AN ANALYSIS OF
THE MICROFAUNA AND MICROFLORA
OF THE
UPPER EOCENE OF THE HAMPSHIRE BASIN

By

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Thesis

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Abstract

The succession of the Upper Bracklesham and Barton beds of Hampshire is discussed in a lithostratigraphic context. Compilations from surface sections and borehole data enable lithological correlations to be made, based on the cyclic pattern of lithofacies. The areal distribution and variations in thickness of lithological units are elucidated and the local palaeogeography is reconstructed. Stratigraphic usage of planktonic and larger Foraminiferida in the North West European Upper Eocene is reviewed. A detailed study of the Nummulites shows the presence of seven morphological units and their distribution as local stratigraphic markers is evaluated. The total microfauna and microflora of the Barton Beds from Christchurch Bay and Alum Bay is examined quantitatively and the percentage distributions of Foraminiferida, Ostracoda and Mollusca are presented graphically. In addition the occurrence of Dinoflagellate and Tasmanitid cysts, Angiosperm seeds, Echinoderm, Sponge, Bryozoan, Annelid and Vertebrate remains are studied qualitatively. The variation in distribution of species and larger units is used to provide a biofacies zonation of the Barton Beds. Two cycles of sedimentation are recognised and and the two sections are compared. The total fauna and flora is classified into 459 indigenous taxonomic and organ groups. Microplankton and Holothuroid ossicles are recorded for the first time from the Barton Beds and 43 species are described and illustrated. 99 species of Foraminiferida, 34 of Ostracoda, 168 species and groups of Mollusca and 28 species of smaller phyla are also described and the majority figured. Finally 26 Echinoderm and 61 Vertebrate organ groups are recorded.

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Section 1 INTRODUCTION,METHODS and LOCALITIES

Section 1:1 INTRODUCTION

1:1:1 The Problem

This project was originally devised to test the feasibility of a quantitative total microfaunal and microfloral study, to apply it to problems of palaeoecology and stratigraphy, and to devise new methods of correlation. The Barton Beds and Headon Beds of Hampshire were initially chosen to provide a model for such a study but the inclusion of the latter division had to be abandoned in view of the practically doubled weight of taxonomic work involved.

The revised thesis falls along two main lines of research, namely the total faunal and the stratigraphical aspects of the Upper Eocene. Quantitative microfaunal and microfaunal investigation is concentrated on the marine parts of the Barton Beds cycle of sedimentation (see Fig.2). All the evidence from dry washed residues is dealt with but palynological aspects had to be curtailed owing to the lack of time. This investigation is associated with biofacies and palaeoecological interpretations (Section 3).

Any such work demands a detailed examination of the stratigraphy. The upper part of the Eocene (see Fig.2) is studied in a lithostratigraphical context. "Classical" biostratigraphy (i.e. use of evolving lineages for zonation and correlation) is applied in the case of one group of fossils, namely the Nummulites (Section 2).

1:1:2 Samples, Depositories and Taxonomy

Two main sections were sampled at close intervals for the quantitative aspects of the project, namely Christchurch Bay (129 samples) and Alum Bay (113 samples). In addition 40 samples from other English Palaeogene localities (London Clay to Middle Oligocene) and 5 samples from the French Paris Basin localities were examined for comparative taxonomic purposes. All are assigned Imperial College Micropalaeontology sample numbers in the series 6481-7199 and residues are deposited in the Micropalaeontology Laboratory, Imperial College of Science and Technology, London, S.W.7.

This study involved a large amount of taxonomic work. A total of 459 indigenous units (species, subspecies, varieties and "organ groups")

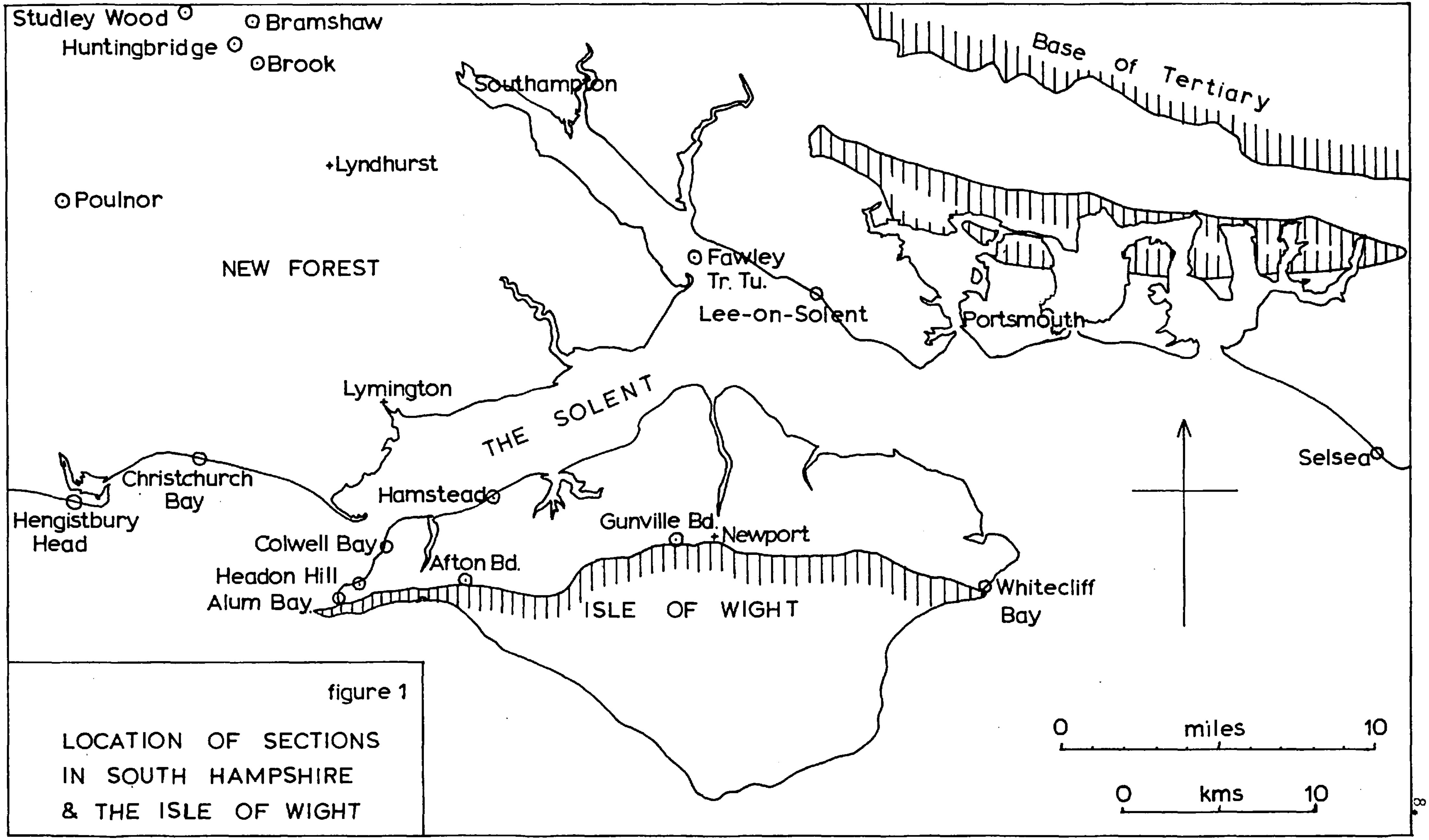


figure 1

LOCATION OF SECTIONS
IN SOUTH HAMPSHIRE
& THE ISLE OF WIGHT

belonging to 10 major groups are described and/or figured from the Barton Beds (see Fig.3). This demanded a less exhaustive treatment of certain groups (particularly Mollusca and Ostracoda) than would have been preferred, especially as some groups had to be studied from first principles (Dinoflagellates, Ostracoda) and some required a new approach (Echinoderms, Vertebrate teeth). No new names have been proposed in view of this less rigorous application and undescribed or unidentifiable units are left as numbers. All figured specimens are deposited in the Micropalaeontology Laboratory, Imperial College.

1:1:3 Acknowledgements

The author is deeply indebted to Mr. D. J. Carter for his general supervision, encouragement and advice. The main part was undertaken at the Department of Geology, Imperial College of Science and Technology, while on a Natural Environmental Research Council Studentship. It was completed while holding a Demonstratorship at University College, London, and the author is grateful to Professor D. T. Donovan for his provision of equipment and facilities.

Particular thanks is also due to Dr. Marjorie Muir for her encouragement throughout the project, for her advice on all aspects of the Dinoflagellate and Tasmanitid work and for her considerable help with the Stereoscan illustrations.

Acknowledgement is gratefully given to Professor D.V.Ager, Mr.D.Curry, Mr.Fowler, Mr.A.King, Mr.C.King and Mr.F.C.Stinton for many fruitful discussions and the provision of samples and specimens, also to Mr.Castell and to Dr. C.Adams for providing access to the collections of Mollusca and Foraminiferida respectively in the British Museum (Natural History).

Technical aid is always essential for work of this kind and the author is particularly indebted to Miss N.Flowerdew for her help with the processing, to Mrs. M.Culpan for operation of the Stereoscan, to Mr.P.Elgar for his help with the photography and reproduction of the plates, to Mr. C.Stuart for reproduction of the diagrams and to many other members of the technical staffs at both Imperial and University Colleges. Finally the author would like to thank his wife for completing the typing and for her help with the

Figure 2. The Main Divisions of theEnglish Palaeogene showing the section studied (X)

Approximate Stages		Cycles	Lithological Units
Rupelian			Up.Hamstead Beds
Lattorfian			Lr.Hamstead, Bembridge, Osborne & Up.Headon Beds M.Headon Beds
Bartonian	X		Lower Headon Beds Barton Sands Barton Clay
Auversian			Up.Bracklesham Beds
Lutetian			M.Bracklesham Beds
Cuisian			Lr.Bracklesham Beds
Ypresian			Bagshot Sands London Clay
Landenian			Woolwich & Reading Beds

Section 1:2 METHODS

a. Sampling

The optimum time for sampling the major coastal exposures proved to be spring, after the winter storms had removed the worst of the slumps and debris. At each locality the section was cleaned prior to measurement with a tape. Samples were taken as 3 inch or more, usually 6 inch blocks. Tables 1 and 2 are to scale and the sample thickness can be elucidated from them. The sample interval varied around 1ft.6ins. Some members were collected at 2ft.0in. to 4ft.0in. intervals and certain lithological boundaries at 1ft.0in. intervals.

All the measurements were taken in feet and inches. The figures listed on Tables 1 and 2 in metres were calculated back from the field measurements, so there are inconsistencies in accumulative metric stratigraphic heights above the base of the Barton Beds.

b. Processing

500 gms. of dry unwashed sample was taken in each case. Predominantly sand grade samples could be broken down merely by boiling in a solution of sodium carbonate. More tenaceous clays and sandy clays had to be disaggregated by the white spirit method as follows. After the roughly broken sample had been thoroughly dried (3 hours at 115°C) it was immersed in turpentine substitute (i.e. white spirit). When this had soaked for 20 minutes the excess white spirit was decanted and water added. The rock immediately commenced breakdown, which was generally complete after several hours. The resulting slurry could then be boiled in a solution of sodium carbonate, washed through a 200 mesh sieve and dried. This method provided excellent, very clean residues and no extra treatment was necessary.

The above methods provide samples with a lower size limit of 76 microns. After the 60-200 mesh (251 - 76 microns) and greater than 60 mesh (251 microns) fractions were weighed a rough grain size analysis could be calculated.

FIGURE 3 Main Taxonomic groups and numbers of species

Group	species and varieties	Other units	Total
Dinoflagellates	30		30
Tasmanitids	10		10
Incertae Sedis	4		4
Angiosperm seeds	3		3
Foraminiferida			99
: Smaller benthos	96		
: Planktonics	1		
: Nummulites (Bart.)	2		
Porifera		1	1
Annelida	3	1	4
Bryozoa	16		16
Ostracoda	34		34
Other Arthropoda		3	3
Mollusca			168
: Pelecypoda	47	6	53
: Scaphopoda	2		
: Gastropoda	108	4	112
: Cephalopoda		1	1
Echinodermata			
: Asteroid ossicles		7	
: Ophiuroid ossicles		7	
: Echinoid ossicles		7	
: Crinoid ossicles		2	
: Holothuroid sclerites		3	
Vertebrates			61
: Teeth		17	
: Scales		5	
: Otoliths	39		
TOTAL INDIGENOUS UNITS			459

c. Photography

The Dinoflagellates, Tasmanitids, "Microforaminifera" and some Holothuroid sclerites were photographed using a Zeiss Photomicroscope (see Dinoflagellate section).

The smaller Foraminiferida, Ostracoda and some Bryozoa, Echinoderms and small groups were illustrated using the Scanning Electron Microscope unit (Stereoscan) in the Department of Geology, Imperial College, London. Specimens were mounted on aluminium stubs using double-sided sellotape and coated with 100-150 Å of carbon, aluminium or gold/palladium. The equipment was run at a filament voltage of 20-30 kV and the microfossils were photographed using an Exa 1a camera body and Adox KB14 or Ilford Pan F film. Details on the theory and use of this revolutionary equipment may be found in HAY & SANDBERG (1967) and from the bibliography therein.

The maximum size for optimum illustration using the Stereoscan is about 1 or 2 mm. and larger micrfossils were best photographed by a third method. This was the Leitz Aristophot equipment in the Department of Geology, University College, London. Good results were obtained using a Leitz Wetzler lens, long extension bellows, double oblique illumination, a Leica camera body and Ilford Pan F film.

Section 1:3 SAMPLE LOCALITIES

1:3:1 Christchurch Bay

Location

The stratotype Bartonian and the Lower Headon Beds are exposed in the coastal section at Christchurch Bay between Mudeford and Milford-on-Sea (Nat.Grid Refs. SZ 192926 to SZ 289913). Access is via Mudeford (Avon Beach) Highcliffe (steps), Barton (steps) and Milford.

Structure

The Upper Eocene shows a very low angle dip to the east, so that successively higher units are exposed towards Milford. They are capped by 20-30 ft. of Pleistocene Plateau Gravel, below which decalcification has occurred to considerable depths.

Aspect

The cliff varies in height to just over 100 ft. (at Barton) and is in an extremely unstable state. Slumps cover a strip several hundred yards in width between Barton and Highcliffe, with the result that the middle and upper parts of the cliff from Highcliffe Castle to the Golf Links and from Becton Bunny to Long Mead End are in a very disturbed state. Recession has reached several yards per annum during the last 20-30 years. Attempts by the local authorities to stabilise the cliff have resulted in, at the last examination (March, 1968), obstructing most of the Middle and Lower Barton Beds. Coastal defences will eventually extend from Highcliffe Castle to Becton Bunny.

Literature and Samples

Excellent descriptions of the Barton Beds may be found in GARDNER, KEEPING & MONCKTON (1888) and BURTON (1929, 1933). CURRY & WISDEN (1958) also provide a clear sketch section, enabling easy location of individual units. The Lower Headon Beds are described in detail by TAWNEY & KEEPING (1883). Additional information is included in CURRY (1958) and CHATWIN (1960). BURTON's (1933) bed classification (lettered from A to L) is used here for convenience.

The heavy slumping and decalcification in the middle and upper cliffs necessitated sampling the base of the section. Here marine erosion exceeds the rate of slumping and low recessional bluffs are kept clean. Unfortunate this meant that only short sections could be taken and two sampling gaps remain. As with practically every other Tertiary section examined there are discrepancies between published thicknesses of individual members and those of the present author. Indeed other workers cannot seem to agree upon such measurements. In this case it is probably due to variations perpendicular to the shore associated with the rapid cutting back of the cliff.

The sample positions, individual short sections and brief lithological descriptions are summarised in Table 1. Sections were located by pacing from known markers (entrance to Chewton Bunny, etc.) and the grid references calculated to the nearest 10 m. from the relevant 1:25,00 O.S. maps (SZ 19, 29). These were last revised in 1959 and so errors of up to 30 m. in northings are envisaged to allow for erosion. The published accounts are practically complete and remarks will have to be restricted here to variations from these records and new observations.

Notes on Individual Members

The white sands with abundant plant remains below the base of the pebble beds, east of Mudeford, contain quicksand structures with an amplitude of up to approximately 4ft. The upper part of this section is deeply weathered and cannot be accurately traced eastwards beyond the wooded slope below Highcliffe Castle.

The Nummulites prestwichianus horizon (where that species occurs as pyritised casts) lies immediately above a 6 inch bed of pale ferruginous clay. The latter seems to correspond to the ironstone bed of GARDNER, KEEPING & MONCKTON (1888) and CURRY (1937). It provides a good field marker for the base of the Barton Beds.

The thickness of beds A1 and A2 are, on the author's measurements, the reverse of that given by BURTON (1933), CURRY (1937) and CURRY & WISDEN (1958). Thus the glauconitic sandy clays of A1 are 11ft.3ins. (3.43 m.) or 13ft.9ins. (4.19 m.) thick, not 20 or 21 ft. as given by those authors. A2 contains abundant calcareous fossils throughout its thickness.

Soft, pale, clay septaria are not mentioned in the literature and have been found towards the base of bed A2. They are discontinuous westwards and reach beach level just west of Chewton Bunny.

A thin (0ft.6ins.) horizon of pale clay in the middle part of bed C has not been previously recorded and marks a change from more to less glauconitic and finer sandy clay upwards. It consists of small, well defined lenticles of glauconitic sandy clay in paler clay and might represent a clay conglomerate or rather irregular burrowing. In either case it marks a break in deposition. A lower discontinuity, mentioned by Curry (pers. comm.) half-way up bed B could not be traced.

Slips, apparently controlled by the bedding, completely obliterate 10.ft. (3.05 m.) of strata in the middle of bed D. A section could not be augered (the glauconitic sandy clay is too hard), but rough levelling from a small foreshore exposure below B.10.B yielded a thickness comparable to that given by BURTON and CURRY & WISDEN. BURTON mentions a sandier bed in this interval.

Most authors give the thickness of bed E (the Earthy Bed) as 5ft. but it is here taken to include two thin seams of Ostrea plicata, and Venericardi sulcata at 2ft.6ins. (0.76m.) and 6ft.6ins. (1.98m.) below the septaria. BURTON mentions finding pebbles in (probably) the lower seam.

The 22ft.6ins. (6.86m.) of bed F, between the two septaria bands may b subdivided on containing abundant Annelid tubes in the lower half and concen trations of a small species of Turritella above.

The top of bed F (6ft.0ins.(1.83m.)above the upper septaria) is marked by a thin but distinctive shell bed crowded with small Turritella and Ostrea. This is probably BURTON's bed G and is locally hardened into an argillaceous limestone.

The boundary between the impervious clays of bed F and the permeable sands of bed H (the Chama Bed) throws up groundwater, with the result that extensive slumps cover most of the latter unit. Only the upper 5ft.6ins (1.68m.) of bed H are exposed where they are protected at the base of a clif below the Golf Links (B.I.C.,B.16.B.). The total thickness of bed H is taken from BURTON and CURRY & WISDEN (18ft.0ins.=5.49m.). Augering was rendered impractical by 6ft. of beach gravel at this locality and a single sample (7152 at B.I.C.) was taken on a visit after a storm had cleared a slightly larger area than is usually exposed.

A one inch bed of lignite is taken as the top of the marine Barton Beds (see TAWNEY & KEEPING, 1883, p.573). The Lower Headon Beds between her (B.20.B.) and Long Mead End are badly slumped and in a very confused state. Beyond that and towards Milford they are heavily overgrown.

1:3:2 Alum Bay

Location

A nearly continuous section from the top of the Upper Chalk to the Oligocene is exposed at Alum Bay at the western extremity of the Isle of Wight (Nat. Grid Ref. SZ 3085). The Barton Beds outcrop at the northern end of the bay (Nat. Grid Refs. SZ 305856 to SZ 304857). Access is by road from Freshwater or Yarmouth and by path behind the Alum Bay Hotel.

Structure

This section is in the vertical limb of the Isle of Wight monocline. The Lower and Middle Barton Beds dip at or near 90°, striking east-west. Soil creep has overturned them at the top of the cliff. The Upper Barton Sands (= Headon Hill Sands) have a reduced dip (down to 45°) and the Lower Headon and higher strata progressively become horizontal..

Aspect

The strata are well exposed in a series of small bluffs, separated by embayments and mud glaciers. A section of the Lower Barton Beds in the valley south of the path can be found by digging at the head of the "corrie". Most higher units are more accessible along the base of the cliffs, where marine erosion keeps them clean during the autumn, winter and spring. A gap in the succession occurs where the small stream valley emerges by the steps and where large scale slumping obliterates the Lower Headon and Upper Barton Sands.

Literature and Samples

Table 2 gives the detailed succession, location of sample positions and lithologies. Most samples were taken along the base of the cliffs. The offset section in the Lower Barton Beds could be readily tied in. Literature on the locality includes GARDNER, KEEPING & MONCKTON (1888), REID & STRAHAN (1889), O.WHITE (1921) and CURRY (in CURRY, MIDDLEMISS & WRIGHT, 1966). The glauconitic beds below the Nummulites prestwichianus Bed are described by FISHER (1862).

Notes on Individual Members

The bed with small pebbles in the middle glauconitic sequence has not been previously recorded.

Specimens of Chama were only found at the level of sample 6703 and the base of the Chama Bed is taken to lie between 6703 and 6702. The upper boundary of this unit cannot be definitely determined but is probably at the base of the white sands.

The white sands have no signs of bedding and the only marker band is 11ft.6ins. (3.51m.) above their base. The dip changes rapidly here and consequently thicknesses could not be measured and it was not sampled. The authors mentioned above give a total thickness of 90ft. (27.43m.) for this unit.

1:3:3 Other Sections

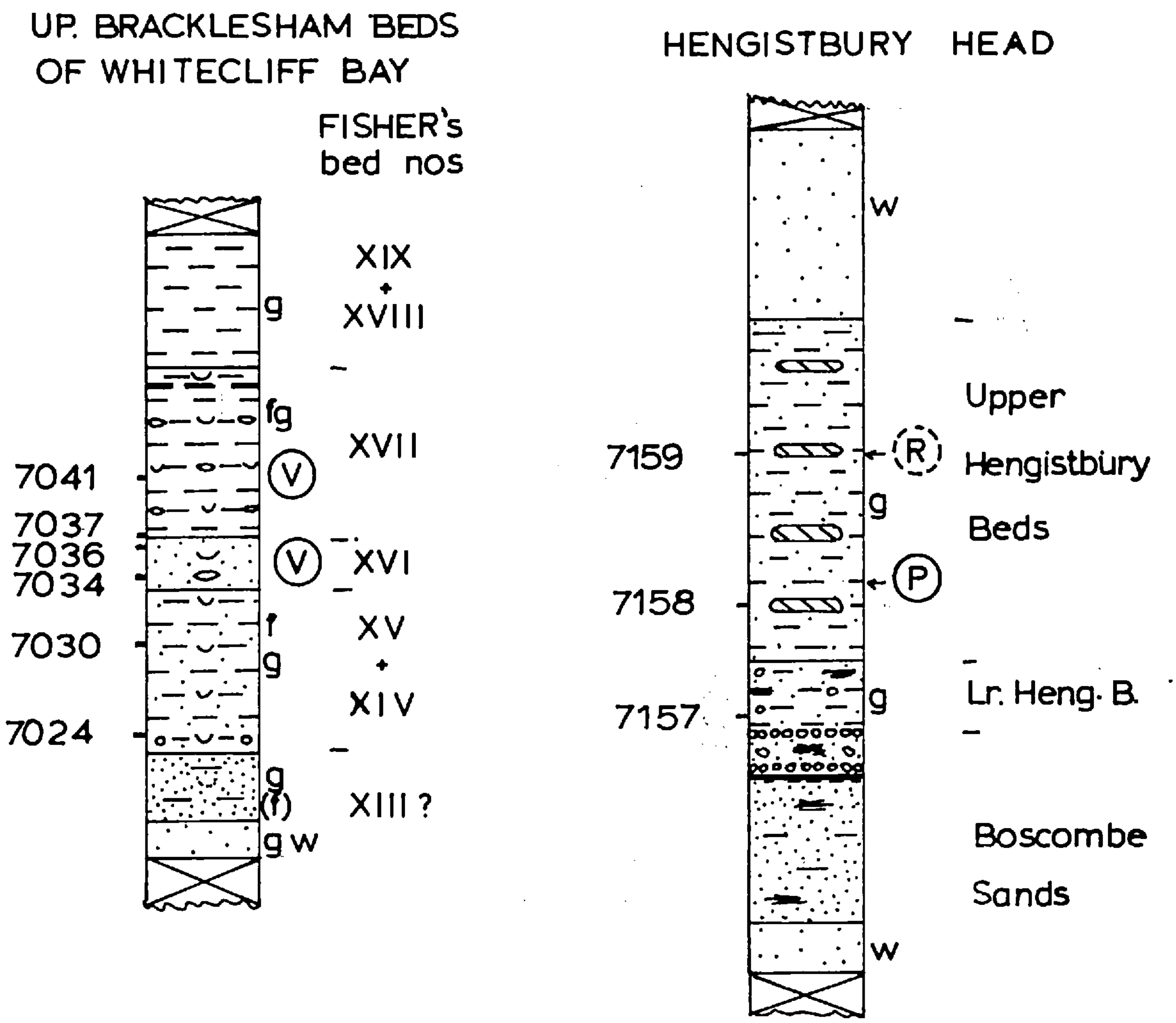
In addition to the two main series 45 samples were examined from 20 localities for comparative and stratigraphic purposes. Of these 5 were from the Imperial College Micropalaeontological collections and 21 were collected by the author. The remaining 19 samples were not collected by the author. These have been assigned Imperial College Micropalaeontological collection numbers and (where known) the original collector's numbers are given in parentheses. National Grid References are given where possible and the general location of sections are shown on Fig. 1. Lithological successions are given on Tables3 and 4.

a. Whitecliff Bay

This section is located at the eastern end of the Isle of Wight in the vertical limb of the monocline. It presents a nearly complete section from Paleocene Reading Beds, resting on Upper Chalk (SZ 638857), to gently dipping Oligocene Bembridge Marls (SZ 654873). Good descriptions may be found in REID & STRAHAM (1889), O.WHITE (1921) and CURRY (in CURRY, MIDDLEMISS & WRIGHT, 1966). Parts of the Bracklesham Beds are described in detail by FISHER (1862) and WRIGLEY & DAVIS (1937). Additional information on the Barton Beds and Oligocene is given in GARDNER, KEEPING & MONCKTON (1888) and FORBES (1856) respectively.

figure 4

SAMPLE POSITIONS AT WHITECLIFF BAY, HENGISTBURY HEAD & STUDLEY WOOD

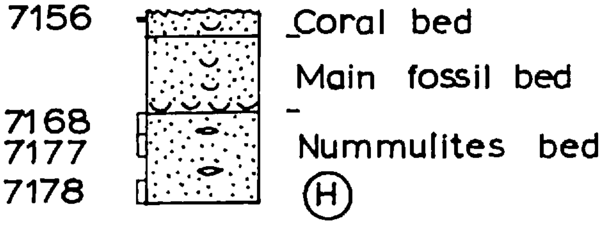


Scale: 1 cm.= 10 ft.= 3·05 m.

For legend see tables 3&4.

STUDLEY WOOD

(after Mr.C.King - pers. comm.)



Sample 7193 was taken from the Bembridge Oyster Bed (Nat.Grid Ref. SZ 645865), 8ft.0ins. (2.44m.) above the top of the Bembridge Limestone and 3ft.0ins. (0.91m.) below the band of Ostrea.

Sample 6500 comes from the brown sands of the Brockenhurst Bed, at the base of the Middle Headon series (Nat.Grid Ref. SZ 642864), 3ft.0ins. (0.91m.) above the clay conglomerate. The Brockenhurst Bed is very poorly exposed in the cliff and no trace of foreshore exposures could be found.

The outcrop of the Barton Beds is also very overgrown. It occurs in the broad valley where the steps reach the beach (SZ 641882) and all that is visible are unfossiliferous Barton Sands and a few small decalcified exposures of clay. Sample 1602 (collector unknown), in the Imperial College collections, is from the Lower Barton Beds of the "cliff steps". It contains abundant Nummulites rectus and is believed to be from the Lower Barton Beds. Foreshore exposures in the Nummulites prestwichianus Bed were described by KEEPING (1887) but are now covered by beach sand.

The upper parts of the Upper Bracklesham Beds are fairly well exposed to the southwest of the steps and samples 7024, 7030, 7034, 7036, 7037, 7041 were taken from FISHER's beds XIV to XVII (see Fig.4.).

Beds VIII to XIII were badly decalcified and overgrown on the occasions of the author's visits. Mr.A.King kindly provided sample 7190 from 8-10ft. (2.44-3.05 m.) above the base of bed VIII. Sample 7191 was collected by the author from the Nummulites laevigatus bed, 4ft.0ins (1.22m. above the base of bed VII. Sample 7192 was taken from the Venericardia planicosta bed (FISHER's bed IV) but its exact position could not be determined due to slumping.

b. Hamstead

A single sample, 7161, from a shell bed immediately below the Plateau Gravel at the summit of Hamstead Cliff (SZ 389908), is from the Upper Hamstead Corbula Bed. The Molluscan fauna is dominated by Pirenella monilifera (DEFRANCE) and Polymesoda convexa (BROGNIART). Descriptions of the section may be found in REID & STRAHAN (1889), O.WHITE (1921) and CURRY, MIDDLEMISS & WRIGHT (1966).

c. Colwell Bay

The section in the Middle Headon Beds at Colwell Bay is described in great detail by TAWNEY & KEEPING (1881). A single continuous section is hard to find but short overlapping outcrops in the cliff enable a complete succession to be elucidated.

Sample 6541 is from 4ft.3ins. (1.29 m.) above the top of the How Ledge Limestone behind the beach huts southwest of Colwell Chine (Nat.Grid Ref. SZ 326878). This is from the lower half of the marine series, below the Oyster Bed and above the top of the non-marine sequence (How Ledge Limestone). Sample 6530 is from the upper part of the succession, 21ft.0ins. (6.40 m.) below the base of the thin, non-marine, Upper Headon limestone. Its outcrop is below the small buckle fold just north of Linstone Chine (Nat. Grid Ref. SZ 330887). The marine and non-marine elements are intercallated in this part of the succession and a good field marker for the Middle/Upper Headon boundary cannot be found.

d. Poulnor

Sample 792, in the Imperial College collections, is from the Barton Clay of Ayles Brickyard, Poulnor, near Ringwood (Nat. Grid Ref. SU 175057). REID (1902, in the Ringwood Memoir) and BURTON (1933) give descriptions of the section. They record blue, fossiliferous clay overlain by white sand and Plateau Gravel. BURTON concludes that the clay represents an equivalent of the upper part of his bed F at Barton.

e. Hengistbury Head

Three samples were collected by the author: 7157 from the Lower Hengistbury Beds (SZ 168907) and 7158, 7159 from the Upper Hengistbury Beds (SZ 172905) (see Fig.4.). In addition, sample 7195 was collected by Mr.D.J.Carter (Hengistbury Head No.2) from the upper division (SZ 179906), probably 20 or 30ft. (6.10 or 9.14m.) above 7159. Details of the succession may be found in GARDNER (1879) and WHITE (1917).

f. Afton Brickyard

This important exposure (SZ 368864) proved to be badly overgrown when visited in September 1967. However one sample, 7160, was taken from what was considered to be the position of the "Rimella canalis" Bed, as described by CURRY (1942). This proved to be decalcified and Mr.Curry very kindly provided specimens of Nummulites from this bed (assigned sample no. 7175).

g. New Forest Upper Bracklesham Beds

Four exposures of Upper Bracklesham Beds are known from the northern part of the New Forest in the area between Cadnam, Lyndhurst and Fordingbridge All are small (usually under a foot high at any one place) and exposed only in the beds of those streams which cut through the Plateau Gravels. Two of them (Brook and Huntingbridge) could not be located. The exact position of the Huntingbridge exposure is hard to determine from FISHER (1862) but is believed to be close to Nat. Grid Ref. SU 250144. Specimens of the Nummulites from Huntingbridge were kindly donated by Mr.D.Curry (assigned sample no. 7176).

The Bramshaw exposure was originally described by FISHER (1862). It occurs in the stream bed of Shepherd's Gutter, southeast of where the road linking Fritham and Bramshaw crosses it. One of the two samples taken, 7154, was from Nat. Grid Ref. SU 263152. The other, 7155, was from about 100 yards downstream and 5 or 10 ft. (1.52 or 3.05 m.) stratigraphically lower in the succession.

The exposure at Studley Wood has not been previously described and its location was communicated by Mr.C.King of Imperial College, London. It occurs in the stream banks at the head of Latchmore Brook, where the stream flows into Studley Wood about 1 km. south of Hope Cottage (Nat. Grid Ref. SU 228160). A sample taken from this position (7154) is at the top of the succession in glauconitic sand. Three samples from an augered section made by Mr.King at the same locality (see Fig.4) contain the Nummulites species otherwise peculiar to Huntingbridge.

h. Lee-on-Solent

Two tubes of residue in the Imperial College collections are both labelled Lee-on-Solent and numbered 788. One of them (788a) has a microfauna identical to that of FISHER's bed XVII at Whitecliff Bay. The other

(788b) is slightly different and is believed to be from FISHER's bed 16 at Lee-on-Solent. This is the *Nummulites variolarius* Bed and is probably equivalent to bed XVII at Whitecliff Bay. Sample 7169 was kindly provided by Mr.C.King (Lee No.5) and is from the *Paracyathus* Bed at Lee-on-Solent (FISHER's bed 20). FISHER (1862) describes the section in detail and a correlation table with the Fawley Transmission Tunnel section is published by CURRY, HODSON & WEST (1968).

i. Bracklesham Bay

The section through the Bracklesham Beds between East Wittering and Selsea consists of foreshore exposures of seasonally variable extent. It was described by FISHER (1862) and his numbered notation of the units (arabic numerals 1-22) is used here. REID (1897) and CURRY & WISDEN (1958) provide additional information. The latter work includes up-to-date directions for locating individual members.

A sample in the Imperial College collections, no.787, is labelled "Clibs, off coast at East Wittering, Selsea Bill". East Wittering is several miles from the nearest exposure of the "Clibs" (= bed 22 in FISHER), the highest unit in the succession of Upper Bracklesham Beds. However, its fauna tallies with that part of the succession in better authenticated material and it is provisionally assigned to bed 22.

Mr.Fowler of East Wittering very kindly provided the author with two samples: one, 7171, from FISHER's bed 21 of Selsea and one, 7174, from the *Nummulites laevigatus* Bed (FISHER's bed 6) of Medmery. In addition, the author collected a second sample from bed 21 at Selsea, 7172, (Nat. Grid Ref. SZ 844929). Mr.A.King also made available Foraminiferida from a Lower Bracklesham Beds sample from East Wittering (BR/1/5, assigned sample no. 7199). All this material contains a variable amount of Recent contamination.

j. Fawley Transmission Tunnel

The new section through Middle Bracklesham to Lower Barton Beds, uncovered by the workings for the Fawley Transmission Tunnel, has recently been described by CURRY, HODSON & WEST (1968). It was excavated beneath

Southampton Water from two vertical shafts (SU 477028 and SU 501041) near Fawley Power Station and Chilling respectively.

Mr.C.King provided sample 7170, which he collected from tips at Chilling while excavations were in progress on CURRY, HODSON & WEST's bed H. These authors note that excavation followed a particular bed for a considerable time and confidence can be expected in the stratigraphic placing of this material.

k. Southampton Dock

A sample in the Imperial College collections (no.786) is from the Middle Bracklesham Beds of Southampton Dock. The section and its macrofauna have been described by WRIGLEY (1934).

l. Portsmouth

Foraminiferida from the Lower Bracklesham Beds of an unspecified locality near Portsmouth were made available by Mr.A.King (P.l., assigned sample no. 7197).

m. Staines

A sample of Middle London Clay, from Wraysbury Reservoir, near Staines, was donated by Mr.A.King (assigned sample no. 7196).

n. Paris Basin

Professor D.V.Ager kindly gave the author a sample of calcareous sand from the Sables d'Auvers of Nogent d'Artaud, east of Paris (assigned sample no.7195).

Mr.A.King provided three samples from the classic French Eocene localities. 7167 is of calcareous sand from the Sables d'Auvers of Le Guepelle (½ km. west of Survilliers, Seine-et-Oise), probably from POMEROL et al. (1965) bed 12 or 13. Sample 7165 is of soft, shelly limestone, from the Calcaire Grossier (ABRARD's (1925) zone IV) of Damery (Marne). 7166 is of shelly sand with abundant Nummulites planulatus from the Sables de Cuise of Pierrefonds (9½ kms. south of Cuise Lamotte). Finally Mr.A.King provided an assemblage of smaller Foraminiferida from the Sables de Cuise of Cuise Lamotte (C.l.M., assigned sample no. 7198).

Section 2 UPPER EOCENE STRATIGRAPHY

Section 2:1 The Problem

There are approximately 2,000 ft. of strata in the Hampshire Palaeogene and up to nearly 600 ft. of these lie in the interval under consideration, namely the Upper Eocene. Stratigraphic synthesis of these beds is hampered by several severe problems. Firstly the Upper Eocene was deposited in a marginal series of environments. These vary from non-marine, through estuarine to neritic conditions. Hiatuses are numerous and lateral variations are extremely rapid, with gradations from non-marine to neritic conditions occurring in the same unit over an interval of a few miles. Most fossil groups, although showing strong distinction between units, tend to be mainly locally facies controlled and do not provide many useful widespread stratigraphic markers.

This study is an attempt to recognise divisions and subdivisions in the English Upper Eocene, as far as possible to correlate the divisions locally and to suggest correlations between Hampshire and the related strata in France and Belgium. The last named problem is fraught with pitfalls and all suggestions in this field must be regarded as highly tentative.

The solution to these problems lie along three main lines of research. Lithological correlations have been made on all available published information. The use of suitable palaeontological stratigraphic markers is here restricted to the Foraminiferida in general and the *Nummulites* in particular. Palaeoecological and palaeogeographic interpretations are based on results of the lithological synthesis. Apart from a few general observations detailed palaeoecological studies have been restricted to the Barton Beds and this will be dealt with in Section 3.

Section 2:2 ENGLISH UPPER EOCENE LITHOSTRATIGRAPHY

2:2:1 Previous Work

An excellent summary of the literature on all aspects of the Lower Tertiary has been made by CURRY (1965). Mention must however be made here of those works which are particularly relevant to the stratigraphy.

Figure 5 Lithological divisions of the Upper Eocene and Lower Oligocene.

	Pebble Beds etc.	
M.Headon Beds Cycle		Bembridge Limestone Up.Headon, Osborne Beds
		"Venus" Bed
		Brockenhurst Bed
Barton Beds Cycle		Lower Headon Beds
		Pale Barton Sands Barton Bunny Clays
		Chama Bed
		Marine Barton Clay
		N.prestwichianus Bed
		"R.canalis" and Huntingbridge Beds
Upper Bracklesham Beds Cycle		N.variolarius Bed
		Tellina Bed
		Brook Bed
		Miocardia Bed
		M.hollowaysi & Little Beds
		Campanile Bed
Lower Bracklesham Beds Cycle		Ostrea tenera Bed
		N.laevigatus Bed
Lower Bracklesham Beds		

PRESTWICH (1846), in the first of his series of papers on the Lower Tertiary, provides the earliest useful subdivision of the Eocene. He included all strata between the base of the London Clay and the top of the Barton Clay in his "London Clay Formation". He subdivided this into a lower or "Bognor Beds" and an upper or "London Clay" unit. In 1857 he realised his mistake and replaced "Bognor Beds" with London Clay and "London Clay" with Bracklesham and Barton Beds. The strata above the Barton Clay he termed the "Fluvio-marine Formation".

The latter half of the 19th century saw the subdivision and labelling of these units much as we see them today. FORBES (1853) divided the "Fluvio-marine Formation" into the Headon, Osborne, Bembridge and Hamstead (recorded as Hemstead) Beds. FISHER (1862) provided a detailed survey of the Bracklesham Beds. He described the sections of Bracklesham Bay, Lee-on-Solent, Whitecliff Bay and the New Forest. The numbered labelling that he gave the units is still very useful and is employed in the present study for the three coastal exposures mentioned. He divided the Bracklesham section into four groups of strata on macrofaunal grounds (D, C, B and A). Of these D and C correspond to the Lower and Middle Bracklesham Beds. Division B includes the lower part of the Upper Bracklesham Beds, namely the Campanile to Macrosolen hollowaysi Bed at Whitecliff Bay (IX to XII) and Selsea (11 to 16). Division A consists of the upper part of the Upper Bracklesham Beds, including the Miocardia to Nummulites variolarius Beds at the same localities (XIII to XVII and 17 to 22).

VON KOENEN (1864) identified the base of the Oligocene in Hampshire with the Brockenhurst Beds and correlated them with strata at Tongres (Belgium) and Lattorf (North Germany). The base of the Oligocene was originally defined with the beds at Lattorf (BEYRICH, 1854). TAWNEY & KEEPING (1881) redescribed the Brockenhurst Beds in detail, subdividing them into a Brockenhurst zone below and a Royden zone above. They also provided descriptions and relationships of the higher parts of the Headon Series.

The Barton Beds received detailed attention from GARDNER, KEEPING &

MONCKTON (1888). They gave a zonation (not used here) and described the relationships between the Upper Bagshot Beds of the Sandhurst area with the Barton Beds of Hampshire. The base of the Barton Beds was at last adequately defined by KEEPING (1887) with the Nummulites prestwichianus Bed at Barton.

STAMP's(1921) description of cycles of sedimentation in the English Palaeogene provided the basis for modern research. He recognised four cycles in the Eocene of Hampshire (London Clay, Lower Bracklesham, Upper Bracklesham and Barton Beds) and labelled them with the stage names of North France and Belgium (Ypresian, Lutetian, Auversian, Bartonian respectively). STAMP pointed out the complete contrast in the succession of the western and eastern parts of Hampshire. He was able to trace cycles which are almost entirely marine in the east (e.g. Middle Bracklesham Beds of Selsea) into entirely non-marine units in the west (part of the Boscombe Sands). WRIGLEY & DAVIS (1937) were able to add the Cuisian stage to this list, when they signalled their discovery of Nummulites planulatus and a molluscan fauna comparable to that of the Sands of Cuise in the Lower Bracklesham Beds.

With WRIGLEY & DAVIS (1937) our general knowledge of the stratigraphic framework of the English Tertiary became complete. This was elaborated by the studies of HAWKIN's (1955), on a series of boreholes in the western part of the London Basin (Enborne area). Additional detailed local correlations were made with the fining of new exposures and particular mention must be made of such works as CURRY (1942), on the Afton and Gunville exposures, and CURRY, HODSON & WEST (1968) on the Fawley Transmission Tunnel. An excellent general review of English Palaeogene stratigraphy was made by CURRY (1965) and definitions of most units can be found in CURRY (1958, in the Lexique Stratigraphique).

2:2:2 Lithological Correlations

An examination of the literature on the Upper Eocene revealed a large number of accounts of sections. Although accounts and correlations between selected sections have been published in the past (CURRY, 1942, 1965; CURRY, HODSON & WEST, 1968) none have included all the available information. Table

3 and 4 show such at attempt at lithological correlation of sections between the Middle Bracklesham Beds and the Middle Headon Beds. The Nummulites prestwichianus Bed(i.e. base of the Barton Beds sensu KEEPING, 1887) is taken as datum and the horizontal distances are not to scale. The information on some sections is considerably less reliable than on others and the evidence and limitations must be discussed before any conclusions can be made.

a. Evidence

Accounts of the land boreholes in Hampshire were compiled by WHITAKER (1910). Some of these records are, to say the least sketchy, and so most correlation with them must be open to question. The boreholes made for the Spithead Forts (Noman and Horse Sand Forts) were described in REID & STRAHAN (1889). Their palaeontology and correlation are discussed by O.WHITE (1915) in the Lymington and Portsmouth Geological Survey Memoir but a new interpretation is used here.

The measurements of FISHER (1862) and REID & STRAHAN (1889) are used for the Whitecliff Bay section. FISHER's bed numbers (Roman Numerals I to XIX) provide convenient labels. Beds XIII to XVII were measured by the author.

There is no satisfactory account of thickness for the Bracklesham Beds of Bracklesham Bay. FISHER (1962) gives a succession measured in paces along the foreshore and his bed numbers (1-22) are used. The section is drawn to a similar scale to that used by CURRY, HODSON & WEST (1968) and the true thicknesses remain conjectural.

The Lee-on-Solent and Fawley Transmission Tunnel sections have recently been discussed by CURRY, HODSON & WEST (1968). The former was very adequately described by FISHER (1862) and his bed numbers are used (3 to 21). CURRY, HODSON & WEST labelled the Fawley section with letters (A to X).

Of the small exposures in the New Forest, BURTON (1933) provides measurements for those at Poulnor, Totton and Bransgore. The stratigraphic separation between the upper and lower Bransgore sections (12a, b) is unknown. The exposures at Brook, Bramshaw and Huntingbridge are described by FISHER (1862), who gives measurements for some of the beds. Thicknesses are taken from his estimates. Measurements of the Studley Wood exposure were kindly provided by Mr. C. King (pers. comm.).

The Afton and Gunville Brickyard exposures are described in detail by CURRY (1942), whose measurements are used here. The author's own measurements are used for the Barton Clay of Alum Bay. Thicknesses for the strata below the *Nummulites prestwichianus* Bed are taken from O.WHITE (1921) and REID & STRAHAN (1889). In the absence of a more detailed system PRESTWICH's (1846) bed numbers are used. CURRY (in CURRY, MIDDLEMISS & WRIGHT, 1966) gives the thickness of Lower Headon Beds as 62ft. (18.9m.).

BURTON's (1933) bed numbers A1 to L are used here for the Christchurch Bay (Barton) section and the measurements are the author's own. TAWNEY & KEEPING's (1883) figure of 83½ft. (25.4m.) for the thickness of Lower Headon Beds is used. The beds below A1 are taken from the account in GARDNER, KEEPING & MONCKTON (1888).

GARDNER's (1879) description of the section at Hengistbury Head is supplemented by the author's own measurements in the pebble bed complex. Th same author (1878, 1882) also described the Bournemouth Beds. However, no complete detailed account could be found and it is left out of the tables. CURRY (1958) gives an estimate of 600ft. for its total thickness. They cons of a thick and laterally variable "Bournemouth Freshwater Series" below. Th upper part passes laterally eastwards into the "Bournemouth Marine Series", which has brackish and estuarine faunal elements. The whole unit probably corresponds approximately to the Bracklesham Beds in stratigraphic position.

b. Lithological Units, Distinctions and Limitations

Fig. 5 shows the lithological units used in the correlations on Tables 3 and 4. Four main criteria are employed in the subdivision and correlation of these strata. These are cycles of sedimentation, breaks in deposition, clear lithological changes and certain known palaeontological elements.

The sedimentary cycle is taken as a unit of strata showing evidence of a transgressive base and topped by the transgression of the succeeding cycle. The transgressive base is most clearly marked when it is represented by a break in deposition. Such breaks include the pebble bed at the bases of the Campanile and "R.canalis" Beds and the conglomerate at the base of the Brockenhurst Bed. Many cycles may also show a regressive closing stage. The Barton Beds show this most clearly, with its gradual passage upwards from marine clays (Barton Clays) through estuarine sands (Barton Sands) to non-marine deposits (Lower Headon Beds). Theoretically pebble beds or similar breaks might be associated with the regressive stage of a cycle but none have been definitely identified. Depositional breaks may also occur within cycles. The pebble bed in the Middle of the Barton Beds at Alum Bay falls within this category.

Clear changes in lithology tend, of course, to be subjective and except where they are definitely present (clay to sand, etc.) such boundaries are treated as questionable. Two lithological units which need comment are septaria and ferruginous levels. Septaria are laterally very unreliable elements. Even within the same section they may disappear andreappear in short horizontal distances (e.g. the septaria at Barton), although they have yet to be observed actually changing level. Ironstone beds however do sometimes do this. At Hengistbury Head paired beds of ferruginous nodules have been observed splitting and rejoining over several hundred yards of exposure. In a few cases ferruginous levels are tentatively thought to represent breaks in deposition (below "R.canalis" Bed at Gunville and in the Barton Clay at Whitecliff Bay).

The use of published and/or observed palaeontological markers are used here with some reservation. In many cases the "fossiliferous" part of a bed is that where fossils are particularly abundant and is thus an acme zone. Sometimes these move up or down from one section to the next. Although there is no direct evidence it is strongly suspected that the Nummulites laevigatus bed is a complex of thin nummulitic beds of this type. Many of the published correlations are based on occurrences of molluscan faunas. Few Mollusca have such a short total range that they can be used even locally and those that do tend to be rare. Some however, have marked abundance in particular beds (*Chama squammosa* in the *Chama* Bed, *Amusium corneum* in the Brook Bed, *Venericardia planicosta* up to and including the Brook Bed). The only fossil group relied on to any extent as characterising specific horizons are the *Nummulites*. These will be dealt with at length in Section 2:3:3.

c. Lithofacies and Biofacies

Six main types of lithofacies are recognised here. These are partly interpretive and are not included in the tables.

Sediments which were not deposited under marine or brackish conditions are represented by such units as the Lower Headon Beds and so-called Bracklesham Beds of Alum Bay. They contain multi-coloured sands, pipeclays, carbonaceous clays, *Lymnaea* and Charophyte limestones and lignites. These were laid down in freshwater fluviatile and lacustrine regimes. Individual units are often discontinuous laterally, showing channels, cross bedding and other evidence of rapidly varying sedimentation. Palaeontologically they are characterised by the abundance of certain groups in low diversity. Thus fluviatile elements contain banks of *Cyrena* and freshwater lacustrine limestones are often coquinas of *Lymnaea*, *Planorbis* and Charophytes. The remains of higher plants are well known from the lignites and pipeclays. In general these units are not subdivided.

A distinctive lithofacies in the Upper Eocene is one composed of fine, white or yellow quartz sands. These occur particularly in the Upper Barton Beds and the Upper Bracklesham Beds of the western sections. Cross bedding has not been observed but quicksand structures have been noted in the sands below the Barton Beds at Christchurch Bay. They may or may not have been decalcified but in any case contain little fauna or flora, apart from Dinoflagellates and some plant debris. They are interpreted as having been deposited in a marginal regime. If they are beach sands they have certainly lost all traces of their Mollusc and Foraminiferal fauna to decalcification. They may represent an estuarine or fluvio-marine environment, although the Microplankton fauna indicates at least some connection with the open ocean.

Associated with the pale sand lithofacies are carbonaceous clays and sandy clays. Examples of these include the Becton Bunny Beds and the Ostrea tenera Bed. To these may be added some units in the Middle Headon Beds (not studied). The macrofauna usually contains many brackish water species (see BURTON, 1933 for the Becton Bunny Bed and CURRY, HODSON & WEST, 1968, for the O.tenera Bed). Sedimentary structures include fine lamination and the two units mentioned are laterally discontinuous.

True marine lithofacies include shallow water sands (with or without glauconite) and deeper water clays. All gradations are seen between these types. Shallow water non-glauconitic or sparsely glauconitic sands include the Tellina Bed of Selsea and bed A3 (= Highcliff Sands of GARDNER, KEEPING & MONCKTON, 1888, not GARDNER, 1879). These two beds are rather different in detail however. Glauconitic sands and sandy clays include the Nummulites laevigatus, N.variolarius and N.prestwichianus Beds at a number of localities and parts of the Middle Barton Beds at Barton (beds B,C,D). The marine clay lithofacies occurs as parts of the Barton Clay (A2, E, F) and the Brook Bed. Finally, a transgressive lithofacies can be recognised, as mentioned above. It may consist of a flint or chalk pebble bed (sub-Barton pebble bed) or of pebbles scattered through a shallow water marine sand or sandy clay with shells (Campanile Bed, mid-Barton pebble at Alum Bay). In less extreme cases marine strata rest on estuarine or non-marine strata without disturbance (Middle Headon "Trigonocoelia" Bed on Lower Headon How ledge limestone at Headon Hill and Alum Bay).

The relationship between the marine lithofacies and biofacies is described quantitively in Section 3, except in the case of certain shallow sands not represented in the Barton Beds. These include the peculiar Tellina and Nummulites variolarius Beds and although not examined rigorously certain comments on their fauna and flora will be made.

In its exposures at Lee-on-Solent, Gunville, Fawley and the New Forest the Nummulites variolarius Bed is in lithological character a deeper water marine clay, usually with a predominance of its nominate species and such Mollusca as Corbula and Turrids in its fauna. In the east however, it is quite different. At Whitecliff Bay and Selsea Nummulites variolarius and smaller Foraminiferida reach rock forming abundances (the Mixon Rock off Selsea Bill). The underlying Tellina Bed also contains N.variolarius in flood, but it is associated with Alveolina fusiformis and Orbitolites sp.. In both units smalle Miliolids dominate the finer fractions and small Mollusca, Corals, Bryozoa and calcareous Algae (Ovulites and Dasyclads) show abundances and types not seen elsewhere in the Hampshire Upper Eocene.

CHEETHAM (1966) described 34 species of Cheilostomatous Bryozoa from bed 21 at Selsea. Of these the club-shaped forms and stick Bryozoa were dominant. LAGAAIJ & GAUTIER (1965) studied the Recent Bryozoan faunas of the Rhone delta and established a remarkedly close correlation between zoarial (colony) forms and the depositional environment. They showed that attached, club-shaped forms (their celleporiform, CHEETHAM's orbituliporiform type) attained minor percentages in sheltered, hard substrate environments. The stick Bryozoa (their adeoniform and vinculariiform, CHEETHAM's cellariiform type) reached sizeable percentages in deep, sheltered water and in shallower (40-50 m.) areas with a stable sandy substrate and slow deposition (their "fonds coralligenes"). In most other Upper Eocene marine clay and sandy clay lithofacies the motile Bryozoa (lunulitiform type of STACH, 1936) predominate.

The environmental picture built up when the Foraminiferal and Bryozoan evidence is considered together is one of slow deposition in warm, sheltered, well oxygenated water, on a stable sandy or hard substrate ("sea-meadow" conditions of CURRY, 1965, 1966). Evidence which does not agree with this interpretation includes the abundance of rolled, blackened and glauconite infilled Foraminiferida. These would indicate very slow deposition or non-deposition on current-swept shelf. Perhaps the two sets of conditions were associated in an alternating series.

d. Notes on the Lithological Correlations

The base of the Middle Headon Beds is probably a diachronous horizon. To the north-east of a line approximately from Ventnor to Fordingbridge the non-marine Lower Headon and the estuarine "Venus" Beds are separated by a basal transgressive lithofacies, the Brockenhurst Beds. This has been reported at Whitecliff Bay, West Cowes (borehole, not shown) and the New Forest (Brockenhurst and Royden) (see CURRY, 1965). At Whitecliff Bay the junction is marked by a clay conglomerate. South-west of that line the "Venus" Beds rest directly on the Lower Headon Beds (on the How Ledge Limestone in West Wight and on the Unio Bed at Christchurch Bay). The Brockenhurst Bed contains more truly marine Foraminiferida (BHATIA, 1957), Molluscan and Coral faunas (TAWNEY & KEEPING, 1881) than the overlying "Venus" Bed and there is strong evidence that it correlates with the basal Oligocene strata of Belgium and North Germany (VON KOENEN, 1864; CURRY, 1966). BHATIA's (1957) figure suggests that the Brockenhurst Beds are a lateral facies equivalent of the lower part of the "Venus" Bed but they may equally well be a lower unit not deposited elsewhere.

The non-marine Lower Headon Beds have not been subdivided on charts 3 and 4 They are very complex, thinly bedded and the correlation of individual units cannot always be accomplished along the same section, let alone over a number of miles (see TAWNEY & KEEPING's, 1881, relationships between the Colwell Bay, Warden Point and Headon Hill sections).

The carbonaceous sandy clays and clays of the Becton Bunny Beds are present only in a restricted area north and east of Christchurch Bay. No record of sizable clay intercallations within the Barton Sands lithofacies could be found for the Isle of Wight.

BURTON (1933), when discussing the New Forest exposures of the Barton Beds, thought that the Chama Bed was unrepresented away from the coast. Decalcification might produce a lithology very similar to that of the Barton Sands and lateral gradations into the latter are thought to occur north and west of Christchurch Bay.

The relationships of the Hengistbury Beds have been discussed in detail by CURRY (1958, in Lexique). They are taken as equating with the lower part of the section at Christchurch Bay. GARDNER (1879) thought that they represented a much lower horizon. COWPER REED (1913) found casts of Mollusca in the Upper Hengistbury Bed, showing a fauna slightly biased towards correlation with the Barton Beds. CHAPMAN's (1913) Foraminiferal fauna is composed entirely of agglutinated forms. A similar assemblage was observed in bed A1 and below at Christchurch Bay but not in the Upper Bracklesham Beds. Such a fauna however is undoubtedly facies controlled. The strongest evidence for correlation with the Lower Barton Beds lies with CURRY's (1942) find of Nummulites prestwichianus in the Upper Hengistbury Bed and the author's own observation of N.rectus (casts) at a slightly higher horizon.

The complex of pebble bed at the base of the Hengistbury Beds probably equate with the main pebble bed below the Barton Beds at Christchurch Bay. Their thickened and more complex nature westwards may represent an increase in clastic supply towards a shoreline. A pebble bed at a similar level can be traced in the records for the Lymington borehole and at Alum Bay. At Afton Brickyard a pebble bed occurs below the "Rimella canalis" Bed but eastwards it cannot be traced. At Gunville a ferruginous layer is tentatively thought to represent a similar depositional break. The stratigraphic relationship between the "R.canalis" and Huntingbridge horizons is completely unknown as they do not occur together. The "R.canalis" Bed is restricted to the Isle of Wight and the Huntingbridge horizon is known only from the north-western area. FISHER's (1862) identification of the latter from casts at Alum Bay is treated as conjecture. The Huntingbridge Bed can however, be definitely traced at Studley Wood and Lee-on-Solent.

Correlation of the fossiliferous units in the Upper Bracklesham Beds has been the subject of numerous papers from FISHER (1862) onwards and is well substantiated by palaeontological evidence (see CURRY, 1942; CURRY, HODSON & WEST, 1968). The Nummulites variolarius Bed is one of the most widely distributed but shows some changes over the area studied. In the New Forest, Fawley and Lee-on-Solent exposures it is a sandy clay with a dominant Molluscan fauna. The upper part of its Whitecliff Bay section is also of this type. At Selsea and its lowerpart at Whitecliff Bay Foraminifera become dominant. The underlying Tellina Bed is of similar type, though sandier, and is only known at those two localities.

The southern series of sections however, show a marked change in characte of the Nummulites variolarius Bed westwards. At Gunville only the lowest portion has calcareous fossils and the upper part is thickened, sandy, glauconitic and decalcified. At Afton the whole section is sandy and decalcified (CURRY, 1942), though possibly originally glauconitic in its lower part. At Alum Bay correlation with any of the fossiliferous Upper Bracklesham Beds cannot be substantiated and all this part of the section i thought to be non-marine. Table 3 shows a suggested pattern, in which successively higher beds have more regressive characteristics and laterally change into more marginal deposits towards the west.

The relationship of most of the boreholes to the known surface sections is conjectural. Some sand/clay boundaries can be traced in the boreholes in the Lymington area but those along Southampton Water (Dibden, Hythe and Eling) lack useful markers. The original loggers seem to have drawn the Bracklesham/Barton Beds boundary at changes from more to less glauconitic sandy clay, a very doubtful criterion.

The Spithead Fort boreholes have been rather more carefully documented but still provide conflicting results. At Norman Fort REID & STRAHAN (1889 record Nummulites variolarius, Corbula, Pinna and Amusium corneum from between 374 and 385 ft. below the Recent sand, correlating the assemblage with theBrook Bed equivalent at Whitecliff Bay (beds XIV and XV). They als found Campanile and Turritella imbricataria near the bottom and thought that this level equated with the Campanile Bed. Such correlations howeve result in an abnormal thickness for the Barton Clay, when compared with Whitecliff Bay.

At Horse Sand Fort "Nummulites variolarius" was recorded by EVANS (1873) at about 200 ft. O.WHITE (1915) thought that this marked the Nummulites variolarius Bed, which would give an abnormally thick Upper Bracklesham section before the next nummulitic sequence was met. An alternative explanation is here tentatively suggested, such that the lower Nummulites horizon equates with the N.laevigatus Bed and the upper one with the Huntingbridge Bed. This would allow the central septaria bed to fall at the same level as the very persistent septaria at beds H and 8 at Fawley and Lee-on-Solent respectively. The fossiliferous sequence below would then correlate with the Macrosolen hollowaysi and Little Bed equivalents. However, neither O.WHITE's nor this new interpretation explain the occurrence of Venericardia planicosta and Tibia sublucida in what must be the Barton Clay.

2:2:3 Conclusions on English Upper Eocene Lithostratigraphy

a. The Upper Bracklesham Beds Cycle

The base of the Upper Bracklesham cycle is taken at the Campanile Bed and its equivalents. WRIGLEY (1940) suggested that its Mollusc fauna was "decidedly Lutetian" in composition. Nevertheless it shows a transgressive lithofacies with a marine fauna and pebbles and overlies the estuarine strata of the Ostrea tenera Bed at Selsea and Fawley or the non-marine beds at Gunville.

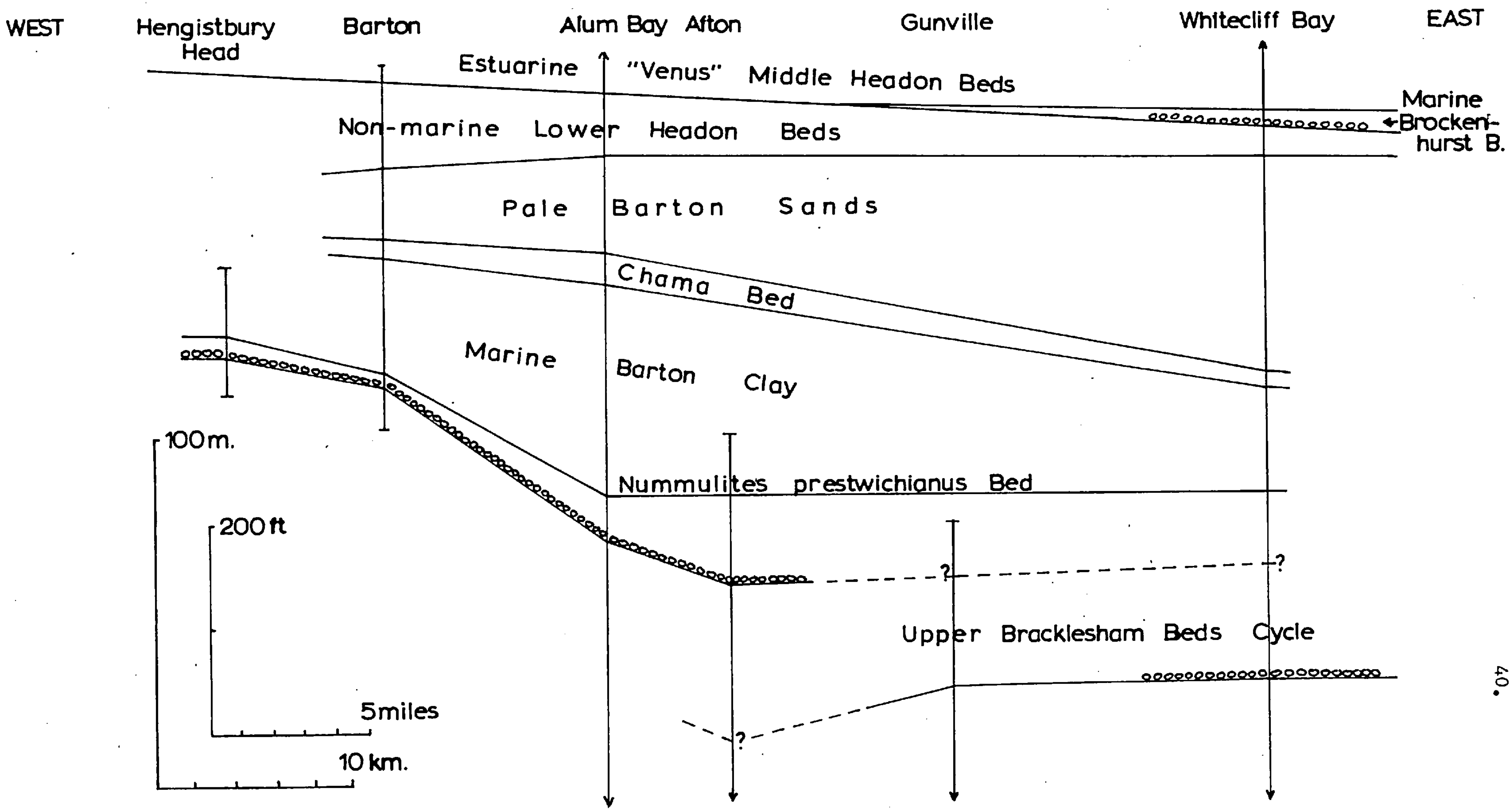
In the northern series the succession continues upwards with the sandy marine beds of the Macrosolen hollowaysi, Miocardia, Little Beds and their equivalents. These are followed by more clayey strata of the Brook and Nummulites variolarius Beds. The base of the Barton Beds cycle is not identifiable and the clays and sandy clay continues without interruption through the Huntingbridge Beds. In the eastern sections the succession is basically the same but the Tellina (at Whitecliff Bay) or Tellina and Nummulites variolarius Beds (at Selsea) become Foraminiferal sands. Throughout these sections the total thickness of the cycle and the thickness of individual units remain essentially constant. Along the southern series the Upper Bracklesham Beds change markedly as described in the preceding section (2:2:2d). In addition to lateral changes in lithofacies they also exhibit anomalous thicknesses. The total thickness at Afton Brickyard is considerably greater than at adjacent sections. The cycle as a whole shows a progressive decrease in marine elements from the base upwards and from east to west. Thus at Whitecliff Bay the whole cycle is composed of marine strata. At Gunville only the lower half and at Afton only the lower third is composed of fossiliferous marine clays. The top of the cycle at Afton contains non-marine beds, which at Alum Bay occupy the whole succession.

b. The Barton Beds Cycle

The main elements of the Barton Beds cycle are shown to scale on fig.6. Its base is defined at the basal transgressive lithofacies of the pebble bed at Christchurch Bay. This does not coincide with the base of the Barton Beds (sensu stricto), which were defined by KEEPING (1887) at the Nummulites prestwichianus Bed. The pebble bed at Alum Bay, Hengistbury Head and Afton is believed to be the lateral equivalent of this level at Christchurch Bay. If this is so then the "Rimella canalis" Bed is also included in the Barton Beds cycle, in spite of its faunal relationships with the Upper Bracklesham Beds (CURRY, 1942). The tentative correlations between these pebble beds and the ironstone bed at Gunville and thence to the top of bed XVII at Whitecliff Bay would probably also put the Huntingbridge Bed in the same cycle. This is based on the very dubious assumption that the basal transgression remains isochronous throughout. In the eastern area the strata are marine across the boundary and, in the absence of well marked breaks in deposition, we have no unequivocal way of defining its position.

The cycle continues above the Nummulites prestwichianus Bed with a considerable thickness of marine clays, sandy clays and sands. This is a heterogenous group which is subdivided faunally in Section 3. For the purposes of this discussion they are treated together as the marine Barton Clay. They are topped by a regressive sequence in all three complete sections (Christchurch Bay, Alum Bay and Barton). The regressive sequence starts with a bed with a distinctive shallow water marine fauna (the Chama Bed) and continues with fine, pale, estuarine or deltaic sands. These are interrupted by the carbonaceous Becton Bunny sandy clays and clays in the west. The cycle is completed by the non-marine complex of Lower Headon Beds and capped by the basal transgressive lithofacies of the Middle Headon Beds.

figure 6 THE MAIN ELEMENTS OF THE BARTON BEDS CYCLE IN THE SOUTHERN SERIES



The peculiar anomalies in thickness of units of this cycle (fig.6) are hard to explain. The regressive sequence occupies approximately half the total thickness at Barton and Alum Bay, but at Whitecliff Bay it is nearly twice as thick as the marine sequence. The marine clays are about equal at Barton and Whitecliff Bay but at Alum Bay they are considerably thicker. Also the sand member thickens progressively eastwards. These observations do not jibe at all with the general east/sea, west/shore pattern so well shown in other parts of the Tertiary. The only changes explicable by this model are the heavy development of coarse clastics in the basal transgressive lithofacies in the west and the progressive thickening of the non-marine Lower Headon Beds in the same direction.

The sand wedge might be explained as part of a deltaic lens or chenier lens. Faunal evidence for its exact position on the margin of a delta or estuary is lacking. The only conclusion to be reached is that the supply of sand was, for some reason, more plentiful in the east. The thickness of marine Barton Clay is even harder to explain. One hypothesis is that it represents a tectonic thickening in the core of the Isle of Wight monocline. However, structural considerations would expect competent strata to show strike faulting and incompetent units, such as the Barton Clay, to be thinned. The cycle as a whole shows also variations in thickness not seen in the Upper Bracklesham cycle. It has a more or less equal total thickness at Alum Bay and Whitecliff Bay. At Barton it is considerably thinner.

c. Palaeogeography

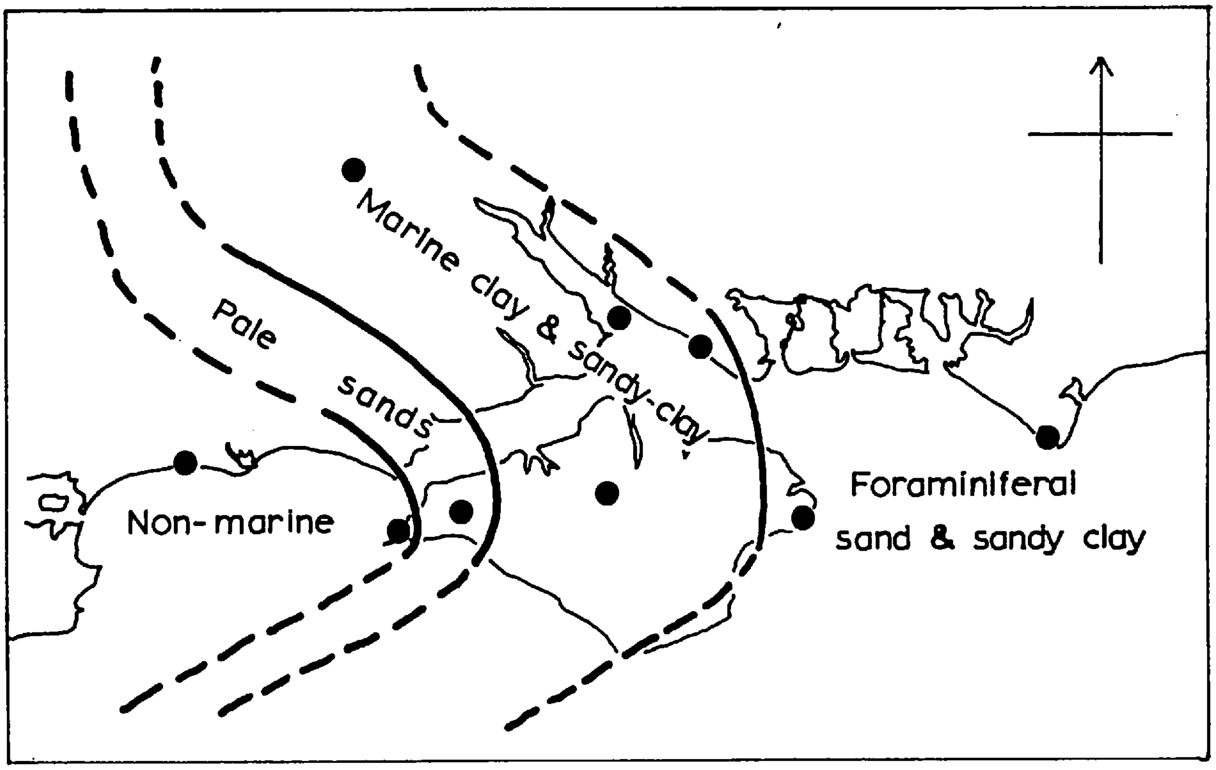
The above remarks lead inevitably to a discussion of shoreline position and palaeogeography but such a study requires a better areal spread of sections than is available for any particular unit of the Barton Beds. The most widespread and definitely identifiable unit is the Nummulites variolarius Bed and the distribution of its lithofacies is shown in Fig.7.

The longest and most definite areal lithofacies boundary is that between the pale sands of the West Wight-Bournemouth area and the marine clays etc. of the New Forest and Southampton Water. This north west/south east

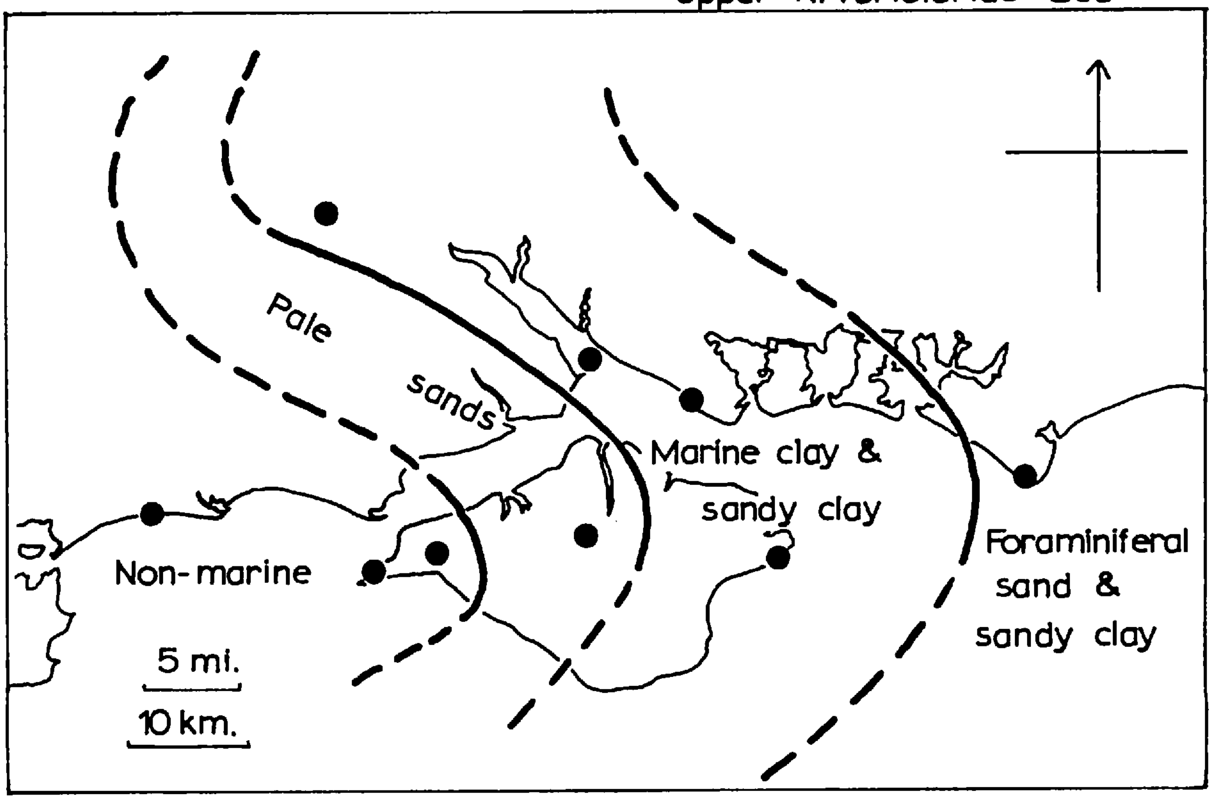
figure 7

AREAL DISTRIBUTION OF LITHOFACIES IN THE NUMMULITES VARIOLARIUS BED

Lower N.variolarius Bed



Upper N. variolarius Bed



shoreline trend (not necessarily an actual shoreline in this position) is perpendicular to that generally accepted for England in the Eocene (see DAVIS & ELLIOTT, 1958 and CURRY, 1966). The most likely explanation for this anomaly appears to be that the Isle of Wight represented a land promontory at this time, with a marine embayement to the north and possibiy, although we have no evidence, to the south. Such a promentory may be further explained as a delta lobe. The presence of a large river supplying material to the area and building a complex deltaic wedge would also provide a reason for the inconsistent thickness of some units along the southern series of sections. It is possible that the Isle of Wight axis, although not yet actively moving in the Eocene, may have been a zone of weakness allowing or aggravated by delta formation.

The differences between the distribution of main lithofacies types of early and late Nummulites variolarius Beds times show that the sea retreated eastwards during that period. This interpretation is, of course, based on the lithological correlations shown in Charts 3 and 4 and must be regarded as tentative.

Section 2:3 UPPER EOCENE PALAEONTOLOGY

CURRY, (1965, 1966) reviews the literature on the major groups and evaluates their use in North West European Tertiary stratigraphy. He shows that the smaller benthonic Foraminiferida, Ostracoda and Mollusca, although present in great abundance and diversity, are very strongly facies controlled. Distinctions between the cycles in terms of total ranges are not very good. Biostratigraphic correlations between the English, French and Belgian basins are confused by facies differences at similar levels and the presence of facies equivalents at different levels.

2:3:1 The Planktonic Foraminiferida

The Globigerinacea, whichhave proved so useful in dividing and correlating strata in other areas, are practically useless in the English and North West European Upper Eocene. Globigerina cf. angustiumbilicata

BOLLI (sensu KAASSCHIETER, 1961, Sands of Ledes, Wemmel, Barton Beds) is the only form observed from the English Lower and Middle Barton Beds. Specimens from the Middle Headon Brockenhurst Bed, referred to *Globigerina sp. indet.* by BHATIA (1955), are identical to those from the Barton Beds. The Middle and Upper Bracklesham Beds, Middle Headon "*Venus*" Bed, Upper Hamstead Beds and Bembridge Oyster Bed have not so far yielded planktonic Foraminiferida.

BRONNIMANN, CURRY, POMEROL & SZOTS (1968) evaluate the faunas from the North West European Eocene and Paleocene. They record only the "*Globigerina angustiumbilicata* group" from the English strata mentioned above and also found it in the French Marinesian and the Belgian Sands of Ledes. No planktonic Foraminiferida were found by them in the French Ludian, Auversian or Upper Calcaire Grossier, nor in the English Upper or Middle Bracklesham Beds. They do however provide fairly long list for the French Middle (10 spp.) and Lower (10 spp.) Calcaire Grossier, the Belgian Sands of Wemmel (2 spp.), Sands of Ledes (12 spp.), and the Sands of Brussels (10 spp.).

True *Globigerina angustiumbilicata* has much too long a range for it to be useful for correlation. It appears in Trinidad in BOLLI's (1957) "*Globorotalia cocoaensis*" zone (Upper Eocene). EAMES et al. (1962) found intermediate stages from *Globigerina officinalis* SUBBOTINA to *G.angustiumbilicata* as low as the top of their *Cribrohantkenina danvillensis* zone, (middle Upper Eocene) in Tanzania. They found it as high as the Middle Miocene of Venezuela and Austria. BRONNIMANN et al. (1968) report it down to the Lower Lutetian in Aquitaine.

CURRY, MURRAY& WHITTARD (1965) record *Globorotalia bullbrooki* BOLLI and *Globorotalia cf. spinuloinflata* (BANDY), associated with a Middle Eocene larger Foraminiferal fauna in a sample from the Western Approaches of the English Channel. In their Upper Eocene samples they also found *Globigerina cf. ouachitaensis gnaucki* BLOW & BANNER and *G.cf. praebulloides occlusa* BLOW

& BANNER with *Nummulites cf. prestwichianus* (JONES); and *Globigerapsis cf. index* (FINLAY) and *Globigerina cf. praebulloides* BLOW associated with *Nummulites fabianii* PREVER, "*N.prestwichianus*" and "*N.cf.rectus*". By comparison with the range charts in EAMES et al. (1962), these assemblages suggest a Middle or Upper Eocene age.

2:3:2 *The Larger Foraminiferida* (excluding the *Nummulites*)

Most of the prolific English Upper Eocene benthonic Foraminiferida are endemic and show little stratigraphic characterisation. A few larger species however can be identified with forms which, in the Tethys, have restricted stratigraphic ranges. The relationship between these faunas and the Tethys can be traced via the submarine exposures of Eocene rocks in the English Channel. As such assemblages in the Paris Basin have in the past been used for correlative purposes, their occurrence in England must be critically evaluated.

As can be seen from Fig.8 these forms are mainly restricted in England to the upper part of the Upper Bracklesham Beds. Five further species have been recorded in the literature from the *N.variolarius-Tellina* Bed horizon; namely *Alveolina cf.elongata* D'ORBIGNY, *A.boscii* (DEFRANCE), *Fabularia ovata* (DE ROISSY), *Eorupertia magna* (LE CALVEZ) and *Fabiania cassis* (OPPENHEIM) (see CURRY, 1960).

Fabularia bella KAASSCHIETER is the only species to range up into the Barton Beds. KAASSCHIETER (1961) describes it from the Sands of Ledes, the Sands of Wemmel, and the Clay of Asse in Belgium. It has not been mentioned from the Paris Basin or Aquitaine Basin. Thus for our purposes it is a local North West European species which appeared in the Upper Bracklesham Beds and/or Sands of Ledes and disappeared in the Middle Barton Beds and/or Clays of Asse. *F.ovata* (DE ROISSY) is more laterally tumid and occurs in the Paris Basin Upper Calcaire Grossier (ABRARD's, 1925, zone IV), the Belgian Sands of Ledes (BLONDEAU et al. 1965, p.207), the so-called "Biarritzian" of North West France, the submarine outcrops off the Channel Islands and the Priabonian of Aquitaine. The occurrence of *F.ovata* (DE ROISSY) in the

Figure 8 The occurrence of certain larger Foraminiferida in English Upper Eocene samples.

