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The Late Cenomanian Anoxic Event; implications for foraminiferal evolution.

by

Paul Niell Leary BSc., DMS.

Thesis submitted in partial fulfillment for the Degree of Doctor of Philosophy to the Council for National Academic Awards.

Doctor of Philosophy

to

The Council for National Academic Awards

Research conducted at Plymouth Polytechnic.

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September 1987.

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The Late Cenomanian Anoxic Event; implications for foraminiferal evolution.

P.N. Leary

Abstract:

This study investigates the effect of the late Cenomanian Oceanic Anoxic Event (OAE) on the planktonic and benthonic foraminifera.

On the former, the OAE was the cause of major extinctions within the population, the return to pre-OAE oxygen levels permitting recolonization of the vacated niches. On the latter, the OAE caused extinctions but resulted in a low oxygen tolerant fauna which slowly evolved into the vacated niches on the post-OAE recovery of oxygen levels.

The changes in the foraminiferal populations have been integrated with changes in other marine organisms through the late Cenomanian.

Declaration:

This is to certify that the work submitted for the Degree of Doctor of Philosophy under the title "The Late Cenomanian Anoxic Event; implications for foraminiferal evolution" is the result of original work.

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

Candidate

P.N. LEARY

Research supervisor MBHORT Prof. M.B. HART

Thoughts for the day:

"Caw", said the Crow.

4

"Balls", said Milligan.

Spike Milligan, Puckoon.

"I am not French, I am Belgian."

Hercule Poirot, Agatha Christie.

"If a little knowledge is a dangerous thing, just think what a lot could do."

Senior tutor. In Porterhouse Blue, Tom Sharpe.

Art is bullshit,

Science is Art with numbers.

Anon.

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Chapter 1: Introduction and History of Previous Research.

1.1 Overview of planktonic foraminiferal evolution.

Modelling of the evolution of planktonic foraminifera has advanced over the past decade in the light of developments in palaeoceanography coupled with a greater understanding of the ontogeny of extant species.

The three iterative radiations have variously been attributed to temperature (Cifelli,1969; Frerichs,1971), or the recolonization of deeper water niches (Hart,1980a; Caron,1983a), brought about by changes in palaeoceanographic conditions. Alternatively, they may be induced by extra-terrestrial influences (Smit,1982), possibly on a regular basis (Raup,1987).

1.2 The late Cenomanian Anoxic Event.

The late Cenomanian Anoxic Event saw world-wide water column stagnation (Jenkyns,1980; Arthur <u>et al.,1987</u>; Schlanger <u>et al.</u> 1987) with a major change in the foraminiferal composition (Hart,1985; Hilbrecht and Hoefs,1986; Hart and Ball,1987). The world-wide off-shore recovery of the Cenomanian - Turonian interval is poor (Figure 1.1), with only 14 of the 36 DSDP Legs encountering pre-Cenomanian sediments and yielding Cenomanian - Turonian rocks. Furthermore,only 4 of these contained well-preserved planktonic faunas. Leg 80, DSDP, forms one of the latter, with several metres of organic-rich laminated clays being recorded (Waples,1985) and a rich planktonic assemblage (Graciansky <u>et al.,1985</u>).

The on-shore Cenomanian - Turonian succession is laterally

Figure 1.1 Plot of DSDP Legs against

21

designated categories



persistant but with many facies overprints on the background carbonate deposition (Jarvis and Woodroof, 1984; Robinson, 1986), and as a result varies in its completeness and suitability for the study of the evolution of foraminifera (see Chapter 6). In the off-shore North Sea Basin, Cenomanian rocks are poorly represented in the Southern North Sea Basin whereas in the Northern North Sea Basin rocks of Cenomanian and Turonian age are well developed. Conversely, in the Northern Viking Graben there is little evidence of Cenomanian strata (Copestake, pers.comm.).

1.3 Foraminiferal studies.

Previous foraminiferal studies of the Plenus Marls (Jeffries,1962),the Albian - Cenomanian (Hart,1970; Carter and Hart,1977) and Turonian (Owen,1970; Hart and Weaver,1977; Hart,1982b) successions have been undertaken. Only the biostratigraphically important foraminifera from **B.P.** Well 93\2-1 have been documented (Williamson,1979).

A study of nine sections across the Boreal Cenomanian -Turonian interval has been undertaken to look in detail at the late Cenomanian foraminiferal turnover.

Chapter 2: Methods.

2.1 Sampling.

At each locality the surface of the rock face was cleaned thoroughly to remove the surface weathered material, primarily to avoid the effects of decalcification on the tests. The size of each sample was between 0.5 and 1.0 kilogrammes. Each sample was placed in a plastic bag which was labelled inside and out, with the location of each recorded against a detailed lithological log. At all times the sampling equipment (hammer and trowel) were kept clean to avoid contamination from undesirable material.

The sample spacing is variable being carried out on a bed by bed basis. When bed thickness was greater than 1 metre a sample from both lower and upper portions was taken. Above and below the target area samples were collected at a 1 metre spacing.

The material provided by the Deep Sea Drilling Project was already in Plymouth Polytechnic; material from B.P and Britoil was requested by the author who had no control over its collection.

2.2 Sample Processing.

In keeping with other foraminiferal studies of chalk (Hart,1970; Bailey,1978), the processing technique depended on

the type of lithology:

(A) For rocks with a high clay content (marls).

The samples were broken with the fingers or, failing that, lightly with a hammer, into approximately 1 - 2centimetre pieces, taking care not to crush the sediment. The pieces were dried for at least 24 hours in a ventilated oven at 60° C.

On removal from the oven, the hot dry samples were placed in a fume cupboard and soaked in white spirit for 2 - 4hours. The white spirit was filtered off for re-use and the samples were immersed in distilled water, again for 2 - 4hours. The disaggregated sample was filtered through a 63 am mesh sieve, great care being taken to thoroughly remove the <63 um fraction. The residue was re-dried in an oven at 60°C and placed in a suitably labelled container.

Samples treated in the above manner were designated with the symbol ${\rm O}$.

(B) For those rocks with a lower clay content the approach of Todd, Low and Mello (1965) was adopted.

The samples were broken as in (A), but then they were placed in a metal bowl containing a simmering solution of washing soda (2 heaped tablespoons of Na_2CQ_210 H₂O per 250 millilitres of distilled water), for 1 - 3 hours.

The solution was washed out through a $63 \, \text{Am}$ sieve along with the < $63 \, \text{Am}$ fraction. As before the residue was dried and placed in a suitably labelled jar.

Samples so treated were designated [].

(C) Rarely, some samples were so heavily cemented that they defied disaggregation by methods (A) and (B). These were thin sectioned. At least six randomly orientated thin sections were obtained for each sample.

Samples thus treated were designated \mathbf{X} .

For some samples all three techniques were used. The different techniques may be ranked in terms of the quality of results and thus preferentially

o>□>☆.

2.3 Residue Examination.

The dried residues were sieved through a nest of sieves containing 500um, 250um, 125um meshes and a collecting tray.

The total faunal picks of the planktonic foraminifera were made from the 500um and 250um fractions. This included broken specimens where they formed more than half of an individual. This approach ensured no picking bias, as opposed to the more common practice of selecting 300 specimens for biostratigraphical study. The latter is only free of bias when the sample is randomly picked.

