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DETAILED STUDIES OF THE CALLOVIAN AND OXFORDIAN MICROPLANKTON FROM THE WARBOYS AND WARLINGHAM BOREHOLES

Robert John Kiteley B.Sc., M.Sc.

Thesis submitted to the Council for National Academic Awards in partial fulfilment for the degree of Doctor of Philosophy

Sponsoring establishment: City of London Polytechnic
Collaborating establishment: University of Sheffield

September
1982

DECLARATION

This is to certify that the work submitted for the degree of Doctor of Philosophy, under the title "Detailed Studies of the Callovian and Oxfordian Microplankton from the Warboys and Warlingham Boreholes", is the result of original work. All authors and works are fully acknowledged. Whilst registered as a candidate for the degree the author has not been a registered candidate for another award of the CNAA or of a university during the research programme. No part of this work has been accepted in substance for any other degree.

CANDIDATE ....
Robert J. Kiteley

DIRECTOR OF RESE ...
Thomas I. Kilenyi

ACKNOWLEDGEMENTS

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I am indebted to the Institute of Geological Sciences for their kind provision of cored-material from the Warboys and Warlingham Boreholes, thus enabling this study to take place. The programme of research was undertaken at the Department of Geology, City of London Polytechnic and thanks are due to Dr. R.R. Skelhorn (Head of Department) for use of departmental facilities. I am particularly indebted to Dr. Tom Kilenyi as Director of Research, for his continued supervision throughout the research project and for his patience in awaiting the completed work. I would also like to thank my supervisor at the Department of Geology, University of Sheffield - Dr. Roger Neves - for his most helpful discussions and suggestions of avenues of research to explore. Also of the University of Sheffield, thanks are due to Mr. Paul Higham for his technical assistance and advice in putting together a palynology laboratory; and also to Mr. Ron Woollam (now of the Institute of Geological Sciences) for his help in identification of dinoflagellate species in the early part of the research programme.

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I am indebted to the technical staff of the Department of Geology, City of London Polytechnic - Mr. H.K. Roberts (Chief Superintendent) for his technical assistance throughout the research programme; Mr. W. Ralph (Photographer) whose expertise produced the plates and text-figures; Mr. Chris Burgess kindly helped in assembling and equipping of the research laboratory. My sincere thanks go to my colleagues for their mutual support and encouragement.

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My final, yet by no means least, thanks go to my wife Alison, without whose unstinting encouragement and personal sacrifice this work would never have been completed.

ABSTRACT

"Detailed Studies of the Callovian and Oxfordian Microplankton from the Warboys and Warlingham Boreholes", by Robert J. Kiteley (September, 1982)

The present thesis deals with biostratigraphic and palaeoenvironmental analyses of microplankton assemblages from the Kellaways Beds and Oxford Clay (Upper Jurassic) of the Warboys and Warlingham Boreholes, based on 118 samples.

Chapter one sets out the aim of the study as being (i) to evaluate the significance of microplankton assemblages in biostratigraphic correlation, (ii) establish a zonation scheme for the interval studied and (iii) investigate the potentiality of quantitative methods in biostratigraphic use of microplankton.

Chapter two deals with the Callovian/Oxfordian stratigraphy of Britain in general and of both boreholes in particular.

Chapter three describes methods of sampling, preparation and examination of the obtained assemblages.

Chapter four concerns the taxonomy of dinoflagellate cysts and acritarchs in terms of morphology and terminology.

Chapter five constitutes the systematic part. From a total of 48 microplankton genera, some 120 dinoflagellate species and 18 acritarch species are described. 9 species are considered to be new and several others are described from the Callovian/Oxfordian for the first time.

Chapter six deals with distribution of microplankton and correlation. After evaluating two previously-described zonation schemes in terms of recognition in the present assemblages, a scheme for the Kellaways Beds and Oxford Clay is proposed using local ranges of dinoflagellate cysts. Conventional methods of biostratigraphy are critically evaluated and the importance of numerical methods assessed. Two statistical methods of correlation are applied to data from the present assemblages.

Chapter seven critically discusses the physical parameters governing distribution of microplankton. Palaeoenvironmental inferrences are made from the distribution of microplankton here using relative abundancies, species diversity and dinoflagellate:acritarch ratios. Assemblages are compared with those previously-published from other localities using the Jaccard Coefficient of Similarity in attempting inter-regional correlation.

Chapter eight summarises the conclusions reached in terms of the aims outlined in chapter one.

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CONTENTS

Chapter one

INTRODUCTION

INTRODUCTION

Palynological assemblages from the Kellaways Beds and Oxford Clay (Upper Jurassic) have hithertoo not been described from the Warboys and Warlingham Boreholes. Early work on Callovian and Oxfordian microplankton assemblages was carried out by Sarjeant in Yorkshire (1960b, 1961a), Dorset (1962b) and Normandy (1965, 1968). More recently Woollam (1977) has investigated assemblages from the Middle and Upper Callovian deposits of the East Midlands (although this work has not been published), whilst Lam and Porter (1977) have described palynomorph assemblages from the Brora Outlier (Jurassic) in North-East Scotland. As far as the author is aware the present work constitutes the first microplankton assemblages described from complete Callovian and Oxfordian successions in Britain.

The Jurassic System in Britain consists of a series of limestones, shales and clays, and forms an almost continuous outcrop running south-west - north-east, from the Dorset to Yorkshire coasts (fig.1.1). The Kellaways Beds and Oxford Clay constitute the lowermost units of the Upper Jurassic (Callovian to Middle Oxfordian). After the widespread transgression of the Cornbrash (Middle Jurassic) there was, in southern and central England, a relatively brief phase of clays and sands in the form of the Kellaways Beds. After this a somewhat longer period of muddy seas produced the Oxford Clay - probably the most uniform deposit in the whole of the British Jurassic. There is however, a considerable variation in thickness due to the 'basin and swell' - type sedimentation which characterises the Jurassic as a whole in Britain, although quite narrowly-defined zones and subzones, as well as lithostratigraphic units, can in fact be traced over great distances.

Exposures of Kellaways Beds and Oxford Clay are limited to the coastal sections in Dorset and Yorkshire, and various clay-pits in and around the East Midlands. None of these localities provide a complete succession. Material for the present study was kindly provided by the Institute of Geological Sciences from each of the survey boreholes at Warboys in Cambridgeshire and Warlingham, Surrey (fig.1.1).

The Warboys Borehole was sunk during the period March to May, 1965 for exploration purposes. The exact location is shown in figure 1.2 and given a National Grid reference of TL 29032 78390, on the six-inch Ordnance Survey map. Drilling started on the Warlingham Borehole on 18th July, 1956 and was completed on 14th March, 1958. The borehole proved a virtually complete succession of rocks from the Upper Creataceous

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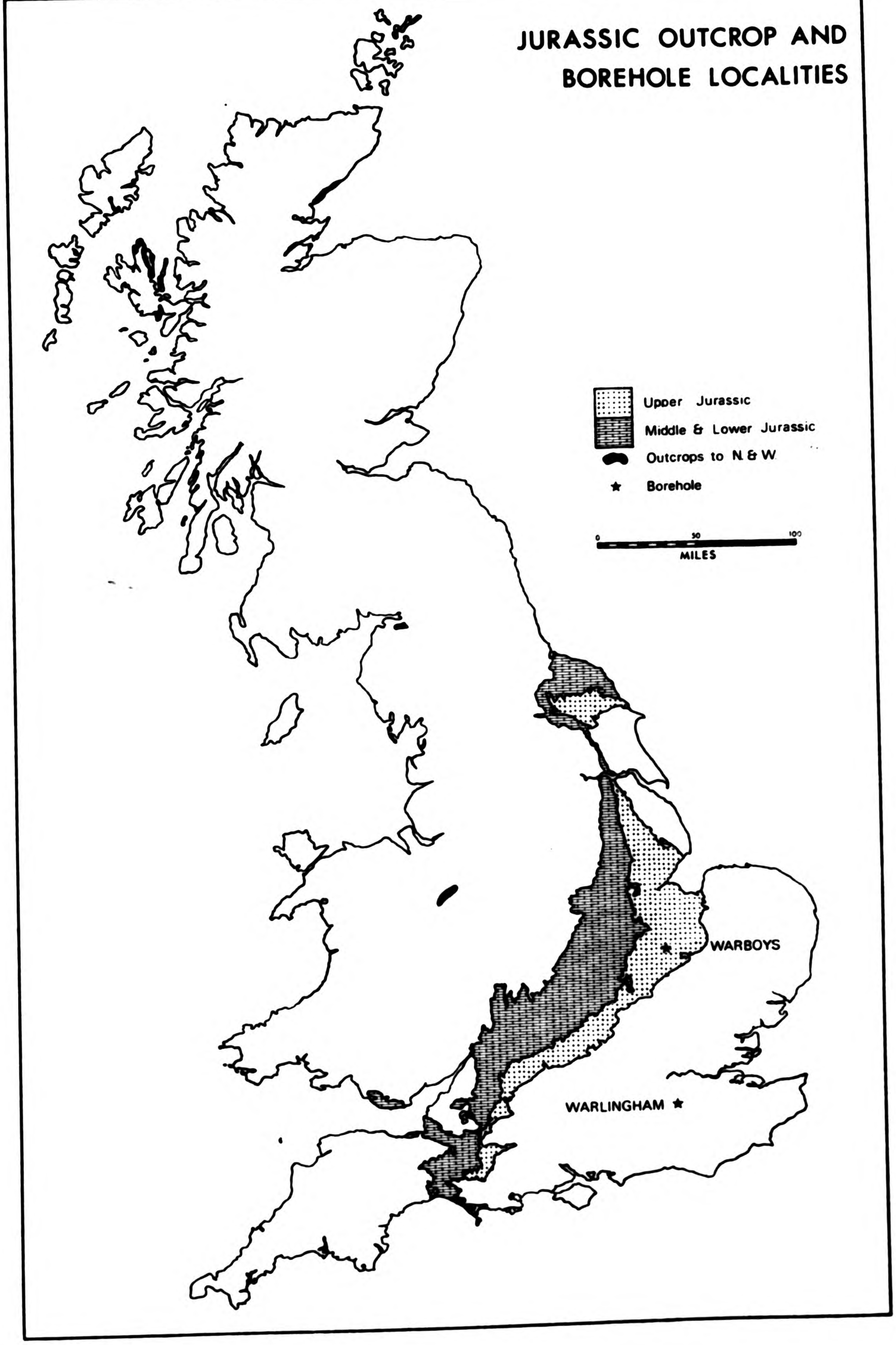
Text-figure 1.1 A map of the British Isles showing the main outcrop of Jurassic rocks and the position of the Warboys and Warlingham boreholes.

JURASSIC OUTCROP AND BOREHOLE LOCALITIES



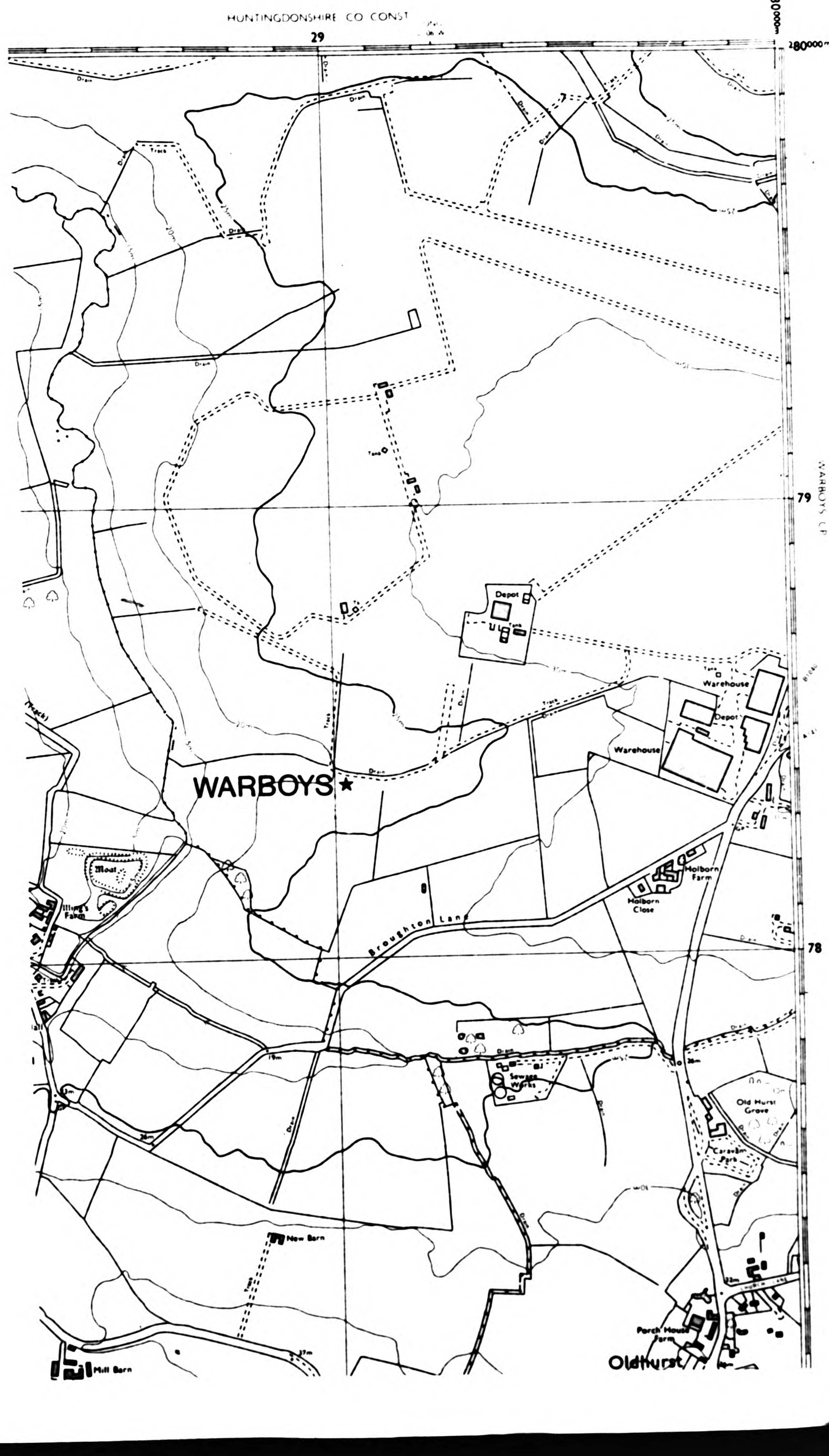
chalk to the Lower Carboniferous limestone, with only the section from the Middle Carboniferous to Triassic missing; a total of some 5001 feet (1524.3 metres) of strata. The exact location is given a National Grid reference of TQ 3476 5719 on the six-inch Ordnance Survey map (fig.1.3).

From both boreholes a complete and undisturbed sequence of Kellaways Beds and Oxford Clay was obtained (although the uppermost part of the Oxford Clay - <u>cordatum</u> to <u>plicatilis</u> zones - is missing at Warboys due to surface erosion), totalling a thickness of 230 feet (70.1 metres) at Warboys and 336 feet (102.4 metres) at Warlingham. The ammonite zones for each locality had already been determined by Dr. J.H. Callomon. The two borehole sequences therefore provided excellent material for biostratigraphic correlation using microplankton assemblages.

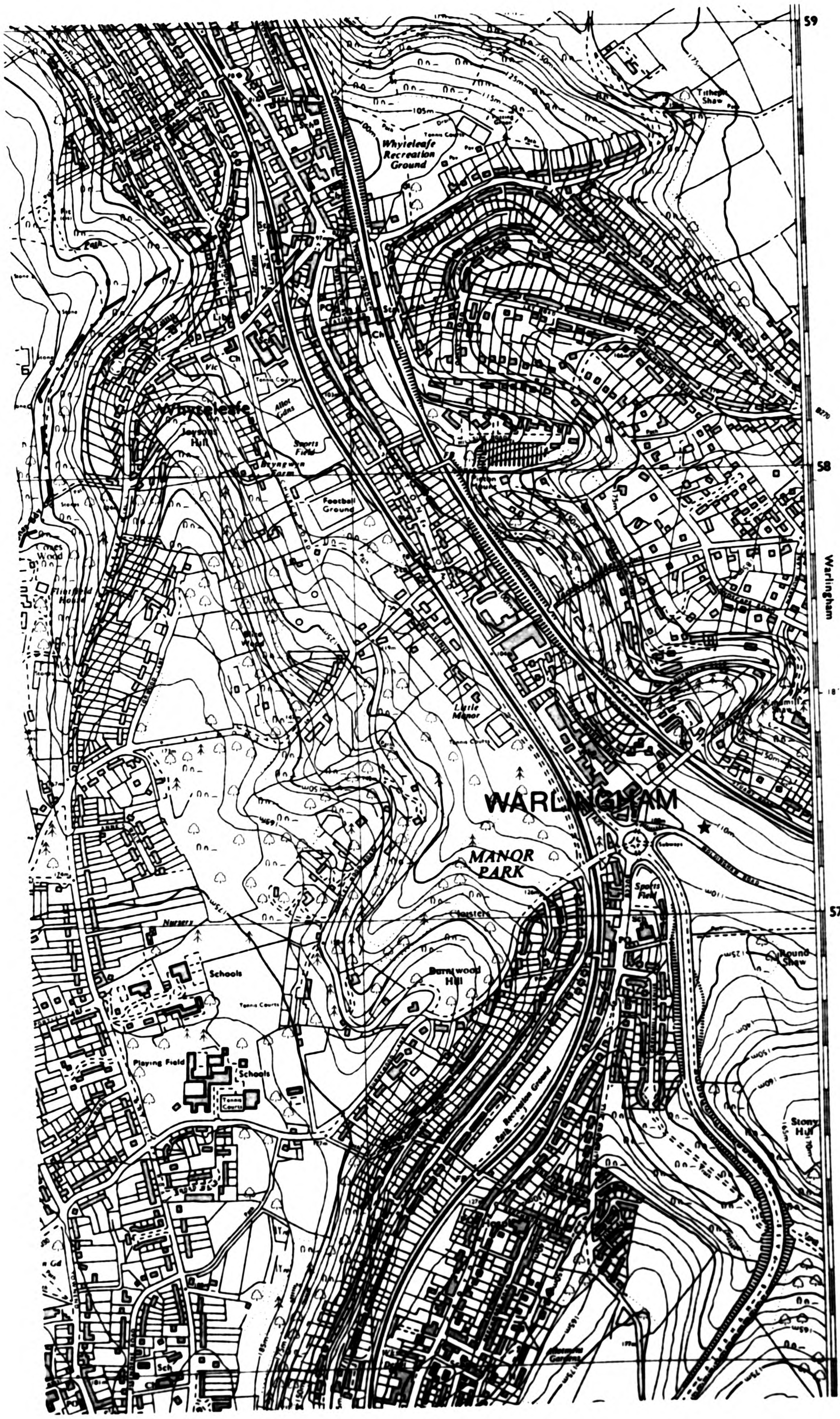
It is quite clear that no fossil group can rival the ammonites for biostratigraphic correlation in the Jurassic. For practical purposes however, alternative biostratigraphical schemes are neccessary, not least because of the extensive exploration for, and increase in the production of, hydrocarbons; one cannot expect to find recogniseable ammonite assemblages even in a large-diameter borehole core, let alone in a side-wall core! Several authors have attempted inter-regional correlation for the Jurassic using dinoflagellate assemblages (e.g., Williams, 1977 and Sarjeant, 1979), but little is known of the factors controlling the distribution of dinoflagellates and resulting assemblages. For this reason it was felt neccessary to undertake a detailed programme of study to determine the reliability of microplankton assemblages for correlating between two localities, each having an identical stratigraphic succession and comparable lithologies, and to use these as standards for comparison with previously published work from other localities.

Both boreholes were sampled at regular intervals of five feet (1.5 metres) giving a total of 118 samples (48 from Warboys and 70 from Warlingham). The samples were processed using standard techniques for extracting palynomorphs (see chapter three) and the obtained assemblages studied in detail using conventional (qualitative) methods as well as numerical (quantitative) methods of analysis. The resulting assemblages are typical of the Upper Jurassic and particularly well-preserved in both sections, with little breakage incurred through preparation techniques. Even the larger, more fragile species such as ***Adnatosphaeridium*** and ***Polystephanephorous*** often retain their delicate, distally-linking trabeculae between adjacent processes. Species such as ***Pareodinia, Kalyptea*** and ***Caligodinium*** often have quite large and undamaged kalyptra present. It is true to say however, that specimens from the Lower Oxford Clay tend

Text-figure 1.2 Part of the six-inch Ordnance Survey map for the Warboys District of Huntingdonshire showing the exact location of the borehole


HUNTINGDONSHIRE CO CONST
29
280000m
530000m
WARBOYS CP
79
78
WARBOYS
Depot
Warehouse
Depot
Warehouse
Holborn Farm
Holborn Close
Broughton Lane
Moat
Illing's Farm
Sewage Works
Old Hurst Grove
Caravan Park
New Barn
Porch House Farm
Oldhurst
Mill Barn
Drain
Track

Text-figure 1.3 Part of the six-inch Ordnance Survey map for the Warlingham District of Surrey showing the exact location of the borehole



59
Whyteleafe Recreation Ground
Whyteleafe
Sports Field
Football Ground
58
Warlingham
Little Manor
WARLINGHAM
MANOR PARK
Sports Field
57
Nursery
Schools
Barnwood Hill
Round Shaw
Playing Field
Schools
Tennis Courts
Stony Hill
56

to be less well-preserved, probably resulting from the more extreme preparation techniques found neccessary to break down the highly bituminous clays, characteristic of the Middle Callovian.

There is little or no indication of re-working in the assemblages, probably indicative of the uniform nature of conditions which prevailed during the deposition of the Oxford Clay. Many of the indeterminate genera illustrated in plates 32 to 34 from the Warlingham Borehole are likely to have come from higher horizons in the borehole as a result of contamination, either from circulating drilling muds or collapse of the core-wall during drilling. Although often abraided they resemble the more exotic forms characteristic of higher levels in the Jurassic and Cretaceous.

Essentially the primary aims of the work may be summarised as being three-fold:

1) To evaluate the importance of fossil microplankton assemblages for inter-regional, biostratigraphic correlation in general, using the two boreholes as tests of this, and the factors which govern their distribution.

2) To establish, as far as is possible, a zonation scheme for the Kellaways Beds and Oxford Clay using assemblages of micro-plankton - dinoflagellate cysts in particular.

3) To investigate the potentiality of statistical and numerical methods of analysis in biostratigraphy using microplankton assemblages.

How far these aims have been achieved are discussed in chapter eight, but in the final analysis must be left to the discretion of the reader. Certainly many of the questions which have been left unanswered can only be solved by further research. It is hoped that the present work will provide a basis for such investigations in the future.

All material, including microscope slides, is deposited in the Department of Geology, City of London Polytechnic. The microscope used for both examination and photography is an OLYMPUS, BHC Binocular -type (serial no: 217743).

Chapter two

STRATIGRAPHICAL CONSIDERATIONS

STRATIGRAPHICAL CONSIDERATIONS

A. CALLOVIAN / OXFORDIAN STRATIGRAPHY

1. Introduction

The Callovian and Oxfordian stages constitute the lower half of the Upper Jurassic, the base of the Callovian being generally accepted as the base of the Upper Jurassic. The lower part of the Upper Jurassic in Britain, the Upper Cornbrash, marks a return everywhere from the regressive, in part deltaic and lagoonal, facies of the preceeding Bathonian to fully marine conditions (Callomon, 1968). Its deposition reflects a major transgression of the seas in Britain, as well as in many other parts of the world such as parts of the U.S.S.R. and the Baltic Shield. Renewed erosion of nearby landmasses provided debris for sedimentation in the newly-formed basins of deposition. Conditions were comparable to Liassic times, the thick dark clays and shales, with thin muddy limestone bands and cementstone concretions, form a marked contrast to the calcareous and arenaceous deposits of the Middle Jurassic.

As the seas became deeper the processes of sedimentation became free from the immediate effects of current and wave action, consequently the deposits immediately succeeding Kellaways Beds were laid down with considerable uniformity. These deposits, the Oxford Clay, are "one of the most uniform deposits in the European Jurassic. Beds a few feet or even inches thick persist over great distances, and the constancy of the faunal successions permits the setting up of a zonal and subzonal scheme of stratigraphic subdivision which has few rivals in the wideness of its applicability" (Callomon ibid. p264).

The main outcrop of the Oxford Clay in Britain runs almost continuously in a north-east - south-west direction, from the Dorset coast at Weymouth to the Yorkshire coast at Scarborough (fig.1.1). Physically the soft deposits weather to a flat, featureless and often marshy landscape, and apart from these coastal sections there would have been few mainland outcrops if it were not for the fact that the Oxford Clay has unique properties for the manufacturing of bricks. Consequently there are a number of man-made exposures in the South and East Midlands where the Oxford Clay supports a large and flourishing brick industry. These workings are concentrated in four main areas: Peterborough, South Bedfordshire, Bletchley and Calvert (near Bicester, Buckinghamshire). In these areas it is mainly the shales of the Lower Oxford Clay that are worked. The more plastic and calcareous Middle and Upper Oxford Clays are worked at Warboys, Woodham (near Calvert) and Purton (5 miles north-

Text-fig. 2.1 The zonal sequence of the Callovian and Lower Oxfordian stages of North-West Europe (after Callomon, 1964)

<table>
<tr><th colspan="2">STAGES</th><th>ZONES</th><th>SUBZONES</th><th>DIVISION</th></tr>
<tr><td rowspan="5">OXFORDIAN</td><td rowspan="5">LOWER</td><td rowspan="3">Cardioceras cordatum</td><td>C. cordatum</td><td rowspan="5">UPPER OXFORD CLAY</td></tr>
<tr><td>C. costicardia</td></tr>
<tr><td>C. bulowskii</td></tr>
<tr><td rowspan="2">Quenstedoceras mariae</td><td>C. praecordatum</td></tr>
<tr><td>C. scarburgense</td></tr>
<tr><td rowspan="13">CALLOVIAN</td><td rowspan="4">UPPER</td><td colspan="2">Quenstedoceras lamberti</td><td rowspan="4">MIDDLE OXFORD CLAY</td></tr>
<tr><td rowspan="3">Peltoceras athleta</td><td>Upper</td></tr>
<tr><td>Middle</td></tr>
<tr><td>Lower</td></tr>
<tr><td rowspan="4">MIDDLE</td><td rowspan="2">Erymnoceras coronatum</td><td>K. grossouvrei</td><td rowspan="4">LOWER OXFORD CLAY</td></tr>
<tr><td>K. obductum</td></tr>
<tr><td rowspan="2">Kosmoceras jason</td><td>K. jason</td></tr>
<tr><td>K. medea</td></tr>
<tr><td rowspan="5">LOWER</td><td rowspan="3">Sigaloceras calloviense</td><td>S. enodatum</td><td rowspan="3">KELLAWAYS ROCK</td></tr>
<tr><td>S. calloviense</td></tr>
<tr><td>P. koenigi</td></tr>
<tr><td rowspan="2">Macrocephalites macrocephalus</td><td>M. kamptus</td><td>KELLAWAYS CLAY</td></tr>
<tr><td>M. macrocephalus</td><td>UPPER CORNBRASH</td></tr>
</table>

west of Swindon). Between them the pits have exposed an almost continuous section of Oxford Clay in Central England, revealing a very complete succession from the Cornbrash to the Corallian.

2. Kellaways Beds

After the widespread transgression of the Cornbrash, there was in Southern and Central England a relatively brief depositional phase of clays and sands which form the Kellaways Beds. They do not commonly exceed 6 metres in thickness, although as much as 18 metres have been reported from Wiltshire (Woodward, 1895). The lower part of the Kellaways Clay is rather poor in fossils, but the succeeding Kellaways Rock is often rich in the zonal ammonite Sigaloceras calloviense. This facies is usually irregularly developed, as is consequently the base of the Oxford Clay above. The Kellaways Beds comprise most of the Lower Callovian - calloviense and macrocephalus zones (fig. 2.1).

The most southern exposure of Kellaways Beds in Britain is to be found at Putton Lane Brickyard, ½ mile south-east of Chikerell Church, near Weymouth, Dorset. At the top of the pit is the Kellaways Rock where about 2.5 metres of sand and clay with doggers and lenticles of hard sandstone are exposed. Below this is 2.5 - 3.0 metres of blue clay with cementstone nodules (Arkell, 1933 p344). Further north the deposits appear to increase in thickness. At Cirencester, some 6 metres of yellow sands with large doggers are present, whilst at Swindon, a boring is said to have proved 18.3 metres of Kellaways Beds (Woodward, 1895; in Arkell, 1933 p346).

In the South Midlands, from Cirencester through the Thames Valley, Kellaways Beds are feebly developed, although at Bedford 3 metres of sands with large doggers are present. The beds continue to thin northwards towards the Market Weighton axis where a maximum of 7.6 metres was recorded at Sudbrook, near Lincoln, although the average thickness appears to be in the order of 0.6 to 3.1 metres.

North of the Market Weighton axis, in the Yorkshire basin, the Kellaways Beds reach their maximum development, producing 15.2 metres at Cayton Bay and 23.2 metres at North Cliff, Scarborough.

In Scotland, at Brora (Sutherland), the chronostratigraphic equivalent of Kellaways Beds is the Roof Bed of the Brora Coal. It is a very hard ferruginous, sandy limestone, varying in thickness from 1 to 1.5 metres, passing down into grey calcareous sandstone with lenticles of coal. In Skye the Lower Callovian comprises the Staffin Bay Formation;

a series of carbonaceous sandstones and dark grey shales, some 17.6 metres thick (Sykes, 1975).

3. Oxford Clay

The Oxford Clay is the lowest of the great clay strata that dominate the Upper Jurassic of Southern and Eastern England. It comprises the middle and upper stages of the Callovian - jason, coronatum, athleta and lamberti zones, and the Lower Oxfordian mariae and cordatum zones (fig. 2.1). The Middle Callovian, Upper Callovian and Lower Oxfordian stages constitute the Lower, Middle and Upper divisions of the Oxford Clay respectively. The outcrop is some 150 metres in Dorset, increasing to 180 metres in Wiltshire; the customary reduction northwards through Oxfordshire into Lincolnshire (90 metres) follows and only 40 metres persist north of the Market Weighton axis. The Oxford Clay in the East Midlands also thins towards the East Anglian Massif.

North of the Market Weighton axis, in the Yorkshire basin, there is a marked lateral change in facies where the Callovian deposits are arenaceous. The deposition of the Kellaways Rock was succeeded, probably after an interval of non-deposition, by the Hackness Rock which is the lateral equivalent of the Lower Oxford Clay of Central and Southern England. In the Yorkshire basin the Middle and Upper Oxford Clay is nowhere more than 40 metres thick, usually considerably less. The 'Oxford Clay' environment was not spreading into the basin until much later than south of the axis.

In the Brora district of North-East Scotland there is again a marked change in facies. Here two distinct lithological formations are developed. The lower unit, the Brora Argillaceous Series, constitutes the calloviense and lamberti zones and is the chronostratigraphic equivalent of the Lower and part of the Middle Oxford Clay. It is between 51 and 77 metres thick. Above this is the Brora Arenaceous Series which corresponds approximately to the Upper Oxford Clay (lamberti to cordatum) and consists of some 68 metres of arenaceous shale (Arkell, 1933; Sykes, 1975). In Skye the Staffin Shale corresponds to the Oxford Clay and is a series of arenaceous shale deposits, varying in thickness from 14 to 48 metres (Sykes, 1975).

Text-fig. 2.2 Zonal and formational sequence in the Oxford Clay and Kellaways Beds of the Warboys area and the Warlingham borehole (After Callomon and Cope, 1971)

Stages	Zones	Subzones	Peterborough–Warboys Area Thickness metres	Peterborough–Warboys Area		Warlingham Borehole Thickness metres	Warlingham Borehole		Depth metres
							— — — FAULT — — —		910·7
Middle Oxford-ian	plicatilis	*antecedens*	(absent through pre-Ampthill Clay erosion)				Corallian Beds 48·7m+		959·4
		vertebrale				1·5	Upper Oxford Clay 56·0m	Oxford Clay 97·4m	
Lower Oxfordian	*cordatum*	*cordatum* *costicardia* *bukowskii*	7·0+	Upper 29·8m	Oxford Clay 72·0m	2·2 4·0 2·1			
	mariae	*praecordatum*	8·1			8·4			
		scarburgense	14·7			37·4			1015·4
Callovian	*lamberti*		3·8	Middle 25·6m		28·9	Middle Oxford Clay 28·9m		
	athleta	(upper) (middle) (lower)	7·9 10·2 9·3						1044·3
	coronatum	*grossouvrei*	5·4	Lower 16·7m		8·4	Lower Oxford Clay 12·5m		
		obductum	4·2			2·1			
	jason	*jason*	0·8			1·2			
		medea	0·3			0·8			1050·7
	calloviense	*enodatum*	0·2	Rock 3·5m	Kellaways Beds 5·6m	0·5		Kellaways Beds 5·3m	
		calloviense *koenigi*	3·5			4·7			
	macrocephalus	*kamptus*	2·1+	Clay 2·1m		?	?	?	1062·8
		macrocephalus	1·5	Upper 1·5m	Cornbrash			Cornbrash	
Bathon-ian	*discus*			Lower 1·5m					

B. BIOSTRATIGRAPHY AND LITHOLOGY OF THE WARBOYS AND WARLINGHAM BOREHOLES

1. Introduction

The Oxford Clay and Kellaways Beds sequences of the Warlingham Borehole and Warboys area are compared in figs. 2.2 to 2.4. At Warboys the Kellaways Beds are fully developed giving a total of 5.6 metres of highly silty-mudstones. At the base the Kellaways Clay is 2.1 metres thick (kamptus sub zone)and succeeded by 3.5 metres of Kellaways Rock (calloviense and koenigi sub zones). In the Warlingham borehole the Kellaways Beds are incompletely developed. They comprise 4.9 metres of clays and siltstones, but without the traditional Kellaways Clay below.

Above the Kellaways Beds lies conformably the Oxford Clay. It is essentially a succession of calcareous silty mudstones. Whilst the Oxford Clay is fully developed in the Warlingham borehole, where a total of 97.5 metres has been recovered, in the Warboys borehole a modern erosional surface truncates the Upper Oxford Clay near the top of the praecordatum sub zone, leaving the cordatum and plicatilis zones missing. Here a total 62.9 metres of Oxford Clay has been recovered. Whilst the Lower Oxford Clay of both boreholes is comparable (15.4 metres at Warboys; 12.5 metres at Warlingham) the Middle and Upper Oxford Clays are considerably thicker in Warlingham (28.9 metres as against 25.4 metres for the Middle Oxford Clay at Warboys; and 37.5 metres as against 14.7 metres for the scarburghense zone of the Upper Oxford Clay).

The zonal sequences and lithologies of both boreholes are compared in fig. 2.3.

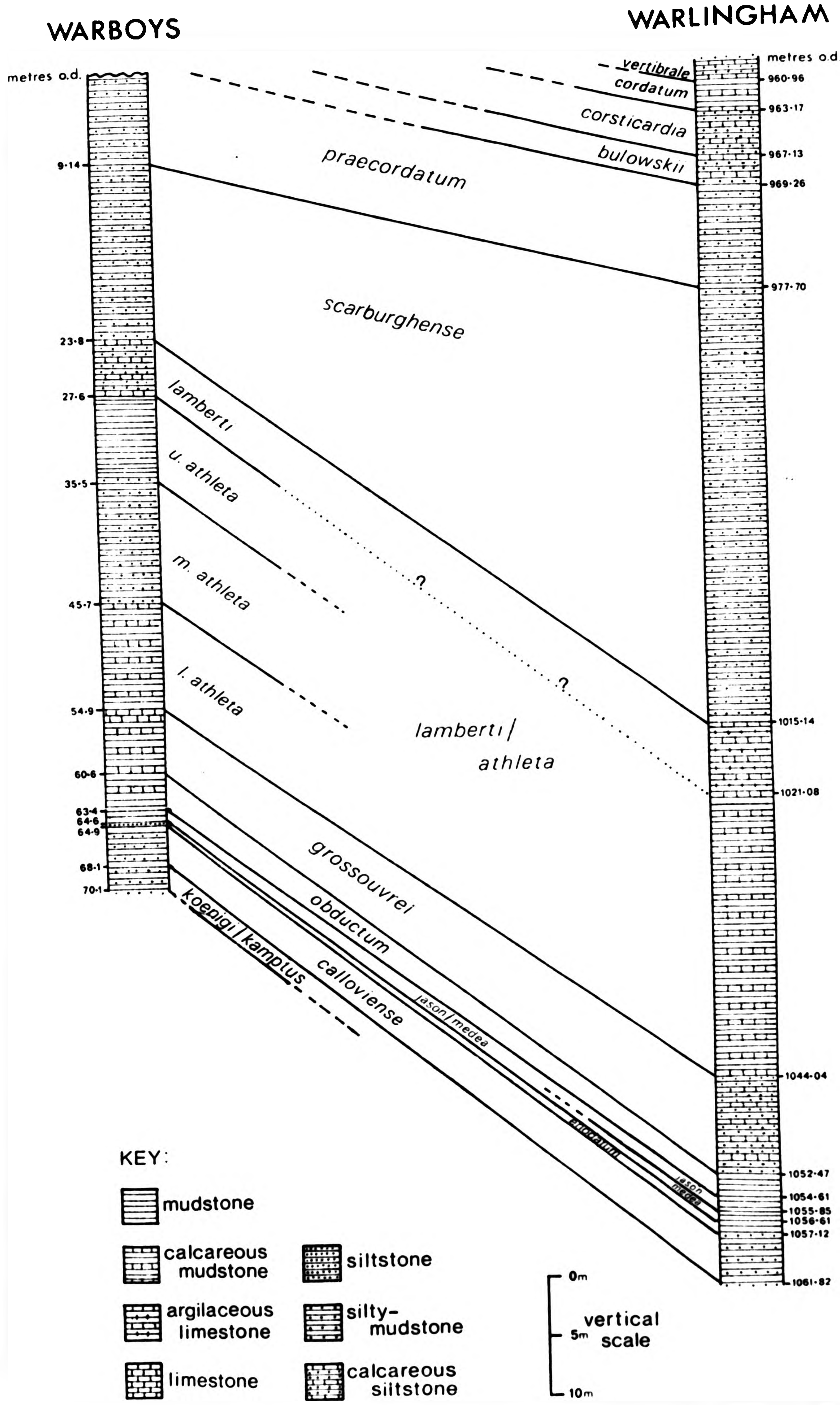
2. Warboys Borehole

The Callovian to Lower Oxfordian succession in the Warboys borehole comprises a total of 70.1 metres of calcareous mudstones and siltstones, with occasional marl or even limestone horizons. Details of the borehole have not as yet been published. The lithological details have been provided by Mr. A. Horton of the Institute of Geological Sciences who initially examined and logged the borehole. Dr. J.H.Callomon has determined the ammonite zonation and lithostratigraphic units and has kindly given permission to include the data here (figs. 2.3 and 3.1).

Q.mariae zone (22.03 metres)

C.praecordatum sub zone consists of 7.43 metres of greenish-grey, weakly-calcareous mudstone with occasional siltstone bands which are of a lighter olive grey. Gryphaea and Pinna are abundant, with occasional ammonite fragments, gastropods and pyritized fucoids and

Text-fig. 2.3 Comparison of lithostratigraphic units and ammonite zonation of the Warboys and Warlingham boreholes



WARBOYS
WARLINGHAM
metres o.d.
metres o.d.
9·14
23·8
27·6
35·5
45·7
54·9
60·6
63·4
64·6
64·9
68·1
70·1
960·96
963·17
967·13
969·26
977·70
1015·14
1021·08
1044·04
1052·47
1054·61
1055·85
1056·61
1057·12
1061·82
vertibrale
cordatum
corsticardia
bulowskii
praecordatum
scarburghense
lamberti
u. athleta
m. athleta
l. athleta
lamberti / athleta
grossouvrei
obductum
calloviense
koenigi / kamptus
jason / medea
jason
medea
KEY:
mudstone
calcareous mudstone
argilaceous limestone
limestone
siltstone
silty-mudstone
calcareous siltstone
0m
5m
10m
vertical scale

encrusting worms. The base is taken at 9.14 metres.

C.scarburghense sub zone. The lithology of the praecordatum sub zone above continues here for 14.6 metres. Lignitic plant debris and finer carbonaceous material is occasionally incorporated into the sediment. Oysters, gastropods and small ammonite fragments dominate the fauna, together with pyritized fucoids. The mudstone becomes hard and massive at the base which is taken at 23.8 metres.

Q.lamberti zone (3.8 metres)

Hard, massive, calcareous mudstone, greenish-grey in colour, with alternating calcareous siltstones of a lighter colour. Carbonaceous material is present but less frequently than in the scarburghense sub zone above. The fauna consists of oysters and pyritized ammonites, fucoids and worm tubes. The base of the zone is taken at 27.6 metres.

P.athleta zone (27.3 metres)

Upper athleta A more uniform calcareous mudstone without silt bands; marl horizons occasionally developed. Varying amounts of shell debris are found throughout. The fauna is dominated by large lamellibranchs, oysters and ammonites, with pyritized fucoids and worm-mottling. The base is taken at 35.5 metres, giving a thickness of 7.9 metres.

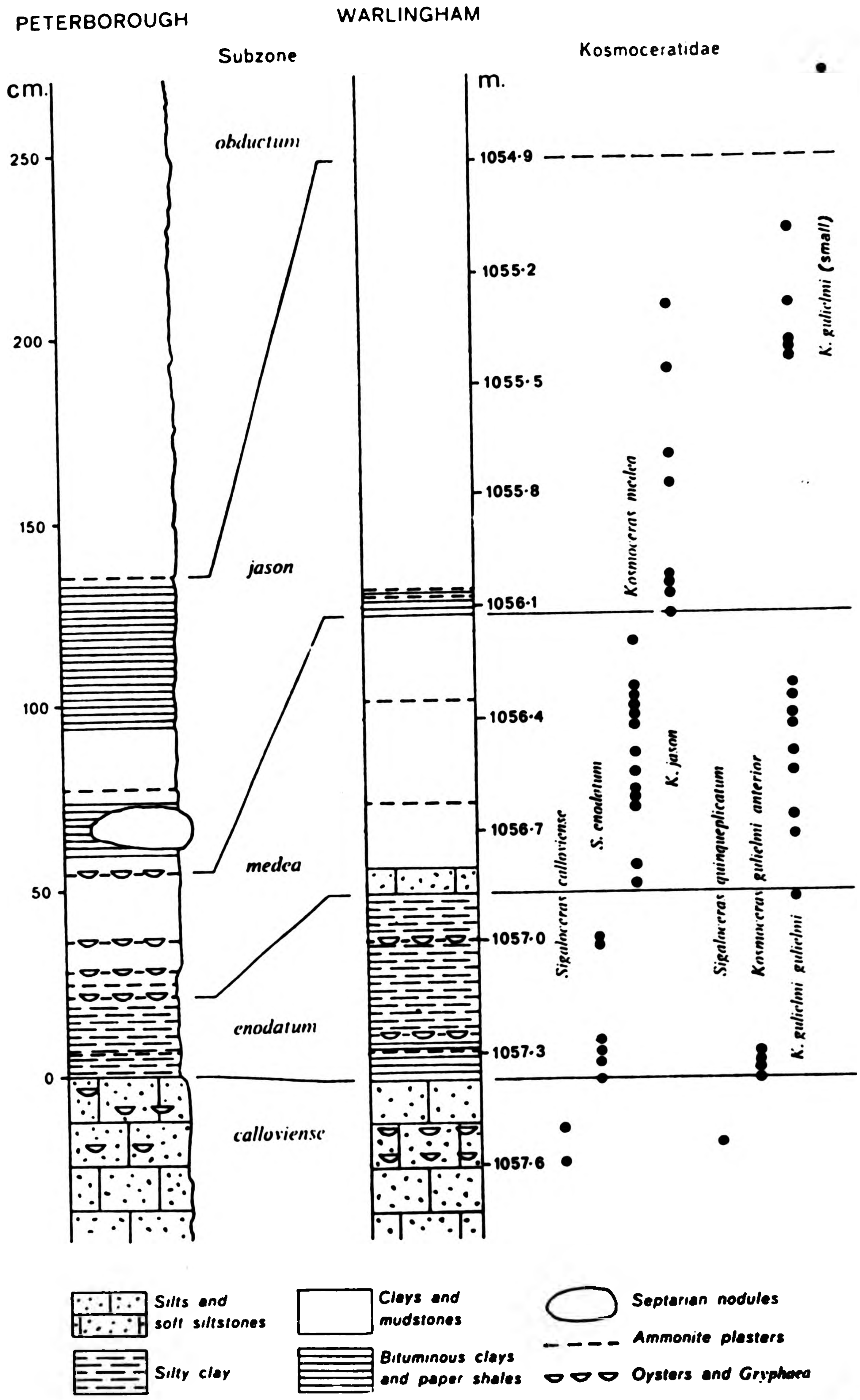
Middle athleta A continuing uniform calcareous mudstone, geenish-grey in colour, with silt incorporated rather than in bands. Marl horizons are occasionally developed, as are bituminous horizons. The fauna consists of oysters, ammonites and pyritized fucoids. The base is taken at 45.7 metres; total thickness 10.2 metres.

Lower athleta 9.2 metres of lithology similar to that of the Upper athleta division, being more argillaceous and less silty. Marl horizons contain high proportions of shell debris. Overall lithology is highly calcareous, with very little pyrite development. Oysters are conspicuously absent, rather large lamellibranchs and ammonites constitute the faunal assemblage. Base taken at 54.9 metres.

E.coronatum zone (8.5 metres)

K.grossouvrei sub zone. This sub zone is marked by a limestone horizon towards the top, below which is a light green/grey calcareous mudstone, totalling some 5.7 metres. Pyritic and carbonaceous patches are developed locally. Lamellibranchs are numerous with the

Text-fig. 2.4 <u>Comparison of the lowest part of the Oxford Clay and topmost Kellaways Beds at Warlingham with the succession in clay-pits at Peterborough</u> (after Brinkmann, 1929 and Callomon and Cope, 1971)


PETERBOROUGH
WARLINGHAM
Subzone
Kosmoceratidae
cm.
m.
250
200
150
100
50
0
obductum
jason
medea
enodatum
calloviense
1054·9
1055·2
1055·5
1055·8
1056·1
1056·4
1056·7
1057·0
1057·3
1057·6
Sigaloceras calloviense
S. enodatum
Kosmoceras medea
K. jason
Sigaloceras quinqueplicatum
Kosmoceras gulielmi anterior
K. gulielmi gulielmi
K. gulielmi (small)
Silts and soft siltstones
Clays and mudstones
Septarian nodules
Ammonite plasters
Silty clay
Bituminous clays and paper shales
Oysters and Gryphaea

occasional large ammonite. Base taken at 60.6 metres.

K.obductum sub zone. A marl band marks the top with green/grey mudstone below which is slightly silty. Abundant shell fragments with occasional pyritic ammonites and gastropods. Thickness 2.8 metres; base taken at 63.4 metres.

K.jason zone (1.2 metres)

K.jason / K.medea sub zone. A calcareous, green/grey, silty mudstone with shell debris and occasional oysters and ammonites. Pyritic development locally. It has not been possible to define the boundary between the K.jason and K.medea sub zones. Base taken at 64.6 metres.

S.calloviense zone (3.5 + metres)

S.enodatum sub zone. A very thin (0.3 metres), light olive-grey siltstone, finely laminated with coarser silt material. Rich in Gryphaea with small ammonites, belemnites and lamellibranchs. Base taken at 64.9 metres.

S.calloviense sub zone. A greenish-grey, weakly-calcareous siltstone, with a silty mudstone at the base, totalling 3.2 metres. Contains finely comminuted plant debris. Large crushed Mytilus dominate the fauna, with abundant shell debris. Base taken at 68.1 metres.

P.koenigi / M.kamptus sub zone. 2.0 metres of non-calcareous, green/grey, slightly silty mudstone with few fossils except for occasional scattered pyritic fucoids. Base taken at 70.1 metres. (It has not been possible to discern the boundary between S.calloviense (P.koenigi) and M.macrocephalus (M.kamptus) sub zones, they are therefore grouped together).

3. Warlingham Borehole

A complete sequence from the Callovian to lower, Middle Oxfordian gives a total of 102.42 metres of calcareous mudstones and siltstones. A rich ammonite fauna has been obtained and a detailed zonation scheme made by Dr. J.H.Callomon, published in Callomon and Cope, 1971 (figs.2.4 and 3.2 herein).

At the base of the sucession the Kellaways Beds comprise 7.5 cm. of siltstone, overlying 0.5 metres of mudstone, which in turn overlies 4.5 metres of silty-sandstone. In its lowest 50 cm. the sandstone is more argillaceous than above; it passes down to a 15 cm. mudstone bed which is classified with the Cornbrash because it contains Melagrinella echinata (Worssam and Ivimey Cook, 1971).

Above Kellaways is a full sequence of Oxford Clay. The division into Upper, Middle and Lower Oxford Clay has been made on grounds of convenience and lithology only and the boundaries are not necessarily isochronous (Callomon and Cope, 1971).

At the base the Oxford Clay is a series of bituminous shales with an abundant fauna. Fossils are profuse, scattered and preserved in friable white Calcium carbonate (often the original aragonite). They tend to be crowded on particular bedding planes forming dense shell beds. The base of the Lower Oxford Clay is taken at 1056.9 metres. Above this the Middle Oxford Clay is marked at the top by a fossiliferous limestone and probably corresponds to the limestone horizon marking the Q.lamberti zone of the Warboys borehole (see fig. 2.3). Below this the Middle Oxford Clay continues in poorly-fossiliferous, calcareous mudstones and siltstones, the whole being well-bedded and transitional with the bituminous shales of the Lower Oxford Clay at the base, which is taken at 1044.3 metres.

At the top of the Upper Oxford Clay the transition into the Corallian Beds is gradual, the boundary being arbitrarily drawn at the base of a bioturbated, ironshot, calcareous siltstone at 959.4 metres. Below this are 56 metres of alternating grey mudstones and pale grey calcareous siltstones in poorly-defined beds. They contain typical pyritized Upper Oxford Clay ammonites.

A detailed description of the lithology and faunal content of each zone and sub zone is given by Dr. J.H.Callomon in Callomon and Cope, 1971 (pp. 163-168) and need not be repeated here.

Chapter three

METHODS AND TECHNIQUES

METHODS AND TECHNIQUES

Dinoflagellates and other organic-walled microfossils may be encountered in a variety of water-deposited sediments. They have been recovered from virtually all types of rudaceous, arenaceous, calcareous, carbonaceous and siliceous rocks. They are particularly abundant in argillaceous rocks and 10 grammes of shale or clay may often yield "between 10,000 and several hundred thousand individuals" (Sarjeant, 1974a, p128). The Oxford Clay therefore, is an ideal lithological unit for collection of dinoflagellates.

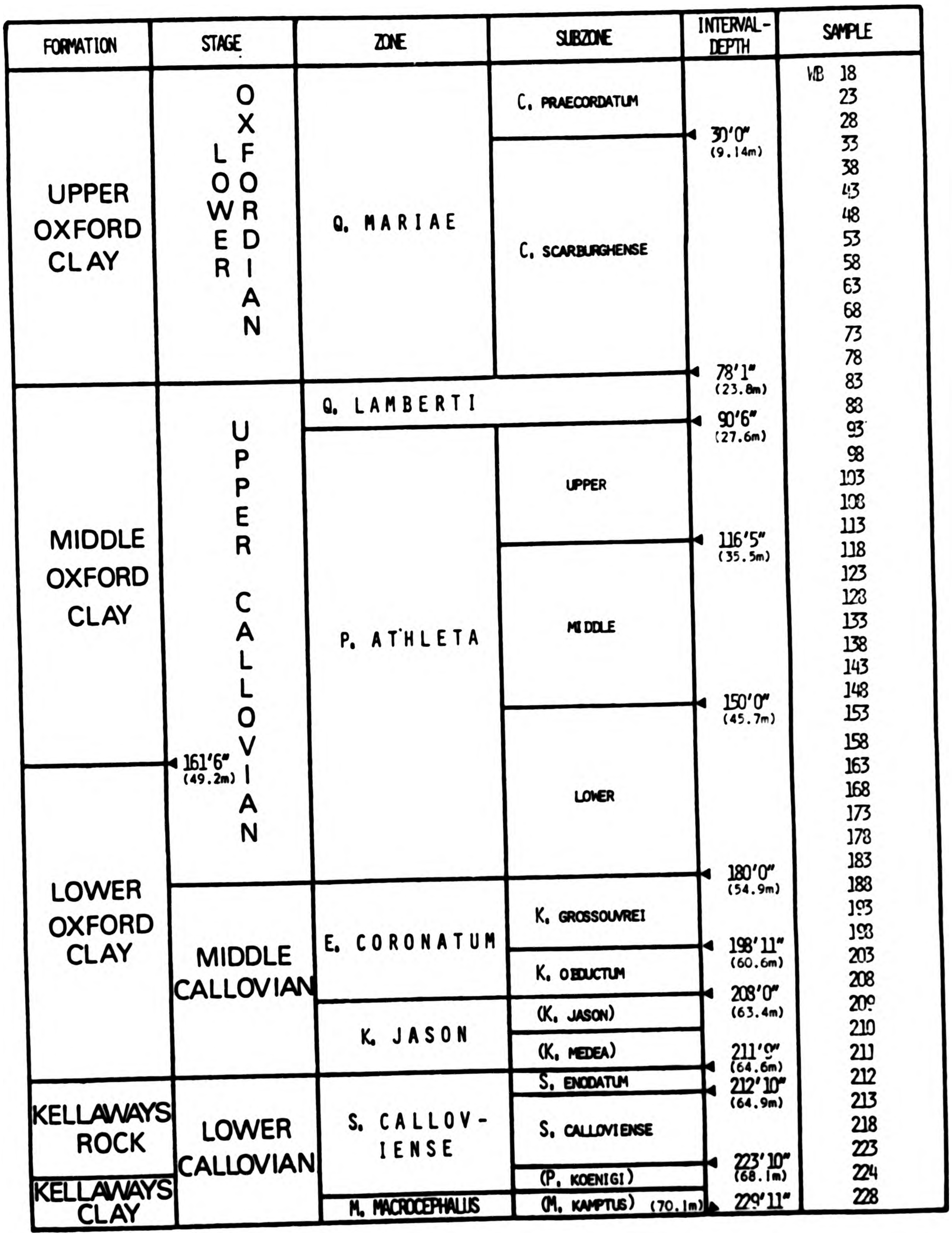
A. COLLECTION OF MATERIAL

Contamination is one of the main difficulties to overcome when both sampling and making preparations of palynological material. The risk of this occuring therefore needs to be minimised as far as possible. Material collected from natural exposures in the form of coastal sections or quarry faces is always subject to the possibility of contamination, either during the collection proceedure or simply due to normal environmental factors of weathering and erosion.

Fresh unoxidised material is vital for accurate study of these microfossils. Material from cored-boreholes is therefore ideal for two reasons: firstly pollution risks are minimal (although care must be taken to ensure that no contamination has occurred from higher horizons caused by drilling muds and collapse of the cored-wall) and the material will not have been subjected to the effects of oxidation that occur at outcrop. Secondly, accurate positional measurements can be made for each sample taken.

Material used for this study was kindly provided by the Institute of Geological Sciences from two borehole localities; one (Warboys) taken from some 12 miles south-west of Peterborough; the other (Warlingham) from about 5 miles south-south-east of Croyden, Surrey (see text-figs. 1.1; 1.2; 1.3). A detailed description of the boreholes has been given in chapter 2.

Both cores were sampled at the Institute of Geological Sciences, Acton depot (West London) under the supervision of Mr.Stuart Hollyer. Samples of at least 60 grammes were carefully taken from each borehole at regular intervals of five feet, or as near as possible. The original core of the Warboys Borehole had been broken into bagged-samples at one-foot intervals, a sample was therefore taken from every fifth bag totalling 48 samples. At the base of the section, where the ammonite zones were less than five-feet thick, at least one sample was taken from each zone (text-fig.



Text-fig. 3.1 Stratigraphic distribution of samples in the Warboys Borehole

FORMATION	STAGE	ZONE	SUBZONE	DEPTH-INTERVAL	DEPTH METRES	DEPTH FT. INS.	SAMPLE
UPPER OXFORD CLAY	MIDDLE OXFORDIAN	P. PLICATILIS	L. VERTEBRALE	3146'9" (959.4m)	959.5	3147'0"	BP 115
					961.0	3152'0"	140
	LOWER OXFORDIAN	P. CORDATUM	C. CORDATUM	3152'9" (961.2m)	962.5	3157'0"	170
			C. COSTICARDIA	3160'0" (963.4m)	964.1	3162'3"	194
					965.6	3167'1"	214
					967.1	3172'0"	246
					968.6	3177'0"	292
			C. BUKOWSKII	3173'0" (967.4m)	970.1	3182'0"	313
		Q. MARIAE	C. PRAECORDATUM	3180'0" (969.5m)	971.7	3187'4-5"	340
					973.2	3192'0"	368
					974.6	3196'9"	395
					976.2	3202'0"	429
					977.7	3207'0"	443
			C. SCARBURGENSE	3207'8" (977.9m)	979.3	3212'0"	455
					980.8	3217'0"	465
					982.3	3222'0"	481
					983.8	3226'9"	500
					985.4	3232'0"	520
					986.8	3236'8"	543
					988.4	3242'0"	554
					989.9	3247'0"	560
					991.5	3252'3"	582
					993.1	3257'6"	605
					994.7	3262'8"	620
					996.0	3267'0"	627
					997.6	3272'0"	640
					998.9	3276'6"	653
					1000.6	3282'0"	669
					1002.1	3287'0"	683
					1003.5	3291'6"	693
					1005.2	3297'0"	702
					1006.7	3302'1"	710
					1008.2	3306'9"	727
					1009.7	3311'9"	742
					1011.2	3316'9"	753
					1012.7	3321'7"	769
					1014.4	3327'2"	785
MIDDLE OXFORD CLAY	CALLOVIAN	Q. LAMBERTI / P. ATHLETA		3330'6" (1015.4m)	1015.9	3332'0"	820
					1017.4	3337'0"	851
					1019.0	3342'2"	884
					1020.4	3347'0"	916
					1021.9	3351'9"	947
					1023.5	3357'0"	963
					1025.0	3362'0"	976
					1026.5	3367'0"	985
					1028.0	3372'0"	1006
					1029.6	3377'0"	1047
					1031.1	3382'0"	1087
					1032.6	3386'10"	1113
					1034.1	3392'0"	1155
					1035.7	3397'3"	1190
					1037.3	3402'3"	1220
					1038.7	3407'0"	1255
					1040.2	3412'0"	1307
					1041.8	3417'0"	1330
					1043.4	3422'5"	1354
LOWER OXFORD CLAY		E. CORONATUM	K. GROSSOUVREI	3425'4" (1044.3m)	1044.8	3426'11"	1399
					1046.3	3431'10"	1450
					1047.8	3436'10"	1486
					1049.4	3442'0"	1531
					1050.9	3447'0"	1552
					1052.3	3452'0"	1605
			K. OBDUCTUM	(1052.7m) 3453'0"	1054.0	3457'0"	1655
		K. JASON	K. JASON	(1054.9m) 3460'0"	1055.5	3462'0"	1697
			K. MEDEA	(1056.1m) 3464'1"	1056.2	3464'4"	1723
KELLAWAYS BEDS	3466'4" (1056.8m)	S. CALLOVIENSE	S. ENODATUM	(1056.9m) 3466'7"	1057.0	3467'0"	1760
			S. CALLOVIENSE	(1057.8m) 3468'3"	1058.5	3471'9"	1813
					1060.0	3477'0"	1833
					1061.5	3481'10"	1880
				3483'8"	1062.3	3483'8"	1898

Text-fig. 3.2 Stratigraphic distribution of samples in the Warlingham Borehole

3.1). In the case of the Warlingham Borehole the entire core was still in its original form; a total of 70 samples were taken from registered specimens as near to the five-foot interval as possible (text-fig.3.2). The 118 samples were individually carefully bagged, labelled both inside and outside the bag and stored for processing.

B. PREPARATION OF MATERIAL

The primary objective during preparation of a sample is to isolate the organic palynomorphs (dinoflagellates, acritarchs, spores, pollen etc.) and to obtain a residue which is free from unwanted organic debris, heavy mineral, bitumen etc. This will facilitate examination of the remaining assemblage of palynomorphs with relative ease.

The preparation technique employed for this study is essentally that used by the Geology Department, University of Sheffield. The author is particularly indebted to Mr. Paul Higham who developed this technique, although a number of modifications have been found necessary after experimentation.

Each individual sample was treated as far as possible in an identical way, except for occasional, more unusual samples where modified treatment was found to be necessary. A record card accompanied each sample throughout the processing cycle on which was recorded details of the sample and treatment (text-fig. 3.3). Each piece of apparatus, previously sterilised with Chromic acid, also carried with it the sample number thus enabling more than one sample to be processed at any one time.

1. Preliminary examination

From the original 60 grammes cf material a sample of 50 grammes was taken for processing(the remaining 10 grammes being retained as a safeguard should the sample be lost at any stage of the proceedure). Where a sample included part of the outer perimeter of the core this was removed to avoid possible contamination from higher horizons caused by drilling muds. The sample was crushed in a pestle and mortar to grains of about 5 mm. diameter. Care was taken to avoid a grinding action to reduce the risk of damage to the specimens. (text-fig. 3.4a).

2. Removal of carbonates

The crushed sample was placed in a 1-litre polythene beaker with a few mls. of water and left to soak for a few minutes. Onto this was

SAMPLE Nº		PROCESSING DATA			
HORIZON: LOCALITY: LITHOLOGY:		REAGENT	REACTION	TIME	EFFECT
		HCl			
		HF			
		HNO_3			
WEIGHT	AMOUNT PROCESSED	SCHULZE			
REMARKS		CENTRIFUGE STAIN – SAFRANIN BISMARCK BROWN Nº OF SLIDES:			

Text-fig. 3.3 Sample card used for recording details of processing carefully poured 100-200 mls. of concentrated Hydrochloric acid (HCl) in order to remove any carbonates present and cause initial break-down of the sediment. The beaker was covered with a watch-glass and left in a fume-cupboard for at least 2 hours. After this a little more HCl was poured onto the sample to test for any further reaction and thus for complete removal of carbonates. The residue was then washed with hot water and left to settle for a half to one hour. The sample was neutralised by decanting of the super-natant liquid and washing several times with water. Complete neutrality of the sample was tested with litmus paper.

3. Breakdown and removal of silicate minerals

The neutralised residue was transferred to a 500 ml. polythene bottle with a perforated screw-on cap. To this was added 200 to 300 mls. of concentrated (40% w/v) Hydrofluoric acid (HF). A little was added at first to test the initial reaction (which can be quite violent). After stirring the sample with a P.T.F.E. rod and replacing the cap, the bottle was placed on a heated sand-tray (kept at 70°C) to accelerate the break-down process of the silicate minerals and left for a period of 2 to 3 days. A little agitation or stirring at intervals assisted breakdown during this period.

The spent acid was carefully decanted off into a polythene container with 2 to 3 litres of 10% Sodium bicarbonate (Na_2CO_3) solution (text-fig. 3.4b) and stored for several days in a large (30 litre) polythene aspirator containing limestone chips in order to ensure complete neutrality of the HF before being discarded. The remaining residue was again washed several times with water and tested for neutrality.

The residue was transferred to a nylon micro-mesh sieve of 10 mu aperture washed for several minutes with hot water (text-fig. 3.4c) and placed in a sinter-glass funnel of porosity 2 (10to20 mu) incorporated in the apparatus as illustrated in text-fig. 3.4d. A small proportion of the residue was retained in a corked specimen bottle at this stage as a safe-guard should the sample be lost during the next (most critical) stage.

4. Oxidation and filtration

A little of the residue was placed on a glass microscope-slide and examined under a microscope to see if this next stage in the proceedure was necessary. At this stage, the residue will contain mostly organic material plus a little heavy mineral. Amongst the organic material there will be, in addition to the desired microfossils, debris of plant and animal origin. Large fragments can be removed by a coarse sieving (150+ apert-

Text-fig. 3.4 Photographs illustrating various stages in processing

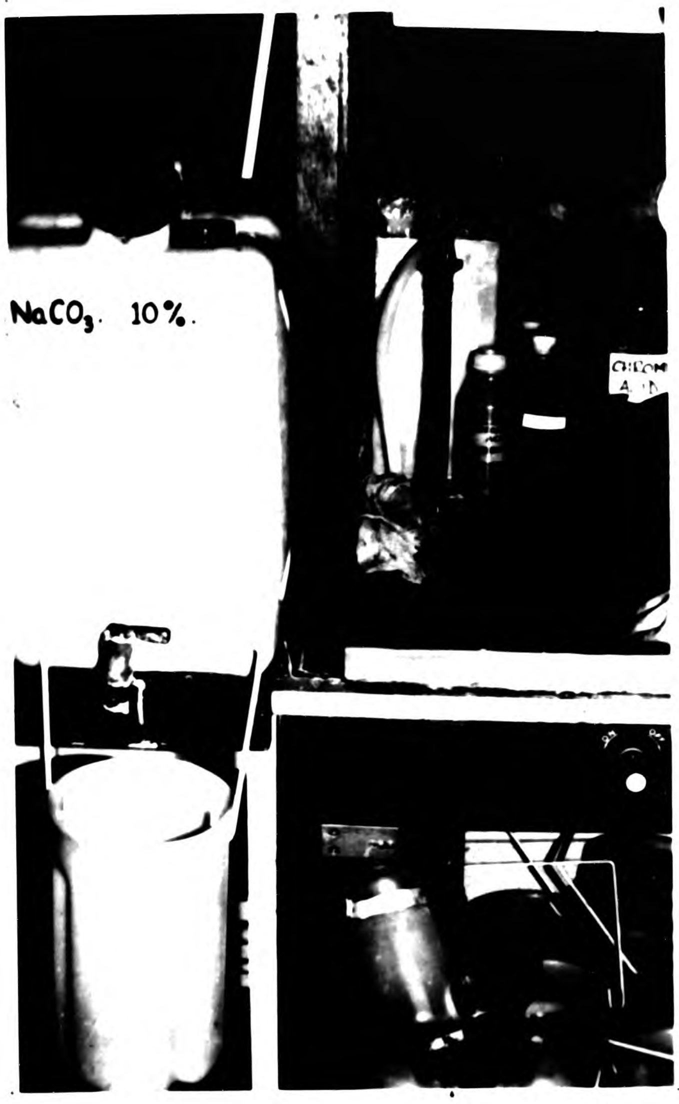
a CRUSHING WITH PESTLE & MORTAR

b DECANTING & NEUTRALISING HYDROFLUORIC ACID

c WASHING RESIDUE THROUGH 10_{mu} SIEVE

d FUMING NITRIC ACID ADDED TO RESIDUE

a CRUSHING WITH PESTLE & MORTAR



b DECANTING & NEUTRALISING HYDROFLUORIC ACID

c WASHING RESIDUE THROUGH 10_{mu} SIEVE

d FUMING NITRIC ACID ADDED TO RESIDUE

a CRUSHING WITH PESTLE & MORTAR

b DECANTING & NEUTRALISING HYDROFLUORIC ACID

c WASHING RESIDUE THROUGH 10_{mu} SIEVE

d FUMING NITRIC ACID ADDED TO RESIDUE

ure). As the microfossils are more resistant to intense oxidation than the unwanted organic debris, this fraction can be removed by a combined process of oxidation and filtration.

To the residue in the sinter-glass funnel 20 to 30 mls. of fuming Nitric acid (HNO_4) of 95% strength was carefully added and left to run through the filtration apparatus for about 10 minutes. The 'blow-ball' was used at intervals to blow air through the sinter-glass plate and prevent clogging of the pores and damage of the microfossils (text-fig. 3.5a). The residue was then washed several times with water until neutralised.

A little of the residue was again examined under the microscope to see if all of the unwanted organic debris had been removed. Often loose material adhered to the microfossils, this was removed by subjecting the sample to ultrasonic vibration for a few minutes and then re-washed through the nylon micro-mesh sieve to remove the fine particles.

5. Removal of heavy mineral

Having concentrated the microfossils, the only unwanted debris left was heavy mineral. This was removed in one of the two following ways:

a. 'Swirling' The residue in suspension was placed on a large watch-glass and swirled in a circular motion (as if 'panning for gold'). After a few minutes the heavy mineral concentrated in the centre of the watch-glass whilst the microfossils remained in suspension and thus could be removed (text-fig. 3.5b).

b. Centrifuging The residue in suspension was placed in a small (15 ml.) centrifuge tube and centifuged for 1 minute to seperate the water from the microfossils. After pouring off the water about 10 mls. of saturated Zinc chloride ($ZnCl_3$) solution was added to the residue and shaken. The tube was returned to the centrifuge and spun for 20 minutes at 2000 r.p.m. On removal of the sample the organic fraction containing the microfossils was found at the top of the tube and the heavy mineral at the bottom (text-fig. 4.5c). The organic part was carefully removed and returned to the sinter-glass funnel and the Zinc chloride removed with Hydrochloric acid; the whole residue again being washed with water to complete neutrality.

Text-fig. 3.5 Photographs illustrating various stages in processing

a OXIDATION WITH FUMING NITRIC ACID

b 'SWIRLING' ON A LARGE WATCH-GLASS TO CONCENTRATE HEAVY MINERAL

c CENTRIFUGING TO SEPERATE HEAVY MINERAL FROM ORGANIC RESIDUE

d MOUNTING OF FINAL PREPARATION ON GLASS COVER-SLIPS

a OXIDATION WITH FUMING NITRIC ACID

b 'SWIRLING' ON A LARGE WATCH-GLASS TO CONCENTRATE HEAVY MINERAL

c CENTRIFUGING TO SEPERATE HEAVY MINERAL FROM ORGANIC RESIDUE

d MOUNTING OF FINAL PREPARATION ON GLASS COVER-SLIPS

6. Staining

Each of the samples was stained using safranin to give the microfossils a red colouration. This was by personal preference rather than necessity, as many of the features were enhanced by the stain, giving greater contrast for photography. Safranin is a water-soluble stain and a little of this solution, made fresh for every sample, was added to the residue in the sinter-glass funnel and left to run through for about 3 minutes. The excess stain was then washed away with water and the effect of the staining examined under the microscope. The density of the staining was found to vary between samples even though the timing was consistent (This was probably due to the variation in intensity of the oxidation process). If the staining was found to be too weak the process was repeated and a few drops of Potassium hydroxide (KOH) solution (10%) added to the residue with the stain.

On completion of the processing cycle the sample was placed in a small, corked, specimen-bottle with a few drops of Formaldehyde (to prevent decomposition or algal/bacterial growths), labelled and stored for examination.

C. PREPARATION OF MICROSCOPE SLIDES

A standard technique was used for making permanent mounts of the microfossils. A small amount (3 to 4 mls.) of the residue in suspension was taken from the specimen bottle and placed in another bottle of similar size. To this was added some 20 mls. of 1% Cellusize (Hydroxethyl cellulose) solution and the whole thoroughly mixed using the sucking action of a pipette. A little of this mixture was carefully pipetted onto a glass cover-slip (32mm. by 22mm.) which had previously been placed on an electric photographic dish-warmer, using the surface-tension of the liquid to contain the suspension on the cover-slip (text-fig. 3.5d). The dish-warmer was then switched on to a low heat (50° to 70°C) and covered to prevent contamination from the atmosphere. After two to three hours the liquid had evaporated leaving the microfossils firmly adhered to the cover-slip, the whole being ready for mounting.

Canada Balsam (neutral, thin) was used for making permanent mounts. A little was placed onto the cover-slip which had previously been placed on a slide-mounting hot-plate (at 100°C) and left for a few minutes for the Xylene to evaporate. Using mounting needles, the cover-slip was then transferred to a standard (1.5cm. by 7.5cm.) glass microscope slide and left to dry on the hot-plate for about 20 minutes. When cooled, the excess

Canada Balsam was removed from around the edge of the cover-slip using Xylene and a soft brush. The slide was dried and labelled ready for examination. Three slides were made of each preparation.

An alternative mounting medium - 'DPX' (an epoxy-resin) was experimented with as an alternative mounting-medium but found to be only about 50% successful. Occasionally shrinkage occurred a few months after mounting, introducing air-bubbles into the mount. However, the mounting is much quicker and cleaner using 'DPX' and requires no heat, the slides being left at least three days to dry. Excess mounting-medium can be peeled from around the edge of the cover-slip using a sharp blade.

D. EXAMINATION OF PREPARED MATERIAL

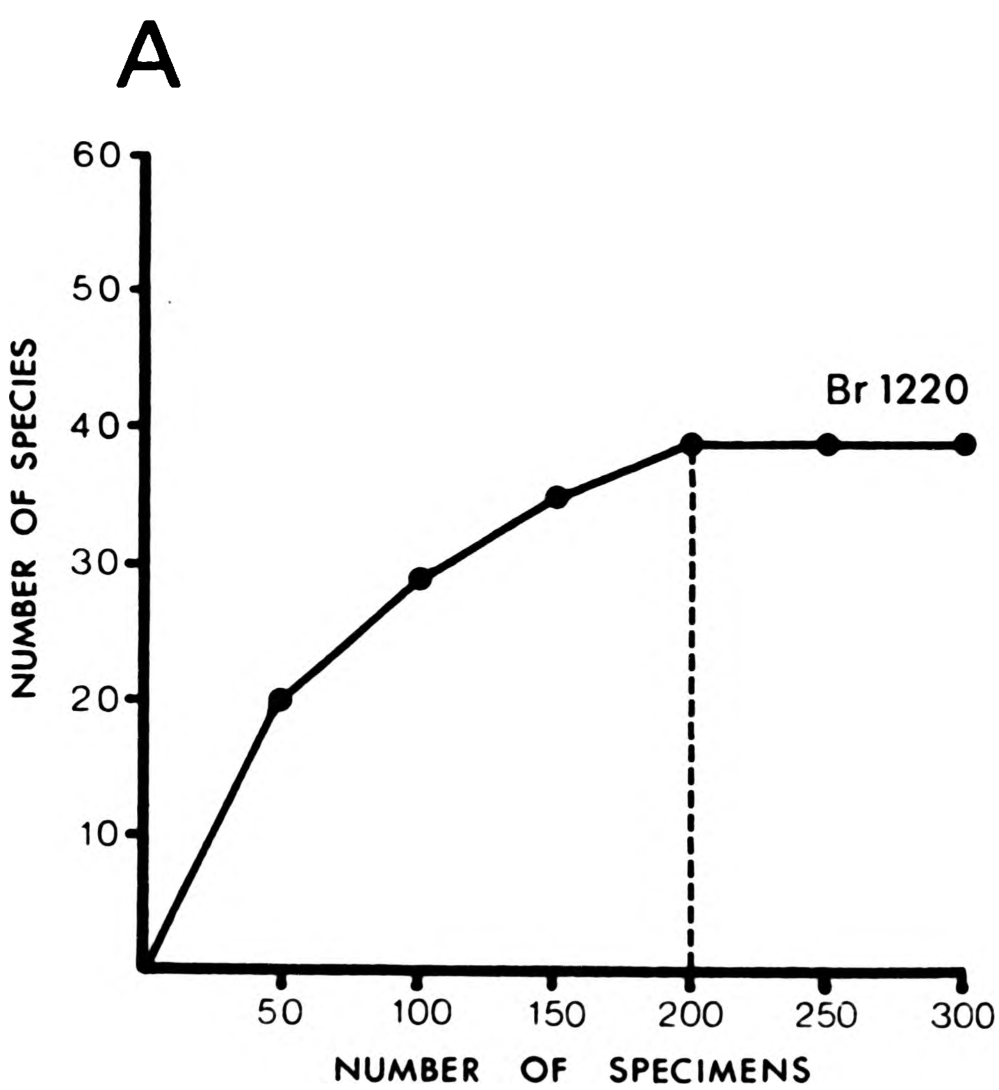
A qualitative analysis of each assemblage was first undertaken, with each dinoflagellate and acritarch being examined and identified. The different types were photographed (including morphological variants) and the photograph mounted to a 8" by 5" index card with appropriate annotations and reference numbers (sample, slide-coordinate and photo-negative numbers). A provisional identification was made and the cards filed in alphabetical order for ease of use. In this way a 'working catalogue' of species was built up.

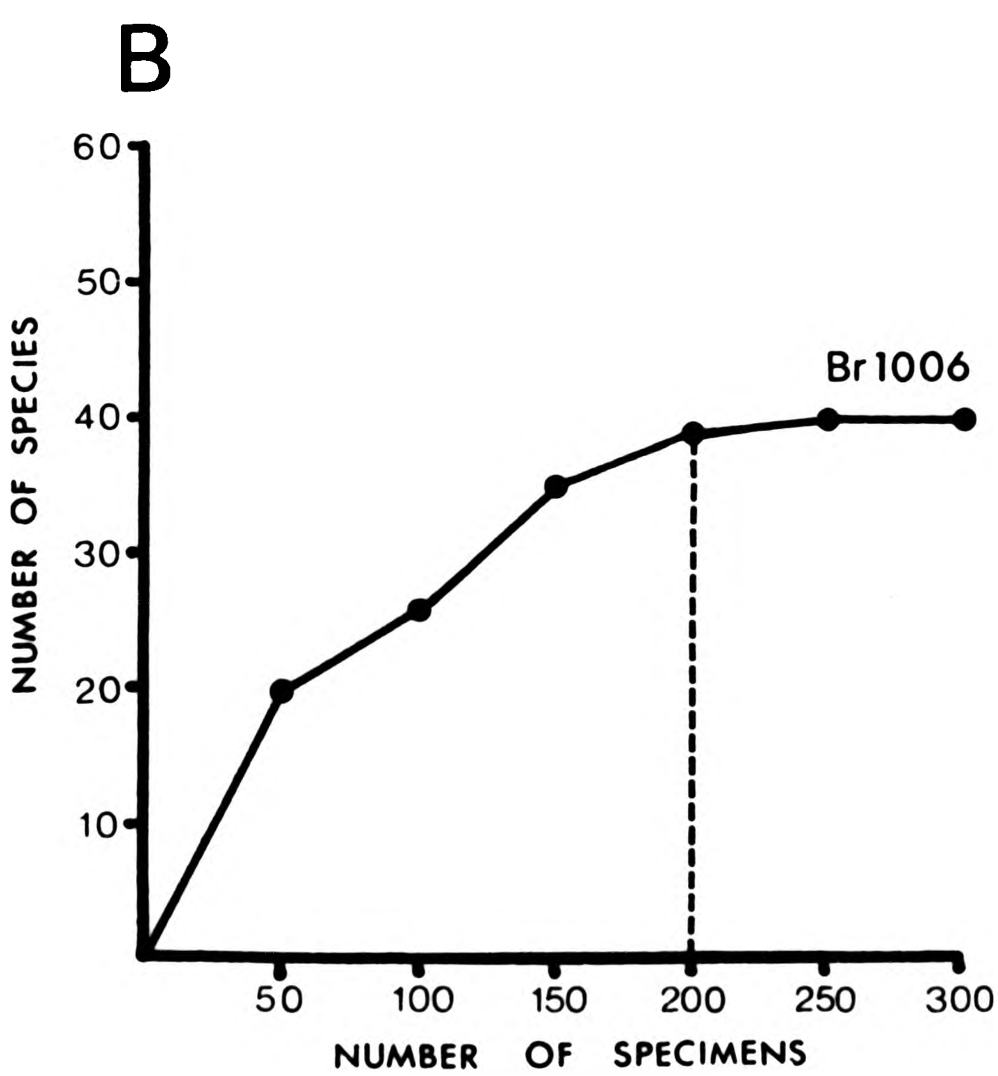
This was followed by a quantitative analysis, or 'logging' of the slide. Two random samples were taken (Br.1006 and Br.1220) and systematically logged to determine the minimum number of specimens necessary to be counted in order to obtain a good representation of species diversity within the sample. In each of these two samples the minimum number was found to be 200, giving a total number of 39 species per 200 specimens in Br.1006 and 40 species per 200 specimens in Br.1220 (text-fig. 3.6). A 200-specimen count was therefore taken to be representative and each sample was logged accordingly. The first 200 specimens were counted and identified as far as possible, the details and total numbers of specimens per species were recorded on four specially-designed log-sheets (text-fig. 3.7). On each log sheet was printed a list of all published microplankton taxa recorded to date from the Upper Jurassic (taken from Lentin & Williams, 1977). Each slide was systematically traversed and absolute numbers recorded, up to and including 200 specimens. The rest of the slide was then examined for any further species which did not appear in the first 200-count. These were found to be minimal and where they did occur were counted as a single occurrence. Only whole identifiable specimens were counted, or identifiable specimens where more than half of the cyst was present.

Text-fig. 3.6 <u>Graphs illustrating number of species per 200-count in samples Br.1220 and Br.1006</u>

A. Sample Br.1220 - 40 species per 200 specimens counted.

B. Sample Br.1006 - 39 species per 200 specimens counted.


A
NUMBER OF SPECIES
60
50
40
30
20
10
Br 1220
50
100
150
200
250
300
NUMBER OF SPECIMENS


B
NUMBER OF SPECIES
60
50
40
30
20
10
Br 1006
50
100
150
200
250
300
NUMBER OF SPECIMENS

PALYNOLOGICAL LOG SHEET

SAMPLE No .... SLIDE No ....

HORIZON .... LOCALITY ....

No OF SPECIMENS COUNTED .... M'PLANKTON : SPORE/POLLEN ....

TAXA		TOTAL
Acanthaulax paliuros		
A. venusta		
Adnatosphaeridium aemulum		
A. aemulum subsp. *integrum*		
A. caulleryi		
A. filamentosum		
A. paucispinum		
A. perforatum		
Broomea ramosa		
B. simplex		
Caligodinium halosa		
Cannosphaeropsis densifilosa		
Chlamydophorella membranoidea		
C. wallala		
Chytroeisphaeridia chytroeides		
C. dictydia		
C. pococki		
Cleistosphaeridium ehrenbergii		
C. lumectum		
C. polyacanthum		
C. polytrichum		
C. sphericum		
C. tribuliferum		
Compositosphaeridium costatum		
Ctenidodinium combazii		
C. continuum		
C. mosaicum		
C. ornatum		
C. pachydermum		
C. rotundum		
C. tenellum		
Cyclodictyon minor		
Dichadogonyaulax gochtii		
D. kettonensis		
D. norrisii		
D. pannea		
D. sellwoodii		
D. stauromatus		
Dingodinium cooksoniae		
D. jurassicum		
D. minutum		

-2-

Ellipsoidictyum cinctum		
E. reticulatum		
Endoscrinium eisenackii		
E. eisenackii subsp. *oligodentatum*		
E. galeritum		
E. galeritum subsp. *fornicatum*		
E. galeritum subsp. *reticulatum*		
E. luridum		
E. oxfordianum		
E. subvallare		
Fodinia pachytheca		
Glomodinium reticulopilosum		
Glossodinium bicuneatum		
Gonyaulacysta ambigua		
G. areolata		
G. canadensis		
G. Cladophora		
G. confusa		
G. dangeardii		
G. dictyophora		
G. downiei		
G. gongylos		
G. granulata		
G. granuligera		
G. jurassica		
G. jurassica subsp. *brevis*		
G. jurassica subsp. *longicornis*		
G. nuciformis		
G. perforans		
G. transparens		
G. whatleyi		
Heslertonia teichophera		
Hystrichogonyaulax nealei		
Leptodinium arcuatum		
L. eumorphum		
L. freakei		
L. milliodii		
L. mirabile		
L. subtile		
Lithodinia acanthosphaera		
L. callomonii		
L. caytonensis		
L. cristulata		
L. deflandrei		
L. ghermanii		
L. jurassica		
L. predae		
L. rioultii		
L. strongylos		
Micrhystridium castinatum		
M. deflandrei		
M. densispinosum		
M. echinoides		
M. fragile		

-3-

Micrhystridium inconspicuum		
M. nannacanthum		
M. piveteaui		
M. polyhedricum		
M. rarispinosum		
M. recurvatum		
M. recurvatum forma *brevispinosa*		
M. recurvatum forma *longispinosa*		
M. recurvatum forma *multispinosa*		
M. recurvatum forma *reducta*		
M. rhopalicum		
M. sydus		
M. variabile		
Nannoceratopsis gracile		
N. pellucida		
N. spiculata		
Netrelytron stegastum		
Palaeostomocystis cylindrica		
P. sinuosa		
Paragonyaulacysta calloviensis		
Pareodinia apotomocerastes		
P. ceratophora		
P. ceratophora subsp. *pachyceras*		
P. ceratophora subsp. *scopaeus*		
P. dasyforma		
P. groenlandica		
P. imbatodinensis		
P. kondratjevii		
P. minuta		
P. osmingtonensis		
P. osmingtonensis subsp. *rostrata*		
P. prolongata		
P. robusta		
P. spinosissima		
P. verrucosa		
Polysphaeridium deflandrei		
Polystephanephorus calathus		
P. paracalathus		
P. speciosus		
Pyxidiella pandora		
Scrinocassis dictyotus		
Scriniodinium ceratophorum		
S. crystallinum		
S. klementii		
S. reticulatum		
Sirmiodinium grossii		
Solisphaeridium brevispinosum		
S. claviculorum		
S. stimuliferum		
Stephanelytron caytonense		
S. redcliffense		
S. scarburghense		

-4-

Surculosphaeridium cribrotubiferum		
S. vestitum		
Systematophora areolata		
S. orbifera		
S. valensii		
Taeniophora iunctispina		
T. iunctispina subsp. *filamentosa*		
Tenua capitata		
T. pilosa		
T. rioultii		
T. varispinosa		
T. verrucosa		
T. villersensis		
Tubotuberella apatela		
T. sphaerocephalis		
Valensiella ovula		
Wanaea acollaris		
W. clathrata		
W. digitata		
W. fimbriata		
W. spectabilis		

ASSEMBLAGE REMARKS

Text-fig. 3.7 Log-sheets used for recording species-diversity

E. PHOTOMICROGRAPHIC TECHNIQUES

The photomicrographs (plates 1 to 34) were taken with an OLYMPUS OM10 camera attachment to an OLYMPUS binocular microscope (BH), using FOTOKEMIA KB14, 35mm film (14 DIN = 20 ASA). Photographs were taken using either a X40 or X100 (oil-immersion) objective, depending on the size of the specimen to be photographed.

Chapter four

TAXONOMY

A. DIVISION PYRRHOPHYTA

1. Introduction

The Pyrrhophyta, or dinoflagellates, are unicellular organisms generally between 20 and 150 mu long, exhibiting both 'plant' and 'animal' characteristics. They are however, usually considered plants because of the presence of cellulose in the cell wall and chlorophyll pigments in the protoplasm. Most dinoflagellates possess two flagella for propulsion and have a prominant nucleus and a sculptured cell wall.

They are essentially marine organisms (although a few are known to tolerate both marine and fresh-water conditions) and have formed an important contingent of oceanic phtyoplankton since early Mesozoic times. Both heterotrophic and autotrophic modes of nutrition occur, although the latter predominate. Dinoflagellates are known to posess a complex life-cycle (Wall & Dale, 1968) which includes a vegetative or 'motile-thecate' stage and an encysted stage (text-fig. 4.1). The organic wall of the encysted stage is extremely tough and readily preserved in the fossil record. The vegetative, motile-thecate stage, by way of contrast, is very delicate and rarely, if ever, preserved.

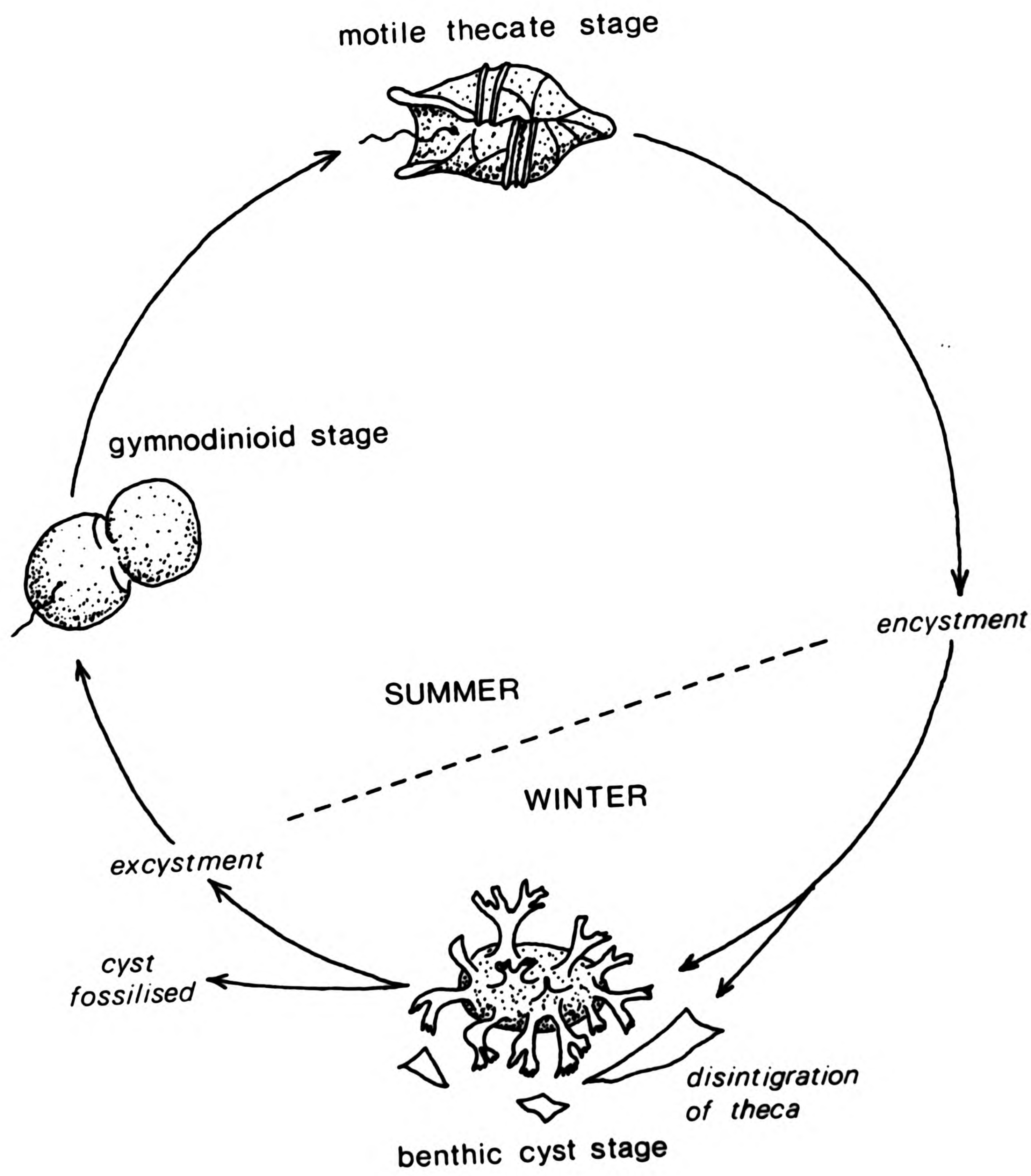
A comprehensive study of the morphology and ecology is given by Sarjeant (1974a). Only a brief outline of cyst-morphology and terminology will be given here.

2. Morphology of the Cyst

The resting cyst is smaller than the motile-stage theca. It is formed within the formerly motile cell and contains the same organelles. The cyst wall, or PHRGAMA is usually two-layered, consisting of an outer PERIPHRAGM and an inner ENDOPHRGAM. Where a single wall layer is present it is termed the AUTOPHRAGM. Occasionally cyts may have three wall layers. Where two layers are present it is the outer periphragm which develops any ornamental features. A cavity may develop between the two wall layers which is known as a PERICOEL. (For a full explanation of cyst-wall terminology, see tables 4.1 & 4.2).

The surface of the theca is commonly divided into a number of polygonal areas known as plates (text-fig. 4.2), the number and arrangement of which constitute the TABULATION. Where two plates lie adjacent to each other, the line of contact is termed a SUTURE. The cyst may develop a

Text-fig. 4.1 Encystment - excystment life-cycle of a hypothetical dinoflagellate. (After Wall & Dale, 1968)


motile thecate stage
gymnodinioid stage
encystment
SUMMER
WINTER
excystment
cyst
fossilised
disintigration
of theca
benthic cyst stage

PREFIX	MEANING	COMBINATION	DEFINITION
auto-	single	autophragm autocyst autocoel	single wall single body single cavity
endo-	inner	endophragm endocyst endocoel	inner wall inner body inner cavity
meso-	middle	mesophragm mesocyst mesocoel	middle wall middle body middle cavity
peri-	outer	periphragm pericyst pericoel	outer wall outer body outer cavity
ecto-	extreme outer	ectophragm ectocyst ectocoel	extreme outer wall extreme outer body extreme outer cavity

STEM	MEANING	COMBINATION	DEFINITION
-phragm	wall	autophragm endophragm mesophragm periphragm ectophragm	single wall inner wall middle wall outer wall extreme outer wall
-cyst	body	autocyst endocyst mesocyst pericyst ectocyst	single body inner body middle body outer body extreme outer body
-coel	cavity	autocoel endocoel mesocoel pericoel ectocoel	single cavity inner cavity middle cavity outer cavity extreme outer cavity

Table 4.1 Wall, body and cavity terminology in dinoflagellate cysts
(After Evitt, et.al., 1977)

NUMBER OF WALL LAYERS	REGULAR PROCESSES, ETC., INTERCONNECT THE LAYERS	IDENTIFICATION OF LAYERS	EXAMPLES
one	---	autophragm	Chytroeisphaeridia Pareodinia Sentusidinium
two	no	endophragm periphragm	Sirmiodiniopsis Belodinium Senoniasphaera
two	yes	autophragm ectophragm	Chlamydophorella Kylindrocysta Stephanelytron
three	no	endophragm mesophragm periphragm	Deflandrea (a few species)
three	yes, with respect to the outer two layers	endophragm periphragm ectophragm	Nematosphaeropsis Wetzeliella (a few species)

Table 4.2 Identification of wall layers in a dinoflagellate cyst (After Evitt, et.al., 1977)

variety of ornamental features in the form of processes, spines, crests, etc., which may be indicative of the original tabulation of the theca. Where this is so the features that reflect the tabulation of the original theca are referred to as PARATABULATION features. Thus, gonyaulacid, peridinioid and ceratioid cysts may be recognised according to the nature of the paratabulation. (The prefix 'para-' refers to features developed on the cyst rather than on the motile-theca).

The positions of the two motile-stage flagella are indicated by the longitudinal furrow or SULCUS and the transverse furrow or CINGULUM. When these features are reflected on the cyst they are termed PARASULCUS and PARACINGULUM respectively. The side of the cyst on which the parasulcus is situated is the ventral; the opposite side is dorsal. The paracingulum usually forms at the mid-point, dividing the cyst into two imperfect halves; the top half forming the EPICYST and the lower half the HYPOCYST (text-fig. 4.2). The paracingulum is usually spiral in nature, where this is the case the term LAEVOROTATORY is used to describe it. The anterior pole of the cyst is termed APICAL, the posterior pole ANTAPICAL.

Three basic types of dinoflagellate cyst are recognised, designated PROXIMATE, CHORATE and CAVATE, although intergradations between these exist (text-fig. 4.4). These three kinds may be distinguished according to the degree of contraction of the cyst within the theca and the development of a pericoel.

Proximate cysts develop within the phragma in contact with the wall of the enclosing theca (text-fig. 4.3a). The tabulation, cingulum and sulcus are all usually reflected in the surface sculpture of proximate cysts (text-fig. 4.4a)

Chorate cysts develop further within the theca, having undergone great contraction during encystment, with the result that there is little morphological similarity between cyst and theca. The cyst is linked to the theca by PROCESSES which may correspond in position with plates or sutures of the thecal tabulation (text-figs. 4.3b; 4.4c). The term SKOLOCHORATE is used to distinguish chorate cysts bearing projections in the form of isolated processes from cysts with other types of projections, such as high septa or winglike membranes.

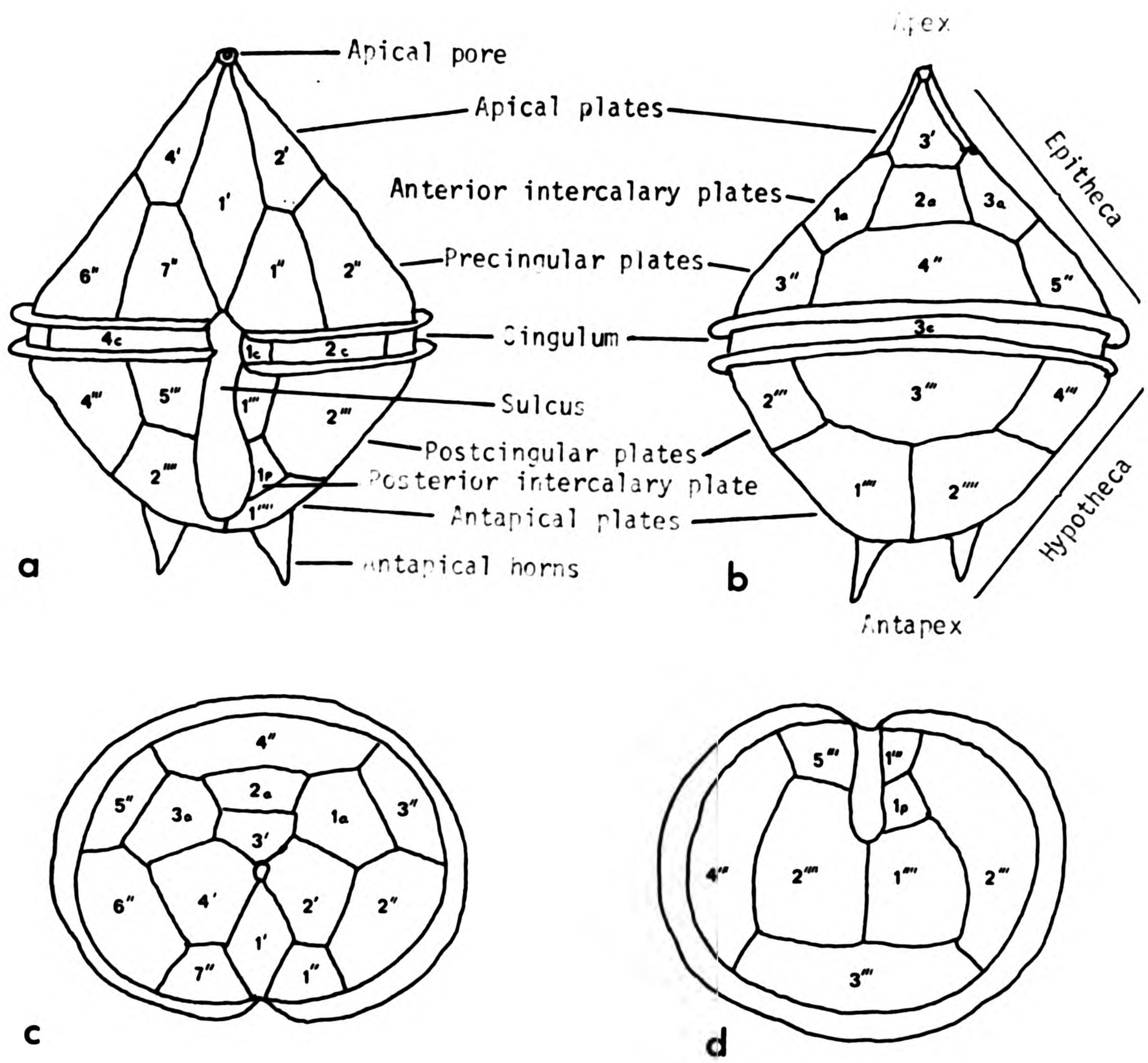
Cavate cysts are those in which the periphragm and endophragm are wholly or partially seperated. The cavity that forms is termed a pericoel and the central body a CAPSULE (text-figs. 4.3c; 4.4b). Traces of the tabulation, cingulum and sulcus may also be seen which suggests that cyst-formation may have taken

Text-fig. 4.2 Diagrams of a hypothetical dinoflagellate illustrating the terminology for the principle thecal structures and symbols used to identify plates (After Evitt, 1961)

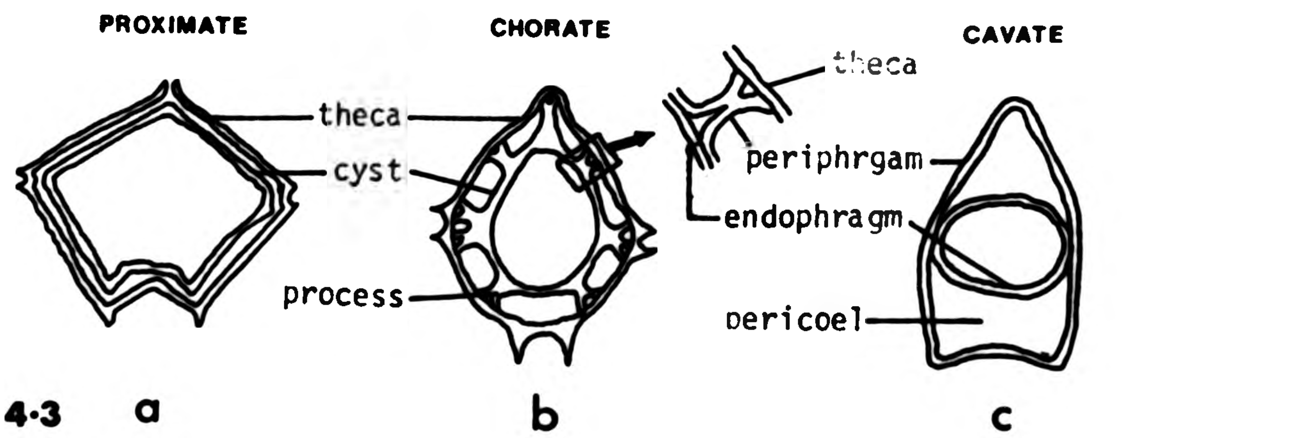
a ventral view b dorsal view

c apical view d antapical view

Text-fig. 4.3 Sections through hypothetical dinoflagellates illustrating the development of the cyst within the motile theca in each of the three main cyst-types (After Evitt, in Tschudy and Scott, 1969)

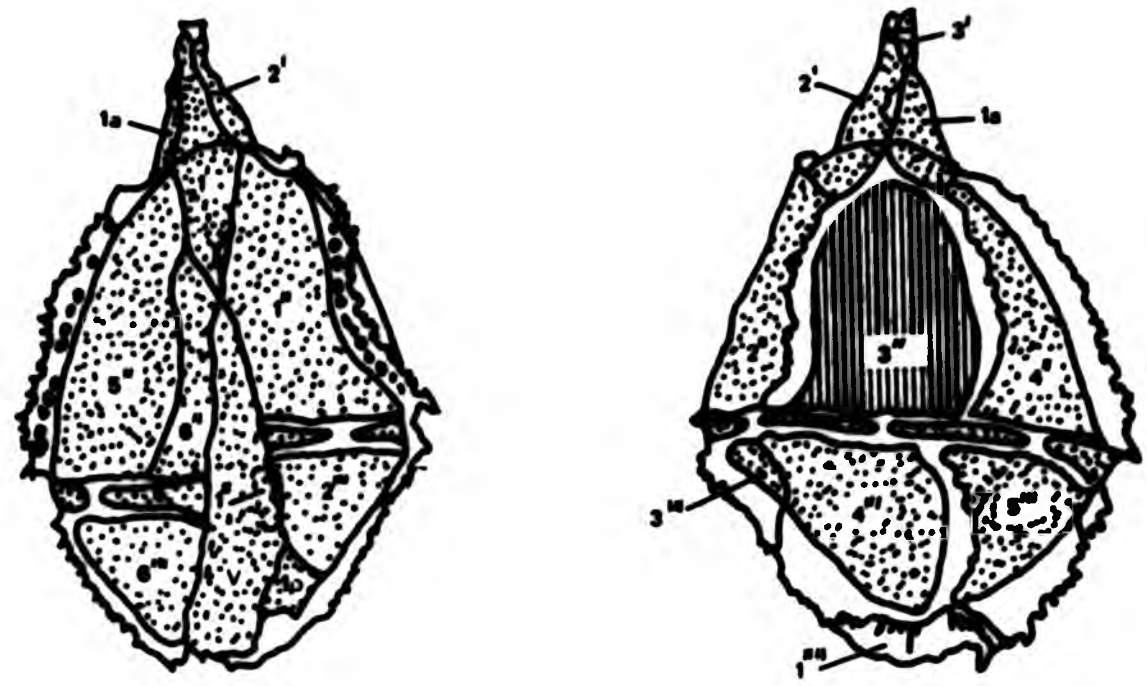

Apical pore
Apical plates
Anterior intercalary plates
Precingular plates
Cingulum
Sulcus
Postcingular plates
Posterior intercalary plate
Antapical plates
Antapical horns
Apex
Epitheca
Hypotheca
Antapex
a
b
c
d

4·2

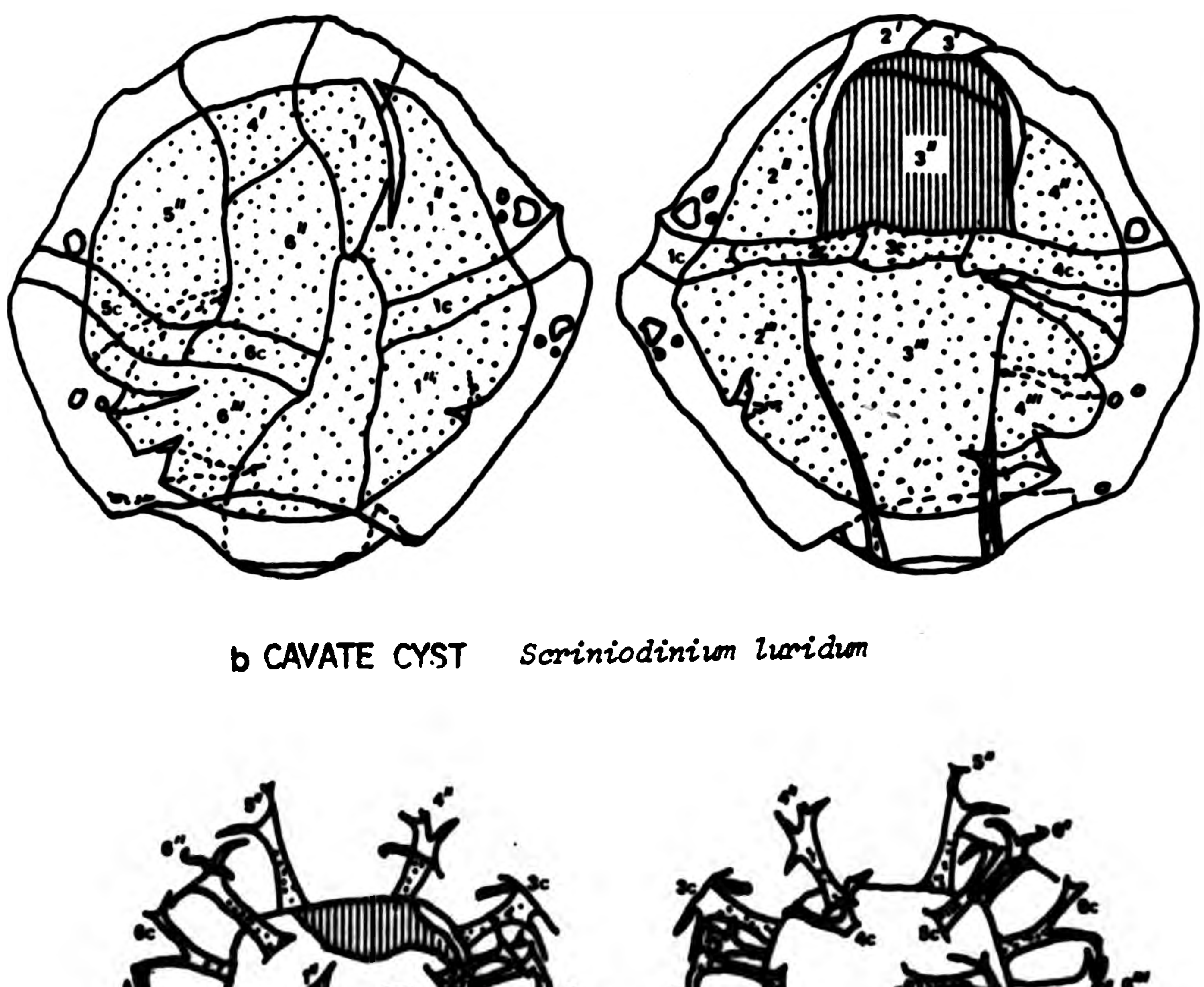

PROXIMATE
CHORATE
CAVATE
theca
cyst
process
theca
periphrgam
endophragm
pericoel
a
b
c

4·3

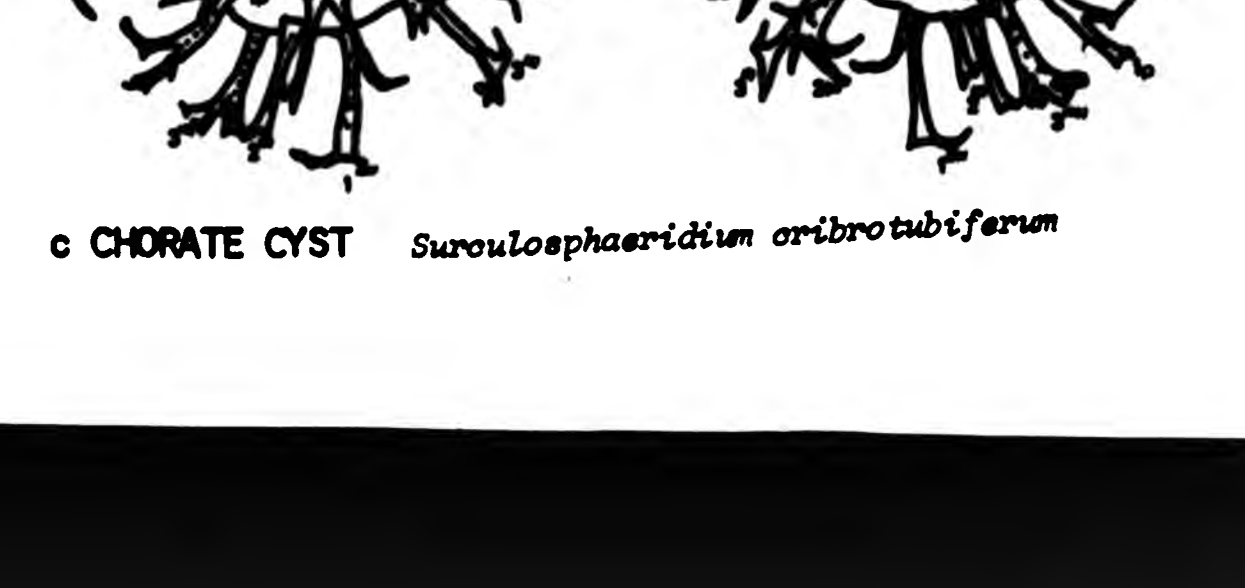
Text-fig. 4.4 Diagrams illustrating examples of the three main groups of dinoflagellate cyst.



a PROXIMATE CYST *Gonyaulacysta jurassica*



b CAVATE CYST *Scriniodinium luridum*



c CHORATE CYST *Surculosphaeridium cribrotubiferum* place close to, but not in contact with, the theca wall. The term HOLOCAVATE is given to cysts with more or less concentric wall layers which are completely seperated but with discontinuous supporting structures always present between the layers. CIRCUMCAVATE is applied to cysts having wall layers which are seperated completely at the margins of the cyst, as seen in dorsal-ventral view, but are in contact in the mid-dorsal and mid-ventral areas. HYPOCAVATE cysts have wall layers that are conspicuously seperated in the posterior part of the hypocyst only. BICAVATE cysts have wall layers which are seperated in the anterior and posterior parts of the cyst, but not elsewhere.

The development of HORNS is characteristic of many dinoflagellate cysts, and are termed according to their position on the cyst as apical, antapical, etc. The surface of the cyst may be smooth or bear ornamentation in the form of fine granules (GRANULATE), coarse granules (VERRUCOSE), irregular ridges (RETICULATE), short spines (SPINOSE), indentations (PUNCTATE), raised crests (SEPTATE) or processes. Processes are variable in form and number; they may be tubular or spine-like, solid or hollow, simple or branched, isolated or grouped, open or closed at their tips (DISTALLY), joined by linking trabeculae or membranes and may form complexes (text-fig. 4.5).

The polygonal opening found on the cyst is termed the ARCHEOPYLE. Cysts open at predetermined positions, the type of opening being consistent in any one species. Thus the archaeopyle is an important taxonomic feature for identification purposes. The archaeopyle is formed either by the loss of one specific paraplate or by a group of paraplates; this is termed the OPERCULUM. The operculum itself may be either attached to the cyst or become completely seperated during archaeopyle formation. The function of the archaeopyle is excystment, that is the aperture through which the protoplasmof the resting cyst stage passes to become the gymnodinioid stage. (text-fig. 4.1). Archaeopyles have been classified into four basic types: APICAL, INTERCALARY, PRECINGULAR and EPICYSTAL depending upon the exact location and number of paraplates involved (text-fig. 4.6). Combinations of these types may also occur. The archaeopyle is always situated on the epicystal half of the cyst. When all of the designated paraplates are clearly involved in the operculum, but the exact number is uncertain or immaterial to the context, the small letter 't' (for total) is used. Thus for example, the designation for the most common type of apical archaeopyles is either $\overline{4A}$ or $\overline{tA}$. Similarly an epicystal archaeopyle can be depicted as $\overline{tAtP}$, without the number of apical or precingular paraplates being specified. (The bar above the letters indicates that the operculum represents

Text-fig. 4.5 Process terminology - distal ends shown uppermost
(After Downie & Sarjeant, 1966)

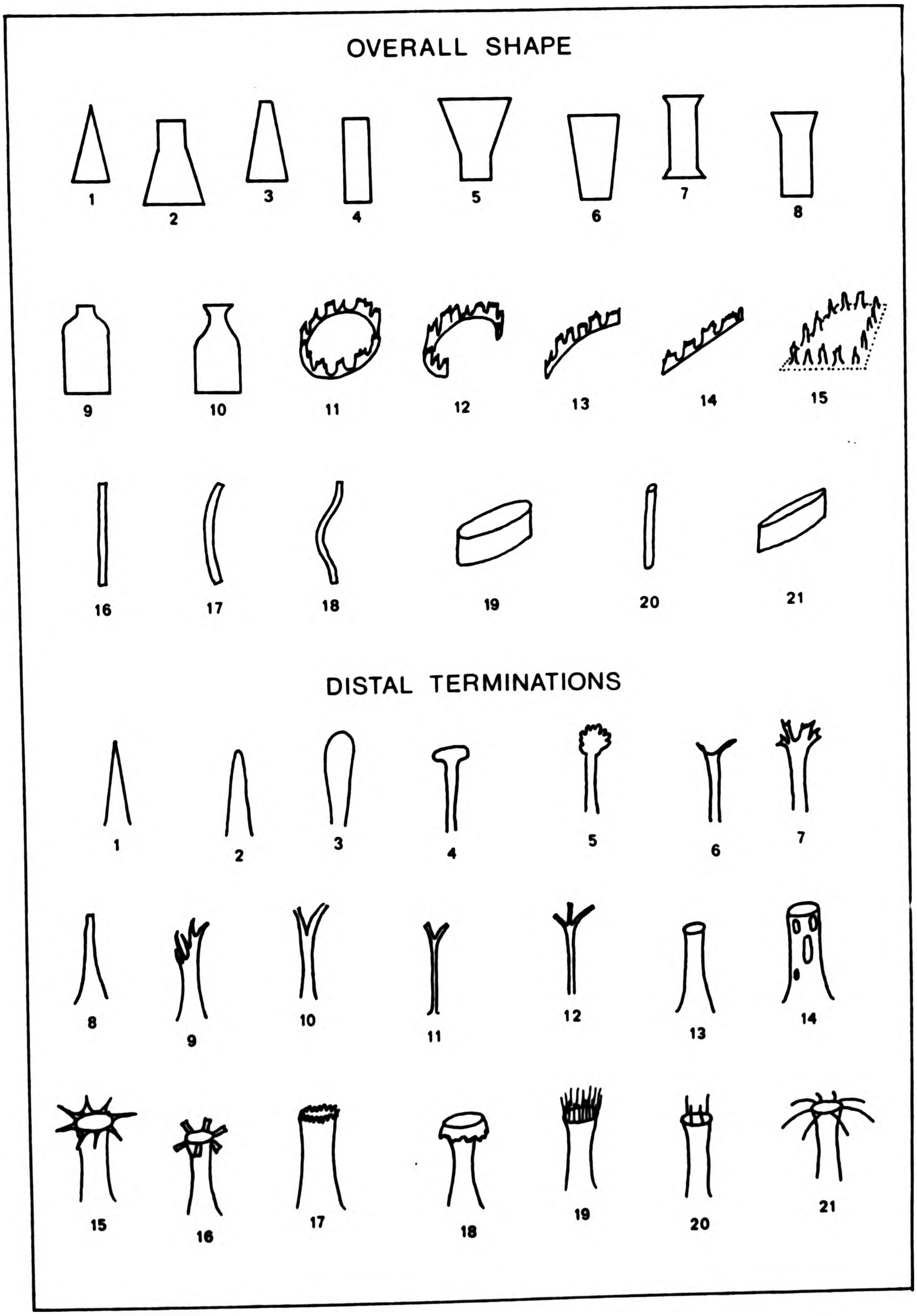
Key:

OVERALL SHAPE

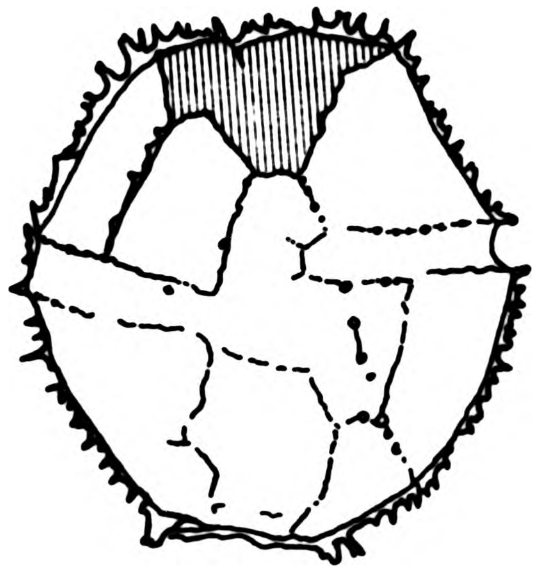
1	Conical	8	Buccinate	15	Stimulate complex
2	Subconical	9	Lagenate	16	Erect
3	Tapering	10	Bulbose	17	Curved
4	Cylindrical	11	Annular complex	18	Sinuous
5	Infundibular	12	Soleate complex	19	Latispinose
6	Flared	13	Arcuate complex	20	Slender
7	Tubiform	14	Linear complex	21	Tacinate

DISTAL TERMINATIONS

1	Acuminate	8	Oblate	15	Arculeate
2	Evexate	9	Digitate	16	Secate
3	Bulbous	10	Branched	17	Denticulate
4	Capitate	11	Bifurcate	18	Recurved
5	Cauliferate	12	Trifurcate	19	Patulate
6	Bifid	13	Entire	20	Divigate
7	Foliate	14	Fenestrate	21	Orthogonal

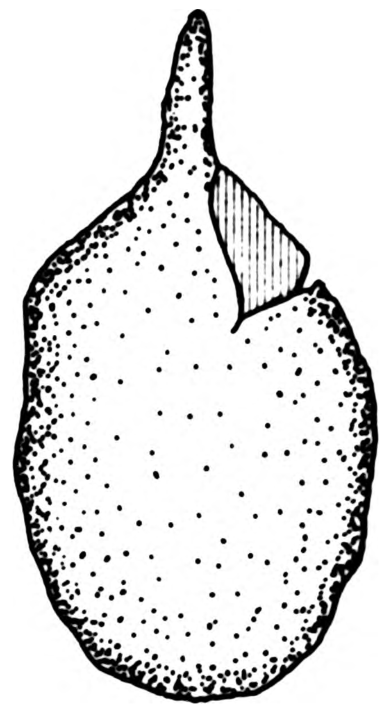

OVERALL SHAPE
DISTAL TERMINATIONS

Text-fig. 4.6 Diagrams illustrating the four main types of archaeopyle development in typical Upper Jurassic dinoflagellate cysts.



