Of the three specimens observed the holotype is the better preserved. The overall shape of the cyst, shape and position of the archaeopyle and the surface ornamentation combine to make this a very distinctive form. The surface tubercles and processes appear to be randomly distributed; no alignment, indicative of a cingulum or reflected tabulation is apparent.

REMARKS: The overall characteristics of this form distinguish it from all previously described genera.

Genus *HEXAGONIFERA* Cookson & Eisenack 1961


*Hexagonifera* sp.

REMARKS: A number of specimens recorded from the Sandringham Sands (Samples S1 and S7) appear to be attributable to this genus. Identification of the species present is not, however, possible due to poor preservation.

Genus *IMBATODINIUM* Vozzhennikova 1967b

*Imbatodinium antennatum* Gitmez & Sarjeant 1972

Plate 10, fig. 31B.


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1972 *Imbatodinium antennatum* Gitmez & Sarjeant; 232–233, pl. 11, figs. 2–3.

**REPORTED RANGE:** Lower - Upper Kimmeridgian.

*Imbatodinium longifilum* sp. nov.
Plate 10, fig. 4, fig. 31A.

**DERIVATION OF NAME:** Latin, *longus*, long; *filum*, thread - with reference to the long thread-like apical projection.

**DIAGNOSIS:** Cyst elongate, apex tapering to form a strong apical horn, antapex tapering to form a strong, but blunt antapical mamelon. Apical horn bearing a long, thread-like distal projection. Ration of apical horn length to thread length 1:3. No indication of tabulation or sulcus; cingulum weakly indicated.

Cyst wall thin, finely granular. Archaeopyle intercalary.

**HOLOTYPE:** Slide D.31(1).

**DIMENSIONS:** Holotype: overall length 103μ, breadth 42μ, length of apical horn 10μ, length of apical thread 31μ. (1 specimen measured).

**DESCRIPTION:** A weakly indicated cingular trace divides the cyst unequally, the epitract being longer than the hypotract. The holotype is enclosed within a film of fleecy organic substance up to 10μ in thickness; this is not however considered to be of any taxonomic significance.

**REMARKS:** A single specimen was observed, but its distinctive morphology is considered to merit the erection of a new species. The most comparable species is *I. antennatum* Gitmez, which is readily differentiated by the shape of its antapex and much shorter apical thread (ration of horn to thread 1:1-2).
**Imbatodinium mutabilis** sp. nov.

Plate 10, figs. 12-14.

1972 *Imbatodinium* cf. *villosum* Vozhennikova; Gitmez & Sarjeant: 233, pl. 11, fig. 1.

**DERIVATION OF NAME:** Latin, *mutabilis*, variable - with reference to the surface processes.

**DIAGNOSIS:** A species of *Imbatodinium* having numerous surface processes of irregular and variable size and form.

**HOLOTYPE:** Slide D.37(4).

**DIMENSIONS:** Holotype: Overall length 75\(\mu\), breadth 33\(\mu\), apical horn length 11\(\mu\), apical thread length 11\(\mu\), process length 2-7\(\mu\). Range: overall length 50-87\(\mu\), breadth 25-43\(\mu\), apical horn length 4-13\(\mu\), apical thread length 4-11\(\mu\), process length 2-8\(\mu\) (22 specimens measured).

**DESCRIPTION:** Individual cysts are frequently folded and very in shape from broadly ovoidal to elongate ovoidal. The apical thread is frequently broken with the "knob-like termination", characteristic of the genus missing. Both the apical horn and the apical thread vary in length, apparently independantly of each other. Considerable variation is evident between individuals in terms of surface ornamentation. The cyst wall varies from smooth to densely granular and bears processes that vary from slender, short and simple to very irregular and frequently branched. This variation may, at a future date be used as a basis for subdivision of this species. It is possible, however, that the variation in ornament may merely represent an environmental or geographical
control; French specimens for example, typically possess the more slender and more widely distributed processes.

REMARKS: *I. mutabilis* differs from all previously described species in the nature of its surface ornamentation. *I. villosum* Vozzhennikova is typically a much larger species and possesses longer processes that are slender and more regular in shape and distribution.

With a progressive decrease in ornamentation *I. mutabilis* becomes morphologically very close to *I. antennatum* Gitmez, which may, on this evidence, be interpreted as an ancestral form.

Gitmez & Sarjeant (1972) recorded this species, as *I. cf. villosum* Vozzhennikova from the Upper Kimmeridgian of England.

**Imbatodinium verrucosum** Vozzhennikova 1967

1967  *Imbatodinium verrucosum* Vozzhennikova: 56, pl. 12, fig. 6.

REMARKS: *I. verrucosum* differs from all other species of this genus by the possession of a finely granular cyst wall covered with short, stout, tuberculate projections.

A single specimen comparable in size and general appearance with the Russian type material was recorded in the Berriasian of Norfolk (sample S7).

REPORTED RANGE: Upper Volgian.

**Imbatodinium villosum** Vozzhennikova 1967

Plate 10, fig. 1.

1967  *Imbatodinium villosum* Vozzhennikova: 56, pl. 12, figs. 1-3; pl. 13, figs. 1-3, pl. 14, figs. 1-2.
REMARKS: The writer has recently (1973 unpublished) observed this species in Portlandian - Lower Cretaceous assemblages from Norway. Its previous reported occurrence was from the Russian Volgian.

REPORTED RANGE: Volgian - Lower Cretaceous (Valanginian).

Imbatodinium spp.

REMARKS: Several very poorly preserved specimens possibly representing new species attributable to this genus were observed, particularly in the Sandringham Sands. An isolated specimen was also received from the Upper Kimmeridgian Clay of Dorset.

Genus KALYPTEA Cookson & Eisenack 1960

Kalyptea sp.

Plate 10, fig. 7.

DESCRIPTION: The cyst wall is of moderate thickness—smooth or granular and frequently folded, particularly around the cyst circumference. This folding at times simulates an inner body, giving a form superficially similar to Netrelytron Sarjeant. An apical horn of variable size is typically developed, usually relatively short and blunt; antapical horns rarely present. The outer diaphanous membrane is variably developed, rarely it is absent, so giving a form perhaps more attributable to Pareodinia ceratophora Deflandre. The archaeopyle when present, is poorly developed, but appears to be intercalary.

REMARKS: Infrequent, intergrading forms, showing considerable variation and assignable to this genus were observed. Subdivision of the forms was not
attempted, allocation to previously described species was not considered practicable.

**Genus MUDERONGIA** Cookson & Eisenack 1958

*Muderongia simplex* Alberti 1961

Plate 9, figs. 10-11, fig. 32A.

1961 *Muderongian simplex* Alberti: 12, pl. 12, figs. 1-6; pl. 2, figs. 1-2.

**REMARKS:** The Upper Jurassic specimens recorded here correspond exactly in size and general morphology with the type material, but differ slightly in possessing some variation in the size and density of the perforations developed in the outer membrane.

Infrequent specimens possess low, intermittent crests on the innerbody surface and short, solid processes linking the innerbody wall to the outer membrane. These features are only developed on certain, well preserved specimens and only visible under a high power, phase contrast objective. The failure to distinguish these features on the majority of specimens may be a consequence of preservation and/or preparation techniques; although several well-preserved specimens were observed that totally lack any indication of these features.

These "ornamented" forms may represent a new species, but pending the availability of additional specimens and a re-examination of Alberti's material, they are included within *M. simplex*.