		Rotalia trochidiformis	Alveolina cf. fusiformis	Orbitolites sp.	Linderina brugesi	Discorinopsis kerfornei	Fabularia bella	Localities		
Barton Beds								Upper Barton Beds	Alum Bay & Barton	
							X	Middle Barton Beds	Alum Bay & Barton	
							X	Lower Barton Beds	Alum Bay	
Upper Bracklesham Beds	Trans.	?	?		X			Huntingbridge Bed	Studley Wood	7168
					X		X			7177
					X					7178
	Upper	X	X	X	X	X		*N. variolarius* Bed	Selsea	787
			X	X					Whitecliff Bay	7041
		X	X	X	X	X	X			7037
									Bramshaw	7055
										7054
			X						Lee-on-Solent	788b
		X	X	X	X			*Tellina* Bed	Selsea	7171
		X	X	X					Whitecliff Bay	7036
		X	X	X						7034
								Brook Bed	Whitecliff Bay	7030
										7024
	Lr.							Bed H	Fawley	7170
M. Bracklesham Beds	Up.							Bed VIII	Whitecliff Bay	7190
	M.							*N. laevigatus* Bed	Whitecliff Bay	7191
									Southampton Docks	786
									Selsea	7174

Upper Bracklesham Beds of Hampshire (CURRY, 1966, p.455) could not be confirmed in the present study.

Rotalia trochidiformis (LAMARCK) occurs in the French Calcaire Grossier and CURRY (1960) mentions it from other formations in North West Europe (Maestrichtian, Holland). Its relationship with similar, though more heavily ornamented forms from the Middle and Upper Eocene of Aquitaine is not clear.

ADAMS (1962) revises the Alveolina faunas of the Upper Bracklesham Beds and shows that two species (A.fusiformis J. de C.SOWERBY and A.cf.elongata D'ORBIGNY) are present. They are only distinguishable in thin section and A.fusiformis is by far the most abundant. He doubts whether the records of A.boscii (DEFRANCE), A.melo (FICHTEL & MOLL), A.ovoidea D'ORBIGNY and and A.subulosa (MONTFORT) from England are correct. Recently CURRY (1966) has recorded A.boscii from the N.variolarius-Tellina Bed horizon. Practical all Alveolinas from this level are eroded, and external characters may thus show spurious differentiation. Without examining orientated thin sections identifications in this genus cannot be confirmed. A.boscii and A.fusiform are known from the Upper Calcaire Grossier (ABRARD's zone IV) of the Paris Basin and the "Biarritzian" of the Cotentin respectively. Another species, A.oblonga D'ORBIGNY, occurs with Nummulites planulatus in the Sables de Cuise. A.oblonga appears to be the only definitely stratigraphically distin species of Alveolina in North West Europe.

LEHMANN's (1961) recent detailed revision of the Orbitolitinae could not be applied to the specimens of Orbitolites found in the English Upper Bracklesham Beds. His species are distinguished on the embryonic apparatus and this was eroded in all the English specimens examined. He describes O.complanatus (LAMARCK) from the Upper Calcaire Grossier (ABRARD's zone IV) of the Paris Basin, O.reicheli LEHMANN and O.armoricensis LEHMANN from the "Biarritzian" of the Lower Loire (Brittany), and O.cotentinensis LEHMANN from the bed with Alveolina and Fabularia in the "Biarritzian" of Cotentin (Normandy). Unidentifiable fragmentary specimens of Orbitolites also occur in the Belgian Sands of Ledes and the French Sands of Auvers (Le Guepelle an

Le Ruel). All these species, including the Upper Bracklesham form, have thin upper and lower imperforate laminae, a feature suggested by LEHMANN to be characteristic of Middle and Upper Eocene *Orbitolites*.

Linderina brugesi SCHLUMBERGER is a very simple Orbitoid which occurs in the *N. variolarius-Tellina* Bed and Huntingbridge horizons in Hampshire, and in the Sands of Auvers and Marines in the Paris Basin. In Aquitaine it is characteristic of "Lutetian" to "Auversian" strata (CURRY, 1960, p.294; CURRY, MURRAY & WHITTARD, 1965, p.257).

An account of the occurrence of *Discorinopsis kerfornei* (ALLIX) (= *Lutuonella kerfornei* of ALLIX, 1921, and *Arenagula kerfornei* of CAVELIER & LE CALVEZ, 1965) was published by CAVELIER & LE CALVEZ. They found it in the topmost Calcaire Grossier of Foulangues (Oise) and mention it from the Upper Bracklesham Beds of Selsea. It also occurs in the so-called "Biarritzian" of Cotentin and the lower Loire. On the basis of this occurrence and the presence of a Calcaire Grossier smaller benthonic Foraminiferal fauna CAVELIER & LE CALVEZ (1965) correlate all the above units under the stage name "Biarritzian". However in Aquitaine *D. kerfornei* ranges from the Lower Lutetian to the top of the Oligocene (POIGNANT, 1961, 1964).

Other Western Tethyan species which occur in the Paris Basin but not in Belgium or England include *Cuvillierina sp.* (Lower Eocene of Pierrefonds only), *Asterocyclina sp.* (Lower Calcaire Grossier), and *Halkyardia minima* (LIEBUS) (Sands of Marines and Marls with *Pholadomya ludensis*).

Eorupertia magna (= *Gyroidinella magna* LE CALVEZ) occurs in Aquitaine from the Middle to Upper Eocene (NEUMANN, 1968) and *Halkyardia minima* from the Upper Eocene to the Lower Miocene.

When followed offshore similar Middle/Upper Eocene strata yield a wider variety of Tethyan species. Recent studies by a number of authors provide the following lists from the English Channel area (N.B. generic names have been corrected in those marked by an asterisk).

CURRY (1962) found few species in the Middle and Upper Eocene of the Central English Channel (between the Isle of Wight and Cherbourg) which were not represented on land (see however his remarks on Buccella cf. tenerrima (BANDY)).

CURRY, MURRAY & WHITTARD (1965) record the following from the Western Approaches (area of 5°W, 49°N):

Alveolina cf. fusiformis J. de C.SOWERBY
Asterocyclina cf. stellaris (BRUNNER)
Discocyclina sp.
Halkyardia minima (LIEBUS)
H.ovata (HALKYARD)
Linderina brugesi SCHLUMBERGER
Discorinopsis kerfornei (ALLIX)*
Orbitolites sp.
Pararotalia lithothamnica (UHLIG)

One sample contained Nummulites fabianii, "N.prestwichianus" and "N.cf.rectus" associated with Halkyardia ovata.

From the area west of the Channel Islands CURRY (1960) listed the following:

Linderina brugesi SCHLUMBERGER
Fabiania cassis (OPPENHEIM)
Sphaerogypsina sp.
Eorupertia magna (LE CALVEZ)
Rotalia trochidiformis (LAMARCK)
Alveolina sp.

Approximately the same area and that towards the coast of Cotentin was studied by BIGNOT, HOMMERIL & LARSONNEUR (1968). They record the following:

Discorinopsis cf. kerfornei (ALLIX)*
Fabularia ovata (DE ROISSY)*
Orbitolites cf.complanatus (LAMARCK)
Opertorbitolites cf. biplanus LEHMANN
Alveolina boscii (DEFRANCE)
Alveolina elongata D'ORBIGNY

Rotalia cf. trochidiformis (LAMARCK)

Asanoina sp.

Kathina sp.

Linderina cf. brugesi SCHLUMBERGER

Sphaerogypsina globulus (REUSS)

Fabiania cassis (OPPENHEIM)

Halkyardia minima (LIEBUS)

Eorupertia magna (LE CALVEZ)*

Nummulites cf. aturicus JOLY & LEYMERIE

Finally BOILLOT & LE CALVEZ (1961) record the following from the area off Roscoff (West Finisterre):

Eorupertia magna (LE CALVEZ)*

Orbitolites complanatus (LAMARCK)

Asanoina sp.

Kathina delseota SMOUT

Linderina brugesi SCHLUMBERGER

Alveolina elongata D'ORBIGNY

Several points arise from considering all the Tethyian elements in North West European faunas. Firstly, with few exceptions all the beds rich in these forms fall into a roughly similar stratigraphic interval, i.e, the upper part of the Middle Eocene and the lower part of the Upper Eocene. This might suggest migration routes were open and that optimum conditions (probably maximum temperatures) prevailed for a fairly short period during this part of the Eocene.

Secondly, the ranges of these species in the nearest part of the Tethys (the Aquitaine Basin) are probably not short enough to justify the refined stratigraphic zonation presented by certain authors (POMEROL, 1964; BLONDEAU et al. 1965). A general and gradual decrease in Tethyan elements along the line Brittany - offshore Normandy - Western Approaches - Cotentin - central Paris Basin - Hampshire - Belgium indicates that environmental barriers (temperature gradients, clastic supply etc.) were probably more influential than time-limited land barriers.

Finally, most of the species mentioned are very strongly facies controlled on a local scale. The bulk of the species discussed above occur in assemblages dominated by *Alveolina*, *Orbitolites* and smaller Miliolids. Such assemblages were probably restricted to areas of very shallow warm water. Thus there is no evidence that these particular associations were isochronous. This point was raised by CURRY (1966, 0.456), while criticising POMEROL's (1964) correlation of the *N.variolarius*-*Tellina* Bed horizon with the Paris Basin upper Calcaire Grossier based on *Alveolina*, *Orbitolites*, etc.

2:3:3 The Nummulites

a. Introduction

In the Palaeogene the Tethys supported a very diverse and rapidly evolving series of *Nummulites* faunas. Certain groups penetrated as far north as the Anglo-Franco-Belgian basin at various times in the Eocene and Oligocene, when temperature and sedimentary conditions were at an optimum. Although these are pale imitations of the Tethyan faunas in terms of variety, their strong stratigraphic differentiation warrants a close look at the material available.

Several limitations must be born in mind when considering the stratigraphic record and application of these assemblages. Firstly, by the nature of the North West European sedimentary pattern there are many baffling gaps in the record. In the Tethys a sequence of strata might be *Nummulites* rich throughout and provide a complete picture of several evolving lineages. In the North West province they only occur at specific levels and are separated by unknown time-equivalents of strata. Thus a distinctive *Nummulites* sequence at one locality might represent a gap in the record of the lineage in an adjacent section. To offset this difficulty the hiatuses provide very sharp taxonomic distinctions between species which might not be easy to defin in a fully represented and continuously changing lineage.

Secondly, although most workers are unanimous as to the North West European faunas being related to those of the Tethys, no exact evaluation of this relationship has been agreed upon. CURRY (1966, p.442) takes the extreme view in stating that no local evolution took place and that each

Figure 9 The occurrence of *Nummulites* in English Upper Eocene samples.

		N. laevigatus-lamarcki	N. variolarius var. 1	N. sp. 1	N. variolarius var. indet.	N. variolarius var. 2	N. sp. 2.	N. sp. 3	N. prestwichianus	N. rectus	Localities		
Barton Beds	Up.										Up. Barton Beds	Alum Bay & Barton	
	M										M. Barton Beds		
	Lr.									X		Alum Bay	6902-19
										X		Barton	6592-6618
									X	X		Alum Bay	6590-91
									X			Alum Bay	6586-89
Upper Bracklesham Beds	Trans.							X			Huntingbridge Bed	Studley Wd.	7168
								X					7177
								X					7178
							X				"R. canalis" Bed	Afton	7175
	Upper				X						*Nummulites variolarius* Bed	Selsea	787
			X			X						Whitecliff Bay	7041
			X			X							7037
					X							Bramshaw	7055
					X								7054
			X			X						Lee-on-Solent	788b
					X						*Tellina* Bed	Selsea	7171
					X							Whitecliff Bay	7036
					X								7034
			X	X							Brook Bed	Whitecliff Bay	7030
			X										7024
	Lr.		X	X							Bed H	Fawley	7170
M. Bracklesham Beds	Up.	X	X								Bed VIII	Whitecliff Bay	7190
	Middle	X									*N. laevigatus* Bed		7191
		X										S-ton	786
		X										Selsea	7174

species was introduced as a discrete migration from the Tethys. This is not believed to be acceptable and in the upper part of the Eocene vigorous local evolution is thought to have been supplemented by influxes from the Tethys.

In general four such migrations probably occurred. The first, in the Lower Eocene (Cuisian), resulted in the appearance in France and England of *N.planulatus* (LAMARCK). WRIGLEY & DAVIS (1937) also found a form closely associated with it which they referred to "*N.lucasi*" (= *N.lucasianus* (D'ARCHIAC)). HOTTINGER, LEHMANN & SCHAUB (1964) believed this to be not *N.lucasianus*, but an intermediate between *N.planulatus* and *N.aquitanicus*. The Middle Eocene (Lutetian) is characterised by *N.laevigatus* (BRUGUIERE) (= *N.lamarcki* D'ARCHIAC & HAIME). BLONDEAU (1965) has studied the variation in English and French (ABRARD's zones I and II) assemblages of *N.laevigatus*. He shows that there is considerable variation in shape; from compressed forms with lax spiral growth ("plates"), through lenticular ("lenticulaires") to laterally inflated forms with tighter spiral growth ("bombees"). The proportions of these different "Morpho-groups" differ systematically with time and allow stratigraphic distinctions to be made. Before *N.laevigatus* disappeared a third migration had occurred. This, in ABRARD'S zone III of the Calcaire Grossier and FISHER's bed VIII at Whitecliff Bay, is marked by the appearance of *N.variolarius* (LAMARCK). The distinction between this and the fourth and final migration of flattened *Nummulites* is complicated by the development of strong local evolution and will be made the object of the present study.

b. Methods of Study

Seven different morphological groups("morpho-groups") could be separated by qualitative means in the Hampshire Basin Upper Bracklesham and Barton Beds. Four of these have been recognised before (*N.rectus*, *N.prestwichianus*, *N.sp.3* and *N.sp.2*), one form (*N.sp.1*) is completely new and one previously known species (*N.variolarius*) is shown to have two distinct variants. Their occurrence in the samples examined is shown in Fig.9 (those specimens of *N.variolarius* which have not been studied in detail are left as "*var indet*.

Figure 10 Provenance of measured specimens of *Nummulites*.

Species and Locality	No. of specimens measured (A & B)	
	External	Internal
N.variolarius var.1 Sample 7030 FISHER's bed VX. Upper Bracklesham Beds. Whitecliff Bay.	13	11
N.variolarius var.2 Sample 7041 FISHER's bed XVII, Upper Bracklesham Beds. Whitecliff Bay.	23	15
N.sp.1 Sample 7171 CURRY, HODSON & WEST's bed H Upper Bracklesham Beds. Fawley Transmission Tunnel.	26	16
N.sp.2 Sample 7175 " Rimella canalis" bed Afton Brickyard.	12	2
N.sp.3 Sample 7176 Huntingbridge Bed, Huntingbridge	12	9
Sample 7169 Huntingbridge Bed, Studley Wood	6	-
N.prestwichianus Sample 6586 Basal Barton Beds, Alum Bay.	18	11
N.rectus Sample 6905 BURTON's bed A2. Lower Barton Beds,Barton.	23	10
Sample 6912 BURTON's bed A2. Lower Barton Beds,Barton.	20	6
Sample 6915 BURTON's bed A3. Lower Barton Beds,Barton.	8	-

Particular taxonomic rank is not necessarily implied by the designation of these groups. Rather they are parts of a completely varying plexus, which has been conveniently defined by a number of stratigraphic hiatuses. The author is a strong adherent to the school of thought that the taxonomic means are justified by the stratigraphic ends. Thus "splitting" here serves a more useful purpose than if applied to a palaeoecological problem (see remarks under Glandulina laevigata and the uses of groups at and above superfamilial rank in Section 3).

The provenance of the material examined is shown in Fig.10. The author would have preferred to have applied more rigorous biometric analysis to a much larger number of specimens but unfortunately time would not allow this. Instead the approach has been mainly qualitative, with some of the characters defined by measurements. Internal characters were examined from equatorial splits, obtained by immersing heated specimens in cold water.

The author is deeply indebted to Mr.D.Curry for providing material from Afton Brickyard (now overgrown) and Huntingbridge. Mr.C.King kindly provided the samples from Fawley and Studley Wood. More detailed descriptions of each "morpho-group" can be found in the taxonomic section.

c. Previous Work

CURRY (1937) provided the first up-to-date study on the Upper Eocene Nummulites. He corrected the errors left by 19th century authors and redefined three species, namely N.variolarius (LAMARCK), N.prestwichianus (T.R.JONES) and N.rectus CURRY (see taxonomic section). He treated the Huntingbridge form (N.sp.3) as a variant of N.prestwichianus but did not recognise any heterogeneity in the N.variolarius group. In 1942 CURRY described a dimorphic species (N.sp.2) from the "Rimella canalis" Bed of Afton Brickyard. He suggested that it lay on the direct line of descent from N.variolarius to N.rectus (not supported here) and named it "N.variolarius var.". BLONDEAU & CURRY (1963) noted the presence of N.variolarius with N.laevigatus in the Upper Calcaire Grossier and FISHER's Bed VIII at Whitecliff Bay. Finally BLONDEAU (1968) examined the Belgian Eocene Nummulites.

d. Morphological Characters

Dimorphism

External dimorphism can only be demonstrated in three Upper Eocene North West European species, namely *N.sp.1*, *N.sp.2* and the Belgian (Sands of Wemmel), *N.orbignyi - wemmelensis*. The last named unfortunately could not be studied here. All other English species have externally indistinguishable microspheric and megalospheric forms.

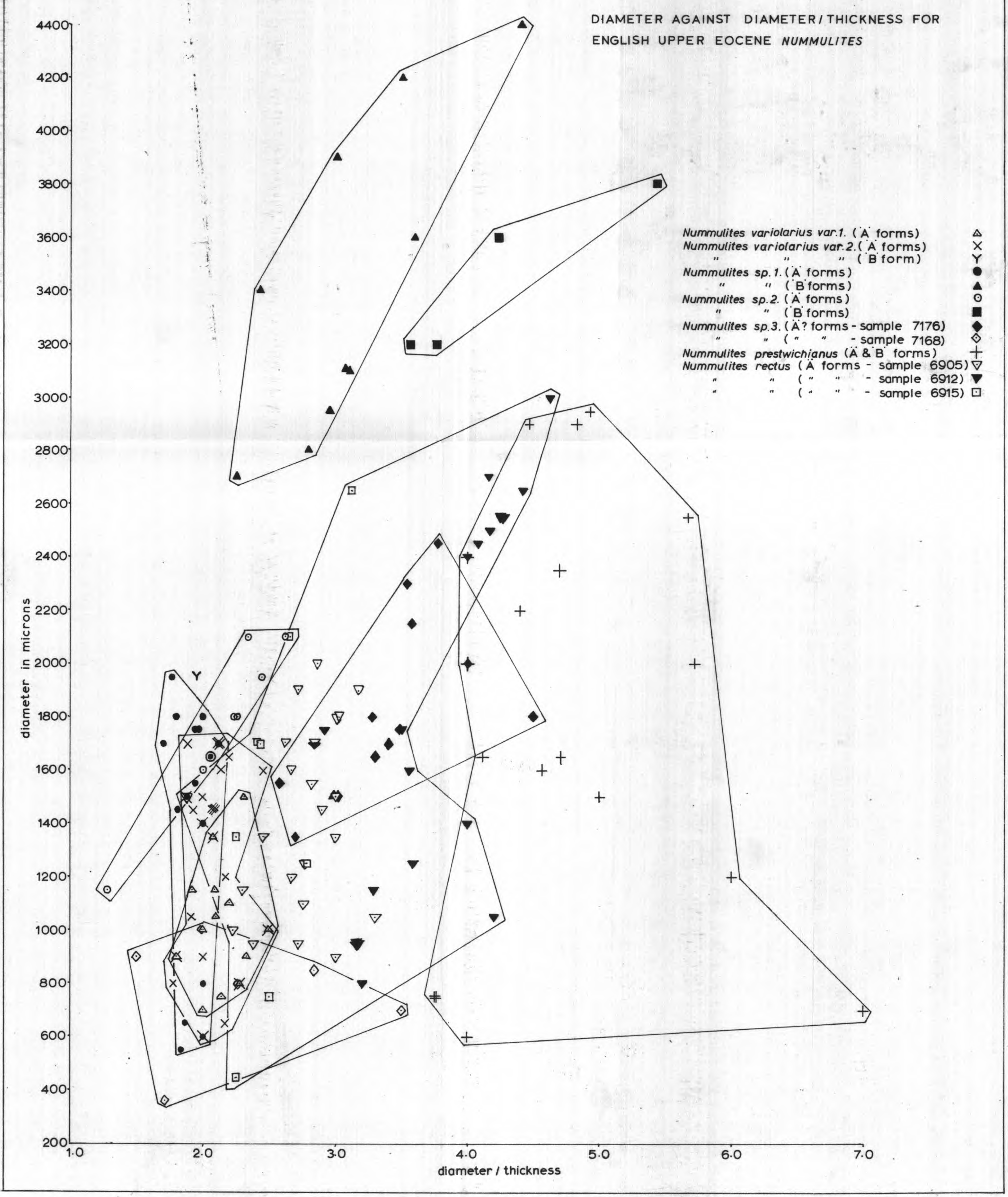
Microspheric *N.variolarius var.1* has not so far been found. Its occurrence as a trimorphic form of *N.sp.1* at Fawley was considered and rejected on the grounds of its association with other species in different samples.

Shape

Fig.11 shows the very strong overlap in the overall shape of megalospheric *N.sp.1*, *N.sp.2*, *N.variolarius var.1* and *N.variolarius var.2*. In general this group have laterally tumid tests with approximately similar diameter/thicness (D/T) ratioes at all stages of growth. Strong overlap is seen between this group and juveniles of *N.sp.3* and *N.rectus*. These two species and *N.prestwichianus* all show far greater variation in D/T ratio The B forms of the dimorphic species (*N.sp.1*, *N.sp.2*) have surprisingly distinct clusters.

Details of shape and the presence, in the adult, of a polar pustule (a linked feature) reveal similar groupings. At least some juveniles of all species bear polar pustules. With the exception of *N.variolarius var.1*, all adult tumid "morpho-groups" have identical, strongly rounded, lenticular outlines in apertural view. Juveniles of these usually show a more or less marked emergent polar pustule, while *N.variolarius var.1* retains this character in the adult. The flattened *Nummulites* can be more clearly differentiated on apertural outline (see taxonomic section for details). Microspheric *N.spp.1* and *2* can be distinguished on the central swelling and broad peripheral flange, present in the former but not the latter. Intra-"specific" variation in the shape of *N.rectus* is discussed elsewhere.

figure 11


DIAMETER AGAINST DIAMETER/THICKNESS FOR ENGLISH UPPER EOCENE *NUMMULITES*

It definitely does not define stratigraphic variants and consequently is of little use for our purposes.

Septal Filaments

Three types of septal filaments are present in the material studied; more or less strongly parasigmoid or even winding filaments; radial or near-radial filaments, which are thickened proximally and associated with small, flush, polar granules; and an unthickened, near-radial type. All these are relatively simple in comparison with types developed by advanced Tethyan species.

All species have at least some juveniles with strongly curved septal filaments. In the adult parasigmoid filaments occur in N.sp.3, N.rectus and N.prestwichianus. They, thus, appear to be linkedwith the overall shape. Microspheric N.spp.1 and 2 have slightly winding septal filaments and in these cases they may be associated with size. Adult "A" forms show distinctive proximal thickenings, as does adult N.variolarius var.2. Their juveniles have simple radial filaments and in N.variolarius var.1 this feature extends to adults. Perhaps it is linked with the presence of a polar pustule.

Septal filament branching is quite widespread in the material studied. It seems to represent a function of gerontic uncoiling, irregular growth or both. No systematic pattern can be seen. Uncoiling of the final whorl is most strongly developed in the flattened forms. N.prestwichianus, which begins to approach the genus Operculina, is sometimes partially unwound for more than one whorl. Fine canals in the walls running perpendicular to the filaments are apparently linked with good preservation. They may represent incipient transverse trabeculae.

Septa, spiral laminae and tightness of coiling

Adult septal shape, chamber proportions and tightness of coiling are closely related parameters. In the N.variolarius group and megalospheric N.spp.1 and 2 the tight coiling is associated with long, low chambers and inclined, continuously curved septa. Microspheric N.sp.1 and N.sp.2

Figure 12 Megalospheric proloculus sizes in microns for English Upper Eocene *Nummulites*.

Species	Sample No	Range of Proloculus size		Average Proloculus size	No. of Specimens
		Small	Large		
N. variolarius var. 1	7030	30	40	35	11
N. variolarius var. 2	7041	50	70	62	14
N. sp. 1	7170	70	120	100	10
N. sp. 2	Afton 7175	120	140	130	2
N. sp. 3	Huntingbr. 7176	70	110	94	7
N. prestwichianus	6586	90	150	108	10
N. rectus	6902	60	80	73	10
N. rectus	6912	70	150	97	6

show looser coiling, more hooked (especially distally), upright septa and larger height/length (H/L) ratios. This condition is even more extreme in *N.sp.3* and *N.prestwichianus*. In the latter the septa are strongly geniculate near the spiral lamina. *N.rectus* differs from all the other species in having strongly curved, bulging septa, which may even be set forwards proximally.

In microspheric *N.sp.1* the spiral lamina is very thick in comparison with all other forms.

Proloculus size

Megalospheric proloculus size provides much sharper distinctions between the "morpho-groups" than any other single character. The results of measurements are shown in Fig.12. *N.variolarius var.1* has the smallest megalospheric proloculus and *N.prestwichianus* and *N.rectus* the largest. *N.prestwichianus* and *N.rectus* show the greatest variation in proloculus size, as they also do in shape. Maybe these two features are linked. The best interspecific distinctions in proloculus size are shown by the *N.variolarius* group, *N.sp.1* and *N.sp.2*. The very strong distinction and lack of overlap between the two varieties of *N.variolarius* is believed to justify this attempt at subdivision.

e. Stratigraphic Characters

When considered in a stratigraphic context the wealth of confusing information outlined above begins to fall into place. Two groups of species become apparent; a flattened group (*N.sp.3*, *N.rectus* and *N.prestwichianus*), and a strongly tumid group (*N.sp.1*, *N.sp.2*, *N.variolarius vars.1* and 2). Taking the Upper Eocene as a whole the flattened group is restricted to the upper part and the tumid group occurs in the lower part. The tumid group allows for the further subdivision of the externally dimorphic species (*N.sp.1*, *N.sp.2*). This leaves the *N.variolarius* group of which *N.variolarius var.1* ranges throughout the lower unit and *var.2* is restricted to the upper part of the lower unit.

f. Phylogeny

A tentative phylogenetic pattern can now be elucidated (see Fig.13). The present evidence indicates that *N.variolarius var.1* makes its appearance earlier than all other forms. It has many characters which might be labelled as "primitive", i.e. radial septal filaments, tight spiral, small proloculus and tumid shape. *N.sp.1* occurs next stratigraphically. If it developed from *N.variolarius var.1* it became strongly dimorphic in the process. The most notable change in the "A" form is the enlargement of the proloculus. Further enlargement in the megalospheric proloculus is seen between *N.sp.1* and *N.sp.2*. This is accompanied in the "B" form by reduction in thickness of the spiral lamina and flattening of the test. Externally the "A" forms of *N.spp.1* and *2* are practically identical. *N.variolarius vars.1* and *2* are very closely relatedmorphologically and possibly also phylogenetically. *N.variolarius var.2* is here thought to have developed from the former.

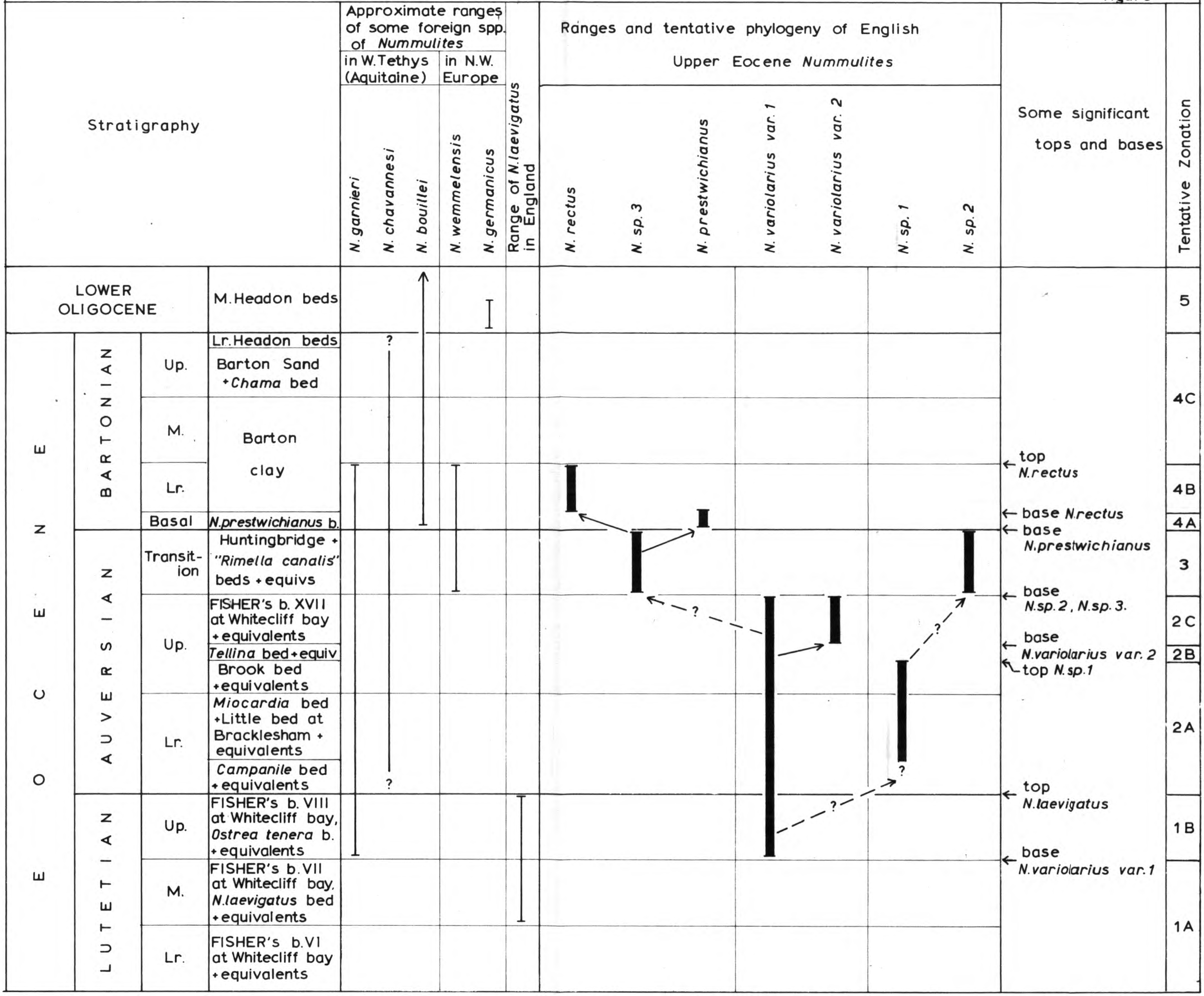
Taken alone proloculus size provides a very useful guide to the development of a lineage. It appears to increase systematically with time along the lines of descent from *N.variolarius var. 1* to *N.variolarius var. 2* and from *N.variolarius var.1* to *N.sp.1* and *N.sp.2*.

It is not so useful when dealing with the flattened forms. The origins of *N.sp.3* remain conjectural. CURRY (1937, 1942) suggested that *N.prestwichianus* (he named *N.sp.3* as a variety) and *N.rectus* were derived from the *N.variolarius* group, possibly via *N.sp.2*. The latter is strongly dimorphic, where the others are not, and a general reduction in megalospheric proloculus size would have been entailed if *N.prestwichianus* and *N.rectus* had evolved direct from *N.sp.2*. This is not thought to be the case and *N.sp.2* is probably the end of the dimorphic lineage in Britain.

Juveniles of *N.sp.3* and *N.variolarius var.1* have much in common. They both have lozenge-shaped outlines and emergent polar pustules. *N.sp.3* is tentatively suggested to have evolved from the latter by the development of a flatter test, a larger megalospheric proloculus and more curved septal

RANGE CHART FOR ENGLISH UPPER EOCENE *NUMMULITES*

figure 13



filaments. It is here that an influx of flattened forms from the Tethys may have influenced the make-up of North West European faunas.

The flattened group can be explained most clearly by the concept of a plexus of forms with complete variation in two directions. One direction is to the slightly more tumid N.rectus and the other to the extreme flattening of N.prestwichianus. N.sp.3 provides the "ancestral" link, with its smaller proloculus and shape overlap with both later species. N.rectus shows a great deal of intraspecific variation between two end members. One is relatively tmid and has straighter septal filaments. The other is much more flattened (approaching N.prestwichianus and N.sp.3) and has strongly parasigmoid filaments.

g. Relationship with Nummulites Faunas outside Hampshire

In North West Europe some aspects of the English fauna are uniformly applicable. The variability of the N.variolarius group in France and Belgium is unfortunately not known. It does however, show directly analgous overlap with N.laevigatus-lamarcki in the upper part of the Calcaire Grossier of the Paris Basin (BLONDEAU & CURRY, 1963). N.variolarius also ranges up through the French Sands of Auvers and has been recorded (CAVELIER, 1968) in the Sands of Marines. None of the flattened forms have been recorded from the Paris Basin.

In the Belgian Sands of Wemmel the flattened group is represented by the strongly dimorphic N.orbignyi (GALEOTTI) (= N.wemmelensis DE LA HARPE). This has a similar shape to N.prestwichianus but consistently bears stronger polar pustules than either N.prestwichianus or N.rectus. The uppermost Eocene and Lower Oligocene of North Germany and the Netherlands have yielded another flattened form, N.germanicus (BORNEMANN). Apart from its strong stratigraphic distinction from N.prestwichianus it differs in having a definitely larger megalospheric proloculus (120-190 microns; BATJES,1958). CURRY, (1966) considers N.prestwichianus and N.germanicus to be conspecific in spite of their separate stratigraphic occurrences. CAVELIER (1968) records N.prestwichianus, N.rectus and N.wemmelensis from the Upper Eocene of Germany and the Ukraine. Unfortunately a lack of comparative material precludes commenting on these occurrences.

The Western Tethys

It is generally agreed that the Western Tethys (Aquitaine Basin) provided the source from which the North West European stocks had their origin. Initial examination of Upper Eocene assemblages from Aquitaine provides a bewildering variety of quite different species. Many Tethyan forms are heavily granular and show external dimorphism. The relationship of smooth northern forms with granular Tethyan species may be explained on theoretical grounds. Assuming the present latitudinal difference between the two basins one would expect lower temperatures to the north. If the temperatures are lower then the solubility product of calcium carbonate will be lower and a granular Foraminiferid would have less calcium carbonate available to secrete or excrete as its test. Thus the granules and pillars might never have been formed in such a species.

A possible Tethyan ancestor of the *N.variolarius* group may be found in *N.garnieri*. This is a granular form but has similar simple, near-radial septal filaments, a tight spiral and a tumid shape. However, no lateral intermediates with *N.variolarius* have so far come to light.

N.bouillei DE LA HARPE (= *N.tourneri* DE LA HARPE) may have provided one of the stocks from which the North West European flattened *Nummulites* evolved. CURRY (1966) records its range as from Upper Eocene to Middle Oligocene in South West France. It is externally dimorphic and sometimes bears heavier, more granular ornament than *N.prestwichianus*.

Evidence from the geographically intermediate outcrops of Normandy and the English Channel is not very helpful. The Cotentin "Biarritzian" has yielded *N.brogniarti*, (see SCHAUB, 1968) and the lists mentioned earlier from the area off the Norman coast include *N.cf.aturicus* JOLY & LEYMERIE. Faunas which are rich in so many other species might have been expected to contain more diverse *Nummulites* assemblages but perhaps their ecological requirements were slightly different.

CURRY, MURRAY & WHITTARD (1965) provide the most promising list, when they record *N.fabianii. N.prestwichianus* and *N.cf.rectus* from the same sample. However, in their discussion they relate their *N.prestwichianus* to *N.bouillei*, not to the English species, and state that their *N.cf.rectus* is closest to an unnamed form from Biarritz.

2:3:4 Stratigraphic Conclusions

Stage names have been used very sparingly in this study. Even as lithostratigraphic labels their application to the North West European Tertiary, which has been so much in vogue recently, implies a precision which does not exist. CURRY (1966) provides the most likely scheme, althou his method of comparing Mollusc assemblages may be facies influenced.

Out of any single group of fossils the *Nummulites* faunas give the best means of subdiving the English Upper Eocene and correlating these strata with the type areas of the classic stages on the Continent. A tentative zonation based on associations is shown in Fig.13 and stage name equivalent (not necessarily chronostratigraphic) are suggested. It is appreciated, indeed hoped, that this will be refined or modified by studies on additioan strata. For example a bad sampling gap in the lower part of the Upper Bracklesham Beds needs further examination.

Zones 1A and 1B correspond to FISHER's (1862) division C and may be correlated with the French Calcaire Grossier (stratotype Lutetian) on the presence of *N.laevigatus* below (1A) and *N.laevigatus* with *N.variolarius va* above (1B) (see BLONDEAU & CURRY, 1963, for French assemblages in Zone 1B). Thus 1A would include ABRARD's zones I and II of the Calcaire Grossier and probably also the Belgian Sands of Brussels.

Zones 2A, 2B and 2C represent FISHER's groups B and A and include the whole of the English Upper Bracklesham Beds cycle. They are thought to correlate with strata with N.variolarius in the Paris Basin (Sands of Auvers) and Belgium (Sands of Ledes), i.e. the Auversian and Ledian. Zone 2A could not be subdivided further owing to lack of material. Its top is marked by the top of *N.sp.1*, here taken at the top of the Brook Bed and its equivalents. Zones 2B and 2C are equivalent to the Tellina and Nummulites variolarius Beds respectively. N.variolarius var.2 is restricted to 2C and both variants of N.variolarius disappear at the top of that zone.

There is some controversy as to the correlation of the Upper Calcaire Grossier, the Sands of Auvers and the English Upper Bracklesham Beds. Certain French authors (POMEROL, 1964, 1965; BLONDEAU et al. 1965, CAVELIER & LE CALVEZ, 1965) equate the whole of the Upper Bracklesham Beds with the Upper Lutetian (ABRARD's Calcaire Grossier zones III and IV). Also they correlate the French Auversian, Marinesian and sometimes the Ludian with the English Bartonian. Furthermore, they suggest that the Upper Bracklesham Tellina-N.variolarius Beds are equivalent to the so-called "Biarritzian" of northern France, on the basis of its peculiar larger Foraminiferal fauna. The stratotype of this last stage is in Aquitaine, where it is poorly characterised (see BIGNOT & BOULANGER, 1968). It lies between the Middle and Upper Eocene and its usefulness for the Norman, Breton and Cotentin larger Foraminiferal faunas is doubted. These faunas have been discussed earlier and their occurrence is thought to have been controlled by environmental conditions at several different times (CURRY, 1966). The strong diachronism shown by the Nummulites, if the above correlations hold true, also seems unlikely. CURRY (1966) equates FISHER's division B of the Upper Bracklesham Beds with the Calcaire Grossier zones III and IV (Upper Lutetian), division A with the Sands of Auvers (Auversian) and the "R.canalis", Huntingbridge and Barton Beds with the Sands of Marines (Marinesian) and Marls with Pholadomya ludensis (Ludian). In the absence of any information to the contrary and in view of CURRY's use of Molluscan correlation coefficients being possibly facies controlled, the correlation of the whole of the Upper Bracklesham Beds cycle with the type Auversian is here preferred.

The relationship between the strata containing N.sp.2 and N.sp.3 (the "R.canalis" and Huntingbridge Beds respectively) is completely unknown and for convenience both horizons are included in zone 3. The base of zone 3 marks the appearance of flattened Nummulites (N.sp.3). In Belgium flattened forms

(*N.orbignyi-wemmelensis*) first appear in the stratotype Wemmelian (Sands of Wemmel). Stages are now defined on their bases and it is possible, although by no means definite, to correlate the base of zone 3 with the base of the Wemmelian. In the absence of additional data this must be regarded as highly tentative, especially if, as the French school suggests, the *Nummulites* faunas were diachronous over large distances.

The base of the Bartonian was originally defined by KEEPING (1887) on the presence of *N.prestwichianus* and this level corresponds to the base of zone 4A. At Alum Bay *N.prestwichianus* and *N.rectus* occur together in two samples (6590, 6591) and the base of zone 4B is taken at the first appearance of the latter species. The top of 4B and the definition of zone 4C are completely arbitrary and are based on the absence of *Nummulites*. This boundary is undoubtedly facies controlled and marks the point at which conditions became untenable for *Nummulites* in Britain.

Zone 5 is included for completeness and represents the base of the Oligocene. In France this part of the column is occupied by non-marine and brackish water strata (the "Sannoisian" and "Stampian"). Such correlations as that of BLONDEAU et al. (1965) which equate the base of the French Oligocen with the top of the Bembridge Marls cannot be substantiated on true marine faunas. The original definition of the base of the Oligocene was made by BEYRICH (1854) to include the beds at Lattorf (Lattorfian). Several authors (CURRY, 1966, gives a good summary), have correlated these with the marine Sands of Glimmertingen (type Tongrian) and the Brockenhurst Bed at the base of the Hampshire Middle Headon Beds, thus provisionally identifying the base of the Oligocene in England.

Section 3 SYNTHESIS OF BARTON BEDS FAUNA and FLORA

Section 3:1 Introduction

The marine part of the Barton Beds cycle and the Barton Clay in particular is here chosen as the model to test the application of total faunal and floral analysis to problems of palaeoecology and correlation in multifacies sequences. No previous attempt at this kind of study has been made and interpretation of the results has not progressed as far as was hoped. This could partly be explained by the weight of material involved and this section is chiefly a presentation of the data.

All this data was quantitative at its collection. The use of true total ranges in the Barton Beds, even as rudimentary zonal indicators, was not found to be very conclusive. A maximum time span of a mere 8 or 9 million years for the interval under consideration (see BONHOMME, ODIN & POMEROL (1968) on Rb/Sr dates) might not have been sufficient for the vigorous evolutionary development of more than one or two lineages (e.g. the Nummulites). A graphical quantitative approach is preferred for subdividing these beds, using levels of change in the proportions of various taxa to delimit change in the environment.

Palaeoecology demands comparison with extant assemblages and this provides special problems. Direct ecological correlation between Recent and Eocene faunules depends on the identification of the same species and very few Recent species range as far back as the Eocene. It further depends on the assumption that ecological controls on those species which do have long time spans remained the same. If this is not so then the interpretation of the environmental controls on extinct species then rests on comparative morphology and can become extremely subjective. The approach preferred here is initially based on the empirical relationship between the ratios of generic, suprageneric and larger taxonomic groups with the lithofacies. The patterns thus obtained can be applied to individual extinct species and details of their palaeoecology can be worked out. This bypasses the possibility of uniformitarianism in Eocene palaeoecology being at fault. Of course, no detailed depth or temperature values can be applied but their use in conjunction with identifiable extant species in some other studies is though to overestimate the value of the evidence.

3:1 Methods

All samples were taken from 500 gms. dry, unwashed material. In fossiliferous samples the numbers of individuals proved much too large to count total absolute abundances. Samples from the clay sequence might contain upto about 1000 Mollusca, 1000 Ostracod valves and perhaps 10,000 Foraminiferida. All counts were made on sieved fractions. The reasons for this are optical, similar sized particles being easier to count; taxonomi as sieving at least partially separates Foraminiferida from Mollusca from Ostracoda; and ecological. Thus a broader size fraction would include different sized individuals which might be unrelated in terms of competition and food supply. Three grain size fractions were separated using British Standard sieves, namely the 10-30 (1676 to 500u), 60-30 (251to 500u) and 60-200 fractions (251-76u). All material greater than 10 sieve size was tr qualitatively only. In addition an initial count of fragments and whole specimens was made. Groups which were dealt with only be fragment analysis include the Echinodermata, plant remains and Vertebrate bone fragments. These groups represent comminuted material whose complete individuals contain an unknown number of elements. An approximate grain size analysis was calculated from the weights of the greater than 60 (251u) and 60-200 (251 to 76u) fractions.

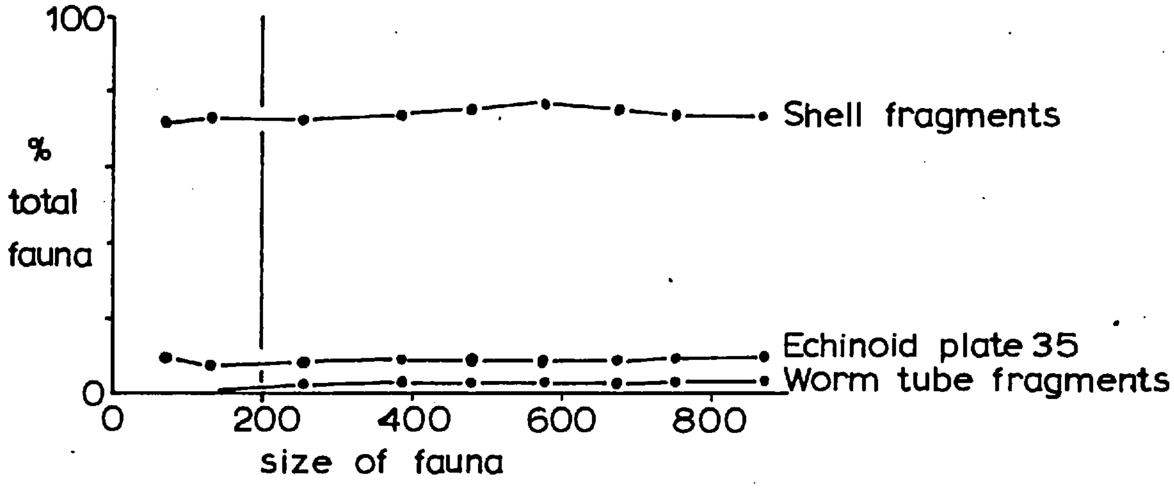
3:1:2 Limits of Accuracy

Figs. 14 to 17 show graphically the variation of percentage with increasing sample size in selected groups in each of the three grain size fractions. Stability in the percentage of a particular species is reached in most cases after 200 specimens have been counted. In less fossiliferous samples a lower limit of 50 specimens was used but the resulting graphs in th parts of the succession must be treated with reserve. Cases where the percen- tages of species changes after counting 200 specimens can be explained by the annoying tendancy of larger and more spherical specimens to roll out of the

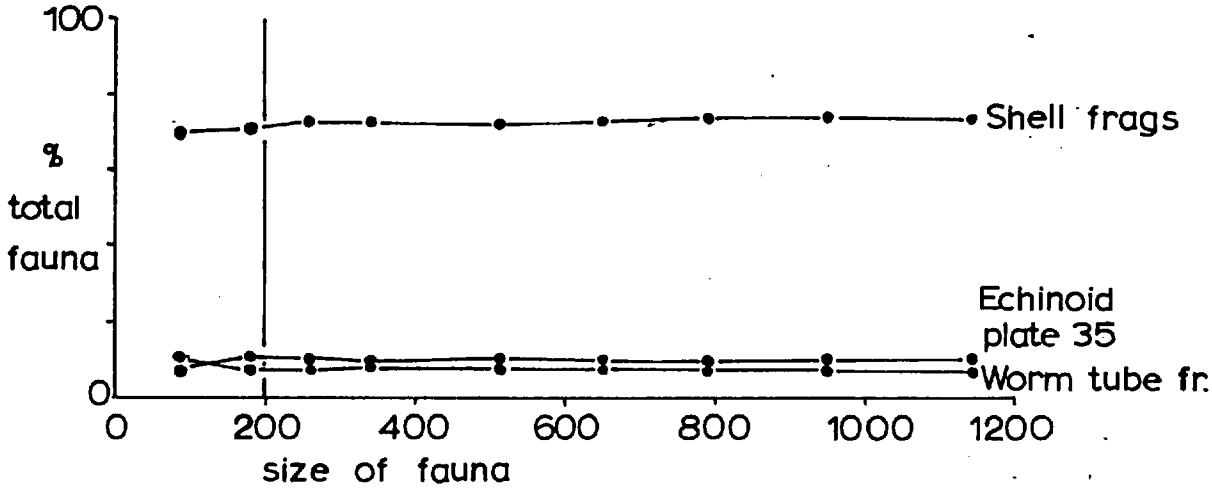
figure 14

VARIATION IN % FRAGMENTS WITH SAMPLE SIZE
(sample 6950)

10 -30 fraction



60-30 fraction



60-200 fraction

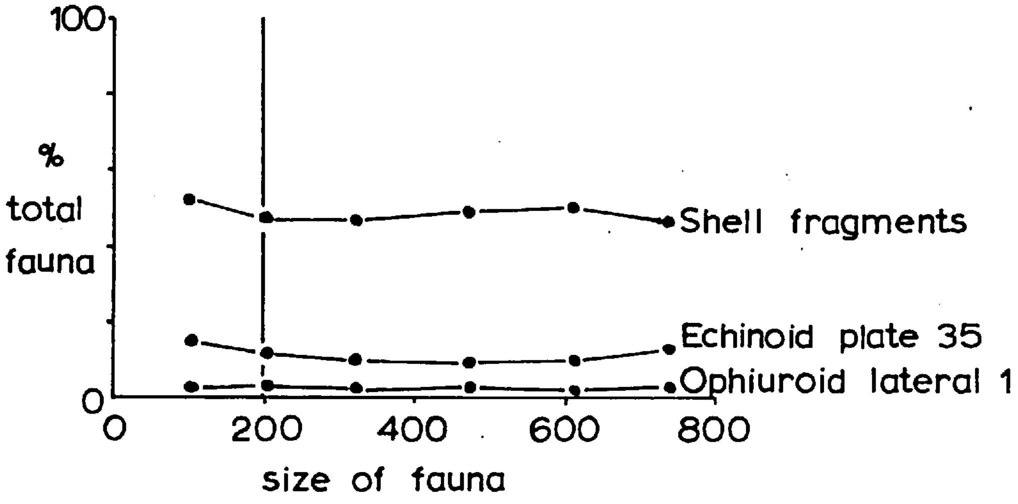
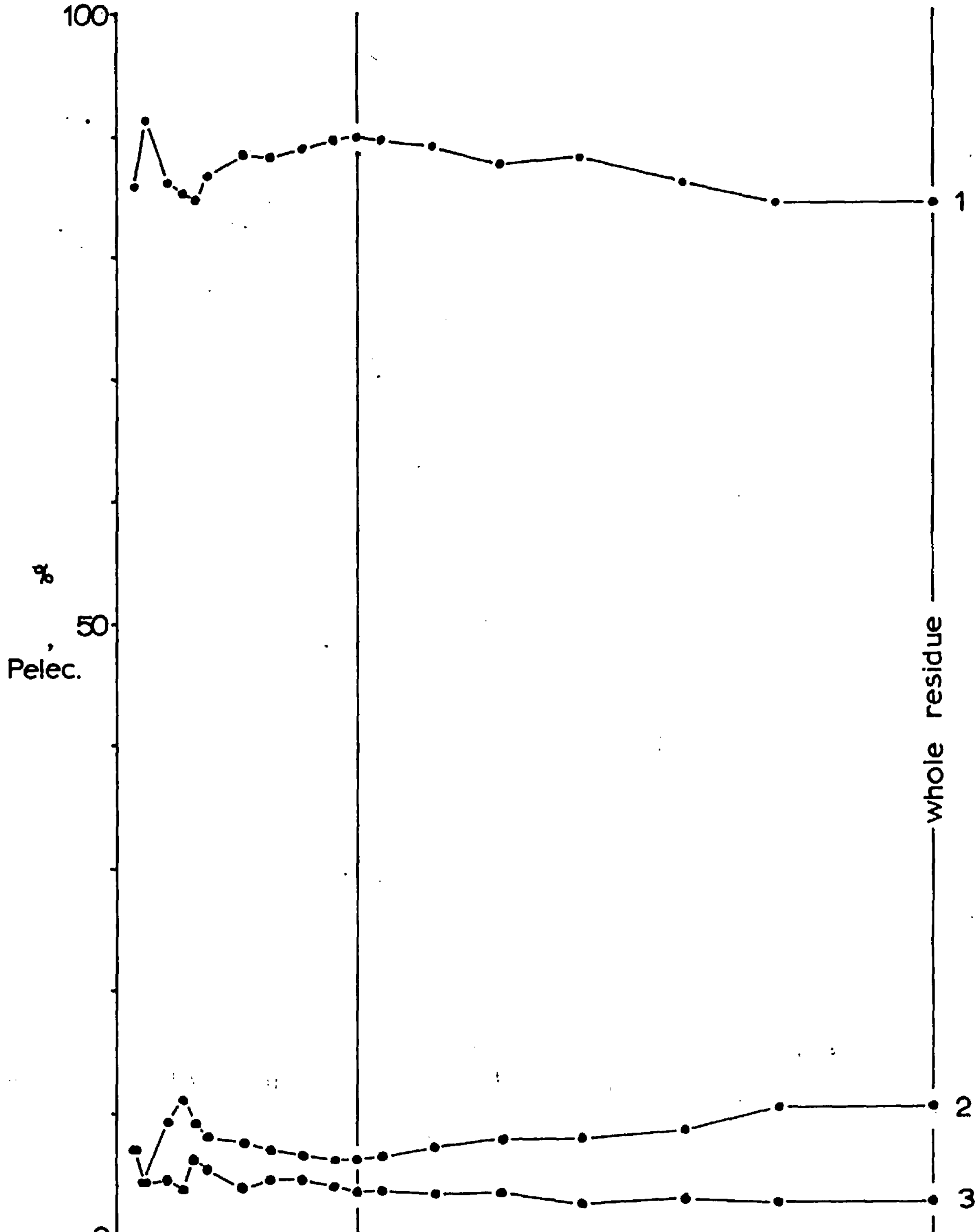


figure 15

VARIATION OF % PELECYPODA WITH SAMPLE SIZE IN 10-30 FRACTION (sample 6950)

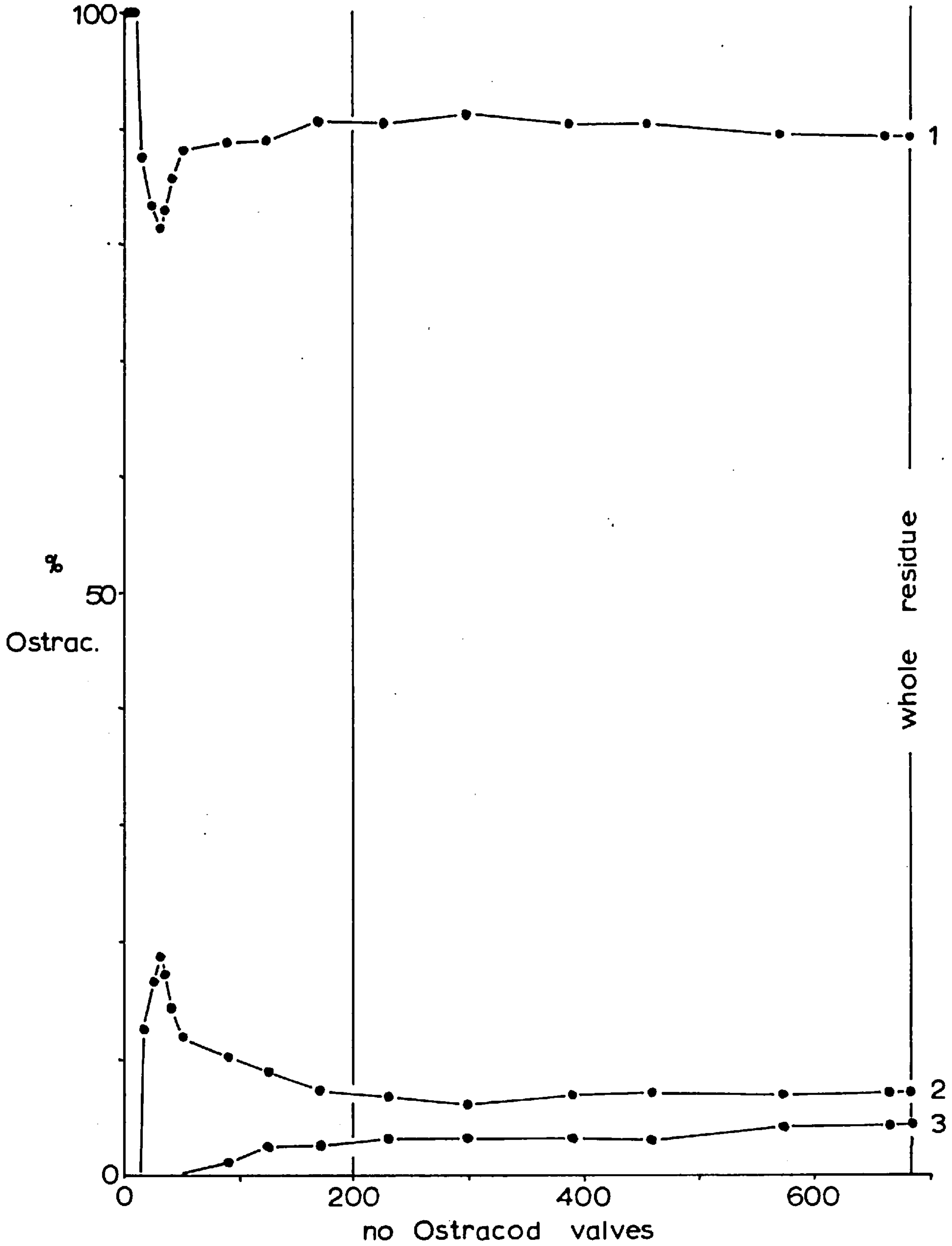


1 *Corbula pisum*
2 *Nuculaha minima*
3 *Lutetia pisiformis*

figure 16

VARIATION OF % OSTRACODA WITH SAMPLE SIZE IN 60-30 FRACTION

(sample 6950)



1 *Leguminocythereis striatopunctata*

2 *Cytheretta laticosta*

3 All other species

figure 17

VARIATION OF % FORAMINIFERIDA WITH SAMPLE SIZE IN 60-200 FRACTION
(sample 6950)

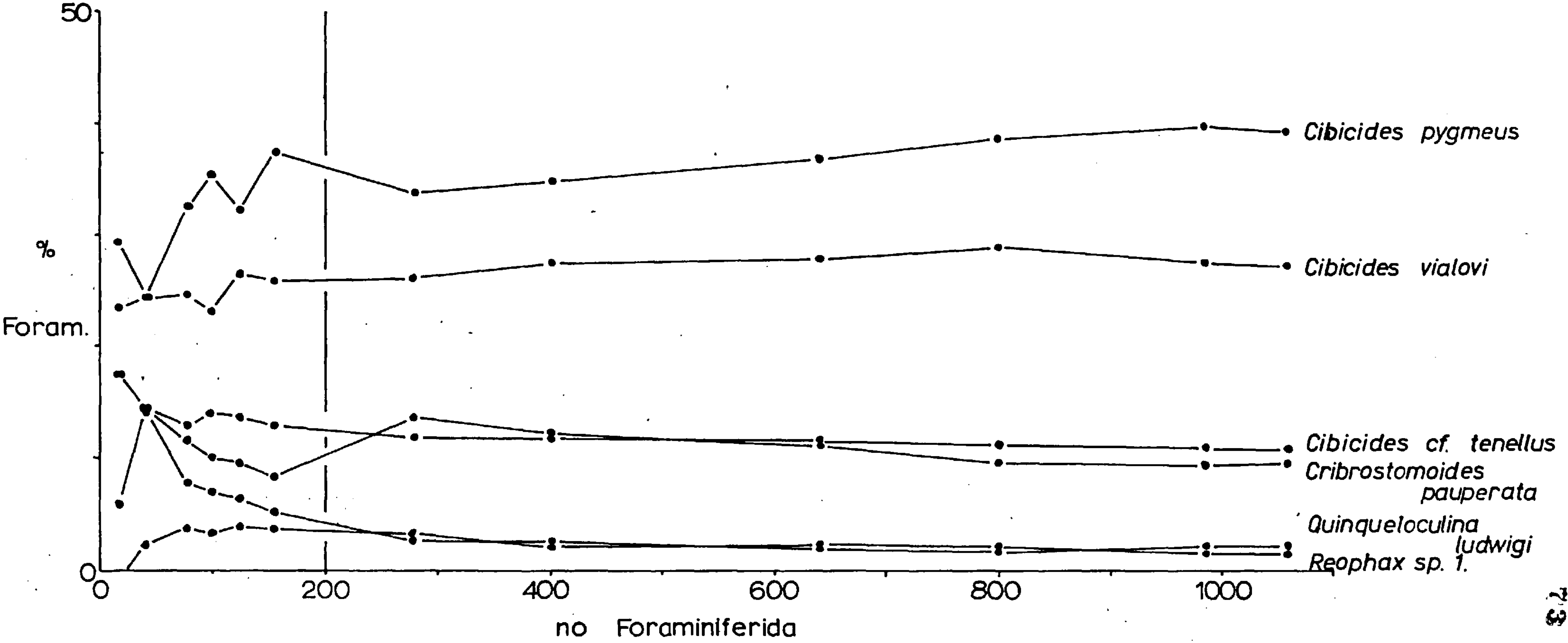
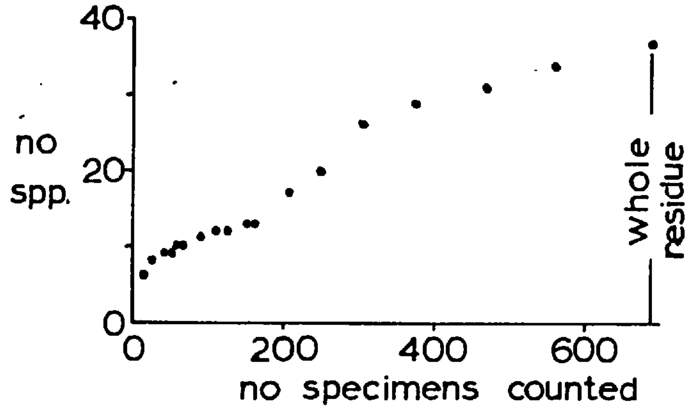


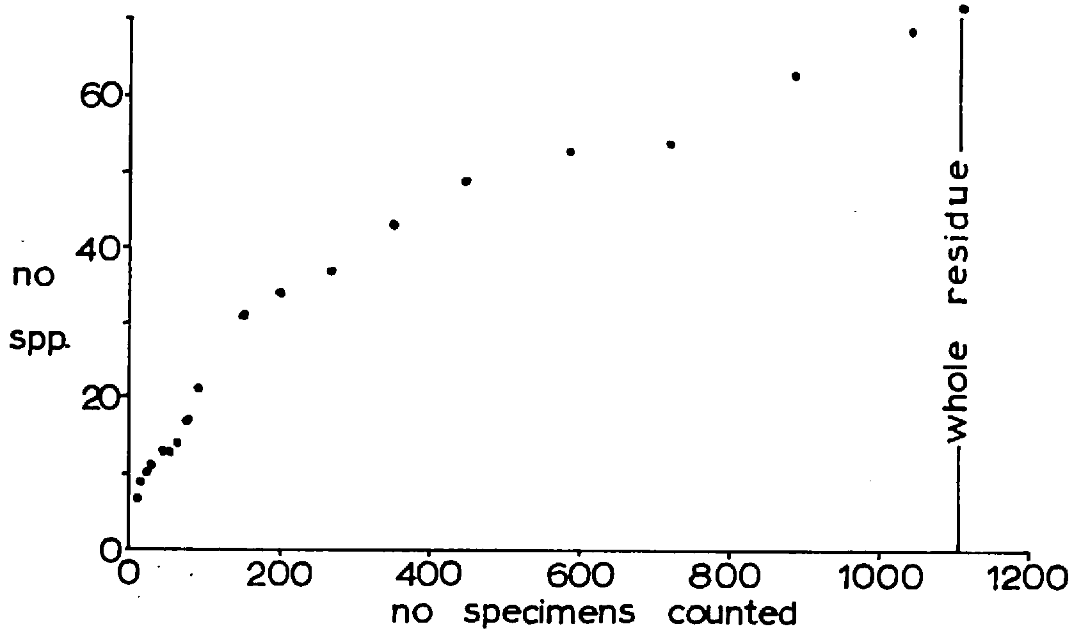
figure 18

VARIATION OF TOTAL DIVERSITY (NOT FRAGMENTS)
WITH SAMPLE SIZE
(sample 6950)

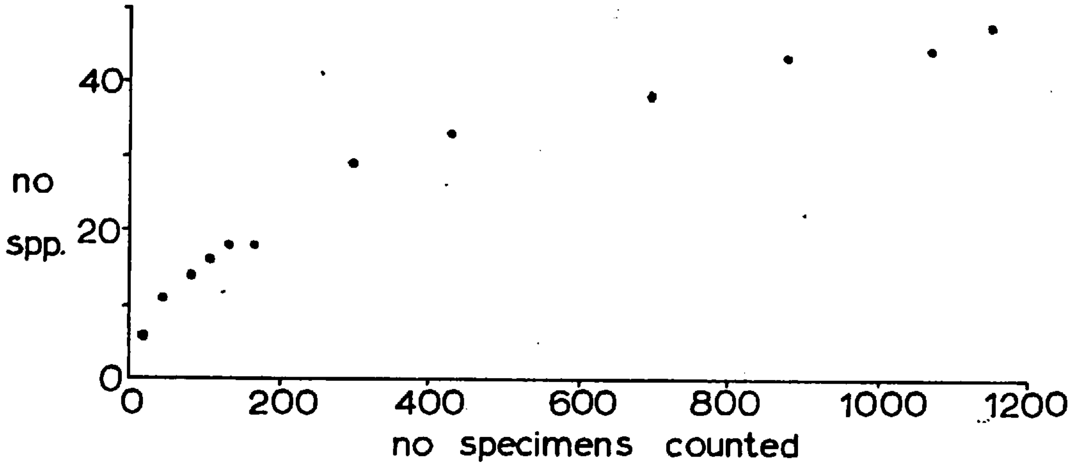
10-30 fraction



60-30 fraction



60-200 fraction



sieve before flatter or more elongate ones. Extra care was taken to ensure standardisation of successive counts and the resulting errors are ignored as being probably smaller than the real variation between samples and across biofacies boundaries.

Fig.18 shows the variation in total diversity with sample size. None of the three grain size fractions reach a true estimate of total diversity but in each case the graph begins to asymtote after 400 specimens had been examined. After the counts had been completed all the remainder of the 10-30 and 60-30 fraction was examined qualitatively. In the case of the 60-200 fraction half of the residue was retained and floated with carbon tetrachloride. Thus the resulting qualitative and diversity data reflects the true content of the 500 gms. sample.

3:1:3 Presentation and Interpretation

As far as possible individual species are plotted as percentage distributions of taxonomic groups, or in the case of fragment analysis, of the total fauna and flora. This method eliminates the problem set by variable dilution of the fauna by sediment supply. All percentages calculated are based on at least 50, and where possible over 200 specimens. They are calculated to the nearest percent and only those over 0.95% are plotted. The latter proviso is to partially eliminate spurious peaks caused by single occurrences of otherwise rare species. The numbers of individual species are not given on the percentage distribution tables, as this would have doubled the already unwieldy quantity of date presented. Figures for the total count used and the sum of the percentage of those species plotted are given in the margins.

Theresults of this investigation are shown in tables 5 to 26. Five main types of graph have been used to demonstrate various features. A total range chart for the Palaeogene is presented for the Foraminiferida and Ostracoda (table 6). This was compiled from literature and by direct observation from comparative samples. A second type shows ranges of species in the Barton Beds. These are obviously not true total ranges but provide a convenient vehicle for recording the occurrences of rarer constituents. The percentage distribution of species in the major groups are shown in a third type of graph. These demonstrate changes in faunal composition most successfully but could only be compiled for the dominant groups (Foraminiferida, Ostracoda, Mollusca). The ratios between larger taxonomic units of well represented groups (Foraminiferida, Microplankton) and of the whole fauna and flora (fragment analyses) are also shown. Finally the residue of locally or poorly represented phyla are shown by approximate abundance graphs. These show the maximum number of specimens present in any grain size fraction for groups such as the Bryozoa or Annelids, which seldom reach a high enough count to plot meaningful percentages.

Levels of change are shown by the limits of total ranges, acme zones and by points on oscillatory graphs. Total ranges are extremely hard to define within the Bartonian and, more often than not, apparent tops or bases may reflect lack of knowledge on adjacent units. The tops and bases of acme zones are much more satisfactorily identifiable. Dominant species may show single or multiple acmes but their limits are usually clear cut and seldom gradational. The acmes of rarer species can often also be demonstrated by their presence or absence. Finally, certain taxa, particularly the Ostracoda, show long acmes and some of their species have percentage distributions which tend to oscillate in antipathy to other species within the group. In an otherwise homogeneous sequence this can be interpreted as representing small changes in environmental conditions.

Two featuresof the Barton Beds sequence and its fauna have bearing on these interpretations. The first is the presence of decalcified zones. These occur at Barton in BURTON's beds A1, B, I and K and at Alum Bay in the possible Highcliff Sands equivalent, in the lower part of the Middle Barton Beds and in the Barton Sands. All calcareous faunas show an obvious break at the boundaries of decalcified zones. Such breaks may be related to the particular lithofacies of that zone but in the absence of other evidence they must be regarded as spurious.

Nothing has been said of the relative ecological equivalence of, to take an extreme example, a Foraminiferid test and an Ophiuroid ossicle. The degree of fragmentation of the fossilisable parts of an organism and their morphological or ontogenetic position often renders the comparison of species belonging to different phyla meaningless. For this reason interphylum comparisons have been used only on the very general scale of fragment analysis and then taking into account that all numbers of Pelecypoda, Ostracoda and Otoliths have to be halved. Only in one case has a direct ratio been calculated across a phylum boundary (Microplankton/Foraminiferal ratios). This was necessary to show the very strong changes in the abundance of Microplankton which could not be demonstrated using the fragment analysis graphs.

Section 3:2 THE DISTRIBUTION OF THE MAJOR GROUPS

3:2:1 Lithology and Grain Size Distribution

Table 5 shows the grain size distribution at Christchurch Bay and Alum Bay. At Christchurch Bay coarse grained, poorly sorted sequences occur in bed A1 and again in beds B,C,D and lower E. Finer silt and clay units occur in beds A2, A3 and above the second coarse unit in beds E and F. Above bed F there is an abrupt change to well sorted coarse sediments, with finer grained intervals in bed J. At Alum Bay the lower coarse grained unit is absent but the lower fine, middle coarse and upper fine sequences are lengthened. The lower part of the well sorted, coarse grained upper unit is present. The middle coarse, poorly sorted unit can be further subdivided into a lower and an upper division.

When considered with the lithological succession these sequences become more meaningful. The two coarse, poorly sorted units correspond to glauconite rich horizons and the finer units with shelly clays. The upper coarse, well sorted section represents the fine, non-glauconitic Barton Sands. Thus there is a clear duplication of the succession in terms of two fining upwards sequences or cycles, capped by a terminal coarse sequence. The small peaks of coarser material in the fine sequences in all cases proved to represent concentrations of calcareous fossils. Two pebble bed horizons at Alum Bay are not shown clearly by the grain size distribution. These occur within the lower half and at the top of the middle coarse unit.

Previous work is lacking on the gross sedimentology and clay mineralogy of the Barton Beds. WALDER (1964) and BLONDEAU & POMEROL (1968) are mainly concerned with the heavy mineral content of the English Tertiary as a whole

The significance of the abundance of glauconite at two levels depends on whether it is authigenic or allochthonous. No glauconite infilled Foraminiferal tests have been found to indicate that it formed in situ. PORRENGA (1967) studied the environmental control of glauconite formation and he showed that glauconite rich zones occur towards the edge of the Continental Shelf. Such a position does not however tally with the observed presence of glauconite infilled Foraminiferida in FISHER's bed XVII of the Upper Bracklesham Beds. CLOUD (1955) reviews the problem and indicates that it only develops in water of normal salinity, has a considerable depth range (10-400 fathoms) and is characteristic of areas of slow sedimentation. The Bartonian glauconite might quite possibly be allochthonous, even reworked in origin. Against the argument must be set it svery fresh appearance. It is provisionally thought to be at least partly authigenic and associated with slow deposition in a fairly shallow water regime.

3:2:2 Fragment and Whole Group Analysis

The results of fragment analyses are plotted for the three grain size fractions on Table 5. The main features are the restricted distribution of Vertebrate teeth, scales and bone fragments; the position of the decalcified and calcite poor zones; and details of the distribution of groups in the calcareous sequences.

At Christchurch Bay Vertebrate debris (excluding Otoliths) is much more abundant in the lower and middle glauconitic sequences than in either of the clay units or the Barton Sands. At Alum Bay Vertebrate debris is more evenly distributed but does show concentrations towards the base of the middle glauconitic sequence.

There is thus a strong association between Vertebrate (i.e. phosphatic) concentrations and high glauconite abundances. Such association was noted by

PETTIJOHN (1957) and his remarks support the theory that the glauconite was authigenic and the coarse grained, poorly sorted sequences accumulated under conditions of slow deposition.

The non-calcareous zones can be identified by the reciprocal relationship of plant remains and calcareous groups in the 10-30 and 60-30 fractions. Where decalcification has occurred plant debris and seeds tend to form the bulk of the assemblage and even Vertebrate debris may be absent. Such levels occur at beds I and K at Barton and in the Highcliffe Sands equivalent, the upper part of the middle glauconitic sequence and the Upper Barton Sands at Alum Bay. All these were possibly decalcified by Recent weathering and should be distinguished from originally non-calcareous or poorly calcareous sequences. The latter include beds A1, A3 to D and J at Barton and the lower part of the middle glauconitic unit at Alum Bay. The 60-200 fraction shows a more detailed pattern in plant remain distribution. Plant debris occurs fairly abundantly even in the calcareous clays. It shows strong diminution only in the upper part of bed F at Barton and at a similar, though less clearly defined level at Alum Bay.

The major abundances of the three most common calcite secreting groups (Mollusca, Foraminiferida, Echinoderms) have an inverse relationship with the abundance of plant debris. Thus all three phyla have peaks in the two clay sequences in all size fractions. Especially high percentages are shown by the Foraminiferida in the Nummulites prestwichianus Bed at Alum Bay and at two nummulitic levels at Barton. Echinoderms show especially marked peaks in the upper part of the lower clay at both sections. The only other group to show particularly sharply limited distribution are the Annelids. These have peaks at the base of the lower clay at Alum Bay, at the base of the upper clay at both sections and near the middle of the upper clay at Barton. The last named peak coincides with the point at which plant debris shows a marked decline in th 60-200 fraction.

Most of the above distributions can be correlated with the double cyclic pattern shown by the lithological succession. The only level which cannot be explained in this way is that of the Annelid peak and plant debris diminution in mid F at Barton.

3:2:3 Marine Algae

The Microplankton are well represented throughout the Barton Beds, as can be seen from Tables 21 and 22. They are the only group present in large quantities in the decalcified Upper Barton Sands. Tasmanitids and Incertae Sedis occur in small quantities and diversity throughout the sections. Dinoflagellate cysts show better characterised distribution.

The use of their total ranges for stratigraphic subdivision is hampered by lack of knowledge on adjacent formations. *Lanternosphaeridium axialis* (EISENACK) is the only species present with a well defined top. This occurs at bed E at Barton and at the pebble bed at Alum Bay. *Cordosphaeridium inodes* (KLUMPP) and *Polysphaeridium subtile* DAVEY & WILLIAMS have a base and top at rather different levels in the two sections. The former is definitely known from higher and lower units.

Dinoflagellates of course, are marine planktonic organisms and their occurrence in the Upper Barton Sands indicates at least some oceanic influence. WILLIAMS & SARJEANT (1967) review the present state of knowledge on Dinoflagellate ecology. Their remarks on the relationship of morphological groups to lithofacies and substrate conditions could not be applied to the Bartonian assemblages.

Certain ecological indications are present. The upper limits of species in the Barton Sands of Christchurch Bay show that progressively fewer species reach progressively higher levels. This does not appear so clearly in the diversity graph but nevertheless suggests, if not a decrease in salinity, at least a systematic decrease in oceanic influence. The losses and gains graph (plotted for Christchurch Bay only) is an unsuccessful adaptation of a method employed by COUSIMINER (1961). He used it to show levels of extinction in the stratigraphic column as a whole but it might also be employed on a much smaller scale to identify "adaptive" (where local bases of assemblages outweigh tops) and "inadaptive" sequences (where local tops outweigh bases of assemblages). Perhaps it would provide a clearer pattern if applied to a larger group.

The best characterised change in Microplankton floras is the sharp drop in "abundance" (here plotted, for convenience only, as the Microplankton/benthonic Foraminiferal ratio) half-way up bed F at Barton and at a similar level at Alum Bay. This corresponds to the drop in plant remains and the peak in Annelid tubes shown in table 5. It is provisionally interpreted as a level at which oceanic influences were temporarily decreased, due perhaps to sill formation or ocean current changes. The diverse benthonic Foraminiferal, Molluscan etc. fauna above this level belies any drop in salinity and the presence of abundant Microplankton in the *Chama* Bed indicates that it was only a temporary episode.

3:2:4 The Foraminiferida

99 species and varieties have been distinguished in the Barton Beds (see tables 7,8) but out of these very few true total ranges are limited to the Barton Beds (table 6). Of the previously described species, *Praeglobobulimina cf. pupoides* (D'ORBIGNY) and *Asterigerina brandhorstiana* GRAMANN have their bases in the Barton Beds. Previously undescribed distinctive species which have their total ranges within the Bartonian include *Sagrina sp.2*, *Sigmomorphina sp.1*, *Elphidium sp.4* and some of the agglutinated forms (*Cribrostomoides sp.3*, *Verneuilina sp.1*). In all these cases the position of the base or top is not constant between Barton and Alum Bay. For this reason total ranges of smaller benthos are not used for stratigraphic subdivision.

A much more complex pattern is shown by the percentage distribution data (see tables 9,10,11). Foraminiferida are very abundant in the clay sections and in some parts of the glauconitic beds. They are absent or poorly represented in the secondarily decalcified sands. The sandy clays of bed J have not yielded very good faunas and this discussion is mainly limited to the strata upto the *Chama* Bed.

An examination of Foraminiferal ratios show that *Cibicides spp.*, the Miliolids and the Agglutinated Foraminiferida dominate most of the faunas. Agglutinated species tend to show highs in the glauconitic sequences, though sometimes as spurious peaks caused by decalcification. The Miliolids are much more abundant in the clay sequences than elsewhere and *Cibicides* is dominant throughout, except in the decalcified zones.

In the lower clay sequence Miliolids are abundant only in its upper half. The 60-30 fraction ratios show that these faunas are dominated by two smooth species, namely Quinqueloculina seminulum (LINNE) and Q.impressa REUSS. The upper clay unit contains these two species throughout but they are joined near the top of bed F (and its equivalent) by peaks of other, more ornate forms. The lower part of bed E and its equivalent is marked by abundances of Q.aff.carinata D'ORBIGNY and Q.costata KARRER. These then become reduced and Q.ludwigi REUSS and more particularly Q.bicarinata D'ORBIGNY show peaks near the top of the clay sequence. Thus in general the upper part of the lower clay is characterised by abundant "simple" Miliolids in low diversity and the upper clay contains the same species associated with several more ornate forms.

Cibicides vialovi BYKOVA and C.pygmeus (HANTKEN) greatly outweigh the other four species of Cibicides in importance and show quite distinct acme zones. C.pygmeus is dominant in the Lower Barton Beds and C.vialovi holds the same position in the Middle Barton Beds. The changeover may be seen particularly clearly towards the base of the middle glauconitic sequence at Alum Bay. C.cf. tenellus (REUSS) shows peaks near the top of the middle glauconitic bed and in the lower part of the upper clay and C.ungerianus (D'ORBIGNY) is common only in the Lower Barton Beds. The other two species are present in very subordinate numbers.

In general the Lagenids, Polymorphinids, Robertinids (one species) and the Buliminids are present in low percentages throughout the calcareous succession, without showing sharp breaks or peaks. The Globigerinacea (one species) has a similar distribution and the theories of STEHLI & CREATH (1964) on planktonic/benthonic ratios cannot be applied. Three groups of Rotaliina however show better characterised peaks, namely Nummulites, the Elphidium and Nonion group and Pararotalia inermis (TERQUEM).

The Nummulites show high abundance at several levels in the lower clay sequence (two at Barton, four at Alum Bay). They are concentrated in the coarser fractions and seem to be independent of lithology and of the other

Foraminiferida. The six common species of *Nonion* and *Elphidium* show peaks at slightly different levels to each other but when plotted together (table 11) the group falls into four distinct highs. These occur at the bottom of the lower clay in the lower part of the middle glauconitic sequence, at the base of the upper clay and at the top of the same unit. Peaks of *Asterigerina brandhorstiana* GRAMANN coincide with the second and third *Nonion* and *Elphidium* peaks at Alum Bay and Barton respectively. Small peaks of two other species are associated in minor percentages with this middle glauconitic bed. These are *Baggina subconica* (TERQUEM) (lower part) and *Lenticulina cf. yaguatensis* (BERMUDEZ) (throughout). Of the two species of *Pararotalia* present, *P.spinigera* (LE CALVEZ) is more or less evenly distributed throughout the two clay sections. *P.inermis* (TERQUEM) however, shows strong peaks at the top of the upper clay and in the *Chama* Bed of both localities.

The variations in indigenous species diversity are shown on table 11. As would be expected these graphs show highs in the two clay beds, smaller peaks in the calcareous parts of the middle glauconitic bed and lows in the decalcified sands and lower glauconitic bed. The reduced diversity in the Becton Bunny Bed at Barton is interesting. All the species at this level range down into lower units and the diversity is the only evidence that ecological conditions were different from that of underlying beds.