In some cases total faunal picks resulted in over a thousand specimens from one sample. Despite the time-consuming nature of the work it was worthwhile in terms of the confidence levels that could be placed on subsequent interpretations.

From the >125um fraction and collecting tray only representative faunal assemblages were taken, especially the gerontic forms of those not present in the top two fractions.

For the 500um and 250um fractions, the species present were sorted and the numbers of each were recorded. The relative percentage of the planktonic foraminifera were graphed at the generic level, with some subdivision into species for those of particular interest. (Figure 2.1).

Due to their very nature, thin sections were approached differently. For each, ten lØx power views were checked and the number of each planktonic species recorded. Thus, for each sample, the number of planktonic foraminifera from some sixty views was amassed. Thin section identification of planktonic foraminifera is poorly covered in the literature. In this study comparisons were made with Glaessner (1937), Pessagno (1967), Postuma (1971) and Fleurry (1980).





2.4 Optical Photomicroscopy.

Plane polarized photomicroscopy was performed using an Olympus Vanox Microscope and overhead mounted Olympus C-35 AD camera with Kodacolour CP135-36 film. For cross polarized photomicroscopy an Olympus Vanox polarising microscope was used with same film and camera attachment.

This arrangement provided the oppurtunity of maintaining a pictorial record of the faunal content. Each photograph was coded and a record kept.

2.5 Scanning Electron Microscopy.

The selected specimens were affixed to the stub with double sided tape. This was coated with approximately 10Å of Au. All pictures were taken using a Joel JSM\T-20 electron microscope. A record was kept of each photograph and a note made of the stub number, magnification, the identity of the specimen and its orientation.

2.6 X-Ray Photomicroscopy.

To facilitate the rapid and efficient biometric analysis of many planktonic specimens, they were X-rayed first and then analysed with an optical microscope. The technique was amended from Hedley (1951), Arnold (1982) and Be <u>et al</u>. (1969) as the Kodak films they advocated are not available in the U.K..

The specimens were photographed using a scanray Torrex 150 D X-ray machine with Mx5 high resolution film (9x12cm) and an exposure of 3.4 mA minutes (20kV) at a distance of 30cms. Specimens were lightly glued and orientated using a paint brush on a cell (Text Figure 2.1) and the source of the specimens recorded.

0.5 cm. perspex Text-figure 2.1 Xray cell Cling film wrapped taut under one surface and affixed to the outer edge

Three cells were photographed at once with metal alphabet labels to avoid confusion. The processed cells were cut to a relevant size and positioned between two labelled glass slides. Optical microscopy was then performed using the same equipment as previously described in 2.4.

Chapter 3: Description of localities.

3.1 Introduction.

The spatial distribution of localities examined during the present study (Enclosure 1) shows that they form a transect from the eastern passive margin of the North Atlantic Ocean (Goban Spur, B.P 93\2-1) through to the clastic dominated and attenuated facies of South East Devon (Beer Stone Adit, Shapwick Grange Quarry), and onto the more marly facies of the Anglo-Paris Basin (White Nothe, Compton Bay, Eastbourne, Dover, BritOil 48\22-1).

As a result of both the marked facies variations and the contrast between studies of off-shore and on-shore material, three different lithostratigraphic schemes exist, (though the Plenus Marls is common to two). No standard lithostratigraphic framework is used for the material recovered by the Deep Sea Drilling Project.

3.2 The eastern Atlantic passive margin.

Structurally, the region is dominated by Mesozoic en-echelon listric normal faults associated with a period of extension (Graciansky <u>et al.</u>, 1985), the South Celtic Sea Basin being separated by an extension of the Cornish Palaeozoic basement (Weighall, 1979).

Figure 3.1 shows the location of B.P borehole $93\2-1$ (lat.50°57'19.8"N; long.06°46'56.5"W), which was drilled to a

Figure 3.1 Location of DSDP Leg80, Site 551 and BP Borehole 93/2-1



Depths are in metres below sea level.Regional ages refer to age of surficial rocks.After de Graciansky, Poag and Foss (1985). Base map after Montadert. Roberts,de Charpel, et al. (1979). depth of 2,127m. The Cretaceous deposits commence at 266m and comprise a thick sequence of chalk (814m), which ranges from soft white micritic limestones to well-indurated micrites. At 1,110m the lithology shows a marked change to calcareous silty mudstones (35m) which are underlain by interbedded calcareous siltstones and mudstones and, at 1,150m by Wealden deposits (Williamson, 1979). Albian, Cenomanian and Turonian sediments are all represented. Above these is a hiatus which is overlain by Campanian and Maastrichtian deposits. The Cenomanian -Turonian boundary is placed at the top of the calcareous silty mudstones (op cit.). Side-wall core and ditch cutting samples were analysed from the Upper Cenomanian and Turonian.

Site 551, Leg 80 is located at lat.48°54.64'N; long.13°30.09'W (Figure 3.1), and was drilled to a depth of 3,887m. The lowest sediments were 4.1m of Late Cenomanian nannofossil chalk which rested unconformably on basaltic basement. These were overlain by 4.1m of black, organic rich, finely laminated shale which grades into pale green nannofossil chalk (2.1m) of early Turonian age. The overlying 31.6m of light grey nannofossil chalk was dated as Late Campanian and Maastrichtian in age, indicating that Upper Turonian – Upper Campanian sediments are absent (Graciansky <u>et al</u>, 1985; Ball, 1985) (see Figure 5.1.).

The syn-rift sedimentary sequences of the Goban Spur are considerably less complete than the more expansive deposits of the South Celtic Sea Basin (B.P $93\2-1$). This may to some

extent be related to the positioning of the Goban Spur DSDP sites on the thinnest Mesozoic drape away from the fault escarpments.

3.3 South-east Devon.

The Cretaceous outliers of south-east Devon contain sediments of Albian-Cenomanian age (Hart, 1982a; Jarvis and Tocher, 1987). The Cenomanian sequence is highly attenuated and comprises a sequence of limestones punctuated by numerous hardgrounds (Jarvis and Woodruff, 1984; Jarvis and Tocher, 1983). As a consequence, a revised lithostratigraphic scheme has been erected which provides much more detail than the standard stratigraphy of the central Anglo-Paris Basin (Hamblin and Wood, 1976; Jarvis and Woodruff, 1984); see 3.4.

The thickest, most complete section is at Hooken Cliffs (Figure 5.3), where the Beer Head Limestone (Cenomanian) attains a thickness of 12.4m. Its uppermost unit, the Pinnacles Member, is a quartzose and glauconitic biomicrite with weakly developed nodular horizons, the top being the heavily indurated Haven Cliff Hardground. The overlying Connett's Hole Member of the Seaton Chalk (Turonian) is a nodular chalk containing abundant inoceramid debris with many incipient hardgrounds at its base (Figure 5.3). Access to Hooken Cliffs was limited because of dense undergrowth, but with the aid of a rope samples could be collected 2m into the Connett's Hole Member.