The Kimmeridgian specimens described and illustrated by Gitmez & Sarjeant (1972) are considered to fall outside the range of variation of *M. simplex* and are discussed elsewhere as *Muderongia* sp. A.
REPORTED RANGE: Valanginian - Barremian.

**Muderongia** sp. A.

Fig. 32B.


DESCRIPTION: A species of *Muderongia*, similar to *M. simplex* in overall appearance, but differing in possessing a relatively shorter apical horn and rounded, blunt, lateral horns that lack the distal notches characteristic of *M. simplex*.

DIMENSIONS: overall length 78-110 μm, overall breadth 65-90 μm. (12 specimens measured; including dimensions quoted by Gitmez & Sarjeant).

REMARKS: Only two specimens of this form were observed in the present study, both poorly preserved. Accordingly, pending the availability of additional specimens and a re-examination of Gitmez & Sarjeant's material, no new name is proposed.

REPORTED RANGE: Upper Kimmeridgian.

? *Muderongonia* sp. B.

Plate 9, fig. 9.

DESCRIPTION: The cyst is broadly ovoidal in shape, bearing 3 or 4 horns formed from the outer membrane. The apical horn is short, blunt and broad-based as are the lateral horns. Owing to folding in the antapical region
it is difficult to determine whether one or two antapical horns are present. The outer membrane is thin delicate and perforate possibly a consequence of preservation. The inner body is subspheroidal in shape, thin walled with a finely granular surface. An apical archaeopyle is indicated, the apex remaining attached.

DIMENSIONS: overall length 82 \mu m, overall breadth 85 \mu m, inner body length 65 \mu m, inner body breadth 67 \mu m, (1 specimen measured).

REMARKS: A single distorted specimen was recorded from the Cinder Bed at the top of the Dorset Portlandian. It is tentatively attributed to the genus Muderogonia on the basis of its overall shape and mode of archaeopyle formation.


REMARKS: Cysts allocated to this genus are consistently enclosed in "a cloak of organic matter" as are those of the related genus Paranetrelytron Sarjeant. Paranetrelytron differs from Netrelytron by the lack of an antapical projection. Two species of this genus N. stegastum and N. parum, are known from the Kimmeridgian, but only one, N. parum, was recovered during the course of this study.

Netrelytron parum Gitmez 1970

1970 Netrelytron parum Gitmez: 314-315, pl. 5, fig. 4; pl. 9, fig. 4.

REMARKS: N. parum is distinguished from N. stegastum by its much less-marked antapical horn and more broadly elongate shape. In possessing a
reduced antapical horn it appears to be a morphological intermediate between the genera Netrelytron and Paranetrelytron.

REPORTED RANGE: Lower - Upper Kimmeridgian

Genus PARANETRELYTRON Sarjeant 1966

REMARKS: Paranet"relytron differs from Netrelytron Sarjeant in lacking an antapical horn. The Kimmeridgian species Netrelytron parum Gitmez, characterised by a poorly developed antapical horn, accordingly appears to be intermediate in morphology between the two genera.

Paranetrelytron sp.

Plate 9, fig. 3.

DESCRIPTION: The outer membrane is spheroidal in shape and bears an apical horn of varying form. This varies from a short, blunt apical horn to a very reduced apical protuberence. The innerbody is sphaeroidal and fits quite closely, except at the apex where there is quite a large expansion of the pericoel. It is thin, virtually transparent and difficult to distinguish. The entire cyst is consistently enclosed in a cloak of adherent organic and inorganic material.

DIMENSIONS: overall length 41-48 µ, breadth 37-48 µ, apical horn length 2-7 µ. (15 specimens measured).

REMARKS: The only previously described species of this genus Paranetrelytron strongylum Sarjeant 1966, from the English Barremian, differs from the observed specimens in being consistently larger (51-58 µ as quoted by Sarjeant) and in always possessing a well developed apical horn.
Several specimens, possessing well-developed apical horns, appear
to be a smaller variety of Sarjeant's species, but lack the faintly indicated
cingulum described by Sarjeant. Accordingly the observed specimens are
compared, rather than attributed, to \textit{P. strongyllum}. They may represent a
new species, or, together with \textit{P. strongyllum} form part of a morphologically
varying plexus.

Genus \textit{PAREODINIA} Deflandre 1947c

1960b \textit{Kalyptea (pars)} Cookson & Eisenack

REMARKS: The genus \textit{Kalyptea} is considered to be, at least in part, a junior
synonym of \textit{Pareodinia}.

The emended diagnosis proposed by Gocht (1970) is herein rejected
for the following reasons:-

(i) The presence of a second (antapical) horn is considered to be an
important morphological feature with adequate justification for taxonomic
separation.

(ii) The presence of a mantle of fleecy-organic substance (termed a
"Kalyptea" by Gocht) is not considered to be a diagnostic feature. Its presence
or absence is more probably a function of preservation and therefore not
suitable as a basis for taxonomic differentiation except on a purely form basis.

\textit{Pareodinia ceratophora} Deflandre 1947

Plate 10, figs. 3, 6, 8-9.

1947 \textit{Pareodinia ceratophora} Deflandre: 4, figs. 1-3.

1958 \textit{Pareodinia aphelia} Cookson & Eisenack: 60, pl. 12, fig. 9.

1958 \textit{Cryptomeriapollenites coralliensis} Lantz: 927, pl. 5, figs. 55-56, pl. 6,
fig. 7.
1958 Incertae sedis Lantz: 927, pl. 6, figs. 58-59.
1959 Pareodina ceratophora var. pachyceras Sarjeant: 337, pl. 3, fig. 10, text-fig. 5.
1960 Kalyptea diceras Cookson & Eisenack: 256, pl. 39, fig. 1.
1960 Kalyptea monoceras Cookson & Eisenack: 257, pl. 39, figs. 2-3.
1961 Pareodina sp. Evitt, pl. 8, fig. 9.
1971 Kalyptea sp. (pars) Davey & Verdier: pl. 4, fig. 2.
1972 Pareodina ceratophora var. pachyceras Sarjeant: 26, pl. 2, fig. 4.
1972 Pareodinia prolongata Sarjeant; Sarjeant: pl. 4, fig. 9.

REMARKS: P. ceratophora is a very variable species in terms of size, shape of apical horn, overall shape and surface ornamentation. Accordingly, the species P. aphelia Cookson & Eisenack is considered to fall within the range of variation of P. ceratophora and is rejected herein as a junior synonym of Deflandre's species. Similarly, the subspecies differentiated by Sarjeant (1959, 1972) as subsp. pachyceras and subsp. scopaeous are not considered to merit taxonomic separation and are accordingly rejected.

The species Kalyptea monoceras Cookson & Eisenack and Cryptomeriapollenites coralliensis Lantz are treated here as junior synonyms of P. ceratophora. The inclusion of Kalyptea diceras into the synonymy of this species by Gocht (1970), admittedly provisional is considered to be unjustifiable (see Sarjeant 1972).

Kalyptea jurassica Alberti 1961, possesses a distinct inner body within a spindle-shaped crypt, hence its inclusion into the synonymy of P. ceratophora.
by Lentin & Williams (1973) is rejected.

Fisher (1974, pers. comm.) has recently observed specimens in the Jurassic of Arctic Canada that are comparable with P. ceratophora in terms of size and general appearance, but possess definite, but variably developed, indications of tabulation. See also Warren (1967).

REPORTED RANGE: Toarcian - Cenomanian (including above synonomies).