A sequence of Foraminiferal associations can now be expounded. This starts at Barton with one dominated by Agglutinated species in the lower glauconitic sequence. The lower part of the lower clay bed contains a *Cibicides*/*Nonion*/*Elphidium* smaller fauna and abundant *Nummulites* in coarser fractions. The upper part of this clay unit is characterised by a low diversity Miliolid larger fauna and a smaller fraction dominated by *Cibicides spp.* In the lower part of the glauconitic sequence Miliolids disappear and a *Cibicides*/*Nonion*/*Elphidium* assemblage reappears. The decalcified sandy bed at Alum Bay and a sampling gap at Barton separate this from a similar association above, in bed E and the lower part of the upper clay bed. The higher parts of the clay bed show a change to high diversity Miliolid faunas in the 60-30 fraction and *Cibicides* dominated fine fractions. Finally in the Chama Bed a *Pararotalia* fauna appears at Barton and a *Cibicides*/*Nonion*/*Elphidium* assemblage at Alum Bay.

Thus a double cyclic pattern repeats that seen by the lithological and fragment analyses. It would help if depth values could be given but comparison with Recent Foraminiferal faunas becomes subjective. Direct correlation with extant species is hampered by the general paucity of such forms and the conflicting data they give. Thus *Pullenia quinqueloba* (REUSS) is today a deep water species (F.L.PARKER,1954; PHLEGER,1960a) and *Buliminella elegantissima* (D'ORBIGNY) is restricted to very shallow water (WALTON, 1955). BHATIA (1957) lays emphasis on the direct correlation of identical species in Recent and English Oligocene strata but some his identifications are thought to be erroneous and, as HAYNES (1958c) pointed out, even long ranging forms may have had different habitats in the Tertiary.

Another method of interpretation depends on morphological comparison between Recent and extinct species. BANDY & KOLPACK (1963), in their well argued monograph on bathyal Californian Tertiary faunas,compare certain extinct species with distinct, though morphologically similar species living in deep water off the Pacific coast of North America. On a more applicable scale BHATIA (1957) compares *Pararotalia subinermis* (= *P.inermis* (TERQUEM))with Recent "*Rotalia*" *calcar* D'ORBIGNY. He quotes the latter from coarse substrates and shallow, warm, well oxygenated water. This suggestion might also apply to the *Chama* Bed at Barton.

A provisional interpretation is based on the assumed close relationship between Foraminiferal faunas and substrate. PHLEGER (1960a, p.133) and CARTER (1951) show that this relationship may be partly controlled by the concentration of thanatocoenoses by transportation. However, the grain size and total Foraminiferal distribution peaks (table 5) do not in general coincide and it is inferred that substantial transportation has not occurred. If this axiom is correct then the *Cibicides*/*Nonion*/*Elphidium* assemblage is associated in sandy glauconitic lithofacies with possibly shallow water and slow deposition. Conversely the low and high diversity Miliolid faunas are from more tranquil, possibly deeper water. Based on their morphology the upper Miliolid fauna may have been from deeper water than the lower Miliolid assemblage. Finally the Chama Bed fauna occurs at the start of the regressive sequence and is thought to represent a shallow, turbulent water interlude.

The association of Miliolids with clay lithofacies in normal salinity environments appears to be rare in Recent seas. Thus PHLEGER (1960a, b, on the Gulf Mexico) and KRUIT (1955 on the Rhone delta) record Miliolids being most common in the nearshore turbulent and beach zones, while more tranquil water biotopes and muddy substrates bearfaunas composed mainly of Agglutinated and small Rotalid Foraminiferida. Also the Nonion/Elphidium assemblage may be heterogeneous. Thus Elphidium laeve (D'ORBIGNY), E.sp.4, E.latidorsatum (REUSS) and Nonion graniferum (TERQUEM) may bear morphological comparison with shallow water extant species with rounded peripheries and small retral processes (e.g. Protelphidium depressulum (WALKER & JACOB) and Elphidium gunteri COLE). Nonion affine (REUSS) however, is morphologically similar both to very deep water forms, such as N.pompilioides (FICHTEL & MOLL), and to shallow, turbulent water forms such as N.asterizans (FICHTEL & MOLL) (see KRUIT, 1955). Little information can be found in the literature on assemblages dominated by Cibicides, as are those of the Barton Beds. In spite of these differences the interpretation presented in the previous paragraph is thought the most likely.

The ecological position of the regressive Upper Barton Sands is hard to determine. The Becton Bunny Bed at Christchurch Bay is the only horizon to yield an "assemblage", as against isolated specimens. These consist exclusively of species which range up from the beds below. An association similar to the restricted Ammoastuta, Miliammina, Jadammina and Nonion faunas described from marsh and other low salinity biotopes from the Gulf of Mexico (see PHLEGER, 1960a) and elsewhere can definitely not be identified. Probably brackish water faunas do occur in England in the Oligocene but these are quite different to the bed J assemblage. On the basis of this and the evidence from the Microplankton, this part of the succession is thought to have been deposited under normal salinity conditions.

3:2:5 The Ostracoda

Five species of Ostracoda have fairly well defined true total range limits in the Barton Beds (table 6). Of these *Krithe bartonensis* (JONES) and *Pterygocythereis fimbriata bartonensis* KEIJ are restricted to the Barton and Huntingbridge Beds. *Quadracythere sp.2* and *Bosquetina sp.1* occur mainly with the Lower Barton Beds (see table 12). *Pterygocythereis pustulosa* HASKINS occurs only in the upper part of the Middle Barton Beds at Alum Bay and HASKINS (1968c) also records it from the *Chama* Bed and Middle Headon Bed A sixth species, *Monoceratina sp.1*, was only found in bed F and its equivalent but HASKINS (1968c) records it from the Lower Barton Beds of Alum Bay.

Ostracoda are abundantly represented in terms of numbers and diversity (tables 11, 12, 13) in both clay sequences and, to a lesser extent, in the middle glauconitic and *Chama* Beds. The faunas are relatively uniform in overall composition and are dominated by spiny and heavily ornamented forms, characteristic of offshore, moderately deep water open sea conditions ("Treatise", ed. MOORE, 1961). No traces of brackish water or intertidal elements could be found, not even in bed J at Barton, where only casts are preserved.

Four species dominate the fauna throughout the succession. The percentage distribution graphs show that one of these, *Leguminocythereis striatopunctata* (ROMER), has an oscillating relationship in antipathy to two of the others (*Cytheretta laticosta* (REUSS) and *Cytheridea (C.) intermedia* (REUSS)). The fourth dominant form, *Pterygocythereis fimbriata bartonensis* KEIJ, seems to oscillate independently to the other three. Species present in less abundant proportions tend to be linked with one of these three types.

These oscillations can be traced in both sections and, by matching the graphs, provide a finely calibrated method of correlation. Of course, this is undoubtedly facies controlled but in what way is hard to define. The much stronger changes shown by other groups of the total fauna and general uniformity of the whole Ostracod assemblages indicate that the oscillations are probably independent of basic physical environmental factors like substrate or water depth. Slight changes in these factors may have initiated oscillations but variations in the biological environment (e.g. competition) could have also been responsible.

3:2:6 The Mollusca

Tables 15 to 20 show that two distinct Mollusc faunas are present in the Barton Beds as a whole, namely the Barton Clay and the Barton Sand (including the Chama Bed) faunas. A study of the true total ranges of Molluscan species was not made. Numerous apparently short ranged species may, or may not, be present in adjacent formations but most faunas were probably strongly facies controlled. (See however, CURRY's (1966) use of correlation coefficients) Diversity data was not plotted, as this parameter is complicated by isolated occurrences of immature specimens of larger species.

The percentage distribution charts show strong differentiation between the two main faunas and also differentiation within them. In the Barton Clay Corbula pisum J.SOWERBY, Nuculana minima (J.SOWERBY) and Venericardia sulcata (SOLANDER) dominate the Pelecypod assemblages throughout. Out of the Gastropoda and Scaphopoda this part of the succession shows fairly constant abundances of Conomitra parva (J.de C.SOWERBY), Dentalium pellucens DESHAYES and the Pyramidellids. The middle galuconitic sequence is marked by peaks of Lutetia pisiformis (CHARLESWORTH), Myrtaea spinulosa (LOWRY) and Acrilla sp.1. The lower part of the upper clay also contains abundant Lutetia pisiformis and Myrtaea spinulosa, associated with Limopsis scalaris (J.SOWERBY), Fossularca lissa (BAYAN), and Naticids. Bed F and its equivalent has a rather different fauna. This contains abundant Limopsis scalaris and Marginella bifidoplicata CHARLESWORTH near its base and Meretricid juvenile type 1, Turritella spp. (juveniles) and Eopleurotoma? sp.1 in its upper part. The later association is highly distinctive and comes in at the position of the Microplankton/Foraminiferida break mentioned earlier.

Changes in the Upper Barton Beds are obscured by decalcified zones but a gradual change via three associations can be made out at Christchurch Bay.

The *Chama* Bed has an assemblage dominated by *Nuculana striata* (LAMARCK), *Glycymeris deleta* (SOLANDER), Meretricids (probably not the same species as below), *Nucula ampla* WOOD, *Calyptraea aperta* (SOLANDER) and of course *Chama squammosa* (SOLANDER) (not shown). In bed J this is replaced by a *Corbula cuspidata* J.SOWERBY, *Lentidium tawneyi* CURRY, *Corbicula deperdita* (LAMARCK), *Bullinella sp.5* association. Finally, at the top of bed K, the fauna has low diversity, high numerical abundances and consists nearly entirely of *Lentidium tawneyi* CURRY, *Corbicula deperdita* (LAMARCK) and *Bayania hordacea* (LAMARCK).

Palaeoecological interpretations are difficult to make owing to the complete absence of Eocene forms in Recent seas, and the substantially different aspect of extant faunas. Considerable evolution is thought to have changed this group since the Tertiary and even morphological comparisons are hard to make (cf. the faunas described by R.H. PARKER, 1960, 1964, from the Gulf of Mexico and Gulf of California). The Barton Clay faunas as a whole are fairly uniform throughout and the differences between clay and glauconitic bed assemblages are possibly due to substrate changes. The Mollusca from the regressive sequence however show analogies with some of the English Ologocene faunas. Of all the fossil groups present the Mollusca are the only ones to indicate lowered salinity in this part of the succession (low diversity, presence of *Corbicula*, *Bayania*, *Lentidium*).

3:2:7 The Bryozoa

Bryozoa proved insufficiently abundant to plot percentage distributions but rough indications of numbers are shown on table 23. Four of the species present dominate the faunas,namely *Lunulites transiens* GREGORY, *Batopora glandiformis* (GREGORY), *Setosellina gregoryi* CHEETHAM and *Teichopora clavata* GREGORY. All others are present as relatively few specimens. STACH (1936) and LAGAAIJ & GAUTIER (1965) showed the strong correlation between zoarial (colony) form and habitat (particularly substrate and rate of sedimentation), and their results can be applied to the Barton Beds. An exhaustive review of the multiplicity of zoarial forms may be found in SCHOPF (1969).

The dominance of lunulitiform Bryozoa (Setosellina gregoryi and Lunulites transiens) is noted throughout the whole Barton Clay sequence. STACH (1936) showed that Recent species of this type are not attached to the substrate in the "adult" and preferred shifting bottom conditions in the zone of more or less active transport and turbulence. It should be noted that the Bartonian species of Setosellina does not belong to LAGAAIJ & GAUTIER's setoselliniform type (an attached group). The same authors note the presence of celleporiform Bryozoa, represented by Batopora glandiformis in the Barton Beds (= orbituliporiform of CHEETHAM, 1966), in small percentages in the shallow inner neritic zone where no transport is occurring. Thus it is probably a more tranquil water type. B. glandiformis occurs mainly in the lower half of the upper clay. These observations obviously do not tally with the interpreted pattern of Foraminiferal faunas, in which shallow, possibly turbulent water conditions occurred in the lower part of the upper clay and deeper water and more tranquil conditions prevailed in the upper part of that unit. One feature which does show clearly is the very subsidiary proportions of stick Bryozoa (vinculariiform, etc.) in the section as a whole, when compared with the Nummulites variolarius-Tellina Beds of Selsea and Whitecliff Bay (see CHEETHAM, 1966).

3:2:8 Small Groups and others

The distribution of sponge spicules (table 23), Echinoderms (table 24), Teleost Otoliths (tables 25 and 26) and Annelids (table 23) has been commented on elsewhere (taxonomy and fragment analysis sections). The only good breaks in distribution occur at the top of the acme of Bregmaceros minimus (FROST) in the middle of the upper clay, and in the occurrence of Annelid tubes (see section 3:3:2).

Phosphatic Vertebrate remains (tables 25 and 26) do not show well characterised distribution of individual units and are best dealt with together (see section 3:3:2).

The single coral species (Turbinolia frederickiana MILNE-EDWARDS & HAIME) is an ahermatypic form. It occurs throughout the clay beds and cannot be used for palaeoecological purposes (see table 23).

Angiosperm seeds are not well represented. They tend to occur most often in the decalcified sections and are linked to the plant remain debris distribution.

Crustacean fragments and scolescodonts are uncommon and irregularly distributed throughout the whole Barton Beds (table 23). Balanus fragments are more localised, being most common in bed K at Barton. This might be associated with shallow, turbulent water conditions shown by other elements of its fauna.

3:2:9 Reworked Elements

Definitely derived spores, Dinoflagellates, Foraminiferida and Ostracoda were found in many samples and their occurrences are shown in the range charts relevant to the particular group.

Reworked land plant microfossils were identified by Dr.M.Muir. They include Palaeozoic Calamospora, which occurs particularly abundantly in the decalcified Highcliffe Sands equivalent at Alum Bay. Megaspores also tend to be concentrated in the decalcified and poorly calcareous units of both sections, where they are associated with high indigenous seed and plant debris counts. Palaeozoic megaspores present include Superbasporites sp. and two other unnamed species. Mesozoic floras are represented by Triletes areolatus HARRIS, Pyrobulospora sp. and Thomsonia sp. In addition a single specimen possibly referable to the Tertiary and Recent genus Selaginella was found in bed J at Barton (sample 6982).

Derived Cretaceous or Jurassic Dinoflagellate cysts occur sporadically throughout both sections. The specimens found belong to various members of the Gonyaulacysta group and do not tend to be localised in abundance.

Upper Cretaceous Foraminiferida are common throughout both sections. They are most abundant in the decalcified beds (especially beds I,J,K at Barton and the middle sand body at Alum Bay), where the majority of specimens are silicified. In the units mentioned they are associated with the presence of silicified chalk fragments. These and the reworked fauna are probably derived from eroded flints (see CURRY, 1964). The unsilicified chalk spheres, which occur in practically every sample examined, are probably laboratory contaminants.

Silicified Upper Cretaceous Ostracoda occur rarely. With the exception of a single specimen from bed K at Barton they were found only in the decalcified middle sandy bed at Alum Bay.

Section 3:3 Conclusions

A synthesis of the data presented is embodied in the zonation shown on Tables 27 and 28. This zonation is based entirely upon the levels of change shown primarily by the two main elements of the fauna (Foraminiferida and Mollusca). It is supported by the evidence from minor groups, such as the Microplankton, Otoliths and Annelids. The relationship between the two section and correlation of biofacies units is shown on table 29.

As said earlier, palaeoecological reconstruction is hampered by lack of direct comparison with Recent conditions and also because the biological evidence is to some extent contradictory. The presence of two holomarine cycles of sedimentation, corresponding approximately to the Lower and Middle Barton Beds; and a long final regressive sequence (the Upper Barton Beds) has been established.

The lower cycle begins at Barton with a glauconitic/phosphatic bed, characterised by its wholly Agglutinated Foraminiferal fauna. CURRY, HODSON & WEST (1968, p.195) interpret similar units in the Upper Bracklesham Beds of Fawley as representing a deeper, more tranquil biotope than believed here. Such a theory would turn the Barton Beds cycles upside down, although it might explain Miliolid abundances in the clays. At Alum Bay this unit is absent and the probably contemporaneous clays contain a fauna identical to that of the next clayey unit at Barton. This has a Nummulites rich larger and Cibicides/ Elphidium/Nonion rich smaller Foraminiferal fauna, associated with the major calcareous benthonic Mollusca (Corbula, Nuculana etc.). At both sections this passes up into a lithologically similar unit with a Miliolid/Cibicides Foraminiferal fauna and a Molluscan assemblage, marked by peaks of Turritella and Echinoderms. Deeper and more tranquil water conditions are thought to have been in force in this interval. The lower cycle is completed by a glauconitic/phosphatic sequence with less calcareous benthos, and a sandy bed at its top at Alum Bay.

No true "Transgression" can be seen at the base of the second cycle. One of the numerous breaks in the glauconitic sequence may represent this level (pale clay in C at Barton, pebble rich zones at Alum Bay etc.).They could equally well be local hiatuses to be expected in a shallow, turbulent, slow depositional regime. The change to finer sedimentation in bed E at Barton and above the pebble bed at Alum Bay is however associated with a distinct, probabl shallow water fauna. This has Miliolid and Nonion/Elphidium/Cibicides dominate Foraminiferal elements; concentrations of Bregmaceros minimus (Otolith) and Ophiuroid ossicles; and abundances of certain Mollusca (Lutetia pisiformis, Myrtaea spinulosa, Acrilla sp.1) and Annelids near the top. The sharp change at the top of this zone cannot be fully explained. The simultaneous decrease in plant remains, Microplankton and the Otolith mentioned above would suggest closing of the area both to land derived material and oceanic influences.. Benthonic calcareous groups show no reductions; though changes in aspect include the initiation of peaks in Turritella, Eopleurotoma? sp.1, Adeorbis elegans, certain Miliolids (especially Quinqueloculina bicarinata), Asteroid and Holothuroid ossicles. All this is taken to indicate the onset of tranquil, deeper water conditions. The presence of lunulitiform Bryozoa (Setosellina gregoryi) and the peculiar association of Miliolids with clay sedimentation provides contradictory evidence.

Microplankton and Foraminiferal data points to normal salinities in most of the regressive Upper Barton Beds. This must be distinguished from the gradu decrease in oceanic influences, a very unsatisfactory physical parameter, shown by the gradual changes in Microplankton assemblages (tops of total ranges.). Mollusc faunas show more concrete changes but even these indicate that salinities did not substantially decrease until the top of bed K at Barton.

The correlations set out in Table 29 are derived mainly from quantitative data (acmes and oscillatory Ostracoda graphs) and are thus strongly facies biased and probably not isochronous. Total ranges are few and not very useful. The main point arising from them is that most of the zones are present in both sections and most are systematically thickened between Barton and Alum Bay. This means that the anomalous thickness of the Barton Clay at Alum Bay cannot be interpreted by intercallation of local zones.

Section 4: TAXONOMY

Section 4:1 ALGAE and INCERTAE SEDIS

4:1 Dinoflagellates

Introduction

Cysts of Dinoflagellates commonly occur in the English Upper Eocene and have been found in most samples from both marine and brackish water sediments. No Acritarchs sensu DOWNIE, EVITT & SARJEANT (1963) were encountered, and only those forms with demonstrably Dinoflagellate affinities will be dealt with in this section.

Techniques

All previous work on this group has been on macerated material and often constitutes part of an enlarged palynological investigation. In this study no macerations were conducted and all the material was picked out dry from the less than 60 mesh fraction carbon tetrachloride floats. The specimens were mounted in melted glycerine jelly in assemblages on glass slides, capped with a cover slip and sealed with candle wax. The assemblage slides were examined and all photographs taken with a Zeiss Photomicroscope using an automatic exposure meter and Adox KB14 film. All slide coordinates were measured using the Zeiss Photomicroscope No.0054 in room No.206A, Geology Department, Royal School of Mines, London, S.W.7., with the numbered slide label on the right (same side as stage controls). All measurements were taken from process terminations.

There is a risk that the use of washed residues for a microplankton study would enable only the larger Dinoflagellates to be extracted. However, the 200 mesh sieves used for sample washing have an aperture size of 76 microns (British Standard) and only the smallest Dinoflagellates and the Micrystridium and Veryhachium group of Acritarchs would be lost.

A study of the literature reveals that in fact very few small species, reported from related formations, were missing in the washed material. Advantages of this method include the possibility of integrating the Dinoflagellate populations with Foraminiferal counts, and examining the morphology of uncompressed specimens with the Scanning Electron Microscope (Stereoscan). Further, where there is a low phytoplankton count large samples can be used giving a richer yield. The samples taken are equivalent to between 250gms. and 500gms. unwashed sample.

Previous Work

EHRENBERG (1838) was the first worker to discover and report Hystrichosphaerids in Upper Cretaceous flint flakes from the Baltic, and he published his findings between 1838 and 1843. He originally identified them as desmid zygospores and named them *Xanthidium*. From 1838 to 1850 EHRENBERG's discoveries stimulated investigations by a number of British workers, namely MANTELL, DEANE, WHITE, READE and WILKINSON. Interest then largely lapsed until O.WETZEL (1933), realising the importance of keeping a more open nomenclature for what were then ambiguous microfossils, grouped the non-tabulate forms in the Hystrichosphaeridae, of unspecified systematic placing. Previous workers had placed the Hystrichosphaerids with the desmids, sponges and Copepods. A much more complete history of early research in this group may be found in DAVEY et al. (1966).

With a few exceptions little work was conducted between 1850 and 1950. In the 1950's and 1960's a large number of descriptive publications appeared, some with useful stratigraphic zonations, covering from the Late Precambrian to the Quaternary. In addition important taxonomic work has finally demonstrated the affinities of the Hystrichosphaerids as resting cysts of Dinoflagellates by the reflection of original tabulation in the process positions and the significance of the archaeopyle positions (EVITT, 1961 and EVITT & DAVIDSON, 1964). Work has also begun on the *in vitro* study of viable cyst and motile stages (WALL & DALE, 1967, 1968), showing that a single species of motile Dinoflagellate may produce several very different organ species of cysts. This line of research will obviously lead to a considerable upheaval of the present nomenclature of fossil cysts.

Most of the recent investigations of European Tertiary Dinoflagellate floras has been done by Belgian and German authors. PASTIELS (1948) and MORGENROTH (1966b) described the floras of the Belgian Ypresian, ROZEN (1964) those of the Belgian Upper Eocene and DE CONINCK (1965) floras from the

Belgian Cuisian. German work on microplankton floras includes W.WETZEL's (1952) work on Danian microplankton of Denmark, KLUMPP's (1953) study of the Middle and Upper Eocene of North Germany, EISENACK's (1938, 1954) work on the Lower Oligocene of East Prussia, GOCHT's (1952) study of the North and Central German Oligocene, WEILER's (1956) study of the Tertiary of the Rhine Basin, ALBERTI's (1961) work on the Tertiary of North Germany, BROSIUS's (1963) study on the Kassel Sand (Upper Oligocene) microplankton, GERLACH's (1961) work on the North German Oligocene and Miocene, MAIER's (1959) work on the Tertiary and Quaternary and MORGENROTH's (1966 a and b) study of the North German Lower Eocene.

In England WETHERELL (1892) briefly recorded Hystrichosphaerids from the London Clay. CURRY (1958) and EAGER & SARJEANT (1963) respectively exhibited and briefly noted Hystrichosphaerids from washed residues of Eocene rocks. DAVEY, DOWNIE, SARJEANT & WILLIAMS (1966) published the only monographic work to date on the Dinoflagellates of the English Tertiary (London Clay), also dealing with Lower Chalk and Speeton Clay floras. Their Lower Eocene material was taken from the Enborne Valley, Sheppey, Whitecliff Bay and Studland Bay. In addition this very useful publication clears up many taxonomic tangles at generic level and erects new taxa following EVITT's (1961) proposals. They also set forward a morphological terminology which is used extensively in the present study.

Several other studies must be mentioned on Tertiary and Upper Mesozoic floras. From North America DRUGG (1967), STANLEY (1965), and MANUM & COOKSON (1964) published accounts of the microplankton of the Maestrichtian/Danian of California and South Dakota and the Upper Cretaceous of Arctic Canada respectively. MANUM (1960) examined the Lower Tertiary microfloras of Spitzbergen. VARMA & DANGWAL (1964) described several new species from the Tertiary of India and COOKSON & CRANWELL (1967) noted and figured several species from the Lower Tertiary of Southern Chile. Studies on European Upper Cretaceous microplankton consulted include GORKA (1963) on the Upper Cretaceous of Poland, O.WETZEL (1961) on the microfloral and microfanual content of Baltic Upper Cretaceous flints and CLARKE & VERDIER (1967) on Isle of Wight Chalk assemblages. A formidable amount has been written on the Upper Mesozoic and Tertiary microfloras of Australasia, including DEFLANDRE & COOKSON (1954, 1955), COOKSON (1953, 1956, 1965 a, b.), COOKSON & EISENACK (1958, 1960 a, b, 1961 a, b, 1962 a, b, 1965 a, b, c, 1967 a, b,) and EISENACK & COOKSON (1960). These span rocks of Lower Cretaceous to Upper Miocene age from south-eastern and western Australia, Tasmania and Papua.

Publications on specific taxa of especial use in the present study not mentioned above include ALBERTI'S (1959 a, b) work on the Deflandrea group, EISENACK's (1963) work, in which he erects the genus Cordosphaeridium, EISENACK & GOCHT's (1960) and GOCHT's (1968) papers on Thalassiphora and its "ontogeny", GOCHT's (1955) study of Wetzeliella (Rhombodinium) and MANUM's (1960) work on Deflandrea. This bibliography is by no means exhaustive and additional references may be found in DAVEY et al. (1966), CLARKE & VERDIER (1967), MORGENROTH (1966 b), DOWNIE & SARJEANT (1964) and EISENACK & KLEMENT (1964).

Morphology

The vast majority of fossil Dinoflagellate remains, including all those found in the English Bartonian, are resting stage cysts. These form as a cellulose, double walled body at varying depths beneath the motile stage wall or theca. The cyst contains the living resting stage until it escapes through a rupture of taxonomically constant position, the archaeopyle. Most Dinoflagellate cyst walls have a cellulose composition, but cysts of silica and calcite have been described.

In the present study the morphological terminology of DOWNIE & SARJEANT in DAVEY et al. (1966) is followed. They divide cysts into three morphological groups. Chorate cysts include those forms, such as Hystrichosphaeridium, which have the two layers of the wall closely appressed, have long processes and represent a considerable condensation from the original theca. Gonyaulacysta is a member of the proximate group of cysts, in which the cyst is condensed in size only slightly from the original theca, with a wall of two closely appressed layers. The cyst surface frequently bears traces of thecal tabulation in the form of clearly marked areas or plates. The short processes, crests and lists between the plates show that only slight condensation has occurred. In the third group (the cavate cysts) the two layers of the cyst wall (the inner endophragm and the outer periphragm) are separated by an extra cavity (the pericoel). The inner capsule, enclosing the endocoel, is frequently ovoid, as in Deflandrea, and the periphragm takes the shape of the inside of the theca. Short periphragmic processes may be present (as in Wetzeliella (Wetzeliella)).

The terminology of the tabulation follows that of EVITT (1961). He uses the notation of the plate areas and processes on the cyst, reflecting the tabulation of the motile stage theca, as used by neontologists on living Dinoflagellates. The plates fall into a number of whorls; namely the apical, anterior intercalary, precingular, cingular, postcingular, posterior intercalary and antapical circlets. The vertical groove perpendicular to the equatorial girdle is covered by the sulcal plate. The processes may be gonal, sutural or intratabular in position and are referred to in relation to the plates with which they are associated. Similarly the archaeopyle may be identified by the plate (haplotabular) or plates (tetratabular etc.) removed by its formation (see EVITT & DAVIDSON, 1964). Additional archaeopyle types used by DOWNIE & SARJEANT (1966) also include the epitractal type, where the whole of the cyst anterior to the cingulum lifts off; and the cingular type, where the archaeopyle forms from the removal of a cingular plate. The descriptive terms for process and process-termination morphology are those of DOWNIE & SARJEANT (1966).

Classification

The taxonomy of the Dinoflagellates is at present in a stage of flux following the disturbing, but frequently prophesied findings of EVITT & DAVIDSON (1964) and WALL & DALE (1967, 1968). Consequently no suprafamilial grouping is used and the familial taxa must be regarded as liable to revision.

One factor which is observed is that the Dinoflagellates, being Algae, are plants and fall under the Botanical Code of Nomenclature (DOWNIE, WILLIAMS & SARJEANT, 1961).

The family units used are those of EVITT (1963). Generic names have been recently emended by DAVEY et al. (1966) and, where applicable, these have been used. Genera related to *Hystrichosphaeridium* and *Baltisphaeridium* have been especially usefully revised, on the basis of the position of the archaeopyle and the reflected tabulation, as shown by process position. A number of genera remain of uncertain taxonomic placing, including *Lanternosphaeridium*, *Palmnickia* and *Thalassiphora*. These all have precingular archaeopyles but do not necessarily fall into the same family as the first is proximate and the other two are cavate.

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Division: ALGAE
Class: DINOPHYCEAE PASCHER
Family: DEFLANDREACEAE EISENACK 1954
Genus: *Deflandrea* EISENACK 1938

(Type species: *Deflandrea phosphoritica* EISENACK, 1938.)

Deflandrea phosphoritica EISENACK, 1938

Plate 1, figs. 1a, b.

Deflandrea phosphoritica EISENACK,1938. p.183,fig.6.
Deflandrea phosphoritica EISENACK:KLUMPP,1953. p.393,pl.19,fig.6.
Deflandrea phosphoritica EISENACK:EISENACK,1954. p.52,pl.9,figs.8-12; pl.12,figs.8,9;text-fig.1.
Deflandrea phosphoritica EISENACK:DEFLANDRE & COOKSON,1955. p.249,pl.4,fig.5.
Deflandrea phosphoritica EISENACK:MAIER,1959. p.292,pl.28,fig.1.
Deflandrea phosphoritica EISENACK:ALBERTI,1959b. p.94,pl.8,fig.6.
Deflandrea phosphoritica EISENACK:MANUM,1960. p.18,pl.1,figs.4-8;text-fig.1.
Deflandrea phosphoritica EISENACK:GERLACH,1961. p.150,pl.21,fig.1.
Deflandrea phosphoritica EISENACK subsp.phosphoritica COOKSON & EISENACK,1961. p.39.
Deflandrea phosphoritica EISENACK:ROZEN,1964. p.292,pl.1,figs.1,2;text-fig.1.
Deflandrea phosphoritica EISENACK:COOKSON & EISENACK,1965a. p.121,pl.11,fig.11.
Deflandrea phosphoritica EISENACK:MORGENROTH,1966b. p.8,pl.1,fig.3.
Deflandrea phosphoritica EISENACK subsp.phosphoritica COOKSON & EISENACK: WILLIAMS & DOWNIE,1966. p.231,pl.26,figs.2,3,6,9.

Description

Cyst chorate, elongate, sharp-angled pentagonal and very distinctive in outline. Endocoel subspherical, with slightly granular endophragm. Pericoelrelatively wide. Periphragm finely granular, with no processes but with two distinct, short, blunt, equal antapical horns and one short, blunt apical horn. The lateral walls characteristically show a convexity just anterior to the cingulum. The cingulum is present as a well marked band, running around periphragm more or less equatorially and linking the lateral angles. The strong sulcus is visible only in the hypostract. The archaeopyle is intercalary in the periphragm haplotabular and is in the form of a broad, low arch. It is clearly polygonal in outline. In the endophragm it appears to be displaced more towards the apex, as mentioned by WILLIAMS & DOWNIE (1966).

Remarks

Deflandrea is a very large genus (34 species listed by MANUM & COOKSON, 1964) but the only other form with this species' characteristic sharp-angled pentagonal outline is D.heterophlycta DEFLANDRE & COOKSON. D.heterophlycta differs from D.phosphoritica in having an endophragm bearing distinct tubercles. These were not observed on the Bartonian material.

EISENACK's (1938) type level for this species is the Lower Oligocene of East Prussia. It has also been recorded from many other Paleogene formations; Upper Eocene of North Germany (KLUMPP, 1953), ?Lower Eocene and Upper Eocene of Victoria, Australia (DEFLANDRE & COOKSON, 1955 and COOKSON & EISENACK, 1965), Paleocene, Lower and Upper Eocene, Middle Oligocene of U.S.S.R. and Upper Oligocene of North Germany (see ALBERTI, 1959b.), Bartonian and Belgium (ROZEN, 1964) Lower Eocene of Belgium and North Germany (MORGENROTH, 1966) and London Clay of England (WILLIAMS & DOWNIE, 1966). Thus it ranges in Europe from the Paleocene to the Upper Oligocene. In the English Bartonian it occurs very rarely in the Upper Barton Beds of Barton (BURTON's Bed I) and the Middle Barton Beds of Alum Bay.

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Deflandrea wetzeli MORGENROTH 1966b

Plate 1, figs. 2a, b.

Deflandrea wetzeli MORGENROTH,1966b. p.9,pl.1,figs.4,5.

Description

Cyst cavate, elongate. Pericoel drawn out into two blunt, equal antapical horns and possibly (torn off) one blunt apical horn. Endocoel subspherical or ovoid, nearly filling the periphragm with the exception of the horns, and leaving only a narrow pericoel around most of its periphery. Posterior lateral ambitus nearly straight, or slightly convex; anterior lateral ambitus slightly convex. Endophragm and periphragm finely granular but without processes. Cingulum present as a distinct band, bounded by ridges in the periphragm. Sulcus strongly developed on the ventral side. Archaeopyle large, rounded triangular and probably intercalary in the periphragm. Tabulation, except for the cingulum, sulcus and archaeopyle is not visible in the periphragm and completely absent from the endophragm.

Remarks

The material from the English Bartonian agrees with MORGENROTH's (1966 figures and descriptions, from the Lower Eocene of North Germany. At Barton one specimen was found in the Upper Barton Beds and at Alum Bay one was found in the Lower and one in the Middle Barton Beds.

Several other species in the literature resemble D.wetzeli but differ in lacking such a well marked cingulum. The nearest is D.pellucida COOKSON & EISENACK (1958). D.bakeri DEFLANDRE & COOKSON (1955), D.belfastensis COOKSON & EISENACK (1961) and D.cooksonae ALBERTI (1959b) are more elongate. D.dakotaensis STANLEY (1965) resembles it in shape but has a weaker cingulum. D.cincta COOKSON & EISENACK (1958), a Lower Cretaceous species, is quite close but has a more strongly marked cingulum. Finally, D.scheii MANUM (1963) resembles D.wetzeli in shape and cingulum but bears clearly marked tabulation on the periphragm. Some species of Deflandrea show intergradation and it is possible that future work will bring to light intermediates with this form.

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Genus: Wetzeliella EISENACK 1938

Subgenus: Wetzeliella (Wetzeliella) EISENACK 1938

(Type species: Wetzeliella (Wetzeliella) articulata EISENACK, 1938.)

Wetzeliella (Wetzeliella) articulata EISENACK, 1938

Plate 1, fig. 3.

Wetzeliella articulata EISENACK, 1938. p.186,text-fig.4.
Wetzeliella articulata EISENACK:GOCHT,1952. p.314,pl.2,figs.38,39.
Wetzeliella articulata EISENACK:KLUMPP,1953. p.393,pl.19,figs.1-5.
Wetzeliella articulata EISENACK:EISENACK,1954. p.55,pl.7,figs.1-11;
pl.8,figs.14-16.
Wetzeliella articulata EISENACK:EVITT,1961. p.397,pl.8,figs.3,5,6.
Wetzeliella articulata EISENACK:GERLACH,1961. p.152,pl.25,fig.2.
Wetzeliella articulata EISENACK:BROSIUS,1963. p.35,pl.6,fig.3.
Wetzeliella articulata EISENACK: DE CONINCK,1965. p.13,pl.1,figs.1-6,text-fig.1.
Wetzeliella (Wetzeliella) articulata EISENACK:MORGENROTH,1966. p.9,pl.1,fig.6.
Wetzeliella (Wetzeliella) articulata EISENACK:WILLIAMS & DOWNIE, 1966.
p.183,pl.18,figs.1-4.

Description

Cyst cavate, pentagonal in outline, dorsoventrally flattened and with five horns all well developed but not exaggerated. One antapical horn is longer than the other. Pericoel narrow, with the endophragm extending into the base of the horns. Periphragm granular, giving rise to numerous, small, similar, hollow, slightly tapering processes, which are open distally, and have aculeate and slightly recurved terminations. Distal connections between the processes are absent. The archaeopyle, when visible is formed by the loss of a single intercalary plate. Simulate complexes, tabulation and cingulum are not identifiable.

Remarks

This species occurs throughout the Barton Clay at Barton and Alum Bay, but has not been found in the Upper Barton Beds above the Chama Bed. As WILLIAMS & DOWNIE (1966) reported in the London Clay, specimens have been found at Barton with longer processes, a larger pericoel and a reduced left antapical horn, which appear to be intermediate with Wetzeliella (W.) symmetrica WEILER, (1956. Records of W. (W.) articulata in the literature are from the Lower Eocene to the Upper Oligocene (Chattian) of Germany and Belgium and from the London Clay of England.

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Wetzeliella (Wetzeliella) coleothrypta WILLIAMS & DOWNIE, 1966

Plate 1, figs. 6, 7a, b.

? Wetzeliella (Wetzeliella) clathrata EISENACK: ALBERTI, 1961. p.7,pl.1,fig.19.
Wetzeliella (Wetzeliella) coleothrypta WILLIAMS & DOWNIE,1966. p.185,pl.18, figs.8,9; text-fig.47.

Description

Cyst cavate, dorsoventrally flattened and pentagonal in outline. The apical horn and two lateral horns are well developed but not exaggerated. Antapical horns subequal and well developed, though in some specimens one is reduced and present as a small protuberance. The smooth endophragm and periphragm are not in contact, leaving a narrow pericoel. Endoceol rounded-pentagonal or quadrilateral in outline and continues up to the bases of the horns. The periphragm gives rise to numerous, small, hollow, slender, curved or erect processes which are closed distally. Processes are intratabular and arranged in simulate complexes reflecting the cyst tabulation. Distally each simulate complex is covered by a thin, smooth, imperforate membrane which is supported by the processes and assumes the shape of the underlying plate. One specimen shows a number of plates picked out by the distal membranes and the cingulum linking the lateral horns. Archaeopyle not seen.

Remarks

WILLIAMS & DOWNIE (1966) differentiate this species from W.(W.)clathrata EISENACK (1938) on the presence of the thin ectophragmic membrane, mirroring the plate boundaries. W.(W.) clathrata bears processes linked distally by ribbons which follow the plate boundaries like bannister rails, and not broad membranes. The features of the Bartonian material agree well with the type figures and description. ALBERTI's (1961) figures appear to agree with W.(W.) coleothrypta, but uncertainty must exist until the figured specimens have been examined. A re-examination of other authors' specimens of W.(W.) clathrata may necessitate placing them in this species.

WILLIAMS & DOWNIE's (1966) type level for this species is the London Clay of Sheppey. ALBERTI's (1961) records are from the Upper Paleocene of North Germany and the Upper Eocene of North Germany and U.S.S.R. In the English Upper Eocene, this species has only been found at Alum Bay, in the Lower, Middle and Upper Barton Beds.

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Wetzeliella (Wetzeliella) cf. reticulata WILLIAMS & DOWNIE, 1966

Plate 1, figs. 8a, b.

? Wetzeliella (Wetzeliella) reticulata WILLIAMS & DOWNIE, 1966. p.187, pl.19, figs.3,6; text-fig.48.

Description

Cyst cavate, dorsoventrally flattened, with five tapering peripheral horns. Endocoel inflated and pericoel narrow, except in the horns. Granular periphragm gives rise to numerous, small, hollow, slightly tapering processes with long distal aculei. These ramify and unite with those of adjacent processes to produce a network over parts of the cyst. The aculei appear to be solid, taeniate in section and do not support spines. The archaeopyle and the presence of simulate complexes of the processes or aculei networks are not visible. Consequently the tabulation is indeterminable.

Remarks

A few eroded specimens can doubtfully be attributed to this species. They show the distal networks of aculei of W.(W.)reticulata WILLIAMS & DOWNIE, W.(W.) tenuivirgula WILLIAMS & DOWNIE and W.(W.) tenuivirgula var. crassoramosa WILLIAMS & DOWNIE, rather than the imperforate ectophragm of W.(W.) clathrata EISENACK and W.(W.) coleothrypta WILLIAMS & DOWNIE. The distinction between the species in the first group (those with the ectophragm in the form of a reticulum) appears to be rather limited in application and the placing of the Barton specimensin the first named must remain very tentative until comparative material has been examined.

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Subgenus: Wetzeliella (Rhombodinium) GOCHT 1955

(Type species: Rhombodinium draco GOCHT, 1955.)

Wetzeliella (Rhombodinium) sp.1.

Plate 1, figs. 4, 5.

Dracodinium solidum ALBERTI,1961. p.11,pl.1,fig.9.
non Dracodinium solidum GOCHT,1955. p.87,text-figs.3-5.

Description

Cyst cavate, with a distinct endocoel and pericoel. Dorsoventrally flattened with a distinct but not exaggerated, apical horn, two lateral horns and one left antapical horn. The right antapical horn is absent or very reduced. Endocoel ronnded, quadrilateral but never spherical and peripherally parallel to the ambitus, except in the horns. Pericoel relatively narrow. Endophragm and periphragm granular, the latter with no processes. Cingulum clearly seen, linking the lateral horns. Archaeopyle haplotabular, rounded triangular in outline and lying near the mid-line and anterior to the cingulum in both endophragm and periphragm.

Remarks

The only published figure which the Bartonian material agrees with is that named by ALBERTI (1961) as Dracodinium solidum GOCHT (1955). WILLIAMS & DOWNIE (1966, p.195) rightly say that this species is not the same as GOCHT's (1955) figures and refer to it as an unnamed species. Dracodinium solidum GOCHT is in fact partly transitional with W.(Wetzeliella) similis (EISENACK) and the genus is invalid. In any case the Bartonian specimens definitely fall in the subgenus Wetzeliella (Rhombodinium) on the basis of shape and complete lack of processes.

W.(Rhombodinium) draco GOCHT (1955) and W.(R.) rhomboidea ALBERTI (1961) differ in having a much wider pericoel, with the endocoel showing a peripheral outline closer to circular. W.(R.) glabra COOKSON (1956) has a spherical endocoel and a much reduced apical horn. W.(R.) draco shows the closest relationship with this species.

ALBERTI (1961) records W.(R.) sp.1 from the Upper Eocene of North

Germany. At Barton it occurs in the Upper and (one specimen) in the Lower Barton Beds. At Alum Bay it occurs in the Lower and Middle Barton Beds.

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Family: ARSOLIGERACEAE EVITT 1963

Genus: Areoligera LEJEUNE-CARPENTIER 1938

(Type species: Areoligera senonensis LEJEUNE-CARPENTIER, 1938.)

Areoligera sp.1

Plate 2, figs. 4, 5a,b, 6a, b.

Palmnickia sp.indet. EISENACK, 1954. p.70 (in text).
Palmnickia sp. ex aff. P.lobifera EISENACK, 1954. p.95 (in list of plates), pl.12,fig.20.
Palmnickia sp. ex aff. P.lobifera EISENACK: EVITT,1961. p.400,pl.8, figs.16,17; pl.9,figs.8-10.

Description

Chorate cyst with a dorsoventrally flattened central body, which is circular in outline. The central body is concavo-convex, with a domed dorsal side and a flat or concave ventral side. Cyst wall finely granular. Processes represented by soleate and linear complexes of smooth, erect membranes, which are probably intratabular. The margin of the ventral face is followed by a single long arcuate membrane, frequently fenestrate proximally and with an entire but undulating distal edge. The distal edge is occasionall foliate or even spinose in some specimens and sometimes shows a broad saddle at the antapex. The margin of the dorsal face bears three wide, short, latispinous processes or membrane complexes, often proximally fenestrate but with entire, undulating distal margins. In addition the dorsal face bears two or three rectangular membranes, just behind the archaeopyle on the areas between the archaeopyle notches. Finally, the central part of the dorsal face has a soleate complex, with the concave side facing the archaeopyle near the mid-line and sometimes continued laterally into two smaller soleate complexes facing the other way. These soleate complexes bear smaller membranes than the marginal systems and are distally spinose.

The central part of the dorsal face is always bare of processes. Archaeopyle apical, tetratabular, with a clearly notched margin. The operculum is sometimes found still attached and bears three of four broad, short, latispinous processes or membrane complexes. Evidence of tabulation on the central body is restricted to the process arrangement and the archaeopyle, as the cingulum and plate boundaries are never seen.

Remarks

The Bartonian specimens agree well with EISENACK's (1954) and EVITT's (1961) figures. As EVITT pointed out, the figured specimens showed no relationship at all with *Palmnickia* and are related to *Cyclonephelium* or *Areoligera*. The Bartonian specimens have only the ventral face bare of processes, unlike *Cyclonephelium* which has both. However, unlike the type species of *Areoligera* and several others, *A.sp.1* has only one dorsal soleate complex. *A.senonensis* has only plate 6'' without processes, whereas *A.sp.1* has several other plate complexes missing as well. Thus, later work may well show either that *A.sp.1* is intermediate morphologically between *Areoligera* and *Cyclonephelium*, or that the two genera should not be fact be separated.

EISENACK's (1954) original material, which was re-examined by EVITT (1961) was from the Lower Oligocene of East Prussia. At Barton and Alum Bay this species is common throughout the Bartonian.

As has been said, most other species of *Areoligera* differ in having a larger number of soleate process complexes. In addition *A.senonensis* LEJEUNE-CARPENTIER, *A.medusettiformis* (O.WETZEL) and *A.coronata* (O.WETZEL) differ in the membranes being much more spinose distally and more divided proximally. Of the many described species of *Cyclonephelium* only *C.membraniphorum* COOKSON & EISENACK has regular, entire marginal membranes. If differs however, in having stiffened supports for the membranes and in lacking soleate complexes on the dorsal face.

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Genus: Adnatosphaeridium WILLIAMS & DOWNIE 1966

(Type species: Adnatosphaeridium vittatum WILLIAMS & DOWNIE, 1966.)

Adnatosphaeridium sp.1.

Plate 2, figs.7a,b.

Cannosphaeropsis reticulensis MORGENROTH,1966b. p.19,pl.4,figs.2,3.
non Cannosphaeropsis reticulensis PASTIELS,1948. p.49,pl.5,figs.7-10.

Description

Chorate cyst, with a subspherical central body. Central body wall very thin and finely granular. The number of processes present is not determinable but is probably not more than 40. Processes similar, simple, hollow, thin-walled, cylindrical and arranged in an indiscernable pattern over the central body surface. Processes about one third the central body diameter in length. Distally the processes are open, with between two and five, usually four, long taeniate aculei. The aculei unite with those of adjacent processes, sometimes with further branching and ramification, to produce a network of narrow ribbons surrounding the central body. Processes not joined to the reticulum and unsupported spines on the reticulum are not present. Archaeopyle apical in position, large and with a zig-zag margin, indicating its tetratabular nature.

Remarks

EVITT (1961) suggested and WILLIAMS & DOWNIE (1966) implemented the subdivision of the genus Cannosphaeropsis on the basis of process and archaeopyle position. Cannosphaeropsis PASTIELS (1948) was emended and reserved for forms with gonal processes, or with a precingular archaeopyle and a distal reticulum. Adnatosphaeridium WILLIAMS & DOWNIE (1966) was erected to accommodate forms with a distal reticulum, intratabular processes and an apical, tetratabular archaeopyle. Nematosphaeropsis DEFLANDRE & COOKSON (1955) has gonal processes, linked proximally by sutural lists, a precingular archaeopyle and a distal network of aculei. The Bartonian material, although resembling C.reticulensis PASTIELS (1948) in process form etc. has an undoubtedly apical, tetratabular archaeopyle and must thus be classified as *Adnatosphaeridium*. No published species has all these features. Some authors' records of *C.reticulensis* may, on re-assessment, require placing with *A.sp.1*. MORGENROTH's (1966b) figures of *C.recticulensis* show all the features of the Bartonian specimens, with a clearly apical archaeopyle.

At Barton and Alum Bay this species occurs infrequently throughout the Barton Beds, but is especially abundant in the Upper Barton Beds at Barton. MORGENROTH (1966b) records it from the Lower Eocene of Belgium.

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Family: *HYSTRICHOSPHAERACEAE* O.WETZEL 1933, emend. EVITT 1963

Genus: *Hystrichospaera* O.WETZEL 1933

(Type species: *Xanthidium ramosum* EHRENBERG, 1838.)

Hystrichosphaera ramosa (EHRENBERG,1838) emend. DAVEY & WILLIAMS, 1966

Remarks

Much has been written on the nomenclatural tangle surrounding the type-species of *Hystrichosphaera* and the validity of *H.ramosa* and *H.furcata*. Rather than add to the confusion it is proposed to follow DAVEY & WILLIAMS (in DAVEY, DOWNIE, SARJEANT & WILLIAMS, 1966). They take *H.ramosa* as the type species in view of the fact that this is the only one of EHRENBERG's holotypes to be subsequently rediscovered (LEJEUNE, 1937). They note the continuous and wide variation in the *H.ramosa-furcata* complex and divide it up as a number of varieties, rather than as separate species. They further propose the inclusion of *H.furcata* in the synonymy of *H.ramosa* var. *ramosa*. For further details of the history of this group and its nomenclature the reader is referred to DAVEY & WILLIAMS (1966).

In the English Bartonian a small number of specimens can be referred to this group. One of them can be identified as *H.ramosa* var. *membranacea*. The others are imperfectly preserved and must remain *H.ramosa* var. *indet.* until new material is found. The type variety, *H.ramosa* var. *ramosa* DAVEY & WILLIAMS (1966) was not encountered.

Hystrichosphaera ramosa (EHRENBERG) var. membranacea (ROSSIGNOL) DAVEY & WILLIAMS 1966

Plate 1, figs. 10a, b.

Hystrichosphaera furcata var.membranacea ROSSIGNOL,1964.p.86,pl.1,figs.4,9,10;
pl.3,figs.7,12.
Hystrichosphaera furcata (EHRENBERG): MORGENROTH,1966b. (part) p.14,pl.7,
fig.5 only.
Hystrichosphaera ramosa var.membranacea (ROSSIGNOL): DAVEY & WILLIAMS, 1966.
p.37,pl.4,figs.8,12.
?Hystrichosphaera aff.furcata (EHRENBERG): DRUGG,1967. p.23,pl.4,figs.3,4.

Description

Cyst proximo-chorate, central body ovoid, elongate. Body wall composed of an inner endophragm and an outer, slightly granular periphragm. Central body traversed by high, membraneouslists, marking out plate boundaries, and showing a Gonyaulacysta type tabulation, with clearly discernable cingular and sulcal regions. Processes are gonal in position, about 2/3rds the body in diameter in length, triangular in section, with three sharp longitudin ridges, hollow only at base and becoming trifurcate 2/3rds of their length distally. The distal terminations of the branches are sometimes bifid and sometimes pointed. Processes in the apical and antapical regions are joined laterally by broad, smooth, thin membranes. These are extensions of the intertabular lists. The apical process is distinctive and slightly longer than all the others. Archaeopyle precingular, haplotabular.

Remarks

One specimen only can be attributed to this variety, from sample 6971 of the Upper Barton Beds. ROSSIGNOL's (1964) type level for this variety is the Pleistocene of Israel. Other records include the Lower Eocene of North Germany, Belgium and England (MORGENROTH, 1966 and DAVEY & WILLIAMS, 1966) and possibly the Maestrichtian/Danian of California (DRUGG, 1967).

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Hystrichosphaera ramosa (EHRENBERG) var.indeterminate

Plate 1, fig. 9.

Description

Cyst chorate, small (about 30 microns), central body subspherical traversed by low but definite, thin, clear lists, reflecting *Gonyaulacysta*-type tabulation. The smooth periphragm gives rise to short (1/3rd body diameter) slender gonal processes, which are triangular in cross-section and become trifurcate distally. Sometimes it additionally bears long irregular branches. Distal terminations sharp, closed and single. Archaeopyle not visible.

Remarks

A few specimens from Alum Bay and Barton, although members of the *H. ramosa* plexus, are not well enough preserved to enable determination to a varietal level.

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Hystrichosphaera crassipellis DEFLANDRE & COOKSON, 1955

Plate 1, fig.11.

Hystrichosphaera crassipellis DEFLANDRE & COOKSON, 1954. p.1236, text-fig.5 Nom.nud.
Hystrichosphaera crassipellis DEFLANDRE & COOKSON: DEFLANDRE & COOKSON, 1955. p.265, pl.6, figs.2,3; text-fig.20.
Hystrichosphaera crassipellis DEFLANDRE & COOKSON: GERLACH, 1961. p.177, pl.27, fig.5; text-figs. 16-18.
Hystrichosphaera cf. *crassipellis* DEFLANDRE & COOKSON: GORKA, 1963. p.52, pl.7, figs.1,2; pl.5, fig.3.
Hystrichosphaera crassipellis DEFLANDRE & COOKSON: MORGENROTH, 1966. p.13, pl.7, figs.3,4.
Hystrichosphaera crassipellis DEFLANDRE & COOKSON: DAVEY & WILLIAMS, 1966. p.40, pl.1, figs.7,8.
Hystrichosphaera crassipellis DEFLANDRE & COOKSON: DRUGG, 1967. p.23, pl.4, fig.1.
Hystrichosphaera crassipellis DEFLANDRE & COOKSON: CLARKE & VERDIER, 1967. p.48, pl.8, fig.11; pl.9, fig.1.

Description

Cyst chorate, central body subspherical, with a very thick wall. Surface of central body densely granular and traversed by high, smooth, membraneous lists, which mark out the plate boundaries. Processes slender, membraneous, gonal in position and joined proximally by the sutural lists. Processes have broad bases and taper to trifurcate, closed terminations. They are occasionally irregularly branched. Archaeopyle visible but its position is not clearly discernable.

Remarks

Although only one imperfect specimen has been found (in the Lower

Barton Beds of Barton - sample 6912) the author has little hesitation in attributing it to this species. The chief characteristics are its unusually thick wall and membraneous lists. Another thick walled species is *Achmosphaera sagena* DAVEY & WILLIAMS (1966), but this does not bear sutural lists.

H.crassipellis was originally described from the Lower Eocene of Victoria, Australia (DEFLANDRE & COOKSON,1955). It has also been recorded from the Cenomanian to Santonian of England (DAVEY & WILLIAMS,1966 and CLARKE & VERDIER, 1967), possibly the Coniacian of Poland (GORKA, 1963), the Danian of California (DRUGG, 1967), the Lower Eocene of North Germany (MORGENROTH, 1966b), the Middle Oligocene and Middle Miocene of Germany (GERLACH, 1961).

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Genus: *Achmosphaera* EVITT 1963

(Type species: *Hystrichosphaeridium ramuliferum* DEFLANDRE, 1937.)

Achmosphaera ramulifera (DEFLANDRE) EVITT, 1963

Plate 2, figs. 1a, b.

Hystrichosphaera cf.ramosa (EHRENBERG): DEFLANDRE,1935. p.69,pl.5,fig.11.
Hystrichosphaeridium ramuliferum DEFLANDRE,1937. p.74,pl.14,figs.5,6; pl.17, fig.10.
Hystrichosphaeridium ramuliferum DEFLANDRE: PASTIELS,1948. p.39,pl.3,figs.17
Hystrichosphaeridium ramuliferum DEFLANDRE: W.WETZEL,1952. p.398,pl.A,fig.9; text-fig.9.
Hystrichosphaeridium ramuliferum DEFLANDRE: GERLACH,1961.p.185,pl.28,fig.3.
Hystrichosphaeridium ramuliferum DEFLANDRE: GORKA,1963. p.59,pl.8,fig.3; pl.6,figs.3,4.
Baltisphaeridium ramuliferum (DEFLANDRE): DOWNIE & SARJEANT,1963. p.92.
Achmosphaera ramulifera (DEFLANDRE): EVITT,1963. p.163.
Achmosphaera ramulifera (DEFLANDRE): COOKSON & HUGHES,1964. p.45,pl.9,fig.10.
Hystrichosphaeridium ramuliferum DEFLANDRE: ROZEN,1964. p.299,pl.3,fig.4; text-fig.8.
Achmosphaera ramulifera (DEFLANDRE): DAVEY & WILLIAMS,1966. p.49,pl.2,fig.3.
Achmosphaera ramulifera (DEFLANDRE): CLARKE & VERDIER,1967. p.40,pl.8,fig.1.

Description

Cyst chorate, central body subspherical or slightly ovoid. Periphragm finely granular. Central body traversed by low ridges (never lists) marking the reflected plate boundaries and giving a *Gonyaulacysta*-type reflected tabulation. Processes numerous, gonal in position and triangular in section, with three sharp longitudinal ribs. They taper slightly from the base and become trifurcate at about 2/3rds of their length. Distal extremities of process branches are generally bifurcate and closed. The cingular processes are sometimes joined in pairs. Archaeopyle not observed.

Remarks

Specimens from throughout the Barton Beds agree well with the numerous published figures and descriptions. This species has been recorded definitely from the Lower Cenomanian (COOKSON & HUGHES, 1964) to the Middle Miocene (GERLACH, 1961). CLARKE & VERDIER (1967) note that GOCHT's (1959) figured specimen of Hystrichosphaeridium ramuliferum (pl.3,fig.9.) from the North West German Neocomiam cannot definitely be attributed to this species. Eocene records include the Lower Eocene of Belgium and England (PASTIELS, 1948 and DAVEY & WILLIAMS, 1966) and the Bartonian of Belgium (ROZEN,1964).

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Achmosphaera alcicornu (EISENACK) DAVEY & WILLIAMS, 1966

Plate 2, figs. 2a, b, 3a, b.

Hystrichosphaeridium alcicornu EISENACK,1954. p.65,pl.10,figs.1,2;text-fig.5.
Hystrichosphaeridium alcicornu EISENACK:GERLACH,1961. p.188,pl.28,fig.7.
?Hystrichosphaeridium alcicornu EISENACK:ROZEN,1964.p.302,pl.2,fig.9;text-fig.11.
Hystrichosphaera tertiara EISENACK & GOCHT: DE CONINCK,1965. p.22,pl.3, figs.8,11,15.
Hystrichosphaera incerta KLUMPP:MORGENROTH,1966b. p.15,pl.7,figs.7,8.
Achmosphaera alcicornu (EISENACK):DAVEY & WILLIAMS,1966. p.50,pl.5,fig.3.

Description

Cyst chorate, central body consisting of a smooth endophragm and a granular periphragm in close contact. Granules on the periphragm are sometimes quite large. The surface of central body is traversed by clearly seen low ridges, delimiting the plate boundaries. Periphragm gives rise to processes at the corners of the plate areas. These are up to half the central body diameter in length, expanded slightly at the base, hollow, single, relatively thick and prismatic in section, with three sharp longitudinal ridges. Distally the processes are markedly expanded and open, with characteristic triangular or hexagonal entire margins. Archaeopyle haplotabular and precingular in position.

Remarks

The Bartonian material corresponds closely with the type figures and description. *Hystrichosphaera tertiara* EISENACK & GOCHT (1960) and *H. incerta* KLUMPP (1953) strongly resemble this species. They differ chiefly in the height of the intertabular ridges, indeed MORGENROTH (1966) considers the two synonymous and figures a specimen exactly like *A. alcicornu*. Further study may show that all three species are in fact an intergrading plexus. *A. ramulifera* (DEFLANDRE,1937) differs in having much more slender processes and *A. neptuni* (EISENACK,1958) has processes with flat forking distal terminations, both not at all like *A. alcicornu*.

A. alcicornu has been reported from the Lower Oligocene of East Prussia (EISENACK's (1954) type locality), the Middle Miocene of North Germany (GERLACH, 1961), the Lower Eocene of North Germany, Belgium and England (MORGENROTH, 1966 and DAVEY & WILLIAMS,1966) and possibly the Bartonian of Belgium (ROZEN,1964). At Barton and Alum Bay it is common in the Lower and Middle Barton Beds and rare in the *Chama* bed.

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Family: HYSTRICHOSPHAERIDIACEAE EVITT 1963

Genus: *Hystrichosphaeridium* DEFLANDRE 1937

(Type species: *Xanthidium tubiferum* EHRENBERG,1838.)

Hystrichosphaeridium salpingophorum (DEFLANDRE) DEFLANDRE, 1937

Plate 2, figs. 8, 9, 10, 11.

Hystrichosphaera salpingophora DEFLANDRE,1935. p.232,pl.9,fig.1.
Hystrichosphaeridium salpingophorum (DEFLANDRE):DEFLANDRE,1937. p.80,pl.13, figs. 1,3.
Hystrichosphaeridium salpingophorum (DEFLANDRE):PASTIELS,1948. p.37,pl.3, figs. 3-7.
?*Hystrichosphaeridium salpingophorum* (DEFLANDRE):W.WETZEL,1952.p.399,text-fig.11.
?*Hystrichosphaeridium salpingophorum* (DEFLANDRE):GOCHT,1952. p.308,pl.1,fig.19; pl.2,fig.20.
Hystrichosphaeridium salpingophorum (DEFLANDRE):DEFLANDRE & COOKSON,1955. p.271,pl.2,fig.9.
Hystrichosphaeridium salpingophorum (DEFLANDRE): DE CONINCK,1965. p.24,pl.5, figs.2,3,5-8,11,12,text-figs.9,10.
Cordosphaeridium inodes (KLUMPP): DE CONINCK, 1965 (part). p.31,pl.9,fig.1 only.
Hystrichosphaeridium salpingophorum (DEFLANDRE):DAVEY & WILLIAMS,1966. p.61,pl.10,fig.6.

Description

Cyst chorate, central body subspherical to oblate sphaeroidal. Surface of periphragm granular. The periphragm gives rise to 20-30 broad, hollow, circular in cross-section, buccinate processes, which are subequal in length, between 1/3rd and 2/3rds the central body diameter in length, with a longitudinally fibrous structure not seen on the central body. Distally the processes are gradually but markedly flared, with entire open, subquadrate margins. The process walls are never fenestrate. The antapical process is occasionally slightly longer than the others and may be closed distally by a conical cap. Archaeopyle apical and tetratabular.

Remarks

Some specimens bear shorter, very broad, distally flared processes, which were originally thought to constitute a distinct species. The complete variation between these and the more typical longer processed forms rules out this possibility. These forms show a relationship to H.tubiferum var. brevispinum DAVEY & WILLIAMS (1966) but differ in their possession of flared, rather than cylindrical processes.

As DAVEY & WILLIAMS (1966) noted in their specimens from the London Clay, H.salpingophorum resembles H.tubiferum s.s. in tabulation and some references to the latter are probably synonymous with H.salpingophorum. H.stellatum MAIER (1959) is also very similar, but differs in having subconical processes. H.costatum DAVEY & WILLIAMS (1966) has longitudinally ridged processes and H.deanei DAVEY & WILLIAMS (1966) has much more variable, often lagenate processes. H.patulum DAVEY & WILLIAMS (1966) and H. aff. latirictum DAVEY & WILLIAMS (1966) bear processes which flare suddenly distally and not gradually. Cordosphaeridium eoinodes (EISENACK, 1958) differs in its process terminations and archaeopyle. The branched processes and distal connections figured by PASTIELS (1948) have not been observed.

DEFLANDRE's (1935) type level for this species is the French Senonian. It has also been described from the Belgian and English Lower Eocene (PASTIELS, 1948 and DAVEY & WILLIAMS,1966),the Danish Danian, (W.WETZEL,1952), the German Oligocene (GOCHT,1952) and the Papuan Lower Cretaceous (DEFLANDRE & COOKSON, 1955). At Barton and Alum Bay it is sporadically common in the Lower and Middle Barton Beds.

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Hystrichosphaeridium aff. latirictum DAVEY & WILLIAMS,1966

Plate 2, figs. 12a, b.

?Hystrichosphaeridium latirictum DAVEY & WILLIAMS,1966. p.66,pl.10,fig.8.

Description

Cyst chorate, central body subspherical. The wall consists of two layers; endophragm and faintly granular periphragm. The periphragm gives rise to 20-30 similar, hollow, tubiform, fibrous walled, unbranched processes. Processes are relatively slender along most of their length and become suddenl flared where they open distally. Margins extremely thin, often entire, and circular or subquadrate. In most specimens they are connected to the margins of adjacent processes by broad, thin, fibrous ribbons. Archaeopyle apical, tetratabular.

Remarks

The Bartonian material can only tentatively be referred to DAVEY & WILLIAMS' type figures and descriptions (London Clay). Their size distinctions would exclude this form but they mention the broadly flared process terminations. They do not describe the distal connections between processes. H.salpingophorum (DEFLANDRE) shows similar feature as does H.sp.1 , but neither have process connections or the sudden distal flaring of the processes. H.cantharellum BROSIUS (1963) and H.paradoxum BROSIUS (1963) also bear a resemblance but one lacks the distal process connections and the other has an elongate central body. The presence of distal process connections might indicate the relationship of the Bartonian material with the genera Cannosphaeropsis or Adnatosphaeridium. A.vittatum WILLIAMS & DOWNIE (1966) has broad, ribbon-like connections, but they are much more regular than those of H. aff. latirictum. Also the processes tend to be taeniate rather than circular in section. Thus these specimens do not fit exactly any described species but show closest affinities with H.latirictum.

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Hystrichosphaeridium sp.1

Plate 2, fig. 13.

Description

Cyst chorate, central body subspherical. The slightly granular periphragm gives rise to 20-30 tubiform, buccinate or flared processes of slightly varying sizes. Process walls are thin, slightly fibrous and circular in cross-section. Distally the processes have deeply aculeate margins and occasionally may be fenestrate, giving them a ragged appearance. They are never connected to adjacent processes. Archaeopyle apical, tetratabular.

Remarks

These specimens cannot be fitted to any described species. It resembles H.salpingophorum (DEFLANDRE) in process arrangement and shape but differs in the ragged process terminations. It is probably closely related to the above form. H.aff.latirictum differs in its distal process connections. Oligosphaeridium dictyoplokus (KLUMPP, 1953) and O.pulcherrimum (DEFLANDRE & COOKSON, 1955) both bear fenestrate process terminations. Those of the former are plate-like and completely different to the species under consideration but the latter does show a resemblance with its fenestrate and finally aculeate process terminations. A fundamental difference however, lies in the reflected tabulation of O.pulcherrimum, withits smaller number of process. H.sp.1 definitely shows Hystrichosphaeridium-type reflected tabulation, with the extra ring of cingular processes.

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Genus: Oligosphaeridium DAVEY & WILLIAMS 1966

(Type species: Xanthidium tubiferum complex WHITE, 1842.)

Remarks

DAVEY & WILLIAMS (1966) erected this genus to include Hystrichosphaeridium like forms with an apical, tetratabular archaeopyle and an absence of cingular processes. Thus there should not be more than 20 processes.

Oligosphaeridium dictyoplokus (KLUMPP) nov.comb.

Plate 3, figs. 1a, b, 2, 3, 4, 5.

Hystrichosphaeridium dictyoplokus KLUMPP,1953. p.392,pl.18,figs.3-7; text-figs. 8-10.
Hystrichosphaeridium dictyoplokus KLUMPP:EISENACK,1954. p.68,pl.10,figs.9,10; text-fig.5.
Hystrichosphaeridium dictyoplokus KLUMPP:MAIER,1959. p.313,pl.31,fig.4.
Cordosphaeridium dictyoplokus (KLUMPP):EISENACK,1963. p.262,pl.29,fig.1.
Cordosphaeridium dictyoplokus (KLUMPP):MORGENROTH,1966b. p.22,pl.4,figs.11,12.
?Cordosphaeridium dictyoplokus (KLUMPP):DAVEY & WILLIAMS,1966. p.91.
Cordosphaeridium dictyoplokus (KLUMPP):COOKSON & CRANWELL,1967. p.205,pl.1, figs.12,13;pl.2,figs.1-3.

Description

Cyst chorate, central body subspherical, with a faintly granular surface and with a thin, almost clear wall, consisting of thin endophragm and periphragm in close contact. Processes are few in number, subequal in length, cylindrical or tubiform and finely fibrous in structure, especially at the base. There are up to six precingular processes, six postcingular processes and up to four in each of the apical and antapical positions. Thus there are never more than 20 processes and usually less. There is some variation in process diameter and length in the Bartonian material, some specimens having long, slender, often sinuous processes and some having shorter fatter processes, often branching and reuniting to leave long, narrow windows. Individual specimens usually show the same type of processes. Distally the processes are extremely distinctive, being expanded into thin, flat, table-like or broad trumpet-shaped membranes which are coarsely reticulate. The holes in the distal membranes are sometimes arranged in concentric patterns and sometimes extend a short way into the top of the processes, especially in more broad-processed forms. The margins of the reticulate membranes are never linked with those of adjacent processes. They always have an entire margin, never spinose, and are sometimes polygonal in shape, possibly reflecting the shape of the underlying plate. Archaeopyle apical, tetratabular, with a notched or zig-zag margin. The notches lie between the precingular processes.

Remarks

The Bartonian material agrees well with the published figures and descriptions, with its extremely characteristic fenestrate membranes. A number of authors place this species in the genus *Cordosphaeridium* on the basis of the fibrous process structure, including DAVEY & WILLIAMS (1966). The number and arrangement of the processes and the obviously tetratabular archaeopyle preclude this placing and its inclusion in *Oligosphaeridium* is not doubted. The forms with slender processes and those with fatter processes were originally thought to represent two species but the complete variation between thetwo makes this unlikely.

Oligosphaeridium pulcherrimum (DEFLANDRE & COOKSON, 1955) has similar fenestrate process terminations but they have characteristically spinose margins and represent a definitely distinct, although related, species. *C.anthophorum* (COOKSON & EISENACK, 1958) and ?*O.dictyophorum* (COOKSON & EISENACK, 1958) are Australasian Upper Jurassic forms, which, although superficially resemble *O.dictyoplokus* with fenestrate process membrane, differ in having a less expanded process form. *O. complex* (WHITE, 1342) and *O.vasiformis* (NEALE & SARJEANT, 1962) have processes which are terminally aculeate, never with reticulate membranes.

This species is common throughout Alum Bay and Barton, except in the topmost Upper Barton Beds. It was originally described from the Middle Eocene of North Germany by KLUMPP (1953). Other records include the Lower and Upper Oligocene of North Germany (EISENACK, 1954; MAIER, 1959) the Lower Eocene of North Germany (MORGENROTH, 1966) and the Paleocene of Chile (COOKSON & CRANWELL, 1967).

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Oligosphaeridium sp.1

Plate 3, figs. 6, 7.

Description

Cyst chorate, central body subspherical, with a thin, finely granular wall. Processes which are few in number, may be short and thick or longer and more slender. They are arranged either as one per plate area or as complexes of two per plate area. Up to six precingular, six postcingular and two antapical processes or process complexes may be present, the cingular circlet being absent. Processes are finely fibrous in structure, tubiform in shape and may be united proximally. Distally they bear broad reticulate membranes, which may be flat and table-like or trumpet-like. The reticulate membranes have entire margins and are often polygonal in shape, reflecting the tabulation. Two adjacent processes may be united by the reticulate membrane, which, if polygonal, takes the shape of a single plate. These united processes are the ones frequently proximally united and may be regarded as double process complexes, one per plate area. Archaeopyle apical with a jagged margin, indicating its tetratabular nature.

Remarks

In number and arrangement of processes, process groups and archaeopyle this species obviously falls within the genus Oligosphaeridium. The distal communication of the processes and presence of more than one per plate might indicate its designation to Adnatosphaeridium WILLIAMS & DOWNIE (1966). However, the former argument is believed to hold more weight, especially as it closely resembles O.dictyoplokus (KLUMPP) in its distal reticulate membranes.

It occurs rather infrequently in the Lower and Middle Barton Beds at Barton and throughout the Barton Beds at Alum Bay.

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Genus: Cordosphaeridium EISENACK 1963, emend. DAVEY & WILLIAMS 1966

(Type species: Hystrichosphaeridium inodes KLUMPP, 1953.)

Remarks

DAVEY & WILLIAMS (1966) restrict this genus to contain species of cysts of the Hystrichosphaeridium group with haplotabular apical archaeopyles. This appears to represent a more important feature in view of the nature of Hystrichospheres as Dinoflagellate cysts than EISENACK's (1963) original distinction based on the fibrosity of the processes, a feature also found in other genera.

Cordosphaeridium inodes (KLUMPF, 1953) EISENACK, 1963

Plate 3, figs. 8, 9, 10.

Hystrichosphaeridium truncigerum COOKSON,1953. (non DEFLANDRE, 1937) p.114, pl.2,figs.21-23.
Hystrichosphaeridium inodes KLUMPP,1953. p.391,pl.18,figs.1,2.
Hystrichosphaeridium inodes KLUMPP: DEFLANDRE & COOKSON,1955. p.277, pl.2,fig.7.
Hystrichosphaeridium inodes KLUMPP: GERLACH,1961. p.136,pl.28,figs.4-6.
Hystrichosphaeridium inodes KLUMPP: BROSIUS,1963. p.40,pl.5,fig.5.
Cordosphaeridium inodes (KLUMPP):EISENACK,1963. p.261,pl.29,fig.3.
Cordosphaeridium inodes (KLUMPP):ROZEN,1964. p.310,pl.4,figs.1,5.
Cordosphaeridium inodes (KLUMPP): DE CONINCK,1965.(part.) p.31,pl.8,figs.1-7; pl.9,figs.2,5only.
Cordosphaeridium inodes (KLUMPF):MORGENROTH,1966. p.23,pl.5,fig.1.
Cordosphaeridium inodes (KLUMPP) minus MORGENROTH,1966. p.24,pl.5,figs.4,5.
Cordosphaeridium inodes (KLUMPP): DAVEY & WILLIAMS,1966. p.83,pl.3,fig.9; text-fig.18.
Cordosphaeridium inodes (KLUMPP): DRUGG,1967. p.28,pl.5,figs.8,9.

Description

Cyst chorate, central body subspherical. The wall consists of two layers: a thin, faintly granular endophragm and a thicker periphragm in the form of a coarse, irregular network over the central body surface. The periphragm gives rise to 30-40 rather variable processes. These are always strongly longitudinally fibrous, with the fibrils radiating from the slightly expanded bases to join the periphragmic network, though without regular petaloid patterns around the bases. Processes may be long or short (up to half the central body diameter in length) and broad or slender. They are tubiform or slightly tapering and the broader processes are often latispinous in cross section. They are sometimes linked proximally and split distally into two unequal branches. Distally the processes are open, with a deeply dissected aculeate margin. The aculei are often unequal in size, rather ragged in shape and usually recurved. Archaeopyle haplotabular and apical in position, with a characteristic rounded triangular shape.

Remarks

A number of the other Lower Tertiary species of Cordosphaeridium show a close resemblance to C.inodes and perhaps the Bartonian material should be subdivided. These species include C.fibrospinosum DAVEY & WILLIAMS (1966), which has broader, distally entire processes and

C.exilimurum DAVEY & WILLIAMS (1966), with an exceptionally thin periphragm. *C.tiara* (KLUMPP, 1953), *C.divergens* (EISENACK,1954) and *C.microtriana* (KLUMPP,1953) all resemble the specimens with the more slender processes. *C.multisponosum* DAVEY & WILLIAMS (1966) resembles Bartonian forms with numerous short processes. *C.floripes* (DEFLANDRE & COOKSON,1955) also has the same type of cysts as *C.inodes* but clearly differs in having a petaloid pattern around the base of each process. Placing of some Bartonian specimens into some of these species, especially *C.microtriana*, *C.divergens* and *C.tiara* must await further detailed study but for the moment the presence of intermediates suggest placing all the material examined in *C.inodes*.

Published records of *C.inodes* show that it ranges from the Paleocene to the Middle Miocene in Europe, North America and Australia. KLUMPP's (1953) type locality was the Upper Eocene of North Germany. At Barton and Alum Bay it occurs commonly between the Middle Barton Beds and the Upper Barton Beds and rarely in the lower parts of the Lower Barton Beds.

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Cordosphaeridium gracilis (EISENACK) DAVEY & WILLIAMS, 1966

Plate 3, figs. 11a, b, 12.

Hystrichosphaeridium inodes subsp. gracilis EISENACK,1954. p.66,pl.3,fig.17; pl.10, figs. 3-8.
Hystrichosphaeridium inodes subsp. gracilis EISENACK:GERLACH,1961. p.187,pl.28,fig.5.
Cordosphaeridium inodes subsp. gracilis (EISENACK):EISENACK,1963. p.261, pl.29, figs.2,3.
Cordosphaeridium inodes gracilis (EISENACK):MORGENROTH,1966b. p.23,pl.5,figs.2,3.
Cordosphaeridium gracilis (EISENACK): DAVEY & WILLIAMS,1966. p.84,pl.3,fig.8; pl.11;figs.4,6,7;text-fig19.

Description

Cyst chorate, central body spherical or subspherical. Surface of periphragm granular of faintly fibrous. The periphragm gives rise to relatively few (20-30) similar, long, sinuous, solid processes, which are longitudinally fibrous in structure and have fine radiating fibres at the slightly expanded bases. Processes usually show division into two or occasionally three subequal branches half-way along their length. The junctions between the branches and the parent processes are characteristically Y-shaped. Distally the processes are slightly expanded, with digitate or seccate terminations, which are sometimes recurved. Archaeopyle apical, haplotabular and triangular or inflated triangular in outline.

Remarks

This species is characterised by its slender branching processes and agrees well with the published figures and descriptions. Its possession of a triangular archaeopyle, formed by the loss of a single apical plate, indicates its correct placing in the genus *Cordosphaeridium*, as emended by DAVEY & WILLIAMS, 1966.

It has been described from the East Prussian Lower Oligocene, EISENACK's (1954) type level; the North West German Oligo-miocene (GERLACH, 1961); the North German and Belgian Lower Eocene (MORGENROTH, 1966); and the London Clay of Sheppey, Kent (DAVEY & WILLIAMS, 1966). Both at Barton and Alum Bay it occurs throughout the Bartonian, often commonly.

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Genus: *Homotryblium* DAVEY & WILLIAMS 1966

(Type species: *Homotryblium tenuispinosum* DAVEY & WILLIAMS, 1966.)

Homotryblium pallidum DAVEY & WILLIAMS, 1966

Plate 3, figs. 14a, b.

Hystrichosphaeridium tuberiferum MORGENROTH, 1966b. (non EHRENBERG 1838). p.31, pl.8, figs.7, 8.

Homotryblium pallidum DAVEY & WILLIAMS, 1966. p.102, pl.12, figs.4, 6; text-fig.22.

Description

Cyst chorate, central body small, subspherical. Wall of central body very thin, giving specimens a very pale colour, with a smooth endophragm and a very faintly granular periphragm. Periphragm gives rise to 22 cylindrical or slightly tubiform, similar, hollow, thin walled, distally open processes, which form a circle where they leave the central body. Distally the process terminations are digitate or seccate and sometimes slightly recurved. The archaeopyle is epitractal and detached opercula and basin shaped hypotracts are commonly seen. A sulcal notch can sometimes be seen in the margin of the archaeopyle. The tabulation cannot be seen on the central body surface but, when compressed, it tears along the polygonal plate boundaries.

Remarks

The Bartonian material fits well with the type figures and descriptions, except that the processes appear to be slightly more regularly cylindrical in shape, more uniform in size and less aculeate distally. DAVEY & WILLIAMS (1966) describe this species from the English London Clay. It differs from *H.tenuispinosum* DAVEY & WILLIAMS (1966) in its more regular and broader processes and lack of surface tabulation traces on the central body. MORGENROTH's (1966) figures of *Hystrichosphaeridium tubiferum* from the German and Belgian Lower Eocene bear a very close resemblance to the Bartonian specimens but he does not show the archaeopyle. *H.cylindratum* MORGENROTH (1966) is similar in shape and process shape but has entire, rather than digitate distal terminations. *H.pseudorecurvatum* MORGENROTH (1966) also shows a resemblance but has an apparently haplotabular archaeopyle. At Barton and Alum Bay *H.pallidum* ranges almost throughout the Bartonian.

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Genus: *Polysphaeridium* DAVEY & WILLIAMS 1966

(Type species: *Polysphaeridium subtile* DAVEY & WILLIAMS,1966.)

Polysphaeridium subtile DAVEY & WILLIAMS, 1966

Plate 3, fig. 13.

Hystrichosphaeridium cf. tubiferum WEILER,1956. p.139,pl.12,figs.4&6(not 5).
Polysphaeridium subtile DAVEY & WILLIAMS,1966. p.92,pl.11,fig.1.

Description

Cyst chorate, central body wall of two layers in close contact. Periphragm slightly granular but not reticulate. Periphragm gives rise to numerous (more than 40), randomly arranged, similar, hollow, relatively narrow and short, tubiform processes. Distally the processes are open, slightly flared and with an aculeate margin. Archaeopyle apical and with a notched edge.

Remarks

Most of the Bartonian specimens correspond well both generically and specifically with the published description and figure. However, a few bear somewhat longer processes and are superficially similar to *Cordosphaeridium divergens* (EISENACK) and *C.microtriana* (KLUMPP):MAIER, 1959 (pl.31,fig.6). They do not show the characteristic haplotabular archaeopyle and fibrous periphragm of these species.

P.subtile occurs fairly commonly in the Lower and lower Middle Barton Beds at Barton and Alum Bay. It has previously only been recorded from European Tertiary deposits.

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Genus: *Cleistosphaeridium* SARJEANT & WILLIAMS 1966.

(Type species: *Cleistosphaeridium diversispinosum* SARJEANT & WILLIAMS,1966)

Remarks

SARJEANT & WILLIAMS (1966) divided up those members of *Baltisphaeridium* with demonstrable Dinoflagellate affinities into a number of genera on the basis of archaeopyle position and process arrangement. *Cleistosphaeridium* was erected to include forms with numerous, distally closed processes, in uncertain arrangement, and with an apical archaeopyle.

Cleistosphaeridium centrocarpum (DEFLANDRE & COOKSON) *nov. comb.*

Plate 4, figs. 1a, b, 2.