To the east, a working concern, Shapwick Grange Quarry

Figure 3.2 Location of Hooken Cliffs, Beer


(Figures 3.3, 5.6), exposes Upper Greensand, Beer Head Limestone (Cenomanian) and Seaton Chalk (Turonian), (Hart <u>et</u> <u>al.</u>, 1979; Jarvis <u>et al</u>. in press). The Upper Greensand comprises yellow to light grey, occasionally trough cross-bedded, medium-coarse calcarenites which locally contain proportions of coarse quartz and glauconite sand. The top of the Upper Greensand is marked by the heavily mineralized Humble Point Hardground.

The Beer Head Limestone (70cm) is much reduced, compared to Hooken Cliffs, and the Humble Point Hardground is overlain by 35cm of strongly indurated yellow nodular micrite with scattered quartz sand and glauconite. This represents the Haven Cliff Hardground portion of the Pinnacles Member. The top surface of the Haven Cliff Hardground marks the base of the Seaton Chalk.

The Seaton Chalk (19m) consists of 0.5-lm thick weakly developed rhythms of alternating nodular and marly chalks. At its base, a 5cm thick moderately indurated nodular hardground is present above the Haven Cliff Hardground (op.cit.), Figure 5.6.

The high clastic component and laterally persistant and accreting hardgrounds are characteristic of the Cenomanian and lower Turonian of south-east Devon. This probably reflects the influence on sedimentation of the high Cornubian Massif to the north-east.

Figure 3.3 Location of Shapwick Grange Quarry



3.4 Southern England onshore Anglo-Paris Basin.

The Cenomanian (65+m) and Turonian (70+m) sequences of S.E England are considerably thicker (Jukes-Browne and Hill, 1903) than those further west and consist of soft white chalks with varying amounts of marl. The early tripartite subdivision of the Chalk Group has recently been revised (Mortimore, 1986; Robinson, 1986) and the relevant lithostratigraphic units, in ascending order, comprise the Abbots Cliff, Plenus Marl and Dover Formations. Four localities (Dover, Figure 3.4; Eastbourne, Figure 3.5; Isle of Wight, Figure 3.6; White Nothe, Figure 3.7) across the interval were sampled.

Only the top few metres of the Abbots Cliff Formation were sampled at all localities. These consist typically of rhythmically bedded chalks and marls (Text Plate 1), often displaying intense bioturbation.

The base of the Plenus Marls is marked by the sub-Plenus erosion surface which can be recognized throughout the Anglo-Paris Basin (Jeffries, 1962, 1963) (Text Plates 2 and 4). In most of the Basin the Plenus Marls consist of 8 distinct units which vary in thickness locally (Text Plates 3 and 4).

The Shakespeare Cliff Formation at Dover consists of finely bedded (0.2-0.3m) nodular chalks containing coarse bioclastic material at its base, expanding into more marly chalks (Text Plate 3). In contrast, the Shakespeare Cliff Formation to the West is more marly (Text Plate 5) throughout.



Figure 3.4 Location of Dover







The Dover section is made up of a composite from Abbots and Shakespeare Cliffs.

3.5 The North Sea.

The high degree of lithostratigraphic resolution possible with on-shore sequences is not possible with off-shore material. A standard lithostratigraphic scheme operates in the North Sea (Deegan and Scull, 1977).

The relevant units comprise the Hidra Formation (Cenomanian), Plenus Marl Formation (Late Cenomanian) and Hod Formation (Turonian to Campanian). The Hidra - Plenus Marl formational boundary is marked by a distinctive higher gamma ray response, and the Plenus Marl - Hod formational boundary by a return to the lower gamma ray signature. The latter boundary may be more transitional than the lower one (Deegan and Scull, 1977).

The Sole Pit Basin contains over 1,000m of Upper Cretaceous chalk sedimentation (Hancock, 1983, 1984). BritOil well 48\22-1 is situated at lat.53°15'15"N; long.01°23'08"E (Enclosure 1), and yielded 86m of Upper Cretaceous carbonates. The weak gamma ray response shows that the Plenus Marl Formation is poorly developed at 121m (Figure 5.16). Washed and dried ditch cuttings were analysed from 50m either side of the Plenus Marl Formation.

Text Plate 1.

Top of Abbots Cliff Formation, Gun Gardens (Eastbourne), showing rhythmic sedimentation. The slight colour contrast in the marl highlighting the intense bioturbation.

The Estwing hammer is approximately Ø.3m long.

Text Plate 2.

Abbots Cliff, Plenus Marl and Dover Formations, Compton Bay, Isle of Wight. The figure is pointing to the the sub-Plenus erosion surface.

View looking east.



Text Plate 3.

Plenus Marls and base of Shakespeare Cliff Member (Dover Formation), Abbots Cliff, Dover. The more nodular chalks of the Shakespeare Cliff Member standing proud above the softer Plenus Marls.

The hammer is approximately Ø.3m long.



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Text Plate 4.

Plenus Marls and Shakespeare Cliff Formations, Gun Gardens, Eastbourne. The figures' head marks the level of the sub-Plenus erosion surface. The basal beds of the Shakespeare Cliff Formation are of a more marly facies than at Dover (Text Plate 3).



Text Plate 5.

Basal beds of Shakespeare Cliff Formation and top of Plenus Marl Formation, Gun Gardens, Eastbourne. Note the more marly former as opposed to Dover.

Figures' head marks base of Shakespeare Cliff Formation.



Chapter 4: Systematic micropalaeontology.

For the purposes of this study the basic classification framework of Loeblich and Tappan (1964) has been followed. Minor generic and specific alterations are recommended and are highlighted at the appropriate points in the text.

All groups have been viewed as moving populations and thus many previously established species are viewed as ecophenotypic variations. Where possible, this has been acknowledged but the high degree of subgeneric subdivision in the literature, especially for the Nodosariidae, has meant the adoption of a "local" taxonomy.

The occurrence of each species is listed as a set of the appropriate samples, the exact position of which may be determined by consulting the relevant sedimentary log.

Unlike the previous foraminiferal studies (Hart, 1970; Owen, 1970) with their emphasis on taxonomic relationships, in this study lists of references are kept to a minimum. If a previous published list of references is thought relevant, it is cited.

The taxonomic revision proposed by the European Working Group on planktonic foraminifera (Robaszynski and Caron, 1979) has largely been adopted. Any evolutionary relationships are covered in Chapters 6 and 7.

Order FORAMINIFERIDA Eichwald, 1830 Suborder Textulariina Delage and Herouard, 1896 Superfamily Ammodiscacea Reuss, 1862 Family Ammodiscidae Reuss, 1862 Subfamily Ammodiscinae Reuss, 1862

Genus <u>Ammodiscus</u> Reuss, 1862 Genotype <u>Ammodiscus infimus</u> Bornemann, 1874

> Ammodiscus cretaceous (Reuss), 1845 Pl. 1, Figs 1-7.

- 1845 Operculina cretacea Reuss, p. 35, pl.8, figs. 64, 65.
- 1860 Cornuspira cretacea (Reuss); Reuss, p.177, pl.1, fig.la, b.