Pareodinia nuda (Downie) Pocock 1972

1957 Palaeoperidium nudum Downie 424, pl. 20, fig. 11.
? 1962 P. nudum Downie; Pocock: 81, pl. 14, fig. 223.
1967 Pareodinia nuda (Downie); Sarjeant: nomen nudum, 253-254.
1972 ? Pareodinia nuda (Downie); Pocock: 96.

REMARKS: P. nuda was originally described from the Middle - Upper Kimmeridgian of England. The specimen illustrated by Pocock (1962) from the Upper Mesozoic of Canada appears to possess a proportionally shorter and hollow ended apical horn and is considered to be of doubtful attribution. Pocock mentions that the top of the apical horn of his specimens, may be hollow or solid and, sometimes, but not always, possesses a spiral groove. His material ranges in age from Jurassic to Upper Cretaceous, but it is not made clear whether this variation in morphology is exhibited throughout.

In contrast to Downie's (1957) comment that P. nuda is a common Kimmeridgian species, it was not recorded by Gitmez (1970) and Gitmez & Sarjeant (1972). It was observed very infrequently during the present study and then only in a poorly preserved state. In the majority of instances its
presence was inferred solely by the occurrence of broken and isolated apical horns that are hollow and bear a spiral groove.


OTHER SPECIES

Pareodinia evitti (Pocock) comb. nov. = Temua evitti Pocock 1972, p. 94-95, pl. 24, fig. 6; text-fig. 11. Upper Jurassic, Canada.

Genus PSEUDOCERATIUM Gocht. 1957

Pseudoceratium spp.

REMARKS: Infrequent, poorly preserved specimens attributable to this genus were observed in the Lower Ryazanian assemblages from Norfolk. Its first appearance, immediately above the Jurassic - Cretaceous boundary, makes it a useful stratigraphic index form.

WALLODINIUM Loeblich & Loeblich 1968


Wallodinium sp.

Plate 9, fig. 4.

1967 Diplotesta aff. krutzschi Alberti; Vozzhennikova: 191, pl. xcvi, fig. 6.

1972 Wallodinium krutzschi (Alberti); Habib: 378, pl. 12, fig. 9; pl. 13, fig. 2.
DESCRIPTION: The cyst is thin-walled, smooth with a somewhat flattened to pointed antapex; the former may however be preservational, the apex is lost in archaeopyle formation. The inner body is elongate - ovoidal with rounded poles, thin-walled and transparent. A median zone of close proximity separates well-developed apical and antapical pericoels.

DIMENSIONS: Length (apex lacking) 52-77μ, breadth 27-37μ; inner body length 44-64μ, breadth 22-34μ. (6 specimens measured).

REMARKS: W. krutzsch (Alberti) from the Lower Cretaceous of Germany is the most similar species, but it is however considerably larger (length 105-125 μ).


UNKNOWN AFFINITIES GROUP

Genus STEPHANELYTRON Sarjeant 1961a emend.


EMENDED DIAGNOSIS: Spherical or ovoidal dinoflagellate cysts. Antapex bearing one or more structures, henceforth termed coronas, that consist of a circular membrane rising upwards from the cyst surface and everted, surrounding a matter of short hairs or spines. Elsewhere the cyst bears tabular processes of varied character and arrangement. Archaeopyle apical.

REMARKS: The diagnosis is emended to include reference to the mode of archaeopyle formation which demonstrates the dinoflagellate affinity of this genus.

**Stephanelytron redcliffense** Sarjeant 1961

1961a **Stephanelytron redcliffense** Sarjeant: 109-110, pl. 15, fig. 11, text-figs. 10, 15.

1972 **S. redcliffense** Sarjeant; Gitmez & Sarjeant: 237-238, pl. 14. fig. 6.

1972 **S. cf. redcliffense** Sarjeant; Gitmez & Sarjeant: 238, pl. 14, fig. 14.

REMARKS: The distinction between **S. redcliffense** and **S. cf. redcliffense** proposed by Gitmez & Sarjeant (1972, p. 238) on the relative thicknesses of the surfaces processes is rejected, the difference is considered to be too trivial for taxonomic separation.

REPORTED RANGE: Lower Oxfordian - Lower Kimmeridgian.

**Stephanelytron scarburghense** Sarjeant 1961

1961a **Stephanelytron scarburghense** Sarjeant: 111, pl. 15, figs. 12-13.

1970 **S. cf. scarburghense** Sarjeant; Gitmez: 297, pl. 10, fig. 2; pl. 13, fig. 8.

REMARKS: The distinction between **S. scarburghense** and **S. cf. scarburghense** proposed by Gitmez (1970, pl. 297) is rejected; slight differences in thicknesses of the processes is considered to be too trivial for taxonomic separation.

REPORTED RANGE: Lower Oxfordian - Lower Kimmeridgian.
Organism A. Gitmez

1970 Organism A Gitmez: 321, pl. 11, fig. 9.
1972 Organism A Gitmez; Gitmez & Sarjeant: 249, pl. 16, fig. 1, pl. 17. fig. 3.

REMARKS: Allocation of this form to the Netromorphitae sub-group by Gitmez (1970) is considered to be totally unsatisfactory. Gitmez stated (p. 321) rather contradictorily, that this form is "similar to members of the sub-group Netromorphitae; however, the details of its shape and position of the opening afford differences from all described species".

It is similar to species of Wallodinium Loeblich & Loeblich and species of Palaeostomocystis especially the species P. laevigata Drugg, but lacks an internal sac-like body.

REPORTED RANGE: Lower - Middle Kimmeridgian.

INCERTAE SEDIS

Group ACRITARCHA Evitt 1963

Sub-group ACANTHOMORPHITAE Downie, Evitt & Sarjeant 1963

Undifferentiated Acanthomorph Acritarchs

Plate 19, figs. 1-3, 5-10, 16-17. Plate 20, figs. 1-8, 10.

Plate 22, fig. 10.

REMARKS: This sub-group, as are many other taxonomic units treated in this thesis, is a purely artificial one delimited by arbitrarily defined boundaries. It embraces a complex of small forms with the spheroidal, subspheroidal or ovoidal
central body bearing spines of variable number, size, shape and distribution. The "cyst" opens by splitting along a straight slit pylome, along an s-shaped pylome, along a c-shaped pylome or by equatorial splitting.

The sub-group includes the genera Baltisphaeridium, Micrhystridium and Solisphaeridium. The taxonomic status of these genera is at present chaotic, this is readily illustrated by comparing the original generic diagnosis and subsequent emendations (see Cramer 1970, pp. 91-95). This may be illustrated even further by considering the generic allocation of Micrhystridium deflandrei Valensi. This particular species accords with the emended diagnosis for the genus Micrhystridium as proposed by Sarjeant (1966) and also with the original diagnosis for Solisphaeridium proposed by Staplin, Jansonius & Pocock (1955). It also accords with the original diagnosis for Micrhystridium as defined by Deflandre 1937; yet it differs completely from the emended diagnosis for Micrhystridium and Solisphaeridium presented by Staplin, Jansonius & Pocock (1965) and Sarjeant (1968) respectively.

A considerable number of Upper Jurassic "species" have been attributed in earlier studies to either or both Micrhystridium and Solisphaeridium. Many of the forms have apparently very long geological ranges. This together with their morphological simplicity suggests two things:

1) The taxa were extraordinarily successful during long periods of time and were exceptionally tolerant to major environment changes;

or 2) Genetically different taxa, as a result of so few ways of morphologically expressing their genetic differences, could only give rise to numerous homologous phenotypes.