Hystrichosphaeridium centrocarpum DEFLANDRE & COOKSON,1955. p.272,pl.8,figs.3,4.
?*Hystrichosphaeridium centrocarpum* DEFLANDRE & COOKSON: MAIER, 1959. p.314,pl.31,fig.7.
Baltisphaeridium centrocarpum (DEFLANDRE & COOKSON):GERLACH,1961. p.192,pl.28,fig.9.
Baltisphaeridium centrocarpum (DEFLANDRE & COOKSON):DOWNIE & SARJEANT,1963.p.91.
Cordosphaeridium palmatum (WHITE):D.CONINCK,1965. p.32,pl.6,figs.8,10.
?*Cordosphaeridium centrocarpum* (DEFLANDRE & COOKSON):DE CONINCK,1965. p.33,pl.9, figs.9-11;pl.11,figs.45,46.
Cordosphaeridium tiara (KLUMPP) subsp. *centrocarpum* (DEFLANDRE & COOKSON): MORGENROTH,1966b. p.26,pl.5,fig.12;pl.6,fig.1.
Baltisphaeridium centrocarpum (DEFLANDRE & COOKSON):DRUGG,1967. p.31,pl.5,fig.13.

Description

Chorate cyst, central body subspherical or ovoid, elongate. The surface of the central body is finely granular and occasionally weakly fibrous. Processes over 40 in number, randomly spaced and covering the whole cyst. They may vary in length from a fifth or sixth to a third the central body diameter. They are generally all of approximately the same length on each specimen. They are solid, slender and taper slightly distally, with three or four extremely small recurved spines at the terminations. At their base the processes have a longitudinally fibrous structure, which continues over the central body wall a short way as radiating fibrils. Archaeopyle large, apical with, in most cases, an entire margin.

Remarks

Although this species has not got a zig-zag archaeopyle it is placed in the genus Cleistosphaeridium because of its undoubtedly apical position. It differs from Cleistosphaeridium tiara (KLUMPP,1953) in its greater number of processes and lack of a strongly fibrous central body. The two species are closely related to their type of archaeopyle, although its placing as a subspecies of C.tiara in the genus Cordosphaeridium by MORGENROTH (1966) cannot be accepted. C.machaerophorum (DEFLANDRE & COOKSON), described from the same formations as the present species, differs in having straighter, more sword-shaped processes, with single sharp terminations.

DEFLANDRE & COOKSON's (1955) type level for C.centrocarpum is the Middle Miocene of Victoria, Australia. It has also been noted from the Oligo-Miocene of North Germany (GERLACH,1961; MAIER,1959), the Lower Eocene of North Germany and Belgium (MORGENROTH,1966) and the Lower Paleocene of California (DRUGG,1967). At Barton and Alum Bay it is common throughout the Bartonian but is most abundant in the Upper Barton Beds at Barton.

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Genus: *Hystrichokolpoma* KLUMPP 1953

(Type species: *Hystrichokolpoma cinctum* KLUMPP, 1953.)

Hystrichokolpoma eisenacki WILLIAMS & DOWNIE, 1966

Plate 4, figs. 3a, b.

Hystrichokolpoma cinctum KLUMPP:EISENACK,1954. p.64,pl.10,figs.11-14.
Hystrichokolpoma cinctum KLUMPP:ROZEN,1964. p.307,pl.3,fig.3;text-fig.18.
Hystrichokolpoma cinctum KLUMPP:MORGENROTH,1966b. p.28,pl.8,fig.11.
Hystrichokolpoma eisenacki WILLIAMS & DOWNIE,1966. p.176,pl.17,figs.1-3; text-fig.46.

Description

Cyst chorate, central body subspherical, wall in two layers, namely a slightly granular endophragm, which continues beneath processes, and a clear periphragm. The periphragm gives rise to two types of processes. Precingular, postcingular and sulcal processes occur one per plate and are large, hollow and lagenate, with broad quadrate bases which almost cover the plates leaving only a narrow margin around them. Distally the processes are open, with slightly serrate or entire margins. Tubular, distally open and entire branches occur on these processes. The cingular processes are long, narrow, tubiform, hollow, distally open and entire, occurring two per cingular plate. The antapical process is longer than all the others. It is usually tapering and closed distally. Archaeopyle apical, tetratabular with a notched margin.

Remarks

This species is highly distinctive and agrees well with the type figures and description. WILLIAMS & DOWNIE (1966) distinguish it from *H.cinctum* KLUMPP (1953) on the presence of open ended tubular branches on the large processes instead of closed spines, a feature noted on the Bartonian material. It differs from *H.rigaudae* DEFLANDRE & COOKSON (1955) in that the large processes are not distally closed and spinose. *H.unispinum* WILLIAMS & DOWNIE (1966) has one, rather than two, narrow processes per cingular plate. *H.biformoides* (EISENACK, 1954) has cylindrical precingular and postcingular processes, nowhere near as wide or as broad-based as those of *H.eisenacki*.

H.eisenacki has been recorded from the Lower Oligocene of East Prussia (EISENACK, 1954), the Bartonian of Belgium (ROZEN, 1964), the Lower Eocene of North Germany and Belgium (MORGENROTH, 1966) and the London Clay of England (the type level of WILLIAMS & DOWNIE, 1966). At Barton and Alum Bay *H.eisenacki* occurs rarely from the Lower to the Upper Barton Beds.

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Hystrichokolpoma biformoides (EISENACK) ROZEN, 1964

Plate 4, figs. 4a, b.

Hystrichosphaeridium biformoides EISENACK, 1954. p.68, pl.11, figs.16-20.
Hystrichokolpoma biformoides (EISENACK): ROZEN, 1964. p.308, pl.3, figs.1,2; text-fig.19.
Hystrichokolpoma rigaudae DEFLANDRE & COOKSON: DE CONINCK, 1965. p.27, pl.7, figs. 7-16.
Hystrichokolpoma biformoides (EISENACK): MORGENROTH, 1966b. p.28, pl.6, figs.9,10.

Description

Cyst chorate, central body subspherical. The wall of the central body consists of a granular endophragm and clear periphragm in close contact. Periphragm gives rise to two types of process. Large precingular and postcingular processes occur one per plate; are about three times as long as they are broad, with quadrate bases, which cover only a small area of the underlying plate. Endophragm continues beneath process bases. These processes are tubiform in shape, without lateral branches or spines, hollow, thin walled and distally open, with foliate or serrate margins. Cingular processes occur two per plate and are slender, tubiform, distally open with aculeate margins. The antapical process is larger than all the others and is often closed distally by a conical cap. Archaeopyle apical, tetratabular and with a notched margin.

Remarks

H.biformoides differs from *H.unispinum* WILLIAMS & DOWNIE (1966) in having two narrow processes per cingular plate area, not one. *H.rigaudae* DEFLANDRE & COOKSON (1955) has large processes which are distally closed and spinose. *H.cinctum* KLUMPP (1953) and *H.eisenacki* WILLIAMS & DOWNIE (1966) have much large precingular and postcingular processes.

EISENACK (1954) first described this form from the Lower Oligocene of East Prussia. Other records include the Bartonian of Belgium (ROZEN, 1964) and the Lower Eocene of North Germany and Belgium (MORGENROTH, 1966). At Barton it occurs rarely in the Upper Barton Beds and at Alum Bay in the Lower Barton Beds.

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Genera of Uncertain Systematic Position

Genus: Lanternosphaeridium MORGENROTH 1966b

(Type species: Lanternosphaeridium lannosum MORGENROTH,1966b.)

Lanternosphaeridium axialis (EISENACK) MORGENROTH 1966

Plate 4, figs. 5a, b, 6.

Cordosphaeridium axialis EISENACK,1965. p.149,figs.14-15.
Lanternosphaeridium axialis (EISENACK): MORGENROTH,1966b. p.38,pl.6,figs.4,5.

Description

Chorate cyst, central body ovoid, with its long axis in an apical/antapical direction. The cyst wall consists of a thick, translucent, orange endophragm and a thin, faintly granular periphragm. Periphragm gives rise to about 35 similar, tubiform, unbranched, hollow, slender processes, all about half the diameter of the central body in length. They are finely fibrous at their slightly expanded bases and the fibrils extend a short way across the central body surface. Distally the processes are slightly expanded with a recurved aculeate margin. It is difficult to determine, in the absence of any plate delimitation, whether the processes are intratabular, sutural or gonal in position. There are one or two rings each of precingular and postcingular processes and definitely two rings of cingular processes. This might indicate that they are gonal or sutural. The apical process is always larger than all the others and very distinctive. It is solid and either irregularly cylindrical or cylindrical with three large, broad, flat, leaf-like terminal branches. The antapical process is not usually differentiated though some specimens bear a slightly longer cylindrical but not foliate antapical process. Archaeopyle precingular, haplotabular and triangular or rounded triangular in shape. It is often quite large.

Remarks

The Bartonian material corresponds well with the type figures and descriptions. It differs from L.lannosum MORGENROTH (1966) and L.radiatum MORGENROTH (1966) in having processes not united either distally or proximally. L.bipolare (COOKSON & EISENACK,1965) is a closely related species from the Australian Paleocene but differs in having both apical and antapical processes larger than the others. It was originally described under the genus Cordosphaeridium but clearly belongs in MORGENROTH's genus Lanternosphaeridium.

In the English Bartonian this species occurs commonly in the Lower and Middle Barton Beds but is not found above the middle of the Middle Barton Beds. It was originally described from the East Prussian Upper Eocene (EISENACK, 1965). MORGENROTH (1966b) records it from the North German and Belgian Lower Eocene.

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Genus: Palmnickia EISENACK 1954

(Type species: Palmnickia lobifera EISENACK, 1954.)

Palmnickia sp.1

Plate 4, figs. 7,8.

"FormF" EVITT, 1961. p.392,pl.6,figs.1-5;pl.7,figs.1,2.

Description

Cyst chorate, elongate. Central body spheroidal, consisting of endophragm and finely granular periphragm in close contact. Apical and antapical poles marked by large foliate complexes of membraneous "processes", which expand slightly distally. Cingulum marked by a relatively broad, sharp-edged shelf running around the cyst equatorially. Additional processes are absent. Archaeopyle large, rounded triangular and precingular in position.

Remarks

Except for the absence of additional small, spine-like processes on the central body, the Bartonian material fits well with EVITT's (1961) figures and descriptions of his Forma F. EVITT suggest a relationship with Palmnickia and the process arrangement and archaeopyle position support this designation. It differs from the type species, P.lobifera EISENACK in having longer and more restricted processes.

The genus Triblastula O.WETZEL (1933) differs in having processes supporting a third membrane, or ectophragm at the poles. T.utinensis O.WETZEL bears an equatorial complex of spiney processes but T.nuda O.WETZEL, T.tubulata O.WETZEL and T.quasicribrata O.WETZEL (all 1961) all have a similar shape to Palmnickia sp.1 and differ mainly in their possession of a polar ectophragm. Certain species of Deflandrea bear a superficial resemblance to the described species, especially in shape. The closest of these are D.tripartita COOKSON & EISENACK (1960), D.victoriensis COOKSON & MANUM (1964), D.thomasi COOKSON & EISENACK (1961), D.verrucosa MANUM (1963) and D.granulifera MANUM (1963). They all have the elongate shape and marked cingulum but differ fundamentally in having difinitely cavate cysts and intercalary archaeopyles.

EVITT described Forma F. from the Lower Eocene Vincetown formation of New Jersey. COOKSON & CRANWELL (1967) questionably found it in the Lower Tertiary of Chile. At Barton this species occurs only in the Upper Barton Beds, but at Alum Bay it occurs rarely throughout the succession.

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Genus: Thalassiphora EISENACK & GOCHT 1960

(Type species: Bion Pelagicum EISENACK, 1938.)

Thalassiphora pelagica (EISENACK) BROSIUS, 1963

Plate 4, figs. 11, 12a, b.

Bion pelagicum EISENACK,1938. p.187.
Pterospermopsis pelagica (EISENACK):EISENACK,1954. p.71,pl.12,figs.17,18.
Pterospermopsis cf. danica WEILER,1956. p.138,pl.11,figs.7,8;pl.13,fig.4;
text-fig.7.
Thalassiphora pelagica (EISENACK)EISENACK & GOCHT,1960. p.513,figs.1-3.
Pterospermopsis pelagica (EISENACK):GERLACH,1961. p.209,pl.28,fig.15.
Pterospermopsis cf. pelagica (EISENACK):ALBERTI,1961. p.40,pl.11,fig.11.
Thalassiphora pelagica (EISENACK):BROSIUS,1963. p.50,pl.3,fig.3.
Thalassiphora velata (DEFLANDRE & COOKSON):DE.CONINCK,1965. p.41,pl.14,figs.1-4.
Thalassiphora pelagica (EISENACK):MORGENROTH,1966b. p.40,pl.11,figs.3,4.

Thalassiphora pelagica (EISENACK): WILLIAMS & DOWNIE,1966. p.234,pl.26,fig.7.
Thalassiphora pelagica (EISENACK): COOKSON & CRANWELL,1967. p.206,pl.2,figs.4,5.
Thalassiphora pelagica (EISENACK): GOCHT,1968. p.153,pls.25,26,27.

Description

Cyst cavate, with an ellipsoidal central body attached dorsally to a broad, saucer-shaped, imperforate, lamellar periphragm. The periphery of the periphragmic membrane is usually folded inwards ventrally. Surfaces of endophragm and periphragm are granular and without processes. The precingular, haplotabular archaeopyle is dorsal in postion and semicircular or expanded triangular in outline. It is seen commonly in the endophragm but only rarely in the periphragm in an analagous but slightly more anterior position. A characteristic strong, transverse keel bisects the periphragmic membrane posterior to the archaeopyle. This represents the track of the cingular girdle. Additional folds are often seen perpendicular to it dividing the periphragm into a number of precingular and postcingular plate areas. The periphragm is sometimes drawn out into a short posterior horn.

Remarks

GOCHT (1968) showed that this species shows an ontogenetic development from a "juvenile" proximate cyst, with high lists and a strong anterior-ventral horn. He was able to determine the tabulation of these forms and trace them to the "adult" cyst. In the Bartonian proximate specimens occur, which are referable to his early stages. Intermediates to the fully developed stages could not be found. "Juveniles" occur in the Upper Barton Sands and tend to be badly corroded. The posterior horn in the endophragm of adults, described by COOKSON & CRANWELL (1967), was not observed. T.pelagica occurs commonly throughout the English Bartonian strata and agrees well with the published figures and descriptions. Published occurrences are restricted to the Tertiary.

T.delicata WILLIAMS & DOWNIE (1966), a related form, differs in its smaller size, its lack of a cingular keel and its thicker periphragm. T.reticulata MORGENROTH (1966a) has a reticulate lamellar periphragm.

Former confusion with the genus Pterospermopsis has been resolved. The outer membrane of Pterospermopsis is attached to the central body equatorially. Also its lack of an archaeopyle and caniculate wall structure indicates its affinities with the Tasmanitids rather than the Dinoflagellates.

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Genus: Kenleyia COOKSON & EISENACK 1965b

(Type species: Kenleyia pachycerata COOKSON & EISENACK, 1965b.)

Kenleyia? sp.1

Plate 4, figs. 9a, b.

Description

Cyst proximate, rounded pentagonal in outline and dorso-ventrally nearly as thick as it is broad. The wall consists of a thin endophragm and a very thick, granular periphragm in close contact. Endocoel ovoid. The periphragm shows extra thickening in the apical, antapical and cingular regions and along some plate boundaries. Apical and antapical areas are marked by upto four blunt periphragmic prominences and the cingulum by a low helical ridge. Periphragmic thickening of the other plate boundaries is restricted to plate 1' and the sulcus. Post- and precingular boundaries on the dorsal side are not thickened but are sometimes faintly visible. Archaeopyle precingular, quadrilateral and formed by the loss of plate 3''.

Remarks

The taxonomic placing of the two specimens found at Barton (samples 6969 and 6970, both Upper Barton Beds) remains doubtful. Several described species of Deflandrea resemble the above form but are cavate and have intercalary archaeopyles. Gardodinium has a thickened periphragm and a precingular archaeopyle, but bears a prominent apical horn and a pillared, externally mammillate or spinose wall. Scriniodinium has a similar shape to the Bartonian material but is usually thin walled and cavate. S.australiense (DEFLANDRE & COOKSON, 1955) shows a very similar wall structure and tabulation but has a single prominent apical horn. Kenleyia was erected to include species with a thick wall, several apical and antapical horns and a precingular archaeopyle, and the Bartonian specimens are questionably referred to this genus. They do not fit any of the published species, all of which are from the Australian Lower Tertiary.

****

Dinoflagellate Incertae Sedis sp.1

Plate 4, fig.10.

Description

Cyst cavate and cup shaped, with the two faintly granular, unornamented membranes separated by a narrow pericoel. The periphragm, and in one case the endophragm, opens by a large circular terminal aperture with a margin indented on one side by a wide semicircular embayment. A pleat, possibly the cingulum, rings the periphragm just behind the aperture, dividing it into two very unequal halves.

Remarks

The interpretation of these cysts as being double layered is possibly erroneous and they might represent the inner capsules of cavate forms such as Deflandrea. If they are complete cysts the semi-circular notch on the aperture may be part of a cingular archaeopyle margin, left after the removal of the epitract. A compound archaeopyle such as this could not be found in the literature, and until more is known about this very uncommon form, no further taxonomic placing can be contemplated.

Three specimens of this form have been found, two from the Upper Barton Beds of Barton (sample 6966 and 6975) and one from the lower Middle Barton Beds of Alum Bay (sample 6627).

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4:1:2 Tasmanitids

Introduction

The Tasmanitids constitute a small group of microfossils, which occur in small numbers in most samples of the marine parts of the succession. Specimens were picked from the carbon tetrachloride floats, mounted in glycerine jelly and studied in transmitted light in the same way as the Dinoflagellates.

The group was first noted by NEWTON (1875), in the Permian "Tasmanite" white coal of Tasmania, whence he described Tasmanites punctatus NEWTON. These sediments are oil shales, one of the two lithofacies in which Tasmanitids have repeatedly been reported in flood abundance; the other being glacio-marine sediments.

NEWTON and other early workers placed the group, mistakenly, with the pollen and spores, and it was not until 1962 that WALL demonstrated the phylogenetic affinities between the cysts of two recent species of alga, Pachysphaera and Halosphaera, and the fossils Tasmanites and Leiosphaeridea respectively. Pachysphaera and Halosphaera are now placed in the class Prasinophyceae, which are chlorophyll bearing planktonic algae. They show an alternation of generations of a motile, scaled, flagellate form and a spherical encysting stage, the latter bearing canals in some genera (e.g. Pachysphaera). For accounts of these recent genera see MANTON, OATES & PARKE(1963), PARKE & HARTOG-ADAMS (1965) and PARKE (1966).

Morphologically the Tasmanitids are very simple. The cyst is hollow and in most cases spherical or originally spherical. The wall may or may not bear radial canals. The canals are sometimes of two types: larger pore canals and the ultrapores of KJELLSTRÖM 1968, which are often punctae penetrating the wall to varying depths in different species. Surface relief may be represented by protuberances or ridges. The thin walled forms are differentiated into the order Leiosphaeridiales, a polyphyletic group, and include what are undoubtedly spherical Dinoflagellate cysts. Simple sperical or flattened circular forms, such as Leiosphaeridia, show almost structure-less folded walls. Others (*Cymatiosphaera*) may bear systems of crests or (*Pterospermopsis*) a broad equatorial membrane.

Recent work has seen the erection of a number of new genera. In 1955 NOREM erected the genus *Tytthodiscus* to include species with a prismatic wall structure and one type of canal. COOKSON & MANUM (1960), placed species with a single type of pore in regular or irregular arrangement, in *Crassosphaera*. MADLER's (1963) excellent revision of the Tasmanitids is unfortunately not a valid publication, as it is not freely available. *Tasmanites* s.s. is still a valid name for species with two types of canal. A much more complete bibliography can be found in MUIR & SARJEANT (in press).

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Class: PRASINOPHYCEAE CHRISTENSEN 1962

Order: TASMANALES SOMMER 1960

Genus: *Tasmanites* NEWTON 1875

(Type species: *Tasmanites punctatus* NEWTON,1875.)

Tasmanites suevicus (EISENACK) nov.comb.

Plate 5, figs. 1a, b, c.

Tytthodiscus suevicus EISENACK,1957. p.241,pl.19,figs.1-3;pl.20,figs.1-2.
Tytthodiscus cf. *suevicus* EISENACK: GOCHT,1959. p.73,pl.6,figs.1-7.
Tytthodiscus suevicus EISENACK: GORKA,1963. p.71,pl.11,figs.5-8.
Tytthodiscus suevicus EISENACK: BROSIUS,1963. p.50,pl.6,fig.4.
Pleurozonaria suevica (EISENACK): MADLER,1963. p.333,pl.17,figs.3-6; pl.18,figs.1-3.
non *Tasmanites suevicus* (EISENACK): WALL,1965. p.163,text-figs.3E-G.

Description

Cyst spherical or flattened discoidal. Wall relatively thin and elastic. Canal types and distribution rather variable. One or two canal types may be present. Larger, cylindrical pore canals, where present, traverse the whole thickness of the wall. They are relatively few in number and random in distribution. Fine punctae are always present and characteristically show a grouping of 5-12 at one or more levels in the wall. These groups are always regularly arranged at the corners of equilateral triangles, producing a hexagonal pattern. In some specimens each group of punctae coalesces at the outer surface into a single, slightly larger pore, which often opens in the floor of a roughly circular pit. The pits cover the surface of the cyst in a regular hexagonal pattern, leaving a network of ridges. This surface relief is sometimes absent, possibly due to erosion, and single or groups of pores open either on a smooth surface or in slight depressions. Downwards the groups of punctae may anastomose further, opening to give a completely random scatter on the inner surface; or they may remain unbranched and emerge as groups on the inner surface; or they may terminate within the thickness of the wall.

Although specimens do show the above variation in morphology the basic features are remarkably constant and weigh against further specific distinction. These features are wall thickness/cyst diameter ratio, grouping of the punctae, average distance between punctae groups and the hexagonal arrangement of groups.

Remarks

The distinctions between the genera Tytthodiscus, Crassosphaera, Pleurozonaria and Tasmanites are not without controversy and the placing of this species in Tasmanites (sensu stricto) must remain tentative. Tytthodiscus has only one type of canal in regular arrangement, the "prismatic structure" of NOREM (1955). Crassosphaera has only one type, **whose arrangement may** be in a regular or irregular distribution. Pleurozonaria has only one type of canal. Tasmanites has been proven by electron microscopy (KJELLSTRÖM (1968) and WILSON & SKVARLA (1967)) to have two types of canals, both nearly always in irregular arrangement. The presence of two types of canals in some of the Bartonian specimens suggests that this species may be placed in Tasmanites s.s.

Not all records of T.suevicus have the Bartonian specimens' features. WALL (1965), BROSIUS (1963) and GOCHT (1959) are the only three authors who mention the presence of grouping of the punctae, but WALL's figures show an irregular distribution of the groups. GOCHT's (1959) and BROSIUS's (1963) figures and descriptions correspond well with the Bartonian material.

EISENACK's type level for this species is the Liassic of South Germany and GOCHT reports it from the Neocomian of North West Germany. Other reports are from the Upper Cretaceous of Poland (GORKA, 1963) and the German Liassic Posidonienschiefer (MADLER, 1963). BROSIUS (1963) is the only author who describes this species from the Tertiary (Kassel Sand, Upper Oligocene, North Germany).

****

Tasmanites sp.1

Plate 5, figs. 3a,b,c.

Description

Cyst flattened, discoidal. Wall elastic, relatively thin and bearing two types of canals. The larger pore canals are scattered, cylindrical, and pass radially through the entire thickness of the wall. The punctae are much finer. They are entirely randomly scattered on the inner surface but unite and pass, via groups of 5-12, into single pores externally. The exterior surface of the wall is devoid of relief.

Remarks

This species is represented by only two specimens and cannot be placed specifically. The punctae are not as closely spaced at any stage as in Tasmanites suevicus. The duality of canal types is typical of Tasmanites s.s., though the convergence of the punctae has not been reported.

****

Tasmanites sp.2.

Plate 5, figs. 2a,b,c.

Description

Cyst flattened discoidal and flexible. Wall thin, smooth on both surfaces and bearing two types of canals. Larger pore canals are nail-shaped, starting just below the external surface and tapering away blindly at about 2/3rds of the wall thickness. The finer punctae are much more numerous, straight, and extend from the outer surface about 1/3rd of the way inward, where they terminate suddenly. The wall thus shows a distinct zonation. The punctae are distributed entirely at random and do not unite in any way.

Remarks

This species is very rare and cannot be placed specifically. Quisquilites buckhornensis WILSON & URBAN (1963) is one of the few species with a multi-layered wall structure, but is kidney shaped. It was described from the Devonian of Oklahoma and is not related to the above form.

****

Genus: Tytthodiscus NOREM 1955

(Type species: Tytthodiscus californiensis NOREM, 1955.)

Tytthodiscus sp.cf. T.californiensis NOREM 1955

Plate 5, figs. 4a, b, c.

?Tytthodiscus californiensis NOREM, 1955. p.695, pl.68, figs.1a-c.

Description

Cyst flattened, discoidal, but originally spherical. Wall relatively thin and elastic. Exterior wall surface smooth, apart from a number of irregular folds resulting from compression. Piercing the wall are a number of unbranched, cylindrical, radial pore canals of a single type. They are very small in diameter, very closely spaced and traverse the entire thickness of the wall. They emerge on the external surface to form a very dense, vaguely prismatic pattern. The canals are approximately equidistant from each other and do not show any form of grouping.

Remarks

This species is represented by a single well preserved specimen from the Lower Barton Beds of Alum Bay (sample 6613) and consequently the author has reservations in placing it in NOREM's species. The Bartonian specimen is somewhat thinner walled than the figured form and the hexagonal prismatic structure noted by NOREM could not be satisfactorily observed.

****

Tytthodiscus chondrotus NOREM, 1955

Plate 5, figs. 5, 6a,b; plate 6, figs.1a,b.

Tytthodiscus chondrotus NOREM,1955. p.695,pl.68,figs.2a-c.
Pleurozonaria chondrotus (NOREM):MADLER,1963. p.331.
Tasmanites globulus (O.WETZEL):MORGENROTH,1966b. p.41,pl.11,figs.8-10.

Description

Cyst spherical. Wall relatively thick and elastic. Exterior surface relief strong, consisting of numerous, closely spaced, hemispherical protuberances. The walls are pierced by a large number of cylindrical radial pore canals of a single type, each of which appears to reach the exterior surface at the summit of a protuberance. They all traverse the entire thickness of the wall. The protuberances and pore canals are arranged regularly at the corners of equilateral triangles. This produces a regular hexagonal pattern over the cyst surface and gives the apparent prismatic structure of Tytthodiscus, which is unlike the random distribution of tubercles in Crassosphaera digitata COOKSON & MANUM 1960. Internally the wall is smooth but sometimes has a number of curious low protuberances of unknown function, none of which bear pore canals.

Remarks

This species shows similarities with several related forms. Crassosphaera digitata COOKSON & MANUM possesses similar protuberances and wall thickness/cyst diameter ratios, but the former are distributed irregularly. Tytthodiscus schandelahensis (THIERGART, 1944) has no protuberances and more closely spaced pores. T.suevicus var. macroporus EISENACK (1957) and Pleurozonaria spongiosa MADLER (1963) show a similar distribution of pores but no protuberances. Pleurozonaria globulus O.WETZEL (1933) is poorly figured. The surface ornamentation cannot be made out in O.WETZEL's (1961) illustrations, but MORGENROTH's (1966b) figures and description correspond exactly with the Bartonian form. Whether T.chondrotus and Pleurozonaria globulus are synonymous is not certain.

NOREM's type level for this species is the Miocene of California. MORGENROTH (1966b) describes P.globulus from the Lower Eocene of North

Germany. At Barton this species is one of the commonest of the Tasmanitids. It occurs throughout the section but most commonly in the estuarine Upper Barton Beds.

****

Order: LEIOSPHAERIDIALES (EISENACK,1958) MADLER,1963

Genus: Leiosphaeridia EISENACK, 1958

(Type species: Leiosphaeridia baltica EISENACK, 1958.)

Leiosphaeridia ralla FELIX, 1965

Plate 6, fig. 2.

Description

Cyst flattened, discoidal but probably originally spherical. Wall very thin, elastic and granular in surface texture. Wall corrugated into numerous, irregularly distributed folds. Pore canals and apertures are not visible.

Remarks

The material shows all the characteristics of the genus. MADLER (1963) erects the genus Campenia to include specimens whose aperture is a split. However, this taxon is invalid since his publication is not freely available. The features of the Bartonian specimens agree well with the published description and figure, whoseprovenance is the Upper Miocene of South Louisiana. It appears rarely in the Lower Barton Beds of both localities and also in the Middle and Upper Barton Beds of Alum Bay.

****

Leiosphaeridia sp.2.

Plate 6, figs. 3a, b.

Description

Cyst saucer or "squashed flask" shaped. Wall relatively thin, questionably double layered and wine red in colour. Scattered, rare canals pass through the entire thickness of the wall. One specimen shows a broad, almost circular opening on a low neck, possibly the "pylome" of EISENACK.

emarks

The morphology of this form is typical for the genus, but the specific placing of the rare specimens from Barton and Alum Bay is obscure. ISENACK (1954) figures Leiosphaera granulata and Leiosphaera cf.solida having circular apertures of "pylomes" but these are thin walled, alaeozoic species and do not have the "squashed flask" shape or the large aperture of the Bartonian species.

****

Leiosphaeridia? sp.3

Plate 6, figs. 4a, b, c, d.

escription

Cyst spherical, brittle. Wall relatively thin and appearing glossy in broken fragments. In optical section numerous fine canals are visible running from the inner surface to about a third of the way outward, where they terminate along a slightly undulating line. The outer half of the wall is faintly laminar in structure. Observation under crossed polaroids shows the "Maltese Cross" as does all other Tasmanitids examined.

emarks

It was impossible to compress specimens for satisfactory examination indeed only a few remained unbroken after mounting. The acid soluble nature of this form raised strong doubts as to its affinities and it was only after careful treatment in very dilute hydrochloric acid that its structure was understood. The interior of most specimens is occupied by a white amorphous powder and this was the first to react with dilute acid, indicating its probable carbonate composition and possible secondary nature. The inner part of the wall then slowly dissolved without effervescence. All that was finally left was the extremely thin, flexible and easily broken outer membrane.

The bulk of the inner wall is composed of either an organic or an inorganic material. The latter case would indicate some kind of secondary deposition, the "canals" being formed accidentally. In this case the presence of the insoluble outer membrane alone would suggest the species' affinity with the Leiosphaeridiales. Other possible explanations of these problematical objects include an inorganic, perhaps volcanic origin, which may be ruled out by their acid soluble nature; or that they may represent some kind of invertebrate egg case. Without the application of microchemical tests this cannot be ruled out, so until this work has been done they are tentatively placed in the genus Leiosphaeridia.

They occur sporadically throughout the Barton Beds in both sections and have been noted in formations above and below.

****

Leiosphaeridia sp.5

Plate 6, fig. 6.

Description

Cyst lanceolate, flattened, shaped like a flattened sphere or disc folded along its diameter. Wall relatively thick and elastic, with an orange or brown coloration. Surface smooth and wall devoid of canals.

Remarks

The folded disc shape and the thick wall are very distinctive in specimens from the Lower and Middle Barton Beds of Alum Bay. It does not fit any described form. MADLER's (1963) genus Lancettopsis differs in being thinner walled and having a double leaf shaped cyst in which two inner sacs have their long axes at an angle.

****

Genus: Pterospermopsis W.WETZEL 1952

(Type species: Pterospermopsis danica W.WETZEL,1952.)

Pterospermopsis sp.cf. P.danica W.WETZEL 1952.

Plate 6, fig. 5.

Incertae sedis - Type specimen No.2 PASTIELS,1948. p.59,pl.6,figs.33,34.
?Pterospermopsis danica W.WETZEL,1952. p.412,pl.A,fig.16;text-fig.34.
Pterospermopsis barbarae GORKA,1963. p.74,pl.11,fig.3.

Pterospermopsis cf. danica W.WETZEL: MORGENROTH,1966b. p.40,pl.11,fig.2.
Pterospermopsis danica W.WETZEL: DRUGG,1967. p.34,pl.6,fig.10.

Description

The cyst consists of a central spherical, ovoid or saucer-shaped body surrounded by a thin conico-annular equatorial skirt. The central body is wine red in colour, appearing solid in some specimens and thin walled in others. The walls have a slightly granular surface texture and contain rare canals which pass completely through. The skirt is also faintly granular and is thrown into a number of pleats, perpendicular to the central body, at its ring of attachment.

Remarks

The red coloration might indicate a reworked provenance but several authors (MORGENROTH, GORKA) mention this and it may be a primary characteristic. W.WETZEL's type level for this species is the Danian of North Germany. MORGENROTH places his material, from the German Lower Eocene, in open nomenclature, and, as his description and figures fit the English material very well, and as W.WETZEL'S figures are not entirely clear, it is thought advisable to do the same. PASTIELS figures a form from the Belgian Lower Eocene which corresponds closely to the English specimens, and he mentions the rare canals. GORKA's P.barbarae, with its ellipsoidal central body, is considered to fall within the range of variation of this species. She reports it from the Campanian of Poland. DRUGG's figure and description, from the Maestrichtian and Danian of California, also correspond well. At Barton P.cf.danica occurs sporadically in the Lower Barton Beds and commonly in a zone half-way up the Middle Barton Beds. It was found throughout the Alum Bay section in small numbers.

****

4:1:3 Incertae Sedis

Genus: Oudhkusumites SRIVASTAVA 1967

(Type species: Oudhkusumites ankleshvarensis SRIVASTAVA, 1967.)

Oudhkusumites sp. cf. O. foveolatus SRIVASTAVA, 1967

Plate 6, figs. 7a, b.

? Oudhkusumites foveolatus SRIVASTAVA, 1967. p.40,pl.1,figs.17,18.

Description

Disc shaped, with a rounded triangular to roughly circular outline. Slightly sinuous, internal fingerlike structures radiate from a pyrite filled central zone. The fingerlike structures are either expanded or rectangular at the periphery and bear a narrow, central, longitudinal canal. A narrow clear zone follows the periphery. One specimen is full of large and small vacuoles.

Remarks

SRIVASTAVA (1967) places this genus in the Incertae Sedis and suggests that they are not algal or fungal in origin. They range from Eocene to Miocene in several parts of India. The specimens found correspond with the published figures and description but the obscure internal zonation precludes definite designation above generic level.

****

Incertae Sedis sp.1.

Plate 6, fig.10.

Problematicum B. MORGENROTH, 1966b. p.42,pl.11,fig.12.

Description

Object approximately globular, consisting of a three dimensional network of fine, black, shiny, apparently carbonaceous rods, of roughly uniform thickness. The rods are straight or curved and are arranged in such a way as to suggest that the object originally consisted of a cluster of 20-30 slightly different sized (completely randomly orientated) spheres. Thus differentiation into anterior and posterior parts or inner and outer layers is completely absent.

Remarks

Only three specimens have been found of this object, all from the Middle Barton Beds. The only reference to it in the literature is by MORGENROTH (1966), who reports it from the Lower Eocene of North Germany.

If the deduction that it originally consisted of a cluster of spherical bodies is correct this species then shows a resemblance to the genus *Palambages* O.WETZEL (1961). The affinities of *Palambages* are still not certain but suggestions include the egg-clusters of marine copepods, and, more likely, colonial green algae (O.WETZEL (1961)). A relationship with certain recent freshwater *Volvoceae* was suggested by GORKA (1963), perhaps with less specialised forms such as *Pandorina*, rather than *Volvox s.s.* MANUM & COOKSON (1964) suggest that the colonies should contain numbers of cells as powers of two (8, 16, 32, 64, etc.) in accordance with the theory of cell formation in these forms. The Bartonian material would tend to fall between one of these multiples but the actual number of original cells is very difficult to determine. All references to *Palambages* have been from the Upper Cretaceous or lowest Paleocene. (O.WETZEL (1961) - Upper Cretaceous of the Baltic; GORKA (1963) - Upper Cretaceous of Poland; MANUM & COOKSON (1964) - Lower Upper Cretaceous of Arctic Canada; DRUGG (1967 - Upper Cretaceous and Danian of California).

****

Incertae Sedis sp.2

Plate 6, fig.9.

Description

Object hollow, thin walled, barrel-shaped and inaperturate. A small number of canals can be seen cutting the walls and the surface is finely granular. The rims of the "barrel" are delimited by folds in the wall. Additional sculpture and ornamentation is not visible.

Remarks

The affinities of this object are not known. Only a single specimen has been found in the Upper Beds of Barton (sample 6968).

****

Incertae Sedis sp.3

Plate 6, figs.8a,b.

Description

Object plano-convex, solid, yellow-orange in colour and oval in outline. One end is irregularly pitted by a number of almost globular depressions, three of which extend about one third of the way into the length of the object. Also opening at the same end are two hollow cylindrical canals, which, branching dichotomously, penetrate nearly to the other end of the object. The inner reaches of the canals are pyrite infilled and have the same diameter as at the open end. The convex surface bears a regular pattern of what looks like small, similar sized scales. These have their rounded endges towards the open end of the object and taper the other way until they are overlapped by those behind and to the sides. Close observation shows that they are not scales but shallow depressions, the margins of the shield like areas being delimited by the low, sharp ridges between the depressions.

Remarks

This object, of which only one specimen has been found (sample 6989, Upper Barton Bed), is of completely unknown affinities.

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Section 4:2 FORAMINIFERIDA

Introduction

With one exception all generic and suprageneric determinations adopted in this study are those laid out by LOEBLICH & TAPPAN (1964) in the "Treatise of Invertebrate Paleontology". Nummulites, which COLE in LOEBLICH & TAPPAN (1964) considers to be a junior synonym of Camerina BRUGUIERE, is here kept as a valid genus. All original descriptions were checked from ELLIS & MESSINA's (1948 et seq.) "Catalogue of Foraminifera".

****

Order: FORAMINIFERIDA EICHWALD 1830

Suborder: TEXTULARIIDA DELAGE & HEROUARD 1896

Superfamily: AMMODISCACEA REUSS 1862

Family: SACCAMMINIDAE BRADY 1884

Genus: Psammosphaera SCHULZE 1875

(Type species: Psammosphaera fusca SCHULZE, 1875)

Psammosphaera? sp.2.

Plate 7, figs. 1a,b.

Description

Test minute, unilocular, tyre shaped, with a smoothly circular or slightly oval outline and with both faces broadly depressed, leaving a raised rim. Wall thick, coarsely agglutinated, with little cement. Aperture not visible.

Remarks

This species, whose true generic placing remains obscure, was encountered rarely in the Lower Barton Beds at Barton. TEN DAM (1944) figures a similar form from the Paleocene of the Netherlands, as Proteonina complanata (FRANKE, 1912). It differs from the Bartonian specimens in having an aperture on a short neck.

Family: AMMODISCIDAE REUSS 1862

Genus: Glomospirella PLUMMER 1945

(Type species: Glomospira umbilicata CUSHMAN & WATERS, 1927.)

Glomospirella sp.1.

Plate 7, fig.2.

Description

Test small, disc-shaped and non-septate. The initial one or two whorls are streptospirally coiled and thereafter planispiral, evolute, with the whorl height increasing gradually with growth. Wall thin, finely agglutinated and frequently deformed. Aperture large, simple and basal.

Remarks

There are several North West European Lower Tertiary records of Ammodiscus which resemble the Bartonian species. KAASSCHIETER (1961) figures A. incertus (D'ORBIGNY) and records it from the Ypres Clay to the Ledes Sand of Belgium. His figures differ from Glomospirella sp.1 in being more regularly coiled and in lacking the initial streptospiral portion. Glomospirella woodi HAYNES (1958b), from the Thanet Sands of Kent, has a much larger streptospiral stage and a laterally more inflated test. Glomospirella kugultinskensis SUBBOTINA (1958), from the Upper Eocene of the Northern Caucasus, has a large planispiral stage. The initial stage, however, is larger and more inflated laterally than the Bartonian species. G. sp.1 occurs sporadically throughout the Barton Beds at both localities.

****

Superfamily: LITUOLACEA DE BLAINVILLE 1852

Family: HORMOSINIDAE HAECKEL 1894

Genus: Reophax MONTFORT 1808

(Type species: Reophax scorpiurus MONTFORT, 1808.)

Reophax sp.1.

Plate 7, figs. 3,4.

Description

Test small, very coarsely agglutinated of quartz grains, with sparse cement. The two or three chambers are uniserially and rectilinearly arranged, slightly inflated equatorially and separated by slight constrictions, though without visible sutures. Aperture roughly circular and terminal on a short, indistinct neck.

Remarks

Because this species is coarsely agglutinated and sparsely cemented, only poorly preserved specimens occur. Usually, only single, broken chambers were recovered. In well preserved specimens small and large quartz grains can be observed making up the wall in an irregular mosaic with small sponge spicules. Variation in chamber size is considerable but the wall structure and chamber shape are distinctive. The species occurs throughout most of the Barton Beds at Barton and Alum Bay. It has also been recovered from the Upper Bracklesham Beds and the English Oligocene.

Thurammina glabra TEN DAM (1944), from the Lutetian of the Netherlands and Hormosina sp. HAYNES (1958b), from the Thanetian of Kent, are the only two North West European Tertiary records of related species. Both are apparently unilocular, much smoother and more finely agglutinated than Reophax sp.1.

****

Family: LITUOLIDAE DE BLAINVILLE 1825

Genus: Cribrostomoides CUSHMAN 1910

(Type species: Cribrostomoides bradyi CUSHMAN, 1910.)

Cribrostomoides pauperata (CHAPMAN)

Plate 7, figs. 5a,b, 6, 7.

Haplophragmium canariense D'ORBIGNY var. pauperata CHAPMAN, 1913. p.556, figs. 1-4.
Lituola simplex CHAPMAN: CHAPMAN, 1913. p.556, figs. 7,8.
Trochammina inflata MONTAGU var. macrescens BRADY: CHAPMAN, 1913. p.557, figs. 5,6.

Remarks

As CHAPMAN (1913) found, this species is frequently crushed and distorted. Undistorted specimens are characteristically planispiral, having four or five low, inflated chambers in the last whorl, with slightly depressed sutures and fine or occasionally coarsely agglutinated walls. The single or multiple slit-like areal aperture, situated just above the base of the apertural face, indicates that it belongs in the genus Cribrostomoides, not Haplophragmoides.

The often abundant material from Barton and Alum Bay compares exactly with topotype material from the Barton Beds of Hengistbury Head. The forms figured by CHAPMAN as Lituola simplex and Trochammina inflata var. macrescens are probably extremely distorted specimens of C.pauperata.

This species differs from Cribrostomoides sp.3 in having fewer (4 to 5, not 6 to 9) and more inflated chambers in the last whorl. It also resembles a form from the Ypres Clay figured as Cribrostomoides sp. by KAASSCHIETER (1961, pl.1,fig.4). The Oligocene species C.latidorsatus (BORNEMANN) (Septaria Clay of Germany), figured by BATJES (1958) from the Belgian Boom Clay, differs in having nearly flush sutures and more chambers per whorl. Specimens recovered from the Middle Headon Beds of Colwell Bay may be referrable to C.latidorsatus. Another closely related species is Haplophragmoides burrowsi, HAYNES (1958b) from the Thanet Sands. This differs in its greater lateral compression, faster increase in chamber size and in its somewhat coarser agglutination.

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Cribrostomoides sp.3

Plate 7, figs. 8a,b.

Description

Test minute, planispiral, laterally compressed, involute, finely agglutinated, with six to nine chambers in the final whorl. The chambers are generally low unless distorted (as in figured specimen). Periphery rounded, slightly lobulate with only slightly depressed, radial sutures. Umbilici open, aperture areal and low on the apertural face.

Remarks

C.sp.3 is restricted to the upper Middle and Upper Barton beds at both localities. It differs from C.pauperata in having more chambers per whorl and from the Oligocene form C.latidorsatus in its greater compression and number of chambers. Trochamminoides sp. HAYNES (1958b), from the English Thanetian, is more evolute and apparently torchospiral.

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Genus: Ammobaculites CUSHMAN 1910

(Type species: Spirolina agglutinans D'ORBIGNY, 1846.)

Ammobaculites sp.1.

Plate 7, figs. 9a,b, 10.

Description

Test small, laterally expanded and coarsely agglutinated, with sparse cement. Initial stage planispiral, involute, with small umbilici. The final one or two chambers are unrolled and uniserial. Chambers high and short but not inflated. Sutures indistinct and slightly depressed. Aperture simple, irregular and terminal.

Remarks

The coarsely agglutinated wall structure and broad test is characteristic of this form. The wall sometimes bears large sand grains interspersed with the smaller grains. In some specimens the coarseness of the agglutination increases with development. The uniserial portion is usually relatively short but occasionally the reverse is found. It occurs rarely throughout both sections.

BOWEN (1957) records Ammobaculites agglutinans (D'ORBIGNY, 1846) (Miocene, Vienna Basin) from Barton but does not figure it. A.agglutinans has been noted by several authors in the North West European Tertiaries, including BHATIA (1955) (Upper Hamstead Beds) and VAN BELLEN (1946) (Dutch Montian). It differs from Ammobaculites sp.2 in having a shorter uniserial portion and being more coarsely agglutinated. A.praelonga TEN DAM (1944) (Dutch Lower Eocene) differs in having a much longer unwound portion and only four globular, planispiral chambers.

****

Ammobaculites sp.2.

Plate 7, figs. 11,12.

Description

Test small, coarsely agglutinated and laterally considerably compressed. Initial stage planispiral, slightly evolute, the last of four or five high chambers with flush, very indistinct sutures. Adult stage uniserial, long, with short, broad chambers and sutures which are slightly indented at the periphery but otherwise very indistinct. Aperture elongate, simple and terminal on a slight neck.

Remarks

The characteristic lateral compression is not thought to be due to deformation of the test. The long uniserial portion and its distinctive short, wide chambers enable differentiation from Ammobaculites sp.1. Usually only broken uniserial and planispiral portions are preserved and the species occurs, not commonly, throughout both sections. A specimen from the Barton Beds of Hengistbury Head is a more coarsely agglutinated variant (plate 7, fig.12).

KAASSCHIETER (1961) figures a compressed form from the Lower Eocene of the Netherlands as Ammobaculites sp. cf. A.americanus CUSHMAN (Recent, Mexico). It differs from Ammobaculites sp.2 in lacking a long uniserial portion and in being composed of very irregular grains.

****

Family: TEXTULARIIDAE EHRENBERG 1838

Genus: Textularia DEFRANCE 1824

(Type species: Textularia sagittula DEFRANCE, 1824.)

Textularia?sp.1.

Plate 7, fig. 14.

Description

Test small, finely agglutinated and apparently biserial throughout. Sutures indistinct and chambers slightly inflated along most of the test. Final two chambers considerably larger and inflated. Aperture broken.

Remarks

The incomplete preservation of the only specimen found (sample 6909, Barton Beds, Barton) preclude an examination of the initial stages and a definite generic placing. The two large final chambers distinguish it from either of the Bartonian species of Gaudryina.

****

Family: TROCHAMMINIDAE SCHWAGER 1877

Genus: Trochammina PARKER & JONES 1859

(Type species: Nautilus inflatus MONTAGU, 1808.)

Trochammina sp.1.

Plate 7, figs. 13a,b,c.

Description

Test minute, finely agglutinated, low trochospirally coiled, with four or more, usually five, chambers in the final whorl. Dorsal side evolute, flat or slightly domed, with up to two whorls visible. Dorsal sutures distinct, slightly depressed and inclined backwards. Ventrally the chambers are inflated in undeformed specimens, with incised, radial sutures and a deep umbilicus. Outline slightly lobulate, periphery subacute but not carinate. Aperture basal and interiomarginal beneath a narrow flap.

Remarks

Distortion often causes dorsoventral compression and the trochospiral coiling is then the only distinguishing feature from crushed Cribrostomoides pauperata. It occurs sporadically throughout the Barton Beds. Trochammina pentagona HAYNES (1958b), from the Thanetian of Kent, is superficially similar but differs in having a non-lobulate, pentagonal outline, dorsally radial sutures and is ventrally much more compressed.

****

Family: ATAXOPHRAGMIIDAE SCHWAGER 1877

Genus: Verneuilina D'ORBIGNY 1839

(Type species: Verneuilina tricarinata D'ORBIGNY, 1840.)

Verneuilina sp.1.

Plate 7, fig.15.

Description

Test minute, finely agglutinated, with rare larger grains. Coiling triserial throughout. Sutures nearly flush but distinct. The test has three strong longitudinal ridges separating flat faces, giving a high pyramidal shape. Apertural face flat and inclined. Aperture a simple, high, loop-shaped arch on the basal structure.

Remarks

This species occurs quite commonly in the basal Barton Beds at Barton but very rarely above. It differs from Verneuilina sp. HAYNES (1958b) in its three sharp longitudinal ridges. No species described in CUSHMAN's (1937) monograph on the "Verneuilinidae" could be matched with the Bartonian form.

****

Genus: Gaudryina D'ORBIGNY 1839

(Type species: Gaudryina rugosa D'ORBIGNY,1840.)

Gaudryina sp.1.

Plate 7, figs. 16, 17.

Virgulina subsquamosa CHAPMAN,1913. (non EGGER,1857.) p.558,fig.9.

Description

Test minute, elongate, finely agglutinated, with rarer larger grains. It tapers gradually for 2/3rds of its length and is nearly parallel sided in the adult 1/3rd. Initial 1/6th triserial, with a subcircular or rounded-triangular cross section and slightly depressed, rather indistinct sutures. Adult 5/6ths biserial, oval in cross section, with slightly inflated, elongate chambers and depressed sutures backward inclined.

Aperture not visible (usually broken off).

Remarks

Gaudryina sp.1 occurs commonly in the Lower Barton Beds at Barton and Alum Bay and rarely in the Middle Barton Beds. In the Barton Beds of Hengistbury Head it is frequent and well preserved. CHAPMAN (1913), erroneously described it from this locallity as Virgulina subsquamosa.

****

Gaudryina sp.2

Plate 7, figs.18,19.

Description

Test minute, elongate and finely agglutinated. Very short (1/6th) initial stage triserial, with sharp angles, giving a characteristic broad, pyramidal apex. Adult stage (5/6ths) biserial, with depressed, indistinct sutures and slightly inflated, elongate chambers. Apertural face rounded, aperture a simple arch on the basal suture.

Remarks

This species is often distorted and occurs frequently in the Lower and Middle Barton Beds at both localities. It differs from Gaudryina sp.1 in its strongly pyramidal initial stage. The theory that Gaudryina sp.2 and Verneuilina sp.1 are two variants of a single species is refuted by the fact that the latter species is always considerably longer and forms a more acute pyramid than the triserial portion of G.sp.2.

Gaudryina subquadrata CUSHMAN (1933) (Eocene, South Carolina) and G.trinitatensis NUTTALL (1928) (Miocene, Trinidad, California) are considerably larger and less slender than the Bartonian species. G.gracilis CUSHMAN & LAIMING (1931) (Miocene, California) has more irregular chambers.

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Suborder: MILIOLINA DELAGE & HEROUARD 1896

Superfamily: MILIOLACEA EHRENBERG 1839

Family: FISCHERINIDAE MILLETT 1898

Genus: Cyclogyra WOOD 1842

(Type species: Cyclogyra multiplex WOOD, 1842.)

Cyclogyra bornemanni (REUSS)

Plate 8, figs. 1a, b.

Cornuspira bornemanni REUSS, 1863. p.39,pl.1,fig.3. (Oligocene,Germany).
Cornuspira bornemanni REUSS:KAASSCHIETER,1961. p.136,pl.1,fig.2. (Sands of Ledes and Wemmel, Belgium).

Remarks

This species is usually restricted at Barton and Alum Bay to the upper part of the Middle Barton Beds. It is characterised by its high tube and the presence of growth lines. The carina mentioned by KAASSCHIETER (1961) was not observed.

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Family: NUBECULARIIDAE JONES 1875

Genus: Spiroloculina D'ORBIGNY 1826

(Type species: Spiroloculina depressa D'ORBIGNY,1826.)

Spiroloculina? sp.1

Plate 8,figs. 2a,b.

Description

Test small, slightly compressed and oval in outline. Coiling apparently spiroloculine but the final two chambers are embracing, obscuring the umbilici. Peripherally the chambers are rounded, with up to five strong longitudinal costae. Aperture narrow and high, with a spike-like tooth.

Remarks

This species is represented by a single broken specimen, from the Middle Barton Beds of Barton (sample 6950). The generic placing must remain in doubt owing to the obscured umbilici, but its septate test rules out its placing in Vertebralina. Of the involute Eocene species of

Spiroloculina figured by KAASSCHIETER (1961) and LE CALVEZ (1947) the S.costigera TERQUEM group bears two or three strong, peripheral, flange-like carinae. The S.tricarinata TERQUEM group has a distinctive dumbell shape in apertural view; features which the Bartonian specimen lacks. The possibility remains that it is an irregularly coiled specimen of Quinqueloculina bicarinata.

****

Family: MILIOLIDAE EHRENBERG 1839

Genus: Quinqueloculina D'ORBIGNY 1826

(Type species: Serpula seminulum LINNE,1758.)

Quinqueloculina seminulum (LINNE)

Plate 8, figs. 3a,b, 4a, b.

Serpula seminulum LINNE,1758. p.786, (Recent, Adriatic).
Quinqueloculina laevigata D'ORBIGNY,1839. (non DESHAYES,1831.) p.143,pl.3, figs.31-33. (Eocene,Paris Basin;Recent,Canary Is.)
Quinqueloculina aknerlana D'ORBIGNY,1846. p.290,pl.18,figs.16-21. (Miocene, Vienna Basin.)
Quinqueloculina laevigata D'ORBIGNY:TERQUEM,1882. p.173,pl.18,figs.14,15.
Miliolina seminulum (LINNE):SHERBORN & CHAPMAN,1886. p.742,pl.14,fig.1. (London Clay, England.)
Quinqueloculina laevigata D'ORBIGNY: LE CALVEZ,1947.p.11 (Lutetian,Paris Basin.)
Quinqueloculina aknerlana D'ORBIGNY:MARKS,1951. p.38.
Quinqueloculina aknerlana D'ORBIGNY:BOWEN,1954. p.158,pl.B,figs.11,12. (London Clay, England.)
Quinqueloculina seminulum (LINNE):BHATIA,1955. p.674,pl.67,fig.8. (Oligocene, Isle of Wight.)
Quinqueloculina aknerlana D'ORBIGNY:BOWEN,1957. p.56.(Barton Beds,Barton.)
Quinqueloculina seminulum (LINNE):BATJES,1958.p.102,pl.1,fig.15. (Oligocene,Belgium.)
Quinqueloculina seminula (LINNE):KAASSCHIETER,1961.p.147,pl.2,figs.5,6. (Lr.Eocene - Asse Clay, Belgium, France. Up.Eocene,England.)

Remarks

This common and widely distributed species (Lower Eocene to Recent) is characterised by its longer than broad, unornamented test, with a rounded to subacute periphery and no apertural neck. Ornamented forms and forms with peripheral carinae are separated as Q.costata KARRER and Q.bicarinata D'ORBIGNY, the latter sometimes showing intermediates with this form. Q.ludwigi REUSS is distinguished by its apertural neck and more incised sutures, but juveniles are sometimes hard to differentiate from Q.seminulum.

The author agrees with KAASSCHIETER (1961) in listing Q.akneriana D'ORBIGNY and Q.laevigata D'ORBIGNY as synonyms of LINNE's species. DESHAYES (1831) originally placed the latter in Miliola LAMARCK. TEN DAM's (1944) figure of Q.laevigata from the Bartonian of the Netherlands appears to be an intermediate with Q.bicarinata.

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Quinqueloculina bicarinata D'ORBIGNY

Plate 8, figs. 7, 8.

Quinqueloculina bicarinata D'ORBIGNY,1826. p.302,modele no.35.
Quinqueloculina bicarinata D'ORBIGNY:TERQUEM,1878. p.68,pl.7,fig.10. (Recent, Italy.)
Quinqueloculina bicarinata D'ORBIGNY:CUSHMAN,1945. p.16,pl.2,fig.9;pl4,fig.2. (et syn.)
?Quinqueloculina bicarinata D'ORBIGNY:BOWEN,1957. p.56 (Barton Beds, Barton.)
Quinqueloculina bicarinata D'ORBIGNY:KAASSCHIETER,1961. p.149,pl.2,figs.12,13. (et syn.) (Sands of Wemmel,Belgium.Bartonian,England.)

Remarks

Adults characteristically show the double peripheral keep, often with additional, longitudinal, striate ornament on the chamber faces. The cross sectional shape serves to distinguish it from Q.seminulum and Q.costata. Juveniles are frequently unicarinate and distinction from Q.sp.aff.Q.carinata is difficult. The lack of striations and the straight, rather than sinuous edges of the chambers are good guides.

At Barton this species is restricted to and abundant in the upper part of the Middle Barton Beds. At Alum Bay it also occurs rarely in the Lower Barton Beds. KAASSCHIETER (1961) found Q.bicarinata restricted to the Upper Eocene and only distinctive in the English Barton Beds. BHATIA's (1955) figures of this species are considerably shorter and broader than the Bartonian material and more closely resemble Q.sp.12.

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Quinqueloculina sp.aff. Q.carinata D'ORBIGNY

Plate 8, figs. 5a,b, 6a, b.

aff. Quinqueloculina carinata D'ORBIGNY,1850. p.410 (Eocene,Paris Basin.)
aff. Quinqueloculina carinata D'ORBIGNY:KAASSCHIETER,1961. p.148,pl.2, figs.9-11. (et syn.) (Lutetian-Asse Clay,Belgium & France.Barton Beds, England).

Remarks

The characteristic features of this rather small form (up to about 600 microns in length) are the smooth chambers, with very acute, sinuous edges. It is never bicarinate, thus differing from Q.bicarinata, never as peripherally rounded as Q.seminula or Q.ludwigi and considerably shorter and broader than the latter. The possibility of its relationship with Q.bicarinata as a juvenile variant is precluded by their percentage distribution peaks being out of phase. It differs from the typical Q.carinata as figured by KAASSCHIETER (1961), in its higher length/width ratio, more irregular chamber shape and smaller maximum size. Some of KAASSCHIETER's records of Q.carinata from Barton may be referrable to Q.bicarinata.

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Quinqueloculina costata KARRER

Plate 9, figs. 5a, b.

Quinqueloculina costata D'ORBIGNY,1826. p.135 (nom.nud.)
Quinqueloculina costata KARRER,1867. p.362,pl.3,fig.4. (Neogene,Rumania.)
Quinqueloculina costata D'ORBIGNY:TERQUEM,1878. p.63,pl.6,figs.3-5. (Pliocene, Rhodes.)
Quinqueloculina costata D'ORBIGNY:TERQUEM,1882. p.183,pl.20,figs.8,9. (Eocene,Paris Basin.)
Quinqueloculina costata D'ORBIGNY:LE CALVEZ,1947. p.9.(Lutetian,Paris Basin.)
Quinqueloculina costata KARRER:KAASSCHIETER,1961. p.150,pl.2,figs.17-19. (Lutetian - Asse Clay, Belgium and France. Barton Beds,England.)

Remarks

Bartonian specimens have more or less rounded, sometimes subquadrate, chamber peripheries as noted by KAASSCHIETER (1961), but they never resemble Q.juleana D'ORBIGNY. Longitudinal striations cover the whole test and are coarser along the chamber edges, where they are sometimes reduced to three or four sharp costae. This positive sculpture differentiates it from

from French Lutetian species with negative ornamentation, such as Q.crassa D'ORBIGNY and Q.crassicosta TERQUEM. In the middle part of the Middle Barton Beds Q.costata occurs abundantly and is one of the largest Foraminiferida found at Barton (up to 2 mm. in length).

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Quinqueloculina impressa REUSS

Plate 9, figs. 1a,b, 2a,b.

Quinqueloculina impressa REUSS,1851. p.87,pl.7,fig.59.(Oligocene,Germany.)
Quinqueloculina cognata BORNEMANN,1855. p.349,pl.19,fig.7.(Oligocene,Germany.)
Quinqueloculina impressa REUSS var.cognata BORNEMANN:BHATIA,1955.
p.671,pl.67,fig.10. (Brockenhurst Bed, Lr.Oligocene,Isle of Wight.)
Quinqueloculina impressa REUSS var.cognata BORNEMANN:BOWEN,1957.
p.56, (Barton Beds, Barton.)
Quinqueloculina impressa REUSS:BATJES,1958. p.103,pl.1,fig.13.
(M. and Up. Oligocene, Belgium and Germany.)
Quinqueloculina impressa REUSS:KAASSCHIETER,1961. p.151,pl.3,figs.4-6.
(Lr.Eocene-Asse Clay,Belgium, Netherlands.London Clay,Bartonian,Englan.)

Remarks

A common, widely distributed form with a distinctive short, broad outline, slightly depressed sutures and smooth, peripherally rounded chambers. The surface roughening and quartz agglutination mentioned by KAASSCHIETER and BHATIA was noted only in the largest specimens. The variety cognata BORNEMANN, referred by various authors to a form with a more rounded periphery, intergrades completely with the typical form.

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Quinqueloculina impressa REUSS var.1

Plate 9, figs. 3a, b, 4a, b.

Remarks

The deeply incised sutures distinguish this form from the typical Q.impressa, which it otherwise resembles in height/width ratio and lack of ornamentation. The chambers are sometimes flattened or nearly subquadrate at the periphery and the aperture is everted into a narrow lip, features not present in the typical form. Intermediates occur uncommonly and it ranges concurrently with Q.impressa in the Middle Barton Beds and Upper Bracklesham Beds. Q.ludwigi differs in being considerably longer and no gradation was observed with *Q.impressa var.1* SHERBORN & CHAPMAN's (1886) figure of *Q.circularis* (BORNEMANN,1855) (Oligocene, Germany), from the London Clay, closely resembles the Bartonian material.

****

Quinqueloculina juleana D'ORBIGNY

Plate 8, figs. 9a,b.

Quinqueloculina juleana D'ORBIGNY,1846. p.298,pl.20,figs.1-3.
(Miocene,Vienna Basin.)
Quinqueloculina juleana D'ORBIGNY:BHATIA,1955. p.672,pl.67,fig.9;text-fig.3.
(Oligocene,Isle of Wight.)
Quinqueloculina juleana D'ORBIGNY:BOWEN,1957. p.57,pl.1,figs.18,19.
(Barton Beds, Barton.)
Quinqueloculina juleana D'ORBIGNY:BATJES,1958. p.103,pl.1,fig.16.
Quinqueloculina juleana D'ORBIGNY:KAASSCHIETER,1961. p.149,pl.2,figs.14,15.

Remarks

BHATIA's (1955) variation of this distinctive species was noted in the rare material from the Middle Barton Beds of Barton and Alum Bay. The peripherally quadrate, unornamented chambers distinguish it from all other species.

****

Quinqueloculina ludwigi REUSS

Plate 9, figs. 6a,b.

Quinqueloculina ludwigi REUSS,1866. p.126,pl.1,fig.12.(Oligocene,Germany.)
Quinqueloculina ludwigi REUSS:BATJES,1958. p.108,pl.1,fig.6.
Quinqueloculina ludwigi REUSS:KAASSCHIETER,1961. p.148,pl.2,figs.6,7.

Remarks

The deeply incised sutures, smooth peripherally rounded chambers and distinct neck distinguish adult specimens from *Q.seminulum*. Juveniles occur rarely and show intermediate morphology. *Q.aff.carinata* differs in having more angular chambers.

At Barton and Alum Bay *Q.ludwigi* occurs commonly in the Middle Barton Beds and rarely in the Lower Barton Beds. The form figured by BHATIA (1955) as *Q.sp.indet.* is possibly conspecific with *Q.ludwigi*. *Q.pertusa* TERQUEM (1882), figured by LE CALVEZ (1947) and BHATIA (1955) from the French Lutetian and the English Lower Oligocene respectively, closely resembles

Q.ludwigi in shape and neck but bears more or less regularly arranged pits. Q.lippa LE CALVEZ (1947) also has the same shape and neck, but has much more angular chambers.

****

Quinqueloculina sp.12.

Plate 8, figs. 10a,b.

?Quinqueloculina bicarinata BHATIA,1955. (non D'ORBIGNY,1826.) p.671,pl.67, fig.12. (Lr.Oligocene, England.)

Description

Test minute, short, broad and thick. Coiling quinqueloculine, sutures distinct and slightly depressed. The three final chambers have a characteristic broad carina, giving the peripheries a subquadrate appearance and the test a pentagonal cross-section. Aperture terminal, not on a neck and with a plate-like tooth.

Remarks

This species has been found only rarely in the Lower Barton Beds of Alum Bay. It very closely resembles BHATIA's (1955) figures of Q.bicarinata except that the latter have a definitely bicarinate periphery. They both differ from the typical Q.bicarinata in being much shorter and broader. Q.impressa has a similar shape but has a rounded perihpery.

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Genus: Triloculina D'ORBIGNY 1826

(Type species: Miliolites trigonula LAMARCK, 1804.)

Triloculina trigonula (LAMARCK)

Plate 10, figs. 1a, b.

Miliolites trigonula LAMARCK,1804. p.351.
Miliolites trigonula LAMARCK:LAMARCK,1807. pl.17,fig.4.(Lutetian,Paris Basin.)
Triloculina trigonula (LAMARCK):TERQUEM,1882. p.165,pl.17,fig.3.
Triloculina trigonula (LAMARCK):LE CALVEZ,1947. p.18.
Triloculina trigonula (LAMARCK):BHATIA,1955. p.675,pl.67,fig.15. (Lr. Oligocene, England)
Triloculina trigonula (LAMARCK):KAASSCHIETER,1961. p.164,pl.5,figs.8-10. (Lr.-Up.Eocene, Belgium; Bartonian,England.)
Triloculina trigonula (LAMARCK) var.inflata D'ORBIGNY:KAASSCHIETER,1961. p.165,pl.5,fig.11.

Remarks

A species occurring in small numbers in most Lower and Middle Barton Bed samples, usually only as small specimens. Most of them fall within D'ORBIGNY's variety inflata, as figured by KAASSCHIETER (1961), but more globose forms show all gradations with typical T.trigonula.

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Genus: Miliolinella WIESNER 1931

(Type species: Vermiculum subrotundum MONTAGU, 1803.)

Miliolinella oblonga (MONTAGU)

Plate 10, figs. 2a,b.

Vermiculum oblongum MONTAGU,1803. p.522,pl.14,fig.9.(Recent,England).
Miliolinella oblonga (MONTAGU):BHATIA,1955. p.671,pl.67,fig.17.
(Lr.Oligocene, England.)
Scutuloris oblonga (MONTAGU):BATJES,1958. p.105,pl.2,fig.1.
(M.Oligocene, Belgium.)
Miliolinella oblonga (MONTAGU):KAASSCHIETER,1961. p.152,pl.3,figs.7,8.
(Ledes Sand and Wemmel Sand,Belgium. Bartonian,England.)

Remarks

A rather variable species, in which two types of specimen occur in about the same proportions and within the same size range: one short and stout, the other more elongate and narrow.

As observed by KAASSCHIETER (1961) and BHATIA (1955) otherwise identical specimens may be either quinqueloculine or triloculine, with intermediates. Thus the genus Scutuloris LOEBLICH & TAPPAN (1953) is probably a junior synonym of Miliolinella.

At Alum Bay this species occurs in the Lower and Middle Barton beds and at Barton in the latter division. It has been observed in preceeding and later formations in the English Eocene and Oligocene. A more elongate form with a subrectangular outline and a short aboral spike was found in the Upper Hamstead Beds of the Isle of Wight and may represent a different species.

****

Genus: Fabularia DEFRANCE 1820

(Type species: Fabularia discolites DEFRANCE,1825 (= Nummulites ovata DE ROISSY,1805).)

Fabularia bella KAASSCHIETER

Plate 10, figs. 3, 4a, b.

Fabularia bella KAASSCHIETER,1961. p.167,pl.6,figs.1-6. (Sands of Ledes and Wemmel, Asse Clay, Belgium.)
Fabularia bella KAASSCHIETER:CURRY,1966. p.446, text-fig.3. (as above and Up.Bracklesham Beds, Huntingbridge Bed, Barton Beds,England.)

Remarks

A few specimens of this very rare species were recovered from the Middle Barton Beds of both sections and one from the Lower Barton Beds of Alum Bay. It was also encountered in the topmost Upper Bracklesham Beds of Studley Wood (the Huntingbridge horizon). They agree well with KAASSCHIETER's (1961) type figures, with their characteristic longitudinal internal partitions and biloculine (in adult), flattened test. The French Paris Basin Lutetian species F.ovata (DE ROISSY) differs in having a more globular test.

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Suborder: ROTALIINA DELAGE & HEROUARD 1896

Superfamily: NODOSARIACEA EHRENBERG 1838

Family: NODOSARIIDAE EHRENBERG 1838

Genus: Nodosaria LAMARCK 1812

(Type species: Nautilus radicula LINNE,1758.)

Nodosaria sp. cf. N.pyrula D'ORBIGNY

Plate 10, fig. 5.

?Nodosaria pyrula D'ORBIGNY,1826. p.253, modele No.13.
Nodosaria cf. pyrula D'ORBIGNY:BECK,1943. p.599,pl.105,figs.19,20. (Up.Eocene,Washington State.)

Remarks

A rare Middle Barton Beds species, whose smooth, similar, equatorially inflated chambers are separated by long necks. Broken single chambers are usually only recovered. It is quite distinct from all other Bartonian species of Dentalina and Nodosaria. It resembles N.longiscata (D'ORBIGNY,1846) (Miocene, Vienna Basin), recorded by SHERBORN & CHAPMAN (1889) and BOWEN (1954) from the English London Clay, and by TEN DAM (1944) from the Belgian Lower Eocene. The chambers of N.longiscata are much less constant in shape, with frequent, sudden constrictions.

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Nodosaria sp.3

Plate 10, fig.6.

Description

Test minute, uniserial and rectilinear. Chambers smooth and globular, with deeply incised sutures. Aperture terminal, entire, with a narrow, everted lip.

Remarks

A very rare species, occurring in the Middle Barton Beds at Barton. KAASSCHIETER's (1961) figures of Dentalina natchitochensis HOWE (Eocene, Louisiana), from the Dutch Lower Eocene, resemble the Bartonian species superficially but are very considerably larger.

****

Nodosaria sp.4

Plate 10, fig.7.

Description

Test minute, uniserial, rectilinear, with two chambers. Eight sharp, similar costae run the whole length of the test. Aperture terminal, broken.

Remarks

A single specimen was recovered from the Middle Barton Beds of Barton. It resembles KAASSCHIETER's (1961) and BATJES' (1958) figures of N.ludwigi REUSS 1866 (Oligocene, Germany) but is considerably smaller.

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Genus: Dentalina RISSO 1826

(Type species: Nodosaria (Dentaline) cuvieri D'ORBIGNY,1826.)

Dentalina sp.cf. D.ewaldi (REUSS)

Plate 10, fig.8.

?Nodosaria ewaldi REUSS,1851. p.58,pl.2,fig.2.(Oligocene,Germany.)
?Nodosaria ewaldi REUSS:BATJES,1958. p.117.(M.Oligocene,Belgium & Germany.)
Dentalina sp.cf.D.ewaldi (REUSS):KAASSCHIETER,1961. p.175,pl.7,figs.15,16.
(Lr.Eocene,Netherlands.Wemmel Sand,Asse Clay,Belgium

Remarks

A species which occurs in small numbers in the Middle and Lower Barton Beds of both sections and in the Chama Bed at Barton. It is usually represented by broken fragments of two or three slightly inflated, elongate chambers with slightly depressed sutures, and agrees fairly well with KAASSCHIETER's (1961) figures. Nodosaria cf. pyrula has drawn out necks between the chambers and Dentalina sp.2 and D.cf.inornata have shorter chambers with more oblique sutures.

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Dentalina inornata D'ORBIGNY

Plate 10, fig. 9.

Dentalina inornata D'ORBIGNY,1846. p.44,pl.1,figs.50,51.(Miocene,Vienna Basin.)
Dentalina inornata D'ORBIGNY:TERQUEM,1882. p.37,pl.1,fig.41.
Dentalina inornata D'ORBIGNY: LE CALVEZ,1952. p.39.
Dentalina inornata D'ORBIGNY: KAASSCHIETER,1961. p.176,pl.7,figs.18,19.
(Lr. - Up. Eocene, Belgium.)

Remarks

A rather variable species, with more or less oblique sutures, smooth, short, inflated chambers, a terminal and slightly offset stellate aperture and sometimes a short prolocular spike. Some megalospheric forms resemble Stilostomella elegans (D'ORBIGNY) (Miocene, Vienna Basin and Lr-Up. Eocene, in KAASSCHIETER,1961). Microspheric individuals are rather narrower in the initial stages than those figured by KAASSCHIETER. It occurs sporadically in the Lower and Middle Barton Beds of both sections.

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Dentalina sp.2

Plate 10, fig.10.

Description

Test minute, uniserial and nearly rectilinear. Chambers smooth, short and slightly inflated. Sutures distinct and slightly depressed. Final chambers inflated orally. Aperture stellate, on a short neck and set on the terminal face, slightly off-centre from the axis.

Remarks

Only the slight eccentricity of the aperture justifies placing this species in Dentalina instead of Nodosaria. It occurs rarely in the Lower Barton Beds of Alum Bay and the Middle Barton Beds of both section. It cannot be matched with any published species. The short chambers and slightly eccentric aperture distinguishes it from D.inornata and D.cf.ewaldi.

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Dentalina sp.4

Plate 10,fig.11.

Description

Test large, uniserial and curvilinear. Chambers elongate, smooth over most of their length, with incised sutures crossed by strong costae. The costae are restricted to the sutural regions. Aperture terminal, off-centre, stellate and drawn out into a neck.

Remarks

The material is restricted to rare specimens from the Middle Barton Beds of Barton and Alum Bay. Its costae and large size distinguishes it from all other Bartonian species of Dentalina and Nodosaria. It differs from the large, costate species described by KAASSCHIETER (1961) from the Lower Eocene and by BATJES (1958) from the Middle Oligocene in its elongate chambers and the restriction of the costae to sutural regions.

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Genus: Lagena WALKER & JACOBS 1798

(Type species: Serpula (Lagena) sulcata WALKER & JACOBS, 1798.)

Lagena globosa (MONTAGU)

Plate 10, fig.12.

Vermiculum globosum MONTAGU,1803. p.523. (Recent,England.)
Lagena vulgaris TERQUEM, 1882. (non WILLIAMSON) p.25,pl.1,fig.3. (Lutetian,Paris Basin.)
Lagena vulgaris var.oxystoma SHERBORN & CHAPMAN,1886. (non WILLIAMSON, non REUSS) p.774,pl.14,fig.15. (London Clay, England.)
Lagena vulgaris TERQUEM: LE CALVEZ,1952. p.39.
Lagena oxystoma SHERBORN & CHAPMAN: BOWEN,1954. p.142. (London Clay,England.)
Lagena globosa (MONTAGU):KAASSCHIETER,1961. p.179,pl.7,fig.27. (Lr-Up. Eocene, Belgium.)
non Lagena globosa SHERBORN & CHAPMAN,1886. p.744,pl.14,figs.11,12.

Remarks

The body of this species is characteristically almost globular, smooth and unornamented. Some specimens are slightly corroded, giving the body a hispid appearance. The neck is cylindrical and non striate. L.vulgaris WILLIAMSON (1858) is very different, with a much more elongate body. Raro occurrences at Barton and Alum Bay are from the Middle and Lower Barton Beds.

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Lagena sp.cf. L.hexagona(WILLIAMSON)

Plate 10, fig. 13.

?Entosolenia squamosa (MONTAGU) var.hexagona WILLIAMSON,1848. p.20,pl.2,fig.23. (Recent,England.)
?Lagena hexagona (WILLIAMSON):BOWEN,1954. p.143. (London Clay,England.)
Lagena squamosa (MONTAGU) var.hexagona (WILLIAMSON):BATJES,1958. p.118,pl.3, fig.9. (M.Oligocene,Germany.)
?Lagena hexagona (WILLIAMSON):HAYNES,1958b. p.72,pl.17,fig.8.(Thanetian,Kent.)
Lagena squamosa (MONTAGU) var.hexagona (WILLIAMSON): KAASSCHIETER,1961.p.179, (Lr.Eocene,Netherlands,M. & Up. Eocene, Belgium).

Remarks

A small, rather variable pear-shaped form, with reticulate or pustulose ornament and a circular aperture on a variably developed neck. Some specimens from the Middle Barton Beds of Barton have a very short neck and faint hexagonal ridges on the body. Specimens from the Middle Barton Beds of Alum Bay are more heavily pustulose and have a longer neck. Intermediates between these variants do occur. Another type from the Upper Bracklesham

Beds of Fawley, is larger, with an elongate, lipped aperture.

Published records of L.hexagona span a range from Upper Cretaceous to Recent.

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Lagena sp.cf. L.lagenoides (WILLIAMSON)

Plate 10, fig.14.

?Entosolenia marginata (WALKER& BOYS) var.lagenoides WILLIAMSON,1858. p.11,pl.1,figs.25,26.(Recent,England.)
?Lagena (Entosolenia) lagenoides (WILLIAMSON): BATJES,1958. p.118,pl.3, fig.7.(M.Oligocene,Germany & Belgium.)

Remarks

BATJES' (1958) figure differs from the rare specimens from the Middle Barton Beds at Barton in having two longitudinal vanes at 180°, instead of three at 120°.

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Lagena striata (D'ORBIGNY)

Plate 10, figs. 15, 16.

Oolina striata D'ORBIGNY,1839. p.21,pl.5,fig.12.(Recent,Falkland Is.)
Lagena striata (D'ORBIGNY): SHERBORN & CHAPMAN,1886. p.745,pl.14,fig.16.
Lagena striata (D'ORBIGNY): BOWEN,1954. p.143. (London Clay, England.)
Lagena striata (D'ORBIGNY): BOWEN,1957. p.55 (Barton Beds, Barton.)
Lagena striata (D'ORBIGNY): BATJES,1958. p.119,pl.3,fig.6.(M.Miocene,Belgium.
Lagena striata (D'ORBIGNY): HAYNES,1958b. p.72,pl.17,fig.7.(Thanetian,Kent.)
Lagena striata (D'ORBIGNY): KAASSCHIETER,1961. p.179,pl.7,fig.26. (Lr-Up.Eocene,Belgium;Barton Beds, Barton.)

Remarks

A common species throughout the Bartonian at both localities, characteised by the numerous, fine, longitudinal striations on a globular to pear-shaped body. It bears up to four longitudinal, slightly helical ridges on an otherwise unornamented neck. The variation of the more elongate specimens tends towards L.cf.tenuis but the latter has its widest point at the base of the test. Typical L.striata bears rings on the apertural neck but in accordance with KAASSCHIETER (1961) and BOWEN (1954, 1957) the present species cannot be classified as the ringless L.sulcata (WALKER & JACOB), this having much stronger costae. L.isabella (D'ORBIGNY) also differs in its stronger ridges.

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Lagena sp.cf. L.tenuis (BORNEMANN)

Plate 10, fig.17.

?Ovulina tenuis BORNEMANN,1855. p.317,pl.12,fig.3.(Septaria Clay, M.Oligocene,Germany.)

Lagena tenuis (BORNEMANN):BATJES,1958. p.119,pl.3,figs.23,24. (M.Oligocene, Belgium,Germany.M.Miocene,Belgium.)

Remarks

As BATJES (1958) remarked, there is nearly continuous variation between this species and L.striata and distinction is sometimes very difficult. It occurs rarely in the Chama Bed at Barton and the Lower Barton Beds at Alum Bay. L.axiformis MATTHES, as figured by TEN DAM (1944) from the Bartonian of the Netherlands, differs in having an acicular test without any basal flattening.

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Lagena sp.1.

Plate 10,fig.18.

Description

Test minute, unilocular, with an elongate, pear-shaped body and a long (1/3rd length of test) apertural neck. Test smooth and completely unornamented. Neck and body without break or shoulder.

Remarks

The narrow, elongate shape is very distinctive. L.globosa has a shoulder beneath the apertural neck. L.elongata (EHRENBERG) has a cylindrical, rather than pear-shaped body, and L.laevis (MONTAGU), as figured by SHERBORN & CHAPMAN (1886, pl.14, fig.13.) has a similar body but lacks a neck. At both localities this species occurs sporadically in the Lower and Middle Barton Beds.

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Genus: Lenticulina LAMARCK 1804

(Type species: Lenticulites rotulata LAMARCK,1804.)

Lenticulina sp.cf. L.ellisori BOWEN

Plate 10, figs. 21a, b.

?Lenticulina ellisori BOWEN,1954. p.146,pl.A,fig.12.(London Clay,England.)
Lenticulina sp.BATJES,1958. p.109,pl.2,fig.13.(not 15). (M.Oligocene,Belgium.)
Lenticulina sp.cf. L.ellisori BOWEN:KAASSCHIETER,1961. p.172,pl.7,fig.4.
(Lr. Eocene, Ypres Clay, Belgium.)

Remarks

This species is characterised by its completely involute, slightly loose coiling, its curved, raised and rounded sutures, its slightly inflated chambers and its subacute to carinate periphery. It occurs in small numbers at a horizon in the lower Middle Barton Beds at Barton and differs from all other English Bartonian species in its limbate sutures.

The specific placing with L.ellisori must remain highly questionable. BOWEN's (1954) typical form has more and (apparently) uninflated chambers. KAASSCHIETER's (1961) figure shows a more regularly coiled specimen but he also figures L.sp.cf. L.costata (D'ORBIGNY) and L.sp.cf. L.jugosa (CUSHMAN & THOMAS), both resembling the present species in some characters. BATJES's (1958) unidentified species is close but shows gradations with a more loosely coiled form.

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Lenticulina sp.cf. L.limbosa (REUSS)

Plate 10, figs. 22a, b.

?Cristellaria (Robulina) limbosa REUSS,1863. p.55,pl.6,fig.69. (Oligocene, Germany.)
?Cristellaria cultrata (MONTFORT):SHERBORN & CHAPMAN,1886. p.754,pl.15, figs.28,29. (London Clay, England.)
?Lenticulina limbosa (REUSS):BOWEN,1954. p.147,(London Clay,England.)
Lenticulina sp.cf. L.limbosa (REUSS):KAASSCHIETER,1961. p.172.
(Lr. Eocene, Belgium.)
Lenticulina cultrata (MONTFORT):KAASSCHIETER,1961. p.172. (Wemmelian,Belgium.)

