

# Lower Cretaceous dinoflagellate biostratigraphy in the Danish Central Trough

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# Lower Cretaceous dinoflagellate biostratigraphy in the Danish Central Trough

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CLAUS HEILMANN-CLAUSEN

with a contribution on the *gottschei* ammonite Zone  
(Hauterivian) in the Adda-2 well by Tove Birkelund

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EFP-83 project:  
Jurassic-Lower Cretaceous stratigraphy  
and basin development of the Danish North  
Sea sector

*Key words:*

Dinoflagellates, Lower Cretaceous,  
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East-west section through the Tail End Graben

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# Preface

The present paper is one of several reports issued as the result of a research project carried out by the Geological Survey of Denmark in cooperation with the Geological Institute at the University of Copenhagen. The project has been financed by special contributions from the Ministry of Energy for the period from August 1st 1983 to December 31st 1986.

The project was entitled "Jurassic – Lower Cretaceous stratigraphy and basin development of the Danish North Sea sector". It has been decided to limit the study area to the Danish Central Trough, and effort has been concentrated on the Middle Jurassic, Upper Jurassic, and Lower Cretaceous.

The scope of the project was to coordinate analyses of the stratigraphy, facies development and burial history in order to create a basis for predicting possible occurrences of reservoir rocks. The following reports have been printed in 1986.

Frandsen, N.: Middle Jurassic deltaic and coastal deposits in the Lulu-1 well of the Danish Central Trough. Danm. geol. Unders., Ser. A, 9.

Hoelstad, T.: Palynology of the Middle Jurassic Lower Graben Sand Formation of the U-1 well, Danish Central Trough. Danm. geol. Unders., Ser. A, 14.

Hoelstad, T.: Palynology and palynofacies analyses of the Middle Jurassic to Lower Cretaceous in the Danish Central Trough. Danm. geol. Unders., Internal report.

Jensen, T.F., Holm, L., Frandsen, N. & Michelsen, O.: Jurassic – Lower Cretaceous lithostratigraphic nomenclature for the Danish Central Trough. Danm. geol. Unders., Ser. A, 12.

Møller, J.J.: Seismic structural mapping of the Middle and Upper Jurassic in the Danish Central Trough. Danm. geol. Unders., Ser. A, 13.

Vejbæk, O.V.: Seismic stratigraphy of the Lower Cretaceous in the Danish Central Trough. Danm. geol. Unders., Ser. A, 11.

The following reports (including the present one) will be issued in 1987:

Heilmann-Clausen, C.: Lower Cretaceous dinoflagellate biostratigraphy in the Danish Central Trough.  
Michelsen, O., Frandsen, N., Holm, L., Jensen, T.F., Møller, J.J. & Vejbæk, O.V.: Jurassic - Lower Cretaceous of the Danish Central Trough; - depositional environments, tectonism, and reservoirs.

Poulsen, N.: Callovian (Jurassic) to Ryazanian (Cretaceous) dinoflagellate biostratigraphy of the Danish Central Trough.

Thomsen, E.: Lower Cretaceous calcareous nannofossil biostratigraphy in the Danish Central Trough.

DGU, 30th November 1986

*Olaf Michelsen*

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# Abstract

This study deals with Lower Cretaceous biostratigraphy based on dinoflagellates in the Central Trough (Danish North Sea sector). The stratigraphical distribution in Northwestern Europe of the species used in the analysis is evaluated on the basis of the literature, and a dinoflagellate range chart for the Lower Cretaceous of Northwestern Europe is presented.

Two wells, Adda-1 and I-1, containing a complete marine Lower Cretaceous sequence, are biostratigraphically analysed, primarily on the basis of ditch cutting samples. All six Lower Cretaceous stages are identified and their probable positions in the wells are indicated. Additional sections which cover minor parts

of the Lower Cretaceous are analysed in the wells M-8, V-1, E-1 and Adda-2 (mainly based on cores and side-wall cores).

The ammonite *Simbirskites* (*Craspedodiscus*) cf. *gottschei*, indicating the Hauterivian *gottschei* Zone, is described from the Adda-2 well.

The lithostratigraphical and seismic stratigraphical units of the Central Trough are dated within the framework of dinoflagellate and ammonite stratigraphy.

The dinoflagellate species are systematically documented in photographic plates with remarks concerning their identification where necessary.

# Introduction

This contribution to the project: "Jurassic – Lower Cretaceous stratigraphy and basin development of the Danish North Sea sector" deals with the biostrati-

graphy, based on dinoflagellates, of the Lower Cretaceous in the Danish part of the North Sea Central Trough (figs. 1, 2).

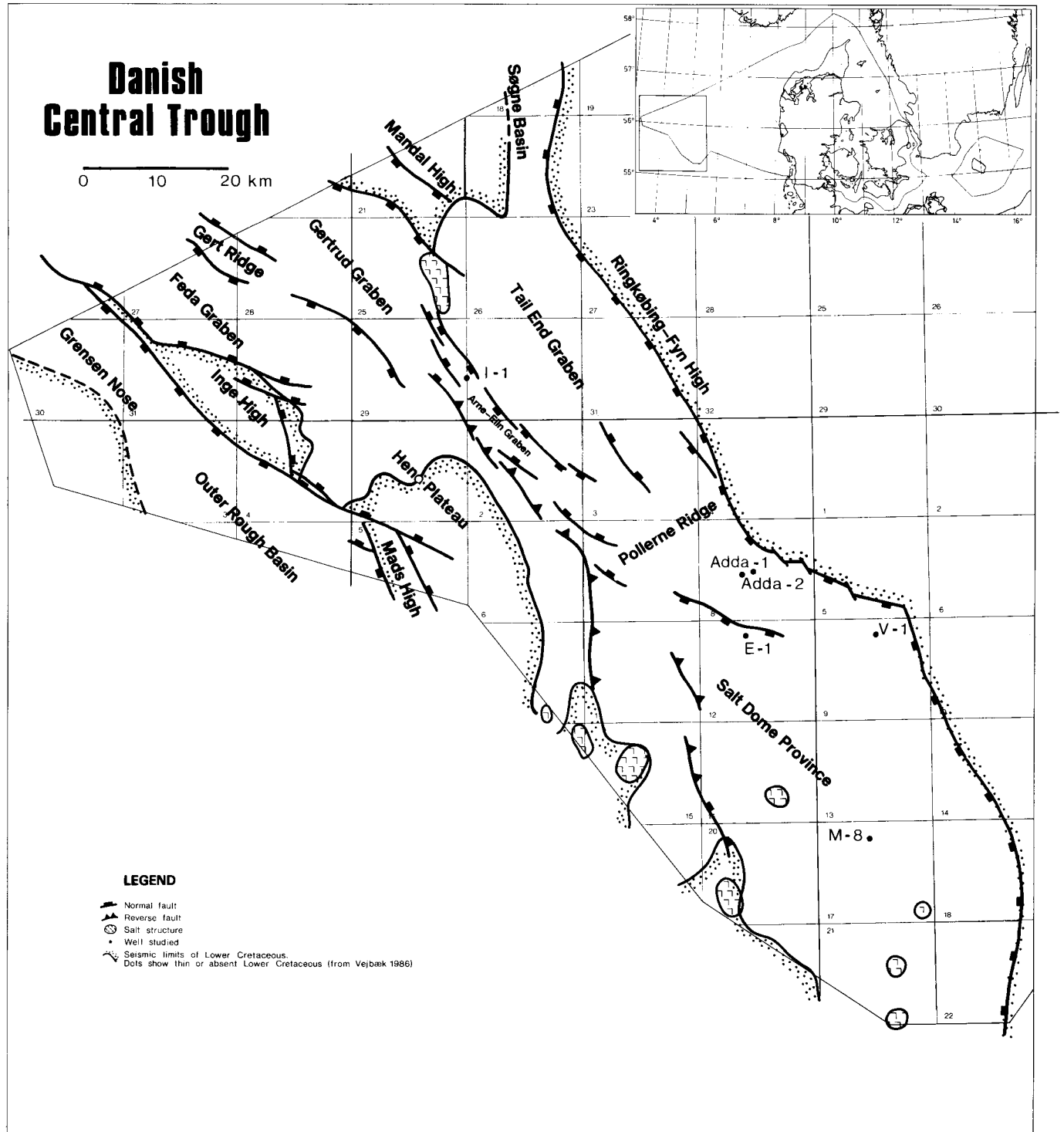


Fig. 1. Structural map of the Danish Central Trough showing location of the studied wells.

Since the mid 1960s and especially in the last decade, it has become clear that dinoflagellates in the Lower Cretaceous deposits of Northwestern Europe are very useful age indicators. Dinoflagellates have proven useful for correlation and age-determination in the North Sea oil-exploration, and here they are probably the most widely used biostratigraphical tool in the marine Lower Cretaceous and Upper Jurassic.

The present contribution consists of three main parts.

The first part is an account of the stratigraphical occurrence of dinoflagellate species in Northwestern Europe. A distribution chart is included in this part (fig. 4) and it forms a standard reference for age-determinations of the Central Trough material.

In the second part an analysis of the dinoflagellate content of the Adda-1 and I-1 wells is carried out and an age determination is presented. These two wells were selected because they are considered to contain the most complete Lower Cretaceous sections and because of their typical development of the various lithological units. Dinoflagellate analyses of shorter sections from other wells are also presented. The facies distribution in the Central Trough is assessed in time and space on the basis of the biostratigraphy.

The third part documents the dinoflagellate assemblages, and most of the species found are figured in plates. Systematic remarks are given to some previously described species, as well as short descriptions of informally established forms.

Dinoflagellates are present in most of the lithological units of the Lower Cretaceous in the Central Trough, but the chalk and marl units in the upper part of the Lower Cretaceous sometimes proved to be barren of organic-walled microfossils. A biostratigraphical study of the calcareous nannoplankton was therefore carried out as part of this project (Thomsen in press).

Ammonites from a core of the Adda-2 well were

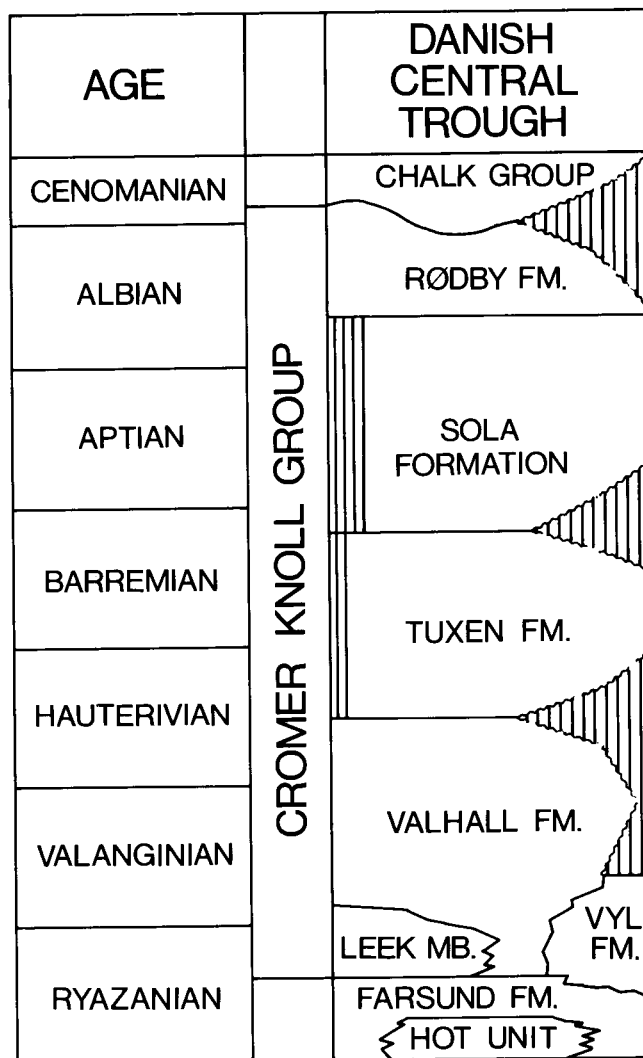


Fig. 2. Lithostratigraphical subdivision of the Lower Cretaceous deposits in the Danish Central Trough.

studied by the late Tove Birkelund and is included in the present volume.



# Materials and methods

## *Materials*

Almost all of the North Sea samples used in this study are ditch cutting samples from North Sea exploration wells. Only a few short cored sections, and a small number of side-wall cores were available. Detailed information of sampled wells, depth and type of samples is given in the distribution charts. Depths of core samples are driller's depths. The locations of the wells examined are shown in Fig. 1.

Ditch cuttings for palynology were taken from the complete Lower Cretaceous intervals in the Adda-1 and I-1 wells. The sample spacing is variable so as to detect and localize as many biostratigraphical boundaries as possible. Samples are more closely spaced in the relatively condensed Barremian-Albian sequence than in the Ryazanian-Hauterivian interval.

Cores were palynologically sampled from the I-1, Adda-2 and E-1 wells. Side-wall cores were sampled from the Adda-1, M-8 and V-1 wells. A few cutting samples from the E-1 and V-1 wells were also analysed.

In addition to the North Sea material, sixteen outcrop samples were collected from the Lower Cretaceous Speeton Clay in Eastern England. The precise stratigraphical location of the samples is described in the following section, p. 18.

## Depository of material

The palynological preparations are housed at the Geological Survey of Denmark where they are accessible for examination. Information on slide location of the figured dinoflagellates is available from the Geological Survey of Denmark or from the author.

## *Preparation*

The samples were processed following a method developed by Hansen and Gudmundsson at the Danish Geological Survey. The method is described in detail by Gudmundsson (1985) and is briefly outlined here:

Acid treatment takes place in a container in which a number (usually 50–100) of samples are treated simultaneously. The samples are placed in bags made of polyester filter cloth with a mesh size of 10  $\mu\text{m}$ . The bags are wrapped in foamy PVC for protection against mechanical damage. After acid treatment, filtration of the samples takes place by washing the bags in a household washing machine. The washing procedure effectively removes particles smaller than the mesh size of

the sample bags. If a sample bag is damaged after washing it is noted on the slides prepared for microscopy so as to be aware of possible contamination from other samples.

## *Interpretation*

The palynological preparations were studied using a transmitted light microscope.

The dinoflagellate assemblages in the cutting samples were usually contaminated by Tertiary species. This was also the case for samples taken after setting of casings in the Tertiary interval to prevent caving from this part of the well. Despite the fact that only washed cuttings were processed, the Tertiary contamination is believed to derive from drilling mud. Caving of certain Lower Cretaceous intervals could also influence the dinoflagellate assemblages in samples from deeper levels. However, since the age determinations were exclusively based on the last occurrence of species (first downhole appearance), contamination from caving and drilling mud was of minor importance.

More serious problems were encountered where the deposits have been reseedimented by turbidity-currents or similar processes, especially in the Valanginian-Hauterivian interval. The use of first downhole appearance for age determination results in too old ages if the determination is based on reworked species. Reworked specimens may sometimes, but far from always, be detected by their different state of preservation. In this study species are regarded as reworked in cases when their first downhole occurrence is before the downhole appearance of younger species, i.e. when the successive downhole appearances of a suite of marker species are out of sequence. To detect reworking is therefore only possible when the true stratigraphical ranges of the individual species are known. The procedure is straightforward when dealing with reworking of much older sediments into younger (e.g. Jurassic into Hauterivian). It is more difficult, or even impossible, to detect reworking when the age difference is minor, as for example when Ryazanian is reworked into Valanginian. Close spacing of samples is therefore necessary in intervals with reworking, in order to pick as many first downhole occurrences as possible. Suspicion of reworking has been substantiated during the study by log-stratigraphical, sedimentological and geophysical information presented by Jensen et al. (1986) and Vejrbæk (1986).

# Dinoflagellate distribution in the Lower Cretaceous of Northwest Europe

## *Chronostratigraphy of sections yielding dinoflagellate information*

The existing literature of dinoflagellate stratigraphy in the Lower Cretaceous of Northwestern Europe is reviewed here to provide a reference for age determination of the North Sea material.

The stratigraphical distribution of dinoflagellates in Northwest Europe is well known today due to the large number of studies from independently dated sections that have been published in the last twenty years. Extensive dinoflagellate records are now available from almost all of the Boreal Lower Cretaceous ammonite zones. Exceptions to this are the Upper Valanginian and the lowermost Aptian (*fissicostatus* ammonite Zone), from which no, or only uncertain, dinoflagellate records exist.

No recent compilation of this large volume of data is available. Various range charts covering the Lower Cretaceous, or parts of it, have been published earlier, in particular by Davey & Verdier (1973), Verdier (1975), Raynaud (1978), Duxbury (1978), Davey (1979c), Fisher & Riley (1980) and Foucher (1981, 1983). Since these publications several papers have added new information, necessitating revision of the ranges and adding new species.

In order to compile the various dinoflagellate records, it was necessary first to correlate the sections yielding dinoflagellate information, and then to plot all relevant dinoflagellate records in a chronostratigraphical scheme. The correlation is based on the ammonite zonation of the sections. The sections yielding dinoflagellate records are shown in fig. 3, and the dinoflagellate distribution chart in fig. 4. In order to minimize the effect of palaeogeographical variation of the dinoflagellate ranges, only information from the Boreal Lower Cretaceous Province of Europe has been used in the dinoflagellate range chart.

The distribution of ammonites in the Lower Cretaceous of Northwestern Europe is probably better known than that of any other fossil group, and the modern Boreal ammonite zonation is the most reliable tool for correlation. The sections analysed for dinoflagellates have, in most cases, been studied previously by ammonite workers.

All sections have been arranged relative to the current ammonite zonation of the English Lower Cretaceous (Rawson et al. 1978). For convenient comparison with the important Speeton Clay Formation in Eastern

England an informal three-fold division of the Barremian Stage is used (again following Rawson et al. (1978)); thus the middle Barremian is typified by the Cement Beds (MB Beds) in the Speeton Clay Formation at Speeton.

The following two modifications of the scheme by Rawson et al. (1978) are made: 1. The Upper Valanginian is not well represented in England, and therefore the German Upper Valanginian ammonite zonation (Kemper et al. 1981) is used. 2. The Hauterivian-Barremian boundary was placed above the *variabilis* Zone in the scheme by Rawson et al. (1978). Following Kemper et al. (1981) this stage boundary is now placed below the *variabilis* Zone.

It should also be noted that the boundary between the Lower and Upper Aptian is placed above the *bowerbanki* Zone, following Casey's (1961) suggestions. In Thomsen (in press) the boundary is placed below the *bowerbanki* Zone.

French and German ammonite zonations are correlated with the English zones by Kemper et al. (1981), Amedro (1980), Rawson (1983) and Rawson et al. (1978). This permits approximate arrangement of the French and German dinoflagellate records in the English zonation scheme. Ammonite and dinoflagellate bearing strata are described from Sklinnabanken and Andøya in Norway by Birkelund et al. (1978) and Aarhus et al. (1986). Casey's (1973) correlation of Ryazanian ammonite zones in Europe and Siberia allows a correlation of the Norwegian ammonite occurrences with the English *stenomphalus* and *albidum* zones.

## **The Jurassic-Cretaceous boundary**

This boundary is equal to the boundary between the Tithonian and Berriasian stages established in the Tethyan Province. In the Boreal Province the Jurassic-Cretaceous boundary has often been equalized with the Volgian-Ryazanian boundary, since a correlation to the Tethyan was formerly missing. Today an indirect, and therefore uncertain, correlation between the Tethyan and Boreal Province is possible near the Jurassic-Cretaceous boundary (see Casey 1973). It seems clear from the combined ammonite and ostracod evidence that the Jurassic-Cretaceous boundary (base of Berriasian) is below the base of the Ryazanian, and it may be located near the base of the Upper Volgian.

A number of papers presenting dinoflagellate data

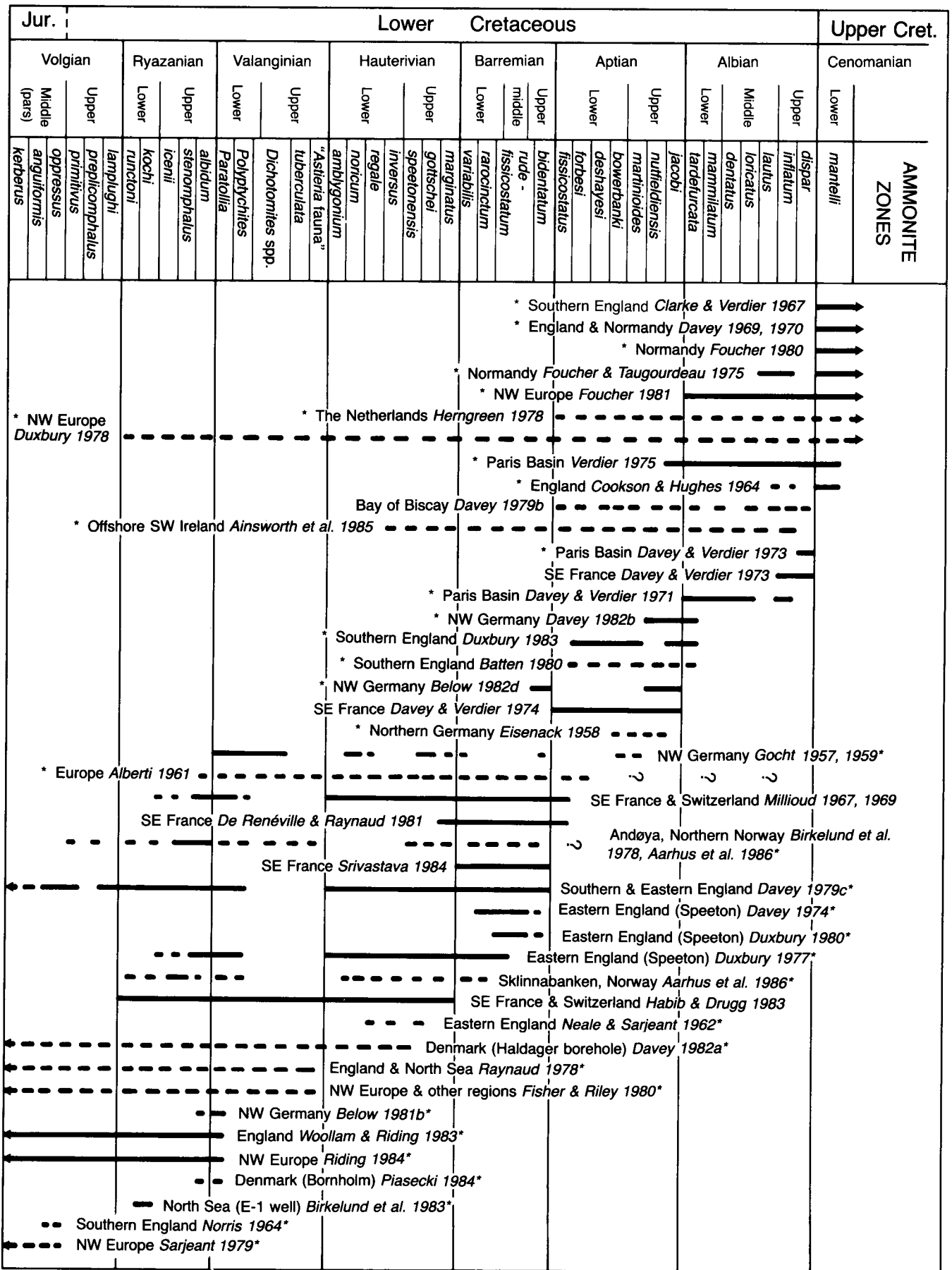


Fig. 3. Approximate stratigraphical coverage of most published dinoflagellate studies of the Lower Cretaceous in western Europe. The ammonite zonation is modified from Rawson et al. (1978) as explained in the text. Solid lines indicate palynological studies of ammonite-dated samples/sections. Dashed lines: studies giving no information on ammonites. Works from the Boreal Province are marked with an asterisk.

needs some comment regarding the stratigraphical position of sections/samples studied, or concerning reworked dinoflagellate occurrences. These papers are commented below.

#### Verdier (1975)

Verdier (1975) presented a range chart of dinoflagellates from the Wissant section at Boulonnais, Northern France. Here the Cenomanian rests unconformably upon the Albian, with the uppermost Albian missing. According to Robaszynski et al. (1980) the basal Cenomanian is a glauconitic and conglomeratic basement bed to the Chalk. The dinoflagellate assemblage in the two Cenomanian samples studied by Verdier (1975) includes some species (see below) which are considered to be reworked.

#### Davey (1969, 1970)

Mainly Cenomanian sections from England, France and North America were studied by Davey (1969, 1970). His lowermost samples 840 and CB 1, just above the base of the Cenomanian, at Fetcham Mill and Compton Bay (Southern England) contain a number of dinoflagellates considered to be restricted to the Albian by Davey & Verdier (1973: 209). These authors, in a discussion of Davey's (1969, 1970) results, threw some doubt on the Cenomanian age of the two samples. Judging from the presence of the ammonite *Schloenbachia varians* (see Davey & Verdier 1973: 210) and the conglomeratic composition of this basal bed, the age is Early Cenomanian and the presence of Albian species is most likely due to reworking.

#### Cookson & Hughes (1964)

The mid-Cretaceous section near Barrington (England) described by Cookson & Hughes (1964) includes Albian sediments unconformably overlain by a less than 1 m thick basal bed to the Chalk termed the Cambridge Greensand, and followed by the Lower Cenomanian Chalk Marl. Cookson & Hughes (1964) placed the Cambridge Greensand, with some uncertainty, in the basal Cenomanian on the basis of ammonite evidence. According to Rawson et al. (1978: 50) the ammonite in question is *Schloenbachia* cf. *varians* subsp. *subplana* and of Cenomanian age.

Davey & Verdier (1973) pointed out the strong Albian element in the Cambridge Greensand dinoflagellate assemblage recorded by Cookson & Hughes (1964) and they threw doubt on the Cenomanian age.

The Cambridge Greensand is rich in reworked Upper Albian ammonites (Cookson & Hughes 1964, Rawson et al. 1978) and it is thus very probable that the Albian dinoflagellates may be reworked.

#### Below (1982d)

An unconformity separates the Upper Aptian from the Upper Barremian in the "Otto Gott" clay pit section

(Northwest Germany) studied by Below (1982d). Several species occurring immediately above the unconformity have not previously been reported higher than the Barremian-Lower Aptian and they are considered as reworked.

#### Duxbury (1983)

The mainly Aptian section described from the Isle of Wight (Southern England) crosses the Aptian-Albian boundary (Casey 1961), but the ammonite data does not permit precise location of the boundary.

#### Gocht (1957, 1959)

In this pioneer work on Lower Cretaceous dinoflagellates twelve samples of Valanginian-Barremian age from Northwestern Germany were studied, eleven of which were cores from boreholes. The ages of the samples and the dinoflagellates are summarized in Gocht (1959: 82-83). The ages are given by Gocht in terms of the contemporaneous German stratigraphical classification (e.g. Bartenstein & Bettenstaedt 1962: 229). This classification is revised and correlated with the English ammonite zonation by Kemper (1971, 1973) and Kemper et al. (1981).

The samples of Gocht (1957, 1959) should probably be correlated with the English ammonite zonation as follows:

Sample 10	Upper Barremian
Sample 12	<i>gottschei/marginatus</i> (or <i>variabilis</i> ) Zones
Sample 9	<i>gottschei</i> Zone
Sample 11	<i>regale</i> Zone?
Samples 6, 7 & 8	<i>noricum</i> Zone
Samples 4 & 5	<i>Dichotomites</i> spp. Zone
Sample 3	<i>Polyptychites/Dichotomites</i> Zones
Sample 2	<i>Polyptychites</i> Zone
Sample 1	<i>Paratollia</i> Zone

#### Alberti (1961)

The major study of Alberti (1961) includes Mesozoic (mainly Lower Cretaceous) and Lower Tertiary material from different parts of Europe and Asia. Many of the samples are from well-cores which cannot be precisely placed relative to the ammonite stratigraphy.

The Upper Aptian and Albian ages given for German samples yielding *Pseudoceratium pelliferum* (Alberti 1961: table opposite p. 44) have been doubted by Davey & Verdier (1974: 650) and Duxbury (1983: 68). Particularly in the light of the works by Davey (1982b), Below (1982d) and Duxbury (1983) it seems highly unlikely that *P. pelliferum* should be present as high as Upper Aptian and Albian at the localities mentioned by Alberti, and the suggestion by Duxbury (1983) that these samples are of Early Aptian age is followed here.

#### Davey (1982a)

This work primarily deals with the dinoflagellates of the Volgian-Lower Hauterivian in the Danish Haldager

Index of species in fig. 4

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<i>Aldorfia spongiosa</i> .....	98	<i>Hystrichodinium furcatum</i> .....	66
<i>Aptea anaphrissa</i> .....	63	<i>Hystrichodinium ramoides</i> .....	56
<i>Aptea polymorpha</i> .....	28	<i>Hystrichosphaeridium arborispinum</i> .....	57
<i>Aptea securigera</i> .....	29	<i>Hystrichosphaeridium scoriaceum</i> .....	78
<i>Apteodinium grande</i> .....	16	<i>Hystrichosphaerina schindewolfii</i> .....	24
<i>Ascodinium scabrosum</i> .....	13	<i>Isabelidinium gallium</i> .....	15
<i>Avellodinium falsificum</i> .....	61	<i>Isthmocystis distincta</i> .....	86
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<i>Carpodinium obliquicostatum</i> .....	3	<i>Litosphaeridium siphoniphorum</i> .....	1
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<i>Gochteodinia villosa</i> subsp. <i>villosa</i> .....	101	<i>Stiphrosphaeridium anthophorum</i> .....	35
<i>Gochteodinia virgula</i> .....	112	<i>Stiphrosphaeridium dictyophorum</i> .....	40
<i>Gonyaulacysta cassidata</i> .....	10	<i>Subtilisphaera perlucida</i> .....	31
<i>Gonyaulacysta cladophora</i> sensu Duxbury 1977 .....	70	<i>Surculosphaeridium</i> sp. III Davey 1982a .....	89
<i>Gonyaulacysta kostromiensis</i> .....	72	<i>Systematophora palmula</i> .....	92
<i>Gonyaulacysta ordocava</i> .....	76	<i>Trabeculodinium quinquetrum</i> .....	65
<i>Gonyaulacysta? perforobtusata</i> .....	74	<i>Trichodinium speetonense</i> .....	58
<i>Gonyaulacysta</i> sp. A Davey 1982a .....	106	<i>Tubotuberella apatela</i> .....	90

Fig. 4. Recorded ranges of selected dinoflagellates in northwestern Europe. The ranges are based on the studies of Boreal European sections shown in fig. 3. Only species which occur in the Danish North Sea Sector are included in the range chart. Solid lines indicate records in ammonite-zoned sections. Dotted lines show records in sections without ammonite control, or uncertain identification of the dinoflagellate species. R: probably reworked occurrence. Species considered the most reliable for correlation are marked with an asterisk.

Jur.		Lower Cretaceous												Upper Cret.		
Volgian		Ryazanian		Valanginian		Hauterivian			Barremian		Aptian		Albian		Cenomanian	
Middle (pars)	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	AMMONITE ZONES
oppressus anguliformis kerberus	prepicromphalus primithyus	lamplughii runcioni kochi icenili	steriomphalus albidum Paratolla	Polyptrychites Dichotomites spp.	"Astieria fauna" tuberculata	regale noticum amblygonium	speetonensis inversus	marginatus gottschei	variabilis tarroinctum	rude - fissicostatum	bidentatum	fissicostatus forbesi	nuttkiadiensis martinioides bowerbanki deshayesi	jacobi tardefurcata mammillatum	dentatus loricatus latus inflatum dispar	
																79 <i>Cymosphaerid. validum</i>
															R	*80 <i>Spin. ramosus primaevus</i>
																81 <i>Kleithriasphaerid. sp. 1</i>
																*82 <i>Muderongia extensiva</i>
																*83 <i>Batioladin. varigranosum</i>
																*84 <i>Phoberocysta tabulata</i>
																*85 <i>G. villosa multifurcata</i>
																*86 <i>Isthmocystis distincta</i>
																*87 <i>Sirmiodiniopsis frisia</i>
																*88 <i>Muderongia sp. 1</i>
																*89 <i>Surculosphaeridium sp. III</i>
																*90 <i>Tubotuberella apatela</i>
																*91 <i>Lagenorhytis delicatula</i>
																92 <i>Systematophora palmula</i>
																93 <i>Pseudoceratium sp. 1</i>
																94 <i>M. simplex microperforata</i>
																95 <i>Chytroeisphaer. cerastes</i>
																*96 <i>Occisucysta evittii</i>
																*97 <i>Endoscrinium pharo</i>
																*98 <i>Aldorfia spongiosa</i>
																*99 <i>Egmontodinium torynum</i>
																100 <i>Canningia compta</i>
																*101 <i>Gochteod. villosa villosa</i>
																*102 <i>Dingodinium spinosum</i>
																103 <i>Oligosphaerid. diluculum</i>
																*104 <i>Batiolad. cf. varigranosum</i>
																*105 <i>Kleithriasp. porosispinum</i>
																*106 <i>Gonyaulacysta sp. A</i>
																*107 <i>Cannosphaeropsis thula</i>
																*108 <i>Dichadogonyaulax culmula</i>
																109 <i>Batioladinium sp. I Davey</i>
																*110 <i>Batioladinium pomum</i>
															R	*111 <i>Egmontodinium expiratum</i>
																*112 <i>Gochteodinia virgula</i>
																*113 <i>Cribroperidinium sp. A</i>
																*114 <i>Egmontodin. polyplacoph.</i>
																*115 <i>Ctenidodinium panneum</i>
																*116 <i>Glossodinium dimorphum</i>

Fig. 4. continued ▶

Jur.		Lower Cretaceous											Upper Cret.			
Volgian		Ryazanian		Valanginian		Hauterivian		Barremian		Aptian		Albian		Cenomanian		
Middle (pars)	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
															AMMONITE ZONES	
																40 <i>Stiphosphaer. dictyophor.</i>
																*41 <i>Achomosphaera? neptunii</i>
																*42 <i>Callaiosphaer. trycherium</i>
																43 <i>Chlamydophor. membranoidea</i>
																*44 <i>Exiguosphaera plectilis</i>
																*45 <i>Pseudoceratium pelliferum</i>
																*46 <i>Ctenidodinium elegantulum</i>
																*47 <i>Heslertonia heslertonens.</i>
																*48 <i>Phoberocysta neocomica</i>
																49 <i>Chlamydophor. trabeculosa</i>
																*50 <i>Diphasioosphaera stolidota</i>
																51 <i>Rhynchodiniopsis aptiana</i>
																52 <i>Ellipsodinium reticulatum</i>
																*53 <i>Cribroperidinium cornutum</i>
																54 <i>Cribroperidinium boreas</i>
																55 <i>Fromea quadrugata</i>
																*56 <i>Hystrichodinium ramoides</i>
																*57 <i>Hystrichosph. arborispin.</i>
																58 <i>Trichodinium speetonense</i>
																*59 <i>Muderongia staurota</i>
																*60 <i>Batiolad. longicornutum</i>
																*61 <i>Avellodinium falsificum</i>
																*62 <i>Cassiculosphaeridia mag.</i>
																*63 <i>Aptea anaphrissa</i>
																64 <i>Spiniferites dentatus</i>
																*65 <i>Trabeculodin. quinquelat.</i>
																*66 <i>Hystrichodinium furcatum</i>
																67 <i>Cribroperidin. sepimentum</i>
																*68 <i>Muderogia simplex</i>
																*69 <i>Kleithriasph. corrugatum</i>
																*70 <i>G. cladophora</i> s. Duxb.-77
																*71 <i>Kleithriasph. fasciatum</i>
																*72 <i>Gonyaulac. kostromiensis</i>
																*73 <i>Canningia</i> cf. <i>reticulata</i>
																74 <i>Gonyaulac. perforobtus</i>
																*75 <i>Nematosphaeropsis scala</i>
																76 <i>Gonyaulacysta ordocava</i>
																*77 <i>Exiguosphaera phragma</i>
																*78 <i>Hystrichosph. scoriaceum</i>

Fig. 4. continued





No. 1 borehole, the ammonite stratigraphy of which is unknown. However much information is also given on dinoflagellate distribution in ammonite-dated Volgian-Early Cretaceous sediments from England.

#### Samples examined from the Speeton Clay

In addition to the published sources of information shown in fig. 3, samples from the following sixteen beds of the Speeton Clay at Speeton (Eastern England) were examined:

Barremian: Cement Beds (middle Barremian), Beds LB1, LB3, LB4  
Hauterivian: Beds C3, C6, C8, C9, D1, D2D  
Valanginian: Beds D3, D4  
Ryazanian or Valanginian: Bed D5  
Ryazanian: Beds D6H, D7G and E

The ammonite zonation of these beds is outlined and discussed by Rawson (1971), Casey (1973), Neale (1974) and Rawson et al. (1978).