In addition there is the question of the wide morphological variation
within the "species" themselves. Various authors including Stockmans & Willicre (1960-1963), Wall (1965) and Sarjeant (1970, 1973) have clearly demonstrated this by creating numerous very similar "species", which can only be differentiated from each other by detailed study of such arbitrary characters as small differences in overall size, relative spine length, number of spines. The practical difficulties in distinguishing such taxonomic units are immense, particularly as in the present study when one is dealing with abundant specimens and is accordingly not attempted here. Furthermore their usefulness in the stratigraphic palynology of the Upper Jurassic is considered to be very dubious. Local palaeoecological control is these forms may however be important, this particular significance is discussed elsewhere in this thesis.

**Acritarch sp. indet. Gitmez & Sarjeant 1972.**

Plate 18, fig. 8.

**1972 Acritarch sp. indet. Gitmez & Sarjeant:** 250, pl. 17, figs. 4-5.

**REPORTED RANGE:** Upper Kimmeridgian.

Subgroup **CYMATIOSPHAERA O. Wezel** emend. Deflandre 1954

**Cymatiosphaera** sp.

Plate 20, fig. 9.

**REMARKS:** Infrequent forms assignable to this genus were identified. Allocation of the forms to previously described species was not considered practical.

Subgroup **NETROMORPHITAE** Downie, Evitt & Sarjeant 1963

**Leiofusa jurassica** Cookson & Eisenack 1955

Plate 19, figs. 13-14.

1955 **Leiofusa jurassica** Cookson & Eisenack: 51, pl. 10, figs. 3-4.

**REMARKS:** The specimens recorded here are comparable with the specimens recorded by Wall (1965) from the English Lias, Davey (1970) from the Cenomanian and Sarjeant (1973) from the Triassic of Pakistan.

A considerable amount of morphological overlap is apparent between Palaeozoic and Mesozoic forms attributed to **L. jurassica** and the numerous Silurian species created by Cramer (1970); accordingly a restudy of the genus is called for before "taxonomic chaos" results.

Subgroup **POLYGONOMORPHITE** Downie, Evitt & Sarjeant 1963.

Genus **VERYHACHIUM** Deunff, emend. Downie & Sarjeant 1963

**REMARKS:** **Veryhachium** is very similar in morphology to the **Micrhystridium - Solisphaeridium** complex of acanthomorph acritarchs, differing in possessing a more polygonal central body bearing a low number of broad based spinose processes.

**Veryhachium aster** Sarjeant 1967

Plate 19, fig. 4.

1967 **Veryhachium aster** Sarjeant: 204-205, pl. 1, fig. 11; text-fig. 1A.

**REMARKS:** Sarjeant (1967) distinguished **V. aster** from **Micrhystridium stellatum** on shape and the lack of ready demarcation between central body and
processes. Sarjeant (ibid.) restricted *Micrhystridium stellatum*, and attributed post Palaeozoic forms to *V. aster*.

REPORTED RANGE: Bajocian - Oligocene (including post - Palaeozoic records of *M. stellatum*).

*Veryhachium hyalodermum* (Cookson) Downie & Sarjeant 1963

Plate 19, figs. 18-19.

1956 *Palaeotetradinium hyalodermum* Cookson: 188-189, pl. 1, figs. 12-16.

1963 *Veryhachium hyalodermum* (Cookson); Downie & Sarjeant: 94.

REPORTED RANGE: Middle Jurassic - Lower Tertiary.

Subgroup *PTEROMORPHITAE* Downie, Evitt & Sarjeant 1963

Genus *PTEROSPERMOSPSIS* Deflandre & Cookson 1955

*Pterospermopsis aureolata* Cookson & Eisenack 1958

Plate 19, fig. 12.

1958 *Pterospermopsis aureolata* Cookson & Eisenach: 49, pl. 9, figs. 10-12.

REMARKS: The observed specimens possess the same wing to body dimensions as *P. aureolata* from the Australian Lower - Upper Cretaceous, but differ in being considerably smaller and subcircular rather than circular in polar view, although the latter may be preservational.

*Pterospermopsis australiensis* Deflandre & Cookson 1956

Plate 19, fig. 11.

1956 *Pterospermopsis australiensis* Deflandre & Cookson: 286-288, pl. 3.
REPORTED RANGE: Kimmeridgian - Lower Tertiary.

Pterospermopsis helios Sarjeant 1959

1959b Pterospermopsis helios Sarjeant: 342, pl. 13, fig. 9.


CLASS CHLOROPHYCEA

Family TASMANACEAE Sommer 1956

Genus TASMANITES Newton 1875

Tasmanites sp.

Plate 19, fig. 14.

DESCRIPTION: Subspherical to broadly ovoidal in shape with a very thick wall (4-5). The wall is penetrated by numerous closely spaced, minute punctae and more widely spaced, coarser pore canals (c.0.5 diameter).

DIMENSIONS: 42-55 µ x 43-55 µ (6 specimens measured).

REMARKS: No attempt was made to speciate the specimens recovered owing to the present taxonomic chaos evident in this group of microfossils. All the specimens recovered are, however, very close to each morphologically and appear to represent a single species.
PART 2

Dinoflagellate cysts.

Adnatosphaeridium paucispinum (Klement); Gitmez & Sarjeant 1972.

Ctenidodinium culmulum (Norris 1965) comb. nov.

Dictyopyxis cf. reticulata (Valensi); Gitmez & Sarjeant 1972.

Endoscrinium cf. campanula (Gocht); Gitmez 1970.

Endoscrinium cf. luridum (Deflandre); Vozzhennikova 1967.

Gonyaulacysta cf. giusepeii (Morgenroth); Gitmez & Sarjeant 1972.

Gonyaulacysta systemmatos Gitmez & Sarjeant 1972

Histiophora cf. ornata Klement; Gitmez 1970

?Leptodinium mosaicum (Downie), Sarjeant 1969

Nannoceratopsis pellucida Deflandre 1938

Netrelytron stegastum Sarjeant 1961

Scriniodinium dictyotum subsp. papillatum Gitmez 1970

Scriniodinium dictyotum subsp. pyrum Gitmez 1970

Scriniodinium cf. galeatum Cookson & Eisenack, Gitmez 1970

Scriniodinium playfordi Cookson & Eisenack 1960

Acritarchs

Baltisphaeridium inusitatum Klement 1960

Pterospermopsis harti Sarjeant 1960

Staplinium cistum Gitmez 1970
PART 3

TAXONOMIC NOTES

In the following section the genus GALEATADINUM gen. nov. is proposed to include certain species formerly allocated to the genus GONYAULACYSTA which do not accord with the emended diagnosis of the genus proposed herein. In addition, the affinities of the genera ANTROSPHAERA Sarjeant 1961 and SPHERIPOLLENITES Couper 1958 emend. Jansonius 1962 are discussed.

1. Genus GALEATADINUM gen. nov.

DERIVATION OF NAME: Latin galeatus, wearing a helmet - with reference to the apical pericoel.

DIAGNOSIS: Spheroidal to broadly ovoidal cysts; periphragm and endophragm in contact except at the apex where they separate to form a well-developed apical pericoel bearing an apical horn. Tabulation 4', 1a, 6", 6c, 6", 1p. 1"'. Archaeopyle precingular, formed by loss of plate 3".