Remarks

As BOWEN (1954,1957) pointed out, many 19th Century authors used L.cultrata (MONTFORT) (Robulus cultratus MONTFORT,1808,p.215,text-fig.)

for a Lenticulina with a thin, well marked keel. MONTFORT's type description and figure are, to say the least, ambiguous and his holotype unavailable. It is considered inadvisable to use this name, in which case L.limbosa (REUSS) takes preference. KAASSCHIETER (1961) distinguishes the two stratigraphically and on chamber number, but does not figure either.

At Barton and Alum Bay L.cf.limbosa occurs in small numbers in a restricted part of the Lower Barton Beds. Its distinct keel is more ragged and spinose than figured in the literature.

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Lenticulina sp.cf. L.yaguatensis (BERMUDEZ)

Plate 11, figs. 1 a, b, 2 a, b.

?Robulus yaguatensis BERMUDEZ,1949. p.132,pl.7,figs.29,30. (Oligocene, Dominican Republic.)
Lenticulina sp.cf. L.yaguatensis (BERMUDEZ):KAASSCHIETER,1961. p.173,pl.7, figs.8,9. (Ledes Sand,Asse Clay,Belgium.)

Remarks

The common Lower and Middle Barton Beds material agrees well with KAASSCHIETER's (1961) figures. It is characterised by its broad test, few chambers, backward leaning, flush sutures, acute periphery and large, clear umbones.

****

Lenticulina sp.1

Plate 11, figs. 3a,b.

Description

Planispirally coiled, completely involute, laterally compressed test, with rounded outline and a subacute periphery. Chambers numerous (8 to 10), sutures curved backwards. Umbilici small and flush filled with clear shell material. Aperture stellate and peripheral.

Remarks

The more numerous, high chambers, upright septa and narrow umbilici distinguish this form from L.sp.cf.L.yaguatensis. It never has the peripheral carina of L.cf.limbosa or the limbate sutures of L.cf.ellisori. It occurs sporadically throughout the Lower and Middle Barton Beds of both sections.

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Genus: Saracenaria DEFRANCE 1842

(Type species: Saracenaria italica DEFRANCE, 1842.)

Saracenaria sp.cf. S.bottcheri (REUSS)

Plate 10, fig. 19.

?Cristellaria bottcheri REUSS,1863. p.49,pl.3,figs.38-42.(M.Oligocene,Germany.)
?Saracenella bottcheri (REUSS):BATJES,1958. p.113,pl.3,fig.14. (M.Oligocene,Belgium and Germany.)

Remarks

This rare Middle Barton Beds species differs slightly from REUSS's and BATJES's typical form in its less depressed sutures and smaller size. Marginulina crepidula (FICHTEL & MOLL, 1803), recorded by BOWEN (1954) and SHERBORN & CHAPMAN (1886) from the London Clay of England, is related but has a smaller uncoiled portion.

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Genus: Pseudarcella SPANDEL 1909

(Type species: Pseudarcella rhumbleri SPANDEL,1909.)

Pseudarcella campanula LE CALVEZ

Plate 10, figs. 20a, b.

Pseudarcella campanula LE CALVEZ,1959. p.91,pl.1,figs.3,4.(Cuisian,Belgium, Paris Basin.)

Remarks

The taxonomic placing of Pseudarcella is still far from certain. Fragments of the acid soluble tests, from the Lower Barton Beds of Alum Bay, appear completely homogeneous, with no pores, laminations, etc. when examined under high power. The whole test is apparently calcitic in composition and is in optical continuity. The reader is referred to LE CALVEZ (1959) regarding its nomenclatural history.

The Bartonian material differs slightly from the typical form in being slightly lower and less inflated, though not as low as P.rhumbleri SPANDEL (Middle Oligocene, Rhenish trough) or P.patella GALLOWAY & HEMINWAY (Upper Oligocene, Puerto Rico). The conical tip is not turned over, or as inflated, as in P.feugueri LE CALVEZ (Cuisian, Belgium). The reticulate surface ornament of typical P.campanula and of P.feugueri is apparently absent.

Identical specimens were recovered at Alum Bay from the Upper Bracklesham Beds. Specimens identical with typical P.campanula occur in the lower part of the Upper Bracklesham Beds of the Fawley Transmission Tunnel (sample 7170).

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Family: POLYMORPHINIDAE D'ORBIGNY 1839

Genus: Sigmomorphina CUSHMAN & OZAWA 1928

(Type species: Sigmomorpha (Sigmomorphina) yokoyamai CUSHMAN & OZAWA,1928.)

Sigmomorphina sp.1

Plate 11, fig.10.

Description

Test large, compressed, elongate and lanceolate in overall shape. Chambers elongate and arranged in an evolute, clockwise sigmoid series, the final chamber extending about half the length down the periphery. Each successive chamber is arranged at about 160° intervals but in large adults the later chambers are nearer to 180° apart; i.e. true biserial coiling as characterised by Polymorphina s.s. The sutures are incised and the chambers inflated, with rounded peripheries. Surface ornament consists of few fine longitudinal costae, usually restricted to the later chambers and radiating from the terminal, stellate aperture.

Remarks

The evolute sigmoid coiling is characteristic of Sigmomorphina, as discussed by CUSHMAN & OZAWA (1930). This feature immediately distinguishes the Bartonian form from Polymorphina striata (BURROWS & HOLLAND) and P.anceps PHILLIPI, as figured by HAYNES, 1958a from the English Paleocene. P.alleni CUSHMAN & OZAWA (1930), of which a few specimens were recovered from the Upper Bracklesham Beds, has longer, peripherally more embracing, biserially arranged chambers and no costae. Sigmomorphina jacksonensis var. costifera (CUSHMAN) (Upper Eocene, Gulf Coast, U.S.A.) has more numerous costae restricted to the median zone. Young specimens of S.sp.1 are sometimes difficult to distinguish from Guttulina pulchella. The latter is more involute, with a lower angle between successive chambers.

At Barton and Alum Bay this species is restricted to the lower part of the Middle Barton Beds.

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Genus: Globulina D'ORBIGNY 1839

(Type species: Polymorphina (Globuline) gibba D'ORBIGNY,1826.)

Globulina gibba (D'ORBIGNY)

Plate 11, figs. 4,5,6.

Polymorphina (Globuline) gibba D'ORBIGNY,1826. p.266, modele no.63.
Globulina gibba (D'ORBIGNY):D'ORBIGNY,1846. p.227,pl.13,figs. 13,14. (Miocene, Vienna Basin.)
Globulina inaequalis REUSS,1850. p.377,pl.48,fig.9. (Miocene,Vienna Basin.)
Globulina gibba (D'ORBIGNY):TERQUEM,1882. p.130,pl.13,figs.23-25,(only).
Polymorphina gibba D'ORBIGNY:SHERBORN & CHAPMAN,1886. p.775,pl.16,fig.5. (Lr. Eocene, England.)
Globulina gibba (D'ORBIGNY):CUSHMAN & OZAWA,1930. p.60,pl.16,figs.1-4.(et syn.)
Globulina inaequalis REUSS:CUSHMAN & OZAWA,1930. p.73,pl18,figs.2-4.(et syn.)
Globulina gibba (D'ORBIGNY):LE CALVEZ,1950. p.17.(Lutetian,Paris Basin.)
Globulina gibba (D'ORBIGNY): BOWEN,1954. p.163, (London Clay, England.)
Globulina gibba (D'ORBIGNY): BHATIA,1955. p.676,pl.67,fig.19. (Lr.Oligocene, England.)
Globulina gibba (D'ORBIGNY): BOWEN,1957. p.57,pl.1,fig.13.(Barton Beds,Barton.)
Globulina gibba (D'ORBIGNY): HAYNES,1958a. p.8,pl.3,fig.10.(Thanetian,Kent.)
Globulina gibba (D'ORBIGNY):var.hollandi HAYNES,1958a. p.9,pl.3,fig.12.
Globulina gibba (D'ORBIGNY): BATJES,1958. p.121,pl.4,fig.9. (Lr-Up.Oligocene, Belgium, Germany.)
Globulina gibba (D'ORBIGNY): KAASSCHIETER,1961. p.183,pl.8,figs.6,7. (Lr-Up.Eocene,Belgium,Netherlands,England,France.)

Remarks

In accordance with KAASSCHIETER (1961) laterally more compressed forms, distinguished by some authors as G.inaequalis, are included with G.gibba. HAYNES' (1958a) G.gibba var. hollandi falls within this range of variation, being intermediate with G.inaequalis.

At Barton and Alum Bay G.gibba is frequently found, as it is throughout the Tertiary. It varies in shape from being more or less elongate to the commoner globular form. The greatest abundance of larger specimens occurs in the Lower Barton Beds. Rare specimens show a fistulose final chamber.

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Globulina gibba (D'ORBIGNY) var.myristiformis (WILLIAMSON)

Plate 11, fig. 8.

Polymorphina myristiformis WILLIAMSON,1858. p.73,pl.6,figs.156,157. (Recent, British Isles.)
Lagena costata TERQUEM,1882. (non WILLIAMSON) p.27,pl.1,fig.11. (Lutetian, Paris Basin.)
Globulina gibba (D'ORBIGNY) var.myristiformis (WILLIAMSON):CUSHMAN & OZAWA, 1930. p.66,pl.16,fig.8;pl.20,fig.6.(et syn.)
Globulina gibba (D'ORBIGNY) var.myristiformis (WILLIAMSON):LECALVEZ,1950.p.18.
Globulina gibba (D'ORBIGNY) var.sulcata (D'ORBIGNY): LE CALVEZ,1950. p.18,pl.4,figs.54,55. (Lutetian, Paris Basin.)
Globulina gibba (D'ORBIGNY) var.myristiformis (WILLIAMSON): KAASSCHIETER,1961. p.184,pl.8,fig.10.(Sands of Ledes,Wemmel,Belgium.)

Remarks

A variety of G.gibba, characterised by its few strong, regular costae. It was only found in the Chama Bed at Barton.

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Globulina gibba (D'ORBIGNY) var.punctata D'ORBIGNY

Plate 11, fig.7.

Globulina punctata D'ORBIGNY,1846. p.229,pl.13,figs.7,8. (Miocene,Vienna Basin.
Globulina rugosa D'ORBIGNY,1846. p.229,pl.13,figs.19,20. (Miocene,Vienna Basin.
Globulina gibba (D'ORBIGNY) var.punctata D'ORBIGNY:CUSHMAN & OZAWA,1930. p.69,pl.17,figs.4,5. (et syn.)
Globulina gibba (D'ORBIGNY) var.punctata D'ORBIGNY:KAASSCHIETER,1961. p.183,pl.8,figs.8,9. (Lr.-Up. Eocene,Belgium,Netherlands,France,England.)

Remarks

There is some variation between typical forms, densely covered with fine granules, and more coarsely granular forms approaching G.gibba var. tuberculata D'ORBIGNY, though the tubercules are never as coarse or as rounded as those figured by CUSHMAN & OZAWA (1930). At Barton and Alum Bay it occurs throughout the Lower and Middle Barton Beds.

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Genus: Guttulina D'ORBIGNY 1839

(Type species: Polymorphina (Guttuline) problema D'ORBIGNY, 1826.)

Guttulina problema (D'ORBIGNY)

Plate 11, fig. 16.

Polymorphina (Guttuline) problema D'ORBIGNY,1826. p.266,modele No.61.
Polymorphina (Guttuline) communis D'ORBIGNY,1826. p.266,pl.12,figs.1-4; modele No.62.
Guttulina problema (D'ORBIGNY): CUSHMAN & OZAWA,1930. p.19,pl.2,figs.1-6; pl.3,fig.1. (et syn.)
Guttulina problema (D'ORBIGNY): LE CALVEZ,1950. p.11,pl.1,figs.7-9. (Lutetian, Paris Basin.)
Guttulina communis (D'ORBIGNY): LE CALVEZ,1950. p.13,pl.1,figs.13-15.
Guttulina problema (D'ORBIGNY): HAYNES,1958a. p.5,pl.3,fig.5. (et syn.) (Thanetian, England.)
Guttulina problema (D'ORBIGNY): BATJES,1958. (part) p.121,pl.4,figs.10,11, (not 12). (Oligocene,Belgium, Germany.)
Guttulina problema (D'ORBIGNY):KAASSCHIETER,1961. p.181,pl.7,figs.30-32; pl.8,fig.1. (Lr.-Up. Eocene,Belgium,France,Neths.,England.)

Remarks

Both CUSHMAN & OZAWA (1930) and HAYNES (1958a) conclude that G.problema and G.communis are synonymous, the differences being based on the very unreliable guide of chamber shape. G.austriaca D'ORBIGNY and G.frankei CUSHMAN & OZAWA, although quinqueloculine, are more elongate with more of the earlier chambers visible than in G.problema. G.problema never has the constant elongate chambers of G.lactea, nor its acute base.

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Guttulina irregularis (D'ORBIGNY)

Plate 11, fig. 9.

Globulina irregularis D'ORBIGNY,1846. p.226,pl.13,figs.9,10.(Miocene,Vienna Basin.)
Guttulina irregularis (D'ORBIGNY):CUSHMAN & OZAWA,1930. p.25,pl.3,figs.4,5; pl.7, figs.1,2. (et syn.)
Guttulina irregularis (D'ORBIGNY):LE CALVEZ,1950. p.14.(Lutetian,Paris Basin.)
Guttulina irregularis (D'ORBIGNY):BHATIA,1955. p.676,pl.67,fig.26. (Lr.Oligocene, England.)
Guttulina irregularis (D'ORBIGNY):KAASSCHIETER,1961. (part) p.181,pl.8,fig.3, (not 2). (Lr.-Up.Eocene,Belgium,Netherlands,France,England.)

Remarks

The rounded-triangular cross-section and outline, with the slightly depressed sutures distinguish this species from G.problema, even in juvenile specimens. BATJES (1958) and KAASSCHIETER (1961) note the similarity and the former author groups the two species under *G.problema*. KAASSCHIETER (1961) thinks BHATIA's (1955) record of *Globulina inaequalis* is of a juvenile *G.irregularis*. This determination appears doubtful as BHATIA's illustrations show a plump form strongly resembling *G.gibba*. Without examining the relevant specimen this question cannot be answered. CUSHMAN & OZAWA (1930) record this species from the Eocene to Recent. It occurs in the Lower and Middle Barton Beds of both localities.

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Guttulina irregularis (D'ORBIGNY) *var.bulloides* (REUSS)

Plate 11, figs. 11, 12.

Globulina bulloides REUSS,1861. p.318,pl.3,fig.4. (Maestrichtian,Netherlands.)
Guttulina bulloides (REUSS):CUSHMAN & OZAWA,1930. p.23,pl.1,figs.7,8.(*et syn.*)
Guttulina bulloides (REUSS):BHATIA,1955. p.676,pl.67,fig.28. (Lr.Oligocene, England.)
Guttulina irregularis (D'ORBIGNY):KAASSCHIETER,1961. (*part*) p.181,pl.8,fig.2, (not 3).

Remarks

Specimens referable to this variety occur in BURTON's bed G and are similar to more typical forms common in the Upper Bracklesham Beds. They differ from typical *G.irregularis* in that the final chamber is laterally removed from the axis. There is complete variation in trigonal cross-section etc. with *G.irregularis*. Indeed KAASSCHIETER (1961) states that the two are synonymous and evidence is lacking for their distinction above varietal level. Peripherally more acute specimens resemble the Upper Cretaceous and Paleocene *G.trigonula* (REUSS). The presence of the offset final chamber and the absence of true longitudinal ridges distinguishes the Bartonian form.

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Guttulina lactea (WALKER & JACOB)

Plate 11, fig.15.

Serpula lactea WALKER & JACOB ,1798. p.634,pl.14,fig.4.(Recent,England.)
Guttulina lactea (WALKER & JACOB.): CUSHMAN & OZAWA,1930. p.43,pl.10,figs.1-4. (*et syn.*)
Guttulina lactea (WALKER & JACOB.): LE CALVEZ,1950. p.14.(Lutetian,Paris Basin.)
Globulina lactea (WALKER & JACOB.): BOWEN,1954. p.163. (London Clay,England.)
Guttulina lactea (WALKER & JACOB.): HAYNES,1958a. p.4,pl.3,fig.1. (Paleocene,England.)

Guttulina lactea (WALKER & JACOB.) var.elongata HAYNES,1958a. p.5,pl.3,fig.5. (Paleocene,England.)
Guttulina lactea (WALKER & JACOB.): KAASSCHIETER,1961. p.182,pl.8,fig.5. (M. & Up. Eocene,Belgium, France, Netherlands.)

Remarks

A small species characterised by its oval cross-section, elongate shape and elongate chambers, which pass back almost the whole length of the test. G.problema never has such an elongate test. HAYNES' var.elongata with its more elongate test and embracing chambers, falls within the range of variation of the Bartonian material. CUSHMAN & OZAWA (1930) show that typical G.lactea ranges from the Eocene to Recent. It is common in the Lower and Middle Barton Beds of both sections.

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Guttulina pulchella D'ORBIGNY

Plate 11, figs.13, 14.

Guttulina pulchella D'ORBIGNY,1839. p.134,pl.2,figs.4-6.(Recent,Caribbean.)
Guttulina pulchella D'ORBIGNY:CUSHMAN & OZAWA,1930. p.33,pl.5,fig.7.(et syn.)
Guttulina spicaeformis (ROEMER) var.australis (D'ORBIGNY):CUSHMAN & OZAWA, 1930. (part) p.32,pl.5,fig.3.
Guttulina spicaeformis (ROEMER) var.parisiensis LE CALVEZ,1950. p.15,pl.1, figs.10-12. (Lutetian, Paris Basin.)
Guttulina pulchella D'ORBIGNY: KAASSCHIETER,1961. p.182,pl.8,fig.4. (Lr.-Up. Eocene,Belgium,Netherlands;Up.Bracklesham Beds,England.)

Remarks

A few specimens from the Lower Barton Beds of Alum Bay are questionably referrable to this species. They resemble the typical form (very common in the Upper Bracklesham Beds) in shape and chamber arrangement, but they are very weakly costae. Specimens in the Middle Barton Beds of Barton also resemble this species but show the high-angle, sigmoid chamber series, characteristic of Sigmomorphina sp.1. The typical Upper Bracklesham Beds form has been placed by various authors as varieties of G.spicaeformis (ROEMER). G.woodi HAYNES (1958a), from the English Paleocene, has more elongate, embracing and striate chambers than G.pulchella.

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Genus: Pyrulina D'ORBIGNY 1839

(Type species: Polymorphina (Pyruline) gutta D'ORBIGNY, 1826.)

Pyrulina thouini (D'ORBIGNY)

Plate 11, fig.17.

Polymorphina thouini D'ORBIGNY,1826. p.265,no.8;modele no.23.(Eocene,Paris Basin.)
Polymorphina thouini D'ORBIGNY:TERQUEM,1882. p.142,pl.14,fig.33.
Pyrulina thouini (D'ORBIGNY):CUSHMAN & OZAWA,1930. p.57,pl.14,fig.6.(et syn.)
Pyrulina thouini (D'ORBIGNY): LE CALVEZ,1950. p.17. (Lutetian,Paris Basin.)
Pyrulina thouini (D'ORBIGNY): KAASSCHIETER,1961. p.185,pl.8,figs.13,14.
(M. & Up.Eocene,Belgium,Netherlands; Bartonian, England.)

Remarks

A narrow, elongate Pyrulina, cylindrical, except at either end. The more rotudd and tapering G.gutta (D'ORBIGNY) was not encountered in the Bartonian, but is common in the Upper Bracklesham Beds. As KAASSCHIETER (1961) noted, possible intermediates with P.cylindroides (ROEMER) occur among more elongate individuals. Typical P.thouini occurs rarely in the Lower and Middle Barton Beds of both sections.

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Family: GLANDULINIDAE REUSS 1860

Genus: Glandulina D'ORBIGNY 1839

(Type species: Nodosaria (Glanduline) laevigata D'ORBIGNY,1826.)

Glandulina laevigata (D'ORBIGNY)

Plate 11, figs.18,19.

Nodosaria (Glanduline) laevigata D'ORBIGNY,1826. p.252,pl.10,figs.1-3.
(Recent,Adriatic. Pliocene,Rhodes.)
Glandulina laevigata (D'ORBIGNY):CUSHMAN & OZAWA,1930. p.143,pl.40,fig.1.
Pseudoglandulina laevigata (D'ORBIGNY):BOWEN,1954.p.156,(London Clay,England.)
Glandulina laevigata (D'ORBIGNY):BHATIA,1955. p.675,pl.67,fig.25.
Glandulina laevigata (D'ORBIGNY):BOWEN,1957. p.55,pl.1,fig.26.(Bartonian,Barto
Glandulina? laevigata (D'ORBIGNY):HAYNES,1958a. p.14,pl.5,fig.1.(Thanetian,Ken
Glandulina laevigata (D'ORBIGNY):BATJES,1958. p.123,pl.4,figs.7,8.
(M.Oligocene,Belgium.)
Glandulina laevigata (D'ORBIGNY): KAASSCHIETER,1961. p.187,pl.8,fig.17.
(Lr.-Up.Eocene,Belgium.Barton Beds,England.)

Remarks

There is complete intergradation in this common Lower and Middle Barton Beds form from typical rotund specimens to a more elongate type. The latter resembles G.aequalis REUSS of BATJES (1958), G.dimorpha (BORNEMANN) of

CUSHMAN & OZAWA (1930), G? ovula D'ORBIGNY of HAYNES (2958a), Rectoglandulina elliptica (REUSS) of BIGNOT (1962) and Dimorphina sp. of KAASSCHIETER (1961). The juvenile stage is alway shorter than in G? ovula or Dimorphina sp. In this study all more or less rotund, nearly entirely uniserial forms are united under G.laevigata, regardless of the coiling in the early stages.

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Genus: Fissurina REUSS 1850

(Type species: Fissurina laevigata REUSS,1850.)

Fissurina laevigata REUSS

Plate 11, fig.20.

Fissurina laevigata REUSS,1850. p.366,pl.46,fig.1. (Miocene,Vienna Basin.)
Entosolenia laevigata (REUSS):BHATIA,1955. p.680,pl.66,fig.12. (Lr. & M. Oligocene, England.)
Lagena (Fissurina) laevigata (REUSS):BATJES,1958. p.118,pl.3,fig.25. (M. & Up.Oligocene, Belgium, Germany.)
Entosolenia laevigata (REUSS):KAASSCHIETER,1961. p.180. (Brussels Sand,Belgium.
Fissurina cf.laevigata REUSS:BIGNOT,1962. p.167,pl.2,fig.23-25.(Cuisian,France.

Remarks

A very small species, occurring throughout the Bartonian at both localities. The material agrees well with the published figures and descriptions.

****

Superfamily: BULIMINACEA JONES 1875

Family: TURRILINIDAE CUSHMAN 1927

Genus: Buliminella CUSHMAN 1911

(Type species: Bulimina elegantissima D'ORBIGNY,1839.)

Buliminella sp.cf. B.elegantissima (D'ORBIGNY)

Plate 12, figs. 1a, b.

?Bulimina elegantissima D'ORBIGNY,1839. p.51,pl.7,figs.13-14. (Recent,Western South America.)
?Buliminella elegantissima (D'ORBIGNY):CUSHMAN & PARKER,1947. p.67,pl.17, figs.10-12. (et syn.)
Buliminella elegantissima (D'ORBIGNY):BHATIA,1955. p.679,pl.66,fig.11. (Lr.&M.Oligocene,England.)
Buliminella elegantissima (D'ORBIGNY):BOWEN,1957.p.54,pl.1,fig.17. (Barton Beds,Barton.)

Remarks

A few small, immature specimens, from the Middle Barton Beds of both sections, and the Lower Barton Beds of Alum Bay, can questionably be referred to this species. Specimens collected from the Bembridge Oyster Bed (see also BHATIA, 1955) are more mature and have a more typical acute apex. The long, narrow chambers and elongate apertural face are considered characteristic by CUSHMAN & PARKER (1947). *B.pulchra* (TERQUEM), recovered from the Upper Bracklesham Beds, has a much larger final coil. *B.striatopunctata* (TERQUEM), extracted from the Bembridge Oyster Bed, is longer with lower, wider chambers and a smaller, apertural face.

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Buliminella carteri BHATIA

Plate 12, fig.2.

Buliminella carteri BHATIA, 1955. p.678,pl.66,fig.10;text-fig.4.
(Lr. & M. Oligocene, England.)
Buliminella carteri BHATIA:BATJES,1958. p.126,pl.4,fig.14.
(M.Oligocene, Belgium.)

Remarks

A small, very short form with four almost globular chambers in the final whorl. It is quite distinctive and agrees well with the type figures and description and with topotype material from the Hamstead *Corbula* Bed, (English M.Oligocene). It was found rarely in the *Chama* Bed at Barton and the Middle Barton Beds of Alum Bay.

****

Family: BOLIVINITIDAE CUSHMAN 1927

Genus: *Bolivina* D'ORBIGNY 1839

(Type species: *Bolivina plicata* D'ORBIGNY,1839.)

Bolivina anglica CUSHMAN

Plate 12, fig.3.

Bolivina punctata SHERBORN & CHAPMAN,1886. (non D'ORBIGNY,1839) p.743,pl.14, fig.10. (London Clay, England.)
Bolivina anglica CUSHMAN,1936. p.50,pl.7,fig.11. (Eocene,England.)
Bolivina punctata SHERBORN & CHAPMAN: BOWEN,1954. p.139, (London Clay,England.)
Bolivina anglica CUSHMAN:KAASSCHIETER,1961.. p.194,pl.9,figs.18,19.
(Lr.-Up. Eocene,Belgium.Lr.Eocene,Netherlands.)

Remarks

A form occurring in the Lower and Middle Barton Beds of both sections and the *Chama* Bed of Alum Bay. It has narrow chambers, straight or slightly curved sutures and a subacute periphery. It never bears the sharp peripheral carina of *B.carinata* TERQUEM, as seen in the Upper Bracklesham Beds. *B.variabilis* (WILLIAMSON) has more horizontal sutures and higher chambers.

****

Bolivina pulchra (TERQUEM)

Plate 12, fig. 6.

Bulimina pulchra TERQUEM,1882. p.114,pl.12,fig.8.(Lutetian,Paris Basin.)
Bolivina pulchra (TERQUEM): LE CALVEZ,1950. p.43,pl.3,figs.43,44.
(Lutetian,Paris Basin.)
Bolivina pulchra (TERQUEM):KAASSCHIETER,1961. p.194,pl.8,figs.23,24.
(Lr.Eocene,Belgium.)

Remarks

At Barton and Alum Bay this species occurs throughout the Barton Beds, as high as the *Chama* Bed. The higher, slightly inflated chambers and the crenulations of the sutures near the axis distinguish it from *B.anglica* CUSHMAN and from *B.variabilis* (WILLIAMSON), as figured by BHATIA (1955). Specimens of the latter were examined from the Middle Oligocene Hamstead *Corbula* Bed.

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Bolivina cookei CUSHMAN

Plate 12, fig.4.

Bolivina cookei CUSHMAN,1922. p.126,pl.29,fig.1. (Oligocene,Mississippi.)
Bolivina cookei CUSHMAN : KAASSCHIETER,1961. p.195,pl.8,figs.25,26.
(Sands of Wemmel,Clay of Asse,Belgium.)

Remarks

A species very similar in chamber and suture form to *B.pulchra* but with a subacute periphery and numerous, fine, longitudinal costae covering the test, especially proximally. *B.fastigia* CUSHMAN (Oligocene of Germany and England) has fewer, stronger costae, a carinate periphery and crenulate sutures. *B.cookei* occurs rarely in the Middle and Upper Barton Beds at Barton and the Lower and Middle Barton Beds at Alum Bay.

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Bolivina crenulata CUSHMAN

Plate 12, fig.5.

Bolivina crenulata CUSHMAN,1936. p.50,pl.7,fig.13.(Eocene,Hungary.)
Bolivina crenulata CUSHMAN: KAASSCHIETER,1961. p.194,pl.9,figs.15-17.
(Lr.-Up.Eocene, Belgium. M.Eocene,Netherlands.)

Remarks

A sharply tapering species with highly crenulate sutures. The crenulations, which are strongest near the axis, occur one above the other on successive whorls and are marked by rounded longitudinal ridges. These features make it easily distinguishable from all other Bartonian species of Bolivina. It occurs rarely throughout the Barton Beds.

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Family: BULIMINIDAE JONES 1875

Genus: Bulimina D'ORBIGNY 1826

(Type species: Bulimina marginata D'ORBIGNY,1826.)

Bulimina parisiensis KAASSCHIETER

Plate 12, fig.7.

Bulimina trigona CUSHMAN & TODD,1945. (non TERQUEM,1882) p.17,pl.4,fig.6.
(Lutetian, Paris Basin.)
Bulimina trigona CUSHMAN & TODD: CUSHMAN & PARKER,1947. p.91,pl.21,fig.18.
Bulimina trigona CUSHMAN & TODD: LE CALVEZ,1950. p.37,pl.3,fig.35.
(Lutetian, Paris Basin.)
Bulimina parisiensis KAASSCHIETER,1961. p.190,pl.8,fig.19;pl.9,figs.3,4.
(Lr.-Up.Eocene,Belgium,France,Netherlands.)

Remarks

A species characterised by its rapidly tapering test, its inflated chambers and its relatively large final coil. It occurs rarely in the Lower Barton Beds of both sections and the Middle Barton Beds of Barton.

KAASSCHIETER (1961) pointed out that the type specimen of Bulimina trigona TERQUEM is a Valvulina. The name had been used for this distinctive species of Bulimina and a new name was needed. He also remarked on its intergradation with a slightly more elongate form, closer to the Bartonian material, which may be referable to B.candida TERQUEM, as refigured by LE CALVEZ. This species was also placed in Valvulina by CUSHMAN & PARKER (1947) and additionally is based on a single broken type specimen. Consequently this name also should not be used.

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Genus: Praeglobobulimina HOFKER 1951

(Type species: Bulimina pyrula D'ORBIGNY var.spinescens BRADY,1884.)

Praeglobobulimina sp.cf. B.pupoides(D'ORBIGNY)

Plate 12, fig. 8.

?Bulimina pupoides D'ORBIGNY,1846. p.185,pl.11,figs.11,12.(Miocene,Vienna Basin.)
?Bulimina pupoides D'ORBIGNY: CUSHMAN & PARKER,1937. (part) p.47,pl.6,figs. 2a, b only. (not figs. 3a,b.)
?Bulimina pupoides D'ORBIGNY: BHATIA,1955. p.680,pl.66,fig.21. (M.Oligocene,England.)
?Praeglobobulimina pupoides (D'ORBIGNY): LOEBLICH & TAPPAN,1964. fig.442: 14a-c.

Remarks

This form occurs rarely in a few samples from the Barton Beds of both sections. It has a short, nearly cylindrical test and sloping sutures. It strongly resembles BHATIA's (1955) and CUSHMAN & PARKER's (1947) figures of B.coprolithoides ANDREAE in shape but does not have the aperture immediately above the junction of the second and third chamber; a diagnostic feature. It also resembles BATJES's (1958) figure of his shortened form of B.elongata D'ORBIGNY, from the Miocene of Belgium. However, he notes a complete gradation between this and more typical elongate forms, similar to those figured by BHATIA (1955) and CUSHMAN & PARKER (1947), which are quite distinct from the Bartonian species. Some of CUSHMAN & PARKER's (1947) illustrations of B.pupoides are very close to this material, while others are quite different. Until more is know of the variation of this form in the Bartonian open nomenclature will be used.

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Genus: Reussella GALLOWAY 1933

(Type species: Verneuilina spinulosa REUSS, 1850.)

Reusselia sp.cf. R.elongata (TERQUEM)

Plate 12, fig.11.

?Verneuilina elongata TERQUEM,1882. p.106,pl.11,fig.13.(Lutetian,Paris Basin.)
?Reusella elongata (TERQUEM): LE CALVEZ,1950. p.46,pl.3,figs.45,46.
?Reusella elongata (TERQUEM): KAASSCHIETER,1961. p.191,pl.9,figs.7-9.
(Lr.-Up. Eocene, Belgium, England, France, Netherlands.)

Remarks

A few specimens from the basal Lower Barton Beds of Alum Bay, agree questionably with this species, as interpreted by KAASSCHIETER (1961). He records it from the Upper Bracklesham Beds, whence more typical specimens have been observed.

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Family: UVIGERINIDAE HAECKEL 1894

Genus: Sagrina D'ORBIGNY 1839

(Type species: Sagrina pulchella D'ORBIGNY, 1839.)

Sagrina sp.2

Plate 12,figs.9,10.

Description

Test minute, elongate, slightly compressed and nearly parallel sided. Initially triserial, then biserial for 3/4 of the length. Adult chambers slightly inflated, long, occurring alternately, with a tendency to become uniserial distally. Periphery rounded, surface finely spinose. Aperture circular, on a short but distinct neck with an everted lip. A short aboral spine is sometimes present.

Remarks

A very distinctive species, restricted at Barton to a narrow zone in the Middle Barton Beds. At Alum Bay it also occurs rarely in the Lower Barton Beds. It has not been found in the Upper Bracklesham Beds, where Sagrina selseyensis (HERON-ALLEN & EARLAND) has a larger test and coarser, pustulose ornamentation. It differs from Uvigerina farinosa HANTKEN, from the Belgian Upper Eocene, and U.batjesi KAASSCHIETER, from the Belgian Lower Eocene, in its less inflated chambers and different mode of coiling.

****

Genus: Angulogerina CUSHMAN 1927

(Type species: Uvigerina angulosa WILLIAMSON,1858.)

Angulogerina muralis (TERQUEM)

Plate 12, fig.12.

Uvigerina muralis TERQUEM,1882. p.119,pl.12,figs.26-29.(Lutetian,Paris Basin.)
Angulogerina muralis (TERQUEM):CUSHMAN & EDWARDS,1937. p.55,pl.8,figs.3-5.
Angulogerina muralis (TERQUEM): LE CALVEZ,1950. p.49. (Lutetian,Paris Basin.)
Angulogerina muralis (TERQUEM): KAASSCHIETER,1961. p.199,pl.10,figs.3,4.
(Lr.-Up. Eocene, Belgium. Lr.-M.Eocene,Netherlands.)
Angulogerina muralis (TERQUEM): BIGNOT,1962. p.166,pl.2,figs.11-14. (Lr.Eocene, N.France.)

Remarks

The single specimen recovered from the Middle Barton Beds of Alum Bay is identical with specimens from the Upper Bracklesham Beds and with the published figures and descriptions. Uvigerina selseyensis HERON-ALLEN & EARLAND (1909), whose type level and locality is given as "fossil", Selsey, is probably a junior synonym of A.muralis. The same authors distinguish Bulimina selseyensis HERON-ALLEN & EARLAND (1911) on its buliminid aperture, but it is uncertain whether this feature merely represents the broken base of the true uvigerinid aperture of A.muralis. BIGNOT (1962) places A.mauricensis HOWE (1939) (Clairborne Eocene of Louisiana) in the synonymy of A.muralis, but the increase in chamber length and whorl size with growth is not as great as in the latter. A.europaea CUSHMAN & EDWARDS (1937) (Montian of France) differs from A.muralis in its shorter, less separated and distally more rounded chambers. It was also recorded by HAYNES (1958b) from the Thanetian of Kent.

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Superfamily: DISCORBACEA EHRENBERG 1838

Family: DISCORBIDAE EHRENBERG 1838

Genus: *Eoeponidella* WICKENDEN 1949

(Type species: *Eoeponidella linki* WICKENDEN, 1949.)

Eoeponidella sp.1

Plate 12, figs. 13a,b,c.

Asterigerina sp. KAASSCHIETER,1961. p.234,pl.15,fig.6.(Lr.-Up.Eocene,Belgium. Upper Bracklesham Beds,Barton Beds,England.)

Description

Test minute, trochospiral. Conical angle variable, with complete gradation from about 100° to 170°, the flatter variant predominating. Dorsally evolute, with up to four whorls visible. Whorls increasing rapidly in size, the final one bearing four or five dorsally and ventrally inflated chambers. Outline lobulate, periphery well rounded, compressed, but never subangular. The incised sutures curve backwards on dorsal side. Umbilicus broad and shallow. Secondary chambers distinct, slightly inflated and lozenge-shaped. Aperture umbilical, covered by a large blister-like bulla, leaving a low, arched, basal opening.

Remarks

This form occurs in large numbers in the Lower and Middle Barton Beds and the *Chama* Bed of both sections. They agree very well with KAASSCHIETER's (1961) *Asterigerina sp.*, but can clearly be assigned to the genus *Eoeponidella*. He suggests that they may be variants of *Asterigerina glabra* (BERMUDEZ), an unlikely theory in view of the lack of intermediates. It differs from *Eoeponidella obesicubicula* POAG (1966) in its higher spire, less globular chambers with more angular secondary chambers, and from *E.parvipatera* POAG (1966) (both from the Lower Miocene of Mississippi) in the absence of a keel. *Asterigerina cf.hadleyi* HOWE & ROBERTS, as figured by BIGNOT (1962) from the French Cuisian, has more curved dorsal sutures and shows looser coiling.

****

Genus: *Epistominella* HUSEZIMA & MARUHASI 1944

(Type species: *Epistominella pulchella* HUSEZIMA & MARUHASI,1944.)

Epistominella? sp.1

Plate 12,figs.14a,b.

Description

Test minute, low trochospiral. Dorsal side nearly flat, with three whorls increasing rapidly in size. Umbilicus narrow and deep. Periphery well rounded, outline smooth with seven chambers in the final whorl and nearly radial dorsal and umbilical sutures. Aperture a short low arch at the base of the semicircular apertural face, displaced slightly towards the umbilicus and with a very narrow lip.

Remarks

A few specimens from the Middle Barton Beds are questionably referrable to this genus on the basis of the almost symmetrically placed aperture. They differ from *E.oveyi* (BHATIA,1955) in having a lower spire and a much more rounded periphery.

****

Genus: *Baggina* CUSHMAN 1926

(Type species: *Baggina californica* CUSHMAN,1926.)

Baggina subconica (TERQUEM)

Plate 12, figs.15a,b,c.

Rotalina subconica TERQUEM,1882. p.61,pl.4,fig.5.(Lutetian, Paris Basin.)
Valvulineria ovalis TERQUEM,1882. p.103,pl.11,fig.10. (Lutetian,Paris Basin.)
Cancris turgidus CUSHMAN & TODD,1942. p.92,pl.24,figs.3,4.(Oligocene,Germany.)
Valvulineria subconica (TERQUEM):LE CALVEZ,1949. p.26,pl.5,figs.87-89.
Valvulineria subconica (TERQUEM): BHATIA,1955. p.683,pl.67,fig.2.
(Brockenhurst Bed, Lr.Oligocene, England.)
Cancris turgidus CUSHMAN & TODD: BATJES,1958. p.149,pl.10,fig.5.
(Lr.Oligocene,Belgium. Up.Oligocene,Germany.)
Cancris subconicus (TERQUEM): KAASSCHIETER,1961. p.213,pl.12,figs.6-8.
(Lr.-Up.Eocene,Belgium, France, Netherlands.)

Remarks

A very distinctive species, whose total range is from Lower Eocene to Lower Miocene. At Barton and Alum Bay it is restricted to the topmost

Lower Barton Beds and lowest Middle Barton Beds. The Bartonian specimens agree well with the published figures and descriptions. They show some variation in the degree of lobulation of the outline and strength of the circum-umbilical protuberances. Most have five chambers in the final whorl. The presence of the imperforate area over the aperture and the rounded periphery indicates that the true generic placing of this species should be in *Baggina* and not in the peripherally carinate *Cancris*.

****

Family: ASTERIGERINIDAE D'ORBIGNY 1839

Genus: *Asterigerina* D'ORBIGNY 1839

(Type species: *Asterigerina carinata* D'ORBIGNY, 1839.)

Asterigerina bartoniana (TEN DAM)

Plate 13, figs. 1a, b, c.

Rotalia granulosa TEN DAM, 1944. (non *Rosalina granulosa* KARRER) p.121, pl.4, fig.2. (Eocene, Netherlands.)
Rotalia bartoniana TEN DAM, 1947. p.186.
Asterigerina bartoniana (TEN DAM): KAASSCHIETER, 1961. p.232, pl.14, figs.2,3. (Lr.-Up.Eocene, Belgium, Netherlands, France, England.)
Asterigerina bartoniana (TEN DAM): GRAMANN, 1964. p.213, pl.20, fig.1.

Remarks

Undoubted specimens of *A. bartoniana* have been found only in the *Chama* Bed at Barton. They are large, ventrally papillate, with small secondary chambers, straight ventral sutures, a broad non-spinose peripheral carina. They fall within the considerable variation described by KAASSCHIETER (1961) and agree well both with the published figures and descriptions, and with Belgian material from the stratotype Wemmelian.

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Asterigerina brandhorstiana GRAMANN

Plate 13, figs. 3a, b, c.

Asterigerina bartoniana BATJES, 1958. (non TEN DAM, 1947) p.158, pl.10, figs.1,8. (Lr. Oligocene, Belgium.)
Asterigerina brandhorstiana GRAMANN, 1964. p.216, pl.20, fig.2; pl.21, fig.4; text-fig.2. (Lr.Oligocene, Germany) (*et syn.*)

Remarks

A small form, occurring abundantly in the Middle Barton Beds, with

5 to 8 dorsally crescentic chambers and a vitreous, radially caniculate, peripheral carina. The secondary chambers are small and triangular. The ventral sutures are characteristically swept backwards distally, not sinuous as in A.haeringensis LUHR, or straight as in A.bartoniana (TEN DAM). The ventral face of the final chamber is often large and anchor shaped. This species has more chambers per whorl than the Lower Eocene A.cf.guerrai (BERMUDEZ), as figured by KAASSCHIETER (1961). The Upper Eocene A.cf.glabra (BERMUDEZ), as figured by KAASSCHIETER (1961), has fewer chambers and large, inverted-triangular, secondary chambers. The latter feature also serves to distinguish A.brandhorstiana from A.gurichi gurichi (FRANKE) and A.gurichi staeschi (TEN DAM & REINHOLD), from the Upper Oligocene and Miocene of Germany respectively. A.sp.indet. BHATIA (1955) has 5 or 6 chambers in the last whorl but has slightly more upright dorsal sutures. GRAMANN (1964) describes A.brandhorstiana from the Lower Oligocene only, but the present material must place the lower limit of its range in the Bartonian. It has not, however, been found below the Middle Barton Beds or recorded from the Belgian Wemmelian.

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Superfamily: SPIRILLINACEA REUSS 1862

Family: SPIRILLINIDAE REUSS 1862

Genus: Spirillina EHRENBERG 1843

(Type species: Spirillina vivipara EHRENBERG, 1843.)

Spirillina simplex LE CALVEZ

Plate 12, figs. 16a,b.

Spirillina simplex LE CALVEZ, 1949. p.13,pl.1,figs.1,2.(Lutetian,Paris Basin.)
?Spirillina simplex LE CALVEZ: KAASSCHIETER,1961. p.137, (M. & U. Eocene, Belgium, France.)

Remarks

A few specimens of an evolute Spirillina were encountered in the Lower and Middle Barton Beds of both sections. They correspond well with LE CALVEZ's type figures, though some (see pl.12,figs.16a,b.) show constrictions on the otherwise unornamented tube.

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Superfamily: ROTALIACEA EHRENBERG 1839

Family: ROTALIIDAE EHRENBERG 1839

Genus: Rotalia LAMARCK 1804

(Type species: Rotalites trochidiformis LAMARCK, 1804.)

Rotalia propingua REUSS

Plate 13, figs. 2a,b,c.

Rotalia propingua REUSS, 1856. p.241,pl.4,fig.53.(Oligocene,Germany.)
Rotalia propingua REUSS: BATJES,1958. p.167,pl.12,fig.11.
(Lr.-Up.Oligocene,Belgium,Germany.)
Rotalia propingua REUSS: KAASSCHIETER,1961. p.243,pl.16,fig.12.
(M.-Up.Eocene,Gelgium,Neths.,France,England.)

Remarks

A common species throughout the Bartonian of both sections. As noted by KAASSCHIETER (1961) there is some variation in dorsal convexity and in the position of the ventral sutural grooves. R.papillosa D'ORBIGNY has a more granular umbilical filling and more chambers in the last whorl. BHATIA's (1955) R.sp.aff.papillosa, from the English Lower Oligocene differs in the same characteristics.

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Genus: Pararotalia LE CALVEZ 1949

(Type species: Rotalia inermis TERQUEM, 1882.)

Pararotalia inermis (TERQUEM)

Plate 13, figs. 4a, b, c.

Rotalina inermis TERQUEM, 1882. p.68,pl.6,fig.1.(Lutetian,Paris Basin.)
Pararotalia inermis (TERQUEM): LE CALVEZ, 1949. p.32,pl.3,figs.54-56.
(Lutetian,Paris Basin.)
Pararotalia subinermis BHATIA,1955. p.683,pl.67,fig.3. (Brockenhurst Bed,
Lr.Oligocene,England.)
Pararotalia inermis (TERQUEM): LOEBLICH & TAPPAN,1957. p.14,pl.1,figs.2,3.
Pararotalia subinermis BHATIA: LOEBLICH & TAPPAN,1957. p.20,pl.5,fig.1.
Rotalia audouini KAASSCHIETER, 1961. (part) (non D'ORBIGNY,1850) p.241,pl.16,
figs.9,10. (not 8) (Lr.-Up.Eocene, Belgium, France, England.)

Remarks

After examining a large number of heavily keeled Pararotalias from the English Upper Bracklesham and Barton Beds, the French Sables des Auvers from La Guepelle, and topotype material of LE CALVEZ from the French Calcaire

Grossier, the author reached the conclusion that P.inermis (TERQUEM) and P.subinermis (BHATIA) are synonymous. LOEBLICH & TAPPAN (1957) distinguish P.subinermis " ..... in the more angled peripheral outline, the flatter spiral side with straight and oblique rather than curved sutures, and the more elevated umbilical side with large umbilical plug which nearly completely fills the umbilicus." BHATIA's type diagnosis of this species differs from LOEBLICH & TAPPAN's emended description in using the greater compression of the test of P.subinermis as one of his distinctions. The latter authors show this relationship to be reversed. The shape of the sutures, lobulation of the periphery and size of the umbilical plug appear to be completely variable. The common Chama Bed material from Barton might be attributed to LOEBLICH & TAPPAN's emended P.subinermis on its ventrally high test, but the dorsally curved sutures, lobulate outline and sometimes small umbilical plug would necessitate its inclusion with P.inermis.

One character which may be distinctive is the ventral chamber shape. Most Bartonian specimens show ventrally flat and angled ventral chamber surfaces and deeply incised sutures. The large suite of typical P.inermis from La Guepelle have adult chambers ventrally inflated, without the sharp angle into the suture incisions. Young stages, however, show the flattened chamber surfaces as in the Barton material. Some large specimens from the Middle Barton Beds of Barton have a few adult chambers with curved surfaces.

KAASSCHIETER (1961) considers the whole Pararotalia group to belong to a single species, Rotalia audouini D'ORBIGNY 1850 (Lutetian, Paris Basin). This is thought to be going too far, as P.inermis (and P.subinermis), P.armata (D'ORBIGNY) and P.spinigera (LE CALVEZ) are distinguishable in all but very juvenile specimens and do not show complete intergradation. Moreover, the areal Pararotalia aperture is frequently visible. P.armata was not encountered at Barton or Alum Bay but good specimens from the Upper Bracklesham Beds at Selsea (FISHER's bed 21) show the characteristic heavy, spined keep of this species, not the inflated chambers of P.spinigera.

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Pararotalia spinigera (LE CALVEZ)

Plate 13, figs. 5a, b, c.

Rotalia canui CUSHMAN,1928. (*part*) (*non Rotalia stellata REUSS,1856*)
p.55,pl.3,fig.2. (M.Oligocene,France.)
Globorotalia spinigera LE CALVEZ,1949. (*non Rosalina spinigera TERQUEM,1882*)
p.39,pl.6,figs.97-99.(Lutetian,Paris Basin.)
Globorotalia spinigera LE CALVEZ: LE CALVEZ,1952. p.48.
Rotalia canui CUSHMAN: BHATIA,1955. p.684,pl.66,fig.32. (Brockenhurst Bed,
L.Oligocene,England.)
Rotalia viennensis BHATIA,1955. (*non Rosalina viennensis D'ORBIGNY,1846*)
p.684,pl.66,fig.30 ("*Venus* Bed, Lr.Oligocene,
England.)
"Rotalia" spinigera (LE CALVEZ): GULLENTOPS,1956. p.17,pl.1,fig.15.
(Lr. Oligocene, Belgium.)
Pararotalia spinigera (LE CALVEZ):LOEBLICH & TAPPAN,1957. p.18,pl.4,figs.1-3.
Pararotalia curryi LOEBLICH & TAPPAN,1957. p.13,pl.3,figs.5-7. (Brockenhurst
Bed, Lr. Oligocene, England.)
Rotalia canui CUSHMAN: BATJES,1958. p.168,pl.12,fig.5-7.(Lr.-Up.Oligocene,
Belgium, Germany.)
Rotalia audouini KAASSCHIETER,1961. (*part*) (*non D'ORBIGNY,1850*) p.241,
(Lr.-Up.Eocene,Belgium,France,England.)
Pararotalia spinigera (LE CALVEZ): BIGNOT,1962. (*part*) p.172,pl.3,figs.14,15,
(not 16). (Cuisian, France.)

Remarks

Juvenile specimens are difficult to distinguish from juvenile *P.inermis* and *P.armata* (D'ORBIGNY), but there is no justification for uniting these species as KAASSCHIETER (1961) has done. The adults differ, with no intergradation. *P.spinigera* has much more glogular chambers with peripheral spines, and never has the triangular chambers of *P.armata* and *P.inermis*, or the heavy keel of the latter. The common Bartonian material agrees well with topotype material from the French Lutetian and with the published figures and descriptions. It should be noted that the peripheral spines are not always present. The areal aperture typical of *Pararotalia* is visible in a large number of specimens.

Topotype material of BHATIA's (1955) *Rotalia viennensis* proved to be conspecific with *P.spinigera*, differing only in the slightly less inflated final chambers. From the literature it appears that *P.curryi* LOEBLICH & TAPPAN (= *Rotalia canui* of some authors) is also synonymous with this species. There is complete gradation between forms with a narrow, spineless keel and typical *P.spinigera*. *P.calvezae* LOEBLICH & TAPPAN (1957) (Lower Eocene of Southern France) and *P.parva* (CUSHMAN) (=*Rotalia dentata* PARKER & JONES var. parva CUSHMAN, 1922, Miocene of Mississippi), as figured by LOEBLICH & TAPPAN (1957), are very similar to this species. Both are from outside the North West European area and, in the absence of topotype material, a valid comparison cannot be made.

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Family: ELPHIDIIDAE GALLOWAY 1933

Genus: Elphidium MONTFORT 1808

(Type species: Nautilus macellus FICHTEL & MOLL var. b FICHTEL & MOLL,1798.)

Elphidium sp.cf. E.hiltermanni HAGN

Plate 14, figs. 1a, b.

?Elphidium hiltermanni HAGN, 1952. p.163,pl.1,fig.6; pl.2,fig.14. (M.Oligocene-Lr.Miocene, Bavaria.)
Elphidium hiltermanni HAGN: BATJES,1958. p.165,pl.12,fig.4. (Up.Oligocene-M.Miocene, Belgium, Germany.)
Elphidium hiltermanni HAGN: KAASSCHIETER,1961. p.240. (Lr.-Up.Eocene,Belgium. Up.Bracklesham Beds, England.)

Remarks

A rare form occurring in the Lower and Middle Barton Beds of both sections and the Chama Bed at Barton. It is laterally slightly compressed, with slightly inflated, peripherally rounded chambers, distinct retral processes and fine papillations about the aperture. It differs from the typical form in having 5 to 9 chambers in the last whorl. Many chambered specimens resemble E.minutum (REUSS) but have more inflated and fewer chambers. The Bartonian specimens are never as rotund as E.latidorsatum (REUSS).

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Elphidium latidorsatum (REUSS)

Plate 14, figs.4a,b.

Polystomella latidorsata REUSS,1864. p.10,pl.1,fig.6. (Up.Eocene,Germany.)
Elphidium latidorsatum (REUSS): CUSHMAN,1939. p.39,pl.10,fig.16.
Elphidium latidorsatum (REUSS): KAASSCHIETER,1961. p.240,pl.15,figs.13,14. (Lr.-Up.Eocene,Belgium, England, Netherlands.)

Remarks

A species occurring, sometimes commonly, throughout the Bartonian. It agrees well with published figures and descriptions and is characterised by its broad, rounded test, with 6-8 uninflated or slightly inflated chambers in the last whorl. It has short, distinct retral processes and a papillate apertural area. Strigillate specimens, as figured by KAASSCHIETER (1961) from the Dutch Lower Eocene, were not encountered. There is some variation in the degree of compression but specimens are never as flattened as E.minutum (REUSS) or E.cf.hiltermanni HAGN. E.minutum further differs in having more chambers in the last whorl. BOWEN (1957) records the latter species from the Barton Beds of Barton, but does not figure it. E.minutum was not encountered and his record may in fact be of E.latidorsatum.

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Elphidium laeve (D'ORBIGNY)

Plate 14, figs. 2a, b.

Nonionina laevis D'ORBIGNY,1826. p.294, modele no.46. (Lutetian,Paris Basin.)
Nonionina laevis D'ORBIGNY: PARKER, JONES & BRADY,1865. pl.3,fig.97.
Nonionina laevis D'ORBIGNY: TERQUEM,1882. p.44,pl.2,figs.12-14.
Nonion laeve (D'ORBIGNY): CUSHMAN,1939. p.3,pl.1,figs. 6,7.
Nonion laeve (D'ORBIGNY): TEN DAM,1944. p.108.
Nonion laeve (D'ORBIGNY): LE CALVEZ,1950. p.52. (Lutetian,Paris Basin.)
Elphidium laeve (D'ORBIGNY): KAASSCHIETER,1961. p.239,pl.16,figs.15,16.
(Lr.-Up.Eocene, Belgium,France,Netherlands,England.)

Remarks

As KAASSCHIETER (1961) noted, the presence of very small retral processes over the deeply incised sutures indicates its correct placing is with Elphidium, not Nonion. The common Bartonian material has a multiple aperture, consisting of a row of small openings near the basal suture, not a single basal arch, as described by CUSHMAN (1939). Juveniles are sometimes very difficult to distinguish from juvenile E.subnodosum (ROEMER). The latter has much less incised sutures, a greater thickness/diameter ratio and larger umbilical plugs which are usually confluent with the chamber surfaces. The third feature was mentioned by KAASSCHIETER and is fairly constant.

The Bartonian specimens agree well with material from the French Lutetian of Damery. Some published figures of E.laeve show a much more rounded periphery, including HAYNES' (1956) from the English Thanetian and KAASSCHIETER's (1961) from the Middle Eocene of Belgium (pl.16, fig.16). CUSHMAN's (1939, p.45,pl.11,fig.22) figure of E.cryptostomum (EGGER) also falls within this category. It was considered by KAASSCHIETER to be possibly synonymous with *E.laeve*. *E.laeve* var. *subexcavata* (BHATIA,1955), from the Lower Oligocene of the Isle of Wight, has a less compressed test and less incised sutures. *Protelphidium sublaeve* (TEN DAM), from the Paleocene of the Netherlands and Kent, differs from *E.laeve* in its lack of retral processes.

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Elphidium subnodosum (ROEMER)

Plate 14, figs. 3a,b.

Robulina subnodosa ROEMER,1838. p.391,pl.3,fig.61.(Miocene,Germany.)
Elphidium subnodosum (ROEMER):CUSHMAN,1939. p.40,pl.11,fig.2. (*et syn.*)
Elphidium subnodosum (ROEMER): TEN DAM & REINHOLD,1942. p.79,pl.5,fig.9. (Oligo-Miocene, Netherlands.)
Elphidium subnodosum (ROEMER): BATJES,1958. (*part*) p.163,pl.8,fig. 13only. (*et syn.*) (Lr.-Up.Oligocene,Belgium,Germany.)
Elphidium subnodosum (ROEMER): KAASSCHIETER,1961. p.239,pl.16,figs.17,18. (Lr.-Up.Eocene,Belgium,Netherlands,England.)

Remarks

As mentioned above, this species differs from *E.laeve* in its less incised sutures (they are depressed only near the umbones) and its chamber surfaces running into the large, glassy umbones, without any separating depression. A few specimens were recovered from the Lower and Middle Barton Beds of both sections, most of which were rather small. The large, heavily keeled form figured by BATJES (1958, pl.8, fig.12) from the Belgian Middle and Upper Oligocene was not encountered. All the Bartonian specimens more closely resemble his figure from the Lower Oligocene.

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Elphidium sp.4

Plate 14, figs. 5a,b.

Description

Test large, planispiral, involute and quite thick, with 12 to 13 chambers in the final whorl. Umbilici filled with two large, glassy, sparsely perforated plugs. Pore canals are mainly restricted to the edges of the plugs, which are separated from the chamber surfaces in adults by a sharp break in slope, never a depression. Sutures upright proximally and slightly curved backwards towards the subangular but not sharp or carinate periphery. Sutures incised slightly proximally, where they bear faint retral processes, and less so towards the periphery. Outline smooth or occasionally slightly lobulate. Area below the apertural face finely papillate. Aperture multiple, consisting of a row of fine holes on the basal suture.

Remarks

This species is restricted to the lower part of the Middle Barton Beds at Barton and Alum Bay. It has not been found outside this horizon in the Bartonian, nor in the Upper Bracklesham Beds or any other older strata examined. It differs from *E.laeve* in being less compressed and having less incised sutures and larger umbilical plugs. Juvenile specimens are sometimes difficult to distinguish from juvenile *E.subnodosum*, but the sutures are seldom as flush as in the latter species. Large specimens of *E.sp.4* differ from large *E.subnodosum*, as figured by CUSHMAN (1939) and BATJES (1958) from the Middle and Upper Oligocene, in their consistant lack of any keel, but the two species are probably closely allied. *E.laeve* var. *subexcavata* (BHATIA) has smaller umbilical fillings and fewer chambers in the last whorl.

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Family: NUMMULITIDAE DE BLAINVILLE 1825

Genus: *Nummulites* LAMARCK 1801

(Type species: *Camerina laevigata* BRUGIERE, 1792.)

Nummulites prestwichianus (T.R.JONES)

Plate 15, figs. 7,8,9.

Nummularia elegans J.de C.SOWERBY, in DIXON, 1850. (part) p.35.
Nummulina planulata var.*prestwichiana* T.R.JONES in FISHER,1862. p.93.
Nummulites wemmelensis var.*prestwichii* (T.R.JONES): DE LA HARPE,1882. p.92.
Nummulites elegans T.R.JONES,1887. p.142,pl.11,figs.1-4.
Nummulites orbignyi var.*elegans*,LISTER,1905. p.304,pl.5,figs.1-7.
Nummulites prestwichianus (T.R.JONES): CURRY,1937. p.242,pl.20,figs.7,8,9; pl.21, fig.10.
Nummulites prestwichianus (T.R.JONES):WHITE,1963. pl.2,fig.2.
non *Nummalaria elegans* J.de C.SOWERBY,1826. p.76,pl.538,fig.2.

Description

The microspheric and megalospheric stages are not distinguishable externally. The large test reached 2950 microns in diameter in the 29 specimens measured, though larger specimens have been recorded (up to 4000 microns, T.R.JONES, 1887). It is characteristically very flat and almost parallel sided. Diameter/thickness (D/T) ratios vary from 3.75 to 7.00. Adults have a subquadrate or rounded periphery in apertural view. Juveniles show a flattened lozenge-shaped section, with a sharp periphery. Ornamentation is absent except for a strong, flush, umbilical granule in adult forms. Occasionally juveniles are found with a marked umbilical protuberance on one side only (a pathological feature).

The septal filaments are characteristically strongly sigmoid in both adults and juveniles. In juveniles they are strongly curved backwards over their whole length, while in adults they are proximally upright or set forward.

In equatorial splits the septa of adult whorls are proximally upright for about a half or two-thirds of their length. Distally they are very strongly swept back to meet the marginal cord at a small angle above the bases of the preceeding septa. Juvenile septa tend to be curved over their whole length, without initial upright portions. The adult chambers are relatively high and short, with a height/length (H/L) ratio of about 1.5 to 2.0. Juvenile chambers have a much lower ratio. Fine canals can frequently be seen in the outer walls running forwards and perpendicular to the septa in all but the most juvenile whorls. These are probably the earliest stages in the development of trabeculae.

The spiral lamina is rather thin in relation to that of N.variolarius and N.sp.1. The whorls are relatively loosely coiled and show a rapid increase of chamber height with age. This tends to produce partially uncoiled gerontic specimens with slight thickenings or small, flush granules where the septal filaments of the final whorl crosses the periphery of the previous one. The megalospheric proloculus is relatively large, varying from 90-150 microns, with an average of 108 microns for 10 specimens.

Remarks

CURRY (1937) very adequately resolves the nomenclatural complications surrounding the early placing of this species. He shows that the type specimens of Nummalaria elegans J.de C.SOWERBY are in fact Nummulites planulatus (LAMARCK), a quite distinct Cuisian species. It has also been frequently attributed to N.orbignyi (GALEOTTI) (=N.wemmelensis DE LA HARPE), which is related both morphologically and stratigraphically. N.orbignyi differs in having external dimorphism and a strong umbilical plug.

This species also closely resembles N.germanicus (BORNEMANN), from the Uppermost Eocene and Lower Oligocene of Germany and the Netherlands (see EAMES, 1958). Its megalospheric proloculus size (120-190 microns) is greater than that of N.prestwichianus and it is stratigraphically distinct.

Specimens of the Tethyan form N.bouillei DE LA HARPE (= N.tourneri DE LA HARPE) from Biarritz were examined. They are somewhat flatter and larger but showed many related features such as loose coiling, swept back septal filaments, etc. It ranges from the Bartonian to the Lower Oligocene and, assuming open migration paths from the Aquitaine Basin, provides at least one possible origin for the plexus of North West European flattened Nummulites.

The type locality of N.prestwichianus is the base of the Barton Beds at Alum Bay. It also occurs as pyritic casts at Barton and has been reported from Whitecliff Bay and Hengistbury Head (CURRY, 1942, pl.3). It is restricted at all these localities to the basal Barton Beds, though it has been observed at Alum Bay overlapping slightly with the range of N.rectus CURRY.

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Nummulites rectus CURRY

Plate 15, figs. 10, 11, 12, 13.

Nummulites variolarius: all records from the Bartonian of Barton and Alum Bay.
Nummulites variolarius, T.R.JONES,1887. (part) pl.11,figs.10,11 only.
Nummulites rectus CURRY,1937. p.241,pl.20,figs.1-3;pl.21,fig.11.

Description

The megalospheric and microspheric forms cannot be distinguished externally. Three equatorial splits were found showing microspheric proloculi. Test large, up to 3000 microns out of the 67 specimens measured. In apertural view adult tests have flattened umbilical areas and well rounded, subquadrate or quite sharp peripheries. Juvenile specimens tend to be more lozenge-shaped, with either a sharp or a well rounded periphery. There is a considerable variation in shape, with the D/T ratios varying from 1.87 to 4.62. Many of the fatter forms proved to be worn specimens from which the peripheral part of the final whorl was missing. One assemblage (6912) from Barton consisted almost entirely of larger, flatter forms but these were almost always perfectly preserved. Real morphological variation (as against preservational variation) does occur but intermediates show that the species is a single plexus, with the shape varying continuously between two rather different end members.

Umbilical granules may or may not be present in adults and juveniles. More rotund specimens, both large and small, show a slightly protruding umbilical granule, indicating a linkage between these two features. Larger, flatter forms show granules (always flush) more rarely. In some large fat specimens the granule is divided into a small cluster, as in the N.variolarius group.

The septal filaments tend in adults to be upright or inclined forwards proximally, curved and swept back distally. They are often slightly sinuou and frequently branched, especially in uncoiled forms. An unusual feature is a preservational effect caused by the periphery of the final whorl being eroded whereby only the proximal, forward inclined parts of the septa are left. In juveniles the septal filaments are straighter and swept back only near the periphery and the youngest forms have septal filaments curved back over their whole length.

In equatorial splits the adult speta are upright or inclined backwards proximally. Distally they become swept back quite strongly (more so in fatter forms), though never as far as those of N.prestwichianus. Juvenile septa are curved back along their whole length. The chamber height tends to be 1.2 to 1.6 times the length in adult whorls, the flatter forms having relatively higher chambers. Canals in the walls running perpendicular to the septa are frequently seen both internally and externally in well preserved specimens. The spiral lamina is very variable in thickness, as is the tightness of coiling, with flattened forms tending to show looser coiling. Partial uncoiling is a common feature and is shown by most adults. It is partly responsible for branching of the septal filaments, otherwise caused by irregular production of the growth spiral. The size of the megalospheric proloculus varies from 60 50 150 microns, with an average of 74 microns for 16 specimens.

Remarks

The great morphological variation in this species would perhaps justify distinction of two varieties if it were not for the presence of a gradational series between them. The complete stratigraphic overlap between the end members also weighs against this distinction, as this would serve no useful stratigraphic purpose (both types occur together in most assemblages).

The species shows affinities with the N.variolarius group, N.sp.3 and N.sp.2. The close morphological similarity between N.sp.3 and some of the flattened forms would indicate a line of descent from the former, rather than through N.sp.2, as suggested by CURRY (1942). The differences between N.rectus and N.variolarius group lie in the greater size, swept back septal filaments and higher D/T ratios of the former.

It differs from N.sp.2 in its lack of external dimorphism and difference in shape of the 'A' forms.

The type level of N.rectus is BURTON's (1933) bed A3 at Barton. It also occurs abundantly in bed A2 and has been reported from bed B (not found by the author). At Alum Bay it occurs at equivalent levels and has been found overlapping with N.prestwichianus. A sample from Whitecliff Bay (1602), from the same part of the Lower Barton Beds, also yielded specimens.

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Nummulites variolarius (LAMARCK)

Lenticulites variolaria LAMARCK, 1804. pp.187-188.
Nummulites heberti D'ARCHIAC & HAIME, 1853. p.147, pl.9, figs.14, 15.

Nummulites variolarius (LAMARCK) var.1

Plate 15, figs. 14, 15, 16.

Description

Only megalospheric specimens could be found. The megalospheric proloculus is small in comparison with other species of Nummulites studied; between 30 and 40 microns, with an average of 35 microns out of 11 specimens measured.

The adult test is small when compared with other Upper Eocene species and only reached 1350 microns out of 24 specimens measured. Both adults and juveniles have a characteristic fat lozenge-shape in apertural view with single large, slightly raised and rounded polar pustules and a sub-quadrate periphery. The septal filaments of most adults and a few juveniles are usually unthickened, upright and straight or slightly sinuous for most of their length, only becoming turned back near the periphery. Parasigmoid septal filaments occur in most juveniles and more rarely in the adult form. Canals running perpendicular to the septal filaments are never seen. Septal filament branching occurs quite frequently and is usually associated with the irregular production of the growth spiral, seldom with uncoiling and then only in the largest specimens.

In equatorial splits the adult septa are backward leaning and straight or very slightly curved over their whole length. They are never strongly curved or distally hooked. Juvenile septa are similar but tend to be slightly more curved and slightly more oblique. The spiral lamina is thin, the coiling tight and the chambers long and low, with an H/L ratio of about 1.0 to 1.3.

Remarks

The lozenge-shaped peripheral profile and very small megalospheric proloculus distinguish this form from all other English Upper Eocene species. The ' A' forms of most other species examined have a similar apertural shape in their immature stages and only develop specific differences in the adult. Only the very juvenile forms of N.variolarius var.2 are lozenge shaped, "adolescents" and adults being centrally much more tumid and rounded. The plots of D/T ratios (which vary from 1.80 to 2.50) against diameter tend to overlap with parts of other groups. It should be born in mind that these measurements reflect the overall shape of the specimen, not the actual lateral contours.

N.variolarius var.1 is a relatively long ranging form, and has been found associated with N.laevigatus (BRUGUIERE) (=N.lamarcki D'ARCHIAC & HAIME) in the Upper Lutetian (FISHER's Bed VIII) of Whitecliff Bay (sample 7190), to as high as the top of FISHER's bed XVII in Whitecliff Bay. It is the dominant species in the Brook Bed equivalent at Whitecliff Bay (FISHER's bed XIV-XV). In other samples it is subordinate in numbers to other species; to N.sp.1 in the lower Upper Bracklesham Beds of Fawley (sample 7170) and to N.variolarius var.2 in FISHER's bed XVII at Whitecliff Bay and its equivalents.

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Nummulites variolarius (LAMARCK) var.2

Plate 15, figs. 17,18,19, 20.

Nummulites variolarius (LAMARCK): T.R.JONES,1887. (part) p.145,pl.11, fig.12 only.

?Nummulites variolarius (LAMARCK): LISTER,1905. pl.4,6 figs.

Nummulites variolarius (LAMARCK): CURRY,1937. p.240,pl.20,figs.4,5,6; pl.21,fig.9.

Nummulites variolarius (LAMARCK): BLONDEAU & CURRY,1963. pl.14,figs.1,2.

Nummulites variolarius (LAMARCK): BLONDEAU,1967. p.912,pl.28,figs.8,20.

Description

The two generations are externally indistinguishable and only one split specimen proved to have a microspheric proloculus. Apart from this and its slightly greater size (1950 microns in diameter) it is identical in all other characters to the 'A' form.

The test is large (up to 1700 microns out of 37 specimens measured). In apertural view adults and most juveniles are strongly tumid and biconvex, with a well rounded or subquadrate periphery. Very immature stages have a lozenge shaped profile and a subquadrate periphery. The D/T ratios are low, varying from 1.78 to 2.50, and overlap strongly with the 'A' forms of N.variolarius var.1 and N.spp.1 and 2 when plotted against the diameter. Overlap with N.sp.3 and N.rectus is less pronounced and is restricted mainly to juveniles. The poles of adults are marked by strong, flush granules, which in large specimens are associated with smaller subsidiary granules and in juveniles become slightly raised to form rounded polar pustules. The septal filaments are characteristically thickened away from the poles, resulting in a series of flush, radially elongate granules distinct from the polar complex. Both adult and juvenile septal filaments are radial and straight or slightly sinuous for most of their length, only becoming swept back slightly very near the periphery. Large specimens occasionally show central whirling of the filaments. Fine, short wall canals are often seen running perpendicular to the septal filaments. Filament branching is quite common and is associated with irregular growth and, in large specimens, with slight uncoiling of the last whorl.

In equatorial splits the shape of the septa, tightness of coiling, thickness of the spiral lamina, and height of the chambers are the same as in *N.variolarius var.1*. The proloculus size is however considerably greater, varying from 50 to 70 microns, with an average of 62 microns for 14 specimens. Thus there is no overlap in size with that of *N.variolarius var.1*.

Remarks

N.variolarius var.2 has been observed only from FISHER's bed XVII and its equivalents at Selsea, Lee-on-Solent and Bramshaw. Its stratigraphic relationship with *N.variolarius var.1* indicates that it might have been derived from that form by an increase in proloculus size. If this hypothesis is correct then *N.variolarius var.1* might be tentatively suggested as the stock from which the other English Upper Eocene *Nummulites* evolved; *N.spp.1* and *2* by the development of external dimorphism, and perhaps *N.sp.3*, *N.prestwichianus* and *N.rectus* by flattening of the test.

The strong distinction in proloculus sizes and subsidiary differences in shape and ornamentation indicate that *N.variolarius* is not the homogeneous species thought by many authors. The relationship of the English form and continental European specimens attributed to the same species (and to the possibly conspecific *N.heberti*) still remains unknown but one would expect at least similar variation to be shown. A related Tethyan species is *N.garnieri*. This is a small Upper Lutetian to Lower Bartonian form from the Aquitaine Basin, which characteristically has slightly sinuous septal filaments, ornamented by raised granules. Reduction in calcificatio as a result of lower temperatures due to higher latitude might have produce members of the *N.variolarius* group from *N.garnieri* by phenotypic variation.

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Nummulites sp.1

Plate 16, figs. 1,2,3,4.

Description

Size dimorphism is pronounced in this species, enabling the microspheric and megalospheric generations to be separated without sectioning.

Megalospheric Form

Test large, up to 1950 microns in diameter out of the 26 specimens measured. In apertural view the adults are lenticular and strongly tumid, with a subquadrate periphery. Juveniles are lozenge shaped in apertural view with a raised polar pustule and a sharp or subquadrate periphery. D/T ratios vary from 1.70 to 2.12 for 16 individuals and overlap strongly with the *N.variolarius* group when plotted against the diameter. Ornamentation in the adult consists of a very strong, flush polar granule, sometimes with ancillary granules. A pitted texture is often present on the test surface, probably caused by pressure solution.

The septal filaments in the adult are proximally thickened and upright. Only near the periphery do they become swept back to meet the marginal cord. Juveniles have more hooked septal filaments, with a shorter proximally upright portion. Septal filament branching is only associated with gerontic individuals.

The adult septa in equatorial splits lean backwards proximally. They curve smoothly backwards, as in *N.variolarius* and *N.sp.2*, meeting the spiral lamina in a relatively large, acute angle. Juvenile septa are similar but are distally curved back farther. The chambers are low and long, with an H/L ratio of approximately 1.0 to 1.3. Coiling is tight, as in *N.variolarius* group, and the spiral lamina is relatively thick. The proloculus is large in comparison with *N.variolarius vars.1* and *2*, varying from 70 to 120 microns, with an average of 100 microns for 10 specimens.

Microspheric Form

This has a large test (up to 4400 microns in diameter out of 16 specimens measured), which is centrally strongly tumid and tapering rapidly to give a characteristic broad, peripheral flange. One or more flush polar granules are strongly developed. The D/T ratios vary from 2.25 to 4.40 in the 10 individuals measured and show a separate (more tumid) cluster from the 'B' form of N.sp.2 when plotted against the diameter.

The septal filaments are radial or slightly winding centrally, straight or slightly sinuous for most of their length and become swept back only near the periphery. Thickenings occur proximally and again at the inner edge of the flange, where they sometimes develop into small granules. Branching is rare and associated only with irregular development of the growth spiral, not with uncoiling of the final whorl, a feature which has not been observed. Canals are frequently seen internally running perpendicular to and forward from the septa.

In equatorial splits the adult septa are proximally upright or set backwards. They become strongly swept back after about two-thirds of their length and meet the spiral lamina at a small angle. Younger septa are as in the 'A' forms. The adult chambers are considerably higher than they are long, with an H/L ratio of about 1.8 to 2.3, while younger chambers are lower, though always with an H/L ratio of more than 1.0.

The spiral lamina is characteristically very thick in comparison with all other Upper Eocene Nummulites. Coiling is rather loose, looser than in the 'B' forms of N.sp.2. Younger whorls are more loosely coiled than those of adult megalospheric N.sp.1.

Remarks

This species occurs in samples 7170 and 7030, from bed H in the Fawley Transmission Tunnel (see CURRY, HODSON & WEST, 1968) and FISHER's bed XIV-XV in Whitecliff Bay (Brook Bed equivalent) respectively.

The microspheric form resembles microspheric N.chavannesi DE LA HARPE (= N.ruetimeyeri DE LA HARPE), an Aquitaine Basin species with a similar centrally tumid, peripherally flanged shape and swept back septal filaments. This ranges from the Bartonian to Lower Oligocene in various parts of the Western Tethys, a somewhat later level than its first appearance in Britain.

The very close morphological similarity of the megalospheric form with the N.variolarius group indicates that it is more likely to be derived directly from the latter than from a possible Tethyan ancestor of N.chavannesi. The 'A' form differs from both varieties of N.variolarius in its larger proloculus. It is externally also considerably larger than N.variolarius var.1, with which it occurs. The strong dimorphism shown by N.sp.1 also indicates its relationship with N.sp.2 and it is possible that the latter could have developed from this species.

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Nummulites sp.2

Plate 16, figs.5,6,7.

?Nummulites variolarius (LAMARCK):var.CURRY,1937. p.241,pl.20,fig.12.
Nummulites variolarius (LAMARCK):var.CURRY,1942. pp.99-101.

Description

Dimorphism marked, both internally and externally, the 'B' forms being considerably larger and flatter than the 'A' forms.

Megalospheric Form

Test large, up to 2100 microns out of the 10 specimens measured. In peripheral view the adults are flat and regularly lenticular, with a sharp or slightly rounded periphery and D/T ratios varying from 1.28 to 2.62. Thus they are very similar to N.variolarius in shape. Ornamentation consists of a cluster of small polar granules, always flush with the surface but rarely completely absent. No juveniles were examined. The septal filaments are proximally thickened as in N.variolarius. They are straight or slightly sinuous and only become swept back near the periphery. Branching of the septal filaments is common but is unaccompanied by uncoiling of the final whorl.

In equatorial splits the adult septa are proximally sloped backwards, becoming continuously curved back along their whole length to meet the marginal cord at a relatively large, acute angle. The juvenile septa are very similar to those of the adults. They do not show the strongly swept back septa of *N.rectus*, *N.prestwichianus* and *N.sp.3*. The chambers are quite low and long, as in *N.variolarius*, with H/L ratios of about 1.0 to 1.3. Canals perpendicular to the septal filaments are rarely seen and are short and very fine.

The spiral lamina is relatively thin in comparison with *N.variolarius*, though the tight coiling and increase in chamber height with age are very nearly the same as in the latter. The megalospheric proloculus is large, an average of 130 microns for 2 specimens (120-140 microns).

Microspheric Form

The 'B' forms of this species are considerably larger than the 'A' forms, up to 3800 microns for the 4 specimens measured. In apertural view they are flattened, though not parallel sided, raised at the poles and tapering at the edges to give a sharp or subquadrate periphery. The D/T ratios are high, ranging from 3.56 to 5.43. A single, large, flush polar granule can be seen in some specimens.

The septal filaments are strongly sinuous, but meet the periphery nearly at right angles. Branching is frequently seen, but the uncoiling noted by CURRY (1942) was not seen in the specimens examined. Trabeculae, which are sometimes visible are short and strong on both sides of the septal filaments.

A single specimen was sectioned to examine the septa. In the adult whorls these are proximally upright for about 3/4 of their length and distally strongly swept back. The juvenile septa are gently curved back along their whole length. The spiral lamina is considerably thinner than in *N.sp.1*. The chambers are higher than they are long, with H/L ratios varying from approximately 1.5 to 2.0; about the same as in *N.sp.1* but not as high as in *N.prestwichianus*. Coiling is tight in comparison with either of the above forms.

Remarks

This species was originally described by CURRY (1942) from the '*R.canalis*' bed, a transitional Auversian-Bartonian horizon, exposed at Afton Brickyard (three miles east of Freshwater, Isle of Wight). He also reported its occurrence in a similar bed at Gunville Brickyard, near Newport, Isle of Wight, and from the Sands of Ledes, from Bambrugge, Belgium. Both the Isle of Wight localities are now deeply weathered and heavily overgrown and the writer is indebted to Mr.Curry for his donation of specimens for study from the former section.

The size dimorphism of *N.sp.2* separates it from all other North West European Upper Eocene species except *N.sp.1* and *N.orbignyi*, although the 'A' forms strongly resemble those of *N.variolarius* and *N.sp.1*. Its differentiation from *N.sp.1* lies in its thinner spiral lamina and higher D/T ratios in microspheric forms. As noted by CURRY (1942) the 'A' forms of *N.orbignyi* are smaller and flatter and the 'B' forms show a marked polar pustule, not seen in this species.

CURRY (1942) placed this species in an intermediate position on the line of descent of *N.rectus* from *N.variolarius*, naming it as a variety of the latter. Such a theory would require the lineage to pass from non-dimorphic to dimorphic to non-dimorphic and the discovery of another Upper Eocene dimorphic species renders it unlikely.

Nsp.1 and *N.sp.2* are closely related forms. Flattening of the test and decrease in the thickness of the spiral lamina of microspheric *N.sp.1* would produce a morphology very similar to that of microspheric *N.sp.2*. The megalospheric forms are almost identical. These two are the only externally dimorphic species of English Upper Eocene *Nummulites* and *N.sp.2* is tentatively thought to have evolved from *N.sp.1*, although their stratigraphic separation precludes drawing a definite line of descent in the absence of intermediates.

There is a strong morphological series between *N.sp.3*, and on one hand, *N.rectus*,and on the other *N.prestwichianus*. This indicates that the *Nummulites* of the Barton Beds (s.s.) developed through the externally non-dimorphic *N.sp.3* rather than from the strongly dimorphic *N.sp.2* as suggested by CURRY (1942). This line of argument indicates that, on present evidence, *N.sp.2* is the final product of the dimorphic lineage in Britain at least.

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Nummulites sp.3

Plate 16, figs.8,9.10,11.

Nummulina cf.variolaria (LAMARCK): FISHER,1862. p.80.
Nummulites elegans (J.deC.SOWERBY):T.R.JONES,1887. (*part*) p.142,pl.11, figs. 5-9 only.
Nummulites prestwichianus (T.R.JONES) var.CURRY,1937. p.243,pl.20,figs.10, 11.

Description

The only difference between the microspheric and megalospheric forms is the proloculus size. Test large; up to 2450 microns in diameter, out of 29 specimens measured. In apertural view the sides of adults are umbilically flattened and rounded towards the periphery, which is usually subquadrate. Juveniles are lozenge-shaped in apertural view, but never have a sharp periphery. A characteristically strong umbilical granule is usually flush in adults or slightly raised to form a polar pustule in some adults and most juveniles. The D/T ratio varies from 2.58 to 4.50 in adults and 1.50 to 3.50 in juveniles, the test thus being considerably more tumid than in typical *N.prestwichianus*. The adult shape overlaps strongly with *N.rectus* and weakly with *N.prestwichianus*. Juveniles overlap strong with *N.variolarius*.