1934 Ammodiscus cretacea (Reuss);Cushman,p.45.

1946 Ammodiscus cretaceus (Reuss);Cushman,p.17,pl.1,fig.35.

Occurrence: B.P. 93/2-1,6,9; SGQ 7,18; WND 1,2,13,14,19,20,22; CBI 1,4-6,8,17,26,32,35,36; EGG 1,11-15,18,20,25,26,31,32; ABC 4, 9,11,13,19; AKS 8,12,13; BritOil 48/22-1 3-16,18.

<u>Remarks: A. cretaceus</u> shows some small variation in outline from circular to ovoid. The number of whorls may be between 6 to 11 but usually number 8.

> Superfamily Lituolacea de Blainville, 1825 Family Lituolidae de Blainville, 1825

Subfamily Lituolinae de Blainville, 1825

Genus <u>Ammobaculites</u> Cushman, 1910 Genotype Spirolina agglutinans D'Orbigny, 1846

Ammobaculites sp.a

Pl. 1, Fig. 8.

<u>Description</u>: The chambers increase moderately in size around the initial planispiral portion of the test but only slightly in the latter uniserial portion. The sutures are markedly depressed. The rounded terminal aperture is large.

Occurrence: WND 10,11; CBI 1,2.

<u>Remarks</u>: The chambers in the uniserial portion of the test may be moderately inflated.

Genus <u>Haplophragmium</u> Maync, 1952 Genotype Haplophragmium aequale Reuss, 1860

Haplophragmium aequale Reuss

Pl. 1, Figs. 9-12

1866 Haplophragmium aequale Reuss, p.218, pl.11, fig.2a.

1946 Haplophragmium aequale Reuss, ten Dam, p. 570, pl. 87, figs. 3-4.

Occurrence: B.P. 93/2-1 1,4,7; WND 1; CBI 5.

Remarks: A very rare species which shows much variation. The later

uniserial portion may be moderately to markedly compressed.

Subfamily Placopsilininae Rhumbler, 1913

Genus <u>Subbdelloidina</u> Frentzen, 1944 Genotype <u>Subbdelloidina</u> haeusleri Frentzen

cf. Subbdelloidina sp.a

Pl.1, Fig. 13

Description: Test finely agglutinated, well rounded chambers with depressed sutures. The chamber size varies slightly.

Occurrence: CBI 4.

<u>Remarks</u>: Only one specimen was found the aperture of which was indistinct.

Family Textulariidae Ehrenburg, 1838 Subfamily Textulariinae Ehrenburg, 1838

Genus <u>Textularia</u> Defrance in de Blainville, 1824 Genotype Textularia saggittula Ehrenburg, 1839

Textularia chapmani Lalicker

Pl. 1, Figs 14,15
Pl. 2, Figs 1-14
Pl. 3, Figs 1-8

1935 <u>Textularia chapmani</u> Lalicker, p. 13, pl. 2, figs. 8, 9.

1962 Textularia chapmani Lalicker; Jefferies, pl. 78, fig. 23.

Occurrence: B.P. 93/2-1 2,7; WND 11,19; CBI 2,12-18; EGG 9-14, 16,17; ABC 8-14; BritOil 48/22-1 8,9.

<u>Remarks</u>: The sutures may be markedly to moderately depressed. The number of chambers varies from 10-15. The aperture may be deep or narrow but is predominantly the former. <u>T. chapmani</u> has been recorded from the rocks of Albian - Cenomanian and Lower Turonian age (Jefferies, 1962; Hart, 1970; Owen, 1970) in southern England. Occasionally, a smaller form, <u>T. minuta</u> Berthelin, has been associated with <u>T. chapmani</u>, in the Plenus Marls (Jefferies, 1962), in the Gault Clay (Hart, 1970). The distinguishing feature of <u>T. minuta</u> being its small size.

A study of the textularid population from Dover, measuring the height and width, (Text Figure 4.1),

Text-figure4.1 Measured characteristcs of *Textularia chapmani* Lalicker

and counting the chambers, shows that there is no simple relationship. The populations from ABC 9-11 show a systematic



linear trend with an increase in size with chamber addition. The populations from ABC 12-14 are too small to show any trend but all the forms are the corresponding size for their respective number of chambers as the specimens from ABC 9-11. Except for one specimen from ABC 13 which exhibits the size equivalent to eleven chambers but possesses thirteen.

Thus the smaller forms, referred to as \underline{T} . <u>minuta</u> are probably immature forms, though there is some evidence of dwarfism in ABC 13. A further study of larger populations and from other localities would be required to completely elucidate any relationships.

Importantly, the moving population does exhibit a reduction in size and a lowering in population numbers.

Subfamily Pseudobolivininae Wiesner, 1931

Genus <u>Pseudobolivina</u> Wiesner, 1931 Genotype <u>Pseudobolivina</u> antarctica

Pseudobolivina sp.a

Pl. 3, Figs 9-10.

<u>Description</u>: Test is coarsely agglutinated, with only the last two chambers tending towards the uniserial form. The test is moderately twisted. The chambers increase moderately in size along the test and the sutures are slightly depressed. The aperture is subrounded, slightly raised and terminally positioned.

<u>Occurrence</u>: Goban Spur 5/2 13-17 <u>Remarks</u>: P. sp.a only appears in one sample and in very small numbers.

> Family Trochamminidae Schwager, 1877 Subfamily Trochammininae Schwager, 1877

Genus <u>Trochammina</u> Parker and Jones, 1859 Genotype <u>Nautilus inflatus</u> Montagu, 1801

> Trochammina depressa Lozo, 1944 Pl. 3, Fig. 11.

1944 Trochammina depressa Lozo, p.552, pl.2, figs 4-5.

1970 Trochammina depressa Lozo; Owen, p. 45, 46, pl.3, figs 14-16.

Occurrence: B.P. 93/2-1 2; WND 11; CBI 2,4.

Remarks: T. depressa was only found in small numbers.

Family Ataxophragmiidae Schwager, 1877 Subfamily Verneuilininae Cushman, 1911

Genus <u>Pseudospiroplectinata</u> Gorbenko, 1957 Genotype <u>Pseudospiroplectinata</u> plana Gorbenko

> <u>Pseudospiroplectinata plana</u> Gorbenko Pl. 3, Figs 12-17.

1957 <u>Pseudospiroplectinata plana</u> Gorbenko,p.879,text fig.l,a-c. 1970 <u>Pseudospiroplectinata plana</u> Gorbenko;Owen,p.87-88,pl.9, fig.l-2.

<u>Occurrence</u>: WND 2-6,8,9; CBI 1,10,15; EGG 2-7; ABC 7,8. <u>Remarks</u>: The initial chambers may be in the same plane as the rest of the test or offset at an angle of 40°. The test is not always totally planar but may be slightly twisted. The number of chambers in the later uniserial portion of the test varies greatly. The aperture may be ovate to subrounded.

Genus Tritaxia Reuss, 1860

Genotype Textularia tricarinata Reuss, 1844

Tritaxia macfadyeni Cushman

Pl. 4, Figs 1-13.

1936 Tritaxia macfadyeni Cushman, p. 3, pl. 1, fig. 6a-b.

1948 <u>Tritaxia macfadyeni</u> Cushman; Williams-Mitchell, p. 48, pl. 8, fig. 2.

1953 <u>Tritaxia macfadyeni</u> Cushman; Barnard and Banner, p. 195, pl.7, fig.2a-b.