TYPE SPECIES: Galeatadinium axicerastes (Sarjeant) comb. nov. = Gonyaulacysta axicerastes Sarjeant 1966, 114, pl. 13, figs. 11-12; text. fig. 25. Middle Barremian, England.

REMARKS: See remarks for the genus GONYAULACYSTA.
OTHER SPECIES

Galeatadinium cassidatum (Eisenack & Cookson) comb. nov. = Gonyaulacysta cassidata (Eisenack & Cookson 1960, 3, pl. 1, figs. 5-6) emend. Sarjeant 1966, 125-126, pl. 14, figs. 3-4; text.-fig. 31 Lower Cretaceous, Australia.

2. Specimens identical to Antrosphaera calloviensis Sarjeant 1961a from the Callovian of Yorkshire were observed sporadically in some of the French assemblages. The observed specimens are, without any doubt, products of Recent angiosperm contamination probably by some member of the Chelopodiaceae. Accordingly, the taxonomic validity of the genus Antrosphaera is open to considerable doubt. Sarjeant (1974 pers. comm.) is proposing to re-study his material in the near future to clarify this.


Spheripollenites occurs in many of the samples examined during the course of this study, and in the writer's opinion, even though its affinities are somewhat doubtful (Batten 1974 pers. comm.), it is more probably a miospore. Norris (1969) included the genus within the Coniferales (Coniferopyta). Spheripollenites occurs in both marine and non-marine sediments; it is particularly abundant in parts of the Wealden (Batten op. cit.) where there is absolutely no evidence for marine conditions, accordingly allocation to the miospores rather than acritarchs is considered to be highly preferable.
FIG. 23

A. **Gonyaulacysta angulosa** Gitmez

Diagrammatic representation illustrating the tabulation. The overall morphology of this form places it very close to **Gonyaulacysta granuligera** (Klement).

Left, Ventral view; right dorsal view. X c. 1280.

B. **Gonyaulacysta sp. A**

From its tabulation this form appears to represent a new species. Note the possession of sparsely distributed surface spines which places this species morphologically intermediate between **Gonyaulacysta** and **Acanthaulax**.

Left, ventral view, right dorsal view. X c.1280.
FIG. 24.

Gonyaulacysta attenuaris sp. nov.

Diagrammatic representation of the holotype showing the tabulation and reduced apical form.

Left, ventral view; right, dorsal view. X c. 770.
FIG. 25.

_Gonyaulacysta cristata_ sp. nov.

Diagrammatic representation illustrating the general morphology, tabulation and archaeopyle formation, plate 3" is missing. On the posterior part of the sulcus some small plates are suggested, but their presence could not be confirmed; they may constitute a subdivided posterior ventral plate. Note the high delicate sutural crests. Left, ventral view; right dorsal view. X c. 1024.
FIG. 26.

A. Gonyaulacysta sp. H. Gitmez & Sarjeant
Tabulation and mode of archaeopyle formation, plate 3″ is missing
Note the pronounced laevorotatory cingulum, and the presence of
only 5 postcingular plates. Left, ventral view; right dorsal view
X c. 640.

B. Gonyaulacysta deflandrei sp. nov.
Diagrammatic representation illustrating the tabulation, mode of
archaeopyle formation, plate 3″ is missing, and the long tapering
apical horn. Left, ventral view; right dorsal view. X c. 983.
A. *Ectenodinium egemenii* (Gitmez) comb. nov.

Diagrammatic representation of the holotype illustrating the tabulation, made of archaeopyle formation (plate 3" is missing) and the pronounced antapical pericoel. Left ventral view; right, dorsal view.

BM (NH) slide V. 52794 (1) X·c. 1280.

B. *Leptodinium subtile* Klement

Diagrammatic representation of the tabulation, described and illustrated by Gitmez (1970), for specimens attributed by her to *L. cf. subtile*. The specimens correspond in general structure, form of crests and dimensions to Klements type material, differing only in the detail of the apical plates and the presence of plate 1a. Left ventral view; right, dorsal view. X·c. 1280.
FIG. 28.

A. *Leptodinium crassinervum* (Deflandre) emend.

Diagrammatic representation of the ventral tabulation of the holotype. Obscuring debris makes determination of the apical tabulation impossible.

B. *Leptodinium callere* sp. nov.

Diagrammatic representation of the holotype illustrating the tabulation, the large archaeopyle formed by the loss of plate 3" and the long conical epitact.

Left, ventral view, right, dorsal view.

BM (NH) slide V. 56346 (1). X c. 960.
FIG. 29.

A. **Leptodinium danutae** sp. nov.

Diagrammatic representation of the holotype.
Tabulation and archaeopyle formation, plate 3" is missing:
Left, oblique ventral view; right, oblique dorsal view.
B. M. (NH) slide V. 56352. X c. 1620.

B. **Leptodinium aceras** (Eisenack)

Diagrammatic representation illustrating the tabulation as described by Gitmez & Sarjeant (1972). Left, ventral view; right dorsal view. X c. 1041.
FIG. 30

A. Occisucysta balios Gitmez

Tabulation and mode of archaeopyle formation; plates 2" and 3" are missing.

Left, ventral view; right, dorsal view. Xc. 1280.

B. Occisucysta aculeata (Klement) comb. nov. Diagrammatic representation illustrating the tabulation, characteristic sutural ornementation and mode of archaeopyle formation; plates 2' and 3' are missing. Left, ventral view; right, dorsal view. Xc 820.
FIG. 31.

Diagrammatic representations illustrating the morphological differences between:

(A) *Imbatodinium longifilum* sp. nov. and

(B) *Imbatodinium antennatum* Gitmez
FIG. 32.

Diagrammatic representations illustrating the structural differences between (A) *Muderongia simplex alberti* and (B) *Muderongia sp. A* (= *Muderogonia simplex* of Gitmez & Sarjeant (1972).)

Note the presence of a longer apical horn and the notches in the lateral horns of *M. simplex*. 
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POST SCRIPT

Recent work by Cope (1974) confirms the view of the writer that the two samples analysed from Marton in Yorkshire are of Upper Kimmeridgian (pectinatus zone) age.
All figured material is held in the author's personal collection; upon validation of the types they will be lodged in the collections of the Institute of Geological Sciences, Leeds. A representative set of slides of the Portuguese material is at present lodged with the above institution.
PLATE 9

FIGS. 1, 2. Concinndinum wilsoni gen. et sp. nov. The holotype illustrating incepient archaeopyle formation with the operculum (apical plates) remaining attached. Reflected tabulation is faintly indicated by very low ridges. Xc. 830.

FIG. 3. Paranetraeytron sp. A typical specimen possessing a small, blunt apical horn, a spherical inner body and the characteristic envelope of finely divided organic debris. Xc. 830.

FIG. 4. Wallodinium sp. A specimen possessing an apical archaeopyle, illustrating the elongate-ovoidal inner body and its broad median zone of contact with the outer membrane. Xc. 830.

FIG. 5. Tubotuberella apatela (Cookson & Eisenack) comb. nov. subsp. rotunda subsp. nov. Dorsal view of the holotype illustrating the rounded apex to the inner-body. A precingular archaeopyle formed by the loss of plate 3" is present, the operculum is detached and has fallen into the central cavity Xc. 830.

FIG. 6. Tubotuberella sphaerocephalus sp. nov. Dorsal view illustrating a pre-cingular archaeopyle and the characteristic denticulations developed on the outer membrane. Xc. 560.