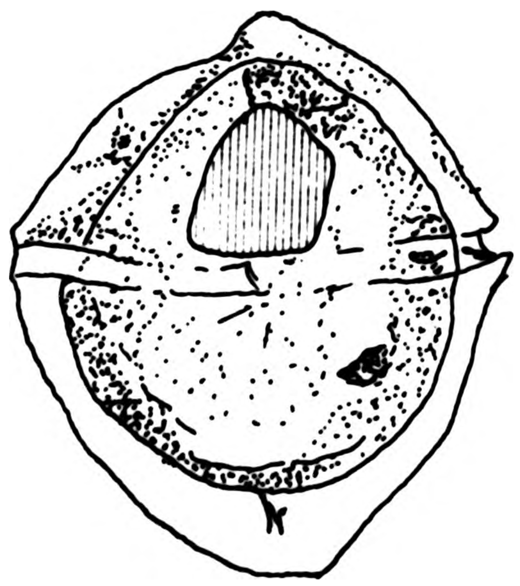
APICAL

Lithodinia jurassica



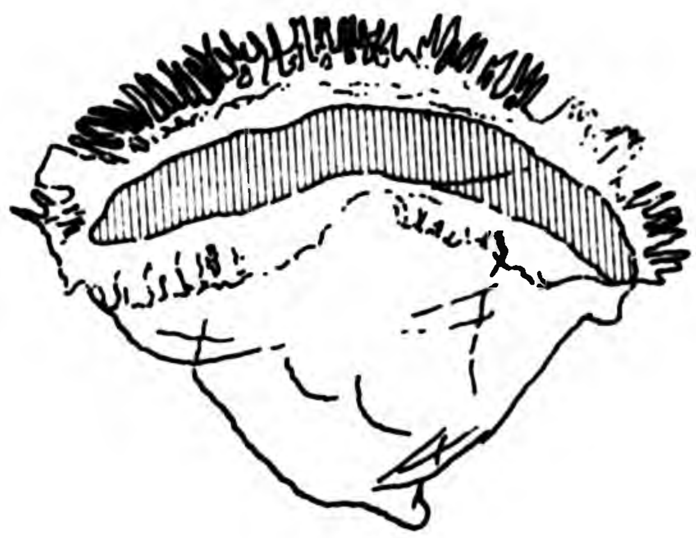
INTERCALARY

Pareodinia ceratophora



PRECINGULAR

Scriniodinium crystallinum



EPICYSTAL

Wanaea digitata

more than one paraplate in a series concerned).

3. Classification

Kingdom PROTISTA
Division PYRRHOPHYTA

Fossil dinoflagellate cysts are classified according to cyst type, reflected tabulation, archaeopyle type, general shape and sculpture (Evitt, 1961, 1963). The majority are ascribed to the class Dinophyceae, which are algae and are treated under the International Code for Botanical Nomenclature.

Formerly many dinoflagellate cysts were classed with the problematic 'hystrichospheres'. However, Evitt (1961, 1963) demonstrated that some of these were true dinoflagellate cysts, the remainder being assigned to the more problematical group Acritarcha.

Within the division Pyrrhophyta there are two main classes:

Class DESMOPHYCEAE. These, thought to be the most primitive, have two flagella of equal length positioned at the anterior end of the motile cell, which is unarmoured. Cysts are unknown, but may be included amongst the acritarchs.

Class DINOPHYCEAE. Most dinoflagellates belong to this class. They posess two unequal flagella originating from the mid-ventral surface. Within this class are three main orders:

Order GYMNODINIALES. These are unarmoured forms, possessing a flexible theca. They are commonly ellipsoidal, traversed by a deep equatorial cingulum and a shallow longitudinal sulcus. Although resting cysts are known, the lack of paratabulation features make bilogical affinities difficult to infer.

Order PERIDINIALES. Includes forms with an armoured motile stage. In these the cingulum is equatorial and laevorotatory; the sulcus is longitudinal. The plates are arranged into apical, precingular, cingular, postcingular and antapical series, with additional intercalary and sulcal plates (text-fig. 4.2). Classification of this group has proceeded along two independent lines; one for the living motile forms and one for the fossil cysts; there is therefore a considerable degree of complication. Most fossil dinoflagellate cysts are included here.

Order DINOPHYSIALES. Although this group is unarmoured, the theca lacks distinctive tabulation. The cingulum is very anterior in position and less spiralled than in the Peridiniales, uniting with the sulcus in a T- or Y-shaped junction. Both furrows are bordered by flange-like crests.

B. GROUP ACRITARCHA

1. Introduction

The acritarchs are a polyphyletic group to which any hollow, organic-walled, unicellular vesicle may be assigned until their true affinities are discovered (Evitt, 1963). However, the majority of described acritarchs do display a remarkable degree of similarity between them. Most are in the order of 20 to 150 mu in size and comprise a single-layered wall enclosing a central cavity. They may be entire or posess an archaeopyle-like opening. They have a much longer history than the dinoflagellates, ranging from late Precambrian to Recent times.

2. Morphology

The acritarch vesicle consists of a CENTRAL BODY, enclosing a CENTRAL CAVITY from which may arise processes in the form of SPINES or CRESTS. The spines may be either hollow and connected with the central cavity, or solid and closed at their base. Distally the spines may be either simple, bifurcate or complexly branched.

The wall of the vesicle is usually single-layered and homogeneous, although some forms have laminar walls with pores, or walls with double layers. When two layers are present these are termed ENDODERM and ECTODERM, for the inner and outer layer respectively. The wall itself is organic, being composed of SPOROPOLLENIN. The exterior surface may be smooth, or finely-ornamented with granules, short spines, indentations or pores.

A PYLOME is frequently developed and presumed to serve the same function as the archaeopyle in dinoflagellate cysts; i.e., excystment. The simplest form of opening is a PARTIAL SPLIT of the vesicle. MEDIAN SPLITTING includes a complete division of the vesicle into two equal halves. If the splitting is incomplete and proceeds along an arcuate fissure to leave a hinged-flap, this is called an EPITYCHE opening. A circular or polygonal opening situated above the equator is termed a

CYCLOPYLE. Cyclopyles usually form an OPERCULUM which may be hinged, released, or fall inside the central cavity after excystment.

3. Classification

Subdivision of the acritarchs has beem hampered by the lack of biological information and so any attempts at a classification have been artificial. All described genera are form-genera only based on their broad morphological features. Downie, Evitt & Sarjeant (1963) have classified the acritarchs into thirteen form-groups, these are:

ACANTHOMORPHITAE	Spherical forms with spines
SPHAEROMORPHITAE	Spherical forms without spines
POLYGONIMORPHITAE	Polygonal forms with spines at apices
NETROMORPHITAE	Elongate forms, with or without spines
DIACROMORPHITAE	Ellipsoidal forms with polarised ornament
HERKOMORPHITAE	Spherical forms with alae or crests
PTEROMORPHITAE	Ellipsoidal forms with equatorial ring
PRISMATOMORPHITAE	Prismatic forms with ornamental crests
OOMORPHITAE	Ovoid forms with ornamentation at one pole
STEPHANOMORPHITAE	Referred to Dinophyceae
DISPHAEROMORPHITAE	Spheroidal forms with a double wall.
DINETROMORPHITAE	Referred to Dinophyceae
PLATYMORPHITAE	Referred to (?)Dinophyaceae

Chapter five

SYSTEMATICS

In the following systematic section species are arranged in alphabetical order within each of the four major groups:

1 Order PERIDINIALES
2 Order DINOPHYCIALES
3 Group ACRITARCHA
4 INCERTAE SEDIS

Synonymy lists have been reduced to a minimum. The first author and subsequent changes in nomenclature which precede the formalisation of the name adopted are given. Full descriptions of new taxa are given. Generic diagnoses are taken from Stover & Evitt, 1978, unless otherwise stated.

Class DINOPHYCEAE Pascher
Sub-class DINOFEROPHYCIDAE Bergh
Order PERIDINIALES Schutt, 1898

Genus ACANTHAULAX Sarjeant, 1968

1966a Acanthaugonyaulax Sarjeant: 132
1968 Acanthaulax Sarjeant: 227

Diagnosis Cysts proximochorate, subspherical, with or without apical protrusion; paratabulation gonyaulacacean, indicated by parasutural ridges with spines or simply rows of spines; spines or tubercles present between parasutural features; surface between spines smooth or has features of low relief.

Type species Acanthaulax venusta (Klement, 1960) Sarjeant, 1968

Acanthaulax senta Drugg, 1978
(Pl.1, figs.1,2)

1961a Gonyaulax areolata Sarjeant: 95
1964 Gonyaulax scarburghensis Sarjeant: 472
1969 Gonyaulacysta scarburghensis Sarjeant: 11
1978 Acanthaulax senta Drugg: 62

Diagnosis Drugg, 1978; p62, pl.3, fig.13; pl.4, figs.1-3

Description A relatively large, rounded to ovoidal proximate cyst. Cyst wall consists of autophragm only, with distinctive but variable, non-tabular ornamentation in the form of spines from 2-4mu in length. Spines are either isolated, or more often linked distally by trabeculae giving an outer mesh-like appearance. Paratabulation indicated by archaeopyle only which is precingular, type P (3" only). A feint paracingulum may be present. A prominant apical horn is always present, formed by elongate anastomosing fibres. More elongate spines are also often present in the antapical region, but not in the form of an antapical horn.

Dimensions Overall length of cyst: 101-127 mu
Overall width of cyst: 88-111 mu
(4 specimens measured)

Remarks Specimens recovered compare very closely to those described by Drugg,(1978),particularly in size-range. They differ from the original description given by Sarjeant (1961a) in being considerably smaller in size, and in the consistent lack of paratabulation features, excepting the archaeopyle. For this reason A.senta Drugg, 1978 is adopted rather than Gonyaulacysta scarburghensis Sarjeant, 1969. Preservation of material is particularly good.

Occurrence Warboys: A single specimen from WB.73 only (scarburghense).
Warlingham: Br.785 to Br.170 (scarburghense to cordatum).
Sporadic occurrences throughout the entire L.Oxfordian in the Warlingham section.

Range Previously recorded from U.Callovian (athleta) to M.Oxfordian (plicatilis).

Acanthaulax cf. senta Drugg, 1978
(Pl.1, figs.3-5)

Description A large, subquadrate proximate cyst. Cyst wall consists of autophragm only, which is smooth showing no surface ornamentation. An apical horn is present formed by anastomosing fibres. Folds are often present in the autophragm. Paratabulation indicated by the archaeopyle only which is precingular type P (3" only) in which the operculum is often attached. A paracingulum may be feintly discernible.

Dimensions Overall length of cyst: 88-113 mu
Overall width of cyst: 78-88 mu
(6 specimens measured)

Remarks Specimens closely resemble A.senta in their gross morphology, but differ in their total lack of surface ornamentation except in the apical region; A. cf. senta is also smaller in size. It is possible that specimens may be abraided forms of A.senta having lost their surface ornamentation. However specimens of both types occur in the same samples. Furthermore, the invariably good preservation and presence of the operculum intact suggests that this is not so. A sub-specific place within A.senta may be warranted to include these specimens.

Occurrence Warboys: single occurrences in WB.228 and WB.209 only (kamptus to jason). Warlingham: sporadic occurrences from Br.727 to Br.292 (scarburghense to bulowskii). Overal range: L.Callovian (kamptus)to U.L.Oxfordian (bulowskii).

Genus ADNATOSPHAERIDIUM Williams & Downie, 1966

Diagnosis Cysts skolochorate, body subspherical with solid or hollow, tubular to funneliform, intratabular processes; adjacent processes connected distally by ribbon-like to fenestrate trabeculae; archaeopyle apical, Type $\overline{tA}$.

Type species Adnatosphaeridium vittatum Williams & Downie, 1966

Adnatosphaeridium aemulum (Deflandre, 1938) Williams & Downie, 1969
(Pl.2, figs.1-5; Pl.3, figs.1,5)

1938 Hystrichosphaeridium aemulum Deflandre: 187
1947a Cannosphaeropsis aemula Deflandre: 1575
1969 Adnatosphaeridium aemulum (Deflandre) Williams & Downie: 17

Diagnosis Deflandre, 1938; p187-9, pl.9,fig.12; Pl.10,figs.5-8; Pl.11 figs.1,7.

Description Intermediate to large skolochorate cyst with a subspherical central body. Autophragm forms body and processes, ectophragm forms slender and smooth, relatively wide and fenestrate, trabeculae that extend between the distal ends of the processes. Intratabular processes are hollow, tubular to funneliform in form; they are equal in length but vary in width, about 15 in number and branch at their mid-point in length. Archaeopyle apical type $\overline{tA}$, operculum free.

Dimensions Overall diameter of cyst: 88-121 mu
Overall diameter of central body: 37-63 mu.
(20 specimens measured)

Remarks Although specimens are variable in size, A.aemulum is differentiated from A.caulleryi (Deflandre, 1938) Williams & Downie, 1969 on the nature of the processes and ratio of the central body to the overall diameter of the cyst; in A.aemulum the processes are tubular and tend to be constant, whereas in A.caulleryi they are solid and greater in number; the central body in A.aemulum is smaller than in A.caulleryi, but the overall size of the cyst is larger.

Occurrence Warboys: WB.224 to WB.43 (koenigi to scarburghense) in relatively low numbers except for sample WB.148 where 24 individuals were encountered.

Warlingham: Br.1833 to Br.115 (calloviense to vertebrale) in fairly low numbers except for samples in U.L.,and M.Oxfordian. Overall range L.Callovian (koenigi) to M.Oxfordian (vertebrale)

Range Previously recorded from Bathonian to Oxfordian.

Adnatosphaeridium caulleryi (Deflandre, 1938) Williams & Downie, 1969
(Pl.1, figs.1,2; Pl.2,fig.6; Pl.3,figs.2-4,6,7)

1938	Hystrichosphaeridium caulleryi Deflandre; 189
1947a	Cannosphaeropsis caulleryi Deflandre: 1575
1969	Adnatosphaeridium caulleryi (Deflandre) Williams & Downie: 17

Diagnosis Deflandre, 1938; p189, pl.11,figs.2,3.

Description Intermediate to large skolochorate cyst, with a spherical to subspherical central body. The autophragm bears a large number of solid processes which are slender and may be either straight or diversely recurved, simple or ramifying. Processes are linked distally by trabeculae at a relatively short distance from the central body. Archaeopyle apical type $\overline{tA}$; operculum free.

Dimensions Overall diameter of cyst: 65-114 mu
Overall diameter of central body: 35-61 mu
(10 specimens measured)

Remarks The relatively short, solid and numerous processes, with their greater variety of form, distinguish this species from A.aemulum (Deflandre, 1938) Williams & Downie, 1969, although in practice the two species are not easily distinguished.

Occurrence Warboys: WB.228 to WB.28 (kamptus to praecordatum)
Warlingham: Br.1813 to Br.140 (calloviense to vertebrale) Never more than 9 specimens in any one sample, usually less than 5. Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range L.Callovian to U.Kimmeridgian (Sarjeant, 1979)

Genus APTEODINIUM Eisenack, 1958

Diagnosis Cysts proximate, subspherical, normally with short apical projection; autophragm may bear some non-tabular features of low relief; paratabulation indicated typically by archaeopyle and paracingulum, occasionally also by faint parasutural features in equatorial area; archaeopyle precingular, type P.

Type species Apteodinium granulatum Eisenack, 1958

Apteodinium granulatum Eisenack, 1958
(Pl.4, figs.1,2)

Diagnosis Eisenack, 1958; p386; pl.23,figs.8-14; text-fig.3.

Description Intermediate to large proximate cyst, subspherical to subpentagonal in outline, with a short apical horn which bifurcates distally. Cyst wall consists of autophragm only which is distinctly folded and bears non-tabular granulations of low relief. Paratabulation indicated by archeopyle which is precingular, type P (3" only). Paracingulum weakly developed.

Dimensions Overall length of cyst: 65-96 mu
Overall width of cyst: 50-76 mu
(4 specimens measured)

Remarks This species of Apteodinium is similar to A.nuciforme (Deflandre, 1938) Stover & Evitt, 1978, but is distinguished by its surface ornamentation which is less dense and of lower relief than A.nuciforme. The presence of folds in the autophragm appears to be distinctive.

Occurrence Warboys: WB.48 (scarburghense) a single specimen only.
Warlingham: Br.1531 to Br.194 (grossouvrei to corsticardia).
Overall range: M.Callovian (grossouvrei) to U.L.Oxfordian (corsticardia).

Range Previously recorded from M.Kimmeridgian to Aptian (Sarjeant, 1979). The range of A.granulatum is therefore extended down to Middle Callovian (grossouvrei) on the basis of this study.

Apteodinium nuciforme (Deflandre, 1938) Stover & Evitt, 1978
(Pl.4, figs.3-7)

1938 Palaeoperidinium nuciforme Deflandre: 180
1962a Gonyaulax nuciformis (Deflandre) Sarjeant: 482
1968 Gonyaulacysta nuciformis (Deflandre) Sarjeant: 227
1978 Apteodinium nuciforme (Deflandre) Stover & Evitt: 142

Diagnosis Sarjeant, 1962a; p482-3; pl.69,fig.6; text-fig.4

Description Intermediate size proximate cyst, subspherical in outline. Apical process short and broad, bifurcating briefly distally, giving rise to a short terminal process. Cyst wall consists of autophragm only which is densely and coarsely granular. Paratabulation difficult to determine, apparently ?4', 1a, 6", 6"', 1p, 1"" (after Sarjeant, 1962a) Paracingulum present. Archaeopyle precingular, type P (3" only).

Dimensions Overall length of cyst: 50-78 mu
Overall width of cyst: 43-64 mu
(7 specimens measured)

Remarks Specimens examined agree closely with those described by Sarjeant (1962a), and with the original illustrations of Deflandre (1938). It is a distinctive species and can easily be distinguished from A.granulatum Eisenack, 1958 by its dense surface granulations and absence of folds in the autophragm.

Occurrence Warboys: WB.93 to WB.68 (U.athleta to L.scarburghense)
Warlingham: Br.1833 to Br.115 (calloviense to vertebrale)
Isolated occurrences in Callovian samples of Warlingham, but continuous in lower and middle Oxfordian. Never occurs more abundantly than 4 specimens per sample.
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale)

Range Previously known range M.Callovian (jason) to Portlandian (Sarjeant, 1979). The range is therefore extended to L.Callovian (calloviense) on the basis of the present study.

Apteodinium cf. nuciforme (Deflandre, 1938) Stover & Evitt, 1978
(Pl.4, figs.8,9)

Description A large, ovoidal to subquadrate, proximate cyst. Cyst wall consists of autophragm only which is folded. Prominant apical horn, bifurcating distally and giving rise to a short terminal process. Wall surface finely granular. Paratabulation indicated by archaeopyle only, precingular type P (3" only), although paracingulum is often present. Other paraplates are faintly discernible.

Dimensions Overall length of cyst: 103-126 mu
Overall width of cyst: 78-93 mu
(2 specimens measured)

Remarks Specimens closely resemble A.nuciforme but differ in size and surface features; A.nuciforme being smaller and having a more coarsely granular surface ornamentation. This species may be an intermediate form between A.nuciforme and A.granulatum Eisenack, 1958, resembling A.granulatum in its size and folded autophragm.

Occurrence Warboys: WB.224 to WB.28 (koenigi to praecordatum)
Warlingham: Br.554 to Br.520 (scarburghense)
Single occurrences only except for sample WB.224 where 3 specimens were encountered.
Overall range: L.Callovian (koenigi) to L.Oxfordian (praecordatum)

Genus BATIACASPHAERA Drugg, 1970

Diagnosis Cysts subspherical and without septa, spines or processes; autophragm variously ornamented with isolated and/or fused features that are typically evenly distributed and generally fine; archaeopyle apical, type $\overline{tA}$.

Type species Batiacasphaera compta Drugg, 1970

Batiacasphaera dictydia (Sarjeant, 1972) Davey, 1979
(Pl.4, figs.10,11,13,14)

1972 Chytroeisphaeridia dictydia Sarjeant: 41
1979 Batiacasphaera dictydia (Sarjeant) Davey: 217

Diagnosis Sarjeant, 1972; p41; pl.3,fig.3; pl.6,fig.6

Description A small spherical to subspherical cyst, consisting of autophragm only which is densely ornamented with fine granulations in the form of minute reticulae. Paratabulation indicated by apical archeopyle only, type $\overline{tA}$. Principle archaeopyle suture zigzag; operculum free.

Dimensions Overall length of cyst: 33-51 mu
Overall width of cyst: 30-56 mu
(8 specimens measured)

Remarks This species was formerly attributed to Chytroeisphaeridia but transferred to Batiacasphaera on account of its apical archaeopyle by Davey (1979, p217). It is closely related to Lithodinia but can be distinguished from it by the absence of paratabulation and in size (Batiacasphaera dictydia being smaller). One specimen (Pl.4,fig.14) appears to exhibit a paracingulum and a series of postcingular paraplates; although attributed to Batiacasphaera here, it may be an intermediate form with Lithodinia.

Occurrence Ranges throughout both sections, giving an overall range: L.Callovian (koenigi) to M.Oxfordian (vertebrale). Specimens vary from single occurrences in some samples to up to 19 in Callovian samples from Warlingham.

Range Previously recorded from U.Bathonian to U.Callovian (Sarjeant, 1979). The range of this species is therefore extended to M.Oxfordian on the basis of the present study.

Genus BELODINIUM Cookson & Eisenack, 1960

Diagnosis Cysts cavate, elongate ellipsoidal with prominant apical horn and antapical pericoel; paratabulation indicated by parasutural folds or ridges; archaeopyle apical, type $\overline{tA}$.

Type species Belodinium dysculum Cookson & Eisenack, 1960

Belodinium asaphum Drugg, 1978
(Pl.5, figs.1-5)

Diagnosis Drugg, 1978; p63; pl.2, figs.8-10

Description Intermediate size cavate cyst, elongate ellipsoidal in outline with small apical horn and antapical pericoel in the form of a bag-like extension of the periphragm beyond the endophragm. Paratabulation indicated by about seven ridge-like parasutural folds or ridges on the periphragm. Six precingular paraplates are suggested by the zigzag edges of the principle archaeopyle suture. Archaeopyle apical, type $\overline{tA}$. A paracingulum is present in the form of an interruption in the longitudinal ridges and located about midway along the cyst length. Both endophragm and periphragm are thin and smooth to faintly granulate.

Dimensions Overall length of cyst: 55-70 mu
Overall width of cyst: 30-38 mu
(8 specimens measured)

Remarks Specimens identify with the description of Drugg (1978) very closely. B.asaphum differs from B.dysculum Cookson & Eisenack, 1960 and B.obsoletum Dodekova, 1975 by exhibiting a more crudely-developed paratabulation and by lacking an obvious horn.

Occurrence Warlingham: Br.669 to Br.115 (scarburghense to vertebrale). Occurs almost continuously from Br.669 to the top of the section, but in relatively low numbers. Only in Br.340 (praecordatum) do more than 5 specimens occur. Was not recorded from the Warboys section, although Drugg's specimens were recovered from the Warboy's Brick Pit.
Overall range: L.Oxfordian (scarburghense) to M.Oxfordian (vertebrale).

Range Previously recorded from the L.Oxfordian (mariae to lower cordatum)(Drugg, 1978). The range is therefore extended to the M.Oxfordian (veretbrale) on the basis of the present study.

Belodinium cf. dysculum Cookson & Eisenack, 1960
(Pl.5, fig.6)

Diagnosis Cookson & Eisenack, 1960; p250; pl.37,fig.14; pl.39,fig.10.

Description A relatively large cavate cyst, ellipsoidal elongate in outline. Periphragm extends beyond the endophragm at both apical and antapical ends of the cyst to form pericoels. The periphragm is divided by several elongate ridges running the entire length of the cyst, being interrupted about midway along the cyst length indicating a paracingulum. These ridges extend into the apical and antapical regions to form teriminal protrusions in the form of wide, blunt horns. Indications of archaeopyle formation are lacking, but presumed apical.

Dimensions Overall length of cyst: 85 mu
Overall width of cyst: 35 mu
(1 specimen only)

Remarks A single specimen only was recovered and placed within B.cf.dysculum, in that it resembles the species B.dysculum by virtue of its size and the presence of both apical and antapical extensions of the periphragm.

Occurrence A single specimen from Warlingham: Br.313 L.Oxfordian (upper praecordatum).

Range Previously recorded from the Upper Jurassic.

Genus CALIGODINIUM Drugg, 1970

Diagnosis Cysts proximate, subspherical to ellipsoidal, with or without surrounding flocculent material, and without elevated features; archaeopyle apical and atypical, operculum composed of three paraplates.

Type species Caligodinium amiculum Drugg, 1970

Caligodinium halosa (Filatoff, 1975) Woollam, 1977
(Pl.5, figs.7-9)

1975 Kalyptea halosa Filatoff: 91
1977 Caligodinium halosa (Filatoff) Woollam: 56

Diagnosis Woollam, 1977; p56; pl.1, fig.4.

Description Intermediate size cyst consisting of a spherical inner body, constituting the autophragm, and an outer membranous kalyptra of diffuse material impregnated with sedimentary debris. Autophragm almost invariably folded, smooth or finely punctate. Archaeopyle apparently apical.

Dimensions Overall diameter of inner body: 22-37 mu
Overal diameter of cyst: 32-60 mu
(6 specimens measured)

Remarks The author aggrees with Woollam (1977) in the transfer of this species from Kalyptea Cookson & Eisenack, 1960 emend. Wiggins, 1975 to Caligodinium Drugg, 1970 on the basis of broad morphology. The emended description of Kalyptea by Wiggins (1975, p110) states that the "ambitus .....has distinct apical and antapical horns". Caligodinium possesses no such structures, but rather a rounded central body, therefore specimens here are well placed within this genus.

Occurrence Warboys: WB.158 to WB.18 (lower athleta to praecordatum)
Warlingham: Br.1880 to Br.115 (calloviense to vertebrale)
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale)
Specimens occur fairly commonly throughout both sections, but never reach more than 19 specimens per sample.

Range Previously described from the middle and upper Jurassic.

Genus CHLAMYDOPHORELLA Cookson & Eisenack, 1958

Diagnosis Cysts proximate, holocavate, subspherical to elongate ellipsoidal, with or without an apical protrusion or horn; autophragm with numerous nontabular processes of essentially uniform height and covered by an ectophragm; archaeopyle apical, type $\overline{tA}$.

Type species Chlamydophorella nyei Cookson & Eisenack, 1958

Chlamydophorella sp.A
(Pl.5, fig. 13)

Description Small to intermediate, spherical, proximate, holocavate cyst. Autophragm with large number of solid, bifurcating, nontabular processes of up to 5 mu in length. Cyst covered by a delicate membranous ectophragm. No archaeopyle structure apparent, although an apical archeopyle is suggested in one specimen.

Dimensions Overall diameter of inner body: 35-40 mu
Overall diameter of cyst: 42-48 mu
(2 specimens measured)

Remarks Specimens cosely resemble C.nyei Cookson & Eisenack, 1958, but differ in lacking any apical structure. Chlamydophorella sp.A differs from Chlamydophorella sp.B in having longer and fewer processes.

Occurrence Warlingham: Br.246 to Br.194 (corsticardia)
Overall range: uppermost L.Oxfordian (corsticardia). No specimens were recovered from Warboys.

Chlamydophorella sp.B
(Pl.5, figs.10-12)

Description Small to intermediate, proximate, holocavate cyst, subspherical to ovoidal in outline. Autophragm with numerous nontabular, solid, bifurcating processes of equal height, covered by a delicate, membranous ectophragm. No archaeopyle structure apparent.

Dimensions Overall diameter of cyst: 26-40 mu
(5 specimens measured)

Remarks Specimens identify with the generic description as set out by Cookson & Eisenack, 1958, p56: "Shell enclosed in a delicate membrane that is supported by closely arranged, slender, bifurcate spines of approximately equal length." They differ from other described species of Chlamydophorella and are therefore grouped here under Chlamydophorella sp.B.

Occurrence Warboys: WB.213 to WB.73 (calloviense to scarburghense)
Warlingham: Br.1833 to Br.246 (calloviense to corsticardia)
They are particularly abundant in the Callovian of both sections, and form more than 10% of the microplankton in the Middle Callovian of Warboys.
Overall range: L.Callovian (calloviense) to uppermost Lower Oxfordian (corsticardia).

Genus CHYTROEISPHAERIDIA (Sarjeant, 1962a) Downie, Evitt and Sarjeant, 1963. emend. Davey, 1979

1958 Leiosphaeridia Eisenack
1976 Tapeinosphaeridium Ioannides et.al: 461

Diagnosis Cysts subspherical and without ridges, septa, spines or processes; autophragm smooth, scabrate or punctate; archaeopyle precingular type P (?3" only); other indications of paratabulation lacking.

Type species Chytroeisphaeridia chytroeides (Sarjeant, 1962a) Downie & Sarjeant, 1964.

Chytroeisphaeridia chytroeides (Sarjeant, 1962a) Downie & Sarjeant, 1964.
(Pl.5, figs 14-23)

1962a Leiosphaeridia (Chytroeisphaeridia) chytroeides Sarjeant: 493
1964 Chytroeisphaeridia chytroeides (Sarjeant) Downie & Sarjeant: 103

Diagnosis Sarjeant, 1962a; p493; pl.10,figs.13,16; text-figs.11,12.

Description Small to intermediate size , subspherical cyst without any form of surface ornamentation. Autophragm smooth and of moderate thickness (0.5 to 1mu). A simple precingular archaeopyle is typically developed formed by the loss of one paraplate (presumably 3"); the operculum often occurs within the cyst.

Dimensions Overall diameter of cyst: 35-62 mu
(13 specimens measured)

Remarks Specimens encountered in this study identify cosely with the original description by Sarjeant (1962a). In U.Callovian samples of Warlingham a number of specimens develop an apical structure above the archaeopyle. Varying degrees of development of this structure can be seen within the specimens and may illustrate a morphological continuum between C.chytroeides (with no apicular structure) and C.cerastes Davey, 1979 (with a well-developed apical structure). These specimens are illustrated in plate 5, figs.17-23.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale)
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).
Specimens from both sections are particularly numerous, and in sample WB.213 (Warboys) 63 specimens were encounted forming 31.5% of the microplankton assemblage.

Range Aalenian to Volgian (Davey, 1979)

Chytroeisphaeridia cerastes Davey, 1979
(Pl.6, figs.1,2)

Diagnosis Davey, 1979; p212; pl.2,figs.8,9.

Description Intermediate to large ovoidal cyst, with a rounded hollow apical horn which merges gradually into the main part of the cyst. Autophragm only, typically slightly folded and smooth. Archaeopyle simple precingular (presumably formed by the loss of paraplate 3").

Dimensions Overall length of cyst: 81-82 mu
Overall width of cyst: 45-50 mu
(2 specimens only)

Remarks Two specimens only were recovered. They identify closely with those described by Davey (1979). It is possible that larger forms of C.chytroeides with a more well-developed apical structure could be included here. Preservation of both specimens particularly good, with the operculum preserved inside the cyst.

Occurrence Warlingham: Br.246 (corsticardia) - uppermost L.Oxfordian.
Not found in Warboys section.

Range Previously recorded from the L.Oxfordian (cordatum) only (Davey, 1979). As specimens here also fall within this range, C.cerastes may be a stratigraphically significant species.

Chytroeisphaeridia mantellii Gitmez & Sarjeant, 1972
(Pl.4, fig.12; Pl.6, figs.3-8)

Diagnosis Gitmez & Sarjeant, 1972; p186; pl.1,figs.3,4; pl.12,fig.3.

Description Intermediate subspherical to elongate cyst. Autophragm is coarsely granular and often shows a degree of folding. Archaeopyle precingular, simple; operculum often attached.

Dimensions Overall length of cyst: 40-60 mu.
Overall width of cyst: 35-60 mu.
(6 specimens measured)

Remarks C.mantellii differs from other described species of Chytroeisphaeridia in having a thick autophragm. It is distinguished from Batiacasphaera dictydia (Sarjeant, 1972) Davey, 1979 in its size, being overall relatively larger and possessing a more ragged principle archaeopyle suture. The archaeopyle in C.mantellii is also precingular, which distinguishes it from B.dictydia.

Occurrence Warboys: 2 specimens only from WB.33 (scarburghense).
Warlingham: Br.1813 to Br.554 (calloviense to scarburghense).
A relatively common species in the Callovian with only sporadic occurrences in the L.Oxfordian of Warlingham.
Overall range: L.Callovian (calloviense) to L.Oxfordian (scarburghense).

Range Previously recorded from the Kimmeridgian only. The range of this species is therefore extended to the L.Callovian (calloviense) on the basis of this study.

Genus CLEISTOSPHAERIDIUM Davey et.al., 1966

Diagnosis Cysts skolochorate, body subspherical, bearing numerous non-tabular processes or spines of similar size and shape that are normally closed distally; indications of paratabulation other than archaeopyle characteristically lacking; archaeopyle apical, type $\overline{tA}$.

Type species Cleistosphaeridium diverispinosum Davey et.al., 1966

Cleistosphaeridium ehrenbergii (Deflandre, 1947b) Davey et.al, 1969
(Pl.6, figs.9-11)

1938 Hystrichosphaeridium cf. hirsutum (Ehrenberg) Deflandre: 191
1947b Hystrichosphaeridium ehrenbergi Deflandre
1961a Baltisphaeridium ehrenbergi (Deflandre) Sarjeant: 103
1969 Cleistosphaeridium ehrenbergi (Deflandre) Davey et.al: 16

Diagnosis Gitmez, 1970; p284; pl.4,fig.7; text-fig-2a

Description Small to intermediate, skolochorate cyst, spherical to globular in outline and bearing simple, solid, nontabular processes which are closed distally. Processes are large in number (30-44) and are approximately one half of the shell diameter in length. Surface of cyst smooth. Archaeopyle apical, type $\overline{tA}$.

Dimensions Overall diameter of inner body: 26-35 mu
Overall length of processes: 11-20 mu

Remarks Although regarded as a problematical species by Stover & Evitt(1978), specimens from both localities identify with previous descriptions and illustrations. C.ehrenbergii is distinguished from other known species in its possession of simple, closed processes. It differs from C.lumectum (Sarjeant, 1960a) Davey et.al., 1969 and C.tribuliferum (Sarjeant,1962a)Davey et.al., 1969 in that all of the processes are pointed and closed distally, and from C.polytrichum (Valensi, 1947) Davey et.al., 1969 in possessing relatively fewer processes.

Occurrence Warboys: WB.228 to WB.38 (kamptus to scarburghense).
Warlingham: Br.1605 to Br.115 (grossouvrei to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertibrale).

Range Previously described from Callovian to Kimmerdigian.

Cleistosphaeridium lumectum (Sarjeant, 1960a) Davey et.al., 1969
(Pl.6, figs.12,13)

1960a Baltisphaeridium lumectum Sarjeant: 139
1969 Cleistosphaeridium lumectum (Sarjeant) Davey et.al: 16

Diagnosis Sarjeant, 1960a; p139; pl.6,fig.1; text-fig.2

Description Intermediate size skolochorate cyst, with a smooth spherical inner body from which long, slender processes arise. The length of processes are between one half and three quarters the diameter of the inner body. The processes are nontabular, simple, bifurcate or trifurcate and often curved to some degree; they number between 35 and 40. Archaeopyle apical, type $\overline{tA}$.

Dimensions Overall diameter of inner body: 32-45 mu
Overall length of processes: 16-20 mu.
(5 specimens measured)

Remarks C.lumectum is differentiated from other species in having processes which are variable distally, rather than being consistently of one type.

Occurrence Warboys: WB.223 to WB-128 (calloviense to middle athleta). two isolated occurrences only.

Warlingham: Br.976 to Br.170 (athleta/lamberti to cordatum). Never occurs more abundantly than 9 specimens per sample; slightly more common in upper mariae.

Overall Range: L.Callovian (calloviense) to uppermost lower Oxfordian (cordatum).

Range Previously recorded from the Oxfordian (Sarjeant, 1979). The known range of this species is therefore extended to the L.Callovian (calloviense) on the basis of the present study.

Cleistosphaeridium polytrichum (Valensi, 1947) Davey et.al., 1969

(Pl.6, figs.14-17; Pl.7, fig.1)

1947 Hystrichosphaeridium polytrichum Valensi: 818
1959 Baltisphaeridium polytrichum (Valensi) Sarjeant: 339
1969 Cleistosphaeridium polytrichum (Valensi) Davey et.al: 16

Diagnosis Valensi, 1947; p818; text-fig.4

Description Intermediate size, skolochorate cyst, subspherical to ellipsoidal in outline with a dense covering of nontabular processes. Processes are simple and closed distally, about one half of the diameter of the inner body in length. Archaeopyle apical, type $\overline{tA}$.

Dimensions Overall diameter of inner body: 30-40 mu
Overall length of processes: 6-15 mu
(15 specimens measured)

Remarks This species of Cleistosphaeridium is distinguished from C.ehrenbergii (Deflandre, 1947b) Davey et.al., 1969 in possessing a greater number of processes. All processes are closed distally and simple in form, and thus this species can be readily distinguished from C.lumectum (Sarjeant, 1960a) Davey et.al., 1969 and C.tribuliferum (Sarjeant, 1962a) Davey et.al., 1969.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).

Warlingham: Br.1880 to Br.115 (calloviense to vertebrale). Occurs irregularly and sporadic in the Callovian, but more continuously in the L.Oxfordian of both localities.

Range Upper Bathonian to Upper Kimmeridgian (Sarjeant, 1979).

Cleistosphaeridium tribuliferum (Sarjeant, 1962a) Davey et.al., 1969
(Pl.7, figs.2-4)

1962a Baltisphaeridium tribuliferum Sarjeant: 487
1969 Cleistosphaeridium tribuliferum (Sarjeant) Davey et.al: 16

Diagnosis Sarjeant, 1962a; p487; pl.70,fig.4; text-fig.6c-7

Description Intermediate size skolochorate cyst, with a spherical to ovoidal , smooth central body, and about 40 to 50 nontabular, slender processes which are greater than half the diameter of the central body in length. The processes are variably furcate distally, having 2-4 branches of varying length and attitude. Archaeopyle apical, type $\overline{tA}$.

Dimensions Overall diameter of central body: 30-40 mu
Overall length of processes: 15-28 mu
(9 specimens measured)

Remarks This species is distinguished from all other known species of Cleistosphaeridium by the nature of the distal furcation of the processes.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum). Sporadic occurrences in the Callovian, but more consistent and common in the L.Oxfordian although never exceeds 9 specimens per sample.

Warlingham: Br.1880 to Br.115 (calloviense to vertebrale). Fairly consistent occurrence in low numbers.

Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously recorded from Bathonian to Kimmerdigian.

Genus COMPOSITOSPHAERIDIUM Dodekova, 1974

Diagnosis Cysts skolochorate, body subspherical with approximately 24 intratabular processes; larger processes polytabular; most processes may be joined proximally by ridges or septa and some may be connected distally by trabeculae; paratabulation gonyaulacacean, indicated by intratabular processes; archaeopyle apical, type $\overline{tA}$.

Type species Compositosphaeridium costatum (Davey & Williams 1966) Dodekova, 1974

Compositosphaeridium costatum (Davey & Williams, 1966) Dodekova, 1974 (monotypic)
(Pl.7, figs.5-7)

1938 Hystrichosphaeridium salpingophorum Deflandre: 186
1966 Hystrichosphaeridium costatum Davey & Williams: 62
1967 Hystrichosphaeridium salpingophorum (Deflandre) Dodekova: 14
1970 Cordosphaeridium costatum (Davey & Williams) Gorka: 489
1974 Compositosphaeridium costatum (Davey & Williams) Dodekova: 26

Diagnosis   Davey & Williams, 1966; p62; pl.10,fig.4

Description   Intermediate size, skolochorate cyst. Central body subspherical with approximately 24 intratabular processes giving the paratabulation formula: ?4', 6", 6c, 5"', 1p, 1"", 1-?s. Processes are fibrous, tubiform, having subquadrate distal openings, which are denticulate with a small number of recurved prolongations; they are joined proximally by ridges or septa which extend the length of the processes, and also extend onto the central body forming a mesh-like structure. Archaeopyle apical, type $\overline{tA}$; operculum free.

Dimensions   Overall diameter of central body: 43-51 mu
Overall length of processes: 14-23 mu
(6 specimens measured)

Remarks   The broad, ribbed processes are very distinctive, and characterise C.costatum.

Occurrence   Warboys: WB.211 to WB.18 (medea to praecordatum).
Occurs in relatively low numbers, excepting WB.158 (lower athleta) where 12 individuals were recovered.

Warlingham: Br.1354 to Br.115 (base of athleta to vertebrale). Occurs commonly in the U.Callovian and abundantly in uppermost lower to middle Oxfordian, where 26 and 52 individuals were recorded from Br.313 (upper praecordatum) and Br.292 (bulowskii) respectively (13 and 26% of the total microplankton assemblages).

Range   Previously recorded from Upper Bathonian to Kimmeridgian.

Genus   CRIBROPERIDINIUM Neale & Sarjeant, 1962 emend. Davey, 1969

Diagnosis   Cysts proximate, subspherical to ellipsoidal, usually with a prominant apical horn; paratabulation gonyaulacacean, indicated by parasutural ridges, septa, or rows of closely spaced projections; accessory ridges or septa present on most paraplates; archaeopyle precingular, type P.

Type species   Cribroperidinium sepimentum Neale & Sarjeant, 1962

Cribroperidinium granuligerum (Klement, 1960) Stover & Evitt, 1978
(Pl.7, figs.8-11)

1960   Gonyaulax granuligera Klement: 41
1966a   Gonyaulacysta granuligera (Klement) Sarjeant: 131
1969   Gonyaulacysta granuligera (Klement) Sarjeant: 10
1978   Cribroperidinium granuligerum (Klement) Stover & Evitt: 150

Diagnosis   Klement, 1960; p41; pl.5,figs.4,5

Description Intermediate size, proximate cyst, subspherical in outline with an apical horn. Paratabulation indicated by low parasutural features to give the gonyaulacacean formula: 4',6", 6c, 6"', ?1p, 1"". The parasutural features are closely spaced spinules which are short, solid and distally accute or blunt. Paracingulum indicated by parallel transverse ridges with spinules. Archaeopyle precingular, type P (3" only); operculum free.

Dimensions Overall length of cyst: 38-60 mu
Overall width of cyst: 35-55 mu
(6 specimens measured)

Remarks Although broadly similar in morphology to C.granulatum (Klement, 1960) Stover & Evitt, 1978, C.granuligerum can be distinguished by the short parasutural spinules. Specimens encountered here are somewhat smaller than those of both Klement (1960) and Gitmez (1970). As previous records of C.granuligerum are from the Kimmerdigian only, these Callovian/Oxfordian forms may be ancestral.

Occurrence Warboys: a single specimen from WB.211 (medea).
Warlingham: Br.313 to Br.115 (upper praecordatum to vertebrale).
Overall range: M.Callovian (medea) to M.Oxfordian (vertebrale).

Range Previously recorded from the Kimmeridgian only (Sarjeant, 1979). The presence of this species here therefore extends the known range to M.Callovian (medea) to Kimmeridgian on the basis of this study.

Genus CTENIDODINIUM Deflandre, 1938 emend. Gocht, 1970

Synonyms Brotzenia Horowitz, 1975
Dichadogonyaulax Sarjeant, 1966b

Diagnosis Cysts proximochorate; body subspherical to ellipsoidal; paratabulation gonyaulacacean, indicated by parasutural rows of isolated or proximally-linked projections or by parasutural ridges or septa, generally with denticulate to spinate crests; epicystal archaeopyle, type tAtP.

Type species Ctenidodinium ornatum (Eisenack, 1935) Deflandre, 1938

Ctenidodinium ornatum (Eisenack, 1935) Deflandre, 1938
(Pl.8, figs.5-8)

1935 Lithodinia jurassica var. ornata Eisenack: 176
1938 Ctenidodinium ornatum (Eisenack) Deflandre: 181
1960 Gonyaulax ornata (Eisenack) Klement: 30
1966b Ctenidodinium ornatum (Eisenack) Sarjeant: 154

1972 Gonyaulacysta ornata (Eisenack) Pocock: 87
1974b Ctenidodinium orntaum (Eisenack) Sarjeant: 55

Diagnosis Deflandre, 1938; p181; pl.9,figs.1-7

Description Intermediate to large proximochorate cyst, polygonal in outline. Paratabulation indicated by parasutural rows of low crests, surmounted by long spines which are generally simple and usually longer on the hypocyst than epicyst. Paratabulation formula: 4', 6", 6"', 1"" but difficult to determine due to breakage. Archaeopyle epicystal, type tAtP; operculum free to attached.

Dimensions Overall length of cyst: 48-88 mu
Overall width of cyst:45-101 mu
(12 specimens measured)

Remarks Appears to be a very variable species and included here are those species with affinities to C.tenellum Deflandre, 1938.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum), in fairly low numbers except for lower and middle Callovian samples.
Warlingham: Br.1898 to Br.140 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously described from Bathonian to Oxfordian.

Ctenidodinium continuum Gocht, 1970
(Pl.8, figs.1-4)

Diagnosis Gocht, 1970; p141; pl.26,fig.3; pl.27,fig.5; pl.29,figs.1,2; pl.32,figs.1-5; pl.33,fig.8

Description Intermediate to large, proximochorate cyst, subspherical to polygonal in outline. Paratabulation indicated by parasutural rows of proximally-linked, short, simple spines, forming crests. Paratabulation formula: 4',6",6"',4', but difficult to determine due to breakage. Archeopyle epicystal, type tAtP; operculum free to attached.

Dimensions Overall length of cyst: 50-96 mu
Overal width of cyst: 50-96 mu
(8 specimens measured)

Remarks Specimens identify closely with those of Gocht(1970). Preservation is generally good, although complete specimens are rare.

Occurrence Warboys: WB.228 to WB.78 (kamptus to lowest scarburghense).
Warlingham: Br.1898 to Br.820 (calloviense to lamberti/athleta) (a single specimen was recovered from Br.560 - scarburghense).
Overall range: Callovian only, except for one isolated occurrence in the

scarburghense subzone of each locality. The disappearance of C.continuum in each of the sections appears to mark the Callovian/Oxfordian boundary.

Range Previously recorded from Bathonian (Sarjeant, 1979) to Callovian and Oxfordian (Davey & Riley, 1978).

Ctenidodinium pachydermum (Deflandre, 1938) Gocht, 1970
(Pl.9, figs.1-6)

1938 Gonyaulax pachyderma Deflandre: 176
1969 Gonyaulacysta pachyderma (Deflandre) Sarjeant: 10
1970 Ctenidodinium pachydermum (Deflandre) Gocht: 142

Diagnosis Deflandre, 1938; p176; pl.7,figs.6-10; text-figs.7-10

Description Intermediate to large proximate cyst, subspherical to subpentagonal in outline with a short but prominant apical horn. Paratabulation indicated by parasutural rows of short, finely-denticulate, simple spines. Paratabulation formula: 4', 6", 6"', 4"", but difficult to determine due to cyst breakage, and heavy granular surface ornamentation. Archaeopyle epicystal, type $\overline{\text{tAtP}}$; operculum free to attached.

Dimensions Overall length of cyst: 93-103 mu
Overall width of cyst: 86-101 mu
(6 specimens measured)

Remarks Specimens identify closely with the original description and illustrations of Deflandre (1938). Whole specimens particularly rare due to loss of epicyst during archeopyle formation.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.170 (calloviense to cordatum).
Overall range: L.Callovian (kamptus) to uppermost L.Oxfordian (cordatum).

Range Previously described from Oxfordian to L.Kimmeridgian (Sarjeant, 1979). The presence of C.pachydermum in Callovian samples here therefore extends the known range.

Ctenidodinium sp.A
(Pl.9, fig.7)

Description Intermediate size proximate cyst, subspherical in outline, without apical or antapical structures. Paratabulation indicated by parasutural ridges bearing short, isolated, simple spines to give the formula: 4', 6", 6"', 1p, 1"", which is clearly discernable. Surface of the cyst is fairly coarsely granular. Archaeopyle epicystal, type $\overline{\text{tAtP}}$; operculum attached.

Dimensions Overall length of cyst: 60 mu
Overall width of cyst: 55 mu
(1 specimen only)

Remarks A single but well-preserved specimen, clearly belonging to the genus Ctenidodinium.

Occurrence A single specimen from Warlingham: Br.340 (praecordatum).

Genus DINOPTERYGIUM Deflandre, 1935 emend. Stover & Evitt, 1978

Synonyms Oodnadattia Eisenack & Cookson, 1960
Toolongia Cookson & Eisenack, 1960

Diagnosis Cysts proximochorate, subspherical to subpolygonal; outline circular, or nearly so, in apical-antapical view; paratabulation gonyaulacacean, indicated by parasutural septa and by intratabular structures between autophragm and ectophragm; archaeopyle epicystal, type $\overline{tAtP}$.

Type species Dinopterygium cladoides Deflandre, 1935

Dinopterygium absidatum Drugg, 1978
(Pl.10, figs.1-6)

Diagnosis Drugg, 1978; p66; pl.4,figs.7-9

Description Intermediate size, proximochorate cyst, more-or-less circular in outline with a parasulcal depression. Hypocyst only, epicyst missing due to archaeopyle formation. Hypocyst cone-shaped bearing antapical extensions formed from the autophragm and flattened ventrally, sloping towards the antapex. Paracingulum prominant and marked by flanges; outline of epicystal paracingular flange is angular and outer edges slightly ragged; hypocystal flange is more rounded in outline, the edges are denticulate. Autophragm of hypocystal paracingular flange is produced into five arch-like openings which are convex distally forming funnels. Paratabulation present but obscure, apparently ?4', 6", Xc, 6"', ?1p, 1"". Archaeopyle epicystal, type $\overline{tAtP}$; operculum free.

Dimensions Overall cyst diameter: 54-85 mu
(17 specimens measured)

Remarks This species is very distinctive on account of its arch-like openings in the autophragm of the hypocystal paracingular flange. Preservation is generally good.

Occurrence Warboys: a single specimen from WB.88 (lamberti).
Warlingham: Br.727 to Br.246 (scarburghense to corsticardia).

Overall range: L.Oxfordian (scarburghense) to uppermost lower Oxfordian (corsticardia).

Range Previously recorded from Callovian (athleta) to L.Oxfordian (mariae) (Drugg, 1978). The upper range of this species is therefore extended to uppermost lower Oxfordian (corsticardia) on the basis of this study.

Genus ELLIPSOIDICTYUM Klement, 1960

Synonym Dictyopryxidia Eisenack, 1961

Diagnosis Cysts proximochorate, subspherical to elongate ellipsoidal; autophragm with curved to straight interconnected septa forming an irregular reticulum; lumina of various shapes and sizes; some septa may be parasutural; archaeopyle apical, probably type $\overline{tA}$.

Type species Ellipsoidictyum cinctum Klement, 1960

Ellipsoidictyum cinctum Klement, 1960
(Pl.10, figs.7-9)

1960	Ellipsoidictyum cinctum	Klement: 78
1960	Dictyopryxidia areolata	Cookson & Eisenack: 255
1976a	Ellipsoidictyum cinctum	Sarjeant: 24

Diagnosis Klement, 1960; p78; pl.6,figs.15,16; pl.7,figs.1,2; text-figs. 36-37.

Description Small to intermediate proximochorate cyst, subspherical to elongate-ellipsoidal in outline. Cyst wall consists of autophragm only which is covered with septa in the form of a relatively coarse reticulate mesh-work. Paratabulation indicated by archaeopyle and distinct paracingulum only, although some septa are almost certainly parasutural. Parasulcus indicated by an area without septa. Archaeopyle apical, type $\overline{tA}$; operculum free.

Dimensions Overall length of cyst: 40-65 mu
Overall width of cyst: 42-50 mu
(5 specimens measured)

Remarks E.cinctum is differentiated from E.reticulatum (Valensi, 1953) Lentin & Williams, 1977 by its larger reticulate pattern and larger overall size. The paracingulum is also more distinct in the former.

Occurrence Warboys: WB.228 to WB.83 (kamptus to lamberti)
Warlingham: Br.1880 to Br.246 (calloviense to corsticardia).

Overall range: L.Callovian (kamptus) to L.Oxfordian (corsticardia).

Range Previously described from Bathonian to Kimmeridgian.

Ellipsoidictyum cf.gochtii Fensome, 1979
(Pl.10, figs.14-16)

1970 Gen. et sp. indet. Gocht: 152
1979 Ellipsoidictyum gochtii Fensome: 20

Diagnosis Fensome, 1979; p20; pl.2,figs.8,9,11,12; text-fig.8

Description Small to intermediate proximochorate cyst, ovoidal to ellipsoidal in outline. Cyst wall consists of autophragm only ornamented by a fine honeycomb-like pattern of pits and regularly distributed, numerous processes which arise from a discontinuous network of low crests. The processes are buccinate, capitate, or either symmetrically or assymmetrically bifurcate distally, solid and approximately 5mu in length. Paratabulation indicated by archaeopyle only. Archaeopyle apical, type $\overline{tA}$; operculum free to attached. Occasionally an indistinct paracingulum is seen.

Dimensions Overall length of cyst: 40-50 mu
Overall width of cyst: 31.5-42 mu
(4 specimens measured)

Remarks Specimens encountered here identify closely with those described by Fensome (1979), but differ in lacking a well-defined paracingulum and are therefore placed here within E.cf.gochtii. However it is likely that they are the same species.

Occurrence Warboys: WB.138 to WB.23 (middle athleta to praecordatum).
Warlingham: Br.1880 to Br.115 (calloviense to vertebrale)
Overall occrrence: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range ?Bathonian to M.Callovian (Fensome, 1979)

Ellipsoidictyum reticulatum (Valensi, 1953) Lentin & Williams, 1977
(Pl.10, figs.10-13)

1953 Palaeoperidinium reticulatum Valensi: 28
1968 Dictyopryxis reticulata (Valensi) Sarjeant: 230
1973 Dictyopryxidia reticulata (Valensi) Lentin & Williams: 47
1977 Ellipsoidictyum reticulatum (Valensi) Lentin & Williams: 56

Diagnosis Valensi, 1953; p28; pl.2,figs.4,5,14,19

Description Small to intermediate proximochorate cyst, rounded to ovoidal in outline. Cyst wall consists of autophragm only, decorated with septa in the form of a coarse reticulate mesh-work, forming polygonal fields on the cyst surface. From the nodes of the septa arise short, solid spines which are slightly smaller at their base and bifurcate distally to form 2 to 4 filaments; these may anastomise with neighbouring spines to form a fine mesh-work covering the entire cyst, but is often not preserved. Paratabulation indicated by archaeopyle and paracingulum only. Archaeopyle apical, type $\overline{tA}$; operculum usually free.

Dimensions   Overall length of cyst: 35-55 mu
Overall width of cyst: 38-55 mu
(6 specimens measured)

Remarks   E.reticulatum differs from E.cinctum Klement, 1960 in posessing small spines at the nodes of the reticulae; and from E.gochtii Fensome, 1979 in the posession of a reticulate mesh-work and generally smaller and more variable spines. Specimens identify closely with those described by Valensi (1953), but preservation is such that the outer mesh-work formed by the anastomosing filaments is rarely ever seen.

Occurrence   Warboys: WB.212 to WB.48 (enodatum to scarburghense); abundant in WB.212 (enodatum) where 36 individuals were encountered, but rare elsewhere.

Warlingham: Br.1813 to Br.292 (calloviense to bulowskii).
Overall range: L.Callovian (calloviense) to L.Oxfordian (bulowskii).

Range   Previously described from Bajocian to Bathonian (Sarjeant, 1979). The range is therefore extended to L.Oxfordian (bulowskii) on the basis of the present study.

Genus   GONYAULACYSTA Deflandre, 1964 emend Stover & Evitt, 1978

Diagnosis   Cysts typically bicavate; endocyst subspherical to ellipsoidal; pericyst subpolygonal and generally elongate longitudinally, with a short to long apical horn. Paratabulation gonyaulac-acean, indicated by parasutural septa with denticulate to spin-ulate crests; archaeopyle precingular, type P.

Type species   Gonyaulacysta jurassica (Deflandre, 1938) Norris & Sarjeant, 1965

Gonyaulacysta jurassica (Deflandre, 1938) Norris & Sarjeant, 1965
(Pl.11, figs.1-6, 14)

1938   Gonyaulax jurassica Deflandre: 168
1964   Gonyaulacysta jurassica (Deflandre) Deflandre: 5
1965   Gonyaulacysta jurassica (Deflandre) Norris & Sarjeant: 65

Diagnosis   Deflandre, 1938; p168; pl.6,figs.2-5; text-figs.1,2

Description   Intermediate size proximate cyst, elongate to subpolygonal in outline with a prominant apical horn and truncate antapically. Cyst typically bicavate, but development of epipericoel and hypopericoel may be reduced or lacking. Parasutural septa present, forming characteristic denticulate to spinose crests. Paratabulation indicated by parasutural features to give the gonyaulacacean formula: 4', 1a, 6", 6c, 6"', 1p, 1"". Archaeopyle precingular, type P (3" only); operculum free. Paracingulum indicated by 6 subrectangular paraplates, strongly laevorotatory. Parasulcus clearly defined, straight to S-shaped.

Dimensions   Overall length of cyst: 45-88 mu
Overall width of cyst: 35-67 mu
(16 specimens measured)

Remarks   A very variable, although distinctive species. Specimens encountered in both sections, whilst possessing the essential features of the species, exhibit a great variation in size, length of apical horn, nature of parasutural crests etc.

Occurrence   Occurs commonly throughout both sections. Very common in Callovian samples from Warboys, where 20+ were counted in many samples. This pattern of occurrence is reflected in the Warlingham sequence, although the greatest number were encountered in uppermost lower Oxfordian (cordatum) and M.Oxfordian (plicatilis).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range   Previously described from U.Bathonian to L.Portlandian (Davey & Riley, 1978).

Gonyaulacysta jurassica (Deflandre, 1938) Norris & Sarjeant, 1965
sub.sp. longicornis (Deflandre, 1938) Lentin & Williams, 1973
(Pl.11, figs.7-10)

1938   Gonyaulax jurassica Deflandre var. longicornis Deflandre:171
1970   Gonyaulacysta jurassica var. longicornis (Deflandre) Gitmez: 260
1973   Gonyaulacysta jurassica (Deflandre) Norris & Sarjeant, 1965 sub.sp. longicornis (Deflandre) Lentin & Williams: 62

Diagnosis   Deflandre, 1938; p171; pl.6,fig.6

Description   Intermediate to large proximate cyst, elongate in outline with an elongated apical horn, making the epicyst at least three times longer than the hypocyst. Cyst markedly bicavate with a well-developed epipericoel extending into the apical horn. Paratabulation indicated by parasutural septa in the form of markedly denticulate crests to give the gonyaulacacean formula: 4', 6", 6c, 5-6"', 1"". Archaeopyle precingular, type P (3" only); operculum free. Paracingulum strongly laevorotatory.

Parasulcus straight to S-shaped.

Dimensions   Overall length of cyst: 75-90 mu
Overall width of cyst: 43-65 mu
(6 specimens measured)

Remarks   This subspecies is distinguished from G.jurassica s.s. by the length of the apical horn and well-developed epipericoel. There does however, appear to be specimens which are intermediate in form between the two and differentiation is not always obvious.

Occurrence   Warboys: WB.223 to WB.18 (calloviense to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall occurrence: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range   Previously recorded from the Upper Jurassic (Gitmez, 1970).

Genus   HESLERTONIA Sarjeant, 1966a

Diagnosis   Cysts proximochorate; body subspherical; paratabulation gonyaulacacean, indicated by high parasutural septa, height of which is greater than one-fourth main body diameter; archaeopyle precingular, type P.

Type species   Heslertonia heslertonensis (Neale & Sarjeant, 1962) Sarjeant, 1966a

Heslertonia teichophera (Sarjeant, 1961a) Sarjeant, 1976b
(Pl.11,figs.11-13; Pl.12,figs.1,2)

1961a   Cymatiosphaera teichophera Sarjeant: 107
1976b   Heslertonia teichophera (Sarjeant) Sarjeant: 8

Diagnosis   Sarjeant, 1976b; p8; pl.1,figs1,4; pl.6,fig.3; text-fig.3

Description   Small to intermediate size proximochorate cyst, subspherical in outline. Cyst wall consists of autophragm only with very high parasutural crests or septa. Paratabulation indicated by parasutural features, formula: 4', 1a, 6", 6c, 6"', 1p, 1"". Crests are finely denticulate distally and striate. Height of crests between one-quarter and one-third diameter of the central body. Archaeopyle precingular, type P (3" only); operculum free.

Dimensions   Overall diameter of cyst: 37-45 mu
(8 specimens measured)

Remarks   H.teichophera differs from other species in the character and relative proportions of the crests, shape and relative position of other plate areas. Specimens are well preserved and usually entire.

Occurrence   Warboys: WB.223 to WB.68 (calloviense to scarburghense).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range   Previously recorded from U.Callovian (athleta) to L.Oxfordian (cordatum). The range is therefore extended to: L.Callovian (calloviense) to M.Oxfordian (vertebrale), on the basis of this study.

Genus   HYSTRICHODINIUM Deflandre, 1935 emend Clarke & Verdier, 1967

Synonym   Heliodinium Alberti, 1961 emend. Sarjeant, 1966a.

Diagnosis   Cysts skolochorate; body subspherical to polyhedral, bearing numerous parasutural spines; paratabulation indicated by archeopyle and clearly to vaguely by alignment of spines; archeopyle precingular, type P.

Type species   Hystrichodinium pulchrum Deflandre, 1935

Hystrichodinium pulchrum Deflandre, 1935
(Pl.12, figs.3-6)

Diagnosis   Deflandre, 1935; p229; pl.5,fig.1; text-fig.9-11

Description Intermediate size, subspherical to polyhedral, skolochorate cyst. Autophragm only, bearing numerous parasutural hollow spines which are simple, blade-like, straight or sinuous and acuminate distally. Areas between spines typically bear circular markings in the form of pores or sharply-defined tuberculae. Paratabulation indicated by precingular archeopyle, type P (3" only) and an apparent gonyaulacacean formula: 4', 6", 6c, 6"', 1p, 1"", which is rarely determinable. Paracingulum usually clearly indicated by low parasutural ridges.

Dimensions   Overall cyst diameter: 27-39 mu
Overall length of spines: 10-20 mu
(4 specimens measured)

Remarks   Specimens identify very closely with those described by Deflandre (1935) and subsequent authors, in their morphology, but tend to be somewhat smaller. Specimens encountered here clearly belong to H.pulchrum.

Occurrence   Warboys: WB.158 to WB.18 (lower athleta to praecordatum).
Warlingham: Br.1880 to Br.140 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range   Previously recorded from Kimmeridgian to Senonian. The presence of H.pulchrum here extends the known range to L.Callovian (calloviense).

Genus HYSTRICHOGONYAULAX Sarjeant, 1969

Diagnosis Cysts proximochorate; body subspherical to polyhedral, with or without an apical horn; paratabulation gonyaulacacean, indicated by parasutural ridges surmounted by normally isolated spines; surface between parasutural ridges smooth or faintly ornamented; archaeopyle precingular, type P.

Type species Hystrichogonyaulax cornigera (Valensi, 1953) Sarjeant, 1969

Hystrichogonyaulax cladophora (Deflandre, 1938) Stover & Evitt, 1978
(Pl.12, figs.7-9)

1938 Gonyaulax cladophora Deflandre: 173
1967 Gonyaulacysta cladophora (Deflandre) Dodekova: 17
1969 Gonyaulacysta cladophora (Deflandre) Sarjeant: 9
1978 Hystrichogonyaulax cladophora (Deflandre) Stover & Evitt:162

Diagnosis Deflandre, 1938; p173; pl.7,figs.1-5; text-figs.5,6

Description Intermediate to large proximochorate cyst, subspherical to polyhedral in outline, with an apical horn. Autophragm only with low parasutural ridges giving rise to rows of short, isolated spines, which may be simple or bifurcate distally. Autophragm between parasutural features finely ornamented. Paratabulation indicated by parasutural features giving the gonyaulacacean formula: 4', 1a, 6", 6"', 1p, 1"". Archaeopyle precingular, type P (3" only); operculum free.

Dimensions Overall length of cyst: 88-113 mu
Overall width of cyst: 81-114 mu
(12 specimens measured)

Remarks There is a fairly wide variation in shape, but general morphology is distinctive. Specimens encountered are generally slightly larger than those described by Deflandre (1938). Occasionally specimens exhibit parasutural spines which anastomise at various points in their length (Pl.12, fig.7). Preservation is generally good.

Occurrence Warboys: WB.223 to WB.18 (calloviense to praecordatum).
Warlingham: Br.1880 to Br. 115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Bathonian to Kimmeridgian (Sarjeant, 1979)

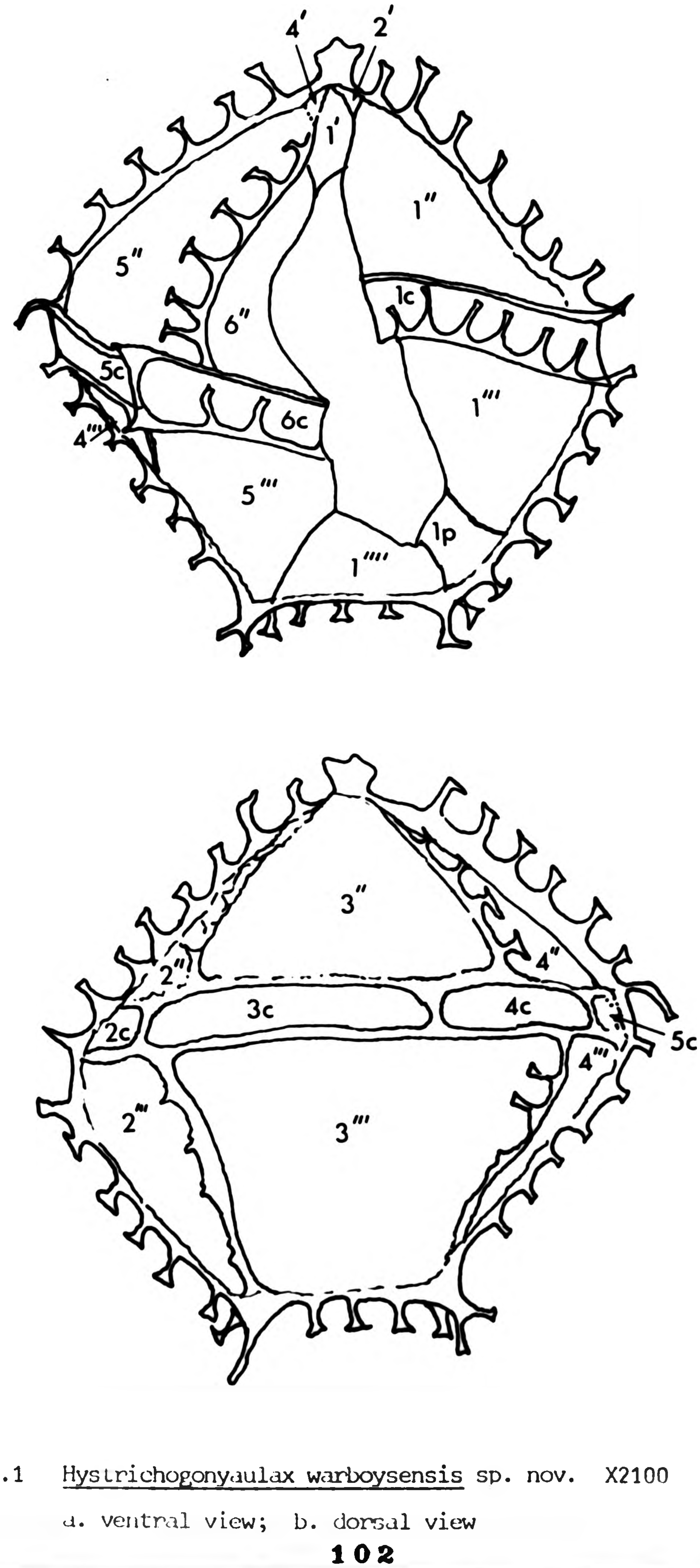
Hystrichogonyaulax warboysensis sp.nov.
(Pl.12,figs.10,11; Pl.13,fig.1; text-fig.5.1)

Derivation of name: After the village of Warboys, Huntingdonshire, from where this species is recorded for the first time.

Holotype Sample WB.128, slide WB.128a; 057/1351 (E414); middle athleta (U.Callovian), Warboys Borehole. Pl.12,fig.11; text-fig.5.1

Diagnosis A species of Hystrichogonyaulax having an intermediate size proximochorate cyst; subspherical to pentagonal in outline, with a small apical horn. Cyst wall consists of autophragm only. Paratabulation indicated by parasutural ridges giving rise to short, simple, bifurcate or trifurcate spines which are consistently buccinate; formula gonyaulacacean: 4', 6", 6c, 5"', 1p, 1"". The surface between parasutural features is smooth. Archaeopyle precingular, type P (3" only); operculum free.

Description A species of Hystrichogonyaulax with a subspherical to pentagonal cyst and a short apical horn, which is not always apparent and may even be absent in some specimens. The apical horn, when present, is short, broad and tends to trifurcate distally to form three blunt projections. Antapically the cyst is truncate. The cyst wall consists of autophragm only which is quite thin. Most specimens tend to be collapsed, being flattened dorso-ventrally. There is no surface ornamentation on the autophragm between the parasutural features. The parasutural features are quite distinct and represented by broad ridges which give rise to a series of spines; the spines occur on all parasutures except in the region of the parasulcus. The spines are of equal size over the entire cyst and approximately 4-6mu in length. They tend to be equally spaced along the parasutural ridges and may be either simple or bifurcate. Distally they are recurved, proximally they broaden forming a link between neighbouring spines. Paratabulation is clearly indicated in the holotype, but less distinct in other specimens due to collapse of the cyst. It conforms to the gonyaulacacean formula: 4', 6", 6c, 5"', 1p, 1"". The four apical paraplates are quite small and not easily distinguished, except 1' which extends into the parasulcal region. The six precingular paraplates are triangular in outline; 3" is lost in archeopyle formation. Only five postcingular paraplates are visible on the holotype; they are trapezoidal in outline. A small posterior ventral paraplate (1p) occurs between 1"' and 1"". The paracingulum is stongly laevorotatory, the ends being offset ventrally twice the width of the paracingulum itself; it consists of six paraplates of approximately equal size. The paracingulum is approximately 5mu in width on the holotype which is typical. The parasulcus is fairly, but not strongly, sinuous, wide but not depressed. The archaeopyle is precingular, type P, formed by the loss of paraplate 3" only. The operculum is free.



Text-fig. 5.1 Hystrichogonyaulax warboysensis sp. nov. X2100

a. ventral view; b. dorsal view

Dimensions Holotype: Overall length of cyst: 47mu
Overall width of cyst: 47mu
Length of apical horn: 5mu
Width of paracingulum: 5mu
Length of spines: 4mu

Range: Overall length of cyst: 40-50mu
Overall width of cyst: 35-47mu
Length of spines: 4-6 mu
(7 specimens measured)

Remarks H.warboysensis sp.nov. is distinguished from H.cladophora (Deflandre, 1938) Stover & Evitt, 1978 primarily by its size, the former being about half the size of the latter. It is also distinguished by the constant nature of the spines arising from the parasutural ridges in size and shape; H.warboysensis also lacks surface ornamentation in the intrasutural areas. An apical horn is always present in H.cladophora, but not always apparent in H.warboysensis. H.cladophora has six postcingular paraplates, whereas H.warboysensis appears to have only five. Only one specimen from Warboys was found preserved in its original form, without dorso-ventral flattening, this has been designated the holotype. It occurs more commonly at Warlingham but all specimens were collapsed. General preservation is, however, good.

Occurrence Warboys: WB.210 to WB.128 (medea to middle athleta)
Warlingham: Br.1898 to Br.605 (calloviense to scarburghense).
Overall range: L.Callovian (calloviense) to L.Oxfordian (scarburghense).

Range L.Callovian (calloviense) to L.Oxfordian (scarburghense) as recorded herein.

Genus HYSTRICHOSPHAERINA Alberti, 1961

Diagnosis Cysts skolochorate, gonyaulacacean; body subspherical with about 18 cylindrical to trumpet-shaped penitabular process groups, each group linked distally by ring trabeculae; paracingular processes slender, branched, and not interconnected distally; archaeopyle apical, type $\overline{tA}$.

Type species Hystrichosphaerina schindewolfii Alberti, 1961

Hystrichosphaerina orbifera (Klement, 1960) Stover & Evitt, 1978
(Pl.13, figs.2,3)

1960 Systematophora orbifera Klement: 66
1978 Hystrichosphaerina orbifera (Klement) Stover & Evitt: 58

Diagnosis Klement, 1960; p66; pl.9,figs.9,10; pl.10,fig.7

Description Intermediate size skolochorate cyst with a subspherical central body. Cyst wall consists of autophragm only which gives rise to about 18 trumpet-shaped, penitabular processes; each group of processes connected distally by ring-trabeculae. Paracingular processes isolated, slender, branched and not interconnected distally. Autophragm between processes smooth. Paratabulation indicated by penitabular process-groups, and less clearly by isolated paracingular processes: ?4', 6", 4-6c, 5-6"', 1p, 1"". Archaeopyle apical, type $\overline{tA}$; operculum free.

Dimensions Overall diameter of central body: 35-45 mu
Overall length of processes: 15-27 mu
(4 specimens measured)

Remarks Stover & Evitt (1978) transferred this species to Hystrichosphaerina, from Systematophora, on the grounds of its possession of ring-trabeculae on the distal ends of the process-groups which are lacking in Systematophora. Preservation is generally quite poor.

Occurrence Warlingham: Br.214 to Br.140 (corsticardia to vertebrale) in fairly low numbers.

Range Previously recorded from Oxfordian (cordatum) to Portlandian (Sarjeant, 1979).

Genus KALYPTEA Cookson & Eisenack, 1960

Synonym Komewuia Cookson & Eisenack, 1960
Netrelytron Sarjeant, 1961a

Diagnosis Cysts proximate, elongate ellipsoidal, with single horns at apex and antapex; autophragm smooth or faintly ornamented, with or without surrounding amorphous cloak (kalyptra); archaeopyle intercalary, type I.

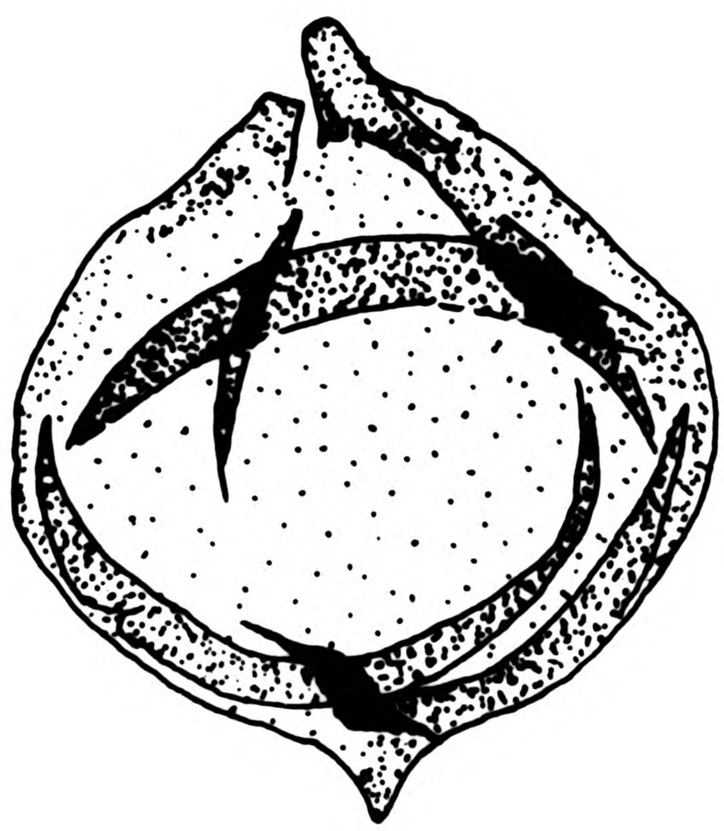
Type species Kalyptea diceras Cookson & Eisenack, 1960

Kalyptea globulus sp.nov.
(Pl.13, figs.7-9; text-fig.5.2)

Derivation of name From the Latin "globulus" meaning "little ball", used in apposition.

Holotype Sample Br.727; slide Br.727a; 095/1296 (J473). Lower scarburghense (Lower Oxfordian), Warlingham Borehole. Plate 13, fig.7; text-fig.5.2

Diagnosis Small, spheroidal to globose cyst, with autophragm only and single horns at apex and antapex; the apical horn being slightly longer



Text-fig. 5.2 Kalyptea globulus sp.nov. X2600 and more bluntly-rounded than the antapical horn. A kalyptra is present but often lost due to preservation. Archaeopyle intercalary, type I (2a only); operculum free. Autophragm distinctly folded and smooth to faintly granular.

Description A species of Kalyptea which is characteristically small, spheroidal to globose in outline, consisting of autophragm only. A horn at both apex and antapex is characteristic of the genus; in K.globulus the apical horn is the larger of the two, bluntly-rounded and finger-like, approximately 7-9mu in length. The antapical horn is comparatively smaller (4-5mu in length), broader at its base and tapers to a rounded point distally. The cyst is covered by a delicate kalyptra which is often not preserved; when present it appears to incorporate very finely diffuse debris. The autophragm is quite smooth to faintly granular, consistently folded to give sickle-shaped folds. Paratabulation features entirely lacking except for the archaeopyle. Archaeopyle intercalary, type I (presumably 2a only), small and often difficult to observe.

Dimensions Holotype: Overall length of cyst: 45mu
Overall width of cyst: 30mu
Length of apical horn: 7mu
Length of antapical horn:4mu

Range: Overall length of cyst: 40-48mu
Overall width of cyst: 30mu
Length of apical horn: 7-9mu
Length of antapical horn:4-5mu
(3 specimens measured)

Remarks Kalyptea globulus sp.nov. differs from all previously described species of Kalyptea primarily by its size, being considerably smaller than all other known species. The reduced nature of the apical and antapical horns are also distinctive, as is the consistent sickle-shaped folding of the autophragm. The extent of the kalyptra is unknown due to preservation.

Occurrence Warlingham: Br.785 to Br.465 (scarburghense).

Range L.Oxfordian (scarburghense) only, as recorded herein.

Kalyptea stegasta (Sarjeant, 1961a) Wiggins, 1975
(Pl.13, figs.4-6)

1961a Netrelytron stegastum Sarjeant: 114
1961 Kalyptea jurassica Alberti: 21
1975 Kalyptea stegasta (Sarjeant) Wiggins: 110

Diagnosis   Sarjeant, 1961a; p114; pl.15,fig.15; text-fig.14

Description   Intermediate to large proximate cyst, elongate ellipsoidal in outline, with prominant apical and antapical horns. Horns vary in length and attitude, tending to be quite long in proprtion to the main body of the cyst and often inclined to the vertical axis of the cyst. Cyst wall consists of autophragm only which is often folded and smooth to faintly granular. Cyst embodied in a definite amorphous kalyptra, impregnated with sediment debris. Paratabulation indicated by archaeopyle only which is intercalary, type I (apparently 2a only).

Dimensions   Overall length of cyst: 58-96 mu
Overall width of cyst: 35-50 mu
(5 specimens measured)

Remarks   Preservation is variable, often the kalyptra is incomplete or lacking altogether. K.stegasta tends to be more inflated and less spindle-shaped than K.diceras Cookson & Eisenack, 1960. It is distinguished from K.globulus sp.nov. by its size.

Occurrence   Warboys: WB.218 to WB.138 (calloviense to middle athleta).
Warlingham: Br.1880 to Br.313 (calloviense to praecordatum).
Overall range: L.Callovian (calloviense) to L.Oxfordian (praecordatum).

Range   Previously recorded from Callovian (?Bathonian) to Lower Kimmeridgian (Davey & Riley, 1978; Sarjeant, 1979)

Genus   KYLINDROCYSTA Fenton, Neves & Piel, 1980

Diagnosis   Cysts proximate, cylindrical, strongly elongate to subquadrate in outline; Paratabulation absent or indistinct; cyst wall complex, consisting of thin endophragm and spongy, fibrous periphragm; surface spinose to granulose; paratabulation formula: 5', ?5", ?5"', 1""; archaeopyle apical, type ?$\overline{tA}$.

Type species   Kylindrocysta spinosa Fenton, Neves & Piel, 1980

Kylindrocysta reticulata sp. nov.
(Pl.13, figs.10-15; text-fig. 5.3)

Derivation of name   From the Latin adjective 'reticulatus', meaning "latticed" or "net-like", describing cyst-ornamentation.

Holotype   Sample Br.976; slide Br.976a; 200/1465 (U294). Upper Callovian (lamberti/athleta), Warlingham Borehole. Plate 13, fig.12; text-fig. 5.3.

Diagnosis   Small to intermediate proximate cyst, cylindrical, ellongate or subquadrate in outline. Cyst wall two-layered, consisting of an innermost

Text-fig. 5.3 Kylindrocysta reticulata sp. nov. X2500 thin autophragm giving rise to a complex system of processes with distally-linking trabeculae forming a reticulate mesh-work, constituting the ectophragm. No apparent paratabulation. Paracingulum very faintly discernible in some specimens, but usually not present. Archaeopyle apical, type ?$\overline{tA}$; operculum free.

Description Cyst is small to intermediate in size, normally elongate, cylindrical in shape, occasionally becoming more subquadrate in outline. The sides of the cyst are straight to slightly convex, the antapex is broadly rounded. The cyst wall is two-layered, comprising a thin autophragm which gives rise to a complex system of non-tabular processes which are numerous and cover the entire cyst. The processes are thin (approximately 1mu) and linked distally by trabeculae in an apparently random fashion to form a reticulate mesh-work, constituting the ectophragm. There is no apparent paratabulation, although parasutural slits are sometimes present along the principle archaeopyle suture. Archaeopyle apical, type ?$\overline{tA}$; operculum free. There are faint indications of a paracingulum in some specimens in the form of an indentation of the ectophragm at mid-point along the cyst length.

Dimensions	Holotype:	Overall length of cyst:	42mu
		Overall width of cyst:	35mu
		Thickness of 'mesh':	4mu
	Range:	Overall length of cyst:	39-45mu
		Overall width of cyst:	22-35mu
		Thickness of 'mesh':	4-5 mu
		(6 specimens measured)	

Remarks The broad morphological description of Kylindrocysta reticulata sp.nov. compares very closely to the generic diagnosis of Kylindrocysta as determined by Fenton, Neves & Piel (1980). It does however, differ from the only other known species, K.spinosa Fenton, Neves & Piel, 1980, in possessing the reticulate ectophragm and in lacking any observed paratabulation. This species is readily identified on its broad morphological features. Specimens are well preserved.

Occurrence Warlingham: Br.1883 to Br.140 (calloviense to vertebrale).

Range L.Callovian (calloviense) to M.Oxfordian (vertebrale) as recorded herein.

Genus LEPTODINIUM Klement, 1960 emend. Stover & Evitt, 1978

Diagnosis Cysts proximochorate, ellipsoidal to subpolygonal, with or without an apical projection or horn. Paratabulation gonyaulacacean, indicated by parasutural septa only; paraplate 4' characteristically shorter than 1', and contact with four- or five-sided paraplate 6" substantial; archaeopyle precingular, type P.

Type species Leptodinium subtile Klement, 1960

Leptodinium gongylos (Sarjeant, 1966a) Stover & Evitt, 1978
(Pl.14, figs.1-3)

1961a Gonyaulax sp. Sarjeant: 97
1966a Gonyaulacysta gongylos Sarjeant: 111
1978 Leptodinium gongylos (Sarjeant) Stover & Evitt: 170

Diagnosis Sarjeant, 1966a; p111; pl.13,figs.1,2; text-fig.6

Description Intermediate size, proximate cyst, rounded to subpolygonal in outline with a short, blunt apical horn. Cyst wall consists of autophragm only. Paratabulation indicated by low, parasutural, denticulate crests to give the gonyaulacacean formula: 4', 1a, 6", 6c, 6"', 1p, 1"". Area between parasutural features smooth. Paraplate 1' is elongate and corresponds to an apical prolongation of the parasulcus. Parasulcus and paracingulum both relatively broad, the latter being laevorotatory and offset ventrally by approximately one width of the paracingulum. Archeopyle precingular, type P (3" only); operculum free.

Dimensions Overall length of cyst: 44-64 mu
Overall width of cyst: 44-56 mu
(6 specimens measured)

Remarks Stover & Evitt transferred this species from Gonyaulacysta to Leptodinium because of the proximochorate nature of the cyst, rather than the typically bicavate cyst-type of Gonyaulacysta; this distinction has been followed here. Specimens compare fairly closely with the original description of Sarjeant (1966a), but differ in lacking paraplate 7c. Paraplate 6" is more elongate but still subquadrate in outline.

Occurrence Warboys: a single specimen from WB.58 (scarburghense).
Warlingham: Br.443 to Br.292 (praecordatum to bulowskii).
Overall range: L.Oxfordian (praecordatum to bulowskii).

Range Lower to Middle Oxfordian (Sarjeant, 1979)

Leptodinium miriabile Klement, 1960

(Pl.14, fig.4)

1960 Leptodinium miriabile Klement: 48
1967 Gonyaulacysta miriabile (Klement) Dodekova: 19
1973 Leptodinium miriabile Klement; Lentin & Williams: 87

Diagnosis Klement, 1960; p48; pl.6,figs.7-10; text-figs.25-27

Description Intermediate size, proximochorate cyst, subspherical to ovoidal in outline with no apicular structure. Autophragm only. Paratabulation indicated by low parasutural septa of uniform height which are smooth, as are the intrasutural areas. Distinct paratabulation gonyaulacacean: 4', 6", 5c, 5"', 1p, 1"", with a more complex paraplate structure in the parasulcal region. Paracingulum marked by five elongate paraplates. Archaeopyle precingular, type P (3" only); operculum free.

Dimensions Overall length of cyst: 70 mu
Overall width of cyst: 60 mu
(1 specimen only)

Remarks A single specimen only was recorded, but clearly belongs to this species. Paratabulation distinct. Preservation very good. Operculum can be seen resting inside the cyst.

Occurrence Warlingham: Br.246 L.Oxfordian (corsticardia).

Range Previously recorded from Middle Oxfordian to Lower Kimmeridgian (Sarjeant, 1979).

?Leptodinium sp.

(Pl.14, figs.5,6)

Description Intermediate size cyst, ovoidal to subquadrate in outline, without apicular or antapicular structures. Generally autophragm only, although some specimens exhibit a 2-layered wall. Paratabulation partially indicated by paracingulum only which is laevorotatory and although distinct, is often represented by folds in the cyst wall; but may also be conventional. Other parasutural septa are only rarely observed, possibly due to state of preservation; when present they are low, smooth and of uniform height. Archaeopyle difficult to determine, presumably precingular.

Dimensions Overall length of cyst: 50-68 mu
Overall width of cyst: 50-60 mu
(4 specimens measured)

Remarks Preservation of specimens generally quite poor and only a tentative assignment to Leptodinium is made.

Occurrence Warboys: WB.223 to WB.108 (calloviense to upper athleta).
Warlingham: Br.115 to Br.194 (lamberti/athleta to corsticardia).
Overall range: L.Callovian (calloviense) to L.Oxfordian (corsticardia).

Genus LITHODINIA Eisenack, 1935 emend. Gocht, 1975

Diagnosis Cysts proximate, subspherical to roundly polyhedral; paratabulation indicated by parasutural rows of short projections whose bases may coalesce; gonyaulacacean, formula: 4', 6", 6c, 5"', 1p, 1"", 1 or more s; archaeopyle apical, type 4A, typically with deep parasulcal notch.

Type species Lithodinia jurassica Eisenack, 1935, emend. Gocht, 1975

Lithodinia jurassica Eisenack, 1935, emend. Gocht, 1975
(Pl.14, figs.7-10)

1935 Lithodinia jurassica Eisenack: 175
1975 Lithodinia jurassica Eisenack, emend. Gocht: 355

Diagnosis Eisenack, 1935; p175; pl.4,figs.5-10; text-figs.1-4

Description Intermediate size, proximate cyst, subspherical to subpolyhedral in outline. Autophragm only, although SEM reveals two wall layers, not discernible with light microscopy. Paratabulation indicated by parasutural crests which vary from low rows of granulations to fairly high spinose features connected at their bases. Paratabulation gonyaulacacean, formula: 4', 6", 6c, 5"', 1p, 1"". Archaeopyle apical, type 4A; principle archaeopyle suture zigzag with a deep parasulcal notch. Operculum free to attached.

Dimensions Overall length of cyst: 45-70 mu
Overall width of cyst: 45-70 mu
(14 specimens measured)

Remarks Following the return to Meiourogonyaulax Sarjeant, 1966a, of the majority of species formerly attributed to Lithodinia by Stover & Evitt, 1978, L.jurassica remains the only species belonging to this genus except for L.pocockii (Sarjeant, 1968) Davey, 1979 which was formerly attributed to Chytroeisphaeridia (Sarjeant, 1962a) Downie, Evitt & Sarjeant, 1963. L.jurassica differs from L.pocockii in its size and possession of distinct paratabulation. "Lithodinia differs from Meiourogonyaulax in having a type 4A archaeopyle with free opercular pieces rather than a type tA archaeopyle. In general the parasutural features are more continuous and higher in Meiourogonyaulax than those on Lithodinia." (Stover & Evitt, 1978, p61). Specimens here tend to be smaller and more typically L.jurassica in lower and middle Callovian samples, becoming larger with more spinose parasutural crests in the upper Callovian (and into the lower Oxfordian of Warlingham).

Occurrence Warboys: WB.228 to WB.83 (kamptus to lamberti); particularly abundant in calloviense and middle athleta, where it forms more than 10% of the total assemblage.

Warlingham: Br.1898 to Br.693 (calloviense to scarburghense).

Overall range: L.Callovian (kamptus) to L.Oxfordian (scarburghense).

Range Previously recorded from Callovian only (Sarjeant, 1979).

Lithodinia pocockii (Sarjeant, 1968) Davey, 1979
(Pl.14, figs.11-15)

1965 Chytroeisphaeridia sp. Sarjeant: 182
1968 Chytroeisphaeridia pocockii Sarjeant: 230
1979 Lithodinia pocockii (Sarjeant) Davey: 217

Diagnosis Sarjeant, 1968; p230; pl.3,fig.9

Description Small proximate cyst, ovoidal to subspherical in outline. The wall is thick and complexly structured internally, giving a spongy or granular appearance, but smooth when observed at the lateral margins of the cyst. The wall is almost invariably folded. Paratabulation indicated by archaeopyle only. Archaeopyle apical, type ?4A; principle archeopyle suture zigzag. Operculum free to attached.

Dimensions Overall length of cyst: 30-40 mu
Overall width of cyst: 30-59 mu
(9 specimens measured)

Remarks L.pocockii differs from L.jurassica Eisenack, 1935 emend Gocht, 1975, in its size, granular texture and lack of parasutural features. Some specimens exhibit a faint paracingulum (pl.14, figs.11-14).

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum), occuring abundantly in most samples, particularly in Callovian.

Warlingham: Br.1898 to Br.140 (calloviense to vertebrale).

Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously recorded from middle and upper Jurassic.

Genus MEIOUROGONYAULAX Sarjeant, 1966a

Diagnosis Cysts proximochorate, subspherical, gonyaulacacean; generally complete paratabulation indicated by smooth, continuous, parasutural ridges or septa of essentially uniform height; archaeopyle apical, type $\overline{tA}$.

Type species Meiourogonyaulax valensii Sarjeant, 1966a

Meiourogonyaulax caytonensis (Sarjeant, 1959) Sarjeant, 1969
(Pl.15, fig.1)

1959 Gonyaulax caytonensis Sarjeant: 330
1969 Meiourogonyaulax caytonensis (Sarjeant) Sarjeant: 14
1977 Lithodinia caytonensis (Sarjeant) Lentin & Williams: 100
1978 Meiourogonyaulax caytonensis (Sarjeant) Sarjeant; Stover & Evitt:63

Diagnosis Sarjeant, 1959; p330; pl.13,fig.1; text-fig.1

Description Intermediate size proximate cyst, subspherical in outline. Cyst wall consists of autophragm only giving rise to high parasutural crests which are irregularly perforate and of uniform height. Intrasutural areas are finely granular. Paratabulation gonyaulacacean: ?4', 6", 6c, 6"', 1"", paraplate 6"' being much reduced in size. Archaeopyle apical, type $\overline{tA}$; principal archaeopyle suture zigzag; operculum free.

Dimensions Overall length of cyst: 60-65 mu
Overall width of cyst: 50-63 mu
(3 specimens measured)

Remarks The characteristically high perforate parasutural crests are distinctive and distinguish this species from all other species of Meiourogonyaulax. Specimens were encountered in lower and middle Callovian samples only. Preservation is generally poor although the distinctive parasutural crests make identification possible even in fragmentary specimens.

Occurrence Warboys: WB.224 to WB.208 (koenigi to obductum).
Warlingham: Br.1898 to Br.1833 (calloviense).
Overall occurrence: L.Callovian (koenigi) to M.Callovian (obductum).

Range Previously recorded from L.Callovian (macrocephalus) only (Sarjeant, 1979). The range is therefore extended to M.Callovian (obductum) on the basis of this study.

Meiourogonyaulax cristulata (Sarjeant, 1959) Sarjeant, 1969
(Pl.15, figs.2,3)

1959 ?Gonyaulax cristualata Sarjeant:332
1969 ?Meiourogonyaulax cristulata (Sarjeant) Sarjeant: 14
1977 ?Lithodinia cristulata (Sarjeant) Lentin & Williams: 100
1978 Meiourogonyaulax cristulata (Sarjeant) Sarjeant 1969; Stover & Evitt: 63

Diagnosis Sarjeant, 1959; p332; pl.13,fig.2; text-fig.2

Description Intermediate size proximate cyst, subspherical in outline. Cyst wall consists of autophragm only with low to moderately high parasutural crests which are in part irregularly perforate. Intrasutural areas finely to coarsely granular. Paratabulation indicated by parasutural features, gonyaulacacean: ?4', 6", ?1a, 6c, 5"', 1p, 1"". Archaeopyle apical, type $\overline{t}A$; principle archaeopyle suture zigzag; operculum free.

Dimensions Overall length of cyst: 50 mu
Overall width of cyst: 45-50 mu
(2 specimens only)

Remarks M.cristulata is similar in gross morphology to M.caytonensis (Sarjeant, 1959) Sarjeant, 1969 but differs in size, the former being smaller. M.cristulata also has 5 postcingular paraplates whereas M.caytonensis has 6. The parasutural crests on M.caytonensis are higher and the irregular perforations are entire rather than in part. Specimens exhibit the same crystalline structures on the cyst wall as illustrated by Sarjeant, (1959).

Occurrence Warboys: WB.224 to WB.218 (koenigi to calloviense).
Warlingham: a single specimen from Br.1833 (calloviense).
Overall range: L.Callovian (koenigi to calloviense).

Range Previously recorded from L.Callovian (macrocephalus) only (Sarjeant, 1979). The range is therefore extended within the L.Callovian to the calloviense subzone on the basis of this study.

Meiourogonyaulax decapitata (W.Wetzel, 1966) Sarjeant, 1969
(Pl.15, figs.4-11)

1966 Gonyaulax decapitata W.Wetzel
1969 Meiourogonyaulax decapitata (W.Wetzel) Sarjeant: 14
1977 Lithodinia decapitata (W.Wetzel) Lentin & Williams: 101
1978 Meiourogonyaulax decapitata (W.Wetzel) Sarjeant, 1969; Stover & Evitt: 63

Diagnosis Sarjeant, 1972; p29; pl.5, fig.3; text-fig.5

Description Intermediate size proximate cyst, broadly ovoidal in outline. Cyst wall consists of autophragm only which is finely granular. Paratabulation indicated by parasutural crests of low to moderate height, often perforate; gonyaulacacean: 4', 0a, 6", 6c, 6"', 1p, 1pv, 1"". Paracingulum weakly laevorotatory; parasulcus broad. Archaeopyle apical, type $\overline{tA}$; operculum free. Principle archaeopyle suture zigzag.

Dimensions Overall length of cyst: 45-65 mu
Overall width of cyst: 50-64 mu
(12 specimens measured)

Remarks Specimens identify closely with the emended description of Sarjeant (1972), but are generally slightly smaller. One specimen has been recovered with the operculum attached (Pl.15, fig.10) where 4 apical paraplates are discernible, which clarifies the uncertainty of the number of apical paraplates stated by Sarjeant. M.decapitata differs from M.caytonensis and M.cristulata in possessing lower parasutural crests, a posterior ventral paraplate and being slightly smaller.

Occurrence Warlingham: Br.1531 to Br.368 (grossouvrei to praecordatum). Overall range: M.Callovian (grossouvrei) to L.Oxfordian (praecordatum).

Range Previously recorded from U.Bajocian and Bathonian (Sarjeant, 1979). The known range of M.decapitata is therefore extended to Lower Oxfordian (praecordatum) on the basis of the present study.

Genus MILLIOUDODINIUM Stover & Evitt, 1978

Diagnosis Cysts proximate; autocyst subspherical to ellipsoidal, usually with a prominant apical horn; paratabulation gonyaulacacean, indicated by generally low parasutural ridges; paraplates without accessory ridges, septa or other rectilinear markings; archaeopyle precingular, type P.

Type species Millioudodinium fetchamense (Sarjeant, 1966a) Stover & Evitt, 1978

Millioudodinium sp.
(Pl.15, figs.12,13)

Description Large proximate cyst, subquadrate in outline with a prominant apical horn which tapers to a bluntly-rounded point. Cyst wall consists of autophragm only and is fairly thin. Parasutural features faintly discernible in part on one specimen in the form of low thin ridges (Pl. 15, fig.12), exhibiting paraplates 1", 1c, 1"' & 2"'. Archaeopyle precingular, ?type P; operculum free. Autophragm folded in the paracingulum region.

Dimensions Overall length of cyst: 103-113 mu
Overall width of cyst: 86-88 mu
(2 specimens measured)

Remarks Two specimens only were recovered from the Warlingham section. Although poorly-preserved, they fit the generic description as defined by Stover & Evitt, 1978; p173. Of all species listed by Stover & Evitt, the most closely-aligned is M.globatum (Gitmez & Sarjeant, 1972) Stover & Evitt, 1978. The holotype for this species, listed by Gitmez & Sarjeant, was recorded from the Kimmeridgian section of the Warlingham Borehole. It is possible therefore, that the two specimens recorded here could by contaminants from higher sections of the borehole.

Occurrence Warlingham: 1 specimen from each of samples Br.727 and Br.465 L.Oxfordian (scarburghense).

Genus PALAEOSTOMOCYSTIS Deflandre, 1937 emend. Deflandre, 1966

Diagnosis Cysts ellipsoidal and reticulate, with narrow muri and small lumina that vary in size and shape; archaeopyle at apex, type uncertain, may have a thickened rim.

Type species Palaeostomocystis reticulata Deflandre, 1937

Palaeostomocystis tornatilis Drugg, 1978
(Pl.16, figs.1-3)

Diagnosis Drugg, 1978; p71; pl.7, figs.4-6

Description Intermediate size, flask-shape cyst, more-or-less elliptical in outline and varying from subcircular, through ovoidal to somewhat elongate. Cyst wall consists of a relatively thick autophragm only which thins towards the apex forming a narrow rim around the archaeopyle. The wall surface is slightly roughened or finely granular and may exhibit minor folding. The archaeopyle is a circular opening at the apex, presumed to be apical, although the type is uncertain. There are no indications of paratabulation.

Dimensions Overall length of cyst: 50-74 mu
Overall width of cyst: 40-58 mu
(6 specimens measured)

Remarks P.tornatilis is a readily recognisable species, the robust nature of the cyst wall makes for good preservation. Specimens identify closely with those described by Drugg (1978).

Occurrence Warboys: WB.83 to WB.18 (lamberti to praecordatum).
Warlingham: Br.1813 to Br.292 (calloviense to bulowskii).
Overall range: L.Callovian (calloviense) to L.Oxfordian (bulowskii).

Range Previously recorded from M.Callovian (coronatum) to L.Oxfordian (mariae) by Drugg, 1978. The range is therefore extended to: L.Callovian (calloviense) to L.Oxfordian (bulowskii) on the basis of this study.

Genus PARAGONYAULACYSTA Johnson & Hills, 1973

Diagnosis Cysts proximate, ellipsoidal, with an apical horn; paratabulation indicated by low parasutural ridges; autophragm smooth; archeopyle intercalary, type 2I.

Type species Paragonyaulacysta calloviensis Johnson & Hills, 1973

Paragonyaulacysta calloviensis Johnson & Hills, 1973
(Pl.16, figs.4,5)

Diagnosis Johnson & Hills, 1973; p207; pl.2,figs.9,15,16(not 13,17); text-fig.9

Description Small to intermediate proximate cyst, ellipsoidal in outline with a prominant, but short, apical horn. Cyst wall consists of autophragm only, which is smooth to faintly granular. Paratabulation indicated by low parasutural ridges, which at junctions with paracingulum bear short spines. Paratabulation formula: 2', 2a, 6", 6c, 6"', 1p, 1"". Paracingulum broad, laevorotatory. Parasulcus a longitudinally-elongate area between paraplates 1' and 1"", wider antapically than apically, bordered by parasutural ridges. Archaeopyle intercalary, type 2I; operculum free.

Dimensions
Overall length of cyst: 55 mu
Overall width of cyst: 45 mu
Length of apical horn: 10 mu
(1 specimen only)

Remarks A single specimen only encountered which clearly belongs to P.calloviensis. Although closely resembles species of Gonyaulacysta in its paratabulation and broad morphology, it is distinguished by the presence of an intercalary, rather than precingular, archaeopyle.

Occurrence Warlingham: Br.395 L.Oxfordian (praecordatum).

Range Previously recorded from Callovian only (Johnson & Hills, 1973). The range is tentatively extended to L.Oxfordian (praecordatum).

Genus PAREODINIA Deflandre, 1947b emend. Stover & Evitt, 1978

Synonyms
Paranelytron Sarjeant, 1966b
Imbatodinium Vozzhennikova, 1967
Glomodinium Dodekova, 1975

Diagnosis Cysts proximate to proximochorate, ellipsoidal with an apical horn only; paratabulation expressed incompletely by archaeopyle only, or by faint, discontinuous parasutural features; autophragm smooth or variously ornamented; archaeopyle intercalary, type 2I or 3I.

Type species Pareodinia ceratophora Deflandre, 1947b

Pareodinia ceratophora Deflandre, 1947b
(Pl.16, figs.13-15)

1947b Pareodinia ceratophora Deflandre: 4
1958 Pareodinia aphelia Cookson & Eisenack: 60
1960 Kalyptea monoceras Cookson & Eisenack: 257
1966b Paranetrelytron strongylum Sarjeant: 201
1967a Pareodinia (Palaeoperidinium) nuda (Downie, 1957) Sarjeant: 253
1975 Pareodinia ceratophora Deflandre; Wiggins: 103

Diagnosis Deflandre, 1947b; p4; text-figs. 1-3

Description Intermediate size proximate cyst, ellipsoidal to ellongate in outline with a long tapering apical horn, being at least half the length of the main cyst body in length. Cyst wall consists of autophragm only which varies from smooth to faintly granular, often folded. Paratabulation indicated by archaeopyle only. Archaeopyle intercalary, type 2-3I; operculum free. Kalyptra absent.

Dimensions Overall length of cyst: 68-99 mu
Overall width of cyst: 28-46 mu
Length of apical horn: 23-26 mu
(3 specimens measured)

Remarks P.ceratophora s.s., although very variable in form, is distinguished from its subspecies by the more elongate nature of the cyst and greater length of the apical horn. P. ceratophora subsp. pachyceras and P.ceratophora subsp. scopeus may well be morphological variants of P.ceratophora s.s., however, the subspecies are retained here.

Occurrence Warboys: WB. 188 to WB.28 (grossouvrei to praecordatum).
Warlingham: Br.1898 to Br.214 (calloviense to corsticardia).
Overall range: L.Callovian (calloviense) to L.Oxfordian (corsticardia).

Range Middle Jurassic to Lower Cretaceous.

Pareodinia ceratophora subsp. pachyceras (Sarjeant, 1959) Lentin & Williams, 1973
(Pl.16, figs. 16-19)

1959 Pareodinia ceratophora var. pachyceras Sarjeant: 337
1973 Pareodinia ceratophora subsp. pachyceras (Sarjeant) Lentin & Williams: 108

Diagnosis Sarjeant, 1959; p337; pl.13,fig.10; text-fig.5a

Description Small to intermediate proximate cyst, broadly ovoidal in outline with an apical horn of about one-third total cyst length. Cyst wall consists of autophragm only which is smooth to faintly granular, usually folded. An outer kalyptra is often present, incorporating sedimentary debris. Paratabulation indicated by archaeopyle only which is intercalary, type 2-3I; operculum free.

Dimensions Overall length of cyst: 50-80 mu
Overall width of cyst: 22-60 mu
Length of apical horn: 8-15 mu
(10 specimens measured)

Remarks This subspecies differs from P.ceratophora s.s. in being more broadly ovoidal, slightly smaller in size and having a shorter, more bluntly-rounded, apical horn. A kalyptra is never present in P.ceratophora s.s.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum); particularly abundant in L.Callovian.
Warlingham: Br.1898 to Br.140 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously recorded from ?Lower Callovian only (Lentin & Williams, 1977). The range is therefore tentatively extended to M.Oxfordian on the basis of this study.

Pareodinia ceratophora subsp. scopeus (Sarjeant, 1972) Lentin & Williams, 1973
(Pl.17, figs.1-5)

1972 Pareodinia ceratophora var. scopeus Sarjeant: 26
1973 Pareodinia ceratophora subsp. scopeus (Sarjeant) Lentin & Williams: 108

Diagnosis Sarjeant, 1972; p26; pl.2,fig.4

Description Small to intermediate proximate cyst, subspherical to ovoidal in outline with a small, bluntly-rounded, apical horn. Cyst wall consists of autophragm only which is smooth and often folded. Paratabulation indicated by archaeopyle only which is intercalary, type 2-3I; operculum free. Entire cyst often encapsulated in a kalyptra of variable thickness, with incorporated sedimentary debris.

Dimensions Overall length of cyst: 45-75 mu
Overall width of cyst: 32-50 mu
Length of apical horn: 7-9 mu
(8 specimens measured)

Remarks	This subspecies is distinguished from P.ceratophora s.s. and P.ceratophora subsp. pachyceras by its overall size, being much smaller. It also differs in having a more rounded cyst body and considerably reduced apical horn.

Occurrence	Warboys: WB.218 to WB.23 (calloviense to praecordatum).
Warlingham: Br.1813 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range	Late Bathonian to Early Callovian (Lentin & Williams, 1977). The range is therefore extended to M.Oxfordian (vertebrale) on the basis of this study.

Pareodinia alaskensis Wiggins, 1975
(Pl.16, figs.6-10)

Diagnosis Wiggins, 1975; p104; pl.2,figs.7,8

Description Intermediate size proximate cyst, ovoidal in outline with a relatively small, but distinct, apical horn. Cyst wall consists generally of autophragm only, some forms exhibiting a possible outer covering in the form of a periphragm, producing pericoels apically and antapically. Wall surface is medium to coarsely granular. Paratabulation indicated by archaeopyle only. Archaeopyle intercalary, type 3I; operculum free, composed of three, nearly equally-sized, paraplates. Indications of a paracingulum occasionally present. Apicular structure present in the form of a short, rod-like thickening.

Dimensions	Overall length of cyst: 60-92 mu
Overall width of cyst: 38-50 mu
(8 specimens measured)

Remarks	Although specimens are variable, the overall gross morphology identifies with the description of Wiggins (1975). P.brachythelis Fensome, 1979 is very similar in all but size and may be synonymous. Specimens are generally well preserved and the operculum remains intact in some. Wiggins does not refer to an outer cyst wall layer in the form of a periphragm; the presence of such a layer in certain specimens here may possibly emend the diagnosis.

Occurrence	Warlingham: Br.1255 to Br.194, U.Callovian (lamberti /athleta) to L.Oxfordian (corsticardia).

Range	Upper Jurassic (Callovian to Kimmeridgian).

Pareodinia cf. apotomocerastes Sarjeant, 1972
(Pl.16, figs.11,12)

Diagnosis Sarjeant, 1972; p27; pl.3,fig.4

Description Intermediate size proximate cyst, broadly ovoidal in outline with a short, pointed, broadly-based apical horn. Cyst wall consists of autophragm only which is coarsely-granular. Paratabulation indicated by archaeopyle only which is intercalary, type 2I; operculum free.

Dimensions Overall length of cyst: 53-60 mu
Overall width of cyst: 38-44 mu
(3 specimens measured)

Remarks Although specimens resemble P.apotomocerastes in their broad morphology, they differ in lacking a periphragm and are therefore here included in P.cf. apotomocerastes.

Occurrence Warboys: WB.212 to WB.188 lower to middle Callovian (enodatum to grossouvrei).

Range Bathonian to Early Callovian (Sarjeant, 1979).

Pareodinia prolongata Sarjeant, 1959
(Pl.17, figs.6-8)

Diagnosis Sarjeant, 1959; p335; pl.13,fig.8; text-fig.4

Description Intermediate to large proximate cyst, elongate-ovoidal in outline, with a prominant apical horn approximately equal to the theca in length. Cyst wall consists of autophragm only which is smooth and often folded. Paratabulation indicated by archaeopyle only, type ?2-3I; operculum free. A kalyptra may or may not be present.

Dimensions Overall length of cyst: 65-90 mu
Overall width of cyst: 25-42 mu
Length of apical horn: 21-37 mu
(4 specimens measured)

Remarks P.prolongata is distinguished from all other known species of Pareodinia by the length of the apical horn.

Occurrence Warboys: WB.228 to WB.103 (kamptus to upper athleta).
Warlingham: Br.1833 to Br.851 (calloviense to upper athleta/lamberti).
Overall range: L.Callovian (kamptus) to U.Callovian (upper athleta/lamberti).

Range Previously recorded from U.Bathonian to Callovian (Sarjeant, 1979)

Pareodinia warlinghamensis sp. nov.

(Pl.17, figs. 9-14,23; text-fig. 5.4)

Derivation of name: After the village of Warlingham, Surrey, from where this species was recorded for the first time.

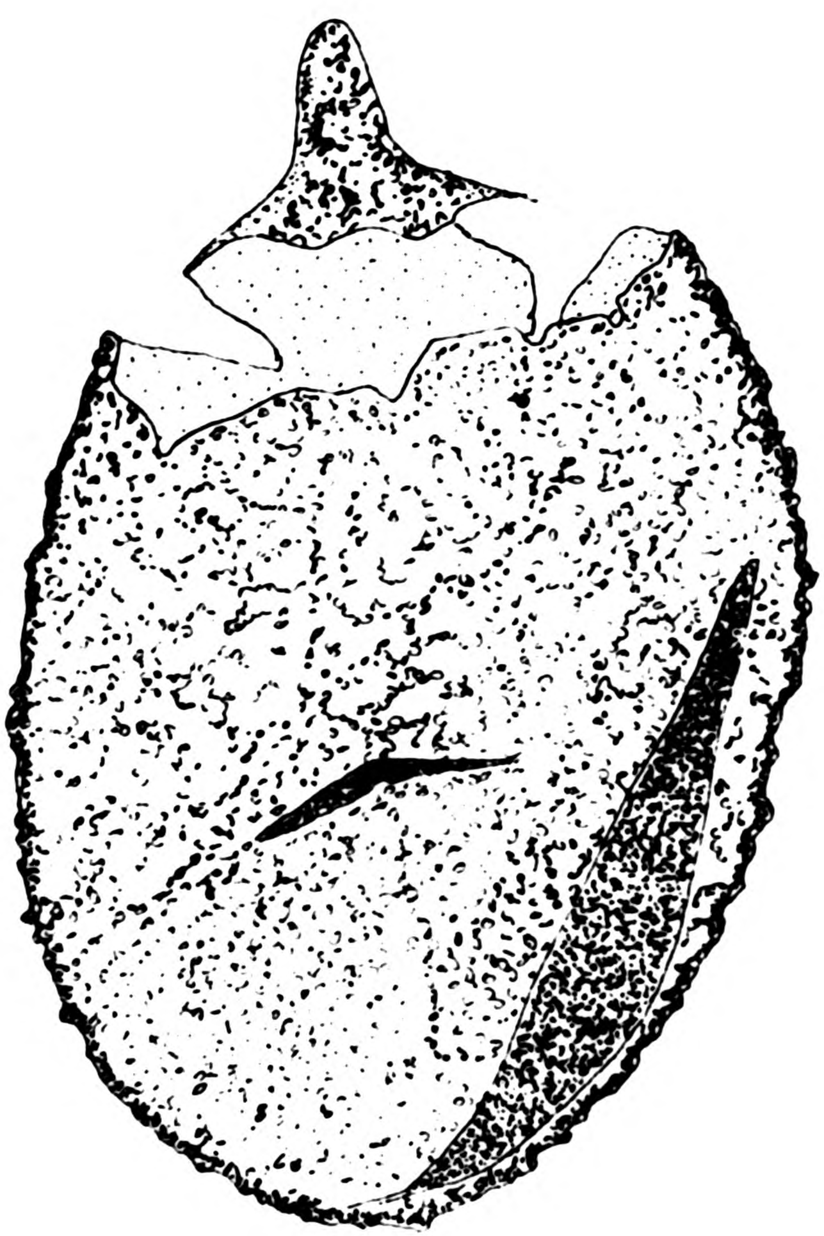
Holotype: Sample Br.1307; slide Br.1307a; 120/1334 (M420). Upper Callovian (lamberti / athleta), Warlingham Borehole. Plate 17, fig.14; text-fig. 5.4

Diagnosis Intermediate size proximate cyst, broadly ellipsoidal to elongate-ovoidal in outline; apical horn small to intermediate in length, bluntly-rounded. Autophragm only, coarsely-granular to rugose, often folded. Paratabulation lacking except for archaeopyle. Archaeopyle intercalary, type ?3I; operculum free. Kalyptra not observed.

Description A species of Pareodinia with an intermediate size proximate cyst; broadly ellipsoidal to elongate-ovoidal in outline. A prominant apical horn is present which varies in length between 8mu and 21mu; bluntly-rounded and uniform in width along its length. The cyst wall consists of autophragm only which is of moderate thickness (2-3mu) and often folded. The surface of the cyst is characteristically ornamented by coarse granulations, becoming rugose in some specimens. Paratabulation is completely lacking except for the archaeopyle. Archaeopyle intercalary; the type of archaeopyle is uncertain as an operculum has not been observed. The nature of the principle archaeopyle suture suggests that the operculum is formed of three paraplates (1a, 2a, and 3a), which would suggest a type 3I archeopyle. No kalyptra has been observed.

Dimensions	Holotype:	Overall length of cyst:	60mu
		Overall width of cyst:	40mu
		Length of apical horn:	8mu
		Width of apical horn:	4mu
	Range:	Overall length of cyst:	55-80mu
		Overall width of cyst:	32-42mu
		Length of apical horn:	8-21mu
		(9 specimens measured)	

Remarks The coarsely-granular to rugose nature of the cyst wall is characteristic of P.warlinghamensis sp.nov., as is the wide archaeopyle and apical horn of uniform thickness. This species differs from P.ceratophora subsp. pachyceras (Sarjeant, 1959) Lentin & Williams, 1973 in its surface ornamentation and lack of a kalyptra. It differs from P.alaskensis Wiggins, 1975 in lacking a mammelon-like apicular structure. Specimens are very well preserved.



Text-fig. 5.4 Pareodinia warlinghamensis sp. nov. X2250

Occurrence Warlingham: Br.1307 to Br.115, U.Callovian (lamberti / athleta) to M.Oxfordian (vertebrale).

Range U.Callovian (lamberti / athleta) to M.Oxfordian (vertebrale), as recorded herein.

Pareodinia wigginsi sp. nov.
(Pl.17, figs.15-18; text-fig. 5.5)

1975 Pareodinia sp.E Wiggins: 109

Derivation of name: After Virgil D. Wiggins of the Standard Oil Company of California, U.S.A., who first recorded this species.

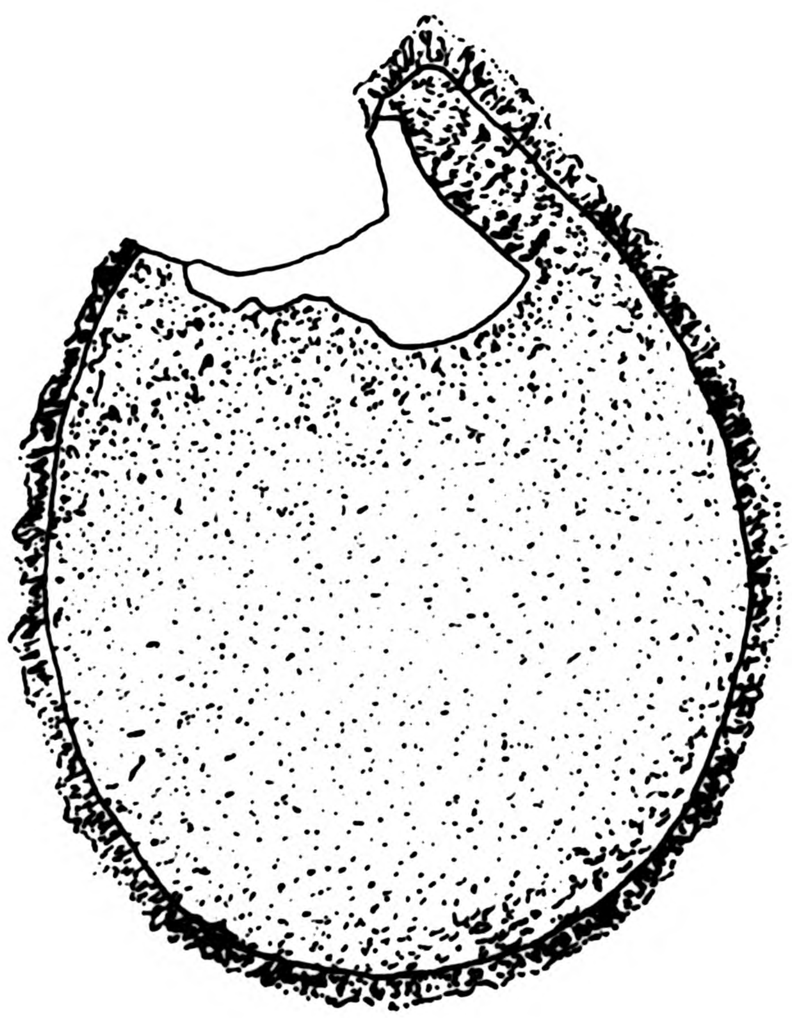
Holotype: Sample Br.727; slide Br.727a; 190/1363 (T400). L.Oxfordian (scarburghense), Warlingham Borehole. Plate 17, fig.15; text-fig. 5.5

Diagnosis A small to intermediate proximate cyst, spherical to ovoidal in outline tapering towards the apex to form a low apical projection. Autophragm only, very coarsely granular giving a fibrous appearance, not folded. Paratabulation indicated by archaeopyle only. Archaeopyle intercalary, type 3I; operculum free to attached. No kalyptra.