### *Dinoflagellate records in the Lower Cretaceous of Northwestern Europe*

The conclusive stratigraphical occurrence in Northwestern Europe of most of the species found in the present North Sea study is shown in fig. 4. The distribution chart is mainly based on the Northwest European studies shown in fig. 3. A few of the records are from the Speeton material examined in this study. The best species for age determination are marked with an asterisk. These are species which are easily identified and have recorded occurrences which are believed to approximate the true ranges in the Boreal province of Europe.

The occurrences of several species require comments which will be given in the following. The number after the species name refers to the position in the distribution chart (fig. 4); citation of authors to species names are given in the systematic section.

#### *Litosphaeridium siphoniphorum* (1)

The first well established occurrence in NW Europe is in the *dispar* Zone (Davey & Verdier 1973). Verdier (1975) extended the range down into the *inflatum* Zone, but it is unclear whether this is based on observations in the Paris Basin or in the Tethyan of SE France.

#### *Odontochitina operculata* (9)

It is most probable that the earliest occurrence in Northwestern Europe is in the Lower Barremian where *O. operculata* is recorded by Davey (1974, 1979c). Only one dubious pre-Barremian record exists (not included in the range chart), this is in Alberti (1961), who mentioned an uncertain occurrence in an Upper Hauterivian core.

The single specimen classified as *O. operculata* by

Gocht (1959) from the Upper Hauterivian or lowermost Barremian and figured in his pl. 6, fig. 12 is undoubtedly a *Batioladinium longicornutum*.

#### *Gonyaulacysta cassidata* (10)

The probable Hauterivian occurrence is based on the form described by Gocht (1959) as *Gonyaulax?* sp. 6.

#### *Spiniferites ramosus* (11)

*S. ramosus* subsp. *primaevus* is not included here, but is shown separately in the range chart.

The earliest occurrence of *S. ramosus* is an isolated record in the Ryazanian from Sklinnabanken, Norway (Aarhus et al. 1986). This occurrence is below a horizon yielding an ammonite marking the *stenomphalus* Zone. The lowermost Valanginian record of *S. ramosus* is in the Upper *Platylenticeras*-Beds in Northwest Germany (Below 1981b). The Valanginian record above this level is based on Davey (1979c), who may have included *Spiniferites multibrevis* (at that time classified as a subspecies of *S. ramosus*) in his concept of *S. ramosus*. The first specified occurrence of *S. ramosus* subsp. *ramosus* is in the basal Hauterivian (Duxbury 1977). The Lower Aptian record of *S. ramosus* is based on Duxbury (1983) and includes the specimens of his *Spiniferites ramuliferus* which show parasutural lines.

#### *Ascodinium scabrosum* (13)

The Cenomanian record of *A. scabrosum* is from Cookson & Hughes (1964) and Davey (1969, 1970). In both cases *A. scabrosum* only occurs in the basal bed of the Cenomanian and is considered as reworked.

#### *Isabelidinium gallium* (15)

The single specimen recorded in the basal Cenomanian (Davey 1970) is considered to be reworked by Davey & Verdier (1973), thus restricting the range to the uppermost Albian.

#### *Apteodinium grande* (16)

The Cenomanian records of this species are from Cookson & Hughes (1964) and Foucher (1980). Cookson & Hughes found *A. grande* in the basal bed of the Cenomanian, and Foucher (1980) recorded the species in his lowermost sample of the Lower Cenomanian where it is very rare. Both of these occurrences are most likely due reworking.

#### *Litosphaeridium conispinum* (17)

The only record of this species in the Cenomanian is by Verdier (1975) who considered the specimens as reworked. In the section studied by Cookson & Hughes (1964) it is recorded in the Upper Albian but not in the Cenomanian (see discussion in Davey & Verdier 1973: 208).

According to Davey & Verdier (1973: 202) *L. conispinum* is absent in the *dentatus* Zone (Paris Basin

Courchelles section), but present in the *inflatum* Zone (Paris Basin Vallentigny section) and becomes extinct at the top of this zone. This is in contrast to Verdier (1975) who showed the species also in the *dispar* Zone.

#### *Cauca parva* (22)

The Upper Albian – Lower Cenomanian records of this species are here regarded as probably reworked, as explained below.

*C. parva* was found by Verdier (1975) in the Lower Cenomanian at Boulonnais in Northern France but it was not recorded by Davey (1969) or Foucher (1980) in the Cenomanian at this site, or in the Cenomanian in England studied by Cookson & Hughes (1964), Clarke & Verdier (1967) and Davey (1969, 1970).

Likewise, *C. parva* was found in the Upper Albian at Boulonnais by Verdier (1975), but it was absent in the Upper Albian studied by Cookson & Hughes (1964) and Davey & Verdier (1971, 1973). The Upper Albian-Lower Cenomanian occurrences at Boulonnais may therefore be reworked, as proposed by Verdier (1975).

*C. parva* is frequent in the lower Middle and Lower Albian of Northwestern Europe (Davey & Verdier 1971, Davey 1982b, Verdier 1975). It occurs regularly in the Upper Aptian and is sporadic in the Lower Aptian on the Isle of Wight (Batten 1980, Duxbury 1983). It is common in the Upper Aptian in Northwest Germany (Davey 1982b, Below 1982d) and Boulonnais (Verdier 1975). It has been recorded by Duxbury (1980) in the middle and Upper Barremian at Speeton, but not by Davey (1974) working in the same section, and may therefore be rare in the Barremian. It was recorded by Below (1982d) in the Upper Barremian in NW Germany.

#### *Kleithriasphaeridium eoinodes* (23)

The single specimen recorded in the Middle Albian (Verdier 1975) is here considered reworked.

#### *Hystrichosphaerina schindewolfii* (24)

The Valanginian occurrence is based on the record in the Haldager No. 1 borehole in Denmark (Davey 1982a). This is the only pre-Barremian record of this species.

#### *Muderongia pariata* (27)

The figured specimen (Davey 1974: pl. 8, fig. 7, as *M. staurota*) from the middle Barremian at Speeton is here referred to *M. pariata*. This is the only pre-Aptian record of this species.

#### *Aptea securigera* (29)

The Upper Aptian forms classified as *Cyclonephelium compactum* (“extreme”) by Duxbury (1983) are here included in *Aptea securigera*. *A. securigera* is also recorded in the Upper Aptian by Below (1982d).

#### *Discorsia nanna* (32)

The possible occurrence in the Upper Valanginian is based on Fisher & Riley (1980).

#### *Dingodinium cerviculum* (34)

The record in the Upper Ryazanian *stenomphalus* Zone is based on occurrences at Sklinnabanken and Andøya, Norway (Aarhus et al. 1986), and the possible Jurassic occurrence is based on Fisher & Riley (1980).

#### *Stiphrosphaeridium anthophorum* (35)

The occurrence in the *kochi* Zone (Ryazanian) is based on the specimen figured in Davey (1979: pl. 3, fig. 4) as *Polystephanephorus sarjeantii* (the identification of this species is commented on in the systematic part). The probable Volgian occurrence is from Sarjeant (1979).

#### *Sirmiodinium grossii* (36)

The last occurrence of *S. grossii* has previously been regarded as marking the top of the Barremian, e.g. by Verdier (1975) and Duxbury (1978), but no detailed study of the NW European Aptian had been carried out at that time. Since Duxbury’s (1983) study of the dinoflagellate distribution in the Aptian from the Isle of Wight (Southern England) it seems clear that the last occurrence of *S. grossii* (and of two other equally distinct species, namely *Pseudoceratium pelliferum* and *Phoberocysta neocomica*, previously believed to be restricted to Barremian and older deposits) is within the Aptian – earliest Albian.

According to the distribution charts of Duxbury (1983) *S. grossii* is not frequent but is present in so many of the samples that it appears unlikely that it could be reworked. This view is supported by Below’s (1982d) Upper Aptian record of *S. grossii* from Northwestern Germany.

The absence of *S. grossii* in the Tethyan Aptian sections from South-eastern France studied by Davey & Verdier (1974) points to provincialism of this species during the Aptian.

#### *Muderongia tetracantha* (38)

Davey (1979c) and Below (1981b) both recorded *Muderongia crucis* in the Lower Valanginian. This species is here considered as a junior synonym of *Muderongia tetracantha*, following Morgan (1980). The species was not figured by Davey (1979c) or Below (1981b), and it cannot be ruled out that their forms should instead be classified with *Muderongia extensiva*, since Duxbury (1977, working in the same section as Davey 1979) recorded *M. extensiva* in the Lower Valanginian and *M. tetracantha* only from the Upper Hauterivian-Lower Barremian. The only record of *M. tetracantha* above the Lower Barremian is by Below (1982d) and the species is therefore considered as more typical of the Hauterivian-Lower Barremian.

*Stiphrosphaeridium dictyophorum* (40)

The Aptian occurrence is based on Eisenack (1958) and on the specimen figured in Davey (1982: pl. 6. 3–5, fig. 5) as *Stiphrosphaeridium anthophorum* (see discussion of *S. dictyophorum* in the Systematic Part). *S. dictyophorum* is present in a sample from bed D7G (*stenomphalus* Zone?) at Speeton (personal observation) whereas other Ryazanian records are from Davey (1982a) and Birkelund et al. (1983).

*Callaiosphaeridium trycherium* (42)

The Hauterivian and Lower Barremian records are in samples from beds LB4 and C6 in the Speeton Clay examined here.

*Pseudoceratium pelliferum* (45)

This species was recorded in samples of presumed Late Aptian and Albian ages by Alberti (1961). As discussed above, the age determination of these samples is believed to be erroneous.

A single sample out of thirteen from the *nutfieldensis* Zone studied by Below (1982d) yielded *P. pelliferum*. This occurrence is regarded as probably reworked.

See also comments to *Sirmiodinium grossii* (36).

*Ctenidodinium elegantulum* (46)

Typical specimens occur in bed D5 (uppermost Ryazanian?) at Speeton (this study).

*Heslertonia heslertonensis* (47)

Below's (1982d) record in one of the thirteen samples from the *nutfieldensis* Zone is regarded here as probably due to reworking.

*Phoberocysta neocomica* (48)

The exact first occurrence of this species is doubtful. In the range charts of Duxbury (1977) and Davey (1979c) the first occurrence is shown in the uppermost Ryazanian *albidum* Zone. However, both Duxbury (1977: e.g. pl. 14, fig. 10) and Davey (1979c) included specimens of a closely related species, *Phoberocysta tabulata*, in their concept of *P. neocomica*. Davey (1982a: 32) suggested that the earliest specimens recorded as *P. neocomica* in Davey (1979c) should instead be classified as *P. tabulata*. (For differentiation of the two species, see the systematic part).

Specimens seen in the present study from beds D5 and D4 at Speeton (?*albidum* – *Paratollia* Zones) belong to *P. tabulata*, while the earliest definitive *P. neocomica* is recorded in bed D3 (*Polyptychites* Zone).

Last occurrence: see comments to *Sirmiodinium grossii* (36).

*Chlamydophorella trabeculosa* (49)

The last occurrence of typical *C. trabeculosa* is in the Lower Aptian *forbesi* Zone on the Isle of Wight (Duxbury 1983). A somewhat different form occurs almost

to the top of the Aptian (recorded by Duxbury 1983 as “*Chlamydophorella nyei* long-horned”). This form can apparently be distinguished by more stout processes, but otherwise is closely similar to *C. trabeculosa*.

Only records of typical *C. trabeculosa* are included in fig. 4. *Gardodinium eisenacki* in Batten (1980: pl. 1, fig. 1) is referred to Duxbury's “*C. nyei* long-horned”.

Alberti (1961), Below (1982d) and Davey (1982b) recorded *C. trabeculosa* in their Upper Aptian material. They did not illustrate the specimens so they may possibly be identical to “*C. nyei* long-horned”. The record based on these authors is therefore shown as uncertain in the range chart.

The probable Valanginian occurrence is based on remarks in Davey (1982a: 7).

*Diphasiosphaera stolidota* (50)

The earliest record is in the Upper Hauterivian (*marginatus* Zone, bed C3) at Speeton (this study).

*Rhynchodiniopsis aptiana* (51)

Following Below (1981a), the Barremian species *Rhynchodiniopsis fimbriata* is regarded as a junior synonym of *R. aptiana*. According to Deflandre (1935) the type specimen of *R. aptiana* is from an Aptian flint. However, the species appear to be more typical of the Barremian.

*Hystrichodinium ramoides* (56)

*H. ramoides* has previously been recorded from the Barremian. In the present study it is also found in the lowermost Hauterivian (*amblygonium* Zone, bed D2D) at Speeton. For differentiation of the closely related species *Hystrichodinium furcatum*, see the Systematic Part.

*Trichodinium speetonensis* (58)

This species, which is often difficult to distinguish from *Trichodinium castanea*, is recorded in the *marginatus* Zone (bed C3) at Speeton (this study).

*Spiniferites dentatus* (64)

Intermediate forms between *Spiniferites dentatus* and *Spiniferites multibrevis* occur in the Lower Valanginian at Speeton. Such forms are not included here.

The presumably reworked occurrence in the Aptian is a record from Below (1982d).

*Muderongia simplex* (68)

This species seems to be rare in the uppermost Hauterivian and Barremian. It was recorded by Duxbury (1977, 1978) from the Barremian at Speeton, but was not found above the Hauterivian by Davey (1979c) or the present author working in the same section. It is shown in Alberti's (1961) range chart from the Lower Aptian, but this record is questioned in his text (p. 12).

*Gonyaulacysta ordocava* (76)

The earliest Valanginian record is from bed D4 at Speeton (this study).

*Exiguosphaera phragma* (77)

In addition to the occurrence in the Lower Hauterivian *regale* Zone at Speeton (Duxbury 1979) and in the lowermost Valanginian *Paratollia* Zone in Northwestern Germany (Below 1981b) this species is recorded in the present study from the Upper Ryazanian – lowermost Valanginian? beds D7G and D5 (*?stenomphalus*, *albidum/Paratollia* Zones) and the lowermost Hauterivian bed D2D (*amblygonium* Zone) at Speeton.

*Hystrichosphaeridium scoriaceum* (78)

This species is previously recorded only by Raynaud (1978) who gives the range as Ryazanian – Lower Valanginian. In the present study it was found in the Lower Valanginian beds D4 and D3 (*Paratollia* and *Polyptychites* Zones) and in the Lower Hauterivian beds C9 and C8 (*regale* Zone) at Speeton.

*Cymososphaeridium validum* (79)

This species has previously been recorded only from the Hauterivian of the North Sea and Denmark (Davey 1982a). In the present study it has been seen in the Lower Hauterivian bed D1 (*noricum/amblygonium* Zone) at Speeton.

*Spiniferites ramosus* subsp. *primaevus* (80)

This subspecies was recorded by Duxbury (1977) from the Lower Valanginian, and in the present study also from the lowermost Hauterivian (*amblygonium* Zone), at Speeton. It was also recorded by Davey (1982a) in beds assigned to the Hauterivian in the Haldager No. 1 borehole in Denmark, and by Below (1982d) in the Upper Aptian of Northwestern Germany where its presence just above a considerable unconformity suggests that it may be reworked.

*Kleithriasphaeridium* sp. 1 (81)

This form is recorded in the present study in the Lower Hauterivian beds D2D and D1 (*amblygonium* – *?noricum* Zones) at Speeton.

*Muderongia extensiva* (82)

As mentioned by Duxbury (1977), the figured specimens named *Muderongia tetracantha* in Alberti (1961) should be referred to *M. extensiva*. The age was given as 'Valendis' and 'Unterhauteriv' and the samples were from Poland and Germany.

The range is further based on Duxbury (1977) and Davey (1982a).

*Phoberocysta tabulata* (84)

While there is little doubt as to the earliest record of this species (see remarks to *P. neocomica*) the last

occurrence is less well documented. It is recorded in the present study as high as the Lower Hauterivian beds D2D and D1 (*amblygonium* – *?noricum* Zones) at Speeton.

*Isthmocystis distincta* (86)

This species was first recorded by Duxbury (1979) from the *Polyptychites* Zone at Speeton. It has subsequently been found in the interval assigned as Early Portlandian – Hauterivian in the Haldager No. 1 borehole, Denmark (Davey 1982a), in the *kochi* Zone of the Danish North Sea E 1 well (Birkelund et al. 1983), and in beds D7G, D4 and D2D (*?stenomphalus*, *Paratollia* and *amblygonium* Zones) at Speeton (this study).

*Muderongia* sp. 1 (88)

This form is recorded by Gocht (1959) in samples from, and just above, the Lower Valanginian *Polyptychiten-Schicht* and by Alberti (1961) from marine incursions in Eastern German Wealden sediments (Upper Ryazanian or Lower Valanginian).

*Surculosphaeridium* sp. III of Davey (1982a) (89)

The present study supports the observations of Davey (1982a) that this species is restricted to the Lower Valanginian at Speeton.

*Tubotuberella apatela* (90)

This species is found in the *Polyptychites* Zone at Speeton (bed D3) in the present study. The only Hauterivian record is in the Haldager borehole (Davey 1982a).

*Lagenorhytis delicatula* (91)

The highest occurrence of *Lagenorhytis delicatula* in the Speeton section is in the *Paratollia* Zone (Duxbury 1977 and this study). In the Haldager No. 1 borehole, however, it is recorded as high as the lowermost sample assigned to the Hauterivian.

The lowermost occurrence is in bed D7G (*?stenomphalus* Zone at Speeton (this study)).

*Pseudoceratium* sp. 1 (93)

This early variety of *Pseudoceratium pelfiferum* includes the specimens from the interval assigned as Lower Valanginian – Upper Ryazanian in the Danish Haldager borehole, figured in Davey (1979c: pl. 4, fig. 1 and 1982a: pl. 10, fig. 16).

*Muderongia simplex* subsp. *microperforata* (94)

According to Davey (1982a: 30) this subspecies occurs in the Upper Ryazanian to Lower Valanginian of the North Sea and in the Haldager No. 1 borehole, although in his range chart Davey (1982a) also shows the subspecies in one of his samples dated as Hauterivian in the Haldager borehole.

*M. simplex* subsp. *microperforata* was also recorded

by Piasecki (1984) in sediments of probably Late Ryazanian age from Bornholm, Denmark.

*Chytroeisphaeridium cerastes* (95)

*C. cerastes* was originally described from the Lower Oxfordian (Davey 1979d). It is recorded in the present study in bed D5 (*Albidum/Paratollia* Zone) at Speeton.

*Occisucysta evittii* (96)

The forms described by Davey (1979c, 1982a) as *Occisucysta* sp. A and *Occisucysta* cf. *evittii* are here regarded as falling within the morphological range of *O. evittii*.

*Aldorfia spongiosa* (98)

A single Lower Hauterivian record is from Sklinna-banken, Norway (Aarhus et al. 1986). The highest record in the North Sea Basin is in the lowermost Valanginian (*Paratollia* Zone) bed D4 at Speeton, Eastern England (this study). *Aldorfia spongiosa* is recorded by Davey (1982a) from the Middle Volgian of Lincolnshire and at the Jurassic – Cretaceous transition in the Haldager No. 1 borehole.

*Gochteodinia villosa* subsp. *villosa* (101)

The Valanginian record of *G. villosa* (Raynaud 1978) is here assumed to be represented by *G. villosa* subsp. *multifurcata*. (The subspecies of *G. villosa* were first described after Raynaud presented his range chart).

*Batioladinium* cf. *varigranosum* sensu Davey (1982a) (104)

This form is recorded in the present study from bed D5 (*Albidum* or *Paratollia* Zone) at Speeton.

*Kleithriasphaeridium porosispinum* (105)

A single Lower Valanginian occurrence is from Sklinna-banken, Norway (Aarhus et al. 1986). Apart from this, *K. porosispinum* is not known with certainty to occur in deposits younger than the Upper Ryazanian *stenomphalus* Zone (Davey 1982a).

*Cannosphaeropsis thula* (107)

The possible record in the *stenomphalus* Zone is based

*Ctenidodinium panneum* (115)

A single Ryazanian occurrence is from Sklinna-banken, Norway (Aarhus et al. 1986). on the occurrence of this species in bed D8 at Speeton (Duxbury 1977, as *Adnatosphaeridium apiculatum*). However, the exact age of bed D8 which occurs just above a major unconformity, is uncertain (cf. Casey 1973).

*Dichadogonyaulax culmula* (108)

According to Riding (1984) the highest record of this species is in the *icenii* Zone. In the present study it was recorded in bed D7G (*stenomphalus* Zone) at Speeton.

*Batioladinium* sp. 1 of Davey (1982a) (109)

In Davey (1982a) two specimens (pl. 5, figs. 12 and 13) are illustrated from the Lower Valanginian but he (p. 22) gives the range as uppermost Volgian – Lower Ryazanian.

*Batioladinium pomum* (110)

This species is recorded in the *lamplughii* Zone in Eastern England (Davey 1982a), the *kochi* Zone in the Danish North Sea E 1 well (Birkelund et al. 1983), in bed D7G (*stenomphalus* Zone) at Speeton (this study), and up to near the top of the Ryazanian in Denmark (Davey 1982a, Piasecki 1984).

*Egmontodinium expiratum* (111)

According to Riding (1984) the first occurrence of *E. expiratum* is in the *kerberus* Zone. Davey (1982a) regarded its presence in the intervals assigned as Upper Ryazanian and Valanginian in the Danish Haldager No. 1 borehole as possibly being due to reworking.

*Egmontodinium polyplacophorum* (114)

A single Ryazanian record is from Sklinna-banken, Norway (Aarhus et al. 1986).

# Dinoflagellate analysis in the Danish Central Trough and ammonites in the Adda-2 well

This section presents the age determinations of selected wells in the Danish Central Trough, and the evidence on which the ages are based.

The ages are based on the Northwest European ranges of species as presented in the previous section.

The results are generally presented with the uppermost sample of a particular well being described first, and the lowermost sample last. This is convenient because the ages are based on first downhole occurrences (last stratigraphical occurrences) of species in ditch cutting samples.

The geographical and structural positions of the wells are shown in fig. 1.

## The Adda-1 well

### Summary of age determinations

ditch cutting samples,  
depths below kelly  
bushing

7510'	Late Cretaceous
7520'	Late Cretaceous or Late Albian
7530'	Late Albian, probably older than the latest Albian <i>dispar</i> ammonite Zone
7540'	Probably Late or Middle Albian
7550'–7570'	Late Aptian?
7580'	Aptian
7590'	Late Barremian?
7600'–7620'	Late to ?middle Barremian
7640'–7670'	middle or possibly Early Barremian
7690'–7700'	middle Barremian – possibly Late Hauterivian
7710'	Early Barremian or Late Hauterivian
7720'	Hauterivian, probably older than the <i>marginatus</i> ammonite Zone
7730'	earliest Hauterivian, probably coeval to the <i>amblygonium</i> ammonite Zone
7760'–7850'	earliest Hauterivian or Late Valanginian
7870'	Valanginian younger than the <i>Paratollia</i> ammonite Zone
7910'–8100'	earliest Valanginian (probably coeval to the <i>Paratollia</i> ammonite Zone)
8170'–8320'	earliest Valanginian-Late Ryazanian
8400'–8460'	Late Ryazanian
8500'–8600'	Late Ryazanian, probably coeval to the <i>stenomphalus</i> ammonite Zone
8650'	Ryazanian
8700'–8850'	Early Ryazanian-Late Volgian
9000'–9150'	Late to Middle Volgian

### Side-wall cores

9170'	Middle Volgian
9378'–9542'	Early to early Middle Volgian

### Discussion of ages

Most of the dinoflagellates recorded from the Adda-1 well are shown in the range charts based on cutting samples (fig. 5) and side-wall cores (fig. 6). The ages are interpreted as follows:

7510'. The Late Cretaceous age is based on a dinoflagellate assemblage composed of a few Upper Cretaceous and several Tertiary species. The latter group is evidently present as a result of drilling-mud contamination, and the small *in situ* assemblage indicates a low dinoflagellate content at this depth. According to Foucher (1979) the presence of *Cyclonephelium membraniphorum* points to a pre-Campanian age.

7520'. The sample only contains contaminated Tertiary species. The age is based on age-indications above and below.

7530'. The sample is rich in dinoflagellate species restricted to the Albian-Cenomanian. The highest occurrences of *Ascodinium scabrosum*, *Litosphaeridium conispinum* and *Apteodinium grande* are considered as confident top-Albian markers, and *Litosphaeridium arundum* points to an age older than the latest Albian *dispar* ammonite zone.

7540'. The probably Middle or Late Albian age is based on the downhole appearance of *Carpodinium granulatum* which indicates an age no younger than the Late Albian *inflatum* Zone. *Dinopterygium cladoides* (several specimens) and *Psaligonyaulax deflandrei* (one questionable specimen) have not been reported below the Middle Albian, and *Isabelidinium gallium*, which occurs here (and again at 7570'), is only known from the latest Albian.

7550'–7570'. No downhole appearances of age-diagnostic species occur in this interval. However, the Albian assemblage present in the samples above is essentially absent which may suggest a pre-Albian age.

At 7580' a considerable number of species make their first downhole appearance. Several of them have previously been reported to occur in the Albian of NW Europe. However, *Cerbia tabulata* and a questionable *Achomosphaera neptunii* point to an age no younger than the Late Aptian. *Aptea securigera* and *Dingodi-*

<h1>ADDA-1</h1> <h2>SIDE-WALL CORES</h2> <p>(Two lowermost samples analysed by N. Poulsen)</p> <p>Legend: as fig. 5 DGU 0187 CHC</p>		Lithostratigraphy	Depth (feet below KB)	Dinoflagellates																		
Age	FARSUND FORM.			<i>Kleithriasphaeridium porosispinum</i>	<i>Tasmanites</i> spp.	<i>Kleithriasphaeridium fasciatum</i>	<i>Gochteodinia villosa</i> subsp. <i>villosa</i>	<i>Occiscyusta evittii</i>	<i>Egmontodinium exspiratum</i>	<i>Pterospermella</i> spp.	<i>Dingodinium spinosum</i>	<i>Canningia compta</i>	<i>Ctenidodinium parneum</i>	<i>Sirmiodinium grossii</i>	<i>Gochteodinia virgula</i>	<i>Aldorfia</i> sp. A Davey 1982a	<i>Dingodinium tuberosum</i>	<i>Cassiculosphaeridia magna</i>	<i>Cribroperidinium?</i> <i>gigas</i>	<i>Meristaulax granulata</i>	<i>Pareodinia ceratophora</i>	<i>Apteodinium nuciforme</i>
EARLY RYAZANIAN -LATE VOLGIAN	8992	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
MIDDLE VOLGIAN	9170								■	■												
EARLY MIDDLE OR EARLY VOLGIAN	9378																					
	9542																					

Fig. 6. Dinoflagellates in side-wall cores of the Adda-1 well.

*nium cerviculum* ranges into the earliest Albian but are more characteristic of the Aptian.

7590'–7620'. Several species make their first down-hole appearance in the sample at 7590'. Among these, *Phoberocysta neocomica*, *Chlamydophorella trabeculosa* and *Pseudoceratium pelliferum* (a questionable specimen) are prominent markers of Early Aptian or older strata. *Diphasio-sphaera stolidota* (doubtfully identified) suggests an earliest Aptian or older age, and *Cribroperidinium boreas* (also doubtfully identified) marks the top of the Barremian. In the next sample (at 7600') *Batioladinium longicornutum*, which is a reliable top Barremian marker, makes its first downhole appearance. The Barremian age is supported by a questionable *Trichodinium speetonensis*. The first downhole occurrence of *Subtilisphaera perlucida* also occurs here. The abundance of this species down to and including the sample at 7660' is possibly of some significance. *S. perlucida* ranges into the Albian, but is very abundant in the middle Barremian sample from Speeton inspected in the present study. At 7610' the first undoubted *Diphasio-sphaera stolidota* and a questionable *Avellodinium falsificum* supports the Barremian age indicated above. A further Barremian indicator, *Cassiculosphaeridia magna*, appears at 7620', and a doubtful *Isthmocystis distincta* in the same sample is presumably reworked from the Hauterivian or older strata, while a *Stephodinium coronatum* is considered to be caved from the latest Aptian or younger levels.

7640'–7670'. The middle or possibly Early Barremian age is based on the first downhole occurrence of *Kleithriasphaeridium corrugatum* at 7640' and its presence in several of the subsequent samples. The stratigraphically highest record of this species is in the lowermost part of the middle Barremian at Speeton (Duxbury 1980), although it is possibly more typical of the Lower Barremian and older deposits. However, a number of species characteristic of the middle to Late

Barremian are also met with here for the first time: *Cribroperidinium cornutum* (questionable at 7640' but certain below), *Ellipsodinium reticulatum* at 7660' and 7670', and *Rhynchodiniopsis aptiana* at 7650'.

7690'–7700'. Two atypical specimens at 7690' have been doubtfully identified as *Gonyaulacysta kostromiensis*. This is a weak indication that layers of earliest Barremian – Hauterivian age may be penetrated here, although no other features of the assemblage indicate a pre-Barremian age. *Sirmiodiniopsis frisia* is considered reworked at 7690'.

7710'. The Early Barremian or Late Hauterivian age is based on the occurrence of *Muderongia tetracantha*, although this species has also been recorded in the Aptian by Below (1982d) (see previous section).

A marked change in the assemblage takes place at 7720'. *Pseudoceratium pelliferum* and *Hystrichodinium voigtii*, which are infrequent above, are abundant in this and the underlying samples, while the *Cribroperidinium orthoceras-edwardsii* group, which is frequent above, now decreases rapidly. Several species make their first downhole appearance. The Hauterivian age is based on the highest occurrence of *Phoberocysta tabulata* which becomes frequent in the subsequent samples, on *Hystrichosphaeridium scoriaceum* and on common to abundant *Muderongia simplex* in all samples from 7720' to 8320'. The Hauterivian age may be further supported by the appearance of *Chlamydophorella membranoidea* which becomes frequent in the subsequent samples. It should be noted, however, that *C. membranoidea* is also recorded in the Upper Aptian of Northwestern Germany (Davey 1982b).

7730'. A large number of species make their first appearance at this depth. The earliest Hauterivian age is based on the first downhole occurrence of *Isthmocys-*

Fig. 5. Dinoflagellates in ditch cuttings of the Adda-1 well.

# ADDA - 1

## DITCH CUTTINGS

KB elevation: 112 feet  
 Castings: 7467, 7795  
 DCU 0187 CHC

### FORMATION/MEMBER

\* = the "A" log-marker

### Depth (feet below KB)

### Oxic/anoxic facies

### Tertiary dinocysts (contamination)

FORMATION/MEMBER	Depth (feet below KB)	Oxic/anoxic facies	Tertiary dinocysts (contamination)	Frequency:
LATE CRETACEOUS	7500			
LT. ALBIAN OR LT. CRET.	7510			
LATE ALBIAN	7530			
LATE OR MIDDLE ALBIAN	7540			
LATE APTIAN?	7570			
APTIAN	7580			
LATE BARREMIAN?	7590			
LATE TO ? MIDDLE BARREMIAN	7610			
MIDDLE OR ? EARLY BARREMIAN	7640			
MIDDLE BARREMIAN- ? LATE HAUTERIVIAN	7660			
BARREM. OR HAUTERIV.	7670			
EARLIEST HAUTERIVIAN	7700			
EARLIEST HAUTERIVIAN	7710			
EARLIEST HAUTERIVIAN	7720			
EARLIEST HAUTERIVIAN	7730			
EARLIEST HAUTERIVIAN	7780			
EARLIEST HAUTERIVIAN	7800			
OR LATE VALANGINIAN	7850			
VALANGINIAN	7870			
EARLIEST VALANGINIAN	7910			
VALANGINIAN	7940			
EARLIEST VALANGINIAN	7950			
VALANGINIAN	7980			
EARLIEST VALANGINIAN	8020			
VALANGINIAN	8100			
EARLIEST VALANGINIAN	8170			
VALANGINIAN	8250			
EARLIEST VALANGINIAN	8320			
VALANGINIAN	8400			
EARLIEST VALANGINIAN	8430			
VALANGINIAN	8460			
LATE RYAZANIAN	8500			
EARLIEST RYAZANIAN	8550			
RYAZANIAN	8600			
EARLIEST RYAZANIAN	8650			
RYAZANIAN	8700			
EARLY RYAZANIAN	8750			
- LATE VOLGANIAN	8800			
LATE TO MIDDLE VOLGANIAN	8850			
FARSUND FORM.	9000			
LATE TO MIDDLE VOLGANIAN	9150			
LEEK MB.				
VALHALL FORMATION				
TUXEN FORMATION				
SOLA FORMATION				
RODDBY				

- Cyclonephelium membraniphorum* 1
- Spinif. ramosus* - *S. multibrevis* gr. 2
- Pterospermella* spp. 3
- Odontochitina operculata* 4
- Hystriochodinium voigtii* 5
- Chlamydroporella nyei* 6
- Ascodinium scabrosum* 7
- Carpodinium obliquicostatum* 8
- Litosphaeridium arundum* 9
- Litosphaeridium conispinum* 10
- Gonyaulacysta cassidata* 11
- Apteodinium grande* 12
- Litosphaeridium siphoniphorum* 13
- Oligosphaeridium complex* 14
- Dinopterygium cladoides* 15
- Carpodinium granulatum* 16
- Isabelidinium gallium* 17
- Psalignonyaulax delandrei* 18
- Tasmanites* spp. 19
- Aptea polymorpha* - *A. securigera* gr. 20
- Cerbia tabulata* 21
- Cyclonephelium hystrix* 22
- Cribroperid. edwardsii* - *C. orthoceras* gr. 23
- Subtilisphaera ventriosa* 24
- Calliaiosphaeridium asymmetricum* 25
- Dingodinium cerviculum* 26
- Achomosphaera ? neptunii* 27
- Diacanthum tenuiceras* 28
- Chlamydroporella trabeculosa* 29
- Trichodinium castanea* 30
- Endoscrinium campanula* 31
- Kleithriasphaeridium eoinodes* 32
- Sirmiodinium grossii* 33
- Cassiculosphaeridia reticulata* 34
- Phoberocysta neocomico* 35
- Protoellipsoidinium spinosum* 36
- Cribroperidinium boreas* 37
- Fromea amphora* 38
- Pseudoceratium pelliferum* 39
- Batioladinium longicornutum* 40
- Subtilisphaera perlucida* 41
- Prolixosphaeridium parvispinum* 42
- Diphasiosphaera stolidota* 43
- Florentinia mantellii* 44
- Exiguosphaera plectilis* 45
- Dapsilidinium multispinosum* 46
- Muderongia parvata* 47
- Maduradinium ? sp. A Davey 1982a* 48
- Cassiculosphaeridia magna* 49
- Gonyaulacysta exanguia* 50
- Stephodinium coronata* 51
- Trichodinium speetonense* 52
- Kleithriasphaeridium corrugatum* 53
- Heslertonia pellucida* 54
- Cribroperidinium ? comutum* 55
- Hystriochosphaerina schindewolfii* 56
- Waliodinium anglica* 57
- Gonyaulacysta diutina* - *G. helicoidea* gr. 58
- Heslertonia heslertonensis* 59
- Rhynchodiniopsis aptiana* 60
- Occiscycta tentoria* 61
- Ellipsoidinium reticulatum* 62
- Ellipsoidictyum imperfectum* 63
- Coronifera oceanica* 64
- Avellodinium falsificum* 65
- Discorsia nanna* 67
- Fromea quadrugata* 68
- Muderongia staurota* 69
- Spiniferites speetonensis* 70
- Calliaiosphaeridium trycherium* 71
- Muderongia tetracantha* 72
- Phoberocysta tabulata* 73
- Muderongia simplex* 74
- Chlamydroporella ? membranoides* 75
- Spiniferites ? dentatus* 76
- Hystriochosphaeridium scoriceum* 77
- Batioladinium ? pelliferum* 78
- Pterodinium premnon* 79
- Gonyaulacysta kostromiensis* 80
- Kleithriasphaeridium fasciatum* 81
- Cribroperidinium sepimentum* 84
- Nematosphaeropsis scala* 85
- Spiniferites ramosus* subsp. *primaevus* 86
- Gonyaulacysta ? fastigiata* 87
- Batioladinium micropodum* 88
- Batioladinium sp. I Davey 1982a* 89
- Isthmocystis distincta* 90
- Lagenorhysis delicatula* 91
- Muderongia simplex* subsp. *microperforata* 92
- Pseudoceratium sp. 1* 93
- Cymososphaeridium sp. I Davey 1982a* 94
- Oligosphaeridium asterigerum* 95
- Batioladinium varigranulosum* 96
- Surculosphaeridium sp. III Davey 1982a* 97
- Tubotuberella apatela* 98
- Ctenidodinium elegantulum* 99
- Gochteodinia villosa* subsp. *multifurcata* 100
- aff. *Bourkidinium granulatum* 101
- Waliodinium cylindricum* 102
- Dingodinium jurassicum* 103
- Endoscrinium pharo* 104
- Chytroelsphaeridia chytroelides* 105
- Sirmiodiniopsis frisia* 106
- Gocht. villosa* subsp. *villosa* et subsp. indet. 107
- Dingodinium tuberosum* 108
- Occiscycta evittii* 109
- Surculosphaeridium sp. I Davey 1982a* 110
- Egmontodinium tornyum* 111
- Aldoria spongiosa* 112
- Ctenidodinium panneum* 113
- Canningia compta* 114
- Exiguosphaera phragma* 115
- Batiolad. cf. varigranulosum* sensu Davey 1982a 116
- Systematophora palmula* 117
- Systematophora vestita* 118
- Systematophora cf. areolata* sensu Davey 1982a 119
- Mendicodinium groenlandicum* 120
- Dingodinium spinosum* 121
- Perisseiasphaeridium pannosum* 122
- Prolixosphaer. granulosum* s. loann. et al. 1977 123
- Oligosphaeridium diluculum* 124
- Kleithriasphaeridium porosispinum* 125
- Valensiella ovula* 126
- Gonyaulacysta sp. A Davey 1982a* 127
- Endoscrinium granulatum* 128
- Stipho. anthrophorum* - *S. dictyophorum* group 129
- Stiphosphaeridium arbustum* 130
- Batioladinium pomum* 131
- Senoniasphaera jurassica* 133
- Waliodinium krutzschii* 134
- Oligosphaeridium sp. GE McInt. & Brid. 1980* 135
- Egmontodinium expiratum* 136
- Cannosphaeropsis thula* 137
- Gonyaulacysta centriconnata* 138
- Systematophora sp. I Davey 1982a* 139
- Gonyaulacysta jurassica* 140
- Cribroperidinium sp. A Davey 1982a* 141
- Cribroperidinium ? gigas* 142
- Dichadogonyaulax culmula* 143
- Kalypetea diceras* 144
- Pareodinia ceratophora* 145

Frequency:  
 ■ abundant (usually > 10 spec.)  
 ■ intermediate (usually 2-9 spec.)  
 ■ one specimen  
 ? doubtful  
 ? identification  
 Occurrences considered as reworked:  
 □ 2-9 specimens  
 □ one specimen

LATE CRETACEOUS  
 LT. ALBIAN OR LT. CRET.  
 LATE ALBIAN  
 LATE OR MIDDLE ALBIAN  
 LATE APTIAN?  
 APTIAN  
 LATE BARREMIAN?  
 LATE TO ? MIDDLE BARREMIAN  
 MIDDLE OR ? EARLY BARREMIAN  
 MIDDLE BARREMIAN- ? LATE HAUTERIVIAN  
 BARREM. OR HAUTERIV.  
 HAUTERIVIAN  
 EARLIEST HAUTERIVIAN  
 EARLIEST HAUTERIVIAN  
 OR LATE VALANGINIAN  
 VALANGINIAN  
 EARLIEST VALANGINIAN  
 VALANGINIAN  
 LATE RYAZANIAN  
 EARLIEST RYAZANIAN  
 RYAZANIAN  
 EARLY RYAZANIAN  
 - LATE VOLGANIAN  
 LATE TO MIDDLE VOLGANIAN



*tis distincta* which is also present in the subsequent samples, and on the presence of *Spiniferites ramosus* subsp. *primaevus*. A questionable *Batioladinium varigranosum* supports an earliest Hauterivian age, since it is recorded as high as the *amblygonium* Zone by Duxbury (1977).