In adult specimens the septal filaments are upright and straight or very slightly sinuous. Only near the periphery do they bend back strongly. The septal filaments of the juveniles are usually similar but occasionally show strong curvature along their whole length. Branching of the septal filaments is fairly common in adults. It is associated with uncoiling or sometimes with irregular development of the growth spiral.

The adult septa in equatorial splits are straight and proximally slightly backward sloping for 3/4 of their length, after which they bend back to meet the marginal cord at a relatively large acute angle. The juvenile septa are proximally much more inclined, then arch back gently along their whole length. The chambers tend to be slightly higher than they are long at all stages of growth, with an H/L ratio of approximately 1.3 to 1.5. They are never high and short as in N.prestwichianus. Very fine, short wall canals or incipient trabeculae are very occasionally seen.

The spiral lamina is relatively thick and is similar in both generations. Coiling tends to be tighter than in N.prestwichianus but not as tight as in N.variolarius. Uncoiling occurs only in the largest, gerontic, specimens. The megalospheric proloculus size varies from 70 to 110 microns with an average of 94 microns for 7 specimens.

Remarks

This form has been referred to in the literature as a variety of N.prestwichianus. Certain strong differences preclude its placing with N.prestwichianus, including its much lower D/T ratios, straighter septal filaments and tighter coiling. It also shows a close similarity with the more flattened members of the N.rectus complex. Some of the juveniles of N.sp.3 show similar D/T ratios, septal filaments and apertural view outlines as some juveniles of the N.variolarius plexus, indicating possible affinities with this group as well. Thus N.sp.3 must be regarded as a form morphologically intermediate between the two stocks of British Upper Eocene Nummulites and provides a possible link between the N.variolarius complex and the two dissimilar Bartonian species: N.prestwichianus and N.rectus. It also shows affinities with N.orbignyi in its strong umbilical plug, but differs in its lack of size dimorphism.

The horizon to which N.sp.3 is at present restricted (the Huntingbridge Bed of Huntingbridge and Studley Wood in the New Forest) has been regarded as uppermost Upper Bracklesham Beds in lithofacies, and faunally transitional between the Auversian and Bartonian. The author is indebted to Mr.D.Curry for his provision of material for study from Huntingbridge.

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Superfamily: GLOBIGERINACEA CARPENTER, PARKER & JONES 1862

Family: GLOBIGERINIDAE CARPENTER, PARKER & JONES 1862

Genus: *Globigerina* D'ORBIGNY 1826

(Type species: *Globigerina bulloides* D'ORBIGNY, 1826.)

Globigerina sp. cf. *G.angustiumbilicata* BOLLI

Plate 12, figs. 17a, b, c.

?*Globigerina ciperoensis angustiumbilicata* BOLLI,1957. p.109,pl.22,figs.12,13; p.164,pl.36,fig.6. (Oligocene? Trinidad.)

Globigerina sp.indet. BHATIA, 1955. p.685,pl.66,fig.28. (Brockenhurst Bed, Lower Oligocene, Isle of Wight.)

Globigerina sp.cf. *angustiumbilicata* BOLLI: KAASSCHIETER, 1961. p.236,pl.15, figs.7,8. (Sands of Ledes,Wemmel.Clay ofAsse,Belgium.Sands of Leds,Neths. Barton Beds, England.)

?*Globigerina angustiumbilicata* BOLLI: EAMES,BANNER,BLOW & CLARKE,1962. p.35, pl.9,figs.X-Z;text-figs.9(4),16(6,7.) (topmost Up.Eocene-?Tortonian, Aquitaine, America.)

Remarks

Large numbers of small *Globigerinae* occur in the Lower and Middle Barton Beds and the *Chama* Bed. They are all of about the same size, more or less hispid, with 4 to 5½ chambers in the final whorl and a narrow umbilicus. They vary continuously between two slightly different end members.

The chambers of one type increase less rapidly in size, giving a slightly higher spire. They have less incised sutures and the chambers are elevated slightly ventrally, giving a tighter umbilicus. The final chamber is displaced slightly ventrally. The other type shows a greater increase in chamber size with development and more incised sutures, giving more globular, sometimes even radially elongate chambers. The spiral side is lower and the umbilicus not so deep, though equally narrow. The complete intergradation and obvious homogeneity of the assemblage precludes division into more than one species. Both end members are usually present in any one sample and neither shows any stratigraphic separation so subspecific differentiation also can be ruled out.

In addition to the Bartonian occurrences KAASSCHIETER (1961) also records and figures identical specimens from the Belgian Upper Eocene.

Topotype specimens of Globigerina sp.indet. BHATIA, (1955), from the Lower Oligocene Brockenhurst Bed of Whitecliff Bay, were examined and found to be conspecific with the Bartonian species. BRONNIMANN et al. (1968) show the distribution of this form in the North West European Tertiary as from Upper Eocene to Lower Oligocene. This is somewhat lower than BOLLI's (1957) type level but EAMES et al. (1962) also record it from the Upper Eocene to the Middle Miocene (Tortonian). Their figures show the typical Tethyan form to be somewhat larger but, in the absence of large quantities of comparative material, no revision of its taxonomic placing is here proposed.

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Superfamily: ORBITOIDACEA SCHWAGER 1876

Family: CIBICIDIDAE CUSHMAN 1927

Genus: Cibicides MONTFORT 1808

(Type species: Cibicides refulgens MONTFORT, 1808.)

Cibicides carinatus (TERQUEM)

Plate 14, figs. 8a,b.c.

Truncatulina carinata TERQUEM,1882. p.94,pl.10,figs.1,2. (Lutetian, Paris Basin.)
Cibicides carinatus (TERQUEM): LE CALVEZ,1949. p.45,pl.4,figs.72-74.
Cibicides carinatus (TERQUEM): KAASSCHIETER,1961. p.221,pl.14,fig.6. (et syn.) (Lr.-Up.Eocene,Belgium,France,Netherlands.)

Remarks

A few specimens of this much compressed, planoconvex, coarsely perforate species were found in the Middle Barton Beds of both sections. They are identical with rare Upper Bracklesham Beds specimens. The only notable difference from C.lobatulus is its broad, vitreous peripheral keel, indeed KAASSCHIETER (1961) considers it to be a deviant of that very variable species.

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Cibicides lobatulus (WALKER & JACOB)

Plate 14, figs. 9a, b, c.

Nautilus lobatulus WALKER & JACOB, 1798. p.642,pl.14,fig.36. (Recent,England.)
Cibicides lobatulus (WALKER & JACOB): LE CALVEZ,1949. p.46. (Lutetian, Paris Basin.)
Cibicides lobatulus (WALKER & JACOB): BATJES,1958. p.153,pl.9,figs.7,8. (et syn.) (Lr.Oligocene-M.Miocene,Belgium,Germany.)
Cibicides lobatulus (WALKER & JACOB): KAASSCHIETER, 1961. p.221,pl.14,fig.5. (et syn.) (Lr. - Up. Eocene, Belgium, France, Netherlands, England.)

Remarks

This species is taken here to include all specimens with a more or less flattened dorsal side, a lobulate periphery and a disc-like dorsal umbilicus. As previous authors have noted, C.lobatulus is probably polyphyletic. It could be an ecophenotypic encrusting form of a number of species, which would explain the similarity of juveniles with juvenile C.proprius, C.dutemplei, C.ungerianus and C.cf.tenellus. In the Bartonian it is extremely difficult to distinguish from juvenile C.ungerianus and C.vialovi, where the dorsal granulation is often not fully developed until later stages. In the literature it has been recorded from all stages from the Paleocene to Recent. In the Bartonian it is present in small numbers throughout most of both sections.

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Cibicides pygmeus (HANTKEN)

Plate 14, figs. 7a, b, c.

Pulvinulina pygmea HANTKEN,1875. p.78,pl.10,fig.8.(Eocene, Hungary.)
Eponides sp.cf. E.pygmeus (HANTKEN): BHATIA,1955. p.683,pl.67,fig.7. (Lr.Oligocene,Brockenhurst Bed, England.)
Eponides pygmeus (HANTKEN): BATJES, 1958. p.146,pl.7,fig.11.(M.Oligocene, Belgium.)
Cibicides pygmeus (HANTKEN): KAASSCHIETER,1961. p.219,pl.14,fig.1. (Up. Eocene,Belgium, England.)

Remarks

This is the dominant species in the Lower Barton Beds and part of the Middle Barton Beds, where it occurs in large numbers. As noted by KAASSCHIETER (1961) the aperture frequently passes to the dorsal side, placing it in Cibicides, not Eponides. It is characterised by being dorsally evolute with a rounded periphery, not angular like that of

C.dutemplei (D'ORBIGNY), or carinate as in C.sulzensis (HERRMANN). The height of the spiral side is rather variable, the more flattened, more involute forms (particularly in the Upper Bracklesham Beds) tending towards C.proprius (BROTZEN). The spiral side is never as coarsely perforate as C.dutemplei and often bears a smooth, glossy dome of clear calcite (not seen in the Stereoscan photographs). It differs from C.cf.tenellus (REUSS) with which it is frequently found, in its rounded noncarinate periphery, flush rather than limbate dorsal sutures, more radial ventral sutures and usually higher, more evolute spiral side.

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Cibicides sp.cf. C.tenellus (REUSS)

Plate 14, figs. 10a, b, c.

?Truncatulina tenella REUSS,1865. p.477,pl.5,fig.6.(Up.Oligocene,Germany)
?Cibicides tenellus (REUSS): TEN DAM & REINHOLD,1942. p.99,pl.8,fig.6;
fig.2. (M. & Up. Oligocene, Netherlands.)
?Cibicides tenellus (REUSS):BATJES,1958. p.151,pl.9,figs.3,4.
(Lr. Oligocene - M.Miocene, Belgium, Germany.)
Cibicides sp.cf. C.tenellus (REUSS): KAASSCHIETER,1961. p.219,pl.14,fig.2.
(Up. Eocene, Belgium, Netherlands,England.)

Remarks

Most of BATJES' (1958) German and Belgian Oligocene specimens, including topotypes of REUSS's, were characterised by the presence of a glossy, ventral, umbilical knob. BATJES (1958) and KAASSCHIETER (1961) found that specimens from the Belgian Lower Tongrian, Ledian and Wemmelian seldom show this feature. Similarly the common Lower and Middle Barton Beds specimens are usually without a ventral knob. They have a large number of chambers in the last whorl with sutures which are characteristically strongly curved and limbate or even beaded dorsally, and are ventrally flush and swept backwards near the acute periphery. Many specimens are rather thicker and dorsally more domed and evolute than KAASSCHIETER's figure. These approach C.pygmeus from which juveniles are sometimes difficult to distinguish when suture limbation is poorly developed. More compressed juveniles are also hard to divide from juvenile C.ungerianus and C.lobatulus, though the adults never develop the dorsal umbilical granules or discs of these two species.

C.crassivellauni WOOD & HAYNES (1957), from the English Paleocene, has fewer chambers in the last whorl and is dorsally much flatter.

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Cibicides ungerianus (D'ORBIGNY)

Plate 14, figs. 11a, b, c.

Rotalina ungeriana D'ORBIGNY, 1846. p.157,pl.8,figs.16-18. (Miocene, Vienna Basin.)

Cibicides ungerianus (D'ORBIGNY): TEN DAM & REINHOLD,1942. p.98,pl.8,fig.5. (Oligocene-Miocene, Netherlands.)

Cibicides ungerianus (D'ORBIGNY): BATJES,1958. p.152,pl.9,fig.6. (M.Oligocene-M.Miocene, Belgium, Germany.)

Cibicides sp.cf. C.ungerianus (D'ORBIGNY): KAASSCHIETER,1961. p.220,pl.14, fig.3. (Lr.-Up.Eocene, Belgium, England, Netherlands.)

Remarks

A Lower Barton Beds form, characterised by its angular periphery and the secondary granules which cover the early whorls on the dorsal side. These are sometimes fused into one or two glassy knobs. The spiral side is convex, with curved, limbate sutures. The ventral sutures similarly are curved backwards, but are almost flush. The dorsal granules are always present, (they are missing in some of KAASSCHIETER's specimens), and serve to separate this species from C.tenellus. However, juveniles may integrade with juvenile C.lobatulus. The acute periphery distinguished C.ungerianus from even the most compressed specimens of C.vialovi BYKOVA. Also the sutures of the latter are never limbate and are always depressed.

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Cibicides vialovi BYKOVA

Plate 14, figs. 12a,b,c.

Cibicides vialovi BYKOVA, 1939. pp.31,37,pl.4,figs.13-15.(Eocene, Uzbeck,S.S.R.

Cibicides vialovi BYKOVA: KAASSCHIETER,1961. p.220,pl.13,fig.8.(Up.Bracklesham Beds, and Barton Beds, England.)

Remarks

In the Middle Barton Beds this species is dominant and is characterised by its depressed sutures and the multiple knobs of clear calcite on the early chambers of the spiral side. These are surrounded in adult specimens by the lipped, relict apertures of earlier chambers. Juvenile specimens are quite distinct from C.ungerianus in their depressed and non-limbate sutures. Some specimens in the upper part, and most from the lower part of the Middle Barton Beds are more compressed and have a more subacute periphery than those dominant in the upper Middle Barton Beds. There is complete intergradation between these and the peripherally better rounded forms.

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Superfamily: CASSIDULINACEA D'ORBIGNY 1839
Family: CAUCASINIDAE BYKOVA 1959
Genus: *Fursenkoina* LOEBLICH & TAPPAN 1961
(Type species: *Virgulina squammosa* D'ORBIGNY, 1826.)

Fursenkoina sp. cf. *F. schriebersiana* (CZJZEK)

Plate 14, fig.6.

?*Virgulina schriebersiana* CZJZEK, 1847. p.147,pl.13,figs.18-21.(Miocene,Vienna Basin.)
?*Virgulina schriebersiana* CZJZEK: CUSHMAN, 1937. p.13,pl.2,figs.11-20.(*et syn.*)
Virgulina schriebersiana CZJZEK: BHATIA, 1955. p.681,pl.66,fig.24;text-fig.6. (M.Oligocene, Up.Hamstead Beds,Englan
?*Virgulina schriebersiana* CZJZEK: BATJES,1958. p.129. (M.Miocene,Belgium.)

Remarks

This species occurs frequently in the Lower and Middle Barton Beds. It agrees well with BHATIA's figures from the Hamstead Corbula Bed, with its initially triserial then twisted biserial elongate testand high aperture. It ranges, according to the literature, from the Middle Oligocene to Recent and BHATIA's is the lowest published record in England. Topotype specimens from the Vienna Basin (Imperial College Collection) are rather larger but its variable nature precludes definite taxonomic placing. The only related form found is an unnamed species of *Cassidella* from the Upper Bracklesham Beds. It has less depressed sutures and is twisted biserial throughout.

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Family: NONIONIDAE SCHULTZE 1854

Genus: *Nonion* MONTFORT 1808

(Type species: *Nautilus incrassatus* FICHTEL & MOLL, 1798.)

Nonion affine (REUSS)

Plate 14, figs. 13a,b.

Noniona affinis REUSS,1851. p.72,pl.5,fig.32.(Oligocene,Germany.)
Nonion affine (REUSS): CUSHMAN,1939. p.9,pl.2,fig.13.(et syn.)
Nonion affine (REUSS): TEN DAM,1944. p.108. (Lutetian,Netherlands.)
Nonion umbilicatulum (WALKER & JACOB) : BHATIA,1955. p.678,pl.66,fig.2. (Lr.Oligocene, England.)
Nonion umbilicatulus (MONTAGU): BOWEN,1957. (non BOWEN,1954) p.57,pl.1,figs.22, 23. (Barton Beds, Barton.)
Nonion affine (REUSS): BATJES,1958. p.140,pl.6,fig.12.(Lr.Oligocene - M.Miocene, Belgium, Germany.)
Nonion affine (REUSS): BOLTOVSKOY,1958. p.195.(et syn.)
Nonion affine (REUSS): KAASSCHIETER,1961. p.203,pl.11,figs.3,4.(Lr.-Up.Eocene, Belgium,France,Netherlands,England.)

Remarks

This smooth, slightly compressed species, with its characteristic deep umbilici occurs commonly in the Lower and lower Middle Barton Beds of both sections. Identical forms are common in the Upper Bracklesham Beds and its total range in the literature is from Eocene to Recent.

There is a large group of smooth, many chambered, biumbilicate *Nonions* and this species has in the past been confused with several of them. BOLTOVSKOY's (1958) well argued paper has gone a long way to clarifying this controversy and the reader should consult it for a full synonymy. *N.chapapotense* COLE differs in having two glossy umbilical plugs. KAASSCHIETER (1961) records specimens like this but none were encountered in the present study. *N.halkyardi* CUSHMAN, *N.soldanii* (D'ORBIGNY) and *N.pompilioides* (FICHTEL & MOLL) are much broader in apertural view than *N.affine*. They are common somewhat higher in the Tertiary and BOLTOVSKOY (1958) considers them to represent a single species. CUSHMAN (1939) records *N.halkyardi* from, among other places, the Upper Bracklesham Beds of Whitecliff Bay but all those found in the present study were true *N.affine*. *N.barleeanum* (WILLIAMSON) and *N.zaandamae* (VAN VOORTHUYSEN), also considered by BOLTOVSKOY to be one species, differ from *N.affine* in having thicker sutures and coarser perforations.

Of the numerous citations of *N.umbilicatulum* (WALKER & JACOB) BHATIA's (1955) and BOWEN's (1957) can fairly confidently be included in *N.affine*. The former considered *N.affine* to be a junior synonym of *N.umbilicatulum*. The type figure of *N.umbilicatulum* is extremely ambiguous, the holotype is missing (see CUSHMAN, 1939, p.21) and it would be very unwise to use this name until more is known of its original character. BOWEN (1954) also recorded "*N.umbilicatulus*" from the London Clay of the Reading Area. Specimens from a sample of London Clay from Wraysbury, near Staines, agree with BOWEN's (1954) figures. They have the same shape etc. as *N.affine* but are definitely slightly trochospiral and thus do not belong in this genus.

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Nonion graniferum (TERQUEM)

Plate 14, figs. 15a, b.

Nonionina granifera TERQUEM, 1882. p.42,pl.2,figs.8,9.(Lutetian,Paris Basin.)
Nonion graniferum (TERQUEM): CUSHMAN, 1939. p.4,pl.1,figs.9-11.
Nonion graniferum (TERQUEM): LE CALVEZ, 1950. p.53,pl.4,figs.58,59.(Lutetian, Paris Basin.)
Nonion depressulum BOWEN, 1957. (non WALKER & JACOB, 1798) p.57,pl.1,figs.20,21. (Barton Beds, Barton.)
Nonion graniferum (TERQUEM): KAASSCHIETER, 1961. p.204,pl.10,fig.15. (Lr.-Up. Eocene, Belgium, France, England.)
Nonion graniferum (TERQUEM): BIGNOT, 1962. (part) p.168,pl.3,figs.4,5 only. (not 1-3). (Lr.Eocene, France.)

Remarks

This species occurs throughout the Barton Beds at both sections. Small specimens are typical, with nearly radial sutures and sparsely,finely granulate umbilici. Larger specimens, particularly those from the Chama Bed, have higher chambers, more curved sutures and more densely granulate umbilici, tending towards the Oligocene species. *N.granosum* (D'ORBIGNY) (=*N.depressulum* of BHATIA, 1955). The granulations on these specimens sometimes spread out of the umbilici around to the base of the apertural face, a feature not seen in those from the Middle and Lower Barton Beds. Larger forms with the much broader, lower chambers of *N.roemeri* CUSHMAN were not encountered. The aperture is nearly always obscured so the relationship with *Protelphidium hofkeri* HAYNES, which has a multiple aperture, could not be elucidated.

****

Nonion sp.8

Plate 14, figs.15a,b.

Description

Test minute, planispiral and deeply biumbilicate. Eight chambers in the final whorl, increases rapidly in size. Periphery rounded, outline stellate, with the adult chambers each showing a circum-cameral, rounded, flange-like extension facing towards the aperture. Apertural face semi-circular. Aperture broad and low, extending into both umbilici.

Remarks

A single specimen was found in the Middle Barton Beds of Barton (sample 6941). It differs from all other species of Nonion by virtue of its peculiar chamber shape, but may be a variant of N.affine.

****

Genus: Nonionella CUSHMAN 1926

(Type species: Nonionella miocenica CUSHMAN, 1926.)

Nonionella spissa CUSHMAN

Plate 15, figs. 1a, b.

Nonionella hantkeni (CUSHMAN & APPLIN) var.spissa CUSHMAN, 1931.
p.58,pl.7,fig.13. (Jackson Eocene, S.Carolina.)
Nonionella hantkeni (CUSHMAN & APPLIN) var.spissa CUSHMAN: CUSHMAN,1939.
p.30,pl.8,fig.5. (et syn.)
Nonionella spissa CUSHMAN: KAASSCHIETER,1961. p.205,pl.11,figs.7,8.
(Lr.-Up.Eocene, Belgium.)

Remarks

The rare Middle Barton Beds specimens agree fairly well with KAASSCHIETER's (1961) figures and correspond to his more compressed type. They are never as lossely coiled as N.wemmelensis KAASSCHIETER, nor do they have the laterally slightly overhanging final chamber. BHATIA's (1955) figure of N.auricula HERON-ALLEN & EARLAND (Recent, English Channel), from the Middle Oligocene Hamstead Beds, appears to be very similar, but in the absence of comparative specimens no decision can be reached.

****

Genus: Pullenia PARKER & JONES 1862

(Type species: Nonionina bulloides D'ORBIGNY, 1846.)

Pullenia quinqueloba (REUSS)

Plate 15, figs. 2a,b.

Nonionina quinqueloba REUSS, 1851. p.71,pl.5,fig.31.(Oligocene,Germany.)
Pullenia quinqueloba (REUSS): SHERBORN & CHAPMAN,1889. p.5,pl.11,fig.29.
(London Clay,England.)
Pullenia quinqueloba (REUSS): BURROWS & HOLLAND,1897. p.47,pl.2,fig.21.
(Thanetian, Kent.)
Pullenia quinqueloba (REUSS): CUSHMAN & TODD, 1943. p.10,pl.2,fig.5;pl.3,fig.8.
Pullenia quinqueloba (REUSS): TEN DAM,1944. p.128.
Pullenia quinqueloba (REUSS): BOWEN,1954. p.139,pl.A,fig.8.(London Clay,England
?Pullenia sp.indet. BHATIA, 1955. p.685,pl.66,fig.27.(Lr.-M.Oligocene,England.)
Pullenia quinqueloba (REUSS): BOWEN,1957. p.55,pl.1,fig.16.(Bartonian,Barton.)
Pullenia quinqueloba (REUSS): HAYNES,1958b. p.76,pl.17,figs.16-21.
(Thanetian, Kent.)
Pullenia quinqueloba (REUSS): BATJES, 1958. p.139,pl.6,fig.8.(M.Ologicene -
M.Miocene, Belgium, Germany.)
Pullenia quinqueloba (REUSS): KAASSCHIETER, 1961. p.202,pl.11,figs.1,2.
(Lr.-Up.Eocene,Belgium,England,Netherlands.)

Remarks

Most of the Bartonian specimens, from the Lower and Middle Barton Beds, have 4½ chambers in the last whorl. They are more laterally compressed than P.quaternaria (REUSS) and P.bulloides (D'ORBIGNY), with a more lobulate outline than the latter. The apertural area is usually papillate or hispid.

****

Family: ANOMALINIDAE CUSHMAN 1927

Genus: Hanzawaia ASANO 1944

(Type species: Hanzawaia nipponica ASANO, 1944.)

Hanzawaia producta (TERQUEM)

Plate 15, figs.4a,b,c,5a,b,

Truncatulina producta TERQUEM,1882. p.92,pl.9,figs.20,21.(Lutetian,Paris Basin.)
Cibicides productus (TERQUEM): LE CALVEZ,1949. p.49,pl.4,figs.69-71.
Hanzawaia producta (TERQUEM): KAASSCHIETER,1961. p.226,pl.13,fig.13. (Lr.-Up.
Eocene,Belgium,England,France,Netherlands.)

Remarks

A single, questionable specimen was found in the Lower Barton Beds of Barton. Like the more typical material from the Upper Bracklesham Beds it is dorsally and ventrally rather involute, with an angular periphery and strongly curves sutures.

****

Superfamily: ROBERTINACEA REUSS 1850

Family: ROBERTINIDAE REUSS 1850

Genus: Robertina D'ORBIGNY 1846

(Type species: Robertina arctica D'ORBIGNY,1846.)

Robertina germanica CUSHMAN & PARKER

Plate 15, figs. 3a, b.

Robertina germanica CUSHMAN & PARKER,1938. p.73,pl.13,fig.2.(Lr.Oligocene, Germany.)
Robertina germanica CUSHMAN & PARKER: CUSHMAN & PARKER,1947. p.73,pl.18,fig.5.
Robertina germanica CUSHMAN & PARKER: KAASSCHIETER,1961. p.201,pl.10,figs. 11 & 12. (Up.Eocene,Belgium,England.)

Remarks

A large form common in the Lower and Middle Barton Beds and the Chama Bed. It is more elongate and has less depressed sutures than R.ovigera CUSHMAN & PARKER (Lutetian, Paris Basin) or R.declivis (REUSS) (M.Oligocene, Germany). R.declivis also differs in having its apertural face displaced laterally.

****

Other Foraminiferal Remains

"Microforaminifera"

Plate 15, fig.6.

Remarks

The tectinous inner linings of the early stages of Foraminiferida occur in many samples and are particularly common in the upper Middle Barton Beds and Chama Bed of Barton. Most are black or brown and translucent in transmitted light. They consist of a number of chamber linings, joined by their foramina and arranged in a planispiral series. The interior of a broken specimen of Cribrostomoides pauperata shows, not the usual pyritic infilling, but part of a "Microforaminiferid". It is not certain whether all the "Microforaminifera" are derived from agglutinated forms. Another type encountered very rarely in the Chama Bed of Barton consists of a flat spiral, without constrictions, such as would be expected from a non-septate, planispiral form like Glomospirella sp.1.

****

Section 4:3 SMALL GROUPS

4:3:1 Angiosperm Seeds

Seeds are not well represented in the samples studied and only three species are distinguished. Two of these could be identified from CHANDLER's (1960) work on the flora of the Barton and Hengistbury Beds. She records 24 species from the Hengistbury Beds and 28 from the Barton Beds, (chiefly from BURTON's bed A3), noting a predominance of water plants and a strong tropical bias in the flora. She concludes that her evidence cannot be used to correlate the two sections. In this study seeds were found most frequently in samples with a high proportion of plant remain debris.

Scirpus lakensis CHANDLER, 1960

Plate 16, fig. 14.

Scirpus lakensis CHANDLER, 1960. p.206,pl.30,fig.26.

Remarks

A cigar-shaped, flexible-walled form, which bears longitudinal corrugations and a distinct neck at each extremity. CHANDLER records it from the Lower Bagshot Beds of Dorset and the Hengistbury Beds.

****

Hordwellia crassisperma (CHANDLER) CHANDLER,1960

Plate 16, fig. 12.

Actinidia crassisperma CHANDLER,1926. p.34,pl.6,fig.2; text-fig.15.
Hordwellia crassisperma (CHANDLER):CHANDLER,1960. p.229,figs.140-144.

Remarks

A single specimen, from the Lower Barton Beds of Barton (sample 6915) could be identified from CHANDLER's figures. She records it from the Lower Bagshot to the Upper Headon Beds and from bed A3 at Barton.

****

Seed sp. 9

Plate 16, fig. 13.

Remarks

This form occurs in small numbers throughout the Barton Beds. It is small, flattened, with a flexible, irregularly corrugated wall, a regular oval outline and a short, distinct micropyle. Brasenia ovula (BROGNIART) (as figured by CHANDLER, (1960, figs. 40,41, 106, 107) range Bournemouth Marine to Hamstead Beds) has a similar oval outline but has fewer ridges.

****

4:3:2 Porifera

Only one type of sponge spicule comes within the size range (greater than 76 microns) studied and this is referred to the organ genus Geodia LAMARCK. Other forms undoubtedly occur. Triaxons (Hexactinellids) and tetraxons (Tetractinellids) have been observed in the test matrix of agglutinated Foraminifera, particularly Reophax sp.1, with the Stereoscan. These are much too small to fall within this size range.

Geodia sp.

Plate 16, fig. 15.

Remarks

Small (about 150 microns in maximum diameter), hollow, rough surfaced, reniform spicules occur throughout the Barton Beds. The walls are cryptocrystalline silica and show a fine radiating structure in polarised light. Sponge spicules having an originally amorphous (opal) structure may become cryptocrystalline during diagenesis.

These structure resemble figures of the sterrasters of Geodia in LAUBENFELS (in MOORE, 1955 - "Treatise", Part E). POKORNY (1965) also illustrates similar forms of polyaxial spicules (see fig. 563:1).

BURROWS & HOLLAND (1897) record Geodia from the Paleocene Thanet Sands of Kent and give a detailed description. CURRY, HODSON & WEST (1968) also found it in the Upper Bracklesham Beds of Fawley. Samples from the Lower, Middle and Upper Bracklesham, Middle Headon and Bembridge Oyster Beds also yielded specimens. In the Barton Beds it occurs in most samples but it is particularly abundant in the glauconitic rich sequences (beds A1, B, C, D) and throughout the brackish water Upper Barton Beds (beds J.K). Abundance is much lower in clay beds, such as F and A2, and in the strongly calcareous parts of the Upper Bracklesham Beds (Nummulites variolarius Bed, Tellina Bed and equivalents). Thus there appears to be a strong correlation between its abundance and the incidence of very shallow water and estuarine conditions.

Siliceous sclerites secreted by certain higher plants (particularly the grasses) may have a similar structure. BAKER (1960) figures a large number of opal-phytoliths but all are either acicular in shape or of much smaller size. Bearing in mind the strong correlation with the estuarine environment, a sample of marram grass (Psamma arenaria), a shore and dune species, was macerated in nitric acid, though without finding similar bodies.

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4:3:3 Coelenterata

Turbinolia fredericiana MILNE-EDWARDS & HAIME

Turbinolia fredericiana MILNE-EDWARDS & HAIME, 1850. p.17, pl.3, fig.2.

Remarks

This small, solitary, ahermatypic form is the only species of Scleractinian coral found in this work. It occurs quite commonly in the Lower and Middle Barton Beds, agreeing with the type figures and with specimens in the Ross collection (University College, London). Shorter, stouter specimens resemble T.forbesi DUNCAN but these features may be due to erosion of the initial stage. BURTON records 7 species of Turbinolia and 6 other Coelenterates from Barton.

****

4:3:4 Annelida

Scolescodonts

Plate 16, fig. 19.

Remarks

Scolescodonts have an almost non-existent record in the Mesozoic and Tertiary, yet they occur in samples from the English Atherfield Clay (D.J.Carter:pers.comm.), Gault Clay, Lower Chalk (M.B.Hart: pers.comm.), London Clay, Bracklesham Beds (Lower, Middle and Upper), Barton Beds and Middle Headon Beds. DAVIS (1936) records similar structures, as "supposed hooklets of parasitic worms", from the London Clay of Sheppey and stated that Venables found them in the same unit at Bognor. POKORNY (1965) surveys the literature and shows that although well known in the Palaeozoic, their Mesozoic record is restricted to a few occurrences and that they have been totally neglected in the Tertiary.

The elements from the Barton Beds are all strongly hooked and usually have a serrate proximal shaft. A few specimens differ in having a deeply divided base. All appear to be referable to the dental plates or forceps in POKORNY's (1965) figures. Certain Teuthids have similar hooks on the tentacles. Specimens of Jurassic Teuthids, examined in the British Museum (N.H.) had considerably larger elements, usually with a marked bulbous base. Specimens of *Nereis* (Lugworm) yielded exactly the same type of hooks as those found fossil and leave no doubt that these structures are in fact derived from Polychaetes.

****

The Serpulids

One group of Polychaete Annelids (the Serpulidae) secrete calcareous structures and these locally occur in large numbers in the Barton Beds. Most Serpulids have an attached calcareous tube, composed of two layers and bearing variable ornament. Two genera (*Sclerostyla* and *Turbinia*) also have specifically differentiated calcareous opercula of a characteristic, conical, "tin-tack" shape. The opercula of most other Recent genera are chitinous and so not likely to be preserved.

WRIGLEY (1951) describes the Eocene Serpulids in detail and records three species from Barton. BURTON (1933) mentions an additional three species. In this study three types are distinguished. The tubes are very fragile and consequently all the material is fragmentary. For this reason one of the types (Worm Tube Type 1) is polyphyletic and consists of fragments of two species, as described by WRIGLEY.

Sclerostyla mellevillei (NYST & LE HON)

Serpula mellevillei NYST & LE HON, 1826. p.1.
Sclerostyla mellevillei (NYST & LE HON): WRIGLEY, 1951. p.185, figs.33-37. (*et syn.*

Remarks

This is the only species found in the present study to be represented by both tubes and opercula. The tube occurs as two layered, seven sided fragments in samples from BURTON's (1933) bed E at Barton, together with the peculiar, slightly eccentric, conical, flat topped and striate opercula. WRIGLEY (1951) also records it from bed A3, the Upper Bracklesham Beds of Selsea and the Middle Bracklesham Beds of Southampton Dock. He distinguishes it from several related Eocene and Oligocene species on characters of the opercula. S.mellevillei is erroneously referred by many earlier English workers to Serpula heptagona J. de C.SOWERBY (1844) (non Serpula heptagona HAGENOW, 1840).

****

Worm Tube Type 1

Remarks

Included here are all smooth, curved or straight, cylindrical, double layered Serpulid fragments. They belong to two species, namely Ditrupa bartonensis WRIGLEY (1951, p.191, figs.56-59) (= D.plana (J.SOWERBY) of early authors) and Protula extensa (SOLANDER, 1766, pl.12, fig.12). The outer layer is orange or light brown in colour and the inner one white and opaque. Complete Ditrupa bartonensis has a curved, tapering, distally bulbous tube, whereas that of Protula extensa is straight, unconstricted and very slightly tapering. Neither species is known to have a calcareous operculum and the fragmented tubes could not be satisfactorily distinguished. This type becomes extremely abundant at Barton in the Middle Barton Beds, especially in beds E and lower F. It also occurs at a similar level at Alum Bay and less frequently in the Lower Barton Beds of both sections.

****

Rotularia? sp.1

Plate 16, fig. 20.

Remarks

A few specimens, from the Middle Barton Beds of Barton and Alum Bay differ from all the above Serpulids in having an irregularly coiled tube. This is flattened on one side, perhaps marking the point of attachment to the substrate. The shell structure is unfortunately obscured by abrasion. The

Gastrapod (Serpulorbis cancellatus DESHAYES) is known from Barton but has a much larger shell, even in the initial stages. The specimens available are tentatively referred to the genus Rotularia on the basis of their coiled natur, resembling R.bognorensis (MANTELL), a London Clay species.

****

4:3:5 Arthropoda (excluding Ostracoda)

Crustacean Fragments

Plate 16, fig. 16.

Remarks

Chelae (claws) and other indeterminate crustacean fragments occur sporadically throughout the Barton Beds, showing slightly higher abundance in the upper part of bed F. They have been referred to the genus Calappa by BURTON (1933) and others. It is uncertain which group of the Cructacea the belong to. Unlike the London Clay, complete Crustacean carapaces are extreme rare in the Barton Beds (BURTON, 1933, p.162). Perhaps this is a preservati feature.

****

Crustacean Gastroliths

Plate 16, fig. 18.

Remarks

FRIZZELL & EXLINE (1958) first drew attention to these objects when they described specimens from the Claiborne Eocene of Texas. They erected a new genus and species, Wechesia pontis, to accommodate their discovery. The very rare specimens from the Lower and Middle Barton Beds of Alum Bay may possibly belong to the same genus. They are irregularly tyre-shaped objects with an excavate interior side and a lobose but not depressed exterior side (FRIZZELL & EXLINE's orientation). W.pontis is excavate on both faces.

****

Balanus Fragments

Remarks

Valves of Cirripedes occur quite frequently in the Chama Bed at Barton. BURTON (1933) and DARWIN (1855) record Balanus unguiformis var erisma DARWIN from the Chama Bed.

****

Insect Thoracic Shield

Plate 16, fig. 17.

Remarks

A single indeterminable thoracic shield was found in BURTON's bed I at Barton (sample 6969). It is externally unornamented and its black, shiny and perhaps carbonised, preservation indicates that it is not a Recent contaminant. Insects have not previously been recorded from the Barton Beds but are known from the London Clay of Bognor (see VENABLES, 1963) and the famous Insect Limestone in the Bembridge Marls (see REID & STRAHAN, 1889).

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SECTION 4:4 THE BRYOZOA

Introduction

16 species of Bryozoa are distinguished here. The material consists of whole colonies (zoaria), zoarial fragments and detached individuals (zooecia). The taxonomy of this group is extremely complex and is a specialist topic. The grouping applied here is primarily into the non-operculate Cyclostomata (2 species) and the operculate Cheilostomata (11 species). Three suborders of Cheilostomata are distinguished; the Anasca (6 species), which lack non-calcified frontal walls; the Acanthostega (=Cribrimorpha of early authors) (2 species), in which the front is protected by a more or less fused series of arched spines; and the Ascophora (3 species), which have a hydrostatic compensation system. The remaining 3 species could not be definitely determined at this level. The ecologically much more useful grouping, based on zoarial form, has been dealt with elsewhere.

GREGORY (1893) provides the first comprehensive monograph on English Tertiary Bryozoa. BURTON (1929 & 1933) describes their distrubtion in the Barton section and records 24 species. Unfortunately he does not figure them and many of his species could not be recognised. DAVIS (1934) monographs the Lutetian Bryozoa fauna of Southampton Dock. The only up to date work is by CHEETHAM (1966). He exhaustively describes and figures 34 species of Cheilostomata from the Upper Bracklesham Beds of Selsea (FISHER's bed 21). All the forms specifically identified here were named with the aid of his work. Further references on European Tertiary Bryozoa, including the diverse French faunas, may also be found in CHEETHAM (1966).

****

Phylum: BRYOZOA EHRENBERG 1831

Class: ECTOPROCTA NITSCHE 1869

Subclass: GYMNOLAEMATA ALLMAN 1856

Order: CYCLOSTOMATA BUSK 1852

Bryozoa sp.11

Plate 17, figs.1a,b.

Remarks

Two zoarial fragments, from the Middle Barton Beds of Barton (sample

6954), have tubular zooecia arranged in two transverse series of short, parallel, uniserial rows. The zoarium has a triangular cross section and the back consists of a convex imperforate face. It resembles some genera of the Tubuliporidae figured in the "Treatise" (Ed. MOORE, 1953), particularly *Clavitubigera* (Upper Cretaceous), *Biretepora* (Upper Cretaceous), *Crisisina* (Cretaceous to Recent) and *Erkosonea* (Eocene).

****

Bryozoa sp.12

Plate 17, fig. 2.

Remarks

This form is represented by three fragmentary specimens from BURTON's bed G at Barton (sample 6963). The zooecia are polygonal and are arranged in irregular, winding, biserial (occasionally uniserial) rows.

****

Order : CHEILOSTOMATA BUSK 1852

Suborder: ANASCA LEVINSEN 1909

Family: SELENARIIDAE BUSK

Genus: *Setosellina* CALVERT 1906

(Type species: *Setosellina roulei* CALVERT, 1906.)

Setosellina gregoryi CHEETHAM

Plate 17, fig. 4.

Biselenaria offa GREGORY, 1893. (part) p.235, pl.30, fig.5.
Biselenaria offa GREGORY: BURTON, 1929. p.238.
Setosellina gregoryi CHEETHAM, 1966. p.25, text-figs.406.(*et syn.*)

Remarks

Unlike some of the recent species of *Setosellina* described by LAGAAIJ & GAUTIER (1965), the adult colony of *S. gregoryi* becomes detached from the substrate and free living (i.e. lunulitiform). Broken zoaria show the ancestrular zooecia attached to fragments of shell material or tests of Foraminiferida. CHEETHAM (1966) states the range of this species to be Auversian to Bartonian in North West Europe. It occurs commonly in the Lower and Middle Barton Beds and shows a strong peak in the upper part of the Middle Barton Beds.

****

Family: LUNULITIDAE LAGAAIJ 1952

Genus: Lunulites LAMARCK 1816

(Type species: Lunulites radiatus LAMARCK, 1816.)

Lunulites transiens GREGORY

Plate 17, figs. 6,7.

Lunulites urceolata LONSDALE in DIXON, 1850. (non LAMARCK, 1816) p.159,pl.1,fig.8
Lunulites transiens GREGORY, 1893. p.233,pl.29,figs.13,14; pl.30,fig.1.
Lunulites transiens GREGORY: CHEETHAM, 1966. p.28,text-figs.7-9.(et syn.)

Remarks

Most of the material consists of very worn zoarial fragments, sometimes with little more than the basal wall preserved. Well preserved specimens agree with CHEETHAM's figures. No complete zoaria were encountered but CHEETHAM states this form to be free living (lunulitiform). The same author gives its distribution as Upper Bracklesham and Barton Beds of England only, relating it to the French Middle Eocene L.urceolata LAMARCK by descent. It occurs in small numbers throughout the Barton Beds as high as BURTON's bed J at Barton.

****

Family: FARCIMINARIIDAE BUSK 1884

Genus: Nellia BUSK 1852

(Type species: Nellia tenella LAMARCK, 1816.)

Nellia tenella (LAMARCK)

Plate 17, fig. 5.

Cellaria tenella LAMARCK, 1816. p.135.
Nellia tenella (LAMARCK): DAVIS, 1934. p.220.
Nellia tenella (LAMARCK): CHEETHAM, 1966. p.48,text-fig.28.(et syn.)

Remarks

This is the only vinculariiform Bryozoan found in the present study. Zoarial fragments occur infrequently in the Lower Barton Beds of Alum Bay and the Middle Barton Beds of both sections. CHEETHAM gives it range as Middle Eocene to Recent but lists some small differences between American Eocene, European Eocene and Recent subtropical material.

****

Anasca Incertae Sedis

Bryozoa sp.6

Plate 17, fig. 3.

Remarks

A single membraniporiform zoarial fragment, from the Lower Barton Beds of Barton (sample 6917), could not be identified with any of the Upper Bracklesham Beds species described by CHEETHAM. It has oval zooecia, sharp mural rims, a subquadrate orifice and a concave, slightly striate cryptocyst. The avicularia are interzooecial in position.

****

Bryozoa sp.10

Plate 17, fig. 8.

Remarks

Infrequent, small zoarial fragments, from the Middle Barton Beds of both localities, appear to represent the nodal portions of a joined species. The clustered drop-shaped zooecia have a strong distal beak and a very narrow cryptocyst. Slightly smaller units with a similar outline may represent avicularia. Some of the Catenicellidae, figured in the "Treatise", have zooecia of similar shape and arrangement but they are listed with the Ascophora.

****

Bryozoa sp.15

Plate 17, fig. 9.

Remarks

A few membraniporiform fragments from the Middle Barton Beds of Alum Bay have elongate, coffin-shaped zooecia, with a very large orifice and a narrow cryptocyst. The walls are very lightly calcified and ornament is lacking.

****

Suborder: ACANTHOSTEGA LEVINSEN 1902

Family: CRIBRILINIDAE HINCKS 1880

Genus: Cribrilaria CANU & BASSLER 1929

(Type species: Eschara radiata MOLL, 1803.)

Cribrilaria sp. cf. C.parisiensis (CANU)

Plate 17, fig. 10.

?Cribrilarina parisiensis CANU, 1926. p.751, pl.27, fig.1; pl.29, fig.6.
?Cribrilaria parisiensis (CANU): CHEETHAM, 1966. p.58, text-figs.35,36 (et syn.)

Remarks

Two zooecia from the Middle Barton Beds of Alum Bay (sample 6685) have a distinctive "cribrimorph" frontal shield and resemble CHEETHAM's figures or C.parisiensis. The frontal shield is convex and bears rounded costae, separated by rows of small elliptical lacunae. CHEETHAM gives its range as Auversian to Stampian. He distinguishes it from the type species, C.radiata (MOLL), on the paired adventitious avicularia, placed one on each side of the orifice. The specimens from Alum Bay have this feature.

****

Acanthostega Incertae Sedis

Bryozoa sp.2

Plate 17, fig. 11.

Remarks

A number of perforate plates, from the Middle Barton Beds of Barton, appear to represent the detached frontal wall of an unidentified Cribrimorph Bryozoan. They are oval in outline, with a sharp mural rim and a row of 5-7 small, oval or circular lacunae along each side. The orifice is slightly larger than the lacunae and is circular.

****

Suborder: ASCOPHORA LEVINSEN 1909

Family: ADEONIDAE JULLIEN 1903

Genus: Teichopora GREGORY 1893

(Type species: Teichopora clavata GREGORY, 1893.)

Teichopora clavata GREGORY

Plate 17, fig. 12.

Teichopora clavata GREGORY, 1893. p.249, pl.31, figs.5-7.
Teichopora clavata GREGORY: BURTON, 1929. p.328.
Teichopora clavata GREGORY: CHEETHAM, 1966. p.88, text-figs.65, 66. (et syn.)

Remarks

This species occurs in the Lower and Middle Barton Beds at Alum Bay but is restricted to the Upper Barton Beds at Barton. BURTON (1929) also records it from bed A3. CHEETHAM gives its complete range as Lower to Upper Eocene in North West Europe.

****

Family: ORBITULIPORIDAE CANU & BASSLER

Genus: Batopora REUSS 1867

(Type species: Batopora stoliczkai REUSS, 1867.)

Batopora glandiformis (GREGORY)

Plate 17, figs. 13a, b, 14.

Heteropora glandiformis GREGORY, 1893. p.261, pl.32, fig.11.
Heteropora glandiformis GREGORY: BURTON, 1929. p.223.
Batopora glandiformis (GREGORY): CHEETHAM, 1966. p.106, text-fig.81.

Remarks

Most zoaria are spherical or club shaped, as figured by CHEETHAM, but a few of the larger colonies become flattened and have a lobulate outline. These are never bilamellar, as in Orbitulipora petiolus (LONSDALE). The latter species is very common in the Upper Bracklesham Beds and has been recorded from the Barton Beds (see CHEETHAM, 1966, p.27) but was not encountered in this study. CHEETHAM places O. petiolus and B. glandiformis in a new zoarial growth form, the orbituliporiform type. Both are approximately club shaped, attached by a short stalk and may be described as celleporiform under

LAGAAIJ & GAUTIER's (1965) classification. *B.glandiformis* occurs in large numbers in the middle part of the Middle Barton Beds at both localities.

* * *

Ascophora Incertae Sedis

Bryozoa sp.8

Plate 17, fig. 15.

Remarks

Two detached zooecia from the Middle Barton Beds of Barton (sample 6940) could not be identified specifically but are placed in theAscophora on the basis of their divided orifice, granular pleurocyst and the presence of areolar pores around the margin. One specimen has a large, globular hyperstomial ovicell.

* * *

Bryozoa of Uncertain Taxonomic Position

Bryozoa sp.4

Plate 17, fig. 17.

Remarks

Several zoarial fragments from the Lower and Middle Barton Beds resemble figures of species described as *Dittosaria* by DAVIS (1934). Their apertural characteristics are far from clear but they appear to be Cyclostomata, whereas *Dittosaria* is listed with the Ascophora in the 'Treatise'. They consist of acutely set, widely spaced zooecia, arranged in an alternating series on each side of the flattened internodes. One specimen bears an ovicell between the zooecia.

* * *

Bryozoa?sp.7

Plate 17, fig. 18.

Remarks

These enigmatic objects occur sporadically throughout the Barton Beds and are only tentatively thought to be Bryozoa. They consist of detached, inflated, pod-like sacs, with a translucent wall. One side appears to represent part of a connecting or stolon system and the opposing side bears a narrow longitudinal slit. Several different groups of Bryozoa have similar zooecia arranged in a chain-like pattern but so also do representatives of the Hydroids.

****

Bryozia sp.13

Plate 17, fig. 16.

Remarks

A single fragment, from the Lower Barton Beds of Alum Bay (sample 6600) consists of two smooth, swollen, tubiform zooecia. They bear areolar pores around the margin, a characteristic of the Ascophora.

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Section 4:5 OSTRACODA

Introduction

In most cases the 34 species of Ostracoda found at Barton and Alum Bay have been classified into the genera described by VAN MORKHOVEN (1962,1963) and the suprageneric taxa laid out in the "Treatise of Invertebrate Paleontology" (ed. MOORE, 1961). This attempt at uniformity failed in the case of some of the Trachyleberididae, where HAZEL's (1967) classification has been adopted. He shows that in this group the central muscle scar patterns are by far the most useful suprageneric nomenclatural features (see remarks under Bosquetina and Quadracythere).

Remarks on the Literature

Following the early authors of the 19th century little or no publications on the Ostracoda of the European Tertiary appeared until the 1950's. The early workers such as JONES and SHERBORN in this country, BOSQUET in France and ROEMER, REUSS and LIENENKLAUS in Germany, had little or no insight into the taxonomic complexities of this group even at the generic level. Recent authors such as KEIJ and HASKINS, have revised the collections of BOSQUET and JONES respectively, and provide the most up to date studies. KEIJ (1957, 1958) also monographed the Belgian, Dutch, French and English faunas and HASKINS (1968a, b, c) has partly completed a revision of the English forms. Other recent works specifically on English Tertiary faunas include those of EAGAR (1965) and BOWEN (1953), both on Ostracoda from the London Clay of the London Basin.

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Subclass: OSTRACODA LATRIELLE 1806

Order: PODOCOPIDA MULLER 1894

Suborder: PLATYCOPINA SARS 1866

Family: CYTHERELLIDAE SARS 1866

Genus: Cytherella JONES 1849

(Type species: Cytherina ovata ROEMER,1840.)

Cytherella compressa (MUNSTER)

Plate 18, figs. 1a, b, 2a, b.

Cythere compressa MUNSTER,1830. p.64.
Cytherina compressa (MUNSTER): ROEMER,1838. p.517,pl.6,fig.14.
Cytherella compressa (MUNSTER): BOSQUET,1852. p.11,pl.1,fig.1.
Cytherella beyrichi (REUSS) var. laevis JONES & SHERBORN,1889. p.48,pl.2,fig.1.
Cytherella compressa (MUNSTER): KEIJ,1957. (part) p.45.
Cytherella (Cytherella) compressa (MUNSTER):HASKINS,1968a. p.252,pl.1,figs.1-8.
(Lr. Barton Beds, England.)

Remarks

HASKINS (1968a) distinguishes this species from C.munsteri (ROEMER) on its complete absence of lateral pores and its dorsally straight, never undulating dorsal margin in the left valve. He has shown that some of KEIJ's (1957) specimens of C.compressa are male C.munsteri. The right valves of C.londinensis JONES (1857) and C.dixoni JONES & SHERBORN (1887), from the English London Clay and Upper Bracklesham Beds respectively, are dorsally more domed in the right valves, the latter with more posteriorly tapering dorsal and ventral margins.

C.compressa is recorded in England by HASKINS only from the Lower Barton Beds. Specimens referrable to this species also occur sporadically in the Middle Barton Beds of Barton and Alum Bay.

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Cytherella munsteri (ROEMER)

Plate 18, figs. 3a, b, 4, 5a, b.

Cytherina munsteri ROEMER,1838. p.516,pl.6,fig.13.
Cytherella munsteri (ROEMER): BOSQUET,1852. p.13,pl.1,fig.2.
Cytherella munsteri (ROEMER): JONES,1857. p.56,pl.5,figs.12-13.
Cytherella muensteri (ROEMER): JONES & SHERBORN,1889. p.47.
Cytherella beyrichi (REUSS) vars 2,3,4,5,6, JONES & SHERBORN,1889. p.48,pl.2, figs. 2,5,6,7,9.
Morrowina munsteri (ROEMER): APOSTOLESCU, 1955. p.243,pl.1,figs.4-5.
Cytherella munsteri (ROEMER): KEIJ,1957. p.46,pl.1,fig.7.

Cytherella (Cytherella) munsteri (ROEMER):HASKINS,1968a. p.253,pl.2,figs.1-10.
(English Up.Bracklesham and Barton Beds.)
non *Cytherella beyrichi* REUSS,1851. p.89,pl.7,fig.65.

Remarks

This species occurs commonly throughout the Lower and Middle Barton Beds of both sections and in the Upper Bracklesham Beds. It includes specimens with and without lateral pores. JONES (1870) erroneously distinguishes the punctate forms as *C.munsteri* var. *rectipunctata*.

Smooth specimens, especially the inflated right valves of females, are sometimes difficult to separate from *C.compressa*. The undulating dorsal margin in the left valve and the corresponding line of the hinge in the right valve are the most constant distinguishing characteristics.

****

Genus: *Cytherelloidea* ALEXANDER 1929
(Type species: *Cythere (Cytherella) williamsoniana* JONES,1849.)

Cytherelloidea chewtonensis HASKINS

Plate 18, figs. 6a, b.

Cytherella (Cytherelloidea) chewtonensis HASKINS,1968a. p.254,pl.2,figs.11-16.
(Lr.Barton Beds (A3), Barton.)

Remarks

The single left valve found can definitely be referred to this species. It has three longitudinal ridges characteristically separated from the anterior marginal ridge. It comes from the Lower Barton Beds of Barton, HASKINS' (1968a) type and only locality.

Specimens of *C.dameriacensis* APOSTOLESCU (1955) recovered from the Upper Bracklesham Hard Bed (sample 7171) show three weaker horizontal ridges which connect with the anterior one. The valves are more inflated laterally, especially in the posterior area, and slope less steeply towards the dorsal and ventral margins. *C.chewtonensis* lacks the pitted surface of the English Lower Oligocene *C.lacunosa* HASKINS (1968a) and the French Lutetian species *C.hieroglyphica* (BOSQUET,1852).

****

Suborder: PODOCOPINA SARS 1866

Superfamily: BAIRDIACEA SARS 1888

Family: BAIRDIIDAE SARS 1888

Genus: Bairdoppilata CORYELL, SAMPLE & JENNINGS 1935

(Type species: Bairdoppilata martyni CORYELL, SAMPLE & JENNINGS, 1935.)

Bairdoppilata sp.cf. B.gliberti KEIJ

Plate 18, fig. 7.

?Bairdoppilata gliberti KEIJ,1957. p.53,pl.1,figs.18-21. (M.-Up.Eocene,Belgium. Lr.-Up. Eocene,France.M.Barton Beds, Barton,England.)
?Bairdoppilata gliberti KEIJ:HASKINS,1968a. p.3,pl.2,figs.29-30. (Barton Beds, Alum Bay.) (et syn.)

Remarks

A single poorly preserved complete carapace, questionably referrable to B.gliberti, was found in sample 6683 (Middle Barton Beds,Alum Bay). It resembles KEIJ's type figures and description in shape but its internal characters could not be determined. Specimens more definitely identifiable as B.gliberti occur in the Upper Bracklesham Beds of Selsea (samples 7171 and 787) and Whitecliff Bay (sample 7037).

****

Superfamily: CYPRIDACEA BAIRD 1845

Family: PARACYPRIDIDAE SARS 1923

Genus: Paracypris SARS 1866

(Type species: Paracypris polita SARS, 1866.)

Paracypris contracta (JONES)

Plate 19, figs.1a,b,2,3.

Bairdia contracta JONES,1857. p.53,pl.5,fig.1.(Barton Beds, Barton.)
Paracypris contracta (JONES): KEIJ,1957. p.51,pl.1,figs.15-17. (M.-Up.Eocene, Belgium. Up.Eocene, France and England.)
Paracypris contracta (JONES): EAGAR,1965. p.16. (London Clay, Reading Area.)
Paracypris contracta (JONES):HASKINS,1968b. p.7,pl.2,figs.14-22. (Up.Bracklesham Beds, Whitecliff Bay. Barton Beds, Barton and Alum Bay.)

Remarks

Abundant material from the Barton Beds of both sections and the Upper Bracklesham Beds of Whitecliff Bay and Selsea compare well with KEIJ's and HASKINS' figures and descriptions. The more elongate shape and dorsally directe posterior angle distinguishes it from *P.whitecliffensis* HASKINS (1968b) (Middle Eocene, Whitecliff Bay). The French Cuisian form *P.trosliensis* APOSTOLESCU is higher with a more rounded posterior.

****

Superfamily: CYTHERACEA BAIRD 1850

Family: BRACHYCYTHERIDAE PURI 1954

Genus: *Pterygocythereis* BLAKE 1933

(Type species: *Cythereis jonesii* BAIRD, 1850.)

Pterygocythereis cornuta (ROEMER)

Plate 19, figs. 4a, b, 5a, b.

Cytherina cornuta ROEMER, 1838. p.518, pl.6, fig.31.
Cythere cornuta (ROEMER): BOSQUET, 1852. p.117, pl.6, fig.4.
Cythere cornuta (ROEMER): REUSS, 1855. p.282, pl.10, fig.10.
Cythereis cornuta (ROEMER): JONES, 1857. p.39, pl.4, fig.19; pl.5, fig.15.
Cythereis cornuta (ROEMER): JONES & SHERBORN, 1889. p.35, pl.4, fig.7.
Alatacythere cornuta (ROEMER): APOSTOLESCU, 1955. p.250, pl.2, fig.28.
Pterygocythereis cornuta (ROEMER): KEIJ, 1957. p.94, pl.13, fig.13; pl.14, fig.5.
(Lr.-Up.Eocene, Belgium, France. Up.Eocene, Netherlands
Pterygocythereis cornuta (ROEMER): HASKINS, 1968c. p.161, pl.1, figs.1-8. (London Cla
Up.Bracklesham, Barton & M.Headon Beds of Hampshir

Remarks

A long ranging species with rather variable marginal flanges but always with long, completely undivided alar prolongations and completely unornamented central lateral areas. The dorsal and anterior marginal flanges are very thin and distally undulose. Their frequent breakage and reduction may substantially alter the lateral outline.

P.tuberosa KEIJ (1957) (Upper Eocene of Belgium and the Netherlands) and *P.pustulosa* HASKINS (1968c) also have entire wing lamellae. However the other marginal flanges are much shorter and more regular and the lateral faces are markedly pustulose. *Pterygocythere hilli* KEIJ (1957) (considered by VAN MARKHOVEN (1963, p.218) to represent a subgenus of *Pterygocythereis*) closely resembles *P.cornuta* externally. It has a much smaller eye tubercle, a distinctively domed dorsal margin and internally the hinge is of the *Brachycythere* type (elongate crenulate posterior element).

****

Pterygocythereis fimbriata (MUNSTER) bartonensis KEIJ

Plate 19, figs. 6, 7, 8a, b.

Cythereis horrescens JONES,1857. (non Cythere horrescens BOSQUET) p.38,pl.5,fig.9.
Pterygocythereis fimbriata (MUNSTER) bartonensis KEIJ,1957. p.95,pl.13,fig.11; pl.14,fig.2. (Lr.-Up.Barton Beds, Barton & Alum Bay.)
Pterygocythereis fimbriata (MUNSTER) bartonensis KEIJ:HASKINS,1968c. p.163,pl.1, figs.11-19.(Lr.-Up.Barton Beds,Barton,Alum Bay,Whitecliff Bay.)

Remarks

This species occurs as one of the four dominant species of Ostracoda throughout the Barton Beds of both sections. It appears to be restricted in Europe to the Barton Beds, with the exception of a single specimen from the transitional Bartonian-Auversian Huntingbridge horizon of Studley Wood (sample 7168).

The alar prolongations are sometimes completely divided into spines and sometimes proximally entire, but the distal edge is never entire as in P.cornuta (ROEMER) or P.pustulosa HASKINS. The carapace is smaller and thicker than in P.fimbriata fimbriata (MUNSTER) and has fewer, more slender lateral spines than P.fimbriata spinigera KEIJ. P.fimbriata laminosa HASKINS, from the Hampshire London Clay, is larger than P.fimbriata bartonensis with an upward directed spine at the distal end of each wing. The Bartonian subspecies sometimes bears a downward directed spine at the end of the wing, but never an upward one.

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Pterygocythereis pustulosa HASKINS

Plate 20, figs. 1a, b.

Pterygocythereis pustulosa HASKINS,1968c. p.164,pl.1,figs.20-28. (Barton Beds, Barton & Alum Bay. M.Headon Beds,Alum Bay & Whitecliff Bay.)

Remarks

Unquestionable examples of this species could only be found in the Middle Barton Beds of Alum Bay, although HASKINS (1968c) also records them from BURTON's bed H at Barton and from the Middle Headon series. It differs from the P.fimbriata group in having fewer, lower, lateral tubercles and from P.tuberosa KEIJ in its smaller size and lighter ornament. The alar prolongations of P.pustulosa are undivided and distally smooth unlike those of the P.fimbriata group.

Certain specimens from the Upper Bracklesham Beds appear to be transitional between P.cornuta (ROEMER) and this species. The central lateral faces, typically smooth in P.cornuta, sometimes bear small lumps. Also the stout, curved, fence-like mid-dorsal ridge, which is a characteristic feature of P.pustulosa, replaces the thin undulating flanges of P.cornuta. Perhaps these specimens indicate the line of descent of the Bartonian species from the latter.

****

Family: BYTHOCYTHERIDAE SARS 1926

Genus: Monoceratina ROTH 1928

(Type species: Monoceratina ventrale ROTH,1928.)

Monoceratina sp.1

Plate 18, figs. 8a,b.

Monoceratina sp. HASKINS,1968c. p.165,pl.1,fig.29.(Lr.Barton Beds,Alum Bay.)

Description

Outline sub-trapezoidal, length about twice the height, with a swollen venter, a rounded anterior outline and a strong posterio-dorsal caudal process. The rounded lateral prolongation continues in some specimens into a pronounced alar spine. A single central vertical sulcus runs from the centre of the wing to the dorsal margin. Carapace thin and smooth or faintly reticulate. Valves subequal. Inner lamella very narrow, with no vestibulum and few simple radial marginal pore canals. Hinge very weak or adont. Muscle scars and sexual dimorphism unknown.

Remarks

The Bartonian specimens, which occur rarely in the upper part of the Middle Barton Beds of both sections, agree with the unnamed species figured by HASKINS. He compares it with two Cretaceous species, M.acanthoptera ALEXANDER, and M.parallela ALEXANDER, both having shallower sulci than M.sp.1.

****

Family: CYTHERETTIDAE TRIEBEL 1952

Genus: *Cytheretta* MULLER 1894

(Type species: *Cytheretta rubra* MULLER, 1894)

Cytheretta costellata (ROEMER)

Plate 20, figs. 3, 4a, b, 5.

Cytherina costellata ROEMER, 1838. p.517, pl.6, fig.24.
Cythere costellata (ROEMER): BOSQUET, 1852. (part) p.58, pl.2, fig.11.
Cythere costellata (ROEMER): JONES, 1857. p.32, pl.5, fig.14.
Cythere costellata (ROEMER) var. *triangulata* JONES & SHERBORN, 1889. p.30, pl.1, fig.21. (Up. Bracklesham Beds, Selsea.)
Cytheretta costellata (ROEMER): KEIJ, 1957. p.132, pl.6, fig.9; pl.22, fig.7. (M.-Up. Eocene, Belgium, France. Up. Bracklesham Beds, Whitecliff Bay, England.)
Cytheretta costellata (ROEMER): HASKINS, 1968c. p.165, pl.2, figs.1-8. (Barton Beds, Alum Bay. Up. Barton Beds, Barton.)

Remarks

Specimens recovered from BURTON's bed G (sample 6963) at Barton and the Middle Barton Beds of Alum Bay are identical with common Upper Bracklesham Beds material. These all show the characteristic numerous lateral longitudinal ridges separated by faintly reticulate grooves. This ornament readily distinguishes them from tricostate species of *Cytheretta* such as *C. laticosta* (REUSS, 1850), *C. gracilicosta* (REUSS, 1855), and *C. concinna* TRIEBEL (1952) and smooth species such as *C. jurinei* (MUNSTER, 1830), *C. eocenica* KEIJ (1957), *C. tenuipunctata* (BOSQUET, 1852), *C. minor* (LIENENKLAUS, 1905) and the *C. rhenana* group. Other European Eocene forms with more than three longitudinal costae including *C. haimeana* (BOSQUET, 1852), *C. bambruggensis* KEIJ (1957), *C. crassivenia* APOSTOLESCU (1955) and *C. decipiens* KEIJ (1957) all show much more deeply sculptured and coarser ornament. *C. scrobiculoplicata* (JONES, 1856) is distinct in that reticulate ornament is dominant.

****

Cytheretta gracilicosta (REUSS)

Plate 20, figs. 6, 7a, b, 8a, b.

Cythere gracilicosta REUSS, 1855. p.280, pl.10, fig.8.
Cytheretta gracilicosta (REUSS): TRIEBEL, 1952. p.29, pl.5, figs.36-39.
Cytheretta gracilicosta (REUSS): KEIJ, 1957. p.135, pl.10, fig.5. (Up. Eocene, Netherlands, Germany, England.)
Cytheretta gracilicosta (REUSS): HASKINS, 1968c. p.166, pl.3, figs.1-10. (Barton Beds, Alum Bay, Whitecliff Bay, Barton. M. Headon Beds, Whitecliff Bay.)

Remarks

A small, strongly tricostate species, which occurs sporadically throughout the Lower and Middle Barton Beds of both sections. The small size and reticulate intercostate ornament distinguishes it from C.laticosta (REUSS, 1850). C.concinna TRIEBEL (1952) and C.decipiens KEIJ (1957) are considerably larger and lack the strong anterior marginal ridge of C.gracilicosta.

****

Cytheretta laticosta (REUSS)

Plate 21, figs. 1a,b, 2a,b, 3.

Cypridina laticosta REUSS,1850. p.87,pl.11,fig.13.
Cythere plicata JONES, 1857. (non MUNSTER) p.33,pl.4,fig.16;pl.5,fig.8; pl.6,fig.17.
Cythere plicata var.laticosta REUSS:JONES & SHERBORN,1889. (non MUNSTER) p.29,pl.1,fig.18.
Cytheretta laticosta (REUSS): KEIJ,1957. p.137,pl.17,figs.15-18;pl.21,fig.16. (Up.Eocene,Belgium,England.)
Cytheretta laticosta (REUSS): HASKINS,1968c. p.166,pl.2,figs.19-29. (London Clay, Lr.&Up.Bracklesham Beds,Barton Beds,M.Headon Beds, Bembridge Marl, Hampshire.)

Remarks

A very abundant species throughout the Barton Beds and the Upper Bracklesham Beds. It is characterised by its large carapace, strong centrally pitted longitudinal ribs and lack of intercostal ornament. Several early English authors confused this form with C.plicata (MUNSTER), the latter being quite distinct with its more slender shape and straighter unpitted ribs.

****

Cytheretta minor (LIENENKLAUS)

Plate 21, figs. 4, 5a,b.

Cythereis jurinii MUNSTER var.minor LIENENKLAUS,1905. fig.32.
Cytheretta minor (LIENENKLAUS):TRIEBEL,1952. p.24,pl.4,figs.22-23.
Cytheretta minor (LIENENKLAUS):HASKINS,1968c. p.167,pl.1,figs.30-35. (Barton Beds,Alum Bay.)

Remarks

Only two specimens of this form were recovered from the Middle Barton Beds of Alum Bay. They agree well with HASKINS (1968c) figures and description of specimens from the same locality. It is a nearly smooth form, ornament consisting of a rather irregular fine pitting over most of the lateral faces. In other weakly ornamented species, such as C.eoconica KEIJ (1957), C.jurinei (MUNSTER) and the C.rhenana TRIEBEL group, the pits are more or less restricted to the central area of the valves and are sometimes arranged in longitudinal rows.

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Cytheretta sp.9

Plate 20, figs. 9a,b.

Remarks

A single, well preserved right valve, from the Middle Barton Beds of Alum Bay (sample 6671), differs from all other species of Cytheretta, both in the Bartonian and in the literature. It is characterised by its lateral ornament of fine, very close-set, low, regular network of ridges. Four of them form incomplete, longitudinal costae but these are not thickened in relation to the rest of the ornament. The carapace is laterally compressed, its margin is bevelled and the internal characters are as for the genus. C.scrobiculoplicata (JONES) and the longitudinally multicostate species mentioned under C.costellata (ROEMER) all have coarser, less regular and more widely spaced reticulate ridges.

****

Family: CYTHERIDEIDAE SARS 1925

Subfamily: CYTHERIDEINAE SARS 1925

Genus: Cytheridea BOSQUET 1852

Subgenus: Cytheridea (Cytheridea) BOSQUET 1852

(Type species: Cythere muellerii MUNSTER,1830.)

Cytheridea (Cytheridea) intermedia (REUSS)

Plate 22, figs. 1, 2, 3, 4, 5.

Cytherina intermedia REUSS,1850. p.86,pl.11,fig.12.(Barton Beds,Barton.)
Cytherina mulleri (MUNSTER) var.intermedia (REUSS):JONES,1857.p.42,pl.5, figs.4-5.
Cytheridea intermedia (REUSS):KEIJ,1957. p.56,pl.4,figs.5-8. (Lr.& Up. Eocene, Belgium. Up.Bracklesham and Barton Beds,England.)
Cytheridea (Cytheridea) intermedia (REUSS):EAGAR,1965.p.17.(London Clay, Reading Area.)

Remarks

An extremely abundant species at Alum Bay, Barton and in the Upper Bracklesham Beds. The shallow median sulcus is not always present but the shape, anterior ridges, anterior and posterior spines and lack of lateral tubercles easily distinguish it from other species.

Cyamocytheridea hebertiana (BOSQUET) differs in having much more rounded posterior angles and low denticles replacing the spines. The hinge of *C.(C.)intermedia* shows the median positive element in the left valve and so can be definitely placed in the subgenus *Cytheridea (Cytheridea)*.

****

Genus: *Cyamocytheridea* OERTLI 1956

(Type species: *Bairdia punctatella* BOSQUET, 1852.)

Cyamocytheridea hebertiana (BOSQUET)

Plate 22, figs. 6a,b, 7.

Bairdia hebertiana BOSQUET, 1852. p.27, pl.1, fig.11. (Up. Eocene, France.)
Haplocytheridea hebertiana (BOSQUET): KEIJ, 1957. p.59, pl.2, figs.7-8. (Lr.-Up. Eocene, Belgium.)
Cyamocytheridea hebertiana (BOSQUET): VAN MARKHOVEN 1963. p.287, figs.446, 447, 450.

Remarks

Examination of the hinge shows that the present material does not belong to species of *Aulocytheridea* with similar external features. Such species as *Aulocytheridea punctatella* KEIJ (1957), *A.mourloni* KEIJ and *A.diegemensis* KEIJ all have a strong accommodation groove in the left valve, a feature which is absent in *C.hebertiana*. Well preserved specimens show the large triangular anterior vestibulum characteristic of *Cyamocytheridea* (see VAN MORKHOVEN, 1963).

Most specimens from the Barton Beds of Alum Bay show the typical shape and pitting of *C.hebertiana*. The few examples from the *Chama* Bed of Barton are more coarsely punctate and resemble *C.heizelensis* KEIJ (1957). Some specimens bear low, indistinct denticles at the posterior angles, as seen in *C.heizelensis* and *C.heinzelini* KEIJ (1957). Further distinctions into these and other closely similar species must await additional material.

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Genus: Schuleridea SWARTZ & SWAIN 1946

Subgenus: Schuleridea (Aequacytheridea) MANDELSTAM 1947

(Type species: Cytherina perforata ROEMER,1838.)

Schuleridea (Aequacytheridea) perforata (ROEMER)

Plate 22, figs. 8, 9, 10a, b.

Cytherina perforata ROEMER,1838. p.516,pl.6,fig.11.
Cytheridea perforata (ROEMER):JONES,1857. p.44,pl.4,fig.14.
Cytheridea perforata (ROEMER) var.insignis JONES,1857. p.46,pl.6,fig.3.
Cytheridea (Cytheridea) perforata (ROEMER):BOWEN,1953. p.279,fig.A4.
Haplocytheridea perforata (ROEMER):APOSTOLESCU,1955. p.248,pl.2,figs.21-24.
Haplocytheridea perforata (ROEMER):KEIJ,1957. p.63,pl.4,fig.20 (et syn.)
(Lr.-Up.Eocene, Belgium.Up.Eocene-Miocene?,Netherlands. M.-Up.Eocene, France. Up.Eocene,England.)
Schuleridea (Aequacytheridea) perforata (ROEMER):EAGAR,1965. p.19 (et syn.)
(London Clay, Reading Area)

Remarks

This species occurs, sometimes abundantly, throughout the Barton Beds of both sections. It is distinguished in its larger size, hingement and more numerous marginal pore canals from Cyamocytheridea hebertiana, which it resembles in shape. It is placed in this subgenus of Schuleridea in accordance with several authors (see VAN MORKHOVEN1963, p.310), the nominate subgenus being reserved for Mesozoic species with fewer marginal pore canals. In North West Europe S.(A.) perforata has a long range: from Lower to Upper Eocene (APOSTOLESCU, 1942, chart), and KEIJ (1957) also records it from the Oligocene and possibly the Miocene.

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Subfamily: CUNEOCYTHERINAE MANDELSTAM 1960

Genus: Cuneocythere LIENENKLAUS 1894

(Type species: Cuneocythere truncata LIENENKLAUS,1894. (=Bairdia marginata BOSQUET,1852.)

Subgenus: Cuneocythere (Monsmirabilia) APOSTOLESCU,1955

(Type species: Monsmirabilia subovata APOSTOLESCU,1955.)

Cuneocythere (Monsmirabilia) triebeli KEIJ

Plate 23, figs. 1a, b, 2, 3.

Cuneocythere (Monsmirabilia) triebeli KEIJ,1957.p.79,pl.9,figs.1-4.
(Lr.-Up.Eocene,Belgium.Up.Eocene,Neths. Up.Bracklesham Beds,Whitecliff Bay.)

Cuneocythere (Monsmirabilia) triebeli KEIJ:HASKINS,1968c. p.174,pl.3, figs.26-34. (London Clay - Up.Barton Beds, Hampshire.)

Remarks

A small species, occurring frequently in the upper Middle Barton Beds of both sections and rarely in the Lower Barton Beds of Alum Bay. It is quite distinct from all other Bartonian species encountered and differs from C.(M.) oblonga APOSTOLESCU (1955) and C.(M.)subovata APOSTOLESCU (1955) in its broad dorsal, anterior and posterior peripheral flange. It is never coarsely pitted like C.(M.)foveolata (BOSQUET,1852), C.(Cuneocythere) marginata (BOSQUET, 1852) or C.(Cuneocythere) lienenklausi KEIJ, (1957) and its narrow accommodation groove in the left valve further distinguishes it from the second two at a subgeneric level.

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Subfamily: KRITHINAE MANDELSTAM 1958

Genus: Krithe BRADY, CROSSKEY & ROBERTSON 1874

(Type species: Ilyobates praetexta SARS, 1866.)

Krithe bartonensis (JONES)

Plate 21, figs.6a,b,7.

Cythere (Cytherideis) bartonensis JONES,1857. p.50,pl.5,fig.2-3. (Barton Beds, Barton.)
Krithe bartonensis (JONES): KEIJ,1957. p.85,pl.8,figs.11-17. (Up.Eocene, Belgium,Netherlands, England.)

Remarks

The Barton Clay of Barton is the type locality of this much abused species, where it occurs both in the Lower and Middle Barton Beds. At Alum Bay it shows the same distribution. KEIJ (1957) and later VAN MORKHOVEN (1963, p.343) questioned the validity of occurrences of K.bartonensis outside the Upper Eocene. The name has been applied to species of Krithe ranging from Cretaceous to Recent and KEIJ places Oligocene and Miocene forms in K.papillosa (BOSQUET) and K.pernoides (BORNEMANN, 1855). VAN MORKHOVEN suggest that K.praetexta (SARS),a recent form, remains the valid type species for the genus. KEIJ also erects a new species, K.rutoti, for European forms from the Lower Eocene to Upper Bracklesham Beds, differentiating them on length/height ratios of populations of complete carapaces and left valves. An examination of specimens from the Upper Bracklesham Beds could not reveal any other more qualitative differences.

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Family: CYTHERURIDAE MULLER 1894

Genus: Cytherura SARS 1866

(Type species: Cythere gibba O.F.MÜLLER,1785.)

"Cytherura" sp.cf. C.bambruggensis KEIJ

Plate 23, figs. 4a, b, 5.

?Cytherura bambruggensis KEIJ,1957. p.145,pl.23,figs.9-10.
(Lr.-Up. Eocene, Belgium.)

Remarks

A few small, poorly preserved specimens, from the Middle Barton Beds of Barton and the Lower Barton Beds of Alum Bay, may be questionably referred to KEIJ's species. Two specimens show the three longitudinal ridges, alar prolongations and the upturned caudal process of "C."bambruggensis.

"C."oedelemensis KEIJ (1957) bears more ridges, a downward pointing caudal process and poorly developed wings. In the absence of comparative material uncertainty must exist as to whether the inner lamella is broad or narrow and so whether the species belongs to the genera Semicytherura or Cytherura respectively.

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Genus: Eucytherura MULLER 1894

(Type species: Cythere complexa BRADY,1866.)

Eucytherura sp.cf. E.perforatina EAGAR

Plate 23, figs. 6a, b, 7.

?Eucytherura perforatina EAGAR,1965. p.21,pl.1,fig.9; pl.2,figs.12-13.
(London Clay, Reading Area.)

Remarks

An extremely small form, which occurs infrequently in the Lower and

Middle Barton Beds of both sections. The small size might indicate it to be a juvenile instar but the strongly and densely pitted ornament, well developed swellings and absence of any obviously related, larger specimens are considered to be evidence for its adult nature. The size, shape, ornament, caudal process and position of the three lateral swellings compare well with EAGER's type figures and description and support the generic placing. However a definite specific placing for such a small species would be unwise without comparative material.

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Genus: Paracytheridea MULLER 1894

(Type species: Paracytheridea depressa MULLER, 1894.)

Paracytheridea gradata (BOSQUET)

Plate 23, figs. 11a, b.

Cythere gradata BOSQUET,1852. p.127,pl.6,fig.11.
Paracytheridea gradata (BOSQUET): APOSTOLESCU,1955. p.249,pl.2,fig.25.
Paracytheridea (Paracytheridea) gradata (BOSQUET):KEIJ,1957. p.159,pl.22, figs.2-4.(Lr.-Up.Eocene,Belgium.M.Eocene,France.Lr.& Up.Eocene,Neths. Up.Bracklesham Beds,England.)
Paracytheridea (Paracytheridea) gradata (BOSQUET): EAGAR,1965. p.22. (London Clay,Reading Area.)

Remarks

The rare specimens from the Lower and Middle Barton Beds of Alum Bay agree well with KEIJ's figures and with specimens from the English Upper Bracklesham Beds. The sharp reticulate ornament, angular wings and caudal process are typical of the species. P.grignonensis KEIJ (1957) has more rounded lateral swellings supporting undulating ribs.

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Genus: Cytheropteron SARS 1866

(Type species: Cythere latissima NORMAN,1865.)

Cytheropteron brimptoni BOWEN

Plate 23, figs. 10a, b.

Cytheropteron (Cytheropteron) brimptoni BOWEN,1953. p.280,fig.A3.
(London Clay,London Basin.
Cytheropteron (Cytheropteron) gulincki KEIJ,1957. p.148,pl.5,fig.2;
pl.23,fig.15. (Upper Eocene, Belgium.)
Cytheropteron (Cytheropteron) brimptoni BOWEN: EAGAR,1965. p.19.
(London Clay, Reading Are

Remarks

EAGAR (1965) has stated that C.(C.) gulincki KEIJ differs from BOWEN's species only in being slightly larger and concludes that they are conspecific. The rare specimens recovered from the Middle Barton Beds of Barton (BURTON's bed E) and the Lower Barton Beds of Alum Bay undoubtedly belong to the same species. They are characterised by having externally nearly smooth subequal valves with a marked caudal process and long, conical alar prolongations.

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Cytheropteron wetherelli (JONES)

Plate 23, figs.8a,b,9a,b,c,d.

Cythere wetherelli JONES, 1854. p.161,pl.3,fig.9.(Woolwich Beds, Kent.)
Cythere wetherelli JONES:JONES,1857. p.26,pl.4,fig.15;pl.6,fig.16.
Cytheropteron (Eocytheropteron) sherborni BOWEN,1953. p.281, fig.,A5.
Cytberopteron cf. C.fiski KEIJ,1957. p.150,pl.18,fig.5;pl.21,fig.7.
(Up. Eocene, Netherlands, Belgium.)
Cytheropteron (Eocytheropteron) wetherelli (JONES):EAGAR,1965. p.20.(et syn.)
(London Clay, Reading Area.)
non Eocytheropteron fiski HOWE & LAW,1936. p.38,pl.2,figs.25-26;pl.3,
figs.19-20.

Remarks

This long ranging species has been wrongly named and renamed several times. EAGAR (1965) states that Eocytheropteron fiski (HOWE & LAW) differs in having coarser surface reticulations and a shorter caudal process than C.wetherelli. C.wetherelli is known from the Upper Paleocene to the Lower Oligocene, It occurs frequently in the Lower and Middle Barton Beds of both sections and identical specimens have been observed from Upper

Bracklesham and Middle Headon Beds material.

The distinctive outline with its strong caudal process, and ventrolaterally bulbous valves, are easily distinguished from C.brimptoni BOWEN. Alar prolongations are never present. The very faint vertical median sulcus is variably developed and is slightly stronger in males. Examination of the fine reticulate lateral ornament using the Scanning Electron Microscope revealed a remarkedly regular pore pattern. Each polygonal area marked out by the ridges had a circle or normal pores located around its edge. Each polygon also had a single large sieve pore, also situated in the pore circlet.

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Family: LEGUMINOCYTHEREIDAE HOWE 1961

Genus: Leguminocythereis HOWE 1936

(Type species: Leguminocythereis scarabaeus HOWE & LAW, 1936.)

Leguminocythereis striatopunctata (ROEMER)

Plate 24, figs. 1a, b, 2a, b.