FIG. 7. Tubotuberella teriostia sp. nov. Dorsal view of the holotype with a pre-cingular archaeopyle formed by the loss of plate 3". Note the characteristic circular, smooth edged aperture at the posterior of the cyst. Xc. 830.

FIG. 8. Dingodinium tuberosus (Gitmez) comb. nov. Specimen illustrating an apical archaeopyle formed by the loss of four apical plates. Tabulation is weakly indicated by faint lines on the outer membrane. Xc. 1300.


FIGS. 10, 11. Muderongia simplex Alberti.
10. Folded specimen illustrating incepient apical archaeopyle formation Xc. 660.
11. Specimen illustrating well developed lateral horns with the characteristic distal notches Xc. 660.

FIG. 12. Ascodinium sp. A poorly preserved specimen illustrating an apical archaeopyle formed by the loss of the entire apical region along an irregular line of breakage. The poor preservation is typical of this form. Xc. 830.

FIG. 13. Barbaraea jurassica (Gitmez & Sarjeant) comb. nov. Specimen illustrating an apical archaeopyle with the operculum remaining attached. The ornamentation developed on the cyst is a combination of occasional tubercles and pyrite grain pressure marks. Xc. 660.

FIG. 14. Dingodinium sp. Xc. 1300.
PLATE 10

FIG. 1. *Imbatodinium villosum* Vozzhennikova. Lateral view illustrating the well-developed, slender processes and the distinctive apical structure.
Slide Phase contrast. Xc.1300.

FIG. 2. *Hexagonidium asperatum* sp. nov. Dorsal view of the holotype illustrating the hexagonal intercalary archaeopyle and the granular - coarsely tuberculate ornamentation.
Slide Phase contrast Xc. 1300.

FIGS. 3, 6, 8-9. *Pareodinia ceratophora* Deflandre. Specimens illustrating the morphological variation exhibited by this species.
3. A broadly ovoidal specimen with a strong, blunt apical horn and incepient archaeopyle formation. Xc. 1300.
6. A specimen again exhibiting incepient archaeopyle formation, but in this example the apical horn is much reduced. Xc. 830.
8. In this example a broad-based tapering apical horn is developed. This form is close to the type material, but the surface granulation is not as pronounced. Xc. 830.

FIG. 4. *Imbatodinium longifillum* sp. nov. The holotype Xc. 830.

FIG. 5. *Cyclonephelium* cf. *vannophorum* Davey        Xc. 830.

FIG. 7. *Kalyptea* sp. Similar to *Pareodinia ceratophora*, but thinner walled, with a very reduced apical horn. Xc. 830.

FIG. 10. *Imbatodinium antennatum* Gitmez. Dorsal view illustrating the distinctive apical structure and an archaeopyle formed by the loss of two intercalary plates. Xc. 830.

FIG. 11. Genus & Species Indet. A. Specimen illustrating the cingulum and weakly defined tabulation. The archaeopyle is formed by the loss of the apical region; Indentations along the archaeopyle margin reflect the precingular tabulation. Xc. 1300.
FIGS. 12-14. *Imbatodinium mutabilis* sp. nov.

12, 14. Dorsal views of the holotype (fig. 14 phase contrast) illustrating the distinctive surface processes and an archaeopyle formed by the loss of two intercalary plates. Xc. 830.

13. Ventral view of a specimen with a shorter apical horn and thread and reduced surface ornamentation. Xc. 830.
FIG. 1  Hystrichodinium pulchrum Deflandre. Dorsal view illustrating the precingular archaeopyle with the operculum (plate 3") remaining in place  Xc. 800.

FIG. 2.  Hystrichodinium voigti (Alberti) comb. nov. Specimen illustrating the long, flexous ribbon like processes and the more easily recognisable tabulation which differentiates this species from H. pulchrum.  Xc. 1200

FIG. 3.  Hystrichosphaeridium sp. B. An oblique view of a distorted specimen illustrating the numerous, short, slender distally flared processes.  Xc. 512.

FIG. 4.  Spiniferites ramosus var. indet. A somewhat damaged specimen illustrating the distinctive sutural processes and the archaeopyle formed by the loss of a single precingular plate (plate 3").  Xc. 1200.

FIGS. 5, 7.  Scriniodinium inritibilum sp. nov.
5. Dorsal view illustrating the distinctive thin outer membrane, the short apical horn formed by the periphragm and the precingular archaeopyle formed by loss of plate 3".  Xc. 800.

7. Dorsal view illustrating the precingular archaeopyle and feebly indicated tabulation.  Xc. 800.

FIG. 6.  Hystrichodinium sp. Dorsal view illustrating the precingular archaeopyle.  Xc. 512.

FIG. 8.  Hystrichodinium telaspinosum sp. nov. Dorsal view of the holotype illustrating the precingular archaeopyle formed by the loss of plate 3". The thin web-like connections between the processes are evident in the apical region.  Xc. 800.

FIG. 9.  Heslertonia pellucida Gitmez. Oblique dorsal view illustrating the pre-cingular archaeopyle (top right) formed by the loss of plate 3".  Xc. 1200.

FIG. 10.  Scriniodinium attadelense (Cookson & Eisenack) Eisenack. Dorsal view.  Xc. 800.
PLATE 12

FIGS. 1, 4, 11. *Fromea amphora* Cookson & Eisenack. Specimens illustrating the characteristic apical archaeopyle with a rounded margin.

1. Specimen lacking all indications of a cingulum. Xc. 1200.

4. Specimen possessing a faint cingular trace. The circular ornamentation present on the cyst is due to compaction amongst pyrite grains. Xc. 1200.

11. A smooth walled variety lacking all indications of a cingulum. Xc. 1200.

FIG. 2. *Chytroeisphaeridia mantelli* Gitmez & Sarjeant. Lateral view illustrating the apical archaeopyle with slits extending posteriorly along presumed reflected sutures. The coarsely granular surface ornamentation is clearly displayed. Xc. 1200.

FIG. 3, 8. *Carpodinium* sp. Specimens illustrating the distinctive shape of the cyst and its characteristic sutural crests and apical horn.

3. Xc. 480.

4. Xc. 1200.

FIG. 5. *Meiourogonyaulax pila* Gitmez & Sarjeant. Dorsal view illustrating the apical archaeopyle with the operculum remaining attached. The tabulation and cingulum are faintly indicated by very low ridges. Xc. 480.

FIGS. 6, 10. *Egmontodinium polyplacophorum* Gitmez & Sarjeant. Specimens illustrating the characteristic, complex tabulation.


FIG. 7. *Cyclonephelium distinctum* Deflandre & Cookson. Lateral view illustrating the large apical archaeopyle and the sutural notches along its margin. The surface processes are short (C.2), the specimen is accordingly attributable to the variety *C. distinctum* var. *brevispinatum* Millioud. Xc. 600.
**FIG. 9.** Canningia sp. Specimen illustrating incepient archaeopyle formation; a line of breakage being evident between the apical and precingular plate. Xc. 600.

**FIG. 12.** Epiplosphaera reticulospinosa Klement. Specimen illustrating an apical archaeopyle (top right) and the characteristic small-meshed surface reticulation. The processes arise at the points of junction of the reticulation. Xc. 480.
FIGS. 1-2. Sirmiodinium grossi Alberti. In these two specimens an archaeopyle is present formed by the loss of the apical plates. Note the characteristic lateral cingular indentations and the posterior opening in the outer membrane. Tabulation is indicated by rather weak lines on the outer membrane. Xc. 800.