Occurrence: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; 5/2 13-17; 5/1 101-106; BSA 1; WND 1,2,4,6,10; CBI 1,4,5,8-10; EGG 1,2,4,7-9; ABC 1,2,4,5,7,8. <u>Remarks</u>: <u>T. macfadyeni</u> varies in the number of chambers present in the late stage, uniserial portion, of the test, though most specimens have 3-4 chambers. In addition, these chambers may not be added along the same axis, forming a twisted test.

Tritaxia pyramidata Reuss

Pl. 4, Fig. 3.

1862 Tritaxia pyramidata Reuss, p. 32, 88, fig.9a-c.

1928 Tritaxia pyramidata Reuss; Franke, p. 138, pl.7, fig. 18a-c.

1948 <u>Tritaxia pyramidata</u> Reuss;Williams-Mitchell,p.98,pl.8, fig.5a-c.

1950 Tritaxia pyramidata Reuss;ten Dam,p.12-13.

1953 <u>Tritaxia pyramidata</u> Reuss;Barnard and Banner,p.195,pl.7, fig.la-b.

Occurrence: B.P. 93/2-1 1; BSA 4; WND 1-11; CBI 1-11; EGG 1-10; ABC 1-6; BritOil 48/22-1 8.

<u>Remarks:</u> <u>T</u>. <u>pyramidata</u> is very distinctive and forms the dominant proportion of the <u>Tritaxia</u> population until its extinction when <u>T</u>. tricarinata takes over.

Tritaxia tricarinata (Reuss) Reuss, 1860

Pl. 5, Figs. 1-7.

1844 Textularia tricarinata Reuss, p. 215.

1845 Textularia tricarinata Reuss; Reuss, p. 39, pl.8, fig. 60.

1860 Tritaxia tricarinata (Reuss); Reuss, p. 228, pl.7, figs 1, 2.

1937 Tritaxia dubia (Reuss);Cushman,p.26,pl.4,figs 1-4.

1953 <u>Tritaxia tricarinata</u> (Reuss);Barnard and Banner,p.193, pl.8,fig.la-e,text fig.3a-j.

1966 Tritaxia tricarinata (Reuss);Butt,p.171,pl.1,fig.1.

<u>Occurrence</u>: Goban Spur 5/2 13-17; BSA 6; SGQ 8,9,12-17,19,20,23; WND 14; CBI 11,17,26,28; EGG 11-17; ABC 5-9,19; AKS 1. <u>Remarks</u>: Through the Plenus Marls the overall test form of <u>T</u>. <u>tricarinata</u> varies (Pl.5, Figs.1-7), with a decrease in the concavity of the test sides and a general rounding of the overall test. Banner and Desai (1985) postulate the phylogenic relationship of <u>T</u>. <u>pyramidata</u> - <u>T</u>. <u>tricarinata</u> but the populations over this interval indicate that they are distinct, although it is possible that this is manifested in specimens from older rocks.

Tritaxia tricarinata var. jongmansi

Pl. 5, Figs. 8-15.

1946 <u>Tritaxia compressa</u> Schijfsma, (non Egger 1899-1900),p.33, pl.1,fig.5a-b.

1950 <u>Tritaxia jongmansi</u> Schijfsma (nom.nov. for <u>T.compressa</u> Schijfsma (1946)),p.43.

1953 <u>Tritaxia jongmansi</u> Schijfsma;Barnard and Banner,p.195-196, pl.8,fig.2a-b,text fig.3k-1.

Occurrence: BSA 10,11; WND 19,21-29; CBI 29,31,34,35; EGG 25,

30-34; AKS 10-12; BritOil 48/22-1 19.

<u>Remarks:</u> <u>T</u>. <u>tricarinata</u> var jongmansi differs from <u>T</u>. <u>tricarinata</u> by the abrupt termination of the test giving it a wider test approximately three-quarters of the way down.

Subfamily Globotextulariinae Cushman, 1927

Genus Arenobulimina Cushman, 1927

The arenobuliminid group has recieved much attention. The European Albian lineages were established as <u>A</u>. <u>chapmani</u> Cushman giving rise to <u>A</u>. <u>frankei</u> Cushman, <u>A</u>. <u>truncana</u> (Reuss), <u>A</u>. <u>obliqua</u> (d'Orbigny) and <u>A</u>. <u>advena</u> (Cushman) in a late Albian radiation. This scenario was confirmed, with minor extinctions and no evolutionary radiations through the Cenomanian, except for the development of <u>A</u>. <u>preslii</u> (Reuss) from <u>A</u>. <u>advena</u> just below the Plenus Marls (Carter and Hart, 1977).

The differentiation of simple interiored forms (under <u>Arenobulimina</u> s.s) and those with partitions (under <u>A</u>. (<u>Voloshinoides</u>)) (Barnard and Banner, 1980), has not been adopted as partitions are difficult to differentiate and their development appears highly variable.

Genotype Bulimina preslii Reuss, 1846

Arenobulimina advena Cushman, 1936 Pl. 6, Figs 5-8.

1936 Hagenowella advena Cushman, p.43, pl.6, fig.21a-b.

1969 Arenobulimina advena (Cushman); Gawor-Biedowa, p.86-90.

1977 <u>Arenobulimina advena</u> (Cushman);Carter and Hart,p.14,pl.2, fig.4.

Occurrence: Goban Spur 6/2 26-29; B.P. 93/2-1 1-4,6,8; BSA 5; WND 1-5,7-10; CBI 1,2,5,6,9,10; EGG 1,3,5,6; ABC 1,2,4,6,7; Britoil 48/22-1 1,2,10,11,13.

Arenobulimina bulletta (Barnard and Banner)

Pl. 6, Figs 1-4.

1980 <u>Arenobulimina</u> (Voloshinoides) <u>bulletta</u> (Barnard and Banner), p.408-410,pl.3,figs 1-6;pl.6,figs 14-20.

Occurrence: ABC 1.

<u>Remarks: A. bulletta</u> is highly distinctive because of its large size and bullet-like test shape. Its appearance is spasmodic and its relationship to the A. advena - A. preslii plexus is unclear.

Arenobulimina preslii (Reuss)

Pl. 6, Figs 9-10.

1845 Bulimina preslii Reuss, p. 38, pl. 13, fig. 72.

1934 <u>Arenobulimina preslii</u> (Reuss);Cushman and Parker,p.29,Pl.5, figs 12-13. Occurrence: B.P. 93/2-1 10-12; CBI 32,34-36; EGG 22,30-34; AKS 2; BritOil 48/22-1 19.

<u>Remarks</u>: This morphotype with a flattened apertural face and inflated chambers is characteristic of the early Turonian (Owen, 1970).

Arenobulimina sp.a

Pl. 6, Figs 11-12.

<u>Description</u>: Test is small and coarsely agglutinated, the chambers increase rapidly in size giving the test an inflated subtriangular appearance. The aperture is small and depressed.

Occurrence: BSA 3-5; WND 3-5,8; CBI 5-10; EGG 2-4,13; ABC 4.