Cytherina striato-punctata ROEMER,1838. p.515,pl.6,fig.3.
Cythere striatopunctata (ROEMER): BOSQUET,1852. p.62,pl.3,fig.1.
Cythere striatopunctata (ROEMER): JONES,1857. p.27,pl.5,figs.6,7, & 10.
Cythere striatopunctata (ROEMER): JONES & SHERBORN, 1869. p.19.
?Hemicythere striatopunctata (ROEMER): BOWEN,1953. p.284,fig. A1.
Leguminocythereis striatopunctata (ROEMER): APOSTOLESCU,1955. p.254,pl.3, figs.47-48.
Leguminocythereis striatopunctata (ROEMER): KEIJ,1957. p.126,pl.12,fig.18; pl.15,fig.8. (Lr.Eocene-Lr.Oligocene,Belgium; Up.Eocene,Neths.,England.)

Remarks

One of the dominant species throughout the Barton Beds of both sections, with a total range above and below that horizon. L.oertlii KEIJ (1958), and L.genappensis KEIJ (1957) are coarsely reticulate like L.striatopunctata. However both have considerably lower carapaces and are not so inflated ventrolaterally. A few specimens from the Middle Barton Beds of both sections resemble L.oertlii, except that they are more inflated laterally and have slightly coarser ornament. They appear to grade into typical male L.striatopunctata and until more specimens are available no further distinction is possible. L.dumonti KEIJ (1957), and more particularly *L.pertusa* (ROEMER, 1838) show the same inflated shape as *L.striatopunctata* but in both the longitudinal ornament is much heavier than the transverse reticulations.

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Family: LOXOCONCHIDAE SARS 1925

Genus: *Loxoconcha* SARS 1866

(Type species: *Cythere rhomboidea* FISCHER, 1855.)

Loxoconcha subovata (MUNSTER)

Plate 23, figs. 12a, b, 13, 14a, b.

Cythere subovata MUNSTER, 1830. p.63.
Cytherina subovata (MUNSTER): ROEMER, 1838. p.515, pl.6, fig.4.
Loxoconcha subovata (MUNSTER): LIENENKLAUS, 1894. p.234, pl.16, fig.4.
Loxoconcha subovata (MUNSTER): KEIJ, 1957. p.144, pl.22, figs.15-16.
(Lr.Eocene-M.Oligocene, Belgium. Up.Eocene, Netherlands.)
Loxoconcha subovata (MUNSTER): EAGAR, 1965. p.23. (London Clay, Reading Area.)

Remarks

A small species occurring infrequently in the Middle Barton Beds of Barton and the Lower and Middle Barton Beds of Alum Bay. The laterally rather inflated valves show the fine, regular reticulate ornament characteristic of this species. Sexual dimorphism is very marked, the males being considerably longer and more slender than the females. The short posterio-ventral longitudinal ridge mentioned by KEIJ (1957) on his males occurs on most of the Bartonian specimens of both sexes. It stretches two-thirds of the way to the anterio-ventral angle and may indicate that theEnglish forms belong to a different species. As all other features are identical with those figured by KEIJ further taxonomic subdivision is considered inadvisable.

L.curryi KEIJ (1957), from the Upper Bracklesham Beds, and *L.grateloupiana* (BOSQUET, 1852) differ from *L.subovata* in their coarser ornament and more angular outline. As figured by KEIJ (1957) *L.subtriangularis* (SPEYER) and *L.punctatella* (REUSS, 1850) have similar ornament to the Bartonian species. The former has a shallow sulcus and the anterior border of the latter bears stronger ornamentation than in

L.subovata. L.kuiperi KEIJ(1957) has considerably finer ornamentation and L.nystiana (BOSQUET, 1852) has a longer straight dorsal margin.

****

Genus: Cytheromorpha HIRSCHMANN 1909

(Type species: Cythere fuscata BRADY, 1869.)

Cytheromorpha brabantica KEIJ

Plate 23, figs.15,16,17.

Cytheromorpha brabantica KEIJ,1957. p.88,pl.16,figs.10-11;pl.23,fig.17. (Ledian,Belgium.)

Remarks

A small species, widely distributed in the Middle Barton Beds of Barton, the Lower and Middle Barton Beds of Alum Bay and the Upper Bracklesham Beds. The vertical sulcus, irregular reticulations and two posterior swellings (one above the other) agree well with KEIJ's figures. There is some variation in the coarseness of the ornament. Specimens from the Upper Bracklesham Beds and some from the Bartonian have deeper pits than others from the Barton Beds. The latter are never as weakly reticulate, or as elongate as C.zinndorfi (LIENENKLAUS,1905), as figured by KEIJ and as represented in the English Middle Headon Beds.

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Family: SCHIZOCYTHERIDAE HOWE 1961

Genus: Schizocythere TRIEBEL 1950

(Type species: Schizocythere hollandica TRIEBEL,1950.)

Schizocythere batjezi KEIJ

Plate 24, figs. 3a,b, 4a, b.

Schizocythere batjezi KEIJ, 1957. p.153,pl.20,figs.16-18;pl.21,fig.18. (Up.Eocene, Belgium, Netherlands, England.)

Remarks

Common specimens from the Lower and Middle Barton Beds of Alum Bay and Barton agree well with the type figures and descriptions, having small, compact, coarsely reticulate carapaces. Specimens from the

Upper Bracklesham Beds of Whitecliff Bay and Selsea show slightly shallower ornamentation. They differ markedly from S.tessellata (BOSQUET,1852) s.l. which also occurs in the Upper Bracklesham Beds, in lacking any posterio-ventral extensions. S.buendensis TRIEBEL, from the Dutch Miocene, has much less deeply developed ornament.

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Genus: Paijenborchella KINGMA 1948

(Type species: Paijenborchella iocosa KINGMA, 1948.)

Paijenborchella eocenica TRIEBEL

Plate 24, figs. 5, 6a, b, 7.

Paijenborchella eocenica TRIEBEL, 1949. p.196,pl.1,figs.1-7;pl2,fig.8.
Paijenborchella eocenica TRIEBEL:KEIJ,1957. p.156,pl.21,fig.6.
(Up.Eocene,Belgium,Neths.,Germany.Up.Bracklesham,Barton Beds,England.)

Remarks

Specimens from the Lower and Middle Barton Beds of both sections are placed in P.eocenica on the basis of the length of the uppermost of the three longitudinal ridges. KEIJ (1957) distinguishes between this species and P.longicosta KEIJ on the ultimate posterior course of these ribs but shows P.longicosta to always have a long upper ridge. The Bartonian specimens examined never bore an upper ridge extending far beyond each side of the median sulcus. Specimens from the Upper Bracklesham Beds of Whitecliff Bay, considered to belong to P.longicosta, had a much longer upper ridge extending almost to the spine below the caudal process. Neither species bears as well marked a posterio-ventral spine on the middle rib as P.lomata TRIEBEL (1949).

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Family: *TRACHYLEBERIDIDAE* SYLVESTER-BRADLEY 1948

Genus: *Trachyleberis* BRADY 1898

Subgenus: *Trachyleberis (Trachyleberis)* BRADY 1898

(Type species: *Cythere scabrocuneata* BRADY, 1880.)

Trachyleberis (Trachyleberis) aculeata (BOSQUET)

Plate 25, figs. 1, 2a, b, 3.

Cythere aculeata BOSQUET, 1852. p.107,pl.5,fig.10.
Cythere approximata BOSQUET,1852. (part) p.88.
Cythere arachnoidea BOSQUET, 1852. p.99,pl.5,fig.4.
Cythereis horrescens JONES, 1857. (non BOSQUET) p.38,pl.5,fig.17.
Cythere bowerbankiana JONES, 1857. p.38,pl.6,figs.7-8.
Trachyleberis aculeata (BOSQUET): APOSTOLESCU,1955. p.271,pl.8,figs.123-124.
Trachyleberis (Trachyleberis) aculeata (BOSQUET): KEIJ, 1957. p.90,pl.13, figs.16-17;pl.16,figs.14-15. (Lr.-Up.Eocene,Belgium, France. Up.Eocene, Netherlands, England.)
Trachyleberis (Trachyleberis) aculeata (BOSQUET): EAGAR,1965. p.24. (*et syn.*) (London Clay, Reading Area.)

Remarks

A large species, which is abundant in the Upper Bracklesham Beds and also occurs commonly at certain levels in the Lower and Middle Barton Beds of both sections.

T.(T.) lichenopora (BOSQUET, 1852) differs from this species in having a more elongate shape and more numerous, irregular, slender blades and knobs on the lateral surface. JONES (1857) erroneously placed London Clay and Barton Clay specimens of *T.(T.)aculeata* in *Cythere bowerbankiana* and *Cythere horrescens* respectively.

A few small specimens from Barton have many elongate cylindrical lateral spines. The central muscle scar pattern shows however that they have the single crescentic antennal scar of *Trachyleberis* and not the double anterior scars of *Hirsutocythere horrescens* (BOSQUET, 1852), a species with similar ornament. They are undoubtedly juvenile instars of *T.(T.) aculeata*.

Genus: Occultocythereis HOWE 1951

(Type species: Occultocythereis delumbata HOWE, 1951.)

Occultocythereis sp.1

Plate 24, figs. 8,9a,b.

Description

Small, laterally compressed carapace, slightly over twice as high as it is long. The straight dorsal and ventral outlines converge posteriorly to a low hinge tubercle with a small spine. A further posterio-ventral extension is marked by four or five short spines. Anterior outline broadly rounded with about ten equal marginal spines. Lateral faces smooth, each with a low subcentral swelling, a straight ventral longitudinal ridge and a straight dorsal longitudinal ridge. Both ridges end posteriorly at sharp angles, the dorsal one reaching farthest, (almost to the posterior cardinal angle). The anterior and posterior marginal ridges are unconnected with the other two. Eye tubercles are present and well developed.

The inner margin and zone of concrescence coincide, leaving no vestibules. The inner lamella broadens anteriorly and posteriorly. Selvage strong and running close to the outer margin. Marginal pore canals visible under the anterior inner lamella only, where they are quite stout, few in number, and bifurcate just before the selvage is reached. Muscle scars not clearly visible.

Hinge holamphidont, with a socket and a simple peg-like anterior tooth in the left valve, followed by a smooth median bar and a posterior socket. Lateral pores few in number and randomly scattered over the lateral surface.

Sexual dimorphism is marked. The ventral longitudinal ridge is considerably reduced in the male right valve, giving the carapace an asymmetrical appearance in ventral view. The females have posteriorly more inflated carapaces and are symmetrical.

Remarks

The bifurcating marginal pore canals and asymmetry of the male carapace leaves no doubt as to the generic placing of this form. The genus Idiocythere also differs in having a more complicated dentition, with two anterior teeth in the left valve. Trachyleberidea aranea (JONES & SHERBORN) differs from the Occultocythereis sp.1 in having reticulate ornament, a median longitudinal ridge and a sharper posterior angle. HASKINS (1963) records it from the English Barton Beds but no specimens were encountered in the present study. O.delumbata HOWE, the type species, has a much sharper posterior angle. An unnamed species of Occultocythereis figured by TRIEBEL (1958), from the Eocene of the Paris Basin,(see VAN MORKHOVEN, 1963, p.195,fig.300) strongly resembles O.sp.1 in shape and ornamentation.

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Genus: Bosquetina KEIJ 1957

(Type species: Cythere pectinata BOSQUET,1852.)

Remarks

On the basis of soft part morphology and central muscle scar patterns in recent forms HAZEL (1967) puts Bosquetina, not in the Brachycytheridae (as in the Treatise - Ed. MOORE, 1961), but with the Trachyleberididae. He includes Bosquetina, Echinocythereis and a new genus in his new subfamily, the Echinocytherininae. The muscle scar patterns are considered to be intermediate between those of the "Hemicytherids" and the "Trachyleberids". In the "Hemicytherids" one or more of the four adductor muscle scars are split laterally and the antennal scar is multiple. Most of the "Trachyleberids" show a pile of four single adductor scars and a single J-shaped antennal scar. Bosquetina (and Echinocythereis) bears double antennal scars and four adductor scars, the second two of which are often elongate, showing a tendancy to divide. For these reasons Bosquetina is placed in the Trachyleberididae, although the present author is not prepared to pursue the nomenclature to a subfamilial level.

Bosquetina sp.1

Plate 26, figs.1a,b,2,3.

Description

Valves subequal, lateral outline tapering from anterior to posterior, height about half the length and maximum at the eye tubercle. Dorsal outline straight, ventral outline slightly convex. Anterior obliquely rounded, with numerous small marginal denticles in ventral quadrant. Posterior bluntly angled, again with a few small marginal spines.

Lateral faces swollen, with a narrow peripheral flange. Eye tubercle prominent, with a short shallow sulcus just behind it. Ornament consists of a fine network of low ridges in the central region giving way to several low longitudinal ridges centroventrally. The latter converge at the base of a short, sharp, conical posterioventral spike. The anterio- and posteriolateral areas are smooth.

Vestibules absent, the inner margin and the line of concrescence coinciding throughout. The inner lamella is slightly broader at the posterior and anterior margins, where it supports a low, almost peripheral selvage and covers a large number of thin, unbranched,. slightly sinuous marginal pore canals.

Hingement holamphidont with, in the right valve, a large, simple, conical anterior tooth followed by a conical socket, a long, narrow, smooth furrow and a crescentic, slightly lobed posterior element. The corresponding anterior tooth and median bar in the left valve are smooth.

Central muscle scars consist of a pile of four elongate adductor muscle scars, the second or sometimes the third of which is banana shaped and overlaps downwards anteriorly. The antennal muscle scars are always two in number and subcircular in shape. Additional small scars are sometimes visible above and in front of the central complex.

Sexual dimorphism marked, the males being longer, and narrower than the females. Females are often more swollen posteriorly in dorsal view.

Remarks

The muscle scar pattern, general shape, hingement and presence of the posterioventral spike is thought to indicate that this form belongs in the genus Bosquetina, although the type species does not have reticulate ornament of this sort. Echinocythereis has similar muscle scars but always bears much more positive ornament. Leguminocythereis has comparable reticulate ornament but lacks the posterioventral spike and elongate second adductor muscle scar. Ruggieria has many of this species' external features, namely longitudinal and reticulate ridges etc., but the antennal muscle scar is definitely single and J-shaped.

From the literature a very close similarity is apparent between this species and Leguminocythereis tenella EAGAR (1965) (London Clay, Reading Area). The main differences lie in the slightly heavier reticulations and the lack of the ventral longitudinal ridges and posterioventral spike on EAGAR's species. Unfortunately he does not figure the muscle scar pattern and so it is impossible to determine if they should belong to the same genus without examining his material.

At Barton and Alum Bay B.sp.1 occurs quite abundantly in the Lower Barton Beds. It has not been found in other formations.

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Family: HEMICYTHERIDAE PURI 1953

Genus: Quadracythere HORNIBROOK 1952

(Type species: Cythere truncula BRADY, 1898.)

Remarks

As pointed out by HAZEL (1967, p.24) and VAN MORKHOVEN (1963, p.144) the double nature of the antennal muscle scar indicates that Quadracythere is a "Hemicytherid" and not a "Trachyleberid" genus. The Treatise (Ed. MOORE, 1961, p.341) erroneously places it with the "Trachyleberids".

Quadracythere? sp.1

Plate 25, figs. 4a, b, 5a, b.

Description

Carapace small, valves subequal, outline subquadrate, with the length about one and a half times the height. Dorsal outline short and straight, ventral outline slightly convex, the two converging slightly posteriorly. Anterior outline slightly rounded, meeting the dorsal and ventral margins at obtuse angles. Posterior cardinal angle marked. Two thin ventrolateral flanges end abruptly in the posterioventral area, the lower one being longer anteriorly. Two thin anterior flanges are present, the outside one being marginal and striated on its inner surface. A strong, striate, triangular, posteriodorsal horn emerges 2/3rds of the way along the dorsal margin. A shallow vertical sulcus runs just anterior to this horn, from the dorsal margin to the centre of the valve. Eye spots absent. Ornament consists of a fine network of ridges (also seen on the interior of the thin valves) associated with small rough knobs.

Inner lamella narrow, without vestibules, widening slightly at the anterior and posterior margins. Selvage strong and the numerous marginal pore canals are simple, radial and slightly sinuous. They appear to continue onto the inner face of the marginal flange as the striations mentioned above. Hingement, musclescar pattern and sexual dimorphism unobservable.

Remarks

This form can only questionably be referred to the genus Quadracythere on the basis of its shape and ornamentation. It may well prove to be an instar of a species already recorded. It is doubtful if it is a juvenile of Quadracythere sp.2 as it lacks the pustules and inequality of the valves of that species, and shows a different stratigraphic distribution. At Barton Q.? sp.1 is restricted to the Middle Barton Beds and at Alum Bay it occurs in the Lower and Middle Barton Beds. It has also been found in the Upper Bracklesham Beds. Q.sp.2 however, is found at Barton only in the Lower Barton Beds. It may represent the juvenile instar of a species of Schizocythere. Schizocythere batjezi KEIJ has a much more reticulate ornament, lacks a posteriodorsal horn and has a median longitudinal ridge absent in this form. S.tessellata (BOSQUET, 1852) has a similar shape but does not occur as an adult in the Barton Beds. Without clear evidence regarding its hingement no decision can be reached regarding its relationship with any species of Schizocythere and although its affinities remain in doubt, it is thought advisable to keep it as a separate taxon for the time being.

****

Quadracythere sp.2

Plate 25, figs.6a,b,7,8a,b.

Description

Carapace small, subquadrate, short and high; the length being about one and a half times the height. Dorsal outline straight in the left valve, and strongly domed in the right valve. Ventral outline slightly convex, except anteriorly where it forms a reentrant where the obliquely rounded anterior outline meets it. Posterior outline angular and turned up.

Valves unequal, the right valve overlapping the left markedly along the dorsal margin. Eye tubercles well developed.

Ornament strong, with well developed anterior, posterior and ventrolateral ridges, the last being weakly lobed. Lateral swellings numerous and marked, especially the large subcentral swelling over the position of the central muscle scar depression and the smaller, slightly irregular posteriodorsal swelling. Other ornamentation consists of rather low, smooth, subsidiary ridges. Lateral pores scattered and large in diameter.

Inner margin and line of concrescence coincide throughout. Inner lamella narrow, widening slightly at the anterior and posterior margins. Selvage strong and situated close to the outer margin. Marginal pore canals simple, radial and numerous in the anterior, posterior and ventral margins. They emerge at a few small marginal denticles posteriorly and at numerous small denticles at the anterioventral margin.

Hinge hemiamphidont. The anterior tooth in the right valve is smooth and stepped (see VAN MORKHOVEN, 1963, p.144) and the posterior tooth is smooth or slightly cusped. In the left valve the median bar is slightly crenulate anteriorly and smooth posteriorly.

The central muscle scar pattern consists of a pile of four similar, slightly elongate adductor scars and two obliquely arranged antennal scars. The adductor muscle scars are situated in a deep circular depression.

Sexual dimorphism is not very marked, the males being slightly lower than the females.

<u>Remarks</u>

This species has a restricted distribution at both sections. Apart from a few specimens from the Middle Barton Beds at Alum Bay it is only found in the Lower Barton Beds.

KEIJ (1957) figures several species of <u>Quadracythere</u> from the North West European Tertiary. Of these <u>Q.macropora</u> (BOSQUET,1852) (from the Oligocene), <u>Q.vermiculata</u> (BOSQUET,1852), <u>Q.orbignyana</u> (BOSQUET, 1852) and <u>Q.angusticostata</u> (BOSQUET, 1852) (all from the French and Belgian Eocene) are much more heavily reticulate than <u>Q.sp.2</u>. <u>Q.lamarckiana</u> (BOSQUET, 1852) (Lr.-Up.Eocene,France) is much smoother but has fewer swellings than the Bartonian species. MOOS (1963, 1965) revises the German Oligo-miocene <u>Quadracythere</u> group and figures <u>Q.diversinodosa</u> (LIENENKLAUS, 1894) (Lr.Oligocene, Germany, France), a species very closely related to <u>Q.sp.2</u>. The swellings and weak reticulate ornament are comparable and the only difference is that the dorsal outline in the right valve is not as domed as in <u>Q.sp.2</u>.

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Section 4:6 MOLLUSCA

Introduction

This is the most diverse group dealt with in this study and proved the most troublesome to identify and classify. CURRY (1966) states that 523 species of described Mollusca are known from the English Barton Beds (BURTON (1933) lists 350 spp., GARDNER, KEEPING & MONCKTON (1888) list 407 described spp.) and estimates that 2500 species are known from the North West European Middle and Upper Eocene. The present difficulties stem from two main sources. A great deal of the material examined consisted of the fragmentary and juvenile stages of large, well documented forms. This problem could be partly overcome by reference to some of the excellent named collections and to the very voluminous literature. The residue of the fauna in the size range examined consisted of very small, adult specimens. Unfortunately these species were largely ignored by the otherwise exhaustive 19th century authors and many are completely undescribed. These had to be left as numbered species.

The important collections of F.E.Edwards, A.G.Wrigley and E.St.John Burton were examined in the British Museum (Natural History), London. In addition the Ross collection, in the Department of Geology, University College, London, contains an excellent range of English Bartonian Mollusca and, although the collection is of uncertain provenance, was very useful for comparative studies on the juvenile stages of large species.

European Tertiary Mollusca have attracted interest from LINNE onwards but unfortunately many of the 18th and early 19th century French and English works of SOLANDER (1766), LAMARCK (1799 onwards), CHARLESWORTH (1851), the SOWERBY's (J. and J.deC.) and several others were inaccessible and could not be consulted. Early references which were obtainable include DESHAYES'(1856-1866) second and beautifully illustrated monograph on the French Eocene faunas, J. de C.SOWERBY (1850 in DIXON's "Sussex"), WOOD's (1877) monograph on the Pelecypoda, EDWARDS & WOOD's (1871) companion volume on the Gastropoda and Cephalopoda, COSSMANN's(1882 onwards) revision of the European Tertiary faunas and COSSMANN & PISSARRO (1906-1913), which is a comprehensive atlas of Paris Basin Eocene Mollusca. Later references include papers by WRIGLEY (for a full list see Proc.Malac.Soc.,London, 30, 157-160), NEWTON (1895), NEWTON & HARRIS (1894), CURRY (1960, 1965), TREMLETT (1953), some by GLIBERT (1936, 1938) and E.WHITE's(1963, 2nd.ed.) illustrated booklet. This list is not complete and the reader should consult R.B.NEWTON's (1891) catalogue for a full bibliography of early works.

The generic and suprageneric taxonomy is at present under revision by GLIBERT and the less complete but more understandable classification of A.M.DAVIES ("Tertiary Faunas", 1935) is used here. Illustrations are limited here to those species which are either unidentifiable or are not figured in any easily obtainable publication.

****

4:6:1 Phylum: MOLLUSCA CUVIER

Class: PELECYPODA GOLDFUSS 1820

Superfamily: NUCULACEA

Genus: *Nucula* LAMARCK 1799

Nucula ampla WOOD

Nucula ampla EDWARDS (m.s.): WOOD, 1871. p.108, pl.18, figs.5,6.

Remarks

WOOD (1871) uses EDWARDS' manuscript name and includes the variety contigua EDWARDS (m.s.) with it. The common material from the *Chama* Bed of Barton agrees well with WOOD's figures and description. BURTON (1933) also records *N.ampla* from the same level. *N.similis* J.SOWERBY (see E.WHITE, 1963, pl.5, figs.1,2) has been recorded from this horizon. It differs from *N.ampla* in having more angular umbones and a more trigonal outline. *N.ampla* is a rather short, tumid form, with broadly rounded umbones and very weak radial and growth ornament.

****

Nucula sp.cf. N.bisulcata J.de C.SOWERBY

?Nucula bisulcata J.de C.SOWERBY in DIXON,1850. pp.93,170,pl.2,fig.13.
?Nucula bisulcata J.de C.SOWERBY: WOOD,1871. p.109,pl.18,fig.13.

Remarks

A few poorly preserved specimens from the Lower and Middle Barton Beds resemble WOOD's figures. They have a compressed, elongate outline and the distinct geniculation marking the anterior end of the hingement characteristic of N.bisulcata. N.praelonga WOOD (1871) has a similar shape but has a smoothly rounded anteriodorsal outline. BURTON (1933) records N.bisulcata from beds D to F at Barton and many of the unidentifiable juveniles may belong here.

****

Nucula sp.cf. N.tumescens WOOD

?Nucula tumescens EDWARDS (m.s.): WOOD,1871. p.121,pl.18,fig.1.

Remarks

A single, broken left valve from BURTON's bed J (sample 6992) shows the trigonal outline and deep interior of this species. BURTON (1933) records it from beds J and K.

****

Nucula spp. (juveniles)

Remarks

A large number of small specimens from all levels are too immature to identify definitely. They all show taxodont dentition, a variable trigonal outline and usually have a nacreous interior. They undoubtedly represent the juveniles of more than one distinct species.

****

Genus: Nuculana LINK 1807

Nuculana minima (J.SOWERBY)

Nucula minima J.SOWERBY,1818. pl.192,fig.8.
Leda minima (J.SOWERBY) var.communis WOOD,1871. p.127,pl.17,figs.7c,d.(not 7a,b.)

Remarks

One of the dominant species in the Lower and Middle Barton Beds of both sections. The weak growth ornament distinguishes it from *N.striata* (LAMARCK). WOOD (1871) and other British workers include both species in *N.minima*. WOOD's figures of *N.minima* var. *communis* agree well with the present material. They also agree with specimens in the Burton, Wrigley and Ross collections.

****

Nuculana striata (LAMARCK)

Nucula striata LAMARCK,1804. p.829.
?*Leda minima* var. *gracilis* WOOD, 1871. (non DESHAYES,1860) p.127,pl.17, figs. 7a, b. (not 7c, d.)
Leda striata LAMARCK: COSSMANN & PISSARRO,1913. pl.33,fig.105:1.
Nuculana cf. *striata* (LAMARCK): GLIBERT,1936. p.1[illegible],text-figs.9,10. (Sands of Wemmel, Belgium.)

Remarks

Specimens from the Upper Barton Beds of both sections, with very strong regular growth ridges and a large resilium pit, are referred to *N.striata*. There is some confusion in the literature between this form and *N.minima*, many authors placing them together. WOOD's figures of *N.minima* var. *gracilis* has the strong ornament of *N.striata* but bears a smaller ligament pit. The same author figures *N.prisca* (DESHAYES), from the Barton Beds, with a deep ligament pit but very smooth lateral surfaces. GLIBERT's (1936) figures of *N.cf. striata* agree well with the Bartonian specimens and differ from his representation of *N.galeottiana* (NYST) only it its larger resilium pit.

****

Superfamily: LUCINACEA

Genus: *Myrtaea* TURTON 1822

Myrtaea spinulosa (LOWRY)

Plate 26, figs. 4,5.

Lucina spinulosa EDWARDS (m.s.): LOWRY, 1866. pl.2.
Myrtaea spinulosa (LOWRY): WRIGLEY,1934. p.9. ([illegible] Bracklesham Beds, Southampton Docks.)

Remarks

Specimens labelled *Lucina spinulosa* EDWARDS (m.s.) in the Burton collection and some labelled *Lucina eximia* EDWARDS (m.s.) in the Ross collection, all from the Barton Beds, compare well with common but fragmentary materi from the lower part of the Middle Barton Beds of both sections. The regular, sharp-crested growth ridges and blade-like spines fringing the lunule (sometimes also around the escutcheon) serve to distinguish it from Lucina (Cavilucina) elegans DEFRANCE. Specimens of the latter also have much lower growth ridges, with radial striae between them.

****

Genus: Divaricella VON MARTENS 1860

Divaricella rigaultiana (DESHAYES)

Lucina rigaultiana DESHAYES,1860. p.631,pl.47,figs.28-30.

Remarks

This species occurs rarely in the Upper Barton Beds of Barton and agrees well with the published figures and specimens in the Ross collection. Fragmentary material, bearing the characteristic divaricate ornament of the genus, occurs in the Upper Barton Beds of Barton and (one specimen) in the Lower Barton Beds of Alum Bay. Fragments from BURTON's bed K of Long Mead End (sample 7004) may belong to this species or to D.colvellensis (EDWARDS, m.s.). BURTON (1933) records the latter only from bed K but no figures or named specimens could be found to aid identification.

****

Genus: Lutetia DESHAYES 1858

Lutetia pisiformis (CHARLESWORTH)

Kellia pisiformis CHARLESWORTH,1851. "Illustrations."
Lutetia parisiensis DESHAYES,1860. p.789,pl.16,figs.34-37.
Lutetia parisiensis DESHAYES: COSSMAN & PISSARRO,1913. pl.33,fig.100:2.
Lutetia pisiformis (CHARLESWORTH): WRIGLEY,1944. p.61.

Remarks

A small form (seldom exceeding 2 mm. in length) with a nearly circular outline and fine concentric growth ornament. It resembles Meretricid Juvenile Type 1 in shape but has a much narrower hinge plate, different dentition and a curved anteriodorsal outline. It occurs abundantly in the Lower and lower Middle Barton Beds of both sections. WRIGLEY (1944) states that CHARLESWORTH's (1851) illustrated cards are valid publications and so the latter's name takes priority over that of DESHAYES (1860).

****

Superfamily: ERYCINACEA

Genus: *Erycina* LAMARCK 1805

Erycina sp.1

Plate 26, figs. 6,7.

Remarks

A thin shelled species with indistinct subcentral umbones, rounded anterior and posterior margins and very weak growth lines. The protoconch is large and well defined.

The dentition consists of two short lamellar, possibly lateral teeth in each valve and one much reduced cardinal tooth. *Erycina nystiana* VINCENT, as figured by GLIBERT (1936, p.126, text-fig.53) from the Belgian Sands of Wemmel, is similar in shape, ornamentation and protoconch form. As only three weathered specimens are available the identification must remain open.

****

Erycina?sp.2

Plate 26, fig. 8.

Remarks

A thin shelled equivalve and equilateral form, with a subquadrate lateral outline, nearly central umbones and a compressed dorsal outline. Ornament consists of fine growth lines and the protoconch is distinct and large. One, internally pyritised complete individual and a broken valve were recovered, so the dentition and generic placing remains questionable. The outline is much shorter and squarer than in *Erycina* sp.1 or *Erycina*?sp.3.

****

Erycina?sp.3

Plate 26, figs. 9,10.

Remarks

As with the previous two species the shell is very thin and the protoconch large and distinct. However, it is markedly inequilateral, the anterior portion being much shorter, with an elongate, terminally rounded posterior outline. Dentition is reduced, with two small lateral teeth in each valve. Two valves of this form come from sample 6669 (Middle Barton Beds, Alum Bay).

****

Superfamily: TELLINACEA

Genus: Tellina (sensu lata)

Tellina ambigua J. de C.SOWERBY

Tellina ambigua J.de C.SOWERBY,1823. pl.403.
Tellina ambigua J.de C.SOWERBY;EDWARDS,1847. p.106,pl.23,fig.5.

Remarks

A species characterised by its elongate shape, small angular umbones and regular, closely set, finely striate growth ornament. BURTON (1933) records it from beds E,G and H. It is commonest in bed G at Barton but at Alum Bay specimens also occur somewhat lower in the Middle Barton Beds. Comparison could be made with specimens in the Ross collection.

****

Tellina sp.cf. T.hantoniensis EDWARDS

?Tellina hantoniensis EDWARDS,1847. p.45,pl.10,fig.1.

Remarks

Two fragmentary specimens from the Lower Barton Beds of Alum Bay may questionably belong to this species. The growth lines are less incised and the juvenile stages are higher than in T.ambigua.

****

Genus: Abra LAMARCK 1818

Abra sp.1

Plate 26, figs.11a,b.

Remarks

Several thin shelled hinge fragments, from the Lower and Middle Barton Beds of Alum Bay, belong in this genus but could not be specifically identified. The umbones are small, more or less central and acute, and two strong cardinal teeth occur in each valve. A large, spoon-shaped resilifer is present.

****

Genus: Psammobia LAMARCK 1818

Psammobia? sp.1

Plate 26, fig.12.

Remarks

A single, broken valve, from the Middle Barton Beds of Barton (sampl 6948), has a thin shell, rectangular outline and a knob-like resilifer. The ornament consists of fine growth lines.

****

Superfamily: SOLENACEA

Genus: Solen LINNE 1767

Solen sp.1

Plate 27, figs.1a,b.

Remarks

Fragmentary specimens from the Chama Bed at Barton belong to an unidentifiable species of Solen. BURTON (1933) records "Solen sp." from that level.

****

Superfamily: MACTRACEA

Genus: Mactra LINNE 1766

Mactra sp.cf. M.compressa DESHAYES

?Mactra compressa DESHAYES, 1830. p.399.
?Mactra compressa DESHAYES: J.de C.SOWERBY in DIXON,1850. p.88,pl.3,fig.3.

Remarks

M.compressa is the only species of Mactra mentioned by BURTON (1933 - bed F) from Barton. COSSMANN & PISSARRO (1913) figure a large adult with tapering anterior and posterior margins. The two specimens recovered from BURTON's bed D (sample 6929) are probably immature. They show the striated laterals of Spisula (see DAVIES, 1935, p.147). Spisula (Eomactra) semisulcata (LAMARCK), as figured by GLIBERT (1936), has the same shape as Mactra compressa but the growth lines are deepened into grooves, a feature not seen on the Bartonian specimens.

****

Superfamily: CHAMACEA

Genus: Chama LINNE 1758

Chama squammosa SOLANDER

Chama squammosa SOLANDER in BRANDER,1766. p.36,pl.7,figs.86,87.
Chama squammosa SOLANDER: WOOD,1871. p.175,pl.25,fig.6.
Chama squammosa SOLANDER: E.WHITE,1963. pl.11,figs.2,3.

Remarks

A large form occurring abundantly in the Chama Bed of both sections. Published figures and specimens in the Ross collection compare well with the material found. This species has been recorded only from the Chama Bed.

****

Superfamily: CARDIACEA

Genus: Cardium (sensu lata)

Cardium ? sp.1

Plate 26, fig.13.

Remarks

A single immature specimen (sample 6934: Middle Barton Beds of Barton) has subcentral umbones and shows the strong lateral and weak cardinal dentition of the superfamily. Further taxonomic designation is impossible.

****

Superfamily: ASTARTACEA

Genus: Crassatella LAMARCK 1799

Remarks

With the exception of a few specimens from the Chama Bed of Barton, all the material examined in this study proved to consist of juveniles. All showed the characteristic ornament of strong growth ridges and the dentition of the group.

Unfortunately former writers have divided the group into a number of genera and species based on characters not always identifiable in the juveniles. DAVIES (1935) lists three Lower Tertiary genera: Crassatella (s.s.) (and the subgenus Crassatellites); Bathytormus, which has a resilium pit extended ventrally; and Crassinella (and the subgenera Gouldia, Crassatina and Pseuderiphyla), which includes small trigonal forms with little or no posterior prolongations. BURTON (1933) lists seven species from Barton. Three are referrable to Crassinella and four to Crassatella (s.s.). WOOD (1871) figures four species which can be put into Crassinella and four into Crassatella (s.s.).

Juveniles examined from the Barton Clay have the short, trigonal outline of Crassinella and a few have a resilium pit extending to the ventral margin of the hinge plate (as in Bathytormus). A close inspection of well preserved adult Crassatella sulcata (SOLANDER) reveals an early stage with no posterior ridge and well developed growth ridges of exactly the same sort and circumscribing the same trigonal outline.

It is evident from these observations that all specimens from the Lower and Middle Barton Beds are in fact juvenile Crassatella sulcata. The suspicion remains that more or less equilateral species such as Crassinella aequalis (WOOD), C.pumilio (WOOD) and C.bartonensis (WOOD) may be present or that they may have been erected on juvenile specimens of Crassatella sulcata.

Crassatella sulcata (SOLANDER)

Tellina sulcata SOLANDER in BRANDER, 1766. p.37,pl.7,fig.89.
Crassatella sulcata (SOLANDER): WOOD,1871. p.170,pl.23,fig.11.(et syn.)
Crassatella sulcata (SOLANDER): E.WHITE,1963. pl.9,figs.11,12.

Remarks

Immature specimens have been compared with the juvenile stages of adults in the Burton, Wrigley and Ross collections. C.sulcata has only been recorded from the Lower and Middle Barton Beds.

****

Crassatella tenuisulcata WOOD

Crassatella tenuisulcata EDWARDS (m.s.):WOOD,1871. p.171,pl.23,fig.2.

Remarks

This is the only form found adult in the present study. It occurs in the Chama Bed of Barton and can be distinguished from C.sulcata on its more accentuated posterior process and its broader, lower growth ridges. C.ensiformis (=C.sulcata var.ensiformis WOOD) is recorded by BURTON (1933) from beds E, F and H at Barton. It is low and elongate like C.tenuisulcata, but bears three posterior longitudinal ridges or folds, not two.

****

"Crassatella" spp.indet.

Remarks

All unidentifiable fragmentary, poorly preserved and juvenile specimens from the Upper Barton Beds of both sections are included here.

****

Superfamily: CARDITACEA

Genus: Venericardia LAMARCK 1801

Venericardia sulcata (SOLANDER)

Chama sulcata SOLANDER in BRANDER,1766. p.40,pl.7,fig.100.
Cardita sulcata (SOLANDER): WOOD,1871. p.152,pl.22,fig.1.(et syn.)
Cardita sulcata (SOLANDER): E.WHITE,1963. pl.9,figs.7,8.

Remarks

A very common species throughout the Lower and Middle Barton Beds of both sections. Much of the material is immature but comparison with the published figures and with specimens in the Wrigley, Burton and Ross collections leave no doubt as to their identification. The radial ribs are never as smooth and acute-edged as in V.simplex (WOOD). V.davidsoni (DESHAYES) has more numerous ridges with rougher, less lobose crests.

****

Venericardia davidsoni (DESHAYES)

Cardita davidsoni DESHAYES,1860. p.764,pl.60,figs.10-12.
Cardita davidsoni DESHAYES: WOOD,1871. p.145,pl.22,fig.17.

Remarks

A few large, well preserved specimens from the Chama Bed of Barton compare well with WOOD's figures and with specimens in the Ross collection. BURTON (1933) records it from beds A3, B, C, F and H but no unquestionable examples could be found below bed H.

****

Venericardia oblonga J.SOWERBY

Venericardia oblonga J.SOWERBY,1821. pl.289,fig.2.
Cardita oblonga (J.SOWERBY): WOOD,1871. p.149,pl.22,fig.14.
Cardita oblonga (J.SOWERBY) var.serratina WOOD,1871. p.149,pl.22,fig.10.
Glans oblonga (J.SOWERBY): E.WHITE,1963. pl.9,fig.6.

Remarks

The distinctive, subrectangular outline distinguishes V.oblonga from the previous two species. BURTON (1933) records it from throughout the Barton Beds of Barton, but it was only found in the Chama Bed in the present study. Specimens of this species and the variety serratina (WOOD) in the Ross collection are identical with the material found.

****

Venericardia sp.indet.

Remarks

A number of worn and poorly preserved specimens from the Upper Barton Beds of Barton (BURTON's beds H and K) could not be positively identified. BURTON records V.oblonga from as high as bed J but the incomplete margin of these specimens would not allow the recognition of the characteristic square outline of that species.

****

Superfamily: CYRENACEA

Genus: Corbicula MUHLFELD 1811

Corbicula deperdita LAMARCK

Cyclas deperdita LAMARCK,1806. p.421.
Cyrena deperdita (LAMARCK): DESHAYES,1824. p.118,pl.19,figs.14,15.
Cyrena deperdita (LAMARCK): WOOD,1877. p.13,pl.3,fig.10 (et syn.)

Remarks

An examination of specimens in the Ross collection labelled under the names Cyrena deperdita (LAMARCK), Cyrena gibbosula FORBES, and Cyrena arenaria WOOD convinced the author that they are all conspecific and should belong under LAMARCK's name. All are from the "Long Mead End Sands and Clays" i.e. the same horizon as the present material. Similarly figures in WOOD (1877) of species named as Cyrena deperdita (LAMARCK), Cyrena gibbosula FORBES, Cyrena cycladiformis DESHAYES, Cyrena pisum DESHAYES and Cyrena obliqua WOOD (not DESHAYES) should also belong here. Differentiation appears to have been made on size and small differences in shape. These are both very unreliable features in a brackish water form. The shape differences are probably also partly due to compression.

In the Upper Barton Beds of Barton (BURTON's beds H, J and particularly K) this form occurs in very large numbers. All attempts at distinguishing more than one taxon failed in the presence of gradational and preservational features. The striate ornament on the strong lateral dentition suggests the correct generic placement to be with Corbicula (given as a subgenus of Cyrena by DAVIES, 1935).

****

Genus: Anisocardia MUNIER-CHALMAS 1863

Anisocardia pectinifera (J.de C.SOWERBY)

Venus pectinifera J.de C.SOWERBY, 1823. p.26,pl.422,fig.4.
Anisocardia pectinifera (J.de C.SOWERBY): COSSMANN,1887. p.157,pl.7,
figs.33-35 (et syn.)

Remarks

Two specimens from the Lower Barton Beds of Alum Bay agree well with COSSMANN's (1877) figures. They are also identical with specimens in the

Ross collection labelled *Anisocardia isocardioides* DESHAYES. It is inequilateral, with an acute posterioventral angle. The few strong smooth growth flanges have fine radial striations between them.

****

Superfamily: VENERACEA

Remarks

Representatives of DAVIES' (1935) subfamily Meretricinae are very abundant in the Barton Beds. TREMLETT (1953) in his revision of the group, describes many species from this part of the stratigraphic column. Unfortunately, specific characters are only developed in adults, which often reach a size of up to several cms. in length. The bulk of the material examined was from the 10-30 and 60-30 size fractions and must be considered largely unidentifiable. With the aid of TREMLETT's monograph two species are recognised from single, large specimens and the rest are arbitrarily divided into two groups.

Genus: *Callista* POLLI 1791

Subgenus: *Microcallista*

Callista (Microcallista) heberti DESHAYES *var.belgica* (VINCENT)

"*Venus elegans* LMK" J.de C.SOWERBY,1823.(non LAMARCK,1806)p.26,pl.422,fig.3.
Pitaria (Paradione) belgica (VINCENT): GLIBERT,1936. p.149,pl.5,fig.6.
Callista (Microcallista) heberti DESHAYES *var.belgica* (VINCENT):TREMLETT, 1953. p.15,pl.3,figs.19-20. (et syn.)
Callista (Microcallista) heberti belgica (VINCENT):E.WHITE,1963. pl.13, figs.7,8.

Remarks

The single identifiable left valve from sample 6929 (bed D) is characterised by being fairly short and high, with relatively few prominent, concentric, growth ribbons increasing slowly in width. TREMLETT (1953a) records it from beds E and C at Barton.

****

Genus: *Tivelina* COSSMANN 1886

Tivelina gravida TREMLETT

Tivelina gravida EDWARDS (m.s.): TREMLETT,1953. p.12,pl.4,figs.28-29(et syn.)

Remarks

One left valve, from the *Chama* Bed of Barton (sample 6964) agrees with TREMLETT's figures and description. He records it only from BURTON's bed H.

****

Meretricid Juvenile Type 1

Plate 27, figs. 2, 3, 4.

Remarks

Included here are all small juvenile Meretricids with more or less circular outlines and fine, concentric growth ridges. This form occurs, sometimes abundantly, throughout the Barton Beds and is undoubtedly a polyphyletic assemblage. The circular outline is not developed in the juvenile stages of all Meretricids but several species of *Pitar* and *Callista* show this feature.

****

Meretricid Juvenile Type 2

Plate 27, fig.5.

Remarks

A somewhat larger form than Meretricid Type 1, usually occurring as massive hinge fragments. The growth ridges are higher and wider than in Meretricid Type 1 and, at growth stages of equivalent development, they have more elongate outlines. This probably represents several taxa and is long ranging in both sections.

****

"*Meretrix*" sp.3

Plate 27, fig.6.

Remarks

A single, large, pyritised, articulated specimen, from the Middle Barton Beds of Barton (sample 6941), has a strong posteriodorsal fold not seen in other material. The length is only slightly larger than the height and the fine concentric growth lines are similar to those of Meretricid Type 1. The external features bear a similarity with *Meroena polita* (LAMARCK), as figured by TREMLETT (1953), but the preservation and inaccessibility of the hinge preclude definite identification.

****

Superfamily: ARCACEA

Genus: Barbatia GRAY 1842

Barbatia appendiculata (J.SOWERBY)

Arca appendiculata J.SOWERBY,1821. pl.276.
Arca appendiculata J.SOWERBY: WOOD,1871. p.79,pl.14,fig.3.

Remarks

Several large specimens, from the Lower Barton Beds of both localities and the Middle Barton Beds of Barton, compare well with WOOD's figures and with specimens in the Wrigley and Burton collections. BURTON (1933) records it from beds C, E and F at Barton.

****

Genus: Andara GRAY 1847

Andara subglobulosa (WOOD)

Arca globulosa (?) var.subglobulosa WOOD,1871. (non DESHAYES,1829) p.84,pl.15, fig.9.

Remarks

By kind permission of Mr.A.King specimens of A.globulosa (DESHAYES) from the Lower Eocene of Cuise Lamotte were examined. They show wider variation, attain a greater size and are more elongate and less tumid than the English form. Also the ornament is not so strongly developed on larger specimens. WOOD refers the Bartonian form to annew variety but erection to specific level is here preferred. A.subglobulosa is restricted to the Lower Barton Beds of both sections. BURTON (1933) only records it (as Andara globulosa) from bed A3.

****

Genus: Fossularca COSSMANN 1887

Fossularca lissa (BAYAN)

Arca laevigata CAILLAT,1835. (non SPENGLER) p.240,pl.9,fig.7.
Arca laevigata CAILLAT: DESHAYES,1860. p.905,pl.58,figs.25-26.
Arca laevigata CAILLAT: WOOD,1871. p.86,pl.15,fig.8.(et syn.)
Arca lissa BAYAN,1873. p.130.
Arca (Fossularca) lissa (BAYAN): COSSMANN & PISSARRO,1913.pl.37,fig.110:57.

Remarks

A distinctive species, characterised by its rounded trapezoidal outline, long straight hinge line and fine growth ornament. It occurs abundantly in the Lower Barton Beds of both sections and infrequently in the Middle Barton Beds. Conspecific specimens occur in the Upper Bracklesham Beds and it has also been recorded from several French Eocene localities. Good compariso is possible with the published figures and with specimens in the Burton collection (labelled Trigonodesma lissa (BAYAN)).

****

Genus: Glycymeris COSTA 1778

Glycymeris deleta (SOLANDER)

Arca deleta SOLANDER in BRANDER, 1766. p.39, pl.7, fig.97.
Pectunculus deletus (SOLANDER): WOOD, 1871. p.97, pl.16, fig.3.
Glycymeris deleta (SOLANDER): E.WHITE, 1963. pl.6, fig.8, 9.

Remarks

This species differs from G.proxima (WOOD) in being much more equilateral The sharp radial ornament of G.deleta figured by WOOD is usually worn in the abundant Chama Bed material. Limopsis scalaris (J.de C.SOWERBY) has much stronger cancellate ornament. Adult L.scalaris are much more inequilateral and lack the long hinge line of Glycymeris deleta.

****

Genus: Limopsis SASSI 1827

Limopsis scalaris (J.SOWERBY)

Pectunculus scalaris J.SOWERBY, 1824. pl.472, fig.2.
Limopsis scalaris (J.SOWERBY): WOOD, 1871. p.104, pl.17, fig.9.
Limopsis scalaris (J.SOWERBY): E.WHITE, 1963. pl.6, figs.5, 6.

Remarks

A frequent form in the Middle Barton Beds of both sections. Juveniles sometimes resemble Glycymeris deleta in their strong ears and equal posterio and anterior margins but differ in the cancellate ornament of L.scalaris. Adult specimens compare well with those in the Ross collection. They are inequilateral and have a distinct internal ligament pit.

****

Genus: Trinacria MAYER 1868

Trinacria curvirostris COSSMANN

Trigonocoelia deltoides (?) var.deltaeformis WOOD,1871. (non LAMARCK) p.105,pl.19,fig.11.
Trinacria curvirostris COSSMANN, 1882. p.117,pl.5,fig.4.
Trinacria curvirostris COSSMANN: E.WHITE,1963. pl.5,figs.7-8.

Remarks

Infrequent specimens from bed J at Barton agree well with the material from the Middle Headon Beds of Colwell Bay and with specimens in the Ross collection. They are characterised by the rounded anterior and drawn out, angular posterior margins.

****

Superfamily: PTERIACEA

Genus: Pteria (sensu lata)

Pteria? sp.1

Plate 26, fig.14.

Remarks

Included here are small, juvenile, strongly inequilateral specimens, with large smooth protoconchs and laterally unornamented shells. The interior is nacreous and the hinge reduced (two posterior laterals are sometimes present). Such material is too immature to identify further and the generic placing may well be questionable.

****

Pteria? sp.2

Plate 26, fig.15.

Remarks

A form identical with P.? sp.1 except that ornament is present on the lateral faces outside the protoconchs. This consists of a series of broad, low, radial ribbons. Both this and the preceding species occur throughout the Lower and Middle Barton Beds.

****

Superfamily: ANOMIACEA

Genus: Anomia LINNE 1758

Anomia sp.2

Plate 26,fig.16.

Remarks

One upper valve and one lower valve of a smooth, thin shelled species of Anomia were encountered in the Middle Barton Beds of Barton. BURTON (1933) and WOOD (1871) record A.tenuistriata DESHAYES from this locality but the specimens are too immature to identify from the latter's figures.

****

Superfamily: PECTINACEA

Genus: Chlamys RODING 1798

Chlamys recondita (SOLANDER)

Ostrea recondita SOLANDER in BRANDER,1766. p.42,pl.8,fig.107.
Pecten reconditus (SOLANDER): WOOD, 1871. p.42,pl.9,fig.3.
Chlamys recondita (SOLANDER): E.WHITE,1963. pl.7,fig.2.

Remarks

Although only fragmentary specimens occur in Middle Barton Beds samples, the characteristic flat-topped or lobose ribbing leaves no doubt as to the specific placing. C.carinata (J.SOWERBY) has ribs with angular crests. Comparison was also made with specimens in the Ross collection.

****

Superfamily: OSTREACEA

Genus: Ostrea (sensu lata)

Ostrea plicata (SOLANDER)

Chama plicata SOLANDER in BRANDER,1766. pl.8,figs.84,85.
Ostrea flabellula LAMARCK, 1806. p.164.
Ostrea flabellula LAMARCK: WOOD,1871. p.21,pl.3,fig.4.
Ostrea plicata (SOLANDER): E.WHITE,1963. pl.9,fig.1.

Remarks

Several fragmentary specimens of left valves agree well with the figures of O.plicata and O.flabellula and with specimens of the latter in the Ross collection. The upturned margin is characteristically strongly corrugated. Several other species of Ostrea are also known from Barton (BURTON, 1933, mentions three) but they could not be recognised in the material studied. Smooth right valves are sometimes encountered but these have few specific characters and are mostly juveniles (see below).

****

Ostrea spp. (juveniles)

Remarks

Juvenile specimens of Ostrea, with a large,well defined protoconch and surfaces bearing only indistinct growth ornament are included here. Some may belong to C.plicata.

****

Superfamily: SEPTIBRANCHIA

Genus: Neaeroporomya COSSMANN 1886

Neaeroporomya argentea (LAMARCK)

Corbula argentea LAMARCK,1806. p.468.
Neaeroporomya argentea (LAMARCK): COSSMANN & PISSARRO,1913. pl.4,fig.26:1.
Neaeroporomya argentea (LAMARCK): WRIGLEY,1934. p.9,fig.1:1.
Neaeroporomya argentea (LAMARCK): GLIBERT,1936. p.200,text-fig.71.(et syn.)

Remarks

Specimens from the Middle Barton Beds of both sections have few widely spaced growth ridges and two strong, radial ridges or folds on the posterior process. They agree with WRIGLEY's (1934) figure, except that none have the internal rod that hementioned (considered to be a pathological feature by that author).

****

Superfamily: ADESMACEA

Genus: Bankia GRAY 1842

Subgenus: Neobankia BARTSCH 1921

Bankia (Neobankia) sp.cf. B.tumida STINTON

?Bankia (Neobankia) tumida STINTON,1957. p.168,pl.25,figs.1-7.

Remarks

Two fragmentary Teredinid valves, both from the Lower Barton Beds of

Alum Bay, can questionably be referred to STINTON's species. The differentiation of Teredinids is based on the form of the pallets (small accessory calcareous plates associated with the siphon) and these have not been found in the present study. Those of E.tumida are figured by STINTON and have a characteristic "cone in cone" structure.

****

Superfamily: MYACEA

Genus: Corbula BRUGUIERE 1797

Corbula pisum J.SOWERBY

Corbula pisum J.SOWERBY,1818. pl.209,fig.4.
Corbula pisum J.SOWERBY: DESHAYES,1860. p.217,pl.15,figs.22-25. (et syn.)
Corbula pisum J.SOWERBY: COSSMANN & PISSARRO, 1913. pl.3,fig.20:6.
Corbula pisum J.SOWERBY: E.WHITE,1963. pl.14,fig.10.

Remarks

This is the dominant species of Lamellibranch in the Lower and Middle Barton Beds. The very tumid, globose and unequal valves bear faint, irregular growth ornament and agree well with material in the Burton, Wrigley and Ross collections. An examination of specimens labelled Corbula globosa J.SOWERBY in the Burton and the Ross collections showed that they are in fact juveniles of C.pisum. The immature stages of large valves of C.pisum have exactly the same outline, shape and ornament as C.globosa.

****

Corbula cuspidata J.SOWERBY

Corbula cuspidata J.SOWERBY,1822. pl.362,figs.4-6.
Corbula cuspidata J.SOWERBY: E.WHITE,1963. pl.14,fig.14.

Remarks

A form occurring quite abundantly in the Upper Barton Beds of Barton; from the Chama Bed to BURTON's bed K. It is usually larger than C.pisum the valves being laterally more compressed and elongate, with a truncated posterior margin. A strong fold runs from the umbo to the posterio-ventral angle. The material agrees well with specimens in the Ross and Burton collections.

****

Corbula sp.cf. C.costata J.de C.SOWERBY

?Corbula costata J.de C.SOWERBY in DIXON,1850. p.165.

Remarks

Rather infrequent specimens, from the Lower and Middle Barton Beds of both sections,have similar outlines and posterior folds as C.cuspidata but are somewhat more laterally inflated. The ornamentation is much stronger, consisting of a number of high, well spaced, rounded crested growth ridges, with finer subordinate growth striae. Specimens with higher growth ridges are similar to COSSMANN & PISSARRO's (1913) figures of C.rugosa LAMARCK but the outline is more elongate in the Bartonian material.

****

Genus: Lentidium CRISTOFORI & JAN 1832

Lentidium tawneyi CURRY

Lentidium tawneyi CURRY,1960a. p.275,fig.4. (et syn.)
Lentidium tawneyi CURRY: E.WHITE,1963. pl.14,fig.1.

Remarks

This is one of the dominant species in the sands at the top of the Upper Barton Beds (bed K). It agrees well with CURRY's (1960) figures and description. Earlier names for the Upper Barton Beds form were shown by CURRY to be preoccupied. Thus Lentidium nitida (J.SOWERBY) should be reserved for the larger and more tumid species found in the Upper Hamstead Bed

****

Lentidium sp.1

Plate 27, figs.7a,b.

Remarks

A species of Lentidium occurring rarely in the Lower and Middle Barton Beds. It is small, elongate, with a broadly rounded posterior outline and a somewhat more produced, narrowly rounded anterior outline. Laterally it is compressed and lacks a strong posterior fold. The ornament is restricted to weak concentric growth striae and the dentition is typical for the genus, with a well marked fissure leading from the internal ligament pit to the umbo.

This form bears a close resemblance to L.tawneyi CURRY but lacks any lateral fold or posterior truncation. It is considered advisable to apply CURRY's name to the Upper Barton Beds species only, keeping this form as a separate taxon.

****

4:6:2 Class: SCAPHOPODA BRONN 1862

Genus: Dentalium LINNE 1758

Dentalium striatum J.SOWERBY

Dentalium striatum J.SOWERBY, 1814. pl.70,fig.4.
Dentalium striatum J.SOWERBY: DESHAYES,1861. p.206,pl.1,figs.9-11.
Entaliopsis striata (J.SOWERBY): NEWTON & HARRIS, 1894. p.68 (et syn.)
Dentalium (Entaliopsis) striatum (J.SOWERBY): COSSMANN & PISSARRO, 1913. pl.1,figs.1:9.
Antaclis striata (J.SOWERBY): E.WHITE,1963. pl.28,fig.11.

Remarks

Fragments with a polygonal section and faint longitudinal striations are common in the Lower and Middle Barton Beds. Comparison with the published figures and with specimens in the Burton, Wrigley and Ross collections show that they undoubtedly belong to this species. In the absence of a well preserved apical portion the subgeneric placing cannot be determined (see LUDBROOK in MOORE (ed.) 1960, "Treatise", Vol.I, Mollusca (1)).

****

Dentalium pellucens DESHAYES

Dentalium pellucens DESHAYES, 1861. p.214,pl.1,figs.21-23.
Fustiariapellucens (DESHAYES): NEWTON & HARRIS,1894. p.65.

Remarks

A species of Dentalium with a smooth, polished surface and ornamented by oblique, elliptical growth striae, is extremely common in a fragmentary state in the Lower and Middle Barton Beds of both sections. It resembles DESHAYES' figures of D.pellucens and specimens in the Ross collection. Subgeneric placement appears to be with Dentalium (Fustiaria)(see Treatise, ed. MOORE, 1960), although the apical characters cannot be determined on the material available.

****

4:6:3 Class: GASTROPODA CUVIER 1797

Subclass: PROSOBRANCHIATA MILNE-EDWARDS 1848

Order: ARCHAEOGASTROPODA THIELE 1925

Family: ADEORBIDAE

Genus: Adeorbis S.WOOD 1842

Adeorbis elegans CHARLESWORTH

Adeorbis elegans CHARLESWORTH,1851. "Illustrations".
Adeorbis politus EDWARDS (m.s.): MORLET,1888. p.196,pl.8,fig.8.
Adeorbis politus MORLET: COSSMANN,1888. p.153,pl.11,figs.38-40.

Remarks

A small discoidal species of Adeorbis, characterised by its low spire, slightly flattened whorl section and very faint spiral striae. It differs from Teinostoma dubia (LAMARCK) in having a more depressed spiral suture and an open umbilicus. Juveniles resemble immature Adeorbis sp.7 and A.sp.8 but have a less inflated whorl section. WRIGLEY (1944, p.61) shows that CHARLESWORTH's name is valid and has priority over MORLET's publication of EDWARDS' manuscript name. A.elegans occurs throughout the Barton Beds and is especially abundant in the topmost Middle Barton Beds. Comparison was made with specimens in the Wrigley and Burton collections.

****

Adeorbis sp. 7

Plate 27, fig.8.

Remarks

This is a small species with a low spire and an inflated whorl section. The surface is ornamented by numerous, regular spiral ridges with finer growth ridges between them, giving the shell a cancellate appearance. The umbilicus is open, but narrower than in A.elegans. The few specimens found were from the upper part of the Middle Barton Beds.

****

Adeorbis sp. 8

Plate 27, fig.9.

Remarks

After a smooth juvenile portion with a round inflated whorl section, this form develops three or four angular spiral ridges or carinae. The areas between the ridges are flat or slightly concave and bear additional faint spiral striae. The ridge nearest the spiral suture is the most pronounced. The umbilicus is narrow and deep, as in A.sp.7. Only two specimens were found, both from BURTON's bed G at Barton (sample 6963).

****

Genus: Teinostoma ADAMS 1853

Teinostoma dubia (LAMARCK)

Helicina dubium, LAMARCK, 1804. p.91.
Tinostoma (Megatyloma) dubium (LAMARCK):COSSMANN,1888. p.47,pl.2,fig.31.

Remarks

This form occurs throughout the Lower and Middle Barton Beds in small numbers. The adult whorls are slightly flattened in section and bear faint spiral and growth striae. They resemble adults of Adeorbis elegans in general shape but have nearly flush sutures. Juveniles are very similar to juvenile specimens of Adeorbis spp. but the umbilicus is always filled by a characteristic callus plug.

****

Order: CAENOGASTROPODA COX 1959

Suborder: MESOGASTROPODA

Family: PYRAMIDELLIDAE

Remarks

This family, together with the Eulimidae and Mathildiidae, is mainly composed of very small species, which in recent forms,have a commensal or parasitic relationship with Echinoderms. The Pyramidellidae are unusual in combining a holostome aperture with a heterostrophic protoconch, indeed the "Treatise" (ed. MOORE,1960) places them with the Opisthobranchs.

Although their diversity is high the English Tertiary Pyramidellids are poorly known. Most have only manuscript names or are undescribed, and in the past their generic placement has been frequently misinterpreted.

In this study a slightly modified version of COSSMANN's (1892) generic classification is used. This is partly based on the form of the heterostrophic protoconch. In *Syrnola*, *Odostomia* and *Turbonilla* the heterostrophic portion is relatively long and at or near a right angle to the adult axis of coiling. In *Syrnola* and *Turbonilla* the initial stage is not overlapped by the first adult whorl. The adult whorls of *Syrnola* are smooth and those of *Turbonilla* bear vertical ribs. *Odostomia* has a heterostrophic portion which is at an acute angle to the adult axis and is partly hidden by the first adult whorl. Adults may be smooth or spirally ornamented. COSSMANN differentiated *Pachysyrnola* on its initial axis of coiling being at right angles to the axis of the embracing adult whorls, but this feature is seldom determinable and *Pachysyrnola* is here included in *Odostomia*. *Belonidium* and *Anisocycla* have relatively short initial stages. In *Belonidiu* this forms a conjunct disc and in *Anisocycla* it is disjunct and shaped like a shepherd's crook.

****

Genus: *Odostomia* FLEMING 1817

Odostomia hordeola (LAMARCK)

Plate 27, figs.10,11.

Auricula hordeola LAMARCK, 1804. p.436.
Auricula hordeola LAMARCK: DESHAYES, 1837. p.68,pl.6,figs.21-22.
Odontostomia hordeola (LAMARCK): COSSMANN & PISSARRO,1913.pl.6,fig.44:3.

Remarks

The straight sided whorls increase in size slowly in this form,givi a relatively high spire. The apical angle decreases with growth, and the spiral suture runs in a well defined groove. Immature specimens may bear closely set, very faint growth striae. The submerged protoconch is typical of *Odostomia*. Comparison was made with specimens in the Burton and Wrigley collections.

****

Odostomia miliola (LAMARCK)

Plate 27, fig. 12.

Auricula miliola LAMARCK,1804. p.553.
Auricula miliola LAMARCK: DESHAYES,1837. p.69,pl.6,figs.19,20.
Odontostomia miliola (LAMARCK): COSSMANN & PISSARRO,1913. pl.6,fig.44:22.

Remarks

This smooth species has an increasing spiral angle with growth, giving the adult shell a rather shorter spire than O.hordeola, though not as short as in O.sp.3. Unlike the latter the whorl section is inflated and the sharp angle at the base of the final whorl is missing or very indistinct. As in both the above species the single columellar fold is small. O.lirifera NEWTON (1895) has a similar shape and lack of ornamentation but has a less inflated whorl section. Specimens in Burton's and Wrigley's collections agree well with the present material, which is abundant throughout both sections.

****

Odostomia sp.1

Plate 27, fig. 13.

Remarks

The characteristic features of O.sp.1 are the distinct spiral grooving, the small columellar fold and the rapid increase in growth of the adult whorls. The submerged heterostrophic protoconch indicates its generic placement.

****

Odostomia sp.2

Plate 27, fig. 14.

Remarks

A species with a similar spiral angle and slightly fainter ornament than O.sp.1. The columellar fold is, however, much more prominent and the whorls have flatter sides. It appears to be restricted to the uppermost Middle Barton Beds and the Chama Bed.

****

Odostomia sp.3

Plate 27, fig.15.

Remarks

This form resembles O.miliola in its lack of ornament, high spiral angle and small columellar fold. The successive whorls overlap earlier ones slightly and adult specimens may be distinguished by the sharp angle at the base of the whorls. It is very abundant in the Middle Barton Beds of both sections.

****

Odostomia sp. 4

Plate 27, fig. 16.

Remarks

The shape and ornament resembles that of O.miliola except that the shell is considerably thicker and the adult whorls increase in length more markedly. Thus the final whorl constitutes over half the shell length. Only a single specimen was found, from the Chama Bed at Barton (sample 6964).

****

Odostomia sp. 7

Plate 27, fig.17.

Remarks

A very common smooth species in the Lower and Middle Barton Beds, with a whorl shape and spiral angle like O.hordeola, but with a very strong, shelf-like columellar fold. A sharp postapertural angle is present on the body whorl, sometimes with a ribbon of original shell colouring on the parietal surface.

****

Odostomia sp. 8

Plate 27, fig.18.

Remarks

Rare specimens from the Middle Barton Beds of both localities are similar to O.miliola. The shell is somewhat thicker, the columellar fold is stronger and the whorls are slightly shorter, with a more excavate parietal face.

****

Genus: Syrnola ADAMS 1860

Syrnola canaliculata (EDWARDS m.s.)

Plate 27, fig. 19.

Remarks

A rather variable form which compares well with specimens labelled Obeliscus canaliculatus in the Edwards and Burton collections. Constant features are the emergent heterostrophic protoconch, the very slightly incised sutures and the short, squarish whorls. The spiral angle may vary, though it is usually small, and the columellar fold is poorly developed or apparently absent. It occurs frequently in the Lower and Middle Barton Beds of both sections.

****

Syrnola excavata (EDWARDS m.s.)

Plate 27, fig. 20

Remarks

This common form agrees well with specimens labelled Obeliscus excavatus EDWARDS (m.s.) in the Burton and Edwards collections. The spire is elongate and the whorl section squarish. The apertural side of the spiral suture is characteristically marked by a raised ribbon, followed by a depression. The protoconch is quite long and emergent.

****

Syrnola excavata (EDWARDS m.s.) var.1

Plate 27, fig. 21.

Remarks

Infrequent specimens, from the Lower and lower Middle Barton Beds of both sections, have the same distinctive whorl shape and protoconch as S.excavata but have a larger spiral angle and show increased size with growth. They are similar to an unnamed specimen of Syrnola in the Wrigley collection, but do not warrant separate specific status.

****

Syrnola polygyra (EDWARDS m.s.)

Plate 27, fig. 22.

Remarks

Abundant material from throughout the Barton Beds compares well with specimens in the Edwards collection. This is a very high spired form like S.excavata, but the whorls are inflated or slightly angular and lack the adapical spiral ribbon. WRIGLEY's (1934) figure of Belonidium polygyratum (DESHAYES), from the Lutetian of Southampton Dock, has a very similar whorl shape to this species. It shows the elongate emergent protoconch of Syrnola, not the disc-like structure of Belonidium.

****

Genus: Anisocycla MONTEROSATA 1834

Anisocycla sp.11

Plate 27, figs.23,24.

Remarks

A few very small specimens from the Middle Barton Beds of Barton have the disjunct heterostrophic protoconch of the genus. The whorls are compressed in section and are very loosely coiled. They are ornamented with fine spiral striae. Another species from the Upper Bracklesham Beds of Selsea has fine vertical ribs.

****

Genus: Belonidium COSSMANN 1892

Belonidium eulimoides (EDWARDS m.s.)

Plate 27, fig. 25.

Remarks

This species bears the distinctive short, flattened protoconch of Belonidium. The spiral angle is small, the coiling quite loose and the spiral suture is only slightly depressed. The elongate apertural outline is distinct from that of any other species of Pyramidellid from Barton. Material from the Lower and Middle Barton Beds of both sections compares well with Edwards' specimens.

****

Genus: Turbonilla RISSO 1826

Turbonilla pulchra DESHAYES

Plate 27, fig. 26.

Turbonilla pulchra DESHAYES,1862. p.567,pl.20,figs.24,25.

Remarks

Frequent specimens from the Lower and Middle Barton Beds of both sections show characteristic rounded, slightly sinuous ribbing, an elongate protoconch and a squarish whorl section. They are identical with specimens in the Wrigley collection. T.notata DESHAYES, as figured by WRIGLEY (1934) from the Middle Bracklesham Beds of Southampton, has shorter ribs and a slightly more inflated whorl section. The high spire and emergent protoconch are otherwise the same.

****

Turbonilla edwardsi GLIBERT

Plate 27, fig. 27.

Turbonilla edwardsi GLIBERT,1938. p.48,pl.1,fig.19; text-fig.21.

Remarks

A few specimens from the Lower and Middle Barton Beds of Barton are identical with Turbonilla edwardsi GLIBERT in the Wrigley collection and T.costellata EDWARDS (m.s.) in the Burton collection. They have rounded vertical ribbing andfaint spiral grooves on adult whorls. The spiral angle is small and the growth rate regular. The juvenile stages could not be observed.

****

Family: EULIMIDAE

Genus: Eulima RISSO 1826

Eulima munda DESHAYES

Eulima munda DESHAYES,1862. p.539,pl.27,figs.30-32.
Eulima (Subularia) munda (DESHAYES): COSSMANN & PISSARRO,1913. pl.7,fig.49:6.
Eulima munda DESHAYES: WRIGLEY,1944. p.48,figs.1,2.(et syn.)

Remarks

A few fragmentary final whorls from the Middle Barton Beds are definitely referrable to this species, as described and figured by WRIGLEY. They show a flush spiral suture, with faint, almost vertical growth lines, very loose coiling and a short, broad, tear-shaped aperture.

****

Eulima sp. 1

Plate 27,fig.28.

Remarks

A frequently occurring, probably polyphyletic and juvenile form. The spiral angle is initially acute but increases slightly with growth. The spiral suture is flush and the labral profile bulges slightly towards the aperture. The base shows a strong angularity. WRIGLEY's (1944) figures of Eulima (Polygyreulima) sowerbyi NEWTON very closely resemble E.sp.1. He mentions that the former is restricted to FISHER's bed 21 at Selsea. Although nearly identical specimens occur in samples from the same level at Selsea, both them and the Bartonian material are composed largely of juveniles and their identification is questionable.

****

Eulima sp.2

Plate 27, fig.29.

Remarks

This species could not be matched with any in the collections examined. It is very similar to E.sp.1 in its smooth surface and flush suture but has a slightly larger apical angle and a much more inflated protoconch. It appears to be restricted to the Lower Barton Beds.

****

Genus: Rostreulima COSSMANN 1813

Rostreulima macrostoma (CHARLESWORTH)

Eulima macrostoma CHARLESWORTH,1851. "Illustrations".
Rostreulima macrostoma (CHARLESWORTH): WRIGLEY,1944. p.55,fig.20(et syn.)

Remarks

Rare specimens from both localities show the large spiral angle, parasigmoid labral profile and large final whorl of R.macrostoma, as figured by WRIGLEY (1944) and seen in the Ross collection.

****

Family: MATHILDIIDAE

Genus: Mathildia SEMPER 1865

Mathildia bourdoti BOURY

Mathildia bourdoti BOURY,1883. p.128,pl.5,fig.2.
Mathildia bourdoti BOURY: COSSMANN & PISSARRO,1913. pl.22,fig.128:2.

Remarks

A small form, restricted at both sections to the Lower Barton Beds. It shows loose coiling, an inflated whorl section, sharp cancellate ornament and a nearly circular aperture.

****

Family: ARCHITECTONICIDAE

Genus: Architectonica RODING 1798

Architectonica sp.1

Plate 28, figs.1,2.

Remarks

Immature material occurs in many samples from the Lower and Middle Barton Beds but unfortunately cannot be specifically identified. The spiral angle is rather higher than in A.bonneti (COSSMANN), although this may change with development to the adult. The large protoconchs are smooth and have an initial direction of coiling down into the umbilicus. They have a circular cross section and show an abrupt change to the typically heavy cancellate ornament of the adolescent stage.

****

Family: SCALARIIDAE

Genus: Scala BRUGUIERE 1792

Scala reticulata (SOLANDER)

Turbo reticulatus SOLANDER in BRANDER,1766. p.17,pl.1,fig.27.
Epitonium (Acrilla) reticulatum (SOLANDER): E.WHITE,1963. pl.17,fig.6.

Remarks

Infrequent large specimens, from the Lower and Middle Barton Beds, show the characteristic regular high spire, vertical flanges and spiral ridges of this species. They compare well with the published figures and with specimens in the Ross collection.

****

Genus: Acrilla ADAMS 1860

Acrilla sp.1

Plate 27, fig.30.

Remarks

A very distinctive species with a distribution restricted to the lower Middle Barton Beds. The spiral angle is small and constant, coiling is loose and the whorl section inflated. An unusual feature is that the spire is covered with agglutinated quartz grains of a constant size. These are embedded in the shell material so that even abraded specimens still bear a considerable number of grains. An examination of COSSMANN & PISSARRO (1913) could not uncover any species with this peculiar feature. Identical specimens in the Burton collection from the same locality are labelled Acrilla sp.

****

Family: PSEUDOMELANIIDAE

Genus: Bayania MUNIER-CHALMAS 1885

Bayania hordacea (LAMARCK)

Melania hordacea LAMARCK,1804. p.431.
Melania hordacea LAMARCK: COSSMANN,1900. p.15,pl.2,fig.13.

Remarks

This species is dominant in BURTON's bed K and less frequent in bed J of the Upper Barton Beds. The last whorl is elongate, making up over half the length of the shell. Ornament is restricted to fine growth lines, which are parasigmoid in shape and retrocurrent at the spiral suture. A narrow shelf borders the suture.

****

Family: LACUNIDAE

Genus: *Lacuna* TURTON 1828

Subgenus: *Epheria* GRAY 1847

Lacuna (Epheria) sp.1

Plate 27, fig. 31.

Remarks

A small formfrom the Middle Barton Beds, characterised by its short spire, large final whorl and broad, inflated aperture. The surface is shiny and ornamented by regularly spaced, very fine spiral striae. A very small umbilicus is partially hidden by the narrow columellar lip and an anterior sinus is weakly developed. The generic identification is from identical but unnamed specimens in the Wrigley collection.

****

Family: RISSOIDAE

Genus: *Rissoa* DESMAREST 1814

Rissoa globulus EDWARDS (m.s.)

Plate 27, fig. 32.

Remarks

Frequent specimens from throughout both sections were identified with material in the Wrigley and Edwards collections. This form may be distinguished from all other species of *Rissoa* and *Alvania* encountered by its completely smooth and shiny surface. The whorl section is inflated and the protoconch appears to be submerged heterostrophic. The aperture is rounded, with a straight unthickened labrum and a narrow columellar lip.

****

Rissoa sp.1

Plate 27, fig.33.

Remarks

The general shape of this species is the same as in R.globulus but the shell is ornamented by short, rounded, parasigmoid ribs, which end abruptly half-way along the final whorl. The labrum is slightly thickened on complete individuals and its profile shows a low bulge anteriorly. Infrequent specimens from the Lower and Middle Barton Beds resemble R.nana (LAMARCK) in the Burton, Wrigley and Edwards collections and figures in DESHAYES' (1866) monograph. They are however considerably smaller, with less strongly developed ribs. They may represent juveniles or another, closely related species.

****

Genus: Alvania RISSO 1826

Alvania bartonensis (CHARLESWORTH)

Rissoa bartonensis CHARLESWORTH,1851. "Illustrations".
Alvania bartonensis (CHARLESWORTH): R.B.NEWTON,1895. p.329,pl.22,figs.11,12. (et syn.)

Remarks

A regularly coiled, rather short spired form, characterised by its ornament of heavy, vertical ribbing, crossed by spiral ribbons. This is a constant and distinctive species and agrees well with NEWTON's (1895) figures and specimens in the Burton and Wrigley collections. It occurs commonly in the Lower Barton Beds and rarely in the Middle and Upper Barton Beds.

****

Alvania sp.3

Plate 27, fig.34.

Remarks

This species bears similar, though lower cancellate ornament to A.bartonensis but is distinguished by its pupiform and more elongate shape. It shows a much stronger labral lobe than any other species of Rissoid encountered. A.villcassina GOUGEROT (1968, p.229, pl.1, fig.4.), from the Lower Lutetian of the Paris Basin, has a similar shaped shell.

****

Family: BITHINIIDAE

Genus: Bithinia LEACH 1818

Bithinia?sp.1

Plate 27, fig.35.

Remarks

Two specimens, both from the upper part of the Middle Barton Beds of Alum Bay, have a thin shell, a rounded rectangular whorl section, a rounded aperture and may possibly belong to this genus. Bithinia is usually restricted to brackish and freshwater environments but these specimens are pyritised and show no signs of the abrasion etc. usually associated with mechanical transportation. The numbers are obviously too few to suggest any useful ecological or provenance conclusions.

****

Family: XENOPHORIDAE

Genus: Xenophora FISCHER 1807

Xenophora sp.1

Plate 27, fig.36.

Remarks

Large, low spired, smooth initial stages and fragments of suturally agglutinated adults are common in the Lower and Middle Barton Beds of both localities, but could not be definitely related to any published species. Diagnostic characters appear to be developed only in adult shells.

X. agglutinans (LAMARCK), a common Barton megafossil, is closely related but the immature stages of specimens available for study were rather higher spired. Agglutinated bodies on fragments of adults include small shells. Foraminifera and, in one case, a valve of Leguminocythereis striatopunctata.

****

Family: CALYPTRAEIDAE

Genus: Calyptraea LAMARCK 1799

Calyptraea aperta (SOLANDER)

Trochus apertus SOLANDER in BRANDER, 1766. p.9, pl.1, figs.1-3.
Calyptraea aperta (SOLANDER): E.WHITE, 1963. pl.17, fig.10.

Remarks

This form is characterised by its very low spire and extremely fast and regular increase of whorl size. Only smooth juvenile stages were encountered but could be positively identified with material in the Burton collection. It occurs rarely in the Lower and Middle Barton Beds of both sections and commonly in the Chama Bed at Barton.

****

Family: CAPULIDAE

Genus: Capulus MONTFORT 1810

Capulus squamaeformis (LAMARCK)

Patella squamaeformis LAMARCK, 1802. p.311.
Capulus squamaeformis (LAMARCK): COSSMANN & PISSARRO, 1913. pl.12, fig.70:5.
Capulus squamaeformis (LAMARCK): WRIGLEY, 1934. p.10, pl.1, figs.15, 16, 17.

Remarks

In this species the rapid increase in growth, as seen in Calyptraea, is taken to the extreme. The small, smooth, low trochospiral protoconch is followed by a short neck and an evenly broadening, undulating disc, which bears annular growth lines. The "spiral cavity" is restricted to a small depression on the reverse side beneath the protoconch. A few specimens of the characteristic young stage and one adult specimen agree well with material in the Ross collection. WRIGLEY (1934) describes this form, mentions that it is often found adhering to Sycostoma and that the protoconch may be discarded by the adult.

****

Capulus sp.2

Plate 28, fig.3.

Remarks

A single specimens of a species of Capulus, from the Middle Barton Beds of Alum Bay (sample 6702),differs from C.squamaeformis in bearing radial (=spiral) ribs, as well as growth lines. The adult stage is more regularly developed than in C.squamaeformis, having an elliptical outline with the protoconch at one focus. WRIGLEY (1934) describes and figures C.aff.onyxoides COSSMANN, from the Lutetian of Southampton Dock. This is ribbed like C.sp.2 but increases in aperture size more slowly with growth, resulting in a disjunct, coiled capriform shell.

****

Genus: Berthelinia CROSSE 1875

Berthelinia sp.cf.B.elegans CROSSE

Plate 28, fig. 7.

?Berthelinia elegans CROSSE,1875. p.79,pl,2,fig.3.
?Berthelinia elegans CROSSE: COSSMANN, 1887. p.170,pl.7,figs.24-29;
pl.8,figs.1-2.

Remarks

One specimen of this extremely unusual form was encountered in the Middle Barton Beds of Alum Bay (sample 6628). It has the appearance of a small, monomyarian Pelecypod, with fine growth striae and an inequilateral elongate outline. From the centre of the "hinge" protrudes a small, disjunct, coiled protoconch. BALUK & JAKUBOWSKI (1968), describing a new species (B.krachi) from the Miocene of Poland, state that although it is in fact a Gastropod the complete shell consists of two hinged valves.

The Bartonian specimen is obviously a juvenile but resembles figures of CROSSE's species in COSSMANN (1887). It is placed questionably with the Capulidae in view of its rapid increase in diameter with growth.

****

Family: CAECIDAE

Genus: Strebloceras CARPENTER 1858

Strebloceras cornuoides CARPENTER

Plate 28, figs.4,5.

Strebloceras cornuoides CARPENTER,1858. p.441.
Strebloceras cornuoides CARPENTER: WRIGLEY,1934. p.11,pl.1,fig.10.

Remarks

Very small specimens agree well with WRIGLEY's (1934) figure. Most specimens show only one collar (collar "c" of WRIGLEY) close to the relatively large, low trochoid protoconch. A few specimens from the Middle Barton Beds of Alum Bay have a much longer smooth section between a smaller, coiled protoconch and the curved, distal tube. These resemble S.solutum CARPENTER (WRIGLEY, 1934, pl.1,figs.8,9) but lack WRIGLEY's second collar ("a" in his figures). Both types are grouped together in this study.

****

Genus: Thecopsella COSSMANN 1888

Thecopsella sp.1

Plate 28, fig.6.

Remarks

Only one specimen of this smooth, slightly curved, elongate, conical shell was recovered from the Lower Barton Beds of Alum Bay (sample 6602). It resembles Thecopsella fischeri MUNIER-CHALMAS, as figured by CURRY (1965, p.369, figs.6a,b), but is straighter, has a more acute apical angle and lacks an apertural lip. Other elongate conical shells known from the European Tertiary include the Pteropod Euchilotheca. Both CURRY

(1965) and WRIGLEY (1934, pl.1,fig.2.) figure this genus, which is considerably thinner shelled and is twisted into a disjunct sinistral helix.

****

Superfamily: NATICACEA

Naticid spp. (juveniles)

Remarks

The Naticacea is a large, diverse and very difficult group, whose subdivisions are distinguished on characters not usually developed in juvenile and fragmentary material. Attempts at distinguishing the numerous genera and species (BURTON, 1933, lists 13) even into arbitrary numbered units failed, and so all forms with the low spire, globular whorls and more or less circular aperture of the superfamily are dealt with together. The calcareous opercula of Naticids are also preserved quite frequently in the Lower and Middle Barton Beds.