The first appearance of undoubted *Gonyaulacysta kostromiensis* and *Nematosphaeropsis scala* also take place at 7730'. These highest occurrences are anomalously low; however, affinity to the earliest Hauterivian appears to be stronger than to younger parts of the Hauterivian.

*Batioladinium* sp. I of Davey (1982a) is probably not reworked since it is present in most samples from 7730' to 8170'.

7760'–7850'. The first downhole appearance at 7760' and consistent presence in the subsequent samples of *Lagenorhysis delicatula* is considered to be a strong indication that earliest Hauterivian or older strata are present. Very little is known about dinoflagellate distribution during the Late Valanginian, as has been discussed in the previous section. *Muderongia simplex* subsp. *microporata* and a questionable *Surculosphaeridium* sp. III of Davey (1982a), which are also present at 7760', are previously found only in the Lower Valanginian, but more distinct Lower Valanginian markers do not appear until 7870', and the presence of the two species may equally indicate younger parts of the Valanginian. Single specimens of *Batioladinium* cf. *varigranosum* sensu Davey (1982a) at 7760' and of *Pareodinia ceratophora* at 7800' are considered as reworked. The first downhole occurrence of *Oligosphaeridium asterigerum* at 7850' is lower than expected.

7870'. The highest occurrence of a number of prominent markers takes place here. Of these, *Gochteodinia villosa* subsp. *multifurcata* and *Batioladinium varigranosum* are known to range as high as the earliest Hauterivian. The Valanginian age is based on the downhole appearance of *Tubotuberella apatela* and undoubted *Surculosphaeridium* sp. III of Davey (1982a), and is supported by the presence of *Ctenidodinium elegantulum* and *Dingodinium jurassicum*. The latter two species have well defined highest occurrences in the I-1 well in the interval assigned as Valanginian above earliest Valanginian.

Earliest Valanginian markers only appear in the underlying samples and an age younger than the earliest Valanginian can therefore be assigned. One species marking the earliest Valanginian, namely *Occisucysta evittii*, does occur here. It is not consistently present until 8100' (or even 8250') and is therefore considered to be reworked.

7910'–8100'. The earliest Valanginian age assigned to this considerable interval (comparable to the thickness of the earliest Valanginian in the I-1 well) is based on the first downhole appearances of several species

which have their highest known on-shore occurrence in the *Paratollia* Zone at Speeton. Furthermore, Ryazanian markers do not appear until 8170' and beneath. The age assignment therefore appears to be well established.

The species on which the age is based and some of the other species occurring in this interval are now considered: *Endoscrinium pharo*, *Sirmiodiniopsis frisia* and *Chytroeisphaeridia chytrooides* appear at 7910'. *E. pharo*, which occurs regularly in the subsequent samples, is a distinct marker of the *Paratollia* Zone and older strata at Speeton. *S. frisia*, reported by Raynaud (1978) to have a highest occurrence at the Middle-Upper Valanginian boundary in the North Sea area appears downhole simultaneously with *Endoscrinium pharo* in the I-1 well. *Chytroeisphaeridia chytrooides* is closely related to *C. cerastes*, which is recorded in the earliest Valanginian at Speeton.

*Occisucysta evittii* is sporadic from 7940' to 8100' and may possibly be reworked since according to Davey (1979c) it occurs consistently in the earliest Valanginian.

*Egmontodinium torynum* appears at 7950', and *Aldorfia spongiosa* at 7980'. *Ctenidodinium panneum*, present at 8020' and 8100', is usually considered to be restricted to the Kimmeridgian-Middle Volgian where it may be frequent, and is therefore possibly reworked. It should be noted, however, that questionable *C. panneum* also occur in the Valanginian of the I-1 well. According to Davey (1982a) the range of *Canningia compta*, appearing at 8020', is Middle Volgian – earliest Valanginian. A single specimen of *Kalyptea diceras* in this sample is considered reworked from the Middle-Late Volgian.

*Batioladinium* cf. *varigranosum* sensu Davey (1982a) appears at 8100'. A single specimen in this sample of *Senoniasphaera jurassica* is considered as reworked, since according to Raynaud (1978) and Davey (1979c) it is restricted to the Volgian and Kimmeridgian.

8170'–8320'. The earliest Valanginian or Late Ryazanian age is based on the questionable presence of the Ryazanian marker *Dingodinium spinosum* at 8170' and 8250'. Safely identified specimens are not encountered until 8400'.

*Systematophora palmula*, also appearing at 8170', appears in the I-1 well simultaneously with in situ *D. spinosum*.

8400'–8460'. The Late Ryazanian age is based on the highest undoubted occurrence of *Dingodinium spinosum* at 8400' and its regular occurrence in the subsequent samples.

8500'–8600'. Late Ryazanian, probably coeval to the *stenomphalus* Zone. The age is based on the appearance and abundance at 8500' of *Oligosphaeridium diluculum*, which is only known with certainty from the *stenomphalus* Zone in Eastern England (Davey 1982a). It is supported by the regular occurrence of *Canningia*

*compta* at 8500' and below, and by the presence of *Kleithriasphaeridium porosispinum* and *Stiphrosphaeridium arbustum*. *S. arbustum* has previously been recorded only from the *icenii* – *stenomphalus* Zones in Eastern England.

At 8500' a marked change in facies indicates penetration of the Farsund Formation. A similar change in facies is observed between 10970' and 11000' in the I-1 well and according to Costa (1981) and Davey (1982a) also when penetrating the Kimmeridge Clay facies (including the Farsund Formation) throughout the North Sea Basin. The change is marked by a sharp increase in the amount of sapropelic organic matter and by the regular occurrence of the facies-dependant *Pterospermella* spp. which are not recorded in the immediately overlying deposits. *Pterospermella* becomes abundant from 8750' and to the base of the studied interval. Furthermore, a sharp downwards increase and subsequent abundance of *Tasmanites* spp. takes place between 8550' and 8600'.

8650'. This age of this interval is interpreted as Ryazanian although several specimens of *Senoniasphaera jurassica* occur at 8650'. According to Raynaud (1978) and Davey (1979c), *S. jurassica* indicates a Middle Volgian or older age. This species is absent, however, in the underlying samples, and reliable Lower Ryazanian markers do not appear until 8700'. Therefore *S. jurassica* may either be reworked here, or it may have been sporadically present during the Ryazanian. *Batioladinium pomum*, which also occurs at 8650', is seen in bed D7G (?*stenomphalus* Zone) at Speeton in this study. *Stiphrosphaeridium dictyophorum* in the same sample is very common in the Lower Ryazanian in Eastern England.

8700'–8850'. The first downhole occurrence at 8700' of *Cannosphaeropsis thula* and *Egmontodinium expiratum* clearly points to an Early Ryazanian-Late Volgian age. *C. thula* is previously recorded as common from the upper part of the Middle Volgian to the Lower Ryazanian in Eastern England while *E. expiratum* in Eastern England ranges from Middle Volgian to lowermost Ryazanian (*runctoni* Zone) (Davey 1982a). According to Raynaud (1978) *Cribroperidinium? gigas* (a questionable specimen) is restricted to the Volgian in the North Sea area. *Systematophora* sp. I of Davey (1982a), which is present at 8850' and in the subsequent samples, is recorded by Davey (1982a) from the Kimmeridgian-Early Ryazanian in Eastern England and is especially common in the Kimmeridgian-Portlandian.

The presence of *Gonyaulacysta jurassica* at 8850' and in the subsequent samples is noteworthy. According to Raynaud (1978) and Riding (1984) the highest *in situ* occurrence of this species is in the lower part of Middle Volgian. As it is a frequent species in the Upper Jurassic, the presence both here and in the interval assigned the same age in the I-1 well may possibly be due to reworking.

Side-wall core at 8992' (fig. 6). The presence of *Egmontodinium expiratum* and of frequent *Tasmanites* points to an Early Ryazanian or Late Volgian age (Davey 1982a) as was indicated by the cutting samples above. *Kleithriasphaeridium fasciatum* is not previously recorded below the uppermost Ryazanian and the presence of this species is possibly due to drilling-mud contamination.

9000'–9150'. The Late to Middle Volgian age is based on the appearance of *Cribroperidinium* sp. A of Davey (1982a) at 9000' and of undoubted specimens of *Cribroperidinium? gigas* at 9150'. *Cribroperidinium* sp. A is recorded by Davey (1982a) from the Middle and Upper Volgian in England, and *C.? gigas* is reported to occur in the Lower and Middle Volgian in the North Sea area (Raynaud 1978).

Side-wall core at 9170' (fig. 6). The age is Middle Volgian, based on the presence of *Ctenidodinium panneum*, *Aldorfia* sp. A of Davey (1982a) and *Gochteodinia virgula*. *G. virgula* is previously known from both the Middle and Upper Volgian while, according to Davey (1982a), *Aldorfia* sp. A is relatively common in the upper Middle Volgian *kerberus* and *anguiformis* Zones in Lincolnshire, England. The last occurrence of *C. panneum* is in the *anguiformis* Zone.

Side-wall cores at 9378' and 9542' (fig. 6). The analysis and age interpretation of these two samples has been carried out by Niels Poulsen, Geological Survey of Denmark. The age is Early or early Middle Volgian based on the occurrence of *Cribroperidinium? gigas* and *Muderongia* sp. A of Davey (1982a), both with a known range within the Lower and Middle Volgian, and *Meristaulax granulata*, which is not recorded above the lower part of Middle Volgian.

## The I-1 well

### Summary of age determinations

ditch cutting samples,  
depths below kelly  
bushing

9340'	Late Cretaceous
9360'	Albian
9370'	Albian, probably earliest Albian
9380'–9420'	earliest Albian or Aptian
9440'	Aptian
9460'	earliest Aptian
9480'	Late Barremian
9490'–9520'	middle Barremian
9540'–9660'	middle or Early Barremian
9760'–9780'	Early Barremian or Late Hauterivian
9810'–9850'	Late Hauterivian?
9870'–9900'	Hauterivian (probably earliest Late Hauterivian or older)

Fig. 7. Dinoflagellates in ditch cuttings of the I-1 well. ▶



9960'–10 020'	Early Hauterivian
10 090'–10 220'	Earliest Hauterivian – ?Late Valanginian
10 290'–10 470'	Valanginian, younger than earliest Valanginian
10 530'–10 750'	Earliest Valanginian (coeval to <i>Paratollia</i> Zone)
10 770'–10 790'	Late Ryazanian
10 810'–10 970'	Ryazanian
11 000'–11 120'	Early Ryazanian
11 150'–11 300'	Late Volgian
<hr/>	
core 5, driller's depths below Kelly bushing	age
<hr/>	
9495'–9524'	middle Barremian – earliest Aptian
9539'	Near Early – middle Barremian boundary
<hr/>	

### Discussion of ages

Most of the dinoflagellates recorded from the I-1 well are shown in the range charts (figs. 7, 8). The ages are interpreted as follows (unless specified otherwise samples are ditch cutting samples):

9340'. The dinoflagellate assemblage in this sample is enriched with Tertiary species due to drilling mud contamination, and only includes few *in situ* species. Of these, *Cyclonephelium membraniphorum* indicates a pre-Campanian age (Foucher 1979). The Late Cretaceous age is based on the absence of Albian markers, which have highest occurrences in the underlying samples.

9360'. The Albian age is based on the presence of *Diacanthum tenuiceras*. However, more distinct Albian markers are not encountered until the next sample.

9370'. The age is probably earliest Albian since *Dinodinium cerviculum* is recorded in this sample. However, the sample also includes the first downhole occurrence of the Late Albian markers *Carpodinium granulatum* and questionable *Ascodinium scabrosum*, and of the Middle Albian marker *Cauca parva*. A more typical earliest Albian or Aptian assemblage does not appear until the next sample, and a condensed younger Albian sequence is probably present between 9370' and 9360'.

9380'–9420'. The earliest Albian or Aptian age is based on the first downhole occurrence of the three earliest Albian markers *Protoellipsodinium clavulum* and *Aptea polymorpha* (at 9380') and *Kleithriasphaeridium eoinodes* (at 9420'). *Aptea polymorpha* becomes abundant at 9420' and in the underlying samples. *Lepodinium cancellatum*, which is present at 9400' and 9420', was previously found near the Aptian/Albian boundary in Northwest Germany and in the northern North Sea (Davey 1982b). A single specimen of *Chlamydothorella membranoidea* at 9380' may support an Aptian rather than earliest Albian age. Minor reworking of Valanginian or older sediments is indicated by a single specimen of *Tubotuberella apatela*.

9440'. The age assignment of this sample is problematical. A single specimen of *Cassiculosphaeridia magna* points to a Barremian age since this species has not previously been recorded above the Barremian. Furthermore, *Spiniferites dentatus* (a single specimen) has only been recorded once above the middle Barremian, namely in the Upper Aptian of Northwestern Germany (Below 1982d). Since earliest Aptian markers are not met with until the next sample, the age is assigned to the Aptian, and *C. magna* and *S. dentatus* are considered as probably reworked.

9460'. The earliest Aptian age is based on the first downhole occurrence of *Phoberocysta neocomica*. This species occurs as high as the earliest Aptian *forbesi* ammonite zone on the Isle of Wight, southern England (Duxbury 1983), and the absence of this characteristic species above the *forbesi* Zone is well documented.

9480'. The appearance of several specimens of *Cassiculosphaeridia magna*, and a questionable specimen of *Avellodinium falsificum* indicate penetration of Barremian strata. A single specimen of *Apteodinium grande* must result from caving since this species is restricted to the Middle-Late Albian.

9490'–9540'. A middle–Early Barremian assemblage is present in the sample at 9490'. This assemblage includes in particular *Kleithriasphaeridium corrugatum*, *Cribopteridinium cornutum*, *Fromea quadrugata*, *Trichodinium speetonensis*, *Muderongia staurota*, *Hystrichosphaerina schindewolfii* and *Pseudoceratium pelliiferum*. Of these *P. pelliiferum* and *H. schindewolfii* are known to range into the Early Aptian and earliest Albian respectively, but the others are absent above the Barremian. *K. corrugatum* has not been reported higher than the lower part of the middle Barremian, and it therefore seems that middle Barremian strata are penetrated at 9490'. *Hystrichodinium ramoides* at 9510' is typical for the middle-Late Barremian.

9540'–9660'. The assemblage in the ditch cuttings at 9540' still has a middle Barremian aspect: *Trabeculodinium quinquetrum* which is relatively common, is restricted to the middle Barremian at Speeton (Duxbury 1980). A questionable *Hystrichodinium furcatum* probably points to the lower part of middle Barremian, or older strata. Despite this apparently clear middle Barremian age indication in the 9540' – ditch cuttings, the age of the interval is given as middle or Early Barremian on the basis of the core sample at 9539' (see below).

The samples from 9580' to 9660' only include relatively few dinoflagellates, and species already recorded above are present. (A questionable *Cerbia tabulata* at 9580' suggests that strata of middle Barremian age are possibly still present). A single *Nannoceratopsis gracilis* at 9600' is reworked from Lower-Middle Jurassic strata.

I-1 CORE 5		FORMATION		Driller's depth (feet below KB)	Cribroperid. edwardsii - C. orthoceras group	Apteodinium granulatum	Pseudoceratium pelliferum	Cyclonephelium hystrix	Cassiculosphaeridia reticulata	Phoberocysta neocomica	Spiniferites ramosus	Dingodinium cerviculum	Heslertonia pellucida	Hystriochodinium voigtii	Protoellipsoidinium spinosum	Odontochitina operculata	Oligosphaeridium complex	Occiscyusta tentoria	Protoellipsoidinium clavulum	Cassiculosphaeridia magna	Kleithriasphaeridium fasciatum	Prolixosphaeridium parvispinum	Chlamydomphorella nyei	Callaiosphaeridium trycherium	Muderongia tetracantha		
		Age	TUXEN FORMATION																								
Legend: as fig. 5 DGU 0187 CHC		FORMATION		9495	■	■	■	■	■	■	?																
		FORMATION		9499								?															
		EARLY APTIAN- MIDDLE BARREMIAN		FORMATION		9507		■						■	■	■											
				FORMATION		9513																					
				FORMATION		9520			■			■					■	■	?	?							
				FORMATION		9524			?	■		■							■	■		■					
				FORMATION		9539	■		■	■								■	■			■	■	■	■	?	?
		MIDDLE OR EARLY BARREMIAN		FORMATION																							

Fig. 8. Dinoflagellates in core 5 of the I-1 well. The sample at 9513' is palynologically barren.

### Core 5

This core falls entirely in the Tuxen Formation. The top of this formation is defined at 9507' on wire-line logs (Jensen et al. 1986). According to the driller's depths used in the present study, core 5 covers the interval 9495' to 9539'. Consequently the top of the Tuxen Formation as defined on wire-line logs should be corrected upwards at least 12' in order to agree with driller's depths.

The organic particles (including the dinoflagellates) are corroded in most of the core samples but a number of stratigraphically significant species have been identified (fig. 8).

Core samples at 9495'–9524' (driller's depths). The assemblage in these samples is characteristic of middle Barremian – Early Aptian. Abundant *Odontochitina operculata* in the lowermost two samples points to an age no older than Early Barremian, while *Protoellipsoidinium clavulum* at 9524' is not recorded below middle Barremian.

Core sample at 9539' (driller's depth). The presence of *Kleithriasphaeridium fasciatum* points to an age no younger than the earliest part of the middle Barremian. On the other hand the abundance of *Odontochitina operculata* indicates that the age cannot be much older than the boundary between Early and middle Barremian.

### Caving

The core samples permit evaluation of the amount of specimens resulting from caving in cutting samples of the same interval and below. The presence of *Aptea polymorpha* in these cutting samples is clearly due to caving, as this species is absent in the core. *A. polymorpha* is restricted to the Aptian and basal Albian in

on-shore sections, and the significant numbers of this species down to 10 470' shows that considerable caving of Aptian layers has taken place during drilling of this sequence. The important amount of *Odontochitina operculata* down to 10 020' may also be derived from this caving since its lowermost on-shore occurrence is in the Lower Barremian.

9760'–9780' (ditch cuttings). The assemblage continues to be poor in this interval, and no age diagnostic species are present. The Early Barremian or Late Hauterivian age is based on age determinations above and below.

9810'–9850'. From 9820' the assemblages gradually become richer until 9870'. At 9810' and 9820' questionable specimens of *Canningia* cf. *reticulata* sensu Duxbury (1977) suggest that Upper Hauterivian strata are possibly penetrated, since this species is only known in the Upper Hauterivian – lowermost Barremian from Speeton (Duxbury 1977). At 9850' and in the subsequent samples *Oligosphaeridium asterigerum* is present and locally abundant. This species has a Hauterivian-Lower Barremian range at Speeton, but is recorded in younger strata in Northwestern Germany. This and the underlying sample include *Oligosphaeridium* sp. 1 which is restricted to this interval and was not recorded in the I-1 well. *Oligosphaeridium* sp. 1 is a distinct form. It is not known from on-shore sections and therefore cannot be used as an age-indicator.

Reworking of Upper Jurassic strata at 9830' is indicated by *Glossodinium dimorphum* and *Gochteodinia mutabilis*, and reworking from the earliest Valanginian or Ryazanian is indicated at 9850' and 9900' by *Egmontodinium torynum*.

9870'–9900'. The age is assigned as Hauterivian, probably earliest Late Hauterivian or older, on the

basis of the following downhole appearances: *Gonyaulacysta* cf. *cladophora* sensu Duxbury (1977) appears at 9870' and is frequent here and in the underlying samples. This species is characteristic of the Lower Hauterivian (Davey 1979c, 1982a) although it is recorded as high as Lower Barremian by Duxbury (1977). At 9900' *Gonyaulacysta perforobtus* indicates an early Late Hauterivian (coeval to *speetonensis* Zone) or older age (Duxbury 1977). *Cymosphaeridium validum* also appears and has previously been reported from the Hauterivian of the North Sea (Davey 1982a). In this study it is also seen in the Lower Hauterivian at Speeton. The Hauterivian marker, *Gonyaulacysta kostromiensis* is consistently present, and locally abundant, from 9900' and below. Both here and in the Adda-1 well the highest occurrence of this species is unusually low compared to the on-shore range.

**Reworking:** The earliest Hauterivian marker *Gochteodinia villosa* subsp. *multifurcata* may be represented by single specimens of this species (subsp. indet.) at 9870' and 9900', but these are considered reworked since they only occur regularly from 10 090', and other earliest Hauterivian markers do not occur until below 10 090'. A single *Cannosphaeropsis thula* at 9900' is reworked from Upper Kimmeridgian-Ryazanian strata.

9960'–10 020'. There is good evidence that Lower Hauterivian strata are penetrated at 9960' since the first downhole occurrence of *Nematosphaeropsis scala*, a distinct marker of the lowermost Upper Hauterivian (*speetonensis* Zone) or older strata, and of *Gonyaulacysta ordocava*, previously only recorded from the Lower Hauterivian, take place here.

Reworking of Volgian or Ryazanian deposits is proven at 9960' by *Dingodinium spinosum*. A single specimen of *Sirmiodiniopsis frisia* in this sample is also considered as reworked. Increased reworking of Volgian to Lower Valanginian sediments is indicated at 10 020' by *Occisucysta evittii*, *Endoscrinium pharo*, *Tubotuberella apatela* and *Cannosphaeropsis thula*.

10 090'–10 220'. The earliest Hauterivian (probably coeval to *amblygonium* Zone) – ?Late Valanginian age of this interval is clearly indicated by the downhole appearance of *Gochteodinia villosa* subsp. *multifurcata* and *Phoberocysta tabulata* at 10 090', of *Lagenorhysis delicatula* and *Kleithriasphaeridium* sp. 1 at 10 160', and of *Muderongia extensiva*, *Isthmocystis distincta*, *Spiniferites ramosus* subsp. *primaevus*, *Muderongia* sp. 1 and *Pseudoceratium* sp. 1 at 10 220'. *G. villosa* subsp. *multifurcata*, *Muderongia extensiva* and *Isthmocystis distincta* are prominent earliest Hauterivian markers allowing safe interpretation of the age, despite the considerable amount of reworking in this part of the well. *Muderongia* sp. 1 and *Pseudoceratium* sp. 1 are not recorded on-shore above the Valanginian, but in the Adda-1 well they also make their first downhole occurrence together with Hauterivian markers.

The downhole appearance of *Muderongia simplex* at 10 160' is noteworthy. As mentioned in the previous section, this species seems to be rare in the uppermost Hauterivian and Barremian. The highest record of *M. simplex* in the Adda-1 well is also in the Hauterivian, although apparently in a younger part.

Since so little is known about the distribution of dinoflagellates in the Upper Valanginian in Northwestern Europe, it cannot be excluded that the interval between 10 090' and 10 220' may also include Upper Valanginian strata. However, the successive appearance of earliest Hauterivian markers throughout this interval favours a Hauterivian age.

Like above, a considerable amount of reworked Volgian to Lower Valanginian sediments is present in this interval. This is confirmed by three species having highest *in situ* occurrences in the Lower Valanginian, namely *Tubotuberella apatela* (rare), *Aldorfia spongiosa* (one specimen) and *Occisucysta evittii*. Also *Egmontodinium expiratum*, which has a known range of Middle Volgian to basal Ryazanian is reworked.

10 290'–10 470'. The Valanginian age, younger than earliest Valanginian *Paratollia* Zone, is based on the following events:

- The first downhole occurrence at 10 290' and the regular presence in the underlying samples of *Surculosphaeridium* sp. III of Davey (1982a) and of *Muderongia simplex* subsp. *microperforata*.
- The regular and common occurrence of *Tubotuberella apatela* from 10 340' and below.
- The presence of *Batioladinium varigranosum* at 10 410'.

Of these species, *Surculosphaeridium* sp. III and *T. apatela* are regarded as most reliable Valanginian markers, while *Batioladinium varigranosum* is recorded on-shore also in the lowermost Hauterivian. The well defined first downhole appearance and regular occurrence beneath, of *Surculosphaeridium* sp. III and *T. apatela* is taken as evidence that these species are *in situ* and not reworked here.

Distinct markers of the lowermost Valanginian *Paratollia* Zone do not occur until the underlying interval, and the presence of a number of Ryazanian and Upper Jurassic species points to considerable reworking. Species considered reworked include:

- At 10 290': *Oligosphaeridium pulcherrimum* sensu Ioannides et al. (1971), with a known range within the Kimmeridgian (Raynaud 1978, Davey 1982a).
- At 10 340': *Glossodinium dimorphum* (Oxfordian-Middle Volgian, Woollam & Riding 1983).
- At 10 410': *Cannosphaeropsis thula* (uppermost Kimmeridgian-Upper Ryazanian, Davey 1982a).
- At 10 470': *Criproperidinium* sp. A of Davey (1982a) (abundant in the Middle-Upper Volgian in Eastern England, Davey 1982a), *Oligosphaeridium diluculum* (Upper Ryazanian), *Gochteodinia virgula* (Middle-Upper Volgian), *Batioladinium pomum* (up-

permost Volgian – Ryazanian), *Dingodinium spinosum* (Middle Volgian- top Ryazanian) and *Perisseiasphaeridium pannosum*, the precise Upper Jurassic range of which is uncertain.

The occurrence of three additional taxa in this interval deserves comments: There is a distinct highest occurrence of *Ctenidodinium elegantulum* in the Valanginian both in the I-1 and the Adda-1 wells. This top may be of local correlative value, although this species is known to range into the Lower Aptian on-shore.

The first downhole appearance of *Dingodinium jurassicum* in both I-1 and Adda-1 may also be a useful feature for correlation. *D. jurassicum* has previously been indicated to have a highest occurrence in the Middle Volgian (Raynaud 1978).

*Chytroeisphaeridia cerastes*, which is present at 10 470' and 10 750', is also recorded near the Ryazanian-Valanginian boundary at Speeton, and the range of this species, originally described from the Oxfordian, may therefore extend into the Valanginian.

10 530'–10 750'. The earliest Valanginian age of this interval is based on the first downhole appearance of *in situ* specimens of the earliest Valanginian marker *Endoscrinium pharo* at 10 530' and its regular occurrence in the samples below. Two additional species with highest occurrence in the Lower Valanginian also appear at 10 530': *Sirmiodiniopsis frisia* and *Cymosphaeridium* sp. I of Davey (1982a).

The occurrence of *Occisucysta evittii* at 10 530' is considered to be *in situ* since it is also present in most of the underlying samples. *O. evittii*, like *E. pharo* has a well documented youngest occurrence in the basal Valanginian *Paratollia* Zone at Speeton. Two further Early Valanginian and older species also appear at 10 570': *Canningia compta* and *Surculosphaeridium* sp. II of Davey (1982a).

Reworking of older sediments is still present, but in this interval appears to be less important than above: *Cannosphaeropsis thula* at 10 530' indicates reworking of uppermost Kimmeridgian- mid Ryazanian deposits. A single specimen of the top Ryazanian marker *Dingodinium spinosum* at 10 730' is also considered as reworked since this species is not consistently present and common until 10 770' and below.

10 770'–10 790'. The downhole appearance of several specimens of *Dingodinium spinosum* at 10 770' and the consistent presence of this species in the subsequent samples indicates the penetration of Ryazanian strata at this depth. *Systematophora palmula*, which also occurs in this sample, is only known with certainty to range from uppermost Ryazanian to lowermost Valanginian.

10 810'–10 970'. The regular occurrence of *Cannosphaeropsis thula* from 10 810' and below suggests that Lower Ryazanian strata are penetrated here, since *C. thula* is rare in the lower part of the Upper Ryazanian, but is consistently present and common in the Lower

Ryazanian in Eastern England (Davey 1982a). The presence of *Egmontodinium expiratum* at 10 850' also suggests an Early Ryazanian age, since the highest well established occurrence of this species is in the *runctoni* ammonite zone (Davey 1982a). However, the occurrence, also at 10 850', of *Oligosphaeridium diluculum* points to a Late Ryazanian (*stenomphalus* Zone) age, since this species is only recorded with certainty in this ammonite zone in Eastern England (Davey 1982a).

Based on this somewhat conflicting evidence, the age is given as undifferentiated Ryazanian.

11 000'–11 120'. The Early Ryazanian age of this interval is based on the downhole appearance of *Stiphrosphaeridium dictyophorum* at 11 000' and its abundance at 11 060'. According to Davey (1982a) this species is very common in the Lower Ryazanian in Eastern England. The range of *Batioladinium* cf. *varigranosum* sensu Davey (1982a), only present at 11 120', is essentially Ryazanian.

Penetration of the Farsund Formation is almost certainly indicated at 11 000', although the top of this formation is defined at 11 018' on the basis of wire-line log patterns (Jensen et al. 1986). At 11 000' there is a strong increase in the amount of sapropelic organic matter. This is associated with a decrease in the dinoflagellate diversity and abundance of *Tasmanites* and *Pterospermella*, all features which usually mark penetration of the Farsund Formation (further discussed in connection with the Adda-1 well).

11 150'–11 300'. The Late Volgian age is based on the appearance of *Gochteodinia virgula* at 11 150', since this species is only known from the Middle and uppermost Volgian in Eastern England (Davey 1982a). *Systematophora* sp. I of Davey (1982a) is present at 11 300'. Although this species occurs in the Lower Ryazanian in Eastern England, it is more frequent in the Volgian (Davey 1982a).

### *The M-8 well*

Six side-wall cores spanning the Middle Volgian to Valanginian have been analysed from this well. The distribution of dinoflagellates and the interpreted age of the samples are shown in fig. 9.

#### Discussion of ages

##### Side-wall core at 7300'

Age: Valanginian, probably Early Valanginian. The assemblage includes several taxa which are characteristic of the Valanginian. The majority of these: *Lagenorhysis delicatula*, *Hystrichosphaeridium scoriaceum*, *Aldorfia spongiosa* and *Pseudoceratium* sp. 1 may possibly range into the Early Hauterivian, but are more well known from the Valanginian, and a pre-Hauterivian age is further supported by the absence of Hauterivian marker species.

*Tubotuberella apatela*, which is common, and a questionable *Sirmiodiniopsis frisia* probably point to an Early Valanginian age.

Side wall core at 7400'

The Early Valanginian age is based on the presence of *Surculosphaeridium* sp. III of Davey (1982a) and *Sirmiodiniopsis frisia*. *Exiguosphaera phragma*, which ranges into the lowermost Hauterivian at Speeton, is only common in the Adda-1 well in the lowermost Valanginian-Upper Ryazanian and supports an Early Valanginian age. A single *Kleithriasphaeridium porosipinum* is considered reworked, since other Ryazanian markers are absent.

Side-wall core at 7490'

The earliest Valanginian age is based on the highest record in this sample of *Occisucysta evittii*. *Pareodinia* sp. I of Davey (1982a) has previously been recorded in the interval assigned to the Late Ryazanian and Valanginian in the Haldager borehole (Davey 1982a). It is noteworthy that several specimens of *Chlamydophorella trabeculosa* were also recorded here. *C. trabeculosa* is not usually found below the Hauterivian although Davey (1982a: 7) considers that forms close to, or identical with, *C. trabeculosa* occur in the Valanginian.

The absence of Ryazanian markers points to a post-Ryazanian age.

Side-wall core at 7590'

Age: Ryazanian, probably equivalent to the *kochi-stenophalus* Zones. The highest occurrence of the reliable top-Ryazanian markers *Dingodinium spinosum* and *Gochteodinia villosa* subsp. *villosa* are recorded here. Frequent *Endoscrinium pharo* also points to a Ryazanian age since this species barely continues into the earliest Valanginian. The frequent occurrence of *Gonyaulacysta* sp. A of Davey (1982a) and the absence of *Muderongia simplex*, *Kleithriasphaeridium fasciatum*, *Pseudoceratium* sp. 1, *Achomosphaera neptunii*, *Phoberocysta tabulata* and *Spiniferites ramosus* (all present in the sample at 7490') clearly point to a pre-*albidum* Zone age.

The sample is very rich in sapropelic organic matter which marks penetration of the Farsund Formation between this and the overlying sample.

Side-wall cores at 7700' and 7800'

Age: Late part of Middle Volgian. The assemblages in the two samples include four distinct species whose concurrent ranges are restricted to the late part of the Middle Volgian: *Dingodinium spinosum* and *Gochteodinia villosa* make their stratigraphical first occurrence in the *okusensis-anguiformis* Zones (formerly *giganteus* Zone) (Davey 1979c, 1982a, Riding 1984), while *Egmontodinium polyplacophorum* and *Ctenidodinium panneum* become extinct above the *oppressus* Zone and *anguiformis* Zone respectively. The frequent occurrence of *Cribroperidinium* sp. A of Davey (1982a) supports this age assignment.