<u>Remarks</u>: A. sp.a occurs as a minor portion of the <u>A</u>. <u>advena</u> population but is very small in comparison. It may well be a variant of that population or the megalosperic form of <u>A</u>. <u>advena</u> (Carter and Hart, 1977).

> Genus <u>Dorothia</u> Plummer, 1931 Genotype Gaudyrına bulleata Carsey, 1926

> > Dorothia gradata (Berthelin) Pl. 6, Figs 13-14.

1880 Gaudrina gradata Berthelin, p.24, pl.1, fig 6a-b.

1937 <u>Dorothia gradata</u> (Berthelin);Cushman,p.74,pl.8,fig 5a-b.
1950 <u>Dorothia gradata</u> (Berthelin);ten Dam,p.16.
1970 Dorothia gradata (Berthelin);Hart,p.110-111,pl.5,figs 1-2.

Occurrence: WND 1-11; CBI 1-6,8-10; EGG 1-7; ABC 1. Remarks: It is only present in very small numbers and forms a minor portion of the benthonic population.

Genus Marssonella Cushman

Genotype Gaudyrina oxycona Reuss, 1860.

Marssonella sp.a

Pl. 7, Figs 1-8.

<u>Description</u>: The initial portion of the test is sub-triangular passing into a sub-ovate form in cross-section. The sutures are depressed.

Occurrence: WND 11-19; CBI 11-18;EGG 9-17; ABC 8-14. Remarks: M. sp.a forms a major portion of the marssonellid population within beds 2-8 of the Plenus Marl Formation.

> Marssonella trochus (d'Orbigny) 1840 Pl. 7, Figs 9-16. Pl. 8, Figs 1-2.

1840 Textularia trochus d'Orbigny, p.45, pl.4, fig 25-26.

1937 Marssonella oxycona (Reuss);Cushman,p.58,pl.6,fig 6-7,16.

Occurrence: Goban Spur 6/2 70-72; B.P. 93/2-1 7,8; BSA 7-8; WND 2,12,14,16,23,24; CBI 2-4,6,11,14,16-18,22,24; EGG 2,10,14,16,19, 22,26,27,29; ABC 2,3,5,8,9; AKS 6,10,11,13; BritOil 48/22-1 4,14, 19.

<u>Remarks</u>: The distinction of <u>M. trochus</u>, <u>M. turris</u> and <u>M. oxycona</u> is largely based on the apical angle: <u>M. oxycona</u> with an angle>45° and <u>M. turris</u> with an angle<45°, (Owen, 1970). This is a function of the rate of increase in chamber height with respect to width as they are added around the test, <u>M. trochus</u> being distinguished by the development of slight concavity when viewed in side view. The closeness between these forms has been noted (Barnard and Banner, 1953; Hart, 1970), with their synonomy under M. trochus.

A scanning electron microscopy study was made of the marssonellid population from Dover. For each specimen the maximum apical angle was measured, as not all specimens were circular in cross-section and plotted against the outcrop (Figure 4.2), and an apical angle frequency was constructed (Figure 4.3). Figure 4.3 shows that the subdivision of the marssonellid population on the basis of the apical angle is artificial and that the apical angle of the population varies consistantly through the section. The "early" forms in each population possess a narrow apical angle, with the development of the population the apical angle increases and decreases as the population wanes. It indicates that there may be several periods of recolonization of the niche after vacation (Figure 4.2).

M. trochus has precedent over M. turris and M. oxycona



Figure 4.2 Apical angle of Marssonellid population from Dover

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Figure 4.2 Apical angle of Marssonellid population from Dover(cont.)


but to note the relevant dominance of each morphotype it is proposed to place \underline{M} . <u>turns</u> and \underline{M} . <u>oxycona</u> as varieties of \underline{M} . trochus.

Marssonella. trochus var. oxycona Pl. 8, Figs 7-9. Pl. 9, Figs 11-16.

1860 Gudryina oxycona Reuss, p.229, pl.12, fig.3.

1937 Marssonella oxycona (Reuss);Cushman,p.56,pl.6,figs 6-7.

Occurrence: Goban Spur 6/2 70-72; 5/2 13-17; B.P. 93/2-1 2-4,6,7, 9,11-15; BSA 10-13; SGQ 8,9,12-17; WND 1-3,5,6,8,22,23,25,26,28; CBI 4,10,14,16,18,19; EGG 2,3,14,15,19,22,26,27,30,33,34; ABC 1-3, 5,6,11,12,21; AKS 1,5,6,9-11; BritOil 48/22-1 12.

> Marssonella. trochus var. turris Pl. 8, Figs 3-6. Pl. 9, Figs 1-10.

1840 Textularia turris d'Orbigny, p. 46, pl. 4, figs 22, 28.

Occurrence: Goban Spur 5/2 13-17; B.P. 93/2-1 1-3,5,6,11-14; BSA 3-8,10,11; SGQ 7,8; WND 1-10,13,15-29; CBI 2-6,8,10-14,18-23, 24; EGG 1-5,11-15,17,19-26,28,29,31-34; ABC 1-3,5,8-14,19,21; AKS 1,3-5,7,9-13; BritOil 48/22-1 1,2,5,7,9,11,13,14,16.

Genus Eggerellina Marie, 1941

Genotype Bulimina brevis d'Orbigny, 1840

The specific subdivision of <u>Eggerellina</u> in the mid-Cretaceous has proved problematic, with consistant morphotypes through the Albian - Cenomanian and Turonian but with a proliferation of forms in the Plenus Marls (Carter and Hart, 1977). Carter and Hart (1977) placed emphasis on this short term proliferation and interpreted all the forms as ecophenotypic variations of <u>E. mariae</u> ten Dam. As this study is primarily concerned with the late Cenomanian the approach of Owen (1970) has been adopted.

> Eggerellina brevis (d'Orbigny) var. <u>conica</u> Marie Pl. 10, Figs 1-6.

1941 <u>Eggerellina brevis</u> (d'Orbigny) var. <u>conica</u> Marie,p.34, pl.7,fig.70.

1970 <u>Eggerellina brevis</u> (d'Orbigny) var. <u>conica</u> Marie;Owen, p.63-64,pl.5,figs 6-9.

<u>Occurrence</u>: Goban Spur 6/2 70-72; B.P. 93/2-1 8; WND 3,5-8,14-16; CBI 2-6,10-13,15-18; EGG 9,10,12,14; ABC 1-3,5,7-12. <u>Remarks: E. brevis</u> (d'Orbigny) var. <u>conica</u> Marie occurs in very large numbers in some samples from the Plenus marls. The variability in the size and shape of the aperture noted by Owen (1970), has been bourne out in this study.

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Eggerellina mariae ten Dam, 1950

Pl. 10, Figs 7-9.

1950 Eggerellina mariae ten Dam, p.15-16, pl.1, fig. 17.

Occurrence: B.P. 93/2-1 1,4-8; WND 3,6,8,11,13-17; CBI 1-2,6, 11-14,16-20;EGG 4,5,10-14,16; ABC 1-3,5-7,9-12; BritOil 48/22-1 7,9.

Eggerellina murchisoniana (d'Orbigny), 1840 Pl. 10, Figs 10-11.