Description A distinctive species of Pareodinia having a small to intermediate size proximate cyst. Subspherical to ovoidal in outline, tapering towards the apex where a low apical protrusion or horn is formed. The overall appearance is 'tear'-shaped. Cyst wall consists of autophragm only which is very heavily ornamented with coarse granulations giving a fibrous appearance. Because of the thickness of the cyst wall (2-3mu) there is no folding, rather the cyst retains its original shape. Paratabulation is lacking on the main body of the cyst and expressed by the archaeopyle only. Archaeopyle intercalary, type 3I; the operculum is formed by paraplates 1a, 2a and 3a and either free or attached. Where the operculum is completely seperated, the walls of the cyst around the archaeopyle form slits, to give a zigzag principle archaeopyle suture. There is no kalyptra.

Dimensions	Holotype:	Overall length of cyst: 52mu
		Overall width of cyst: 40mu
	Range:	Overall length of cyst: 50-60mu
		Overall width of cyst: 40-50mu
		(4 specimens measured)

Remarks The coarsely-granular surface ornamentation of the cyst, together with the very low apical horn are characteristic of P.wigginsi sp.nov.



Text-fig. 5.5 Pareodinia wigginsi sp. nov. X2125

This species is almost certainly that described as 'Pareodinia sp.E' by Wiggins (1975, p109; pl.3, figs.6,7). There is however, no rod-like apicular stucture as described by Wiggins, although he states that this feature may or may not be present. The specimens here are also slightly smaller than the two specimens described by Wiggins. The thickness of the cyst wall makes the cyst very robust and specimens are generally well preserved with no dorso-ventral flattening.

Occurrence Warlingham: Br.1006 to Br.170 U.Callovian (lamberti / athleta) to L.Oxfordian (cordatum). Essentially a L.Oxfordian species.

Range U.Callovian (lamberti / athleta) to L.Oxfordian (cordatum), as recorded herein. Wiggins' Pareodinia sp.E is recorded as U.Jurassic.

Pareodinia sp.B
(Pl.17,fig.19; text-fig. 5.6)

Description A small proximate cyst, elongate-ovoidal in outline, tapering towards the apex to form a short, pointed apical horn. The overall appearance is that of an elongate-droplet. Cyst wall consists of autophragm only which is thin and ornamented with large granulations in the form of verrucae, scattered irregularly over the entire cyst. Paratabulation expressed by archaeopyle only which is large. Archaeopyle compound intercalary, type ?3I; operculum free.

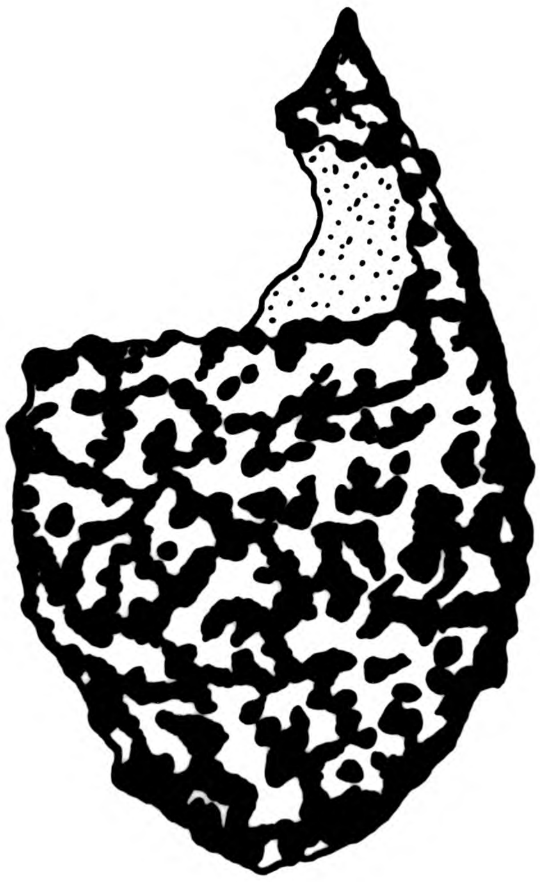
Dimensions Overall length of cyst: 45 mu
Overall width of cyst: 26 mu
(1 specimen only)

Remarks Although only a single specimen was encountered the broad morphology clearly enables this species to be placed with Pareodinia. It resembles P.verrucosa (Vozzhennikova, 1967) Wiggins, 1975 in its ornamentation but differs in the nature of the apical horn and in lacking paratabulation features and an antapical structure.

Occurrence Warlingham: a single specimen from Br.560, L.Oxfordian (scarburghense).

Genus PLURIARVALIUM Sarjeant, 1962b

Diagnosis Cysts proximate, ellipsoidal, with an apical horn; paratabulation indicated by low to moderately high parasutural ridges delimiting numerous preapical and posterior intercalary paraplates in addition to precingular, paracingular and postcingular paraplates; archaeopyle intercalary, type I or 3I.



Text-fig. 5.6 Pareodinia sp.B X2100

Type species Pluriarvalium osmingtonense Sarjeant, 1962b

Pluriarvalium osmingtonense Sarjeant, 1962b
(Pl.17, figs. 20,21)

1962b Pluriarvalium osmingtonense Sarjeant: 262
1975 Pareodinia osmingtonense (Sarjeant) Wiggins: 105
1978 Pluriarvalium osmingtonense Sarjeant; Stover & Evitt: 119

Diagnosis Sarjeant, 1962b; p262; pl.1,fig.5; text-fig.6

Description Intermediate size proximate cyst, ovoidal in outline with a prominant apical horn. Epicyst and hypocyst are approximately equal. The apical horn is broadly-based and tapers to a point; antapically the cyst is broadly-rounded. Cyst wall consists of autophragm only which is smooth to finely granular. Paratabulation indicated by low parasutural ridges giving a possible formula: 7acl, 6', 6a, 6", 7c, 7"', 3"", plus a certain number of parasulcal paraplates and posterior intercalary paraplates. Archaeopyle intercalary and may be either type I or 3I. Apicular structure commonly present. Kalyptra occasionally evident and usually fragmental.

Dimensions Overall length of cyst: 48-57 mu
Overall width of cyst: 33-45 mu
(4 specimens measured)

Remarks P.osmingtonense is characterised by the complex nature of the pareodiniacean paratabulation, although complete paratabulation is apparently never present on any one cyst, the paratabulation formulae given by Sarjeant, 1962b and Wiggins, 1975 being hypothetical. It superficially resembles Paragonyaulacysta calloviense Johnson & Hills, 1973 but is distinguished by its less-rounded outline and complex paratabulation.

Occurrence Warboys: WB.224, L.Callovian (koenigi); a single specimen.
Warlingham: Br.683 to Br.543 L.Oxfordian (scarburghense).
Overall range: L.Callovian (koenigi) to L.Oxfordian (scarburghense).

Range Previously recorded from M.Oxfordian only (Sarjeant, 1979). The range is therefore tentatively extended to the L.Callovian (koenigi).

Pluriarvalium cf.osmingtonense Sarjeant, 1962b
(Pl.17, fig.22)

Description Intermediate size proximate cyst, ovoidal to subquadrate in outline with a prominant apical horn which tapers distally to a point. Cyst wall consists of autophragm only which is smooth to faintly granular.

Paratabulation expressed by the intercalary archaeopyle only, although indication of a paracingulum at the cyst's widest point is discernible.

Dimensions   Overall length of cyst: 63 mu
Overall width of cyst: 43 mu
Length of apical horn: 10 mu
(1 specimen only)

Remarks   Although surface features are generally lacking, the broad morphology fits the description of Pluriarvalium and is therefore tentatively placed within P.cf.osmingtonense.

Occurrence   Warboys: a single specimen from WB.224, L.Callovian (koenigi), with a further questionable occurrence in WB.43, L.Oxfordian (scarburghense).

Pluriarvalium sp.A
(Pl.18, fig.1)

Description   Intermediate size proximate cyst, ellipsoidal in outline with a prominant apical horn. Cyst wall consists of autophragm only which is densely granular. The apical horn is broadly-based and tapers rapidly to a rounded point with an apicular structure; it is hollow and about one-fifth the length of the cyst body. Paratabulation is expressed in the form of pandasutural features, a formula difficult to determine exactly: ?', 6", Xc, 5-6"', 1"". The archaeopyle is compound intercalary, probably type 3I; operculum free.

Dimensions   Overall length of cyst: 70 mu
Overall width of cyst: 38 mu
Length of apical horn: 15 mu
(1 specimen only)

Remarks   Although only a single specimen, preservation is good. The coarsely-granular surface and pandasutural features are characteristic. The species is only tentatively placed within Pluriarvalium and is quite probably a new genus.

Occurrence   Warboys: a single specimen from WB.228, L.Callovian (kamptus).

Genus   POLYSPHAERIDIUM Davey & Williams, 1966

Diagnosis   Cysts skolochorate, body subspherical with numerous hollow, nontabular processes of similar size and shape, which are normally open distally; indications of paratabulation other than archaeopyle characteristically lacking; archaeopyle apical, type $\overline{tA}$.

Type species Polysphaeridium subtile Davey & Williams, 1966

Polysphaeridium deflandrei (Valensi, 1947) Davey & Williams, 1969
(Pl.18, figs. 2-4)

1947 Hystrichosphaeridium deflandrei Valensi: 817
1969 ?Polysphaeridium deflandrei (Valensi) Davey & Williams: 6

Diagnosis Valensi, 1947; p817; text-fig.3

Description Small skolochorate cyst, subspherical in outline with numerous processes. Cyst wall consists of autophragm only which is smooth. Processes are hollow, open distally and stepped to give a 'telescopic' appearance. Minute spines are present at the distal termination of the processes (being orthogonal) and at the stepped point along their length. Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$ and rarely discernible.

Dimensions Diameter of central body: 15-18 mu
Length of processes: 4-5 mu
(4 specimens measured)

Remarks The size and 'telescopic' appearance of the processes distinguish P.deflandrei from other known species of Polysphaeridium. The generic assignment of this species has been questioned by both Davey & Williams (1969) and Stover & Evitt (1978) on the grounds that the apical archaeopyle has never been observed. At least one specimen here (pl.18, fig.2) has an apical archaeopyle with the operculum remaining attached; the generic assignment can therefore be no longer questioned on these grounds.

Occurrence Warboys: WB.88 to WB.43 (lamberti to scarburghense).
Warlingham: Br.1898 to Br.140 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Has previously been described from the middle Jurassic only (Sarjeant, 1979). The presence of P.deflandrei here therefore extends the known range to M.Oxfordian (vertebrale).

Genus POLYSTEPHANEPHOROUS Sarjeant, 1961b

Diagnosis Cysts skolochorate, subspherical in outline with groups of processes arising from the autophragm arranged in set patterns at constant intervals over the cyst surface. Processes are linked distally by ring-trabeculae. Paratabulation possibly expressed by process groups; unknown formula. Archaeopyle unknown.

Type species Polystephanephorous calathus (Sarjeant, 1961b) Downie & Sarjeant, 1964.

Polystephanephorous paracalathus (Sarjeant, 1960a) Downie & Sarjeant, 1964.
(Pl.18, figs.5-8)

1960a Polystephanosphaera paracalathus Sarjeant: 143
1964 Polystephanephorous paracalathus (Sarjeant) Downie & Sarjeant:141

Diagnosis Sarjeant, 1960a; p143; pl.6,fig.4; text-fig.3b

Description Small to intermediate skolochorate cyst with a spherical to subspherical central body. Cyst wall consists of autophragm only which is smooth and gives rise to a series of groups of processes which are spaced at regular intervals over the cyst body. The processes are hollow, each group containing from 3 to 8 individual processes, linked distally by ring-trabeculae. The ring-trabeculae are formed by the bifurcating of each process at its distal end linking with its neighbouring process, thus forming a ring-like structure which tends to funnel outwards. The whole structure appearing like a skeletal vase with a bell mouth. Each group of processes are linked to their neighbouring group by a trabecula. Paratabulation pressumably expressed by the process-groups; formula uncertain. Archaeopyle type uncertain.

Dimensions Diameter of central body: 37-65 mu
Length of processes: 20-23 mu
(4 specimens measured)

Remarks P.paracalathus is a distinctive species and is distinguished from P.calathus (Sarjeant, 1961b) Downie & Sarjeant, 1964 by the presence of linking trabeculae between the process-groups. Although the exact nature of the archaeopyle has not been described, at least one specimen here (pl.18, fig.8) exhibits an apical archaeopyle with a somewhat ragged principle archaeopyle suture.

Occurrence Warboys: WB.224, L.Callovian (koenigi), a single specimen.
Warlingham: Br.1898 to Br.500 (calloviense to scarburghense).
Overall range: L.Callovian (koenigi) to L.Oxfordian (scarburghense).

Range Previously recorded from M.Callovian (jason) to L.Oxfordian (mariae). The known range is therefore extended to L.Callovian (koenigi) on the basis of this study.

Genus PROLIXOSPHAERIDIUM Davey et.al., 1966 emend. Davey, 1969

Diagnosis Cysts proximochorate to skolochorate, body elongate ellipsoidal with numerous nontabular processes that are normally simple and closed distally; archaeopyle apical, type $\overline{tA}$.

Type species Prolixosphaeridium parvispinum (Cookson & Eisenack, 1958) Davey et.al., 1966

Prolixosphaeridium granulosum (Deflandre, 1937) Davey et.al., 1966
(Pl.18, figs.9-12)

1937 Hystrichosphaeridium xanthiopyxides var. granulosum Deflandre:29
1960 Baltisphaeridium xanthiopyxides var. granulosum (Deflandre) Klement: 59
1962b Baltisphaeridium granulosum (Deflandre) Sarjeant: 264
1966 Prolixosphaeridium granulosum (Deflandre) Davey et.al: 172

Diagnosis Deflandre, 1937; p29; pl.16, fig.4

Description Intermediate size, proximate cyst; elongate-ellipsoidal in outline. Cyst wall consists of autophragm only which is granulose and gives rise to a number of nontabular processes. Processes are simple, acuminate and closed distally; they may be either straight or slightly sinuous. Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$; operculum free to attached.

Dimensions Overall length of cyst: 40-57 mu
Overall width of cyst: 27-36 mu
Length of processes: 11-15 mu
(8 specimens measured)

Remarks P.granulosum is distinguished from all other species of Prolixosphaeridium by the nature and number of the nontabular processes and the finely-granular texture of the cyst wall. Specimens are generally well preserved, often with the operculum attached. Where the operculum is free, the principle archaeopyle suture is zigzag.

Occurrence Warboys: WB.88 to WB.23 (lamberti to praecordatum).
Warlingham: Br.785 to Br.115 (scarburghense to vertebrale).
Overall range: U.Callovian (lamberti) to M.Oxfordian (vertebrale).

Range Previously described from Middle Jurassic to Lower Cretaceous (? Lower Eocene).

Genus REUTLINGIA Drugg, 1978

Diagnosis Cyst small and ovoidal with a deeply incised paracingulum. The parasulcus is clearly expressed. Broad based acuminate spines crudely delineate a paratabulation which is seemingly

1', 5", 0c, 5"', 1"". The archaeopyle is probably apical. (From Drugg, 1978, p72)

Type species Reutlingia gochtii Drugg, 1978

Reutlingia gochtii Drugg, 1978
(Pl.18, figs.13-15)

Diagnosis Drugg, 1978; p72; pl.7,fig.7-10

Description Small proximate cyst, ovoidal to rectangular in outline with a deeply-incised paracingulm. Cyst wall consists of autophragm only which is smooth and gives rise to a series of broadly-based acuminate projections about 4mu in length and open to the interior of the cyst. Some specimens exhibit clusters of projections which are connected proximally. Paratabulation is probably 1', 5", 0c, 5"', 1"". Archaeopyle is apparently apical.

Dimensions Overall length of cyst: 28 mu
Overall width of cyst: 23 mu
(2 specimens measured)

Remarks During examination of material, R.gochtii was originally recorded as 'algae', either present or absent. Its affinities to a dinoflagellate cyst was not recognised until Drugg's paper of 1978 was investigated. R.gochtii is recorded as present or absent for range-chart purposes. (The exact location of the figured specimens is unknown).

Occurrence Warboys: WB.211 to WB.88 (medea to lamberti).
Warlingham: Br.1723 to Br.500 (medea to scarburghense).
Overall range: M.Callovian (medea) to L.Oxfordian (scarburghense).

Range Drugg (1978) records R.gochtii from U.Callovian (athleta) only. The known range is therefore extended to: M.Callovian (medea) to L.Oxfordian (scarburghense). The occurrence here also marks the first record of R.gochtii from Great Britain.

Genus SCRINIOCASSIS Gocht, 1964

Diagnosis Cysts proximate, holocavate, subspherical to ellipsoidal; space between autophragm and ectophragm occupied by an imperfect reticulation; height of muri varies; archaeopyle precingular, exact type uncertain; apparently specimens with type P, 2P or possibly 3P included in the genus.

Type species Scriniocassis weberi Gocht, 1964

Scriniocassis dictyotus (Cookson & Eisenack, 1960) Beju, 1971
(Pl.19, figs.1-4)

1960 Scriniodinium dictyotum Cookson & Eisenack: 248
1971 Scriniocassis dictyotus (Cookson & Eisenack) Beju: 299

Diagnosis Cookson & Eisenack, 1960; p248; pl.37,fig.9

Description Intermediate to large holocavate cyst, subspherical to ovoidal in outline. Space between wall layers occupied by irregular reticulum giving a 'honeycomb' appearance. Ectophragm smooth or faintly ornamented, often extended to form a broadly-based, blunt, short apical projection. Broad paracingulum dividing cyst into two equal halves. Archeopyle precingular, type P; operculum free.

Dimensions Overall length of cyst: 81-88 mu
Overall width of cyst: 78-86 mu
(4 specimens measured)

Remarks Specimens identify closely with the original diagnosis of Cookson & Eisenack (1960), although are slightly smaller here. S.dictyotus differs from Sciniodinium crystallinum (Deflandre, 1938) Klement, 1960 in possessing the supporting reticulum between wall layers.

Occurrence Warlingham: Br.465 to Br.214, L.Oxfordian (scarburghense to praecordatum).

Range Callovian to Kimmeridgian (Sarjeant, 1979)

Genus SCRINIODINIUM Klement, 1957

Synonym Endoscrinium (Klement, 1960) Vozzhennikova, 1967

Diagnosis Cysts proximate, generally circumcavate, lenticular to subellipsoidal, with or without an apical horn and/or a medial antapical elongation; paratabulation indicated by archaeopyle and paracingulum, additionally by low parasutural ridges on some forms; archeopyle precingular, type P.

Type species Scriniodinium crystallinum (Deflandre, 1938) Klement, 1960

Scriniodinium crystallinum (Deflandre, 1938) Klement, 1960
(Pl.19, figs.5,6; Pl.20, figs.1-4)

1938 Gymnoidinium crystallinum Deflandre: 165
1960 Scriniodinium crystallinum (Deflandre) Klement: 18

Diagnosis Deflandre, 1938; p165; pl.5,figs.1-3

Description Intermediate to large, holocavate cyst; lenticular to subellipsoidal, 'kite'-shaped in outline, with a subspherical central body. Endophragm and periphragm distinct, smooth, with a cavity between the two layers; cavity usually larger apically and antapically, forming short, broadly-rounded protrusions. Paratabulation indicated by archaeopyle and paracingulum only. Archaeopyle precingular, type P (3" only); operculum free. Paracingulum broad and deep, dividing the cyst into two equal halves.

Dimensions   Overall length of cyst: 71-90 mu
Overall width of cyst: 58-80 mu
(9 specimens measured)

Remarks   A distinctive species, usually well preserved.

Occurrence   Warboys: WB.88 to WB.18 (lamberti to praecordatum).
Warlingham: Br.884 to Br.115 (lamberti/athleta to vertebrale).
Overall range: U.Callovian (lamberti) to M.Oxfordian (vertebrale).

Range   L.Callovian to L.Kimmeridgian (Sarjeant, 1979).

Scriniodinium cf. crystallinum (Deflandre, 1938) Klement, 1960
(Pl.19, figs.7-9)

Description   Intermediate size, holocavate cyst, ovoidal to subellipsoidal in outline. Cyst wall consists of endophragm and periphragm with a narrow cavity between the two layers. A larger cavity is often formed apically and usually antapically. Surface of endophragm appears to be irregularly reticulate or granular. Periphragm smooth. Paratabulation indicated by archaeopyle and paracingulum only. Archaeopyle precingular, type P (3" only). Paracingulum fairly broad, dividing the cyst into two equal halves.

Dimensions   Overall length of cyst: 65-72 mu
Overall width of cyst: 52-67 mu
(4 specimens measured)

Remarks   Similar to S.crystallinum in gross morphology but differs in the surface ornamentation of the endophragm and in being slightly smaller.

Occurrence   Warboys: WB.178 (lower athleta) only.
Warlingham: Br.1330 to Br.443 (athleta to praecordatum).
Overall range: U.Callovian (athleta) to L.Oxfordian (praecordatum).

Scriniodinium galeritum (Deflandre, 1938) Klement, 1960
(Pl.20, figs.5-7)

1938   Gymnoidinium galeritum Deflandre: 167
1960   Scriniodinium galeritum (Deflandre) Klement: 22

Diagnosis   Deflandre, 1938; p167; pl.5,figs.7-9; pl.6,fig.1

Description Intermediate to large proximate cyst, holocavate in form, lenticular to subquadrate in outline. Endophragm broadly-rounded, smooth; periphragm thin and faintly to coarsely granular, extended apically and antapically to form short, broadly-based, rounded extensions with larger cavities. Paratabulation indicated by fold-like crests on periphragm, to give apparent formula: 3-?4', 6", 5"', 0p, 0"". Archaeopyle precingular, type P (3" only); operculum free. Paracingulum indicated by parallel, transverse, parasutural ridges, generally shallow and dividing the cyst into two unequal halves; the epicyst forming about one-third and the hypocyst about two-thirds of the total cyst.

Dimensions Overall length of cyst: 74-113 mu
Overall width of cyst: 61-101 mu
(13 specimens measured)

Remarks S.galeritum is distinguished from S.crystallinum (Deflandre, 1938) Klement, 1960 by the characteristically granular periphragm and folded parasutural crests. Specimens are particularly well-preserved.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range L.Callovian (?Bajocian) to L.Kimmeridgian (Sarjeant, 1979).

Scriniodinium luridum (Deflandre, 1938) Klement, 1960
(Pl.21, figs.2,3)

1938 Gymnoidinium luridum Deflandre: 166
1960 Scriniodinium luridum (Deflandre) Klement: 20

Diagnosis Deflandre, 1938; p166; pl.5,figs.4-6

Description Intermediate size holocavate cyst, broadly-rounded to subquadrate in outline. Endophragm rounded and smooth; periphragm thin, faintly granular with large ellipsoidal perforations. Periphragm slightly extended apically to form a short, angular, truncated protrusion; antapically to form a slightly broader, truncated protrusion. Paratabulation indicated by very low parasutural crests, formula: 3-?4', 6", 5"', 1p, 0"". Archaeopyle precingular, type P (3" only); operculum free. Paracingulum and parasulcus faintly discernible.

Dimensions Overall length of cyst: 62-71 mu
Overall width of cyst: 65-90 mu
(3 specimens measured)

Remarks Characterised by its broadly-rounded to subquadrate outline and large perforations in the periphragm. The antapical protrusion is also distinctive.

Occurrence Warlingham: Br.246 to Br.115 L.Oxfordian (corsticardia) to M.Oxfordian (vertebrale).

Range Previously described from M.Callovian to L.Kimmeridgian (Sarjeant, 1979).

Scriniodinium subvallare Sarjeant, 1962b
(Pl.21, figs.4-7; Pl.22, fig.1)

Diagnosis Sarjeant, 1962b; p262; pl.1,fig.10; text-fig.7

Description Small to intermediate proximate cyst, holocavate in form, rounded to polygonal in outline. Endophragm smooth to granular; periphragm smooth with large, isolated perforations. Periphragm often extended apically to form a short spine with a secondary pointed spine distally. Paratabulation indicated by high, striated, denticulate crests, formula: ?4', 6", 6"', 0p, 0-?1"". Archaeopyle precingular, type P (3" only); operculum free. Paracingulum narrow, laevorotatory; parasulcus wide.

Dimensions Overall length of cyst: 55-68 mu
Overall width of cyst: 55-67 mu
(6 specimens measured)

Remarks A distinctive species of Scriniodinium, the yellowish-brown body colour being characteristic. Specimens identify closely with the original diagnosis of Sarjeant (1962b) although he fails to describe any apical structure; he also records no antapical paraplate (1"") which is clearly present in some specimens here. S.subvallare is distinguished from S.luridum (Deflandre, 1938) Klement, 1960 by its characteritically high, striate, denticulate parasutural crests.

Occurrence Warboys: WB.183 to WB.18 (lower athleta to praecordatum).
Warlingham: Br.976 to Br.246 (athleta to corsticardia).
Overall range: U.Callovian (athleta) to L.Oxfordian (corsticardia).

Range Previously described from middle and upper Oxfordian (Sarjeant, 1962b and 1979). The range is therefore extended to U.Callovian (athleta) on the basis of the present study.

Scriniodinium sp.A

(Pl.20, fig.8; Pl.22, figs.3,4)

1978 Endoscrinium sp Muir & Sarjeant: 202

Description Small to intermediate size proximate cyst, holocavate in form, subpolygonal to rhomboidal in outline. Endophragm smooth to finely-granular, roundly reflecting the periphragm in shape. Periphragm smooth, with short apical horn which is broadly-based, surmounted by a secondary spine. A broadly-rounded antapical protrusion is developed. Paratabulation indicated by high,denticulate parasutural crests; formula: 4', 0a, 6", 6-?7c, 5"', 1p, 1"". Archaeopyle precingular, type P (3" only); operculum free. Paracingulum narrow, stongly laevorotatory. Parasulcus fairly broad.

Dimensions Overall length of cyst: 54-58 mu

Overall width of cyst: 43-52 mu

(3 specimens measured)

Remarks Three specimens only were encountered, two of which are poorly-preserved. The well-preserved specimen (pl.20, fig.8) is almost identical with Endoscrinium sp. of Muir & Sarjeant (1978). It is broadly similar to S.subvallare Sarjeant, 1962b but differs in having a more complex paratabulation. The 'false archaeopyle' recorded by Muir & Sarjeant, occurring on paraplates other than 3" are also seen here, although it seems more likely that these are areas where the endophragm and periphragm come into contact.

Occurrence Warlingham: Br.1006 to Br.194, U.Callovian (athleta) to L.Oxfordian (praecordatum), three specimens only.

Range The specimens recorded by Muir & Sarjeant (1978) are from the M.Callovian (coronatum).

Scrniodinium sp.B

(Pl.22, fig.2)

Description Intermediate size cavate cyst, subquadrate in outline. Endophragm finely granulate; periphragm smooth and seperated from the endophragm apically and antapically. Projections are formed apically and antapically by an extension of the periphragm; broadly rounded antapically and more pointed apically. Paratabulation indicated by archaeopyle and paracingulum only. Archaeopyle precingular, type P (3" only); operculum free. Paracingulum faintly discernible at mid point on the cyst.

Dimensions Overall length of cyst: 65 mu

Overall width of cyst: 55 mu

(1 specimen only)

Remarks Scriniodinium sp B differs from Scriniodinium sp.A in lacking paratabulation features. It may be a distorted form of S.luridum (Deflandre, 1938) Klement, 1960.

Occurrence Warlingham: a single specimen only from Br.1006, U.Callovian (athleta).

Genus SENONIASPHAERA Clarke & Verdier, 1967

Diagnosis Cysts proximate, circumcavate, lenticular to compressed peridinioid; lateral protrusions may be present; paratabulation probably gonyaulacacean, indicated incompletely by parasutural features; archaeopyle apical, type $\overline{tA}$; parasulcal notch offset.

Type species Senoniasphaera protrusa Clarke & Verdier, 1967

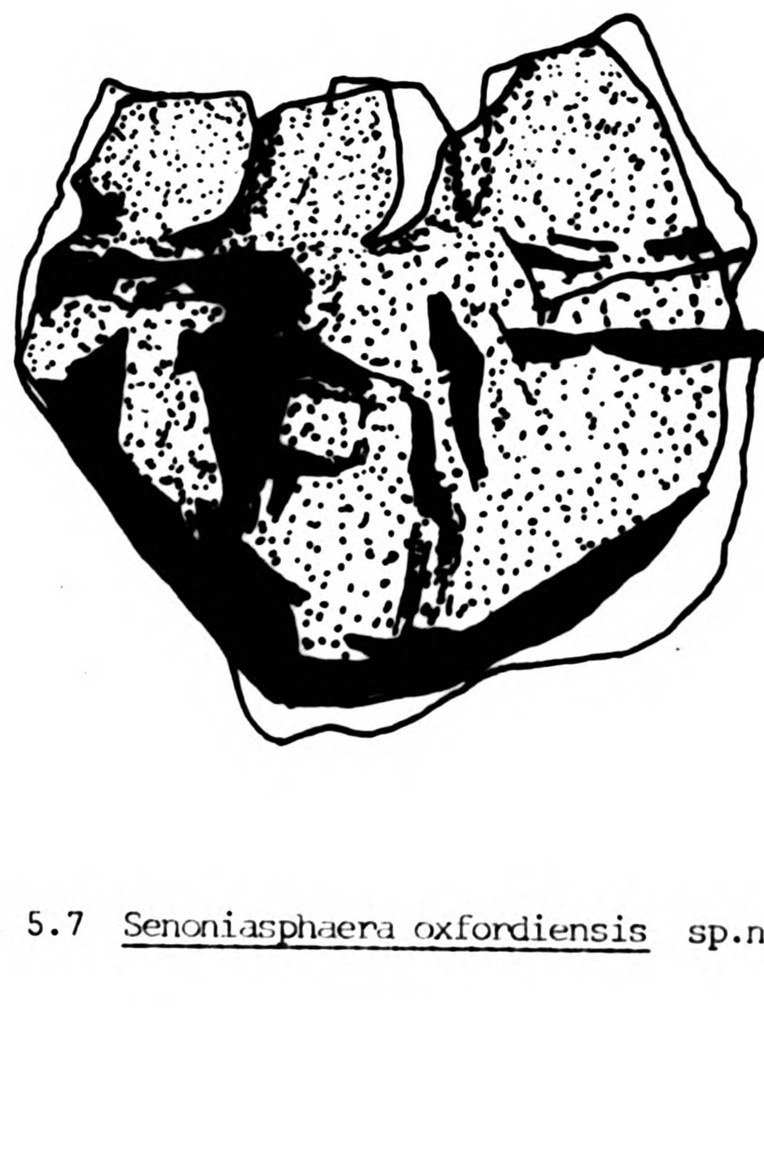
Senoniasphaera oxfordiensis sp. nov.
(Pl.22, figs.5-8; text-fig. 5.7)

Derivation of name: After the Oxfordian Stage, from which this species was first recorded.

Holotype: Sample Br.683; slide Br.683a; 165/1284 (R482). Lower Oxfordian (scarburghense), Warlingham Borehole. Plate 22, figs.6a,b; text-fig. 5.7

Diagnosis Small proximate cyst, circumcavate in form, broadly-rounded to subcircular in outline. Endophragm finely granular; periphragm smooth not usually extended antapically. Paratabulation incomplete, probably gonyaulacacean, indicated by parasutural features and apical archaeopyle. Archaeopyle apical, type $\overline{tA}$ with zigzag principle archaeopyle suture and parasulcal notch; operculum free. Paracingulum broad.

Description A small species of Senoniasphaera having a proximate cyst, circumcavate in form. The outline is broadly-rounded to subcircular, usually lacking any apical or antapical structures, although a few specimens tentatively assigned to this species exhibit a short, broad antapical projection (Pl.22, fig.5). Apex lost in archaeopyle formation. The cyst wall consists of two layers, the inner endophragm is finely granular in texture; the outer periphragm smooth and thinner; the two layers lie in close proximity to each other so that only a narrow cavity is formed. Paratabulation is present but incompletely expressed by parasutural features; six precingular paraplates are usually discernible; parasutural features on the hypocyst are vague and inconsistent. The archaeopyle is apical, type $\overline{tA}$; principle archaeopyle suture is zigzag with an offset parasulcal notch. The operculum is free and possibly consists of four apical paraplates. A paracingulum is always present and usually broad (5mu in holotype), occurring at the mid-point on the cyst.



Text-fig. 5.7 Senoniasphaera oxfordiensis sp.nov. X2250

Dimensions   Holotype: Overall length of cyst: 33mu
Overall width of cyst: 37mu
Width of paracingulum: 5mu

Range: Overall length of cyst: 33-55mu
Overall width of cyst: 37-53mu
(5 specimens measured)

Remarks   S.oxfordiensis sp.nov., is unlike previously described species of Senoniasphaera in that it typically lacks development of apical and antapical structures. However, the Kimmeridgian species S.jurassica (Gitmez & Sarjeant, 1972) Lentin & Williams, 1976, although morphologically similar, is in fact almost twice the size of S.oxfordiensis. It is possible that S.oxfordiensis may be ancestral to S.jurassica. Specimens are generally well preserved, although the operculum is consistently lost in archaeopyle formation.

Occurrence   Warlingham: Br.693 to Br.115, L.Oxfordian (scarburghense) to M.Oxfordian (vertebrale).

Range   L.Oxfordian (scarburghense) to M.Oxfordian (vertebrale), as recorded herein.

Genus   SENTUSIDINIUM Sarjeant & Stover, 1978

Diagnosis   Cysts proximate to proximochorate; subspherical autophragm bears numerous short, generally evenly distributed, normally isolated, nontabular projections; archaeopyle apical, type $\overline{tA}$.

Type species   Sentusidinium rioultii (Sarjeant, 1968) Sarjeant & Stover,1978

Sentusidinium rioultii (Sarjeant, 1968) Sarjeant & Stover,1978
(P122, figs.14-17)

1968   Tenua rioultii Sarjeant: 231
1978   Sentusidinium rioultii (Sarjeant) Sarjeant & Stover: 50

Diagnosis   Sarjeant, 1968; p231; pl.1,figs.12,22; pl.2,figs.1,2,4

Description   Intermediate size proximate cyst, broadly-ovoidal in outline. Cyst wall consists of autophragm only, bearing numerous, well-spaced, non-tabular spines which vary in length although are generally quite short. The spines vary in both thickness and form; they may be capitate, bifurcate, trifurcate etc. Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$. Principle archaeopyle suture zigzag. Paracingulum sometimes faintly discernible.

Dimensions   Overall length of cyst: 45-70 mu

Overall width of cyst: 50-76 mu
(9 specimens measured)

Remarks S.rioultii is differentiated from S.villersense (Sarjeant, 1968) Sarjeant & Stover, 1978 in having fewer spines which are greater in length and more variable in character.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (praecordatum).

Range Previously recorded from U.Bathonian to L.Oxfordian (Sarjeant, 1979). The range is therefore extended to M.Oxfordian (vertebrale) on the basis of this study.

Sentusidinium pilosum (Ehrenberg, 1843) Sarjeant & Stover, 1978
(Pl.22, figs.9-13)

1843	Xanthidium pilosum Ehrenberg: 61
1904	Ovum hispidum (Xanthidium) pilosum (Ehrenberg) Lohmann: 21
1933	Hystrichosphaera pilosa (Ehrenberg) O.Wetzel: 43
1937	Hystrichosphaeridium pilosum (Ehrenberg) Deflandre: 79
1961a	Baltisphaeridium pilosum (Ehrenberg) Sarjeant: 101
1966	Cleistosphaeridium pilosum (Ehrenberg) Davey et.al: 170
1968	Tenua pilosa (Ehrenberg) Sarjeant: 231
1978	Sentusidinium pilosum (Ehrenberg) Sarjeant & Stover: 50

Diagnosis Sarjeant, 1968; p231; pl.2,fig.7

Description Small proximate cyst, elongate-ovoidal to ellipsoidal in outline. Apex generally lost in archaeopyle formation. Cyst wall consists of autophragm only with numerous, evenly-distributed, isolated, nontabular spines which are short, tapering distally where they are pointed or capitate and always closed. Paratabulation indicated by archaeopyle only. Archaeopyle apical, type $\overline{tA}$; principle archaeopyle suture zigzag; operculum free to attached.

Dimensions Overall length of cyst: 25-48mu
Overall width of cyst: 30-40mu
(6 specimens measured)

Remarks A characteristic and readily recognisable species of Sentusidinium. The small size and ellipsoidal outline are characteristic.

Occurrence Warboys: WB.224 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.118 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously described from M.Callovian (coronatum) to

U.Kimmeridgian (Sarjeant, 1979). The known range is therefore extended to L.Callovian (kamptus) on the basis of this study.

Sentusidinium varispinosum (Sarjeant, 1959) Sarjeant & Stover, 1978
(Pl.22, figs.18,19; Pl.23,fig.1)

1959 Baltisphaeridium varispinosum Sarjeant: 338
1972 Tenua varispinosa (Sarjeant) Sarjeant: 43
1978 Sentusidinium varispinosum (Sarjeant) Sarjeant & Stover: 50

Diagnosis Sarjeant, 1959; p338; pl.13,fig.7; text-fig.6

Description An intermediate size, proximate to proximochorate cyst, spherical in outline. Cyst wall consists of autophragm only which is covered in numerous spines which vary from about one-quarter to one-third of the cyst-diameter in length. The spines are nontabular and may be either single or branched; they taper distally where they may be either bifurcate or trifurcate. Paratabulation entirely lacking, although an apical archaeopyle may be present.

Dimensions Overall cyst diameter: 40-42 mu
Overall length of spines: 5-11 mu
(4 specimens measured)

Remarks S.varispinosum is characterised by its long spines which vary in length, and may in this respect be differentiated from S.rioultii (Sarjeant, 1968) Sarjeant & Stover, 1978.

Occurrence Warboys: WB.228 to WB.148 (kamptus to middle athleta).
Warlingham: Br.1898 to Br.465 (calloviense to scarburghense).
Overall range: L.Callovian (kamptus) to L.Oxfordian (scarburghense).

Range Previously recorded from U.Bathonian to L.Callovian (?L.Bathonian to ?L.Oxfordian)(Sarjeant, 1979).

Sentusidinium verrucosum (Sarjeant, 1968) Sarjeant & Stover, 1978
(Pl.23, figs.2,3)

1968 Tenua verrucosa Sarjeant: 232
1978 Sentusidinium verrucosum (Sarjeant) Sarjeant & Stover: 50

Diagnosis Sarjeant, 1968; p232; pl.1,fig.17; pl2,figs.3,6

Description Small proximate cyst, spherical to broadly-ovoidal in outline. Cyst wall consists of autophragm only which is ornamented with dense granulations each bearing a very short (less than 1mu) spine and giving a 'warty' appearance. Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$; principle archaeopyle suture zigzag.

Dimensions Overall length of cyst: 45-50 mu
Overall width of cyst: 45-55 mu
(4 specimens measured)

Remarks The 'warty'-like appearance of the surface granulations is distinctive.

Occurrence Warboys: WB.212 to WB.138 (enodatum to middle athleta).
Warlingham: Br.1898 to Br.500 (calloviense to scarburghense).
Overall range: L.Callovian (enodatum) to L.Oxfordian (scarburghense).

Range Previously recorded from Upper (?Lower) Callovian to Lower (?Middle Oxfordian).

Sentusidinium villersense (Sarjeant, 1968) Sarjeant & Stover, 1978
(Pl.23, fig.4)

1961a Baltisphaeridium fimbricatum Sarjeant: 102
1968 Tenua villersense Sarjeant: 231
1978 Sentusidinium villersense (Sarjeant) Sarjeant & Stover: 50

Diagnosis Sarjeant, 1968; p231; pl.1,fig.16; pl.2,figs.5,10

Description Intermediate size proximate cyst, spheroidal to broadly-ovoidal in outline. Cyst wall consists of autophragm only which bears numerous, short, well-spaced spines. The spines are nontabular, slender and of a constant length, usually capitate or bifurcate distally. Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$; operculum free; principle archaeopyle suture zigzag.

Dimensions Overall diameter of cyst: 50mu
(1 specimen only measured)

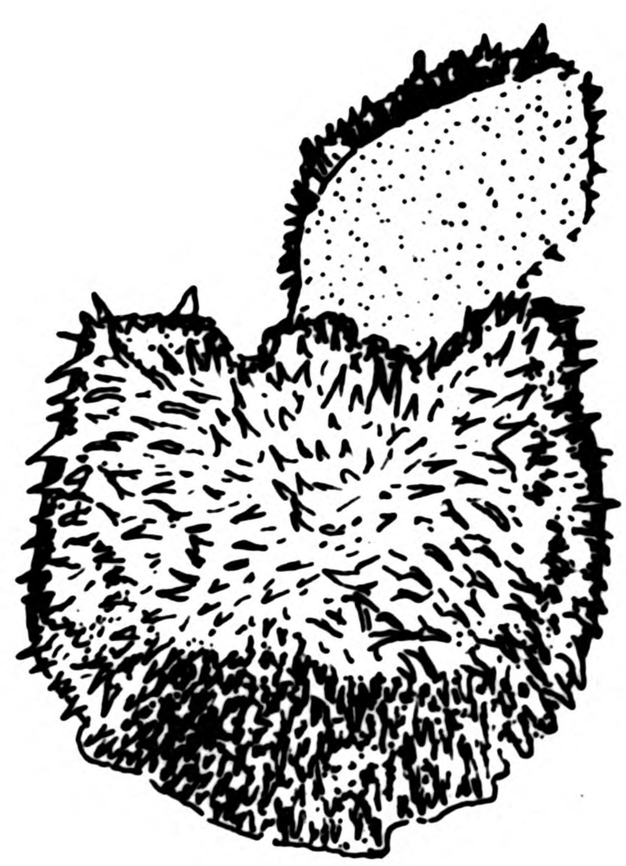
Remarks S.villersense is broadly similar to S.rioultii (Sarjeant, 1968) Sarjeant & Stover, 1978 but has less-variable spines which are shorter in length.

Occurrence Warboys: WB.218 to WB.168 (calloviense to lower athleta).
Warlingham: Br.1880 (calloviense); a single specimen only.
Overall range: L.Callovian (calloviense) to U.Callovian (lower athleta).

Range U.Bathonian to L.Oxfordian (Sarjeant, 1979).

Sentusidinium woollamii sp. nov.
(Pl.23, figs.5-7; text-fig. 5.8)

1977 Tenua n.sp. Woollam: 82



Text-fig. 5.8 Sentusidinium woollami sp. nov. X1800

Derivation of name: After Mr. R.Woollam of the Institute of Geological Sciences, who first recorded this species.

Holotype: Sample WB.78, Slide WB.78a; 145/1418 (0344). Lower Oxfordian (scarburghense), Warboys Borehole. Plate 23, figs.5a,b; text-fig. 5.8

Diagnosis A small species of Sentusidinium, proximate in form, ellipsoidal to subspherical in outline. Autophragm only, covered with numerous dense, thick, short and simple spines, pointed distally. Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$; principle archaeopyle suture zigzag; operculum free to attached.

Description A small proximate cyst, subspherical to ellipsoidal in outline although the apex is truncated due to archaeopyle formation. Cyst wall consists of autophragm only which is fairly thick and bears a dense covering of short, nontabular spines, about 2-3mu in length. The spines are simple, acuminate and taper rapidly towards a point distally where they are closed. Paratabulation entirely lacking except for the archaeopyle. The archaeopyle is apical, type $\overline{tA}$, having a zigzag principle archaeopyle suture. The operculum is free to attached.

Dimensions	Holotype:	Overall length of cyst: 40mu
		Overall width of cyst: 34mu
	Range:	Overall length of cyst: 30-40mu
		Overall width of cyst: 32-34mu
		(4 specimens measured)

Remarks A very distinctive species of Sentusidinium which superficially resembles S.pilosum (Ehrenberg, 1843) Sarjeant & Stover, 1978, but is distinguished from it by the nature of the nontabular spines which are shorter and less slender in S.woollami sp. nov. Specimens are generally well preserved due to the robust nature of the cyst. Specimens here are slightly larger than those described by Woollam, 1977.

Occurrence Warboys: WB.148 to WB.18 (middle athleta to praecordatum).
Warlingham: Br.976 to Br.560 (lamberti/athleta to scarburghense).
Overall range: U.Callovian (middle athleta) to L.Oxfordian (praecordatum).

Range Woollam (1977) records this species from U.Callovian (middle athleta) to L.Oxfordian (scarburghense); the range is therefore extended to L.Oxfordian (praecordatum).

Sentusidinium sp.A

(Pl.23, figs.8-10; text-fig.5.9)

Description A small to intermediate size, proximochorate cyst, subspherical to subovoidal in outline with apex truncated due to archaeopyle formation. Cyst wall consists of autophragm only giving rise to numerous non-tabular processes. The processes are variable in form and length (6-10mu) and may be either isolated, or randomly arranged in annular, arcuate or linear groups being connected proximally; they may either be entire or branched, bifurcate or trifurcate; distally they are usually capitate. Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$; operculum free. Principle archaeopyle suture zigzag.

Dimensions Overall length of cyst: 40-45 mu
Overall width of cyst: 42-47 mu
Length of spines: 6-10 mu
(3 specimens measured)

Remarks A rather distinctive species of Sentusidinium characterised by its very variable spines, particularly by the development of annular, arcuate and linear groups of spines; these features distinguish it from all other known species of Sentusidinium. It superficially resembles Systematophora but the processes here are shorter and lack any anastomosing branches.

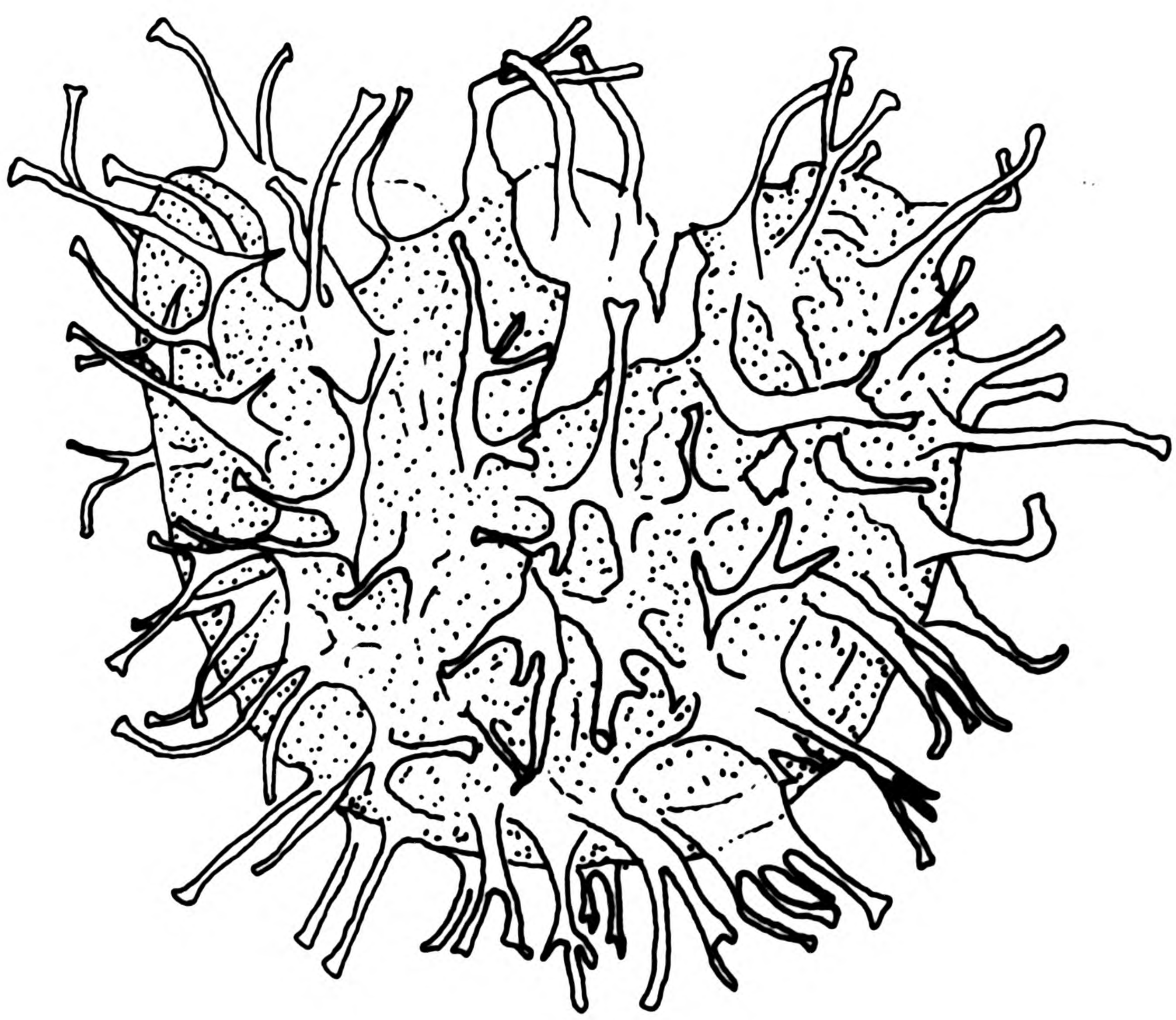
Occurrence Warlingham: Br.1229 to Br.292 U.Callovian (athleta) to L.Oxfordian (bulowskii).

Sentusidinium sp.B

(Pl.23, figs.13,16,17)

Description A small proximate cyst, broadly ellipsoidal in outline with apex truncated in archaeopyle formation. Cyst wall consists of autophragm only which gives rise to numerous, very short, well-spaced spines which are variable and often resemble verrucae; when examined closely, the spines are very short and simple, acuminate or capitate distally. Paratabulation is indicated by archaeopyle only which is apical, type $\overline{tA}$; operculum free to attached; principle archaeopyle suture zigzag, often deeply incised and indicating six precingular paraplates.

Dimensions Overall length of cyst: 30-40 mu
Overall width of cyst: 37-40 mu
(4 specimens measured)



Text-fig. 5.9 Sentusidinium sp.A X2230

Remarks Sentusidinium sp.B closely resembles Sentusidinium sp.D of Fensome, 1979 (p18, pl.2, fig.3; text-figs.7a-c), in all aspects except for the nature of the spines which appear to be more variable in Fensome's specimens.

Occurrence Warlingham: Br.1898 to Br.605, L.Callovian (calloviense) to L.Oxfordian (scarburghense).

Sentusidinium sp.C
(Pl.23, fig.18)

Description A small proximate cyst, spheroidal in outline. Cyst wall consists of autophragm only which gives rise to numerous nontabular spines about one-tenth of the central body diameter in length. The spines are fairly broad, capitate distally and appear to be connected at their bases. Paratabulation indicated by archaeopyle only, type ?$\overline{\text{tA}}$.

Dimensions Overall diameter of cyst: 30mu
Length of spines: 3mu
(1 specimen only)

Remarks Although only a single specimen was recovered, it clearly belongs to Sentusidinium. Morphologically it exhibits similarities with Sentusidinium sp.A, but is considerably smaller.

Occurrence Warlingham: Br.1155, a single specimen only from U.Callovian (athleta).

Sentusidinium sp.D
(Pl.24, figs.1-3)

Description Intermediate size proximate cyst, ovoidal in outline with apex truncate due to archaeopyle formation. Cyst wall consists of autopragm only which is thin, giving rise to numerous very small spines or verrucae. Paratabulation indicated by archaeopyle only which is apical, type $\overline{\text{tA}}$; principle archaeopyle suture zigzag, indicating six precingular paraplates. Operculum free.

Dimensions Overall length of cyst: 50-60 mu
Overall width of cyst: 50-71 mu
(3 specimens measured)

Remarks In its shape and lack of paracingulum, Sentusidinium sp.D resembles certain species of Chytroeisphaeridia; however, its possession of an apical rather than precingular archaeopyle clearly identifies it as a species of Sentusidinium. In its broad morphology it is similar to Sentusidinium sp.B of Fensome, 1979, but is somewhat smaller and possesses a thinner autophragm

Occurrence   Warlingham: Br.884 to Br.465 U.Callovian (lamberti/athleta) to L.Oxfordian (scarburghense).

Sentusidinium sp.F
(Pl.23, figs.11,12)

Description   An intermediate size proximate cyst, broadly ovoidal to ellipsoidal in outline; apex truncate due to archaeopyle formation. Cyst wall consists of autophragm only which is fairly thick and covered in dense, very short spines (resembling verrucae). Paratabulation indicated by archaeopyle only which is apical, type $\overline{tA}$; principle archaeopyle suture zigzag, indicating six precingular paraplates. Operculum free.

Dimensions   Overall length of cyst: 30-62 mu
Overall width of cyst: 37-65 mu
(4 specimens measured)

Remarks   This species is morphologically similar to Sentusidinium sp.D but differs in possessing a much thicker autophragm and more dense covering of spines in the form of granulations.

Occurrence   Warboys: WB.108 (upper athleta).
Warlingham: Br.1655 to Br.246 (obductum to corsticardia).
Overall range: M.Callovian (obductum) to L.Oxfordian (corsticardia).

?Sentusidinium sp.
(Pl.23, figs.14,15)

Description   A small proximate cyst, spheroidal in outline. Cyst wall consists of autophragm only which is thin and often folded. The surface of the cyst is covered with numerous, short, well-spaced spines, approximately one-twelth of the central body diameter in length; capitate distally. No indication of paratabulation features or archaeopyle development.

Dimensions   Overall diameter of cyst: 30-35 mu
(2 specimens measured)

Remarks   These cysts resemble Chytroeisphaeridia in all aspects except for the presence of spines. As an archaeopyle has not been observed it is only tentatively placed within Sentusidinium.

Occurrence Warlingham: Br.1450 to Br.465, M.Callovian (grossouvrei) to L.Oxfordian (scarburghense).

Genus SIRMIODINIOPSIS Drugg, 1978

Diagnosis Cysts subcircular in outline and dorsoventrally flattened. Endocyst more or less circular in outline. The archaeopyle is apical and the operculum does not tend to remain attached. Paracingulum and parasulcus developed on the periphragm. Additional paratabulation present but obscure. Two fairly large openings are present in the periphragm, one each side of the antapex. (From Drugg, 1978, p73).

Type species Sirmiodiniopsis orbis Drugg, 1978

Sirmiodiniopsis orbis Drugg, 1978
(Pl.24, figs.4-8)

1970 Gen. et sp. indet. 1 Gocht: 148
1977 Sirmiodinium n.sp. Woollam: 76
1978 Sirmiodiniopsis orbis Drugg: 73

Diagnosis Drugg, 1978; p73; pl.7,fig.11; pl.8,figs.1-4

Description A small to intermediate size circumcavate cyst, subcircular in outline. Endocyst is more or less circular in outline. Endophragm and periphragm are in contact dorsally and ventrally, but pericoels are developed laterally and antapically. The surface of the endophragm is finely-granular; periphragm smooth. Paratabulation indicated by archeopyle and paracingulum only. Archaeopyle apical, type $\overline{tA}$; operculum usually free. Principle archaeopyle suture may develop parasutural notches, thus indicating six precingular paraplates. Paracingulum fairly wide (3-4mu), delineated by very low, narrow ridges, slightly concave. Two elliptical openings in the periphragm either side of the antapex on the hypocyst are characteristic.

Dimensions Overall length of cyst: 40-55 mu
Overall width of cyst: 35-58 mu
(9 specimens measured)

Remarks S.orbis is a distinctive species and readily recognised by its apical archaeopyle (which is unusual in cavate cysts) and the two antapical openings in the periphragm. One specimen (Pl.24,fig.7) was recorded with the operculum intact. S.orbis is undoubtedly the same species as Gen. et sp. indet 1 of Gocht (1970) and Sirmiodinium n.sp. of Woollam (1977).

Occurrence Warboys: WB.212 to WB.18 (enodatum to praecordatum).

Warlingham: Br.1880 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Previously recorded from M.Callovian (jason) to U.Callovian (athleta)(Drugg, 1978). The range of S.orbis is therefore extended to: L.Callovian (calloviense) to M.Oxfordian (vertebrale) on the basis of this study.

Genus SIRMIODINIUM Alberti, 1961 emend. Warren, 1973

Diagnosis Cysts circumcavate, dorso-ventrally flattened, outline rounded pentagonal to strongly trilobate with short apical protrusion; gonyaulacacean; paratabulation nearly indiscernible to distinct, indicated by low parasutural ridges or pandasuturate areas; combination archaeopyle, type $\overline{tA}$a+Pa.

Type species Sirmiodinium grossii Alberti, 1961 (monotypic)

Sirmiodinium grossii Alberti, 1961
(Pl.24, figs.9-14)

1961 Sirmiodinium grossii Alberti: 22
1967 Sirmiodinium sp. Evitt
1973 Sirmiodinium grossii Alberti, 1961; emend. Warren: 104

Diagnosis Warren, 1973; p104; pl.1,figs.1-16; pl.2,figs.1-10; pl.3,figs.1-8; text-figs. 3-6

Description An intermediate to large, circumcavate cyst, rounded pentagonal to strongly trilobate in outline with short apical projection. Seperation between wall layers greatest on hypocyst. Low parasutural or striate pandasuturate areas present on periphragm which is otherwise smooth or faintly ornamented, locally perforate. Endophragm scabrate to granulate. Paratabulation almost indiscernible to distinct; when present is indicated by low parasutural ridges and pandasuturate areas; gonyaulacacean, formula: 4', 6", 6c, 6"', 1p, 1"", 0-5s. Archaeopyle combination, type $\overline{tA}$a+Pa; operculum composed of two pieces - one corresponds to apical paraplates, the other to 3". Paracingulum indicated by low, parallel, transverse parasutural ridges, slightly above mid-point on cyst. Parasulcus a 'teardrop'-shaped area.

Dimensions Overall length of cyst: 55-76 mu
Overall width of cyst: 60-80 mu
(7 specimens measured)

Remarks A characteristic species, readily identifiable, being the only species of the genus Sirmiodinium. It differs from Sirmiodiniopsis orbis Drugg, 1978, in being considerably larger and more variable in form.

More rounded specimens of S.grosii can be distinguished from Sirmiodiniopsis orbis by the nature of the archaeopyle; a single antapical opening in the periphragm is also often present as distinct from two in the latter.

Occurrence Warboys: WB.223 to WB.28 (calloviense to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Previously recorded from Upper Jurassic to Lower Cretaceous.

Genus STEPHANELYTRON Sarjeant, 1961a emend. Stover, Sarjeant & Drugg, 1977

Diagnosis Cysts proximochorate, subspherical to ellipsoidal; holocavate except at antapical pole; autophragm seperated from ectophragm by short tubular processes; processes nontabular, penitabular, intratabular or combination thereof; body with one or, rarely two antapical coronas; paratabulation gonyaulacacean, archaeopyle apical.

Type species Stephanelytron redcliffense Sarjeant, 1961a emend.Stover, Sarjeant & Drugg, 1977

Stephanelytron redcliffense Sarjeant, 1961a emend. Stover, Sarjeant & Drugg, 1977
(Pl.25, figs.7,8,10-12)

1960b	Organism A	Sarjeant: 404
1961a	Stephanelytron redcliffense	Sarjeant: 109
1977	Stephanelytron redcliffense	Sarjeant, emend. Stover, Sarjeant & Drugg: 331

Diagnosis Stover, Sarjeant & Drugg, 1977; p331, pl.1,figs.1-6; text-fig.1

Description Small to intermediate size, proximochorate cyst, subellipsoidal in outline. Cyst wall consists of an inner autophragm which is smooth to faintly granular and an outer ectophragm which is very thin and envelopes the entire cyst. Parasutural rows of tubiform processes arise from the autophragm; they are normally slightly expanded proximally, more so distally; 5-9mu in length. Distal tips of adjacent processes may be connected distally. Paratabulation indicated by parasutural alignment of processes to give the formula: 1', 5", Xc, 5"', 1"", 2s. Paracingulum expressed by transverse alignment of groups of processes about midlength on cyst. Archeopyle apical; operculum normally free. Antapical paraplate gives rise to a smooth-walled corona which is a narrowly-truncated cone in shape.

Dimensions Overall length of cyst: 42-65 mu
Overall width of cyst: 30-45 mu
(14 specimens measured)

Remarks Specimens identify closely with the emended diagnosis of Stover, Sarjeant & Drugg, 1977. S.redcliffense is distinguished from S.caytonense Sarjeant, 1961a, emend. Stover, Sarjeant & Drugg, 1977 in being slightly smaller and having more clearly-defined rows of parasutural processes.

Occurrence Warboys: WB.212 to WB.18 (enodatum to praecordatum).
Warlingham: Br.1605 to Br.115 (grossouvrei to vertebrale).
A common species in Middle & Upper Callovian, but occurs more rarely in Oxfordian.
Overall range: L.Callovian (enodatum) to M.Oxfordian (vertebrale).

Range Previously described from M.Callovian to L.Kimmeridgian.

Stephanelytron caytonense Sarjeant, 1961a, emend. Stover, Sarjeant & Drugg, 1977
(Pl.25, figs.1-6,9)

1961a	Stephanelytron caytonense	Sarjeant: 110
1977	Stephanelytron caytonense	Sarjeant, emend. Stover, Sarjeant & Drugg: 332

Diagnosis Stover, Sarjeant & Drugg, 1977: p332; pl.1,figs.7,8

Description Intermediate size, proximochorate cyst, holocavate in form except at antapical pole. Subspherical to ellipsoidal in outline. Ectophagm thin, often incomplete, covering the entire cyst. Autophragm up to 1mu thick, smooth and forming relatively few processes arranged in ill-defined rows. Processes tubiform, normally expanded proximally and distally, commonly finely-perforate, 6-11mu in length, 1-2mu wide at mid-length. Tips of processes rarely connected. A single, well-developed corona is consistently present at the antapical pole, it is large, smooth and truncated-cone shape in appearance. Archaeopyle apical; operculum generally free.

Dimensions Overall length of cyst: 45-67 mu
Overall width of cyst: 30-60 mu
(14 specimens measured)

Remarks The relatively large corona and ill-defined rows of processes are characteristic of S.caytonense and distinguish it from all other known species of Stephanelytron. Specimens recovered are exceptionally well-preserved, many retaining the ectophragm.

Occurrence Warboys: WB.143 to WB.23 (middle athleta to praecordatum).
Warlingham: Br.1354 to Br.246 (lower athleta to corsticardia).
Overall range: U.Callovian (lower athleta) to L.Oxfordian (corsticardia).

Range Previously described from M.Callovian (cornatum) to L.Oxfordian (cordatum).

Stephanelytron eccentricum sp. nov.
(Pl.25, figs.22-26; Pl.26, figs.1,2; text-fig.5.10)

Derivation of name: From the Latin adjective meaning "eccentric" (off-centred), describing the position of the corona in this species.

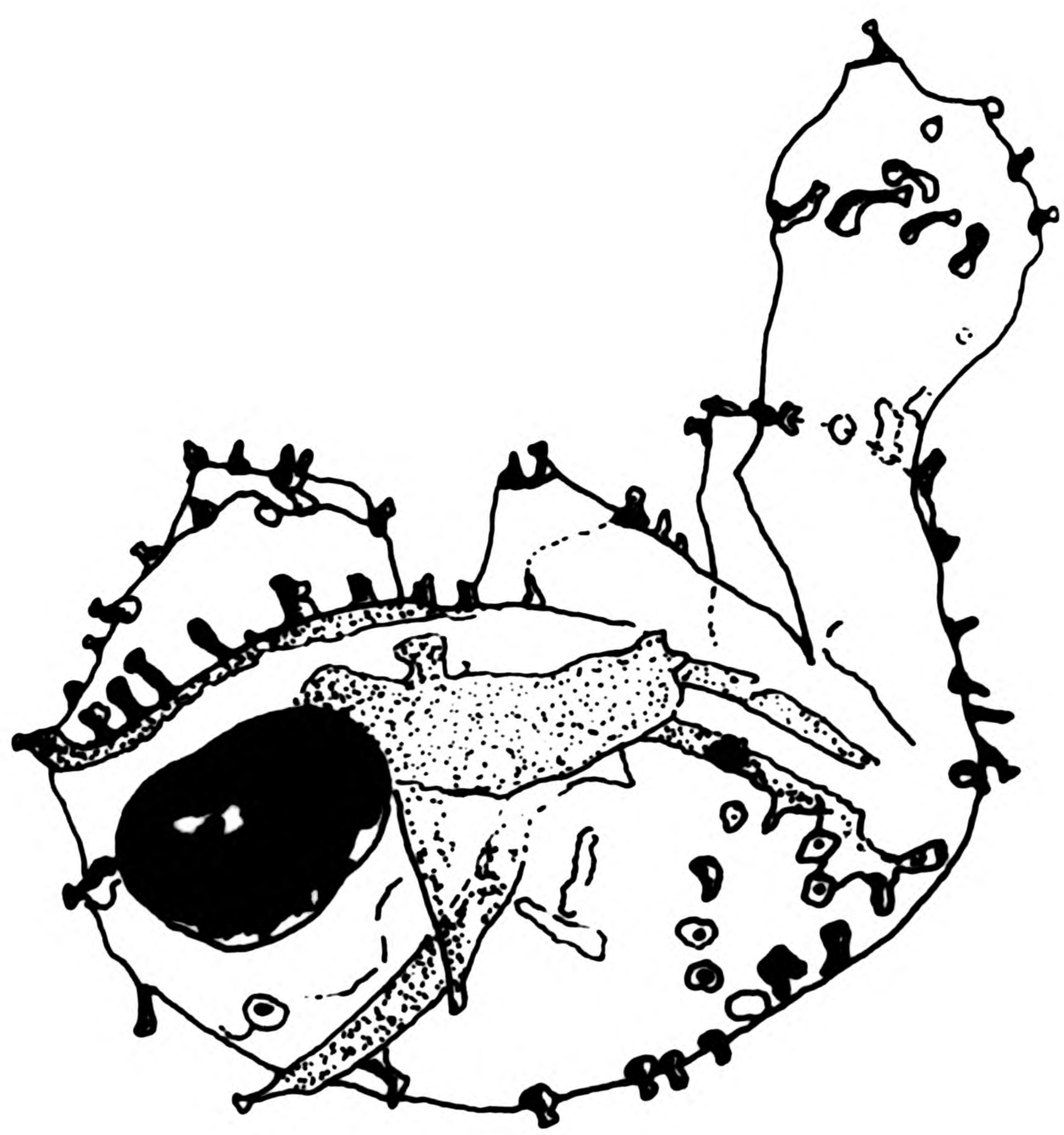
Holotype: Sample Br.884, slide Br.884a; 100/1393 (K373), U.Callovian (lamberti/athleta), Warlingham Borehole. Plate 26, fig.1; text-fig.5.10

Diagnosis A small species of Stephanelytron, proximochorate in form, broadly-rounded in outline. Ectophragm as yet unobserved; autophragm thin, bearing a moderate number of short parasutural processes, captitate in form. Paratabulation vaguely discernible in the form of five precingular paraplates and a paracingulum. Archaeopyle apical, type $\overline{tA}$; operculum free to attached. Corona a fairly large, disc-like structure situated irregularly on the hypocyst at some point immediately below the paracingulum.

Description A small proximochorate cyst, broadly-rounded in outline, often truncated at the apex due to archaeopyle formation. Cyst wall consists of autophragm only (ectophragm as yet unobserved but likely to be present), which is thin and smooth between parasutural features. A moderate number of short parasutural processes are developed on the autophragm, arranged in rows, approximately 2-5mu in length. Processes are tubiform, expanded both proximally and distally. Tips of processes never connected. Paratabulation is present but not easily discernible; parasutural notches formed along principle archaeopyle suture reveals five precingular paraplates. Paratabulation on the hypocyst indeterminate. A single corona is always present on the hypocyst and consistently off-centred antapically, being found at some point immediately below the paracingulum. Paracingulum fairly broad, delineated by rows of parasutural processes. Archaeopyle apical, type $\overline{tA}$, formed by the loss of ?4 apical paraplates. Principle archaeopyle suture zigzag; operculum free to attached.

Dimensions	Holotype:	Overall length of cyst:	35mu (excluding operculum)
		Overall width of cyst:	50mu
		Diameter of corona:	8mu
		Length of processes:	2-4mu
	Range:	Overall length of cyst:	32-47mu
		Overall width of cyst:	32-50mu
		(10 specimens measured)	

Remarks S.eccentricum sp.nov. differs from all previously described species of Stephanelytron in the nature of the corona which, as the name implies, is consistently off-centred antapically. The normal position for the corona is at the antapical pole. S.echinatum sp.nov.(herein) also has



Text-fig. 5.10 Stephanelytron eccentricum sp. nov. X2200 a slightly off-centred corona, but the gross morphology of the cyst is quite different. S.eccentricum superficially resembles S.tabulophorum Stover, Sarjeant & Drugg, 1977, but lacks a distinct paratabulation and antapically-positioned corona.

Occurrence Warboys: WB.208 to WB.93 (obductum to upper athleta).
Warlingham: Br.1760 to Br.742 (enodatum to scarburghense).
Overall range: L.Callovian (enodatum) to L.Oxfordian (scarburghense).

Range L.Callovian (enodatum) to L.Oxfordian (scarburghense) as recorded herein.

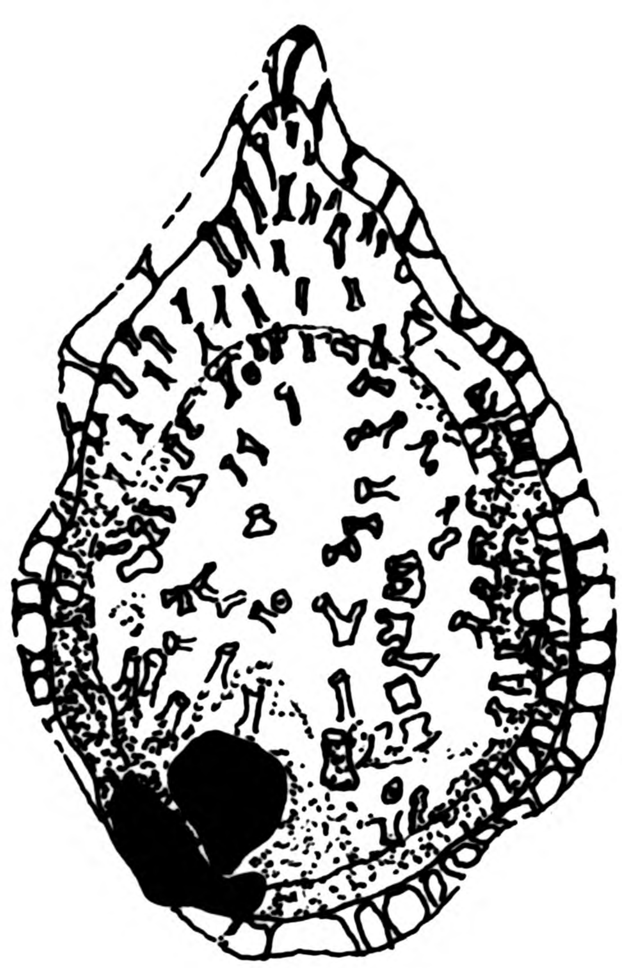
Stephanelytron echinatum sp. nov.
(Pl.26, figs.3-7; text-fig. 5.11)

Derivation of name: From the Latin adjective 'echinatus' meaning "spiny" or "prickly", describing the appearance of this species.

Holotype: Sample WB.88, slide WB.88a; 203/1457 (U304). U.Callovian (lamberti), Warboys Borehole. Plate 26, fig.7; text-fig. 5.11.

Diagnosis Small to intermediate proximochorate cyst; flask, or 'teardrop' shaped with apical protrusion, broadly-rounded antapically. Cyst wall with apparently three layers: an inner ovoidal endophragm, a middle periphragm and an outer ectophragm which covers the entire cyst. Periphragm gives rise to numerous nontabular processes which are short, simple or branched, tubiform and expanded both proximally and distally; processes may or may not be connected distally. A large apical process is often present. A single or double corona always present, usually eccentric of the antapical pole. Paratabulation entirely lacking, as is any archaeopyle structure.

Description A small to intermediate size, proximochorate cyst. Characteristically flask-shaped, or 'teardrop'-shaped; broadly-rounded antapically tapering to a point apically. The cyst wall appears to consist of three layers: an inner ovoidal endophragm; a middle periphragm which gives the cyst body its characteristic shape and an outer ectophragm which is very thin and encloses the entire cyst. Each layer is smooth. The periphragm gives rise to numerous, short, nontabular processes, randomly arranged on the cyst; they may be either simple or branched; tubiform and expanded both proximally and distally where they may be connected at their distal tips. A large terminal process is usually present at the apex, being as much as twice the size of the other processes. A single or double corona ia always present and may be rounded, subspherical or lacking any distinct shape. It is always situated near to, but rarely at, the antapex. Para-



Text-fig. 5.11 Stephanelytron echinatum sp. nov. X2000 tabulation features entirely lacking. Archaeopyle unknown.

Dimensions Holotype: Overall length of cyst: 50mu
Overall width of cyst: 32mu

Range: Overall length of cyst: 37-50mu
Overall width of cyst: 32-37mu
(6 specimens measured)

Remarks The flask or 'teardrop'-shape is characteristic of S.echinatum sp. nov. and as such is readily recogniseable. The possession of numerous tubular processes and a corona place this species within Stephanelytron. However, the presence of a third layer to the cyst wall is hitherto unknown amongst species of Stephanelytron and it may be necessary to create a new genus to accomodate such species.

Occurrence Warboys: WB.212 to WB.83 (enodatum to lamberti).
Warlingham: Br.1760 to Br.560 (enodatum to scarburghense).
The main range at Warlingham is to Br.884 (lamberti/athleta) which would restrict this species to the Callovian only, however an isolated occurrence in Br.560 may extend the range to L.Oxfordian (scarburghense).

Range L.Callovian (enodatum) to U.Callovian (lamberti)(?L.Oxfordian - scarburghense), as recorded herein.

Stephanelytron scarburghense Sarjeant, 1961a emend. Stover, Sarjeant & Drugg, 1977
(Pl.25, figs.13-18)

1961a Stephanelytron scarburghense Sarjeant: 111
1977 Stephanelytron scarburghense Sarjeant, emend. Stover, Sarjeant & Drugg: 333

Diagnosis Stover, Sarjeant & Drugg, 1977; p333; pl1,figs.9,10

Description A small proximate cyst, spheroidal to broadly-ovoidal in outline. Cyst wall consists of autophragm and ectophragm; autophragm smooth, gives rise to numerous nontabular, tubiform processes which are expanded distally (less so proximally) and frequently interconnected at their distal tips; about 5-8mu in length. Ectophragm smooth and very thin, enveloping the entire cyst. Paratabulation not expressed. Archaeopyle apical. Antapical area with one, occasionally two, coronas; base of corona thicker than autophragm, densely setate and convex distally, broadly truncated-cone shape.

Dimensions Overall length of cyst: 30-48 mu
Overall width of cyst: 30-48 mu
(14 specimens measured)

Remarks S.scarburghense is distinguished from S.caytonense by being slightly smaller, more rounded and possessing a greater number of nontabular processes; the processes in S.caytonense are not linked distally. S.scarburghense differs from S.redcliffense in its outline, the former being more rounded and lacking paratabulation features.

Occurrence Warboys: WB.211 to WB.18 (medea to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Previously recorded from M.Callovian (jason) to L.Kimmeridgian (Stover, Sarjeant & Drugg, 1977), the presence of S.scarburghense in the L.Callovian (calloviense) here therefore extends the known range.

Stephanelytron tabulophorum Stover, Sarjeant & Drugg, 1977
(Pl.25, figs.19,20)

Diagnosis Stover, Sarjeant & Drugg; p333; pl.1,figs.12,13

Description Small to intermediate size proximochorate cyst, ellipsoidal to broadly-ovoidal in outline. Cyst wall consists of autophragm and ectophragm. Autophragm is smooth to faintly granular and bears relatively short, closely-spaced, tubiform, parasutural and penitabular processes, which are expanded distally; 2-4mu in length. Ectophragm thin, enveloping the entire cyst. Paratabulation indicated by rows of parasutural and penitabular processes, formula: ?1', 5", 6c, 5"', 1"", 1p, 2s. Paracingulum clearly delineated by parallel rows of parasutural processes. Archaeopyle apical; operculum free. Principle archaeopyle suture zigzag, producing quite deeply-incised parasutural notches. Antapical corona smooth-walled and short (2-4mu) and disc-like in appearance.

Dimensions Overall length of cyst: 40-65 mu
Overall width of cyst: 39-50 mu
(9 specimens measured)

Remarks Specimens identify closely with the original diagnosis of Stover, Sarjeant & Drugg (1977). However, the presence of an apical archeopyle in specimens described here constitutes an amendment to the original description where there is no mention of an archaeopyle structure. S.tabulophorum is broadly similar to S.eccentricum sp.nov. (herein) but differs in posessing an antapically-centred corona and definite ectophragm.

Occurrence Warboys: WB.210 to WB.118 (medea to middle athleta).
Warlingham: Br.1760 to Br.916 (enodatum to lamberti/athleta).
Overall range: L.Callovian (enodatum) to U.Callovian (lamberti/athleta).

Range Previously described from Upper Callovian (athleta to lamberti) (Stover, Sarjeant & Drugg, 1977). The presence of S.tabulophorum in the Lower Callovian (enodatum) here extends the known range.

Genus SURCULOSPHAERIDIUM Davey et.al., 1966

Diagnosis Cysts skolochorate, body subspherical with approximately 25 solid, isolated, distally-branched, intratabular processes; paratabulation gonyualacacean, indicated by intratabular processes; archaeopyle apical, type $\overline{tA}$.

Type species Surculosphaeridium cribrotubiferum (Sarjeant, 1960a) Davey et.al., 1966

Surculosphaeridium cribrotubiferum (Sarjeant, 1960a) Davey et.al, 1966
(Pl.26, figs.8,9; Pl.27,fig.1)

1960a Hystrichosphaeridium cribrotubiferum Sarjeant: 137
1966 Surculosphaeridium cribrotubiferum (Sarjeant) Davey et.al: 160

Diagnosis Sarjeant, 1960a; p137; pl.4,figs.2,3; text-fig.1

Description Intermediate to large skolochorate cyst with a spherical central body bearing about 15 to 20 solid, distally-closed, perforate processes. Cyst wall consists of autophragm only which is smooth. Paratabulation indicated by intratabular processes, gonyaulacacean, process formula: 4', 6", 6c, 6"', 1p, 1"", 1s. Archaeopyle apical, type $\overline{tA}$; operculum free.

Dimensions Overall diameter of central body: 33-66 mu
Overall length of processes: 12-25 mu
Overall diameter of cyst: 60-102 mu
(6 specimens measured)

Remarks S.cribrotubiferum is mophologically similar to S.vestitum (Deflandre, 1938) Davey et.al., 1966 but differs in the nature of the processes which tend to be larger, branched and ramifying in the latter.

Occurrence Warboys: WB.228 to WB.23 (kamptus to praecordatum).
Warlingham: Br.1655 to Br.115 (obductum to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously described from the Callovian and Oxfordian.

Surculosphaeridium vestitum (Deflandre, 1938) Davey et.al., 1966
(Pl.26, figs.10-12)

1938 Hystrichosphaeridium vestitum Deflandre: 189
1960b Baltisphaeridium vestitum (Deflandre) Sarjeant: 397
1966 Surculosphaeridium vestitum (Deflandre) Davey et.al: 162

Diagnosis Deflandre, 1938; p189; pl.11,figs.4-6

Description Intermediate to large skolochorate cyst, with a subspherical central body. Cyst wall consists of autophragm only which is smooth and gives rise to 20 to 25 slender processes of variable form which are simple, or distally-ramifying. Paratabulation indicated by intratabular processes, gonyaulacacean, formula: 4', 6", 6c, 6"', 1p, 1"", 1s. Archaeopyle apical, type $\overline{tA}$; operculum free.

Dimensions Overall diameter of central body: 34-55 mu
Overall length of processes: 15-31 mu
Overall diameter of cyst: 70-113 mu
(15 specimens measured)

Remarks The processes are very variable in form and length. S.vestitum is distinguished from S.cribrotubiferum (Sarjeant, 1960a) Davey et.al., 1966 by the nature of the processes which are more variable and distally ramifying, in S.vestitum.

Occurrence Warboys: WB.210 to WB.18 (medea to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overal range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Previously described from U.Callovian (athleta) to U.Oxfordian (Sarjeant, 1979). The range is therefore extended to L.Callovian (calloviense) on the basis of this study.

Genus SYSTEMATOPHORA Klement, 1960

Synonym Taeniophora Klement, 1960

Diagnosis Cysts skolochorate, gonyaulacacean; body subspherical with 20 to 26 penitabular process-groups, each group generally arising from basal ridges and typically without distal connections or trabeculae; archaeopyle apical, type $\overline{tA}$.

Type species Systematophora areolata Klement, 1960

Systematophora areolata Klement, 1960
(Pl.27, figs.2,3)

Diagnosis Klement, 1960; p62; pl.9,figs.1-8; text-figs.32-35

Description Intermediate to large skolochorate cyst with a subspherical central body. Cyst wall consists of autophragm only which is smooth to faintly granular; gives rise to a system of penitabular processes which arise from annular ridges as slender projections, not connected distally. The processes may be simple or branched and bifurcate at their tips. Paratabulation indicated incompletely by penitabular process-groups. Archeo-pyle apical, type $\overline{tA}$; operculum free.

Dimensions Overall diameter of central body: 35-64 mu
Overall length of processes: 12-30 mu
Overall diameter of cyst: 43-74 mu
(8 specimens measured)

Remarks S.areolata differs from S.valensii (Sarjeant, 1960a) Downie & Sarjeant, 1964 in having fewer and more simple penitabular processes.

Occurrence Warlingham: Br.395 to Br.115 L.Oxfordian (praecordatum) to M.Oxfordian (vertebrale).

Range Previously described from L.Oxfordian to Kimmeridgian.

Systematophora valensii (Sarjeant, 1960a) Downie & Sarjeant, 1964
(Pl.27, figs.4-8)

1960a Polystephanosphaera valensii Sarjeant: 142
1964 Systematophora valensii (Sarjeant) Downie & Sarjeant

Diagnosis Sarjeant, 1960a; p142; pl.6,5-7; text-fig.3c

Description Intermediate to large skolochorate cyst with a subspherical central body. Cyst wall consists of autophragm only which is faintly granular and gives rise to a system of penitabular processes. The processes are arranged in groups arising from annular ridges on the central body and vary in form; they are bifurcate or ramifying, slender or widened, sometimes linked to adjacent processes in the same group either at their bases or by trabeculae at some point along their length but never at their outer extremity. Paratabulation indicated incompletely by penitabular processes. Archaeopyle apical, type $\overline{tA}$; operculum free.

Dimensions Overall diameter of central body: 35-51 mu
Overall length of processes: 7.5-25 mu
Overall diameter of cyst: 50-101 mu
(10 specimens measured)

Remarks S.valensii differs from S.areolata Klement, 1960 in being slightly larger in overall diameter. The nature of the processes are also different; they are more simple in S.areolata and never linked by trabeculae except at their bases.

Occurrence Warlingham: Br.170 to Br.140 L.Oxfordian (cordatum) to M.Oxfordian (vertebrale).

Range Previously described from U.Callovian (lamberti) to M.Oxfordian (plicatilis).

(?)Systematophora valensii (Sarjeant, 1960a) Downie & Sarjeant, 1964
(Pl.34, figs.1-3)

Description Intermediate size skolochorate cyst with a subspherical central body. Cyst wall consists of autophragm only which gives rise to a system of penitabular processes. The processes are very variable in form and are arranged in groups arising from annular, arcuate or rectilinear ridges; they are fairly short and may be either simple, branched or ramifying. Paratabulation presumably indicated by groups of penitabular processes but formulation difficult to extrapolate. Archaeopyle apical.

Dimensions Overall diameter of central body: 35-55 mu
Overall length of processes: 8.5-12.5 mu
Overall cyst diameter: 58-60 mu
(4 specimens measured)

Remarks Specimens resemble S.valensii but show a considerable degree of variation in the nature of the processes. They are generally shorter than in S.valensii and do not usually arise from ring-complexes.

Occurrence Warboys: WB.128 to WB.18 (middle athleta to praecordatum).
Warlingham: Br.1813 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range L.Callovian (calloviense) to M.Oxfordian (vertebrale), as recorded herein.

Genus TUBOTUBERELLA Vozzhennikova, 1967

Diagnosis Cysts proximate, bicavate, elongate ellipsoidal, with or without an apical horn; hypocyst has prominent four-sided pericoel with pore-like opening; endocyst subspherical to ovoidal; paratabulation gonyaulacacean, indicated by smooth to denticulate parasutural ridges or septa; archaeopyle precingular, type P.

Type species Tubotuberella rhombiformis Vozzhennikova, 1967

Tubotuberella apatela (Cookson & Eisenack, 1960) Ioannides et.al, 1976
(Pl.28, figs.1-5)

1960	Scriniodinium apatelum	Cookson & Eisenack: 249
1969	Psaligonyaulax apatela	(Cookson & Eisenack) Sarjeant: 15
1976	Tubotuberella apatela	(Cookson & Eisenack) Ioannides et.al: 464
1977	Glabridinium apatelum	(Cookson & Eisenack) Brideaux: 35
1978	Tubotuberella apatela	(Cookson & Eisenack) Ioannides et.al.; Stover & Evitt, 1978

Diagnosis Cookson & Eisenack, 1960; p249; pl.37,figs.12,13

Description Intermediate to large proximate cyst, bicavate in form, elongate-ellipsoidal in outline with apical and antapical extensions. Cyst wall consists of an inner ovoidal to rhomboidal endophragm and an outer periphragm which is smooth, thin and extended apically and antapically. Apically the periphragm is produced into a cylindrical, truncate horn; antapically, the cyst narrows towards a cylindrical to subpolygonal opening with a smooth or setate edge. Paratabulation indicated by paracingulum and archaeopyle only; paracingulum weakly laevorotatory, delineated by parallel, transverse, parasutural ridges of low relief. Parasulcus expressed as a longitudinally-elongate area between parasutural ridges. Archaeopyle precingular, type P (3" only); operculum free.

Dimensions Overall length of cyst: 63-92 mu
Overall width of cyst: 30-50 mu
(10 specimens measured)

Remarks T.apatela differs from T.sphaerocephalis Vozzhennikiva, 1967 and T.eisenackii (Deflandre, 1938) Stover & Evitt, 1978 in lacking denticulate parasutural crests. It differs from T.dangeardii (Sarjeant, 1968) Stover & Evitt, 1978 in being more elongate-ellipsoidal rather than pentagonal in outline. Specimens are generally well-preserved.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously described from M.Oxfordian to Cretaceous (Davey & Riley, 1978; Sarjeant, 1979). The known range is therefore extended to L.Callovian (kamptus) on the basis of the present study.

Tubotberella dangeardii (Sarjeant, 1968) Stover & Evitt, 1978
(Pl.28, figs.6,7,10)

1968 Gonyaulacysta dangeardi Sarjeant: 226
1978 Tubotuberella dangeardii (Sarjeant) Stover & Evitt: 197

Diagnosis Sarjeant, 1968; p226; pl.1,fig.21; pl.3,figs.8,15; text-fig.3

Description A large proximate cyst, bicavate in form, roughly pentagonal in outline. Cyst wall consists of two layers; an inner endophragm, broadly-rounded to subquadrate in outline filling the middle region; an outer layer, the periphragm, which is smooth and thin. The periphragm is extended apically into a narrow cylindrical, truncate horn; antapically into a truncated quadrate, cone-shaped horn, tapering distally. Paratabulation indicated by very low parasutural ridges; gonyaulacacean, formula: 4', ?0a, 6", ?6c, 6"', 1p, 1"". Paracingulum narrow, laevorotatory. Parasulcus broad. Archaeopyle precingular, type P (3" only).

Dimensions Overall length of cyst: 62-97 mu
Overall width of cyst: 45-64 mu
(6 specimens measured)

Remarks The pentagonal outline is characteristic of T.dangeardii. Specimens are well-preserved.

Occurrence Warboys: WB: 224 to WB.18 (koenigi to praecordatum).
Warlingham: Br.1880 to Br.292 (calloviense to bulowskii).
Overall range: L.Callovian (koenigi) to L.Oxfordian (bulowskii).

Range Previously described from U.Callovian (athleta) to L.Oxfordian (cordatum) (Sarjeant, 1979). The known range is therefore extended to L.Callovian (koenigi) on the basis of this study.

Tubotuberella eisenackii (Deflandre, 1938) Stover & Evitt, 1978
(Pl.28, figs.8,9,12,13; Pl.29,figs.1-3)

1938	Gonyaulax eisenacki Deflandre: 171
1965	Gonyaulacysta eisenacki (Deflandre) Gorka: 299
1970	Endoscrinium eisenacki (Deflandre) Gocht: 146
1978	Tubotuberella eisenackii (Deflandre) Stover & Evitt: 197

Diagnosis Deflandre, 1938; p171; pl.6,figs.7-10; text-figs. 3,4

Description Intermediate to large proximate cyst, bicavate in form, subpentagonal in outline. Cyst wall consists of two layers; an inner endophragm which is broadly-rounded to subquadrate in outline and fills the middle body; the outer periphragm is smooth and extended apically to give a short, cylindrical, truncated cone-shape horn and antapically to produce a subquadrate, truncated cone-shape horn which is open distally. Paratabulation indicated by parasutural crests which vary from low crenulate to denticulate or spiny. Paracingulum laevorotatory, narrow, delineated by parallel parasutural crests. Parasulcus fairly wide and sinuous. Archeopyle precingular, type P (3" only); operculum free.

Dimensions Overall length of cyst: 55-88 mu
Overall width of cyst: 35-69 mu
(16 specimens measured)

Remarks The nature of the parasutural crests are very variable in form, although distinctive.

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).

Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Known range is L.Callovian to L.Kimmeridgian (Sarjeant, 1979).

Tubotuberella sphaerocephalis Vozzhennikova, 1967
(Pl.29, fig.4)

Diagnosis Vozzhennikova, 1967; p181; pl.103,figs.1-3; pl.104,figs.4-5a,b

Description Intermediate to large proximate cyst, bicavate in form, elongate-ellipsoidal in outline. Cyst wall consists of two layers; an inner endophragm which is ovoidal in outline and fills the middle region of the cyst; the outer periphragm is thin and extended apically to form a cylindrical, truncated-cone shape horn and antapically to form a subquadrate, truncated-cone shape horn. Paratabulation indicated by parasutural rows of setate or spiny crests; the spines are either simple or bifurcate, capitate distally. Paracingulum present but indistinct. Archaeopyle precingular, type P (3" only); operculum free

Dimensions Overall length of cyst: 73-93 mu
Overall width of cyst: 30-46 mu
(5 specimens measured)

Remarks The spiny or setate parasutural crests are distinctive and distinguish this species from all other known species of Tubotuberella.

Occurrence Warboys: WB.218 to WB.58 (calloviense to scarburghense).
Warlingham: Br.1813 to Br.543 (calloviense to scarburghense).
Overall range: L.Callovian (calloviense) to L.Oxfordian (scarburghense).

Range Previously described from the late Jurassic only (Sarjeant, 1979). The presence of T.sphaerocephalis here therefore extends the known range to L.Callovian (calloviense).

Genus WANAEA Cookson & Eisenack, 1958

Diagnosis Cysts proximochorate, subspherical to broadly conical; autophragm smooth or with parasutural ridges or septa; paratabulation indicated by parasutural features on hypocyst, or suggested by paracingulum; combination epicystal archaeopyle, type $\overline{\text{tAtP}}$ or $\overline{\text{tAtPa}}$.

Type species Wanaea specatbilis (Deflandre & Cookson, 1955) Cookson & Eisenack, 1958

Wanaea acollaris Dodekova, 1975
(Pl.29, figs.5-8)

Diagnosis Dodekova, 1975; p20; pl.2,figs.9,10; pl.3,figs.1-7,9

Description Intermediate to large proximate cyst, subspherical to broadly-conical in outline (complete specimens rarely seen). Cyst wall consists of autophragm only which is smooth to faintly granular and forms a distinct, short, rounded antapical horn. Paratabulation usually indiscernible, formula apparently: Xc, 5-6"', 1p. Paracingulum is located at the broadest part of the cone, narrow and obscure. Archaeopyle combination epicystal type $\overline{\text{tAtP}}$; operculum free.

Dimensions Overall length of hypocyst: 50-71 mu
Overall width of hypocyst: 60-96 mu
(7 specimens measured)

Remarks The lack of any features along the principle archaeopyle suture is characteristic of Wanaea acollaris.

Occurrence Warboys: WB.228 to WB.98 (kamptus to upper athleta).
Warlingham: Br.1833 to Br.785 (calloviense to scarburghense).
Overall range: L.Callovian (kamptus) to L.Oxfordian (scarburghense).

Range Previously recorded from U.Bajocian to M.Callovian (Davey & Riley, 1978). The known range is therefore extended to lowermost Oxfordian (scarburghense), on the basis of this study.

Wanaea digitata Cookson & Eisenack, 1958
(Pl.29,figs.9,10; Pl.30,figs.1,2)

Diagnosis Cookson & Eisenack, 1958; p58; pl.9,figs.2-5

Description Intermediate to large proximochorate cyst, broadly-conical in outline. Cyst wall consists of autophragm only which is smooth and narrows towards a short, rounded antapical horn. Paratabulation features entirely lacking. Archaeopyle combination epicystal, type $\overline{\text{tAtP}}$; operculum free. Principle archaeopyle suture ornamented by a narrow fringe of finger-like processes which, although they may anastomise tangentially or coalesce proximally, remain free distally.

Dimensions Overall length of hypocyst: 57-94 mu
Overall width of hypocyst: 75-101 mu
(6 specimens measured)

Remarks W.digitata is distinguished from W.acollaris Dodekova, 1975 in posessing a fringe of processes around the principle archaeopyle suture. It differs from W.fimbriata Sarjeant, 1961a in that its processes remain free distally.

Occurrence Warboys: WB.208 to WB.78 (jason to scarburghense).
Warlingham: Br.1255 to Br.702 (athleta to scarburghense).
Overall range: M.Callovian (jason) to L.Oxfordian (scarburghense).

Range Previously recorded from M.Callovian to L.Oxfordian (Sarjeant, 1979).

Wanaea fimbriata Sarjeant, 1961a
(Pl.30, figs.3-7)

Diagnosis Sarjeant, 1961a; p112; pl.15,fig.14; text-fig.13

Description Intermediate to large proximochorate cyst, broadly-conical in outline, narrowing to a short, rounded antapical horn. Cyst wall consists of autophragm only which is smooth. Paratabulation features entirely lacking. Archaeopyle combination epicystal, type $\overline{\text{tAtP}}$; operculum free. Principle archaeopyle suture ornamented by a wide fringe which narrows in the sulcal region; a mesh-like network of irregular structure, its distal edges being free.

Dimensions Overall length of hypocyst: 30-101 mu
Overall width of hypocyst (including fringe): 71-121 mu
(19 specimens measured)

Remarks W.fimbriata differs from W.digitata Cookson & Eisenack, 1958 in possessing a meshed network fringe rather than isolated processes along the principle archaeopyle suture. It is very similar to W.clathrata Cookson & Eisenack, 1958, but differs in having an open outer edge to the fringe rather than an entire edge. Specimens are extremely well-preserved.

Occurrence Warboys: WB.78 to WB.58 (scarburghense).
Warlingham: Br.785 to Br.246 (scarburghense to corsticardia).
Overall range: L.Oxfordian (scarburghense to corsticardia) only.

Range L.Oxfordian (mariae to cordatum)only (Sarjeant, 1979). The first appearance of W.fimbriata denotes the Callovian/Oxfordian boundary.

Order DINOPHYCIALES Lindemann, 1921

Genus NANNOCERATOPSIS Deflandre, 1938 emend. Evitt, 1961

Diagnosis Cysts proximate, compressed laterally, usually with two antapical horns, of which the ventral horn may be reduced or undeveloped; epicyst minute, hypocyst large; dorsal, ventral and antapical surfaces narrow, lateral surfaces wide; archaeopyle epicystal, probably analogous to type $\overline{AP}a$.

Type species Nannoceratopsis pellucida Deflandre, 1938 emend. Evitt, 1961

Nannoceratopsis pellucida Deflandre, 1938 emend. Evitt, 1961
(Pl.31, figs.1,4,5)

1938 Nannoceratopsis pellucida Deflandre: 183
1961 Nannoceratopsis pellucida Deflandre; emend. Evitt: 306

Diagnosis Evitt, 1961; p306; pl.1,figs.15-18; pl.2,figs.30,31; text-fig.8

Description Intermediate to large proximate cyst, compressed laterally, triangular in outline with pronounced concavity between antapical horns. Ventral horn may be reduced or completely undeveloped. Epicyst minute, seperated by subapical paracingulum, from hypocyst which constitutes most of the cyst. Cyst wall consists of autophragm only which is smooth to areolate. Paratabulation not indicated. Archaeopyle epicystal; operculum free to attached.

Dimensions Overall length of cyst: 80-100 mu
Overall width of cyst: 42-55 mu
(5 specimens measured)

Remarks Both antapical horns are usually fully developed in specimens here, which distinguishes it from N.plegas Drugg, 1978.

Occurrence Warboys: WB.228 to WB.78 (kamptus to scarburghense).
Warlingham: Br.1898 to Br.140 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously described from U.Bathonian to U.Oxfordian (Sarjeant, 1979)

Nannoceratopsis plegas Drugg, 1978
(Pl.31, figs.2,3)

Diagnosis Drugg, 1978; p71; pl.6,figs.8,9; pl.7,fig.3

Description Intermediate to large proximate cyst, compressed laterally, triangular to sickle-shape in outline. The dorsal horn is elongate; the ventral horn is comparatively short. The antapical concavity is broad and flattened to arcuate. Cyst wall consists of autophragm only which is finely pitted or areolate. Epicyst is minute, seperated from hypocyst by subapical paracingulum; hypocyst constitutes most of the cyst. Paratabulation not indicated. Archaeopyle epicystal; operculum free to attached.

Dimensions Overall length of cyst: 70-80 mu
Overall width of cyst: 50 mu
(4 specimens measured)

Remarks The elongated doesal horn, affecting the outline of the cyst is characteristic.

Occurrence Warboys: WB.228 to WB.133 (kamptus to middle athleta).
Warlingham: Br.1880 to Br.627 (calloviense to scarburghense).
Overall range: L.Callovian (kamptus) to L.Oxfordian (scarburghense).

Range Previously described from the Lower Jurassic only (Drugg, 1978). The presence of N.plegas here therefore constitutes an extended range to Upper Jurassic, L.Oxfordian (scarburghense).

Group ACRITARCHA Evitt, 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus MICRHYSTRIDIUM Deflandre, 1937 emend. Sarjeant, 1967b

Diagnosis Vesicle spherical to polygonal, of small to moderate size. Ornamented with several to numerous hollow spines which are continuous with, and open into, the vesicle. Spines simple, straight or recurved with closed tips. No differentiation in texture between spines and vesicle. (After Staplin, Jansonius and Pocock, 1965)

Type species Micrhystridium inconspicuum (Deflandre, 1935) Deflandre, 1937

Micrhystridium inconspicuum (Deflandre, 1935) Deflandre, 1937
(Pl.31, fig.15)

1935 Hystrichosphaera inconspicua Deflandre: 233
1937 Micrhystridium inconspicuum (Deflandre) Deflandre: 32

Diagnosis Deflandre, 1937; p32; pl.12,figs.11-13

Description The spherical, globular shell has a smooth surface from which arise short, simple and distally-closed spines, about 20 to 30 in number.

Dimensions Overall diameter of shell: 16 mu
(2 specimens measured)

Remarks M.inconspicuum is distinguished from M.deflandrei Valensi, 1948 in posessing about half the number of spines. The spines are also shorter and less conical than in M.recurvatum Valensi, 1953

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Middle Jurassic to Cretaceous.

Micrhystridium deflandrei Valensi, 1948
(Pl.31, figs.6,7,11)

Diagnosis Valensi, 1948; p545; text-fig.5, nos.3-5

Description Small spherical shell, which is smooth and thin-walled, bearing numerous minute, simple spines.

Dimensions Overall diameter of shell: 18-23 mu
(4 specimens measured)

Remarks The minute, numerous spines are characteristic and distinguish M.deflandrei from all other known species of Micrhystridium.

Occurrence Warboys: WB.183 (lower athleta), a single specimen.
Warlingham: Br.1605 to Br.115 (grossouvrei to vertebrale).
Overall range: M.Callovian (grossouvrei) to M.Oxfordian (vertebrale).

Range Previously described from the L.Jurassic (Sinemurian) to U.Jurassic (Oxfordian).

Micrhystridium densispinum Valensi, 1953
(Pl.31, figs.8-10)

Diagnosis Valensi, 1953; p52; pl.7,figs.6-9,13,17,18; pl.14,fig.4

Description Small spherical shell which has a fairly thick wall and numerous fine spines which give a fibrous appearance to the outer part of the shell.

Dimensions Diameter of shell: 15-24 mu
Length of spines: 3-5 mu
(4 specimens measured)

Remarks The dense covering of spines giving a fibrous appearance to the outer part of the shell is distinctive.

Occurrence Warboys: WB.211 to WB.33 (medea to scarburghense).
Warlingham: Br.1898 to Br.246 (calloviense to cordatum).
Overall range: L.Callovian (calloviense) to L.Oxfordian (cordatum).

Range Previously described from the Upper Jurassic.

Micrhystridium fragile Deflandre, 1947b
(Pl.31, figs.12,13)

Diagnosis Deflandre, 1947b; p8; text-figs.13-18

Description The spherical to subspherical shell is smooth and thin-walled, bearing 10 to 18 spines. The spines are strong, straight or curved, hollow; acuminate and closed distally.

Dimensions Diameter of shell: 18-20 mu
Length of spines: 10-11 mu
(3 specimens measured)

Remarks M.fragile is similar to Solisphaeridium stimuliferum (Deflandre, 1938) Sarjeant, 1968, but is considerably smaller with hollow spines.

Occurrence   Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range   Previously described from the Middle and Upper Jurassic.

Micrhystridium nannacanthum Deflandre, 1945
(Pl.31, fig.16)

Diagnosis Deflandre, 1945; p66; pl.3,figs.5-7

Description Small spherical shell with a fairly thick and smooth wall from which some 15 to 20 spines arise. Spines are short and stoutly-conical. There appears to be a pylome developed on the shell surface.

Dimensions   Diameter of shell: 14 mu
Length of spines: 3 mu
(1 specimen only measured)

Remarks   M.nannacanthum is one of the smallest acanthomorph acritarchs. It differs from M.inconspicuum (Deflandre, 1935) Deflandre, 1937 in being smaller and having fewer spines.

Occurrence   Warboys: WB.48 to WB.33 (scarburghense), 2 specimens only.
Warlingham: Br.1605 to Br.292 (coronatum to bulowskii).
Overall range: M.Callovian (coronatum) to L.Oxfordian (bulowskii).

Range   Lower Jurassic (Hettangian) to Upper Jurassic (Oxfordian).

Micrhystridium polyhedricum Valensi, 1948
(Pl.31, figs.17,18)

Diagnosis Valensi, 1948; p548; text-fig.6

Description Small subspherical to polyhedral shell with smooth surface, from which arise 6-10 short, conical spines which are quite wide proximally and pointed distally.

Dimensions   Diameter of shell: 13-20 mu
Length of spines: 4.5-7 mu
(5 specimens measured)

Remarks   The polyhedral outline of the shell is distinctive.

Occurrence   Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.481 (calloviense to scarburghense).
Overall range: L.Callovian (kamptus) to L.Oxfordian (scarburghense).

Range Previously recorded from the Jurassic.

Micrhystridium rarispinum Sarjeant, 1960b
(Pl.31, figs.25,26)

Diagnosis Sarjeant, 1960b; p400; pl.14,figs.6-8; text-fig.11

Description Small spherical shell, surface smooth, with a small number (14 to 20) of very short, slender, hollow spines which are pointed distally and usually curved; length of spines about one-fifth of the shell diameter.

Dimensions Diameter of shell: 17-19 mu
Length of spines: 2 mu
(4 specimens measured)

Remarks M.rarispinum differs from M.fragile Deflandre, 1947b in having fewer spines which are shorter in length.

Occurrence Warboys: WB.210 to WB.18 (medea to praecordatum).
Warlingham: Br.1655 to Br.194 (obductum to corsticardia).
Overall range: M.Callovian (medea) to L.Oxfordian (corsticardia).

Range Previously recorded throughout the Jurassic.

Micrhystridium recurvatum Valensi, 1953
(Pl.31, figs.19,20)

Diagnosis Valensi, 1953; p43; pl.6,figs.1-4; pl.13,fig.16

Description Shell spherical to subspherical bearing some 18 to 30 simple, hollow processes which may be straight, or more usually incurved. Shell wall smooth.

Dimensions Diameter of shell: 15-25 mu
Length of spines: 3-8 mu
(6 specimens measured)

Remarks M.recurvatum differs from M.sydus Valensi, 1953 in having a greater number of spines which are shorter in length.

Occurrence Warboys: WB.223 to WB.18 (calloviense to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Previously recorded throughout the Jurassic.

Range Previously recorded from the Jurassic.

Micrhystridium rarispinum Sarjeant, 1960b
(Pl.31, figs.25,26)

Diagnosis Sarjeant, 1960b; p400; pl.14,figs.6-8; text-fig.11

Description Small spherical shell, surface smooth, with a small number (14 to 20) of very short, slender, hollow spines which are pointed distally and usually curved; length of spines about one-fifth of the shell diameter.

Dimensions Diameter of shell: 17-19 mu
Length of spines: 2 mu
(4 specimens measured)

Remarks M.rarispinum differs from M.fragile Deflandre, 1947b in having fewer spines which are shorter in length.

Occurrence Warboys: WB.210 to WB.18 (medea to praecordatum).
Warlingham: Br.1655 to Br.194 (obductum to corsticardia).
Overall range: M.Callovian (medea) to L.Oxfordian (corsticardia).

Range Previously recorded throughout the Jurassic.

Micrhystridium recurvatum Valensi, 1953
(Pl.31, figs.19,20)

Diagnosis Valensi, 1953; p43; pl.6,figs.1-4; pl.13,fig.16

Description Shell spherical to subspherical bearing some 18 to 30 simple, hollow processes which may be straight, or more usually incurved. Shell wall smooth.

Dimensions Diameter of shell: 15-25 mu
Length of spines: 3-8 mu
(6 specimens measured)

Remarks M.recurvatum differs from M.sydus Valensi, 1953 in having a greater number of spines which are shorter in length.

Occurrence Warboys: WB.223 to WB.18 (calloviense to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Previously recorded throughout the Jurassic.

Micrhystridium recurvatum forma brevispinosa Valensi, 1953
(Pl.31, figs.21,22)

Diagnosis Valensi, 1953; p44; pl.6, figs.9,10

Description Small spheroidal shell with spines which are incurved and sometimes bulbous at their base. Spines are short (one-sixth to one-quarter of the shell diameter in length) and between 20 and 27 in number. A splitting of the shell is occasionally observed.

Dimensions Diameter of shell: 12-18 mu
Length of spines: 4-5 mu
(4 specimens measured)

Remarks This species resembles M.rarispinum Sarjeant, 1960b, but is distinguished from it in having a greater number of spines.

Occurrence Warboys: WB.211 to WB.18 (medea to praecordatum).
Warlingham: Br.1898 to Br.170 (calloviense to cordatum).
Overall Range: L.Callovian (calloviense) to L.Oxfordian (cordatum).

Range Previously recorded from the Jurassic.

Micrhystridium recurvatum forma longispinosa Valensi, 1953
(Pl.31, fig.21)

Diagnosis Valensi, 1953; p44, pl.6, fig.6

Description Shell small and spheroidal, surface smooth and gives rise to about 30 spines which are slightly curved and about half the shell-diameter in length.

Dimensions Diameter of shell: 16 mu
Length of spines: 7 mu
(1 specimen only measured)

Remarks The length of spines in proportion to the shell diameter are distinctive.

Occurrence Warboys: WB.193 to WB.33 (grossouvrei to scarburghense).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (veretebrale).

Range Previously recorded from the Jurassic.

Micrhystridium recurvatum forma multispinosa Valensi, 1953
(Pl.31, fig.24; Pl.32, figs.1,2)

Diagnosis Valensi, 1953; p44; pl.6, fig.5

Description Shell small and spheroidal with many short spines which may be slightly swollen proximally and are closed and pointed distally.

Dimensions Diameter of shell: 20-24 mu
Length of spines: 2-5 mu
(5 specimens measured)

Remarks M.recurvatum forma multispinosa is similar to M.inconspicuum (Deflandre, 1935) Deflandre, 1937 but is differentiated from it by the nature of the spines which are much broader at their base in the former.

Occurrence Warboys: WB.193 to WB.33 (grossouvrei to scarburghense).
Warlingham: Br.1697 to Br.292 (jason to bulowskii).
Overall Range: M.Callovian (jason) to L.Oxfordian (bulowskii).

Range Previously described from the Jurassic.

Micrhystridium recurvatum forma reducta Valensi, 1953
(Pl.32, fig.3)

Diagnosis Valensi, 1953; p44; pl.6,figs.7,8; pl.13,fig.16

Description Shell small, spheroidal to subspheroidal with about 16 slightly incurved spines which are broad proximally and pointed distally.

Dimensions Diameter of shell: 15-20 mu
Length of spines: 2-3 mu
(3 specimens measured)

Remarks Specimens identify closely with the original description of Valensi, 1953

Occurrence Warboys: WB.228 to WB.18 (kamptus to praecordatum).
Warlingham: Br.1898 to Br.115 (calloviense to vertebrale).
Overall Range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously described from the Jurassic.

Micrhystridium sydus Valensi, 1953
(Pl.32, figs.4-6)

Diagnosis Valensi, 1953; p59; pl.8,fig.40; pl.9,figs.3-5,11,17,23,24

Description The spherical to subpolygonal shell bears 12 to 14 broadly-based, conical spines. The spines are hollow and distally pointed and closed; their cavity connects to the shell cavity.

Dimensions Diameter of shell: 16-20 mu
Length of spines: 5-15 mu
(5 specimens measured)

Remarks The long conical spines with their broad base are distinctive. This species was the most abundant, forming up to 50% of the total microplankton assemblage in the middle athleta of Warboys.

Occurrence Occurs abundantly in all.samples from both sections. Overall range: L.Callovian (kamptus) to M.Oxfordian (vertebrale).

Range Previously recorded from the middle and upper Jurassic.

Micrhystridium variabile Valensi, 1953
(Pl.32, figs.7,8)

Diagnosis Valensi, 1953; p47; pl.3,figs.12,13,17; pl.4,figs.1,2;pl.13,fig.8

Description Shell small, spherical with numerous short slender spines. The spines are variable in form and capitate at their distal tips; a collar-like structure is present at the mid-point of each spine.

Dimensions Diameter of shell: 22-24 mu
Length of spines: 2-3 mu
(3 specimens measured)

Remarks The variable nature of the spines are very distinctive.

Occurrence Warboys: WB.223 to WB.93 (calloviense to upper athleta).
Warlingham: Br.1898 to Br.170 (calloviense to cordatum).
Overall range: L.Callovian (calloviense) to L.Oxfordian (cordatum).

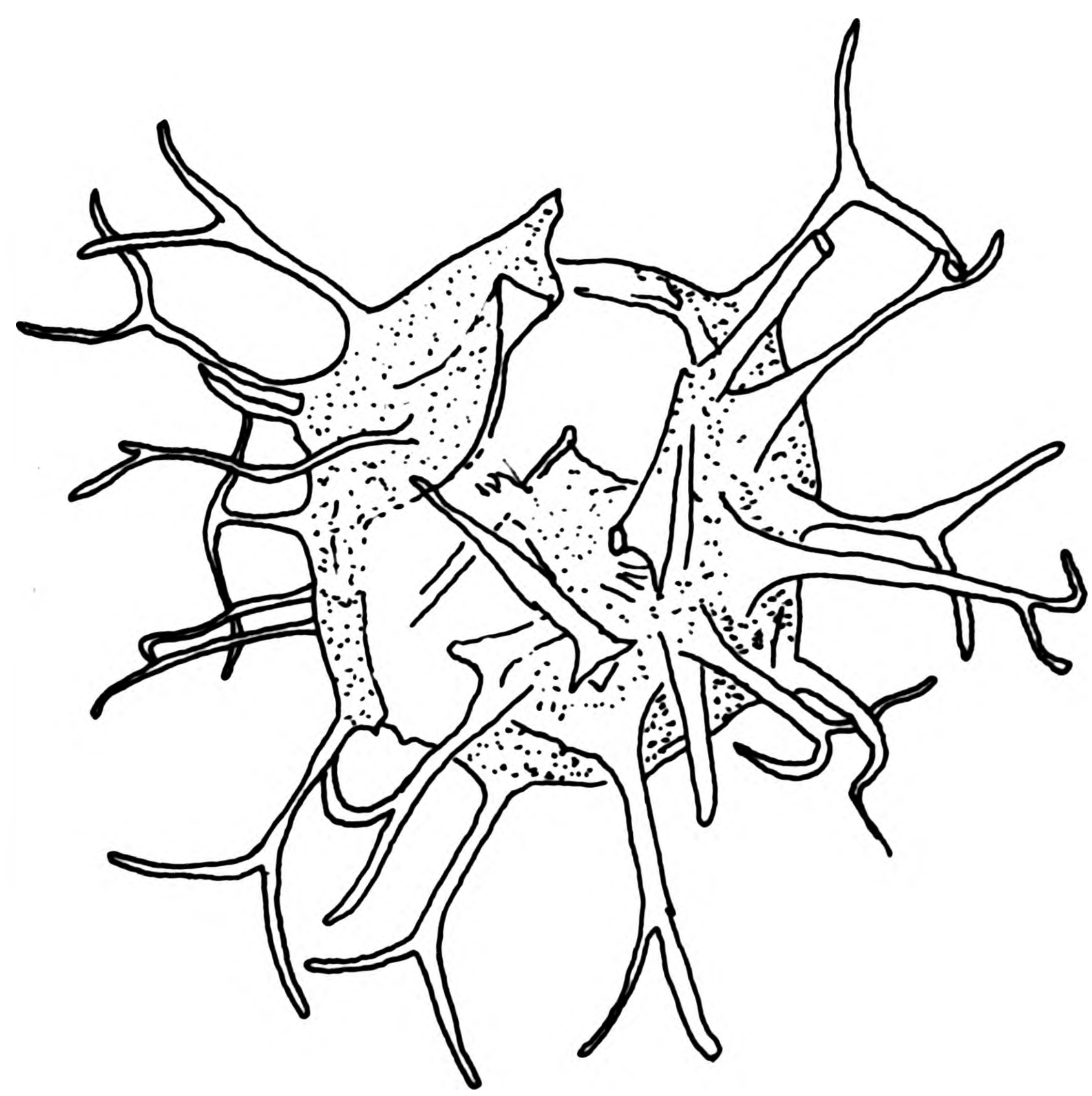
Range Previously recorded from the middle and upper Jurassic.

Genus MULTIPLICISPHAERIDIUM Staplin, 1961

Diagnosis Vesicle ellipsoidal to spherical; processes seperate, narrow-based, tips multifurcate, expanded, dissected or otherwise modified but not open; processes all of one type, not differentiated into distinctive orders or kinds of processes; wall surface exclusive of processes laevigate to finely granulose. (From Staplin, 1961; p410)

Type species Multipicisphaeridium ramispinosum Staplin, 1961

Multiplicisphaeridium sp.
(Pl.32, figs.9-11; text-fig. 5.12)



Text-fig. 5.12 Multiplicisphaeridium sp. X2850

Description A species of Multiplicisphaeridium having a small spherical to subspherical shell which is smooth and gives rise to about 20 seperate, hollow processes. Processes bifurcate and closed distally. A split-like opening is observed in some specimens.

Dimensions Diameter of shell: 18-21 mu
Length of processes: 8-12 mu
(3 specimens measured)

Remarks Three specimens only were recorded from the upper Callovian (athleta) of the Warlingham section. The morphological features exhibited by specimens here closely fit the generic diagnosis of Staplin, 1961, p410. The bifurcate processes are distinctive, differentiating it from species of Micrhystridium.

Occurrence Warlingham: Br.985 to Br.947 U.Callovian (athleta).

Genus SOLISPHAERIDIUM Staplin, Jansonius & Pocock, 1965 emend. Sarjeant, 1968

Diagnosis Shell spherical, with a relatively firm and rigid wall. Spines hollow or solid, straight or curving, with closed tips; the spine-cavity, where present, typically communicates with the shell interior. Length of spines variable. Pylome lacking; opening of shell by splitting or by loss of an irregularly-shaped piece of the shell wall. Mean shell diameter typically greater than 20mu. (From Sarjeant, 1968, p222)

Type species Solisphaeridium stimuliferum (Deflandre, 1938) Staplin, Jansonius & Pocock, 1965

Solisphaeridium stimuliferum (Deflandre, 1938) Staplin, Jansonius & Pocock, 1965
(Pl.32, figs.14-16)

1938 Hystrichosphaeridium stimuliferum Deflandre: 192
1960b Baltisphaeridium stimuliferum (Deflandre) Sarjeant: 397
1965 Solisphaeridium stimuliferum (Deflandre) Staplin, Jansonius & Pocock: 183

Diagnosis Staplin, Jansonius & Pocock, 1965; p183; pl.18,figs.1,2; text-figs.3,10

Description Shell small, spherical to ovate in outline with a smooth, thin wall. The spines are hollow, conical, straight or curved and variable in length. The spine-cavities are connected with the shell-cavity.

Dimensions Diameter of shell: 20-22 mu
Length of spines: 8.5-15 mu
(4 specimens measured)

Remarks S.stimuliferum has more spines than S.claviculorum (Deflandre, 1938) Sarjeant, 1968 which are not restricted proximally. Superficially, S.stimuliferum resembles Micrhystridium fragile Deflandre, 1947b, but is generally larger in size with broader spines.

Occurrence Warboys: WB.133 to WB.33 (middle athleta to scarburghense).
Warlingham: Br.1880 to Br.115 (calloviense to vertebrale).
Overall range: L.Callovian (calloviense) to M.Oxfordian (vertebrale).

Range Recorded throughout the Jurassic.

Solisphaeridium claviculorum (Deflandre, 1938) Sarjeant, 1968
(Pl.32, fig.13)

1938 Hystrichosphaeridium claviculorum Deflandre: 191
1963 Baltisphaeridium claviculorum (Deflandre) Downie & Sarjeant: 91
1968 Solisphaeridium claviculorum (Deflandre) Sarjeant: 223

Diagnosis Sarjeant, 1968; p223; pl.2, figs.13,15

Description Shell small, spheroidal, thin-walled bearing some 20 lanceolate spines. Shell wall smooth. Spines constricted proximally, tapering to a point distally.

Dimensions Diameter of shell: 25-26 mu
Length of spines: 7.5-12 mu
(2 specimens measured)

Remarks Specimens identify closely with those of Sarjeant (1968). The proximally-restricted spines are distinctive and thereby is distinguished from S.stimuliferum (Deflandre, 1938) Staplin, Jansonius & Pocock, 1965, which also has fewer spines.

Occurrence Warboys: WB.108 to WB.33 (upper athleta to scarburghense).
Warlingham: Br.1605 to Br.115 (grossouvrei to vertebrale).
Overall range: M.Callovian (grossouvrei) to M.Oxfordian (vertebrale).

Range Previously recorded from the Upper Jurassic.

Subgroup PTEROMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus PTEROSPERMOPSIS W.Wetzel, 1952

Diagnosis Spherical capsule of organic material with an equatorially-placed membranous fringe. (From Norris & Sarjeant, 1965; p52).

Type species Pterospermopsis danica W.Wetzel, 1952

Pterospermopsis harti Sarjeant, 1960b
(Pl.32, fig.12)

Diagnosis Sarjeant, 1960b; p402; pl.14,fig.16; text-fig.3

Description Shell small, circular to ovoidal in outline with a small, rounded central body surrounded by a radially-folded equatorial fringe.

Dimensions Diameter of central body: 10mu
Width of fringe: 5-6mu
Overall diameter: 23mu
(1 specimen only measured)

Remarks The equatorial fringe is distinctive. (The exact occurrence of P.hartii has not been recorded here).

Occurrence Occurs throughout both sequences.

Range Previously recorded from the Upper Jurassic.