M-8 SIDE-WALL CORES Legend: as fig. 5 DGU 0187 CHC	Age					
	EARLY? VALANGINIAN	EARLY VALANGINIAN	EARLIEST VALANGINIAN	MIDDLE RYAZANIAN	LATE PART OF MIDDLE VOLGIAN	MIDDLE VOLGIAN
Formation	VALHALL			FARSUND		
Depth (feet below KB)	7300	7400	7490	7590	7700	7800
Facies: an=anoxic				an		an
<i>Cannosphaeropsis thula</i>			?			
<i>Glossodinium dimorphum</i>					?	
<i>Cribroperidinium</i> sp. A Davey 1982a						
<i>Egmontodinium polyplacophorum</i>						
<i>Systematophora</i> sp. I Davey 1982a						
<i>Ctenidodinium panneum</i>	?					?
<i>Oligosphaeridium diluculum</i>				?		
<i>Gochteodinia villosa</i> subsp. <i>villosa</i>						
<i>Dingodinium spinosum</i>					?	
<i>Tasmanites</i> spp.						
<i>Canningia compta</i>						
<i>Gonyaulacysta</i> sp. A Davey 1982a						
<i>Endoscrinium pharo</i>						
<i>Dingodinium tuberosum</i>						
<i>Systematophora palmula</i>			?			
<i>Perisseiasphaeridium pannosum</i>			?	?		
<i>Pareodinia</i> sp. I Davey 1982a						
<i>Occisucysta evittii</i>						
<i>Chlamydophorella trabeculosa</i>						
<i>Systematophora</i> cf. <i>areolata</i> sensu Davey 1982a						
<i>Heslertonia heslertonensis</i>		?				
<i>Surculosphaeridium</i> sp. I Davey 1982a		?				
<i>Kleithriasphaeridium porosipinum</i>						
<i>Exiguosphaera phragma</i>						
<i>Endoscrinium granulatum</i>						
<i>Spiniferites multibrevis</i>						
<i>Isthmocystis distincta</i>						
<i>Occisucysta tentoria</i>						
<i>Muderongia</i> sp. 1						
<i>Muderongia simplex</i>						
<i>Heslertonia pellucida</i>						
<i>Surculosphaeridium</i> sp. III Davey 1982a						
<i>Cassiculosphaeridia reticulata</i>						
<i>Cyclonephelium hystrix</i>						
<i>Systematophora complicata</i>						
<i>Kleithriasphaeridium eoinodes</i>						
<i>Cribroperidinium? gigas</i>						
<i>Sirmiodiniopsis frisia</i>	?					
<i>Tubotuberella apatela</i>				?		
<i>Hystrichodinium voigtii</i>						
<i>Pseudoceratium</i> sp. 1						
<i>Hystrichosphaeridium scoriaceum</i>						
<i>Trichodinium castanea</i>						
<i>Achomosphaera? neptunii</i>						
<i>Phoberocysta tabulata</i>						
<i>Gonyaulacysta diutina</i> - <i>G. helicoidea</i> group						
<i>Endoscrinium campanula</i>						
<i>Kleithriasphaeridium fasciatum</i>						
<i>Lagenorhynchus delicatula</i>						
<i>Sirmiodinium grossii</i>						
<i>Fromea amphora</i>						
<i>Dingodinium jurassicum</i>						
<i>Aldorfia spongiosa</i>						
<i>Ctenidodinium elegantulum</i>						
<i>Chlamydophorella nyei</i>						
<i>Wallodinium cylindricum</i>						
<i>Oligosphaeridium complex</i>						

Fig. 9. Dinoflagellates in side-wall cores of the M-8 well.



V-1		Formation	Depth (feet below KB) SWC = side-wall core. 8930' - 8940' = ditch cuttings	Tertiary species (contamination)	Cassiculosphaeridia magna	Spiniferites ramosus	Florentinia mantellii	Oligosphaeridium complex	Phoberocysta neocomica	Occisucysta evittii	Cyclonephelium hystrix	Hystriochodinium voigtii	Achomosphaera? neptunii	Kleithriasphaeridium fasciatum	Kleithriasphaeridium corrugatum	Phoberocysta tabulata	Kleithriasphaeridium porosispinum	Cannosphaeropsis thula	
Legend: as fig. 5 DGU 0187 CHC																			
Age																			
BARREMAIN OR OLDER		VALHALL	8942 SWC																
EARLIEST VALANGINIAN - LATE RYAZANIAN		VALHALL	8930-8940	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
EARLY RYAZ.-LT.MID. VOLGIAN		VYL FM.	8954 SWC																
		VYL FM.	9066 SWC		■														
		FARSUND	9198 SWC															■	

Fig. 10. Dinoflagellates in the V-1 well. The sample at 8942' is palynologically barren.

### The V-1 well

This is the only well in which the Vyl Formation is penetrated.

Only a poor quality set of palynological preparations were available for this study. The few dinoflagellates identified in these samples and the age determination are presented in fig. 10.

#### Discussion of ages

Side-wall core at 8942'. No dinoflagellates were recovered in the preparation from this sample.

Cutting sample at 8930'–8940'. *Cassiculosphaeridia magna* indicates an age no younger than Barremian. If not caved, *Florentinia mantellii* probably points to a Barremian age.

Side-wall core at 8954'. The age is interpreted as latest Ryazanian or earliest Valanginian, based on the frequent *Occisucysta evittii* which is not recorded above the lowermost Valanginian, and the following species which are not recorded below the uppermost Ryazanian: *Achomosphaera neptunii*, *Kleithriasphaeridium fasciatum*, questionable *K. corrugatum* and questionable *Phoberocysta tabulata*.

Side-wall core at 9066'. The presence of several specimens of *Spiniferites ramosus* points to an age no older than Late Ryazanian. Only one published occurrence in pre-Valanginian deposits is known to the present author, namely an isolated Ryazanian record at Sklinnabanken, Norway (Aarhus et al. 1986).

Side-wall core at 9190'. Abundant *Cannosphaeropsis thula* indicates a late Middle Volgian – Early Ryazanian age.

### The E-1 well

Two intervals have been investigated, from 9700' to

9740' covering the boundary between the Farsund and Valhall Formations (cutting samples), and 8181'–6''–8234'6'' covering parts of the Tuxen and Sola Formations (core 7).

#### Discussion of ages

1. Upper Farsund and lower Valhall Formation  
Birkelund et al. (1983) have previously given a biostratigraphical account of the sequence from 9700' to 9792' on the basis of ammonites, bivalves and dinoflagellates. The material studied by them included core 8 (Farsund Formation) and three cutting samples (Farsund-Valhall Formation boundary). Core 8 was referred to the *kochi* Zone (Lower Ryazanian) on the basis of ammonites, while the three cutting samples were assigned a Valanginian age on the basis of dinoflagellates.

In the present study the above-mentioned cutting samples (9700', 9720' and 9740') were reinvestigated and the age is interpreted as being latest Ryazanian (probably equivalent to *albidum* Zone). The assemblages in the three samples are very similar and they are therefore discussed together.

The assemblage recorded by Birkelund et al. (1983) and in the present study is dominated by species characteristic of the Valanginian, but with known or assumed stratigraphical first occurrence in the uppermost Ryazanian *albidum* Zone. These species include in particular *Pseudoceratium* sp. 1, *Phoberocysta tabulata*, *P. neocomica*, *Muderongia simplex*, *Kleithriasphaeridium fasciatum*, *Heslertonia heslertonensis* and *Ctenidodinium elegantulum*. An earliest Valanginian or older age is indicated especially by *Endoscrinium pharo* and *Occisucysta evittii*, while several specimens of *Dingodinium spinosum* (not recorded by Birkelund et al. 1983) are reliable evidence of age no younger than the latest

Ryazanian *albidum* Zone. *D. spinosum* is present in all three samples and for this reason it is not considered as reworked. A latest Ryazanian age is therefore assumed. *Gochteodinia villosa* subsp. *multifurcata* and *Surculosphaeridium* sp. III of Davey (1982a) not previously recorded below the Lower Valanginian, are considered as caved.

2. Upper Tuxen and lower Sola Formation (core 7) Ten samples were processed palynologically. The distribution of dinoflagellates and the interpreted age are shown in fig. 11.

#### Tuxen Formation

Of the six samples processed, only one (at 8233'3''), from the Munk Marl Bed, contained a few corroded dinoflagellates. The other five samples were palynologically barren. Only *Cassiculosphaeridia magna* was identified with certainty (known range: Upper Jurassic-top Barremian).

#### Sola Formation

8208'10''. The age is probably middle Barremian. This sample includes three species regarded as reliable indicators of Barremian or older strata. Of these species *Kleithriasphaeridium corrugatum* is not recorded above the middle Barremian, while *Cribooperidinium cornutum* is restricted to the middle and Upper Barremian. The highest known record of *Batioladinium longicornutum* is at the top of the Barremian (for possible basal Aptian occurrence of top Barremian markers, see below). Although the sample is taken only 0.5 m above the base of the Sola Formation, reworking is not likely. The lower part of the Sola Formation consists of a laminated mudstone deposited under quiet conditions. On this basis, and since several specimens of *K. corrugatum* were found, it is unlikely, that they could be reworked.

8200', 8194' and 8191'6''. Age: Barremian or possibly earliest Aptian (*fissicostatus* Zone). The age is based on the consistent presence of *Batioladinium longicornutum* which is a prominent top Barremian indicator. It should be noted, however, that no information of dinoflagellate distribution in the basal Aptian *fissicostatus* Zone of NW Europe is available, and *B. longicornutum* (like other species known up to the top of the Barremian) may possibly range into this lowermost Aptian Zone. The presence of typical *Diphasiosphaera stolidota* also points to a Barremian or *fissicostatus* Zone age. *Phoberocysta neocomica*, which is common, has not been recorded above the Lower Aptian *forbesi* Zone. It should finally be noted that none of the species known to have first occurrence in the Aptian on-shore are found in these samples.

The age determination of the Sola Formation given above is broadly in agreement with that based on calcareous nannoplankton (Thomsen in press), but differs

Lithostratigraphy	EARLIEST APTIAN (FISSICOSTATUS ZONE) OR BARREMIAN		MIDDLE BARREMIAN		BARREMIAN OR OLDER					
	SOLA FORM.	TUXEN F. MUNK MARL								
Driller's depth (below KB)	8191'6"	8194'	8200'	8208'10"	8213'	8219'	8224'4"	8229'6"	8233'3"	8234'6"
<i>Muderongia staurota</i>									?	
<i>Cassiculosphaeridia magna</i>										
<i>Kleithriasphaeridium fasciatum</i>				?						
<i>Kleithriasphaeridium corrugatum</i>										
<i>Heslertonia heslertonensis</i>									?	
<i>Cribooperidinium cornutum</i>										
<i>Exiguosphaera plectilis</i>										
<i>Muderongia</i> sp. 1										
<i>Cerbia tabulata</i>										
<i>Pseudoceratium pelliferum</i>										
<i>Trichodinium speetonense</i>										
<i>Hystrichodinium voigtii</i>										
<i>Chlamydotheca membranoidea</i>										
<i>Occisucysta tentoria</i>										
<i>Chlamydotheca ordinalis</i>										
<i>Florentinia cooksoniae</i>										
<i>Batioladinium longicornutum</i>										
<i>Odontochitina operculata</i>										
<i>Spiniferites ramosus</i>										
<i>Chlamydotheca trabeculosa</i>										
<i>Phoberocysta neocomica</i>										
<i>Diphasiosphaera stolidota</i>										
<i>Kleithriasphaeridium eoinodes</i>										
<i>Achomosphaera? neptunii</i>										
<i>Sirmiodinium grossii</i>										
<i>Endoscrinium campanula</i>										
<i>Hystrichosphaerina schindewolfii</i>										
<i>Dingodinium cerviculum</i>										
<i>Subtilisphaera perlucida</i>										
<i>Prolixosphaeridium parvispinum</i>										
<i>Florentinia mantellii</i>										
<i>Florentinia laciniata</i>										

Fig. 11. Dinoflagellates in core 7 of the E-1 well. The Tuxen Formation, apart from the Munk Marl Bed, is palynologically barren.

significantly from the age interpretation based on foraminifers in the same interval of the core (Buch 1969). According to Buch (1969) the age is early Late Aptian to Early Albian. This is based in particular on the presence of the foraminifers *Valvulineria gracillima* Ten Dam 1947 and a variety of *Gavelinella intermedia* which, according to Buch (1969), is known to range from the upper part of the Lower Aptian to the lowermost Albian. The reason for this considerable difference between dinoflagellate- and foraminifer-based age interpretations is not yet clear.

#### The Adda-2 well

Nearly 100 m of Upper Hauterivian to ?Upper Aptian strata were continuously cored (cores 1-4). Age deter-

ADDA-2 CORES 1-4		Age		LATE? APTIAN APTIAN		LATE EARLY? APTIAN EARLY EARLY APTIAN		LATE HAUTERIVIAN		GOTTSCHEI Z.	
Legend: as fig. 5 DGU 0187 CHC		Formation		RODBY OR SOLA		SO LA		TUXEN			
Driller's depth (below KB)				7753'3"		7756'		7762'		7774'	
				7781'-7808': five samples		7813'		7814'-7832': four samples		7833'	
				7838'-7852': three samples							
Ammono- nites	<i>Simbirskites (Craspedodiscus) cf. gottschei</i>										
	<i>Simbirskites</i> sp.										●
Dinoflagellates	<i>Kleithriasphaeridium corrugatum</i>										
	<i>Walloginium krutzschii</i>										
	<i>Florentinia cooksoniae</i>										
	<i>Hystrichosphaerina schindewolfii</i>										
	<i>Sirmiodinium grossii</i>										
	<i>Maduradinium</i> sp. A Davey 1982a										
	<i>Phoberocysta neocomica</i>										
	<i>Cauca parva</i>										
	<i>Heslertonia heslertonensis</i>										
	<i>Fromea amphora</i>										
	<i>Kleithriasphaeridium eoinodes</i>										
	<i>Dingodinium cerviculum</i>										
	<i>Hystrichodinium voigtii</i>										
	<i>Ellipsodinium reticulatum</i>										
	<i>Achomosphaera ramulifera</i>										
	<i>Chlamydophorella trabeculosa</i>										
	<i>Pseudoceratium pelliferum</i>										
	<i>Kiokansium polypes</i>										
	<i>Cyclonephelium hystrix</i>										
	<i>Odontochitina operculata</i>										
	<i>Spiniferites ramosus</i>										
	<i>Cepadinium variabile</i>										
	<i>Achomosphaera? neptunii</i>										
	<i>Oligosphaeridium complex</i>										
	<i>Walloginium anglicum</i>										
	<i>Prolixosphaeridium parvispinum</i>										
	<i>Florentinia laciniata</i>										
	<i>Callaiosphaeridium trycherium</i>										
	<i>Ellipsod. imperfect. - Cass. reticulata g</i>										
	<i>Aptea polymorpha - A. securigera group</i>										
	<i>Callaiosphaeridium asymmetricum</i>										
	<i>Florentinia mantellii</i>										
<i>Cerbia tabulata</i>											
<i>Muderongia parvata</i>											
<i>Spiniferites dentatus</i>											
<i>Pterodinium aliferum group</i>											
<i>Muderongia staurota</i>											
<i>Protoellipsodinium spinosum</i>											
<i>Pterodinium premnon</i>											
<i>Coronifera oceanica</i>											
<i>Stephodinium spinulosum</i>											

Fig. 12. Ammonites in cores 3-4 and dinoflagellates in core 1 of the Adda-2 well. The Tuxen Formation is palynologically barren.

mination in these cores have been carried out on the basis of ammonites in the Hauterivian and on the basis of dinoflagellates in the Aptian. All samples of the

Tuxen Formation were palynologically barren. Distribution of ammonites and dinoflagellates and the interpreted age of cores 1-4 are shown in fig. 12.

#### Discussion of ages

##### Ammonites

The occurrence of the ammonites and the interpreted age are shown in fig. 12. The specimens were identified by Birkelund and Owen and are shown in plate 17, prepared by Birkelund. *Simbirskites* sp., occurring at 7812'6"-7813', indicates the Upper Hauterivian, while *Simbirskites (Craspedodiscus) cf. gottschei*, at 7833'-7833'6"', indicates the *gottschei* Zone (middle part of the Upper Hauterivian). According to Owen (written communication 1985), *Simbirskites (Craspedodiscus) gottschei* is restricted to its zone, which is represented both in Eastern England and Northern Germany, and in his opinion there is little doubt that the sediments containing *S. cf. gottschei* in Adda-2 can be correlated with this widely represented *gottschei* Zone interval.

##### Dinoflagellates

##### Tuxen Formation

Twelve samples were processed palynologically and proved essentially barren; no dinoflagellate species could be identified.

##### Sola Formation

In contrast to the Tuxen Formation well preserved dinoflagellates were recovered here.

7774'. The common occurrence of *Phoberocysta neocomica* is a reliable marker of an Early Aptian (*forbesi* Zone) or older age. The absence of *Batioladinium longicornutum* and *Diphaiosphaera stolidota*, both occurring with *P. neocomica* in the lower part of the Sola Formation in the E-1 well, points to a younger age (equivalent to the *fissicostatus* or *forbesi* Zone) of the Sola Formation in Adda-2 than the cored part of this formation in E-1. *Cepadinium variabile* (not found in E-1) is previously known only from the Lower Aptian *forbesi* to *bowerbanki* Zones of the Isle of Wight (Duxbury 1983).

7762'. The age is probably late Early Aptian. The first occurrence of the *Aptea polymorpha - A. securigera* group takes place in this sample. Also of note is the presence of *Chlamydophorella trabeculosa*. The absence of *Phoberocysta neocomica* in this and the overlying samples points to an Aptian age, younger than the *forbesi* Zone, although typical *C. trabeculosa* is not recorded with certainty above the *forbesi* Zone. If the last occurrence of *P. neocomica* is a reliable feature for correlation, the first occurrence of the *Aptea polymorpha - A. securigera* group in the Central Trough must be delayed in comparison with the Isle of Wight where this group is known from the lowermost Aptian (*forbesi* Zone) to lowermost Albian (Duxbury 1983). The continued presence of *Cepadinium variabile* may possibly

indicate an age no younger than the *bowerbanki* Zone, although the potential value of this species for correlation is not known.

#### Sola or Rødby Formation

The lower boundary of the Rødby Formation is placed at 7760' by Jensen et al. (1986) but it should probably be placed above the cores, i.e. above 7750', according to Jensen & Buchardt (1986).

7756'. The organic material in this sample is corroded, and the lack of good marker species allows no discrimination relative to ages below and above.

7753'3''. The age is Aptian, probably Late Aptian. Although the organic material is dominated by highly degraded, inertinitic particles, a rich and well preserved dinoflagellate assemblage was recovered here. The age is unquestionably Aptian, since *Cerbia tabulata* is abundant. Numerous *Aptea polymorpha* and *A. securigera* also show the age to be no younger than earliest Albian. Of importance for a more precise age determination is the presence of *Cepadinium variabile*, the *Pterodinium aliferum* group and of *Stephodinium spinulosum* as discussed in the following.

*Cepadinium variabile* points to an Early Aptian age no younger than the *bowerbanki* Zone, although the reliability of this species for correlation is unknown. On the other hand *Stephodinium spinulosum* and the *Pterodinium aliferum* group point to a Late Aptian age. *S. spinulosum* is only known from the uppermost Aptian *jacobi* and lowermost Albian *tardefurcata* Zones of the Isle of Wight (Duxbury 1983). However, *S. spinulosum* is very similar to *Stephodinium daveyii*, which is only known from the mid-Upper Aptian *nutfieldiensis* Zone in NW Germany (Below 1982d). It cannot be excluded that *S. daveyii* is present in older strata than the *nutfieldiensis* Zone, since in the section studied by Below (1982d), *S. daveyii* occurs from the base of the zone which unconformably overlies Barremian strata. The *Pterodinium aliferum* group is described from imprecisely dated Upper Aptian in Northwestern Germany by Eisenack (1958). Most evidence therefore favours a Late Aptian age, although the evidence is not conclusive.

The Aptian age determinations arrived at in Adda-2 on the basis of dinoflagellates are broadly in agreement with those based on calcareous nannoplankton (Thomsen in press).

# Correlation of the studied wells

The ages of the various lithological units and some of the seismostratigraphical units in the Danish Central Trough are outlined in this chapter. The lithological units are defined by Jensen et al. (1986) and the seismic units by Vejbæk (1986).

The analysis of only two complete sections, mainly on the basis of ditch cutting samples, with a few short supplementary sections is obviously an inadequate background for wide ranging generalisations, and the conclusions should therefore be regarded as preliminary.

## *Chronostratigraphy*

The assumed positions of the Lower Cretaceous stages in the Adda-1 and I-1 wells are shown in fig. 13. The stages identified in the shorter sections are shown in figs. 9–12. The analysis leaves out the exact age of several intervals. It is clear, nevertheless, that the sediments in the Danish Central Trough represents all stages and most of the substages of the Lower Cretaceous. Within detection limits only local hiati are found, and none of the distinct lithological boundaries seem to be general unconformities.

The six Lower Cretaceous stages are represented by the Cromer Knoll Group and the upper part of the Farsund Formation. Fig. 13 shows that very thick deposits accumulated during early Early Cretaceous (Ryazanian-Early Hauterivian), while much thinner sequences were deposited during the late Early Cretaceous. The high accumulation rate took place during deposition of the upper Farsund Formation and most of the Valhall Formation. The Valhall Formation is interpreted to include gravity-flow deposition in several intervals (Jensen et al. 1986, Vejbæk 1986). The frequent occurrence of reworked dinoflagellates (especially in the I-1 well) supports this interpretation. The seismic stratigraphy shows that differential subsidence of basins took place in the Danish Central Trough during early Early Cretaceous (Gowers & Sæbøe 1985, Vejbæk 1986).

The accumulation rate gradually decreased during the Hauterivian and Barremian. This tendency was accentuated during the Aptian and the highly condensed Rødby Formation, probably deposited during most of the Albian, marks the culmination of this development as evident from fig. 13. According to Vej-

bæk (1986) the tectonic activity gradually decreased during the Early Cretaceous. This led to a more uniform subsidence of the Central Trough (although occasionally with events of inversion) from the Late Hauterivian. The deposits in the late Early Cretaceous were mainly marls and chalk oozes (Jensen et al. 1986).

## *Age of lithological and seismostratigraphical units*

### **The Farsund Formation-Valhall Formation boundary**

The uppermost samples of the Farsund Formation are in all cases of Ryazanian age. Most evidence favours a Late Ryazanian age, but the ages are somewhat different in the four sections studied. In Adda-1 and M-8 there is good evidence that the Farsund Formation ranges into the Upper Ryazanian, coeval to the *Stenomphalus* Zone. In M-8 the uppermost analysed sample of the Farsund Formation is 76' below the top, leaving open the possibility of even younger strata within the formation. In E-1, ammonites of the uppermost Lower Ryazanian *kochi* Zone were identified by Birkelund et al. (1983). The *kochi* Zone was identified 56' below the top of the Farsund Formation, allowing for a possible inclusion of Upper Ryazanian strata in the formation. A restudy of the cutting samples in the basal Valhall Formation in E-1 points to a latest Ryazanian age. If this new age determination is accepted it rules out the suggestion of Birkelund et al. (1983) that the Farsund Formation might here range into the Valanginian.

In I-1 the top of the Farsund Formation is interpreted to be of Early Ryazanian age. However, as the Ryazanian ages in the I-1 well are based on rather conflicting evidence, this age is somewhat uncertain. Pronounced reworking was found in the Valangian and it cannot be ruled out that the anomalously old ages near the Farsund-Valhall boundary could be due to the entire assemblage having been reworked.

Most evidence points to a Late Ryazanian age of the basal layers of the Valhall Formation (Adda-1, E-1). In M-8 the lowermost sample studied (24' above the boundary) is dated as earliest Valangian, and it cannot be excluded that the basal part is Upper Ryazanian.

The fine biostratigraphical resolution of the Ryazanian-Lower Valangian supports the view that no unconformity is developed at the boundary between the Far-

# I-1

# ADDA-1

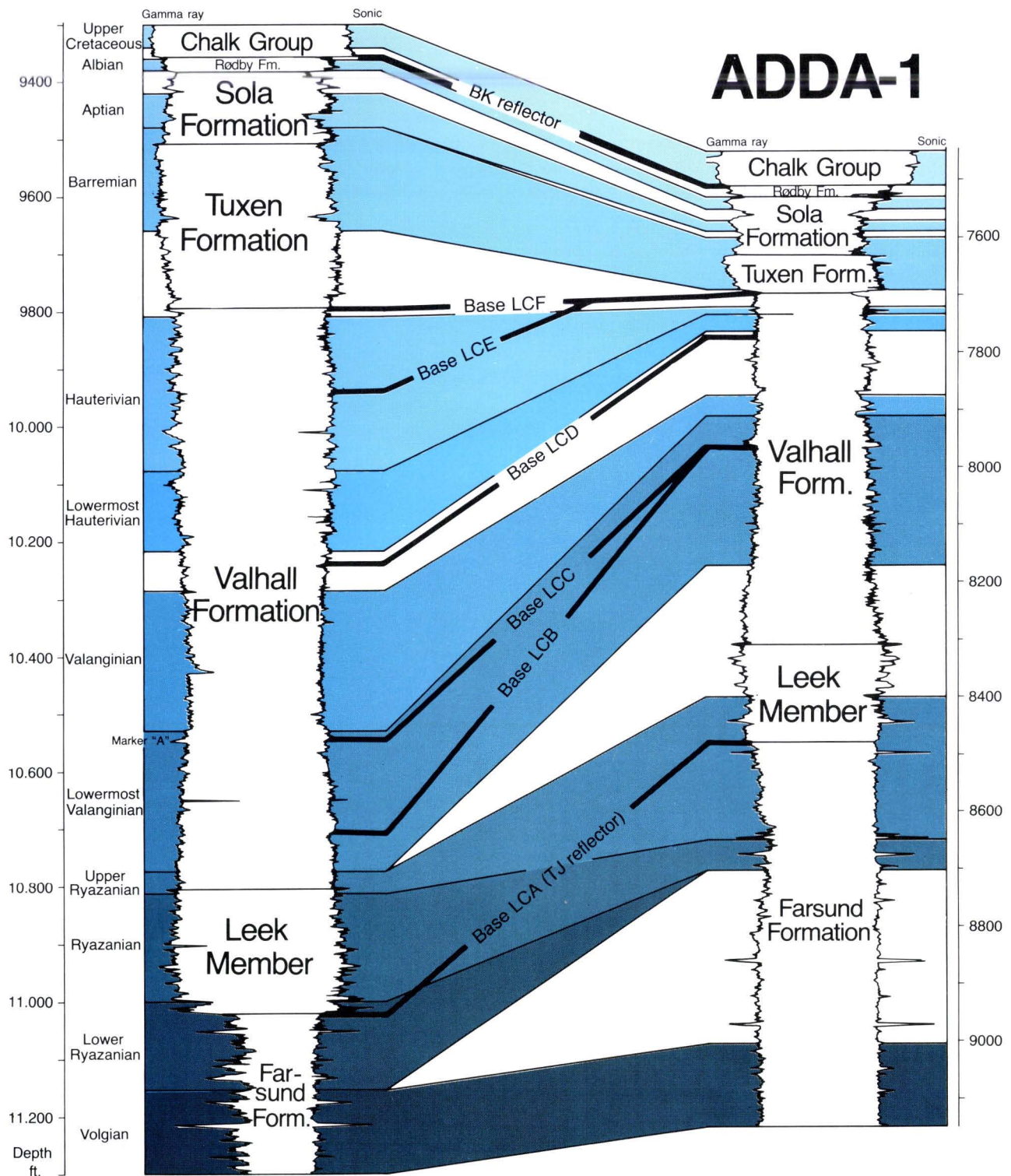


Fig. 13. The probable position of the Lower Cretaceous stages in the I-1 and the Adda-1 wells. The ages of uncoloured intervals are less certain. Also shown are lithostratigraphical subdivision, reflectors separating the seismic units LCA to LCF and the log-marker "A". Lithostratigraphy and seismic stratigraphy are from Jensen et al. (1986) and Vejlbæk (1986).

sund and Valhall Formations. The palynofacies change from mainly sapropelic (amorphous) organic matter in the upper Farsund Formation to mainly structured organic matter in the Valhall Formation points to a shift from an anoxic to a generally oxygenated bottom environment.

### **Leek Member**

This basal member of the Valhall Formation is present in the Adda-1 and I-1 wells and the age of its base is discussed above (base of Valhall Formation). The top of the Leek Member in Adda-1 is in the lowermost Valanginian or Upper Ryazanian. In I-1 it is between samples dated as Late Ryazanian and samples dated as undifferentiated Ryazanian. This suggests a diachronous age of the top of this member, but it should be recalled that age determinations in this part of the I-1 well are less certain.

### **Vyl Formation**

This formation is only drilled in the V-1 well (fig. 10), and the poor samples available for palynology only give uncertain ages; the following ages can nevertheless be interpreted: Twenty feet above the top a sidewall-core gives an earliest Valangian or latest Ryazanian age, while a sidewall-core within the formation (92' below the top) is Late Ryazanian. Finally, a sidewall-core 82' below the base is most likely of Early Ryazanian age.

### **Seismic units LCA, LCB, LCC, LCD and LCE**

The probable positions of these units in the I-1 and Adda-1 wells are shown in fig. 13. According to Vej-bæk (pers. comm. 1985) it is very difficult to point out the precise depths of the unit boundaries, especially in the I-1 well. Too much emphasis should not, therefore, be placed on the biostratigraphical evaluation of these units.

Unit LCA is present in both wells and the presumed top falls in the thick sequence dated as lowermost Valanginian at both sites. Unit LCB is only present in the I-1 well where it is also in the lowermost Valangian. The biostratigraphical resolution is not fine enough to evaluate the possibility of an intra-earliest Valanginian hiatus at the LCA-LCC boundary in Adda-1.

The base of unit LCC is just below the biostratigraphically very distinct top of the lowermost Valanginian, and is therefore most likely isochronous between the two wells.

As evident from fig. 13, the base LCD-reflector may also be isochronous near the Valanginian – Hauterivian boundary in both I-1 and Adda-1.

Unit LCE, which is only drilled in the I-1 well (Vej-bæk pers. comm.) falls in the interval dated as Upper Hauterivian to possibly Barremian. The base of the

unit is close to the presumed Lower/Upper Hauterivian boundary. In Adda-1 the Hauterivian above lowermost Hauterivian is extremely thin, about 30'. It falls in the underlying seismic unit LCD, and the seismically suggested hiatus in the Upper Hauterivian is therefore plausible when comparing with the present biostratigraphical results.

Finer biostratigraphical resolution of this interval in the Adda-1 well is achieved on the basis of calcareous nannofossils (Thomsen in press). It should be noted that Thomsen's (in press) results indicate a condensed, but continuous sedimentation across the boundary between the seismic units LCD and LCF.

### **The Valhall Formation-Tuxen Formation boundary and seismic unit LCF**

The palynological results in the intervals containing this boundary in Adda-1 and I-1 are uncertain, and on the basis of the palynological study the boundary can only be placed somewhere in the Late Hauterivian – middle Barremian time interval. However, in core 4 from the Adda-2 well, the mid-Upper Hauterivian *gottschei* Zone is identified 21' above the boundary by Birkelund (herein) on the basis of the index-fossil of the zone. This points to a mid-Late Hauterivian or older age for the basal part of the Tuxen Formation, and agrees with the results of Thomsen (in press). In Adda-1 and I-1 the calcareous nannofossils show a mid-Late Hauterivian age of the boundary and point to continuous sedimentation (Thomsen in press).

A seismic unit boundary (base of unit LCF) seems to coincide with the boundary between the Valhall and Tuxen Formations. The calcareous nannofossil results of Thomsen (in press) show this seismic reflector to be isochronous.

### **The Tuxen Formation-Sola Formation boundary**

The dinoflagellate assemblages near this boundary include several marker species, allowing reliable age-assignments. Both in Adda-1 and I-1 the cutting samples at the top of the Tuxen Formation point to an age no younger than the middle Barremian. Core 5 of the Tuxen Formation in I-1 yielded less age-restricting species, and only allows a broader middle Barremian – Early Aptian age determination, while the cores of this formation in Adda-2 and E-1 were barren of palynomorphs.

The earliest beds of the Sola Formation are determined to be of Barremian age in three of the four sections (Adda-1, I-1 and E-1) while in the Adda-2 core the age is determined as Early Aptian, both on the basis of calcareous nannofossils (Thomsen, pers. comm.) and dinoflagellates.

In I-1 a reliable top-Barremian marker, *Cassiculospaeridia magna*, occurs in cutting samples 10' and 36'

above the base of the Sola Formation, although a diverse middle Barremian assemblage is not met until in the Tuxen Formation below.

In the core of E-1 a sample two feet above the boundary includes two Barremian markers, of which one, *Kleithriasphaeridium corrugatum*, marks the middle Barremian or older, while the overlying, cored part of the Sola Formation is Barremian or possibly lowermost Aptian (*fissicostatus* Zone). The calcareous nanofossils suggest a Late Barremian or possibly an Early Aptian age of the same level (Thomsen, pers. comm. 1986).

Summarizing these observations, it appears reasonable to place the earliest beds of the Sola Formation in the Upper Barremian, or possibly even middle Barremian. The biostratigraphy indicates that the Sola Formation in the Adda-2 well is younger than the cored lower part of this formation in E-1. This probably indicates a hiatus at the formation boundary in Adda-2.

#### **The boundary between the Sola and Rødby Formations**

In the I-1 well the uppermost beds in the Sola Formation occur in the interval reliably assigned as lowermost Albian or Aptian. Lowermost Albian may even be present 11' above the boundary, but here the age determination is less certain. The lowermost Albian and Aptian is marked by a major change in the dinoflagellate assemblages as compared to the higher Albian. The age of the boundary is based on several of these species and therefore seems reliable.

In Adda-1 the uppermost sample dated as Albian (probably older than the youngest Albian *dispar* Zone, but still most likely Late Albian) is three feet below the top of the Sola Formation, according to the log-defined boundary. Even 13' below the boundary the age still

appears to be Late or Middle Albian. 23' below the boundary the Albian assemblage disappears, but top Aptian markers are not met until 53' below the boundary.

In comparison with the results from I-1, this suggests marked diachronism of the boundary between the Sola and Rødby Formations. However, caution should be exercised when interpreting the age of the boundary. Firstly, the overlying Rødby Formation is extremely thin (15' in Adda-1) and probably contains a condensed Albian sequence. Cavings from this part into older levels would lead to erroneously young ages if the *in situ* beds contain no age-diagnostic assemblages. Secondly, the wireline-log defined depth of the boundary may differ enough from the cutting depth to give a significantly younger age. Much more material, preferably from cores, would be necessary to evaluate the regional age of this boundary.

The thickness of the Rødby Formation is only 26' in the I-1 well and 15' in the Adda-1 well. The single sample of the Rødby Formation in Adda-1 was barren, while the three samples in I-1 yielded assemblages suggesting a condensed sequence covering much of the Albian stage. Most or all of the Albian also seems to be represented by a condensed sequence in Adda-1, but here it apparently occurs in the uppermost Sola Formation, as discussed above.

#### **The Cromer Knoll Group-Chalk Group boundary**

This boundary occurs below samples referred to the Upper Cretaceous in both wells. The poor *in situ* assemblages above the boundary lack any of the top-Albian markers, but include *Cyclonephelium membraniphorum*, indicating a pre-Campanian age. This is weak evidence that the group boundary may coincide with the Lower-Upper Cretaceous boundary.



# Systematics

No detailed systematic study has been carried out in this project, and no new taxa are formally erected. Only brief descriptions of informally established forms found in the North Sea material, and remarks to some previously described species, are given below.

The alphabetical list (after genus) gives all taxa presented in the range charts and used for the biostratigraphical analysis. The generic allocation of dinoflagellate species follows Lentin & Williams (1985). The numbers refer to the position in the two major range charts (A-numbers for the Adda-1 well and I-numbers for the I-1 well). Taxa for which systematic remarks are given are indicated with an asterisk. Plate and figure numbers are mentioned for taxa figured in plates 1–16.

## *Organic-walled microplankton*

Except for *Pterospermella* Eisenack, 1972 and *Tasmanites* Newton, 1875, all taxa listed below are dinoflagellates (division Pyrrhophyta, class Dinophyceae Fritsch, 1929). *Pterospermella* and *Tasmanites* are classified with the green algae (division Prasinophyta Round, 1971, order Pterospermatales Schiller, 1925).