****

Family TURRITELLIDAE

Genus: Turritella LAMARCK 1799

Turritella spp. (juveniles)

Remarks

Several species of Turritella are known from the Barton Beds. T.imbricataria (LAMARCK) is probably the most common and widespread in the lower and middle parts of the succession. T.edita (SOLANDER) occurs in the Chama Bed and BURTON (1933) refers to the small form, dominant at the top of his bed F, as a new unnamed species. All of thesehave characters which are not distinctive in juvenile and abraded specimens so for the purpose of this study no specific differentiation is possible.

****

Genus: Mesalia GRAY 1842

Mesalia sp.4

Plate 28, fig.8.

Remarks

A high spired form, with a spiral angle significantly greater than that of Turritella. The whorls are straight sided or slightly concave and are unornamented, apart from a single heavy, spiral ridge just above the suture. Rare specimens from the Middle Barton Beds of both sections could not be identified from the literature studied. M.fasciata LAMARCK, from the Bracklesham Beds and the French Calcaire Grossier, has a similar spiral angle but bears much heavier and more diverse ornament.

****

Suborder: NEOGASTROPODA

Family: CERITHIIDAE

Genus: Aneurychilus COSSMANN 1889

Aneurychilus sp.1

Plate 28, fig.9.

Remarks

This species occurs infrequently in the Lower and Middle Barton Beds of both localities and was identified with specimens labelled Aneurychilus sp. in the Wrigley collection. It is thin shelled, turreted and has a very short anterior sinus. Its ornament consists of fine radial and vertical ridges, with a single heavier, denticulate, spiral ridge. It never bears the granular or varicate ornament of Bittium.

****

Genus: Bittium LEACH 1847

Bittium semigranosum (LAMARCK)

Cerithium semigranosum LAMARCK,1804. p.437.
Cerithium concinnum CHARLESWORTH,1851. "Illustrations".

Remarks

Apparently identical specimens occur in two widely separated levels in the Bartonian; in BURTON's beds A2 and A3 of the Lower Barton beds and in the Chama Bed. BURTON only records this form from the Chama Bed. Specimens in the Burton, Wrigley and Ross collections agree well with the material found, which is characterised by sharp granular ornament developed at the intersections of vertical and spiral ridges. The spiral angle is larger than in B.terebrale, B.sp.2, or B.sp.5.

****

Bittium terebrale (LAMARCK)

Cerithium terebrale LAMARCK,1804. p.437.
Cerithium terebrale LAMARCK: DESHAYES,1833. p.401,pl.56,figs.29-31.

Remarks

A rare Lower Barton Beds species which differs from other species of Bittium in its ornament of varices (at approximately 120°intervals), crossed by numerous fine, spiral striations. Specimens from the same level were examined in the Ross collection and BURTON (1933) also records it from the Chama Bed.

****

Bittium sp.2

Plate 28, fig. 10.

Remarks

This species has granular ornament similar to that of B.semigranosum. However, the spiral angle is considerably smaller and decreases with growth, resulting in a pupiform shell. The whorl section is more inflated and the granules more widely spaced than in B.sp.5. It occurs infrequently in the Lower and Middle Barton Beds.

****

Bittium sp.3

Plate 28, fig. 11.

Remarks

A form from the Lower Barton Beds of Alum Bay with a larger spiral angle than other members of this genus. The granular ornament breaks down on the broad sutural shelf, where it is replaced by fine growth striae. It could not be identified from the collections.

****

Bittium sp.5

Plate 28, fig.12.

Remarks

Specimens were recovered only from BURTON's (1933) bed G (sample 6963). It has a small spiral angle similar to that of B.sp.2 and very regular granular ornament developed at the intersections of equally strong vertical and spiral ribs, resulting in a series of closely spaced pillars. It resembles Pirenella monilifera (DEFRANCE), (Upper Hamstead Beds) but is much smaller and its apertural characteristics are not clear.

****

Genus: Batillaria BENSON 1842

Batillaria concava (J.SOWERBY)

Potamidae concavus J.SOWERBY,1822. pl.339,figs.1,2.
Batillaria concava (J.SOWERBY):E.WHITE,1963. pl.19,fig.10.

Remarks

A number of poorly preserved specimens from the uppermost Barton Beds (BURTON's bed K) of Barton were identified with the published illustrations and with comparative material from the Middle Headon Beds of Colwell Bay.

****

Genus: Potamides BROGNIART 1810

Subgenus: Ptychopotamides SACCO 1895

Potamides (Ptychopotamides) vagus (SOLANDER)

Turbo vagus SOLANDER in BRANDER,1766. p.26,pl.3,fig.50.
Potamides (Ptychopotamides) vagus (SOLANDER):E.WHITE,1963. pl.19,figs.3,

Remarks

A single large fragmentary specimen from BURTON's bed K (sample 7004) agrees well with published accounts and with Middle Headon Beds material. It is a heavily ornamented form, with a small spiral angle and a narrow sutural shelf.

****

Genus: Triforis DESHAYES 1824

Triforis ? sp.1

Plate 28, fig.13.

Remarks

Many Lower and Middle Barton Beds samples contain an unusual and extremely small Cerithid. It is thin shelled, sinistrally coiled, with a large spiral angle, a subquadrate aperture and a short but well defined anterior sinus. The ornament consists of two, or sometimes three, smooth, entire, spiral ribs, separated by finer vertical striae. It is uncertain whether they represent juvenile or adult stages as larger specimens have not been found. Cerithids showing sinistral coiling are known from the European Tertiary. COSSMANN & PISSARRO (1913) figure species of Triforis with this feature, though none of his figures are the same as this form in size and shape.

****

Family: STROMBIDAE

Genus: Hippochrenes MONTFORT 1810

Hippochrenes amplus (SOLANDER)

Strombus amplus SOLANDER in BRANDER, 1766. p.34, pl.6, fig.76.
Hippochrenes amplus (SOLANDER): WRIGLEY, 1938. p.75, pl.5, figs.27-31, 34, 36. (et syn.)
Hippochrenes amplus (SOLANDER): E.WHITE, 1963. pl.20, fig.10.

Remarks

Specimens representing the initial stages of this form occur rarely in the Lower Barton Beds and quite frequently in the Middle Barton Beds, particularly in BURTON's (1933) bed E at Barton. They are high spired, smooth shelled and bear a single groove just above the spiral suture. The third or fourth whorl of the protoconch is characteristically swollen. As WRIGLEY (1938) and BURTON (1933) state, the initial stages are far more common than the wellknown but seldom seen large forms. Both authors also state that the spectacularly flanged specimens represent adults but cannot explain the virtual absence of "adolescent" stages. It is possible that the flanged form represents gerontic individuals, which might explain their scarcity.

****

Genus: Rimella AGASSIZ 1841

Rimella rimosa (SOLANDER)

Murex rimosus SOLANDER in BRANDER,1766. p.18,pl.1,fig.29.
Rimella rimosa (SOLANDER): WRIGLEY,1938. p.67,pl.4,figs.11-14,17.(et syn.
Rimella rimosa (SOLANDER): E.WHITE,1963. pl.20,fig.2.

Remarks

Juvenile stages of R.rimosa occur fairly frequently in the Lower and Middle Barton Beds. The specimens recovered lack any signs of the posterior sinus but comparison with the initial stages of specimens in the Wrigley and Ross collections, and with figures of protoconchs in WRIGLEY (1938) leave no doubt as to their identification. The ornament consists of regular, closely spaced spiral grooves crossing more widely spaced, rounded, vertical or curved ribs. Varices are sometimes present. Juveniles of several species of Tibia (T.lucida (J.SOWERBY) and T.sublucida (EDWARDS)) have similar ornament but their protoconchs are never ribbed as near the apex as in R.rimosa.

****

Genus: Dientomochilus COSSMANN 1904

Dientomochilus bartonensis (J.SOWERBY)

Murex bartonensis J.SOWERBY,1813. p.77,pl.34.
Dientomochilus bartonensis (J.SOWERBY): WRIGLEY,1938. p.73,pl.4, figs.24,25.(et syn.)
Dientomochilus bartonensis (J.SOWERBY):E.WHITE,1963. pl.20,fig.7.

Remarks

A single, well preserved specimen was encountered in sample 6916 (Lower Barton Beds,Barton). It corresponds well with the published figures and with material in the Ross collection.

****

Family: BUCCINIDAE

Genus: Cominella GRAY 1850

Cominella deserta (SOLANDER)

Buccinum desertum SOLANDER in BRANDER,1766. p.13,pl.1,figs.15.
Cominella deserta (SOLANDER): COSSMANN,1889. p.132.(et syn.)

Remarks

One large specimen, from the Lower Barton Beds of Alum Bay (sample 6617), could be definitely identified with named material in the Ross collection. BURTON (1933) also records it from a similar level at Barton.

****

Family: MURICIDAE

Genus: Murex LINNE 1758

Murex sp.cf. M.tricarinatus LAMARCK

?Murex tricarinatus LAMARCK,1803. p.223.
?Murex tricarinatus LAMARCK: WRIGLEY,1930. p.93,pl.9,figs.2-5,32.(et syn.)
?Pterynotus tricarinatus (LAMARCK): E.WHITE,1963. pl.23,fig.2.

Remarks

A few poorly preserved and fragmentary specimens from the Lower and Middle Barton Beds could be questionably identified as M.tricarinatus They show three marked, sharp edged varices at 120° and three intermediat ribs. WRIGLEY (1930) attempts to unravel the group's nomenclature and concludes that M.asper SOLANDER (non LINNE) should belong in the synonymy of M.tricarinatus. After examining a great deal of material he describes four "forms" of which one, M.tricarinatus form tricuspidatus DESHAYES, occurs in the English Barton Beds.

****

Genus: Typhis MONTFORT 1810

Typhis pungens (SOLANDER)

Murex pungens SOLANDER in BRANDER,1766. p.35,pl.3,fig.81.
Typhis pungens (SOLANDER): WRIGLEY,1930. p.112,pl.10,fig.39.(et syn.)
Typhis pungens (SOLANDER): E.WHITE,1963. pl.23,fig.3.

Remarks

Fragmentary and immature material from the Middle Barton Beds of both localities could definitely be identified with this well known species. It is characterised by its four strong varices and tubular spines. Specimens in the Burton, Wrigley and Ross collections, and figures in the literature agree well with the material found.

****

Family: FUSINIDAE

Genus: Fusinus RAFINESCU 1815

Fusinus porrectus (SOLANDER)

Murex porrectus SOLANDER in BRANDER,1766. p.21,pl.2,figs.35,36.
Fusinus porrectus (SOLANDER): WRIGLEY,1927. p.220.(et syn.)
Fusinus porrectus (SOLANDER): E.WHITE,1963. pl.23,fig.11.

Remarks

Rare fragmentary and juvenile specimens from the Lower and Middle Barton Beds agree with the published figures and descriptions. They have a large, inflated protoconch and an ornament of narrow spiral ribbons crossing rounded vertical ribs. In F.asper (J.SOWERBY) the protoconch is similar but the spiral ribbing is accentuated into narrow flanges.

****

Genus: Euthriofusus COSSMANN 1901

Euthriofusus sp.cf. E.regularis (J.SOWERBY)

?Murex regularis J.SOWERBY,1818. p.195,pl.187,fig.2.
?Euthriofusus regularis (J.SOWERBY): WRIGLEY,1927. p.243.(et syn.)
?Euthriofusus regularis (J.SOWERBY): E.WHITE,1963. pl.24,fig.11.

Remarks

A number of short spired, anteriorly siphonate juveniles have been questionably referred to this species after examining specimens in the Ross collection. They occur in the Lower and Middle Barton Beds and resemble the figures of E.regularis mut.ytenae in WRIGLEY (1927).

****

Family: XANCIDAE

Genus: Sycostoma COX 1931

Sycostoma pyrus (SOLANDER)

Murex pyrus SOLANDER in BRANDER,1766. p.26,pl.4,figs.52,53.
Sycum pirus (SOLANDER): COSSMANN,1889. p.163. (et syn.)
Sycostoma pyrus (SOLANDER): E.WHITE,1963. pl.24,fig.5.

Remarks

Juveniles from the Lower and Middle Barton Beds, referrable to the genus Sycostoma, show the characters of the S.pyrus end of its gradational series with S.bulbus (SOLANDER). The protoconchs are smooth or have faint, very oblique growth lines. They show a rapidly increasing spiral angle and a broadening sutural shelf. In S.bulbus this shelf is narrower and the spiral angle increases even more markedly with growth.

****

Family: VOLUTIDAE

Volutid spp. (juveniles)

Remarks

In the Lower and Middle Barton Beds infrequent, small, turreted shells with a cancellate ornament can be identified as the immature stages of Volutids. Some resemble the protoconch of Athleta (Volutospina) luctator

(SOLANDER), as figured by E.WHITE (1963, pl.25,fig.9), and one larger specimen may be a juvenile of Volutocorbis ambigua (SOLANDER). Material is not common enough to permit a useful variation study and further specific designation is impossible.

****

Family: MITRIDAE

Genus: Mitra MARTYN 1784

"Mitra" volutiformis EDWARDS

Mitra volutiformis EDWARDS,1877. p.186,pl.24,fig.5.

Remarks

Specimens from the Middle Barton Beds of Barton (BURTON's bed E) and the Lower Barton Beds of Alum Bay agree well with EDWARDS' description and figures. This is a small, turreted form with strong, rounded vertical ribbing and much less frequent spiral striae. The anterior siphonal canal is short and narrow, the base is markedly excavate and the three oblique columellar folds give way spirally to a number of unconnected spiral ridges around the distal end of the siphon. GOUGEROT (1968) refers to this form as a Turricula and compares it with his new species T.(Costellaria) ruellensis, from the Sables de Cresnes. The English species does not show the labral notch and fasciole of the Turrids.

****

Genus: Conomitra CONRAD 1865

Conomitra parva (J.de C.SOWERBY)

Mitra parva J.de C.SOWERBY,1825. p.37,pl.430,fig.1.
Mitra pumila J.de C.SOWERBY, 1825. p.37,pl.430,fig.2.
Mitra parva J.de C.SOWERBY: EDWARDS,1877. p.183,pl.24,figs.1,2.(et syn.)
Conomitra parva (J.de C.SOWERBY): E.WHITE,1963. pl.25,fig.6.

Remarks

The ornament of this very abundant species shows a continuous gradation between the cancellate nominate variety and the smooth var. pumila (J.de C.SOWERBY). A few specimens also show a further gradation to the smooth and slightly more basally excavate "*Mitra obesa*" EDWARDS (1877, p.185,pl.24,fig.4.). The latter may thus also belong with *C.parva*. *C.porrecta* EDWARDS is more slender and has a less tapering anterior sinus.

****

Family: MARGINELLIDAE

Genus: *Marginella* LAMARCK 1799

Marginella bifidoplicata CHARLESWORTH

Marginella bifidoplicata CHARLESWORTH,1851. "Illustrations".
Marginella bifidoplicata CHARLESWORTH: EDWARDS,1877. p.139,pl.18,fig.2.
Marginella (Stazzania) bifidoplicata CHARLESWORTH: COSSMANN & PISSARRO,1913. pl.46,fig.208:12.
Marginella (Stazzania) bifidoplicata CHARLESWORTH: E.WHITE,1963. pl.26,fig.5.

Remarks

This species is biconical and smooth, with flush sutures, a subrectangular aperture and a thickened labrum. In the adult the columella is marked by three bifurcating folds. Juvenile forms have a less thickened labrum and unbranched columellar folds. Such specimens resemble *M.eburnea* LAMARCK and *M.gracilis* EDWARDS. However, these two species have a slightly narrower outline. Specimens in the Durton and Wrigley collections are identical with the common material from the Lower and Middle Barton Beds.

****

Family: OLIVIDAE

Genus: *Ancilla* LAMARCK 1799

Ancilla sp.1

Plate 28, fig.14.

Remarks

Specimens from the Lower and Middle Barton Beds resemble *A.dubia* (DESHAYES) in shape, apertural features and ornamentation. They are however much smaller than specimens of *A.dubia* studied in the collections but may represent juveniles. They cannot readily be compared with the material found, as the earlier whorls are typically hidden beneath the callus and designation of such juveniles would be unwise. The anterior sinus is never as wide as in A.canalifera LAMARCK, though both species show a caniculate suture and two very oblique columellar folds.

****

Family: TRICHOTROPIDIDAE

Genus: Cerithioderma CONRAD 1860

Cerithioderma costulatum WRIGLEY

Cerithioderma costulatum WRIGLEY, 1942. p.101, pl.3, fig.2.

Remarks

A few specimens from the Middle Barton Beds of Alum Bay and Barton can be referred to WRIGLEY's species. They have the narrow umbilical chink, seven regular spiral ridges and rounded, widely spaced vertical ridges that he mentions. The protoconch is flattened (planorbid) and similar to that of C.reticulatum, as figured by WRIGLEY (1942, pl.3, fig.8.). The spire is slightly lower and stouter than his figures, resembling C.latum WRIGLEY (1942, pl.3, fig.1.) in shape but this is probably a result of immaturity. C.reticulatum WRIGLEY and C.bartonensis WRIGLEY are both higher spired than this form.

****

Family: CANCELLARIIDAE

Genus: Coptostoma COSSMANN 1899

Coptostoma quadratum (J.SOWERBY)

Cancellaria quadrata J.SOWERBY, 1822. p.83, pl.360.
Coptostoma quadratum (J.SOWERBY): WRIGLEY, 1935. pl.32, fig.1; pl.35, fig.46. (et syn.)
Coptostoma quadratum (J.SOWERBY): E.WHITE, 1963. pl.26, fig.9.

Remarks

This species is represented in sample 6699 (Middle Barton Beds of Alum Bay) by a single initial portion and fragments. WRIGLEY (1935) figures the initial stages of a number of Palaeogene Cancellariids, and his figure of that of C.quadratum shows it to increase, from a small first coil, quite rapidly in size and spiral angle. No other species has a protoconch with such a small spiral angle. The adult whorls are coiled quite loosely and characteristically ornamented by close set, regular, vertical and spiral ridges without varices. Bonellitia evulsa and Sveltella microstoma have much more widely spaced, rounded and less regular vertical ridges. The latter also bears external varices.

****

Genus: Sveltella COSSMANN 1889

Sveltella microstoma (CHARLESWORTH)

Cancellaria microstoma CHARLESWORTH,1851. "Illustrations".
Cancellaria microstoma CHARLESWORTH: R.B.NEWTON,1895. p.327,pl.22,figs.3,4.
Sveltella microstoma (CHARLESWORTH): WRIGLEY,1935. p.361,pl.32,figs.6,7; pl.35,fig.45.
Sveltella microstoma (CHARLESWORTH): E.WHITE,1963. pl.26,fig.6.

Remarks

The initial stages agree with those figured by WRIGLEY. They are initially small, with a rapid increase in growth and show the development of vertical ribbing earlier than the spirals. Later whorls have narrow spiral ridges and rounded, rather irregular vertical ribs with varices. It occurs frequently in the Lower and Middle Barton Beds of both sections and compares well with specimens in the Burton and Wrigley collections.

****

Genus: Bonellitia JOUSSEAUME 1887

Bonellitia evulsa (SOLANDER)

Buccinum evulsum SOLANDER in BRANDER,1766. p.13,pl.1,fig.14.
Bonellitia evulsa (SOLANDER): WRIGLEY,1935. p.364,pl.33,figs.12,13; pl.35,fig.44.(et syn.)
Bonellitia evulsa (SOLANDER): E.WHITE,1963. pl.26,fig.7.

Remarks

The protoconch of this species is much larger and more globular than in Sveltella microstoma. It is initially flattened but increases rapidly in size, so that the first ornamented whorl is larger than the corresponding growth stage in S.microstoma. Infrequent immature specimens from the Lower and Middle Barton Beds agree well with WRIGLEY's figures and specimens in the Burton and Wrigley collections.

****

Genus: Unitas HARRIS & PALMER 1947

Unitas nassaeformis WRIGLEY

Uxia nassaeformis WRIGLEY,1925. p.246,fig.12.
Uxia nassaeformis WRIGLEY: WRIGLEY,1935. p.376,pl.34,figs.32,33; pl.35,figs.42,43.
Unitas nassaeformis (WRIGLEY): E.WHITE,1963. pl.26,fig.12.

Remarks

Three specimens from the Lower and Middle Barton Beds can be referred to this species on the form of the protoconch. This is characteristically conical with, in its later stages, three strong, slightly denticulate spiral ribs. WRIGLEY (1935, fig.42) figures a form from the Chama Bed of Barton with a slightly more inflated protoconch but none were found in this study.

****

Unitas sp.cf. U.elongata(NYST)

?Cancellaria elongata NYST,1845. p.476,pl.38,fig.21.
?"Uxia" elongata (NYST): WRIGLEY,1935. p.377,pl.34,figs.36,37;pl.35,fig.53. (et syn.)

Remarks

A single broken juvenile specimen, from BURTON's (1933) bed J at Barton (sample 6988), resembles the immature stages of "U." elongata form vectensis as figured by WRIGLEY (1935, fig.53). Both WRIGLEY and BURTON record it from the Upper Barton Beds of Barton and WRIGLEY also mentions it from the Lower Oligocene of England and Germany. The early whorls have a smaller angle and finer cancellate ornament than U.granulata (NYST) and lack the strong spiral ribs of U.nassaeformis.

****

Family: TURRIDAE

Remarks

The Turrids are one of the most diverse groups of Mollusca in the Barton Beds, and as such, their identification provided an exceptionally difficult task. BURTON (1933) records 47 species and EDWARDS (1877) describes 40 species from the Barton Beds. In all 24 species could be distinguished in this study, mainly on immature material. Of these, 12 could be specifically identified by comparison with the literature and with collections. Two are identified to generic level, 10 are left as numbered species of "Turrid" and all protoconchs and very juvenile specimens are grouped as "Turrid spp. (juveniles)". EDWARDS lumps most species of Turrid into the genus Pleurotoma, but his work proved very useful for its specific descriptions. Where possible the generic names used by BURTON have been applied.

As a group the Turridae are characterised by their biconical or fusiform shape and strong anterior siphonal canal. The position of the posterior siphon is marked in the shell by a labral notch and fasciole. The ornament can be strongly developed and complex. Generic differentiation is based on the position and form of the labral sinus and the shell outline. Specific differences are mainly those of ornamentation and shape.

****

Genus: Asthenotoma HARRIS & BURROWS 1891

Asthenotoma biconus (EDWARDS)

Pleurotoma biconus EDWARDS, 1877. p.318, pl.33, fig.7.
Asthenotoma biconus (EDWARDS): BURTON, 1933. p.155.

Remarks

Juveniles of this form occur rarely in the Middle Barton Beds of both sections and agree with EDWARDS' figures. They are biconical, with a rather short spire and two spiral rows of rounded denticulations. A. conoides, another biconical species, has heavier, more widespread denticulate ornament.

****

Asthenotoma conoides (SOLANDER)

Murex conoides SOLANDER in BRANDER,1766. p.14,pl.1,fig.17.
Pleurotoma conoides (SOLANDER): EDWARDS,1877. p.317,pl.33,fig.5.
Asthenotoma conoides (SOLANDER): BURTON,1933. p.155.

Remarks

Rare but well preserved specimens from the Middle Barton Beds could be identified from EDWARDS' figures and specimens in the Ross collection. It is more heavily and sharply tuberculate than A.biconus. Hemiconus scabriculus SOLANDER (see E.WHITE, 1963, pl.27,fig.10) bears similar ornament but is much lower spired and has a narrower sutural shelf.

****

Asthenotoma pupa (EDWARDS)

Pleurotoma pupa EDWARDS,1877. p.253,pl.28,fig.9.
Asthenotoma pupa (EDWARDS): BURTON,1933. p.155.

Remarks

A fusiform species, with short, rather low vertical ribs and a labral fasciole marked by fine, close-set lines. The last whorl is broadly rounded and very slightly excavate in outline. It occurs rarely in the Middle Barton Beds of Barton and the Lower Barton Beds of Alum Bay and could be compared with material in the Ross collection.

****

Asthenotoma zonulata (EDWARDS)

Pleurotoma zonulata EDWARDS,1877. p.317,pl.32,fig.6.
Asthenotoma zonulata (EDWARDS): BURTON,1933. p.155.

Remarks

This distinctive species is characterised by its predominant spiral ornament. The regular, subequal, flat-topped spiral ribbons (3 or 4 per whorl) give the spire a screw-like appearance. They are separated by close-set growth lines, which are interrupted along a broad labral notch band at the second spiral from the suture. A.helicoides (EDWARDS) has similar spiral ornament but the notch band lies in a broad excavate area between the spirals and the whorl section is not so inflated. A. zonulata occurs quite frequently in the Lower and Middle Barton Beds of both localities.

****

Genus: Bathytoma HARRIS & BURROWS 1891

Bathytoma turbida (SOLANDER)

Murex turbidus SOLANDER in BRANDER, 1766. p.19,pl.2,fig.31.
Pleurotoma turbida (SOLANDER): EDWARDS,1877. p.311,pl.32,fig.2.(et syn.)
Bathytoma turbida (SOLANDER): BURTON,1933. p.155.
Bathytoma turbida (SOLANDER): E.WHITE,1963. pl.26,figs.16,17.

Remarks

Most species encountered were either immature or broken but could be identified from the published figures and the collections. The spire is rather low, with a large spiral angle. The ornament consists of fine spiral and growth lines, with two rows of large, squarish tubercles; one just below the suture and one on the shoulder. The latter lie in the labral notch band.

****

Genus: Bela GRAY 1847

Bela juncea (SOLANDER)

Murex junceus SOLANDER in BRANDER,1766. p.17,pl.1,fig.26.
Metula juncea SOLANDER: EDWARDS,1877. pl.33,fig.10.
Bela juncea (SOLANDER): BURTON,1933. p.156.

Remarks

This is an unusually high spired Turrid, ornamented by a regular network of fine ridges. It occurs infrequently in the Lower and Middle Barton Beds and agrees with EDWARDS' figures and specimens in the Ross collection.

****

Genus: Drillia GRAY 1838

Drillia formosa (CHARLESWORTH)

Pleurotoma formosa CHARLESWORTH,1851. "Illustrations".
Pleurotoma granulata EDWARDS,1877. (non LAMARCK,1804) p.264,pl.28,fig.4.
Drillia granulata (EDWARDS): BURTON,1933. p.156.

Remarks

A very common species in the Lower and Middle Barton Beds of both sections. It agrees with EDWARDS' figures and with specimens in the Ross and Burton collections. Identical specimens in the Wrigley collection are labelled Drillia (Tripia) formosa (CHARLESWORTH). EDWARDS (1877) erroneously considers the slightly shorter spired English form to be conspecific with D.granulata (LAMARCK), from the French Middle Eocene. D.formosa is characterised by its rather large protoconch, regular cancellate ornament and inflated whorl section. Similar, low, rounded tubercles are developed at the intersections of spiral and growth ridges.

****

Drillia innexa (SOLANDER)

Murex innexus SOLANDER in BRANDER, 1766. p.19,pl.21,fig.30.
Pleurotoma innexa (SOLANDER): EDWARDS,1877. p.241,pl.28,fig.1.(et syn.)
Drillia innexa (SOLANDER): BURTON,1933. p.156.

Remarks

Infrequent specimens from the Lower and Middle Barton Beds agree well with EDWARDS' figures and material in the Ross collection. They are basally excavate and are ornamented by short, thick, widely spaced vertical ribs. These are sometimes sinuous on the last whorl. The anterior canal is short and the labral fasciole interrupts the fine growth striae near the top of the ribs. D.inflexa (LAMARCK), a closely related Upper Bracklesham Beds form, has more closely spaced ribs and a higher spire.

****

Genus: Eopleurotoma COSSMANN 1889

Eopleurotoma? sp.1

Plate 28, fig. 15.

Remarks

This form becomes abundant at the top of the Middle Barton Beds, but occurs in small numbers down to the base of that division. It never attains a large size and could not be identified with the juvenile stages of named species in the collections. Identical specimens in the Burton and Wrigley collections are labelled "Pleurotoma sp." and "Turrid sp." respectively.

The shell is fusiform, with a smooth conical protoconch, inflated whorls, a slightly excavate base and a short, broad canal. Ornament on the earlier whorls consists of slightly irregular, closely spaced, sinuous growth ridges. Later stages of mature specimens also bear subordinate spiral lines. The labral notch band is marked by the curved ribs, and follows the shoulder. On the basis of the position of the labral fasciole and the predominantly vertical ribbing this species is tentatively placed in Eopleurotoma (sensu DAVIES,1935).

****

Genus: Hemipleurotoma COSSMANN 1889

Hemipleurotoma callifera (EDWARDS)

Pleurotoma callifera EDWARDS,1877. p.291,pl.30,figs,9.10.
Hemipleurotoma callifera (EDWARDS): BURTON,1933. p.157.

Remarks

A basally excavate species, ornamented by relatively few spiral ridges separated by concave striate areas. The shoulder band is the heaviest of the spirals. It is broken up into subquadrate tubercles and is coincident with the labral fasciole. Asthenotoma zonulata and A.helicoides are lower spired, have more numerous spirals and are less excavate basally. H.callifera occurs quite frequently in the Lower, and lower Middle Barton Beds. It was compared with specimens in the Ross collection.

****

Genus: Surcula ADAMS 1853

Surcula rostrata (SOLANDER)

Murex rostratus SOLANDER in BRANDER,1766. p.21,pl.2,fig.34.
Pleurotoma rostrata (SOLANDER): EDWARDS,1877. p.218,pl.26,fig.8.(et syn.)
Surcula rostrata (SOLANDER): BURTON,1933. p.158.
Turricula rostrata (SOLANDER): E.WHITE,1963. pl.26,fig.10.

Remarks

A single immature specimen, from the Middle Barton Beds of Alum Bay (sample 6676), could be compared with the early whorls of specimens in the Ross collection. The shoulder is marked by narrow spiral ridges and, unlike in other Bartonian species of Surcula, is broken up by numerous short oblique furrows.

****

Surcula sp.cf. S.attenuata (J.SOWERBY)

?Pleurotoma attenuata J.SOWERBY,1816. p.103,pl.146,fig.1.
?Pleurotoma attenuata J.SOWERBY: EDWARDS,1877. p.237,pl.27,fig.7.(et syn.)

Remarks

Two broken specimens from the Lower Barton Beds, onefrom Barton (sample 6910) and one from Alum Bay (sample 6617), were identified questionably with this species after examining the early whorls of material in the Ross collection. The whorls are marked by 5 to 7 large swellings. These are flattened above, by the sutural ramp, and are crossed by a number of strong spiral ridges. At a comparable stage of growth S.lanceolata (EDWARDS) lacks such strong swellings. S.macilenta (SOLANDER), S.exorta (SOLANDER) and S.sp.4 have similar swellings but they are not truncated above by the sutural ramp and do not bear such strong ridges. Adult stages, of course, develop much stronger specific differences.

****

Surcula sp.cf. S.lanceolata (EDWARDS)

?Pleurotoma lanceolata EDWARDS,1877. p.226,pl.26,fig.11.
?Surcula lanceolata (EDWARDS): BURTON,1933. p.158.

Remarks

One damaged, badly worn specimen, from the Lower Barton Beds of Barton (sample 6910), shows similar features to the juvenile stages of the material in the Ross collection.

****

Surcula sp. 4

Plate 28, fig. 16.

Remarks

Infrequent juvenile specimens, from the Middle Barton Beds of both localities, bear a close resemblance to specimens of S.exorta (SOLANDER) and S.macilenta (SOLANDER) at similar stages of development in the Ross collection. All have large, rounded swellings (about 5 or 6 per whorl) crossed by fine spiral ridges. The upper sides of the swellings are not flattened, as in S.cf.attenuata. The protoconch is large and the spiral angle quite high. Specific differentation between S.macilenta and S.exorta appears to be difficult even in the adult and, rather than place the material available wrongly, a separate taxon is used here.

****

Turrid sp. 3

Plate 28, fig. 17.

Remarks

A high spired, basally excavate species, which appears to be restricted to the Lower Barton Beds. It is characteristically ornamented by widely spaced, sinuous vertical ribs. Each of these bears two peaks, one at the suture and one at the shoulder. Very fine growth striae are also present and show a labral notch band at the shoulder. This species resembles Eopleurotoma rotella (EDWARDS)(specimens examined from the Ross collection) but is somewhat smaller and has a more acute spiral angle.

****

Turrid sp. 4

Plate 28, fig. 18.

Remarks

A very small form, resembling T.sp.3 in its excavate base and lack of spiral ornament. The ribs have the same shape but are much narrower. Eopleurotoma? sp.1 has a less excavate last whorl and more closely set ribs, which are never developed into peaks. T.sp.4 occurs rarely in the Lower Barton Beds of both sections.

****

Turrid sp.10

Plate 28, fig. 19.

Remarks

After the second ornament whorl this species develops a strong shoulder, giving it the appearance of an increasing spiral angle. The shell is high spired, basally excavate and has a short anterior canal. It is ornamented with strong, rounded, sinuous ribs, crossed by fine spiral ribbons. The ribs protrude at the shoulder mentioned above. It occurs frequently in the Middle Barton Beds and rarely in the Lower Barton Beds.

****

Turrid sp.11

Plate 28, fig. 20.

Remarks

A single specimen, from the Middle Barton Beds of Barton (sample 6935), differs from all other species examined in its sharp denticulate ornament. The denticles are set along spiral ribs and are more widely separated than in Drillia formosa. Also the whorls are less inflated, the spire is higher and the protoconch is smaller in T.sp.11.

****

Turrid sp.14

Plate 28, fig. 21.

Remarks

A common Middle Barton Beds form, which is closely related to T.sp.10. The main differences are that it does not develop such strong vertical ridges and shoulder. The spiral angle remains more constant with growth, the base is not so excavate and the whorl section is more inflated. Specimens which are intermediate in some characters do occur and further study may show them to belong to the same taxon.

****

Turrid sp.15

Plate 28, fig. 22.

Remarks

As with Drillia innexa this species is basally excavate and is ornamented with short ribs. However, these ribs are restricted to the shoulder region, are never sinuous and are set obliquely. The anterior canal is slightly longer than in D.innexa. T.sp.15 occurs infrequently in the Lower and Middle Barton Beds.

****

Turrid sp.17

Plate 28, fig. 23.

Remarks

The vertical ornament in this form is dominant. It consists of high, rounded ribs, set almost perpendicular to the suture, which traverse the whole whorl without interruption from the labral fasciole. They are crossed by fine, regularly spaced, spiral ribbons. Very indistinct growth lines form a labral notch band just above the shoulder. The base is never excavate as in most other species of Turrid. It occurs in the Lower and Middle Barton Beds and resembles Raphitoma acuticosta (NYST) and R.plicata (LAMARCK) in ornament. Both species, as figured by EDWARDS (1877) ,are much lower spired.

****

Turrid sp.18

Plate 28, fig. 24.

Remarks

A number of immature specimens from the upper part of the Middle Barton Beds are included here. They resemble Drillia innexa and T.sp.15 in their excavate base and high spire but the vertical ribbing is reduced to two rows of rounded tubercles, one at the suture and one at the shoulder. These are supplemented by numerous, narrow, spiral ridges. More adult specimens resemble Drillia gomphoidea (EDWARDS) in the Wrigley and Ross collections. The shoulder tubercles do not increase very rapidly with growth with the result that the adult shell has a very different appearance when later features of ornament are developed.

****

Turrid sp.20

Plate 28, fig. 25.

Remarks

A single broken specimen was recovered from the Middle Barton Beds of Alum Bay (sample 6677). It is low spired and has a very shallow labral notch band situated in a concave hollow between two rows of spirally elongate tubercles.

****

Turrid sp.21

Plate 28, fig. 26.

Remarks

This form is closely related to T.sp.17. The single specimen (Middle Barton Beds of Alum Bay, sample 6673) has similar strong, regular, vertical ribbing. However, the base is slightly more excavate and the spiral ridges are higher, standing out as a series of flanges.

****

Turrid spp. (juveniles)

Remarks

All indistinguishable protoconchs and juvenile stages are included here.

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Subclass: OPISTHOBRANCHIA MILNE-EDWARDS 1848

Family: ACTEONIDAE

Genus: Acteon MONTFORT 1810

Acteon gardneri COSSMANN

Acteon gardneri COSSMANN,1889. p.299,pl.8,fig.38.
Acteon gardneri COSSMANN: COSSMANN & PISSARRO,1913. pl.53,fig.233:2.

Remarks

The low spire, heterostrophic protoconch and regularly pitted surface are characteristic of this species. Specimens from throughout the Barton Beds agree well with the published figures and with material in the Wrigley and Burton collections.

****

Genus: Crenilabium COSSMANN 1889

Crenilabium elongatum (J.de C.SOWERBY)

Acteon elongatus J.deC.SOWERBY,1824. pl.460,fig.3.

Remarks

This species was found only in the Lower Barton Beds. It differs from Acteon gardneri in having a thinner shell and in being higher spired. The spiral angle is smaller and the later whorls are more elongate and narrow. Ornament is restricted to rather irregular, faint spiral striae and growth lines. The material available, although mostly fragmentary, agrees with specimens in the Wrigley, Burton and Ross collections.

****

Family: RINGICULIDAE

Genus: Ringicula DESHAYES 1838

Ringicula parva NEWTON

Ringicula parva R.B.NEWTON,1895. p.328,pl.22,figs.5,6.(et syn.)

Remarks

A thin shelled form, with a globular whorl section, striate spiral ornament and thickened, ornate labral and columellar callus. It occurs throughout the Barton Beds and could be compared with specimens in the Ross, Wrigley and Burton collections.

****

Family: TORNATINIDAE

Genus: *Volvulella* R.B.NEWTON 1891

Volvulella charlesworthi NEWTON

Bulla acuminata CHARLESWORTH,1851. (non BRUGUIERE) "Illustrations".
Volvulella charlesworthi (EDWARDS m.s.):R.B.NEWTON,1895. p.330,pl.22,
figs.13,14(*et syn.*)

Remarks

This species occurs infrequently in the Lower and Middle Barton Beds and agrees with NEWTON's figures and with specimens in the collections. The shell is thin walled, oval, uniumbilicate and the final whorl embraces the earlier stages. *V.hastula* (CHARLESWORTH) (=*V.lanceolata* J.deC.SOWERBY and later authors) differs in being widest below the middle of the shell and in bearing spiral lines of pits. *V.charlesworthi* is ornamented only by very faint spiral striae near each end of the columella.

****

Family: SCAPHANDRIDAE

Genus: *Scaphander* MONTFORT 1810

Scaphander? sp.1

Plate 28, fig. 27.

Remarks

The single broken specimen, from the Middle Barton Beds of Alum Bay (sample 6675), can questionably be referred to *Scaphander*. It is rather thicker shelled than is typical of *Scaphander*, but shows the characteristic very loose coiling. It differs from *S.parisiensis* D'ORBIGNY, as represented in the Ross collection from Barton, in lacking a tight spiral umbilicus and in being completely smooth externally.

****

Family: AKERIDAE

Genus: *Akera* MULLER 1776

Akera striatella (LAMARCK)

Bulla striatella LAMARCK, 1804. p.221.
Acera striatella (LAMARCK): COSSMANN & PISSARRO, 1913. pl.55, fig.244:1.

Remarks

A single specimen, recovered from the Lower Barton Beds of Alum Bay (sample 6600), is characteristed by its low spire, smooth columella and broad anterior siphonal canal. The spiral suture is strongly caniculate and the ornament is restricted to faint spiral striae.

****

Family: BULLINELLIDAE

Genus: *Bullinella* R.B.NEWTON 1891

Bullinella constricta (J.de C.SOWERBY)

Bulla constricta J.de C.SOWERBY, 1824. pl.464, fig.2.

Remarks

Immature specimens referable to this species occur frequently in the Lower and Middle Barton Beds and rarely in the *Chama* Bed. Adult *B.constricta* has a straight sided, slightly tapering outline and no ornament. Juveniles are more parallel sided and approach *B.angystoma* (DESHAYES). The latter has a more excavate lower columellar lip. *B.sowerbyi* (NYST) is parallel sided but bears distinct spiral striae and *B.elliptica* (J.de C.SOWERBY) has an inflated, elliptical outline. Specimens in the Ross and Burton collections were examined.

****

Bullinella coronata (LAMARCK)

Bulla coronata LAMARCK, 1804. p.222.
Bulla coronata LAMARCK: DESHAYES, 1864. p.631. (*et syn.*)
Roxania (Acrostemma) coronata (LAMARCK): COSSMANN & PISSARRO, 1913.
pl.55, fig.242:8.

Remarks

This form differs from other species of *Bullinella* in its development of a thickened collar around the spiral extremity of the shell. It is otherwise devoid of ornament and has a slightly inflated outline like B.elliptica (J. de C.SOWERBY). It occurs rarely in the Lower and Middle Barton Beds and agrees with specimens in the Ross, Wrigley and Burton collections.

****

Bullinella sowerbyi (NYST)

Bulla sowerbyi NYST,1845. p.456.

Remarks

The fine, closely set spiral grooves differentiate B.sowerbyi from the preceding species, even in the juvenile stages. It is elongate, with a narrow aperture and slightly convex sides. Infrequent specimens from the Middle Barton Beds of Barton and the Lower and Middle Barton Beds of Alum Bay compare well with specimens in the Ross collection.

****

Bullinella sp.3

Plate 28, fig. 28.

Remarks

A small species of Bullinella, occurring throughout the Barton Beds, cannot be identified with described forms or with specimens in the collections. It has an inflated, elliptical to globular outline, a narrow, basally excavate aperture and lacks ornament. It resembles B.elliptica in shape but is too immature to identify definitely.

****

Bullinella sp.5

Plate 28, fig.29.

Remarks

This species is rather short and stout, with a basally inflated outline and a strong shoulder around the spiral umbilicus. The aperture is narrow, curved and does not become markedly excavate at the base. The ornament consists of distinct, close-set spiral striae. It appears to be restricted to BURTON's bed J, in the Upper Barton Beds of Barton, where it occurs quite commonly. It could not be named from the literature but closely resembles specimens labelled "Bulla sp." in the Ross collection, which come from the Long Mead End Beds (= BURTON's bed K).

****

Family: LIMACINIDAE

Genus: Skaptotion CURRY 1965

Skaptotion bartonense CURRY

Homalaxis sp. BURTON, 1933. p.157.
Skaptotion bartonense CURRY, 1965. p.366, figs. 11, 13 & 14. (et syn.)

Remarks

S. bartonense was the only Pteropod encountered in this study. It occurs, sometimes abundantly, throughout the Lower and Middle Barton Beds of both localities and BURTON (1933) also records it from the Chama Bed at Barton. The protoconch is low trochospiral and slightly heterostrophic. The later whorls are inflated, planispiral and unornamented. CURRY figures a thin, everted terminal lip on adult specimens but this feature was not preserved on any of the material examined. The shell is very thin, as in most Pteropods, and is often lost to solution. However, it is usually infilled with pyrite and the casts are easily identified.

****

Gastropoda Incertae Sedis

Gastropod genus H. sp. 1.

Plate 28, fig. 30.

Remarks

Fragments of this enigmatic form occur in the Middle Barton Beds and Chama Bed. The fragments are parts of an "externally" striate, slightly convex and roughly triangular plate. One corner bears a swollen calcareous mass on the "inner" surface. The "left" and "lower" margins are convex and the "right" margin is concave, with a broad, smooth lip. The "external" ornament is divided into two different zones of fine, closely spaced parallel and sharp crested ridges. "Internally" the mass at the "top" of the shell shows a series of incomplete ridges and furrows which are curved helically in a clockwise manner (i.e. sinistral coiling). No true aperture is visible.

DAVIES (1935) figures several of the Calyptraeidae with apertural flaps bearing similar ornament to this form. *Calyptraea chinensis* (LINNE) (the type species) has a convex, sinistrally coiled flap, with a concave lip and an ornament of growth ridges. The zone of different ornament along the one side may represent a part of the normal, dextrally coiled cone. Unfortunately, an examination of all available specimens of *Calyptraea*, *Trochatella* and related forms failed to reveal any specimens with an apertural lip preserved. In the absence of such conclusive evidence the above remarks must only be considered as hypothesis.

****

4:6:4 Class: CEPHALOPODA CUVIER 1797

Subclass: NAUTILOIDEA AGASSIZ 1847.

Nautiloid Siphuncle?

Plate 28, fig. 31.

Remarks

A single fragment, from BURTON's bed E at Barton (sample 6938), is questionably thought to represent the siphuncle of a Nautiloid. It consists of a straight, smooth tube, flared at one end and with a narrower tube emerging from the funnel. Other Cephalopods recorded from Barton include *Nautilus sp. indet.* BURTON (1933), from beds A3, B, E, G, H and J, and the Coleoid *Belosepia sepioidea* (BLAINVILLE).

****

SECTION 4:7 THE ECHINODERMATA

Introduction

Echinoderms occur throughout the Barton Beds but are particularly abundant in the marine clays of the Lower and Middle Barton Beds. They are preserved entirely as dissociated ossicles and consequently no formal taxonomic scheme can be applied. The grouping is into the major taxonomic divisions and then into numbered ossicles of similar morphological position (i.e. organ names). This is accomplished by comparison with the literature and with extant species (- disaggregated by boiling in a solution of sodium hydroxide). In approximate order of abundance the groups represented are Echinoids, Ophiuroids, Asteroids, Holothuroids and Crinoids. The last two have not been previously recorded from the Barton Beds.

Literature

POKORNY (1965) is the only author who deals with all the Echinoderms from a micropalaeontological viewpoint, although HOWE (1942) rather optimistically reviews their possible importance in the North American Tertiary. The "Treatise on Invertebrate Paleontology" (ed. MOORE, vol U(3), 1966) provide a great deal of useful data on the different morphological units, but is mainly concerned with the complete organism. The Echinoids have not attracted much attention from Micropalaeontologists. However, GEISS (1936) describes a large number of pedicellaria (not encountered in this study) and some other Echinoid ossicles. Studies on the ossicles of Ophiuroids which are of particular use include BERRY (1935, 1937, 1938, on the Pliocene of Trinidad, the Oligocene of the Gulf Coast and the Dutch Maestrichtian respectively) and HESS (1962, on the Lias of Switzerland). They indicate that the most promising line for future research will be in statistical association studies on very rich assemblages. The literature on Holothurian sclerites has multiplied in recent years, with interest mainly centered on the Upper Palaeozoic. CRONEIS & McCORMACK (1932) and FRIZZELL & EXLINE (1955) have provided the basis for a viable organ classification. Descriptive work on the European Tertiary was begun by SCHLUMBERGER

(1888, 1890). His work was revised by RIOULT (1965) and many of the organ species described probably have a wide distribution in the Tertiary of North West Europe.

Studies of the above type on the English Tertiary have not been previousl attempted. The Echinoids, which have a very poor preservational record, were formally described by FORBES (1852) and revised by GREGORY (1891). The latter records only six species from the Barton Beds. BURTON (1933) records five Echinoids and one Ophiuroid from Barton. FORBES also describes Asteroid, Ophiuroid and Crinoid remains, mainly from the London Clay. Asteroid, Ophiuroid and Crinoid ossicles are recorded but not described from the London Clay of Sheppey and Bognor by DAVIS (1936) and VENABLES (1962) respectively. DAVIS records "Trochostoma sp." from the London Clay of Sheppey and relates it to the Recent Indo-Pacific form T.(Molpadia) violacea STUDER. This appears to represent the only mention of Holothuroids from the English Lower Tertiary.

Comparative Material

With relevant literature so scarce comparison had to be made with disaggregated Recent forms. Asteroids examined in this way included an unnamed specimen from Dover, two small unnamed forms from near the Eddystone Lighthouse and a fragment of Oreaster reticulatus from the Bahamas. All these included ambulacra similar to those found fossil. Unfortunately, no Recent examples of the Goniaster group were available and comparison of their characteristic marginals was restricted to those of Upper Cretaceous specimens of Metopaster. A small Ophiuroid from the vicinity of Eddystone yielded some sclerites, some resembling the Bartonian forms; and a pelagic crinoid (labelled Antedon) bore brachials and other ossicles similar to some from the London Clay.

In addition to Recent material the author was able to examine two rich assemblages from the London Clay of Bognor and Wraysbury (near Staines) by kind permission of Mr.C.King. The Bognor sample, from the "Starfish Bed", contained Ophiuroid ossicles from similar morphological positions to those of the Barton Beds. The dominant Crinoid elements included brachials and columnals.

Distribution

Most of the Echinoderms present in the Bartonian were probably burrowing or soft bottom forms and their remains are most abundant in the clay sections of the Lower and Middle Barton Beds. Echinoids are represented throughout the succession but are more abundant in the Lower Barton Beds. They are dominated by the thin spines and plates of probably irregular, burrowing types. The author was fortunate in finding while sampling two complete pyritised specimens in BURTON's bed A2 at Barton. They are of an irregular species, questionably referable to Hemiaster? branderi FORBES, and are deposited in the collections of the Department of Geology, Imperial College, London. Ophiuroids have a similar total range to the Echinoids but show a peak in the Middle Barton Beds. Holothuroids are commonest in the upper part of the Middle Barton Beds, as are Asteroids. The distinction between Asteroids of the Goniasterid type and the more familiar stellate type is uncertain. The former group appears to be dominant. Crinoid remains are very rare and are represented by only a few specimens.

A comparison of these assemblages with those of the Lower Eocene reveals some strong differences. Echinoids, particularly burrowing forms, appear to be very much reduced in numbers in the London Clay. Goniasterids are much more common than in the Barton Beds. Perhaps the most startling difference is the complete lack of stalked Crinoids in the Bartonian. Whether these features are due to variations in temperature, substrate or depth is uncertain.

****

4:7:1 Asteroid Ossicles

Asteroid? Ossicle Type 22

Plate 29, fig. 5.

Remarks

This form has a furrowed stem widening to a slightly excavate, spadelike extremity. The calcite characteristically has a longitudinally ropey texture. It resembles ossicles, of unknown morphological position, in the Recent specimens of Asteroid from Dover and Eddystone.

****

Asteroid Marginal Type 23

Plate 29, figs. 1, 2a,b.

Remarks

Large marginals of the Goniaster group are quite common in the upper par of the Middle Barton Beds. They form a double row around the margin of the disc and arms. Individual ossicles are large, squarish, and have two sides bearing pustules on a raised platform. Some specimens are more elongate and probably represent the ultimate superiomarginals (see MOORE 1966, p.22, fig.27). The Upper Cretaceous genus Metopaster has a similar structure. London Clay specimens have been referred to several genera ("Goniaster","Archastropecten" etc.). The material examined differs from London Clay specimens in having a narrower raised central area and is ornamented by clear granules, rather than fibrous pustules.

****

Asteroid Paxilla Type 24

Plate 29, fig. 6.

Remarks

Paxillae are aboral granules, distally bearing a crown of small spines. The Barton Beds specimens are club shaped, the base having a rounded outline. They do not agree with those present in the Recent material examined but similar ones are figured in MOORE (1966).

****

Asteroid Paxilla Type 45

Plate 29, fig.7.

Remarks

A single specimen, from the Lower Barton Beds of Alum Bay, has exactly the same shape as the aboral ossicles from one of the Recent Eddystone speci

The base has four sides and gives rise to a low, cylindrical, distal knob. Some of the paxillae from the Recent specimen are basally triangular and some are quadrilateral.

****

Asteroid Ambulacral Ossicle Type 26

Plate 29, fig. 3.

Remarks

Infrequent ossicles referable to Asteroid ambulacra have a characteristic geniculate, boot-like shape. They agree with specimens from all the Recent Asteroids examined and with illustrations in POKORNY (1965).

****

Asteroid Terminal Ossicle Type 29

Plate 29, fig. 4.

Remarks

Terminal ossicles of Asteroids, other than the Goniaster group, occur rarely in the Middle Barton Beds. They are narrow, horseshoe shaped, with a small internal groove and slightly pustulose 'exterior' surfaces. POKORNY (1965) figures a broader type.

****

Asteroid? Ossicle Type 36

Plate 29, fig. 8.

Remarks

This rare Lower Barton Beds form could not be matched with any of the Recent ossicles examined. It is questionably placed with the Asteroids on its approximation to the ambulacral ossicles in shape. It has a slightly fibrous structure, like Asteroid? Ossicle Type 22.

****

4:7:2 Crinoid Ossicles

Crinoid Facetal? Type 33

Plate 29, fig. 18.

Remarks

A few specimens from the Lower Barton Beds of Barton could be compared with figures of facetal ossicles in POKORNY (1965, fig.1048, f.). His specimens were from the Middle Devonian of Czechoslovakia and this comparison must be regarded with extreme caution in view of the completely different Crinoid faunas of that time.

****

Crinoid Brachial Type 46

Plate 29, fig.17.

Remarks

A single specimen, from the Middle Barton Beds of Alum Bay, has the characteristic corrugate articulatory face, food groove and asymmetry of Tertiary Comatulid Crinoid arm ossicles. Both stalked forms, from the London Clay, and pelagic species, such as Antedon, have similar ossicles with the shape of a twisted half tube.

****

4:7:3 Echinoid Fragments

Echinoid Spine Type 2

Plate 29, fig.10.

Remarks

This type is extremely common in many Lower and Middle Barton Beds samples. It consists of a narrow cylindrical rod, bearing regular longitudinal ridges. The ridges are separated by short transverse struts. Distal terminations, when preserved, are very acute and pointed, sometimes with one side slightly excavate. Identical spines occur from Upper Cretaceous to Recent and correspond to the undifferentiated aboral spines of irregular burrowing Echinoids. A specimen of a Recent species of Echinocardium, from the English Channel, proved to have its aboral surface covered by such spines. Some Asteroids also bear similar spines so this grouping may be polyphyletic.

****

Echinoid Spine Type 4

Plate 29, fig.11.

Remarks

The shaft of this type is identical in structure to that of Echinoid Spine Type 2. It is flared distally to give an excavate, spoon-like termination. Specimens of Recent Echinocardium bear identical spines on the plastron, where they are adapted for locomotion.

****

Echinoid Spine Type 6

Plate 29, fig.12.

Remarks

A somewhat stouter spine with a circular or oval cross section, corrugated longitudinal ridges and lateral, thorn-like processes. It is much rarer than types 2 or 4 and is possibly related to type 37.

****

Echinoid Spine Type 37

Plate 29, fig.13.

Remarks

This type is very similar to type 6 but is thicker, with stronger corrugated longitudinal ribs and a lack of any lateral spines. It shows some resemblance to the radioles of Echinopedina edwardsi (FORBES) (1852, pl.3, fig.2.), the only regular Echinoid recorded from Barton.

****

Echinoid Spine Type 44

Plate 29, fig.9.

Remarks

Specimens from the Lower Barton Beds of Alum Bay and the Middle Barton

Beds of both localities correspond to figures of "Cidaris websteriana" FORBES (1852, p.22,pl.3,fig.4.). GREGORY (1891) rightly doubts the validity of this name, which was erected solely on the spines. It is a relatively long, stout form, with a well defined base and a tapering, ornamented shaft. The ornament is very distinctive, consisting of a series of longitudinal rows of rounded, slightly elongate or lozenge-shaped tubercles. They were probably born by a surface-living regular Echinoid.

****

Echinoid Interambulacral Plate Type 35

Plate 29, figs. 14,15.

Remarks

A very abundant type, including all thin Echinoid plates with small tubercles and an absence of pore pairs. They are occasionally found still attached to ambulacral plates. No heavily tuberculate or thick plates were encountered in this study.

****

Echinoid Ambulacral Plate Type 38

Plate 29, fig. 16.

Remarks

Elongate plates, each with a single pair of pores are quite common throu-out the Lower and Middle Barton Beds. They bear low tubercles, as do the interambulacral plates, and undoubtedly belong to the same species. The pores are sometimes situated in a shallow depression. Petaloid and compound ambulacral plates were not found.

****

4:7:4 Ophiuroid Ossicles

Ophiuroid Lateral Arm Plate Type 1

Plate 29,figs.26,27.

Remarks

Lateral arm plates of Ophiuroids are U-shaped in cross section and more or less elongate. The outer face is broadly rounded, with ridges of clear calcite running across it. The inner face is occupied by a broad longitudinal furrow, which is generally interrupted by a low, oblique partition. BERRY, MOORE and several other authors figure lateral arm plates and they could also be identified from the Recent Ophiuroid studied. At least three types of these ossicles are present in the Barton Beds; a narrow elongate form; a larger shorter type; and a very stout, short one. This variation may be controlled by the position along the arm but BERRY (1937, 1938) uses lateral arm plates to distinguish his species. In either case no further differentiation on the Barton Beds material was attempted.

****

Ophiuroid Vertebral Ossicle Type 13

Plate 29, figs.19,20.

Remarks

These very distinctive structures are quite common in the Lower and Middle Barton Beds. As with the lateral arm plates three types are present: narrow, broad and intermediate forms. Again no further attempt was made to divide them specifically as the author is far from certain about their variation along individual arms.

****

Ophiuroid Jaw Ossicle Type 16

Plate 29, fig.23.

Remarks

Rather irregular ossicles of this type occur infrequently in the Middle Barton Beds of both sections. They roughly resemble BERRY's (1938, pl.14, figs. 22, 25) figures of Ophiuroid jaws. However, the disaggregated Recent Ophiuroid yielded similar plates joined in pairs along their upright faces. The top of the pair were further joined by another elongate ossicle. It is uncertain whether these compound structure then represent vertebral supports.

****

Ophiuroid Dorsal Arm Plate Type 39

Plate 29, fig.25.

Remarks

Small, shield-shaped plates, with a shallow longitudinal furrow on the inner surface occur in the Lower and Middle Barton Beds. They agree well with BERRY's illustrations of ventral arm plates and with specimens from the Recent specimen. There is little variation in the Bartonian material and they are thought to represent a single species. London Clay specimens and some of BERRY's figures are much thicker, with kite-shaped outlines and squarish margins.

****

Ophiuroid Ventral Arm Plate Type 40

Plate 29, fig. 24.

Remarks

This type has a distinctive pentagonal "arrowhead" outline and an inner furrow. It compares well with BERRY's figures and the Recent material and, as with the dorsal arm plates, shows little variation.

****

Ophiuroid Disc Ossicle? Type 41

Plate 29, fig. 21.

Remarks

Infrequent, oval, smooth and laterally concavo-convex ossicles are thou to have a provenance on the aboral shield of the Ophiuroid's central disc. No examples could be found in the Recent material but some of BERRY's figures resemble the Bartonian specimens.

****

Ophiuroid Genital Plate? Type 42

Plate 29, fig. 22.

Remarks

BERRY (1938) figures genital plates with a massive base and a hook-like extension, similar to those from the Barton Beds. No trace of such ossicles could be found in the Recent specimen and it is uncertain whether this form is not in fact part of the radial shield.

****

4:7:5 Holothuroid Sclerites

The author here follows the "Treatise of Invertebrate Paleontology" (FRIZZELL, EXLINE & PAWSON in MOORE, 1966) in using FRIZZELL& EXLINE's (1955) classification. It was erected as a Linnaean system when sufficient data on extant and fossil forms became available for a natural classification to be applicable. DEFLANDRE-RIGAUD's (1953) previous scheme is a non-Linnaean system using CRONEIS's (1938) "ordo militaris".

Family: PRISCOPEDATIDAE FRIZZELL& EXLINE 1956

Genus: *Priscopedatus* SCHLUMBERGER 1890

(Type species: *Priscopedatus pyramidalis* SCHLUMBERGER,1890.)

Priscopedatus multiforis SCHLUMBERGER

Plate 30, fig. 1.

Priscopedatus multiforis SCHLUMBERGER,1890. p.202,figs.31-32.
Priscopedatus multiforis SCHLUMBERGER: CRONEIS & McCORMACK,1932. p.128,pl figs. 8, 10.
Priscopedatus multiforis SCHLUMBERGER: FRIZZELL&EXLINE,1955. p.107,pl.5, figs. 15, 19.
Priscopedatus multiforis SCHLUMBERGER: POKORNY,1965. fig.1069: 8,10.
Priscopedatus multiforis SCHLUMBERGER: FRIZZELL, EXLINE & PAWSON in MOORE,1966. p.661.
Priscopedatus multiforis SCHLUMBERGER: RIOULT,1965. p.166,pl.1,figs.1,2; pl.2,fig.1.

Remarks

Rare specimens from the Lower Barton Beds of Alum Bay have the characteristic table structure of the species, as figured in the literature. The disc has four lobes, corresponding to the four struts of the stirrup. The disc perforations are small, smooth and arranged in two or three circlets, the outer circlet being restricted to the lobes. The four fold stirrup overlies a large circular hole and gives rise to an elevated spire with four buttresses. All previous records of this form have been from the Calcaire Grossier of the Paris Basin.

****

Family: SYNAPTITIDAE FRIZZELL & EXLINE 1956

Genus: Rigaudites FRIZZELL & EXLINE 1957

(Type species: Synaptites cuvillieri DEFLANDRE-RIGAUD, 1949)

Rigaudites cuvillieri (DEFLANDRE-RIGAUD)

Plate 30, figs. 2,3.

Synaptites cuvillieri DEFLANDRE-RIGAUD, 1949. p.3, text-figs.1-3.
Synaptites cuvillieri DEFLANDRE-RIGAUD; FRIZZELL & EXLINE, 1955. p.145, pl.9, fig.8.
Rigaudites cuvillieri (DEFLANDRE-RIGAUD): FRIZZELL, EXLINE & PAWSON in MOORE, 1966. p.670, fig.534:8.

Remarks

Fragmentary material from the Lower Barton Beds of Alum Bay and the Middle Barton Beds of Barton agree with the published illustrations. The fragments are parts of large perforate anchor plates. The perforations are numerous, subcircular and have a finely denticulate margin. Two specimens also bear the socket end and show characters reminiscent of Synaptites eocoenus (SCHLUMBERGER) (see RIOULT, 1965, pl.1, figs.6,7; pl.2, fig.3). In these specimens the socket is backed by a strong perforate lobe, which is flanked by elongate, acute ears. Typical S. eocoenus bears fewer perforations and tapers smoothly towards the socket end, without ears or lobes.

****

Holothuroid? Sclerite Type 1

Plate 30, figs. 4,5.

Remarks

A number of small, subcircular, perforate plates, from the upper part of the Middle Barton Beds of Barton, can be questionably referred to Holothuroidea. The perforations have smooth margins and are arranged in a random pattern, without the typical Holothuroid cruciform initial stage. Larger specimens are sometimes double layered in the central area but no additional structures (spires, sockets, etc.) are attached. RIOULT (1965) figures several species of Cucumarites, from the Burdigalian of the Aquitaine Basin, having a similar structure. However none are double layered and most of them show a hexagonal pore arrangement. The Jurassic genus Paracucumarites has a central double structure and Elgerius, from the Oligocene of Germany, is peripherally double layered (both are figured in the "Treatise").

****

Section 4:8 THE VERTEBRATES

4:8:1 Vertebrate Bones, Scales and Teeth

Introduction

Vertebrate bone fragments are relatively abundant in certain levels of the Barton Beds. Unlike the teleost otoliths they are, by nature of their preservation, seldom of use for taxonomic purposes. Distinction, even into fish, amphibian, reptilian and mammalian elements is usually impossible. Identifiable vertebrae, gill arches and various rib structures occur rarely in a large quantity of phosphaticmaterial from various sources, which can only be described as 'vertebrate debris'. Although no proof can be applied, the bulk of these skeletal fragments are probably derived from bony fish.

No attempt has been made in the present study to differentiate bone fragments either into skeletal elements (vertebrae, rib structures etc.) or into the major vertebrate taxa. The use of all the fragments counted togethe. provides a much more ecologically and stratigraphically significant paramete.

Scales and Teeth

Only teeth and scales have been subdivided in this study. The subdivisi. is purely arbitrary into numbered morphological types. Specimens are mostly smaller than identified material in collections and the application of the names in use for such elements as shark teeth is applied only as a secondary, very tentative measure. A much more satisfactory division is into units of similar function. The basis of vertebrate taxonomy used here is that of ROMER (1945). Additional reference was made to ZITTEL (1932), A.M.DAVIES (1935) and WOODWARD (1899) for various shark group organ names.

The Shark Group

Although the cartilaginous fish are represented only by teeth and scales they can quite accurately be divided into cutting teeth, grinding teeth and dermal denticles on their morphology. Teeth have been shown in the past to be interspecifically variable elements and the same probably holds true for the small specimens from the English Bartonian.

Cutting Teeth

These are sharp edged and pointed teeth set at, or near, a right angle to the jaw. Fish bearing this type of dentition include the present day active, carnivorous, fish-eating sharks. Most of the named genera are stratigraphically long ranging and can be assumed to have inhabited a wide depth range.

Tooth Type 1

Plate 30, figs. 9,10.

Remarks

A small symmetrical form, with two equal and slightly convex sides to the crown. A portion of undivided root is often preserved. The apical angle is rather variable and this type includes both shorter, squatter and more elongate individuals. No reference to this form could be found in the literature.

****

Tooth Type 3

Plate 30, figs. 11,12.

Remarks

The crown of this type has similar faces, as in Tooth Type 1, but is set obliquely on a more or less elongate root. Single and multiple cusped specimens have been found, the latter resembling Notidanus.

****

Tooth Type 4

Plate 30, fig. 13.

Remarks

An elongate, slightly sinuous, acute crown tops a deeply divided root. Small lateral cusps may be present on large specimens. The cross section of the crown characteristically shows one face much more convex than the other. Large specimens resemble figures of Odontaspis.

****

Tooth Type 18

Plate 30, fig. 14.

Remarks

This form occurs up to quite a large size in some samples. The crown has a slightly oblique, short, broad central cusp with two or more lateral cusps. The root is large, arcuate and divided centrally. Large specimens resemble forms figured as Lamna (= Otodus of earlier authors).

****

Tooth Type 33

Plate 30, fig. 15.

Remarks

A small rare type, whose crown consists of a number of rather short, irregular striate cusps. It could not be identified from the literature.

****

Tooth Type 34

Plate 30, fig.16.

Remarks

A small curved form with a broad base and a subcircular cross section. The convex side bears a single cutting edge. This form could not be identified from the literature and may not belong to the shark group, but to the teleosts.

****

Crushing Teeth

Members of the shark group with a molluscan diet have low crowned teeth with a flat or domed distal surface for crushing shells. Such teeth lack sharp edges and acute points. Recent representatives include some of the skates and rays, which have a bottom hugging mode of life.

****

Tooth Type 28

Plate 30, fig.17.

Remarks

An oblique, sometimes corrugated, rhomboidal crown tops a strongly divided root. One edge of the crown has a turned-up rim. Representatives of an Upper Palaeozoic group, the Bradyodonts have teeth of this form (see ROMER, 1945). ZITTEL (1932) figures representatives of the Trygonids (sting rays) with rhombic double-rooted teeth.

****

Tooth Type 31

Plate 30, fig. 7.

Remarks

This form has a very low, elongate, smooth laterally tapering crown. It could not be identified from the literature.

****

Tooth Type 32

Plate 30, fig. 18.

Remarks

A form questionably related to this group. It has an elongate, backward pointing, trowel-shaped crown with a broad groove along its convex side. The root is divided.

****

Tooth Type 39

Plate 30, fig. 8.

Remarks

An elongate hexagonal form with corrugations running parallel to the short axis on the root. This form is the central element of the typical dentition of Myliobatis (an eagle ray). The complete pattern consists of a row of these elongate elements in each jaw with three rows of more equitant hexagonal teeth on each side. Only a single specimen was recovered from the Middle Barton Beds of Alum Bay (sample 6638).

****

Dermal Denticles

The skin of the shark group is protected by overlapping bony denticles. Five types of these shield-like or posteriorly spinose elements could be distinguished. Unlike teleost scales, dermal denticles have well developed roots and are thought to represent the source from which the buccal dentition was developed. None of the forms found could be matched with published species.

Dermal Denticle Type 5

Plate 30, fig. 19.

Remarks

Included in this type are all the small forms with a smoothly rounded anterior margin, one or more posterior angles and two or more well defined longitudinal ridges. Cushion shaped roots are frequently preserved.

****

Dermal Denticle Type 15

Plate 30, fig. 22.

Remarks

A distinct type with a rounded anterior margin and a horseshoe-like lateral ridge, surrounding an excavate longitudinal furrow. The furrow continues posteriorly along an acute spine. Roots are often present.

****

Dermal Denticle Type 20

Plate 30, fig. 21.

Remarks

A very small cushion-/or shield-shaped form with a smooth lateral surface. The anterior edge is marked by three or four short ridges.

****

Dermal Denticle Type 22

Plate 30, fig. 20.

Remarks

The lateral face of this shield-shaped form is flat and completely smooth. The edges are vertical, and the posterior margin is drawn out into one or two sharp spines. Roots are usually present.

****

Dermal Denticle Type 37

Plate 30. fig. 23.

Remarks

This type is similar to Dermal Denticle Type 5 in shape, but is considerably larger and has a leading edge marked by numerous short, low, irregular, ridges. The central spine is accentuated and may be distally conical.

****

The Holostean Group

These are primitive bony fish (the Ganoidea of DAVIES,1935), which survived in reduced numbers from the Mesozoic into the Tertiary. Recent representatives include the sturgeons. Holostean scales are heavy and provide an armoured skin. The three types mentioned below are questionably included with the holosteans on the basis of the scale thickness, and the type of teeth (see below).

Scale Type 16

Plate 30, fig. 26.

Remarks

A few fragments of thick scale with a regular pustulose pattern are included here.

****

Scale Type 21

Plate 30, fig. 27.

Remarks

As with Scale Type 16 the thickness of this rare form might indicate its Holostean affinities. The surface is covered by numerous, irregularly arcuate, sharp-edged ridges.

****

Tooth Type 17

Plate 30, fig. 6.

Remarks

A large, rather low, oval-conical, concentrically striate form with a truncated, sometimes faceted, apex. Some doubt remains about the function and affinities of this type as no reference to it could be found in the literature. Collectively they may form the dermal armour of a holostean. On the other hand one group of holosteans, the Pycnodonts, have a buccal dentition made up of a large number of cushion-like vomerine teeth, similar to this type; a possible adaptation to coral-feeding (DAVIES, 1935).

****

The Teleost Group

Fossilisable remains of teleost, or true bony fish, include teeth, scales, bones and otoliths. Of these only the otoliths have any diagnostic characters in the disaggregated state and these are dealt with later. Most of the skeletal material common in the Barton Beds is probably of teleost origin, with very subsidiary reptilian (mainly Chelonid) material. One type of tooth and a very empirical division into three types of scale are rec

The taxonomic significance of any of these units is extremely slight.

Tooth Type 2

Plate 30, figs.24,25.

Remarks

All conical, curved or straight teeth, on a more or less well developed caniculate root are included here. The height and conical angle of the crown is very variable, as is the crown/root-length ratio. As all gradations are present no further subdivision is attempted.

Most active, unadapted teleosts have teeth of this type, as do some of the smaller reptiles. A large number of unrelated species are thus undoubtedly included.

****

Scale Type 1

Remarks

A thin type of scale with closely set, parallel, concentric striations, broken up by straight, radiate lines. Complete examples are very rare.

****

Scale Type 4

Remarks

Thin scales with an unbroken,concentric,rather widely spaced and irregular ornament of striae. Both cycloid and ctenoid types of scale have been found and are not distinguished (see ZITTEL, 1932).

****

Scale Type 14

Remarks

This form differs from the other two types in having straight, closely spaced, parallel, unbroken striae over its surface. Even large specimens show no signs of any concentric pattern. One edge of large specimens is sometimes bevelled, the unbevelled side always bearing the ornament. Partially unornamented specimens are common.

****

4:8:2 Teleost Otoliths

Introduction and Morphology

The 39 types of otoliths distinguished in the present study are calcareous granules associated with the paired stato-acoustic organs of fish and occur only in the Teleosts or true bony fish. Each organ consists of three semi-circular canals arising from a three lobed sac, where the otoliths are housed. The function of the organ is partly auditory and partly to control balance and its simplified structure corresponds to the mammalian inner ear. Three otoliths in each organ; the sacculith (= sagitta), utriculith (= lapilli) and lagenalith (= astericus) lying in the sacculus, utriculus and lagena respectively. The complete fish thus bears six otoliths.

In the bulk of Teleost groups the largest otolith is in the sacculus.

The lagenalith and utriculith are usually small, relatively featureless and seldom preserved. In a few groups the lagenalith is the largest otolith. An excellent example of one of these, Arius crassus (KOKEN), was recovered from the Lower Barton Beds of Alum Bay. Saccular otoliths show remarkable specific and generic differentiation. In the usual absence of well preserved in situ skeletal material they can give a very useful picture of fossil fish faunas and have been used to trace palaeoclimatic and ecological patterns as well as phylogenetic trends.

The occurrence of otoliths as disaggregated units, often divorced from well preserved skeletal material, led early authors into many mistakes regarding the affinities of particular specimens. Recent work in dissecting otoliths from extant species has enabled valid generic names to be applied to fossil otoliths. In the absence of such studies fossil material is given organ species names in the form "Otolith sp." or "Otolithus sp.", sometimes associated with the family name.

Morphologically the sacculith consists of a calcareous disc composed of layered, fibrous radiate calcite. The outer face is smooth, lobose or umbonate, and has little diagnostic value. The inner face and the outline are the best features for distinguishing species. A horizontal groove (the sulcus) divides the inner face into dorsal and ventral areas. The sulcus opens anteriorly at the excisura and is often divided into two portions by a constriction; the ostium anteriorly and the cauda posteriorly. More information on otolith morphology, as well as an excellent review of stratigraphic distribution and history of research, may be obtained from POKORNY (1965, pp.380-391).

Occurrence in the Barton Beds

Mr.F.C.Stinton very kindly identified part of the collection of otoliths for this study. The 25 species he identified are presented below and figured without further comment. His broad knowledge of English Tertiary Otoliths and their relation to recent genera enables valid zoological names to be applied. Of the remaining 14 species, one (Arius crassus) was identified from E.T.NEWTON (1889) and 13 are figured and described briefly as numbered species. No further literature study of this very difficult topic was undertaken as Mr.Stinton is in the process of monographing the Bartonian faunas and the present author has no facilities for useful comparative studies on living forms. Further literature on the topic may be found from POKORNY (1965, pp.441-445), STINTON (1956) and BURTON (1933).

Otoliths show a very uneven distribution in the Barton beds and seldom show any relationship with vertebrate bone fragments. They occur either as one's or two's in a sample, or in large numbers, as what are probably mechanical segregations. Only one species, *Bregmaceros minimus* (FROST) is particularly abundant with a well defined distribution. This occurs in the lower part of the Middle Barton Beds and specimens sometimes reach over 100 in the 10-30 fraction. Similar accumulations of a closely related Recent species have only been noted in the South China Sea at a depth of several hundred feet (STINTON, pers.comm.). Species with frequent occurrences spread more or less evenly throughout the Lower and Middle Barton Beds include *Anthias nota*, *Lutianus concavus* and *Pterothrissus bartonensis*. Certain other species occur throughout the Lower and Middle Barton Beds and are more frequent in the lower (*Gadus dimidiatus*, *Neobythites waltoni*, *Bathyconger sp*.) or upper (*Apogon bellovacinus*, *Merluccius shepherdi*, *Ogilbia subregularis*) parts of the succession. Most of the remaining species are much less common and a few are represented by single specimens.

Species Identified by Mr.Stinton

Antheas nota (SHEPHERD)	Plate 30, figs.28,29.
Apogon bellovacinus (PRIEM)	Plate 30, fig.32.
Argentina hantoniensis (SCHUBERT)	Plate 30, fig.31.
Bathyconger sp.	Plate 30, fig.30.
Beryx lerichei (SCHUBERT)	Plate 31, fig. 3.
Bregmaceros minimus (FROST)	Plate 31, fig. 4.
Callionymus sp.	Plate 31, fig. 1.

Cepola pantanelli (BASSOLI & SCHUBERT)	Plate 31, fig.5.
Citharichthys helectaroides STINTON	Plate 31, fig. 2.
Gadus dimidiatus (SCHUBERT)	Plate 31, fig. 6.
Genypterus bartonensis (SCHUBERT)	Plate 31, fig. 8.
Gymnocranius denticulatus (FROST)	Plate 31, fig. 7.
Hilsa regularis STINTON	Plate 31, fig.19.
Lutianus concavus (PRIEM)	Plate 31, fig. 9.
Merluccius shepherdi (SCHUBERT)	Plate 31, fig.10.
Muraenesox eocenicus (FROST)	Plate 31, fig.11.
Muraenesox ovatus (FROST)	Plate 31, fig.12.
Neobythites waltoni (SCHUBERT)	Plate 31, fig.13.
Ogilbia subregularis (SCHUBERT)	Plate 31, fig.15.
Plesiops sp.	Plate 31, fig.17.
Peristedion denticulatus (n.sp.,STINTON, m.s.)	Plate 31, fig.14.
Pterothrissus bartonensis (SCHUBERT)	Plate 31, fig. 16.
Solea bartonensis (FROST)	Plate 31, fig.18.
Synodus rectus (FROST)	Plate 31, fig.20.
Trachichthodes circularis STINTON	Plate 31, fig.21.

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Species identified by the author

Arius crassus (KOKEN)

Plate 31, fig.31.

Otolithus (incertae sedis) crassus KOKEN, 1884. p.559,pl.12,fig.13.
(M.Headon,Headon Hill.)
Arius crassus (KOKEN): E.T.NEWTON,1889. p.204,pl.21,fig.3.
(Barton Beds, Barton.)

Remarks

A single large specimen of a lagenalith was found in the Lower Barton Beds of Alum Bay (sample 6617). It lacks the sulcus typical of all sagittae and agrees with NEWTON's figures based on in situ material from Barton.

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Unnamed species

Otolith sp.39

Plate 31, fig. 22.

Remarks

A small form occurring sporadically throughout the Lower and Middle Barton Beds of both sections. The outline is subquadrate with a rounded rostrum. The sulcus is short, central, horizontal and very shallowly indented, with an elongate ostium and a very short cauda. It does not emerge at either end. The outer face is usually lobose.

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Otolith sp. 42

Plate 31, fig. 24.

Remarks

A very small species, restricted to BURTON's bed J of Barton. The inner face is very slightly domed with an unindented, straight sided, oblique sulcus of two subequal portions. The ostium is considerably broader than the cauda and opens on the straight anterior margin without any excisural re-entrant. The rostrum is angular but not drawn out and a posterior angle is also present. The outline is slightly inflated triangular.

This species resembles Otolith sp.44 but always has a sharper, more angular outline.

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Otolith sp. 43

Plate 31, fig. 25.

Remarks

A form resembling juvenile Antheas nota (SHEPHERD) in shape but with a flatter inner face and a shorter, straighter-sided cauda. The sulcus is never sinuous, as in A.nota and the margin is smooth, not crenulate.

****

Otolith sp. 44

Plate 31, fig. 26.

Remarks

This species closely resembles Otolith sp.42 but the anteriodorsal dome and the posterior are always broadly rounded, never angular. It occurs infrequently in the Lower Barton Beds of Alum Bay only.

****

Otolith sp. 45

Plate 31, fig. 28.

Remarks

The two specimens recovered from the Lower and Middle Barton Beds of Alum Bay show the straight, parallel sided sulcus and dorsal and ventral furrows of Citharichthys helectaroides STINTON. The outline, however, is much squatter and there is no rostral beak.

****

Otolith sp. 46

Plate 31, fig. 32.

Remarks

A distinctive species occurring rarely in the Middle Barton Beds of both sections. It has an oval, denticulate outline with a short, subequal rostrum and antirostrum and a deep excisura. The inner face is slightly domed, with a long, broad, apparently undivided, slightly sinuous sulcus and very low cristae.

****

Otolith sp. 47

Plate 31, fig. 29.

Remarks

The single specimen from sample 6639 (Middle Barton Beds, Alum Bay) shows a smooth, domed ventral area and concave dorsal area with a shallow, posteriorly narrowing, curved and undivided sulcus, opening anteriorly just above a rounded rostrum. The smooth, excavate dorsal area distinguishes it from all other species examined.

****

Otolith sp. 48

Plate 31, fig. 35.

Remarks

A number of fragments in sample 6673 (Middle Barton Beds, Alum Bay), when fitted together, form a single large specimen resembling Merluccius shepherdi (SCHUBERT). The sulcal shape, with its elongate, inflated ostium and cauda, is very similar in both forms but in the absence of an unbroken outline this specimen cannot definitely be placed with M. shepherdi.

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Otolith sp. 49

Plate 31, fig. 33.

Remarks

A single specimen from the Middle Barton Beds of Alum Bay, has the elongate outline and posteriorly curved sulcus of Plesiops sp. and Callionymus sp. It is considerably larger than either of these species.

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Otolith sp. 50

Plate 31, fig. 34.

Remarks

This small smooth form has a domed inner surface, a deep, posteriorly curved sulcus, a pointed rostrum and a rounded antirostrum. The antirostrum is situated out of the plane of the rest of the margin. Only one specimen was recovered (Middle Barton Beds, Alum Bay, sample 6681).

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Otolith sp. 51

Plate 31, fig. 27.

Remarks

The single specimen recovered (sample 6683, Middle Barton Beds, Alum Bay) has the same outline and shape as Cepola pantanelli (BASSOLI & SCHUBERT). The sulcus in this species shows a different pattern, with the ostium and cauda forming a straight line, not en echelon.

****

Otolith sp. 54

Plate 31, fig. 23.

Remarks

Three fragments in sample 6669 (Middle Barton Beds, Alum Bay) fitted together into a specimen resembling Cepola pantanelli (BASSOLI & SCHUBERT). The en echelon cauda and ostium is comparable in both forms but Otolith sp.54 has a much more acute rostrum and posterior angle.

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Otolith sp. 55

Plate 31, fig. 30.

Remarks

Two specimens from the Chama Bed of Alum Bay (sample 6703), one broken and one in fragments, have a similar short subquadrate shape to Beryx lerichei (SCHUBERT). The sulcus however is completely different, with a much narrower, curved cauda and a shorter ostium.

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