Group INCERTAE SEDIS

Gen. et sp. indet. A
(Pl.33, figs.1-3)

Description An intermediate size proximochorate cyst, subrounded to ovoidal in outline. Cyst wall consists of autophragm only which is fairly thick and bears numerous processes which appear to arise from a reticulate mesh-work covering the surface of the cyst. The processes appear to be formed in rings arising from each reticulum and connected at their base, becoming seperate and capitate distally. Paratabulation present but obscure. Archaeopyle apical. Paracingulum a fairly wide area free of processes, situated at midpoint on the cyst. Parasulcus also present; broad, consisting of a number of paraplates.

Dimensions Overall length of cyst: 38-55 mu
Overall width of cyst: 38-52 mu
(7 specimens measured)

Remarks The paratabulation features and development of an archaeopyle clearly indicate that this is a dinoflagellate cyst. Specimens could possibly be assigned to Valensiella Eisenack, 1963a, but lack an outer membranous layer, although it is possible that this could have been destroyed during preservation.

Occurrence Warboys: WB.211 to WB.28 (medea to scarburghense).
Warlingham: Br.1118 to Br.115 (athleta to vertebrale).
Overall Range: M.Callovian (medea) to M.Oxfordian (vertebrale).

Gen. et sp. indet. B
(Pl.33,figs.4-8; text-fig. 5.13)

Description An intermediate size proximate cyst, holocavate in form, subspherical to subpentagonal in outline. Cyst wall consists of two layers; the endophragm is broadly-rounded in outline, filling most of the central cavity and densely-ornamented with coarse rugae, giving a warty-appearance. The autophragm is thin and smooth, covering the entire cyst and extended apically to form a low conical process. Paratabulation is present in some specimens but indeterminate, although an apical paraplate (1') and six precingular paraplates (6") are visible on some specimens; where present, paratabulation seen on endophragm only. Some specimens develop faintly-determinable parasutural crests on the autophragm with short spines; but specimens never exhibit paratabulation features on both endophragm and autophragm. Archaeopyle complex, some specimens exhibiting an apical arch-

Group INCERTAE SEDIS

Gen. et sp. indet. A
(Pl.33, figs.1-3)

Description An intermediate size proximochorate cyst, subrounded to ovoidal in outline. Cyst wall consists of autophragm only which is fairly thick and bears numerous processes which appear to arise from a reticulate mesh-work covering the surface of the cyst. The processes appear to be formed in rings arising from each reticulum and connected at their base, becoming seperate and capitate distally. Paratabulation present but obscure. Archaeopyle apical. Paracingulum a fairly wide area free of processes, situated at midpoint on the cyst. Parasulcus also present; broad, consisting of a number of paraplates.

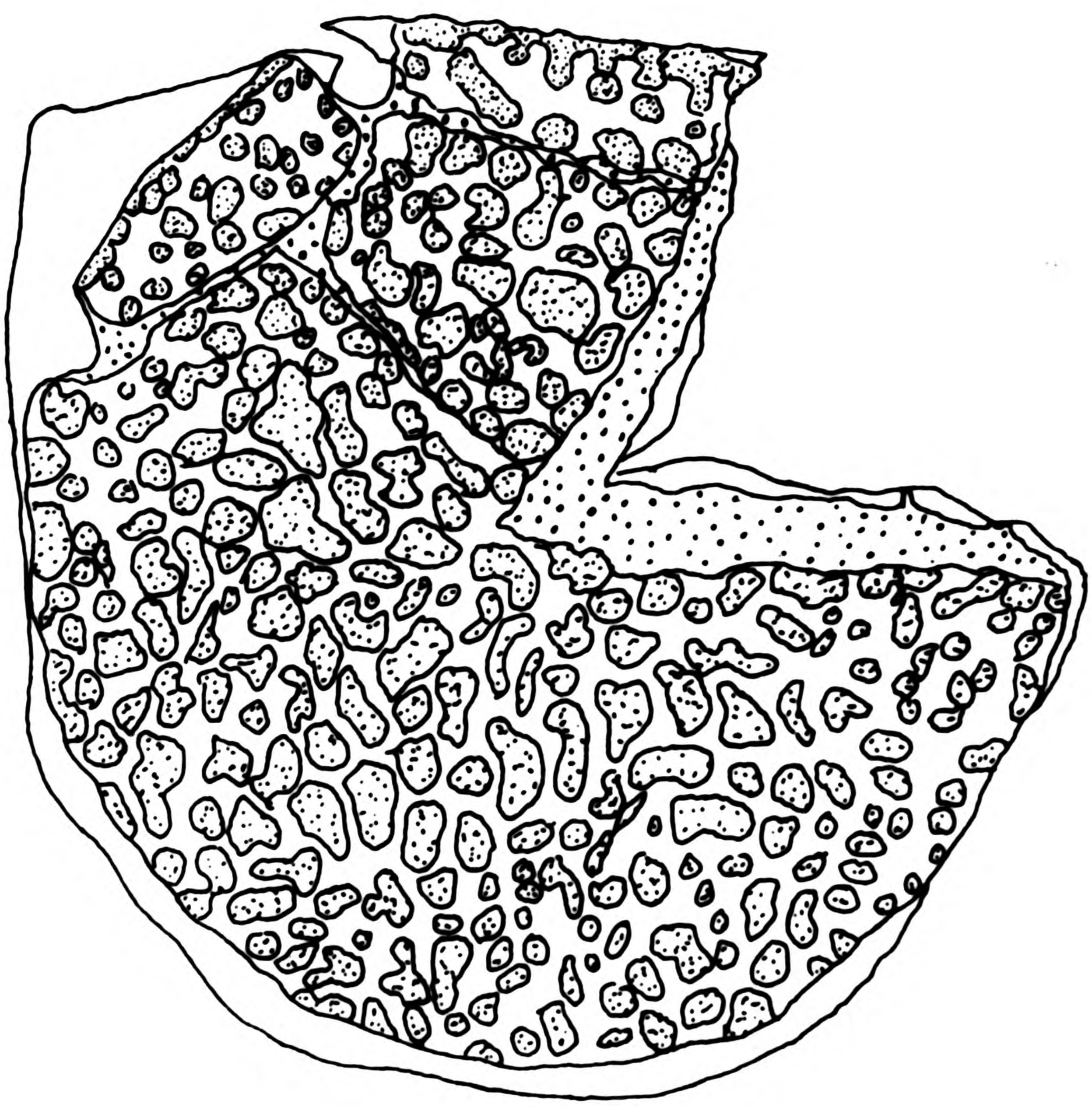
Dimensions Overall length of cyst: 38-55 mu
Overall width of cyst: 38-52 mu
(7 specimens measured)

Remarks The paratabulation features and development of an archaeopyle clearly indicate that this is a dinoflagellate cyst. Specimens could possibly be assigned to Valensiella Eisenack, 1963a, but lack an outer membranous layer, although it is possible that this could have been destroyed during preservation.

Occurrence Warboys: WB.211 to WB.28 (medea to scarburghense).
Warlingham: Br.1118 to Br.115 (athleta to vertebrale).
Overall Range: M.Callovian (medea) to M.Oxfordian (vertebrale).

Gen. et sp. indet. B
(Pl.33,figs.4-8; text-fig. 5.13)

Description An intermediate size proximate cyst, holocavate in form, subspherical to subpentagonal in outline. Cyst wall consists of two layers; the endophragm is broadly-rounded in outline, filling most of the central cavity and densely-ornamented with coarse rugae, giving a warty-appearance. The autophragm is thin and smooth, covering the entire cyst and extended apically to form a low conical process. Paratabulation is present in some specimens but indeterminate, although an apical paraplate (1') and six precingular paraplates (6") are visible on some specimens; where present, paratabulation seen on endophragm only. Some specimens develop faintly-determinable parasutural crests on the autophragm with short spines; but specimens never exhibit paratabulation features on both endophragm and autophragm. Archaeopyle complex, some specimens exhibiting an apical arch-



Text-fig. 5.13 Gen. et sp. indet. B X2170 eopyle, whilst others exhibit a splitting along the paracingulum, indicating an epicystal archaeopyle; some specimens exhibit both. Paracingulum expressed on some specimens as a folded area at mid-point on the cyst.

Dimensions Overall length of cyst: 50-68 mu
Overall width of cyst: 48-60 mu
(7 specimens measured)

Remarks The broad morphological features are that of a dinoflagellate cyst. However specimens cannot, as yet, be assigned to a known genus; designation of a new genus may be appropriate.

Occurrence Warboys: WB.224 to WB.43 (koenigi to scarburghense).
Warlingham: Br.1531 to Br.313 (grossouvrei to praecordatum).
Overall range: L.Callovian (koenigi) to L.Oxfordian (praecordatum).

Gen. et sp. indet. C
(Pl.33, fig.13)

Description An intermediate size proximate cyst, broadly-rounded to ovoidal in outline. Cyst wall consists of autophragm only; smooth to faintly granular. Paratabulation indicated by broad pandasutural areas to give the approximate formula: 1', ?5", 0c, 5"', 1"". The pandasutural areas are broad and deep, bordered by fairly high crests without ornamentation. Archaeopyle ?apical. Paracingulum broad, laevorotatory. Parasulcus narrow on epicyst, broadens on hypocyst.

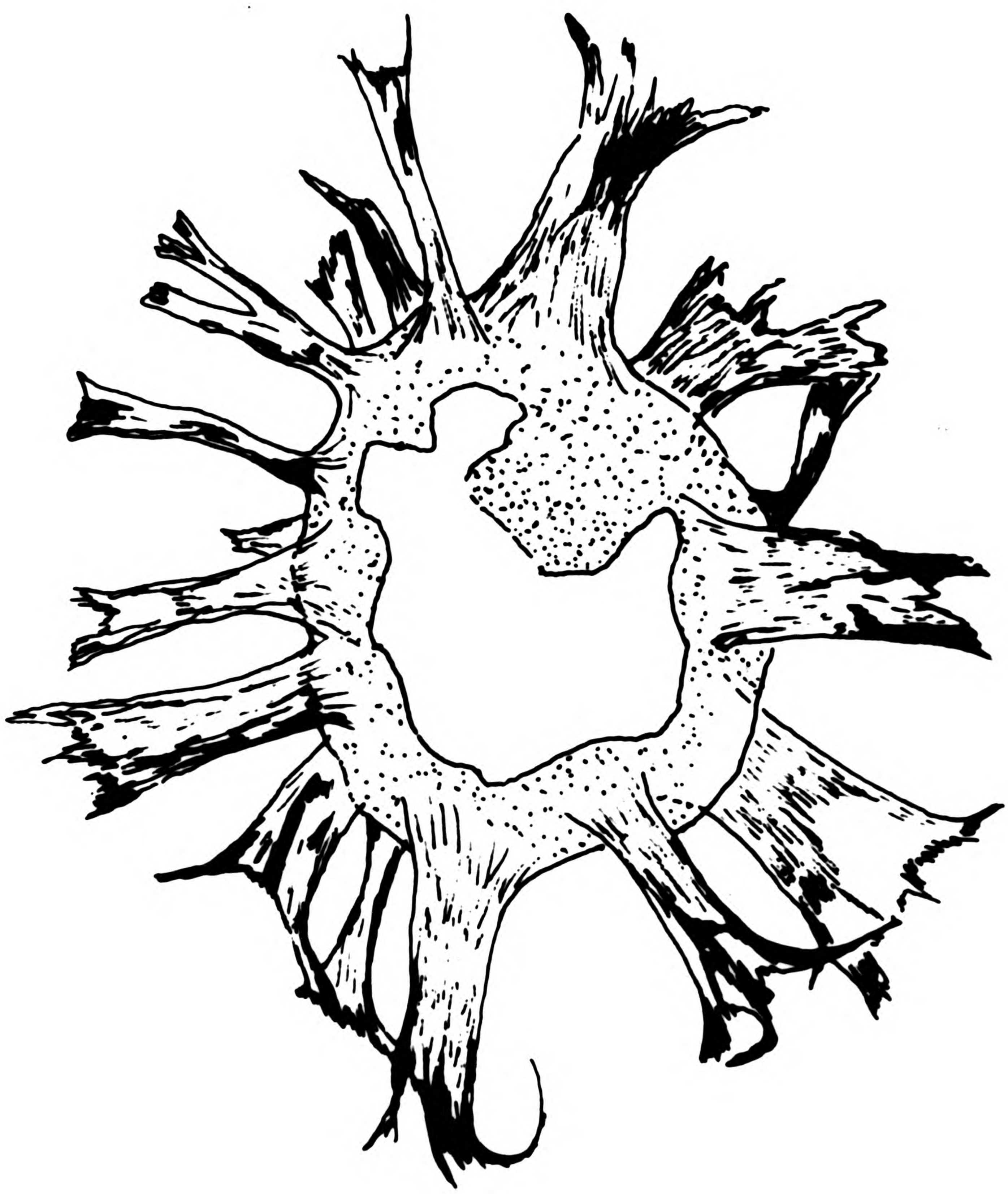
Dimensions Overall length of cyst: 50-53 mu
Overall width of cyst: 45-47 mu
(2 specimens measured)

Remarks The broad morphological features clearly are those of a dinoflagellate cyst. The pandasutural areas are distinctive. Cannot, as yet, be assigned to an existing genus.

Occurrence Warboys: WB.178 (lower athleta); 2 specimens only.
Warlingham: Br.1531 (grossouvrei); 1 specimen only.
Overall range: M.Callovian (grossouvrei) to U.Callovian (lower athleta).

Gen. et sp. indet. D
(Pl.33, figs.9-12; text-fig. 5.14)

Description Intermediate to large skolochorate cyst, body subspherical in outline. Cyst wall consists of autophragm only which is faintly granular and gives rise to 20 to 25 fibrous, hollow, intratabular processes.



Text-fig. 5.14 Gen. et sp. indet. D X1800

Processes vary in thickness and length; fibrous in form and usually simple, although branching may occur; slightly trumpet-shaped and open distally with a ragged edge. Paratabulation indicated by the intratabular processs. Archaeopyle ?apical.

Dimensions   Diameter of central body: 37-51 mu
Length of processes: 20-30 mu
(4 specimens measured)

Remarks   Specimens are morphologically similar to the Tertiary genus Cordosphaeridium Eisenack, 1963b, emend Davey, 1969. The trumpet-shaped intratabular processes are very distinctive.

Occurrence   Warlingham: Br.500 to Br.292 L.Oxfordian (scarburghense to bulowskii).

Gen. et sp. indet. E
(Pl.34, fig.4)

Description   A large skolochorate cyst, subspherical in outline with large trumpet-shaped processes which are openly-recurved distally. The processes are wide, hollow and fibrous.

Dimensions   Overall diameter of cyst: 60mu
(1 specimen only)

Remarks   A single, poorly-preserved specimen only, which, like Gen. et sp. indet. D., possibly belongs to Cordosphaeridium.

Occurrence   Warlingham: Br.246 L.Oxfordian (corsticardia); a single specimen.

Gen. et sp. indet. F
(Pl.32, figs.21a-c)

Description   Small proximate cyst, pentagonal in outline. Cyst wall consists of autophragm only which is smooth and gives rise to parasutural crests. The parasutural crests themselves give rise to a series of short spines which are capitate and connected distally. Paratabulation indicated by parasutural crests; gonyaulacacean, formula: 4', 6", 6c, 5"', ?1p, 1"". Archaeopyle precingular, type P (3" only); operculum free. Paracingulum strongly laevorotatory. Parasulcus strongly sinuous.

Dimensions   Overall length of cyst: 40 mu
Overall width of cyst: 38 mu
(1 specimen only)

Remarks   A single specimen only was encountered which clearly exhibits a gonyaulacacean paratabulation formula and possibly belongs to the genus Hystrichogonyaulax Sarjeant, 1969. It resembles H.warboysensis sp.nov. (herein), but is smaller and has parasutural spines which are connected distally.

Occurrence   Warlingham: Br.620 L.Oxfordian (scarburghense) a single specimen.

Gen. et sp. indet. G
(Pl.32, fig.20)

Description   Small to intermediate proximochorate cyst, spheroidal to 'droplet'-shape in outline. Cyst wall consists of autophragm only which is smooth and gives rise to numerous small hollow processes; processes are isolated and recurved distally. Paratabulation not indicated. Archeopyle not indicated.

Dimensions   Overall diameter of cyst: 50 mu
(1 specimen only)

Remarks   The broad morphological features clearly indicate that this specimen is a dinoflagellate cyst, although it cannot be assigned to a known genus. It resembles Stephanelytron echinatum sp.nov. (herein) but has no outer ectophragm or corona structure; the processes are also recurved distally.

Occurrence   Warlingham: Br.605 L.Oxfordian (scarburghense); a single specimen only.

Gen. et sp. indet. H
(Pl.32, fig.20)

Description   A small proximochorate cyst, spheroidal in outline. Cyst wall consists of autophragm only which gives rise to numerous processes whichbifurcate or trifurcate towards their distal tips, each branch being recurved slightly. Paratabulation not indicated. Archaeopyle ?apical.

Dimensions   Overall length of cyst: 25 mu
Overall width of cyst: 8.5 mu
(1 specimen only)

Remarks   The morphological features clearly indicate that this specimen is a dinoflagellate cyst, but a generic assignment has not been possible from this single specimen.

Occurrence Warlingham: Br.884 U.Callovian (lamberti/athleta); a single specimen only.

Gen. et sp. indet. I
(Pl.32, figs.17,19)

Description A small subspherical to ellipsoidal cyst which is thick-walled and gives rise to numerous hair-like processes which give a dense covering to the cyst. The processes are about one-quarter of the shell diameter in length. The shell is usually split at some point on the surface.

Dimensions Diameter of shell: 30-33 mu
Length of processes:7-10 mu
(3 specimens measured)

Remarks Specimens are probably an acanthomorphic acritarch, although they tend to be somewhat larger than the majority of acritarchs. It broadly resembles *Micrhystridium densispinum* Valensi, 1953 in all except size.

Occurrence Warlingham: Br.727 to Br.368 L.Oxfordian (scarburghense to praecordatum).

Chapter six

STRATIGRAPHICAL DISTRIBUTION AND CORRELATION

STRATIGRAPHICAL DISTRIBUTION AND CORRELATION

A. STRATIGRAPHICAL DISTRIBUTION

1. General stratigraphical distribution of dinoflagellates

Dinoflagellate cysts have proved to be of considerable value in the biostratigraphy of marine Mesozoic and Caenozoic sediments. Sarjeant (1967c) and Harker and Sarjeant (1975), amongst others, have outlined the stratigraphical distribution of dinoflagellate cysts. More recently G.L. Williams (1977) has divided the Late Triassic, Jurassic, Cretaceous and Tertiary into thirty concurrent-range zones and twelve subzones, based on index species of dinoflagellate cysts together with associated assemblages characteristic of each zone and subzone. Williams claims that these assemblages are usually cosmopolitan in the Jurassic, Cretaceous, Palaeocene and Eocene, and regional in the Oligocene, Miocene and Pliocene. (The merits of this scheme as applied to the present study are discussed later in this chapter).

In relation to other parts of the geological column, the Jurassic has been studied in some considerable detail - a consequence of the extensive hydrocarbon exploration programme carried out over the last quarter of a century. However, as pointed out by Davey and Riley (1978), much of the data obtained is filed away in confidential company reports and there is still a lack of published research papers. Much of the early work by authors in the 1960's and early 1970's, particularly that of W.A.S.Sarjeant, has been updated by more recent studies.

The first major attempts to provide comprehensive range-charts for Jurassic microplankton was made by Riley and Sarjeant (1972). More recently Davey and Riley (op.cit.) have produced charts summarising some of the data currently available for North-West Europe and adjacent areas. Species and morphological groups depicted by them are considered to be stratigraphically significant and/or morphologically diagnostic. Sarjeant (1979) has extended the known data to include the "whole world (excluding North America)" in producing a new zonal scheme for the Middle and Upper Jurassic. In practice however, the 'world' in his paper is restricted to North-West Europe and Greenland! Although Sarjeant's paper appeared in 1979, the data included had not been updated since the original manuscript was submitted in 1977; the work is therefore contemporary with that of Davey and Riley (op.cit).

In the present study the ranges of the majority of species as recorded in chapter 5 are compared with the published ranges of Davey and Riley (op.cit) and Sarjeant (op.cit), these being the most recently published range-charts available. Ammendments have been made where appropriate.

2. Stratigraphical Distribution of Dinoflagellates in the Callovian and Oxfordian

G.L. Williams (1977) and Sarjeant (1979) have divided the Callovian and Oxfordian into a number of zones based on dinoflagellate cysts (fig.6.1). Davey and Riley (1978), whilst not providing a zonal scheme, have noted certain characteristic species and assemblages within the Callovian and Oxfordian. A brief description of each scheme is given here.

a) Zonation scheme of G.L. Williams (1977)

Williams divides the Lower Callovian to Middle Oxfordian into three concurrent-range zones, each being characterised by the following assemblages:

Adnatosphaeridium caulleryi zone (= Early Callovian)
Based on assemblages from Southern England, and Scotia Shelf-Grand Banks. Species include: ***Adnatosphaeridium caulleryi, A. fillamentosum Cleistosphaeridium tribuliferum, Gonyaulacysta jurassica, Hystrichogonyaulax cladophora, Meiourogonyaulax cristulata, M. rioultii, Millioudodinium ambigua, Polystephanephorous paracalathus*** and ***Scriniodinium crystallinum.***

Adnatosphaeridium aemulum zone (= Late Callovian)
Based on assemblages from Poland (Gorka, 1970), France, Southern England and Scotia Shelf-Grand Banks. Species include:
Adnatosphaeridium aemulum, Aldorfia aldorfensis, Cleistosphaeridium lumectum, Ctenidodinium ornatum, C. pachydermum, Ellipsoidictyum cinctum, Hexagonifera jurassica, Leptodinium regale, Lithodinia jurassica, Meiourogonyaulax deflandrei, Sentusidinium pilosum, S.rioultii, S. verrucosum, S. villersense, Stephanelytron caytonense, S. scarburghense, Surculosphaeridium vestitum, Systematophora cf. areolata, Tubotuberella dangeardii, Valensiella ampulla, V. ovulum, Wanaea digitata and ***W. fimbriata.***

Gonyaulacysta jurassica zone (= Oxfordian)
Recognised throughout Western Europe, Scotia Shelf and Grand Banks, and in Arctic Canada. In Southern England it is divided into 3 subzones:

(i) Polystephanephorous clathus - Hystrichosphaeridium polonicum (?= ***Compositosphaeridium costatum***) subzone (= Lower Oxfordian)

Text-fig. 6.1 The zonation schemes of Williams (1977) and Sarjeant (1979) for the Callovian to Middle Oxfordian, based on dinoflagellate cysts nt(1979)

<table>
<tr><th>FORMATION</th><th>STAGE</th><th>ZONE</th><th>SUB ZONE</th><th colspan="2">WILLIAMS 1977</th><th>SARJEANT 1979</th></tr>
<tr><td rowspan="6">UPPER OXFORD CLAY</td><td>M. OXFORDIAN</td><td>plicatilis</td><td>vertibrale</td><td rowspan="6">Gonyaulacysta jurassica</td><td>A. fillamentosum</td><td>Stephanelytron redcliffense</td></tr>
<tr><td rowspan="5">LOWER OXFORDIAN</td><td rowspan="3">cordatum</td><td>cordatum</td><td rowspan="5">Polystephanephorous calathus / Hystrichosphaeridium polonicum (?= Compositosphaeridium costatum)</td><td rowspan="9">Wanaea fimbriata</td></tr>
<tr><td>costicardia</td></tr>
<tr><td>bulowskii</td></tr>
<tr><td rowspan="2">mariae</td><td>praecordatum</td></tr>
<tr><td>scarburghense</td></tr>
<tr><td rowspan="3">MIDDLE OXFORD CLAY</td><td rowspan="4">UPPER CALLOVIAN</td><td colspan="2">lamberti</td><td colspan="2" rowspan="4">Adnatosphaeridium aemulum</td></tr>
<tr><td rowspan="3">athleta</td><td>u</td></tr>
<tr><td>m</td></tr>
<tr><td rowspan="5">LOWER OXFORD CLAY</td><td>l</td></tr>
<tr><td rowspan="4">MIDDLE CALLOVIAN</td><td rowspan="2">coronatum</td><td>grossouvrei</td><td colspan="2" rowspan="8">Adnatosphaeridium caulleryi</td><td rowspan="7">Polystephanephorous paracalathus</td></tr>
<tr><td>obductum</td></tr>
<tr><td rowspan="2">jason</td><td>(jason)</td></tr>
<tr><td>(medea)</td></tr>
<tr><td rowspan="4">KELLAWAYS</td><td rowspan="4">LOWER CALLOVIAN</td><td rowspan="3">calloviense</td><td>enodatum</td></tr>
<tr><td>calloviense</td></tr>
<tr><td>(koenigi)</td></tr>
<tr><td>macrocephalus</td><td>(kamptus)</td><td>M. callomonii</td></tr>
</table>

Characterised by the presence of: *Acanthaulax paliuros, Apteodinium nuciforme, Cleistosphaeridium tribuliferum, Eisenackia, Gonyaulacysta jurassica, Hystrichogonyaulax nealei, Hystrichosphaeridium polonicum (? = Compositosphaeridium costatum), Pareodinia ceratophora, Polystephanephorous calathus, Prolixosphaeridium granulosum, Senoniasphaera spp., Sentusidinium pilosum* and *Stephanelytron redcliffense*.

(ii) Adnatosphaeridium filamentosum subzone (= Middle Oxfordian)
Charactersied by the following species: *Adnatosphaeridium aemulum, A. filamentosum, Ctenidodinium spp.* (especially *C. ornatum*), *Hystrichogonyaulax cladophora, Hystrichosphaerina orbifera, Pluriarvalium osmingtonense, Systematophora fasciculigera* and *Tubotuberella eisenackii*.

(iii) Hystrichosphaerina orbifera subzone (= Upper Oxfordian)
Species of *Gonyaulacysta* dominate in abundance and variability.
Other species include: *Chytroeisphaeridia chytroeides, Cleistosphaeridium tribuliferum, Gonyaulacysta jurassica, Hystrichogonyaulax cladophora, Hystrichosphaerina orbifera, Lanterna bulgarica, Occisucysta spp., Palaeostomocystis spp., Scriniocassis dictyotus, Scriniodinium crystallinum* and *Sentusidinium rioultii*.

b) Zonation scheme of Sarjeant (1979)

In his zonation scheme for the Middle and Upper Jurassic, Sarjeant has divided the Callovian and Oxfordian into four 'parazones' (fig. 6.1). (Because the geological column has already been subdivided into zones by the use of fossils that are characteristic of particular systems (ammonites in the case of the Jurassic), Sarjeant suggests that the term 'parazone' is used for any subsequent zonation based on other fossil groups).

Meiourogonyaulax callomonii parazone (= Upper Bathonian - aspidoides to Lower Callovian - macrocephalus).
Characterised by nine species of *Meiourogonyaulax: M. callomonii, M. ?cantrellii, M. caytonensis, M. cristulata, M. decapitata, M. insulofigurata, M. reticulata, M. strongylos* and *M. valensii*., and four species of *Pareodinia: P. apotomocerastes, P. ceratophora, P. groenlandica* and *P. prolongata*. Species of *Chytroeisphaeridia* and *Sentusidinium* are also prominant. *Ctenidodinium* and genera with cavate cysts are subordinate, including *Gonyaulacysta*.

Polystephanephorous paracalathus parazone (= Lower Callovian - calloviense to Middle Callovian - coronatum).
Characterised by an abundance of *Gonyaulacysta*. *Polystephanephorous*

paracalathus is prominent. Assemblages consist of *Adnatosphaeridium spp.*, *Cleistosphaeridium spp.*, *Apteodinium nuciforme*, *Gonyaulacysta jurassica* and *Hystrichogonyaulax cladophora*. *Meiouorogonyaulax* is of diminished importance.

Wanaea fimbriata parazone (= Upper Callovian - athleta to Lower Oxfordian - cordatum).
Characterised by the genus *Wanaea*. *Gonyaulacysta* and related genera are numerous and varied, including *Heslertonia*. *Acanthaulax* appears to be restricted to this parazone. Species of *Polystephanephorous*, *Surculosphaeridium*, *Compositosphaeridium*, *Prolixosphaeridium*, *Endoscrinium*, *Scriniodinium* and *Sentusidinium* are present. *Systematophora* and *Stephanelytron* appear towards the top of the parazone.

Stephanelytron redcliffense parazone (= Middle Oxfordian - plicatilis to Lower Kimmeridgian - baylei).
Gonyaulacysta jurassica is extremely numerous. *Gonyaulacysta* and other related genera including *Acanthaulax*, *Leptodinium*, *Hystrichogonyaulax* and *Tubotuberella* are abundant. *Systematophora*, *Adnatosphaeridium* and *Surculosphaeridium* are prominent, as are species of *Endoscrinium* and *Scriniodinium*. *Sentusidinium pilosum* is a noteworthy species, together with species of *Stephanelytron*. *Ctenidodinium ornatum* and species of *Wanaea* fade out early in this parazone. *Nannoceratopsis*, *Compositosphaeridium* and *Taeniophora* also dissappear here.

c) Davey and Riley (1978)

Whilst not providing a zonation scheme for the Callovian and Oxfordian, Davey and Riley note particular assemblages at certain stratigraphic horizons. For example, the *Lithodinia caytonensis* group, together with the *Ctenidodinium gochtii/kettonensis* plexus (included in the present work under *Ctenidodinium pachydermum*), figure prominently in Early Callovian assemblages. They also note that *Wanaea acollaris* and the *Lithodinia caytonensis* group become extinct within the Callovian.

Several "typically Oxfordian" taxa appear within the Late Callovian, including *Acanthaulax senta*, *Wanaea digitata* and species of *Stephanelytron*. The top of the Callovian is marked by the highest occurrence of *Pareodinia prolongata* and a downsection influx of *Mendicodinium groenlandicum*.

Species which have stratigraphical 'tops' within the Oxfordian include *Compositosphaeridium costatum*, *Acanthaulax senta* and *Ctenidodinium ornatum*. *Wanaea digitata*, *W. fimbriata* and elements of the *Kalyptea stegasta* group are restricted to Early Oxfordian and older assemblages.

Although detailed comparisons between these three authors reveal a number of variances, there are certain broad similarities. The Callovian/ Oxfordian may be broadly divided into the following three units:

3 MIDDLE & UPPER OXFORDIAN	= Hystrichosphaerina orbifera and Adnatosphaeridium filamentosum subzones of Williams (1977), and Stephanelytron redcliffense parazone of Sarjeant (1979)
2 LOWER OXFORDIAN & UPPER CALLOVIAN	= Adnatosphaeridium aemulum zone and Polystephanephorous calathus / Hystrichodinium polonicum (=?*Compositosphaeridium costatum*) subzone of Williams (1977), and Wanaea fimbriata parazone of Sarjeant (1979).
1 LOWER & MIDDLE CALLOVIAN	= Adnatosphaeridium caulleryii zone of Williams (1977), and Polystephanephorous & Meiourogonyaulax callomonii parazones of Sarjeant (1979).

1 LOWER & MIDDLE CALLOVIAN

Both Sarjeant and Williams have the following taxa in common: ***Adnatosphaeridium, Cleistosphaeridium, Meiourogonyaulax, Polystephanephorous paracalathus*** and ***Gonyaulacysta*** group (especially ***G. jurassica*** and ***Hystrichogonyaulax cladophora***). Davey and Riley also note that ***Dichadogonyaulax*** (now ***Ctenidodinium***) figure prominently in Early Callovian assemblages. They also include ***Sentusidinium rioultii*** plus two of the four species of ***Pareodinia (P. ceratophora*** and ***P. prolongata)*** mentioned by Sarjeant as being characteristic of the Early Callovian.

2 LOWER OXFORDIAN & UPPER CALLOVIAN

The following taxa are common to both Sarjeant and Williams: ***Compositosphaeridium, Ctenidodinium ornatum, Gonyaulacysta*** group, ***Polystephanephorous, Prolixosphaeridium, Sentusidinium*** (especially ***S. rioultii***, ***S. verrucosum*** and ***S. villersense), Surculosphaeridium, Valensiella*** and ***Wanaea.***

Sarjeant (1979) considers members of the ***Stephanelytron*** group to appear in the Lower Oxfordian only (although he notes that ***S. caytonense*** occurs in the Upper Callovian - lamberti zone). Williams (1977) however notes ***S. caytonense*** and ***S. scarburghense*** occurring in the Late Callovian, with ***S. redcliffense*** appearing in the Lower Oxfordian (also followed by Davey and Riley (1978)). ***Wanaea*** is also an important taxon with the first occurrence of ***W. fimbriata*** marking the Callovian/Oxfordian boundary.

Davey and Riley (1978) likewise note that this boundary is delineated by the highest occurrence of ***Pareodinia prolongata***.

There are however important differences between the assemblages described by Williams and Sarjeant. Whilst both agree that the ***Gonyaulacysta*** group becomes important and diverse, ***Acanthaulax senta*** and ***Heslertonia*** are not mentioned by Williams, neither are the important genera ***Scriniodinium*** and ***Systematophora***.

3 MIDDLE & UPPER OXFORDIAN

The following taxa are common to both Sarjeant and Williams: ***Adnatosphaeridium, Ctenidodinium, Gonyaulacysta*** group, (including ***G. jurassica*** and ***Hystrichogonyaulax cladophora***), ***Scriniodinium, Sentusidinium, Systematophora*** and ***Tubotuberella eisenackii***. (Many of these taxa are also included in the assemblages described by Davey and Riley (1978) for the Middle and Upper Oxfordian).

It will be noted from these comparisons that broad similarities are present between the assemblages of these larger stratigraphic units. There are however considerable disparities when the more precise stratigraphic ranges of individual taxa are compared and a more narrowly-defined zonal scheme attempted. It is clear that biostratigraphical studies of dinoflagellates are far from complete and considerably more research is neccessary to discover the more precise stratigraphical ranges of diagnostic taxa.

Because of their cosmopolitan nature (in terms of their known occurrence in fresh water to open-marine environments), dinoflagellate cysts are probably much more widely distributed than ammonites; they are, never-the-less, also controlled by environmental parameters. It is clear that a boreal population existed during Jurassic times, distinct in many aspects from the Tethyan population (see Norris, 1975). It is much more likely that other such populations will be recognised in the future. Even within a particular realm (such as the Jurassic Boreal) it is likely that there will be regional differences in assemblages, particularly if dinoflagellates are sensitive to fluctuations in such environmental parameters as temperature, water depth, current patterns etc., as they indeed appear to be. (These considerations and their implications for distribution patterns are discussed in chapter 7).

Table 6.1 List of total microplankton species present in the Warboys and Warlingham boreholes

001 *Acanthaulax senta* *+
002 *A.* cf. *senta* *+
003 *Adnatosphaeridium aemulum* *+
004 *A. caulleryi* *+
005 *Apteodinium granulatum* *+
006 *A. nuciforme* *+
007 *A.* cf. *nuciforme* *+
008 *Batiacasphaera dictydia* *+
009 *Belodinium asaphum* +
010 *B.* cf. *dysculum* +
011 *Caligodinium halosa* *+
012 *Chlamydophorella* sp.A +
013 *Chlamydophorella* sp.B *+
014 *Chytroeisphaeridia cerastes* +
015 *C. chytroeides* *+
016 *C. mantellii* *+
017 *Cleistosphaeridium ehrenbergii* *+
018 *C. lumectum* *+
019 *C. polytrichum* *+
020 *C. tribuliferum* *+
021 *Compositosphaeridium costatum* *+
022 *Cribroperidinium granuligerum*
023 *Ctenidodinium continuum* *+
024 *C. ornatum* *+
025 *C. pachydermum* *+
026 *Ctenidodinium* sp.A +
027 *Dinopterygium absidatum* *+
028 *Ellipsoidictyum cinctum* *+
029 *E.* cf. *gochtii* *+
030 *E. reticulatum* *+
031 *Gonyaulacysta jurassica* *+
032 *G. jurassica* sub.sp. *longicornis* *+
033 *Heslertonia teichophera* *+
034 *Hystrichodinium pulchrum* *+
035 *Hystrichogonyaulax cladophora* *+
036 *Hystrichogonyaulax warboysensis* sp.nov. *+
037 *Hystrichosphaerina orbifera* +
038 *Kalyptea stegasta* *+
039 *K. globulus* sp.nov. +
040 *Kylindrocysta reticulata* sp.nov. +
041 *Leptodinium gongylos* *+
042 *Leptodinium miriabile* +
043 ?*Leptodinium* sp. *+
044 *Lithodinia jurassica* *+
045 *Lithodinia pocockii* *+
046 *Meiourogonyaulax caytonensis* *+
047 *M. cristulata* *+
048 *M. decapitata* +
049 *Millioudodinium* sp. +
050 *Palaeostomocystis tournatilis* *+
051 *Paragonyaulacysta calloviensis* +
052 *Pareodinia alaskensis*
053 *P.* cf. *apotomocerastes* *
054 *P. ceratophora* *+
055 *P. ceratophora* sub.sp. *pachyceras* *+
056 *P. ceratophora* sub.sp. *scopeus* *+
057 *P. prolongata* *+
058 *P. warlinghamensis* sp.nov. +
059 *Pareodinia* sp.B +
060 *P. wigginsi* sp.nov. +
061 *Pluriarvalium osmingtonense* *+
062 *P.* cf. *osmingtonense* *
063 *Pluriarvalium* sp.A *
064 *Polysphaeridium deflandrei* *+
065 *Polystephanephorous paracalathus* *+
066 *Prolixosphaeridium granulosum* *+
067 *Reutlingia gochtii* *+
068 *Scriniocassis dictyotus* +
069 *Scriniodinium crystallinum* *+
070 *S.* cf. *crystallinum* *+
071 *Scriniodinium galeritum* *+
072 *S. luridum* +
073 *S. subvallare* *+
074 *Scriniodinium* sp.A +
075 *Scriniodinium* sp.B +
076 *Senoniasphaera oxfordiensis* sp.nov. +
077 *Sentusidinium pilosum* *+
078 *S. rioultii* *+
079 *S. varispinosum* *+
080 *S. verrucosum* *+
081 *S. villersense* *+
082 *Sentusidinium* sp.A +
083 *Sentusidinium* sp.B +
084 *Sentusidinium* sp.C +
085 *Sentusidinium* sp.D +
086 *S. woollami* sp.nov. *+
087 *Sentusidinium* sp.F *+
088 ?*Sentusidinium* sp. +
089 *Sirmiodiniopsis orbis* *+
090 *Sirmiodinium grossii* *+
091 *Stephanelytron caytonense* *+
092 *S. redcliffense* *+
093 *S. scarburghense* *+
094 *S. tabulophorum* *+
095 *S. eccentricum* sp.nov. *+
096 *S. echinatum* sp.nov. *+
097 *Stephanelytron* sp.A *
098 *Surculosphaeridium cribrotubiferum* *+
099 *S. vestitum* *+
100 *Systematophora areolata* +
101 *S. valensii* +
102
103 gen. et sp. indet J *
104 *Tubotuberella apatella* *+
105 *T. dangeardii* *+
106 *T. eisenackii* *+
107 *T. sphaerocephalis* *+
108 *Wanaea acollaris* *+
109 *W. digitata* *+
110 *W. fimbriata* *+
111 *Nannoceratopsis pellucida* *+
112 *N. plegas* *+
113 gen. et sp. indet.A *+
114 gen. et sp. indet.B *+
115 gen. et sp. indet.C *+
116 gen. et sp. indet.D *+
117 gen. et sp. indet.E +
118 gen. et sp. indet.F +
119 gen. et sp. indet.G +
120 gen. et sp. indet.H +
121 gen. et sp. indet.I +
122 *Micrhystridium deflandrei* *+
123 *M. densispinum* *+
124 *M. fragile* *+
125 *M. inconspicuum* *+
126 *M. nannacanthum* *+
127 *M. polyhedricum* *+
128 *M. rarispinum* *+
129 *M. recurvatum* *+
130 *M. recurvatum forma brevispinosa* *+
131 *M. recurvatum forma longispinosa* *+
132 *M. recurvatum forma multispinosa* *+
133 *M. recurvatum forma reducta* *+
134 *M. sydus* *+
135 *M. variabile* *+
136 *Multiplicisphaeridium* sp. +
137
138 *Pterospermopsis hartii* +
139 *Solisphaeridium claviculorum* *+
140 *S. stimuliferum* *+

* Indicates species present in Warboys Borehole
\+ Indicates species present in Warlingham Borehole

3. Stratigraphical Distribution of Microplankton in the Callovian and Oxfordian of the Warboys and Warlingham Boreholes.

a) Distribution in general terms

From a total of 48 microplankton genera (44 dinoflagellate taxa and 4 acritarch taxa) some 120 dinoflagellate species and 18 acritarch species were recorded from the material studied (see table 6.1). Of this total, 87 dinoflagellate species (72.5% of the total species recorded) and 16 acritarch species (88.8% of the total acritarch species recorded) were recorded from the Warboys borehole. In the Warlingham borehole 116 dinoflagellate species (96.6%) and 18 acritarch species (100%) were recorded. Of the total 138 species of microplankton, 98 (71%) were found occurring in both boreholes; 5 species (3.6%) were unique to Warboys and 35 species (25.4%) to Warlingham.

Figures 6.2 and 6.3 illustrate the ranges of the microplankton species as recorded in the Warboys and Warlingham boreholes respectively. In these charts the species are arranged in order of their last occurrence ('tops') and indication is given as to the relative abundance of species in each sample per 200 count.

The assemblages obtained are typical of the Callovian and Oxfordian and compare very closely with those described from North-West Europe (eg., Sarjeant, 1960b, 1961a, 1962b, 1965, 1968 etc.; Woollam, 1977; Lam and Porter, 1977; Davey and Riley, 1978). However, eight species are recorded from the Callovian and Oxfordian for the first time:

> ***Apteodinium granulatum, Cribroperidinium granuligerum, Ellipsoidictyum reticulatum, Hystrichodinium pulchrum, Meiourogonyaulax decapitata, Polysphaeridium deflandrei, Tubotuberella sphaerocepahalis*** and ***Nannoceratopsis plegas.***

The known ranges of several other taxa are revised as a result of their occurrence at certain levels within the Callovian and Oxfordian here. The following nine species are considered to be new and are here given provisional names:

> ***Hystrichogonyaulax warboysensis, Kalyptea globulus, Kylindorcysta reticulata, Pareodinia warlinghamensis, Pareodinia wigginsi, Senoniasphaera oxfordiensis, Sentusidinium woollami, Stephanelytron eccentricum*** and ***Stephanelytron echinatum.***

It is interesting to note that when comparing the local-ranges of the same species in the two boreholes an intriguing regularity becomes apparent. In most cases species occur earlier in Warboys than in Warlingham. The same

Text-figs. 6.2 and 6.3 Range charts for the Warboys and Warlingham boreholes based on the local-ranges of microplankton

Errata:

for:	read:
Cribroperidinium granulatum	*Cribroperidinium granuligerum*
Gonyaulacysta longicornis	*Gonyaulacysta sub.sp. longicornis*
Hystrichosphaera orbifera	*Hystrichosphaerinia orbifera*
Palaeostomocystis tournatilis	*Palaeostomocystis tornatilis*
Tubotuberella apatella	*Tubotuberella apatela*
Tubotuberella sphaerocephalus	*Tubotuberella sphaerocephalis*
Micrhystridium varispinosum	*Micrhystridium varispinum*
Micrhystridium densispinosum	*Micrhystridium densispinum*

Text-figs. 6.2 and 6.3 Range charts for the Warboys and Warlingham boreholes based on the local-ranges of microplankton

Errata:

for:	read:
Cribroperidinium granulatum	*Cribroperidinium granuligerum*
Gonyaulacysta longicornis	*Gonyaulacysta sub.sp. longicornis*
Hystrichosphaera orbifera	*Hystrichosphaerinia orbifera*
Palaeostomocystis tournatilis	*Palaeostomocystis tornatilis*
Tubotuberella apatella	*Tubotuberella apatela*
Tubotuberella sphaerocephalus	*Tubotuberella sphaerocephalis*
Micrhystridium varispinosum	*Micrhystridium varispinum*
Micrhystridium densispinosum	*Micrhystridium densispinum*

rlingham
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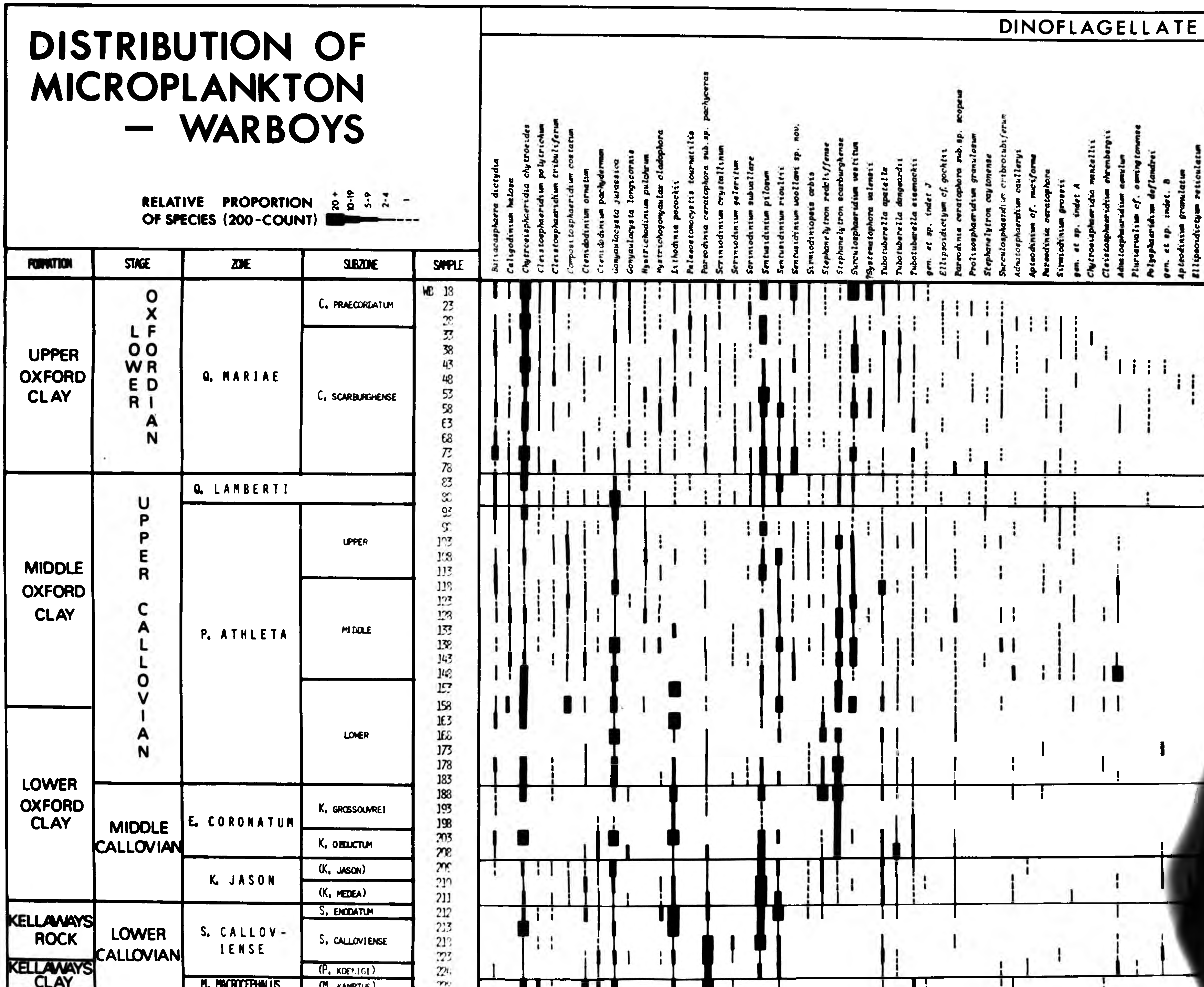

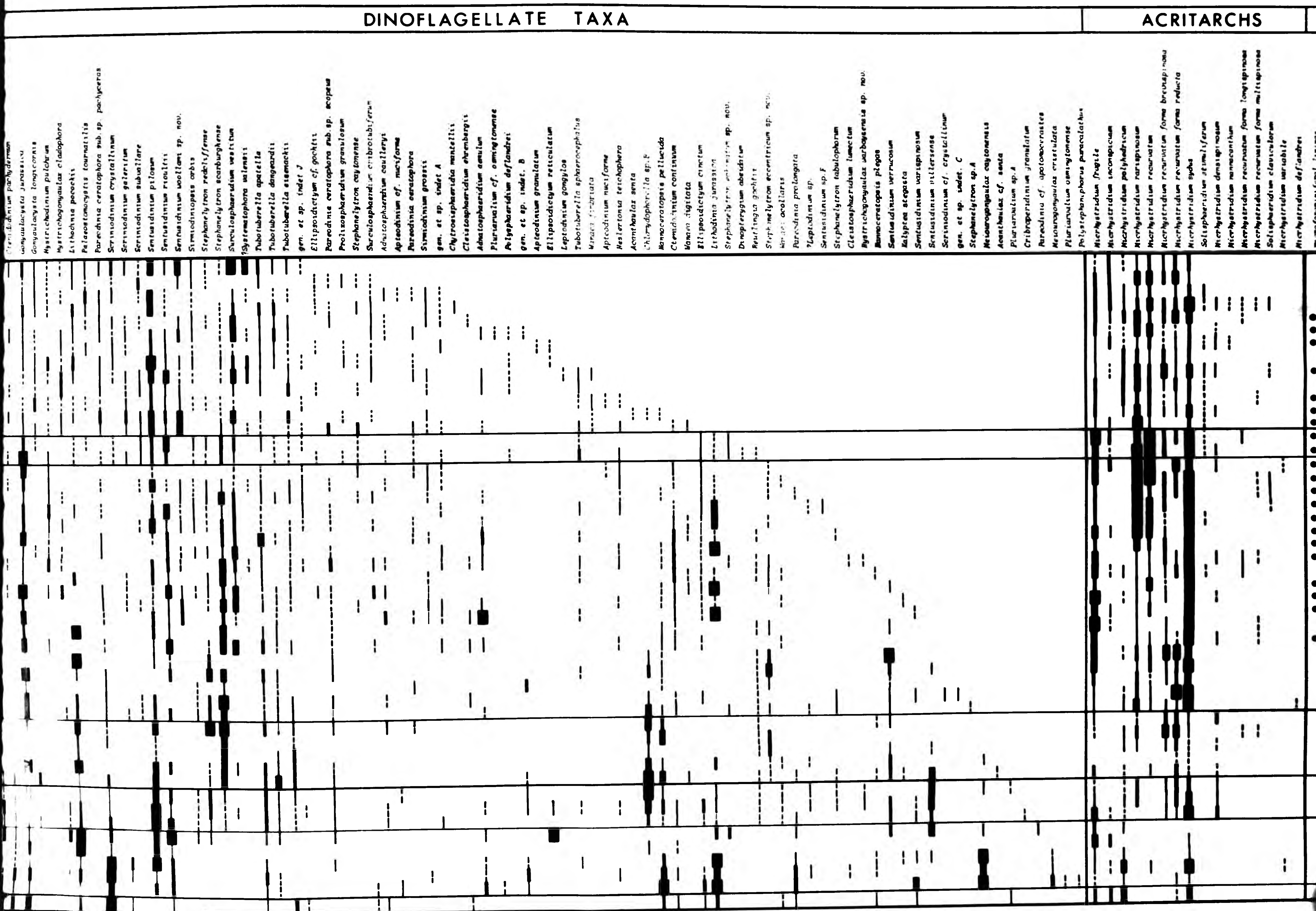

DINOFLAGELLATE TAXA
ACRITARCHS
Ctenidodinium pachydermum
Gonyaulacysta jurassica
Gonyaulacysta longicornis
Hystrichodinium pulchrum
Hystrichogonyaulax cladophora
Lithodinia pocockii
Palaeostomocystis tournatilis
Pareodinia ceratophora sub.sp. pachyceras
Scriniodinium crystallinum
Scriniodinium galeritum
Scriniodinium subvallare
Sentusidinium pilosum
Sentusidinium rioultii
Sentusidinium woollami sp. nov.
Sirmiodiniopsis orbis
Stephanelytron redcliffense
Stephanelytron scarburghense
Surculosphaeridium vestitum
?Systematophora valensii
Tubotuberella apatela
Tubotuberella dangeardii
Tubotuberella eisenackii
gen. et sp. indet J
Ellipsoidictyum cf. gochtii
Pareodinia ceratophora sub.sp. scopeus
Prolixosphaeridium granulosum
Stephanelytron caytonense
Surculosphaeridium cribrotubiferum
Adnatosphaeridium caulleryi
Apteodinium cf. nuciforme
Pareodinia ceratophora
Sirmiodinium grossii
gen. et sp. indet A
Chytroeisphaeridia mantellii
Cleistosphaeridium ehrenbergii
Adnatosphaeridium aemulum
Pluriarvalium cf. osmingtonense
Polysphaeridium deflandrei
gen. et sp. indet. B
Apteodinium granulatum
Ellipsoidictyum reticulatum
Leptodinium gongylos
Tubotuberella sphaerocephalus
Wanaea fimbriata
Apteodinium nuciforme
Heslertonia teichophera
Acanthaulax senta
Chlamydophorella sp.F
Nannoceratopsis pellucida
Ctenidodinium continuum
Wanaea digitata
Ellipsoidictyum cinctum
Lithodinia jurassica
Stephanelytron sp. nov.
Dinopterygium abeidatum
Reutlingia gochtii
Stephanelytron eccentricum sp. nov.
Wanaea acollaris
Pareodinia prolongata
?Leptodinium sp.
Sentusidinium sp.F
Stephanelytron tabulophorum
Cleistosphaeridium lumectum
Hystrichogonyaulax warboysensis sp. nov.
Nannoceratopsis plegas
Sentusidinium verrucosum
Kalyptea stegasta
Sentusidinium variaspinosum
Sentusidinium villersense
Scriniodinium cf. crystallinum
gen. et sp. indet. C
Stephanelytron sp.A
Meiourogonyaulax caytonensis
Acanthaulax cf. senta
Pluriarvalium sp.A
Cribroperidinium granulatum
Pareodinia cf. apotomocerastes
Meiourogonyaulax cristulata
Pluriarvalium osmingtonense
Polystephanephorus paracalathus
Micrhystridium fragile
Micrhystridium inconspicuum
Micrhystridium polyhedricum
Micrhystridium rarispinosum
Micrhystridium recurvatum
Micrhystridium recurvatum forma brevispinosa
Micrhystridium recurvatum forma reducta
Micrhystridium sydus
Solisphaeridium stimuliferum
Micrhystridium densispinosum
Micrhystridium nannacanthum
Micrhystridium recurvatum forma longispinosa
Micrhystridium recurvatum forma multispinosa
Solisphaeridium claviculorum
Micrhystridium variabile
Micrhystridium deflandrei
microforaminiferal linings

Harlingham
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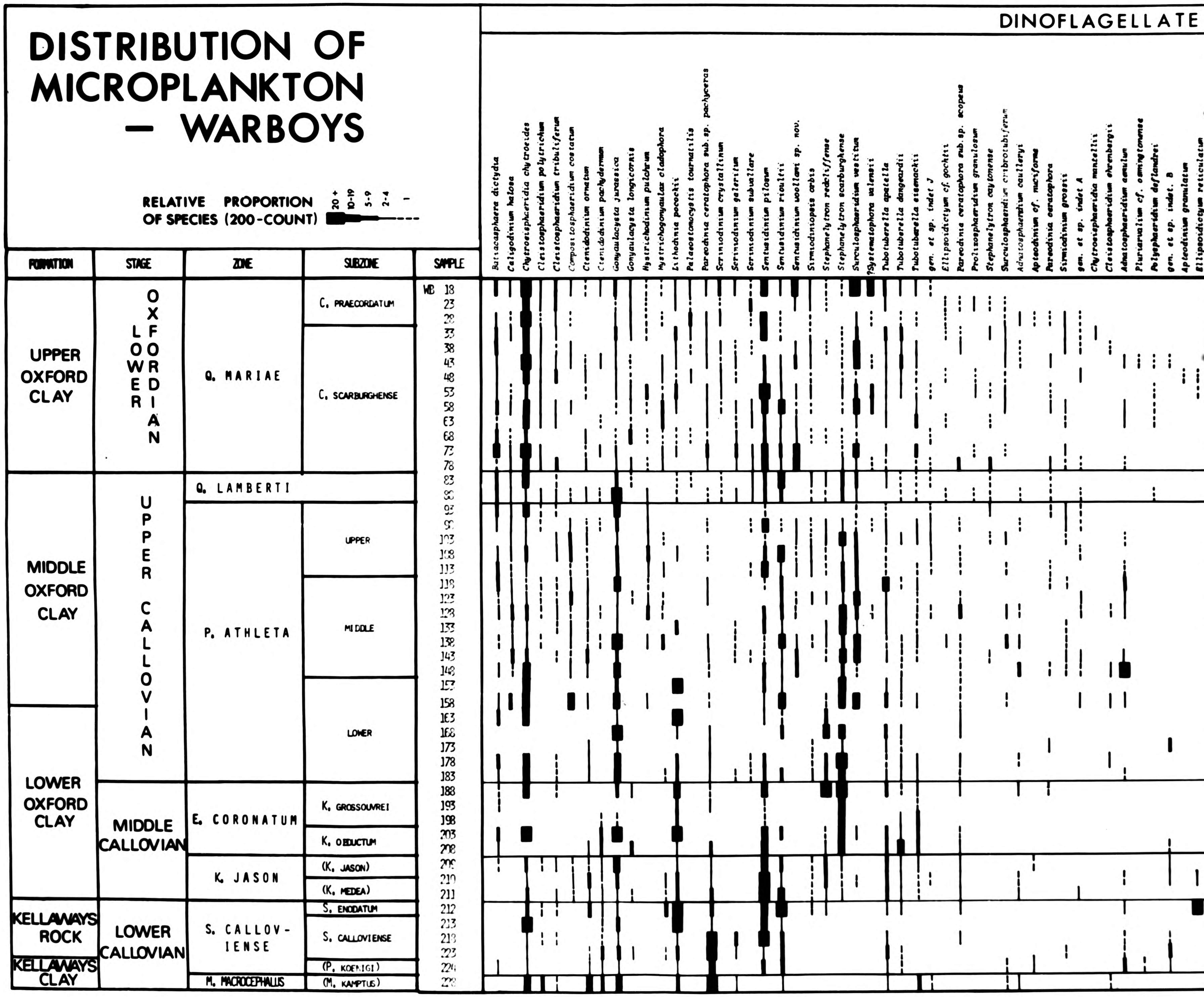
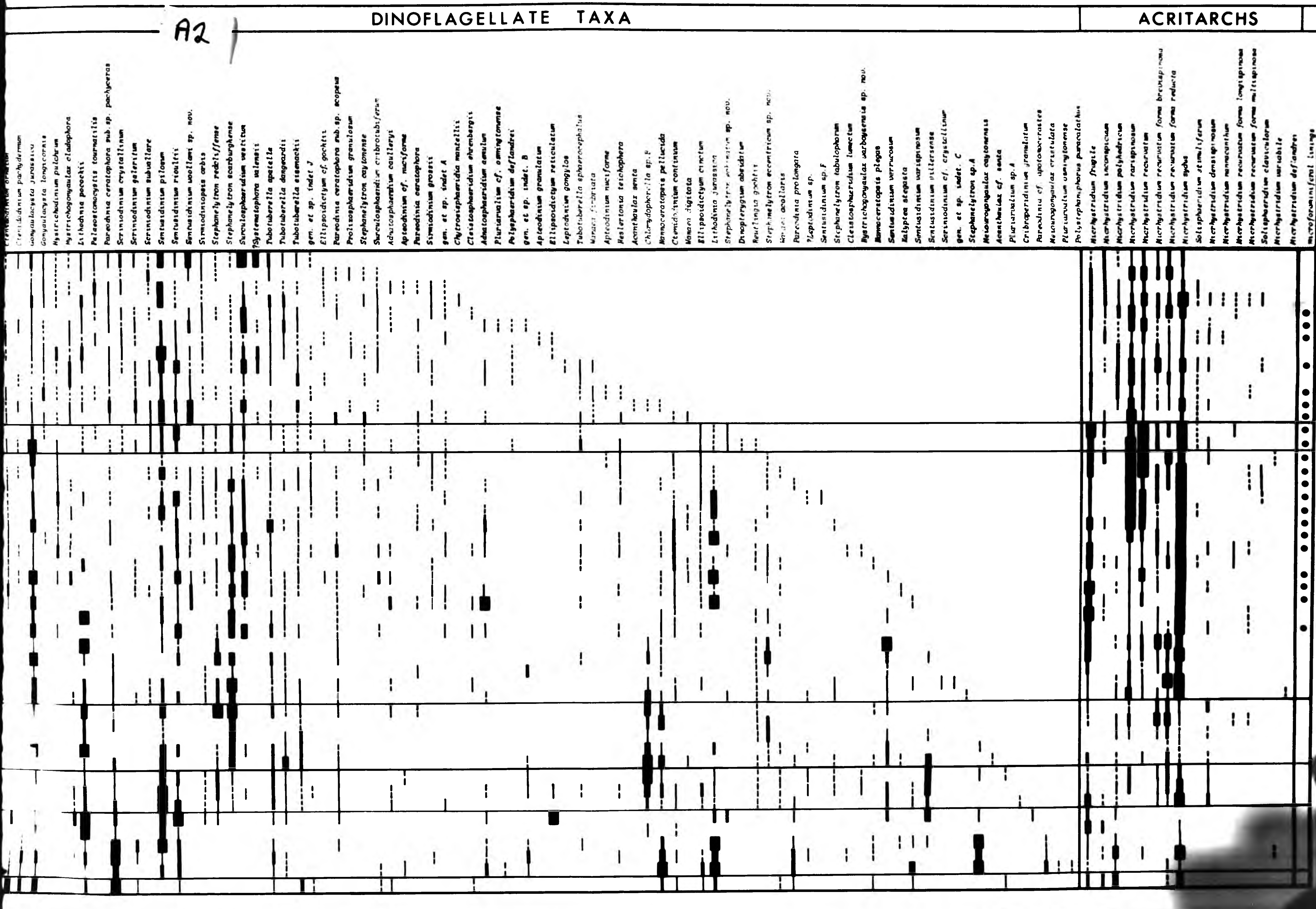
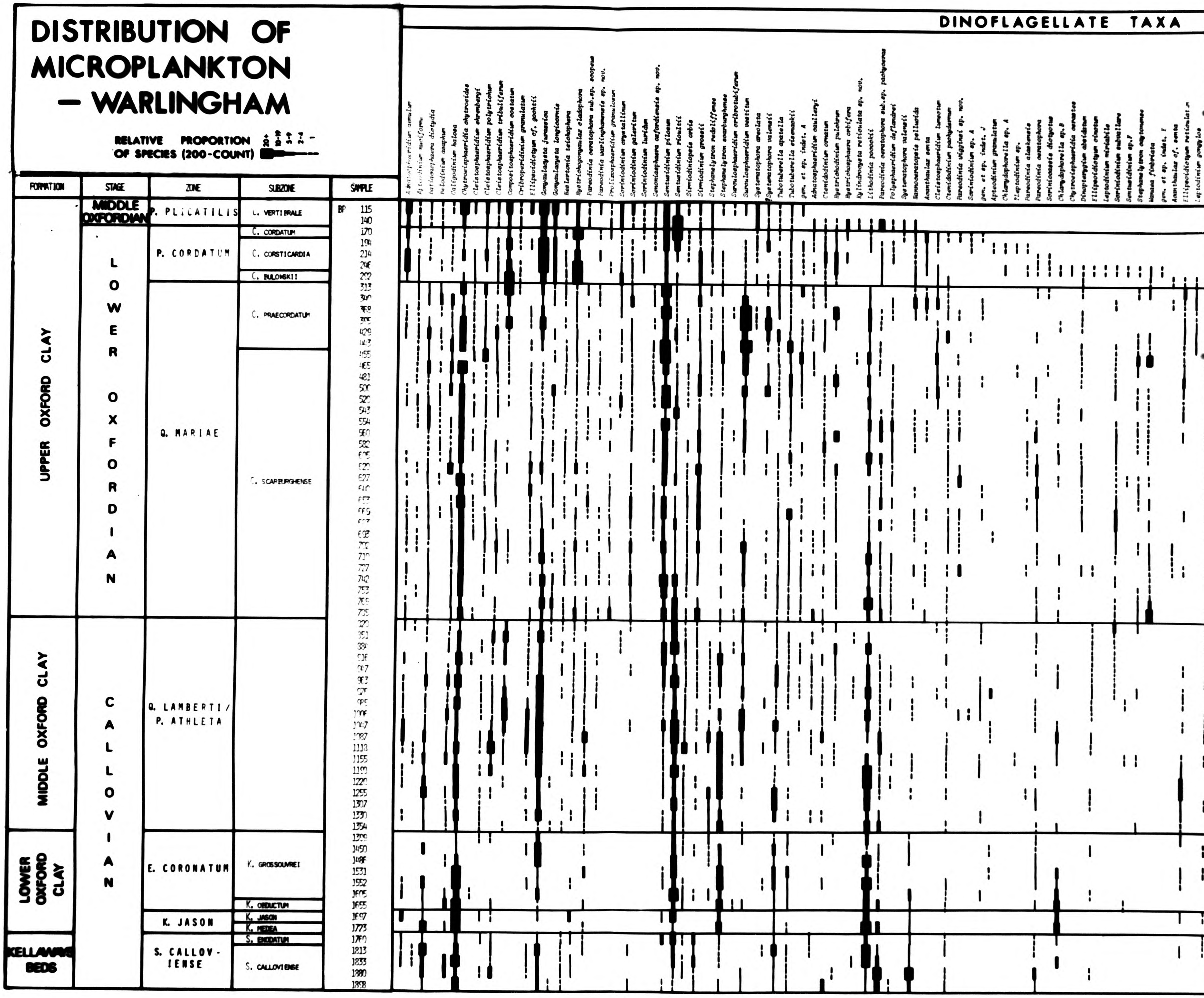
A1

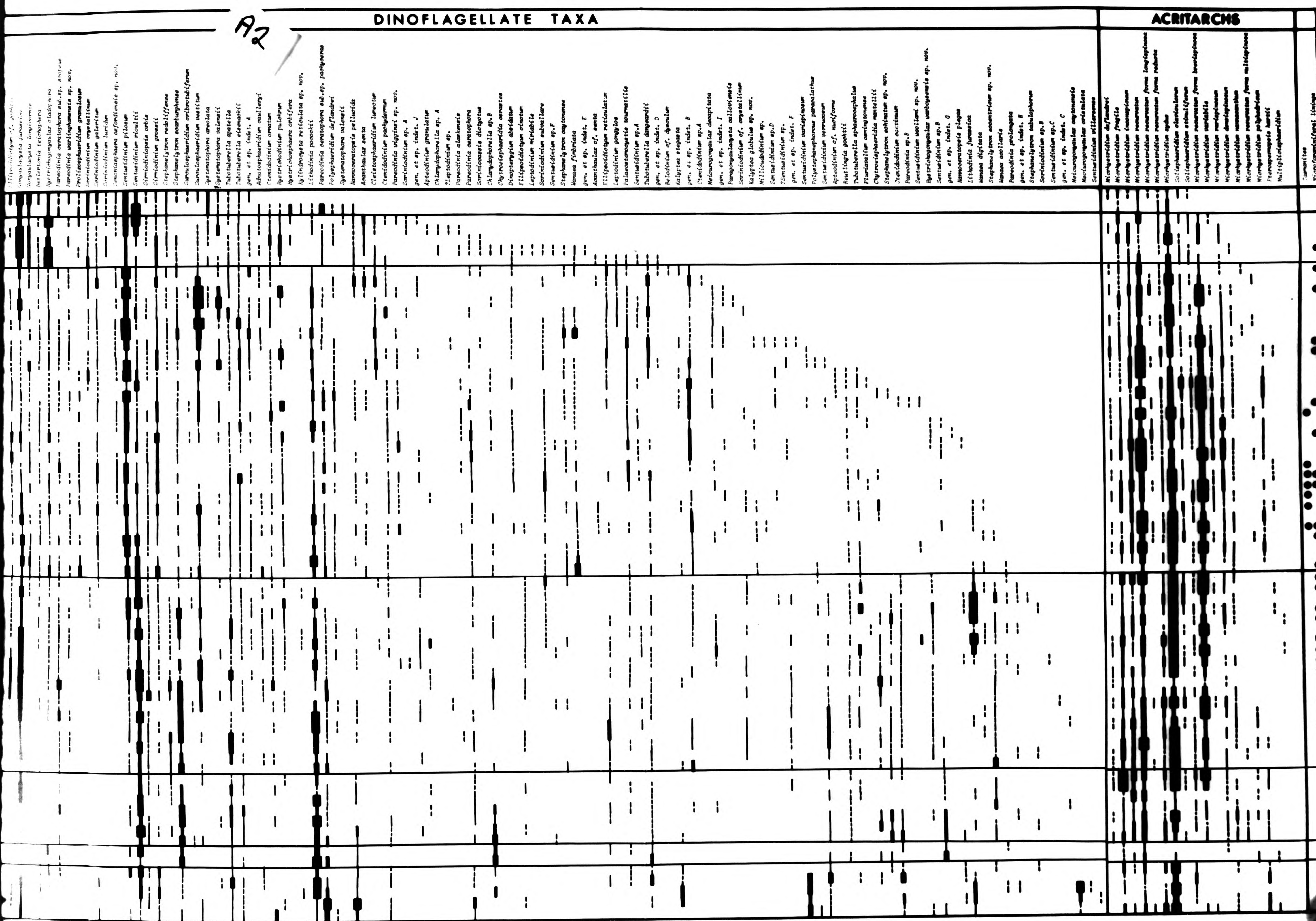




A2
DINOFLAGELLATE TAXA
ACRITARCHS
Ctenidodinium pachydermum
Gonyaulacysta jurassica
Gonyaulacysta longicornis
Hystrichodinium pulchrum
Hystrichogonyaulax cladophora
Lithodinia pocockii
Palaeostomocystis tournatilis
Pareodinia ceratophora sub. sp. pachyceras
Scriniodinium crystallinum
Scriniodinium galeritum
Scriniodinium subvallare
Sentusidinium pilosum
Sentusidinium rioultii
Sentusidinium woollami sp. nov.
Striatodiniopsis orbis
Stephanelytron redcliffense
Stephanelytron scarburghense
Surculosphaeridium vestitum
?Systematophora valensii
Tubotuberella apatella
Tubotuberella dangeardii
Tubotuberella eisenackii
gen. et sp. indet J
Ellipsoidictyum cf. gochtii
Pareodinia ceratophora sub. sp. scopeus
Prolixosphaeridium granulosum
Stephanelytron caytonense
Surculosphaeridium cribrotubiferum
Adnatosphaeridium caulleryi
Apteodinium cf. nuciforme
Pareodinia ceratophora
Stiphrodinium grossii
gen. et sp. indet A
Chytroeisphaeridia mantellii
Cleistosphaeridium ehrenbergii
Adnatosphaeridium aemulum
Pluriarvalium cf. osmingtonense
Polysphaeridium deflandrei
gen. et sp. indet. B
Apteodinium granulatum
Ellipsoidictyum reticulatum
Leptodinium gongylos
Tubotuberella sphaerocephalus
Apteodinium nuciforme
Heslertonia teichophera
Acanthaulax senta
Chlamydophorella sp. F
Nannoceratopsis pellucida
Ctenidodinium continuum
Wanaea digitata
Ellipsoidictyum cinctum
Lithodinia jurassica
Dinopterygium abeidatum
Reutlingia gochtii
Stephanelytron eccentricum sp. nov.
Paraodinia prolongata
?Leptodinium sp.
Sentusidinium sp. F
Stephanelytron tabulophorum
Cleistosphaeridium lumectum
Hystrichogonyaulax warboysensis sp. nov.
Nannoceratopsis plegas
Sentusidinium verrucosum
Kalyptea stegasta
Sentusidinium varispinosum
Sentusidinium villersense
Scriniodinium cf. crystallinum
gen. et sp. indet. C
Stephanelytron sp. A
Meiourogonyaulax caytonensis
Acanthaulax cf. senta
Pluriarvalium sp. A
Cribroperidinium granulatum
Pareodinia cf. apotomocerastes
Meiourogonyaulax cristulata
Pluriarvalium osmingtonense
Polystephanephorus paracalathus
Micrhystridium fragile
Micrhystridium inconspicuum
Micrhystridium polyhedricum
Micrhystridium rarispinosum
Micrhystridium recurvatum
Micrhystridium recurvatum forma brevispinosa
Micrhystridium recurvatum forma reducta
Micrhystridium sydus
Solisphaeridium stimuliferum
Micrhystridium densispinosum
Micrhystridium nannacanthum
Micrhystridium recurvatum forma longispinosa
Micrhystridium recurvatum forma multispinosa
Solisphaeridium claviculorum
Micrhystridium variabile
Micrhystridium deflandrei
microforaminiferal linings

A1

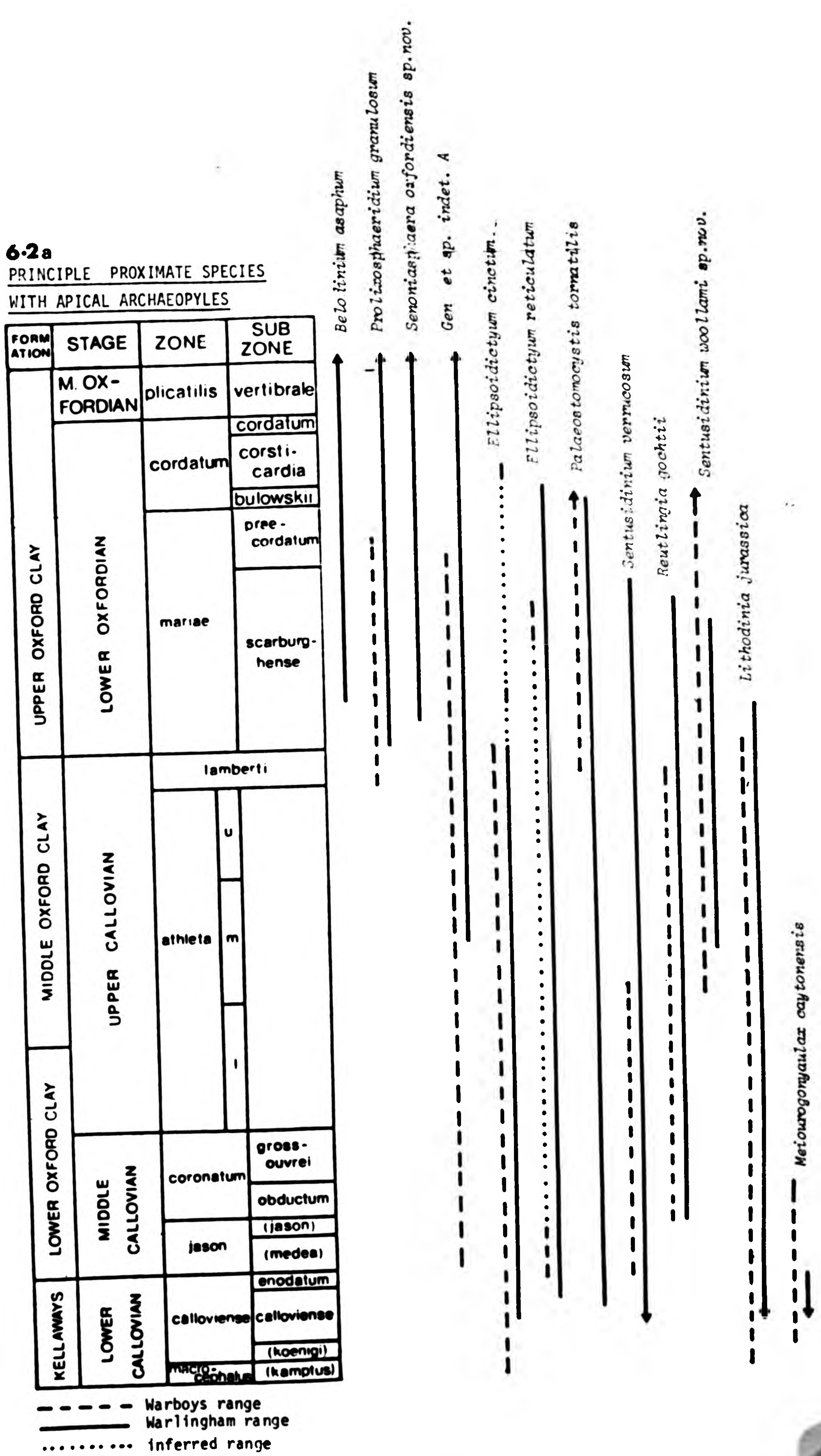

DISTRIBUTION OF MICROPLANKTON – WARLINGHAM
RELATIVE PROPORTION OF SPECIES (200-COUNT)
DINOFLAGELLATE TAXA
FORMATION
STAGE
ZONE
SUBZONE
SAMPLE
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS BEDS
MIDDLE OXFORDIAN
LOWER OXFORDIAN
CALLOVIAN
P. PLICATILIS
P. CORDATUM
Q. MARIAE
Q. LAMBERTI/ P. ATHLETA
E. CORONATUM
K. JASON
S. CALLOVIENSE
C. VERTEBRALE
C. CORDATUM
C. COSTICARDIA
C. BUKOWSKII
C. PRAECORDATUM
C. SCARBURGHENSE
K. GROSSOUVREI
K. OBDUCTUM
K. JASON
K. MEDEA
S. ENODATUM
S. CALLOVIENSE
BP
115
140
170


A2
DINOFLAGELLATE TAXA
ACRITARCHS

Tables 6.2 a-f Ranges of selected dinoflagellates illustrated for Warboys and Warlingham together

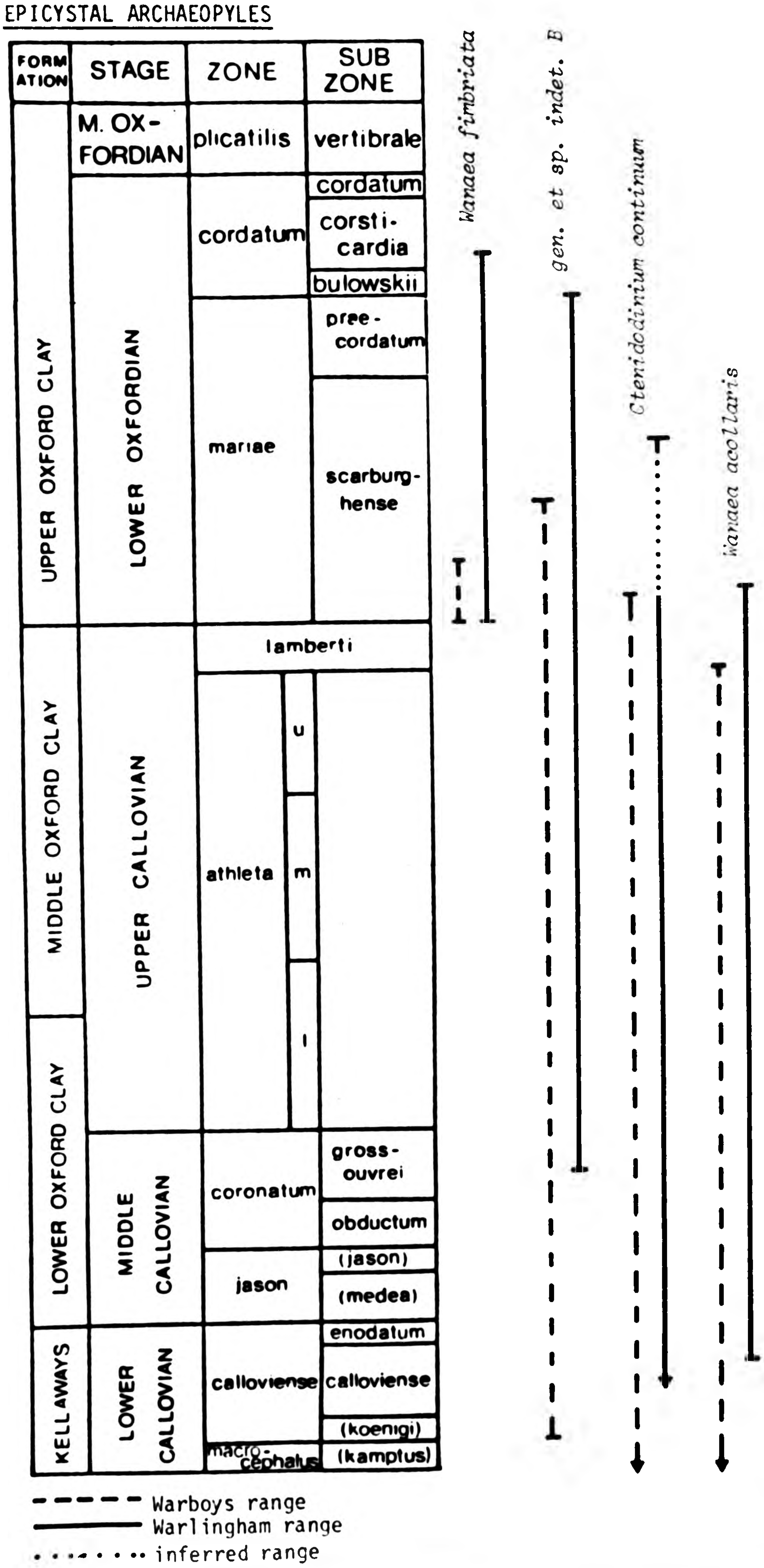
6·2a

PRINCIPLE PROXIMATE SPECIES WITH APICAL ARCHAEOPYLES



6·2b

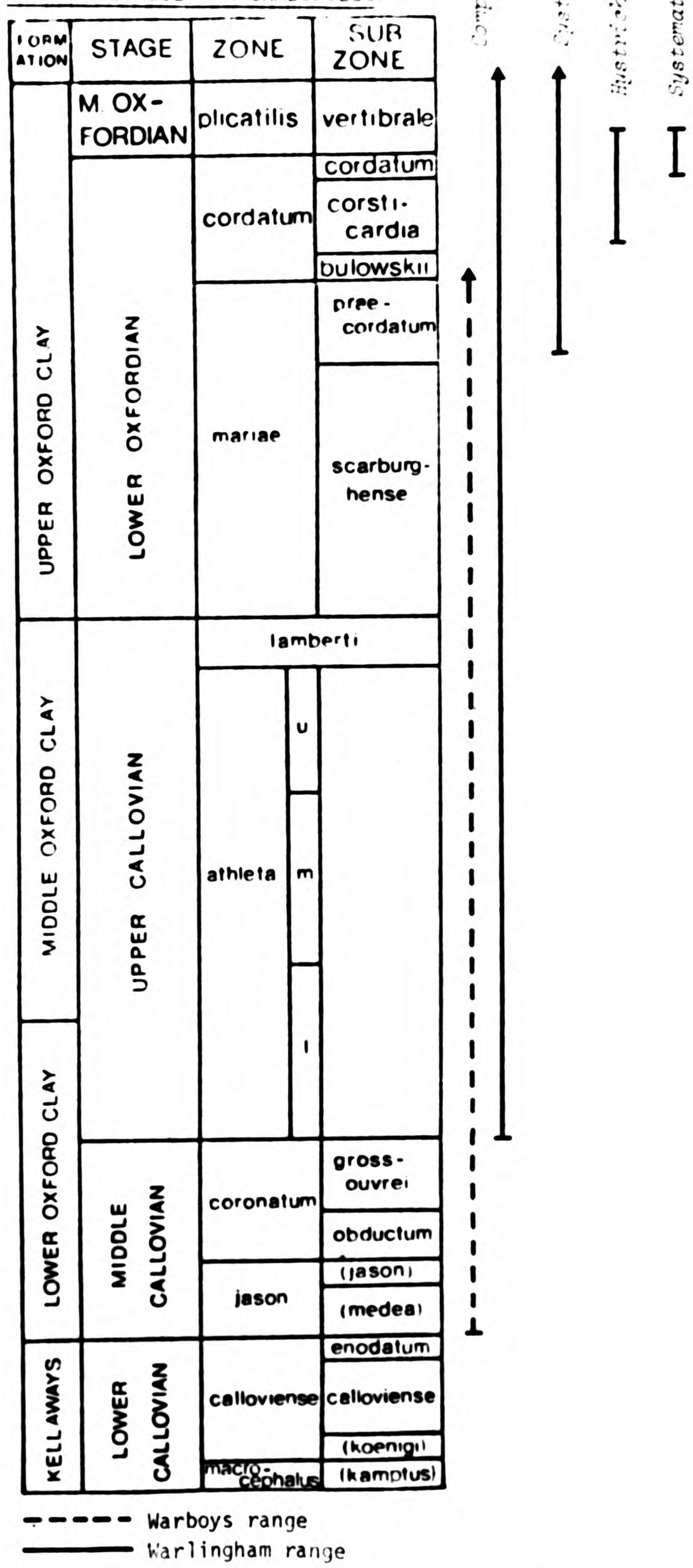
PRINCIPLE SPECIES WITH EPICYSTAL ARCHAEOPYLES



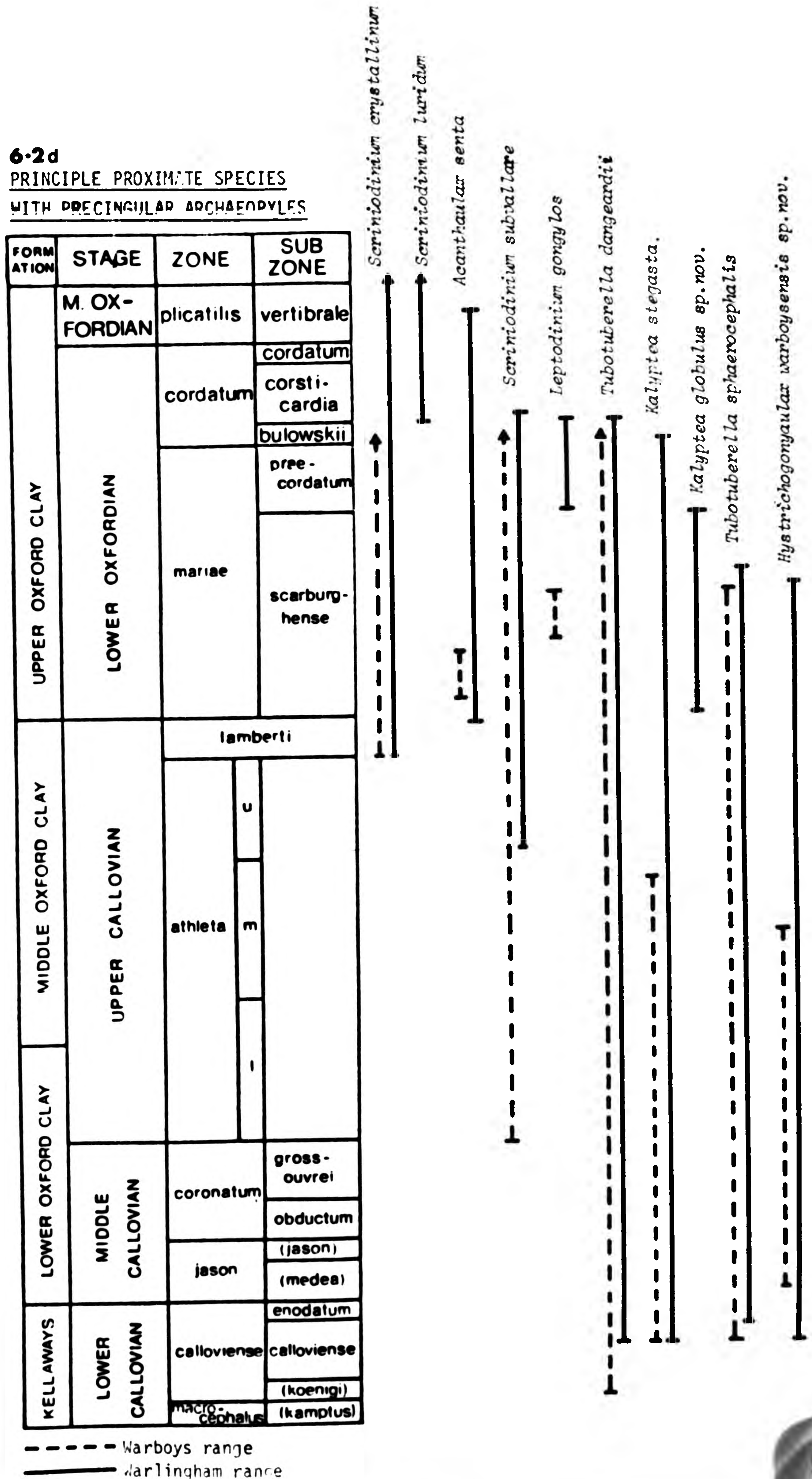
6·2c

PRINCIPLE CHORATE SPECIES

WITH PRECINGULAR ARCHAEOPYLES

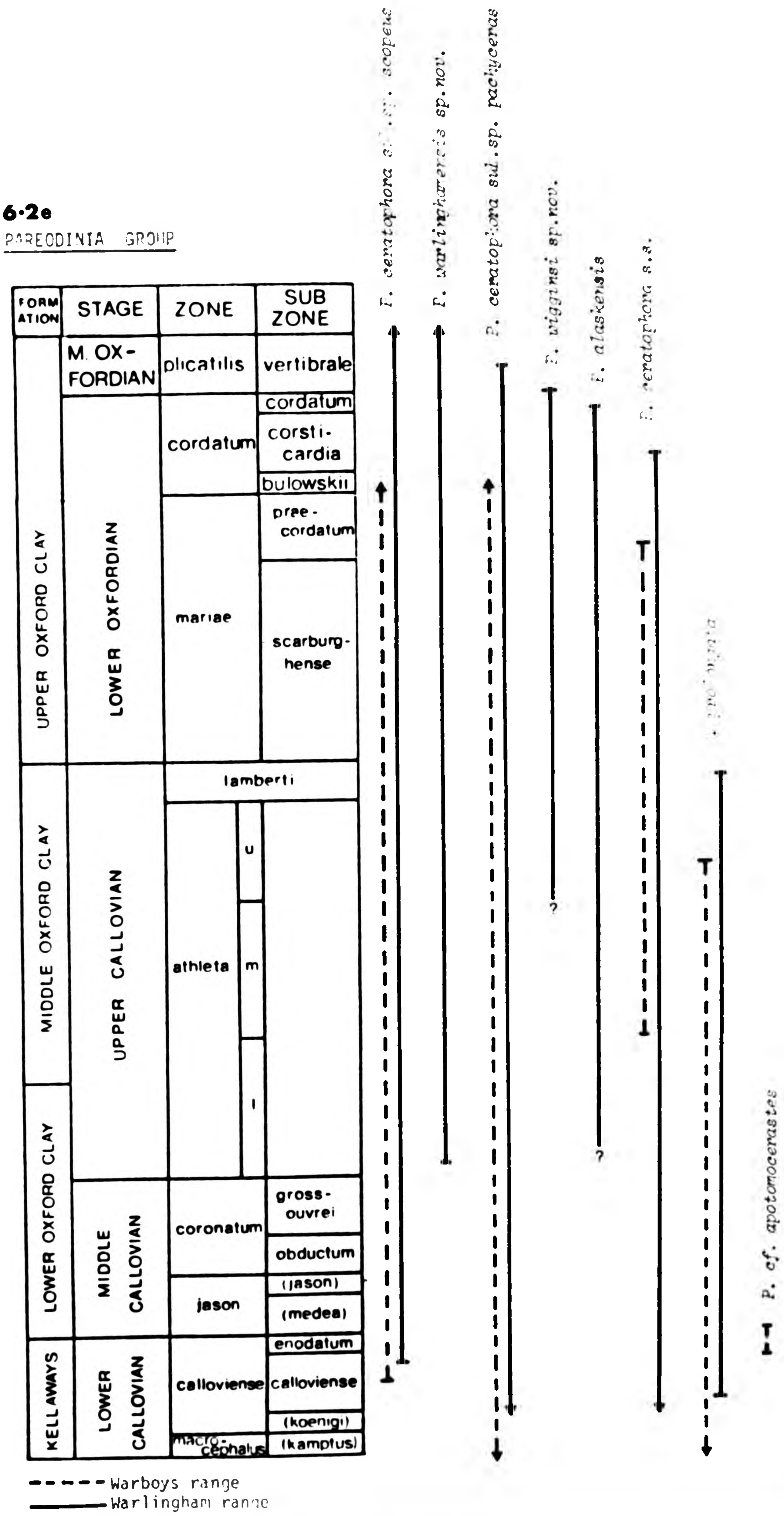


6·2d
PRINCIPLE PROXIMATE SPECIES
WITH PRECINGULAR ARCHAEOPYLES



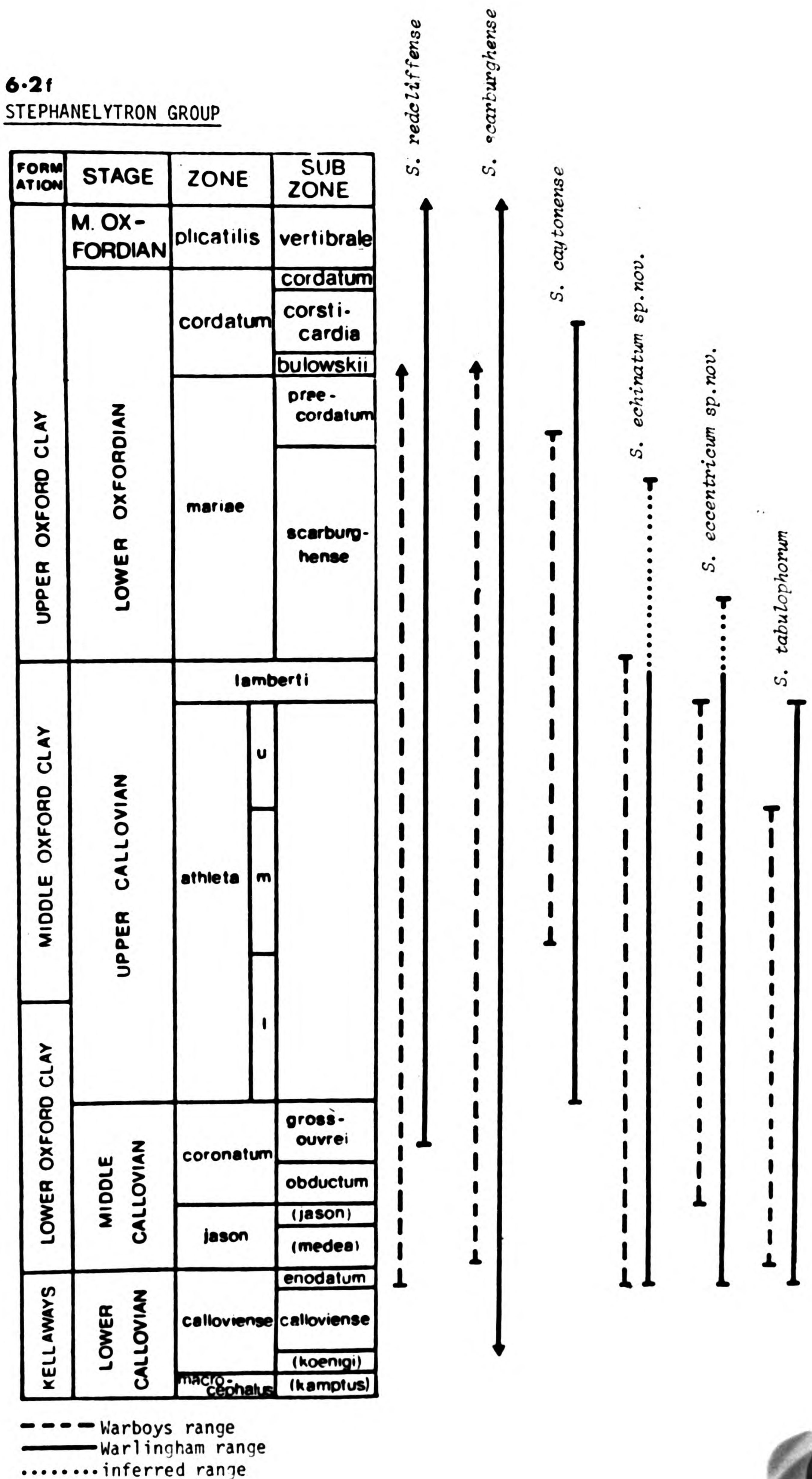
6·2e

PAREODINIA GROUP



6·2f

STEPHANELYTRON GROUP



applies to their extinction (see tables 6.2 a-f). The present author can offer no satisfactory explanation for this phenomenon.

Table 6.3 illustrates the main assemblages for each of the five stages: Lower, Middle and Upper Callovian, Lower and Middle Oxfordian, for the Warboys and Warlingham boreholes. Only species considered to make a significant contribution to the assemblages are included. Taxa which are particularly important constituents are marked *; a + indicates that either a particular species appears for the first time in the stage, or else appears in significant numbers for the first time. Conversely, the symbol - indicates that the species occurs for the last time in a particular stage. It will follow that the symbols + and - together indicates that the species is unique to that particular stage and will therefore usually be of biostratigraphic importance.

b) Assemblages as compared with those described by Williams (1977) and Sarjeant (1979).

It is interesting to compare the assemblages described by both Williams (1977) and Sarjeant (1979), which define their zonal schemes (fig.6.1),with the assemblages recorded in the present study. Similarities are apparent but there is considerable disparity at certain levels within the sequence.

1) Williams (1977)

Adnatosphaeridium caulleryi zone has the following six species in common with the present assemblages: ***Adnatosphaeridium caulleryii, Cleistosphaeridium tribuliferum, Gonyaulacysta jurassica, Meiourogonyaulax cristulata*** and ***Polystephanephorous***. Williams included the first appearance of ***Scriniodinium crystallinum*** as one of the delineating features of this zone; however, at both Warboys and Warlingham, ***S. crystallinum*** does not appear until latest Upper Callovian, becoming common in the Lower Oxfordian.

Adnatosphaeridium aemulum zone has the following twelve species in common with the present assemblages: ***Adnatosphaeridium aemulum, Cleistosphaeridium lumectum, Ctenidodinium ornatum, Ellipsoidictyum cinctum, Palaeostomocystis spp.***, (includes ***P. tornatilis*** here), ***Sentusidinium pilosum, S. rioultii, S. verrucosum, Stephanelytron Caytonense, S. scarburghense*** (particularly abundant in the present assemblages),***Tubotuberella dangeardii*** and ***Wanaea digitata***. (It is interesting to note that Williams includes ***Wanaea fimbriata*** as a characteristic species of this zone when it is widely accepted that this species does not, in fact, appear until Earliest Oxfordian!)

Table 6.3 Microplankton assemblages for each of the divisions Lower, Middle and Upper Callovian, Lower and Middle Oxfordian, from the Warboys and Warlingham boreholes

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	WARBOYS		WARLINGHAM	
MIDDLE OXFORDIAN	no exposure		-• Systematophora valensii -• Hystrichosphaerina orbifera • Systematophora areolata - Nannoceratopsis pellucida - Polysphaeridium deflandrei - Lithodinia pocockii - Hystricodinium pulchrum - Ctenidodinium ornatum - Adnatosphaeridium caulleryi - P. ceratophora sub.sp. pachyceras Stephanelytron redcliffense Sirmiodinium grossii Sentusidinium rioultii Sentusidinium pilosum Hystrichogonyaulax cladophora	Senoniasphaera oxfordiensis sp.nov. Scriniodinium galeritum Scriniodinium crystallinum Prolixosphaeridium granulosum Gonyaulacysta jurassica G. jurassica sub.sp. longicornis P. ceratophora sub.sp. scopeus Cribroperidinium granuligerum Compositosphaeridium costatum Cleistosphaeridium tribuliferum Cleistosphaeridium polytrichum Chytroeisphaeridia chytroeides Batiacasphaera dictydia Apteodinium nuciforme Adnatosphaeridium aemulum
LOWER OXFORDIAN	+• Palaeostomocystis tournatilis +• ?Systematophora valensii • Cleistosphaeridium polytrichum • Cleistosphaeridium tribuliferum • Scriniodinium crystallinum • Stephanelytron caytonense • Sentusidinium woollami sp.nov. - Tubotuberella sphaerocephalis - Hesiertonia teichophera - Nannoceratopsis pellucida - Wanaea digitata - Ctenidodinium continuum - Adnatosphaeridium aemulum - Sirmiodinium grossii - Pareodinia ceratophora - P. ceratophora sub.sp. scopeus Batiacasphaera dictydia Caligodinium halosa Chytroeisphaeridia chytroeides Gonyaulacysta jurassica Hystrichodinium pulchrum Hystrichogonyaulax cladophora	• G. jurassica sub.sp. longicornis Lithodinia pocockii P. ceratophora sub.sp. pachyceras Scriniodinium galeritum Scriniodinium subvallare Scriniodiniopsis orbis Sentusidinium pilosum Sentusidinium rioultii Surculosphaeridium vestitum Tubotuberella dangeardii Tubotuberella apatella Tubotuberella eisenackii Micrhystridium sydus Micrhystridium polytrichum Micrhystridium fragile Micrhystridium inconspicuum Micrhystridium rarispinum Micrhystridium recurvatum M. recurvatum forma brevispinosa M. recurvatum forma reducta Solisphaeridium stimuliferum	+• Kalyptea globulus sp.nov. +• Leptodinium gongylos +• Wanaea fimbriata +• Dinopterygium abaidatum +• Acanthaulax senta +• Prolixosphaeridium granulosum -• Palaeostomocystis tournatilis -• Gen.et sp. indet. B • Pareodinia wigginsi sp.nov. • Surculosphaeridium vestitum • Sirmiodinium grossii • Sentusidinium pilosum • Scriniodinium galeritum • Scriniodinium crystallinum • Systematophora areolata • Senoniasphaera oxfordiensis sp.nov. • Scriniodinium luridum • Cribroperidinium granuligerum • Belodinium asaphum - Lithodinia jurassica - Hystrichogonyaulax warboysensis sp.nov. - Chytroeisphaeridia mantellii - Tubotuberella sphaerocephalis - Reutlingia gochtii - Sentusidinium verrucosum - Meiourogonyaulax decapitata - Kalyptea stegasta - Tubotuberella dangeardii - Ellipsoidictyum reticulatum - Stephanelytron caytonense - Scriniodinium subvallare - Chlamydophorella sp. B - Pareodinia ceratophora - Pareodinia alaskensis - Ctenidodinium pachydermum - Cleistosphaeridium lumectum	- Micrhystridium polyhedricum - Micrhystridium rarispinum - Micrhystridium variabile - Micrhystridium densispinum - M. recurvatum forma brevispinosa Nannoceratopsis pellucida Pareodinia warlinghamensis sp.nov. P. ceratophora sub.sp. pachyceras P. ceratophora sub.sp. scopeus Lithodinia pocockii Hystrichodinium pulchrum Ctenidodinium ornatum Adnatosphaeridium caulleryi Tubotuberella eisenackii Tubotuberella apatella ?Systematophora valensii Stephanelytron scarburghense Sirmiodiniopsis orbis Sentusidinium rioultii Hystrichogonyaulax cladophora Hesiertonia teichophera Gonyaulacysta jurassica G. jurassica sub.sp. longicornis Ellipsoidictyum cf. gochtii Compositosphaeridium costatum Cleistosphaeridium ehrenbergii Cleistosphaeridium tribuliferum Cleistosphaeridium polytrichum Chytroeisphaeridia chytroeides Caligodinium halosa Batiacasphaera dictydia Apteodinium nuciforme Adnatosphaeridium aemulum Gen. et sp. indet. A - Wanaea digitata - Ctenidodinium continuum
UPPER CALLOVIAN	+• Compositosphaeridium costatum +• Micrhystridium recurvatum -• Stephanelytron eccentricum sp.nov. • Ctenidodinium continuum • Adnatosphaeridium aemulum • Micrhystridium fragile • Micrhystridium sydus • Surculosphaeridium vestitum • Sentusidinium woollami sp.nov. • Hystrichodinium pulchrum • Caligodinium halosa • Scriniodinium subvallare • Stephanelytron caytonense • Prolixosphaeridium granulosum • Micrhystridium rarispinum - Sentusidinium verrucosum - Sentusidinium villersense - Ellipsoidictyum cinctum - Lithodinia jurassica - Stephanelytron echinatum sp.nov.	Hesiertonia teichophera Cleistosphaeridium ehrenbergii Tubotuberella apatella Stephanelytron scarburghense Stephanelytron redcliffense Sirmiodiniopsis orbis Sentusidinium rioultii Sentusidinium pilosum Lithodinia pocockii Gonyaulacysta jurassica Chytroeisphaeridia chytroeides Batiacasphaera dictydia Micrhystridium inconspicuum Micrhystridium densispinum M. recurvatum forma brevispinosa M. recurvatum forma reducta M. recurvatum forma longispinosa M. recurvatum forma multispinosa Solisphaeridium claviculorum	• Hystrichogonyaulax warboysensis sp.nov. • Ellipsoidictyum cinctum • Ellipsoidictyum cf. gochtii • Scriniodinium cf. crystallinum • Scriniodinium subvallare • Surculosphaeridium vestitum • Sentusidinium pilosum • Compositosphaeridium costatum • Cleistosphaeridium polytrichum • Pareodinia warlinghamensis sp.nov. Stephanelytron eccentricum sp.nov. Stephanelytron scarburghense Stephanelytron redcliffense Stephanelytron echinatum sp.nov. Lithodinia jurassica Lithodinia pocockii Sentusidinium woollami sp.nov. Ctenidodinium continuum Ellipsoidictyum reticulatum	Tubotuberella sphaerocephalis Tubotuberella dangeardii Tubotuberella apatella Sentusidinium verrucosum Sentusidinium rioultii P. ceratophora sub.sp. pachyceras P. ceratophora sub.sp. scopeus Hystrichodinium pulchrum Hystrichogonyaulax cladophora Ctenidodinium ornatum Sirmiodiniopsis orbis Gonyaulacysta jurassica Cleistosphaeridium tribuliferum Chytroeisphaeridia chytroeides Caligodinium halosa Batiacasphaera dictydia Adnatosphaeridium aemulum Chytroeisphaeridia mantellii Gen. et sp. indet. B
MIDDLE CALLOVIAN	+• Chlamydophorella sp.B • Sentusidinium villersense • Stephanelytron redcliffense + Stephanelytron scarburghense + Stephanelytron eccentricum sp.nov. + Compositosphaeridium costatum + Reutlingia gochtii - Meiourogonyaulax caytonensis Cribroperidinium granuligerum Sentusidinium verrucosum Nannoceratopsis pellucida Tubotuberella eisenackii Tubotuberella dangeardii Tubotuberella apatella P. ceratophora sub.sp. pachyceras	Sentusidinium rioultii Sentusidinium pilosum Lithodinia pocockii Gonyaulacysta jurassica Ctenidodinium pachydermum Ctenidodinium ornatum Chytroeisphaeridia chytroeides Micrhystridium fragile Micrhystridium polyhedricum Micrhystridium rarispinum Micrhystridium sydus Micrhystridium densispinum M. recurvatum forma brevispinosa M. recurvatum forma reducta	• Chlamydophorella sp.B • Sentusidinium sp.B + Stephanelytron scarburghense + Stephanelytron redcliffense + Reutlingia gochtii Stephanelytron eccentricum sp.nov Stephanelytron echinatum sp.nov. Ctenidodinium continuum Chytroeisphaeridia mantellii Sentusidinium verrucosum	P. ceratophora sub.sp. pachyceras P. ceratophora sub.sp. scopeus Lithodinia pocockii Nannoceratopsis pellucida Tubotuberella eisenackii Tubotuberella apatella Sentusidinium rioultii Lithodinia jurassica Chytroeisphaeridia chytroeides Batiacasphaera dictydia
LOWER CALLOVIAN	+ -• Meiourogonyaulax cristulata +• Ellipsoidictyum reticulata +• Meiourogonyaulax caytonensis • Sentusidinium varispinosum • Pareodinia prolongata • P. ceratophora sub.sp. pachyceras • Ctenidodinium ornatum • Hystrichosphaeridium cladophora • Adnatosphaeridium aemulum • Sirmiodiniopsis orbis • P. ceratophora sub.sp. scopeus • Stephanelytron redcliffense • Sentusidinium pilosum • Sentusidinium verrucosum • Sentusidinium villersense - Pareodinia cf. apotomocerastes	Pluriarvalium osmingtonense Polystephanephorous paracalathus Lithodinia jurassica •Nannoceratopsis pellucida Sentusidinium rioultii Scriniodinium galeritum Lithodinia pocockii Gonyaulacysta jurassica Ctenidodinium pachydermum Cleistosphaeridium polytrichum Chytroeisphaeridia chytroeides Micrhystridium fragile Micrhystridium inconspicuum Micrhystridium sydus Micrhystridium polyhedricum • Hystrichogonyaulax cladophora	+• Kalyptea stegasta -• Meiourogonyaulax caytonensis -• Meiourogonyaulax cristulata -• Sentusidinium villersense • Ctenidodinium continuum • Sentusidinium varispinosum • Nannoceratopsis pellucida • Tubotuberella dangeardii + Adnatosphaeridium aemulum + Cleistosphaeridium tribuliferum + Caligodinium halosa Lithodinia jurassica	Sentusidinium verrucosum Pareodinia ceratophora P. ceratophora sub.sp. pachyceras Lithodinia pocockii Tubotuberella apatella Sirmiodinium grossii Sentusidinium rioultii Gonyaulacysta jurassica Chytroeisphaeridia chytroeides Batiacasphaera dictydia Micrhystridium sydus Micrhystridium polyhedricum

• Significant species or very abundant
+ Appears for first time or becomes significant for first time
- Last occurrence

Gonyaulacysta jurassica zone

(i) Polystephanephorous calathus / Hystrichodinium polonicum (?= *Compositosphaeridium costatum*) subzone has the following eight species in common with the present assemblages: ***Apteodinium nuciforme, Cleistosphaeridium tribuliferum, Compositosphaeridium costatum (?= Hystrichodinium polonicum), Gonyaulacysta jurassica, Prolixosphaeridium granulosum*** (marks the top of this zone in both boreholes here), ***Senoniasphaera spp.,*** (includes ***S. oxfordiensis sp.nov.*** here), ***Sentusidinium pilosum*** and ***Stephanelytron redcliffense.***

(ii) Adnatosphaeridium filamentosum subzone has the following five species in common with assemblages from Warlingham only: ***Ctenidodinium ornatum, Tubotuberella eisenackii*** and ***Hystrichosphaerina orbifera. Adnatosphaeridium aemulum*** and ***Hystrichogonyaulax cladophora*** are particularly common here, in aggreement with Williams.

2) Sarjeant (1979)

Meiourogonyaulax callomonii parazone has the following three species in common with assemblages here: ***Meiourogonyaulax caytonensis, M. cristulata*** and ***Pareodinia prolongata. Chytroeisphaeridia spp.,*** and ***Sentusidinium spp.,*** are also present. ***Gonyaulacysta jurassica*** and ***Ctenidodinium spp.,*** are quite common here, and not subordinate as suggested by Sarjeant.

Polystephanephorous paracalathus parazone has only abundant ***Gonyaulacysta jurassica*** in common. ***Polystephanephorous paracalathus*** is present, but not a prominent species as Sarjeant suggests.

Wanaea fimbriata parazone has the following taxa in common with the present assemblages: ***Wanaea fimbriata, Gonyaulacysta jurassica*** and related genera including ***Heslertonia (H. teichophera*** here). All other genera described by Sarjeant for this parazone are present in the assemblages here in varying abundancies. Of particular note is ***Acanthaulax senta*** whose range limits as recorded in Warlingham define the top and bottom of this parazone, thus agreeing with Sarjeant. Sarjeant notes that ***Stephanelytron*** appears towards the top of this parazone, but almost all species of this genus occur in the Callovian here and in considerable abundance.

Stephanelytron redcliffense parazone. In agreement with Sarjeant, ***Gonyaulacysta jurassica, Adnatosphaeridium, Scriniodinium, Surculosphaeridium*** and ***Systematophora*** are all abundant in the equivalent horizon at Warlingham. ***Ctenidodinium ornatum*** also fades

Gonyaulacysta jurassica zone

(i) Polystephanephorous calathus / Hystrichodinium polonicum (?= **Compositosphaeridium costatum**) subzone has the following eight species in common with the present assemblages: ***Apteodinium nuciforme, Cleistosphaeridium tribuliferum, Compositosphaeridium costatum (?= Hystrichodinium polonicum), Gonyaulacysta jurassica, Prolixosphaeridium granulosum*** (marks the top of this zone in both boreholes here), ***Senoniasphaera spp.,*** (includes ***S. oxfordiensis sp.nov.*** here), ***Sentusidinium pilosum*** and ***Stephanelytron redcliffense.***

(ii) Adnatosphaeridium filamentosum subzone has the following five species in common with assemblages from Warlingham only: ***Ctenidodinium ornatum, Tubotuberella eisenackii*** and ***Hystrichosphaerina orbifera. Adnatosphaeridium aemulum*** and ***Hystrichogonyaulax cladophora*** are particularly common here, in aggreement with Williams.

2) Sarjeant (1979)

Meiourogonyaulax callomonii parazone has the following three species in common with assemblages here: ***Meiourogonyaulax caytonensis, M. cristulata*** and ***Pareodinia prolongata. Chytroeisphaeridia spp.,*** and ***Sentusidinium spp.,*** are also present. ***Gonyaulacysta jurassica*** and ***Ctenidodinium spp.,*** are quite common here, and not subordinate as suggested by Sarjeant.

Polystephanephorous paracalathus parazone has only abundant ***Gonyaulacysta jurassica*** in common. ***Polystephanephorous paracalathus*** is present, but not a prominent species as Sarjeant suggests.

Wanaea fimbriata parazone has the following taxa in common with the present assemblages: ***Wanaea fimbriata, Gonyaulacysta jurassica*** and related genera including ***Heslertonia (H. teichophera*** here***).*** All other genera described by Sarjeant for this parazone are present in the assemblages here in varying abundancies. Of particular note is ***Acanthaulax senta*** whose range limits as recorded in Warlingham define the top and bottom of this parazone, thus agreeing with Sarjeant. Sarjeant notes that ***Stephanelytron*** appears towards the top of this parazone, but almost all species of this genus occur in the Callovian here and in considerable abundance.

Stephanelytron redcliffense parazone. In agreement with Sarjeant, ***Gonyaulacysta jurassica, Adnatosphaeridium, Scriniodinium, Surculosphaeridium*** and ***Systematophora*** are all abundant in the equivalent horizon at Warlingham. ***Ctenidodinium ornatum*** also fades

Gonyaulacysta jurassica zone

(i) Polystephanephorous calathus / Hystrichodinium polonicum (?= *Compositosphaeridium costatum*) subzone has the following eight species in common with the present assemblages: ***Apteodinium nuciforme*, *Cleistosphaeridium tribuliferum*, *Compositosphaeridium costatum* (?= *Hystrichodinium polonicum*), *Gonyaulacysta jurassica*, *Prolixosphaeridium granulosum*** (marks the top of this zone in both boreholes here), ***Senoniasphaera* spp.**, (includes ***S. oxfordiensis* sp.nov.** here), ***Sentusidinium pilosum*** and ***Stephanelytron redcliffense***.

(ii) Adnatosphaeridium filamentosum subzone has the following five species in common with assemblages from Warlingham only: ***Ctenidodinium ornatum*, *Tubotuberella eisenackii*** and ***Hystrichosphaerina orbifera***. ***Adnatosphaeridium aemulum*** and ***Hystrichogonyaulax cladophora*** are particularly common here, in aggreement with Williams.

2) Sarjeant (1979)

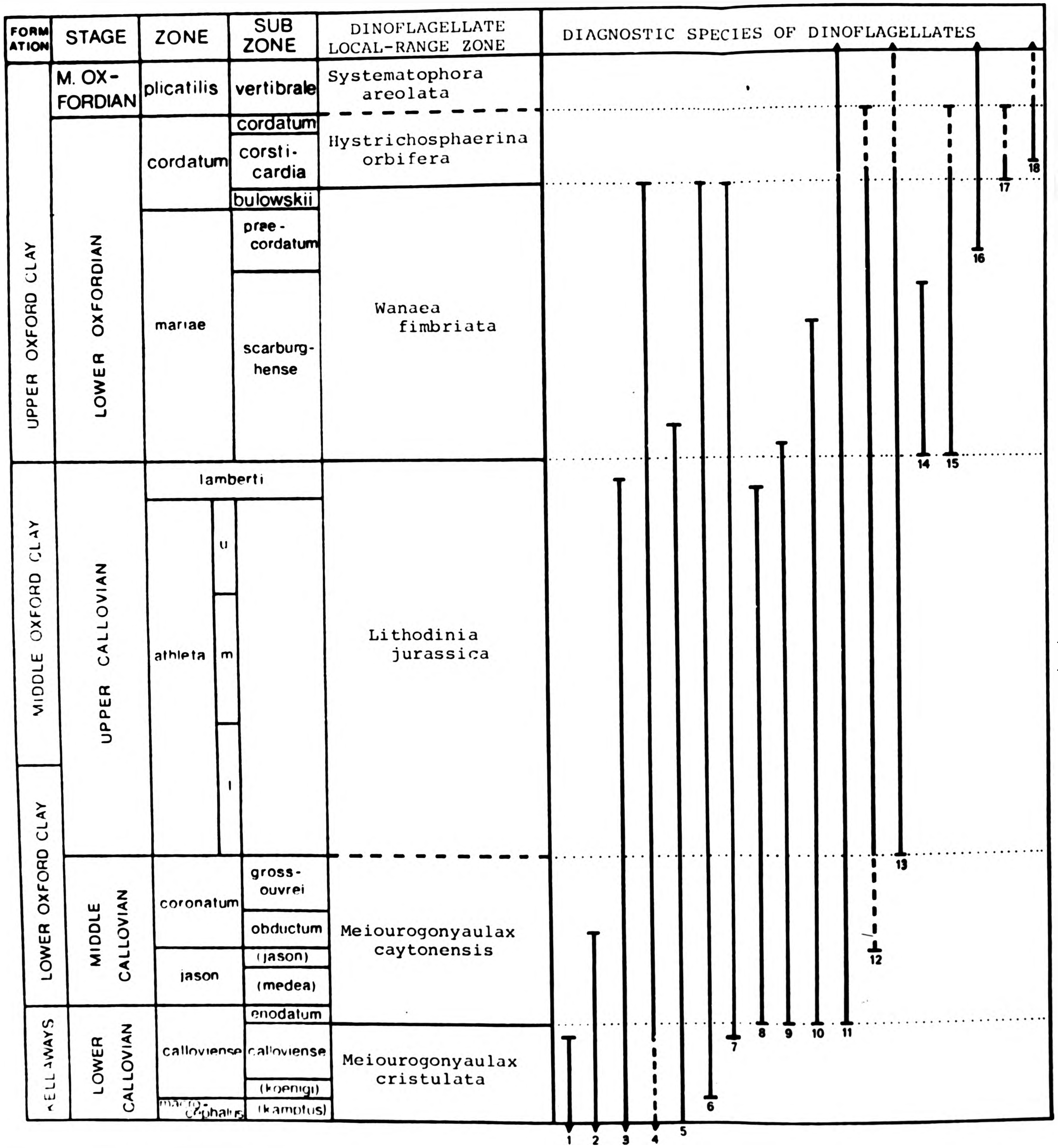
Meiourogonyaulax callomonii parazone has the following three species in common with assemblages here: ***Meiourogonyaulax caytonensis*, *M. cristulata*** and ***Pareodinia prolongata***. ***Chytroeisphaeridia* spp.**, and ***Sentusidinium* spp.**, are also present. ***Gonyaulacysta jurassica*** and ***Ctenidodinium* spp.**, are quite common here, and not subordinate as suggested by Sarjeant.

Polystephanephorous paracalathus parazone has only abundant ***Gonyaulacysta jurassica*** in common. ***Polystephanephorous paracalathus*** is present, but not a prominent species as Sarjeant suggests.