*Achomosphaera? neptunii* (Eisenack, 1958) Davey & Verdier, 1966a (A 27, I 56) pl. 11, figs. 26–29  
*Achomosphaera ramulifera* (Deflandre, 1937b) Evitt, 1963 (Adda-2)  
*Aldorfia spongiosa* (McIntyre & Brideaux, 1980) Davey, 1982a (A 112, I 151) pl. 9, fig. 7  
*Aldorfia* sp. A Davey, 1982a (Adda-1, swc)  
*Aptea anaphrissa* (Sarjeant, 1966c) Sarjeant & Stover, 1978 (I 75)  
\**Aptea polymorpha* Eisenack, 1958 – *A. securigera* Davey & Verdier, 1974 group (A 20, I 22) pl. 4, figs. 13, 14, 17–19  
*Apteodinium grande* Cookson & Hughes, 1964 (A 12, I 52) pl. 9, figs. 8, 9  
*Apteodinium granulatum* Eisenack, 1958 (I-1, core 5)  
*Apteodinium nuciforme* (Deflandre, 1938b) Stover & Evitt, 1978 (Adda-1, swc)  
*Ascodinium scabrosum* Cookson & Hughes, 1964 (A 7, I 20) pl. 5, figs. 8, 9  
*Avellodinium falsificum* Duxbury, 1977 (A 65, I 53) pl. 12, fig. 16  
*Batioladinium jaegeri* (Alberti, 1961) Brideaux, 1975 (I 33) pl. 3, fig. 12

*Batioladinium longicornutum* (Alberti, 1961) Brideaux, 1975 (A 40, I 72) pl. 3, figs. 13–16  
*Batioladinium micropodum* (Eisenack & Cookson, 1960) Brideaux, 1975 (A 88)  
*Batioladinium? pelliferum* (Alberti, 1961) Brideaux, 1975 (A 78, I 64) pl. 3, figs. 7–9  
*Batioladinium pomum* Davey, 1982a (A 131, I 122) pl. 3, figs. 10, 11  
*Batioladinium radiculatum* Davey, 1982a (I 121)  
*Batioladinium* sp. I Davey, 1982a (A 89, I 119) pl. 2, figs. 20–22  
*Batioladinium varigranosum* (Duxbury, 1977) Davey, 1982a (A 96, I 117) pl. 3, figs. 1, 2  
*Batioladinium* cf. *varigranosum* sensu Davey, 1982a (A 116, I 145) pl. 3, figs. 3–6  
\*aff. *Bourkidinium granulatum* Morgan, 1975 (A 101, I 87) pl. 13, figs. 22–24  
*Callaiosphaeridium asymmetricum* (Deflandre & Courteville, 1939) Davey & Williams, 1966b (A 25, I 32) pl. 12, figs. 18, 19  
*Callaiosphaeridium trycherium* Duxbury, 1980 (A 71, I 66) pl. 12, figs. 20, 21  
*Canningia compta* Davey, 1982a (A 114, I 127) pl. 6, figs. 6, 7  
*Canningia* cf. *reticulata* sensu Duxbury, 1977 (I 74)  
*Cannosphaeropsis thula* Davey, 1982a (A 137, I 137) pl. 11, figs. 19, 20, 25  
*Carpodinium granulatum* Cookson & Eisenack, 1962b (A 16, I 13) pl. 8, figs. 2–5  
*Carpodinium obliquicostatum* Cookson & Hughes, 1964 (A 8) pl. 8, fig. 1  
*Cassiculosphaeridia magna* Davey, 1974 (A 49, I 48) pl. 8, figs. 16, 22, 23  
\**Cassiculosphaeridia reticulata* Davey, 1969a (A 34, I 1) pl. 8, figs. 17–19  
*Cauca parva* (Alberti, 1961) Davey & Verdier, 1971 (I 11) pl. 6, figs. 3–5  
*Cepadinium variabile* Duxbury, 1983 (Adda-2) pl. 5, figs. 1, 2  
*Cerbia tabulata* (Davey & Verdier, 1974) Below, 1981a (A 21, I 73) pl. 4, figs. 9–11  
\**Chlamydophorella? membranoidea* Vozzhennikova, 1967 (A 75, I 27) pl. 12, figs. 30, 31  
\**Chlamydophorella nyei* Cookson & Eisenack, 1958 (A 6, I 34) pl. 12, fig. 32  
*Chlamydophorella ordinalis* (Davey, 1974) Davey, 1978 (E-1)

- \**Chlamydophorella trabeculosa* (Gocht, 1959) Davey, 1978 (A 29, I 82) pl. 12, figs. 27–29
- Chytroisphaeridia cerastes* Davey, 1979d (I 123) pl. 8, figs. 6, 7
- Chytroisphaeridia chytrooides* (Sarjeant, 1962a) Downie & Sarjeant, 1965 (A 105)
- Coronifera oceanica* Cookson & Eisenack, 1958 (A 64, I 81) pl. 13, figs. 28, 29
- Cribroperidinium boreas* (Davey, 1974) Helenes, 1984 (A 37)
- Cribroperidinium?* *cornutum* Davey, 1974 (A 55, I 58) pl. 10, figs. 12, 15–16
- \**Cribroperidinium edwardsii* (Cookson & Eisenack, 1958) Stover & Evitt, 1978 – *C. orthoceras* (Eisenack, 1958) Davey, 1969a group (A 23, I 36)
- Cribroperidinium?* *gigas* (Raynaud, 1978) Helenes, 1984 (A 142) pl. 10, fig. 13
- Cribroperidinium sepimentum* Neale & Sarjeant, 1962 (A 84, I 97) pl. 10, fig. 14
- Cribroperidinium* sp. A Davey, 1982a (A 141, I 153) pl. 10, fig. 6
- Ctenidodinium elegantulum* Millioud, 1969 (A 99, I 113) pl. 12, figs. 2–4
- Ctenidodinium panneum* (Norris, 1965) Lentin & Williams, 1973 (A 113, I 118) pl. 12, figs. 5, 11
- Cyclonephelium hystrix* (Eisenack, 1958) Davey, 1978 (A 22, I 21) pl. 4, figs. 12, 15, 16
- Cyclonephelium membraniphorum* Cookson & Eisenack, 1962b (A 1, I 5)
- Cymososphaeridium validum* Davey, 1982a (I 91) pl. 14, fig. 20
- Cymososphaeridium* sp. I Davey, 1982a (A 94, I 125)
- Dapsilidinium multispinosum* (Davey, 1974) Bujak et al., 1980 (A 46, I 26) pl. 14, figs. 1–3
- Diacanthum tenuiceras* (Eisenack, 1958) Stover & Evitt, 1978 (A 28, I 9) pl. 9, fig. 1
- Dichadogonyaulax culmula* (Norris, 1965) Loeblich & Loeblich, 1968 (A 143, I 138)
- \**Dingodinium cerviculum* Cookson & Eisenack, 1958 (A 26, I 18) pl. 13, figs. 1–5
- \**Dingodinium jurassicum* Cookson & Eisenack, 1958 (A 103, I 104) pl. 13, figs. 6, 12
- Dingodinium spinosum* (Duxbury, 1977) Davey, 1979c (A 121, I 132) pl. 13, figs. 7–11
- \**Dingodinium tuberosum* (Gitmez, 1970) Fisher & Riley, 1980 (A 108, I 120) pl. 13, fig. 13
- Dinopterygium cladoides* Deflandre, 1935 (A 15, I 3)
- Diphasioisphaera stolidota* Duxbury, 1980 (A 43, I 131) pl. 11, figs. 21–24
- Discorsia nanna* (Davey, 1974) Duxbury, 1977 (A 67, I 96)
- Egmontodinium expiratum* Davey, 1982a (A 136, I 141) pl. 14, figs. 10–13
- Egmontodinium polyplacophorum* Gitmez & Sarjeant, 1972 (M-8) pl. 14, fig. 14
- Egmontodinium torynum* (Cookson & Eisenack, 1960b) Davey, 1979c (A 111, I 130) pl. 14, figs. 6–8
- Ellipsodinium reticulatum* Duxbury, 1980 (A 62) pl. 8, figs. 12, 13
- Ellipsodinium rugulosum* Clarke & Verdier, 1967 (I 10)
- \**Ellipsoidictyum imperfectum* (Brideaux & McIntyre, 1975) Lentin & Williams, 1977b (A 63, I 17) pl. 8, figs. 20, 21, 24
- Endoscrinium campanula* (Gocht, 1959) Vozzhennikova, 1967 (A 31, I 14) pl. 7, figs. 15, 16
- Endoscrinium granulatum* (Raynaud, 1978) Lentin & Williams, 1981 (A 128) pl. 7, figs. 14, 17
- Endoscrinium pharo* Duxbury, 1977 (A 104, I 126) pl. 7, figs. 13, 18, 19
- Exiguisphaera phragma* Duxbury, 1979a (A 115, I 61) pl. 9, figs. 2–4
- Exiguisphaera plectilis* Duxbury, 1980 (A 45) pl. 9, figs. 5, 6
- Fromea amphora* Cookson & Eisenack, 1958 (A 38, I 50) pl. 6, figs. 12, 13
- Fromea quadrugata* Duxbury, 1980 (A 68, I 55) pl. 6, figs. 10, 11
- \**Florentinia cooksoniae* (Singh, 1971) Duxbury, 1980 (I 7) pl. 16, figs. 20, 21
- Florentinia laciniata* Davey & Verdier, 1973 (Adda-2, E-1) pl. 16, fig. 14
- \**Florentinia mantellii* (Davey & Williams, 1966) Davey & Verdier, 1973 (A 44, I 16) pl. 16, figs. 15, 16, 18, 19
- Glossodinium dimorphum* Ioannides et al., 1977 (I 150)
- Gochteodinia mutabilis* (Riley in Fisher & Riley, 1980) Davey, 1982a (I 149)
- \**Gochteodinia villosa* subsp. *multifurcata* Davey, 1982a (A 100, I 101)
- \**Gochteodinia villosa* subsp. *villosa* (Vozzhennikova, 1967) Norris, 1978 et subsp. indet. (A 107, I 102) pl. 2, figs. 8, 11, 13–15, 18, 19
- Gochteodinia virgula* Davey, 1982a (I 146) pl. 2, figs. 12, 16, 17
- Gonyaulacysta cassidata* (Eisenack & Cookson, 1960) Sarjeant, 1966b (A 11) pl. 11, fig. 7
- Gonyaulacysta centriconnata* Riding, 1983 (A 138)
- Gonyaulacysta cladophora* sensu Duxbury, 1977 (I 88) pl. 10, fig. 11
- \**Gonyaulacysta diutina* Duxbury 1977 – *G. helicoidea* (Eisenack & Cookson 1960) Sarjeant, 1966b group (A 58, I 35) pl. 10, figs. 2, 3
- Gonyaulacysta exanguia* Duxbury, 1977 (A 50, I 86) pl. 10, fig. 1
- Gonyaulacysta?* *fastigiata* Duxbury, 1977 (A 87, I 77) pl. 10, figs. 4, 5
- Gonyaulacysta jurassica* (Deflandre, 1938b) Norris & Sarjeant, 1965 (A 140, I 154)
- Gonyaulacysta kostromiensis* (Vozzhennikova, 1967) Sarjeant, 1969 (A 80, I 89) pl. 11, figs. 1–4
- Gonyaulacysta ordocava* Duxbury, 1977 (I 95) pl. 10, fig. 9
- Gonyaulacysta?* *perforobtusata* Duxbury, 1977 (I 90) pl. 10, fig. 8

- Gonyaulacysta* sp. A Davey, 1982a (A 127) pl. 10, fig. 7
- Heslertonia heslertonensis* (Neale & Sarjeant, 1962) Sarjeant, 1966b (A 59, I 69) pl. 12, figs. 12–15
- Heslertonia pellucida* Gitmez, 1970 (A 54, I 98) pl. 12, figs. 6–8
- \**Hystrichodinium furcatum* Alberti, 1961 (I 71)
- \**Hystrichodinium ramoides* Alberti, 1961 (I 67) pl. 6, fig. 1
- Hystrichodinium voigtii* (Alberti, 1961) Davey, 1974 (A 5, I 46) pl. 6, figs. 2, 8, 9
- Hystrichosphaeridium arborispinum* Davey & Williams, 1966b (I 78)
- Hystrichosphaeridium scoriaceum* Raynaud, 1978 (A 77, I 112) pl. 15, figs. 15–18
- Hystrichosphaerina schindewolfii* Alberti, 1961 (A 56, I 59) pl. 15, fig. 14
- Isabelidinium gallium* (Davey & Verdier, 1973) Stover & Evitt, 1978 (A 17) pl. 5, figs. 6, 7
- Isthmocystis distincta* Duxbury, 1979a (A 90, I 109) pl. 9, figs. 18–20
- Kalyptea diceras* Cookson & Eisenack, 1960b (A 144)
- Kiokansium polypes* (Cookson & Eisenack, 1962b) Davey, 1979b (I 12) pl. 13, figs. 25–27
- Kleithriasphaeridium corrugatum* Davey, 1974 (A 53, I 60) pl. 16, figs. 5–7
- Kleithriasphaeridium eoinodes* (Eisenack, 1958) Davey, 1974 (A 32, I 37) pl. 16, figs. 1–4
- Kleithriasphaeridium fasciatum* (Davey & Williams, 1966b) Davey, 1974 (A 81, I 93) pl. 16, figs. 8, 13
- Kleithriasphaeridium porosispinum* Davey, 1982a (A 125) pl. 16, figs. 9–11
- \**Kleithriasphaeridium* sp. 1 (A 82, I 105) pl. 16, figs. 12, 17
- Lagenorhysis delicatula* (Duxbury, 1977) Duxbury, 1979b (A 91, I 103) pl. 8, figs. 8–11
- Leberidocysta chlamydata* (Cookson & Eisenack, 1962b) Stover & Evitt, 1978 (I 19) pl. 5, fig. 10
- Leptodinium cancellatum* Brideaux & McIntyre, 1975 (I 30) pl. 8, figs. 14, 15
- Litosphaeridium arundum* (Eisenack & Cookson, 1960) Davey, 1979b (A 9) pl. 14, fig. 5
- Litosphaeridium conispinum* Davey & Verdier, 1973 (A 10)
- Litosphaeridium siphoniphorum* (Cookson & Eisenack, 1958) Davey & Williams, 1966b (A 13) pl. 14, fig. 4
- Maduradinium?* sp. A Davey, 1982a (A 48, I 40) pl. 5, figs. 11–13
- Membranilarnacia polycladiata* Cookson & Eisenack, 1963a (I 38) pl. 5, figs. 14, 16, 17
- Mendicodinium groenlandicum* (Pocock & Sarjeant, 1972) Davey, 1979c (A 120) pl. 12, fig. 1
- Meristaulax granulata* (Klement, 1960) Sarjeant, 1984a (Adda-1, swc)
- Muderongia extensiva* Duxbury, 1977 (I 108) pl. 1, figs. 1, 3
- Muderongia parviata* Duxbury, 1983 (A 47, I 51) pl. 1, figs. 2, 4, 6, 8
- Muderongia simplex* Alberti, 1961 (A 74, I 106) pl. 1, figs. 9, 10
- Muderongia simplex* subsp. *microperforata* Davey, 1982a (A 92, I 114) pl. 1, fig. 7
- Muderongia staurota* Sarjeant, 1966c (A 69, I 63) pl. 1, fig. 5
- Muderongia tetracantha* (Gocht, 1957) Alberti, 1961 (A 72)
- \**Muderongia* sp. 1 (A 83, I 107) pl. 2, figs. 1–4
- Muderongia* sp. A Davey, 1982a (Adda-1, swc)
- Nannoceratopsis gracilis* Alberti, 1961 (I 148)
- Nematosphaeropsis scala* Duxbury, 1977 (A 85, I 94) pl. 11, figs. 13, 14
- \**Nematosphaeropsis* sp. 1 (I 85) pl. 11, fig. 18
- \**Occisucysta evittii* (Dodekova, 1969) Gitmez, 1970 (A 109, I 129) pl. 9, figs. 10–13
- Occisucysta tentoria* Duxbury, 1977 (A 61, I 39) pl. 9, figs. 14–17
- Odontochitina operculata* (O. Wetzel, 1933a). Deflandre & Cookson, 1955 (A 4, I 28) pl. 1, fig. 11
- Oligosphaeridium abaculum* Davey, 1979a (I 76)
- Oligosphaeridium asterigerum* (Gocht, 1959) Davey & Williams, 1969 (A 95, I 84) pl. 15, figs. 5, 6
- Oligosphaeridium complex* (White, 1842) Davey & Williams, 1966b (A 14, I 15) pl. 15, figs. 7, 10
- Oligosphaeridium diluculum* Davey, 1982a (A 124, I 139) pl. 15, fig. 4
- Oligosphaeridium perforatum* (Gocht, 1959) Davey & Williams, 1969 (I 83)
- Oligosphaeridium prolixispinosum* Davey & Williams, 1966b (I 2) pl. 15, fig. 1
- Oligosphaeridium pulcherrimum* sensu Davey, 1982b (I 24)
- Oligosphaeridium pulcherrimum* sensu Ioannides et al., 1977 (I 152)
- Oligosphaeridium* sp. GE McIntyre & Brideaux, 1980 (A 135, I 100) pl. 15, fig. 2
- \**Oligosphaeridium* sp. 1 (I 79) pl. 15, fig. 3
- Palaeoperidinium pyrophorum* (Ehrenberg, 1838) Sarjeant, 1967b (I 6)
- Pareodinia ceratophora* Deflandre, 1947c (A 145)
- \**Pareodinia* sp. 1 (I 25) pl. 4, figs. 1–4
- Perisseiasphaeridium pannosum* Davey & Williams, 1966b (A 122, I 144)
- \**Phoberocysta neocomica* (Gocht, 1957) Millioud, 1969 (A 35, I 43) pl. 2, figs. 9, 10
- \**Phoberocysta tabulata* Raynaud, 1978 (A 73, I 99) pl. 2, figs. 5–7
- Prolixosphaeridium granulosum* sensu Ioannides et al., 1977 (A 123)
- Prolixosphaeridium parvispinum* (Deflandre, 1937b) Davey et al., 1969 (A 42, I 44) pl. 13, figs. 19–21
- Protoellipsodinium clavulum* Davey & Verdier, 1971 (I 23) pl. 13, 14, 16

- Protoellipsodinium spinosum* Davey & Verdier, 1971 (A 36, I 45) pl. 13, figs. 17, 18
- Psaligonyaulax deflandrei* Sarjeant, 1966b (A 18)
- Pseudoceratium pelliferum* Gocht, 1957 (A 39, I 54) pl. 3, figs. 17–20
- \**Pseudoceratium* sp. 1 (A 93, I 110) pl. 3, figs. 21–24
- \**Pterodinium aliferum* Eisenack, 1958 group (Adda-2) pl. 11, figs. 11, 16
- Pterodinium prenon* Duxbury, 1980 (A 79)
- Pterospermella* Eisenack, 1972, spp. (A 3, I 49) pl. 6, figs. 18–20
- Rhynchodiniopsis aptiana* Deflandre, 1935 (A 60) pl. 10, fig. 10
- Senoniasphaera jurassica* (Gitmez & Sarjeant, 1972) Lentin & Williams, 1976 (A 133) pl. 5, figs. 23, 24
- Sirmiodiniopsis frisia* (Raynaud, 1978) Lentin & Williams, 1981 (A 106, I 124) pl. 7, figs. 1–5
- Sirmiodinium grossii* Alberti, 1961 (A 33, I 42) pl. 7, figs. 6–9
- \**Spiniferites? dentatus* (Gocht, 1959) Lentin & Williams, 1973 (A 76, I 41) pl. 11, figs. 5, 6, 9, 10
- \**Spiniferites ramosus* (Ehrenberg, 1838) Loeblich & Loeblich, 1966 – *S. multibrevis* (Davey & Williams, 1966a) Below 1982c group (A 2, I 8)
- Spiniferites ramosus* subsp. *primaevus* Duxbury, 1977 (A 86, I 111) pl. 11, fig. 15
- Spiniferites speetonensis* Duxbury, 1980 (A 70, I 62) pl. 11, fig. 8
- Stephodinium coronatum* Deflandre, 1936a (A 51, I 29) pl. 12, figs. 24–26
- \**Stephodinium spinulosum* Duxbury, 1983 (Adda-2) pl. 12, fig. 23
- \**Stiphrosphaeridium anthophorum* (Cookson & Eisenack, 1958) Davey, 1982a – *S. dictyophorum* (Cookson & Eisenack, 1958) Davey, 1982a group (A 129, I 31) pl. 15, figs. 8, 9, 12, 13
- Stiphrosphaeridium arbustum* Davey, 1982a (A 130) pl. 15, fig. 11
- Subtilisphaera? paeminosa* (Drugg, 1978) Bujak & Davies, 1983 (I 143)
- Subtilisphaera perlucida* (Alberti, 1959b) Jain & Millepied, 1973 (A 41) pl. 5, fig. 5
- Subtilisphaera ventriosa* (Alberti, 1959b) Jain & Millepied, 1973 (A 24, I 47) pl. 5, figs. 3, 4
- Surculosphaeridium* sp. I Davey, 1982a (A 110) pl. 14, fig. 19
- Surculosphaeridium* sp. II Davey, 1982a (I 128) pl. 14, fig. 18
- Surculosphaeridium* sp. III Davey, 1982a (A 97, I 115) pl. 14, figs. 15–17
- Systematophora* cf. *areolata* sensu Davey, 1982a (A 119, I 140) pl. 14, figs. 9, 21
- Systematophora complicata* Neale & Sarjeant, 1962 (I 92) pl. 14, fig. 22
- Systematophora palmula* Davey, 1982a (A 117, I 133)
- Systematophora vestita* (Deflandre, 1938b) Davey, 1982a (A 118, I 136)
- Systematophora* sp. I Davey, 1982a (A 139, I 147)
- Taleisphaera hydra* Duxbury, 1979a (I 80) pl. 12, figs. 17, 22
- Tasmanites* Newton, 1875, spp. (A 19, I 4) pl. 6, figs. 14–17
- Trabeculodinium quinquetrum* Duxbury, 1980 (I 68) pl. 11, figs. 12, 17
- Trichodinium castanea* (Deflandre, 1935) Clarke & Verdier, 1967 (A 30, I 70) pl. 4, figs. 5–7
- Trichodinium speetonense* Davey, 1974 (A 52, I 57) pl. 4, fig. 8
- Tubotuberella apatela* (Cookson & Eisenack, 1960b) Ioannides et al., 1977 (A 98, I 116) pl. 7, figs. 10–12
- Valensiella ovula* (Deflandre, 1947c) Eisenack, 1963a (A 126) pl. 12, figs. 9, 10
- Walloodinium anglicum* (Cookson & Hughes, 1964) Lentin & Williams, 1973 (A 57, I 65) pl. 5, figs. 15, 18, 22
- Walloodinium cylindricum* (Habib, 1970) Duxbury, 1983 (A 102, I 135) pl. 5, figs. 19–21
- Walloodinium krutzschii* (Alberti, 1961) Habib, 1972 (A 134, I 134)

**Genus *Aptea* Eisenack, 1958; emend. Davey & Verdier, 1974; emend. Dörhöfer & Davies, 1980**

*Aptea polymorpha* Eisenack, 1958 – *A. securigera* Davey & Verdier, 1974 group  
Pl. 4, figs. 13, 14, 17–19

In the present material a continuous gradation between *Aptea polymorpha* and *A. securigera* is observed, although most specimens may be referred to *A. securigera*. Since the two species appear to have the same stratigraphical range they have been grouped together.

**Genus *Bourkidinium* Morgan, 1975**

aff. *Bourkidinium granulatum* Morgan, 1975  
Pl. 13, figs. 22–24

The specimens bear precingular processes, while the equatorial zone is devoid of processes. In this morphology they are intermediate between *Bourkidinium granulatum*, which only bears processes in the apical and antapical region, and *Tanyosphaeridium regulare* Davey & Williams, 1966b, with uniformly distributed processes. The latter species occurs in the North Sea material together with aff. *Bourkidinium granulatum*, but is not included in the present study.

**Genus *Cassiculosphaeridia* Davey, 1969a**

*Cassiculosphaeridia reticulata* Davey, 1969a  
Pl. 8, figs. 17–19

*Cassiculosphaeridia reticulata* and *Ellipsoidictyum imperfectum* (Brideaux & McIntyre, 1975) Lentin & Williams, 1977b) are shown separately in the range charts of Adda-1 and I-1 (figs. 5,7). However, this caused difficulties; the material here studied shows a continuous transition in morphology between the two species with many intermediate forms, and distinction between the two species in the two wells is therefore not entirely reliable. In Adda-2 the two species are grouped together (fig. 12).

**Genus *Chlamydophorella* Cookson & Eisenack, 1958; emend. Duxbury, 1983**

*Chlamydophorella? membranoidea* Vozzhennikova, 1967  
Pl. 12, figs. 30, 31

This species is distinguished from *Chlamydophorella nyei* by the presence of a corona. In the present material, the corona is usually indistinct and can often only be seen at  $\times 1000$  magnification. It is likely that several unfavourably oriented specimens of *C.? membranoidea*, without visible corona, have been included in *C. nyei* in the range charts.

*Chlamydophorella nyei* Cookson & Eisenack, 1958  
Pl. 12, fig. 32

See remarks to *Chlamydophorella trabeculosa*.

*Chlamydophorella trabeculosa* (Gocht, 1959) Davey, 1978  
Pl. 12, figs. 27–29

Typical *C. trabeculosa* can be clearly distinguished from typical *Chlamydophorella nyei* Cookson & Eisenack, 1958, by development of the apical horn and the processes. In *C. trabeculosa* the horn is long and the processes are thin (thread-like, massive?) while in *C. nyei* the horn is short and the processes are wider and sometimes hollow. Specimens with long horns like *C. trabeculosa*, but with wide and hollow processes, like in *C. nyei* occur in the Upper Aptian on the Isle of Wight (Batten 1980, pl. 1, fig. 1, Duxbury 1983, pl. 3, fig. 10). Delimitation of the two species is therefore questionable. In the present work the Upper Aptian forms mentioned are allocated with *C. nyei*, following Duxbury (1983).

**Genus *Cribroperidinium* Neale & Sarjeant, 1962; emend. Davey, 1969a; emend. Sarjeant, 1982; emend. Helenes, 1984**

*Cribroperidinium edwardsii* (Cookson & Eisenack, 1958) Stover & Evitt, 1978 – *C. orthoceras* (Eisenack, 1958) Davey, 1969a group

The two species seem to differ only in minor details in their development of the parasutural ridges and no distinction between them has been attempted in the present study.

**Genus *Dingodinium* Cookson & Eisenack, 1958; emend. Mehrotra & Sarjeant, 1984b**

*Dingodinium cerviculum* Cookson & Eisenack, 1958  
Pl. 13, figs. 1–5

Following Mehrotra & Sarjeant (1984b), *Dingodinium albertii* Sarjeant, 1966 is considered to be a junior synonym of *Dingodinium cerviculum*. *D. cerviculum* was originally described from Australia. The European specimens are generally distinctly smaller and have previously been classified with *Dingodinium albertii* by most workers. Specimens recovered in the present study are closely comparable in size to “*D. albertii*”. The study of Mehrotra & Sarjeant (1984b) shows, however, that the size-dependant separation of the two species is untenable.

*Dingodinium jurassicum* Cookson & Eisenack, 1958  
Pl. 13, figs. 6–12

In the present study specimens without a clearly marked apical horn, but otherwise similar to *Dingodinium cerviculum*, are included in *D. jurassicum*. It sometimes proved difficult to separate the two species since forms with very short horns are also present in the material.

*Dingodinium tuberosum* (Gitmez, 1970) Fisher & Riley, 1980  
Pl. 13, fig. 13

Specimens showing parasutural lines on the periphragm, but otherwise similar to *Dingodinium jurassicum*, are classified with *D. tuberosum*.

**Genus *Ellipsoidictyum* Klement, 1960**

*Ellipsoidictyum imperfectum* (Brideaux & McIntyre, 1975) Lentin & Williams, 1977b  
Pl. 8, figs. 20, 21, 24

See remarks to *Cassiculosphaeridia reticulata*.

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

*Florentinia cooksoniae* (Singh, 1971) Duxbury, 1980  
Pl. 16, figs. 20, 21

In the range charts for the Adda-1 and I-1 wells some of the specimens classified as *Florentinia mantellii* should perhaps be classified with *F. cooksoniae*. The two species are closely related and it may often be difficult to distinguish between them (e.g. pl. 16, figs. 15, 16). Typically the processes in *F. cooksoniae* are simple, while some of the processes in *F. mantellii* are distally divided.

*Florentinia mantellii* (Davey & Williams, 1966) Davey & Verdier, 1973  
Pl. 16, figs. 15, 16, 18, 19

See remarks to *Florentinia cooksoniae*.

**Genus *Gochteodinia* Norris, 1978**

*Gochteodinia villosa* (Vozzhennikova, 1967) Norris, 1978

*G. villosa* subsp. *multifurcata* Davey, 1982a  
Pl. 2, figs. 18, 19

See remarks below

*G. villosa* subsp. *villosa* and subsp. indeterminate  
Pl. 2, figs. 8, 11, 13–15

The two subspecies of *G. villosa*, subsp. *multifurcata* and subsp. *villosa*, are distinguished on the distal extremity of the processes: In subsp. *multifurcata* at least three distal spines are developed at some of the processes, while in subsp. *villosa* the processes are typically acuminate, but may briefly bifurcate. In the present study only specimens clearly showing the diagnostic process endings are classified with subspecies *multifurcata*. In the Adda-1 and I-1 wells specimens of *G. villosa*, which could not be identified at the subspecies level, were grouped together with undoubted subspecies *villosa*.

**Genus *Gonyaulacysta* Deflandre, 1964; emend. Sarjeant, 1969; emend. Stover & Evitt, 1978; emend. Sarjeant, 1982**

*Gonyaulacysta diutina* Duxbury, 1977 – *G. helicoidea* (Eisenack & Cookson, 1960) Sarjeant, 1966b group  
Pl. 10, figs. 2, 3

According to Duxbury (1977), *G. diutina* is closely comparable with specimens referred by Sarjeant (1966a) to *Gonyaulacysta helicoidea*, although they are separable on general cyst outline and size. A comparison of *G. diutina* with the type material of *G. helicoidea*, as illustrated in Eisenack & Cookson (1960), shows even greater similarity, and in the present writers opinion, *G. diutina* should probably be considered as a junior synonym of *G. helicoidea*.

**Genus *Hystrichodinium* Deflandre, 1935; emend. Sarjeant, 1966b; emend. Clarke & Verdier, 1967**

*Hystrichodinium furcatum* Alberti, 1961

See remarks below.

*Hystrichodinium ramoides* Alberti, 1961  
Pl. 6, fig. 1

*H. ramoides* and *H. furcatum* are closely related species. Both have distally furcated processes; in *H. furcatum* the processes are only divided once, usually giving rise to two short branches, while in *H. ramoides* the distal end is more complexly branched (some of the branches are again split into “twigs”).

**Genus *Kleithriasphaeridium* Davey, 1974**

*Kleithriasphaeridium* sp. 1  
Pl. 16, figs. 12, 17

This form differs from *K. fasciatum* (Davey & Williams, 1966) Davey, 1974 and *K. corrugatum* Davey, 1974 in the presence of membraneous lateral connections between some of the processes. In *K. fasciatum* and *K. corrugatum* the processes are free. In other characters, especially in the longitudinal ribbing of the processes and membranes, *Kleithriasphaeridium* sp. 1 is closely comparable to *K. corrugatum* and *K. fasciatum*.

**Genus *Muderongia* Cookson & Eisenack, 1958**

*Muderongia* sp. 1  
Pl. 2, figs. 1–4

1959 Dinoflagellat gen. et sp. indet. (1) – Gocht, p. 52, pl. 5, figs. 4–6  
1961 *Muderongia* sp. A – Alberti, p. 13, pl. 2, figs. 10, 11

This form is intermediate between *Muderongia simplex*, which is devoid of processes, and *Phoberocysta tabulata* having many parasutural processes. *Muderongia* sp. 1 is ornamented with fine sutural lines. A small number of spines arise from these sutures.

**Genus *Nematosphaeropsis* Deflandre & Cookson, 1955**

*Nematosphaeropsis* sp. 1  
Pl. 11, fig. 18

Only a single specimen has been seen. It is smooth-walled with strong gonial and some intergonial processes, connected proximally by relatively high parasutural septa. The processes are distally furcate (usually trifurcate) with bifid endings. In several cases thin trabeculae are seen to connect the endings of adjacent processes. This form basically conforms to the architecture of *Trabeculodinium quinquetrum* Duxbury, 1980, from which it differs in the possession of distinct parasutural septae.

**Genus *Occisucysta* Gitmez, 1970**

*Occisucysta evittii* (Dodekova, 1969) Gitmez, 1970  
Pl. 9, figs. 10–13

Specimens classified as *Occisucysta* cf. *evittii* and *Occisucysta* sp. A in Davey (1979, 1982a) are here considered to be within the morphological range of *O. evittii*.

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

*Oligosphaeridium* sp. 1  
Pl. 15, fig. 3

This form appears to be similar to *Oligosphaeridium asterigerum* (Gocht, 1959) Davey & Williams, 1969, except for the presence of long, fine and irregular, occasionally branching, threads arising from the spines in the distal end of the processes. In some instances the fine threads are seen to connect two processes. Most, or all, of the delicate threads may be broken trabeculae between processes. Unfortunately most specimens observed have been damaged, preventing more precise description of this distinct form.

**Genus *Pareodinia* Deflandre, 1947c; emend. Gocht, 1970b; emend. Johnson & Hills, 1973; emend. Wiggins, 1975; emend. Stover & Evitt, 1978**

*Pareodinia* sp. 1  
Pl. 4, figs. 1–4

1982b *Pareodinia* sp. – Davey, pl. 6. 3–6, fig. 7

This species is finely granular and possesses an apical horn of short to moderate length. The archaeopyle is

intercalary; the number of opercular plates is uncertain. *Pareodinia* sp. in Davey (1982b) is similar, except for being considerably larger, judging from the photographed specimen. *Pareodinia* sp. 1 in Davey (1982a) differs in having a generally longer, more abruptly rising apical horn.

**Genus *Phoberocysta* Millioud, 1969**

*Phoberocysta neocomica* (Gocht, 1957) Millioud, 1969  
Pl. 2, figs. 9, 10

See comments below.

*Phoberocysta tabulata* Raynaud 1978  
Pl. 2, figs. 5–7

This species is differentiated from *P. neocomica* by its far better expressed paratabulation. However, incipient paratabulation may also be developed in *P. neocomica* as can be seen in text-fig. 7 in Gocht (1957) which shows the dorsal surface of the holotype. Continuous gradation of morphologies between the two species has been observed in the present material.

**Genus *Pseudoceratium* Gocht, 1957; emend. Dörhöfer & Davies, 1980**

*Pseudoceratium* sp. 1  
Pl. 3, figs. 21–24

1979c *Pseudoceratium pelliferum* – Davey, pl. 4, fig. 1  
1982a *Pseudoceratium pelliferum* (early representative) – Davey, pl. 10, fig. 16

This form, which should only be regarded as a variety of *Pseudoceratium pelliferum* Gocht, 1957, is recognized by much shorter horns than in typical individuals of *P. pelliferum*.

**Genus *Pterodinium* Eisenack, 1958; emend. Yun, 1981**

*Pterodinium aliferum* Eisenack, 1958 group  
Pl. 11, figs. 11, 16

This group includes *Pterodinium aliferum* and the forms figured in Eisenack (1958, pl. 24, figs. 7–9) as *Pterodinium* sp. and *Pterodinium?* These forms have more irregular septa than *P. aliferum*.

**Genus *Spiniferites* Mantell, 1850; emend. Sarjeant, 1970**

*Spiniferites? dentatus* (Gocht, 1959) Lentin & Williams, 1973; emend. Duxbury, 1977  
Pl. 11, figs. 5, 6, 9, 10

Intermediate forms between *S.? dentatus* and *Spiniferites multibrevis* (Davey & Williams, 1966a) Below, 1982c occur in the Lower Valanginian at Speeton and have also been seen in the North Sea samples (e.g. pl. 11, fig. 5). These intermediate forms have parasutural crests of only low to moderate height, in contrast to the high crests in *S. dentatus*. On the other hand they resemble *S. dentatus* in bearing a larger number of processes arising from the parasutural crests than are present in *S. multibrevis*.

*Spiniferites ramosus* (Ehrenberg, 1838) Loeblich & Loeblich, 1966 – *S. multibrevis* (Davey & Williams, 1966a) Below, 1982c group

For convenience *S. ramosus* and the closely related species *S. multibrevis* (formerly classified as a subspecies of *S. ramosus*) are treated as a group in the range charts of the Adda-1 and I-1 wells. Only one subspecies of *S. ramosus*, namely subsp. *primaevus* Duxbury, 1977 has been kept separate since it is both morphologically and stratigraphically distinct.

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

*Stephodinium spinulosum* Duxbury, 1983  
Pl. 12, fig. 23

This species is very similar to *Stephodinium daveyii* Below, 1982. The main difference between the two species is the presence of an apical pericoel in *S. daveyii*, which apparently lacks in *S. spinulosum*. Furthermore, the parasutural ridges and processes, present in both species, appear to be slightly better developed in *S. spinulosum* than in *S. daveyii*.