1840 Bulimina murchisoniana d'Orbigny, p.41, pl.4, fig. 15.

1953 Eggerellina intermedia (Reuss);Barnard, in Barnard and Banner,p.203.

1970 Eggerellina murchisoniana (d'Orbigny);Owen,p.64-65,pl.6, figs 1-4.

Occurrence: ABC 10,11.

<u>Remarks: E. murchisoniana</u> only occurs in small numbers when present.

Subfamily Valvulininae Berthelin, 1880

Genus <u>Plectina</u> Marsson, 1878 Genotype <u>Gaudyrina ruthenica</u> Reuss, 1851

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Plectina mariae (Franke)

Pl. 11, Figs 1-2.

1928 <u>Gaudyrina ruthenica</u> Reuss var. <u>mariae</u> Franke,p.146,pl.13, fig.15a-b.

1937 <u>Plectina ruthenica</u> (Reuss) var. <u>mariae</u> (Franke);Cushman, p.106,pl.11,fig.15.

1970 <u>Plectina mariae</u> (Franke);Owen,p.84-86,pl.9,figs 4-7,text fig.32.

Occurrence: B.P. 93/2-1 6-8; BSA 3; WND 3-10; CBI 1-6,9,10; EGG 2,4-9; ABC 1-3; BritOil 48/22-1 15,16,17.

<u>Remarks</u>: The variability in the size, shape and position of the aperture as noted by Owen (1970), has been bourne out in this study.

Plectina cenomana (Carter and Hart)

Pl. 11, Figs 13-14.

1970 "Plectina" sp.21, sp.nov. Hart, p.114, pl.5, fig.12.

1977 Plectina cenomana Carter and Hart, p.12-13, pl.2, fig.9.

<u>Occurrence</u>: WND 3,6,7,10,12; CBI 2-7; EGG 1,5-10; ABC 5,7,8. <u>Remarks: P. cenomana</u> occurs after the disappearance of <u>P. mariae</u>. It may be an ecophenotypic variation of the latter, but has been noted from lower in the Cenomanian (zones 11-13 of Carter and Hart, 1977). Subfamily Ataxophragmiinae Schwager, 1877

Genus <u>Ataxophragmium</u> Reuss, 1860 Genotype <u>Bulimina variabilis</u> d'Orbigny, 1840

> Ataxophragmium depressum (Perner) 1892 Pl. 12, Figs 1-11.

1892 Bulimina depressa Perner, p.55, pl.3, fig. 3a-b.

1964 <u>Ataxophragmium depressum</u> (Perner);Loeblich and Tappan, p.C283,fig.191.3,4.

Occurrence: B.P. 93/2-1 4; BSA 4,6; WND 1; CBI 1,4,9,10; EGG 8; ABC 3,5-8.

<u>Remarks</u>: <u>A</u>. <u>depressum</u> first appears in the very top of the Abbots Cliff Formation with small and rare specimens, increasing rapidly both in the size of the specimens and abundance in bed 1 of the Plenus Marls to disappear at the top of bed 1.

> Family Pavonitinidae Loeblich and Tappan, 1961 Subfamily Pfenderininae Smout and Sugden, 1962

Genus <u>Pseudotextulariella</u> Barnard, in Barnard and Banner.

Genotype Textulariella cretosa Cushman, 1932

<u>Pseudotextulariella cretosa</u> (Cushman), 1932 Pl. 13, Figs 1-3.

1926 <u>Textulariella cretosa</u> Cushman, p. 97, pl.11, figs 17-19. 1953 <u>Pseudotextulariella cretosa</u> (Cushman); Barnard (in Barnard and Banner), p. 198, fig. 6b-c.

1977 <u>Pseudotextulariella cretosa</u> (Cushman);Carter and Hart,p.23, pl.2,figl2.

Occurrence: B.P. 93/2-1 2; BSA 1,3,5,6; BritOil 48/22-1 6-8,10, 11,13.

<u>Remarks: P. cretosa</u> is particularly common in the lower levels of the Cenomanian (Hart, 1970; Carter and Hart, 1977). It only occurs in very small numbers in the Upper Cenomanian and the specimens were much smaller than those described (op cit.).

Suborder Miliolina Delage and Herouard, 1896 Superfamily Miliolacea Ehrenburg, 1839 Family Nubeculariidae Jones, 1875 Subfamily Quinqueloculininae Cushman, 1917

Genus <u>Quinqueloculina</u> d'Orbigny, 1826 Genotype <u>Serpula seminulum Linne</u>, 1758

> Quinqueloculina antiqua Franke Pl. 13, Figs 4-5.

1891 Miliolina venusta Karrer; Chapman, p.9, pl.9, figs 5-6.

1928 <u>Miliolina</u> (<u>Quinqueloculina</u>) <u>antiqua</u> Franke,p.126,pl.11, fig.26.

Occurence: B.P. 93/2-1 6; WND 4; CBI 17,19,20,22,24,32; EGG 5; BritOil 48/22-1 15,16.

<u>Remarks: Q. antiqua</u> occurs in very small numbers when it is present.

Suborder Rotaliina Delage and Herouard, 1896 Superfamily Nodosariacea Ehrenburg, 1838 Family Nodosariidae Ehrenburg, 1838 Subfamily Nodosariinae Ehrenburg, 1838

Genus <u>Nodosaria</u> Lamarck, 1812 Genotype Nautilus radicula Linne, 1758

Nodosaria sp.a

Pl. 13, Figs 6-15.

<u>Description</u>: The chambers may be rounded, or flush, with depressed or indistinct sutures. The chambers may increase slightly in size in both width and length on addition. The aperture may be radiate and well-developed, but many forms possess indistinct apertures or with subordinate rays.

<u>Occurrence</u>: Goban Spur 6/2 70-72; 6/2 26-29; B.P. 93/2-1 2,9; WND 1,2,5,6,8; CBI 1,2,5,6,10,12,14,16,17; EGG 3-7,11,14; ABC 3-5, 8,10; BritOil 48/22-1 2. <u>Remarks</u>: The variability in test size, chamber addition, sutures, chamber shape and the development of the aperture affords little systematic subdivision of N. sp.a.

Genus <u>Astacolus</u> De Montfort, 1808 Genotype <u>Astacolus crepidulatus</u> De Montfort, 1808

Astacolus sp.a

Pl. 14, Figs 1-2.

<u>Description</u>: The test is slightly compressed with a sub-triangular terminal chamber. The sutures are moderately depressed and subtended at around 40° to the test. The aperture is well-developed with equal rays.

Occurrence: CBI 13; EGG 10,13; ABC 4,8.

Genus Dentalina Risso, 1826

Genotype Nodosaria (Dentaline) cuvieri d'Orbigny, 1826

Dentalina sp.a

Pl. 14, Figs 3-6.

<u>Description</u>: The chambers increase moderately in size on addition, dominantly lengthways as opposed to width. The sutures are strongly depressed and at 90° to the test.

Occurrence: CBI 7,8; EGG 6; ABC 4.

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Remarks: D. sp.a is markedly smaller than D. sp.b and D. sp.c.

Dentalina sp.b

Pl. 14, Figs 7-15.

<u>Description</u>: The chambers are slightly longer than wide giving the test an elongate appearance. The chambers vary in their relative increase in size on addition. The sutures are moderate to welldepressed. The apertural region may be rounded to sub-angular with an equi-ray aperture.