FIG. 3. Scriniodinium inritibilum sp nov. Dorsal view of the holotype illustrating the precingular archaeopyle formed by the loss of plate 3", the thin outer membrane and its apical extension forming a small blunt horn. A narrow cingular is present and faint lines on the outer membrane reflect the tabulation. Xc. 600.

FIG. 4. Dingodinium alberti Sarjeant. Specimen illustrating the strong, broad-based apical horn formed from the outer membrane. Xc. 1230.

FIGS. 5, 9, 11-12. Membraniaulax harryi gen. et sp. nov
9. Dorsal view illustrating the precingular archaeopyle.
11. Ventral view of the holotype illustrating the distinctive antapical fins.

FIG. 8. Dingodinium tuberosus (Gitmez) comb. nov. Entire specimen illustrating the surface ornamentation and the hollow apical horn with a hole at its apex. An equatorial cingulum is evident and tabulation is weakly indicated by lines on the outer membrane. Xc. 1230.

FIG. 10. Membraniaulax sp. View illustrating the dorsal tabulation and the reduced and bluntly rounded antapical processes. Xc. 800.

FIGS. 6 - 7. Chlamydophorella nyei Cookson & Eisenack
6. Possible incepient apical archaeopyle formation is evident by the irregular breakage seen to the north. Xc. 960.

7. The processes are shorter and much more slender than those of the type material and as such this form appears to intermediate to some extent between C. nyei and C. discreta Clarke & Verdier. Xc. 960.
PLATE 14.

FIG. 1. **Leptodinium** sp. Ventral view illustrating the high denticulate/spinose sutural crests. Xc. 730.

FIG. 2. **Leptodinium danutae** sp. nov. Dorsal view (inverted orientation) showing the precingular archaeopyle formed by the loss of plate 3". Xc. 1150.

FIG. 3. **Leptodinium arcuatum** Klement. Dorsal view illustrating a precingular archaeopyle with plate 3" missing. Xc. 730.

FIG. 4. **Lantera bulgarica** Dodekova. Dorsal view illustrating an apical archaeopyle with sutural notches along its margin. Plate boundaries and the cingulum are indicated by an absence of the surface ornamentation. Xc. 730.

FIG. 5. **Gonyaulacysta helicoidea** (Cookson & Eisenack) Sarjeant emend. Xc. 1150.


FIG. 7. **Coalitapoma unica** gen. et sp. nov. Dorsal view of the holotype. The cingulum and tabulation are weakly indicated by low ridges. Inceipient combination archaeopyle formed by the loss of the apical plates and one precingular plate (3") is indicated by a line of breakage. Xc. 730.

FIGS. 8-9, 13. **Leptodinium callere** sp. nov. Note the large precingular archaeopyle formed by the loss of plate 3".

8. Xc. 585.
9. Xc. 1150.
13. Xc. 585.

FIG. 10. **Ctenidodinium panneum** (Norris) Lentin & Williams. Oblique view illustrating the complex tabulation and distinctive sutural ornamentation. Xc. 480.
FIG. 11. *Xenicodinium* sp. Dorsal view illustrating the large precingular archaeopyle and faintly indicated cingulum. Xc. 730.

Gonyaulacysta globata Gitmez & Sarjeant.
1. Dorsal view Xc. 790.
2. Lateral view. Inception archaeopyle formation indicated by a line of breakage around plate 3". Xc. 540.

Gonyaulacysta attenuaris sp. nov. Xc. 790.

Gonyaulacysta ehrenbergii Gitmez. Specimen illustrating the large precingular archaeopyle formed by loss of plate 3" and the somewhat reduced apical horn. Xc. 790.

Gonyaulacysta deflandrei sp. nov. Ventral view of the holotype illustrating the structure of the apical horn and the distinctive sutural ornamentation. Xc. 500.

? Meiourogonyaulax sp. B. Specimen illustrating the dorsal tabulation. Inception archaeopyle formation is indicated by a line of breakage posterior to the apical plates. Xc. 540.

Meiourogonyaulax pila Gitmez & Sarjeant, Dorsal views illustrating apical archaeopyle formation with the operculum remaining attached.

7. Specimen bearing pyrite-grain pressure marks. Xc. 790.

Meiourogonyaulax sp. Gitmez & Sarjeant. Dorsal view illustrating the weakly defined cingulum and an apical archaeopyle with attached operculum. Xc. 630.

Meiourogonyaulacysta staffinensis Gitmez. Dorsal view illustrating an apical archaeopyle with detached operculum and the moderately high sutural crests. The circular areas on the cyst are pyrite grain pressure marks. Xc. 790.

Gonyaulacysta sp. B. Specimen illustrating the typical preservation of this form. Note the thick cyst wall, the coarse surface granulation and the strong apical horn. Xc. 500.

FIG. 12. ? *Meiourogonyaulax pannosa* sp. nov. Dorsal view of the holotype. The precingular tabulation is indicated by deep slits which extend posteriorly from the archaeopyle margin along reflected sutures. A cingulum is very faintly indicated. Xc. 500.
PLATE 16.

FIG. 1. Leptodinium amabilis (Deflandre) Sarjeant. Dorsal view illustrating a precingular archaeopyle. Xc. 1150.


FIG. 4. Cryptarchaeodinium calcaratum Deflandre. Dorsal view illustrating a precingular archaeopyle formed by loss of plate 3". Xc. 1150.

FIG. 5. Leptodinium amabilis (Deflandre) Sarjeant. Dorsal view illustrating a precingular archaeopyle formed by loss of plate 3". Note the small, blunt apical horn formed by the periphragm only. Xc. 1150.

FIG. 6. Apteodinium maculatum Eisenack & Cookson. Dorsal view illustrating a precingular archaeopyle formed by loss of plate 3". This corresponds with the "hoof-shaped pylome" described in the original diagnosis. Xc. 700.

FIG. 7. Gonyaulacysta pennata sp. nov. Ventral view of the holotype. Note the narrow cingulum, the long, narrow sulcus and the characteristic form of the apical horn. The "feathery-extension" of the latter being formed from the periphragm. Xc. 580.

FIG. 8. Gonyaulacysta cristata sp. nov. Dorsal view of the holotype illustrating a precingular archaeopyle formed by loss of plate 3". Note the characteristic sutural ornamentation in the form of high, delicate, irregularly perforate crests with smooth distal edges. Xc. 560.
PLATE 16.


FIG. 4. *Cryptarchaeodinium calcaratum* Deflandre. Dorsal view illustrating a precingular archaeopyle formed by loss of plate 3". Xc. 1150.

FIG. 5. *Leptodinium amabilis* (Deflandre) Sarjeant. Dorsal view illustrating a precingular archaeopyle formed by loss of plate 3". Note the small, blunt apical horn formed by the periphragm only. Xc. 1150.

FIG. 6. *Apteodinium maculatum* Eisenack & Cookson. Dorsal view illustrating a precingular archaeopyle formed by loss of plate 3". This corresponds with the "hoof-shaped pylome" described in the original diagnosis. Xc. 700.

FIG. 7. *Gonyaulacysta pennata* sp. nov. Ventral view of the holotype. Note the narrow cingulum, the long, narrow sulcus and the characteristic form of the apical horn. The "feathery-extension" of the latter being formed from the periphragm. Xc. 580.