**Genus *Stiphrosphaeridium* Davey, 1982a**

*Stiphrosphaeridium anthophorum* (Cookson & Eisenack, 1958) Davey, 1982a – *S. dictyophorum* (Cookson & Eisenack, 1958) Davey, 1982a group  
Pl. 15, figs. 8, 9, 12, 13

The two species *S. anthophorum* and *S. dictyophorum* are basically similar, but the differences in their morphology have been clarified by Davey (1982a); thus *S. anthophorum* has wider and more fenestrate processes than *S. dictyophorum*. Strictly following this criterion for separation, it appears that both species occur at two discrete stratigraphical levels, namely near the Jurassic-Cretaceous boundary and in the Upper Aptian (further accounted for in a previous section, p. 20). Since it was realized during this study that many specimens with an intermediate morphology cannot easily be identified with one particular species of the two, they have been treated as a single group.



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# PLATES 1–17

## PLATE 1

All magnifications  $\times 500$ .

*Muderongia extensiva* Duxbury, 1977

Fig. 1. I-1, 10340'.

Fig. 3. I-1, 10340'.

*Muderongia parvata* Duxbury, 1977

Fig. 2. Adda-2, 7756'.

Fig. 4. Adda-2, 7753'3''.

Fig. 6. I-1, 9490'.

Fig. 8. I-1, 9480'.

*Muderongia staurota* Sarjeant, 1966c

Fig. 5. Adda-2, 7753'3''.

*Muderongia simplex* subsp. *microperforata* Davey, 1982a

Fig. 7. Adda-1, 7800'.

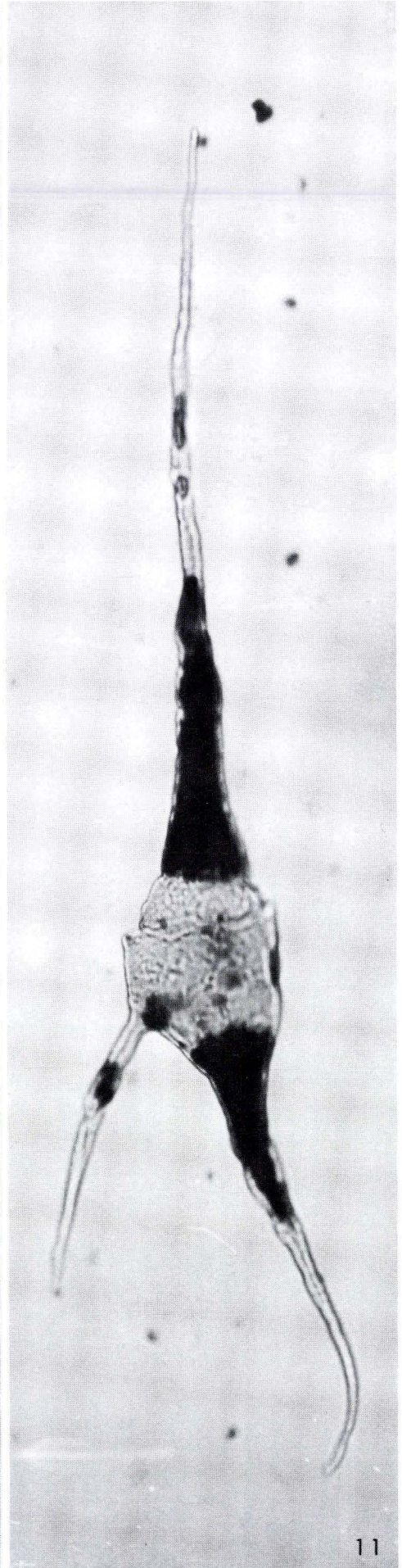
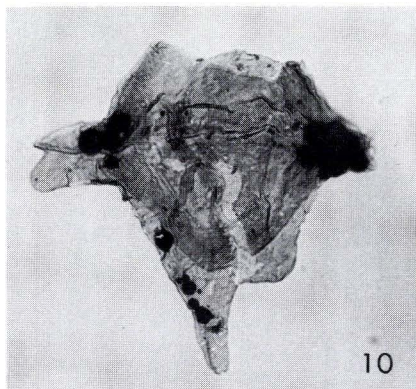
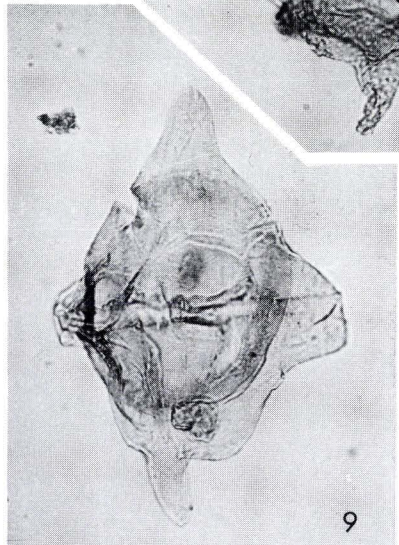
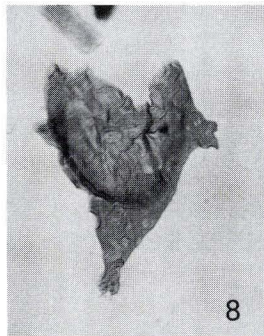
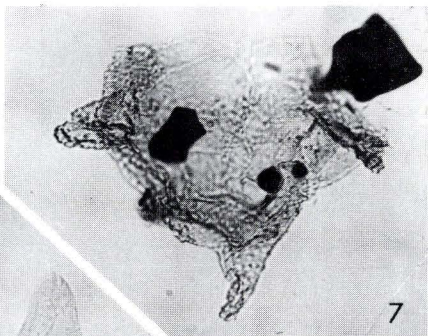
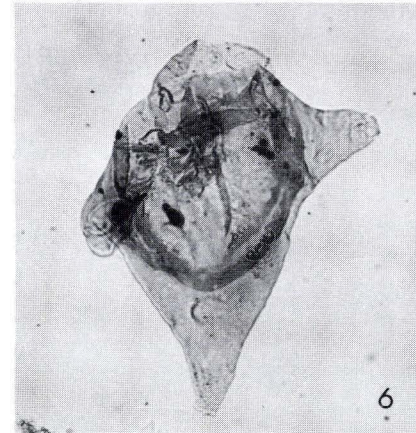
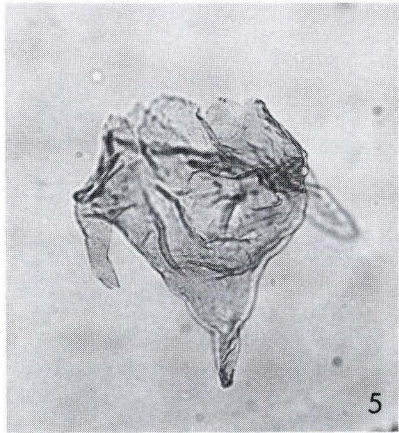
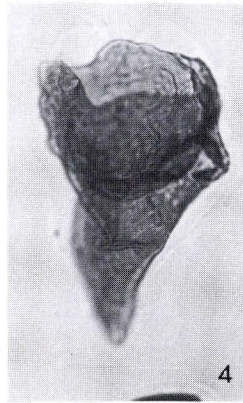
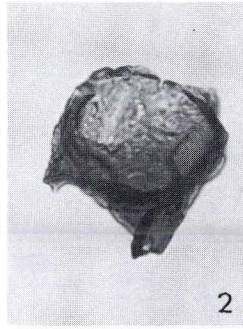
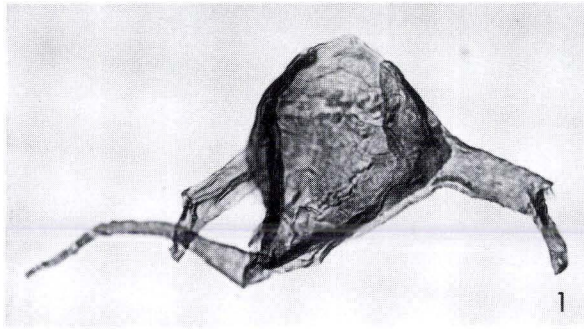
*Muderongia simplex* Alberti, 1961

Fig. 9. Adda-1, 8100'.

Fig. 10. I-1, 10290'.

*Odontochitina operculata* (O. Wetzel, 1933a) Deflandre & Cookson, 1955

Fig. 11. E-1, 8200'.



## PLATE 2

All magnifications  $\times 500$

### *Muderongia* sp. 1

Fig. 1. I-1, 10530'.

Fig. 2. Adda-1, 7940'.

Fig. 3. I-1, 10290'.

Fig. 4. I-1, 10340'.

### *Phoberocysta tabulata* Raynaud, 1978

Fig. 5. Adda-1, 7950'.

Fig. 6. Same specimen as in fig. 5

Fig. 7. I-1, 10670'.

### *Phoberocysta neocomica* (Gocht, 1957) Millioud, 1969

Fig. 9. Adda-1, 7720'.

Fig. 10. I-1, 9495'.

### *Gochteodinia villosa* (Vozzhennikova, 1967) Norris, 1978

Fig. 8. Subspecies indeterminate, I-1, 10570'.

Fig. 11. Subspecies indeterminate, I-1, 10340'.

Fig. 13. Subspecies *villosa*. Early specimen with very fine processes. M-8, 7800'.

Fig. 14. Subsp. *villosa*, Adda-1, 7950'.

Fig. 15. Subsp. *villosa*, Adda-1, 9150'.

Fig. 18. Subsp. *multifurcata* Davey, 1982a, I-1, 10530'.

Fig. 19. Subsp. *multifurcata* Davey, 1982a, I-1, 10890'.

### *Gochteodinia virgula* Davey, 1982a

Fig. 12. I-1, 11300'.

Fig. 16. Adda-1, 9170'.

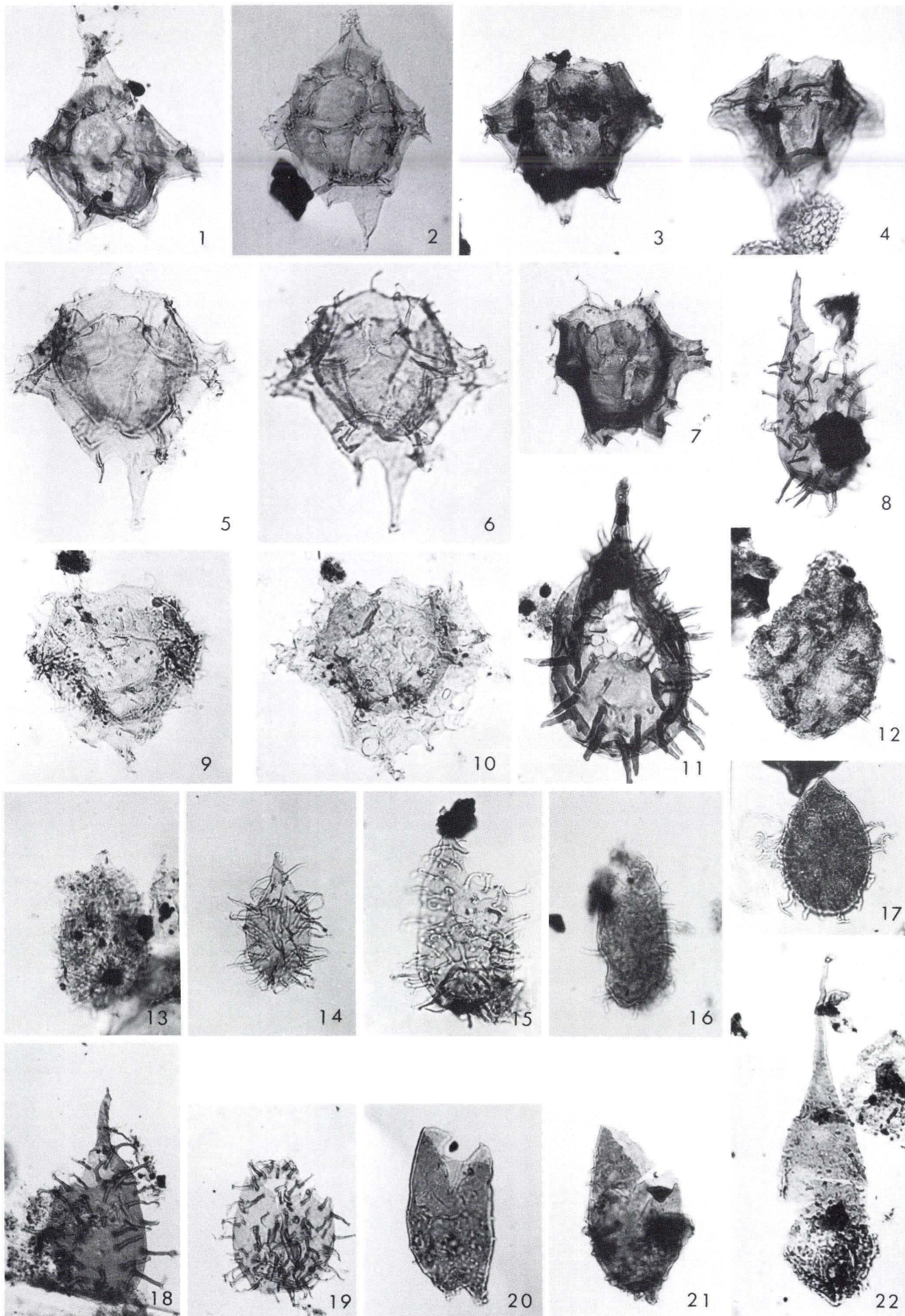
Fig. 17. I-1, 10470'.

### *Batioladinium* sp. 1 Davey, 1982a

Fig. 20. Adda-1, 7800'.

Fig. 21. I-1, 10530'.

Fig. 22. Adda-1, 7870'.





### PLATE 3

All magnifications  $\times 500$

*Batioladinium varigranosum* (Duxbury, 1977) Davey, 1982a

Fig. 1. Adda-1, 8170'.

Fig. 2. I-1, 10890'.

*Batioladinium* cf. *varigranosum* sensu Davey, 1982a

Fig. 3. Adda-1, 8100'.

Fig. 4. Adda-1, 8100'.

Fig. 5. Adda-1, 8250'.

Fig. 6. Adda-1, 7760'.

*Batioladinium?* *pelliferum* (Alberti, 1961) Brideaux, 1975

Fig. 7. An almost smooth-walled specimen. Adda-1, 7720'.

Fig. 8. I-1, 9510'.

Fig. 9. Adda-1, 7800'.

*Batioladinium pomum* Davey, 1982a

Fig. 10. I-1, 10470'.

Fig. 11. Adda-1, 8650'.

*Batioladinium jaegeri* (Alberti, 1961) Brideaux, 1975

Fig. 12. I-1, 9420'.

*Batioladinium longicornutum* (Alberti, 1961) Brideaux, 1975

Fig. 13. E-1, 8200'.

Fig. 14. Adda-1, 7600'.

Fig. 15. I-1, 9900'.

Fig. 16. I-1, 9900'.

*Pseudoceratium pelliferum* Gocht, 1957

Fig. 17. I-1, 9900'.

Fig. 18. Adda-1, 8460'.

Fig. 19. I-1, 10890'.

Fig. 20. I-1, 10220'.

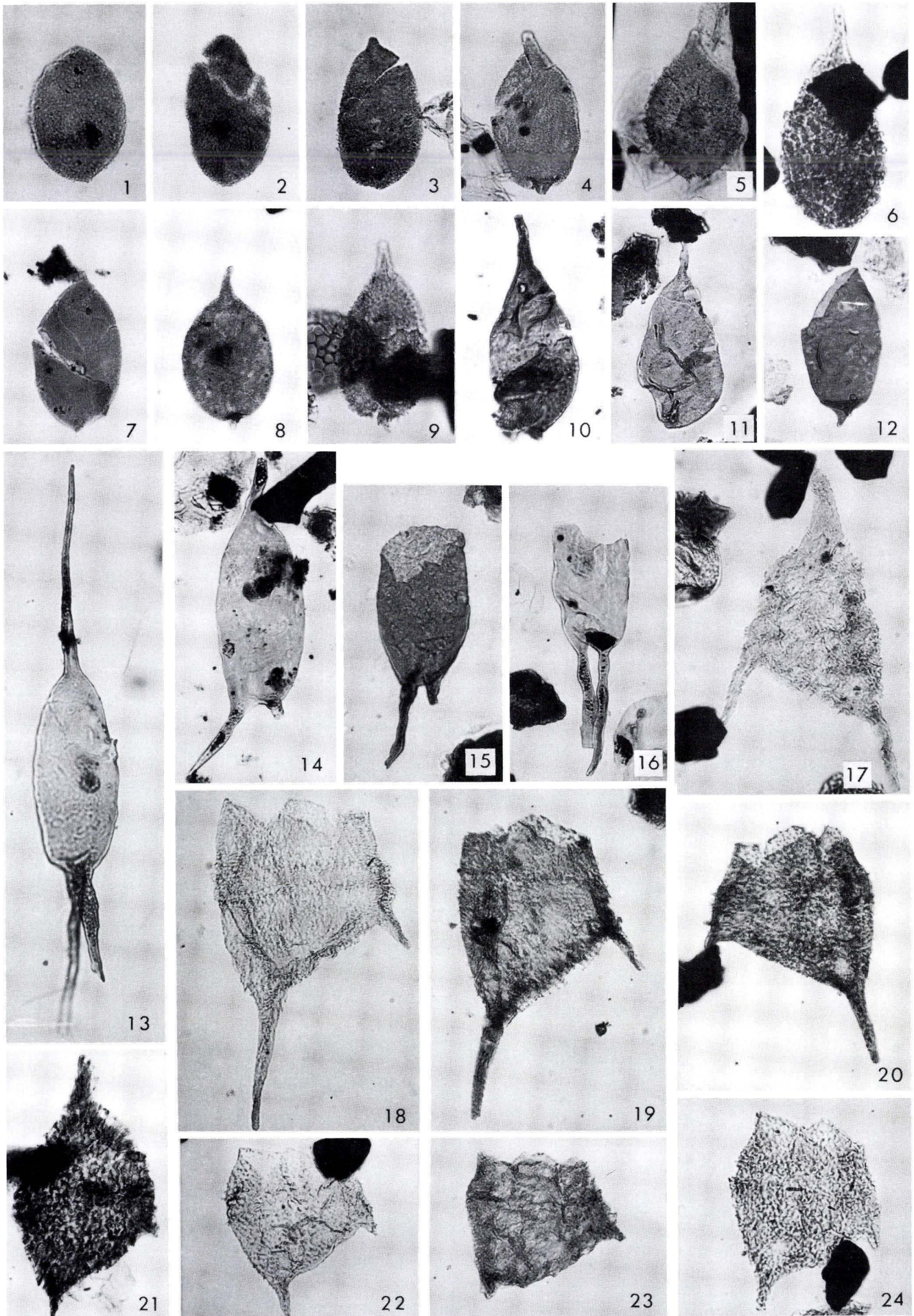
*Pseudoceratium* sp. 1

Fig. 21. I-1, 10530'.

Fig. 22. Adda-1, 8800'.

Fig. 23. I-1, 10220'.

Fig. 24. Adda-1, 8020'.



## PLATE 4

All magnifications  $\times 500$ .

### *Pareodinia* sp. 1

Fig. 1. I-1, 9490'.

Fig. 2. I-1, 9420'.

Fig. 3. I-1, 9420'.

Fig. 4. I-1, 9540'.

### *Trichodinium castanea* (Deflandre, 1935) Clarke & Verdier, 1967

Fig. 5. I-1, 10340'.

Fig. 6. I-1, 10570'.

Fig. 7. Adda-1, 8170'.

### *Trichodinium speetonense* Davey, 1974

Fig. 8. Adda-1, 7710'.

### *Cerbia tabulata* (Davey & Verdier, 1974) Below, 1981a

Fig. 9. Adda-2, 7753'3''.

Fig. 10. I-1, 9780'.

Fig. 11. Adda-2, 7753'3''.

### *Cyclonephelium hystrix* (Eisenack, 1958) Davey, 1978

Fig. 12. A specimen with very stout processes. I-1, 10890'.

Fig. 15. I-1, 9490'.

Fig. 16. I-1, 9540'.

### *Aptea securigera* Davey & Verdier 1974

Fig. 13. Adda-1, 7580'.

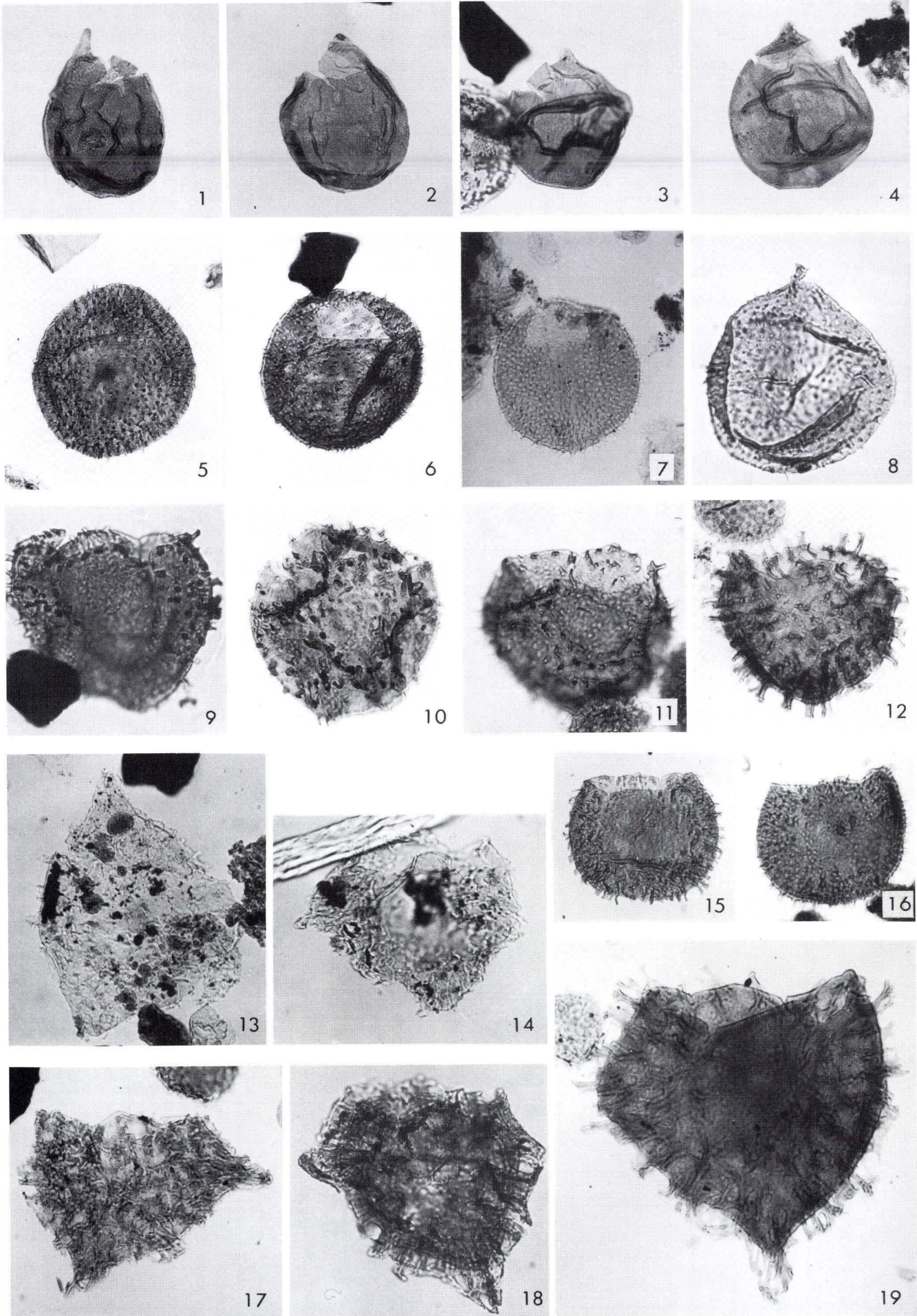
Fig. 14. Adda-1, 7580'.

### *Aptea polymorpha* Eisenack, 1958

Fig. 17. I-1, 9490'.

Fig. 18. Adda-2, 7753'3''.

Fig. 19. I-1, 9780'.



## PLATE 5

All magnifications  $\times 500$ .

*Cepadinium variabile* Duxbury, 1983

Fig. 1. A three-layered specimen. Adda-2, 7762'.

Fig. 2. Note archaeopyle margin. Adda-2, 7753'3''.

*Subtilisphaera ventriosa* (Alberti, 1959b) Jain & Millepied, 1973

Fig. 3. Adda-1, 7650'.

Fig. 4. I-1, 9490'.

*Subtilisphaera perlucida* (Alberti, 1959b) Jain & Millepied, 1973

Fig. 5. Adda-1, 7720'.

*Isabelidinium gallium* (Davey & Verdier, 1973) Stover & Evitt, 1978

Fig. 6. Adda-1, 7540'.

Fig. 7. Adda-1, 7570'.

*Ascodinium scabrosum* Cookson & Hughes, 1964

Fig. 8. Adda-1, 7530'.

Fig. 9. Adda-1, 7530'.

*Leberidocysta chlamydata* (Cookson & Eisenack, 1962b) Stover & Evitt, 1978

Fig. 10. I-1, 9370'.

*Maduradinium?* sp. A Davey, 1982a

Fig. 11. I-1, 10340'.

Fig. 12. Adda-1, 7660'.

Fig. 13. Adda-1, 7800'.

*Membranilarnacia polycladiata* Cookson & Eisenack in Eisenack, 1963a

Fig. 14. I-1, 9490'.

Fig. 16. I-1, 9540'.

Fig. 17. I-1, 9850'.

*Walloodinium anglicum* (Cookson & Hughes, 1964) Lentin & Williams, 1973

Fig. 15. Adda-2, 7753'3''.

Fig. 18. Adda-1, 7910'.

Fig. 22. Adda-1, 7800'.

*Walloodinium cylindricum* (Habib, 1970) Duxbury, 1983

Fig. 19. Adda-1, 8650'.

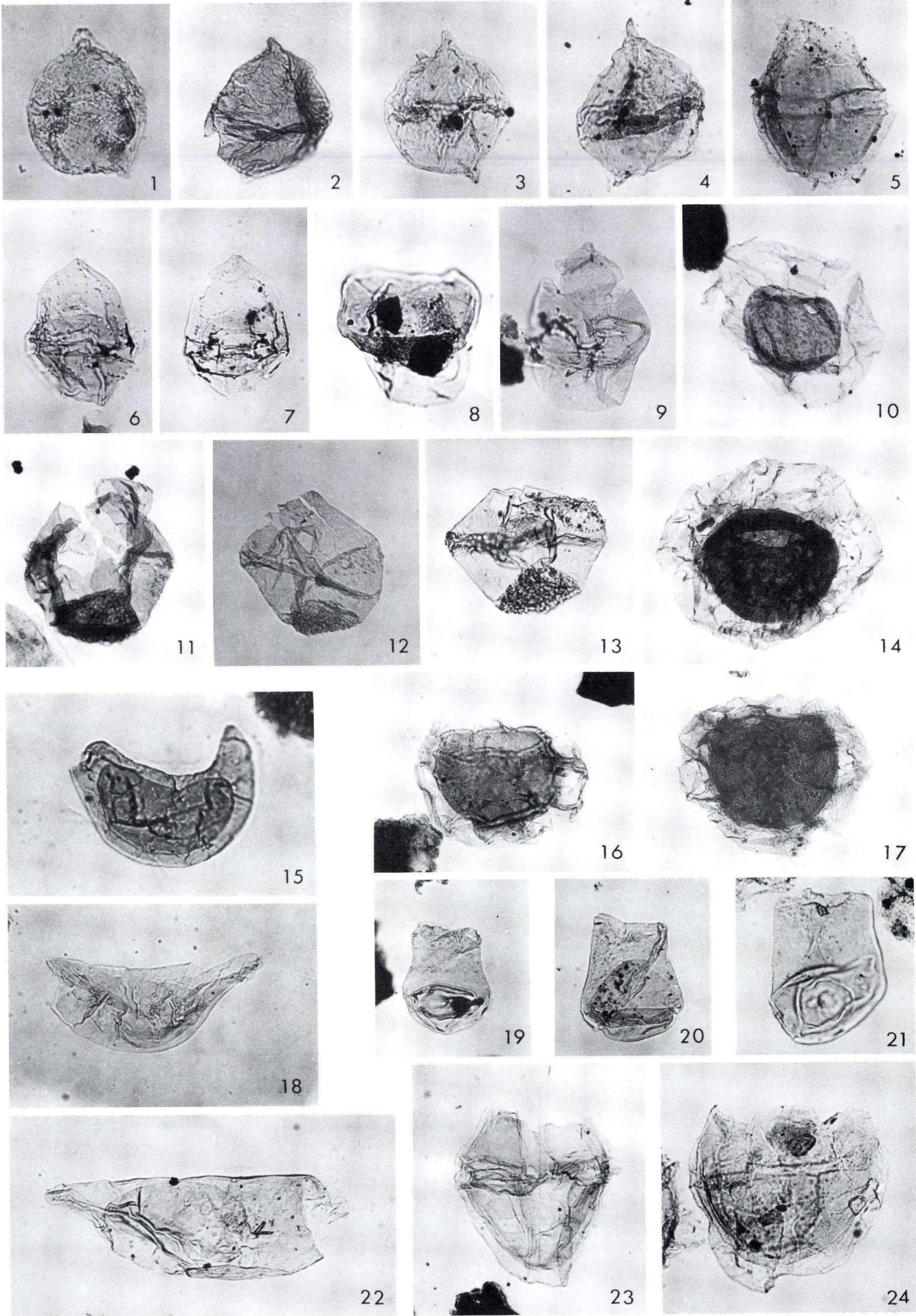
Fig. 20. Adda-1, 7980'.

Fig. 21. Adda-1, 8500'.

*Senoniasphaera jurassica* (Gitmez & Sarjeant, 1972) Lentin & Williams, 1976

Fig. 23. Adda-1, 8650'.

Fig. 24. Adda-1, 8170'.



## PLATE 6

All magnifications  $\times 500$ .

*Hystrichodinium ramoides* Alberti, 1961

Fig. 1. I-1, 9520'.

*Hystrichodinium voigtii* (Alberti, 1961) Davey, 1974

Fig. 2. I-1, 9540'.

Fig. 8. I-1, 10810'.

Fig. 9. I-1, 10670'.

*Cauca parva* (Alberti, 1961) Davey & Verdier, 1971

Fig. 3. I-1, 10160'.

Fig. 4. I-1, 9370'.

Fig. 5. I-1, 9370'.

*Canningia compta* Davey, 1982a

Fig. 6. Adda-1, 8500'.

Fig. 7. I-1, 10570'.

*Fromea quadrugata* Duxbury, 1980

Fig. 10. I-1, 9820'.

Fig. 11. Adda-1, 7690'.

*Fromea amphora* Cookson & Eisenack, 1958

Fig. 12. Adda-1, 7660'.

Fig. 13. I-1, 9560'.

*Tasmanites* Newton, 1875

Fig. 14. I-1, 9540'.

Fig. 15. Adda-1, 8600'.

Fig. 16. I-1, 11060'.

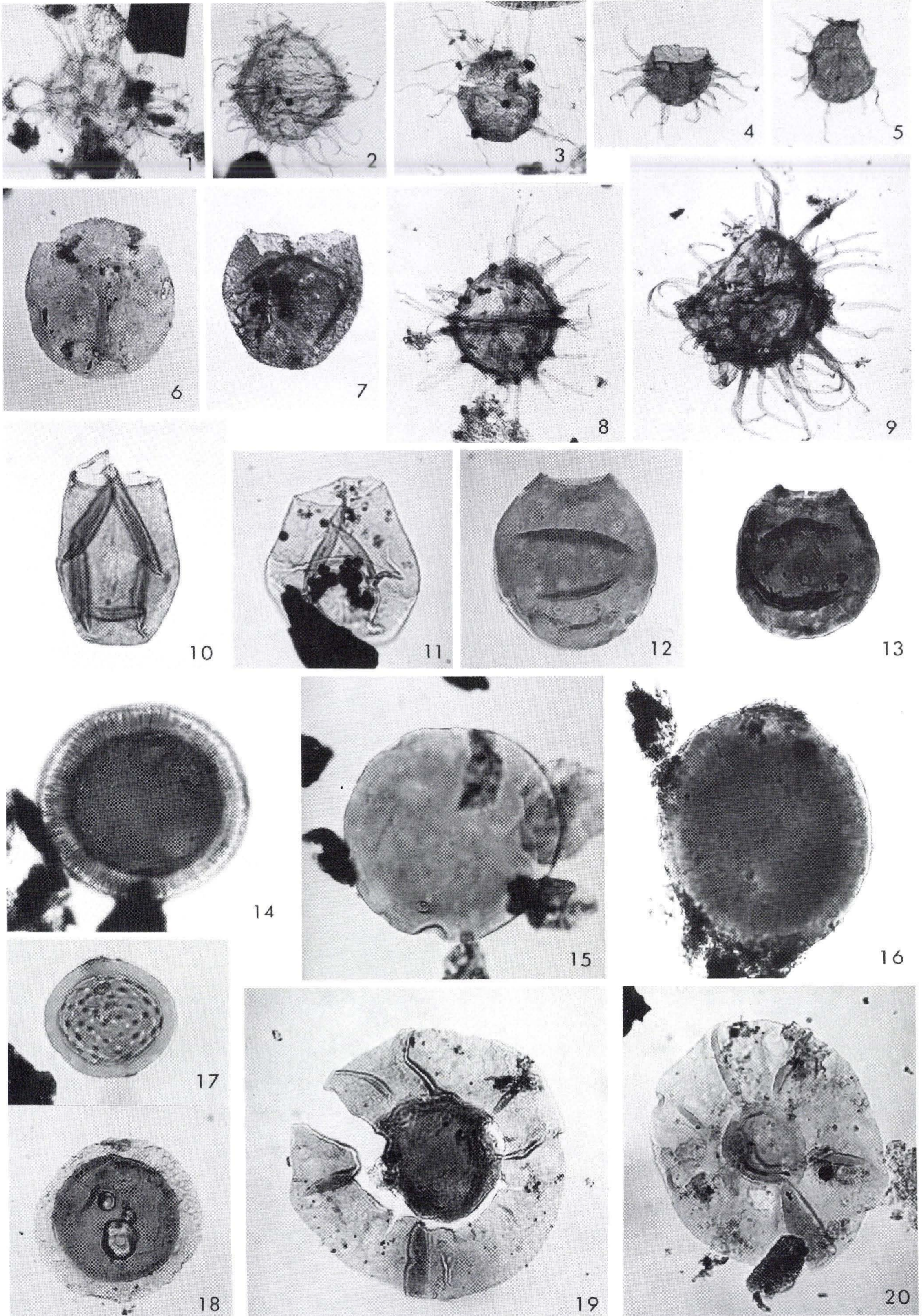
Fig. 17. Adda-1, 8600'.

*Pterospermella* Eisenack, 1972

Fig. 18. I-1, 10730'.

Fig. 19. I-1, 10730'.

Fig. 20. Adda-1, 8500'.





## PLATE 7

All magnifications  $\times 500$ .

*Sirmiodiniopsis frisia* (Raynaud, 1978) Lentin & Williams, 1981

Fig. 1. I-1, 10530'.

Fig. 2. Adda-1, 8320'.

Fig. 3. I-1, 10570'.

Fig. 4. Adda-1, 8460'.

Fig. 5. I-1, 10890'.

*Sirmiodinium grossii* Alberti, 1961

Fig. 6. I-1, 10410'.

Fig. 7. I-1, 10570'.

Fig. 8. Adda-1, 7910'.

Fig. 9. Adda-1, 8460'.

*Tubotuberella apatela* (Cookson & Eisenack, 1960b) Ioannides et al., 1971

Fig. 10. Adda-1, 7950'.

Fig. 11. I-1, 10750'.

Fig. 12. Adda-1, 8250'.

*Endoscrinium pharo* Duxbury, 1977

Fig. 13. Adda-1, 9000'.

Fig. 18. I-1, 10770'.

Fig. 19. I-1, 10750'.