Wanaea fimbriata parazone has the following taxa in common with the present assemblages: ***Wanaea fimbriata*, *Gonyaulacysta jurassica*** and related genera including ***Heslertonia* (*H. teichophera*** here). All other genera described by Sarjeant for this parazone are present in the assemblages here in varying abundancies. Of particular note is ***Acanthaulax senta*** whose range limits as recorded in Warlingham define the top and bottom of this parazone, thus agreeing with Sarjeant. Sarjeant notes that ***Stephanelytron*** appears towards the top of this parazone, but almost all species of this genus occur in the Callovian here and in considerable abundance.

Stephanelytron redcliffense parazone. In agreement with Sarjeant, ***Gonyaulacysta jurassica*, *Adnatosphaeridium*, *Scriniodinium*, *Surculosphaeridium*** and ***Systematophora*** are all abundant in the equivalent horizon at Warlingham. ***Ctenidodinium ornatum*** also fades

Text-fig. 6.4 <u>Proposed zonation scheme for the Oxford Clay based on the local-ranges of diagnostic dinoflagellate taxa</u>



PROPOSED ZONATION SCHEME FOR THE OXFORD CLAY, BASED ON THE LOCAL-RANGES OF SELECTED DINOFLAGELLATE TAXA

Occurrence within the Warboys & Warlingham Boreholes

Known occurrence outside of this study

Key to species:

1 *Meiourogonyaulax cristulata*
2 *Meiourogonyaulax caytonensis*
3 *Pareodinia prolongata*
4 *Ellipsoidictyum reticulatum*
5 *Lithodinia jurassica*
6 *Tubotuberella dangeardii*
7 *Palaeostomocystis tornatilis*
8 *Stephanelytron tabulophorum*
9 *Stephanelytron eccentricum* sp.nov.
10 *Stephanelytron echinatum* sp. nov.
11 *Stephanelytron redcliffense*
12 *Stephanelytron caytonense*
13 *Scriniodinium subvallare*
14 *Kalyptea globulus* sp.nov.
15 *Wanaea fimbriata*
16 *Systematophora areolata*
17 *Chytroeisphaeridia cerastes*
18 *Hystrichosphaerina orbifera*

out within the early part of this horizon.

4) <u>A Zonation Scheme Proposed for the Present Study</u>

From the above comparison of the floras from the present study with the assemblages described by Williams (1977) and Sarjeant (1979), it is clear that no precise correlation can be made. There are certain elements of the assemblages in common, but it would be difficult to identify in total either of these zonation schemes in the Warboys and Warlingham boreholes. It seems that Arkell's first rule for zonation of the Jurassic using ammonites also applies to dinoflagellates:

> "Zones are units of more restricted purpose and use (than stages), but with special advantageous qualities which are lost if the area of their application is expanded farther than the ascertained facts of distribution admit. There must therefore always be seperate zonal tables for each faunal province" (Arkell, 1946, p30).

In view of this it seems appropriate to propose a tentative zonation scheme for the Oxford Clay based on the <u>local</u> ranges of certain diagnostic species of dinoflagellates. How far this scheme could be applied geographically is obviously open to the findings of future work. Norris (1975) suggests that several Callovian/Oxfordian species are cosmopolitan, occurring in the Canadian Arctic, western interior of North America, East Greenland, North-West Europe, Western Australia and New Guinea; e.g., ***Adnatosphaeridium aemulum, Ctenidodinium ornatum, Gonyaulacysta jurassica, Nannoceratopsis pellucida, Scriniodinium crystallinum, S. luridum*** and ***Wanaea digitata***. All of these species are present in both Warboys and Warlingham. However, as is often the case with cosmopolitan species, they have long stratigraphical ranges and are consequently of limited use for detailed biostratigraphical work.

The scheme proposed here is based on the local ranges of 18 species considered to be diagnostic for the Oxford Clay and is illustrated in figure 6.4. The following is a description of the local-range zones:

<u>Meiourogonyaulax cristulata</u> local-range zone

The zone incorporates the Lower Callovian subzones <u>kamptus</u> to <u>calloviense</u>, and is characterised by the presence of the nominate taxon - ***M. cristulata*** whose known stratigraphic range is confined to this zone. The base of the zone has no definition and may or may not extend into the Bathonian below. The top of the zone is marked by the first occurrence of species of ***Stephanelytron*** (excluding ***S. scarburghense*** which first appears within this zone). ***Heslertonia teichophera, Sirmiodinium grossii*** and ***Tubotuberella sphaerocephalis*** all appear for the first time in this zone. *Palaeostomocystis tornatilis* first appears at the very top of the zone.

The assemblage is characterised by an abundance of *Meiourogonyaulax caytonensis* and *Pareodinia ceratophora sub.sp. pachyceras*. Other species include *Batiacasphaera dictydia, Chytroeisphaeridia chytroeides, Cleistosphaeridium tribuliferum, C. polytrichum, Ctenidodinium continuum, C. ornatum, C. pachydermum, Gonyaulacysta jurassica, Kalyptea stegasta, Lithodinia jurassica, L. pocockii, Pareodinia prolongata, Scriniodinium galeritum, Sentusidinium pilosum, S. rioultii, S. varispinosum, S. villersense* and *Tubotuberella apatella*, most of which range higher into the sequence. *Micrhystridium fragile, M. sydus* and *M. polyhedricum* are the main components of the acritarch assemblage.

Meiourogonyaulax caytonensis local-range zone

The top of the zone is tentatively placed at the Middle Callovian/ Upper Callovian transition (top of the grossouvrei subzone), and is marked here by the first appearance of *Scriniodinium subvallare*. The base of the zone coincides with the base of the enodatum subzone (Lower Callovian) and is marked by the first occurrence of four species of *Stephanelytron: S. redcliffense, S. tabulophorum, S. eccentricum sp.nov., and S. echinatum sp.nov. S. caytonense* also appears for the first time within the zone. The range of the nominate taxon extends into the lower half of the zone, dissappearing in the coronatum zone.

The following four species appear for the first time within the zone: *Apteodinium granulatum, Reutlingia gochtii, Wanaea digitata* and *Gen. et sp. indet. B.* Important new constituents of the assemblage are *Hystricogonyaulax cladophora, Pareodinia ceratophora sub.sp. scopeus, Sentusidinium verrucosum* and *Chlamydophorella sp.B. Lithodinia pocockii, Sentusidinium pilosum* and *S. rioultii* become very abundant. The following taxa become subordinate: *Adnatosphaeridium, Ctenidodinium, Cleistosphaeridium tribuliferum, Ellipsoidictyum cinctum, Heslertonia teichophera, Lithodinia jurassica* and *Pareodinia ceratophora sub.sp., pachyceras*. Many of the long-ranging species of acritarchs become abundant for the first time in the zone, continuing as such throughout the sequence.

Lithodinia jurassica local-range zone

Constitutes the whole of the Upper Callovian (athleta and lamberti zones). The base of the zone is marked by the first occurrence of *Scriniodinium subvallare* and the top by that of *Wanaea fimbriata* and *Kalyptea globulus sp.nov.*, thus delineating the Callovian/Oxfordian boundary. Both *Pareodinia prolongata* and *Stephanelytron tabulophorum* become extinct at or near the top of the zone. There is a very marked influx of acritarchs at, or just below, the base of the zone. The following five species occur for the first time within the zone: *Dinopterygium absidatum, Pareodinia alaskensis, P. warlinghamensis sp.nov., P. wigginsi sp.nov.,* and *Sentusidinium woollami sp.nov.* The nominate taxon is very abundant and becomes extinct just within the base of the succeeding Wanaea fimbriata zone.

Adnatosphaeridium aemulum, Compositosphaeridium costatum, Hystrichodinium pulchrum, Pareodinia ceratophora sub.sp. scopeus, Polysphaeridium deflandrei, Stephanelytron caytonense and *Surculosphaeridium vestitum* all appear in significant numbers for the first time. *Sentusidinium verrucosum* is a prominent species at the base of the zone. *Chytroeisphaerdia chytroeides, Gonyaulacysta jurassica, Lithodinia pocockii, Sentusidinium pilosum, S.rioultii, Stephanelytron scarburghense* and *Tubotuberella apatella* are all important constituents of the assemblage, often becoming very abundant, whilst *Nannoceratopsis pellucida* becomes subordinate.

Wanaea fimbriata local-range zone

Constitutes the interval between the scarburghense and bulowskii sub-zones of the Lower Oxfordian. The base of the zone is marked by the first appearance of the nominate taxon and also *Kalyptea globulus sp.nov.* The top is defined by the extinction levels of *Ellipsoidictyum reticulatum, Palaeostomocystis tornatilis* and *Tubotuberella dangeardii.*

Belodinium asaphum, Leptodinium gongylos, Senoniasphaera oxfordiensis sp.nov., and *Systematophora areolata* all appear for the first time within the zone; *Acanthaulax senta* and *Dinopterygium absidatum* becoming significant constituents of the assemblage. *Lithodinia jurassica* and *Stephanelytron eccentricum sp.nov.* become extinct near the base of the zone; *Stephanelytron echinatum sp.nov.* and *Kalyptea globulus sp.nov.* in the middle of the zone.

Gonyaulacysta jurassica sub.sp. longicornis becomes an important constituent of the assemblage. *Chytroeisphaeridia chytroeides, Sentusidinium pilosum, ?Systematophora valensii, Surculosphaeridium vestitum, Tubotuberella dangeardii* and *T. eisenackii* are all fairly common species. *Gonyaulacysta jurassica* becomes conspicuously subordinate, whilst *Lithodinia pocockii* also becomes less common. *Adnatosphaeridium aemulum, Compositosphaeridium costatum, Sentusidinium* and *Kalyptea globulus sp.nov.*, thus delineating the Callovian/Oxfordian boundary. Both *Pareodinia prolongata* and *Stephanelytron tabulophorum* become extinct at or near the top of the zone. There is a very marked influx of acritarchs at, or just below, the base of the zone. The following five species occur for the first time within the zone: *Dinopterygium absidatum, Pareodinia alaskensis, P. warlinghamensis sp.nov., P. wigginsi sp.nov.,* and *Sentusidinium woollami sp.nov.* The nominate taxon is very abundant and becomes extinct just within the base of the succeeding Wanaea fimbriata zone.

Adnatosphaeridium aemulum, Compositosphaeridium costatum, Hystrichodinium pulchrum, Pareodinia ceratophora sub.sp. scopeus, Polysphaeridium deflandrei, Stephanelytron caytonense and *Surculosphaeridium vestitum* all appear in significant numbers for the first time. *Sentusidinium verrucosum* is a prominent species at the base of the zone. *Chytroeisphaerdia chytroeides, Gonyaulacysta jurassica, Lithodinia pocockii, Sentusidinium pilosum, S.rioultii, Stephanelytron scarburghense* and *Tubotuberella apatella* are all important constituents of the assemblage, often becoming very abundant, whilst *Nannoceratopsis pellucida* becomes subordinate.

Wanaea fimbriata local-range zone

Constitutes the interval between the scarburghense and bulowskii sub-zones of the Lower Oxfordian. The base of the zone is marked by the first appearance of the nominate taxon and also *Kalyptea globulus sp.nov.* The top is defined by the extinction levels of *Ellipsoidictyum reticulatum, Palaeostomocystis tornatilis* and *Tubotuberella dangeardii.*

Belodinium asaphum, Leptodinium gongylos, Senoniasphaera oxfordiensis sp.nov., and *Systematophora areolata* all appear for the first time within the zone; *Acanthaulax senta* and *Dinopterygium absidatum* becoming significant constituents of the assemblage. *Lithodinia jurassica* and *Stephanelytron eccentricum sp.nov.* become extinct near the base of the zone; *Stephanelytron echinatum sp.nov.* and *Kalyptea globulus sp.nov.* in the middle of the zone.

Gonyaulacysta jurassica sub.sp. longicornis becomes an important constituent of the assemblage. *Chytroeisphaeridia chytroeides, Sentusidinium pilosum, ?Systematophora valensii, Surculosphaeridium vestitum, Tubotuberella dangeardii* and *T. eisenackii* are all fairly common species. *Gonyaulacysta jurassica* becomes conspicuously subordinate, whilst *Lithodinia pocockii* also becomes less common. *Adnatosphaeridium aemulum, Compositosphaeridium costatum, Sentusidinium* *rioultii* and *Stephanelytron scarburghense* become subordinate.

Hystrichosphaerina orbifera local-range zone

Incorporates the corsticardia and cordatum subzones of the uppermost Lower Oxfordian. The base of the zone is defined by the first occurrence of *Chytroeisphaeridia cerastes* (which appears to be restricted to this zone) and *Chlamydophorella sp.A*; the base is also marked by the extinction of *Ellipsoidictyum reticulata, Palaeostomocystis tornatilis* and *Tubotuberella dangeardii*. The top of the zone is tentatively placed at the extinction level of *Stephanelytron caytonense* and *Wanaea fimbriata*. The nominate taxon first appears just above the base of the zone, as does *Leptodinium miriabile*. *Chlamydophorella sp.B, Cleistosphaeridium lumectum, Dinopteryigium absidatum* and *Pareodinia wigginsi sp.nov.* become extinct within the zone.

The following taxa are important constituents of the assemblage: *Acanthaulax senta, Adnatosphaeridium aemulum, Cleistosphaeridium polytrichum, Compositosphaeridium costatum, Gonyaulacysta jurassica* (including *G. jurassica sub.sp. longicornis*), *Hystrichodinium pulchrum, Hystrichogonyaulax* (particularly common), *Sentusidinium pilosum* and *S. rioultii*. *Chytroeisphaeridia chytroeides, Scriniodinium crystallinum, S. galeritum* and *Surculosphaeridium vestitum* are subordinate.

Systematophora areolata local-range zone

Comprises at least the plicatilis zone of the Middle Oxfordian. The base of the zone is tentatively placed at the base of the Middle Oxfordian and marked by the extinction of *Chytroeisphaeridia cerastes, Stephanelytron caytonense* and *Wanaea fimbriata*. The upper limits of the zone cannot be defined here. The nominate taxon first appears in the praecordatum subzone of the Lower Oxfordian and ranges into the Kimmeridgian.

Polysphaeridium deflandrei, Systematophora valensii and *Pareodinia ceratophora sub.sp. pachyceras* all become extinct just above the base of the zone (the latter quite suddenly after becoming very abundant). *Ctenidodinium ornatum* and *Kylindrocysta reticulata sp.nov.* appear also to become extinct within the zone.

Adnatosphaeridium aemulum, Chytroeisphaeridia chytroeides, Cleistosphaeridium polytrichum, Gonyaulacysta jurassica (including *G. jurassica sub.sp. longicornis*) *Hystrichosphaerina orbifera, Scriniodinium crystallinum, S. galeritum, Sentusidinium pilosum,* *S. rioultii* and *Systematophora areolata* are all important constituents of the assemblage. *Hystrichogonyaulax cladophora* and *Hystrichodinium pulchrum* are subordinate.

B. STRATIGRAPHICAL CORRELATION BY STATISTICAL METHODS

In recent years several authors have attempted various methods of chronostratigraphic and biostratigraphic correlation using statistical techniques (e.g., Hazel, 1970). The main reason for adopting such methods is in order to minimise, or overcome altogether, the many problems inherent in traditional methods of correlation; the problems of human error and bias in both sampling and processing data being perhaps the chief factors. By using statistical methods it is possible to obtain consistent results that have taken into account a wide variety of factors which may affect the distribution of organisms.

Two statistical methods of correlation have been applied to the data obtained from the Warboys and Warlingham boreholes: (1) The Graphic Correlation Method and (2) Cluster Analysis. The methods and merits of each are briefly outlined, results presented and conclusions discussed.

1. The Graphic Correlation Method

a) The method outlined

The Graphic Correlation Method is based essentially on the work of Shaw (1964), being a method of palaeontological correlation that utilizes the total ranges of fossils to develop time-stratigraphical control in sedimentary rock sequences. This method was further adapted and applied to palynological studies in the Upper Cretaceous rocks of Southwestern Wyoming, U.S.A., by Miller (1977). Miller's paper describes fully the principle and use of the technique.

Essentially the idea behind the method is to establish a fixed point of correlation between two vertical sections which cover an equivalent interval of geological time. The two sections to be compared are plotted on the X and Y axis of a graph in units of thickness and a line of correlation (LOC) is calculated and plotted between them. The method is based on the premise that rock-accumulation takes place over a particular interval of time and therefore at a certain rate. It will naturally follow that the LOC will ideally represent the rate of rock-accumulation in both sequences and, by definition, be at an angle of 45°

from the point of origin if rock-accumulation is consistent in both localities being compared. The rate of rock-accumulation will of course, in turn, affect the stratigraphic distribution of the fossils entombed in the sediment.

Essentially the job of the palaeontologist is to establish the LOC between the two sections by using the fossils within them. This is done by plotting the first and last occurrences of those fossils whose local-range occurs within both sections. The tops of the sections are marked with the symbol (●) and the bases with the symbol (■); a line is then constructed between them. Each individual fossil species is identified with a number. Ideally all the dots should plot in the upper right-hand side of the graph and the squares in the lower left-hand side. The LOC is then drawn through the tops and bases of those fossils whose local range in one section most closely approaches that in the other. One section should be chosen as the standard reference section (SRS) against which all subsequent correlations are made, ammendments to the local-ranges of species being made where appropriate. The SRS should have the following characteristics: (i) a large and varied fossil content; (ii) be the thickest section possible and (iii) be a complete and unfaulted stratigraphic succession.

b) <u>The method applied to the Warboys and Warlingham boreholes</u>

In theory this method should work well when correlating between the two boreholes in this study. Indentical and undisturbed stratigraphic sections are present and the local ranges of microplankton taxa have been determined. This technique was in fact used and the graph of the correlation is illustrated in fig. 6.5. Here a standard thickness line of correlation has been plotted (being a hypothetical LOC if rock-accumulation was uniform in both sections). The ammonite zones have been taken as standard and form a basis for comparison. It is worth noting that the ammonite LOC follows closely the standard thickness LOC for the Callovian, indicating that rock-accumulation was fairly uniform in both sections for this time interval. However at the Callovian/Oxfordian boundary, the ammonite LOC makes a marked departure from the standard thickness LOC indicating an increase in the rate of rock-accumulation at Warlingham during the Lower Oxfordian. (Comparison with figure 2.3 verifies this fact).

It is interesting to note that, without exception, all of the microplankton ranges fall bellow the standard thickness LOC and the ammonite zone LOC, thus indicating considerably longer ranges for species in Warlingham than in Warboys. This is illustrated by the ranges of selected from the point of origin if rock-accumulation is consistent in both localities being compared. The rate of rock-accumulation will of course, in turn, affect the stratigraphic distribution of the fossils entombed in the sediment.

Essentially the job of the palaeontologist is to establish the LOC between the two sections by using the fossils within them. This is done by plotting the first and last occurrences of those fossils whose local-range occurs within both sections. The tops of the sections are marked with the symbol (●) and the bases with the symbol (■); a line is then constructed between them. Each individual fossil species is identified with a number. Ideally all the dots should plot in the upper right-hand side of the graph and the squares in the lower left-hand side. The LOC is then drawn through the tops and bases of those fossils whose local range in one section most closely approaches that in the other. One section should be chosen as the standard reference section (SRS) against which all subsequent correlations are made, ammendments to the local-ranges of species being made where appropriate. The SRS should have the following characteristics: (i) a large and varied fossil content; (ii) be the thickest section possible and (iii) be a complete and unfaulted stratigraphic succession.

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It is interesting to note that, without exception, all of the microplankton ranges fall bellow the standard thickness LOC and the ammonite zone LOC, thus indicating considerably longer ranges for species in Warlingham than in Warboys. This is illustrated by the ranges of selected

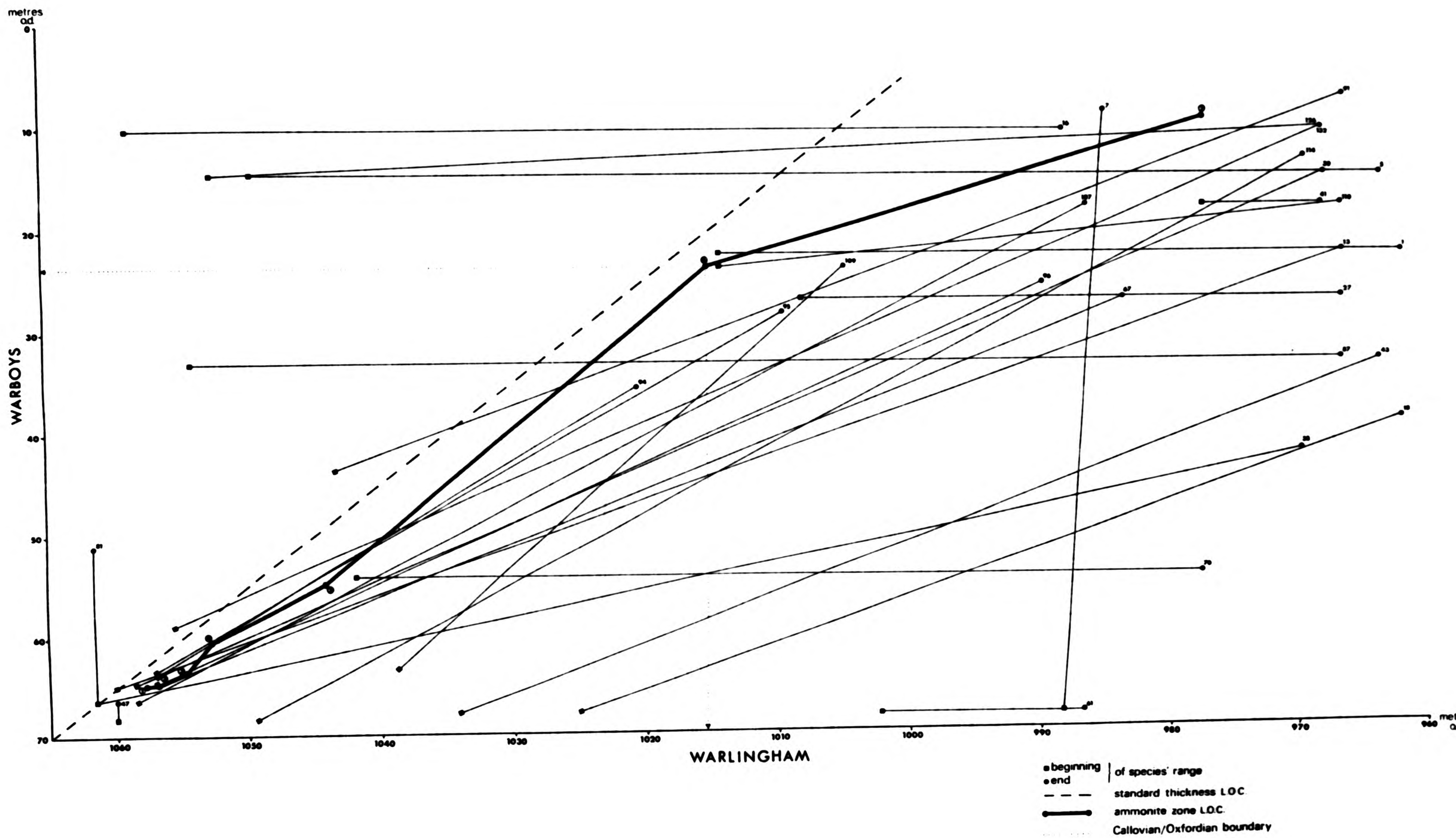
Text-fig. 6.5 Graph illustrating the composite ranges of species whose local-range occurs within the Warboys and Warlingham boreholes, using the Graphic Correlation Method (after Shaw, 1964 and Miller, 1977).

Key to ammonite zone boundaries:

(1) calloviense/enodatum
(2) enodatum/medea
(3) jason/obductum
(4) obductum/grossouvrei
(5) grossouvrei/athleta
(6) lamberti/scarburghense
(7) scarburghense/praecordatum

Key to species:

1 *Acanthaulax senta*
5 *Apteodinium granulatum*
7 *Apteodinium cf. nuciforme*
13 *Chlamydophorella sp.B*
16 *Chytroeisphaeridia mantellii*
18 *Cleistosphaeridium lumectum*
27 *Dinopterygium absidatum*
30 *Ellipsoidictyum reticulatum*
38 *Kalyptea stegasta*
41 *Leptodinium gongylos*
43 *?Leptodinium sp.*
47 *Meiourogonyaulax cristulata*
61 *Pluriarvalium osmingtonense*
67 *Reutlingia gochtii*
70 *Scriniodinium cf. crystallinum*
81 *Sentusidinium villersense*
87 *Sentusidinium sp.F*
91 *Stephanelytron caytonense*
94 *Stephanelytron tabulophorum*
95 *Stephanelytron eccentricum sp.nov.*
96 *Stephanelytron echinatum sp.nov.*
107 *Tubotuberella sphaerocephalis*
109 *Wanaea digitata*
110 *Wanaea fimbriata*
114 *Gen. et sp. indet.B*
126 *Micrhystridium nannacanthum*
132 *Micrhystridium recurvatum forma multispinosa*



WARBOYS
metres od
WARLINGHAM
metres od
beginning
end
of species' range
standard thickness L.O.C.
ammonite zone L.O.C.
Callovian/Oxfordian boundary

taxa in tables 6.2 a-f .

Whilst it would be difficult to construct a precise LOC based on the ranges of the microplankton species alone attention is drawn to the ranges of fossils 91, 94, 95, 96, 107 and 110, whose ranges closely parallel the ammonite zone LOC (although consistently fall bellow it). Fossil 110 is of particular note as it follows closely the change in the rate of rock-accumulation at the Callovian/Oxfordian boundary as discussed above. Certain anomalies will however be apparent in the plotting of several species whose ranges completely 'cut accross' the trend of the majority. Fossils 1, 5, 16, 27, 41, 61, 70, 87 and 126 have very restricted ranges in Warboys, whilst fossils 47 and 81 have restricted ranges in Warlingham. This may either reflect a genuine tight ecological control over these particular species or represent errors in processing and/or examination techniques.

Whilst the Graphic Correlation Method could prove to be a useful tool in correlating between sections with comparable stratigraphic sequences, it is important to note that the method can only be as reliable as the fossils themselves are. Ecological control of both flora and fauna will not neccessarily be uniform, even in quite restricted geographical areas, and therefore local-ranges of certain fossils may not reflect the rate of rock-accumulation as a basis for comparison. In conjunction with other methods of comparison however, this technique will certainly be a valuable tool in the hands of the biostratigrapher.

2. Cluster Analysis

a) Problems of conventional biostratigraphy

Conventional forms of biostratigraphic analysis have always depended upon the total-ranges of individual fossil species (as far as they are known), or fossil-assemblages for inter-regional correlation. Innumerable zonation schemes have been proposed for various parts of the geological column based on these methods. In practice however, rarely is the biostratigrapher confronted with a geological succession in which previously-proposed and described zones can be identified fully in the sequence before him. We have already noted earlier in this chapter that data obtained from the two boreholes in this study does not correlate precisely with that of other authors. Even between the two boreholes themselves there are discrepancies with detailed comparison.

Traditionally all zonation schemes are based on either range zones or assemblage zones. Whilst such methods of correlation are indeed useful (one such scheme has been propsed here for the Oxford Clay), and in certain cases proved to be accurate, it must be recognised that such methods of corellation have their natural limitations. In the case of range-zones only extreme ranges of fossils can, by definition, be used to define zonal boundaries. In practice however it is not always possible for the biostratigrapher to know whether or not the full range of a particular taxon is represented in the sequence. Similarly, with assemblage zones one can never be sure exactly what interplay of palaeoenvironmental parameters have affected the contents of a particular assemblage in a given geographical area. Certain species will obviously be affected by particular external factors in preference to other others, thus influencing their distribution. Consequently an assemblage obtained from area A will not neccessarily be fully represented in area B even though certain elements of the assemblage will be present. The biostratigrapher can never know whether or not his assemblage is fully representative. There is therefore a need for more rigorous methods of biostratigraphy, i.e., objective methods which are repeatable in different geographical areas of study.

There are a number of important reasons why (potentially at least) numerical methods in biostratigraphy are preferable to conventional, non-quantitativemethods. These may be summarised as follows:

(i) Objectivity. The assesment of similarities between samples or the associations between species is based on mathematical or statistical criteria and not on the judgement of the investigator. Thus no ***a priori*** assumptions are made on the basis of the palaeoenvironment or the known ecological requirements of certain species, or even the presence of certain species in any sample.

(ii) Repeatability. The use of mathematical methods should lead to the same results when applied by different workers to the same case, or even more important, provide strictly comparable results. This applies particularly when numerical methods are used which result in hierarchical ordination of the data (dendrograms).

(iii) Rapid computations. The neccessary computations of similarity coefficients and their clustering into dendrograms can be carried out extremely rapidly with a computer.

b) The principles of numerical methods

Numerical taxonomy is "the numerical evaluation of the affinity of similarity between taxonomic units and the ordering of these units

Table 6.4 <u>Listing of the computer programme used for Cluster Analysis in this study</u>.

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UNIVERSITY OF MINNESOTA FORTRAN COMPILER (VERSION 5.4 - 79/10/25) ON THE C174 UNDER  N O S 1.1.8 ON 81/02/19 AT 20.24
                 MNF5(T)

0000303        PROGRAM DIST(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
0021319        DIMENSION DAT(140,70),TDAT(70),NAME(70),SIMMAT(3300),ELEVL(80),
              1IDEND(80,3),ISYMB(5)
0021313        COMMON DAT,TDAT,NAME,SIMMAT,ELEVL,IDEND
0021313        DATAISYMB/1H+,1H-,1H*,1H ,6H      /
0021319        NLOC=70
0021369        NCHAR=140
0021373        IDOWN=1
0021403        IWEIT=1
0021413         IOPUT=1
0021413        PCENT=0.0
0021423        ITOP=1
0021433        DO 120  J=1,NLOC
0021533   120  READ(5,1000)  NAME(J),(DAT(I,J),I=1,NCHAR)
0022143  1000  FORMAT(A6,37F2.0/40F2.0/40F2.0/23F2.0)
0022143        DO 130  J=1,NLOC
0022239   130  TDAT(J)=DAT(1,J)
0022533        DO 140  J=1,NLOC
0022623        DO 150  I=2,NCHAR
0022733        IF(DAT(I,J).GT.TDAT(J))  TDAT(J)=DAT(I,J)
0023153   150  CONTINUE
0023213   140  CONTINUE
0023259        DO 160  J=1,NLOC
0023339        DO 170  I=1,NCHAR
0023433        DAT(I,J)=DAT(I,J)/TDAT(J)
0023439   170  CONTINUE
0023713   160  CONTINUE
0023763        II=0
0023763        DO 1  I=1,NLOC
0024059        JJ=I
0024059        DO 2  J=1,JJ
0024153        II=II+1
0024163        DUM=0.
0024169        DO 3  L=1,NCHAR
0024273     3  DUM=DUM+(DAT(L,I)-DAT(L,J))**2
0024603        DUM=1.-(SQRT(DUM/FLOAT(NCHAR)))
0024733        SIMMAT(II)=DUM
0025003     2  CONTINUE
0025053     1  CONTINUE
0025113        IT=NLOC
0025113        CALL CLUS1(SIMMAT,IDEND,NAME,IT,IDOWN,IWEIT,PCENT,ITOP,IOPUT)
0025153        M=NLOC
0025158        DO 180  I=1,M
0025253        II=I*(I-1)/2+I
0025268   180  ELEVL(I)=SIMMAT(II)
0025413        CALL DENDI(IDEND,NAME,ELEVL,M,ISYMB)
0025459        STOP
0025463        END
```

LIST OF VARIABLE AND ARRAY NAMES IN ADDRESS ORDER IN EACH BLOCK

BLOCK	LENGTH					
.LOCAL	20	0021318 ISYMB	0026538 II	0026548 J	0026558 IWEIT	0026569 IOPUT
		0026578 PCENT	0026609 ITOP	0026618 NCHAR	0026628 NLOC	0026639 JJ
		0026649 IDOWN	0026658 I	0026668 DUM	0026678 L	0026700 IT
		0026718 M				
//	13560	0000008 DAT	0231198 TDAT	0232168 NAME	0233248 SIMMAT	0316708 ELEVL
		0320109 IDEND				

```
3000003        SUBROUTINE CLUS1(SIMMAT,IDEND,NAME,IT,IDOWN,IWEIT,PCENT,ITOP,
              1IOPUT)                                                           ACLUS
       C             CLUS1                                                      B
       C             R J  HOWARTH, APPLIED GEOCHEMISTRY, IMPERIAL COLLEGE       CCLUS
       C             CLUSTER EXTRACTION BY WEIGHTED OR UNWEIGHTED VARIABLE OR   CCLUS
       C             PAIR GROUP METHODS FROM SIMILARITY MATRIX                  DCLUS
       C             FORTRAN-IV, 7094 GENERAL,VERSION-9.57/R                    E
       C             MULTIVARIATE STATISTICS                                    FCLUS
       C             CASES OR VARIABLES LINKED AT GIVEN LEVELS OF SIMILARITY BY A FCLUS
       C             FORM A HEIRARCHICAL CLASSIFICATION PRINTED BY DENDI        FCLUS
       C             SIMILARITY MATRIX (EG CORRELATION COEFFICIENT) EXTRACTED TO GCLUS
       C             SOKAL AND SNEATH,PRINCIPLES OF NUMERICAL TAXONOMY. FREEMAN GCLUS
       C             SAN FRANCISCO AND LONDON (1963).                           HCLUS
       C             INPUT VARIABLES -                                          HCLUS
       C             SIMMAT=VECTOR HOLDING LOWER TRIANGULAR ELEMENTS OF THE     HCLUS
       C                    SIMILARITY MATRIX, ORDERED ROW-BY-ROW . FOR A 5*5   HCLUS
       C                    MATRIX THE 15 ELEMENTS OF SIMMAT WOULD CORRESPOND TO HCLUS
       C                    THE FOLLOWING POSITIONS IN THE SIMILARITY MATRIX -  HCLUS
```

```
                C                                                                      HCLUS
                C          I/J 1  2  3  4  5                                           HCLUS
                C          -------------------                                         HCLUS
                C          1 I 1                                                       HCLUS
                C          2 I 2  3                                                    HCLUS
                C          3 I 4  5  6                                                 HCLUS
                C          4 I 7  8  9  10                                             HCLUS
                C          5 I 11 12 13 14 15                                          HCLUS
                C                                                                      HCLUS
                C     IT    = NO OF OTUS.                                              HCLUS
                C     IDOWN= +1 THEN CLUSTERING WILL BE DOWNWARDS (FROM HIGHEST        HCLUS
                C              SIMILARITY VALUE).                                      HCLUS
                C           -1 THEN CLUSTERING WILL BE UPWARDS (FROM LOWEST            HCLUS
                C              SIMILARITY VALUE).                                      HCLUS
                C     IWEIT= +1 THEN METHOD WILL BE WEIGHTED,ELSE UNWEIGHTED.          HCLUS
                C     PCENT= PERCENTAGE FACTOR, REAL IN RANGE 0.0-1.0                  HCLUS
                C            IF 0.00 PAIR GROUP METHOD IS EXECUTED                     HCLUS
                C            ELSE VARIABLE GROUP METHOD IS EXECUTED, WHICH WILL        HCLUS
                C            FIND ALL OTUS LYING WITHIN THE PERCENT FACTOR PCENT       HCLUS
                C            OF THE CYCLE.                                             HCLUS
                C     ITOP  = +1 THEN PERCENTAGE DIFFERENCE (PCENT) CONSIDERED IN      HCLUS
                C            THE VARIABLE GROUP METHOD IS FROM THE TOP LEVEL VALUE     HCLUS
                C            OF THE PAIR OF OTUS INITIATING THE CLUSTER WITHIN THE     HCLUS
                C            SAME CYCLE.                                               HCLUS
                C            ELSE PCENT CONSIDERED WILL BE FROM THE PREVIOUS LEVEL     HCLUS
                C            VALUE.                                                    HCLUS
                C     NAME  = VECTOR CONTAINING ALPHAMERIC NAMES OF OTUS.              HCLUS
                C     OUTPUT VARIABLES -                                               HCLUS
                C     IOPUT= +1 THEN OUTPUT FOR SUBROUTINE DEND1 WILL BE LISTED.       HCLUS
                C     IDEND= ARRAY CONTAINING OUTPUT FOR DRAWING DENDROGRAM IN         HCLUS
                C            SUBROUTINE DEND1                                          HCLUS
                C     SIMMAT AS DESCRIBED ABOVE. NOW CONTAINS LATEST LEVEL VALUES      HCLUS
                C            FOR OTUS FOR USE IN DEND1. MAY ALSO BE USED TO OBTAIN     HCLUS
                C            COPHENETIC VALUES SUBSEQUENTLY.                           HCLUS
                C     NAME = AS ABOVE                                                  HCLUS
                C     REVR1,FORTRAN-IV                                                 ICLUS
                C     CHAI1,FORTRAN-IV                                                 ICLUS
                C     DEND1,FORTRAN-IV                                                 ICLUS
                C     UP TO 200 OTUS ALLOWED                                           JCLUS
                C   HOWARTH EP/13. BASED ON ALGOL PROGRAM BY G. SHADAKSHARAPPA.
  2.   0000003       DIMENSION SIMMAT(3390),NAME(90),IDEND(80,3)
                C
                C
                C    LISTING OF CONTROL OPTIONS
  3.   0000003    10 FORMAT(20H1  PROCEDURE CLUSTER)
  4.   0000009    11 FORMAT(15H   NO OF OTUS =,I5)
  5.   0000008    21 FORMAT(28H DOWNWARDS CLUSTERING OPTION)
  6.   0000008    22 FORMAT(28H UPWARDS CLUSTERING OPTION  )
  7.   0000003    31 FORMAT(18H PAIR GROUP METHOD)
  8.   0000003    32 FORMAT(22H VARIABLE GROUP METHOD)
  9.   0000008    33 FORMAT(48H PERCENTAGE CRITERION TO ENTER EXISTING CLUSTER=,F6.3)
 10.   0000003    34 FORMAT(51H PERCENTAGE DIFFERENCE CONSIDERED IS FROM TOP LEVEL/
                    115H VALUE OF CYCLE)
 11.   0000003    35 FORMAT(51H PERCENTAGE DIFFERENCE CONSIDERED IS FROM PREVIOUS /
                    121H LEVEL VALUE OF CYCLE)
 12.   0000008    40 FORMAT(19H METHOD IS WEIGHTED)
 13.   0000003    50 FORMAT(21H METHOD IS UNWEIGHTED)
                C
 14.   0000003       WRITE(6,10)
 15.   0000063       WRITE(6,11)IT
 16.   0000158         IF(IDOWN-1)110,120,120
 17.   0000173   110 WRITE(6,22)
 18.   0000268       GO TO 130
 19.   0000278   120 WRITE(6,21)
 20.   0000363   130   IF(PCENT-.0001)140,140,150
 21.   0000423   140 WRITE(6,31)
 22.   0000513       GO TO 180
 23.   0000523   150 WRITE(6,32)
 24.   0000613       WRITE(6,33)PCENT
 25.   0000703         IF(ITOP-1)160,170,160
 26.   0000713   160 WRITE(6,35)
 27.   0001013       GO TO 180
 28.   0001029   170 WRITE(6,34)
 29.   0001118   180   IF(IWEIT-1)190,195,190
 30.   0001133   190 WRITE(6,50)
 31.   0001233       GO TO 200
 32.   0001248   195 WRITE(6,40)
                C
                C    ENTER MAIN PART OF PROCEDURE
                C
 33.   0001333   200 ITL = IT-1
 34.   0001358         IF(IDOWN) 201,202,202
                C    CHANGE SIGNS OF ALL OFF DIAGONAL ELEMENTS OF ARRAY SIMMAT
                C    WHEN UPWARDS CLUSTERING IS REQUIRED
 35.   0061373   201 CALL REVR1(SIMMAT,IT)
```

```
                C
0001463            202 DO 203 I=1,IT
0001503            203 IDEND(I,3)=1
0001733                K=0
                C      COUNTER K SET TO ZERO
0001733            205   IF(K-ITL)207,300,500
0001779            207     DO 210 I=2,IT
0002113                  IF(IDEND(I,3))212,210,212
0002163            212 NT=I*(I-1)/2+1
0002223                CORMAX=SIMMAT(NT)
0002263                MAXROW=I
0002273                MAXCOL=1
                C      CORMAX NOW SET TO FIRST OFF DIAGONAL ELEMENT OF SIMMAT
0002313                GO TO 220
0002313            210 CONTINUE
                C
                C      FIND HIGHEST VALUE OF SIMILARITY COEFFICIENT IN ARRAY SIMMAT.
                C      SET CORMAX EQUAL TO IT AND STORE OTUS CORRESPONDING TO IT IN
                C      MAXCOL AND MAXROW. THIS PAIR OF OTU INITIATES A CLUSTER.
                C
0002373            220 DO 225 I=2,IT
0002503                  IF(IDEND(I,3))230,225,230
0002553            230 II=I*(I-1)/2
0002613                IA=I-1
0002613                  DO 236 J=1,IA
0002713                  IF(IDEND(J,3))232,236,232
0002763            232 IIJ=II+J
0003013                  IF(SIMMAT(IIJ)-CORMAX)236,236,234
                C        RESET CORMAX
0003103            234   IIJ=II+J
0003133                  CORMAX=SIMMAT(IIJ)
0003203                  MAXROW=I
0003223                  MAXCOL=J
0003233            236   CONTINUE
0003303            225 CONTINUE
                C
0003343            240 DOWN=IDOWN
                C      OUTPUT LEVEL AT WHICH TWO OTUS JOIN (CORRECTED FOR SIGN DEPENDING
                C      ON UP OR DOWN CLUSTERING DIRECTION)
0003363                PROD=CORMAX*DOWN
                C      OUTPUT NAMES OF OTUS AND LEVEL
0003378                WRITE(6,242)NAME(MAXCOL),NAME(MAXROW),PROD
0003423            242 FORMAT(3X,A6, 9H  JOINS  ,A6,21H AT A LEVEL VALUE OF,F7.3)
                C
                C      INCREMENT COUNTER OF NUMBER OF JOINED PAIRS (K)
0003523                K=K+1
0003533                KA=K*(K-1)/2+K
                C
0003643                IDEND(K,1)=MAXCOL
0003713                IDEND(K,2)=MAXROW
0003763                EEVL=CORMAX
0004003                SIMMAT(KA)=CORMAX
                C
0004053            250 ITL=IT-1
0004113                  IF(K-ITL)260,500,500
                C      SET ITEST TO ZERO
0004133            260 ITEST=0
0004153                II=MAXCOL*(MAXCOL-1)/2
0004179                JJ=MAXROW*(MAXROW-1)/2
0004223                  IF(MAXCOL-1)300,300,270
0004233            270 MA=MAXCOL-1
0004268                DO 290 J=1,MA
0004350                  IF(IDEND(J,3))281,290,281
0004423            281   IF(IWEIT-1) 283,282,283
                C      COMPUTE AVERAGE CORRELATION OF PROSPECTIVE MEMBER WITH CLUSTER- SN
                C      WEIGHTED -
0004453            282   IIJ=II+J
0004503                  JJJ=JJ+J
0004523                  SIMMAT(IIJ)=(SIMMAT(IIJ)+SIMMAT(JJJ))*0.5
0004649                GO TO 284
                C      UNWEIGHTED -
0004653            283 DENDA=IDEND(MAXCOL,3)
0004758                DENDB=IDEND(MAXROW,3)
0005029                  IIJ=II+J
0005039                  JJJ=JJ+J
0005053                SIMMAT(IIJ)=(DENDA*SIMMAT(IIJ)+DENDB*SIMMAT(JJJ))/(DENDA+DENDB)
                C
                C      CLUSTERING CRITERION TESTED
                C                IF VARIABLE GROUP GOTO 295
0005238            284   IF(PCENT-.0001)300,300,295
0005303            285   IF(J-1)286,285,287
0005333            286 IIJ=II+J
0005369                SN=SIMMAT(IIJ)
0005433                ITEST=1
0005453            287 IIJ=II+J
0005508                  IF(SIMMAT(IIJ)-SN)280,290,299
```

```
 98.    000557B    298 IIJ=II+J
 99.    000562B           IF(CORMAX-SIMMAT(IIJ)) 299,299,249
                 C      RESET AVERAGE SIMILARITY VALUE
100.    000571B    299 IIJ=II+J
101.    000573B        SN=SIMMAT(IIJ)
102.    000600B        ITEST=J
103.    000601B
104.    000601B    249 CONTINUE
                 C
                 C      REGARDING *SIMMAT* IN EXPANDED FORM IE AS LR DIAG MATRIX, THEVALUE
                 C      IN THE COLUMN CORRESPONDING TO *MAXCOL* IS RECALCULATED.
                 C
105.    000607B    300 MA=MAXCOL+1
106.    000611B        DO 310 J=MA,IT
107.    000623B           IF(IDEND(J,3)) 320,310,320
108.    000630B    320    IF(J-MAXROW) 330,310,330
109.    000634B    330 I=J*(J-1)/2
110.    000640B           IF(J-MAXROW) 331,332,332
                 C      DIF = DIFFERENCE BETWEEN SIMILARITY LEVEL OF PROSPECTIVE MEMBER OF
                 C            CLUSTER AND CRITERION VALUE PCENT IN VARIABLE GROUP METHOD
                 C
111.    000642B    331 JJJ=JJ+J
112.    000645B        DIF=SIMMAT(JJJ)
113.    000652B        GO TO 340
114.    000654B    332 IMAXR=I+MAXROW
115.    000657B        DIF=SIMMAT(IMAXR)
116.    000664B    340    IF(IW=IT-1) 342,341,342
                 C      WEIGHTED -
117.    000670B    341 IMAXC=I+MAXCOL
118.    000673B        SIMMAT(IMAXC)=(SIMMAT(IMAXC)+DIF)*0.5
119.    000702B        GO TO 350
                 C      UNWEIGHTED -
120.    000703B    342 DENDA = IDEND(MAXCOL,3)
121.    000713B        DENDB = IDEND(MAXROW,3)
122.    000720B        IMAXC=I+MAXCOL
123.    000721B        SIMMAT(IMAXC)=(DENDA*SIMMAT(IMAXC)+DENDB*DIF)/(DENDA+DENDB)
                 C      TEST FOR VARIABLE GROUP METHOD (IF NOT GOTO 400)
124.    000733B    350    IF(PCENT-.0001) 400,400,351
125.    000740B    351    IF(ITEST) 352,355,352
126.    000742B    352 IMAXC=I+MAXCOL
127.    000745B        IF(SIMMAT(IMAXC)-SN) 310,310,354
128.    000754B    354 IMAXC=I+MAXCOL
129.    000757B           IF(CORMAX-SIMMAT(IMAXC)) 310,355,355
130.    000766B    355 IMAXC=I+MAXCOL
131.    000770B        SN=SIMMAT(IMAXC)
132.    000775B        ITEST=J
133.    000777B    310 CONTINUE
                 C
                 C
134.    001004B    400 IDEND(MAXCOL,3)=IDEND(MAXCOL,3)+IDEND(MAXROW,3)
135.    001016B        IDEND(MAXROW,3)=0
136.    001022B    410    IF(PCENT-.0001) 205,205,412
                 C      VARIABLE GROUP GOTO 412
137.    001027B    412 DOWN=IDOWN
                 C
                 C      TEST TO SEE IF ADDING PROSPECTIVE MEMBER TO ESTABLISHED VARIABLE
                 C      GROUP CLUSTER PRODUCES AVERAGE CORRELATION BETWEEN MEMBER AND
                 C      CLUSTER LOWER THAN PREVIOUS LEVEL OF JUNCTION BY MORE THAN THE
                 C      CRITERION - IF SO THEN IT IS NOT ADMITTED, PROG RETURNS TO 205
                 C
138.    001031B        A= ABS(CORMAX-SN)
139.    001034B        B= CORMAX*PCENT*DOWN
140.    001036B           IF(A-B) 420,420,205
                 C      NEW MEMBER ADMITTED TO CLUSTER
                 C      INCREMENT COUNTER K
141.    001041B    420 K=K+1
                 C
                 C      EXPRESS DIFFERENCE BETWEEN AVERAGE CORRELATION AND OTU CORRELATION
                 C      WITHIN CRITERION AS DEFINED BY PCENT FACTOR AS PERCENTAGE
142.    001043B        DIF= 100.0*(CORMAX-SN)/CORMAX
143.    001046B         JJ=ITEST
144.    001047B           IF(MAXCOL-JJ) 424,424,422
145.    001052B    422 IDEND(K,1)=JJ
146.    001061B        IDEND(K,2)=MAXCOL
147.    001066B        GO TO 430
148.    001070B    424 IDEND(K,1)=MAXCOL
149.    001077B        IDEND(K,2)=JJ
150.    001104B    430    IF(ITOP-1) 432,434,432
                 C      PERCENTAGE DIFFERENCE(AS SPECIFIED BY PCENT) CONSIDERED IS FROM
                 C      PREVIOUS LEVEL VALUE OF THE CYCLE
151.    001110B    432 CORMAX=SN
152.    001113B    434 DOWN=IDOWN
153.    001115B        MAXCOL=IDEND(K,1)
154.    001123B        MAXROW=IDEND(K,2)
155.    001130B        SD=SN*DOWN
156.    001132B        KB=(K*(K-1)/2)+K
```

```
157.   0011353            SIMMAT(KB)=EEVL
                    C
158.   0011423        440 WRITE(6,442)NAME(MAXCOL),NAME(MAXROW),SD,DIF
159.   0011578        442 FORMAT(3X,A6,9H  JOINS  ,A6,21H  AT A LEVEL VALUE OF,F7.3,
                        124H PERCENTAGE DIFFERENCE =,F7.2)
160.   0011673            GO TO 250
                    C
                    C
                    C     LAST PART OF PROCEDURE CLUSTER -
                    C     AT EXIT FROM PROCEDURE DIAGONAL ELEMENTS OF SIMMAT HOLD LATEST
                    C     LEVEL VALUES FOR DRAWING DENDROGRAM IN DEND1.
                    C
161.   0011703        500 ITEST=1
162.   0011713            IDEND(1,3)=1
163.   0011728            II=1
                    C
164.   0011733            CALL CHAI1(ITEST,IT,II,IDEND)
                    C
165.   0012013        510   IF(IOPUT-1)540,512,540
                    C     PRINT OUTPUT FOR DENDROGRAM
166.   0012039        512 WRITE(6,514)
167.   0012138            WRITE(6,516)
168.   0012219            WRITE(6,518)
169.   0012273        514 FORMAT(38H LISTING OF INPUT DATA FOR DENDROGRAM,)
170.   0012273        516 FORMAT(51H ROW NAMES OF PAIRS        ROW NAME    OTU   JOINING )
171.   0012273        518 FORMAT(51H JOINING IN SUCCESSION    FOR LIST   NAME    AT LEVEL)
                    C
172.   0012278            ITL=IT-1
173.   0012309            DO 525 I=1,ITL
174.   0012373            IS=I*(I+1)/2
175.   0012403            WRITE(6,520)(IDEND(I,J),J=1,3),NAME(I),SIMMAT(IS)
176.   0013008        520 FORMAT(2X,I10,I11,I11,2X,A6,F7.3)
177.   0013003            WRITE(6,530)IDEND(IT,3),NAME(IT)
178.   0013239        525 CONTINUE
179.   0013243        530 FORMAT(22X,I11,2X,A6)
                    C     TEST CLUSTERING DIRECTION OPTION
180.   0013243        540   IF(IDOWN) 542,550,550
181.   0013263        542 CALL REVR1(SIMMAT,IT)
                    C
182.   0013358        550 RETURN
                    C     END OF SUBROUTINE CLUSTER
183.   0013403            END
       CAUTION   --------------------------------------------STATEMENT NUMBER 410 WAS NEVER USED
       CAUTION   --------------------------------------------STATEMENT NUMBER 240 WAS NEVER USED
       CAUTION   --------------------------------------------STATEMENT NUMBER 440 WAS NEVER USED
       CAUTION   --------------------------------------------STATEMENT NUMBER 510 WAS NEVER USED

LIST OF VARIABLE AND ARRAY NAMES IN ADDRESS ORDER IN EACH BLOCK
----------------------------------------------------------------

 BLOCK     LENGTH

.LOCAL        33     0021038 PROD     0021048 II       0021059 I        0021068 K        0021079 ITL
                     0021108 NT       0021118 MAXROW   0021129 MA       0021138 EEVL     0021149 CORMAX
                     0021158 JJ       0021169 SU       0021179 DOWN     0021208 MAXCOL   0021218 IA
                     0021228 J        0021238 IIJ      0021248 KA       0021258 ITEST    0021268 JJJ
                     0021279 DENJA    0021309 DENOB    0021318 DIF      0021328 IMAXR    0021339 IMAXC
                     0021348 A        0021359 B        0021368 SD       0021378 KB       0021409 IS

  1.   0000003            SUBROUTINE REVR1(SIMMAT,IT)                                   AREVR
                    C          REVR1                                                    B
                    C          R J  HOWARTH, APPLIED GEOCHEMISTRY, IMPERIAL COLLEGE     CREVR
                    C          REQUIRED BY CLUS1                                        DREVR
                    C          FORTRAN-IV,7094,GENERAL,VERSION-A,37/5                   E
                    C          MULTIVARIATE STATISTICS                                  FREVR
                    C          CHANGES SIGN OF *SIMMAT* WHEN UPWARDS CLUSTERING REQUIRED IREVR
                    C          CLUS1,FORTRAN-IV
                    C
  2.   0000003            DIMENSION SIMMAT(3309)
  3.   0000005            DO 100 I=2,IT
  4.   0000103              II=I*(I-1)/2
  5.   0000118              JA=I-1
  6.   0000128              DO 200 J=1,JA
  7.   0000229            IIJ=II+J
  8.   0000239            SIMMAT(IIJ) = -SIMMAT(IIJ)
  9.   0000309        200   CONTINUE
 10.   0000323        100 CONTINUE
 11.   0000378            RETURN
 12.   0000413            END
```

```
------------------------------------------------------------------
BLOCK      LENGTH
.LOCAL         5        0000710 IIJ         0000720 II          0000733 I           0000748 JA          0000759 J

   1.   0000004          SUBROUTINE CHAI(ITEST,IT,II,IDEND)                                           ACHAI
                   C          CHAI1                                                                   B
                   C          R J HOWARTH, APPLIED GEOCHEMISTRY, IMPERIAL COLLEGE                     CCHAI
                   C          REQUIRED BY CLUS1                                                       DCHAI
                   C          FORTRAN-IV,7094,GENERAL,VERSION-A,5/75                                  FCHAI
                   C          CLUSTER ANALYSIS                                                        FCHAI
                   C          FINDS CORRECT STRING OF ROW-NAMES IN *IDEND(I,3)* IN ORDER TO           FCHAI
                   C          DRAW DENDROGRAM WITH DENDI                                              ICHAI
                   C          CLUS1,FORTRAN-IV
   2.   0000033          DIMENSION IDEND(33,3)
   3.   0000003     100  IIA=0
   4.   0000013          KTEST=2
   5.   0000023     200  IK=II-1
   6.   0000053          DO 700 J=1,IK
                   C     TEST FOR NUMBER OF JOINED OTUS - IF EQUAL TO *ITEST* ENTER LIST
   7.   0000143          IF(IDEND(J,1)-ITEST)700,300,700
   8.   0000223     300  II=II+1
                   C     INCREMENT COUNTER FOR LIST OF OTU NAMES
   9.   0000253          IF(ITEST-1)320,320,400
                   C     SET MARK OF OTU *ITEST* POSITION IN LIST - SEARCH FOR JOINED OTUS
  10.   0000273     400  DO 450 K=KTEST,II
  11.   0000433          IF(IDEND(K,3)-ITEST)450,500,450
  12.   0000433     450  CONTINUE
                   C     OTU NOT IN LIST GO FAR
  13.   0000463          GO TO 320
  14.   0000473     500  KTEST=K
                   C     INCREMENT *IIA* COUNT OF OTUS JOINED WITH *ITEST*
  15.   0000513          IIA=IIA+1
  16.   0000523          IF(KTEST-(II-IIA))600,650,600
                   C     GOTO 650 IF *KTEST* IS LAST MOST ENTRY IN *IDEND(K,3)*
                   C     I.E. IF IT EQUALS *ITEST*
                   C     REORDER ALL *IDEND(K,3)* ENTRIES FROM LAST ENTRY BACKWARDS TO
                   C     POSITION FOLLOWING LAST OTU JOINED TO *ITEST* IN LIST.
  17.   0000653     600  KOUNT = II
  18.   0000703     610  KOUNTA=KOUNT-1
  19.   0000733          IDEND(KOUNT,3)=IDEND(KOUNTA,3)
                   C     TEST FOR LIST ENTRY FOLLOWING LAST OTU JOINED TO *ITEST*
  20.   0001033          IF(KOUNT-(K+IIA+1))650,650,620
  21.   0001073     620  KOUNT = KOUNT - 1
  22.   0001123          GO TO 610
                   C     INSERT OTU JOINED TO *ITEST* INTO CORRECT POSITION IN LIST
  23.   0001133     650  NEWIT=K+IIA
  24.   0001153          IDEND(NEWIT,3)=IDEND(J,2)
  25.   0001273          GO TO 700
                   C
  26.   0001313     320  IDEND(II,3)=IDEND(J,2)
  27.   0001433     700  CONTINUE
                   C     TEST FOR COMPLETION OF ORDERED LIST
  28.   0001519     800  IF(II-IT)910,820,920
  29.   0001543     910  ITEST=ITEST+1
  30.   0001573          GO TO 100
  31.   0001573     920  RETURN
  32.   0001643          END
        CAUTION  ---------------------------------------------STATEMENT NUMBER 200 WAS NEVER USED
        CAUTION  ---------------------------------------------STATEMENT NUMBER 820 WAS NEVER USED

LIST OF VARIABLE AND ARRAY NAMES IN ADDRESS ORDER IN EACH BLOCK
------------------------------------------------------------------

BLOCK      LENGTH
.LOCAL         8        0002673 IIA         0002703 IK          0002713 K           0002728 KTEST       0002733 J
                        0002743 KOUNT       0002758 KOUNTA      0002768 NEWIT

   1.   0000003          SUBROUTINE DENDI(IDEND,NAME,FLEVL,IT,ISYMB)                                  ADENO
                   C          DENDI                                                                   B
                   C          R J HOWARTH, APPLIED GEOCHEMISTRY, IMPERIAL COLLEGE                     CDENO
                   C          DRAWS A DENDROGRAM (TREE-DIAGRAM) SHOWING HIERARCHY OF                  CDENO
                   C          CLASSIFICATION ON LINE-PRINTER. USES OUTPUT FROM CLUS1                  DDENO
                   C          FORTRAN-IV,7094,GENERAL,VERSION-B,5/75                                  E
                   C          MULTIVARIATE STATISTICS                                                 ICENO
                   C          CLUS1,FORTRAN-IV                                                        HCENO
                   C          INPUT PARAMETERS ARE AS FOLLOWS                                         HDENO
                   C          *NAME* = ALPHAMERIC IDENTIFICATION OF OTUS HELD AS VECTOR               HDENO
                   C          *IDEND*= OUTPUT FROM CLUS1                                              HDENO
                   C          *FLEVL*= DIAGONAL ELEMENTS (1TO IT) OF *SIMMAT* OUTPUT FROM
```

```
C             CLUS1. MUST BE FORMED PRIOR TO CALLING DEND1.
C        *IT*    = NO OF OTUS
C        *ISYMB*= PLOTTING SYMBOLS FOR DRAWING DENDROGRAM (+,-,I, , )
C        CLUS1,FIRST,AN-IY
C        UP TO 200 OTUS MAY BE USED (IT).
C
C     HOWARTH  EP/13. BASED ON ALGOL PROGRAM BY G. SHADAKSHARAPPA.
C
      DIMENSION IDEND(99,3),IPOINT(1000,4),SCALE(11),NAME(98),ISYMB(5),
     1 ELEVL(99),IOUTC(101)
C     ARRAY ISYMB CARRIES PLOTTING SYMBOLS FOR DENDROGRAM AS FOLLOWS
C     IPLUS=ISYMB(1)
C     INEG =ISYMB(2)
C     IVERT=ISYMB(3)
C     IBLANK=ISYMB(4)
C     IBLANF=ISYMB(5)
C
C     SET UP PLOTTING SCALE FOR DENDROGRAM = TOTAL WIDTH/KOL WHERE
C     KOL = NO OF LINE-PRINTER COLUMNS ASSIGNED TO PLOT.
C     IOUTC = VECTOR OF DIMENSION KOL ACTING AS BUFFER TO HOLD PLOT
C             ELEMENTS AS THEY ARE CALCULATED.
C
      KOL= 101
C
      ITL = IT-1
   20 IFIRST =ELEVL(1)+0.5
        IF(IFIRST)21,21,22
   21 IFIRST=ELEVL(1) + 1.0
      IF(IFIRST) 24,24,23
   22 FIRST=1.0
      GO TO 25
   23 FIRST=0.5
      GO TO 25
   24 FIRST=0.0
   25 ILAST = ELEVL(ITL) + 1.0
      IF(ILAST) 27,27,26
   27 ILAST = ELEVL(ITL) + 1.5
      IF(ILAST) 29,29,28
   26 SMALL=0.0
      GO TO 30
   28 SMALL=-0.5
      GO TO 30
   29 SMALL=-1.0
C     RANGE OF DENDROGRAM DETERMINED - NOW OUTPUT SCALE FOR PLOT
   30 COL =KOL
      RSCALE =(FIRST-SMALL)/COL
      DO 31 I=1,11
      C=I-1
   31 SCALE(I)=FIRST-10.0*C*RSCALE
      WRITE(6,32)SCALE
      WRITE(6,34)
   32 FORMAT(1H1,5X,F5.2,10F10.2)
   34 FORMAT(109H   0 U  +---------+---------+---------+---------+------
     1---+---------+---------+---------+---------+---------+)
C
C     FILL ARRAY IPOINT WITH ROW-NAMES OF PAIRS
      DO 60 I=1,IT
         KP=IDEND(I,2)
         IPOINT(KP,1)=I
      DO 62 K=1,IT
            IF(IDEND(K,3)-IDEND(I,1))62,64,62
   64       KP=IDEND(I,2)
            IPOINT(KP,2)=K
            GO TO 60
   62    CONTINUE
   60 CONTINUE
C
      DO 500 I=1,IT
  100 N=IDEND(I,3)
C     PRINT NEW LINE AND SET UP FIRST ELEMENTS.OF OUTPUT ARRAY
      IOUTA=NAME(N)
      IOUTB= ISYMB(1)
C     CLEAR PLOTTING ARRAY *IOUTC(K)*
      DO 510 K=1,KOL
  510 IOUTC(K) = ISYMB(4)
C
      ITEST = 0
C     SET COUNTER FOR OUTPUT OF LINE OF SYMBOLS IN DENDROGRAM TO ZERO
      K=0
  110 IF(I-1)120,120,200
  120 ITL=IT-1
      DO 130 JLOOP=1,ITL
C       LOOP GOES FROM  J=ITL,1,-1 INTERNALLY
      J=ITL+1-JLOOP
        IF(IDEND(J,1)-IDEND(I,3))130,140,130
  140 JJ=((FIRST-ELEVL(J))/RSCALE)
```

```
 56.     0103573            JJ=JJ+1-K
 57.     0103613          IF (JJ) 151, 151, 145
 58.     0103633      145    DO 150 KK=1,JJ
                 C               SET UP PLOT ARRAY WITH SYMBOL -
 59.     0103733               K=K+1
 60.     0103743          IOUTC(K) = ISYMB(2)
 61.     0104003      150    CONTINUE
 62.     0104043      151 GO TO 400
 63.     0104053      130 CONTINUE
                 C
 64.     0104133      200 KP=IDEND(I,3)
 65.     0104213           J=IPOINT(KP,1)
 66.     0104268          JJ=((FIRST-ELEVL(J))/RSCALE)
 67.     0104353          JJ=JJ+1-K
 68.     0104373          LJ=JJ-1
 69.     0104403          IF (LJ) 211, 211, 205
 70.     0104413      205 DO 210 II=1,LJ
                 C               SET UP PLOT ARRAY WITH SYMBOL -
 71.     0104523               K =K+1
 72.     0104533          IOUTC(K) = ISYMB(2)
 73.     0104573      210 CONTINUE
                 C        SET UP PLOT ARRAY WITH SYMBOL I
 74.     0104638      211 K=K+1
 75.     0104653          IOUTC(K) = ISYMB(3)
 76.     0104713      220 IF(I-IT)230,500,230
 77.     0104763      230 I1 = I+1
 78.     0105013          DO 300 II=I1,IT
 79.     0105133            KP=IDEND(II,3)
 80.     0105173             IF(IPOINT(KP,2)-I)240,240,300
 81.     0105273      240      IF(ITEST) 250,250,260
 82.     0105323      250      IF(IPOINT(KP,2)-I)260,300,260
 83.     0105423      260      J=IPOINT(KP,1)
 84.     0105518          JJ=((FIRST-ELEVL(J))/RSCALE)
 85.     0105603               JJ=JJ+1-K
 86.     0105623      270      IF(JJ)280,290,290
 87.     0105653      280        KJOIN=IDEND(JOIN,3)
(87) -  CAUTION  ------------------------------------------------------------JOIN IS NOT SET ABOVE
 88.     0105743                 IPOINT(KP,1)=IPOINT(KJOIN,1)
 89.     0105843                 IPOINT(KP,2)=JOIN
(89) -  CAUTION  ------------------------------------------------------------JOIN IS NOT SET ABOVE
                 ------USED IN LINE:     87.
 90.     0106113                 GO TO 300
 91.     0106133      290      JOIN=II
 92.     0106158               DO 294 KK=1,JJ
 93.     0106248          K=K+1
 94.     0106253      291      IF(KK-JJ)292,293,293
                 C             FILL ARRAY IOUT WITH A BLANK OR I
 95.     0106313      292 IOUTC(K) = ISYMB(4)
 96.     0106403               GO TO 294
 97.     0106423      293 IOUTC(K) = ISYMB(3)
 98.     0106518      294 CONTINUE
 99.     0106578      300 CONTINUE
                 C
100.     0106633      400 ITEST=ITEST+1
101.     0106653          IF(ITEST-2)420,500,500
                 C
                 C        PRINT OUTPUT LINE OF DENDROGRAM
102.     0106673      420 WRITE(6,810)IOUTA,IOUTB,IOUTC
103.     0107033          IOUTA=ISYMB(5)
104.     0107033          IOUTB = ISYMB(4)
                 C        CLEAR PLOTTING ARRAY *IOUTC(K)*
105.     0107053          DO 520 K=1,KOL
106.     0107153      520 IOUTC(K) = ISYMB(4)
                 C        RESET K FOR NEW LINE
107.     0107338          K=0
108.     0107333          GO TO 230
                 C
109.     0107353      500 WRITE(6,810)IOUTA,IOUTB,IOUTC
110.     0107523          WRITE(6,34)
111.     0107618          WRITE(6,820) SCALE
112.     0107718          WRITE(6,830)
                 C        NOTE - ASTERISK IN CARRIAGE CONTROL FIELD OF FORMAT NOS. 810, 820
                 C        CAUSES THE SUPPRESSION OF THE BLANK LINES AT THE TOP OF A NEW PAGE
113.     0107778      810 FORMAT(1H*,A6,A1,101A1)
114.     0107773      820 FORMAT(1H*,5X,F5.2,10F10.2)
115.     0107773      830 FORMAT(1H1)
116.     0107773          RETURN
117.     0110013          END
         CAUTION  -----------------------------------------------STATEMENT NUMBER 100 WAS NEVER USED
         CAUTION  -----------------------------------------------STATEMENT NUMBER 110 WAS NEVER USED
         CAUTION  -----------------------------------------------STATEMENT NUMBER 20 WAS NEVER USED
         CAUTION  -----------------------------------------------STATEMENT NUMBER 270 WAS NEVER USED
         CAUTION  -----------------------------------------------STATEMENT NUMBER 220 WAS NEVER USED
         CAUTION  -----------------------------------------------STATEMENT NUMBER 291 WAS NEVER USED


LIST OF VARIABLE AND ARRAY NAMES IN ADDRESS ORDER IN EACH BLOCK
---------------------------------------------------------------