FIG. 8. *Gonyaulacysta cristata* sp. nov. Dorsal view of the holotype illustrating a precingular archaeopyle formed by loss of plate 3". Note the characteristic sutural ornamentation in the form of high, delicate, irregularly perforate crests with smooth distal edges. Xc. 560.
Gonyaulacysta nuciformis (Deflandre) Sarjeant.
Two specimens taken at the same magnification to illustrate size variation within this species. Note the small, spinose form of the apical horn, the coarse surface granulation and the characteristic spinose sutural ornamentation. In Fig. 9, the precingular archaeopyle formation is indicated by a line of breakage around plate 3. Xc. 600.

Gonyaulacysta perforans (Cookson & Eisenack) Sarjeant.
Ventral view. Compare with Gonyaulacysta pennata from which it differs in the form and structure of its apical horn and sutural crests. Xc. 720.

Gonyaulacysta fuscina sp. nov. Lateral view of the holotype. Note the large precingular archaeopyle formed by loss of plate 3, and the characteristic distal termination of the apical horn. Xc. 580.


Apteodinium granulatum Eisenack. Xc. 700.

Gonyaulacysta sp. indet. A thick-walled densely granular specimen of Gonyaulacysta. Indeterminate forms such as these occur frequently in the English and French Upper Jurassic assemblages. The illustrated specimen probably represents a new species. Xc. 460.
PLATE 17.

FIG. 1. Cleistosphaeridium spinosum sp. nov. The holotype illustrating the characteristic "thorn-like" processes. The preservation is typical for these forms recovered from the bituminous sediments. Xc. 480.

FIGS. 2-3. Tanyosphaeridium cf. variecalamum Davey & Williams
2. Xc. 1200.
3. Xc. 1200.

FIGS. 4-5, 7. Cleistosphaeridium sp. Illustrating variation in process density and size.
4. Xc. 1200.
5. Xc. 1200.
7. Xc. 1200.

FIGS. 6, 11. Systematophora orbifera Klement.

8. Apical archaeopyle, operculum remaining attached Xc. 580.


FIG. 13. Adnatosphaeridium sp. Poorly preserved specimen illustrating the loose net-work of processes and the shorter branches bearing spines arising from near the points of branching. Xc. 460.

The preservation of the specimens illustrated in figs. 12 and 13 is typical for those forms recovered from high-energy sediments.
PLATE 18.

FIG. 1. *Hystrichosphaeridium* sp. A. Lateral view illustrating the short tubular processes that open distally with a serrate-spinose margin. Xc. 1600.

FIGS. 2, 3, 5. *Oligosphaeridium pulcherrimum* (Deflandre & Cookson) Davey & Williams.

2. Close-up view illustrating the complex fenestrate, distal terminations of the processes. Xc. 1600.

3. Xc. 800.

5. Specimen illustrating the archaeopyle formed by the loss of four apical plates. The remaining processes clearly indicate a reflected tabulation of 4', 6'', 1p, 1pv. Xc. 800.

FIG. 4. *Fibraeosphaeridium insignitum* gen. et sp. nov. Lateral view of the holotype illustrating the distinctive fibrous processes and a pre-cingular archaeopyle formed by loss of plate 3''.

FIG. 6. *Oligosphaeridium anthophorum* (Cookson & Eisenack) Eisenack & Kjellström. Specimen exhibiting an apical archaeopyle formed by the loss of four apical plates. Xc. 800.

FIG. 7. *Cleistosphaeridium tribuliferum* (Sarjeant) Davey et al.

A specimen, partly obscured by bituminous sapropel, illustrating the distinctive process terminations. An apical archaeopyle is just visible to the north. Xc. 800.

PLATE 19.

FIGS. 1-3, 5-10, Acanthomorph acritarchs. Specimens illustrating the range of morphological variation exhibited by this group of microfossils. Xc. 1600.

FIG. 4. **Veryhachium aster** Sarjeant Xc. 1600.

FIG. 11. **Pterospermopsis australiensis** Deflandre & Cookson. Xc. 1000

FIG. 12. **Pterospermopsis aureolata** Cookson & Eisenack. Xc. 1600.

FIGS. 13-14. **Leiofusa jurassica** Cookson & Eisenack. Xc. 1600.

FIG. 14. **Tasmanites** sp. Note the thick wall and the coarse pore canals. Xc. 1600.


20. **Inaperturopollenites turbatus** Balme. Xc. 1600.

21. **Classopollis** sp. Xc. 1600.
FIGS. 1-8, 10. Acanthomorph acritarchs. Specimens illustrating the range of morphological variation exhibited by this group of microfossils. Xc. 1600.

FIG. 9. *Cymatosphaera* sp. Xc. 1600.

PLATE 21.

FIG. 1. Schizaeaceae spore. Xc. 850.

FIG. 2. Deltoidospora sp. Xc. 850.

FIG. 3. Alisporites sp. Xc. 850.

FIGS. 4-6. Classopollis sp. Xc. 850.

FIGS. 7-8, 10-11. Exesipollenites scabrosus Norris Xc. 850.

FIG. 9. ? Classopollis sp. Xc. 850.
FIGS. 1, 3. Araucariacites sp. Xc. 850.

FIG. 2. Araucariacites australis Couper Xc. 850.

FIGS. 4-5. Duplexisporites problematicus (Couper) Playford & Dettman. Xc. 850.

FIG. 6. Converrucosisporites varierrucaus (Couper) Norris Xc. 850.

FIG. 7. Cicatricosisporites australiensis (Cookson) Patonie Xc. 850.

FIG. 8. Pityosporites microaletus Couper. Xc. 850.


FIG. 10. Acanthomorph acritarch indet. Xc. 1200.

FIG. 11. Microforaminifera Xc. 850.

FIG. 12. ? Fragment of insect/arthropod carapace (chitin) Xc. 850.

APPENDIX

Stratigraphic position and location of the samples analysed from the Sandringham Sands. (Figs. 7, 8).

All of the samples examined are scrapings taken from the adhering matrix of ammonites collected by Dr. R. Casey from the Sandringham Sands and lodged in the collections of the Institute of Geological Sciences, London. The prefixes refer to the registered numbers of the fossils.

The stratigraphical and georeaphical details are as given by Dr. Casey to the writer and use his preferred Boreal stage nomenclature.

CE4974. Sample S7. Unnamed horizon at the top of the Ryazanian. Road cutting at Pylon site near Church Farm, Bawsey. Kings-Lynn By-pass, Norfolk. TF6997. 2080.


Sample S2. Sample taken from washings. Locality and horizon as sample S1.

CE5778. Sample S1. Paracrasispedites horizon. Top of Middle Volgian. No. 4 Feeder, North Sea Gas pipe-line trench, crossing the A45 near Kings Lynn Norfolk TF645. 169.
ERRATA

1. Column 21, enclosure 1(b), should read Meiourogonyaulax sp.

2. Column 37, enclosure 1(b), should read Leptodinium danutae.

3. Column 51, enclosure 1(b), should read Gonyaulacysta attenuaris.

4. Column 54, enclosure 1(b), should read Gonyaulacysta globata.

5. Column 60, enclosure 1(b), should read Leptodinium arcuatum.

6. Column 5, enclosure 1(c), should read Chytroeisphaeridia chytroeides.

7. Column 24, enclosure 1(c), should read Chytroeisphaeridia mantelli.

8. Foot note on enclosures 1a - c, should read, Occurrences reported in literature.