*Endoscrinium granulatum* (Raynaud, 1978) Lentin & Williams, 1981

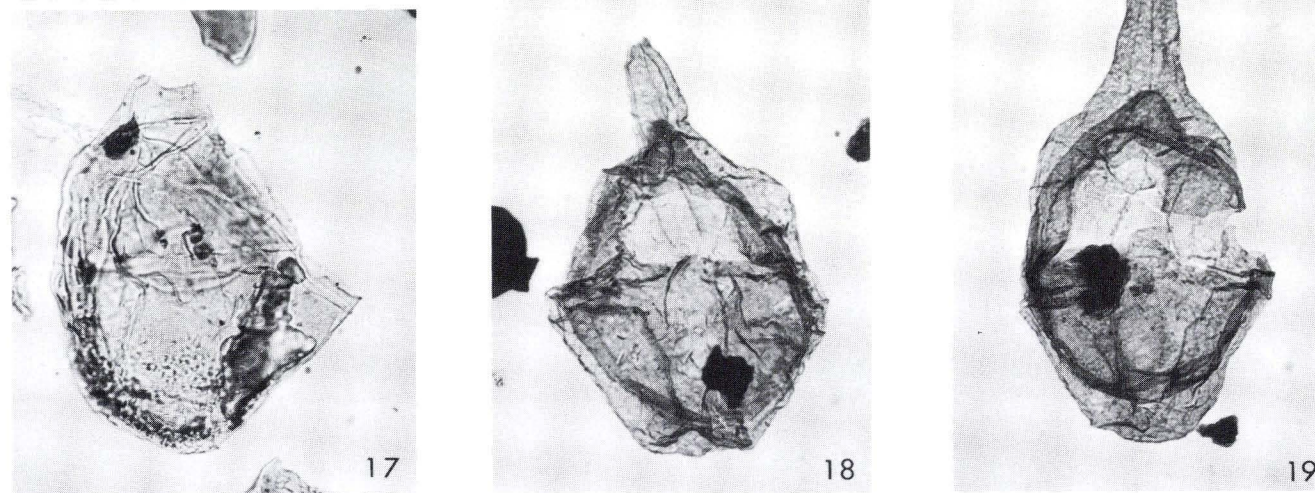
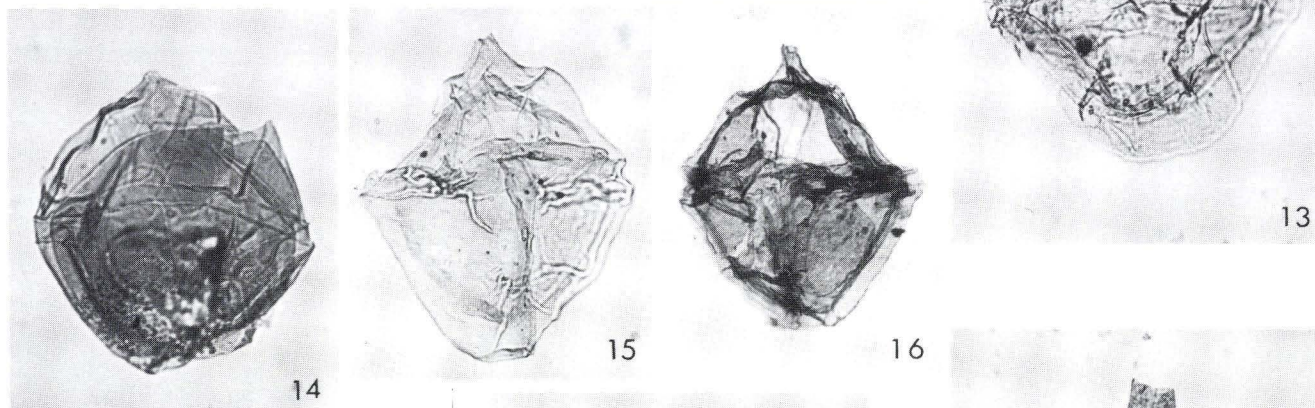
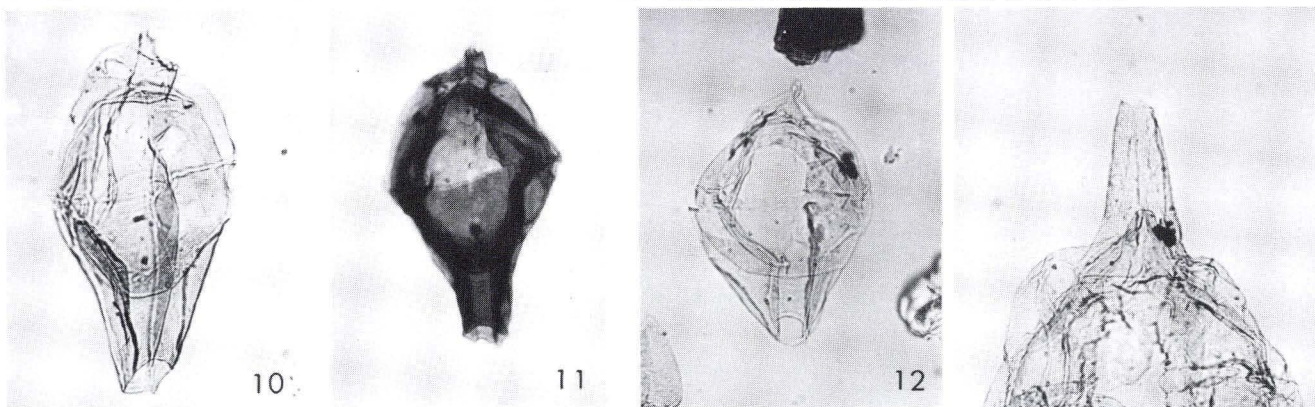
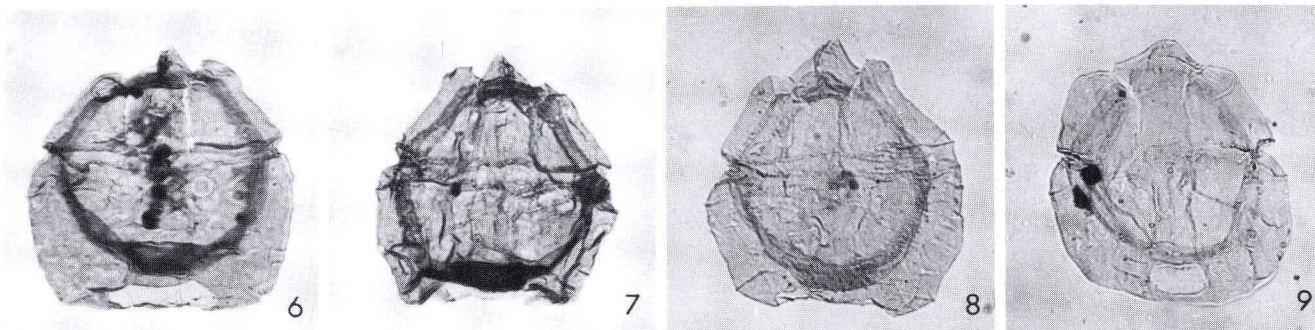
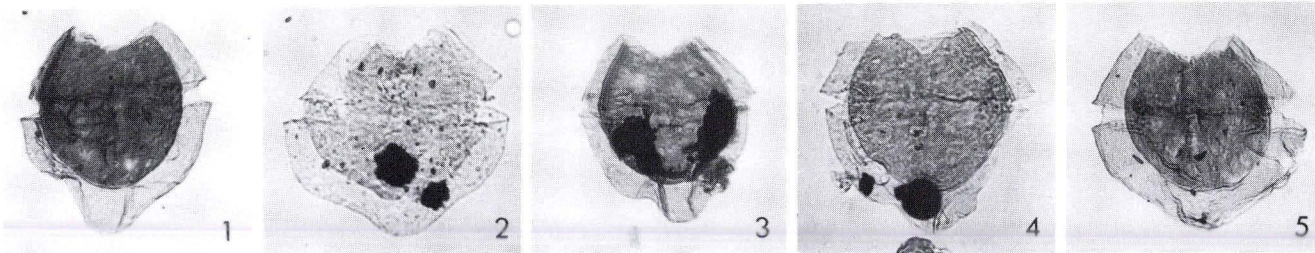
Fig. 14. E-1, 9720'.

Fig. 17. Adda-1, 8800'.

*Endoscrinium campanula* (Gocht, 1959) Vozzhennikova, 1967

Fig. 15. Adda-1, 8170'.

Fig. 16. I-1, 10570'.



## PLATE 8

All magnifications  $\times 500$

*Carpodinium obliquicostatum* Cookson & Hughes, 1964  
Fig. 1. Adda-1, 7530'.

*Carpodinium granulatum* Cookson & Eisenack, 1962b  
Fig. 2. I-1, 9370'.  
Fig. 3. I-1, 9380'.  
Fig. 4. I-1, 9420'.  
Fig. 5. I-1, 9480'.

*Chytrioisphaeridia cerastes* Davey, 1979d  
Fig. 6. I-1, 10750'.  
Fig. 7. I-1, 10470'.

*Lagenorhysis delicatula* (Duxbury, 1977) Duxbury, 1979b  
Fig. 8. Adda-1, 7940'.  
Fig. 9. I-1, 10710'.  
Fig. 10. Adda-1, 7910'.  
Fig. 11. A small specimen, morphologically transitional to  
*Chytrioisphaeridia cerastes*. Adda-1, 7950'.

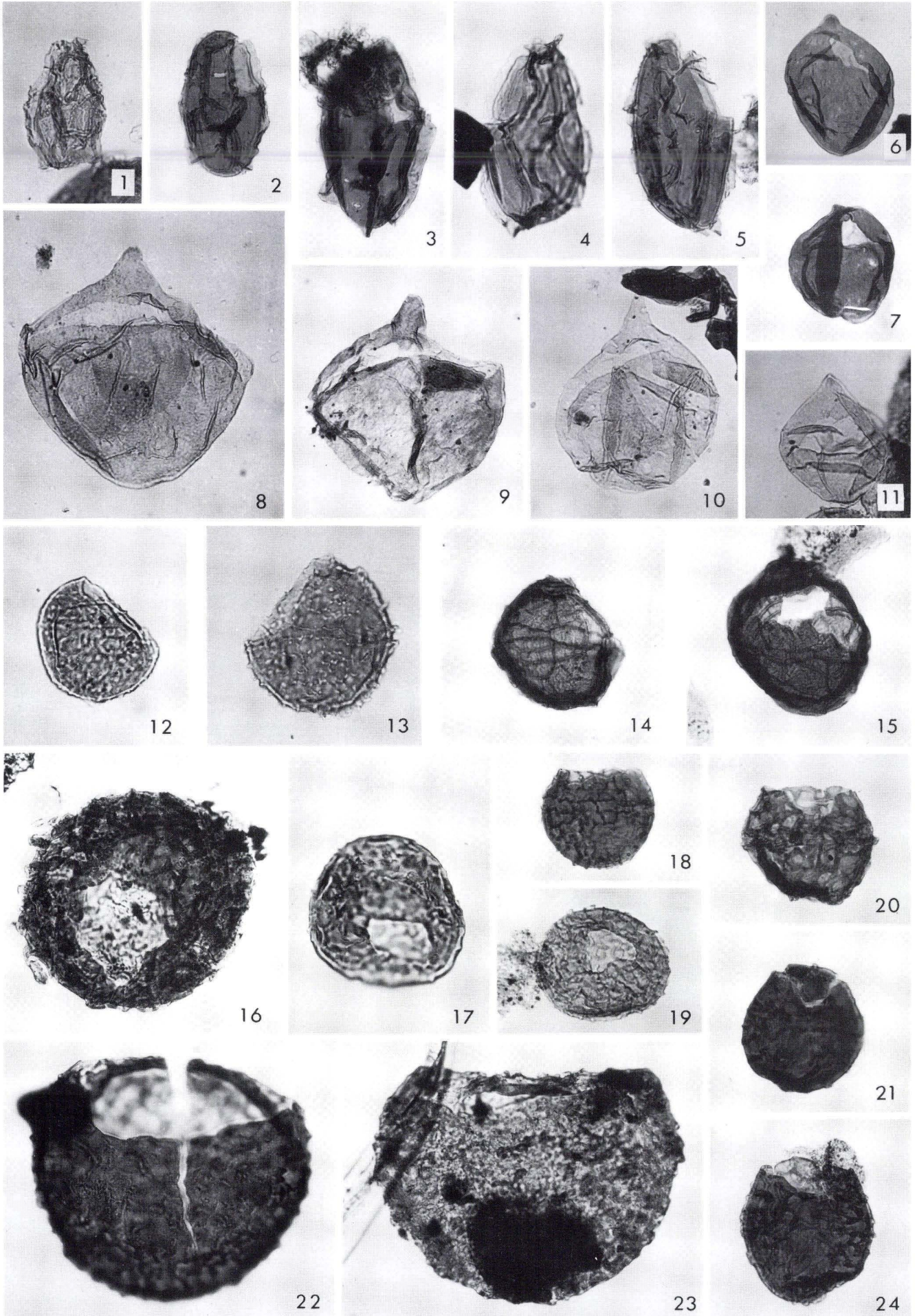
*Ellipsodinium reticulatum* Duxbury, 1980  
Fig. 12. Adda-1, 7660'.  
Fig. 13. Adda-2, 7762'.

*Leptodinium cancellatum* Brideaux & McIntyre, 1975  
Fig. 14. I-1, 9400'.  
Fig. 15. I-1, 9420'.

*Cassiculosphaeridia magna* Davey, 1974  
Fig. 16. I-1, 10890'.  
Fig. 22. I-1, 10220'.  
Fig. 23. I-1, 9539'.

*Cassiculosphaeridia reticulata* Davey, 1969a  
Fig. 17. I-1, 9340'.  
Fig. 18. I-1, 9380'.  
Fig. 19. Adda-1, 7670'.

*Ellipsoidictyum imperfectum* (Brideaux & McIntyre, 1975)  
Lentin & Williams, 1977b  
Fig. 20. I-1, 9420'.  
Fig. 21. I-1, 9420'.  
Fig. 24. I-1, 9380'.



## PLATE 9

All magnifications  $\times 500$

*Diacanthum tenuiceras* (Eisenack, 1958) Stover & Evitt, 1978  
Fig. 1. Apical view. I-1, 9360'.

*Exiguisphaera phragma* Duxbury, 1979a  
Fig. 2. Adda-1, 8170'.  
Fig. 3. Adda-1, 8250'.  
Fig. 4. Adda-1, 9150'.

*Exiguisphaera plectilis* Duxbury, 1980  
Fig. 5. Adda-1, 7610'.  
Fig. 6. Adda-1, 7640'.

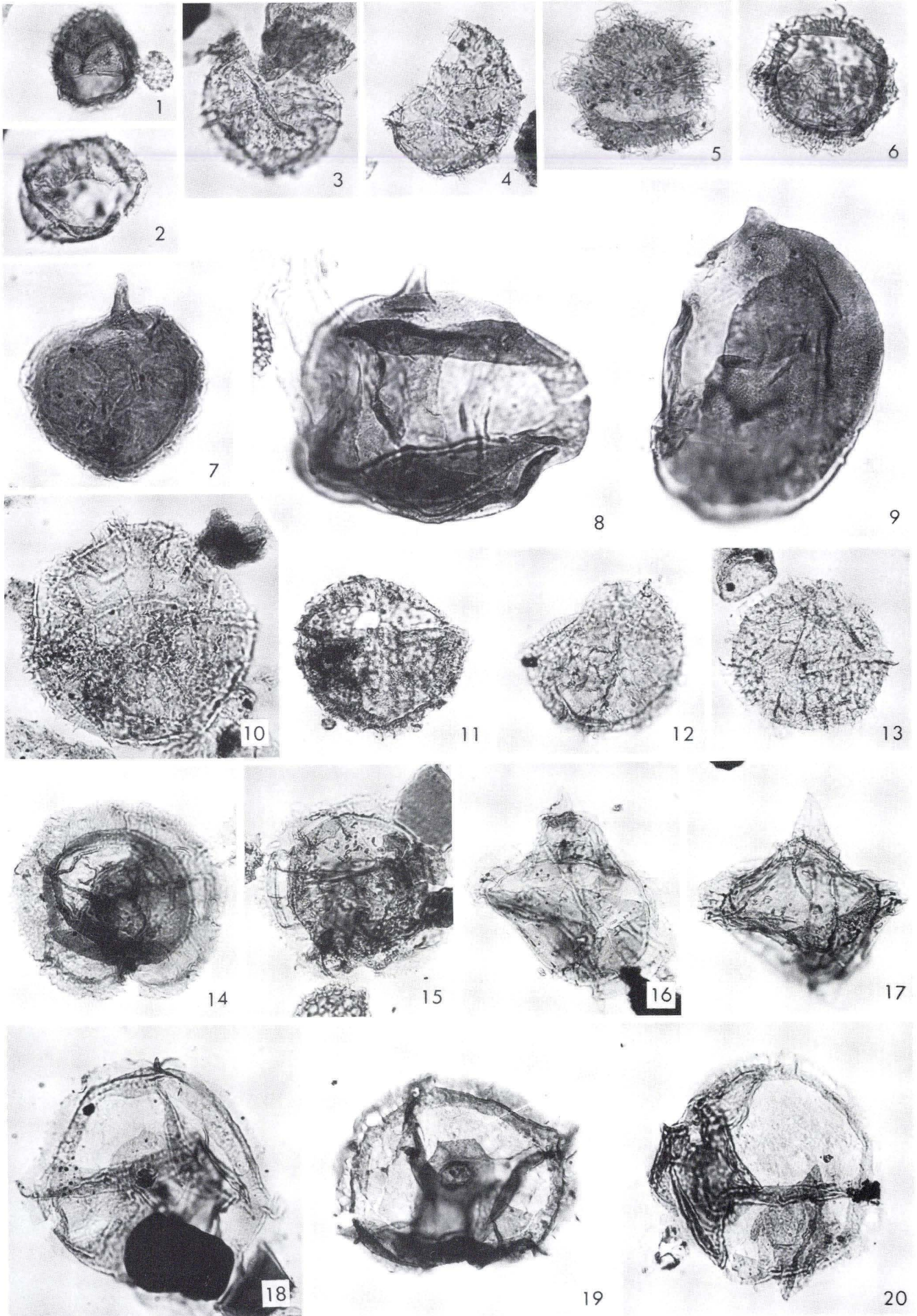
*Aldorfia spongiosa* (McIntyre & Brideaux, 1980) Davey,  
1982a  
Fig. 7. M-8, 7300'.

*Apteodinium grande* Cookson & Hughes, 1964  
Fig. 8. Adda-1, 7540'.  
Fig. 9. Adda-1, 7530'.

*Occisucysta evittii* (Dodekova, 1969) Gitmez, 1970  
Fig. 10. Adda-1, 8430'.  
Fig. 11. Adda-1, 8500'.  
Fig. 12. Adda-1, 8400'.  
Fig. 13. Adda-1, 8400'.

*Occisucysta tentoria* Duxbury, 1977  
Fig. 14. I-1, 9490'.  
Fig. 15. Adda-1, 8650'.  
Fig. 16. Adda-1, 7940'.  
Fig. 17. Adda-1, 7940'.

*Isthmocystis distincta* Duxbury, 1979a  
Fig. 18. M-8, 7490'.  
Fig. 19. I-1, 10290'.  
Fig. 20. Adda-1, 7850'.



## PLATE 10

All magnifications  $\times 500$

*Gonyaulacysta exanguia* Duxbury, 1977

Fig. 1. Adda-1, 8500'.

*Gonyaulacysta helicoidea* (Eisenack & Cookson, 1960) Sarjeant, 1966b

Fig. 2. Adda-1, 7950'.

Fig. 3. Adda-1, 7800'.

*Gonyaulacysta? fastigiata* Duxbury, 1977

Fig. 4. Adda-1, 8170'.

Fig. 5. I-1, 10410'.

*Cribroperidinium* sp. A Davey, 1982a

Fig. 6. M-8, 7800'.

*Gonyaulacysta* sp. A Davey, 1982a

Fig. 7. Adda-1, 8550'.

*Gonyaulacysta perforobtusa* Duxbury, 1977

Fig. 8. I-1, 9900'.

*Gonyaulacysta ordocava* Duxbury, 1977

Fig. 9. I-1, 9960'.

*Rhynchodiniopsis aptiana* Deflandre, 1935

Fig. 10. Adda-1, 7650'.

*Gonyaulacysta cladophora* sensu Duxbury, 1977

Fig. 11. I-1, 10570'.

*Cribroperidinium? cornutum* Davey, 1974

Fig. 12. I-1, 9600'.

Fig. 15. Adda-1, 7650'.

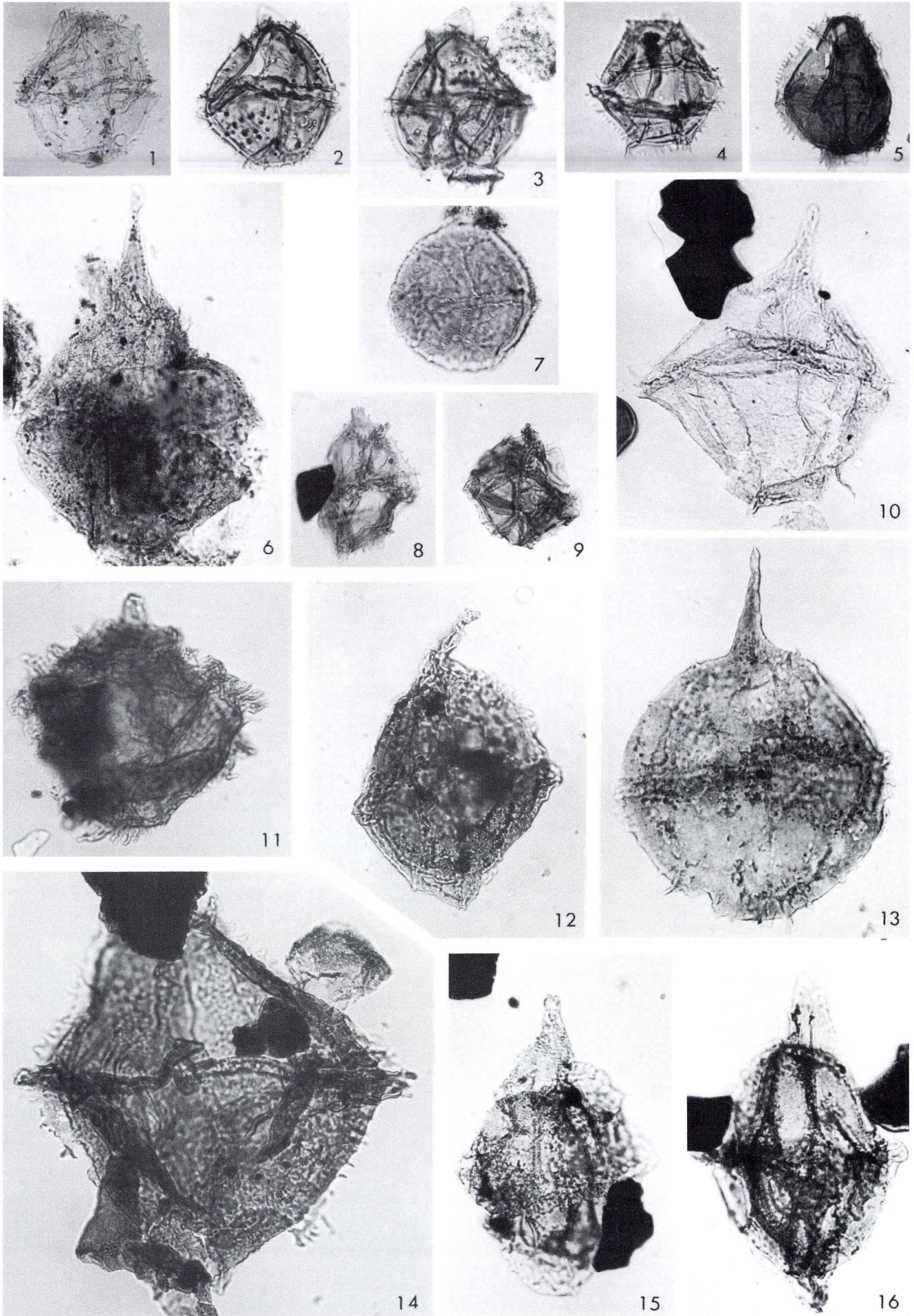
Fig. 16. Adda-1, 7710'.

*Cribroperidinium? gigas* (Raynaud, 1978) Helenes, 1984

Fig. 13. Adda-1, 9150'.

*Cribroperidinium sepimentum* Neale & Sarjeant, 1962

Fig. 14. I-1, 10160'.





## PLATE 11

All magnifications  $\times 500$

*Gonyaulacysta kostromiensis* (Vozzhennikova, 1967) Sarjeant, 1969

Fig. 1. Adda-1, 7760'.

Fig. 2. I-1, 9900'.

Fig. 3. I-1, 10020'.

Fig. 4. I-1, 10730'.

*Spiniferites? dentatus* (Gocht, 1959) Lentin & Williams, 1973

Fig. 5. A specimen showing affinity to *Spiniferites multibrevis*. Adda-1, 7910'.

Fig. 6. I-1, 10850'.

Fig. 9. I-1, 10810'.

Fig. 10. Adda-1, 7720'.

*Gonyaulacysta cassidata* (Eisenack & Cookson, 1960) Sarjeant, 1966b

Fig. 7. Adda-1, 7530'.

*Spiniferites speetonensis* Duxbury, 1980

Fig. 8. Adda-1, 7700'.

*Pterodinium* cf. *aliferum* Eisenack, 1958

Fig. 11. Adda-2, 7753'3''.

*Pterodinium aliferum* Eisenack, 1958

Fig. 16. Adda-2, 7753'3''.

*Trabeculodinium quinquetrum* Duxbury, 1980

Fig. 12. I-1, 9780'.

Fig. 17. I-1, 9820'.

*Nematosphaeropsis scala* Duxbury, 1977

Fig. 13. I-1, 9960'.

Fig. 14. I-1, 10090'.

*Spiniferites ramosus* subsp. *primaevus* Duxbury, 1977

Fig. 15. I-1, 10410'.

*Nematosphaeropsis* sp. 1

Fig. 18. I-1, 9850'.

*Cannosphaeropsis thula* Davey, 1982a

Fig. 19. Adda-1, 8700'.

Fig. 20. I-1, 10970'.

Fig. 25. Adda-1, 9150'.

*Diphasiosphaera stolidota* Duxbury, 1980

Fig. 21. Adda-1, 7730'.

Fig. 22. Adda-1, 7760'.

Fig. 23. Adda-1, 7690'.

Fig. 24. E-1, 8191'6''.

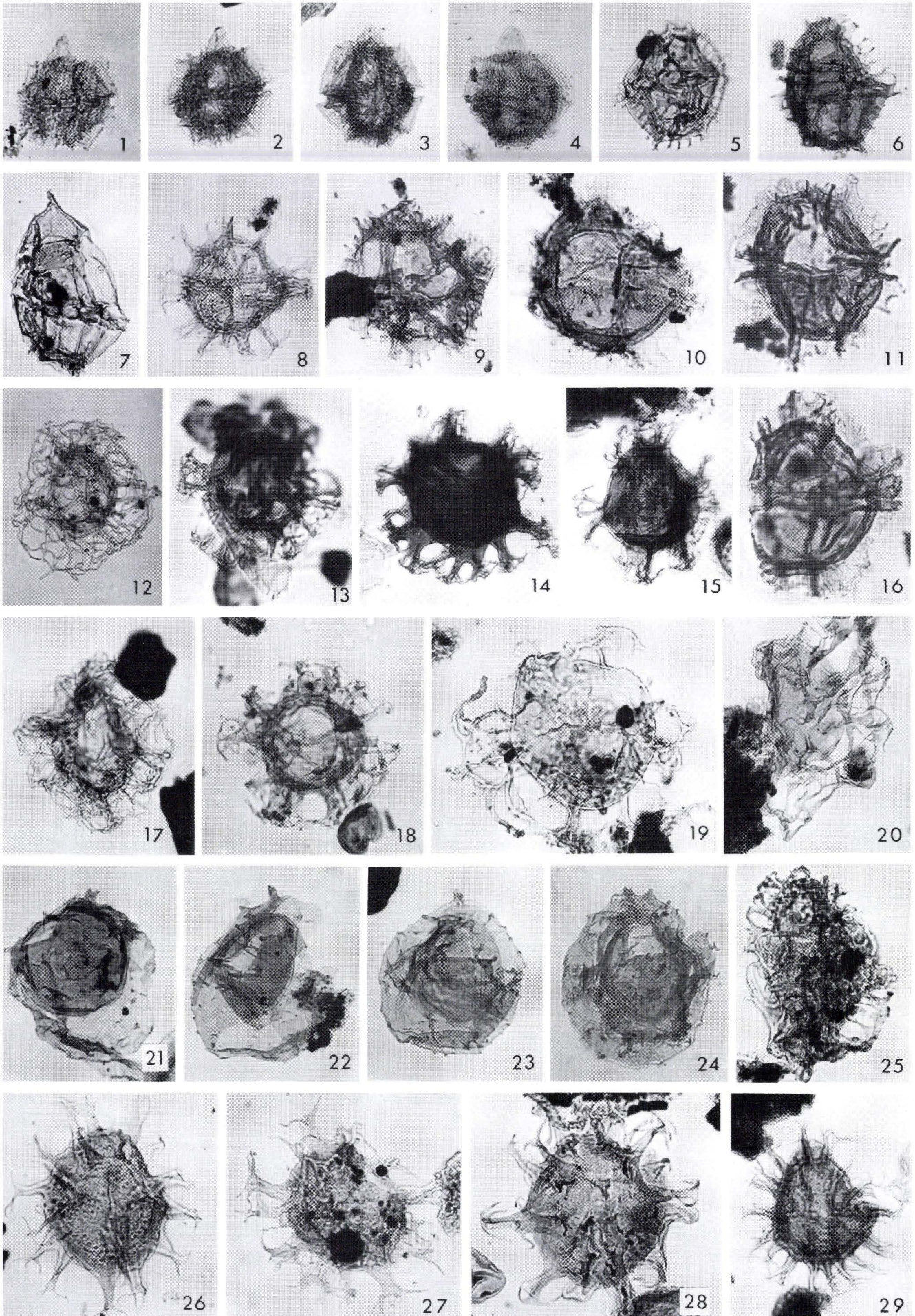
*Achomosphaera? neptunii* (Eisenack, 1958) Davey & Verdier, 1966a

Fig. 26. Adda-1, 7690'.

Fig. 27. I-1, 10890'.

Fig. 28. Adda-1, 7640'.

Fig. 29. I-1, 9540'.



## PLATE 12

All magnifications  $\times 500$

*Mendicodinium groenlandicum* (Pocock & Sarjeant, 1972)  
Davey, 1979c

Fig. 1. Adda-1, 8250'.

*Ctenidodinium elegantulum* Millioud, 1969

Fig. 2. E-1, 9720'.

Fig. 3. E-1, 9720'.

Fig. 4. I-1, 10530'.

*Ctenidodinium panneum* (Norris, 1965) Lentin & Williams,  
1973

Fig. 5. I-1, 10410'.

Fig. 11. Adda-1, 8250'.

*Heslertonia pellucida* Gitmez, 1970

Fig. 6. I-1, 10850'.

Fig. 7. I-1, 10020'.

Fig. 8. I-1, 10020'.

*Valensiella ovula* (Deflandre, 1947c) Eisenack, 1963a

Fig. 9. Adda-1, 8550'.

Fig. 10. Adda-1, 8600'.

*Heslertonia heslertonensis* (Neale & Sarjeant, 1962) Sarjeant,  
1966b

Fig. 12. Adda-1, 7650'.

Fig. 13. Adda-1, 7670'.

Fig. 14. Adda-1, 7850'.

Fig. 15. I-1, 10850'.

*Avellodinium falsificum* Duxbury, 1977

Fig. 16. Adda-1, 7690'.

*Taleisphaera hydra* Duxbury, 1979a

Fig. 17. I-1, 9850'.

Fig. 22. I-1, 9850'.

*Callaiosphaeridium asymmetricum* (Deflandre & Courteville,  
1939) Davey & Williams, 1966b

Fig. 18. I-1, 9490'.

Fig. 19. I-1, 9490'.

*Callaiosphaeridium trycherium* Duxbury, 1980

Fig. 20. Adda-2, 7753'3''.

Fig. 21. Adda-2, 7753'3''.

*Stephodinium spinulosum* Duxbury, 1983

Fig. 23. Adda-2, 7753'3''.

*Stephodinium coronatum* Deflandre, 1936a

Fig. 24. Adda-1, 7620'.

Fig. 25. I-1, 9780'.

Fig. 26. I-1, 9400'.

*Chlamydophorella trabeculosa* (Gocht, 1959) Davey, 1978

Fig. 27. Adda-1, 7640'.

Fig. 28. M-8, 7490'.

Fig. 29. Adda-1, 7710'.

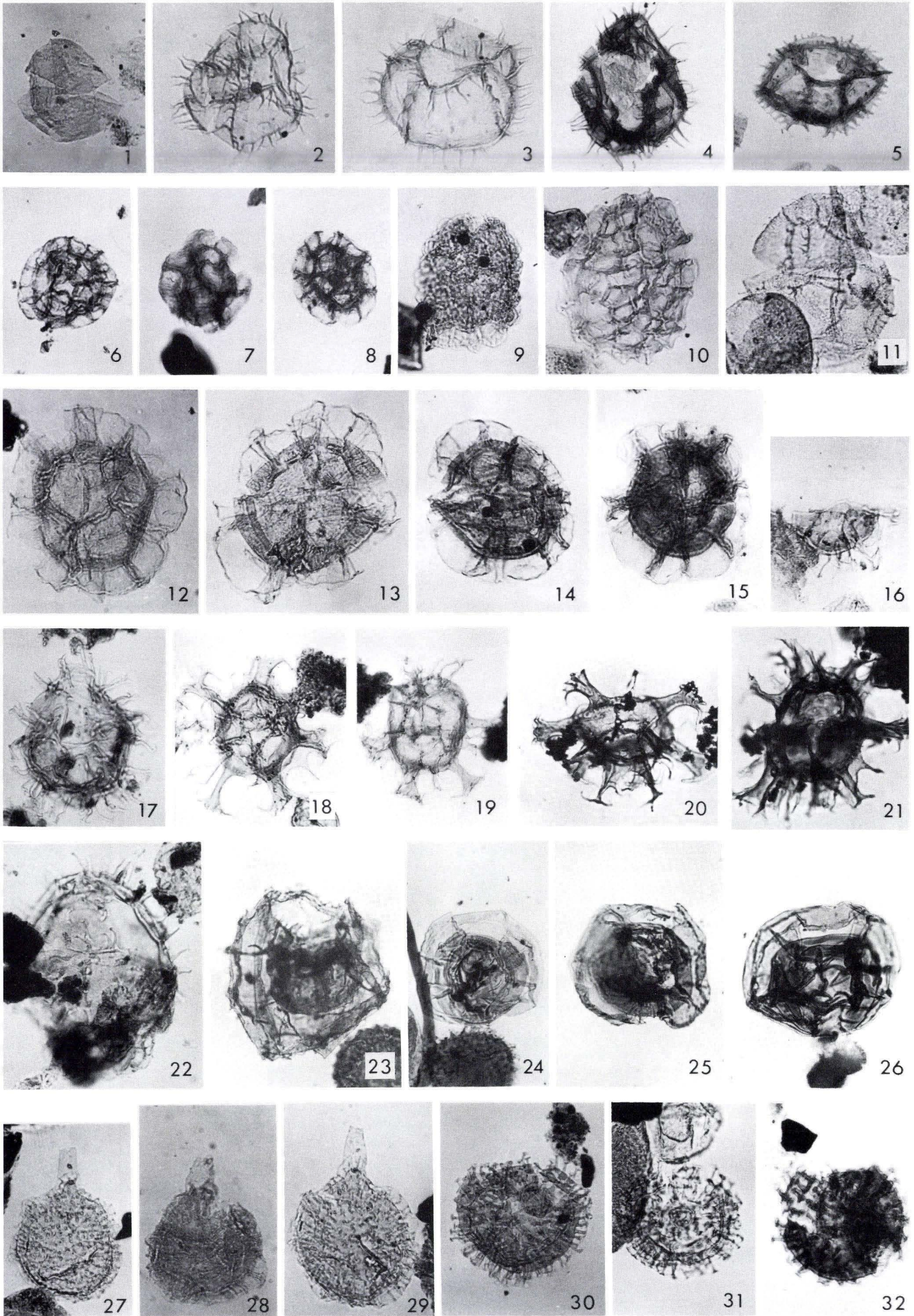
*Chlamydophorella membranoidea* Vozzhennikova, 1967

Fig. 30. Adda-1, 7980'.

Fig. 31. Adda-1, 7950'.

*Chlamydophorella nyei* Cookson & Eisenack, 1958

Fig. 32. I-1, 10570'.



## PLATE 13

All magnifications  $\times 500$

*Dingodinium cerviculum* Cookson & Eisenack, 1958

Fig. 1. Adda-1, 7710'.

Fig. 2. Adda-2, 7774'.

Fig. 3. I-1, 9960'.

Fig. 4. I-1, 10410'.

Fig. 5. Adda-1, 8460'.

*Dingodinium jurassicum* Cookson & Eisenack, 1958

Fig. 6. Adda-1, 8430'.