 BLOCK    LENGTH

.LOCAL     4137     0000008 IPOINT    0076608 IOUTC    0100053 SCALE    0112508 FIRST    0112518 RSCALE
                    0112528 C         0112533 COL      0112548 LJ       0112558 I        0112568 SMALL
                    0112578 KOL       0112608 IT       0112618 ITEST    0112628 KK       0112638 KP
                    0112648 IFIRST    0112658 ILAST    0112668 JLOOP    0112678 IOUTA    0112708 K
                    0112718 N         0112728 IOUTB    0112738 J        0112748 JJ       0112758 II
                    0112768 I1        0112778 JOIN     0113008 KJOIN
```

into taxa based on their affinities" (Sokal and Sneath, 1963 p48). These methods have however, a wider application and have been used in a variety of fields ranging from plant ecology to philology and political science. Cheetham and Deboo (1963) and Hazel (1970) are amongst several authors who have applied these methods to biostratigraphy. The methods are fully described in Sokal and Sneath (op.cit.) and need not be repeated here.

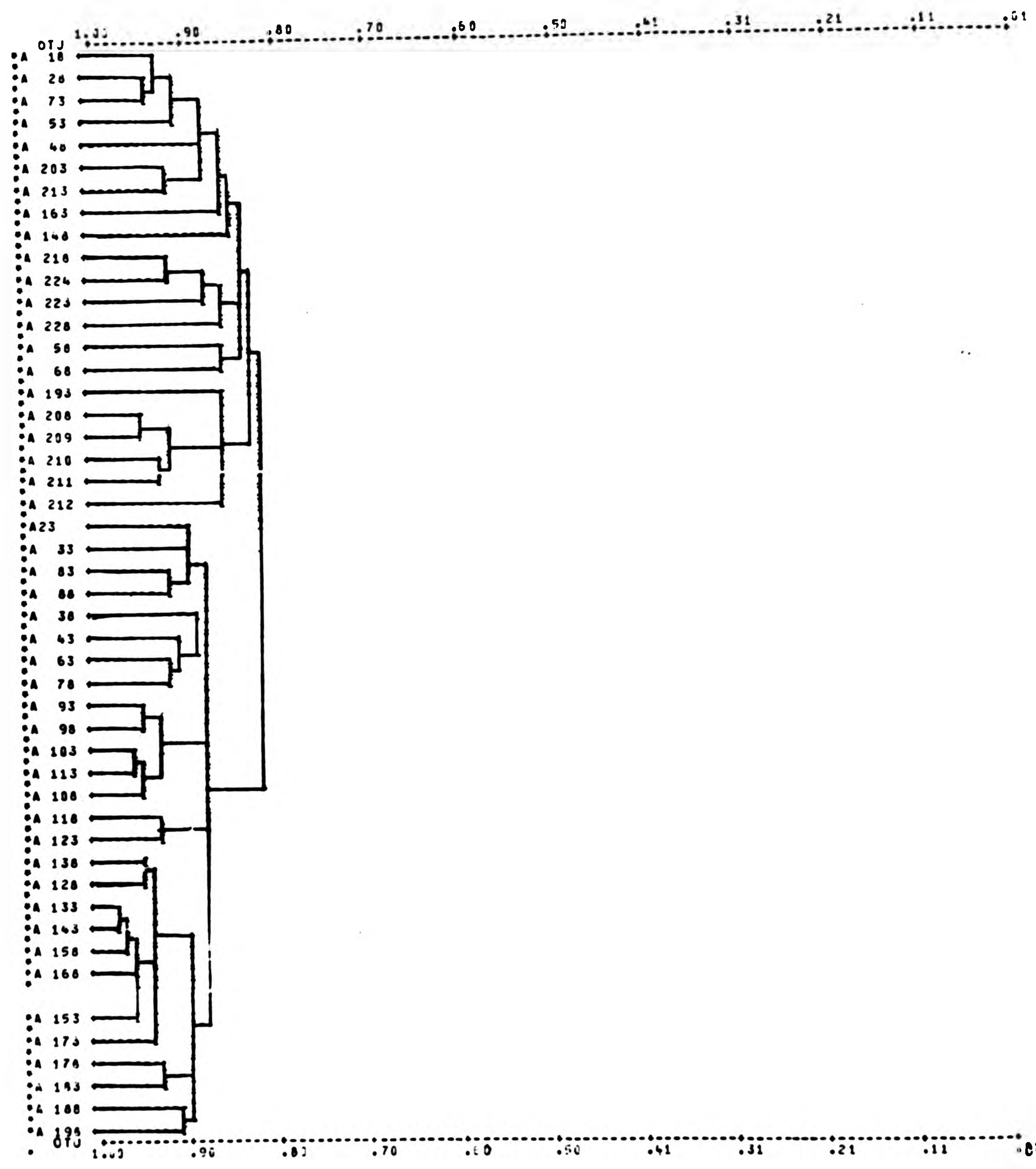
Cluster analysis is a simple form of correlation analysis, a method of searching for relationships in a large symmetrical matrix and first developed by psychologists. It is a straightforward, logical, pair-by-pair comparison between samples, objects or variables. The results of cluster analysis can be presented in an easily understood, two-dimensional hierarchical diagram (dendrogram) on which the 'natural breaks' between groups will be obvious. The observer can also pick off groups at any desired level of similarity. The method employs Q- and R-mode analysis and produces cluster dendrograms from which associations can be easily evaluated. In Q-mode, objects (samples) are related to each other on the basis of their attributes (species). In R-mode, attributes are related to each other on the basis of the objects in which they are found. It will follow that for biostratigraphical purposes Q-mode analysis is employed.

c) The method applied to data from Warboys and Warlingham boreholes

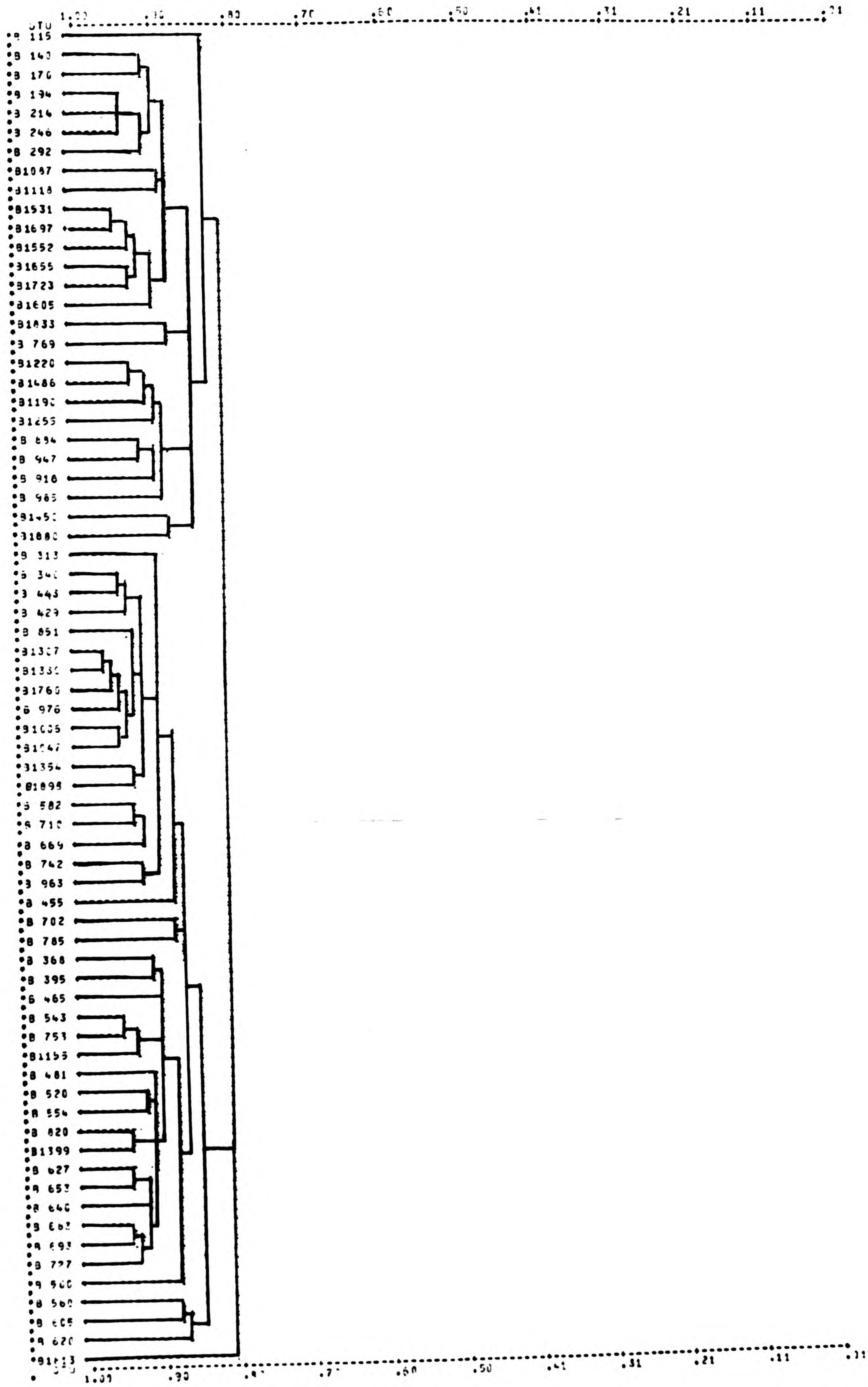
A great variety of matching coefficients are available, many of which are based on two-character state (presence/absence) data using the 2 X 2 contingency table, e.g., the Simple Matching Coefficient and the Jaccard Coefficient. Other matching coefficients have been used to take into consideration more than simply presence/absence data; one such method is the Distance Coefficient. Because of the potential significance of relative abundancies of microplankton it was decided to use the Distance Coefficient to take this factor into account. The correlation coefficient of similarity was computed between all samples for each of the boreholes independently and then for the two boreholes together. The programme used was based on the work of Sokal and Sneath (op.cit.), adapted by R.J. Howarth of Imperial College of Science abd Technology, London and executed by Dr. J. Fergusson also of Imperial College. A complete listing of the programme is given in table 6.4.

Having computed the correlation coefficients, the data was clustered using an unweighted pair-group method and the results plotted on dendrograms (figs. 6.6 to 6.8).

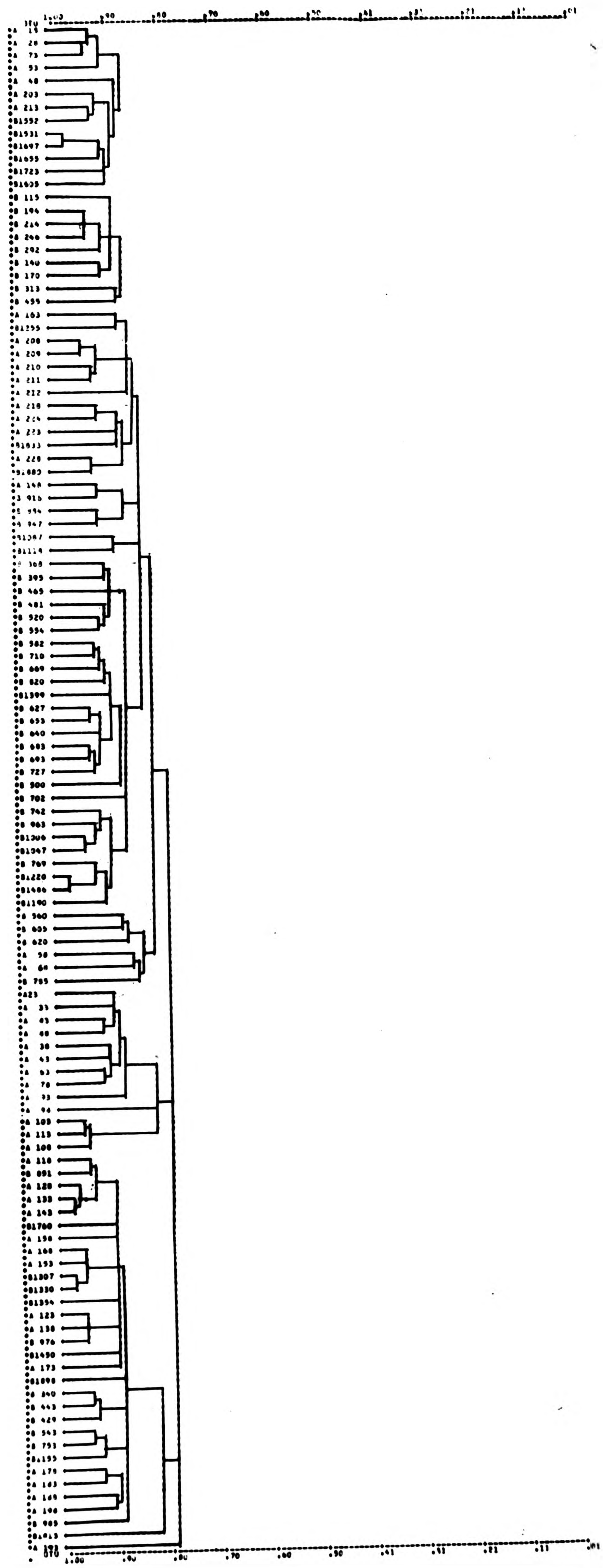
Text-figs. 6.6 to 6.8 <u>Cluster Analysis Dendrograms for the Warboys borehole (fig.6.6), Warlingham borehole (fig.6.7) and both boreholes together (fig.6.8)</u>



Text-fig. 6.6

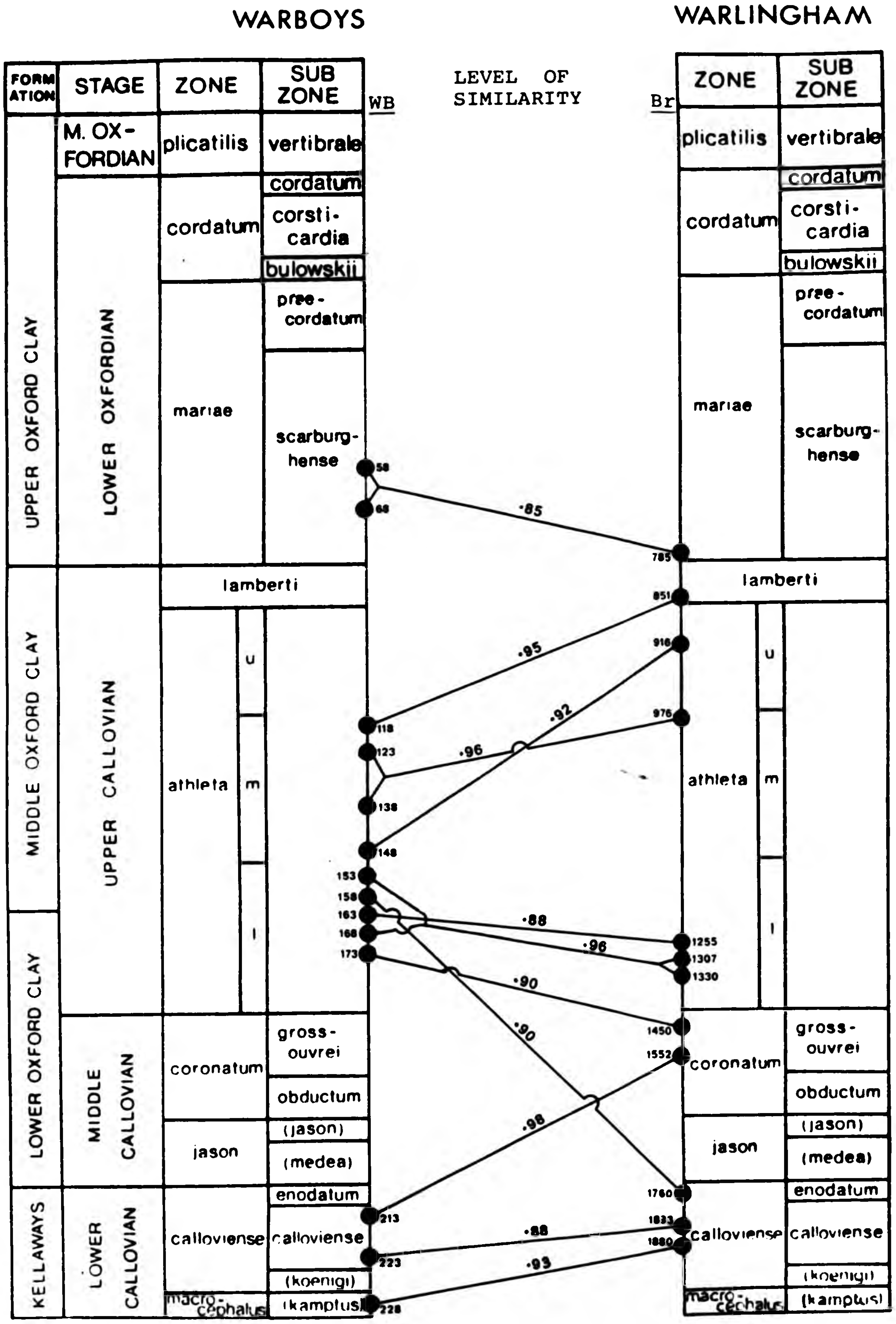


Text-fig. 6.7



Text-fig. 6.8

Text-fig. 6.9 Points of Correlation between Warboys and Warlingham, from the data in fig. 6.8



WARBOYS
WARLINGHAM
FORMATION
STAGE
ZONE
SUB ZONE
WB
LEVEL OF SIMILARITY
Br
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OXFORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
vertibrale
cordatum
corsticardia
bulowskii
praecordatum
mariae
scarburghense
lamberti
athleta
u
m
l
coronatum
grossouvrei
obductum
jason
(jason)
(medea)
enodatum
calloviense
(koenigi)
macrocephalus
(kamptus)
·85
·95
·92
·96
·88
·96
·90
·90
·98
·88
·93

d) Discussion of results

The reason for using this method of correlation was an attempt to arrive at a zonation scheme which would eliminate the problems of conventional biostratigraphy outlined above, and be always recogniseable; the basic idea of the method being to group together those samples with a very similar floral content. The computer did this and the results are illustrated in the dendrograms shown in figures 6.5 to 6.8.

Initial observation of these dendrograms shows that all samples have clustered at a high level of similarity: .82 for Warboys (fig. 6.6); .81 for Warlingham (fig. 6.7) and .79 for Warboys and Warlingham plotted together (fig. 6.8). The most obvious corollary from this is that all samples show a high degree of similarity in terms of floral content. On closer examination however, it will be noticed that at higher levels of similarity definite groups of samples have clustered together. In some instances, particularly for Warboys (fig. 6.6), the groups reflect the ammonite zones almost exactly. For example, samples WB208, 209, 210 and 211 cluster at a level of .92 and depict closely the jason zone of the Middle Callovian; similarly WB83 and 88 cluster at .92 and represent the lamberti zone of the Upper Callovian. Unfortunately however, the clusters are not totally consistent and all of the ammonite zones cannot be determined in this way. Neither can a readily-identifiable zonation scheme be determined from the groupings alone.

Figure 6.9 shows the two stratigraphical sections for Warboys and Warlingham and illustrates the points at which a sample from one borehole has clustered with a sample from the other borehole at a high level of similarity using the data from fig.6.8. Again there are instances where close correlations can be made but this is not consistent; some correlations being made between samples from different stages, e.g., WB158 with Br1760 and WB213 with Br1552.

Whilst results from this technique have not proved wholly satisfactory in terms of absolute correlation and the errection of a useful zonation scheme, the author feels that such numerical methods could be a useful tool for biostratigraphic work using microplankton. Further time for experimentation may have resulted in more conclusive results. The use for example, of either the Simple Matching or Jaccard Coefficients based on presence/absence data may prove to be more successful in providing a zonation scheme, taking into account local ranges of species only. It seems that the third variable (absolute abundancies) has confused the resulting picture.

C. <u>CONCLUSIONS</u>

The assemblages obtained from the Warboys and Warlingham Boreholes are typical of the Upper Jurassic. Whilst many species are long-ranging and consequently of little use for detailed biostratigraphical purposes, some have more restricted ranges and are useful for determining horizons within the Callovian and Oxfordian. The ***Meiourogonyaulax*** group are restricted to the Lower and Middle Callovian in the present assemblages, whilst the related species ***Lithodinia jurassica*** dominates the whole of the Callovian. The extinction of ***Pareodinia prolongata*** together with the appearance of ***Wanaea fimbriata*** seem to be almost universally accepted as marking the Callovian / Oxfordian boundary, the present study being no exception. Perhaps the most biostratigraphically-important genus in the Callovian/Oxfordian assemblages is ***Stephanelytron*** (see tab.6.2f), the majority of species first appearing in the uppermost Lower Callovian and being restricted to the Callovian/Oxfordian. The long-ranging species ***S. redcliffense*** and ***S. scarburghense*** however range into the Lower Kimmeridgian. The biostratigraphical significance of the nine species considered to be new has yet to be established.

With regards to statistical and numerical methods in biostratigraphy using microplankton, it is clear that further research is neccessary. It is felt however that exploration of such methods could lead to a more applied approach in biostratigraphy.

Chapter seven

PALAEOENVIRONMENTAL CONSIDERATIONS

PALAEOENVIRONMENTAL CONSIDERATIONS

Introduction

The full potential of dinoflagellate cysts as palaeoenvironmental indicators has yet to be established. Even the ecology of living dinoflagellates is imperfectly known and permits only generalisations concerning distribution patterns. Williams, D (1971 a&b), Wall (1971) and Wall et.al., (1977) have very much pioneered current investigations into the distribution and ecology of Recent and Quaternary dinoflagellates. Because so little is known of the relationships between fossilized cysts and their motile counterparts, palaeoenvironmental studies in the Caenozoic and Mesozoic are very much in their infancy stages. From this it is quite clear that a considerable amount of further work is neccessary before any definite conclusions may be drawn and palaeoenvironmental inferences made from palynological studies. There are however, certain preliminary conclusions that have been made from the early studies by both Williams and Wall, and more recently by Zeitzschel (1978).

A. PHYSICAL PARAMETERS AFFECTING THE DISTRIBUTION OF MICROPLANKTON

Dinoflagellates are found in all aquatic environments, from fresh-water to open-oceanic, and have a wide distibution in the marine realm of modern seas. Whilst they are a useful asset for the purposes of stratigraphic correlation (as we have seen in chapter 6) they may prove a liability when the aim is to determine past environmental conditions; indeed closely similar assemblages of dinoflagellate cysts may be extracted from quite dissimilar lithologies (Sarjeant, 1974a, p20). Until recently the presence of dinoflagellate cysts have been taken to indicate marine conditions. For example, G. von der Brelie (1963) was able to identify marine incursions into the coal swamps of the German Upper Oligocene and Miocene by the presence of dinoflagellate cysts. Dinoflagellates are however being recorded increasingly from fresh-water sediments and their presence can no longer therefore be taken to prove marine environments; although the majority of species are marine and may be sensitive to changes in water mass, including salinity changes.

1. Water Depth

Work by Staplin (1961), Vozzhennikova (1965) and Scull et.al., (1966) has shown that cyst morphology may be related to water depth and shoreline positions. Generally speaking cysts with thickened, double-layered walls are characteristic of near-shore, unstable environments; as are forms without spines or processes (or in which they are considerably reduced in size). Wall (1965), studying the Lias of England and Wales, found this to be true of the acritarch genus ***Micrhystridium***, a genus which is characteristic of inshore, basinal environments; whereas species with longer spines were charateristic of more stable, possibly deeper water, environments. Furthermore, the off-shore assemblages proved to be richer and of a greater diversity. Sarjeant (1974a), from his work in the Middle and Upper Jurassic also claims that an abundance of ***Micrhystridium*** may be indicative of near-shore conditions, whereas assemblages in which these acritarchs are few are likely to be from deeper waters.

2. Temperature

The limits of temperature-tolerance of dinoflagellates vary according to species. In general, forms inhabiting deeper seas are able to tolerate lower temperatures than those living in shallower water environments and vice-versa (Sarjeant, 1974a p9). Harland (1972) has shown that the known tolerance limits are about $1^{\circ}C$ to $35^{\circ}C$, with an optimum for most species within the range $18^{\circ}C$ to $25^{\circ}C$.

Studies relating fossil dinoflagellate assemblages and palaeotemperatures are in their early stages. Wall and Dale (1968) identified five facies associations in Early Pleistocene marine sediments of Norfolk, England, which included cysts identical with those of some living species whose environmental requirements are known. But applications of these studies to pre-Quaternary assemblages is virtually impossible as so little is known of the relationship between the cyst and its living motile counterpart in fossil dinoflagellates. It is quite likely however, that temperature-tolerant species would have a more cosmopolitan distribution, whilst temperature-sensitive species a more restricted distribution, usually to warm water (Williams, D. 1971a, p93).

3. Currents

Dinoflagellates are particularly abundant in waters containing high concentrations of nutrients. Work by Davey (1971) and Cross et.al., (1966) has shown that concentrations of dinoflagellates are particularly high where there is a mixing of currents or upwelling, corresponding with concentrations of nutrients such as phosphate, nitrate, silicate etc. Areas rich in these nutrients are known to provide ideal environments for increased phytoplankton productivity, or 'blooms'. The obvious corollary is that sediments which are particularly rich in dinoflagellates may well reflect areas of current-upwelling or mixing. Furthermore, a knowledge of the distribution of dinoflagellate populations may provide an index to past patterns of oceanic circulation. Williams, D. (1971b) has used such evidences to recognise at least eight distinct biofacies in Recent sediments of the North Atlantic ocean. But very extensive investigations, based on accurate stratigraphic correlations, independently confirmed by studies of other fossil groups, will be neccessary before dinoflagellate cysts can be used reliably to reconstruct past patterns of oceanic circulation.

It must be emphasised that little is known of the physical parameters which govern the distribution of fossil microplankton. Many of the conclusions reached, as outlined above, are centred upon circular argumentation. For example, if dinoflagellate cysts with thickened walls are found in sediments which are considered to be near-shore deposits in one locality, it does not neccessarily follow that the same species, when found in another locality, will indicate a near-shore depositional environment for that locality. It is in fact becoming increasingly clear that water depth in palaeoenvironments is extremely difficult to determine with any degree of accuracy. Such factors as oceanity (distance from shore) however are more easily determinable.

Even the possible determination of past patterns of oceanic circulation is open to suspect. Concentrations of dinoflagellate cysts in particular sediments may not neccessarily be indicative of phytoplankton blooms at all, but rather be directly proportional to the rate of sedimentation in a particular locality, or post-depositional transportation. It will obviously follow that dinoflagellate cysts will be particularly abundant in areas with a low rate of sedimentation, and vice-versa.

We know that in modern ecological studies there is a very complex interplay of external factors governing the movement of any group of organisms. Any one factor may have an overriding precedence to another. Determination of palaeoenvironments will likewise be subject to a similar complex array of physical parameters. We may therefore conclude that the presence of a certain species, or even assemblage of species, will not neccessarily indicate the same palaeoenvironmental conditions in every locality from which they are obtained. Williams and Sarjeant (1967) have shown the potentiality of microplankton for indicating palaeoenvironments whilst at the same time noting the many obstacles to definitive interpretation.

B. DISTRIBUTION OF MICROPLANKTON IN THE WARBOYS AND WARLINGHAM BOREHOLES AND PALAEOENVIRONMENTAL INTERPRETATIONS

Some of the difficulties in making palaeoecological inferrences from conclusions reached by studying recent microplankton have been outlined above. It is, therefore, only possible to make general observations on the distribution of microplankton in the material studied here in terms of palaeoenvironmental interpretation. However, where appropriate, tentative conclusions have been made.

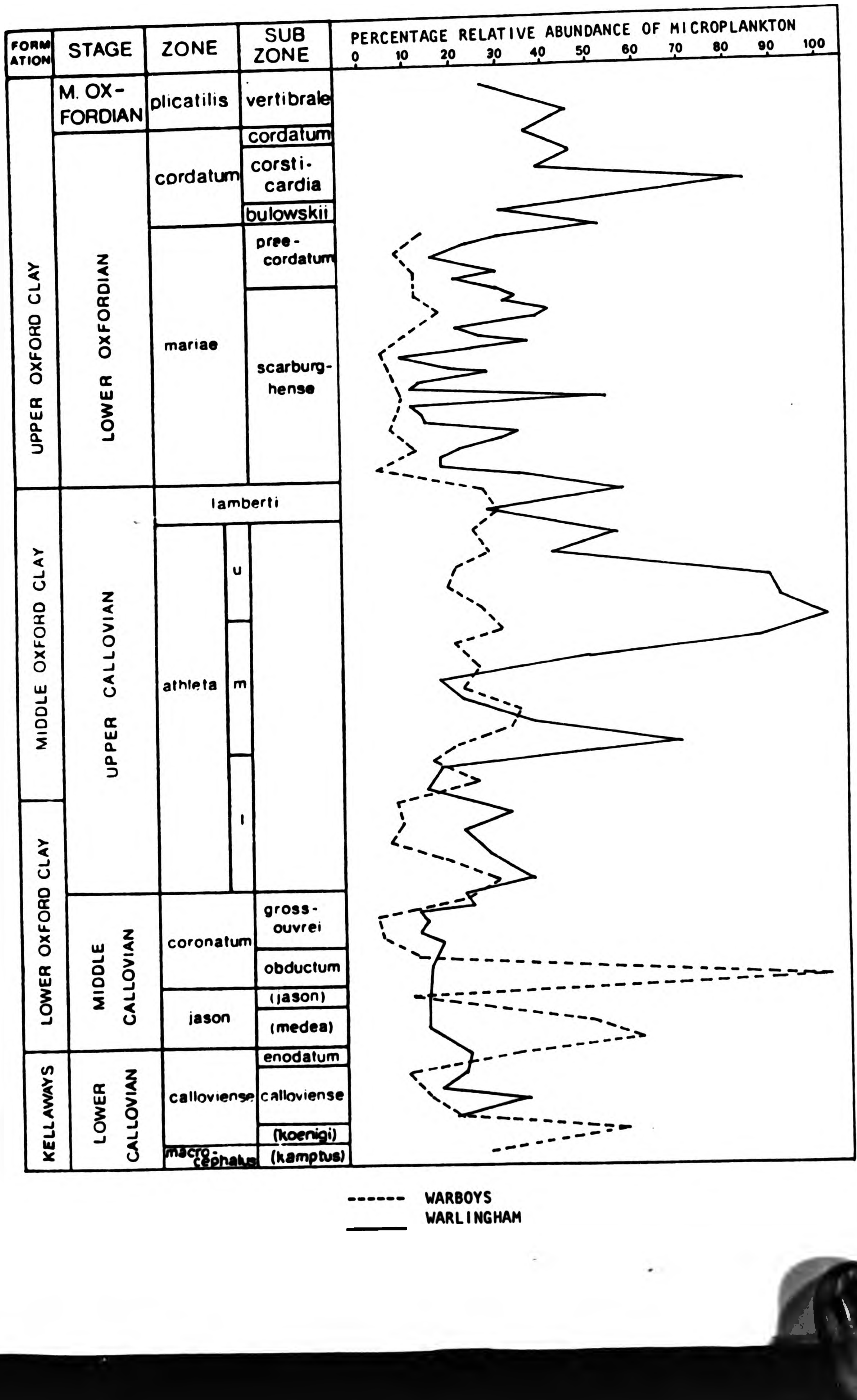
1. Relative Abundancies

Any quantitative analysis of fossil microplankton is difficult to make (with any degree of accuracy) because of the nature of the material studied and techniques of extraction. The graphs illustrated in fig.7.1 are an estimate of the relative abundancies of microplankton made from counting absolute numbers in one complete traverse of each prepared micro-slide. Samples containing the highest frequency of microplankton are WB 208 (for Warboys) and Br 976 (for Warlingham) where 137 and 120 individuals were counted for each sample respectively. All other counts are expressed as a percentage of these two samples for each borehole.

Apart from the two peaks in the Middle Callovian of Warboys and Upper Callovian of Warlingham, the two graphs are remarkably similar. There is however, an obviously greater variation in relative abundance in Warlingham than in Warboys. It will be noticed that the greatest disparity is in the Lower and Middle Callovian. From the Upper Callovian upwards however, the graphs show a greater conformity, particularly in the Lower Oxfordian. It will be further noticed that Warlingham displays a greater relative abundance of microplankton than Warboys, particularly in the Lower Oxfordian, whilst for the Lower and Middle Callovian the reverse is true.

The increasing conformity with time between the two graphs probably reflects an increasing uniformity of palaeoenvironmental conditions between the two localities. It is interesting to note however, that an increase in microplankton frequency does not appear to correlate with a reduction in the rate of sedimentation as one might at first expect. When comparing the graphs in fig.7.1 with the diagram in fig.2.3 we might expect to find a greater abundance of microplankton in the scarburghense subzone of Warboys because of the reduced thickness. Fig.7.1 however shows that the relative frequency of microplankton is greater at Warlingham for the same time-interval. We must therefore conclude that factors other than the rate of sedimentation have affected the relative

Text-fig. 7.1 <u>Graphs illustrating the relative abundance of microplankton occurring in the Warboys and Warlingham boreholes</u>



FORMATION
STAGE
ZONE
SUB ZONE
PERCENTAGE RELATIVE ABUNDANCE OF MICROPLANKTON
0 10 20 30 40 50 60 70 80 90 100
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OX-FORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
cordatum
mariae
lamberti
athleta
coronatum
jason
calloviense
macro-cephalus
vertibrale
cordatum
corsti-cardia
bulowskii
pree-cordatum
scarburg-hense
u
m
l
gross-ouvrei
obductum
(jason)
(medea)
enodatum
calloviense
(koenigi)
(kamptus)
WARBOYS
WARLINGHAM

frequencies of microplankton.

Williams and Sarjeant (1967, p410) have noted that "there is an overall increase in absolute frequencies of dinoflagellate cysts with distance from shoreline". If this is the case then we may infer from the data in fig.7.1 that at Warboys there was a greater fluctuation in oceanity during Lower and Middle Callovian times, becoming more stable in the Upper Callovian and Lower Oxfordian. At Warlingham however, the greatest fluctuation in oceanity appears to have been in the Upper Callovian and again in the uppermost Lower Oxfordian. The most uniform conditions at both localities appears to have been during the Lower Oxfordian where more near-shore conditions seem to have prevailed. It is worth noting that numbers of spores and pollen are particularly high in the Lower Oxfordian at Warlingham, (compared with frequencies of microplankton), a feature which is also indicative of near-shore conditions.

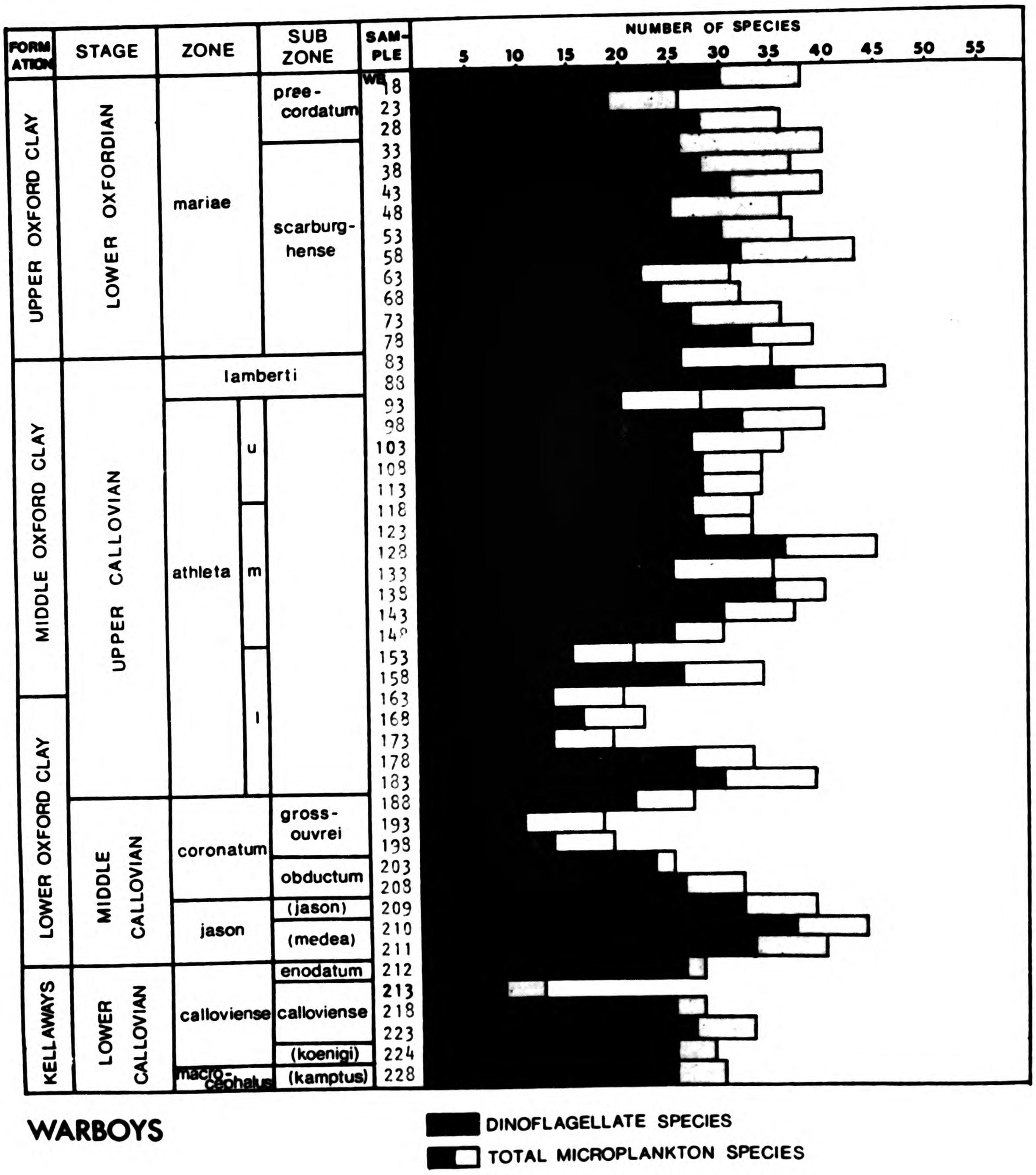
2. Species Diversity

The term 'species diversity' can be taken to mean a number of things and therefore requires definition. Here the term is used in a simple sense to express the number of species present in any one sample. We have already noted that quantitative studies of fossil microplankton have inherent difficulties due to the nature of occurrence and methods of extraction. It terms of absolute species diversity it must be recognised that a complete representation of all species present in any one assemblage can never be obtained. However, statistical methods have been used to determine the optimum number of specimens required in order to obtain as good-a-representation of species diversity as possible. In this study 200 specimens were found to be the minimum number of individuals required for such a representation (see chapter 3, section D and fig.3.6).

Figs 7.2 and 7.3 illustrate the total number of species per sample (species diversity) for Warboys and Warlingham respectively. Fig.7.4 displays the same data (total microplankton) with frequencies from both boreholes plotted together for ease of comparison (fig.7.5 is species diversity for dinoflagellates only). From an initial observation of these graphs a fairly high degree of similarity will be apparent in terms of general trend. However, as with the relative abundancies (fig.7.1), the total number of species per sample is higher at Warlingham than at Warboys in the Upper Callovian and Lower Oxfordian, whilst being similar in both Lower and Middle Callovian. It is likely that the same environmental parameters are affecting the distribution in both cases.

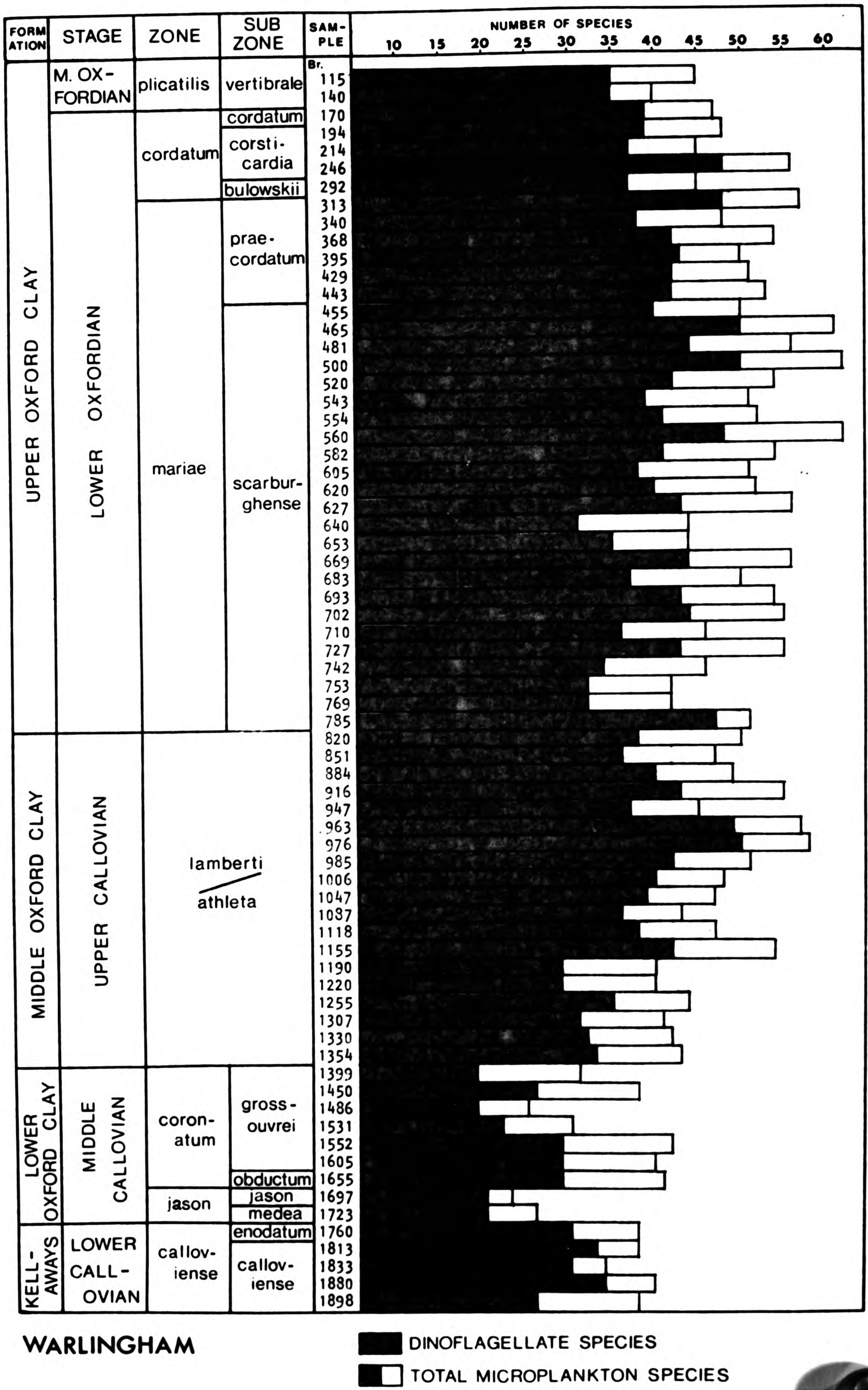
Ther overall trend for both boreholes is a distinctive increase

Text-fig. 7.2 Histogram illustrating species diversity for the Warboys borehole

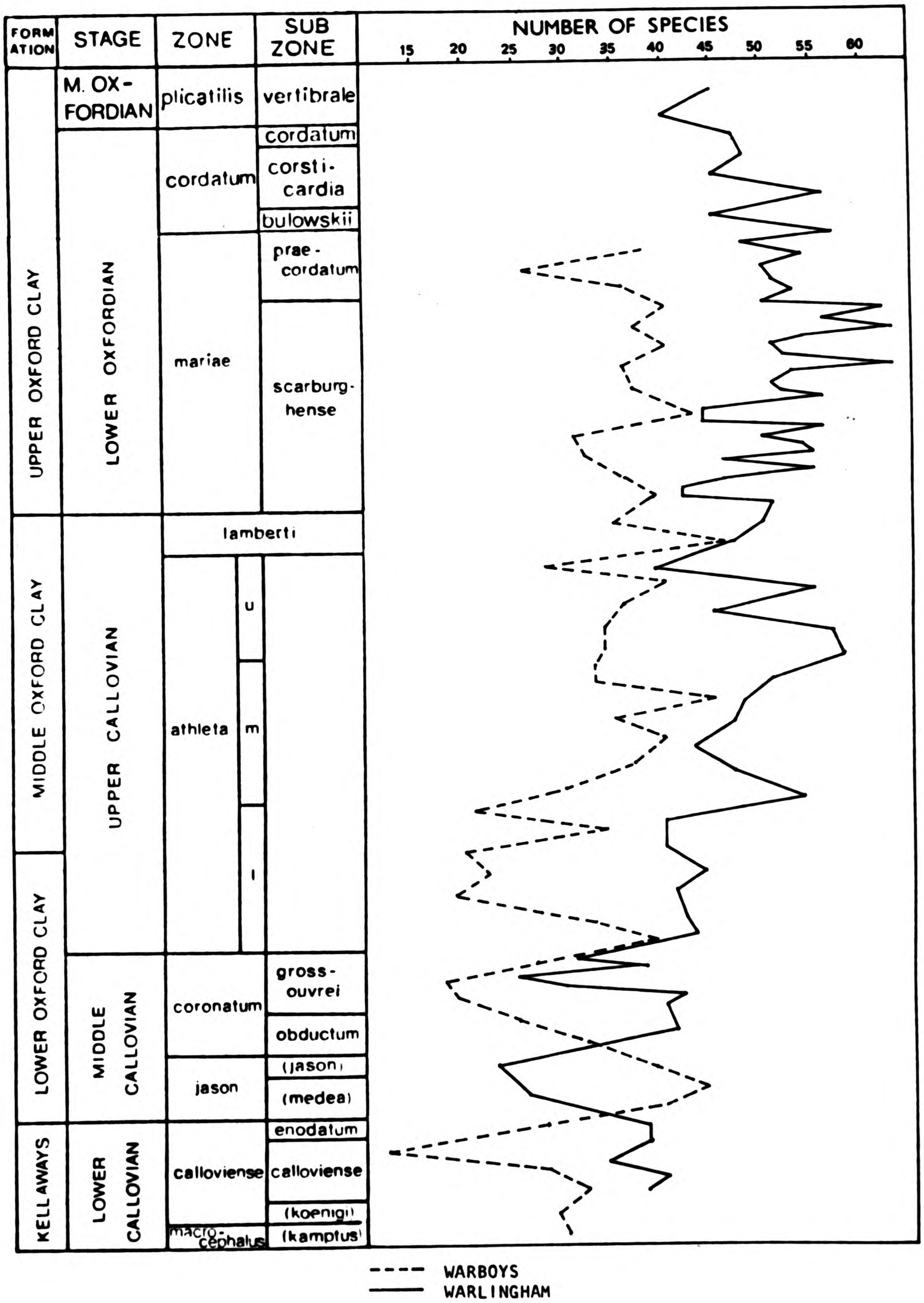

FORMATION
STAGE
ZONE
SUB ZONE
SAMPLE
NUMBER OF SPECIES
5 10 15 20 25 30 35 40 45 50 55
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
mariae
lamberti
athleta
coronatum
jason
calloviense
macrocephalus
pree-cordatum
scarburg-hense
u
m
l
gross-ouvrei
obductum
(jason)
(medea)
enodatum
calloviense
(koenigi)
(kamptus)
WB 18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
98
103
108
113
118
123
128
133
138
143
148
153
158
163
168
173
178
183
188
193
198
203
208
209
210
211
212
213
218
223
224
228
DINOFLAGELLATE SPECIES
TOTAL MICROPLANKTON SPECIES

WARBOYS

Text-fig. 7.3 Histogram illustrating species diversity for the Warlingham borehole

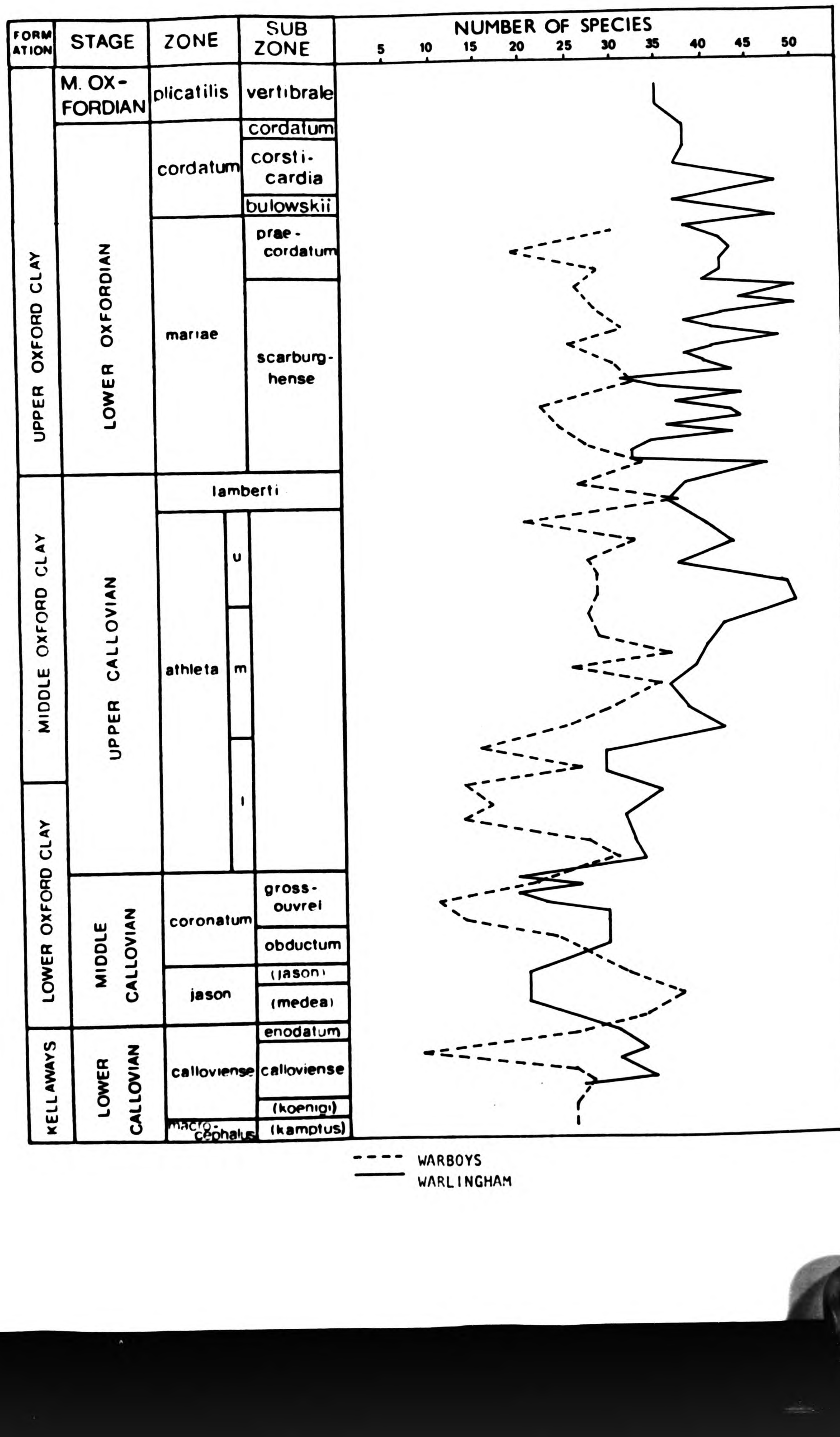

FORMATION
STAGE
ZONE
SUB ZONE
SAMPLE
NUMBER OF SPECIES
10 15 20 25 30 35 40 45 50 55 60
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OXFORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
cordatum
mariae
lamberti / athleta
coronatum
jason
calloviense
vertibrale
cordatum
corsticardia
bulowskii
praecordatum
scarburghense
grossouvrei
obductum
jason
medea
enodatum
calloviense
Br.
115 140 170 194 214 246 292 313 340 368 395 429 443 455 465 481 500 520 543 554 560 582 605 620 627 640 653 669 683 693 702 710 727 742 753 769 785 820 851 884 916 947 963 976 985 1006 1047 1087 1118 1155 1190 1220 1255 1307 1330 1354 1399 1450 1486 1531 1552 1605 1655 1697 1723 1760 1813 1833 1880 1898
WARLINGHAM
DINOFLAGELLATE SPECIES
TOTAL MICROPLANKTON SPECIES

Text-fig. 7.4 Graphs illustrating species diversity for the Warboys and Warlingham boreholes (total microplankton)



FORMATION
STAGE
ZONE
SUB ZONE
NUMBER OF SPECIES
15 20 25 30 35 40 45 50 55 60
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OX-FORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
cordatum
mariae
lamberti
athleta
coronatum
jason
calloviense
macro-cephalus
vertibrale
cordatum
corsti-cardia
bulowskii
prae-cordatum
scarburg-hense
u
m
l
gross-ouvrei
obductum
(jason)
(medea)
enodatum
calloviense
(koenigi)
(kamptus)
WARBOYS
WARLINGHAM

Text-fig. 7.5 Graphs illustrating species diversity for the Warboys and Warlingham boreholes (Dinoflagellates only)



FORMATION
STAGE
ZONE
SUB ZONE
NUMBER OF SPECIES
5 10 15 20 25 30 35 40 45 50
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OX-FORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
cordatum
mariae
lamberti
athleta
coronatum
jason
calloviense
macro-cephalus
vertibrale
cordatum
corsti-cardia
bulowskii
prae-cordatum
scarburg-hense
u
m
l
gross-ouvrei
obductum
(jason)
(medea)
enodatum
calloviense
(koenigi)
(kamptus)
WARBOYS
WARLINGHAM

in species diversity with time, possibly reflecting a development of more stable palaeoenvironmental conditions, thus favouring diversity. This could however reflect a more general evolutionary trend in terms of appearance of new species with time. If the increase in species diversity were due to environmental parameters one would expect this trend to be indicative of deeper water, more open-marine conditions. We have already noted that relatively high numbers of spores and pollen (in proportion to microplankton) are present in the Lower Oxfordian of Warlingham (and to a lesser extent at Warboys), and that this is normally taken to indicate near-shore conditions in terms of oceanity. It seems reasonable therefore to conclude that the overall increase in species diversity probably reflects evolutionary development.

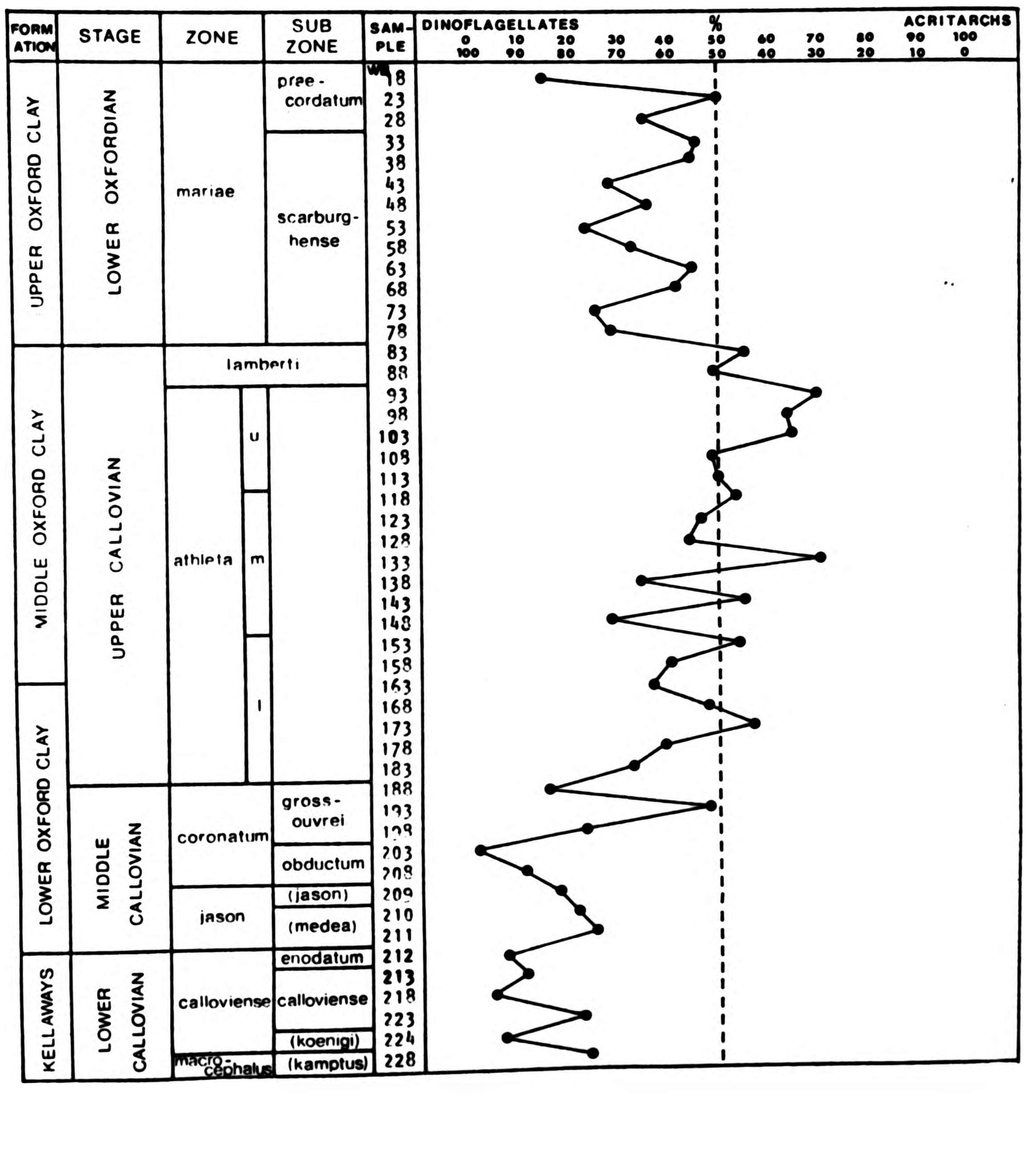
It is difficult to determine the factors which cause fluctuation in species diversity. The very marked fluctuations in the Middle and lowermost Upper Callovian are quite likely due to the presence of bitümen, a feature characteristic of the Lower Oxford Clay. Bitumen tends to have a 'clumping' effect on preparations and specimens are easily obscured. Attempts to remove bitumen from the preparations using Schulze's solution and ultrasonic techniques may well destroy the more delicate species (see chapter 3).

3. Dinoflagellate:Acritarch Ratios

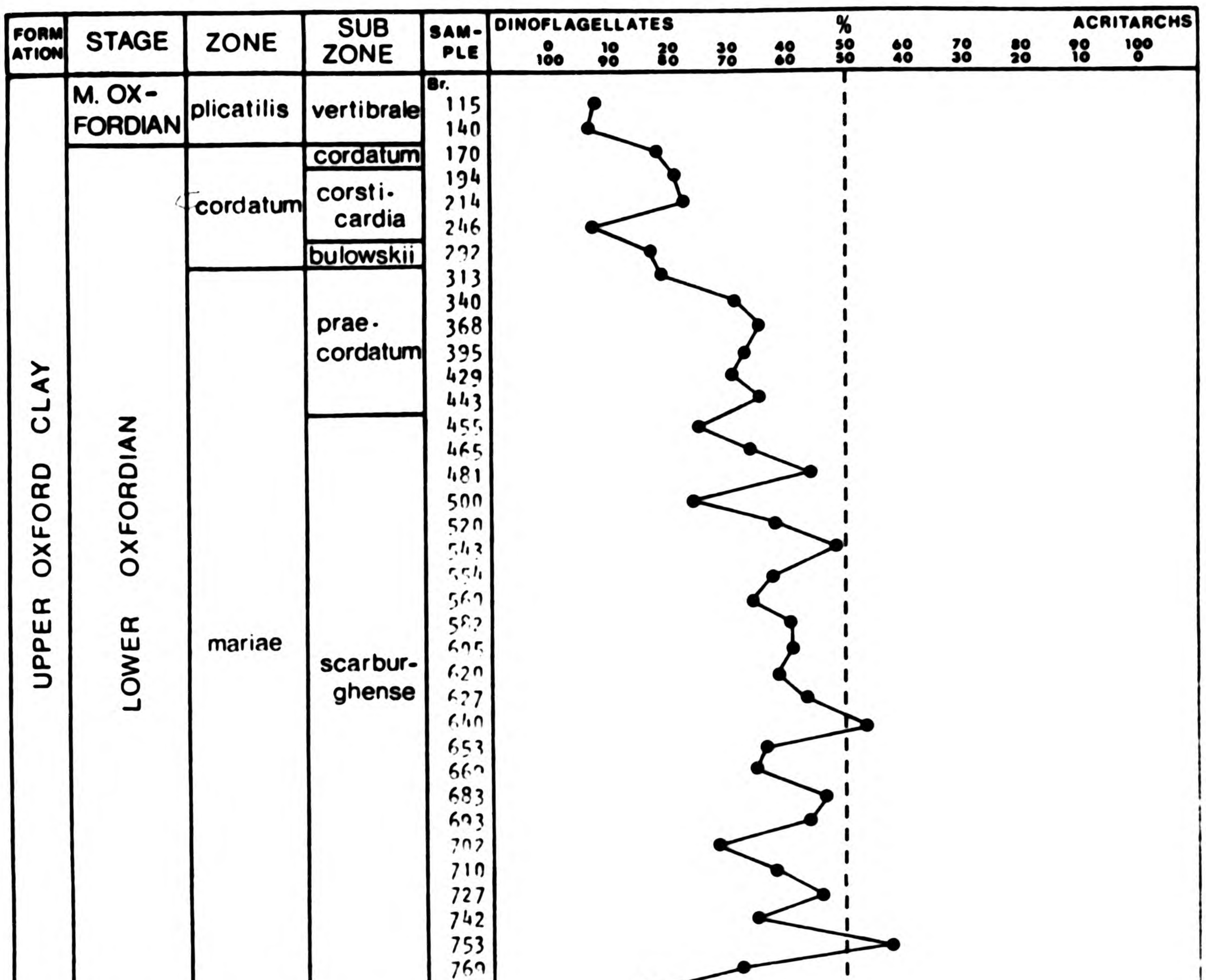
It has been known for a considerable time that miospore: microplankton ratios are environmentally contorlled (Williams and Sarjeant, 1967); the relative proportions of microplankton to miospores being a direct result of the distance of a locality from a major land mass (='oceanity'). The nearer a locality is to a land mass the higher the proportion of miospores will be in an assemblage, and vice versa (Sarjeant, 1974a). Little, if anything, is known of the environmental factors governing the ratios of dinoflagellates to acritarchs in fossil assemblages, and whether or not such ratios are useful in determining oceanity. Unfortunately time has not permited study of the miospore content of the material here. However the relative proportions of dinoflagellates to acritarchs have been calculated and the resulting data represented graphically in figs.7.6 to 7.8.

Whilst it would be impossible to deduce any conclusive evidence concerning palaeoenvironmental conditions from this data, it is interesting to make comparisons of the two graphs and tentative inferences. As with comparison of relative abundancies (fig.7.1) and species diversity (figs.7.2 to 7.5), the graphs for dinoflagellate:acritarch ratios show

Text-fig. 7.6 Dinoflagellate:acritarch ratios in the Warboys borehole

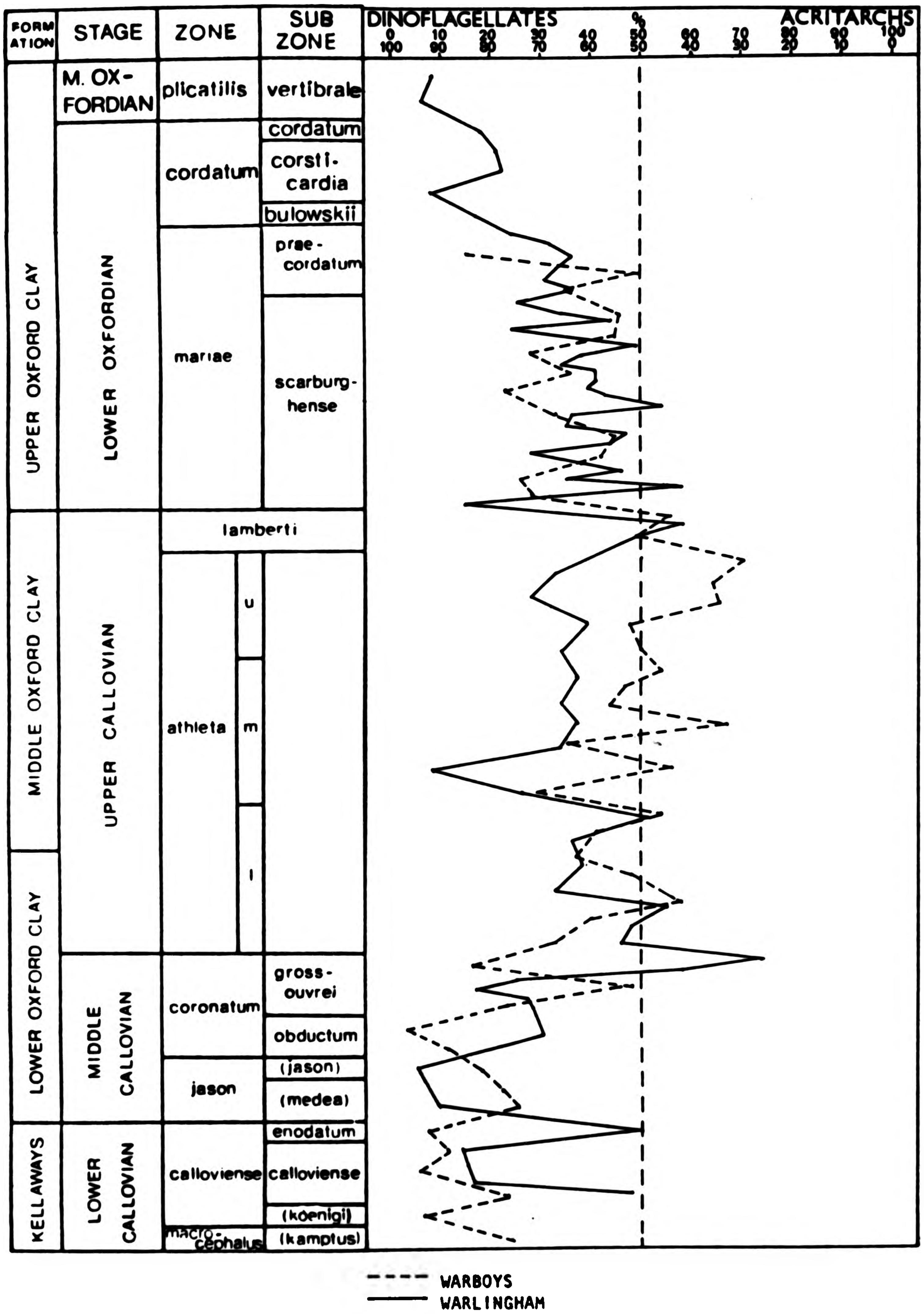

FORMATION
STAGE
ZONE
SUB ZONE
SAMPLE
DINOFLAGELLATES
%
ACRITARCHS
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
mariae
lamberti
athleta
coronatum
jason
calloviense
macrocephalus
praecordatum
scarburghense
u
m
l
grossouvrei
obductum
(jason)
(medea)
enodatum
calloviense
(koenigi)
(kamptus)
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
98
103
108
113
118
123
128
133
138
143
148
153
158
163
168
173
178
183
188
193
198
203
208
209
210
211
212
213
218
223
224
228

Text-fig. 7.7 <u>Dinoflagellate:acritarch ratios in the Warlingham borehole</u>

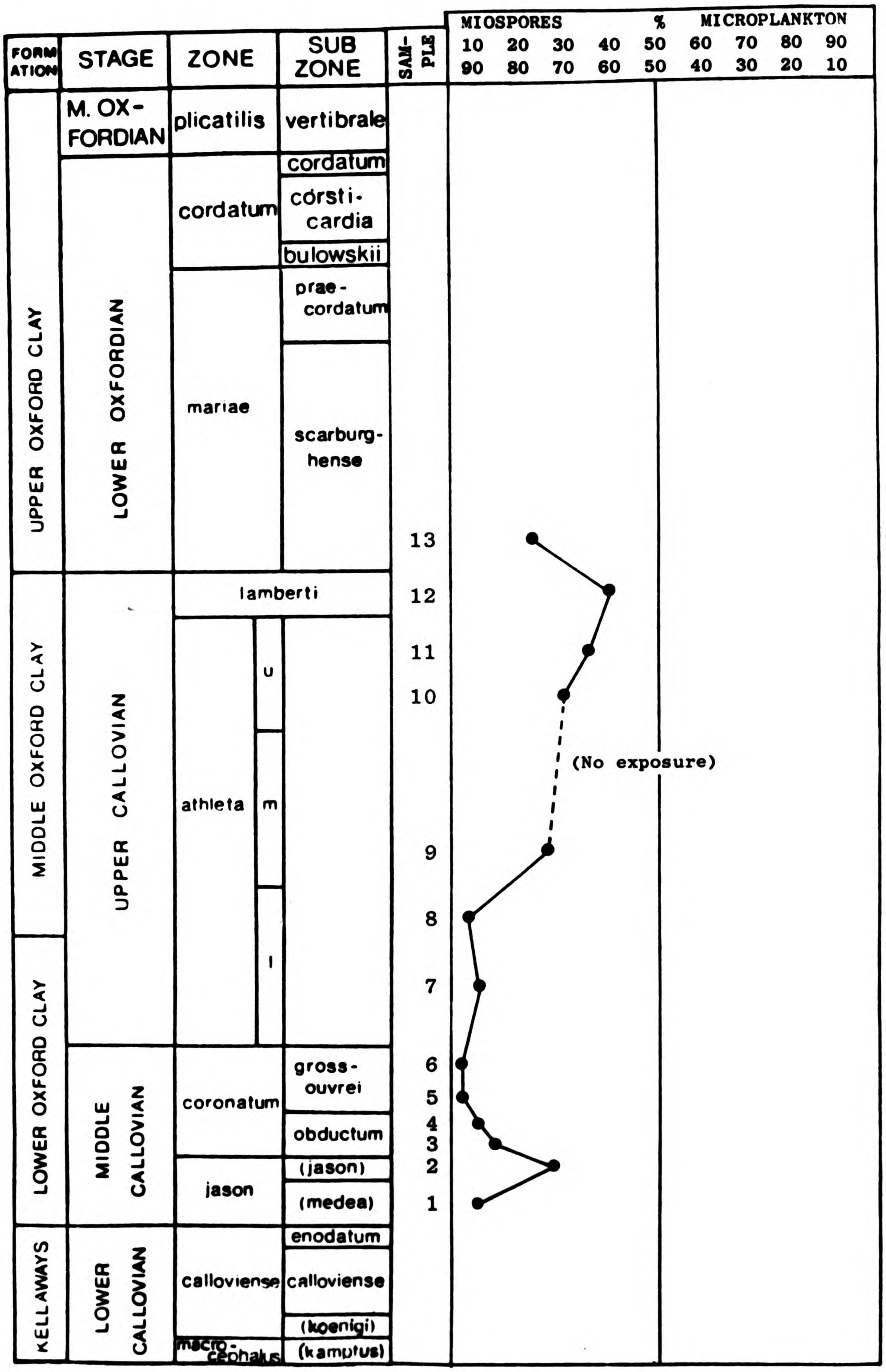


FORMATION
STAGE
ZONE
SUB ZONE
SAMPLE
DINOFLAGELLATES
%
ACRITARCHS
0 100
10 90
20 80
30 70
40 60
50 50
60 40
70 30
80 20
90 10
100 0
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OXFORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
cordatum
mariae
lamberti
athleta
coronatum
jason
calloviense
vertibrale
cordatum
corsticardia
bulowskii
praecordatum
scarburghense
grossouvrei
obductum
jason
medea
enodatum
calloviense
Br.
115
140
170
194
214
246
313
340
368
395
429
443
465
481
653
683
710
727
742
753
785
1155
1307
1531
1813
1833

Text-fig. 7.8 Dinoflagellate:acritarch ratios in the Warboys and Warlingham boreholes


FORMATION
STAGE
ZONE
SUB ZONE
DINOFLAGELLATES
%
ACRITARCHS
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OX-FORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
cordatum
mariae
lamberti
athleta
coronatum
jason
calloviense
macro-cephalus
vertibrale
cordatum
corsti-cardia
bulowskii
prae-cordatum
scarburg-hense
u
m
l
gross-ouvrei
obductum
(jason)
(medea)
enodatum
calloviense
(koenigi)
(kamptus)
WARBOYS
WARLINGHAM

Text-fig. 7.9 <u>Relative frequencies of microplankton to miospores in samples from the Oxford Clay of the East Midlands (after Woollam, 1977)</u>



FORMATION
STAGE
ZONE
SUB ZONE
SAMPLE
MIOSPORES % MICROPLANKTON
10 20 30 40 50 60 70 80 90
90 80 70 60 50 40 30 20 10
UPPER OXFORD CLAY
MIDDLE OXFORD CLAY
LOWER OXFORD CLAY
KELLAWAYS
M. OXFORDIAN
LOWER OXFORDIAN
UPPER CALLOVIAN
MIDDLE CALLOVIAN
LOWER CALLOVIAN
plicatilis
cordatum
mariae
lamberti
athleta
coronatum
jason
calloviense
macrocephalus
vertibrale
cordatum
corsticardia
bulowskii
praecordatum
scarburghense
u
m
l
grossouvrei
obductum
(jason)
(medea)
enodatum
calloviense
(koenigi)
(kamptus)
13
12
11
10
9
8
7
6
5
4
3
2
1
(No exposure)

a similar trend. In both boreholes, Lower and Middle Callovian, and Lower Oxfordian samples contain a higher percentage of dinoflagellates than acritarchs, whilst there is a noticeable increase in the ratios of acritarchs to dinoflagellates in the Upper Callovian, especially so in Warboys (fig.7.8).

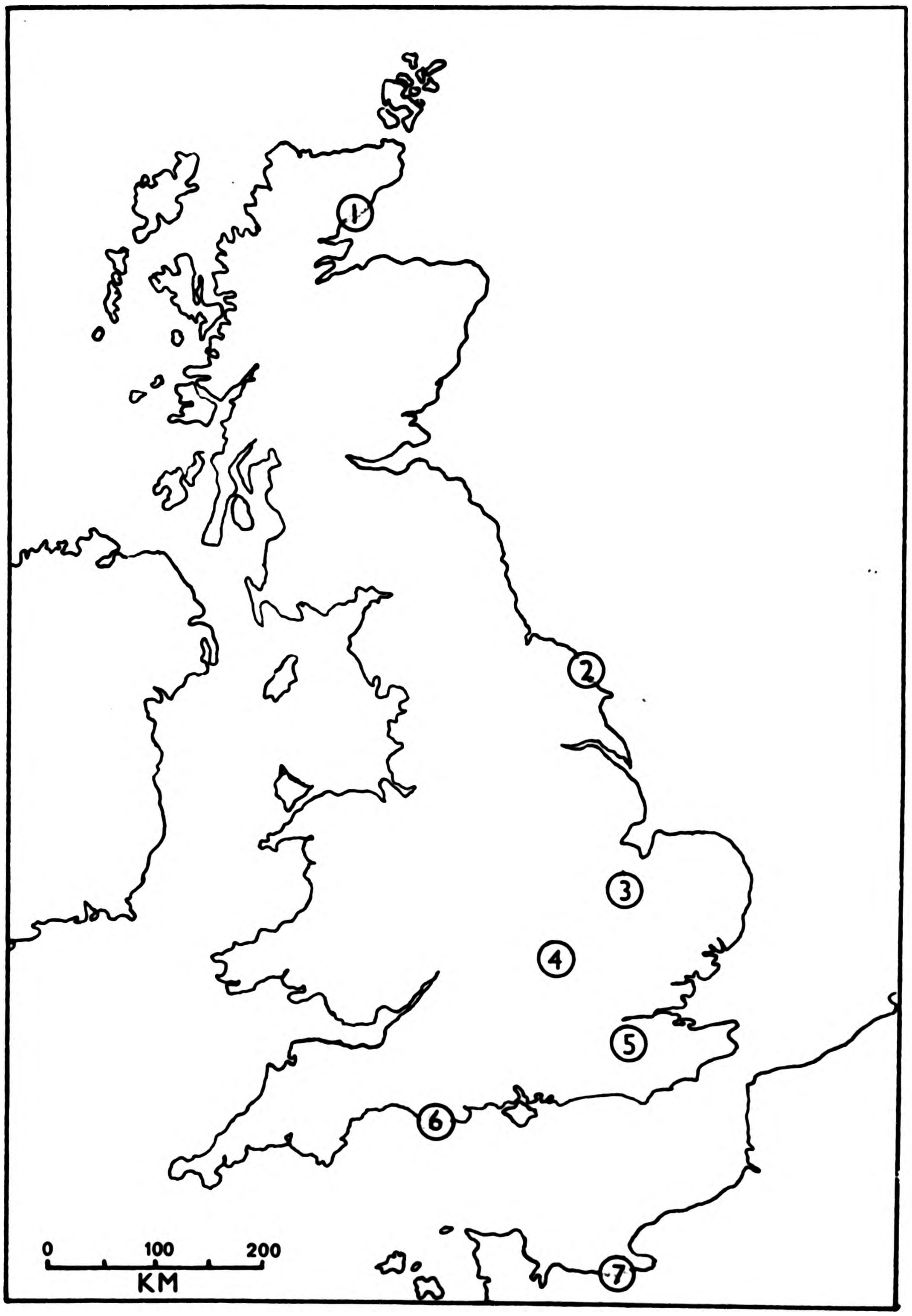
Fig.7.9 illustrates the relative frequencies of microplankton to miospores in Middle Callovian to Lower Oxfordian samples from the Oxford Clay of the East Midlands (after Woollam, 1977). It is interesting to compare the trend shown here with the dinoflagellate:acritarch ratios in fig.7.8 where the similarity is quite striking. In fig.7.9 the higher proportions of miospores in the upper coronatum and lower athleta zones tend to correspond, broadly speaking, with higher proportions of acritarchs at the same level at Warlingham (fig.7.7) and similarly (although to a lesser extent)at Warboys (fig.7.6). The gradual increase in the proportion of microplankton to miospores in fig.7.9 is similarly reflected in the steady increase in the proportion of dinoflagellates to acritarchs at Warlingham (fig.7.7), throughout the Upper Callovian and into the Lower Oxfordian.

From these comparisons we may tentatively conclude that palaeoenvironmental conditions were, in all probability, similar in each of the three localities during Middle and lowermost Upper Callovian times, continuing to be comparable between Warlingham and the East Midlands until at least early Oxfordian times. From our discussions concerning the relative abundance of microplankton and the presence of high numbers of miospores in the Lower Oxfordian of Warlingham, we have already noted that there may have been fluctuations in oceanity during Lower and Middle Callovian times with a gradual deepening of the marine environment during the Upper Callovian, becoming shallower for the Lower Oxfordian. This development seems to have been similar in the East Midlands during this time (fig.7.9). From these comparisons it appears that dinoflagellate: acritarch ratios may also be affected by oceanity; an increase in the proportion of acritarchs corresponding to more open-marine conditions, and vice-versa.

C. FLORAL SIMILARITIES AND REGIONAL CONSIDERATIONS

Having compared microplankton associations at Warboys and Warlingham (and to a certain extent with the East Midlands), an attempt has been made to compare data obtained here with similar data from other parts Great Britain and North West France (fig.7.10). Data from Warboys

Text-fig. 7.10 Localities used for comparison of microplankton assemblages in plotting coefficients of similarity



1	North-East Scotland	-	Lam & Porter, 1977
2	Yorkshire	-	Sarjeant, 1960b; 1961a
3	Warboys	-	Herein
4	East Midlands	-	Woollam, 1977
5	Warlingham	-	Herein
6	Dorset	-	Sarjeant, 1962b
7	Normandy	-	Sarjeant, 1965; 1968

and Warlingham has been compared with published data from the Callovian and Oxfordian of North-East Scotland (Lam and Porter, 1977), Yorkshire (Sarjeant, 1960b, 1961a), East Midlands (Woollam, 1977), Dorset (Sarjeant, 1962b) and Normandy (Sarjeant, 1965, 1968). Each locality was compared with every other locality for the five intervals - Lower, Middle and Upper Callovian, Lower and Middle Oxfordian, and a simple coefficient of similarity computed for each comparison using the formula:

$$\frac{b}{a_1 + a_2 - b} \% = c$$

where a_1 and a_2 are the total number of species in each of the two localities being compared; b is the number of species common to both localities and c is the percentage-similarity between them. Essentially the technique used is the Jaccard Similarity Coefficient expressed as a percentage. The raw data is illustrated in figs.7.11 a-e; the computed data illustrated diagramatically in figs.7.12 a-e and graphically in fig. 7.13.

In an ideal situation this simple method of chronostratigraphic correlation would prove very useful indeed. Christensen and Kilenyi (1970) have successfully used this technique for correlation of the Northern and Western European Kimmeridgian deposits using ostracod assemblages. However, use of the technique in this study highlights some of the problems encountered in attempting to establish a coherent picture of palaeo-environmental conditions from a variety of different sources. Two such problems are outlined briefly as follows:

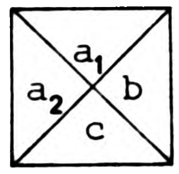
(i) Problems of sampling