Fig. 12. I-1, 10160'.

*Dingodinium spinosum* (Duxbury, 1977) Davey, 1979c

Fig. 7. Adda-1, 9000'.

Fig. 8. Adda-1, 9000'.

Fig. 9. Adda-1, 9000'.

Fig. 10. Adda-1, 8550'.

Fig. 11. I-1, 10890'.

*Dingodinium tuberosum* (Gitmez, 1970) Fisher & Riley, 1980

Fig. 13. I-1, 10410'.

*Protoellipsoidinium clavulum* Davey & Verdier, 1971

Fig. 14. I-1, 9400'.

Fig. 15. I-1, 9380'.

Fig. 16. I-1, 9524'.

*Protoellipsoidinium spinosum* Davey & Verdier, 1971

Fig. 17. I-1, 9490'.

Fig. 18. Same specimen as in fig. 17.

*Prolixosphaeridium parvispinum* (Deflandre, 1937b) Davey et al., 1969

Fig. 19. I-1, 9460'.

Fig. 20. Adda-1, 7650'.

Fig. 21. I-1, 10090'.

aff. *Bourkidinium granulatum* Morgan, 1975

Fig. 22. Adda-1, 7870'.

Fig. 23. Adda-1, 7940'.

Fig. 24. I-1, 10770'.

*Kiokansium polypes* (Cookson & Eisenack, 1962b) Davey, 1979b

Fig. 25. I-1, 9420'.

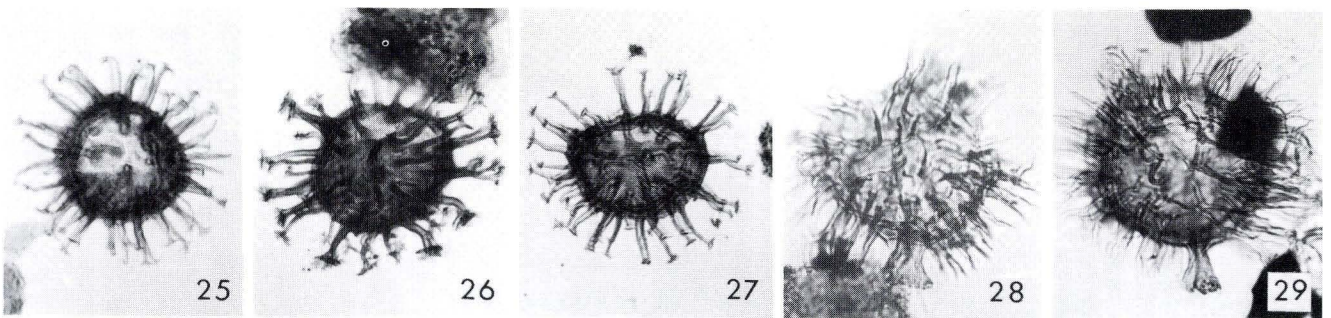
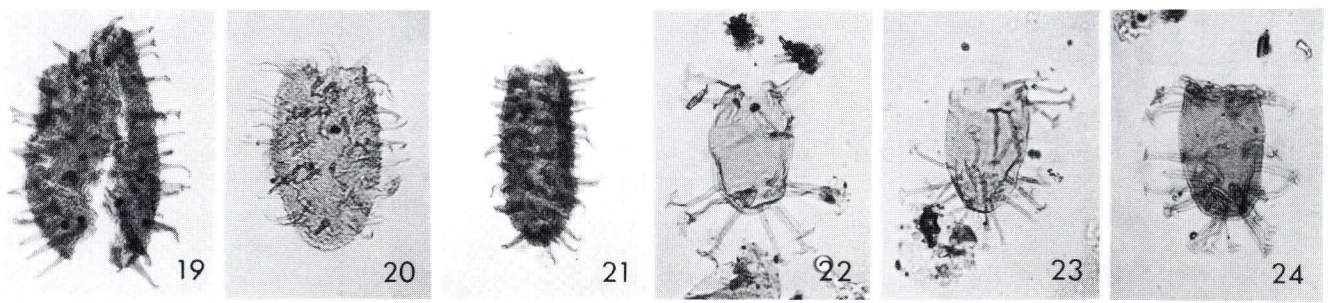
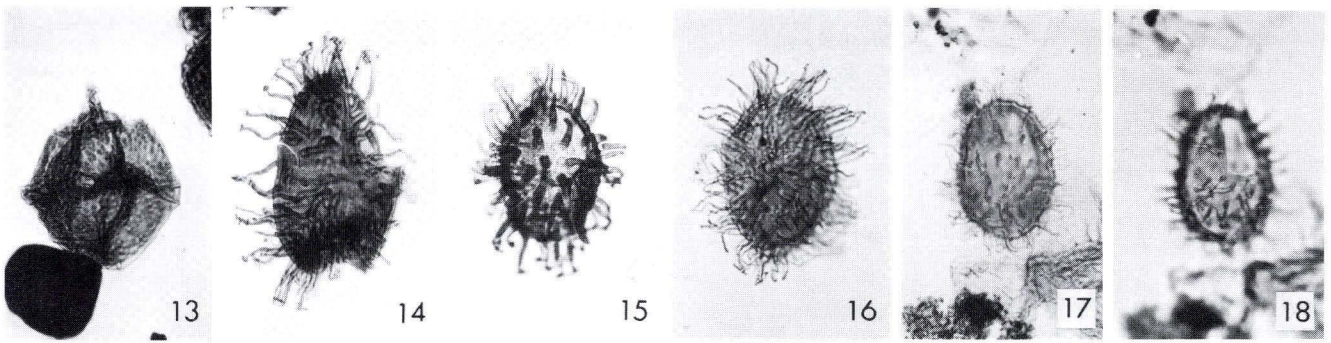
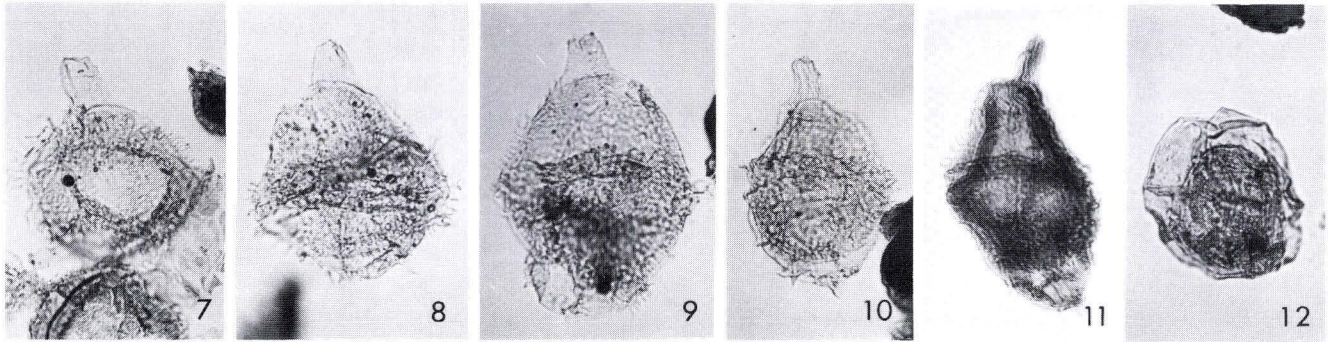
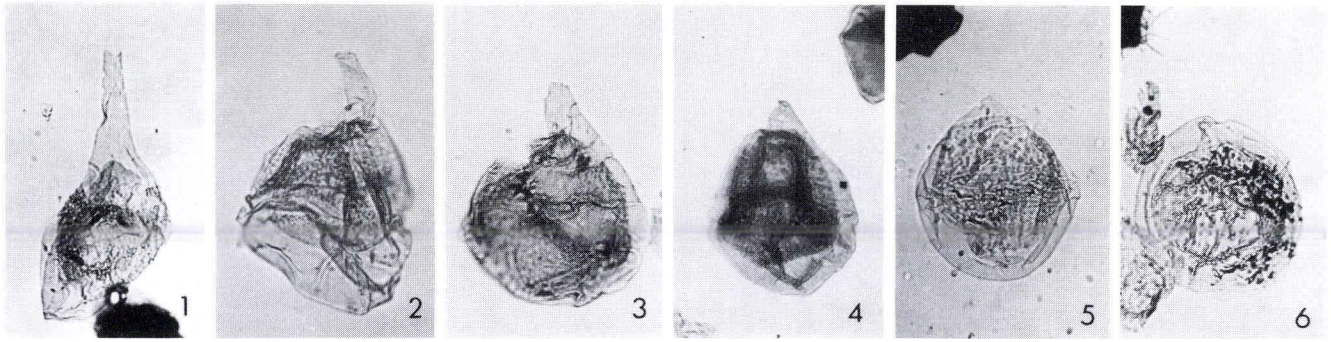
Fig. 26. I-1, 9420'.

Fig. 27. I-1, 9490'.

*Coronifera oceanica* Cookson & Eisenack, 1958

Fig. 28. Adda-2, 7753'3''.

Fig. 29. Adda-2, 7753'3''.



## PLATE 14

All magnifications  $\times 500$

*Dapsilidinium multispinosum* (Davey, 1974) Bujak et al., 1980

Fig. 1. Adda-1, 8850'.

Fig. 2. I-1, 9490'.

Fig. 3. I-1, 9900'.

*Litosphaeridium siphoniphorum* (Cookson & Eisenack, 1958) Davey & Williams, 1966b

Fig. 4. Adda-1, 7540'.

*Litosphaeridium arundum* (Eisenack & Cookson, 1960) Davey, 1979b

Fig. 5. Adda-1, 7530'.

*Egmontodinium torynum* (Cookson & Eisenack, 1960b) Davey, 1979c

Fig. 6. Adda-1, 8600'.

Fig. 7. I-1, 10850'.

Fig. 8. I-1, 10890'.

*Systematophora* cf. *areolata* sensu Davey, 1982a

Fig. 9. Adda-1, 8460'.

Fig. 21. I-1, 10970'.

*Egmontodinium expiratum* Davey, 1982a

Fig. 10. A specimen transitional to *Egmontodinium torynum*.  
I-1, 10850'.

Fig. 11. Adda-1, 8700'.

Fig. 12. Adda-1, 9150'.

Fig. 13. I-1, 10850'.

*Egmontodinium polyplacophorum* Gitmez & Sarjeant, 1972

Fig. 14. M-8, 7800'.

*Surculosphaeridium* sp. III Davey, 1982a

Fig. 15. M-8, 7400'.

Fig. 16. I-1, 10570'.

Fig. 17. Adda-1, 7910'.

*Surculosphaeridium* sp. II Davey, 1982a

Fig. 18. I-1, 10570'.

cf. *Surculosphaeridium* sp. I Davey, 1982a

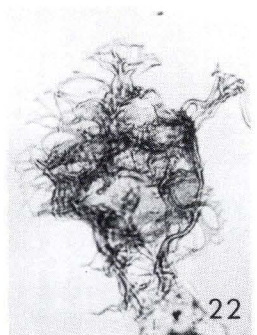
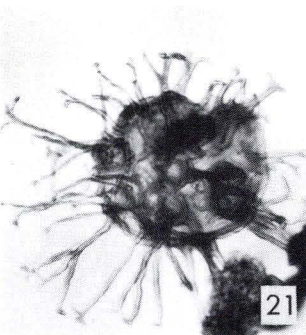
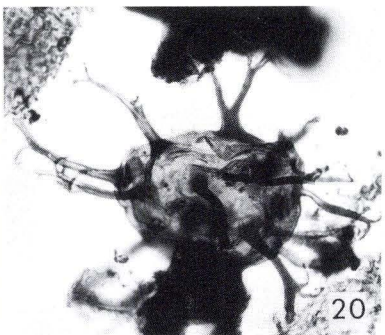
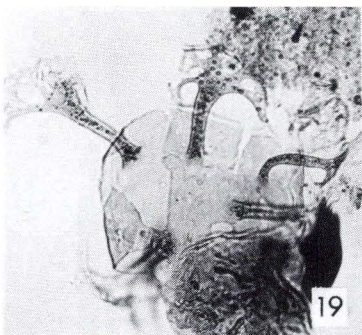
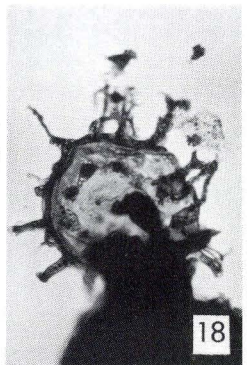
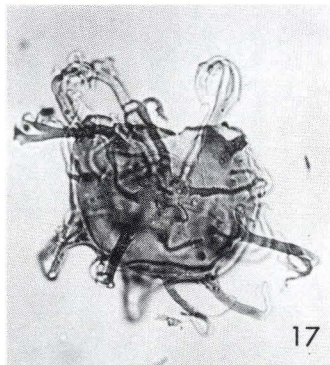
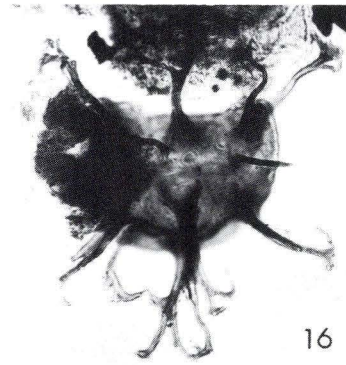
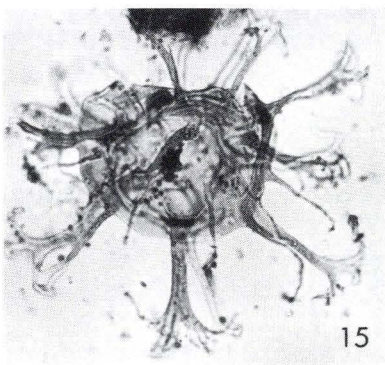
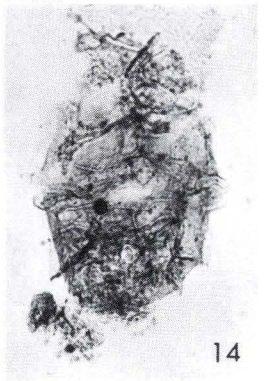
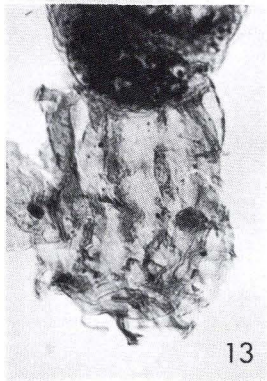
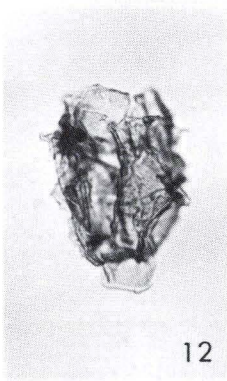
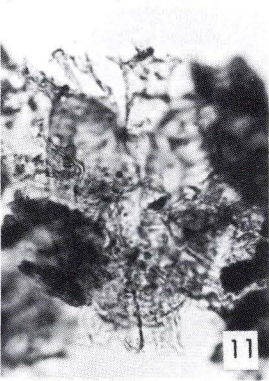
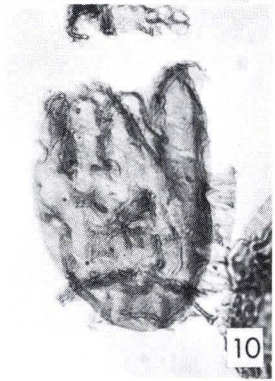
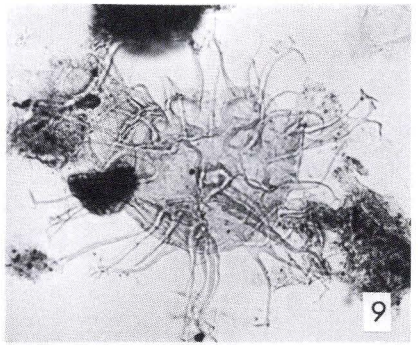
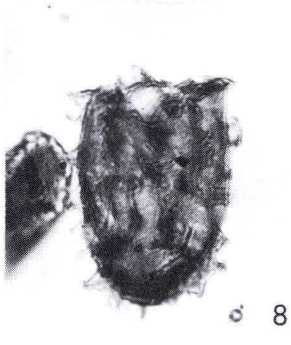
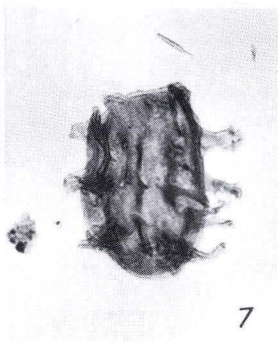
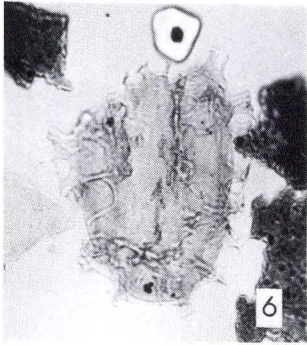
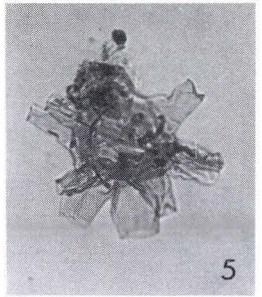
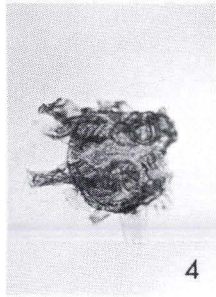
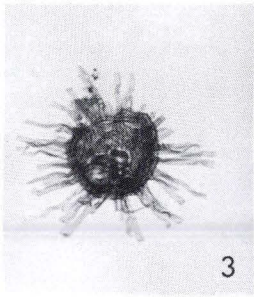
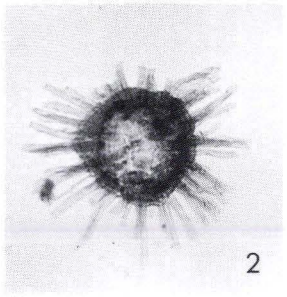
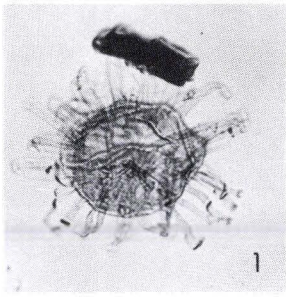
Fig. 19. Incomplete specimen. Adda-1, 7940'.

*Cymososphaeridium validum* Davey, 1982a

Fig. 20. I-1, 10290'.

*Systematophora complicata* Neale & Sarjeant, 1962

Fig. 22. I-1, 9900'.





## PLATE 15

All magnifications  $\times 500$

*Oligosphaeridium prolixispinosum* Davey & Williams, 1966b  
Fig. 1. I-1, 9340'.

*Oligosphaeridium* sp. GE McIntyre & Brideaux, 1980  
Fig. 2. Adda-1, 8700'.

*Oligosphaeridium* sp. 1.  
Fig. 3. I-1, 9850'.

*Oligosphaeridium diluculum* Davey, 1982a  
Fig. 4. E-1, 9720'.

*Oligosphaeridium asterigerum* (Gocht, 1959) Davey & Williams, 1966b  
Fig. 5. I-1, 9850'.  
Fig. 6. Adda-1, 7850'.

*Oligosphaeridium complex* (White, 1842) Davey & Williams, 1966b  
Fig. 7. I-1, 10020'.  
Fig. 10. Adda-2, 7762'.

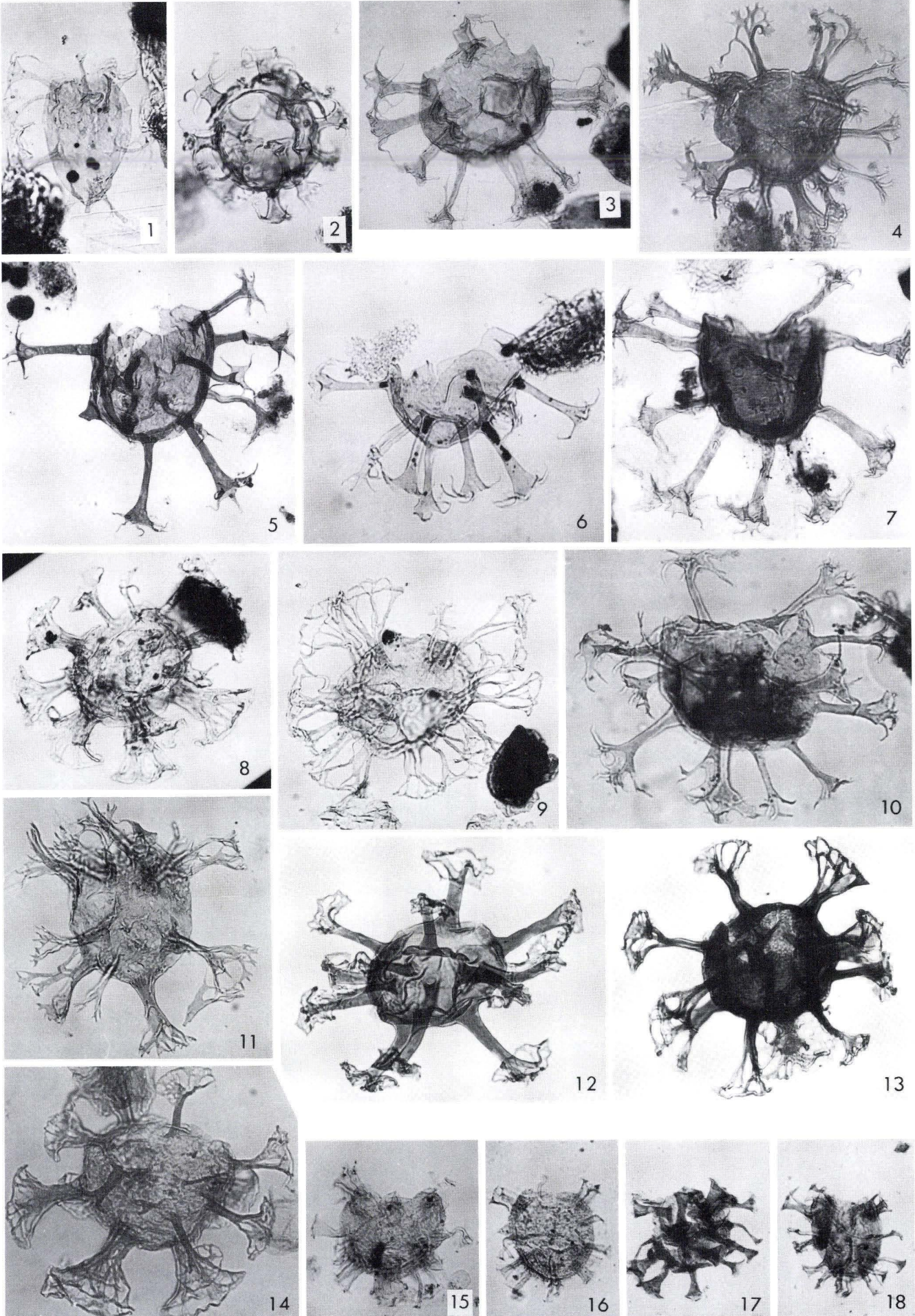
*Stiphrosphaeridium anthophorum* (Cookson & Eisenack, 1958) Davey, 1982a  
Fig. 8. Adda-2, 7774'.  
Fig. 9. Adda-1, 8600'.

*Stiphrosphaeridium arbustum* Davey, 1982a  
Fig. 11. Adda-1, 8600'.

*Stiphrosphaeridium dictyophorum* (Cookson & Eisenack, 1958) Davey, 1982a  
Fig. 12. I-1, 9420'.  
Fig. 13. I-1, 10020'.

*Hystrichosphaerina schindewolfii* Alberti, 1961  
Fig. 14. A single, simple paracingular process is visible. E-1, 8191'6''.

*Hystrichosphaeridium scoriaceum* Raynaud, 1978  
Fig. 15. Adda-1, 7980'.  
Fig. 16. Adda-1, 7980'.  
Fig. 17. I-1, 10290'.  
Fig. 18. I-1, 10810'.



## PLATE 16

All magnifications  $\times 500$

*Kleithriasphaeridium eoinodes* (Eisenack, 1958) Davey, 1974

Fig. 1. Adda-1, 7800'.

Fig. 2. I-1, 9510'.

Fig. 3. I-1, 10220'.

Fig. 4. I-1, 10530'.

*Kleithriasphaeridium corrugatum* Davey, 1974

Fig. 5. Adda-1, 9150'.

Fig. 6. I-1, 9490'.

*Kleithriasphaeridium* cf. *corrugatum* Davey, 1974

Fig. 7. Adda-2, 7774'.

*Kleithriasphaeridium fasciatum* (Davey & Williams, 1966b)  
Davey, 1974

Fig. 8. E-1, 9720'.

Fig. 13. Adda-1, 9000'.

*Kleithriasphaeridium porosipinum* Davey, 1982a

Fig. 9. Adda-1, 8800'.

Fig. 10. M-8, 7800'.

Fig. 11. Adda-1, 9150'.

*Kleithriasphaeridium* sp. 1.

Fig. 12. I-1, 10710'.

Fig. 17. I-1, 10220'.

*Florentinia laciniata* Davey & Williams, 1973

Fig. 14. Adda-2, 7762'.

*Florentinia mantellii* (Davey & Williams, 1966) Davey & Verdier, 1973

Fig. 15. A specimen transitional to *Florentinia cooksoniae*.  
Adda-2, 7762'.

Fig. 16. A specimen transitional to *Florentinia cooksoniae*.  
Adda-1, 7640'.

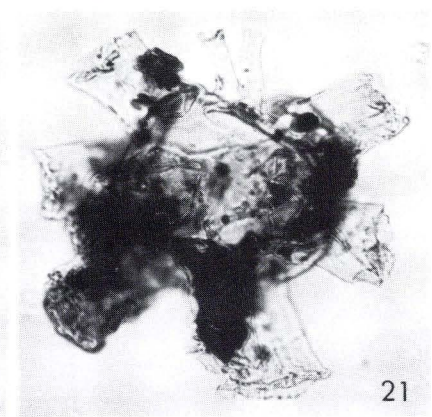
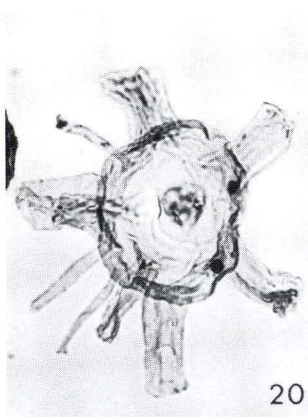
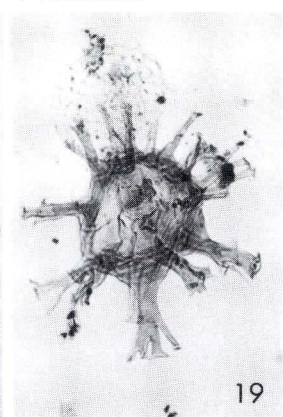
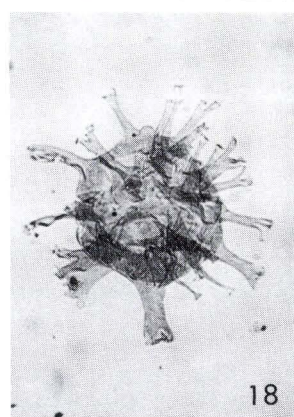
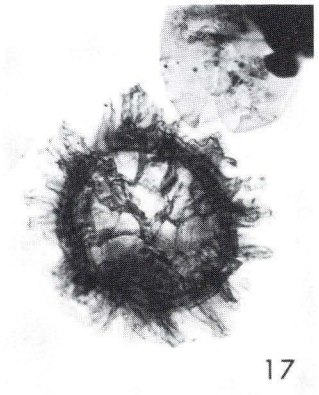
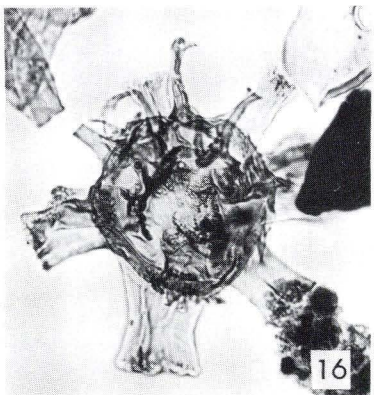
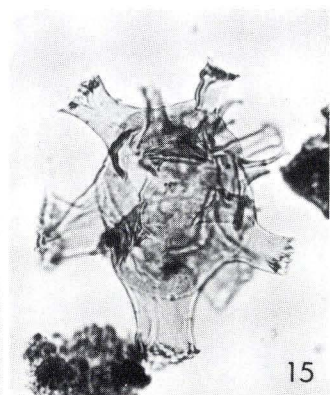
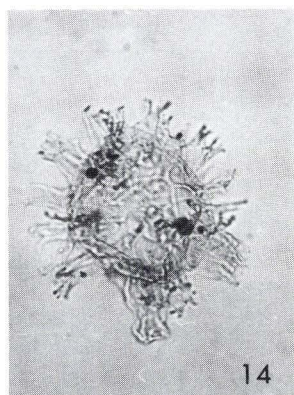
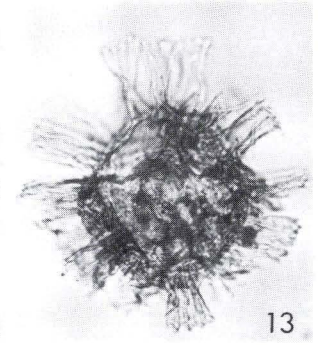
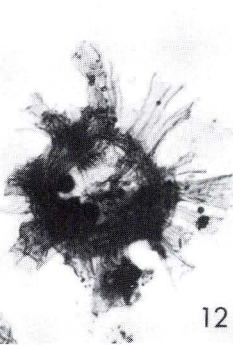
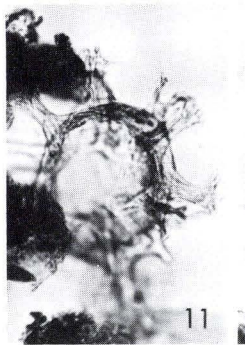
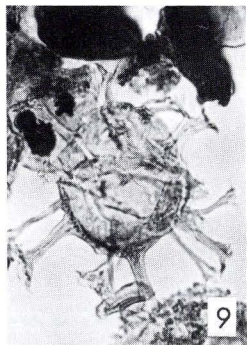
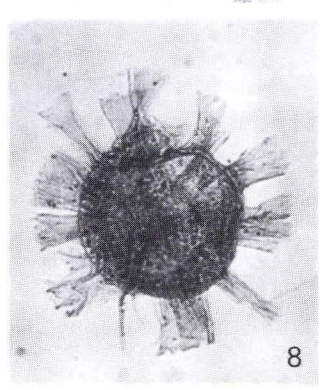
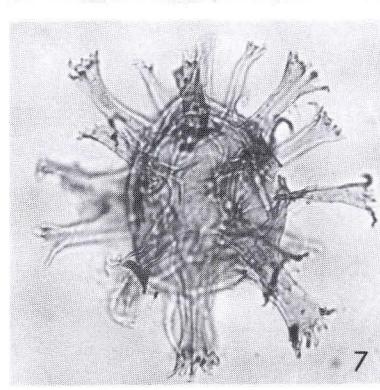
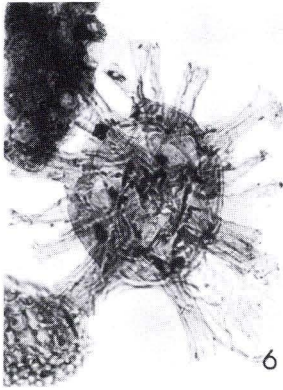
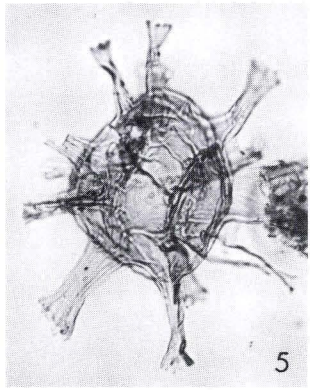
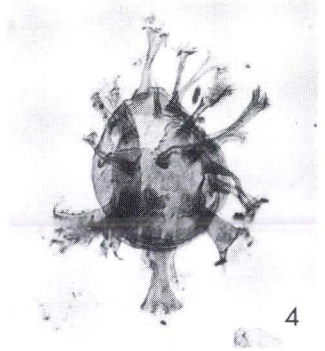
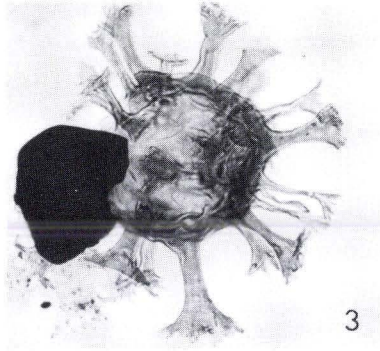
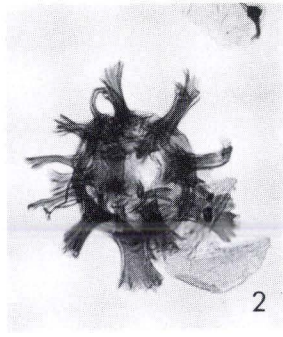
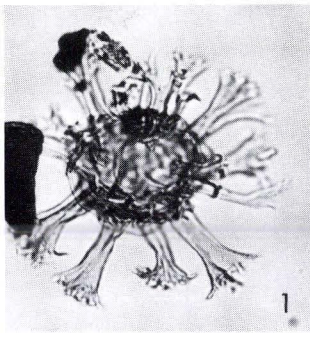
Fig. 18. I-1, 9780'.

Fig. 19. I-1, 9460'.

*Florentinia cooksoniae* (Singh, 1971) Duxbury, 1980

Fig. 20. I-1, 9420'.

Fig. 21. I-1, 9850'.

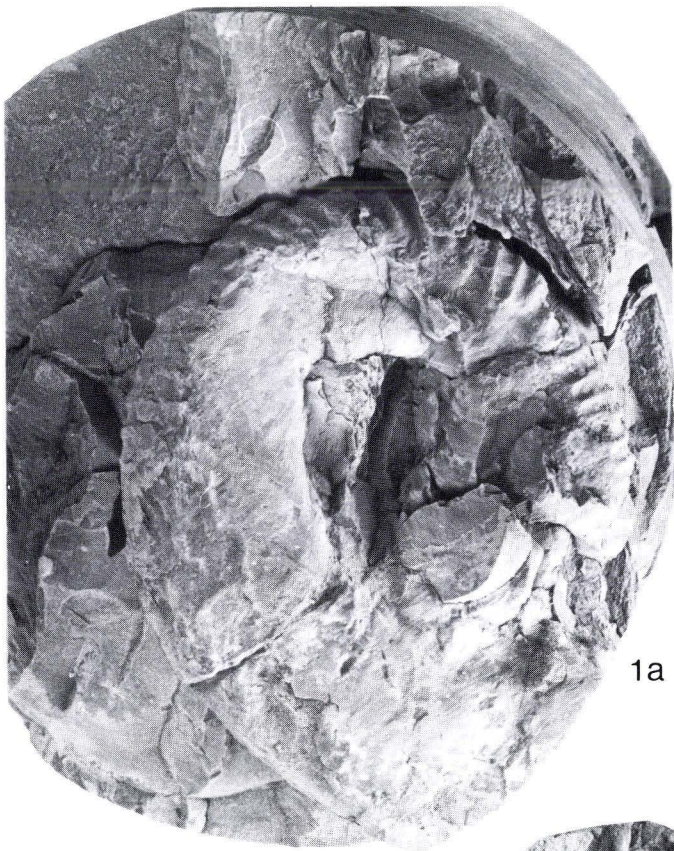


## PLATE 17

By Tove Birkelund

Figs. 1a-c *Simbirskites* sp. Part of body chamber and last chambers of phragmocone are preserved, showing the characteristic *Simbirskites* ribbing pattern and suture pattern. Note the embedding of the ammonite in a debris flow horizon. Fig. 1c slightly reduced. Adda-2, core 3, 7812½' - 7813'. Upper Hauterivian.

Figs. 2a-b *Simbirskites* (*Craspedodiscus*) cf. *gottschei* (v. Koenen). Adda-2, core 4, 7833' - 7833½'. The species is known from Bed C4L of Speeton Clay, belonging to the *gottschei* Zone of the Upper Hauterivian (see Rawson 1971).



1a



1b



2a



1c



2b

**This paper documents the age of the formations and seismostratigraphic units of the North Sea Central Trough. All six Lower Cretaceous stages are shown to be present in the area.**

**The ages are interpreted on the basis of the author's study of dinoflagellates, which are fully illustrated in photographic plates.**

**The analysis also includes a revised distribution chart of dinoflagellates in the Lower Cretaceous of NW-Europe.**