It is clear that a uniform method of sampling is highly desireable, and in particular the interval at which stratigraphic sequences are sampled. For example, Sarjeant (1961a) describes Lower Callovian (calloviense zone) to Lower Oxfordian (mariae zone) microplankton assemblages from only four samples! He similarly describes assemblages representing the same time interval using five samples from Normandy (Sarjeant, 1965, 1968). Lam and Porter (1977) and Woollam (1977) each use thirteen samples to describe Callovian/Oxfordian assemblages from North-East Scotland and the East Midlands respectively. By way of contrast, Lower Callovian to Lower Oxfordian microplankton assemblages described here are from forty-eight and seventy samples from Warboys and Warlingham respectively. It will obviously follow that the closer the sample-interval, the more representative will be the assemblages and consequently a more accurate picture obtained. This is highlighted by the close similarity displayed between localities 3,4 and 5 in figs.7.12 a-d.

Text-figs. 7.11 a-e <u>Data tables for coefficient of similarity plots illustrated in figs. 7.12 a-e</u>

Legend to figs. 7.11 a-e

Key:



a - Total Number of Species

b - Number of species common to both localities in a

c - % Similarity $\frac{b}{a_1 + a_2 - b}$ % = c

North-East Scotland	-	Lam & Porter, 1977
Yorkshire	-	Sarjeant, 1960b; 1961a
Warboys	-	Herein
East Midlands	-	Woollam, 1977
Warlingham	-	Herein
Dorset	-	Sarjeant, 1962b
Normandy	-	Sarjeant, 1965; 1968

Fig. 7.11a

LOWER CALLOVIAN

(jason / calloviense)

	NORTH-EAST SCOTLAND	YORKSHIRE	WARBOYS	EAST MIDLANDS	WARLINGHAM	DORSET
YORKSHIRE	11 / 10 / 4 / 23.5					
WARBOYS	11 / 53 / 8 / 14.3	10 / 53 / 6 / 10.5				
EAST MIDLANDS	11 / 24 / 6 / 20.7	10 / 24 / 3 / 9.7	53 / 24 / 11 / 16.7			
WARLINGHAM	11 / 71 / 9 / 12.3	10 / 71 / 6 / 8.0	53 / 71 / 47 / 61.0	24 / 71 / 15 / 18.8		
DORSET	11 / 0 / 0 / 0	10 / 0 / 0 / 0	53 / 0 / 0 / 0	24 / 0 / 0 / 0	71 / 0 / 0 / 0	
NORMANDY	11 / 30 / 4 / 10.8	10 / 30 / 6 / 17.7	53 / 30 / 12 / 19.7	24 / 30 / 7 / 14.9	71 / 30 / 12 / 13.5	0 / 30 / 0 / 0

Fig. 7.11b

MIDDLE CALLOVIAN

(coronatum)

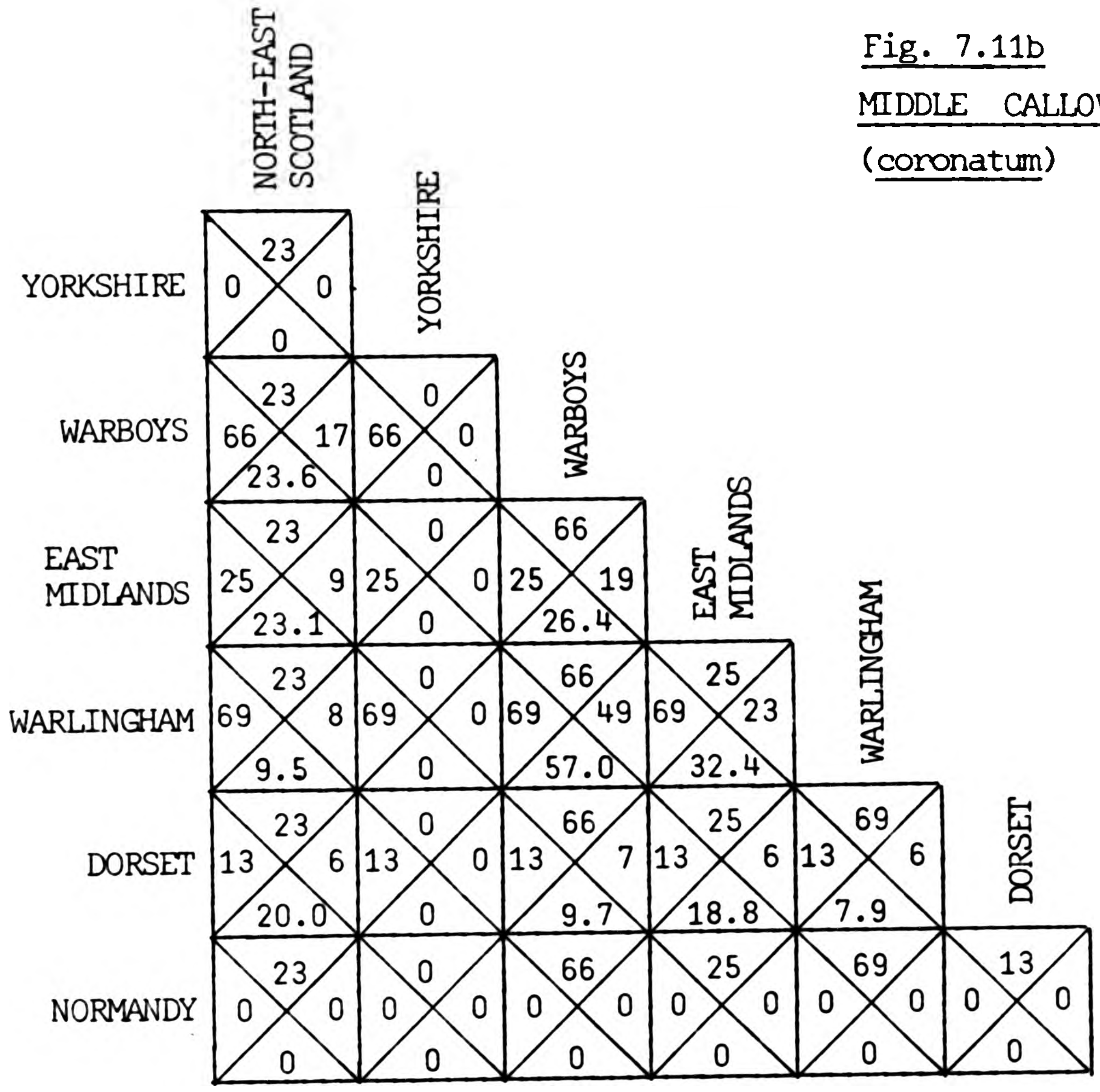


Fig. 7.11c

UPPER CALLOVIAN

(athleta / lamberti)

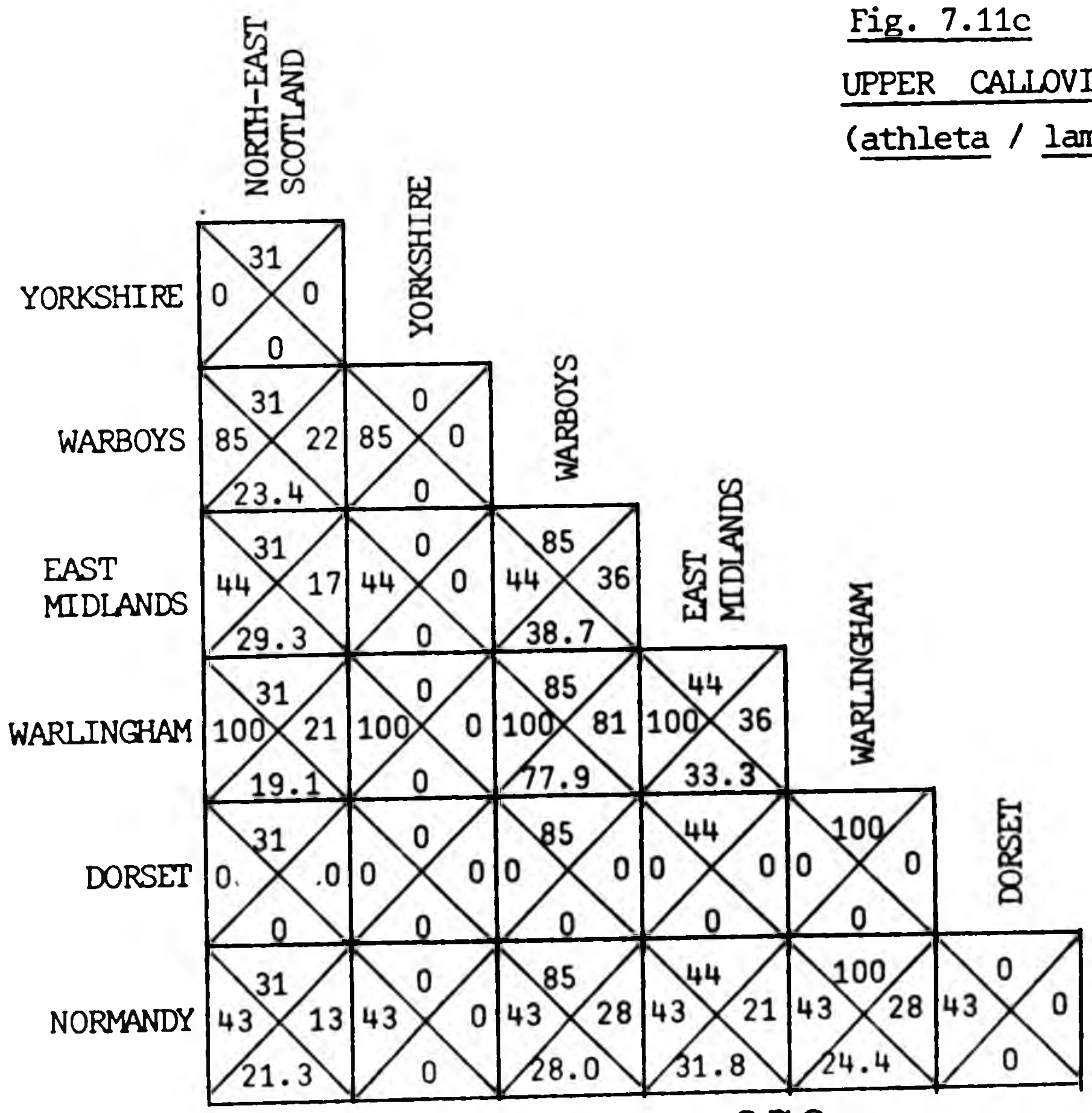


Fig. 7.11d
LOWER OXFORDIAN
(*mariae* / *cordatum*)

	NORTH-EAST SCOTLAND	YORKSHIRE	WARBOYS	EAST MIDLANDS	WARLINGHAM	DORSET
YORKSHIRE	0 34 0 0					
WARBOYS	0 72 0 0	34 72 19 21.8				
EAST MIDLANDS	0 35 0 0	34 35 12 21.1	72 35 30 39.0			
WARLINGHAM	0 126 0 0	34 126 20 14.3	72 126 70 54.7	35 126 32 24.8		
DORSET	0 18 0 0	34 18 11 26.8	72 18 12 15.4	35 18 10 23.3	126 18 13 9.9	
NORMANDY	0 43 0 0	34 43 11 16.7	72 43 27 30.7	35 43 19 32.2	126 43 29 20.7	18 43 14 29.8

Fig.7.11e
MIDDLE OXFORDIAN
(*plicatilis*)

	NORTH-EAST SCOTLAND	YORKSHIRE	WARBOYS	EAST MIDLANDS	WARLINGHAM	DORSET
YORKSHIRE	20 12 5 18.5					
WARBOYS	20 0 0 0	12 0 0 0				
EAST MIDLANDS	20 0 0 0	12 0 0 0	0 0 0 0			
WARLINGHAM	20 55 14 23.0	12 55 7 11.7	0 55 0 0	0 55 0 0		
DORSET	20 14 7 25.9	12 14 5 23.8	0 14 0 0	0 14 0 0	55 14 10 17.0	
NORMANDY	20 0 0 0	12 0 0 0	0 0 0 0	0 0 0 0	55 0 0 0	14 0 0 0

(ii) Species identification

It is equally clear that uniformity in identification of species between localities is of paramount importance. Difficulties arise here because of the constant revision of diagnoses of species and also because the list of known microplankton taxa is rapidly expanding. This problem can be overcome, to a certain extent, if research work is well-documented and species adequately described and illustrated. Unfortunately this varies between authors and comparisons are therefore not so easily made.

If such problems were able to be minimized effectively, or ideally overcome altogether, then this method of chronostratigraphic correlation between regions would be an invaluable tool for determination of palaeoenvironmental conditions, and changes affecting the regional distribution of microplankton. If employed on a larger scale, this technique may prove useful in our, as yet limited, understanding of dinoflagellate provincialism. (Norris, 1975, has given an outline of the present knowledge of dinoflagellate provincialism in the Upper Jurassic).

With reference to figs. 7.12 a-e an attempt to draw certain tentative conclusions can be made. An initial observation of these figures will reveal that the highest similarities are between localities in relatively close proximity, particularly between localities 3,4 and 5. This will not be surprising since one would expect to find a greater similarity between microplankton assemblages in a restricted geographical area. Conversely a greater variation in assemblages will naturally occur over a wider geographic area due to changes in the physical environment.

In the Lower Callovian (fig.7.12a) there is a fairly low percentage-similarity between all localities (excepting 3,4 and 5), presumably indicating a variety of palaeoenvironmental conditions throughout the realm at this time. This reflects the fluctuations in oceanity inferred from the dinoflagellate:acritarch ratios (fig.7.8) and relative abundance of microplankton (fig.7.1). By Middle Callovian times (fig.7.12b) a clearer and more uniform pattern is beginning to emerge. There is an increasing percentage-similarity in the whole area east and south-east of the Midlands (localities 3, 4 and 5), with a stronger link being established between these areas and North-East Scotland (locality 1); a feature which continues into the Upper Callovian (fig.7.12c). A link with Dorset (locality 6) is established during the Middle Callovian but is only short-lived and with relatively few species in common with other localities.

The Upper Callovian (fig.7.12c) shows the greatest percentage-

Text-figs. 7.12 a-e   Regional correlations using the simple coefficient of similarity

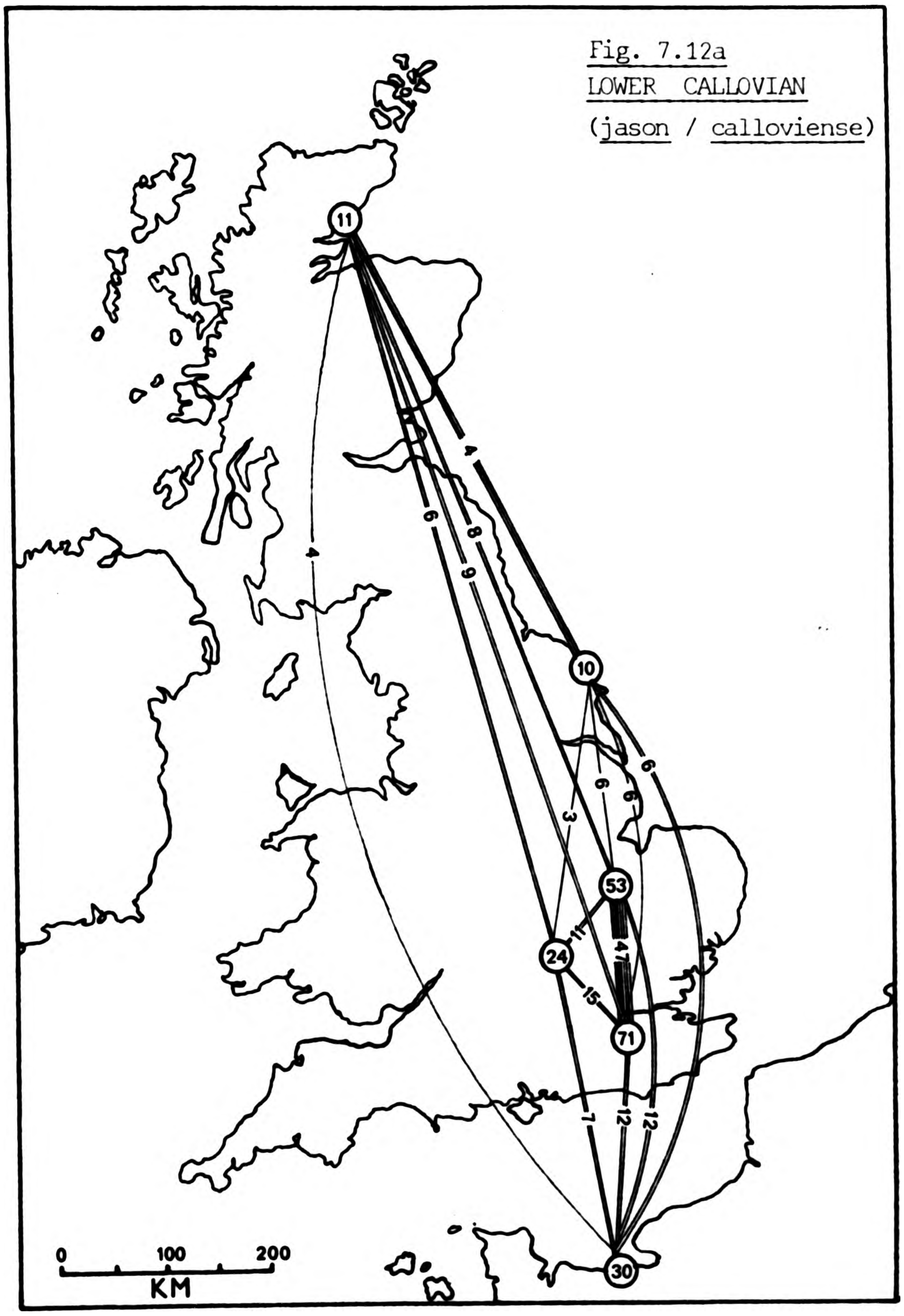


Fig. 7.12a
LOWER CALLOVIAN
(jason / calloviense)

(0) Locality, with total number of species

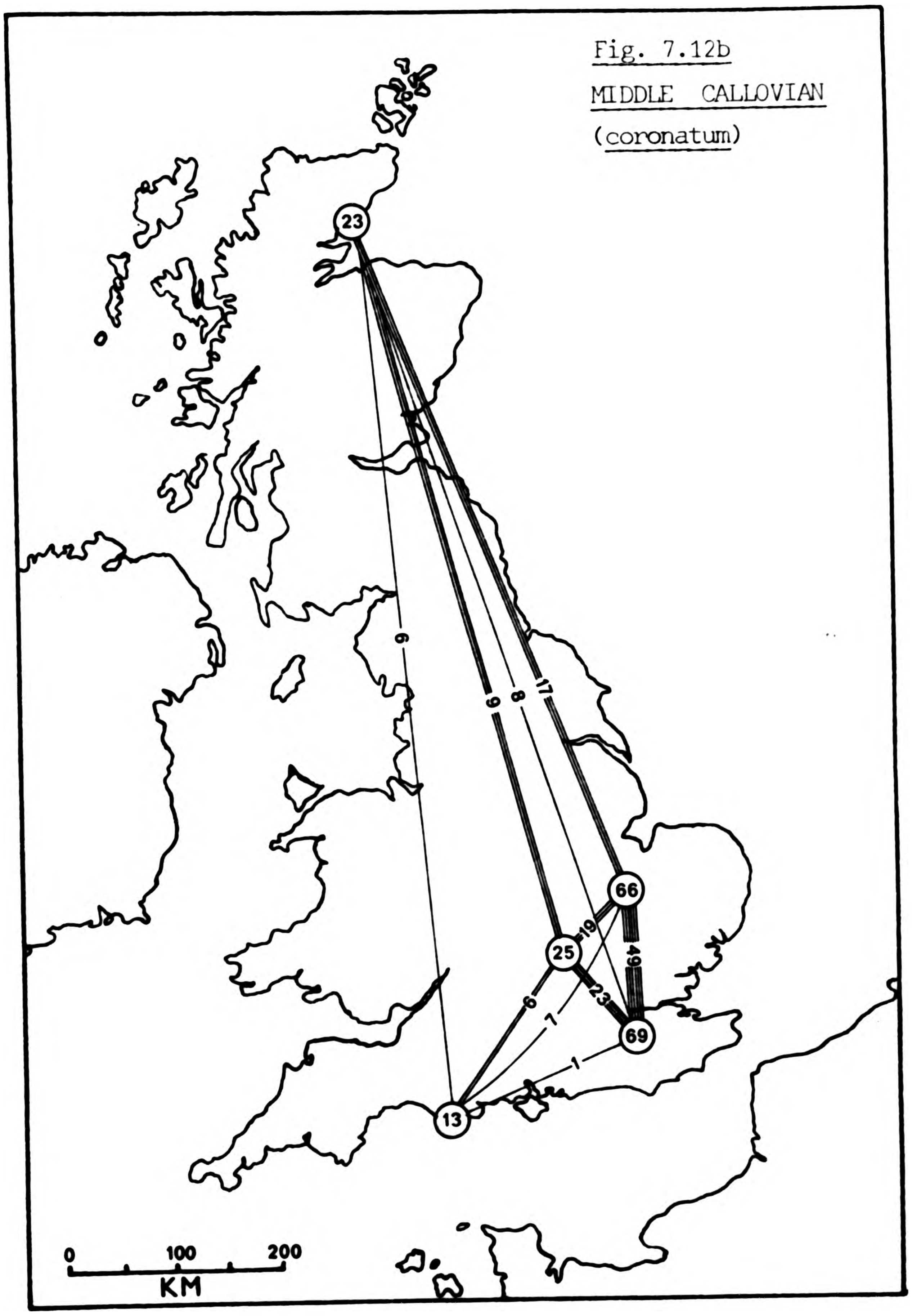
b Number of species common

1-10%
11-20%
21-30% etc.

Percentage species in common:

$$\frac{b}{a_1 + a_2 - b}\ \% = \text{percentage similarity}$$

Fig. 7.12b
MIDDLE CALLOVIAN
(coronatum)



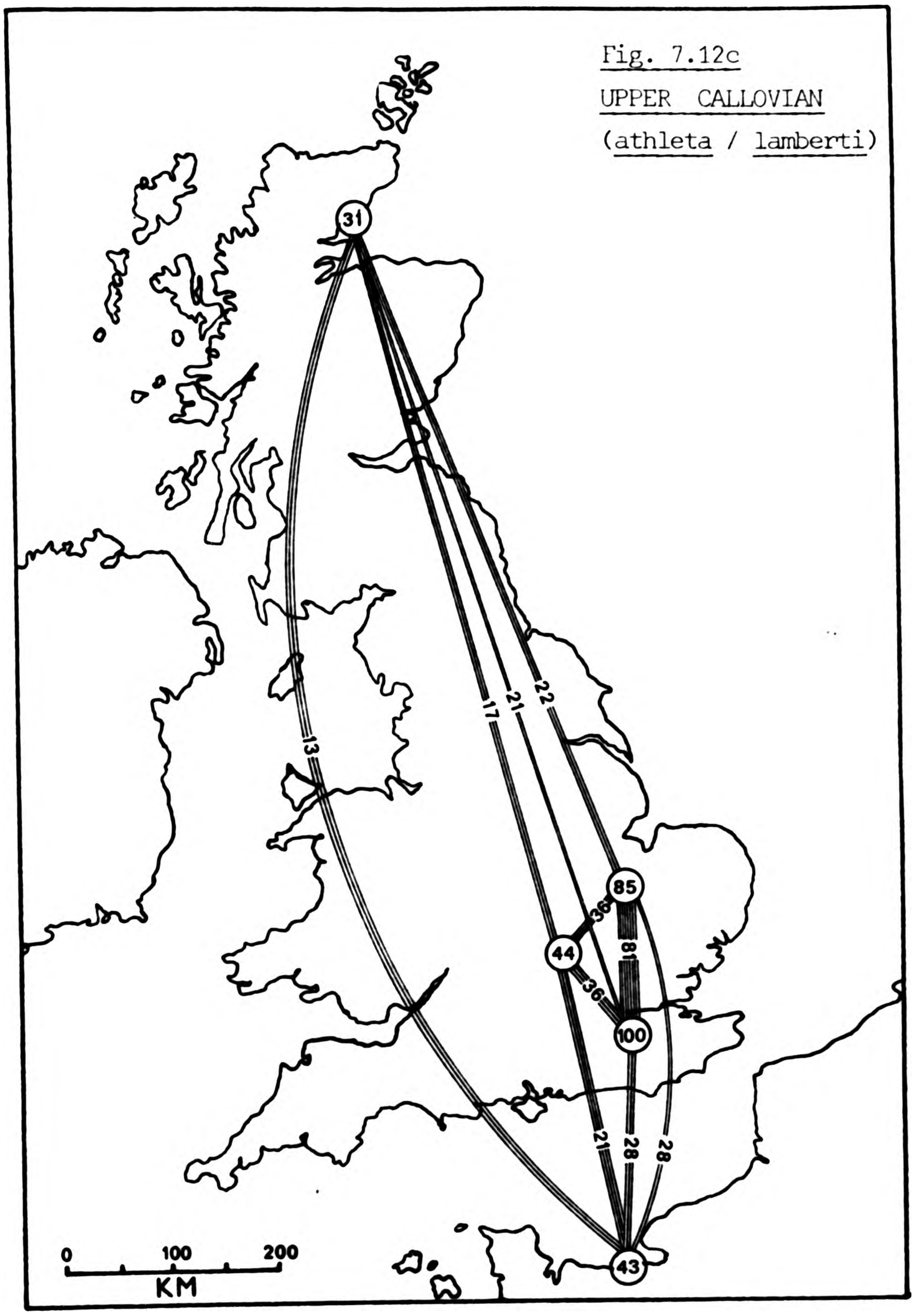
(0) Locality, with total number of species

b Number of species in common

1-10%
11-20%
21-30% etc.

Percentage species in common:

$$\frac{b}{a_1 + a_2 - b}\ \% = \text{percentage similarity}$$



Locality, with total number of species

b Number of species in common

1-10%
11-20%
21-30% etc.

Percentage species in common:

$$\frac{b}{a_1 + a_2 - b} \% = \text{percentage similarity}$$

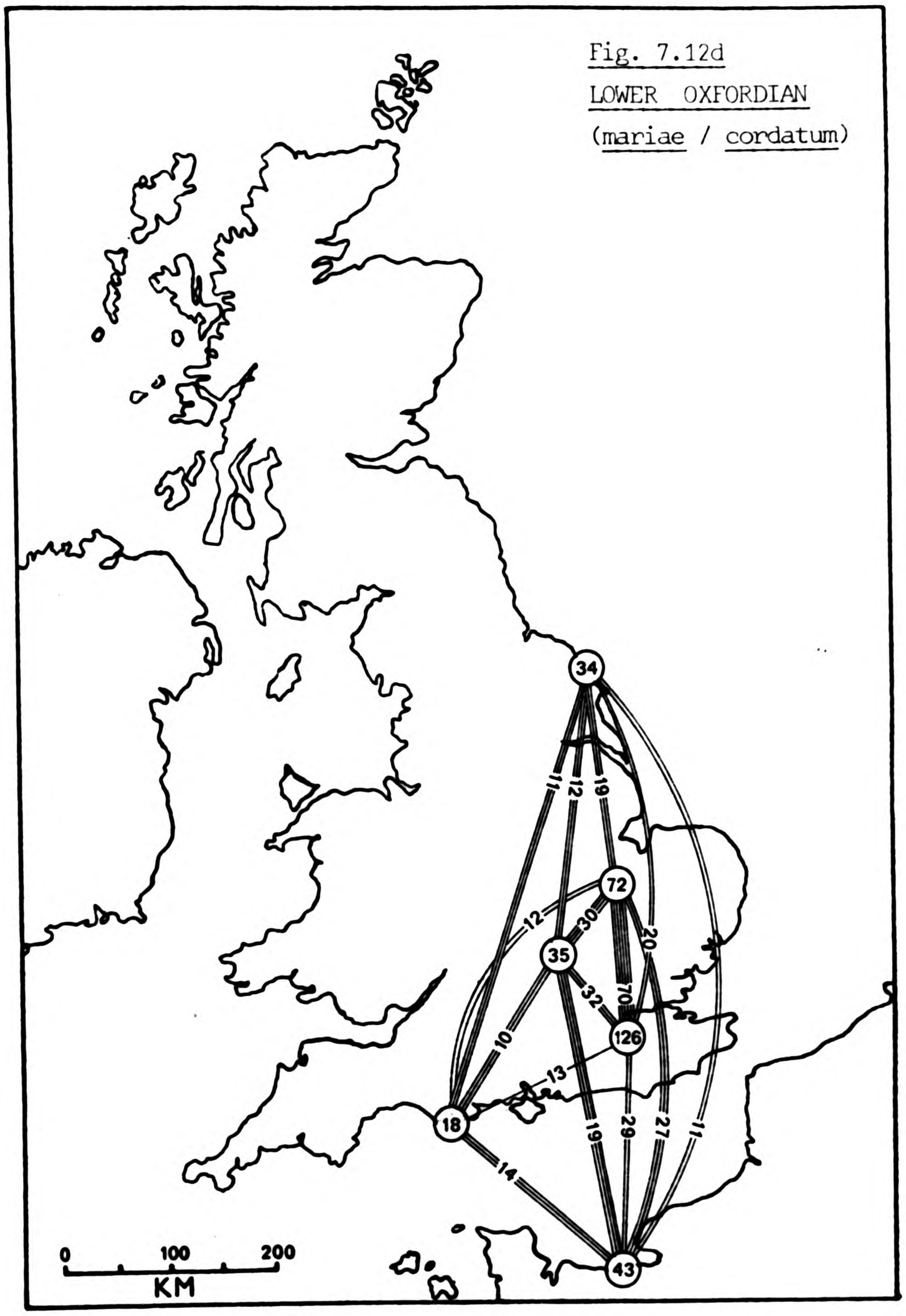


Fig. 7.12d

LOWER OXFORDIAN

(mariae / cordatum)

(0) Locality, with total number of species

b Number of species in common

1-10%

11-20%

21-30% etc.

Percentage species in common:

$$\frac{b}{a_1 + a_2 - b}\ \% = \text{percentage similarity}$$

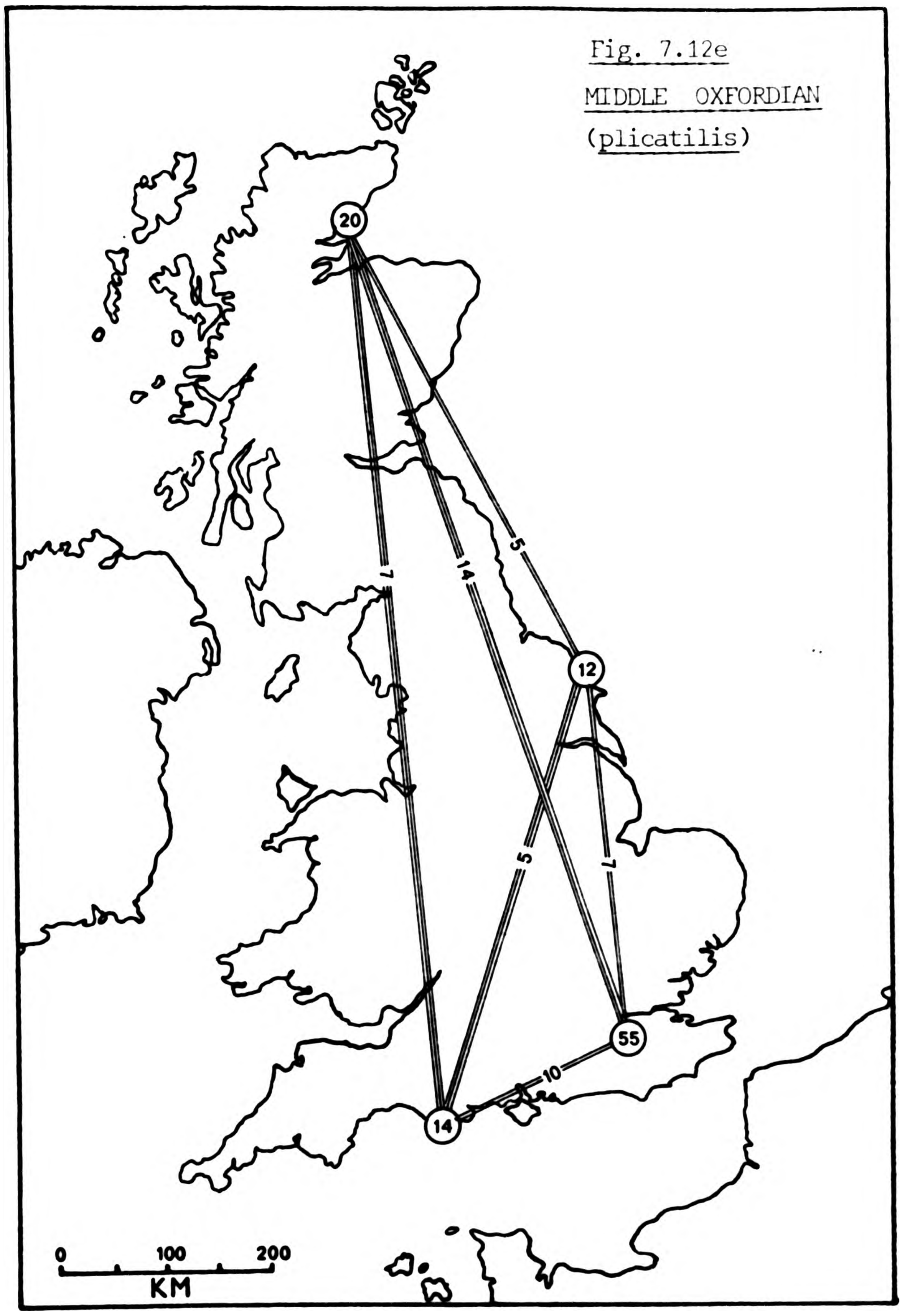


Fig. 7.12e

MIDDLE OXFORDIAN

(plicatilis)

(0) Locality, with total number of species

b Number of species in common

1-10%

11-20%

21-30% etc.

Percentage species in common:

$$\frac{b}{a_1 + a_2 - b} \% = \text{percentage similarity}$$

similarity over the widest geographic area, thus indicating the more uniform palaeoenvironmental conditions characteristic of the Middle Oxford Clay sea. This again is reflected by an increase both in the relative abundance of microplankton (fig.7.1) and the proportion of acritarchs to dinoflagellates (fig.7.8).

The picture portrayed by the similarity plots for the Lower Oxfordian (fig.7.12d) is one of uniformity of palaeoenvironmental conditions for the whole of the area east and south-east of the Midlands (localities 2,3,4,5,6 and 7). High percentage-similarities are recorded for all localities representing the cosmopolitan nature of the microplankton assemblages, possibly due to a mixing of floras by currents in the shallowing basin of deposition. (Little comment can be made for the Middle Oxfordian (fig.7.12e) because of the incomplete data available for this time interval).

D. <u>CONCLUSIONS</u>

From the various studies made of the floral assemblages it is possible to infer certain conclusions regarding the palaeoenvironmental conditions which prevailed during the deposition of the Oxford Clay in the regions studied.

The general sequence of Kellaways Rock through to the bituminous shales of the Lower Oxford Clay appear to have been deposited in fairly shallow water. This view is supported by Hallam (1967) in that bituminous shales appear to be laid down in relatively shallow water. The presence of diverse benthic fauna indicates that conditions during deposition of the Lower Oxford Clay were not as anaerobic as many authors have suggested. Hallam (ibid.) has further suggested that small changes in sea level could vary the position of the shoreline, a factor likely to have been responsible for the many small scale alternations of shallow water lithologies in the Lower Oxford Clay and depicted by small shell horizons. The marked fluctuations in dinoflagellate:acritarch ratios (fig.7.8) may well reflect this changing environment.

Work by Hudson and Palframan (1969) in the East Midlands shows that the higher beds of the Middle Oxford Clay correspond to the fossiliferous, deeper water lithologies of clays and shales deposited in more anaerobic waters (Woollam, 1977). Again the increase in proportion of acritarchs to dinoflagellates (fig.7.8) during the Upper Callovian would correspond closely with this, as would the increase in relative abundance of microplankton (fig.7.1).

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Text-fig. 7.13 Histograms illustrating percentage species-similarity between localities illustrated in fig. 7.10

Key to histograms:

Vertical axis: Percentage species similarity between two localities being compared.

A localities 1 & 2
B localities 1 & 3
C localities 1 & 4
D localities 1 & 5
E localities 1 & 7
F localities 1 & 8
G localities 2 & 3
H localities 2 & 4
I localities 2 & 5
J localities 2 & 6
K localities 2 & 7
L localities 3 & 4
M localities 3 & 5
N localities 3 & 6
O localities 3 & 7
P localities 4 & 5
Q localities 4 & 6
R localities 4 & 7
S localities 5 & 6
T localities 5 & 7
U localities 7 & 8

Horizontal axis: Divisions of theCallovian/Oxfordian stages.

1 Lower Callovian (jason/calloviense zones)

2 Middle Callovian (coronatum zone)

3 Upper Callovian (athleta/lamberti zones)

4 Lower Oxfordian (mariae/cordatum zones)

5 Middle Oxfordian (plicatilis zone)

species-
strated in

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llovian/Oxfordian

zones)

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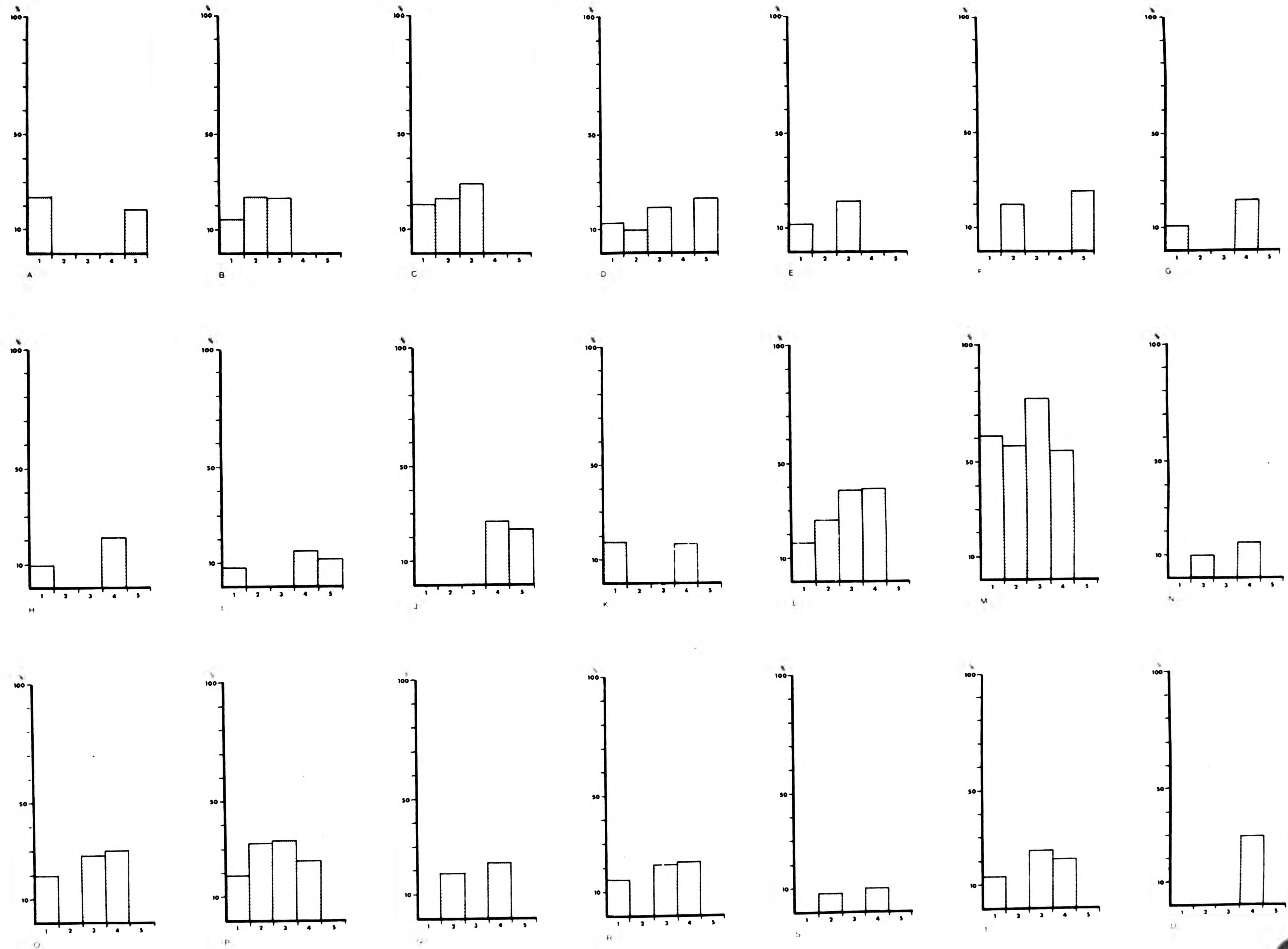

It appears that the Oxford Clay sea reached its maximum development at around the Callovian/Oxfordian transition. The decrease in relative abundance of microplankton (fig.7.1) in the Lower Oxfordian, together with an increase in the proportion of dinoflagellates to acritarchs (fig.7.8) suggests a shallowing of the marine environment, probably due to a silting-up of the basin of deposition. Unfortunately surface erosion has removed the remaining Oxfordian deposits (praecordatum zone upwards) at Warboys. At Warlingham however, the Oxford Clay sequence gives way to the Corallian Beds above. Wilson (1967) has suggested that the great mass of Coralline Limestone at Warlingham (from 913.13 metres to 953.95 metres) was deposited in a littoral, intertidal environment, under calmer water than that in which a true 'coral rag' facies would have developed. Worssam amd Ivimey-Cook (1971) conclude that "the development of a coralline facies in the Corralian Beds at Warlingham and in East Kent, in contrast to the predominantly clay facies proved by boreholes in the Central Weald, is due to the influence of the London Platform to the North" (ibid., p41). It is clear from this that the Oxford Clay sea must have been shallowing during Lower Oxfordian times. The increasing abundance of miospores in the Upper Oxford Clay at Warlingham towards the top of the sequence is further evidence of this, and gives weight to the proposition here that an increase in the relative proportions of dinoflagellates to acritarchs may be indicative of shallow water environments.

Chapter eight

SUMMARY OF CONCLUSIONS

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In chapter one the primary aims of the programme of research were stated as being three-fold and outlined as being:

1) To evaluate the importance of fossil microplankton assemblages for inter-regional, biostratigraphic correlation in general, using the two boreholes as tests of this, and the factors which govern their distribution.

2) To establish, as far as is possible, a zonation scheme for the Kellaways Beds and Oxford Clay using assemblages of microplankton - dinoflagellate cysts in particular.

3) To investiagte the potentiality of statistical and numerical methods of analysis in biostratigraphy using microplankton assemblages.

By way of conclusion, how far these aims have been achieved are briefly summarised.

There is no doubt in the author's mind concerning the value of microplankton assemblages for purposes of biostratigraphic correlation, at both local and inter-regional levels. The fact that they are planktonic organisms, occuring in vast numbers in relatively small samples of sediment and extracted with relatively simple techniques, makes for their importance in this role. In chapter seven we have examined the present position with regards to our understanding of the palaeoenvironmental parameters governing distribution of microplankton and have noted that considerable further work is neccessary before definite conclusions can be drawn. As a result of the present work it is felt that the dinoflagellate:acritarch ratios in fossil assemblages may well be palaeoenvironmentally significant in determining oceanity, although further tests of this are obviously neccessary. Inter-regional correlation using the Jaccard Coefficient of Similarity, expressed as a percentage (chapter seven) is considered to be a potentially useful tool in the hands of biostratigraphers working with microplankton assemblages, being easily calculated and the results portrayed in a simple visual format.

From our discussion of the value of dinoflagellate cysts for the purposes of biostratigraphic correlation in chapter six, certain conclusions can be drawn. We have looked in some considerable detail at the work of Williams (1977) and Sarjeant (1979) as examples of proposed zonation schemes for the Callovian and Oxfordian using dinoflagellate cysts. Furthermore an attempt has been made to recognise each of these schemes in the present assemblages. Because a cored-borehole, sampled at both close and regular intervals, provides the most ideal material for biostratigraphic analysis, one would have expected to have identified such previously-published zonation schemes. We have seen however that such is not the case. From this we may infer that dinoflagellate provinciallism may have a tighter geographical control over distribution patterns than originally conceived. Distinctive and recogniseable populations may well exist within the larger known floral provinces. The zonation scheme proposed here for the Kellaways Beds and Oxford Clay is based on the local ranges of dinoflagellate cysts and associated assemblages. It is not intended to be definitive but rather to provide a basis for future work.

We have noted in chapter six some of the problems inherent in conventional methods of biostratigraphy and pointed out the need for more rigorous and repeatable methods, based on quantitative rather than purely qualitative analyses. The two methods employed here (The Graphic Correlation Method and Cluster Analysis), whilst not giving wholly satisfactory results, will hopefully also provide a basis for future research.

ADDENDUM

At the binding stage of the present thesis the following publication appeared:

Riding, J.B. Jurassic dinocysts from the Warboys Borehole, Cambridgeshire, England. J. Micropalaeontol., 1, pp13-18. July, 1982

As the paper is directly related to the present work it was felt neccessary to comment briefly.

Riding describes dinocyst assemblages from 26 samples from the whole of the borehole (Toarcian to Early Oxfordian). However, assemblages are not described from the calloviense and jason zones of the Lower and Middle Callovian. Whilst many of the species listed occur in the present study there are several important differencies to be noted.

Middle/Late Callovian

In agreement with Riding, ***Ctenidodinium continuum*** is restricted to the Callovian. ***Reutlingia gochtii*** however is not restricted to the Upper athleta zone. In the present study ***R. gochtii*** was recorded consistently from samples between the Middle Callovian (jason zone) and Upper Callovian (lamberti zone) in the Warboys Borehole, extending into the Lower Oxfordian (scarburghense subzone) at Warlingham.

Callovian/Oxfordian Boundary

In the present study ***Polystephanephorous paracalathus*** is restricted to the Lower Callovian (koenigi subzone) at Warboys, extending into the Lower Oxfordian (scarburghense subzone) at Warlingham. Similarly ***Dinopterygium absidatum*** and ***Belodinium asaphum*** are restricted to the Lower Oxfordian at Warlingham; ***B. asaphum*** extending into the Middle Oxfordian (plicatilis zone). These species therefore appear to be not as characteristic of the Callovian/Oxfordian boundary as Riding suggests.

REFERENCES

REFERENCES

Alberti, G. 1961 Zur Kenntnis mesozoischer und altteriärer Dinoflagellaten und Hystrichosphaerideen von-Nord-und Mitteldeutschland sowie einigen anderen europäischen Gebieten. Palaeontographica Band 116, abt.A, pp1-58

Arkell, W.J. 1933 "The Jurassic System in Britain" Oxford University Press. 681pp

" 1946 Standard of the European Jurassic. Bull. Geol. Soc. Amer. 57(1), pp1-34

Beju, D. 1971 Jurassic microplankton from the Carpathian Foreland of Roumania. Magy. allam földt, Intéz Éuk. 54, pp275-316

Brelie, G. von der. 1963 Nachweis mariner Becinflüssung mit Flagellaten, Hystrichosphaerideen und Pollen. Fortschr. Geol. Rheinld, Westf. vol.10,pp107-120

Brideaux, W.W. 1977 Taxonomy of Upper Juassic - Lower Cretaceous microplankton from the Richardson Mountains, District of Mackenzie. Geol. Surv. Can. Bull. 259, 89pp.

Brinkmann, R. 1929 Statistisch-biostratigraphische Unterschungen an mittel-jurassischen Ammoniten über Artbegriff und Stammesentwicklung. Abhandl. Ges. Wiss. Göttingen, Math-phys. Kl., N.F. 13, pp1-249

Callomon, J.H. 1964 Notes on the Callovian and Oxfordian stages. Compte rendu et Mém. Coll. Jur. Luxembourg. 1962. Inst. Gr-due. Sect. Sci. nat. phys .math. pp269-291

" 1968 The Kellaways Beds and the Oxford Clay. in: Sylvester-Bradley, P.C., and Ford, T.D. "The Geology of the East Midlands". Leicester University Press. pp264-290.

Callomon, J.H. and Cope, J.C.W. 1971 The Stratigraphy and ammonite succession of the Oxford and Kimmeridge Clays in the Warlingham Borehole.
Bull. Geol. Surv. Gt.Br. No.36

Cheetham, A.H. and Deboo, P.B. 1963 A numerical index for biostratigraphic zonation in the Mid-Tertiary of the Eastern Gulf.
Gulf Coast Assoc. Geol. Socs. Trans., 13, pp139-147

Christensen, O.B. and Kilenyi, T.I. 1970 Ostracod Biostratigraphy of the Kimmeridgian in Northern and Western Europe.
Geol. Surv. Denmark, II Series, No.95, 65pp

Clarke, R.F.A. and Verdier, J.P. 1967 An investigation of microplankton assemblages from the chalk of the Isle of Wight, England.
Konikl. Nederlandse Akad. Wetensch. Verh., Afd. Natuurk., Eerste Recks, 24, pp1-96, pl.1-17

Cookson, I.C. and Eisenack, A. 1958 Microplankton from Australian and New Guinea Upper Mesozoic sediments.
Proc. Roy. Soc. Victoria, 70, pp19-79

" 1960 Upper Mesozoic microplankton from Australia and New Guinea.
Palaeontology 2, part 2, pp243-261

Cross, A.T., Thompson, G.C. and Zaitzeff, J.B. 1966 Source and distribution of palynomorphs in bottom sediments, Southern part of Gulf of California.
Mar. Geol., 4, pp467-524

Davey, R.J. 1969 Non-calcareous microplankton from the Cenomanian of England, northern France and North America, part 1.
Bull, Br. Mus. nat. hist. (Geol.) 17, pp103-180 pl.1-11

" 1971 Palynology and palaeoenvironmental studies, with special reference to the Continental Shelf sediments of S.Africa.
Proc. II Plankt. Conf. Roma. 1970, pp331-347

Davey, R.J. 1979 A re-apraisal of the Genus ***Chytroeisphaeridia*** Sarjeant, 1962.
Palynology, 3, pp209-218, 2pls.

Davey, R.J., Downie, C., Sarjeant, W.A.S. and Williams, G.L. 1966 Studies on Mesozoic and Caenozoic dinoflagellate Cysts.
Bull. Br. Mus. nat. Hist. (Geol.) Supplement 3, 248 pp.

" 1969 Appendix to "Studies..."

Davey, R.J., and Riley, L.A. 1978 Late and Middle Jurassic Dinoflagellate Cysts. in "Distribution of Biostratigraphically Diagnostic Dinoflagellate Cysts and Miospores from the Northwest European Continental Shelf and Adjacent Areas" ed. Thusu, B.
I.K.U. publ. 100. pp31-46

Davey, R.J., and Williams, G.L. 1966 The genus ***Hystrichosphaeridium*** and its allies.
in Davey, R.J., et.al., 1966, pp53-106

" 1969 Generic reallocations
in Davey, R.J., et.al., 1969, pp4-7

Deflandre, G. 1935 Considérations biologiques sur les microorganismes d'Origine planctonique conservés dans les silex de la crai.
Bull. Biol. France et Belgique, 69, pp213-244, pl.5-9

" 1937 Microfossiles des silex Cretaces.
Part Two: Flagelles 'incertae sedis', Hystrichosphaerides, Sarcodines. Organismes divers.
Ann. Paleont. 26, pp51-103

" 1938 Microplancton des mers Jurassiques conserve dans les marnes de Villers-sur-mer (Calvados). Etude luminaire et considerations generales.
Stat. Zool. Wimereux, Trav., 13, pp147-200

" 1945 Dinoflagellés II. Gymnodiniales et Dinoflagellés incertae sedis. Flagellés incertae sedis.

Fichier Micropaléontologique, Sér.5, Archives Originales Serv. Documentation C.N.R.S. no.235 cards 752-859

Deflandre, G. 1947a Sur une nouvelle Hystrichosphère des silex Crétacés et sur les affinités du genre *Cannosphaeropsis* O.We. Acad. Sci. Comptes Rendus. 224, pp1574-1576

" 1947b Sur quelques microorganismes planctoniques des silex jurassiques. Inst. Oceanog. Monaco Bull. no.921, pp1-10

" 1964 Remarques sur la classification des Dinoflagellés fossiles, à propos d'*Evittodinium*, nouveau genre crétacé de famille des Deflandreaceae. Acad. Sci. Comptes Rendus. 258, pp5027-5030

" 1966 Addendum à mon Mémoire - Microfossiles des silex crétacés: Cahiers Micropaléontologie, sér.1, no.2, Archives Originales Centre Documentation C.N.R.S. no.419, pp1-9, pl.1

Deflandre, G., and Cookson, I. 1955 Fossil microplankton from Australian Late Mesozoic and Tertiary sediments. Australian Jour. Marine & Freshwater Research, 6, pp242-313, pl.1-9

Dodekova, L. 1967 Les Dinoflagelles et acritarchs de l'Oxfordien - Kimmeridgien de la Bulgarie du Nord-Est. Sofia, Univ. Faculte Geol. Geogr. Ann., 60, book 1 (1965/1966), pp9-30

" 1974 *Compositosphaeridium* gen.n. - a new genus dinoflagellate cyst. Bulgarian Acad. Sci. Comm. Géol. Bull. Géol. Inst. Sér. Paleont., 23, pp25-30, pl.1-2

Dodekova, L — 1975 — New Upper Bathonian dinoflagellate cysts from north-eastern Bulgaria.
Bulgarian Acad. Sci. Palaeo. Strat. and Lith., 2 pp17-34, pl.1-6

Downie, C., Evitt, W.R., and Sarjeant, W.A.S. — 1963 — Dinoflagellates and the classification of the Acritarchs.
Stanford Univ. Publ. Geol. Sci., 7, pp1-16

Downie, C., and Sarjeant, W.A.S. — 1964 — Bibliography and index of fossil dinoflagellates and acritarchs.
Mem. Geol. Soc. Am., no.94, 180pp

Drugg, W.S. — 1970 — Some new genera, species and contributions of phytoplankton from the Lower Tertiary of the Gulf Coast, U.S.A.
North. Am. Paleont. Convention, Chicago 1969, Proc. G., pp809-843

" — 1978 — Some Jurassic dinoflagellate cysts from England, France and Germany.
Palaeontographica Abt.B., 168, pp61-79, pl.1-8

Ehrenberg, C.G. — 1843 — Uber die verbreitung des jetzt wirkerden kleinsten organischen lebers in Asien, Australien und Afrika und uber die vorhernschende Bildung auch des Oolithalkes der Jura formation aus Kleinen polythalomischen thieren.
Verh. preuss. Akad. Wiss, Ber., pp100-106

Eisenack, A. — 1935 — Mikrofossilien aus Doggergeschieben Ostpreussens.
Z. Geschiebeforsch., 11, pp167-184, pl.4,5

" — 1958 — Mikroplankton aus dem norddeutschen Apt nebst einigen Bemerkungen über fossile Dinoflagellaten.
Neves Jahrb. Geologie u. Paläontologie Abh., 106, pp383-422, pl.21-27

" — 1961 — Einige Eröterungen über fossile Dinoflagellaten rebst Übersicht über die zur zeit bekannten

Gattungen.
Neues Jahrb Geologie u. Paläontologie Abh., 112, pp281-324, pl.33-37

Eisenack, A. 1963a Zur *Membranilarnax* - Frage.
Neues Jahrb. Geologie u. Paläontologie Monatsch., pp98-103

" 1963b *Cordosphaeridium* n. gen., ex *Hystrichosphaeridium*, Hystrichosphaeridea.
Neues Jahrb. Geologie u. Paläontologie Abh., 118, pp260-265, pl.29

Eisenack, A., and Cookson, I.C. 1960 Microplankton from Australian Lower Cretaceous Sediments.
Royal Soc. Victoria Proc., 72, pp1-11, pl.1-3

Evitt, W.R. 1961 Observations on the morphology of fossil dinoflagellates.
Micropalaeontology, 7, pp385-420

" 1963 A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs.
Proc. Natn. Acad. Sci., 49, pp158-164; 298-302

" 1967 Dinoflagellate studies II. The archeopyle.
Stanford Univ. Publs. (Geol. Sci.), 10, no.3, pp1-88, pl.1-9

Evitt, W.R, Lentin,J.K Millioud,M.E, Stover,L.E. and Williams,G.L. 1977 Dinoflagellate cyst terminology.
Canada, Geol. Surv., Paper 76-24, pp1-11, text-figs.1-6

Fensome, R.A. 1979 Dinoflagellate cysts and acritarchs from the Middle and Upper Jurassic of Jameson Land, East Greenland.
Grønlands Geologiske Undersøgelse. Bull. 132 98pp, 9pls.

Fenton, J.P.G., Neves, R. & Piel, K.M. 1980 Dinoflagellate cysts and acritarchs from Upper Bajocian to Middle Bathonian strata of Central and Southern England.
Palaeontology, 23, part 1, pp151-170, pl.14-16

Filatoff, J. 1975 Jurassic palynology of the Perth Basin, Western Australia.
Palaeontographica, Abt.B, 154, pp1-113

Gitmez, G.U. 1970 Dinoflagellate cysts and acritarchs from the Basal Kimmeridgian (Upper Jurassic) of England, Scotland and France.
Bull. Br. Mus. nat. Hist. (Geol.), 18, no.7, pp221-331, pl.1-14

Gitmez, G.U. & Sarjeant, W.A.S. 1972 Dinoflagellate cysts and acritarchs from the Kimmeridgian (Upper Jurassic) of England, Scotland and France.
Bull. Br. Mus. nat. Hist. (Geol.), 21, pp171-257, pl.1-17

Gocht, H. 1964 Planktonische Kleinformen aus dem Lias - Dogger - Grenzbereich Nord - und Süddeutschlands.
Neues Jahrb. Geologie u. Paläontologie Abh., 119, pp113-133, pl.15-17

" 1970 Dinoflagellaten-Zysten aus dem Bathonium des Erdölfeldes Aldorf (NW-Deutschland).
Palaeontographica, Abt.B, 129, Lfg.4-6, pp125-165

" 1975 Morphologie und Wandstrukter von ***Lithodinia jurassica*** Eisenackm 1935 (Dinoflagellata, Oberjura)
Neues Jahrb. Geologie u. Paläontologie Monatsch. pp343-359

Gorka, H. 1965 Les microfossiles du Jurassique Supérieur de Magnuszew (Pologne).
Acta Palaeont. Polonica, 10, pp291-327, pl.1-5

" 1970 Dinoflagellate cysts from Callovian of Lukow (Poland).
Acta Palaeont. Polonica,15, pp479-498, pl.1-6

Hallam, A. 1967 The depth significance of shales with bituminous laminae.
Marine Geol., 5, pp481-493

Harker, S.D., & Sarjeant, W.A.S. 1975 The stratigraphic distribution of the organic-walled dinoflagellate cysts in the Cretaceous and Tertiary. Rev. Palaeobot. Palynol., 20, pp217-316

Harland, R. 1972 A summary review of the morphology and classification of fossil Peridiniales (dinoflagellates) with respect to their modern representatives. Geophytology, 1 (for 1971), pp135-150

Hazel, J.E. 1970 Binary coefficients and clustering in biostratigraphy. Geol. Soc. Am. Bull., 81, pp3237-3252

Horowitz, A. 1975 Kystes de Dinoflagellés du Trias du Sud d'Israel. Rev. Micropaleontologie, 18, pp23-27, pl.1

Hudson, J.D., & Palframan, D.F.B. 1969 The ecology and preservation of the Oxford Clay fauna at Woodham, Bucks. Q.J.G.S.London, 124, pp387-418

Ioannides, N.S., Stavrinos, G.N., & Downie, C. 1976 Kimmeridgian microplankton from Clavell's Hard, Dorset, England. Micropaleontology, 22, no.4, pp443-478

Johnson, C.D. & Hills, L.V. 1973 Microplankton zones of the Savik Formation (Jurassic), Axel Heiberg and Ellesmere Islands, District of Franklin. Bull. Canad. Petroleum Geol, 21(2), pp178-218

Klement, K.W. 1957 Revision der Gattungszugehörigket einge in die Gattung ***Gymnodinium*** eingestufter Arten jurassicher Dinoflagellaten. Neues Jahrb. Geologie u. Palaöntologie Monatsh, pp408-410

" 1960 Dinoflagellaten und Hystrichosphaeriden aus dem unteren und Mittleren Malm Sudwestdeutschlands. Palaeontographica, A., 114, pp1-104

Lam, K., & Porter, R. 1977 The distribution of palynomorphs in the Jurassic rocks of the Brora Outlier, N.E. Scotland. Jl. geol. Soc. Lond., 134, pp45-55

Lentin, J.K. & Williams, G.L. 1973 Fossil Dinoflagellates - index to genera and species. Canada Geol. Survey, Paper no.73-42, pp1-176

" 1976 A monograph of fossil peridinioid dinoflagellate cysts. Bedford Inst. Oceanography Rept., BI-R-75-16, pp1-237

" 1977 Fossil Dinoflagellates - index to genera and species, 1977 edition. Canada Geol. Survey, Paper no.BI-77-8. 300pp

Lohmann, L.G. 1904 Eier und sogenannte Vysten der Plankton-Expedition. Anhang : cyphonantes. Wiss. Ergebn. der Plankton-Exped. Humboldt-Stiftung, Kiel, new ser., 4, pp1-62. pl.1-7

Miller, F.X. 1977 The Graphic Correlation Method in Biostratigraphy. in Kauffman, E.G., et.al. (ed) "Concepts and Methods of Biostratigraphy"., pp165-186 Dowden, Hutchinson & Ross, Pennsylvania.

Muir, M.D. & Sarjeant, W.A.S. 1978 The palynology of the Langdale Beds (Middle Jurassic) of Yorkshire and its stratigraphical implications. Rev. Palaeobot. Palynol., 25, pp193-239

Neale, J.W. & Sarjeant, W.A.S. 1962 Microplankton from the Speeton Clay of Yorkshire. Geol. Mag., 99, no.5, pp439-458

Norris, G. 1975 Provincialism of Callovian - Neocomian Dinoflagellate cysts in the Northern and Southern hemispheres. in A.A.S.P., Ser. Contrib., no.4 (ed. Evitt, W.R.), pp29-35

Norris, G. & Sarjeant, W.A.S. 1965 A descriptive index of genera of fossil Dinophyceae and Acritarcha. N.Z. geol. Surv. Paleont. Bull., no.40, 72pp

Pocock, S.A.J. 1972 Palynology of the Jurassic sediments of Western Canada, pt.2. marine species. Palaeontographica, Abt.B, 137, pp85-153, pl.22-29

Riley, L.A. & Sarjeant, W.A.S. 1972 Survey of the stratigraphic distribution of dinoflagellates, acritarchs and tasmanitids in the Jurassic. Geophytology, 2, pp1-40

Sarjeant, W.A.S. 1959 Microplankton from the Cornbrash of Yorkshire. Geol. Mag., 96(5), pp329-346

" 1960a New hystrichospheres from the Upper Jurassic of Dorset. Geol. Mag., 97(2), pp137-144

" 1960b Microplankton from the Corallian rocks of Yorkshire. P.Y.G.S., 32(4), no.18, pp389-408

" 1961a Microplankton from the Kellaways Rock and Oxford Clay of Yorkshire. Palaeontology, 4, no.1, pp90-118

" 1961b *Systematophora* Klement and *Polystephanosphaera* Sarjeant. Journ. Paleont., 35, pp1095-1096

" 1962a Microplankton from the Ampthill Clay of Melton, South Yorkshire. Palaeontology, 5, no.3, pp478-497

" 1962b Upper Jurassic microplankton from Dorset, England. Micropalaeontology, 8,no.2, pp255-268

" 1964 New name and diagnosis for an Upper Jurassic

species of ***Gonyaulacysta*** (Dinophyceae).
Palaeontology, 7(3), pp472-473

Sarjeant, W.A.S. 1965 Microplankton from the Callovian (***S. calloviense*** zone) of Normandy.
Rev. de Micropal., 8, no.3, pp175-184

" 1966a Dinoflagellate cysts with ***Gonyaulax*** - type tabulation. in Davey, R.J., et.al., 1966
pp107-156, pl.13-16, tab.4

" 1966b Further dinoflagellate cysts from the Speeton Clay. in Davey, R.J., et.al., 1966
pp199-214, pl.21-23, tab.5

" 1967a The genus ***Palaeoperidinium*** Deflandre 1934 (Dinophyceae).
Grana Palynologica 7, no.1, pp241-258

" 1967b Observations on the acritarch genus ***Micrhystridium*** (Defl.)
Rev. Micropaléont., 4, pp201-208

" 1967c The stratigraphical distribution of fossil dinoflagellates.
Rev. Palaeobot. Palynol., 1, pp323-343

" 1968 Microplankton from the Upper Callovian and Lower Oxfordian of Normandy.
Rev. de Micropal. 10, no.4, pp221-242

" 1969 Taxonomic changes in Appendix to "Studies on Mesozoic and Caenozoic Dinoflagellate Cysts".
Bull. Br. Mus. nat. Hist.(Geol.), Appendix to suppl.3. London. pp7-15

" 1972 Dinoflagellate cysts and acritarchs from the the Upper Vardekløft formation (Jurassic) of Jameson Land, East Greenland.
Meddelser om Grønland. Udgivne Af. Kommissionen For Videuskabelgie Undersøgelser 1 Grønland.
Bd.195, Nr.4, pp1-61, pl.1-9

Sarjeant, W.A.S.	1974a	"Fossil and Living Dinoflagellates". Academic Press, 182pp.
"	1974b	Jurassic dinoflagellate cysts with epitractal archeopyles. Grana Palynologica. 14, pp49-56
"	1976a	Dinoflagellate cysts and acritarchs from the Great Oolite Limestone (Jurassic, Bathonian) of Lincolnshire, England. Geobios. no.9, fasc.1, pp5-46
"	1976b	English Jurassic dinoflagellate cysts and acrtitarchs: a reexamination of some type and figured specimens. Geoscience and Man. 15, pp1-24
"	1979	Middle and Upper Jurassic dinoflagellate cysts: The world excluding North America. A.A.S.P., Contrib. Series, No.5B. pp133-156
Sarjeant, W.A.S. & Stover, L.E.	1978	***Cyclonephelium*** and ***Tenua*** - a problem in dinoflagellate cyst taxonomy. Grana Palynologica. 17, pp47-54
Scull, B.J, Felix,C.J, McCaleb, S.B. & Shaw, W.G.	1966	The inter-discipline approach to palaeoenvironmental interpretations. Trans. Gulf-Cst. Ass. geol. Socs. 16, pp81-117 pl.1-9
Shaw, A.B.	1964	"Time in Stratigraphy" New York, McGraw-Hill. 365pp.
Sokal, R.R. & Sneath, P.H.A.	1963	"Principles of Numerical Taxonomy" San Francisco, W.H. Freeman & Co. 359pp.
Staplin, F.L.	1961	Reef-controlled distribution of Devonian microplankton in Alberta. Palaeontology, 4, pp392-424

Staplin, F.L., Jansonius, J., & Pocock, S.A.J.	1965	Evaluation of some acritarchous hystrichosphere genera. Neues Jahrb. Geologie u. Palaeönt. Abh., Stuttgart, 123, pp167-201, pl.18-20
Stover, L.E. & Evitt, W.R.	1978	Analysis of Pre-Pleistocene organic-walled dinoflagellates. Stanford Univ. Publ. 300pp.
Stover, L.E., Sarjeant, W.A.S. & Drugg, W.S.	1977	The Jurassic dinoflagellate ***Stephanelytron***: emendation and discussion. Micropaleontology, 23(3), pp330-338
Sykes, R.M.	1975	The stratigraphy of the Callovian and Oxfordian stages (Middle-Upper Jurassic) in northern Scotland. Scott. J. Geol. 11(1), pp51-78
Valensi, L.	1947	Note preliminaire a une etude des microfossiles des silex jurassiques de la region de Poitiers. C. R. Acad. Sci. Paris. 225, pp816-818
"	1948	Sur quelques microorganismes planctoniques des silex du Jurassique moyen du Poiton et de Normandie. B.S.G.F. (5), XVIII, pp536-550, 6figs.
"	1953	Microfossiles des silex Jurassique moyen. Remarques petrographiques. Soc. Geol. Fr. Mem. no.68, 100pp.
Vozzhennikova, T.F.	1965	Introduction to the study of fossil peridinid algae. (in Russian). Moscow : Izdatel. "Nauka". 156pp. (Translation published by Boston Spa, Yorkshire; National Lending Library, 1967; 231 + viii pp.)
"	1967	Fossilized peridinid algae in the Jurassic, Cretaceous and Palaeogene deposits of the U.S.S.R. (R.Lees, trans., W.A.S. Sarjeant, ed.) Boston Spa, Yorkshire, England. Natl. Lending Library for Science & Technology, 1971

Wall, D. 1965 Microplankton, pollen and spores from the Lower Jurassic in Britain. Micropalaeontology. 11, pp151-190

" 1971 The lateral and vertical distribution of dinoflagellates in Quaternary sediments. in Funnel, B.M. & Riedel, W.R. "The Micropalaeontology of the Oceans". Cambridge Univ. Press, 1971. Ch.30, pp399-405

Wall, D. & Dale, B. 1968 Modern dinoflagellate cysts and evolution of the Peridiniales. Micropaleontology. 14(3) pp265-304, pl.1-4

Wall, D., Dale, B., Lohmann, G.R. & Smith, W.K. 1977 The environmental and climatic distribution of dinoflagellate cysts in modern marine sediments from regions in the North and South Atlantic Oceans and adjoining seas. Mar. Micropaleont. 2, pp121-200

Warren, J.S. 1973 Form and variation of the dinoflagellate *Sirmiodiniim grossi* Alberti, from the Upper Jurassic and Lower Cretaceous of California. J. Paleont. 47, no.1, pp101-114

Wetzel, O. 1933 Die in organischer Substanz erhalten Mikrofossilie des baltischen Kreide-Feuersteins mit einem sediment-petrographischen und stratigraphischen Anhang. Palaeontographica, Abt.A, pp1-110, pl.1-7

Wetzel, W. 1966 Charakteristik des marinen Planktons und Pseudoplanktons der Amaltheen-Schichten Deutschlands und Lothringens. Neues Jahrb. Geologie u. Paläontologie Abh., 124, pp313-326, pl.30,31

Wiggins, V.D. 1975 The dinoflagellate family Pareodiniaceae - a discussion. Geoscience and Man. 11, pp95-115, pl.1-5

Williams, D.B. 1971a The distribution of marine dinoflagellates in relation to physical and chemical conditions. in Funnel, B.M. & Riedel, W.R. "The Micropalaeontology of Oceans". Cambridge Univ. Press, 1971. ch.4, pp91-95

" 1971b The occurrence of dinoflagellates in marine sediments. in Funnel, B.M. & Riedel, W.R. "The Micropalaeontology of Oceans". Cambridge Univ. Presss, 1971. ch.14, pp231-243

Williams, D.B. & Sarjeant, W.A.S. 1967 Organic-walled microfossils as depth and shoreline indicators. Mar. Geol. 5, pp389-412

Williams, G.L. 1977 Dinocysts: Their classification, biostratigraphy and palaeoecology. in "Oceanic Micropalaeontology" ed. Ramsay, A.T.S. vol.2, pp1231-1325

Williams, G.L. & Downie, C. 1966 Further dinoflagellate cysts from the London Clay. in Davey, R.J., et.al. 1966. pp.215-235

" 1969 Generic reallocations. in Davey, R.J., et.al. 1969. p7

Wilson, R.C.L. 1967 Upper Oxfordian palaeogeography of Southern England. Palaeogeog. Palaeoclimatol. Palaeoecol. 4 (1968) pp5-28

Woollam, R. 1977 A palynological study of part of the Oxford Clay from the East Midlands. unpublished M.Sc. thesis, Univ. Sheffield.

Worssam, B.C. & Ivimey-Cook, H.C. 1971 The stratigraphy of the Geological Survey Borehole at Warlingham, Surrey. Bull. Geol. Surv. Gt. Br. No.36. pp1-146

Zeitzschel, B. 1978 Oceanographic factors influencing the distribution of plankton in space and time. Micropaleontology. 24, pp139-159

PLATES

PLATES

Key to references given for each figure:-

Sample no.   Microscope coordinate   Phase-contrast

Br.727a;   155/1468   (Q292)*

Slide ref.   England-Finder ref.

All figures are X750 unless otherwise indicated.

PLATE 1

Figs

1,2 Acanthaulax senta Drugg, 1978

1. Br.785a; 105/1317 (K450) 2. Br.785a; 160/1319 (Q444)

3-5 Acanthaulax cf. senta Drugg, 1978

3. Br.727a; 055/1286 (E480) 4. Br.727a; 185/1483 (S283)
5. Br.727a; 070/1293 (G470)

6,7 Adnatosphaeridium caulleryi (Deflandre, 1938) Williams & Downie, 1969

6. Br.194a; 165/1334 (Q433) 7. Br.429a; 175/1248 (S521)

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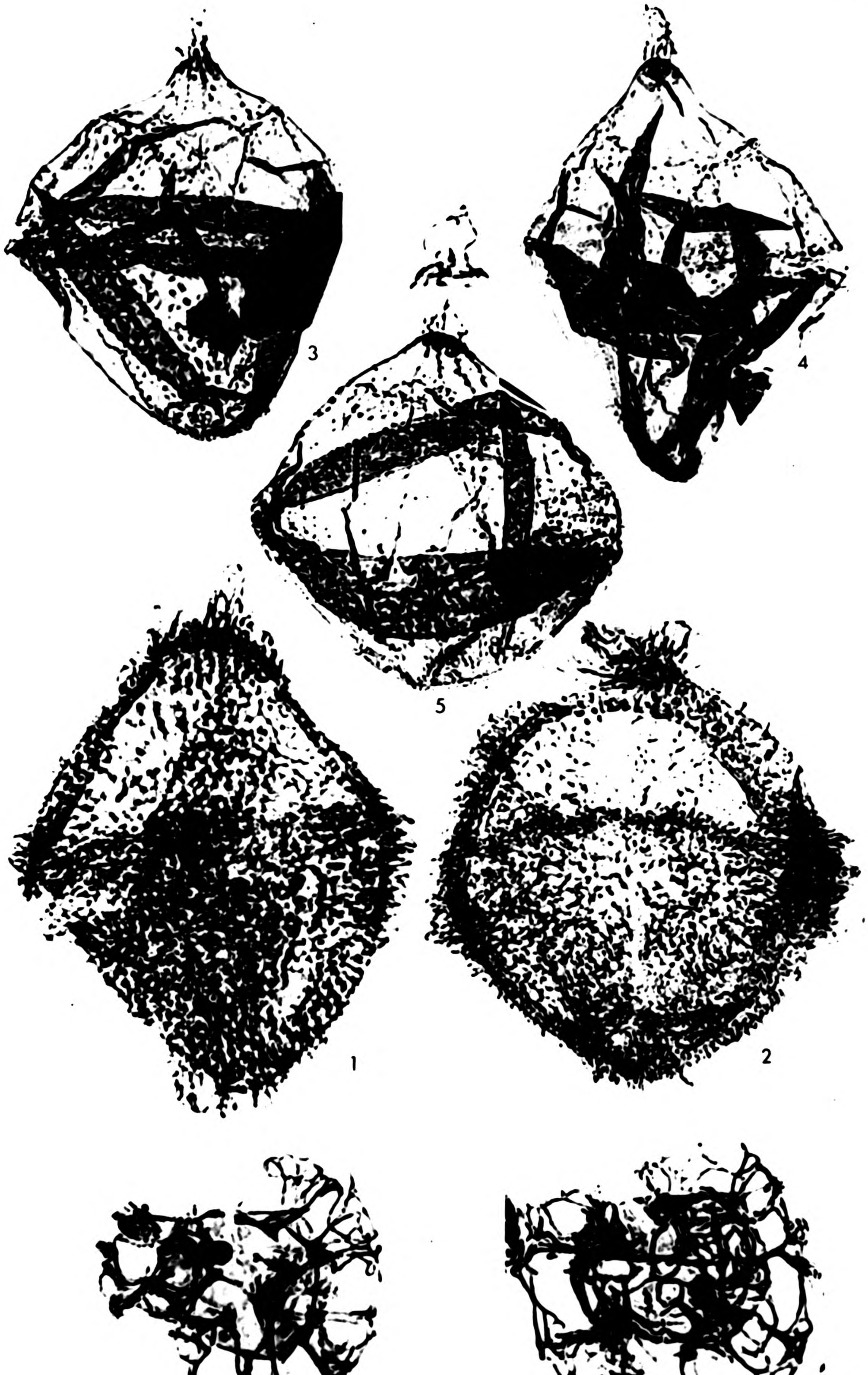

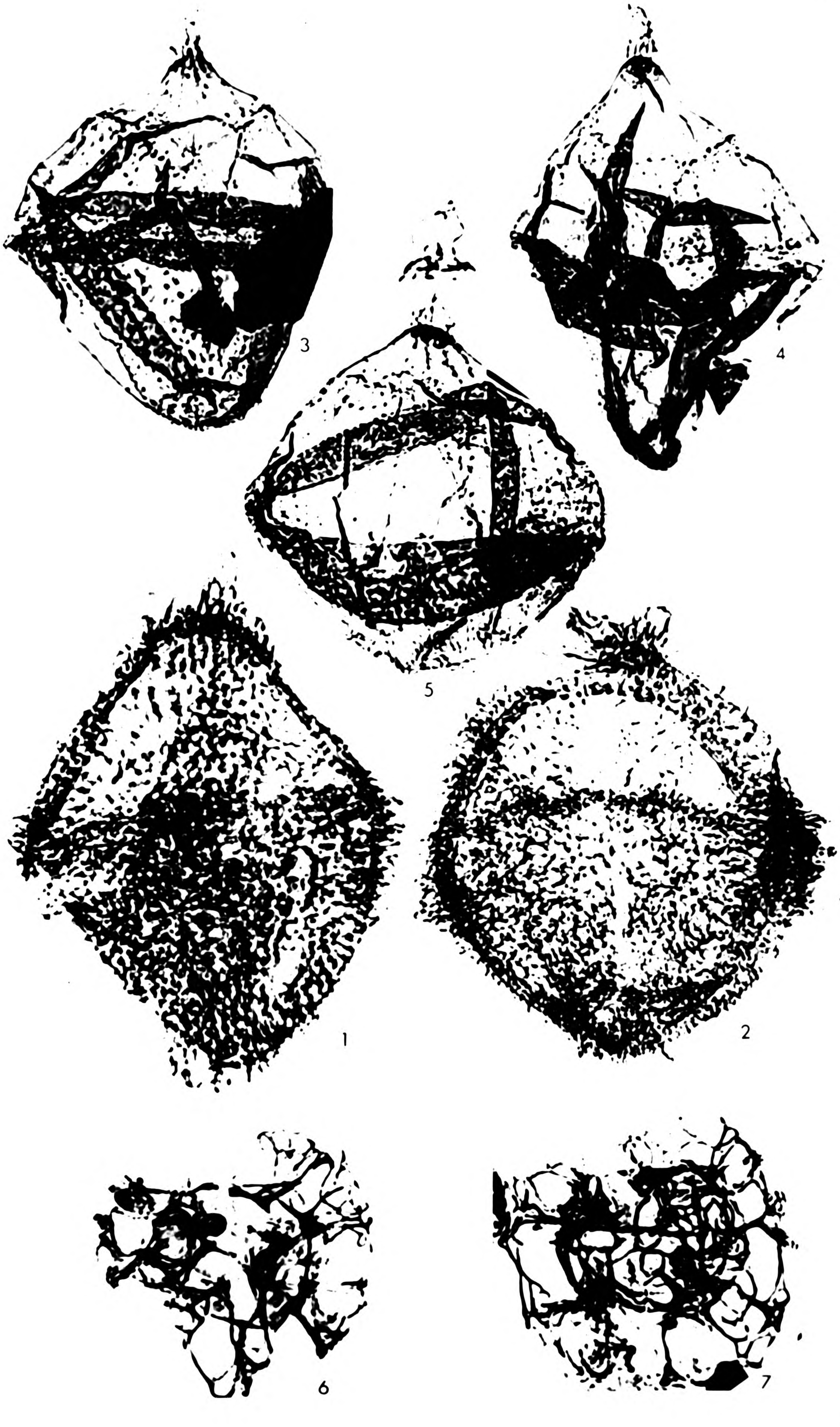

PLATE 2

Figs

1-5 Adnatosphaeridium aemulum (Deflandre, 1938) Williams & Downie 1969

1. Br.985a; 055/1411 (E350) 2. Br.1118a; 105/1471 (K293)

3. Br.785a; 175/1342 (R423) 4. Br.742a; 060/1228 (F540)

5. Br.1118a; 110/1315 (L451)

6 Adnatosphaeridium caulleryi (Deflandre, 1938) Williams & Downie 1969

6. WB.210a; 131/1167 (N600)

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(K293)
(F540)

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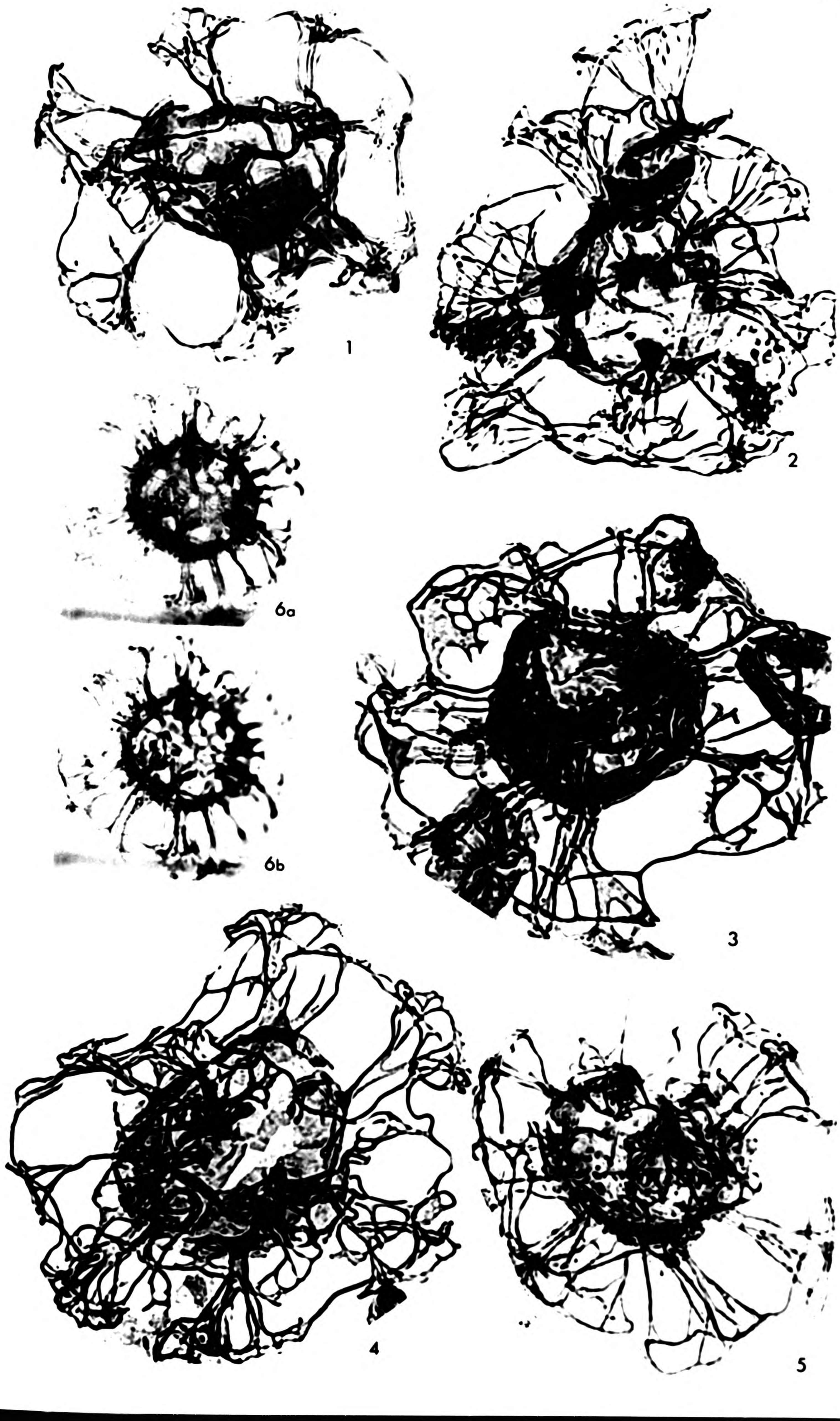

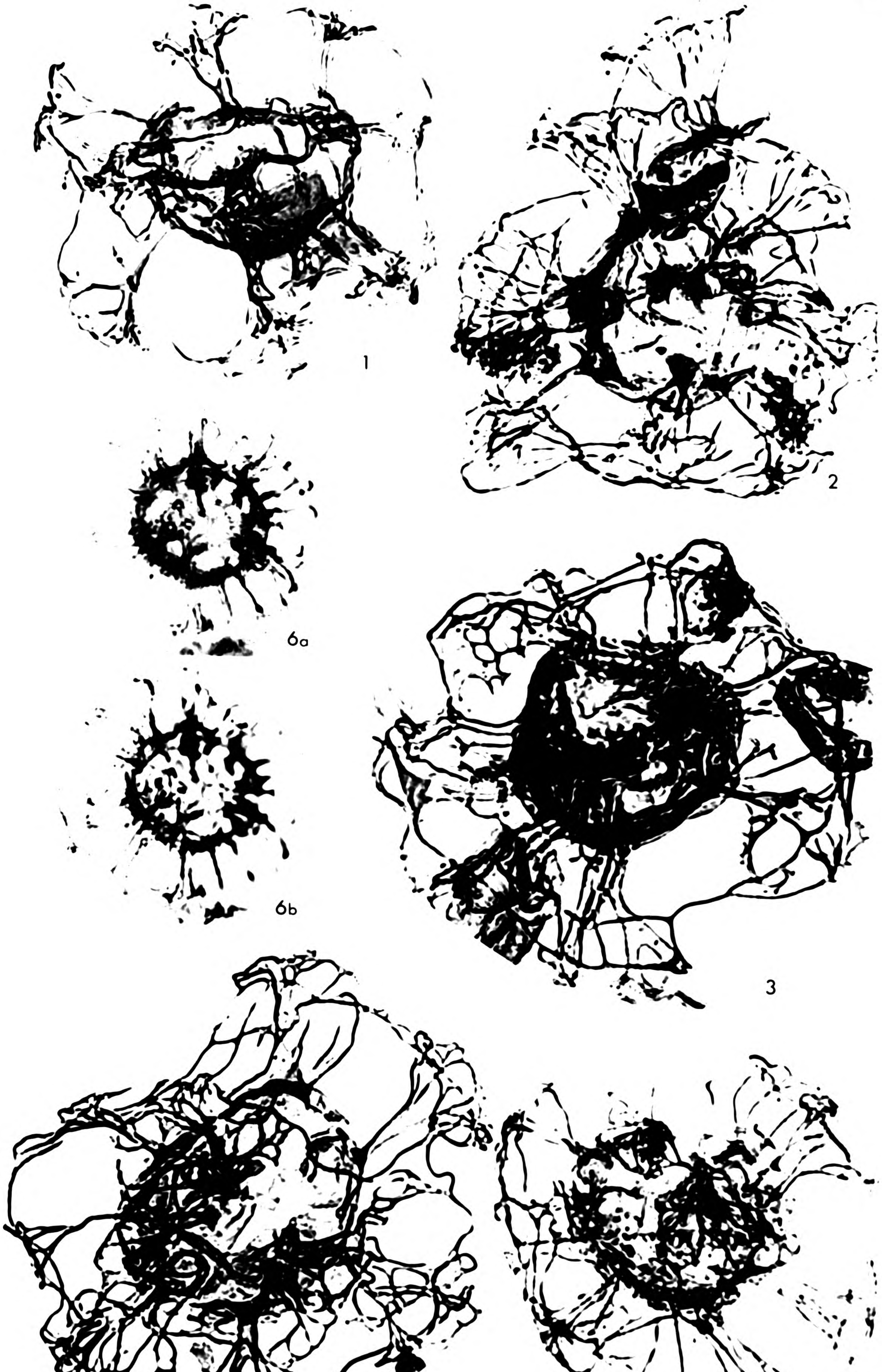
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PLATE 3

Figs

1 *Adnatosphaeridium aemulum* (Deflandre, 1938) Williams & Downie 1969

1. Br.246a; 214/1411 (V353)

2-4 *Adnatosphaeridium caulleryi* (Deflandre, 1938) Williams & Downie 1969

2. Br.785a; 145/1487 (O283) 3. Br.947a; 190/1226 (T540)

4. Br.785a; 060/1271 (F492)

5. *Adnatosphaeridium aemulum* (Deflandre, 1938) Williams & Downie 1969

5. Br.727a; 215/1366

6,7 *Adnatosphaeridium caulleryi* (Deflandre, 1938) Williams & Downie 1969

6. Br.395a; 150/1250 (P523) 7. Br.985a; 225/1240 (X521)

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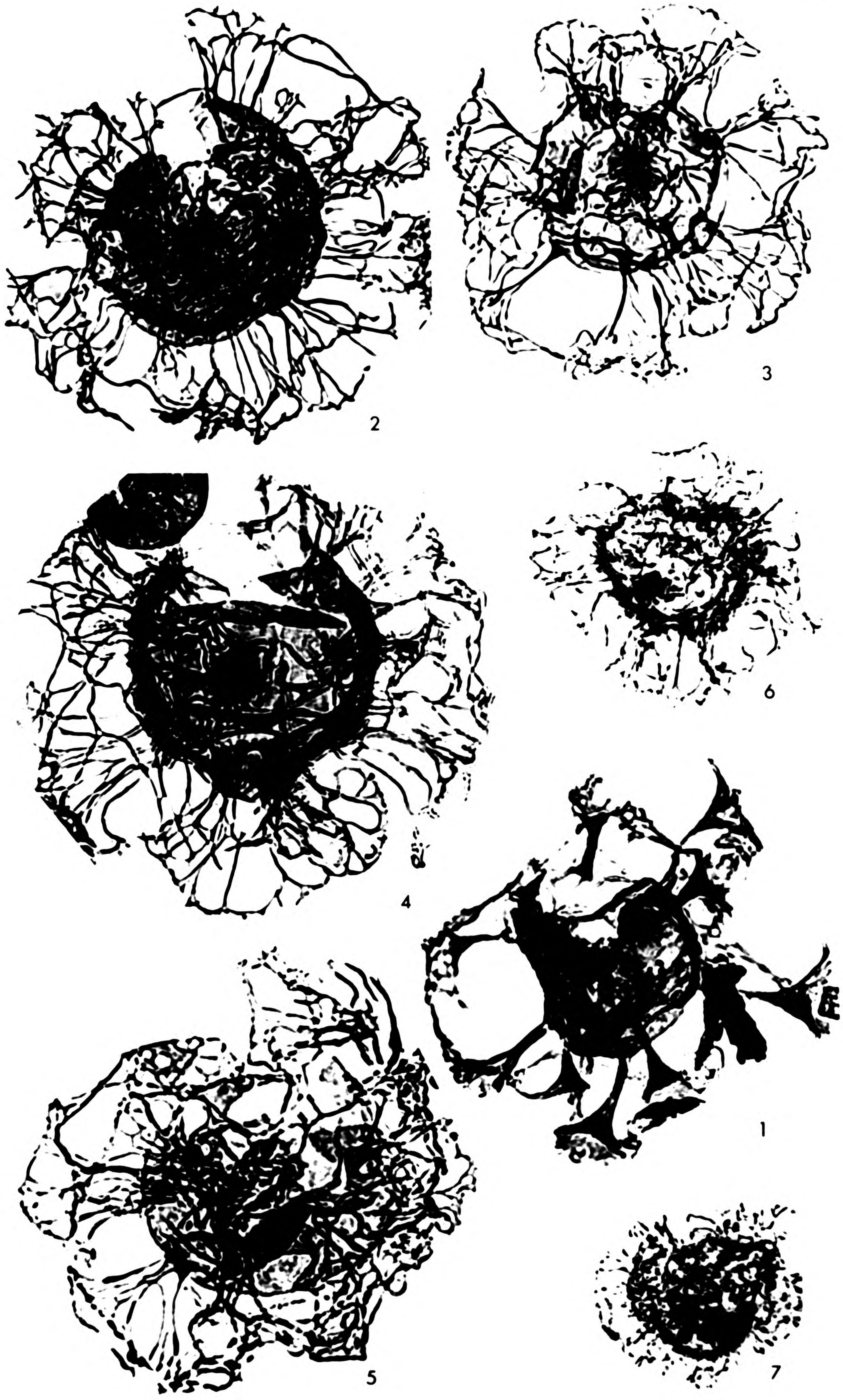

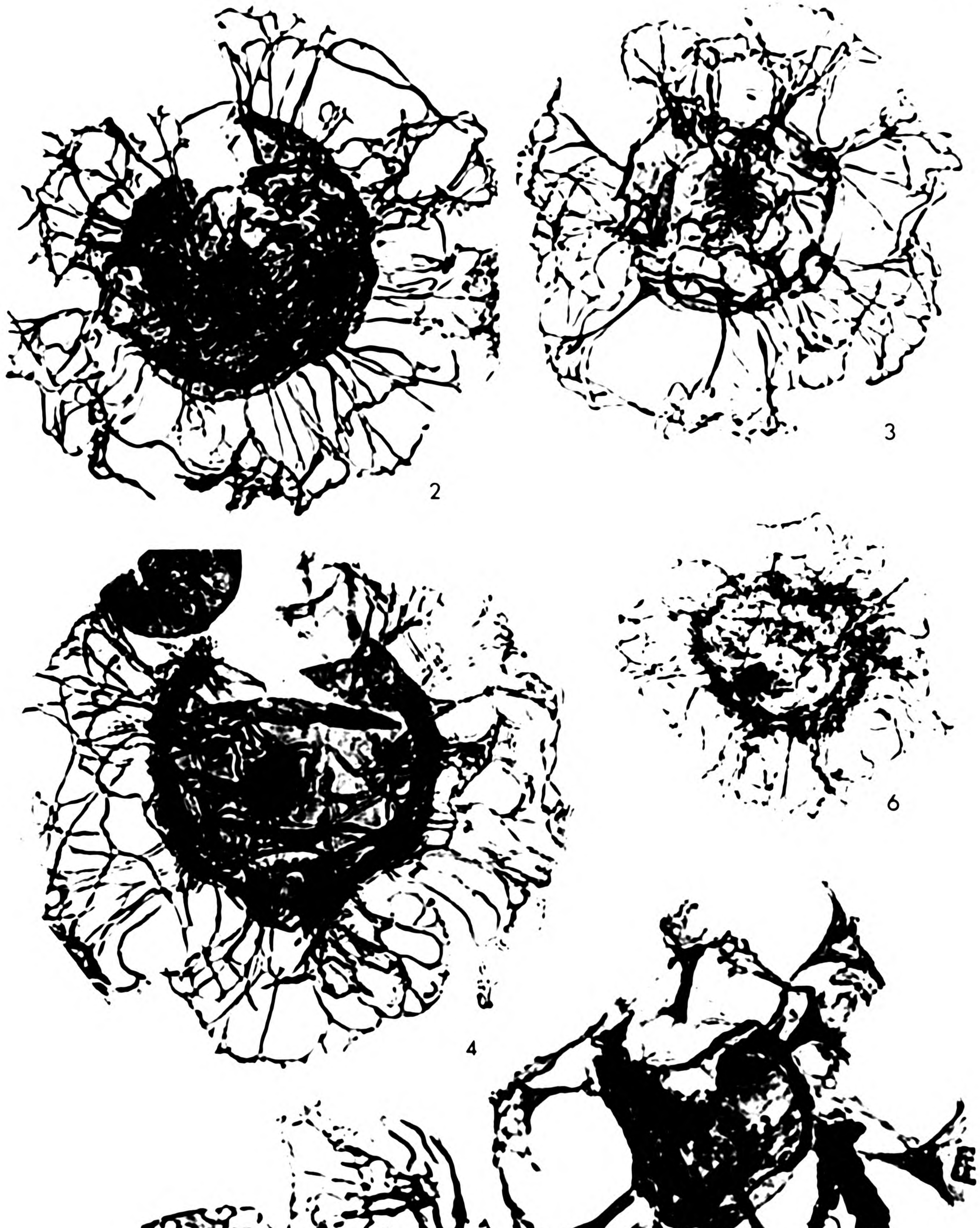
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PLATE 4

Figs

1,2 Apteodinium granulatum Eisenack, 1958
1. Br.1450a; 210/1461 (V301) 2. Br.1087a; 185/1308 (T452)

3-7 Apteodinium nuciforme (Deflandre, 1938) Stover & Evitt, 1978
3. Br.368a; 170/1366 (R400) 4. Br.465a; 070/1332 (G432)
5. Br.170a; 120/1456 (M304) 6. WB93a; 100/1343 (K420)
7. Br.292a; 110/1338 (L431)

8,9 Apteodinium cf. nuciforme (Deflandre, 1938) Stover & Evitt, 1978
8. Br.554a; 150/1326 (P440) 9. WB28a; 030/1429 (C330)

10,11 Batiacasphaera dictydia (Sarjeant, 1972) Davey, 1979
10. WB138a; 039/1465 11. WB73a; 210/1378 (V393)

12 Chytroeisphaeridia mantellii Gitmez & Sarjeant, 1972
12. Br.465a; 195/1420 (T340)

13,14 Batiacasphaera dictydia (Sarjeant, 1972) Davey, 1979
13. WB78a; 045/1324 (D440) 14. Br.1450a; 185/1377 (S384) (14b*)

308 (T452)

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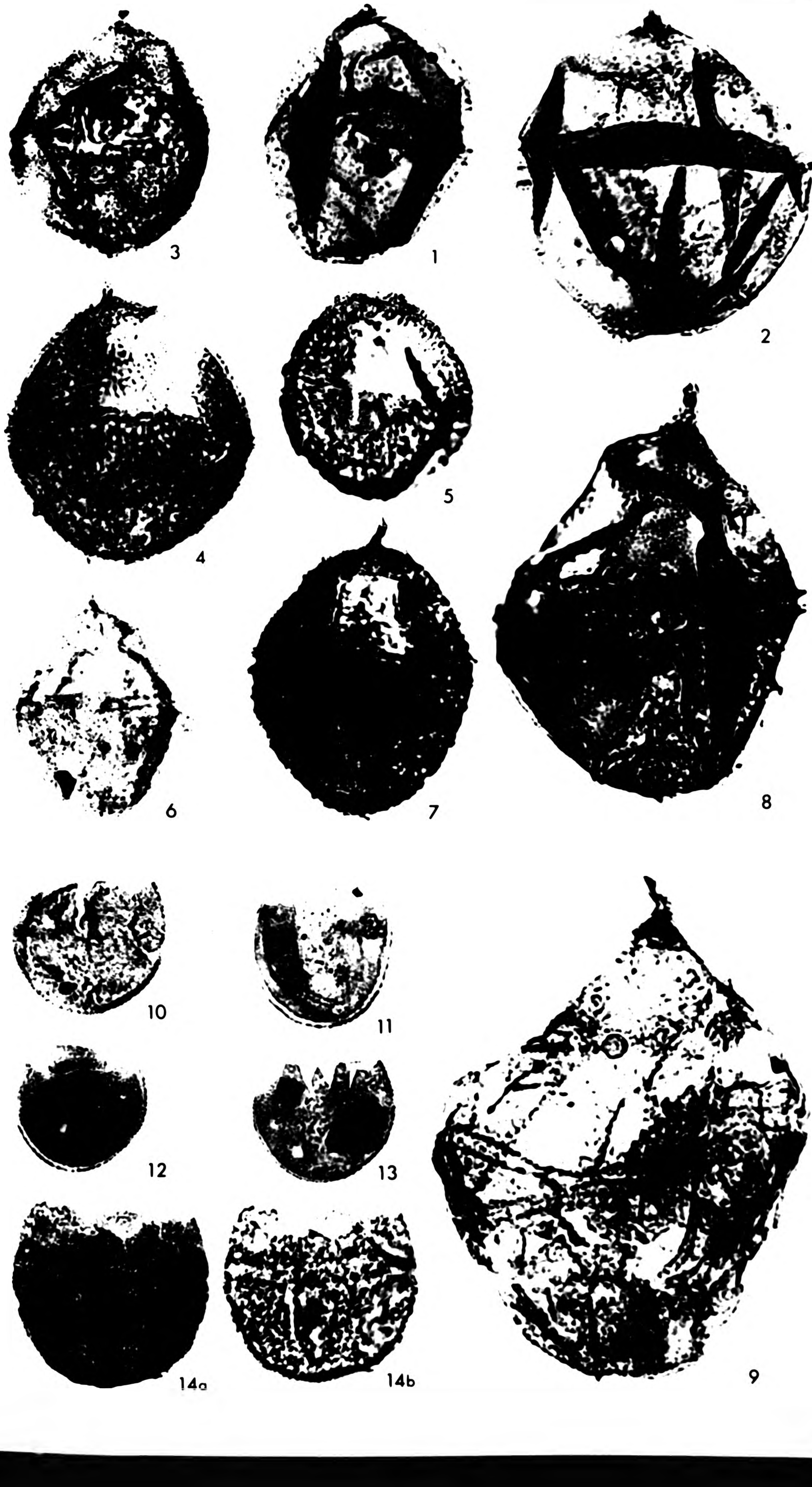


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PLATE 5

Figs

1-5 Belodinium asaphum Drugg, 1978

1. Br.669a; 035/1398 (C364)(b*)   2. Br.443a; 180/1232 (S534)
3. Br.554a; 190/1444 (T323)   4. Br.443a; 070/1486 (G270)
5. Br.554a; 220/1329 (W443)

6 Belodinium cf. dysculum Cookson & Eisenack, 1960

6. Br.313a; 165/1290 (R481)

7-9 Caligodinium halosa (Filatoff, 1975) Woollam, 1977

7. WB58a; 095/1442 (K341)   8. WB118a; 180/1382 (S380)
9. Br.481a; 295/1405 (V361)

10-12 Chlamydophorella sp.B

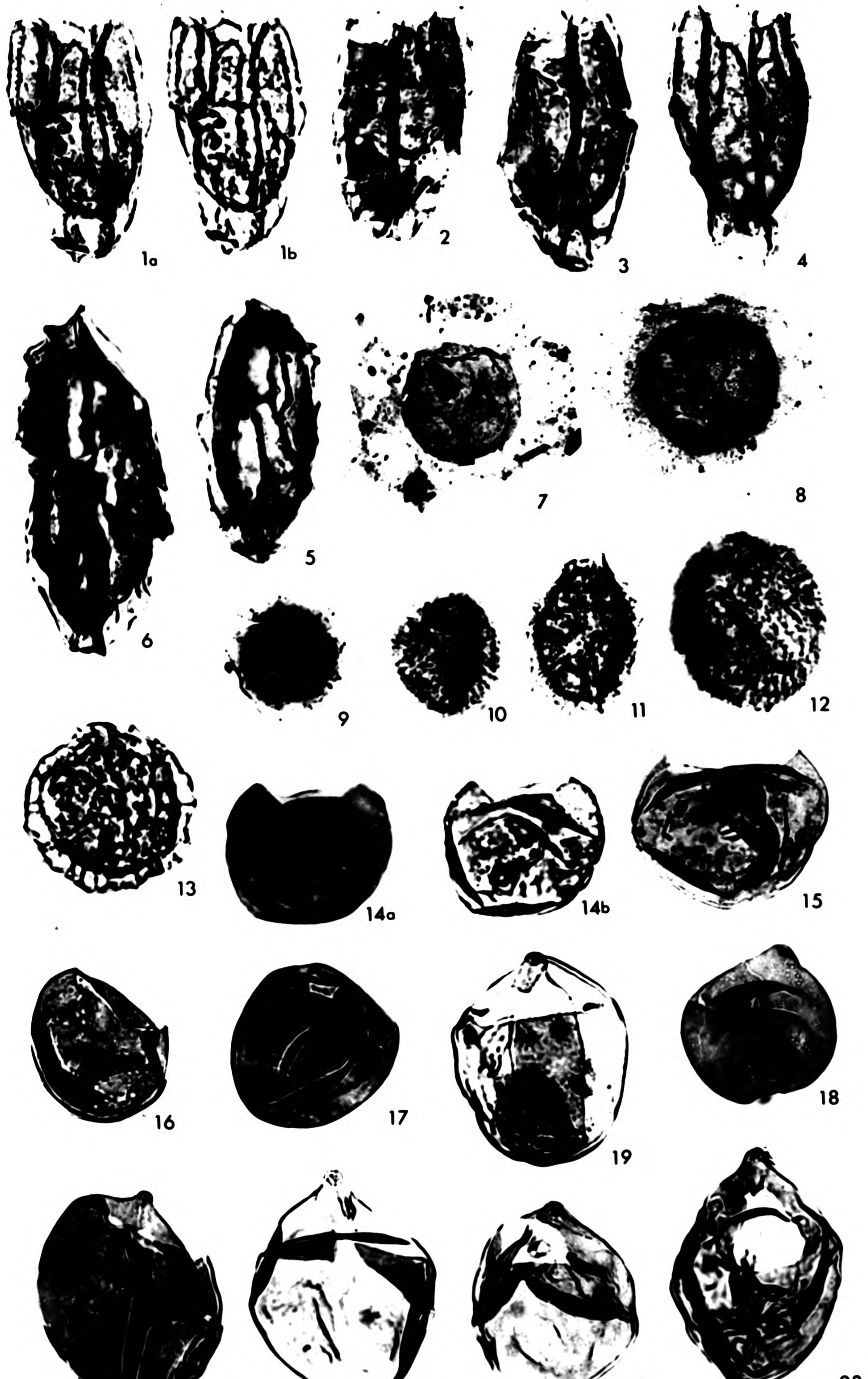
10. Br.1723a; 080/1328 (G441)   11. Br.963a; 120/1187 (M580)
12. Br.1605a; 045/1350 (D410)

13 Chlamydophorella sp.A

13. Br.246a; 205/1380 (V380)*

14-23 Chytroeisphaeridia chytroeides (Sarjeant, 1962a) Downie & Sarjeant, 1964

14. Br.1531a; 050/1255 (G510)(b*)   15. WB.123a; 125/1433 (M333)
16. WB.33a; 145/1299 (P470)   17. Br.963a; 130/1217 (N550)
18. Br.851a; 150/1543 (P222)   19. Br.963a; 145/1206 (P561)
20. Br.985a; 135/1266 (N503)   21. Br.963a; 210/1371 (V393)
22. Br.963a; 105/1208 (K563)   23. Br.963a; 070/1329 (G430)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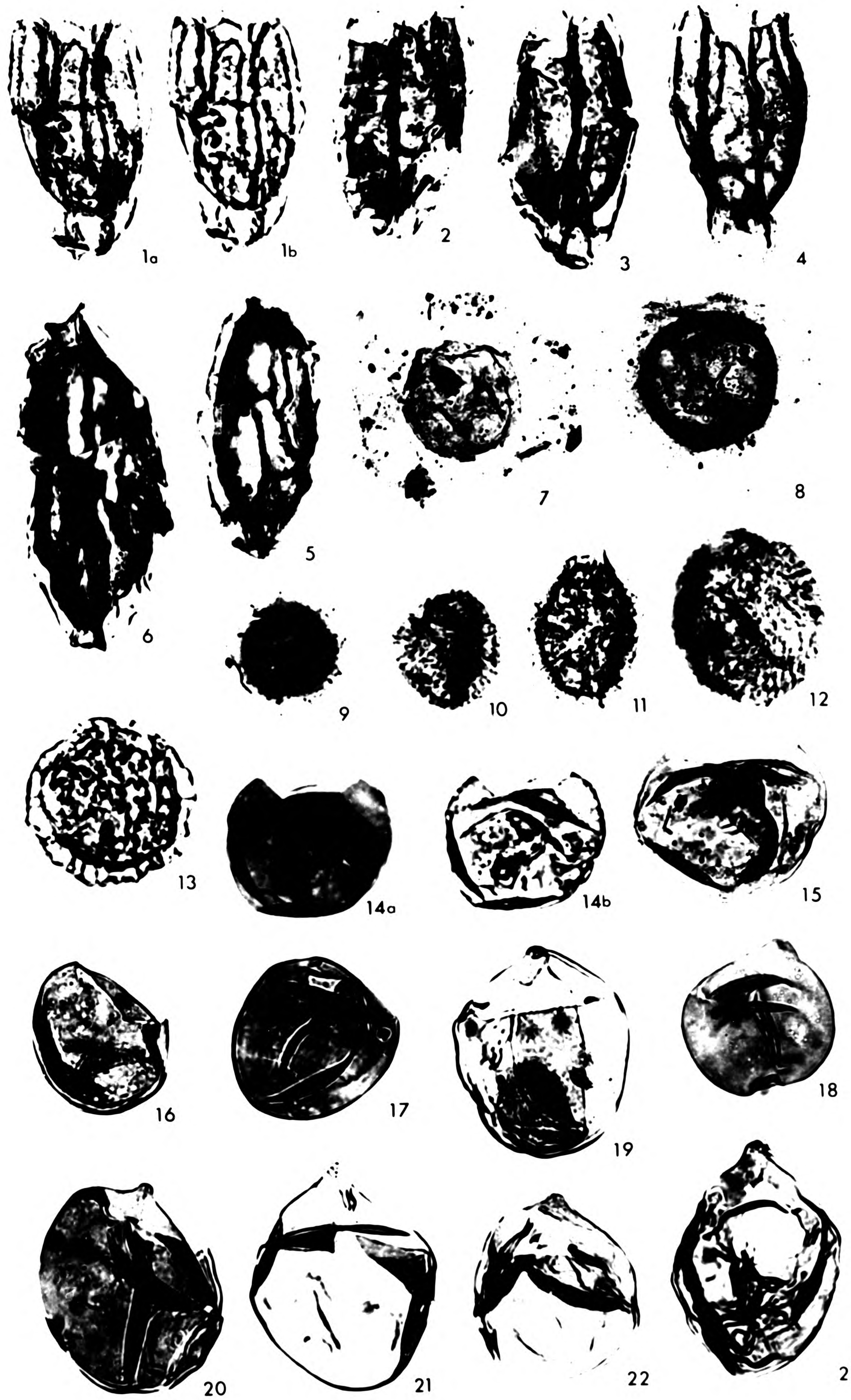

PLATE 6

Figs

1,2 Chytroeisphaeridia cerastes Davey, 1979

1. Br.246a; 125/1332 (M434) 2. Br.246a; 105/1391 (L372)

3-8 Chytroeisphaeridia mantellii Gitmez & Sarjeant, 1972

3. WB.33a; 110/1358 (L402) 4,8* Br.1006a; 100/1226 (K540)

5. Br.1552a; 100/1268 (K500)9b*) 6. Br.1723a; 080/1231 (H532)

7. Br.1307a; 190/1443 (T323)

9-11 Cleistosphaeridium ehrenbergii (Deflandre, 1947) Davey et.al. 1969

9. WB.128a; 170/1350 (R410) 10. Br.693a; 160/1242 (Q524)

11. Br. 560a; 200/1289 (U483)

12,13 Cleistosphaeridium lumectum (Sarjeant, 1960a) Davey et.al. 1969

12. Br.500a; 145/1451 (P311) 13. Br.820a; 110/1344 (L420)

14-17 Cleistosphaeridium polytrichum (Valensi, 1947) Davey et.al, 1969

14. Br.976a; 115/1227 (M540) 15. WB88a; 190/1298 (T470)

16. WB.133a; 110/1394 (L373) 17. WB.58a; 100/1435 (K331)

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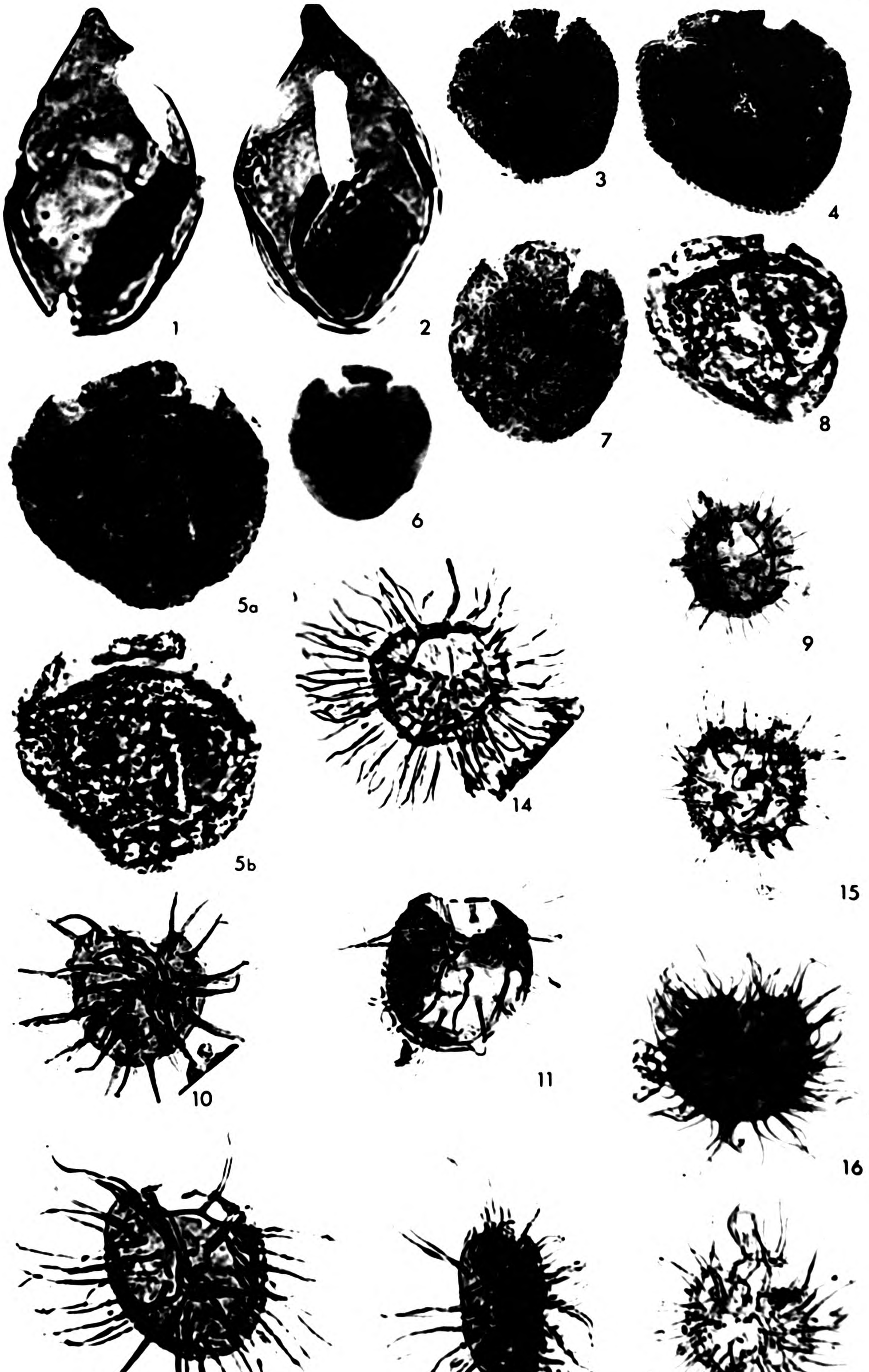

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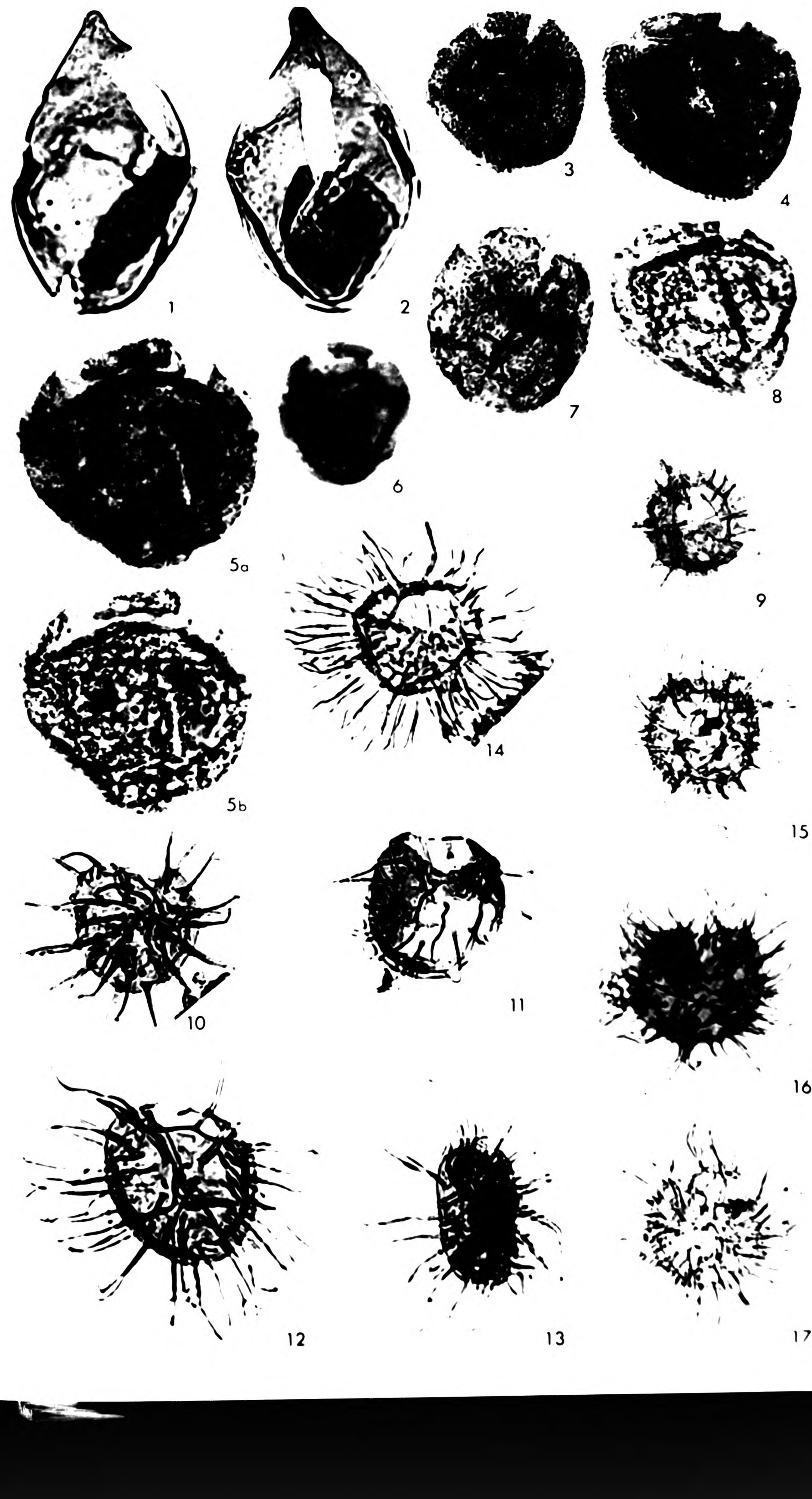

PLATE 7

Figs

1 Cleistosphaeridium polytrichum (Valensi, 1947) Davey et.al. 1969

1. Br.985a; 150/1240 (P520)

2-4 Cleistosphaeridium tribuliferum (Sarjeant, 1962a) Davey et.al. 1969

2. Br.916a; 085/1423 (H340) 3. WB108a; 135/1392 (O372)

4. Br.605a; 070/1346 (G421)

5-7 Compositosphaeridium costatum (Davey & Williams, 1966) Dodekova, 1974

5. Br.292a; 205/1452 (V310)* 6. Br.851a; 165/1542 (Q234)

7. WB.43a; 220/1287 (W480)

8-11 Cribroperidinium granuligerum (Klement, 1960) Stover & Evitt, 1978

8. WB.211a; 136/1261 (N504) 9. Br.170a; 170/1243 (R524)

10. Br.313a; 135/1420 (O342) 11. Br.194a; 150/1430 (P330)

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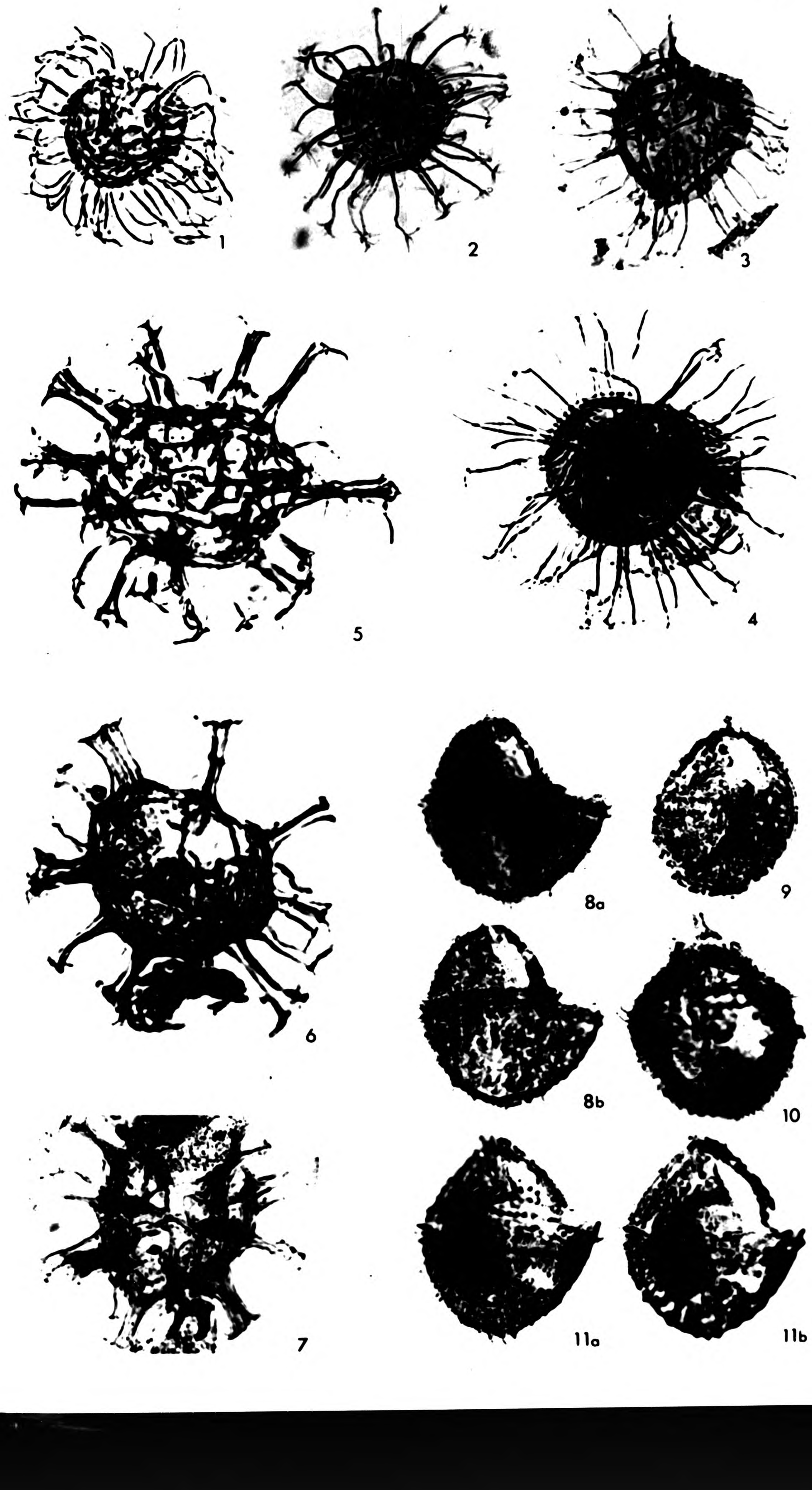

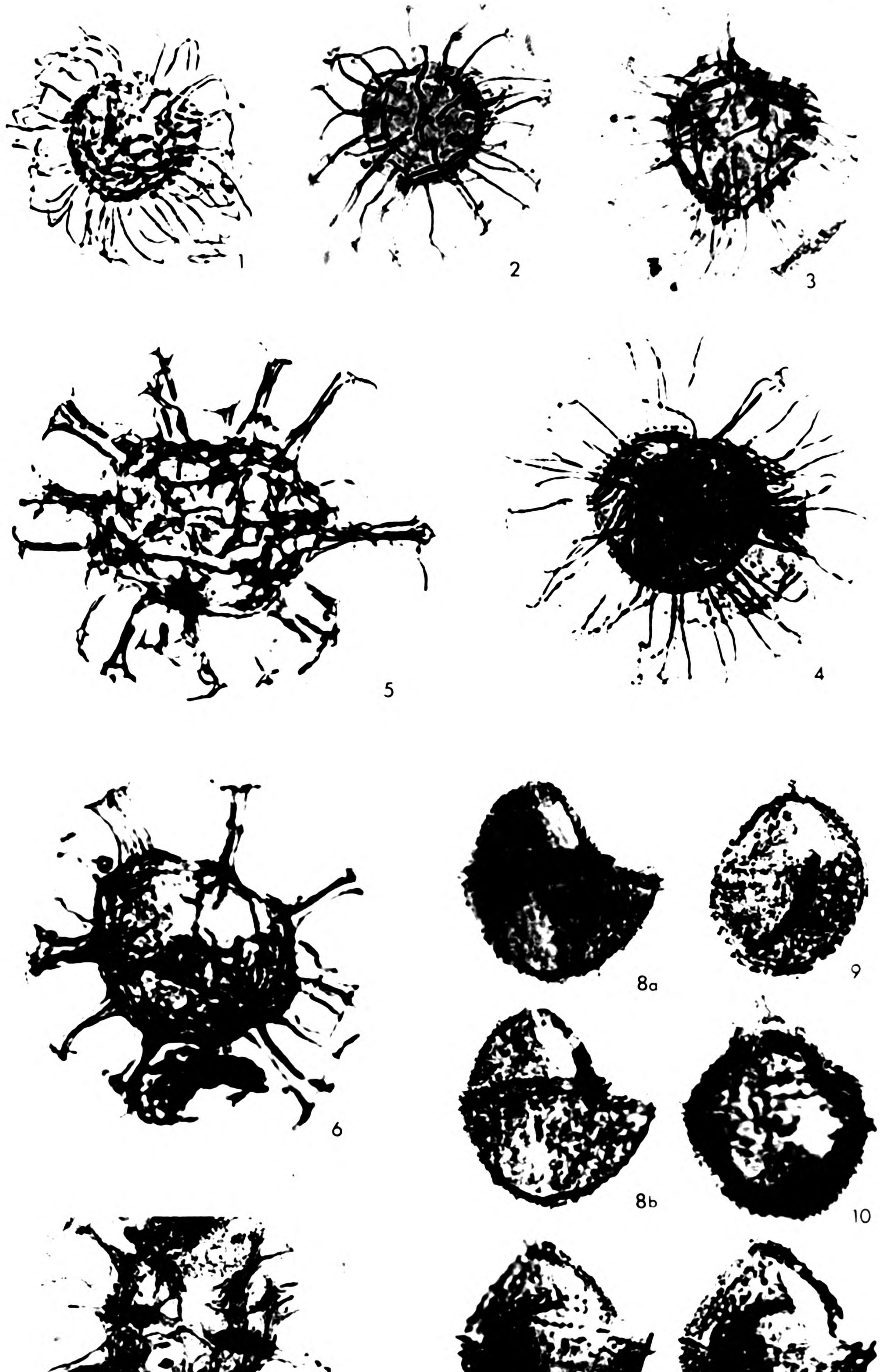
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PLATE 8

Figs

1-4 Ctenidodinium continuum Gocht, 1970

1. Br.1006a; 135/1240 (N524) 2. WB.133a; 160/1362 (Q400)

3. WB.128a; 085/1354 (H413) 4. Br.916a; 025/1201 (B564)

5-8 Ctenidodinium ornatum (Eisenack, 1935) Deflandre, 1938

5. Br.1155a; 090/1406 (J352)* 6. Br.582a; 080/1202 (H562)

7. Br.1155a; 170/1390 (R370) 8. WB.88a; 175/1237 (R533)

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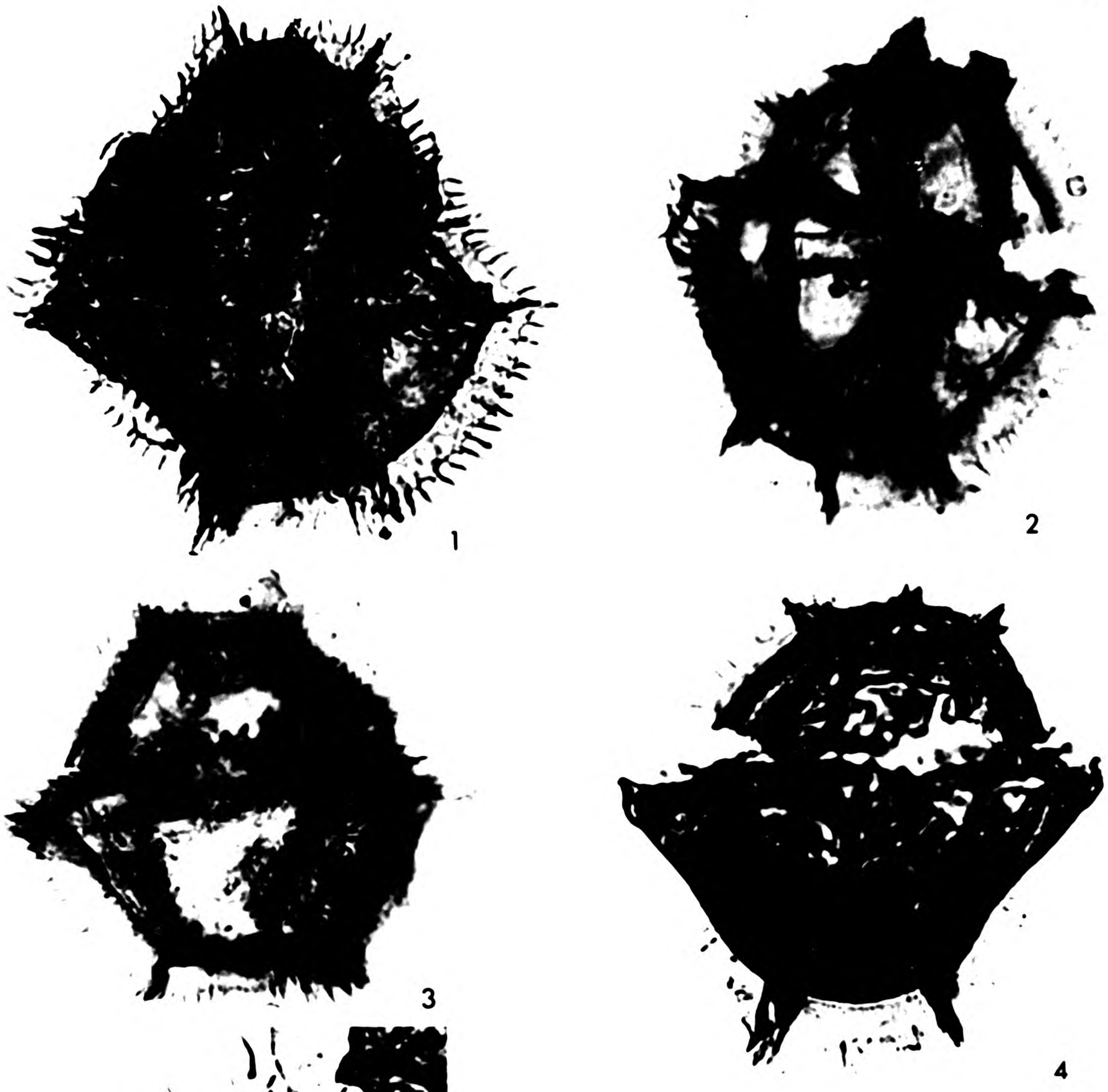

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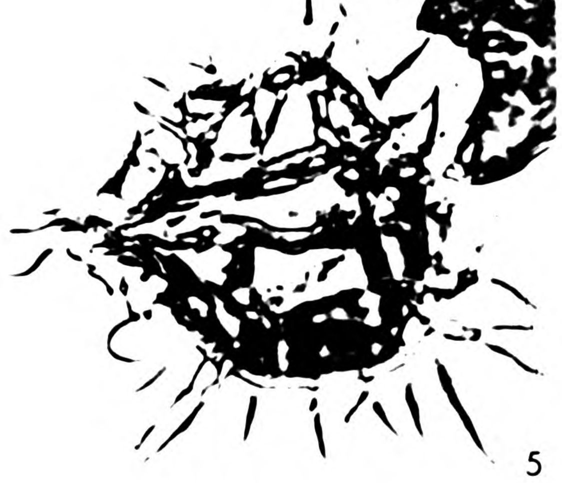

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PLATE 9

Figs

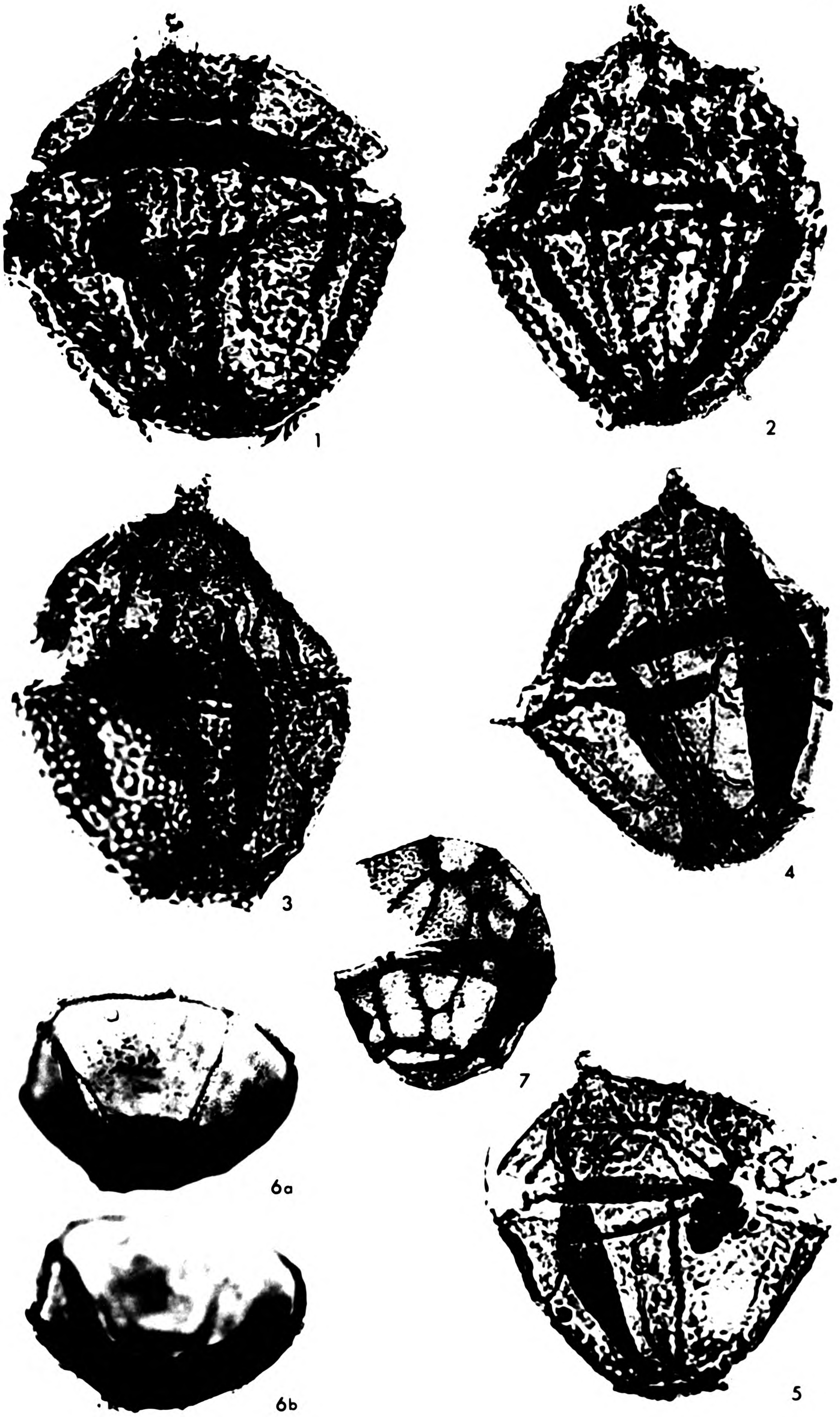
1-6 Ctenidodinium pachydermum (Deflandre, 1938) Gocht, 1970

1. Br.481a; 210/1424 (V341)
2. Br.560a; 110/1303 (L460)
3. Br.560a; 045/1370 (D392)
4. Br.560a; 140/1351 (O410)
5. Br.560a; 045/1450 (D314)
6. WB.203(2)a; 118/1378 (M382)

7 Ctenidodinium sp.A

7. Br.340a; 150/1472 (P290)

t, 1970
/1303 (L460)
/1351 (O410)
118/1376 (M362)



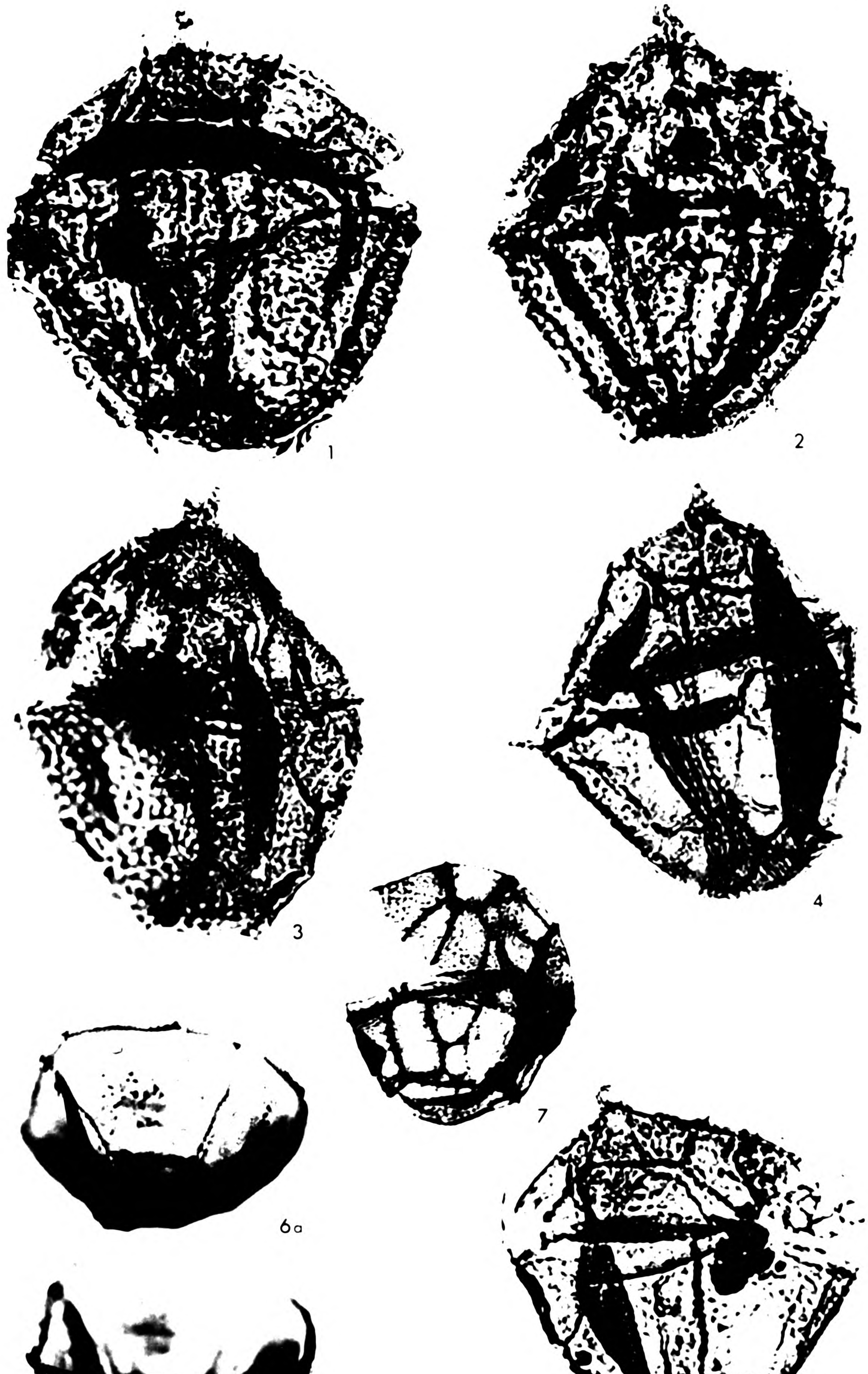

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PLATE 10

Figs

1-6 Dinopterygium absidatum Drugg, 1978

1. Br.683a; 130/1260 (N511)
2. Br.669a; 200/1277 (U493)
3. Br.246a; 160/1237 (Q534)
4. Br.313a; 140/1305 (O460)
5. Br.683a; 070/1500 (G260)*
6. Br.669a; 205/1268 (V500)

7-9 Ellipsoidictyum cinctum Klement, 1960

7. WB.223a; 127/1431 (N331)
8. WB128a; 175/1396 (S371)
9. WB.118a; 089/1343 (J421)

10-13 Ellipsoidictyum reticulatum (Valensi, 1953) Lentin & Williams, 1977

10. Br.976a; 145/1289 (O483)
11. Br.455a; 065/1405 (F360)
12. Br.543a; 115/1328 (L443)
13. Br.481a; 180/1379 (S384)

14-16 Ellipsoidictyum cf.gochtii Fensome, 1979

14. Br.115a; 090/1216 (J550)
15. Br.115a; 100/1340 (K420)
16. Br.947a; 065/1322 (F440)(b*)

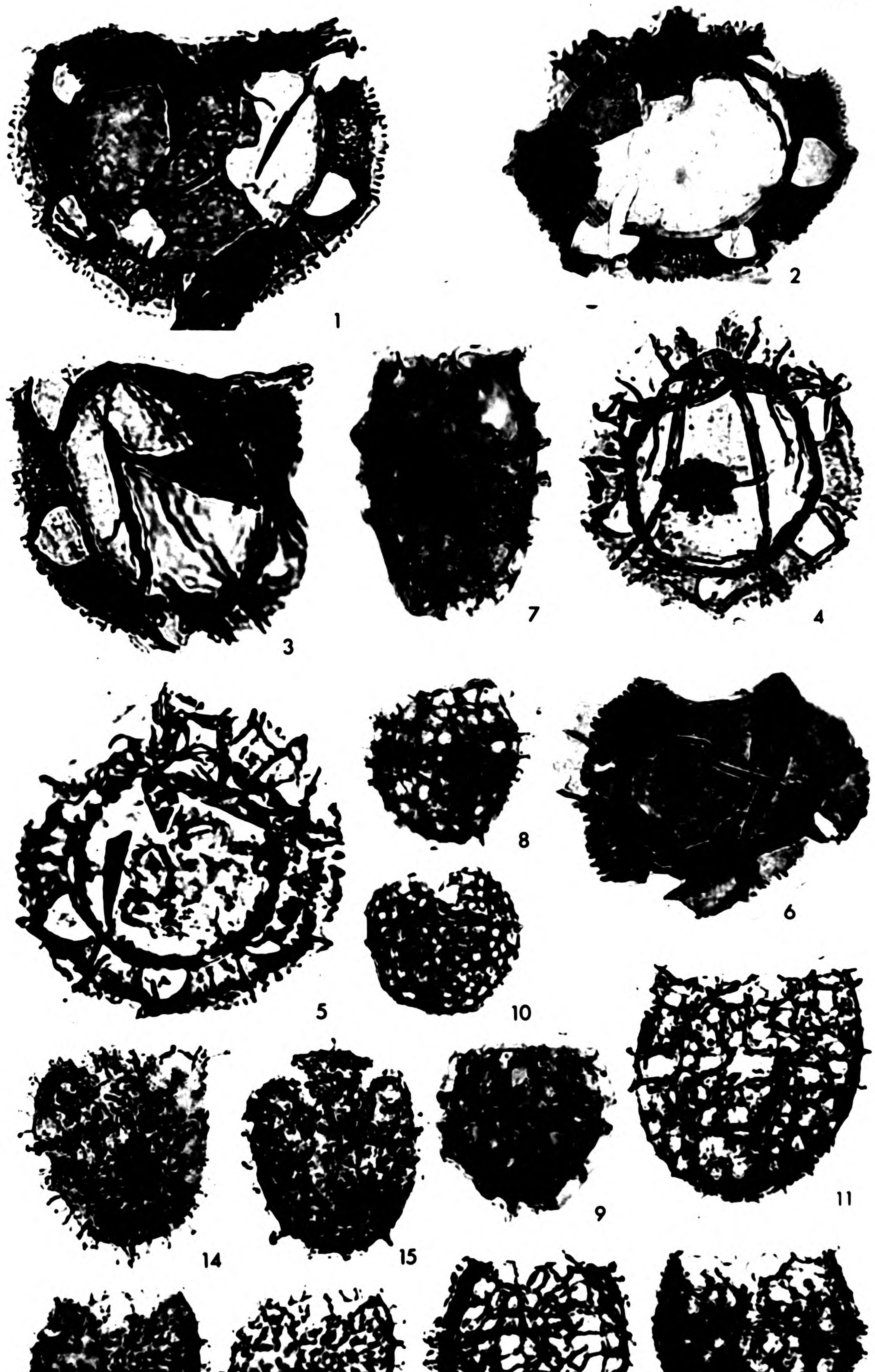
)0/1277 (U493)
40/1305 (O460)
)5/1268 (V500)

5/1396 (S371)

atin & Williams,

065/1405 (F360)
180/1379 (S384)

100/1340 (K420)



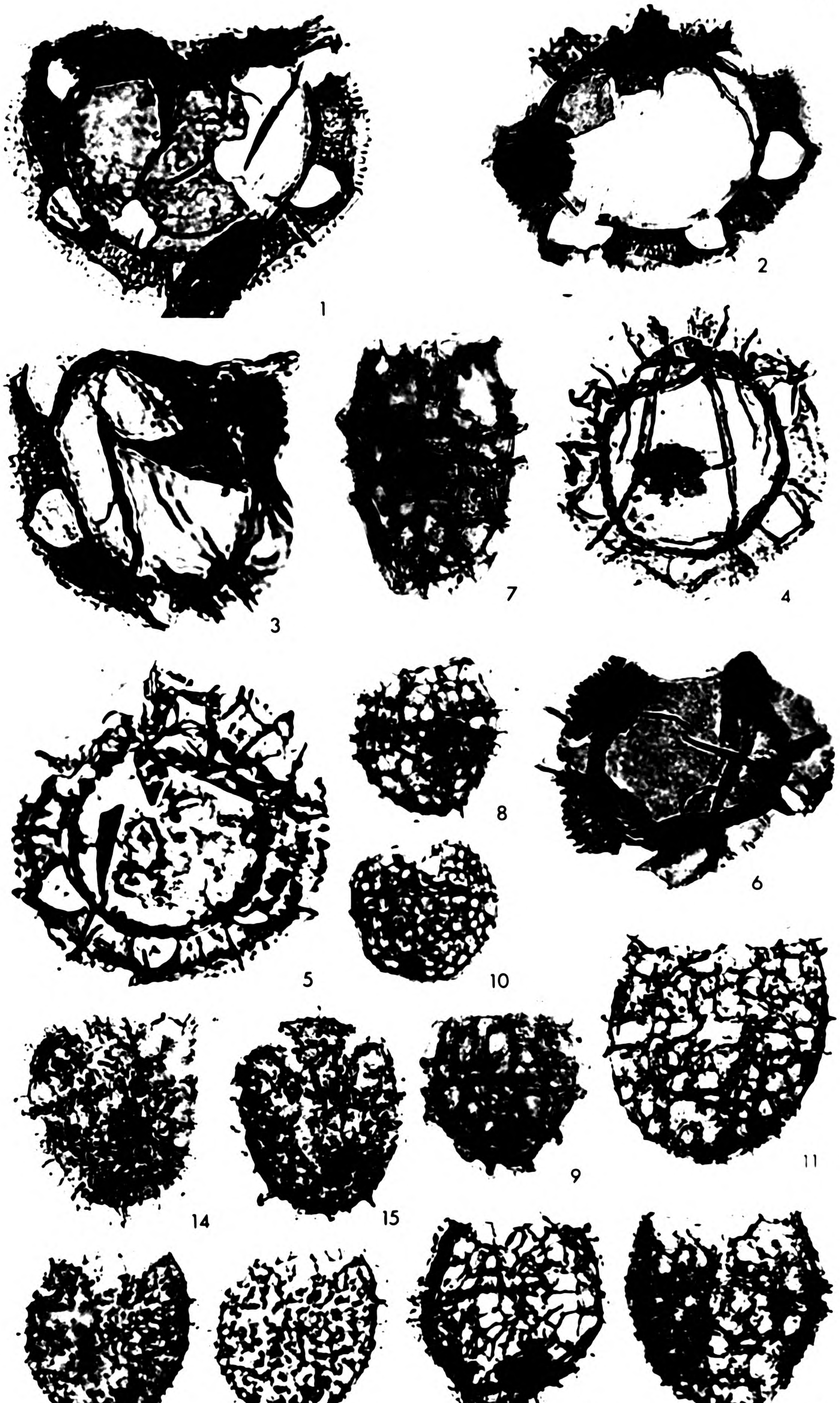


PLATE 11

Figs

1-6 Gonyaulacysta jurassica (Deflandre, 1938) Norris & Sarjeant, 1965

1. WB.88a; 158/1192 (Q583) 2. WB.123a; 062/1403 (F360)
3. Br.963a; 215/1235 (W530) 4. WB.68a; 090/1332 (J432)
5. WB.148a; 055/1390 (E370) 6. WB88a; 098/1468 (K290)

7-10 Gonyaulacysta jurassica (Deflandre, 1938) Norris & Sarjeant, 1965 var. longicornis (Deflandre, 1938) Lentin & Williams, 1973

7. Br.710a; 115/1210 (M560) 8. Br.753a; 135/1292 (N474)
9. WB.68a; 150/1233 (P530) 10. WB.68a; 165/1472 (R291)

11-13 Heslertonia teichophera (Sarjeant, 1961a) Sarjeant, 1976b

11. Br.246a; 150/1284 (P480) 12. Br.976a; 220/1313 (W450)
13. WB.68a; 185/1376 (T391)

14 Gonyaulacysta jurassica (Deflandre, 1938) Norris & Sarjeant, 1965

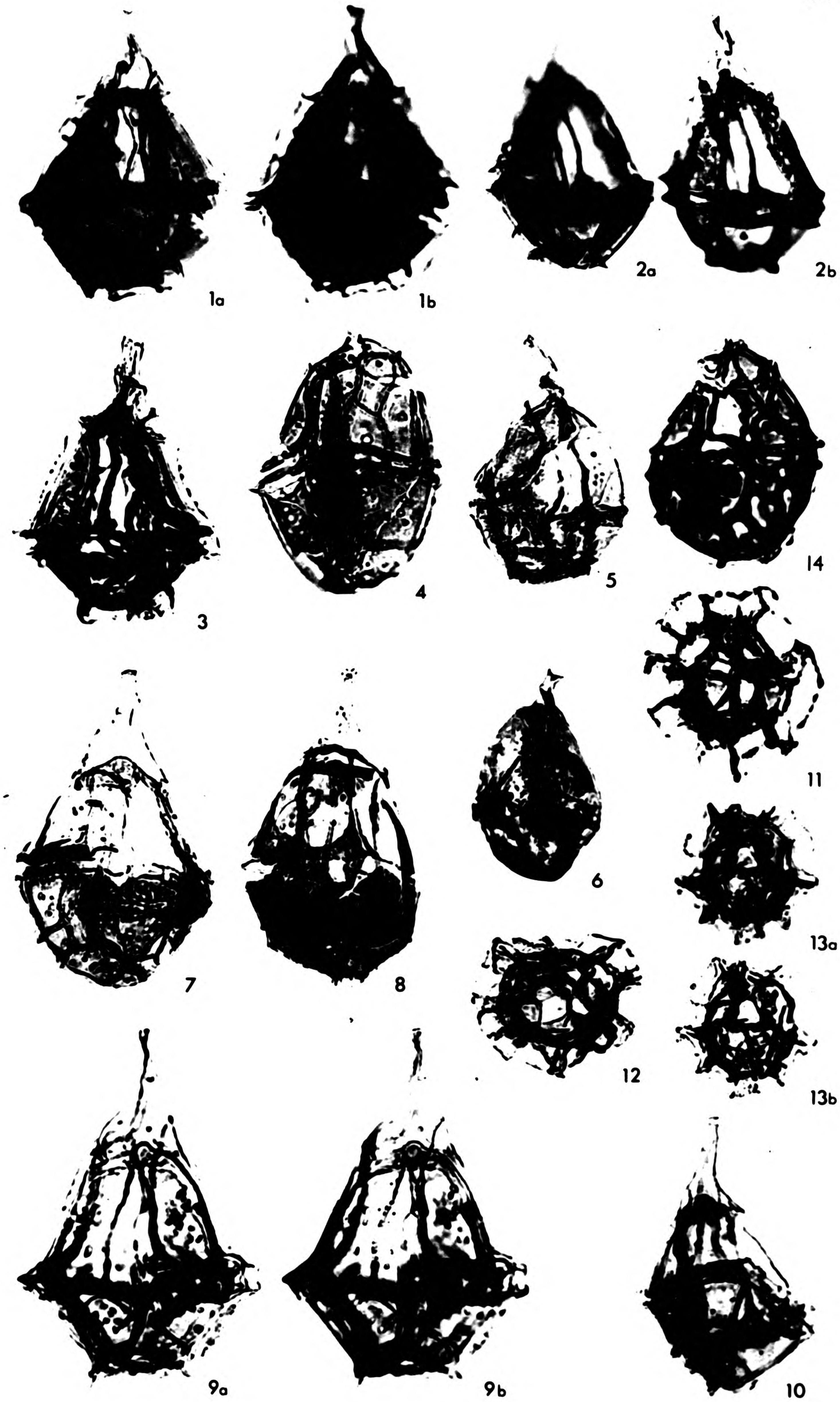
14. Br.246a; 160/1346 (Q420)

rjeant, 1965
(F360)
(J432)
K290)

rjeant, 1965
1973
(N474)
(R291)

976b
3 (W450)

rjeant, 1965



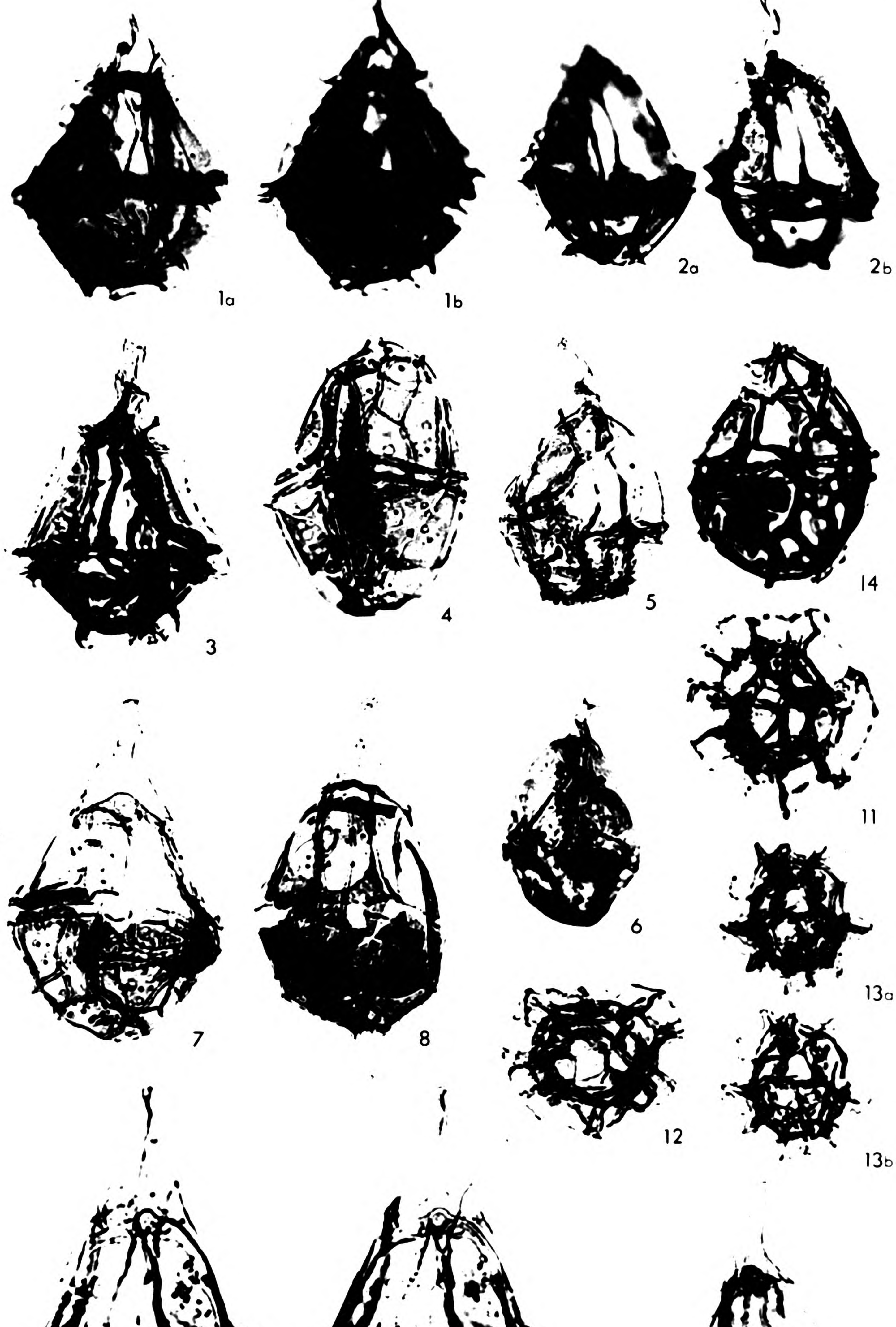

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PLATE 12

Figs

1,2 Heslertonia teichophera (Sarjeant, 1961a) Sarjeant, 1976b

1,2. WB128a; 177/1347 (S412)

3-6 Hystrichodinium pulchrum Deflandre, 1935

3. Br.884a; 210/1439 (V320)
4. Br.1399a; 225/1297 (X470)
5. WB.128a; 180/1412 (S353)
6. WB.53a; 060/1234 (F532)

7-9 Hystrichogonyaulax cladophora (Deflandre, 1938) Stover & Evitt, 1978

7. Br.710a; 120/1339 (M433)
8. Br.710a; 090/1307 (J460)
9. Br.916a; 140/1388 (O374)

10,11 Hystrichogonyaulax warboysensis sp.nov.

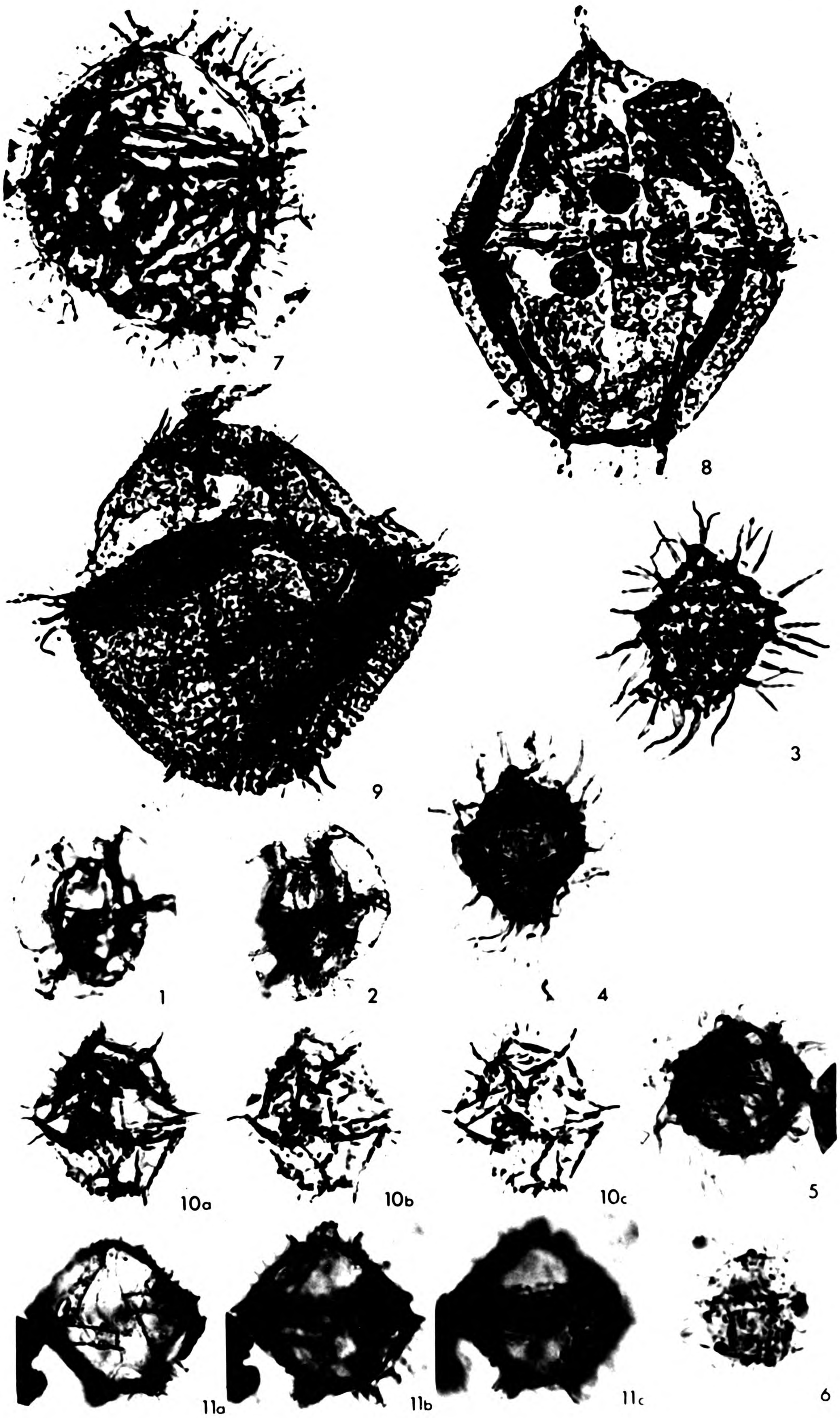
10. Br.1307a; 185/1389 (T370)(b,c*)
11. WB.128a; 057/1351 (E414) Holotype

t, 1976b

/1297 (X470)
234 (F532)

tover & Evitt,

1307 (J460)



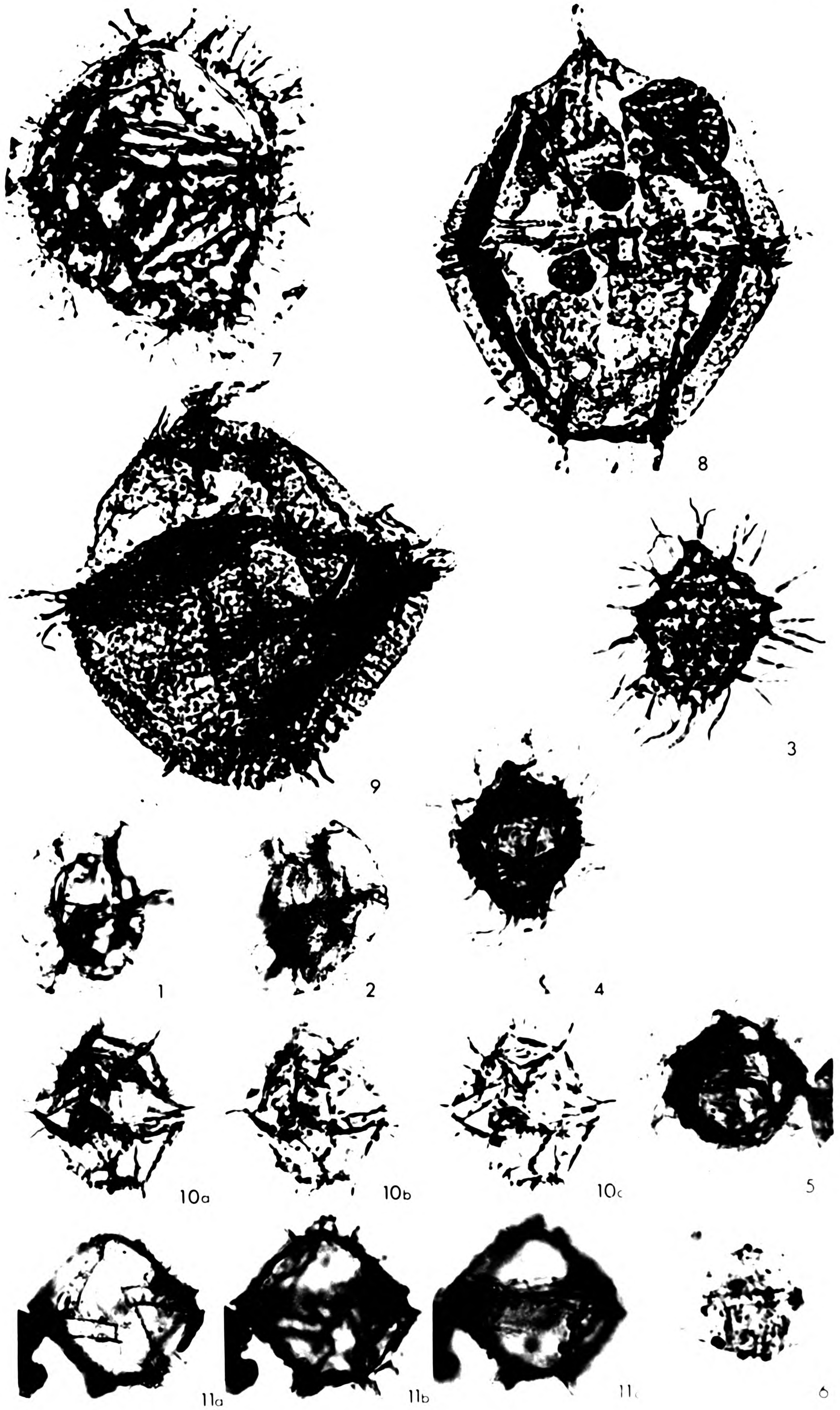

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PLATE 13

Figs

1 Hystrichogonyaulax warboysensis sp.nov.

1. Br. 1330a; 130/1323 (N440)(b,c*)

2,3 Hystrichosphaerina orbifera (Klement, 1960) Stover & Evitt, 1978

2. Br.170a; 190/1287 (T480)* 3. Br.214a; 175/1454 (R304)

4-6 Kalyptea stegasta (Sarjeant, 1961a) Wiggins, 1975

4. Br.1880a; 155/1263 (Q502) 5. Br.1354a; 170/1276 (R490)
6. Br.465a; 045/1257 (D410)

7-9 Kalyptea globulus sp.nov.

7. Br.727a; 095/1296 (J473) Holotype
8. Br.785a; 175/1263 (S500) 9. Br.727a; 210/1259 (V513)

10-15 Kylindrocysta reticulata sp.nov.

10. Br.963a; 025/1269 (B503)(a*) 11. Br.1833a; 140/1363 (O400)
12. Br.976a; 200/1465 (U294)(a*) Holotype
13. Br.627a; 020/1460 (B300)(a*) 14. Br.1833a; 120/1370 (M390)
15. Br.851a; 215/1359 (W402)

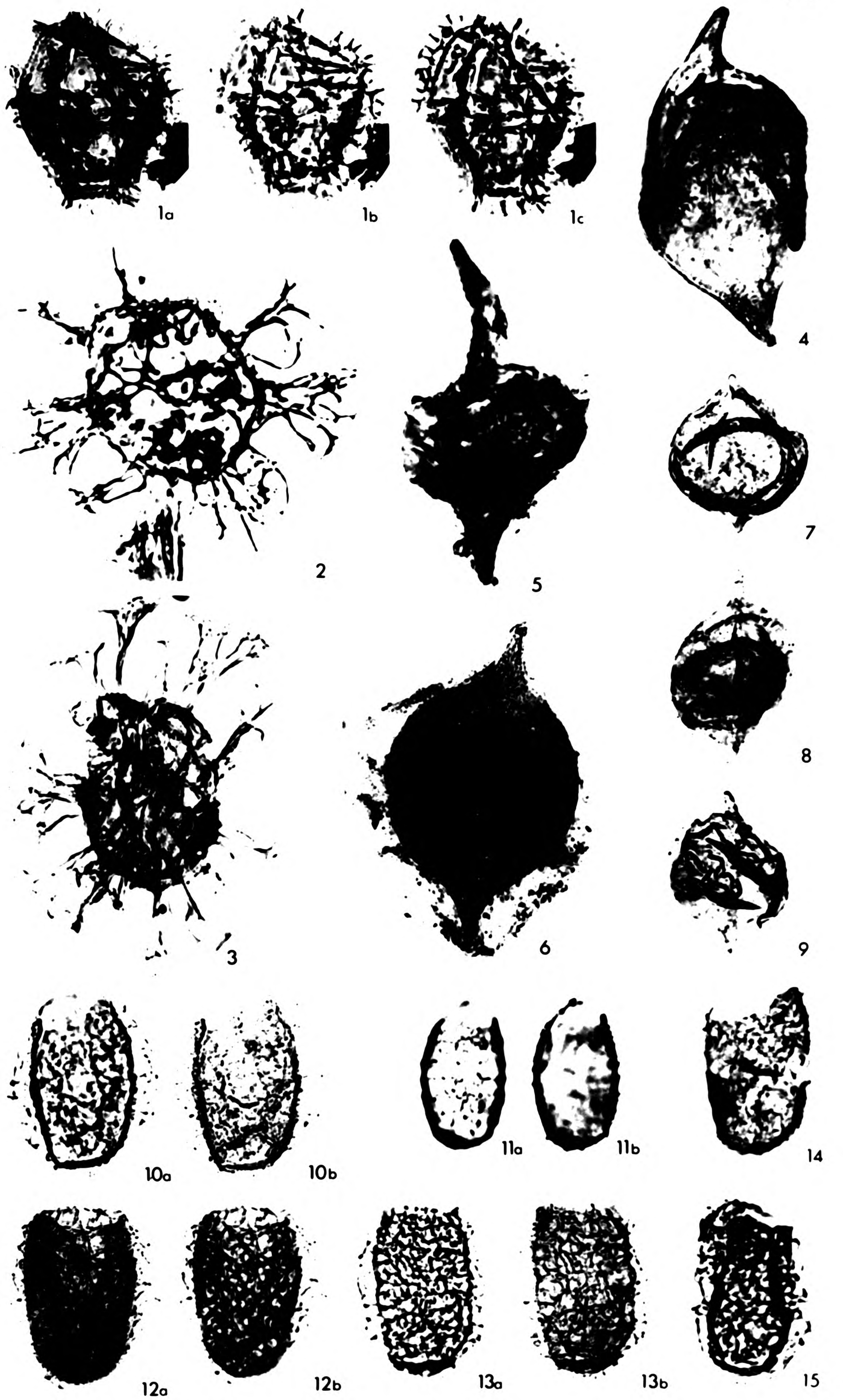
r & Evitt, 1978
1454 (R304)

/1276 (R490)

1259 (V513)

0/1363 (O400)

0/1370 (M390)



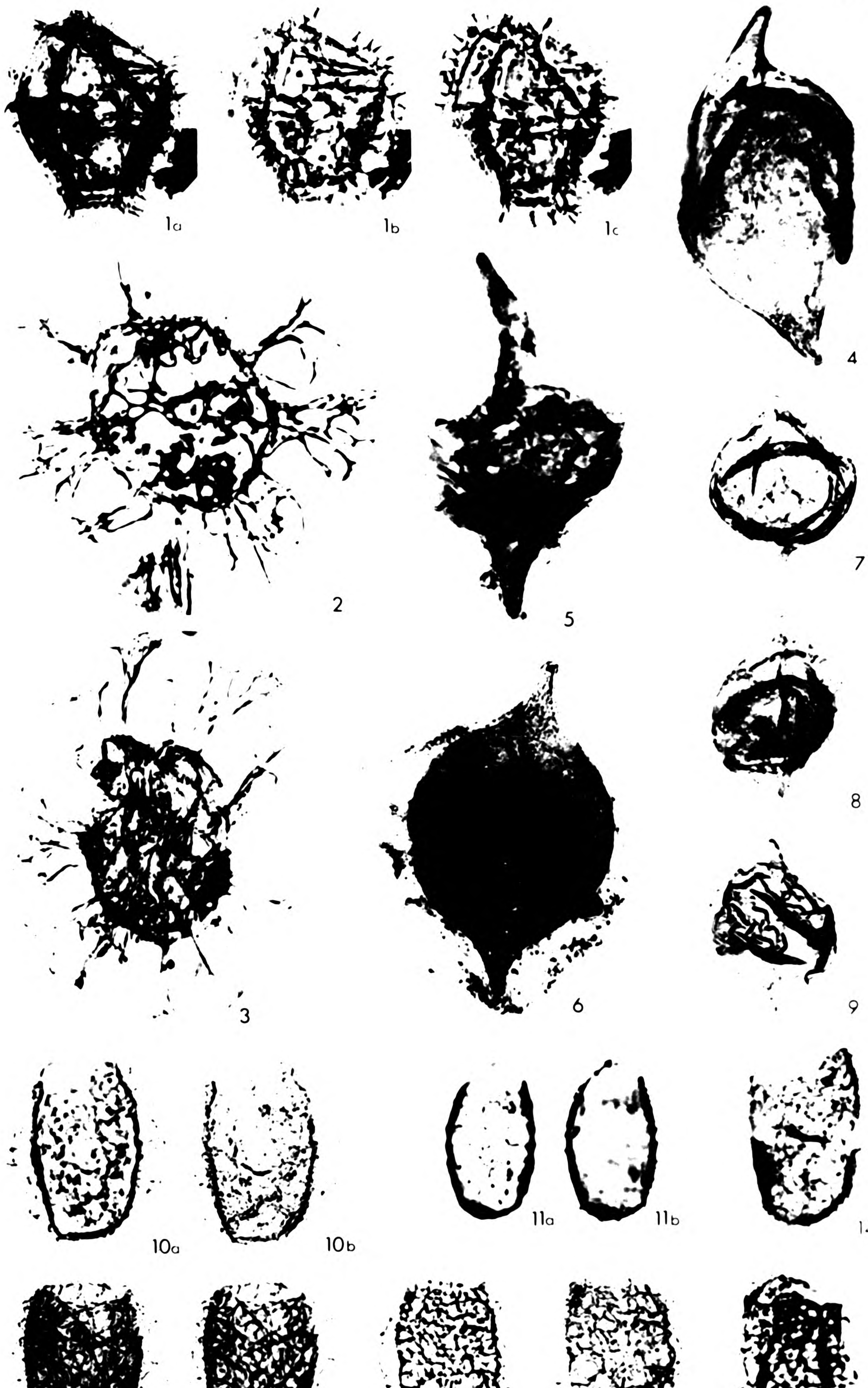

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PLATE 14

Figs

1-3 Leptodinium gongylos (Sarjeant, 1966a) Stover & Evitt, 1978
1. Br.429a; 155/1472 (P280) 2. WB.58a; 145/1272 (P492)
3. Br.395a; 120/1400 (M360)

4 Leptodinium miriabile Klement, 1960
4. Br.246a; 080/1392 (H370)(b,c*)

5,6 ?Leptodinium sp.
5. Br.194a; 095/1400 (J364) 6. Br.465a; 165/1300 (Q473)

7-10 Lithodinia jurassica Eisenack, 1935 emend. Gocht, 1975
7. WB.224a; 044/1323 (D440) 8. WB.224a; 194/1460 (T303)
9. WB.218a; 108/1278 (L491) 10. Br.1813a; 075/1213 (H552)

11-15 Lithodinia pocockii (Sarjeant, 1968) Davey, 1979
11. Br.976a; 200/1456 (U300) 12. Br.1486a; 155/1240 (Q531)(b*)
13. Br.1723a; 075/1430 (F330) 14. Br.1220a; 115/1419 (L344)
15. Br.1354a; 220/1350 (W410)(b*)

Evitt, 1978
1272 (P492)

/1300 (Q473)

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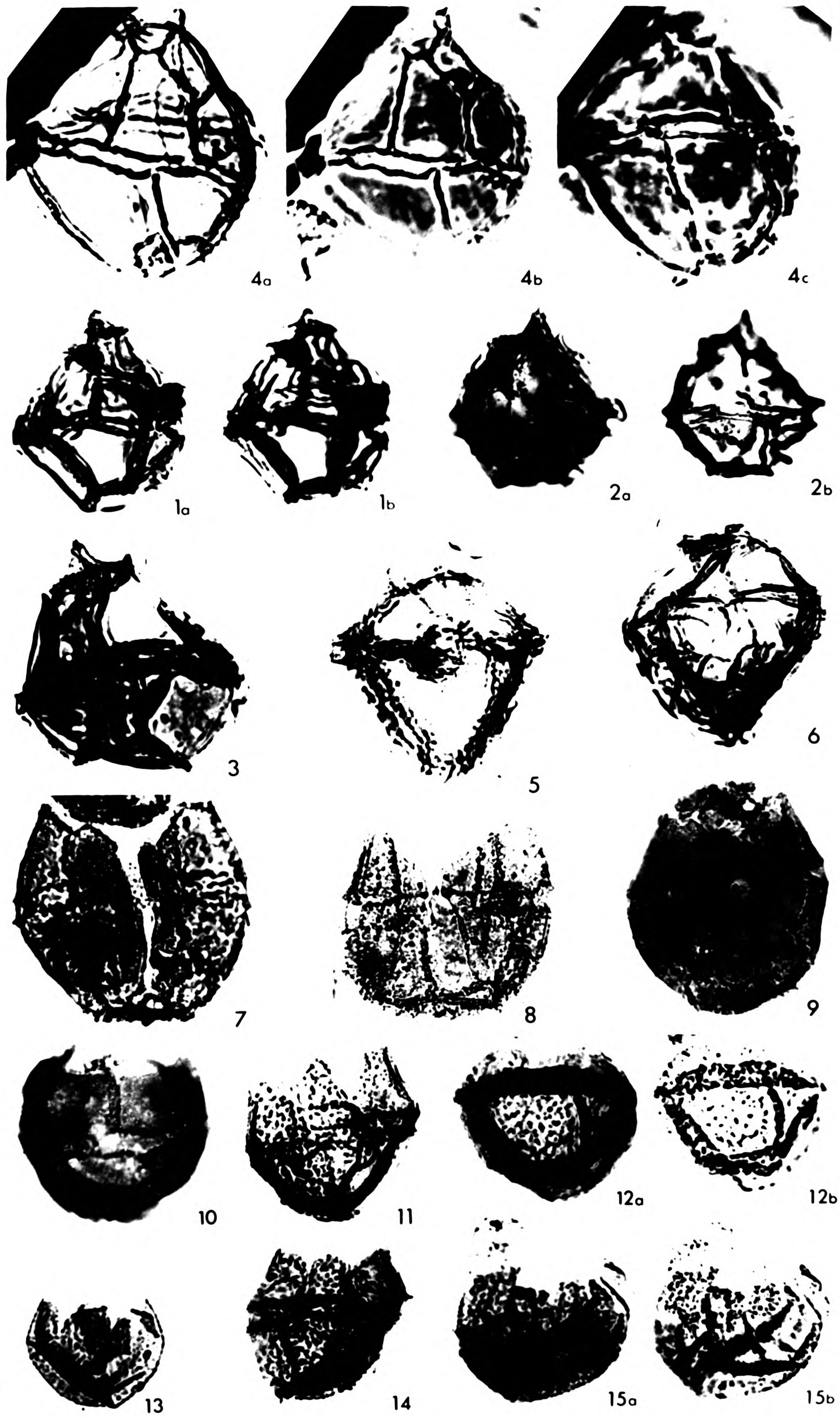
/1460 (T303)
075/1213 (H552)

155/1240 (Q531)(b*)
115/1419 (L344)



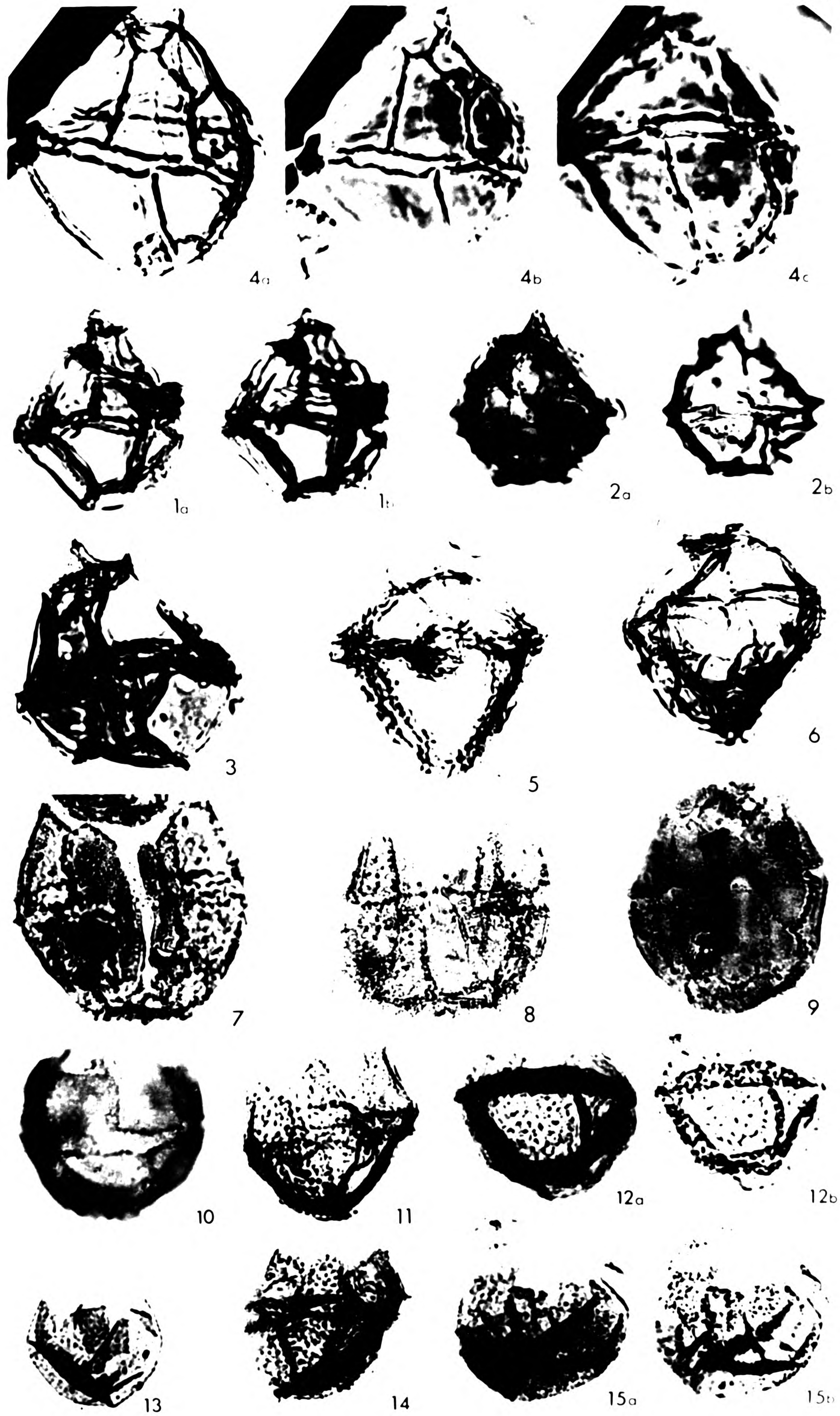

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PLATE 15

Figs

1 <u>Meiourogonyaulax caytonensis</u> (Sarjeant, 1959) Sarjeant, 1969
1. WB.224a; 033/1190 (C580)

2,3 <u>Meiourogonyaulax cristulata</u> (Sarjeant, 1959) Sarjeant, 1969
2. WB.224a; 045/1356 (D410) 3. Br.1833a; 145/1229 (P541)

4-11 <u>Meiourogonyaulax decapitata</u> (W.Wetzel, 1966) Sarjeant, 1969
4. Br.653a; 115/1355 (M411) 5. Br.554a; 160/1445 (Q312)
6. Br.963a; 100/1463 (K292) 7. Br.742a; 205/1242 (V522)
8. Br.985a; 195/1475 (U282) 9. Br.395a; 055/1463 (F292)
10. Br.560a; 160/1229 (Q540) 11. Br.985a; 220/1265 (W503)

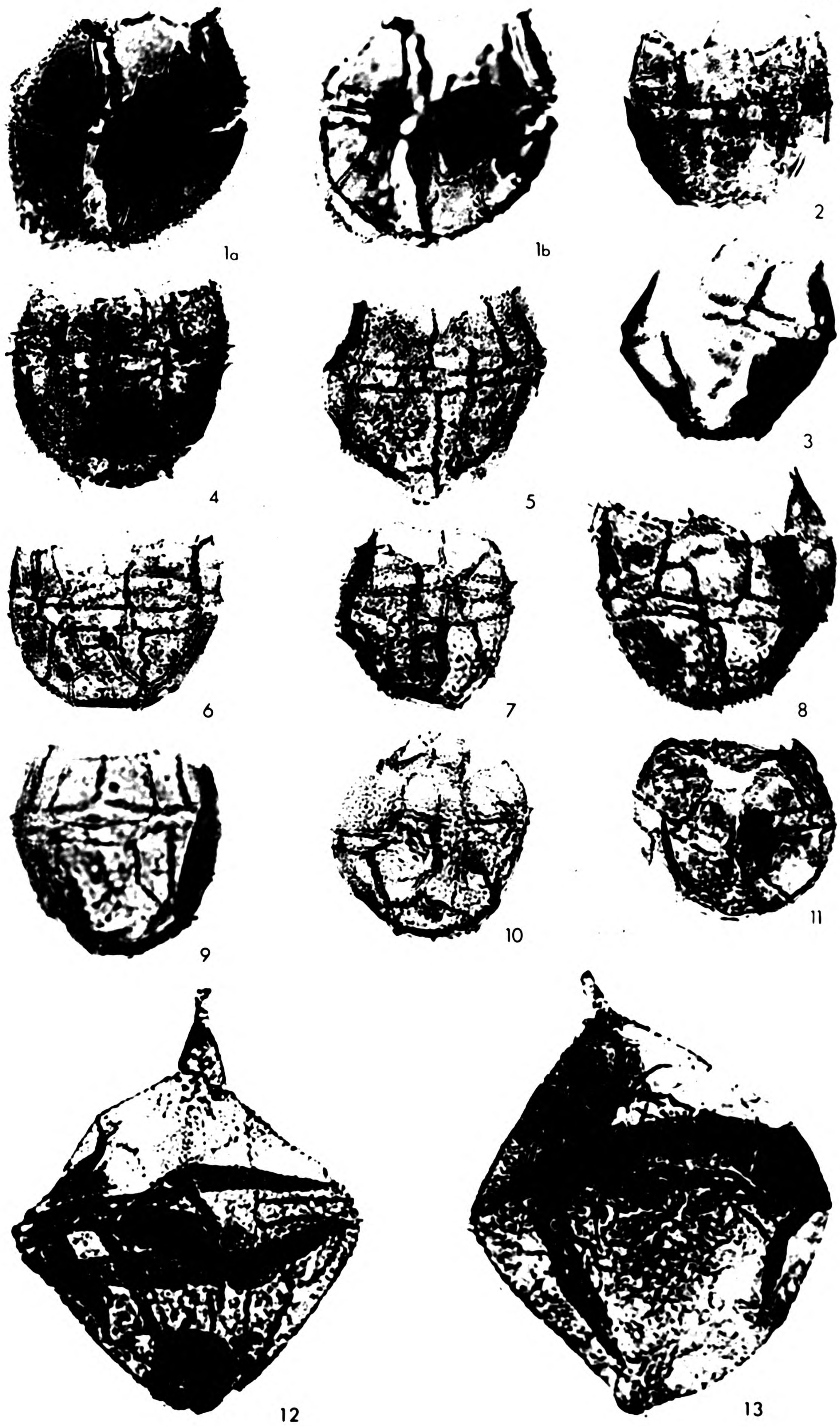
12,13 <u>Millioudodinium</u> sp.
12. Br.465a; 085/1465 (H303) 13. Br.727a; 125/1423 (N341)

arjeant, 1969

arjeant, 1969
145/1229 (P541)

arjeant, 1969
60/1445 (Q312)
05/1242 (V522)
55/1463 (F292)
220/1265 (W503)

125/1423 (N341)



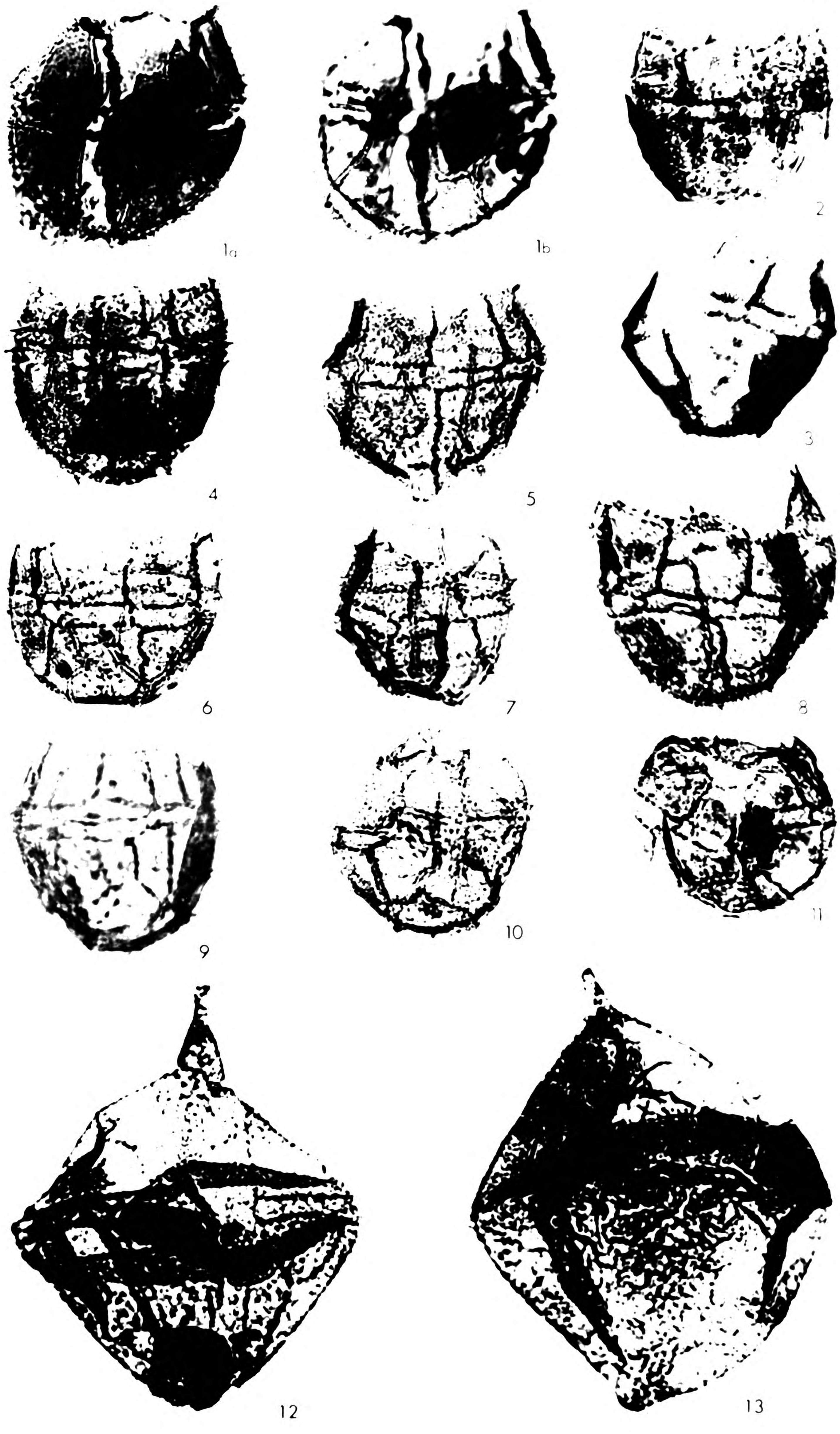

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PLATE 16

Figs

1-3 Palaeostomocystis tornatilis Drugg, 1978
1. WB.28a;147/1342 (P420) 2. WB.48a; 028/1331 (B434)
3. WB.83a; 090/1240 (J531)

4,5 Paragonyaulacysta calloviensis Johnson & Hills, 1973
4,5. Br.395a; 170/1269 (R503)(5*)

6-10 Pareodinia alaskensis Wiggins, 1975
6. Br.582a; 120/1230 (M543) 7. Br.653a; 090/1382 (J380)
8. Br.582a; 180/1220 (S553) 9. Br.194a; 080/1406 (H361)
10. Br.620a; 075/1277 (G490)

11,12 Pareodinia cf. apotomocerastes Sarjeant, 1972
11. WB.188a; 175/1388 (S372) 12. WB.209a; 058/1313 (P450)

13-15 Pareodinia ceratophora Deflandre, 1947b emend. Gocht, 1970
13. WB.88a; 220/1363 (W403) 14. WB.58a; 040/1396 (D371)
15. Br.1047a; 170/1249 (R514)

16-19 Pareodinia ceratophora sub.sp. pachyceras (Sarjeant, 1959) Lentin & Williams, 1973
16. Br.785a; 220/1390 (W374) 17. WB.211a; 093/1279 (J491)
18. WB.138a; 060/1420 (E343) 19. Br.727a; 180/1292 (S470)

8/1331 (S434)

, 1973

90/1362 (J360)
80/1406 (H361)

058/1313 (P450)

Gocht, 1970
0/1396 (L371)

eant, 1959)

94/1274 (J481)
8./1292 (S470)

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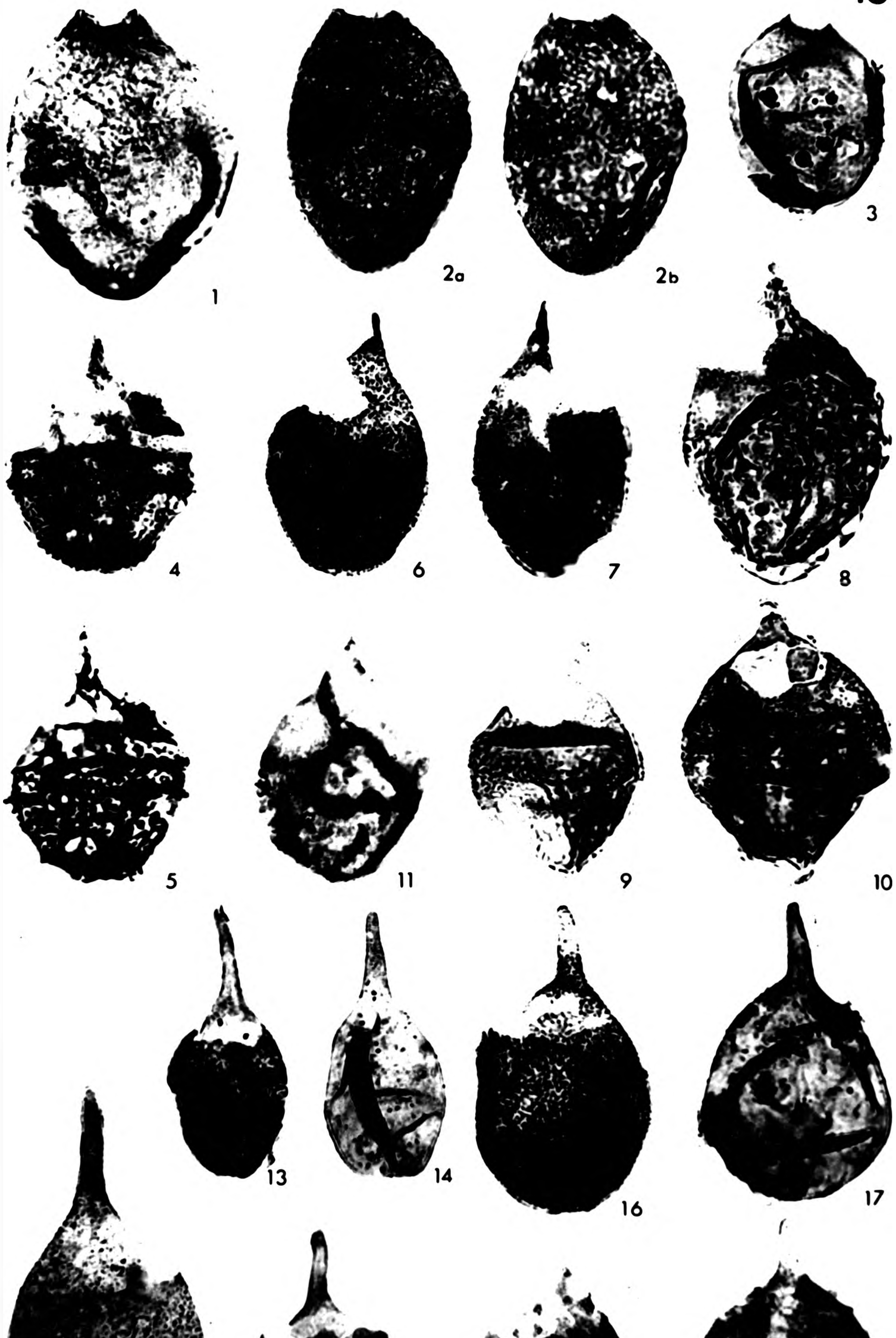

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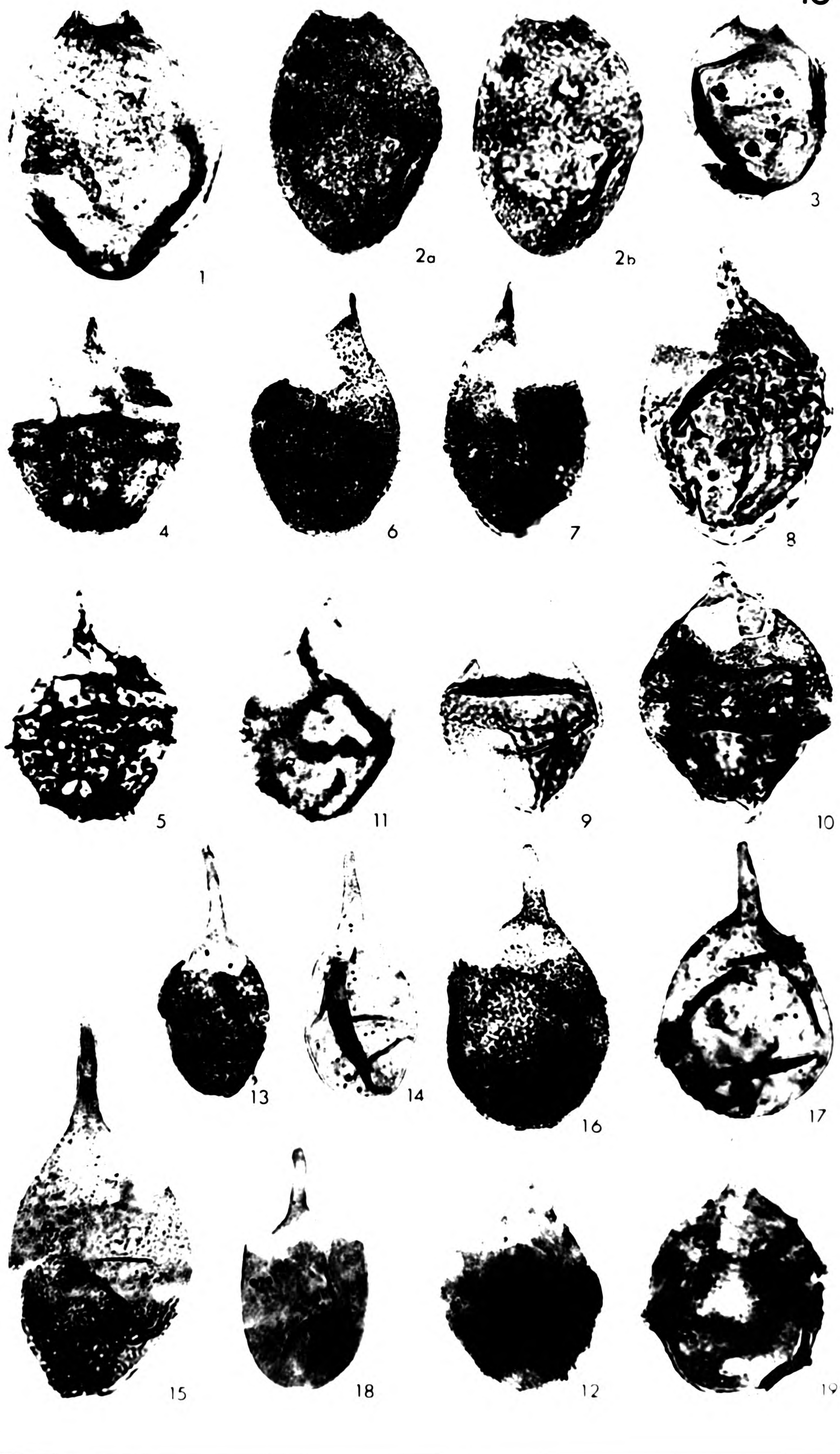

PLATE 17

Figs

1-5 Pareodinia ceratophora sub.sp. scopeus (Sarjeant, 1959) Lentin & Williams, 1973

1. Br.140a; 130/1288 (N483) 2. WB.128a; 210/1342 (V420)
3. WB.188a; 081/1326 (H440) 4. WB.133a; 195/1245 (U520)
5. WB.123a; 087/1472 (J282)

6-8 Pareodinia prolongata Sarjeant, 1959

6. Br.1552a; 195/1300 (U462)(b*) 7. WB.228a; 130/1230 (N534)
8. Br.1880a; 037/1274 (C494)

9-14 Pareodinia warlinghamensis sp. nov.

9. Br.481a; 150/1359 (P402) 10. Br.916a; 055/1407 (E363)
11. Br.455a; 140/1435 (O330) 12. Br.1235a; 055/1298 (E473)
13. Br.963a; 095/1372 (K391)
14. Br.1307a; 120/1334 (M420)(b*) Holotype

15-18 Pareodinia wigginsi sp. nov.

15. Br.727a; 190/1363 (T400) Holotype
16. Br.727a; 185/1329 (T432) 17. Br.702a; 060/1215 (F520)
18. Br.627a; 200/1219 (U553)

19 Pareodinia sp.B

19. Br.560a; 205/1452 (V311)

20,21 Pluriarvalium osmingtonense Sarjeant, 1962b

20. Br.963a; 060/1432 (F331) 21. Br.543a; 055/1233 (E534)

22. Pluriarvalium cf. osmingtonense Sarjeant, 1962b

22. WB.224a; 065/1258 (F504)

23. Pareodinia warlinghamensis sp.nov.

23. Br.976a; 060/1409 (F350)

, 1959)

/1342 (V420)
/1245 (U520)

/1230 (N534)

/1407 (E363)
5/1298 (E473)

/1215 (F520)

/1233 (E534)

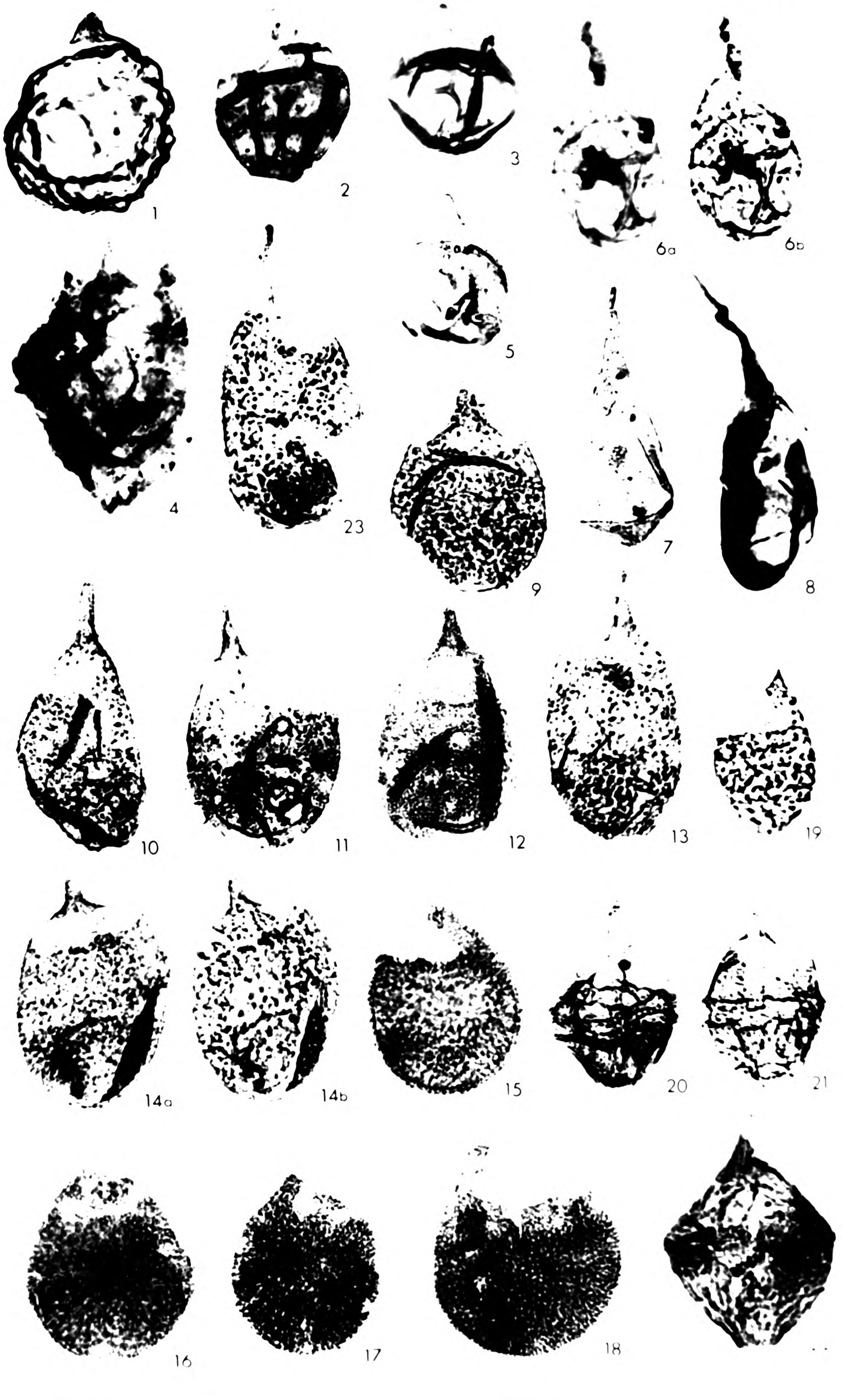
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PLATE 18

Figs

1 *Pluriarvalium* sp.A

1. WB.228a; 094/1421 (J340)

2-4 *Polysphaeridium deflandrei* (Valensi, 1947) Davey & Williams, 1969

2. Br.963a; 085/1416 (H344)(a*) 3. Br.554a; 070/1232 (G532)*
4. Br.963a; 070/1307 (G460)*

5-8 *Polystephanephorous paracalathus* (Sarjeant, 1960a) Downie & Sarjeant, 1964

5. WB.224a; 032/1206 (C560) 6. Br.1898a; 215/1230 (W541)
7. Br.1898a; 095/1332 (J430) 8. Br.785a; 155/1436 (Q331)

9-12 *Prolixosphaeridium granulosum* (Deflandre, 1937) Davey et.al, 1966

9. Br.653a; 145/1279 (P491) 10. WB.53a; 137/1270 (O501)
11. WB.88a; 195/1207 (U560) 12. Br.693a; 135/1441 (N324)(a*)

13-15 *Reutlingia gochtii* Drugg, 1978

& Williams, 1969
/1232 (G532)*

a) Downie &

5/1230 (W541)
/1436 (Q331)

Davey et.al, 1966
/1270 (O501)
5/1441 (N324)(a*)

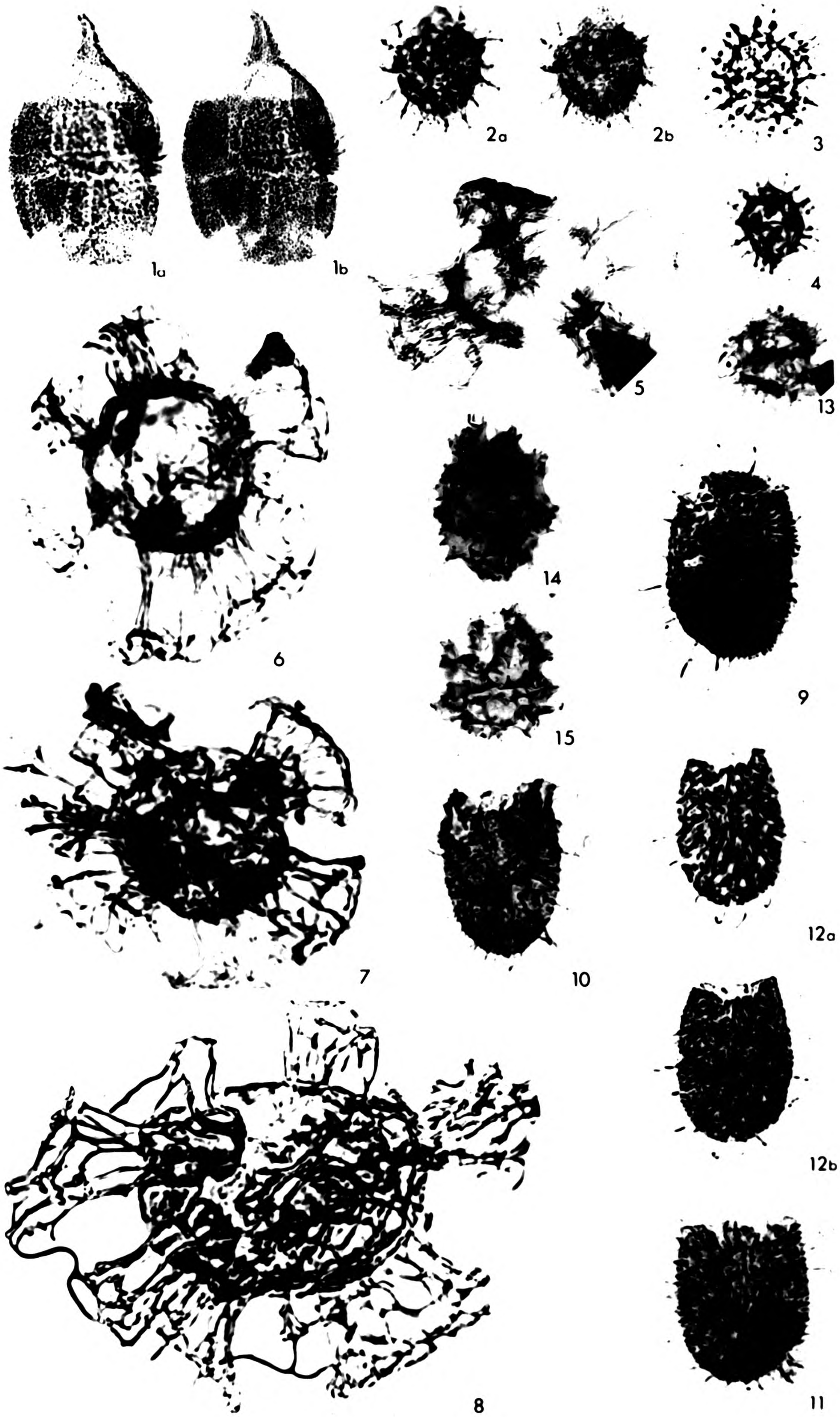


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PLATE 19

Figs

1-4 Scriniocassis dictyotus (Cookson & Eisenack, 1960) Beju, 1971

1. Br. 246a; 150/1439 (P320) 2. Br.246a; 145/1442 (O323)

3. Br.465a; 200/1331 (U434) 4. Br.214a; 125/1489 (M270)

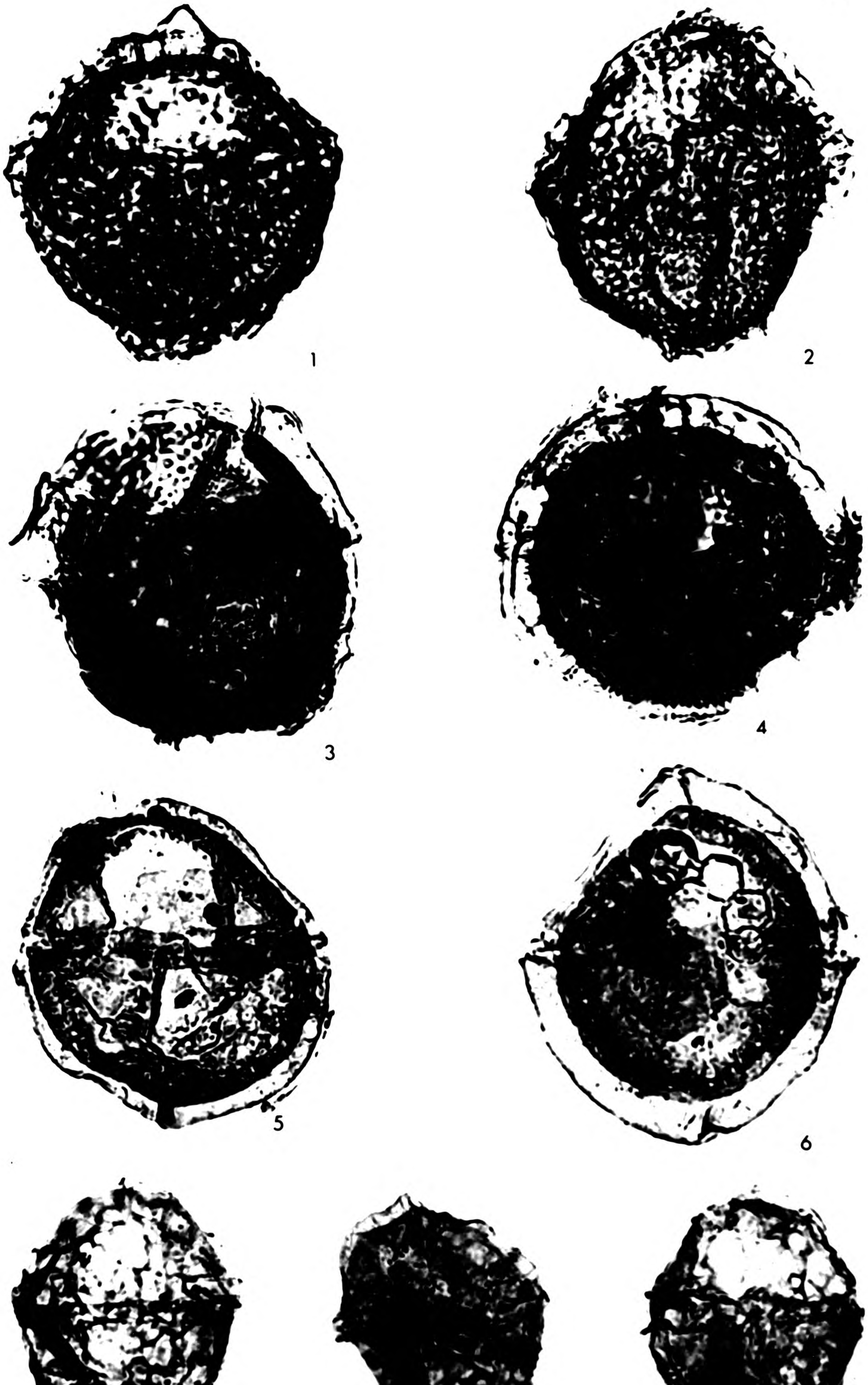
5,6 Scriniodinium crystallinum (Deflandre, 1938) Klement, 1960

5. Br.1255a; 175/1394 (S371) 6. WB.28a; 090/1343 (J420)

7-9 Scriniodinium cf.crystallinum (Deflandre, 1938) Klement, 1960

7. Br.1330a; 020/1470 (B290) 8. WB.178a; 125/1182 (N591)

9. Br.1330a; 190/1301 (T460)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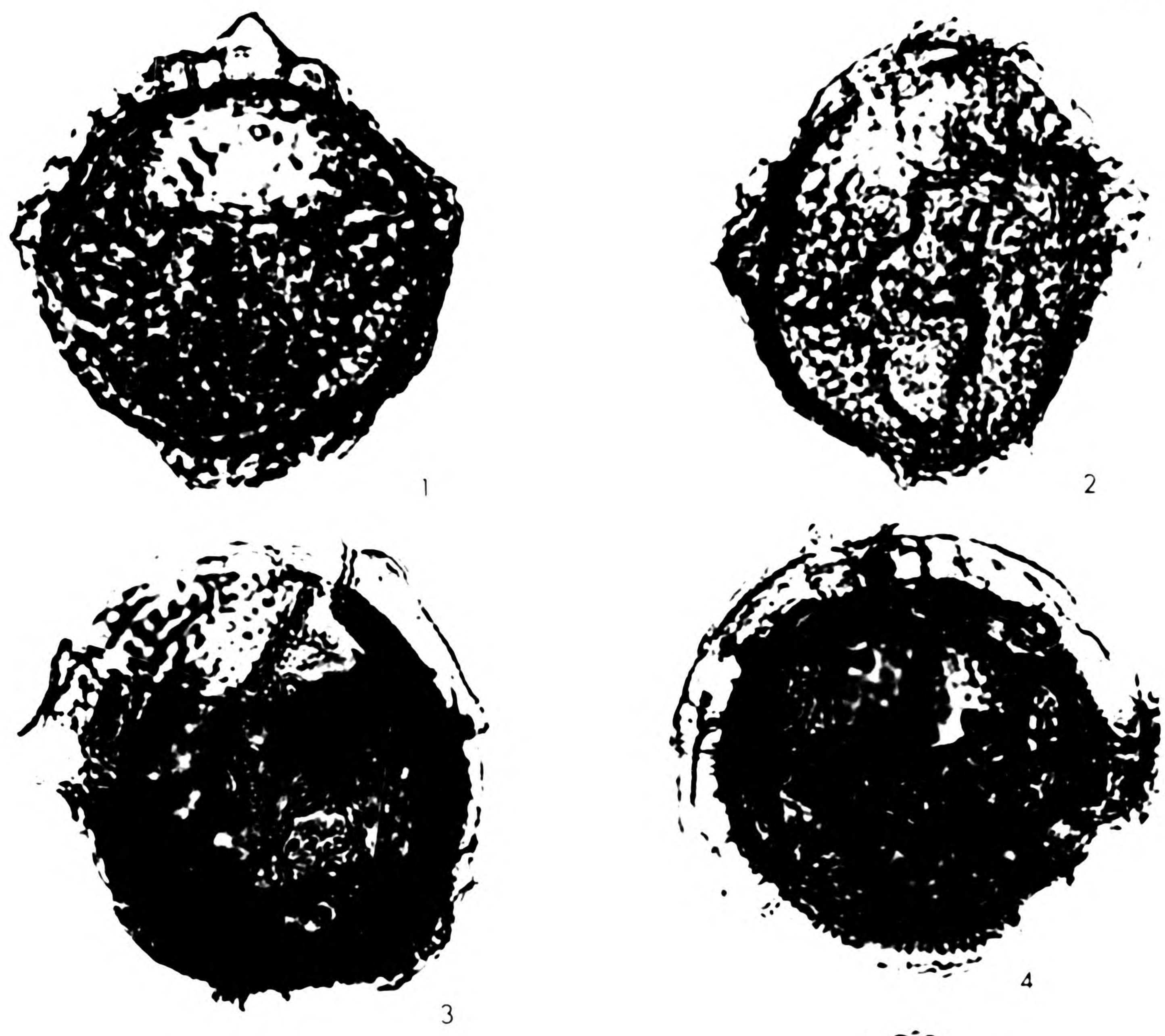
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PLATE 20

Figs

1-4 *Scriniodinium crystallinum* (Deflandre, 1938) Klement, 1960

1. Br.884a; 150/1297 (P471) 2. Br.520a; 160/1278 (Q490)

3. WB.38a; 145/1420 (O344) 4. WB.28a; 155/1414 (P343)

5-7 *Scriniodinium galeritum* (Deflandre, 1938) Klement, 1960

5. Br.820a; 115/1232 (L534) 6. Br.785a; 125/1339 (M424)

7. Br.340a; 200/1255 (U510)

8 *Scriniodinium* sp.A

8. Br.1006a; 165/1271 (Q494)

lement, 1960
60/1278 (Q490)
5/1414 (P343)

nt, 1960
25/1839 (M424)


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PLATE 21

Figs

1 Scriniodinium sp.A

1. Br.947a; 205/1350 (V410)

2,3 Scriniodinium luridum (Deflandre, 1938) Klement, 1960

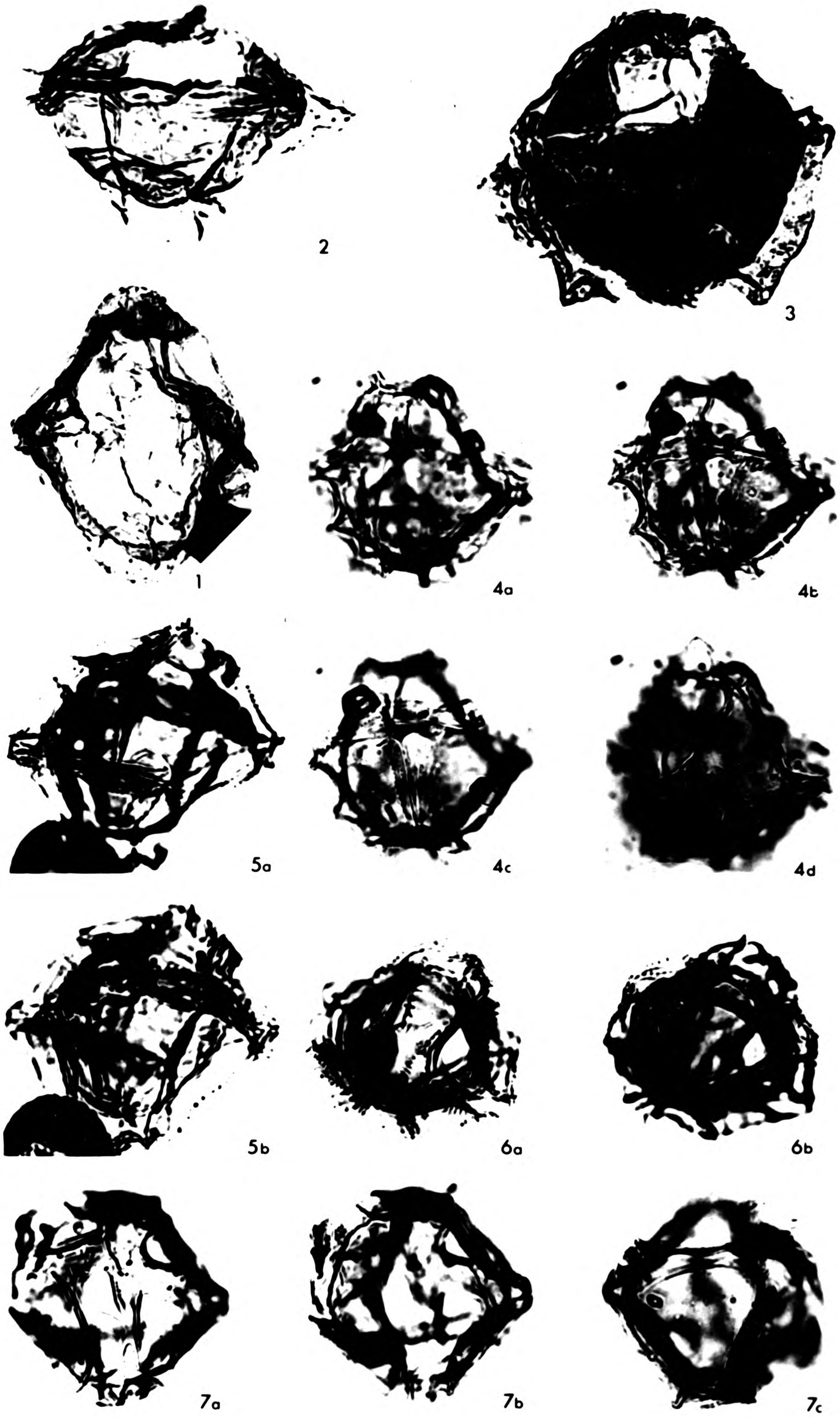
2. Br.246a; 075/1262 (G504) 3. Br.214a; 085/1448 (H314)

4-7 Scriniodinium subvallare Sarjeant, 1962b

4. WB.138a; 110/1257 (L511) 5. Br.916a; 155/1193 (Q572)

6. Br.884a; 100/1188 (K580) 7. WB.78a; 059/1271 (E492)

1960
/1448 (H314)
/1193 (Q572)
1271 (E492)



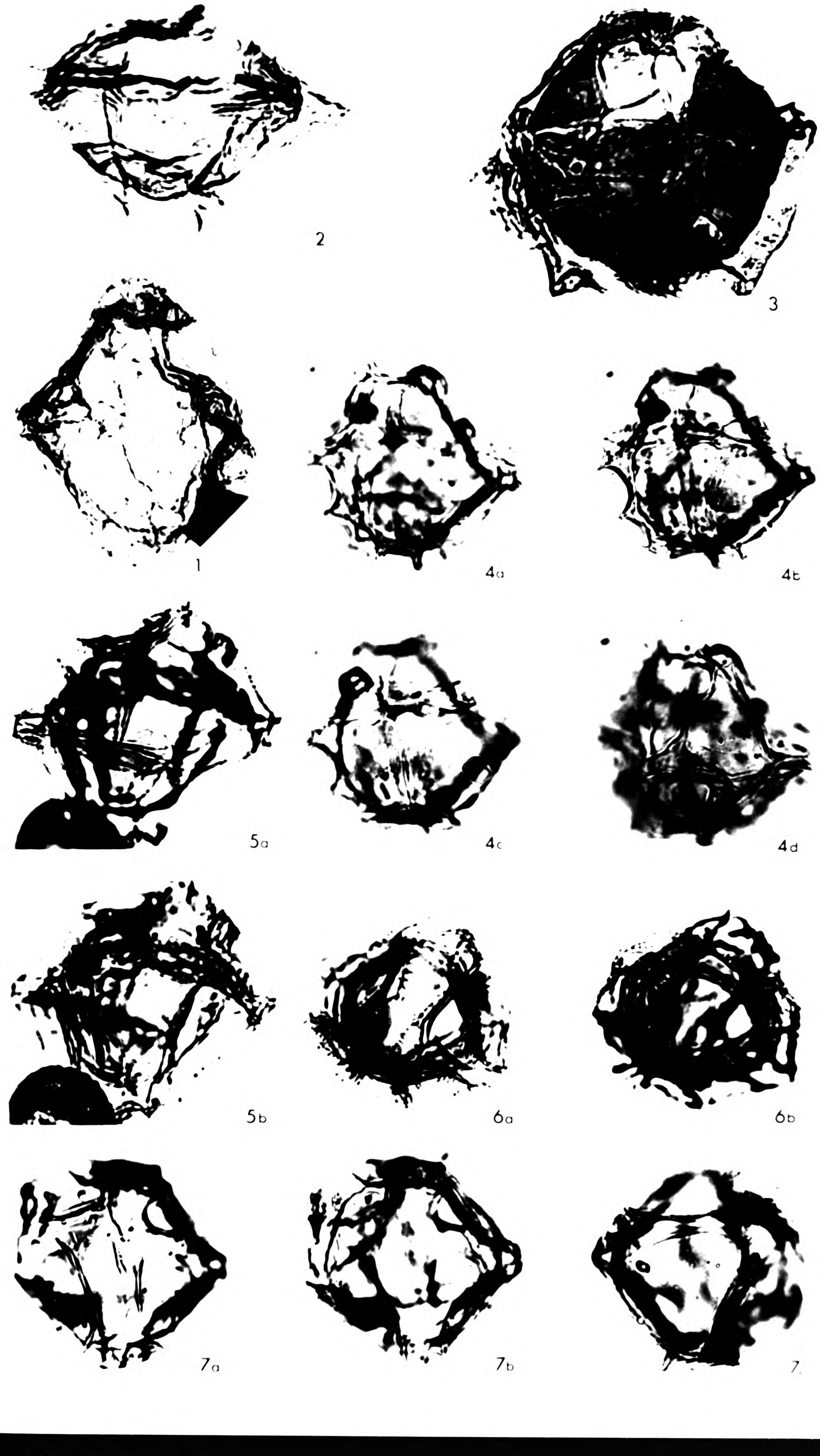

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PLATE 22

Figs

1 Scriniodinium subvallare Sarjeant, 1962b
1. Br.560a; 210/1421 (V340)

2 Scriniodinium sp.B
2. Br.170a; 040/1292 (D472)

3,4 Scriniodinium sp.A
3. Br.194a; 155/1450 (Q310) 4. Br.429a; 070/1458 (G300)

5-8 Senoniasphaera oxfordiensis sp.nov.
5. Br.669a; 190/1330 (T432)
6. Br.683a; 165/1284 (R482)(a*) Holotype
7. Br.465a; 185/1266 (S504) 8. Br.640a; 045/1314 (D450)

9-13 Sentusidinium pilosum (Ehrenberg, 1843) Sarjeant & Stover, 1978
9. WB.53a; 152/1486 (P274) 10. WB.33a; 145/1299 (P471)
11. Br.947a; 200/1250 (U523) 12. Br.313a; 110/1335 (L430)
13. WB.58a; 200/1233 (U534)

14-17 Sentusidinium rioultii (Sarjeant, 1968) Sarjeant & Stover, 1978
14. Br.976a; 065/1456 (F304) 15. WB.128a; 200/1299 (U464)
16. WB.108a; 215/1337 (W431) 17. Br.963a; 095/1387 (J374)

18,19 Sentusidinium varispinosum (Sarjeant, 1959) Sarjeant & Stover, 1978
18. WB.224a; 040/1418 (C343) 19. Br.1898a; 210/1370 (V390)

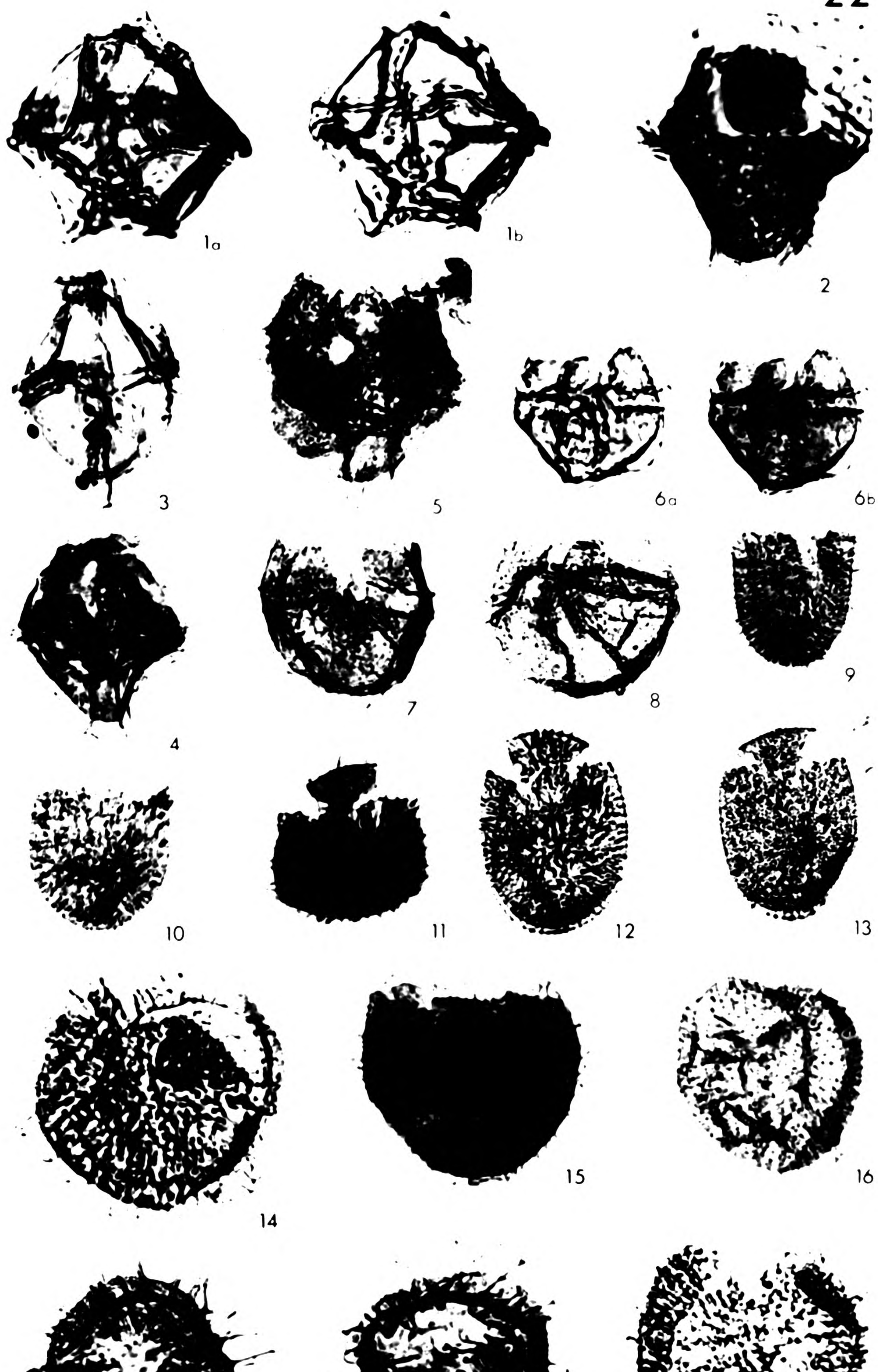
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PLATE 23

Figs

1 Sentusidinium varispinosum (Sarjeant, 1959) Sarjeant & Stover, 1978

1. Br.560a; 170/1239 (R533)

2,3 Sentusidinium verrucosum (Sarjeant, 1968) Sarjeant & Stover, 1978

2. WB.210a; 193/1185 (U582) 3. WB.208a; 183/1349 (S414)

4 Sentusidinium villersense (Sarjeant, 1968) Sarjeant & Stover, 1978

4. WB.209a; 078/1226 (H540)

5-7 Sentusidinium woollami sp. nov.

5. WB.78a; 145/1418 (O344) Holotype

6. Br.976a; 215/1300 (W471) 7. WB.63a; 155/1131 (Q461)

8-10 Sentusidinium sp.A

8. Br.1155a; 200/1265 (U500) 9. Br.1155a; 140/1323 (O440)(a*)

10. Br.963a; 195/1346 (U412)

11,12 Sentusidinium sp.F

11. Br.1155a; 185/1383 (S383) 12. WB.108a; 195/1337 (U431)

13,16, 17 Sentusidinium sp.B

13. Br.560a; 225/1506 (X250) 16. WB.211a; 137/1200 (O571)

17. WB.208a; 189/1488 (T270)

14,15 ?Sentusidinium sp.

14. Br.1450a; 220/1295 (W470) 15. Br.1354a; 160/1211 (Q554)

18 Sentusidinium sp.C

18. Br.1155a; 190/1367 (T400)

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183/1349 (S414)

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5/1131 (Q461)

40/1323 (Q440)(a*)

95/1337 (Q431)

37/1200 (Q571)

60/1211 (Q554)

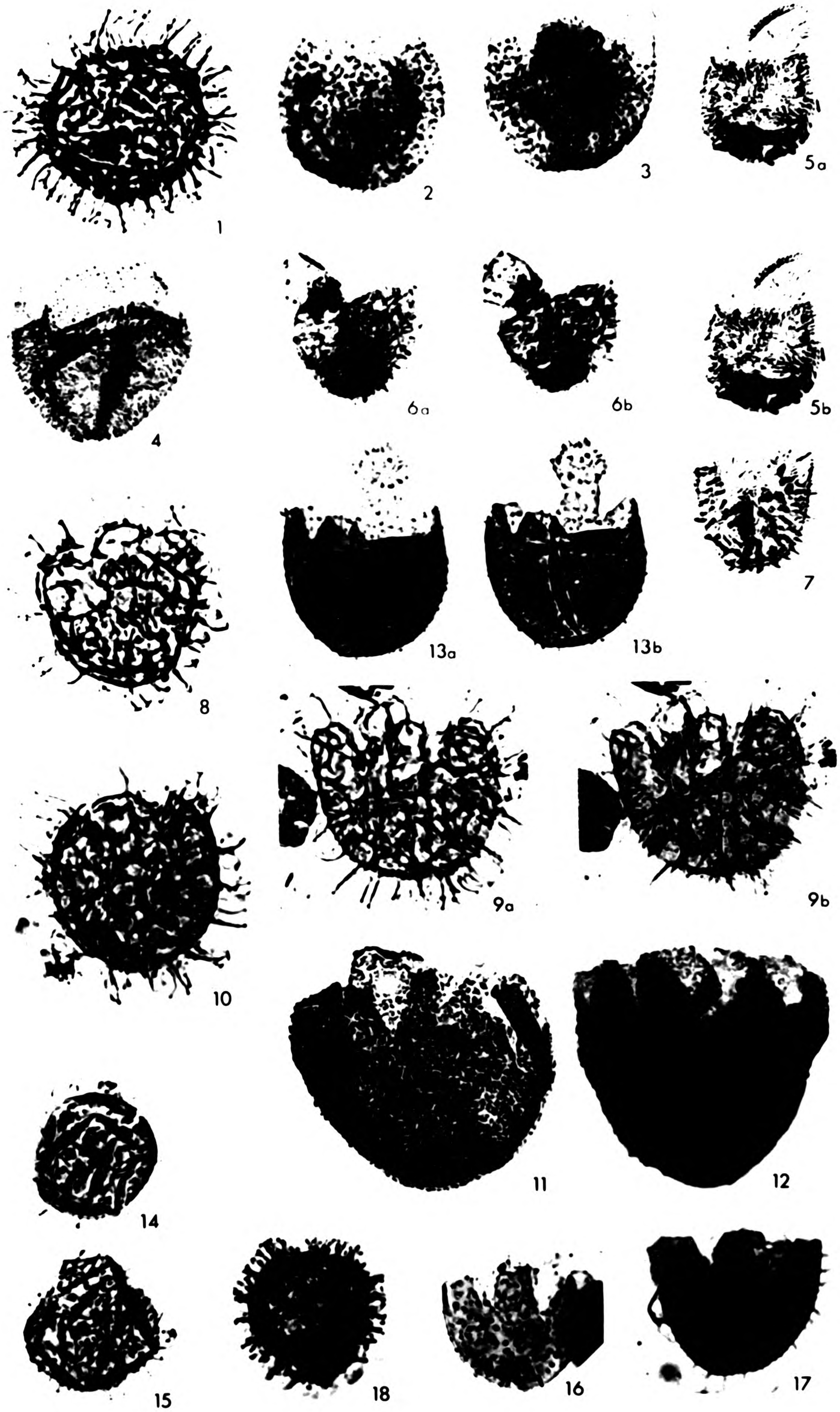


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PLATE 24

Figs

1-3 Sentusidinium sp.D

1. Br.560a; 185/1500 (S263)   2. Br.550a; 190/1310 (T452)

3. Br.884a; 210/1469 (V290)

4-8 Sirmiodiniopsis orbis Drugg, 1978

4. WB.123a; 190/1252 (T514)   5. WB.113a; 215/1218 (W551)

6. WB.123a; 155/1203 (Q560)   7. Br.963a; 065/1249 (G521)

8. Br.1605a; 200/1491 (U273)*

9-14 Sirmiodinium grossii Alberti, 1961

9. Br.1760a; 210/1464 (V294)   10. Br.727a; 155/1468 (Q292)*

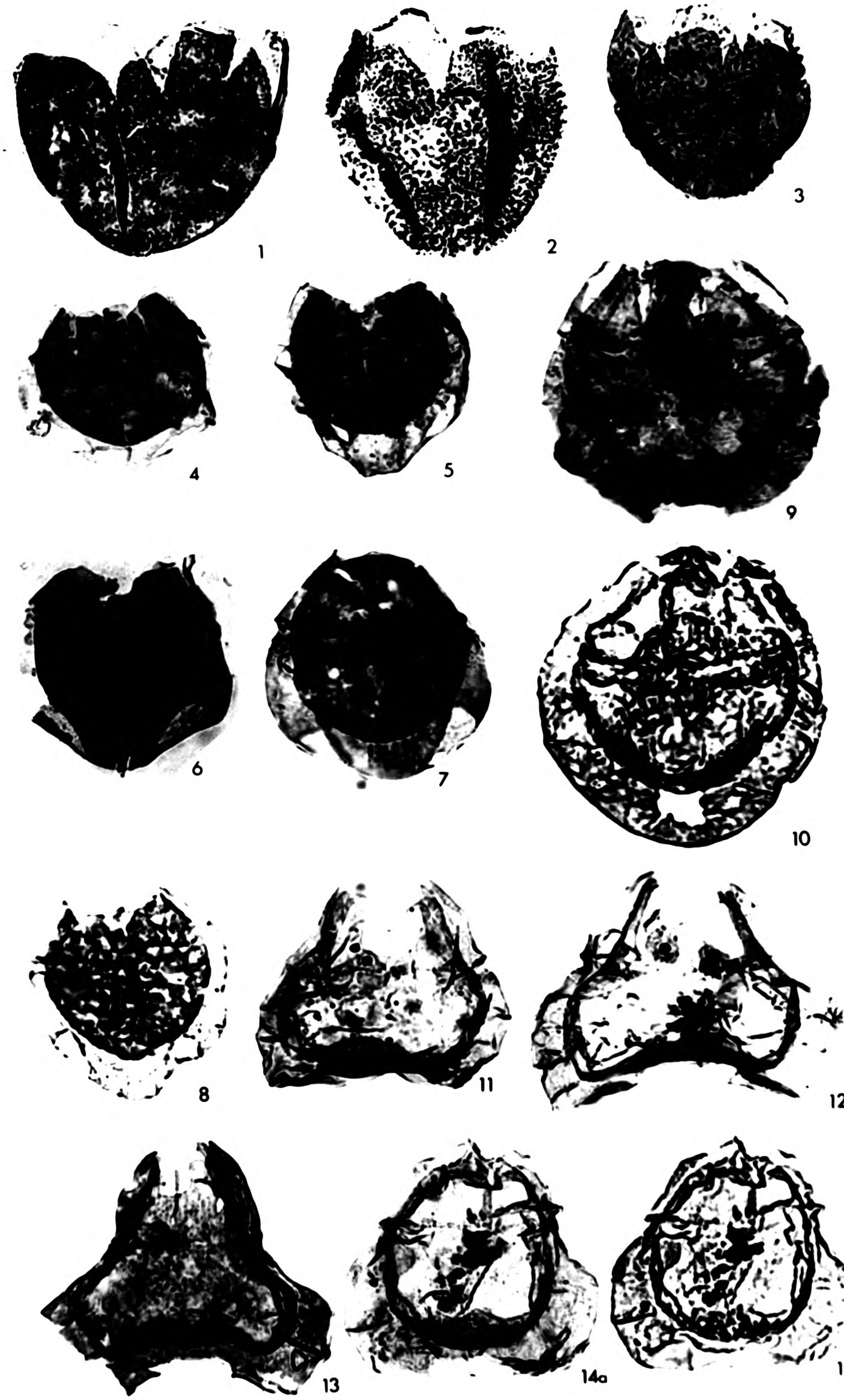
11. WB.58a; 070/1313 (G450)   12. Br.702a; 055/1200 (E570)

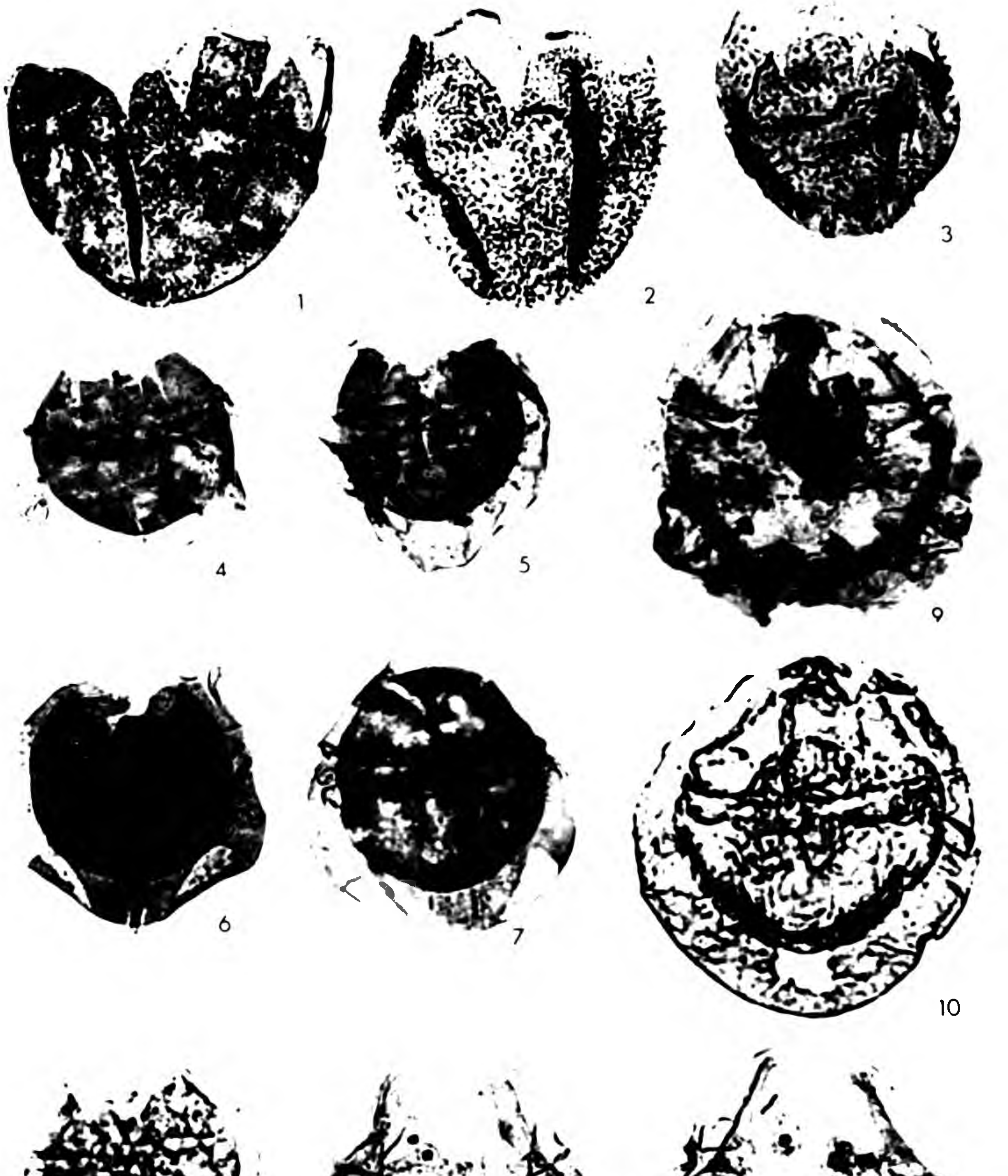
13. Br.702a; 155/1248 (Q520)   14. Br.916a; 105/1333 (L432)(b*)

1310 (T452)

1218 (W551)
1249 (G521)

/1468 (Q292)*
/1200 (E570)
/1333 (L432)(b*)

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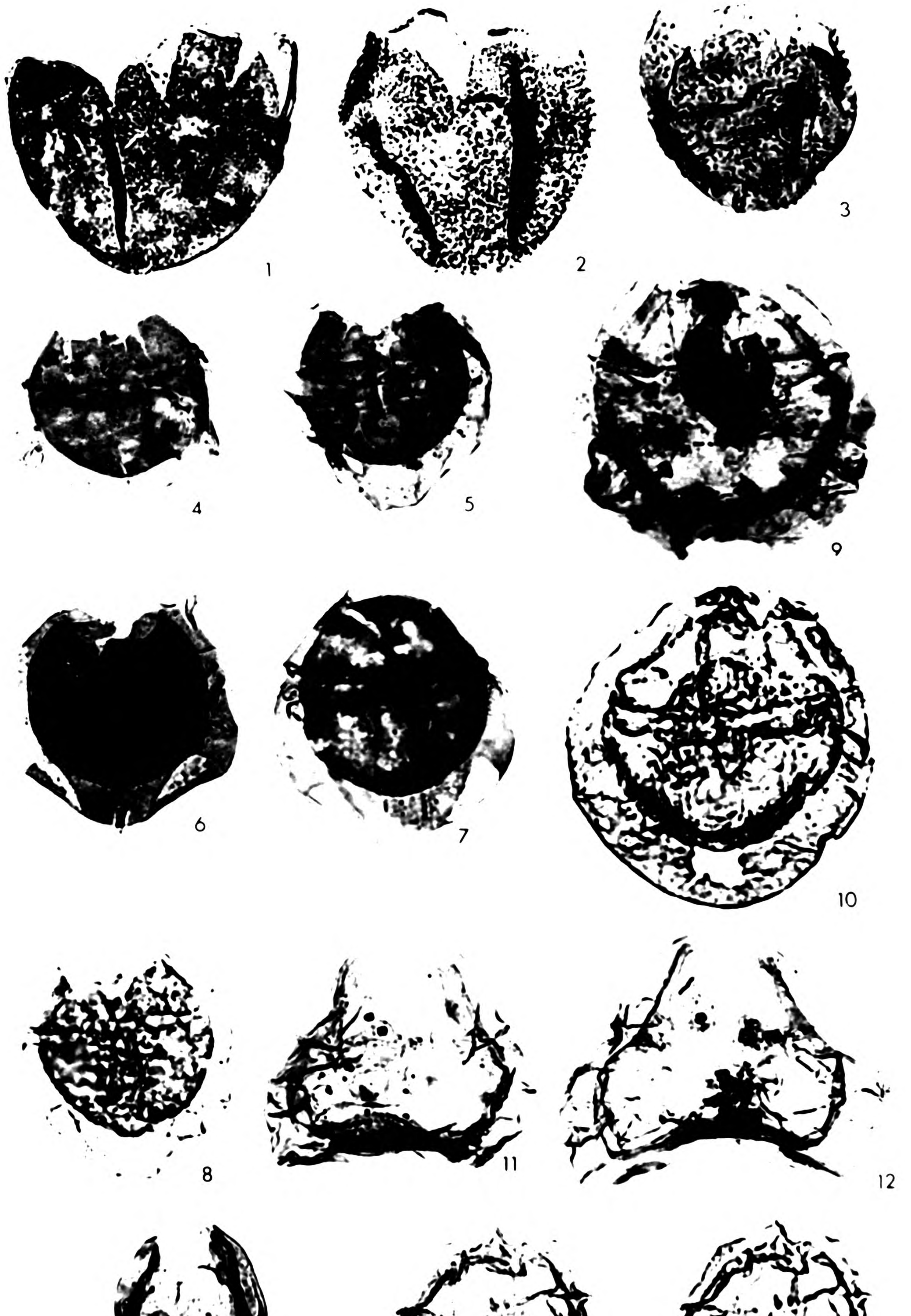
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PLATE 25

Figs

1-6, 9 Stephanelytron caytonense Sarjeant, 1961a emend. Stover, Sarjeant & Drugg, 1977

1. Br.455a; 185/1460 (S303) 2. WB.78a; 094/1418 (K342)
3. WB.78a; 188/1169 (T600) 4. WB.33a; 135/1306 (N463)
5. Br.455a; 190/1221 (T553) 6. WB.38a; 050/1462 (E300)
9. Br.1155a; 175/1448 (S310)

7,8, 10-12 Stephanelytron redcliffense Sarjeant, 1961a emend. Stover, Sarjeant & Drugg, 1977

7. Br.1087a; 170/1382 (R380) 8. WB.143a; 210/1353 (V410)
10. WB.83a; 185/1372 (T390) 11. WB.188a; 197/1230 (U543)
12. Br.1399a; 090/1303 (J460)*

13-18 Stephanelytron scarburghense Sarjeant, 1961a emend. Stover, Sarjeant & Drugg, 1977

13. WB.158a; 195/1255 (U510) 14. Br.1087a; 070/1482 (G272)
15. WB.188a; 070/1381 (G380) 16. WB.33a; 075/1489 (G273)
17. Br.1354a; 170/1315 (R450) 18. Br.1552a; 115/1344 (L423)

19-21 Stephanelytron tabulophorum Stover, Sarjeant & Drugg, 1977

19. WB.183a; 155/1289 (Q481) 20. WB.210a; 200/1460 (U300)
21. Br.1605a; 110/1471 (L290)(a*)

22-26 Stephanelytron eccentricum sp. nov.

22. WB.198a; 115/1257 (M511) 23. WB.198a; 205/1430 (V330)
24. WB.193a; 161/1282 (Q484) 25. WB.193a; 232/1369 (X394)
26. Br.1354; 200/1264 (U504)

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8 (K342)
6 (N463)
2 (E300)

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353 (V410)
1230 (U543)

. Stover,

/1482 (G272)
1489 (G273)
5/1344 (L423)

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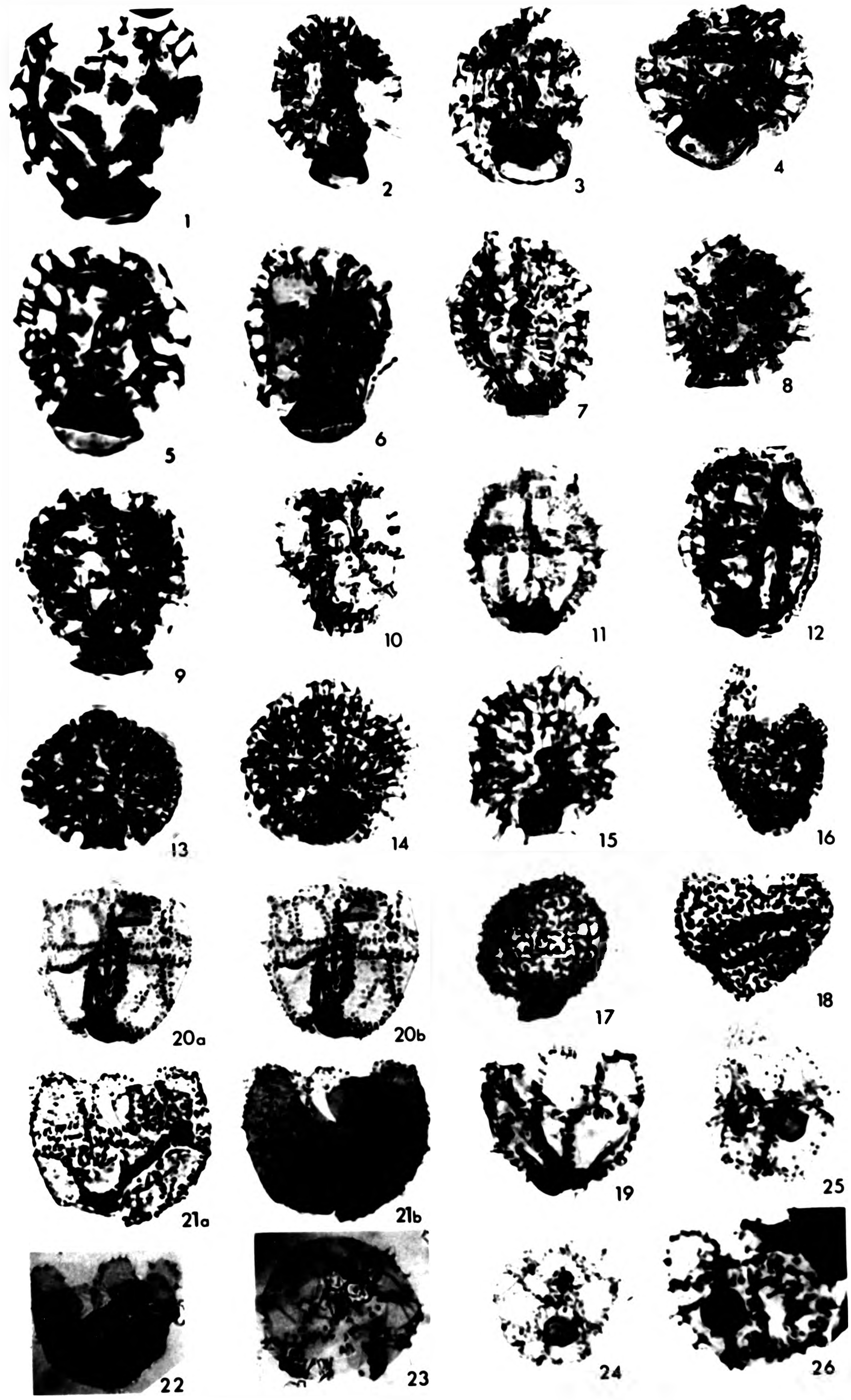
/1460 (U300)

/1430 (V330)
/1369 (X394)



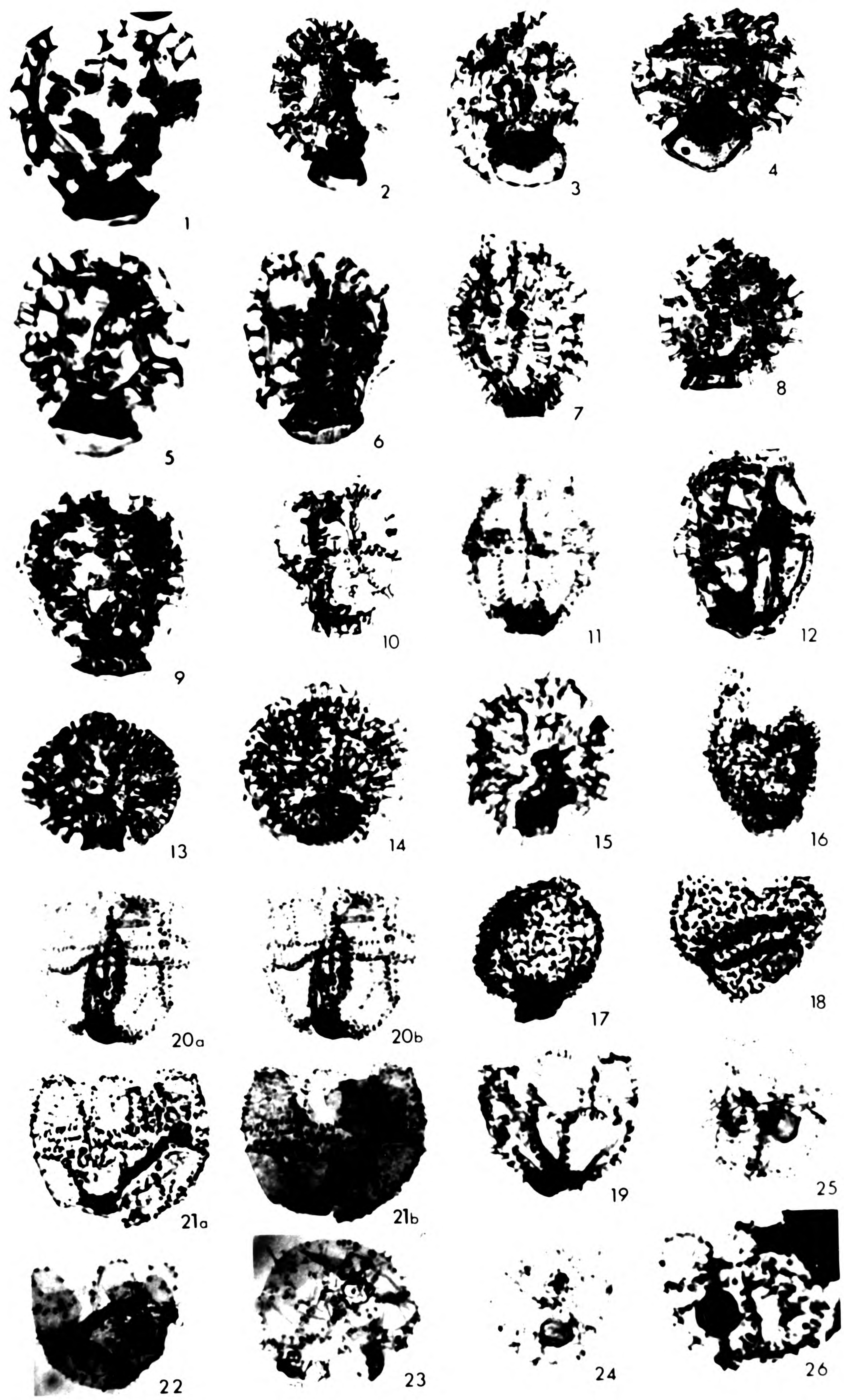

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PLATE 26

Figs

1,2 Stephanelytron eccentricum sp.nov.

1. Br.884a; 100/1393 (K373) Holotype
2. Br.1255a; 175/1242 (R524)(b,c*)

3-7 Stephanelytron echinatum sp. nov.

3. WB.208a; 141/1287 (O374)
4. WB.88a; 195/1188 (U580)
5. Br.916a; 158/1243 (Q520)
6. Br.1354a; 170/1268 (R503)(b*)
7. WB.88a; 203/1457 (U304) Holotype

8,9 Surculosphaeridium cribrotubiferum (Sarjeant, 1960a) Davey et.al., 1966

8. WB.58a; 155/1391 (Q372)
9. Br.785a; 165/1463 (R292)

10-12 Surculosphaeridium vestitum (Deflandre, 1938) Davey et.al., 1966

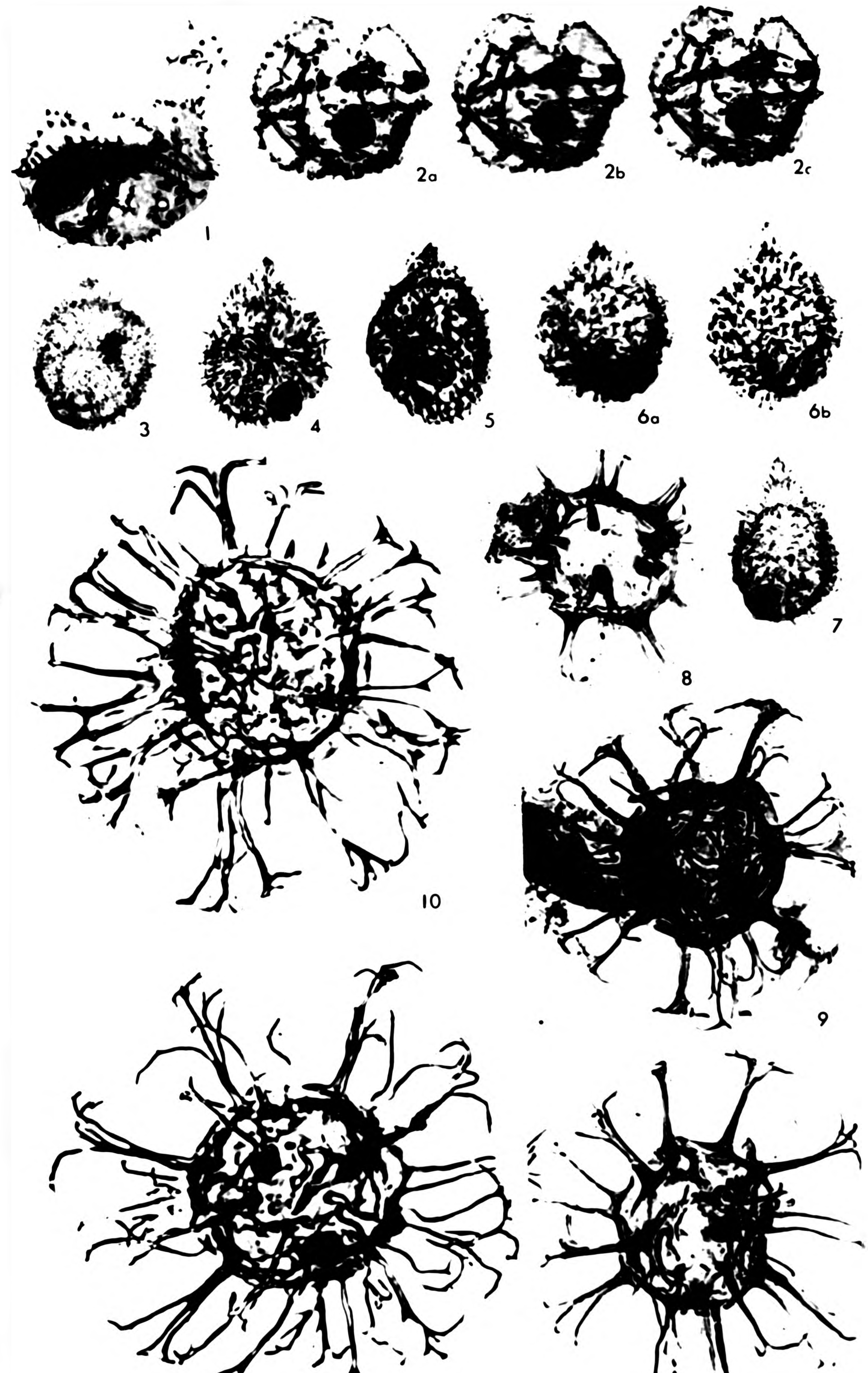
10. Br.710a; 095/1342 (J424)*
11. Br.443a; 075/1248 (H520)*
12. Br.520a; 120/1452 (M311)

/1186 (U560)
73/1268 (R533)(b*)

950a) Davey et.al.,

55/1468 (R292)

Davey et.al., 1966
075/1248 (H520)*



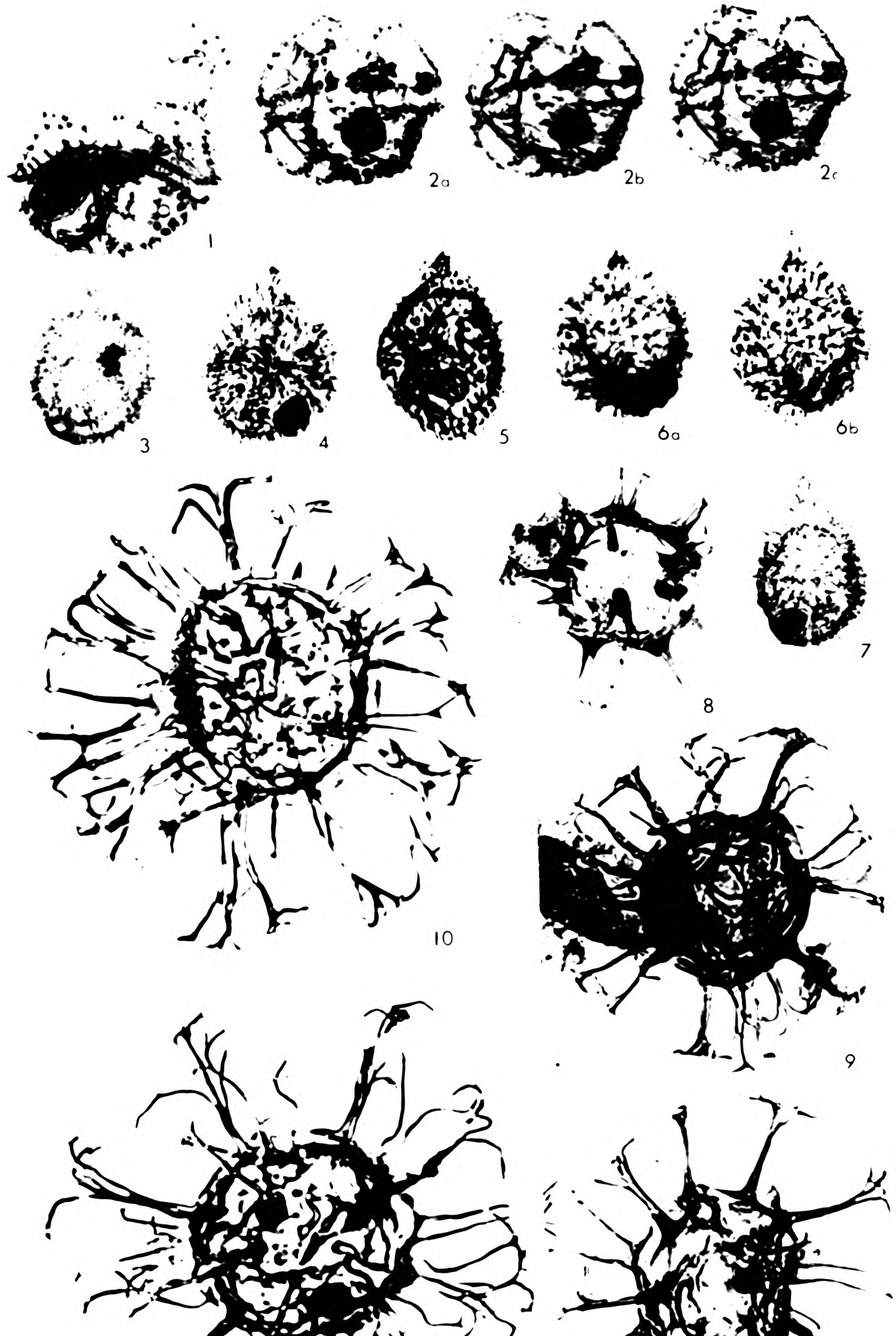

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PLATE 27

Figs

1 Surculosphaeridium cribrotubiferum (Sarjeant, 1960a) Davey et.al., 1966

1. Br.884a; 195/1216 (U552)

2,3 Systematophora areolata Klement, 1960

2. Br.115a; 210/1472 (V290)
3. Br.194a; 130/1482 (N283)*

4-8 Systematophora valensii (Sarjeant, 1960a) Downie & Sarjeant, 1964

4. Br.170a; 145/1439 (P322)*
5. Br.140a; 190/1383 (T380)*
6. Br.985a; 205/1251 (V510)
7. Br.560a; 225/1437 (X322)
8. Br.395a; 095/1500 (J263)

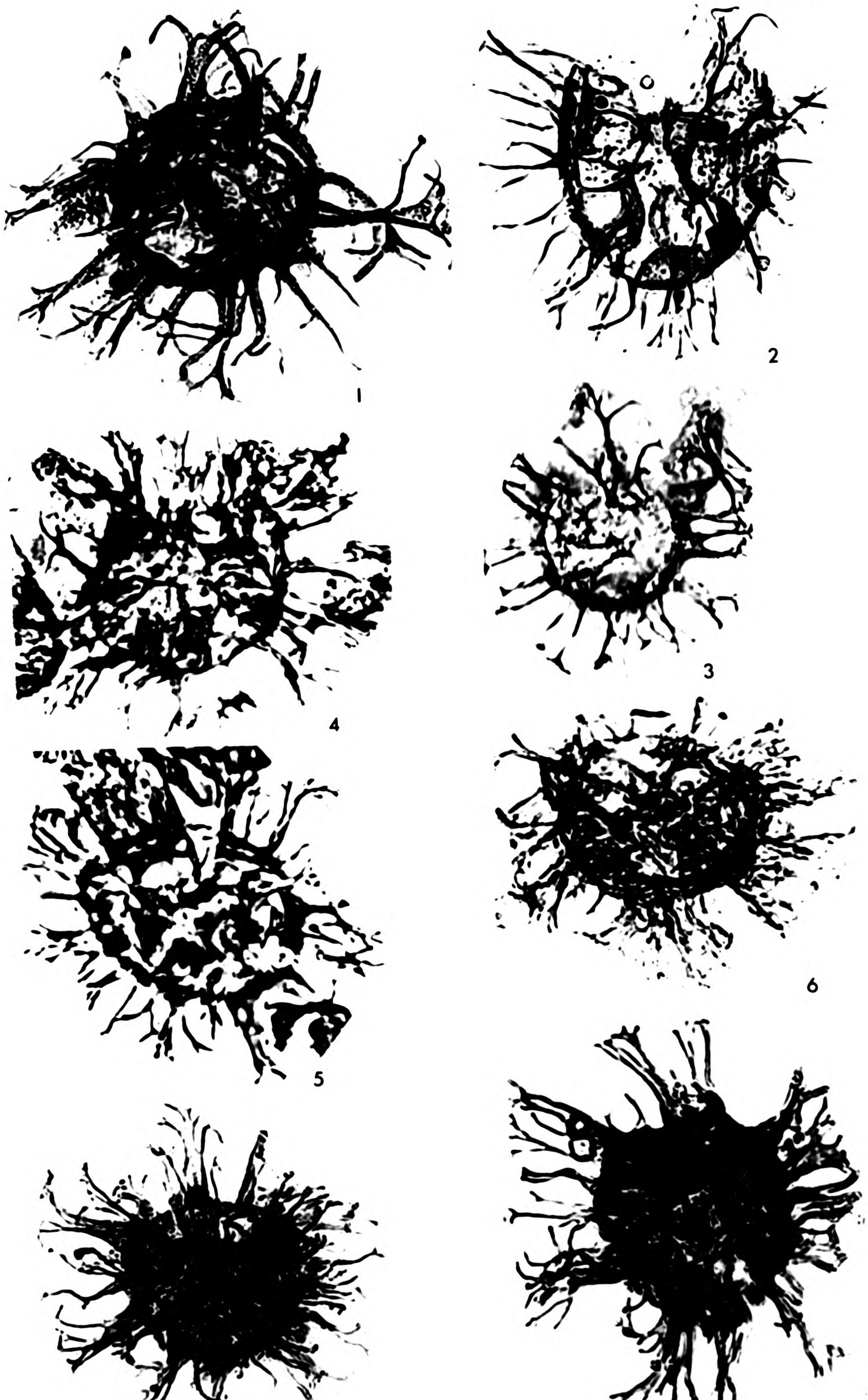

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PLATE 28

Figs

1-5 Tubotuberella apatella (Cookson & Eisenack, 1960) Ioannides et. al., 1976

1. WB.208a; 195/1213 (U552)
2. Br.1331a; 150/1489 (P270) (b*)
3. WB.103a
4. WB.210a; 144/1337 (O430)
5. WB.128a

6,7,10 Tubotuberella dangeardii (Sarjeant, 1968) Stover & Evitt, 1978

6. WB.43a; 125/1292 (N472)
7. WB.53a; 196/1455 (U300)
10. Br.785a; 045/1220 (D543)

8,9,12,13 Tubotuberella eisenackii (Deflandre, 1938) Stover & Evitt, 1978

8. Br.443a; 160/1280 (Q484)
9. Br.543a; 145/1425 (O334)
12. Br.976a; 085/1191 (H583)(b*)
13. Br.985a; 185/1436 (S324)

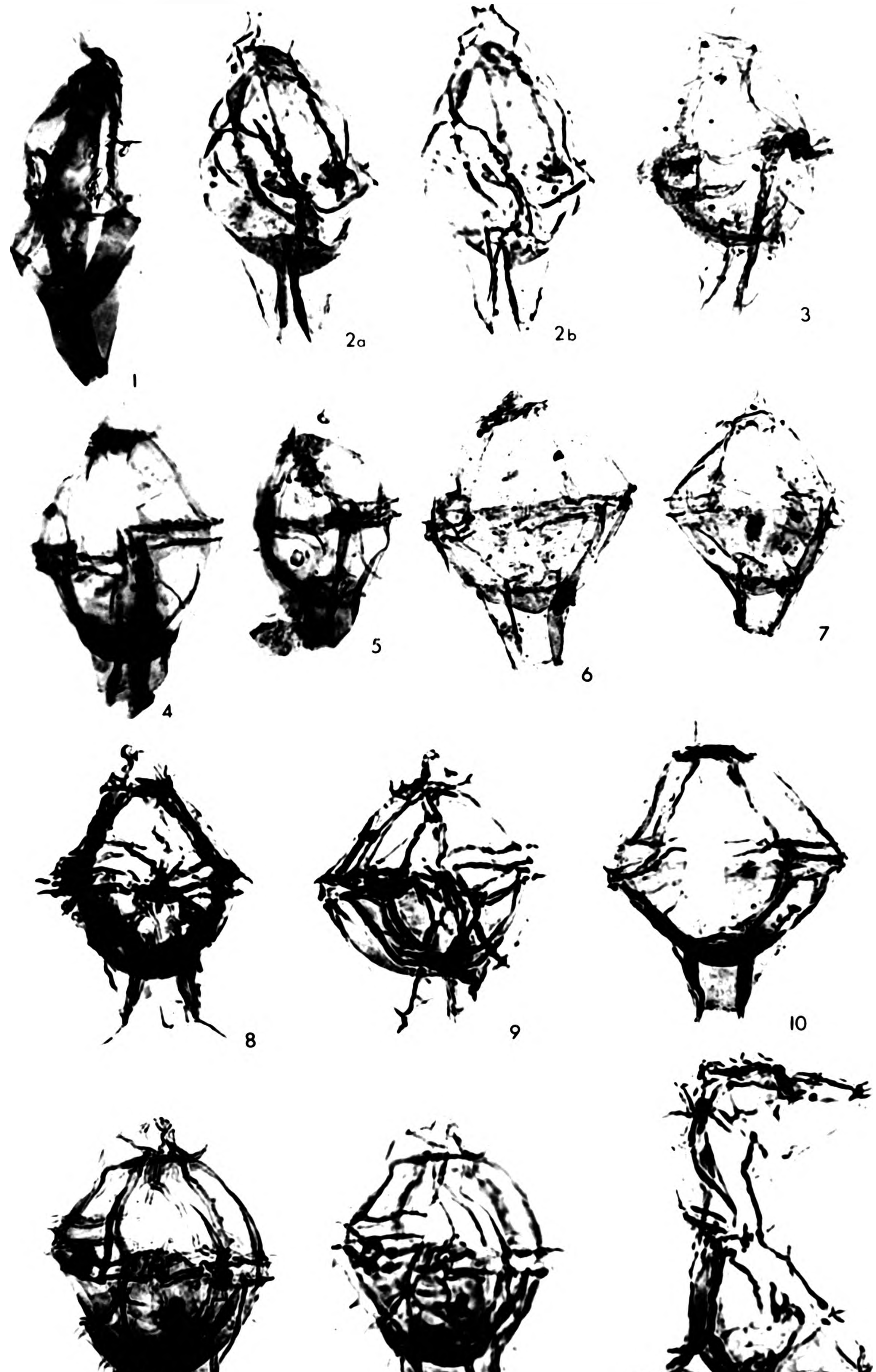
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PLATE 29

Figs

1-3 Tubotuberella eisenackii (Deflandre, 1938) Stover & Evitt, 1978

1. Br.560a; 065/1519 (F240) 2. WB.203(2)a; 142/1428 (O331)

3. WB.63a; 020/1257 (B510)

4 Tubotuberella sphaerocephalis Vozzhennikova, 1967

4. WB.128a; 143/1217 (O553)

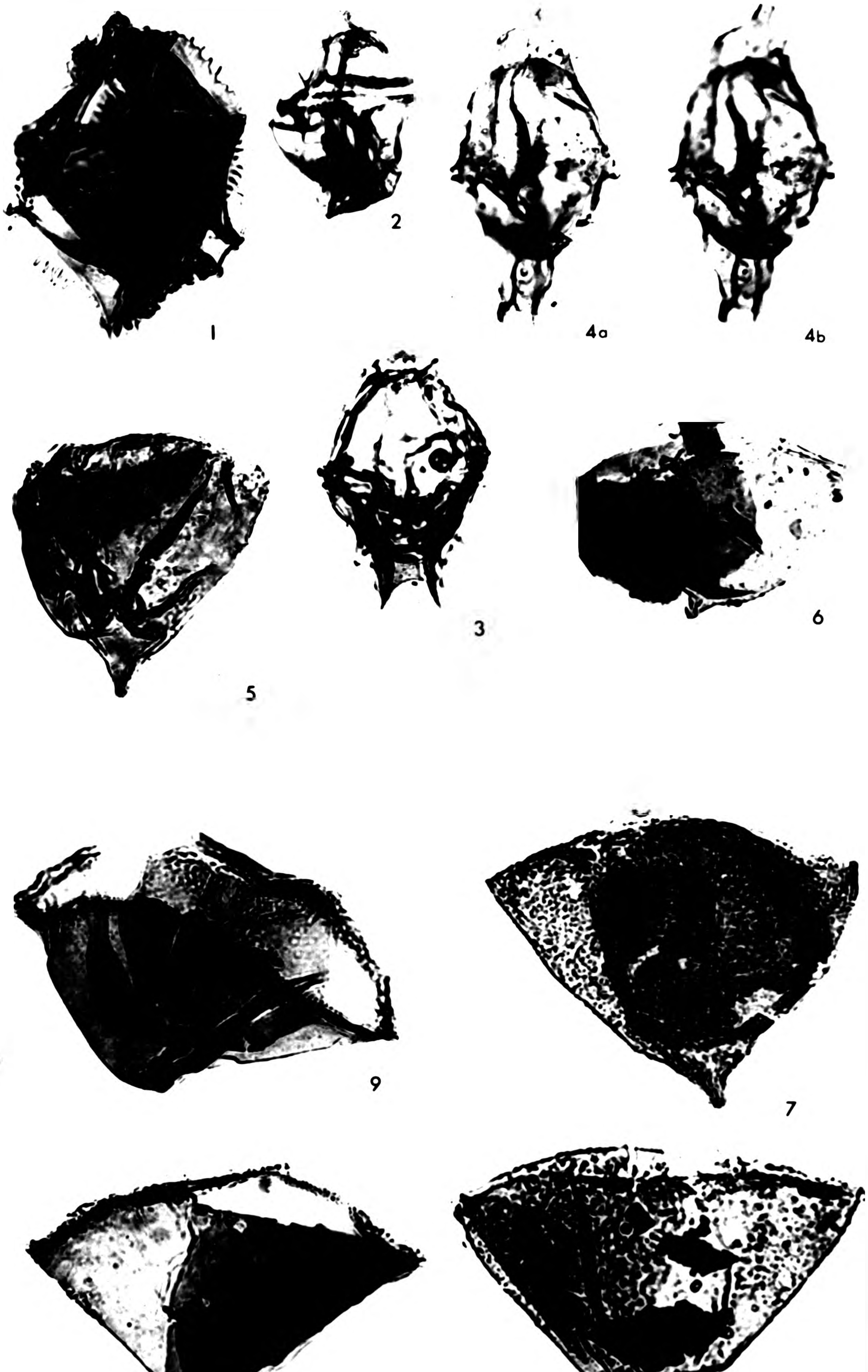
5-8 Wanaea acollaris Dodekova, 1975

5. Br.1006a; 195/1226 (U540)* 6. WB.210a; 147/1355 (P411)

7. Br.820a; 140/1420 (O340) 8. Br.820a; 125/1304 (M464)

9,10 Wanaea digitata Cookson & Eisenack, 1958

9. Br.976a; 165/1460 (R301) 10. Br.963a; 195/1266 (U501)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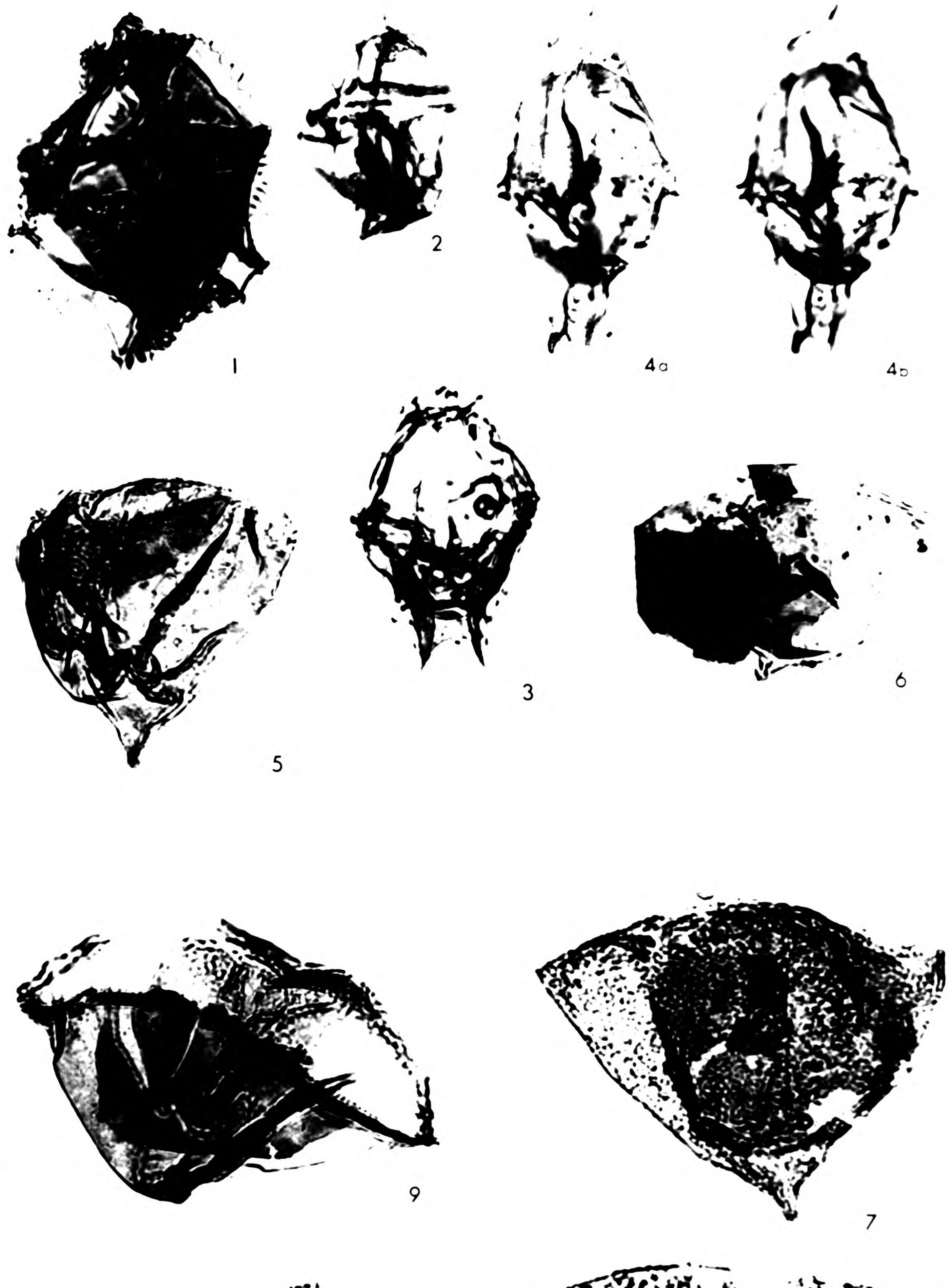
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PLATE 30

Figs

1,2 *Wanaea digitata* Cookson & Eisenack, 1958

1. WB.138a; 153/1388 (L382)
2. Br.702a; 070/1311 (G461)

3-7 *Wanaea fimbriata* Sarjeant, 1961a

3. Br.753a; 145/1430 (O334)
4. Br.742a; 165/1237 (Q533)
5. Br.785a; 150/1428 (P332)
6. Br.785a; 150/1337 (P430)
7. Br.785a; 165/1489 (Q270)*

e; 37 /1311 (Q461)

e; 165/1237 (Q533)

a; 157/1337 (P440)

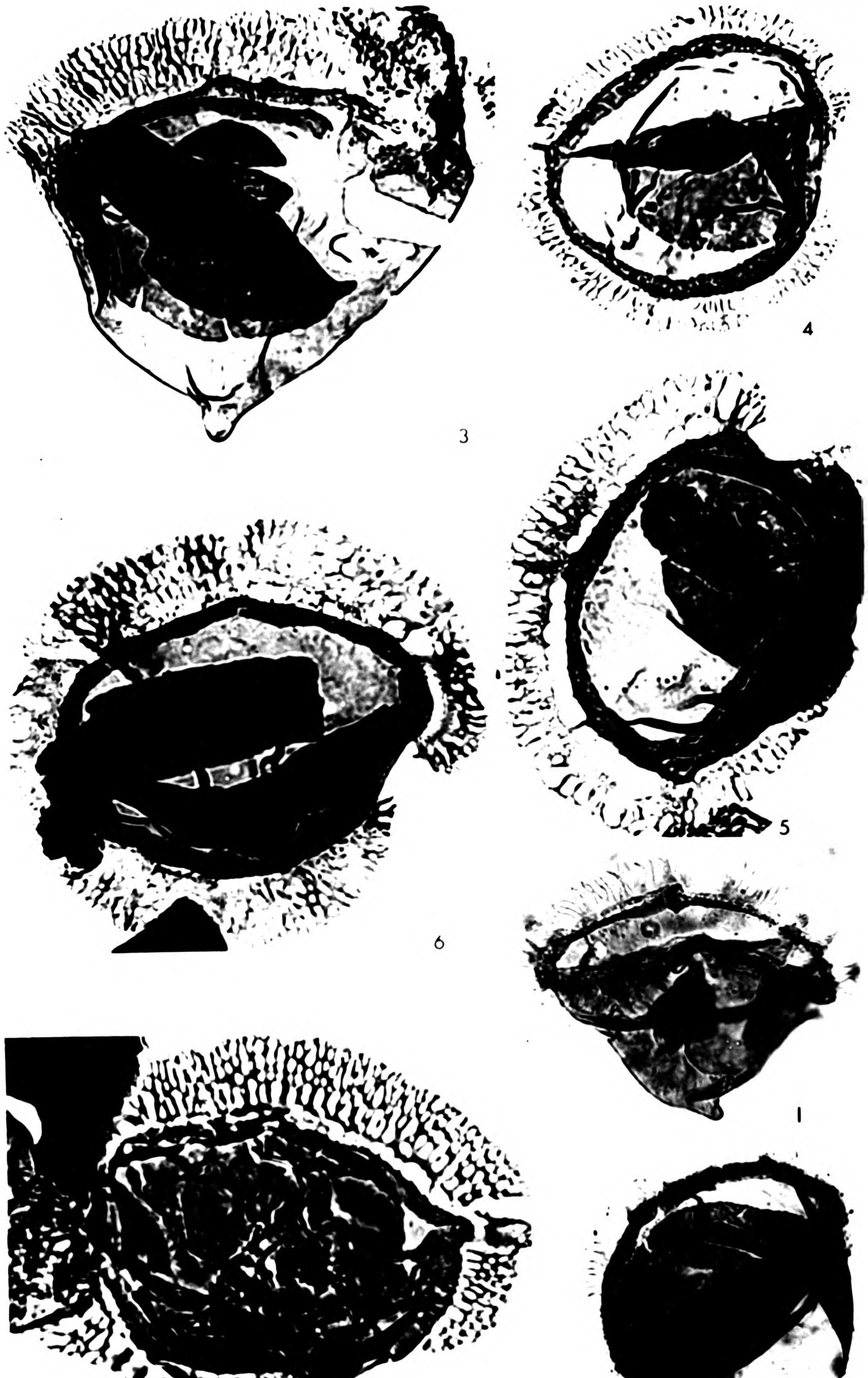

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PLATE 31

Figs (Figs. 1-5 X750; Figs. 6-26 X1,000)

1,4,5 Nannoceratopsis pellucida Deflandre, 1938
1. Br.313a; 155/1292 (Q472) 4. WB.211a; 143/1270 (O501)
5. Br.1006a; 125/1336 (M433)(b*)

2,3 Nannoceratopsis plegas Drugg, 1978
2. WB.218a; (100/1441 (K320) 3. WB.133a; 170/1265 (R500)

6,7, 11 Micrhystridium deflandrei Valensi, 1948
6. Br.985a; 200/1195 (U570) 7. Br.1047a; 140/1348 (O410)
11. Br.1330a; 210/1282 (V484)

8-10 Micrhystridium densispinum Valensi, 1953
8. Br.693a; 130/1382 (N380) 9. Br.1155a; 185/1417 (T340)
10. WB.211a; 155/1193 (P583)

12,13 Micrhystridium fragile Deflandre, 1947
12. Br.851a; 220/1408 (W350) 13. Br.520a; 190/1445 (T523)

15. Micrhystridium inconspicuum (Deflandre, 1935) Deflandre, 1937
15. WB.213(2)a; 130/1414 (M344)

16. Micrhystridium nannacanthum Deflandre, 1945
16. WB.183a; 195/1445 (U321)

17,18 Micrhystridium polyhedricum Valensi, 1948
17. WB.228a; 132/1302 (N460) 18. Br.753a; 125/1372 (N390)

19,20 Micrhystridium recurvatum Valensi, 1953
19. Br.947a; 220/1442 (W323)(b*) 20. Br.605a; 205/1502 (V261)(b*)

21,22 Micrhystridium recurvatum forma brevispinosa Valensi, 1953
21. Br.727a; 175/1447 (R314)* 22. WB.88a; 190/1186 (T584)

23 Micrhystridium recurvatum forma longispinosa Valensi, 1953
23. WB.83a; 205/1225 (V342)

24 Micrhystridium recurvatum forma multispinosa Valensi, 1953
24. WB.68a; 140/1273 (O490)

25,26 Micrhystridium rarispinum Sarjeant, 1960b
25. Br.1655a; 220/1244 (W524) 26. WB.73a; 210/1427 (U343)

1270 (O501)

1265 (P500)

/1348 (O410)

/1417 (T340)

/1445 (T523)

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5/1372 (N330)

5/1502 (V261)(b*)

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/1186 (T534)

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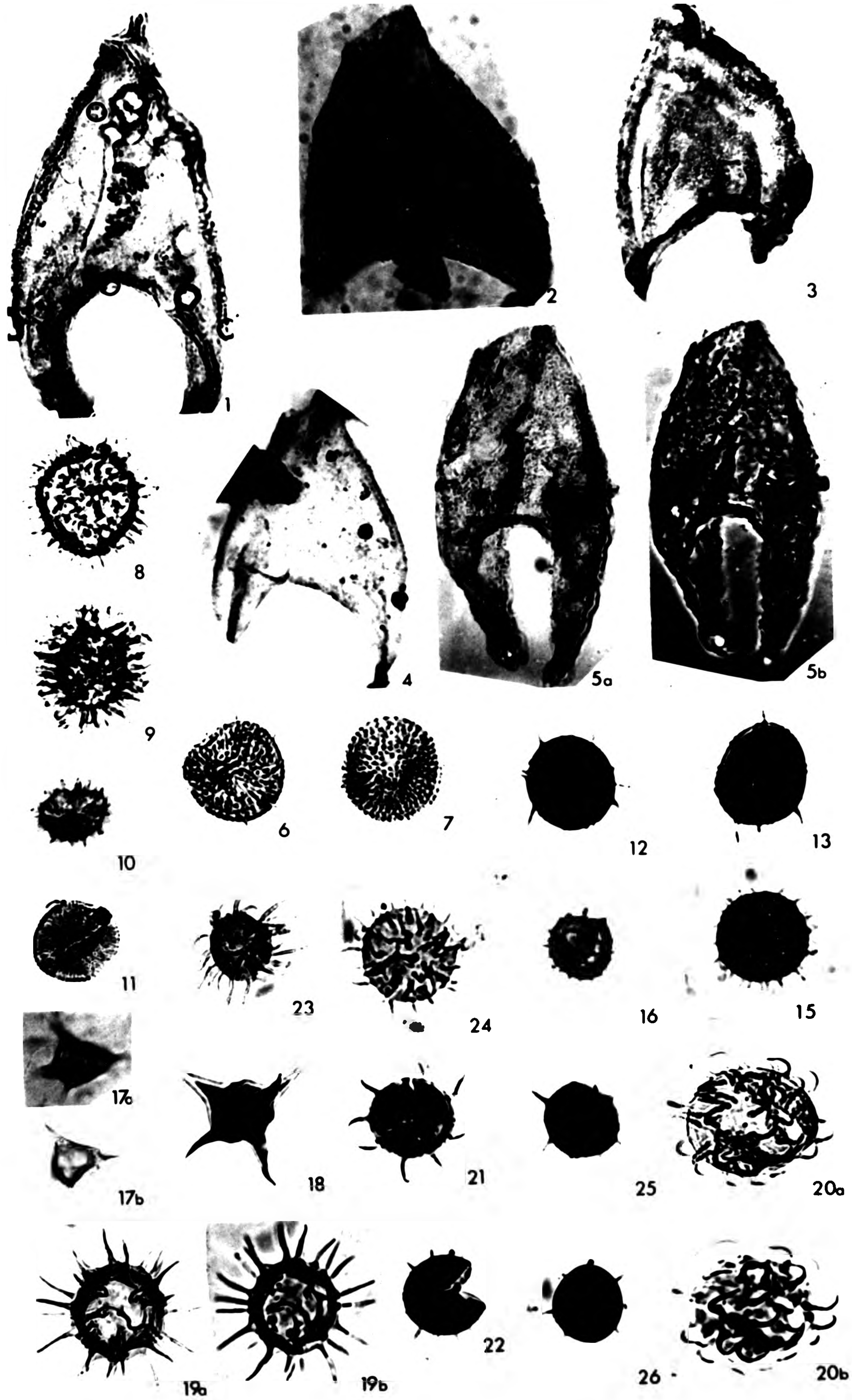

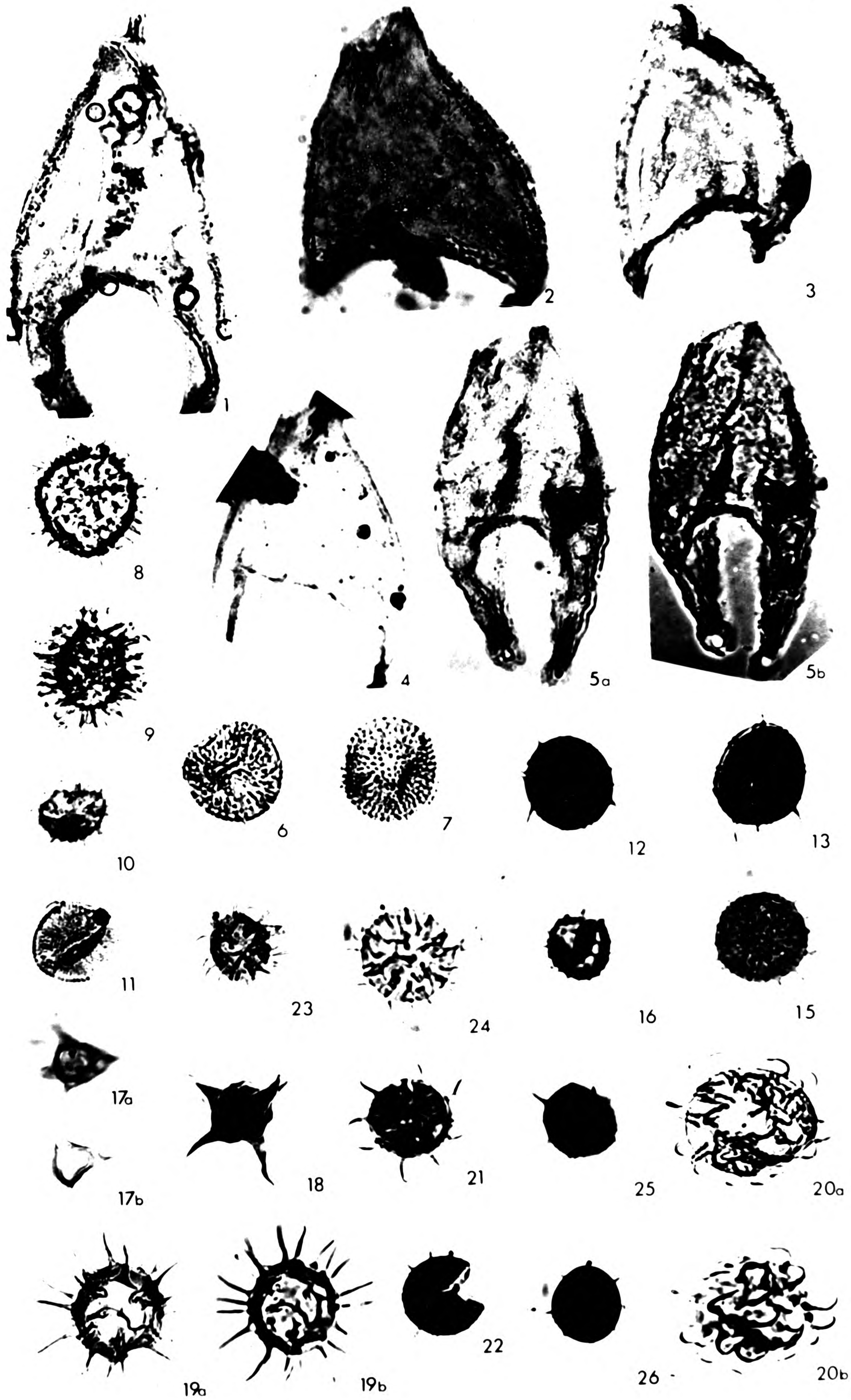
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PLATE 32

Figs (Figs. 1-17,19 X1,000; Figs. 18,20,21 X750)

1,2 Micrhystridium recurvatum forma multispinosa Valensi, 1953
1. Br.1723a; 160/1415 (Q353) 2. WB.98a; 200/1446 (U314)

3 Micrhystridium recurvatum forma reducta Valensi, 1953
3. WB.103a; 200/1330 (U434)

4-6 Micrhystridium sydus Valensi, 1953
4. WB.133a; 127/1382 (N381) 5. WB.33a; 105/1342 (L422)
6. Br.1898a; 185/1182 (T591)(b*)

7,8 Micrhystridium variabile Valensi, 1953
7. Br.465a; 180/1277 ((S490)* 8. Br.669a; 210/1420 (V344)*

9-11 Multiplicisphaeridium sp.
9. Br.947a; 185/1452 (T311) 10. Br.985a; 220/1371 (W390)
11. Br.985a; 075/1434 (G333)

12 Pterospermopsis harti Sarjeant, 1960b
12. WB.198a; 158/1378 (Q391)

13 Solisphaeridium claviculorum (Deflandre, 1938) Sarjeant, 1968
13. WB.108a; 054/1304 (E460)

14-16 Solisphaeridium stimuliferum (Deflandre, 1938) Staplin, Jansonius & Pocock, 1965
14. Br.947a; 185/1361 (S403) 15. Br.1450a; 180/1272 (S494)
16. WB.58a; 220/1210 (W563)

17,19 Gen. et sp. indet. I
17. Br.727a; 055/1216 (E554) 19. Br.1155a; 080/1194 (H570)(b*)

18 Gen. et sp. indet. G
18. Br.605a; 045/1460 (D300)(a*)

20 Gen. et sp. indet. H
20. Br.884a; 075/1453 (G313)(a*)

21 Gen. et sp. indet. F
21. Br.620a; 070/1455 (G311)

nsi, 1953
446 (U314)

1953

342 (L422)

/1420 (V344)*

0/1371 (W390)

Sarjeant, 1968

Staplin,

/1172 (C494)

(H570)(b*)

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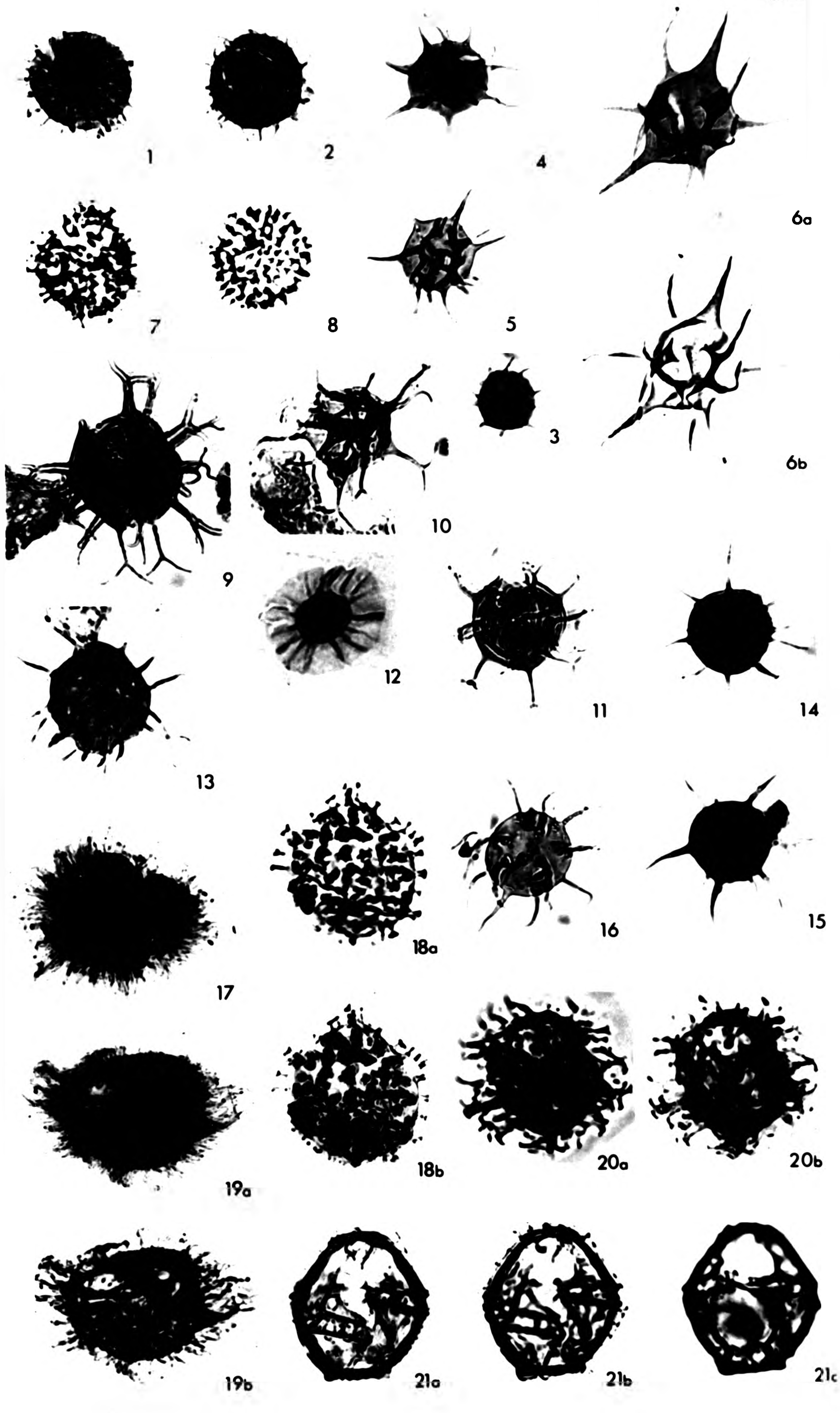

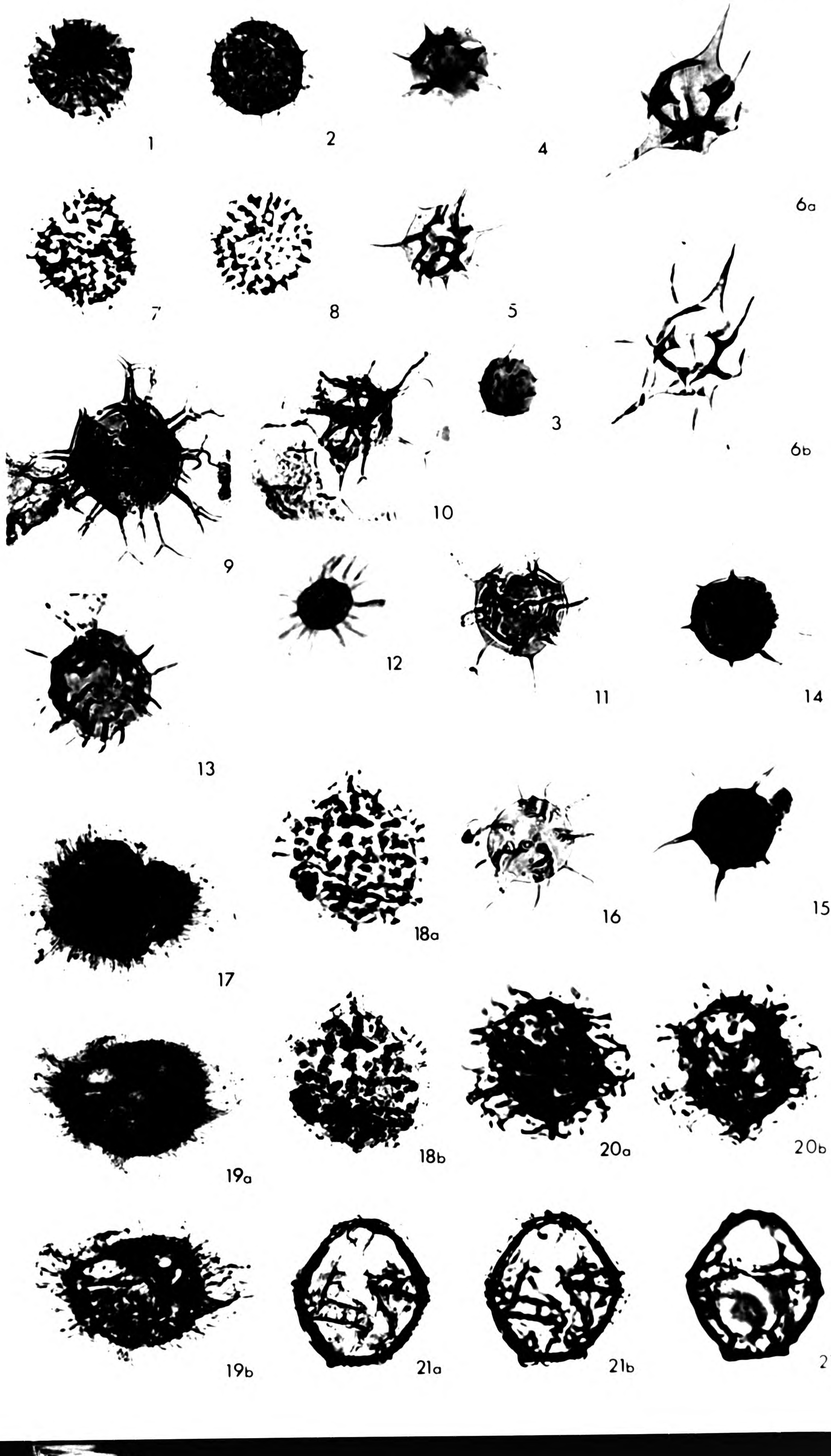
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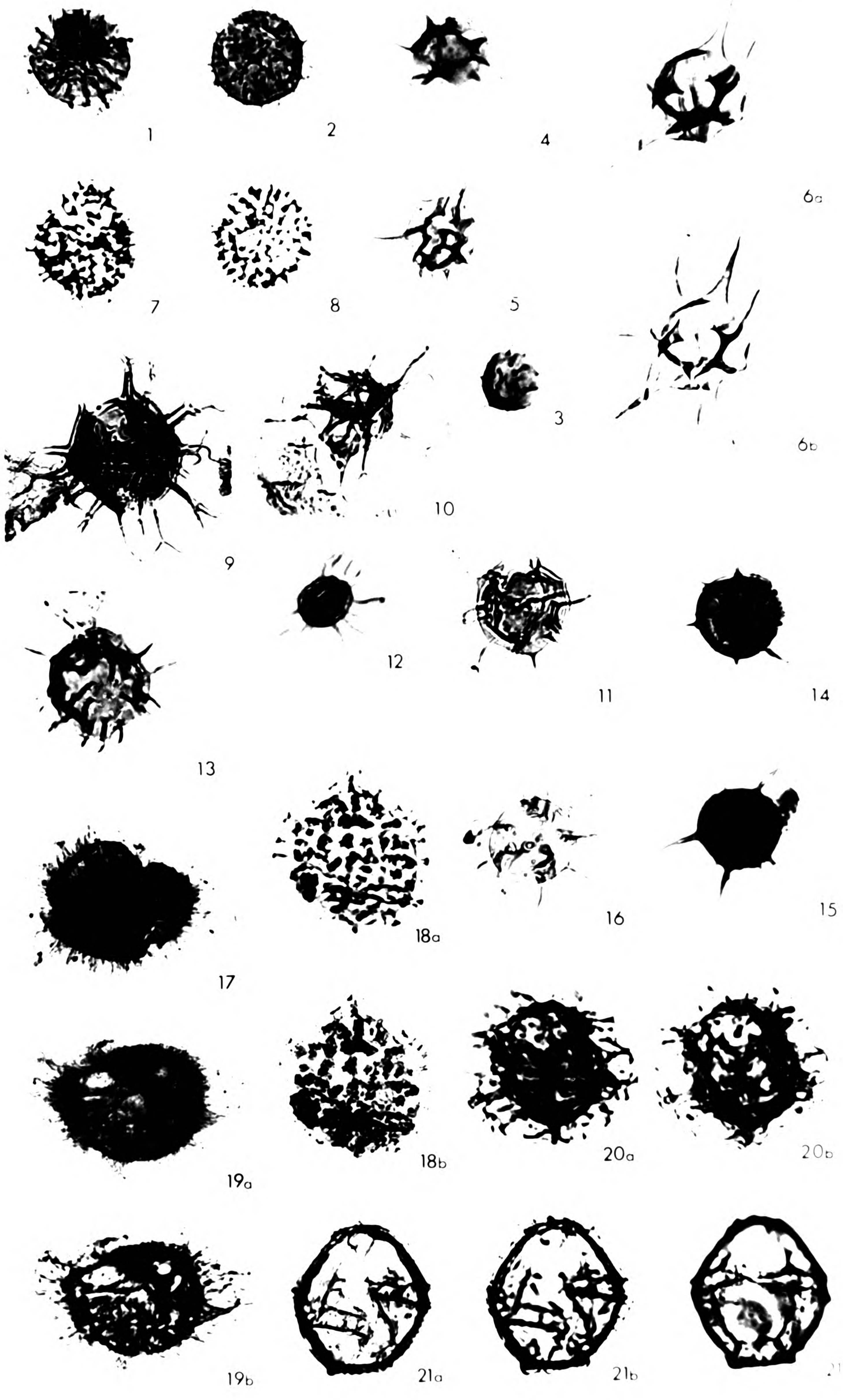
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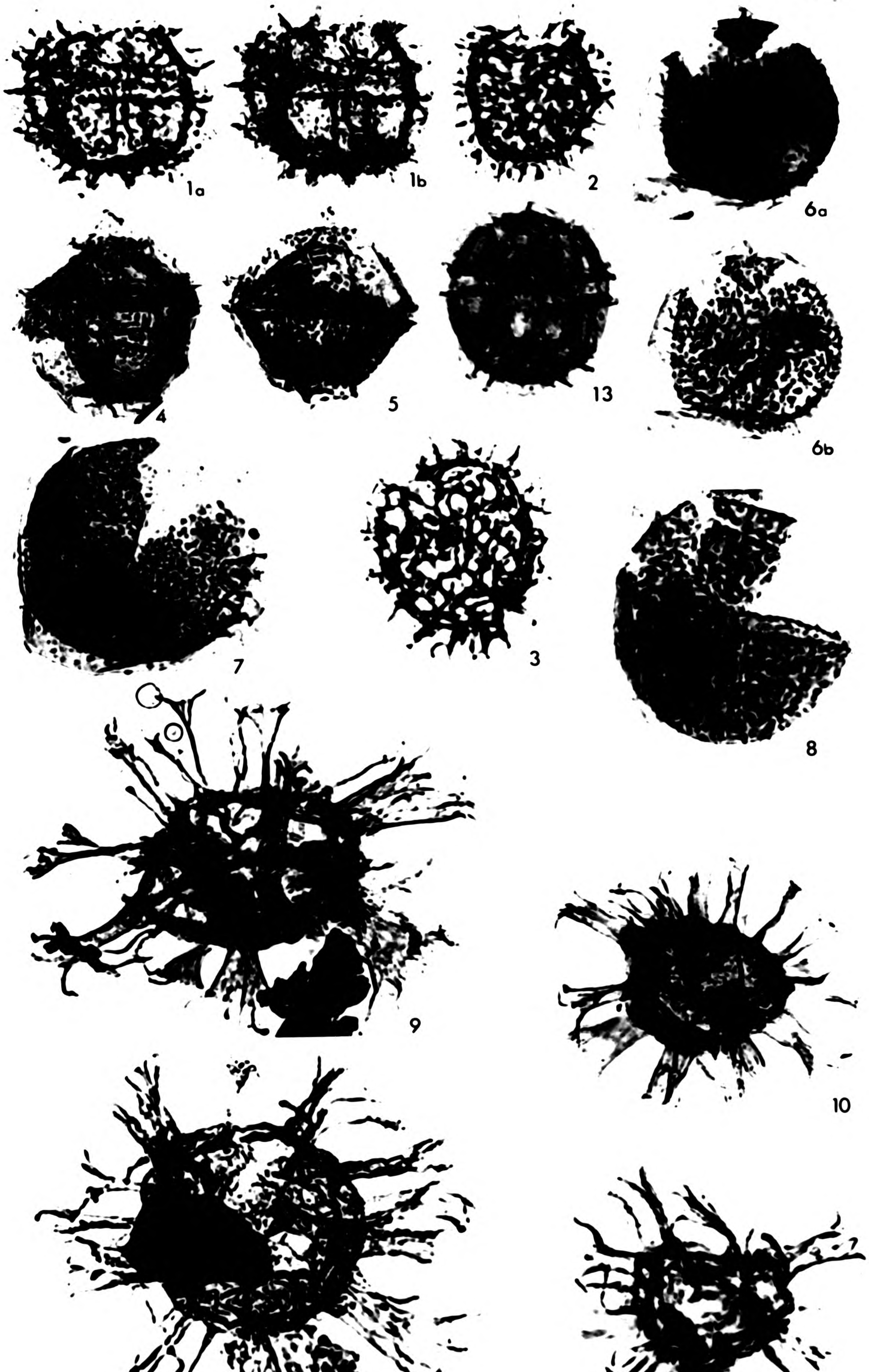
PLATE 33

Figs

1-3	Gen. et sp. indet. A	
	1. Br.313a; 145/1234 (P532)(a*)	2. Br.916a; 160/1240
	3. Br.916a; 190/1289 (T481)	
4-8	Gen. et sp. indet. B	
	4. Br.785a; 175/1487 (R273)	5. Br.785a; 195/1221 (T544)
	6. Br.1354a; 205/1456 (V302)(b*)	7. WB.43a; 140/1304 (O460)
	8. Br.1047a; 205/1424 (U334)	
9-12	Gen. et sp. indet. D	
	9. Br.313a; 105/1502 (K263)	10. Br.500a; 060/1291 (F472)
	11. Br.500a; 035/1407 (C354)	12. Br.292a; 170/1411 (R350)
13	Gen. et sp. indet. C	
	13. WB.178a; 119/1446 (M312)	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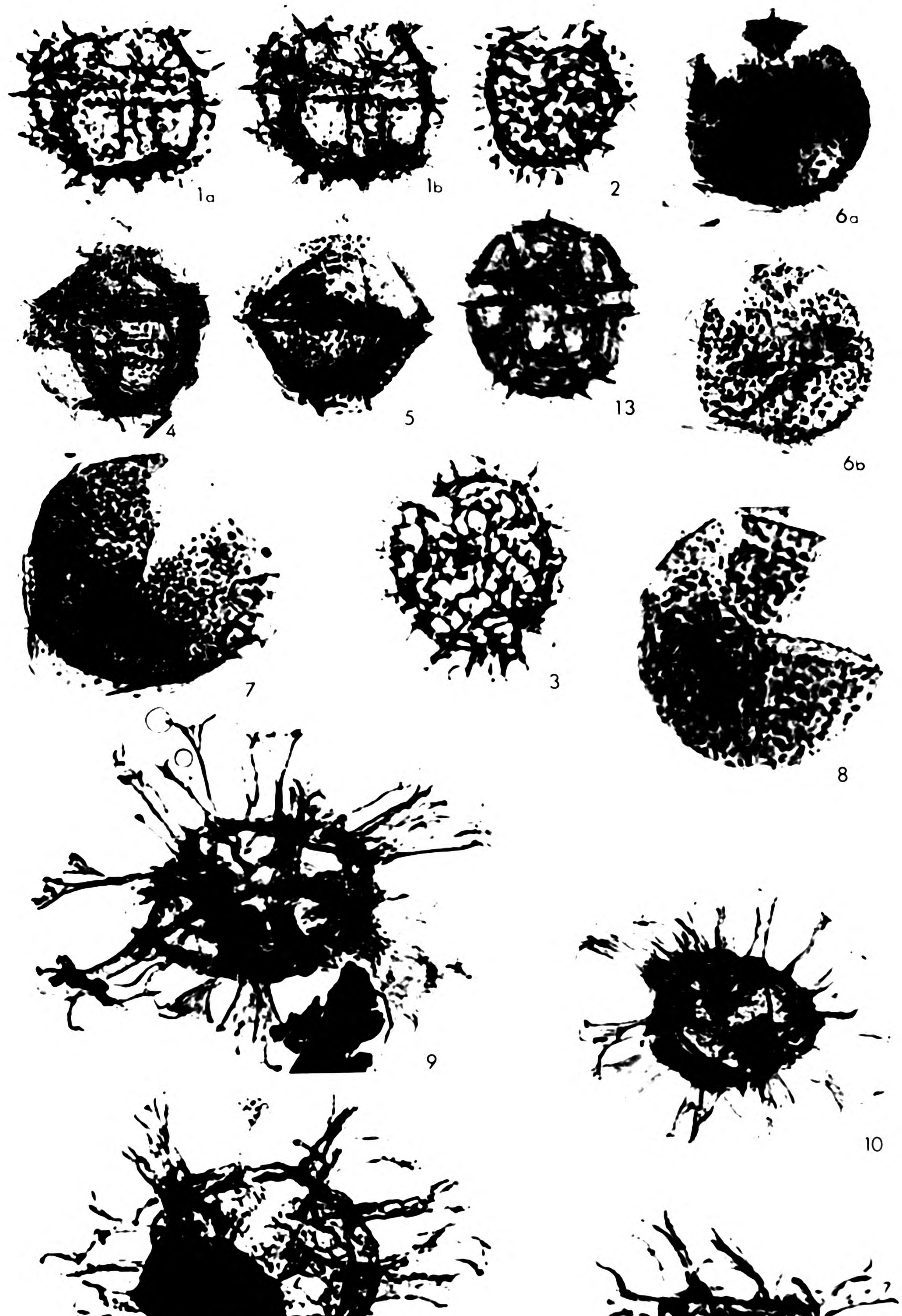
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PLATE 34

Figs

1-3 ?Systematophora valensii (Sarjeant, 1961a) Downie & Sarjeant, 1964

1. WB.108a; 175/1384 (R384)   2. WB.128a; 162/1408 (Q350)

3. WB.103a; 195/1471 (U282)

4 Gen. et sp. indet. E

4. Br.246a; 155/1318 (Q451)

5-7 Microforaminifera linings

5. Lenticulina sp. WB.128a; 075/1273 (G494)

6. Dentalina sp. WB.73a; 085/1350 (J412)

7. Frondicularia sp. WB.148a; 078/1354 (H410)

8,9 Scolecodonts

8. WB.138a; 127/1565 (N192)   9. Br.683a; 220/1349 (W412)

10,11 Tasmanites sp.

10. Br.582a; 050/1403 (E360)   11. Br.727a; 190/1389 (T374)

12 Organism A*

12. Br.957a; 110/1221 (L544)

& Sarjeant,

1438 (Q350)

/1349 (W412)

0/1389 (T374)

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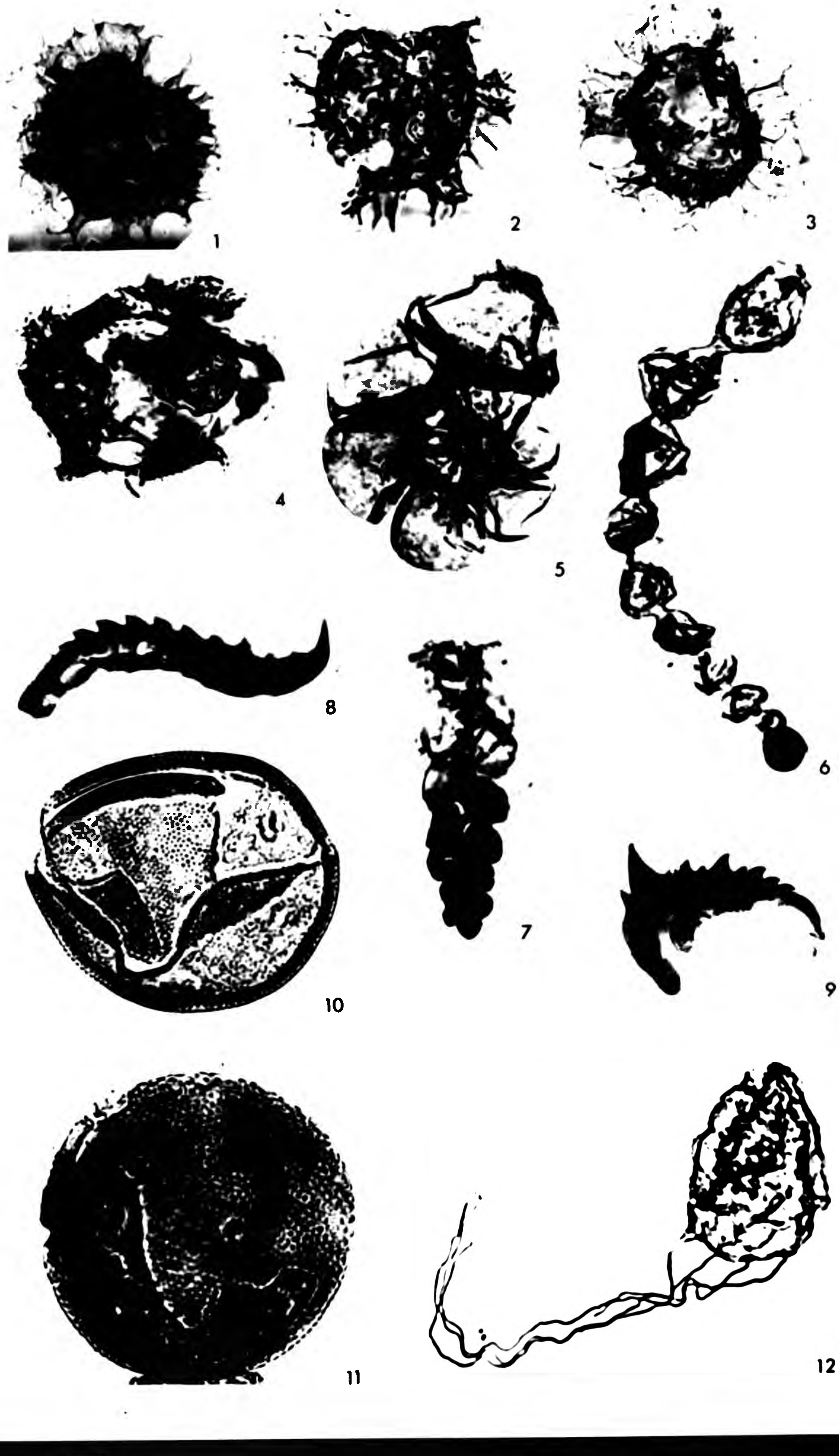

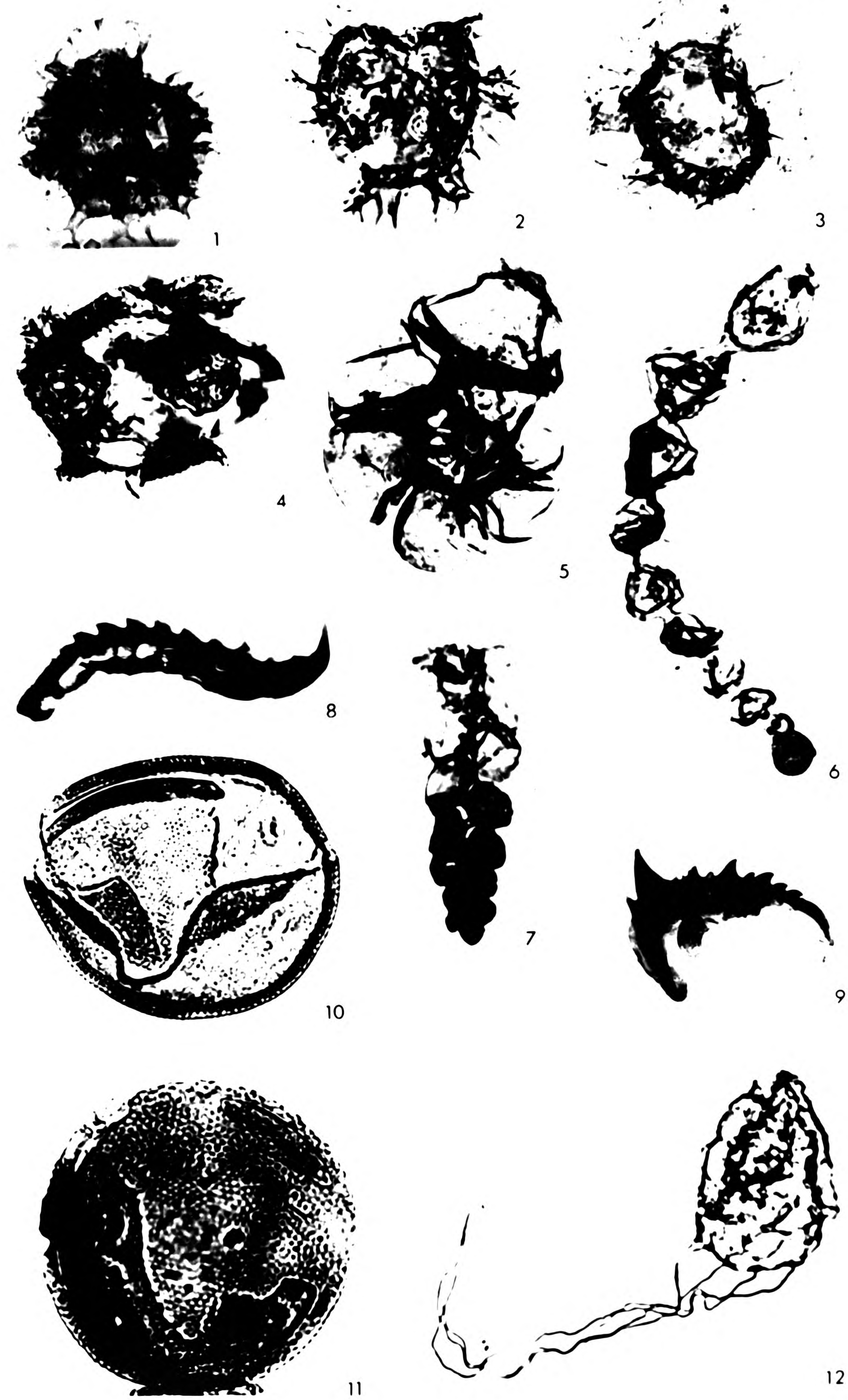
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