Occurrence: WND 3; CBI 1,3,5,6,8,10,12,14; EGG 3,5,7,11-14; ABC 5, 7-10.

<u>Remarks</u>: <u>D</u>. sp.b is more common than <u>D</u>. sp.a and <u>D</u>. sp.c and formed the dominant morphotype in the Dentalina population.

Dentalina sp.c

Pl. 14, Figs 16-18.

<u>Description</u>: The chambers increase moderately in size on addition, with well-rounded form on the more arcuate side of the test. The sutures are subtended at a low angle $(15^\circ - 20^\circ)$ to the test and are moderately depressed. The aperture is well pronounced radiate.

Occurrence: WND 2; CBI 1,2,6,8,10,12,18; EGG 5,13-15; ABC 8.

Genus <u>Frondicularia</u> Defrance in d'Orbigny, 1826 Genotype Renulina complanata Defrance, 1824

Frondicularia cordai Reuss, 1844

Pl. 15, Fig. 1.

1844 Frondicularia cordai Reuss, p. 302.

1970 Frondicularia cordai Reuss; Hart, p. 136, pl.9, fig. 12.

Occurrence: EGG 2,11; ABC 5.

<u>Remarks: F. cordai</u> is extremely rare in the sections studied but is more common in the early Cretaceous (Hart, pers. comm.).

Frondicularia gaultina Reuss, 1860

Pl. 15, Fig. 2.

1860 Frondicularia gaultina Reuss, p. 194, pl.5, fig.5.

1970 Frondicularia gaultina Reuss; Hart, p.136-137, pl.9, fig.13.

Occurrence: WND 13,24; CBI 2,9,11,14; EGG 10,13; ABC 3,21; AKS 3, 8,9,13.

<u>Remarks: F. gaultina</u> was recorded only in the Middle to Upper Albian clays by Hart (1970) and is very rare in the late Cenomanian.

Frondicularia sp.a

Pl. 15, Figs 3-4.

<u>Description</u>: The test is gradually tapering with the new chambers widening along their length. The sutures may be very prominent.

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Occurrence: WND 5,10,13,14; CBI 36; EGG 5,6,8; AKS 11. Remarks: In keeping with the other representatives of the genus, F. sp.a is very rare.

> Genus <u>Lagena</u> Walker and Jacob in Kanmacher,1798 Genotype <u>Serpula</u> (Lagena) <u>sulcata</u> Walker and Jacob,1798

Lagena sp.a

Pl. 15, Figs 5-6.

Description: The test is nearly spherical and highly perforate. The aperture is placed on a thick, gradually tapering neck.

Occurrence: Goban Spur 6/2 70-72

Genus <u>Lenticulina</u> Lamarck, 1804 Genotype Lenticulites rotulata Lamarck, 1804

> Lenticulina ovalis (Reuss) 1845 Pl. 15, Figs 7-9.

1845 <u>Cristellaria ovalis</u> Reuss, p. 34, pl. 12, fig. 19, Pl. 13, fig. 62.
1941 Lenticulina ovalis (Reuss); Marie, p. 99, pl. 9, fig. 103.

Occurrence: AKS 6.

<u>Remarks</u>: <u>L. ovalis</u> is most distinctive because of its large proloculus leading to uninflated chambers giving it a pyramidal form. It may well be an extreme form of the <u>L</u>. rotulata var. b population.

Lenticulina rotulata var. a Pl. 15, Figs 10-11. Pl. 16, Figs 1-6.

<u>Description</u>: The swept back sutures are slightly thickened and raised forming slightly concave chambers. This produces a slight squaring of the chambers in peripheral view.

Occurrence: BSA 3,4; WND 1-3,6,10,12,25; CBI 1,2,4,9,10,12,14-16; EGG 1,2,4,7; ABC 1,3-10; AKS 5,11-13; BritOil 48/22-1 6. Remarks: The raised ribs and squaring of the chambers distinguishes L. rotulata var. a. from L. rotulata var. b. In addition, the latter is predominantly thinner when viewing the apertural face.

Lenticulina rotulata var. b

Pl. 16, Figs 7-12. Pl. 17, Figs 1-12.

<u>Description</u>: The test surface is smooth with a smooth periphery. The degree of enrollment of the test varies considerably as does the height to width ratio. The angle of the test at the periphery is predominantly narrow forming a slight keel.

Occurrence: Goban Spur 6/2 70-72; 26-29; 6/1 30-33; 5/2 13-17; B.P. 93/2-1 1,4,8-10; BSA 5,6,8,10,12; SGQ 8,12-17,19-21,23; WND 1-25; CBI 1-22,24-26,28,30-32,34-36; EGG 1,2,4-11,13,14,16-19,22, 28,31-34; ABC 1 - AKS 13; BritOil 48/22-1 1,2,4,5,11,12,15,16,18. <u>Remarks</u>: The variability of <u>L</u>. rotulata var. b would allow the erection of many "species" but such a subdivision would confuse the characters contained within the population.

Lenticulina rotulata var. c

Pl. 17, Figs 13-14.

Description: The test is smooth, with a smooth periphery. The test is slightly unrolled.

Occurrence: B.P. 93/2-1 1,5,8,9,12; BSA 8; WND 9,10; CBI 10,12, 13; EGG 8; AKS 13.

<u>Remarks</u>: <u>L. rotulata</u> var. c contains all the features of <u>L</u>. <u>rotulata</u> var. b but is so unrolled as to warrant separation from the latter.

Lenticulina sp.a

Pl. 18, Figs 1-3.

<u>Description</u>: The test is small with a poorly developed keel. The chambers are markedly depressed giving the test a corrugated appearance.

Occurrence: Goban Spur 5/2 13-17; 5/1 101-106; 76-78. Remarks: Lenticulina sp.a is very distinctive and the specimens present are all of the same size.

Genus Marginulina d'Orbigny, 1826

Genotype Marginulina raphanus d'Orbigny, 1826

Marginulina sp.a

Pl. 18, Figs 4-5.

<u>Description</u>: The sutures are strongly depressed and are subtended to the test at an angle of 40° . The chambers are moderately inflated.

Occurrence: SGQ 14.

Remarks: M. sp.a is very rare in the sections studied.

Genus Marginulinopsis Silvestri

Genotype Marginulinopsis densicostata Thalmann, 1937

Marginulinopsis acuticostata Reuss

Pl. 18, Figs 6-8.

1845 Cristellaria acuticostata Reuss, p.36.

1985 <u>Lenticulina</u> (<u>Marginulinopsis</u>) <u>acuticostata</u> (Reuss); Ball, p.241,pl.5,fig.8.

Occurrence: BritOil 48/22-1 7,8.

Genus <u>Neoflabellina</u> Bartenstein Genotype <u>Flabellina rugosa</u> d'Orbigny, 1840

Neoflabellina sp.a

Pl. 19, Fig. 9.

Description: Chambers increase moderately in size on addition with less pronounced sutures in last portion of test.

Occurrence: WND 14; ABC 10

<u>Remarks</u>: <u>N</u>. sp.a is very rare and only occurs in the upper levels of the Plenus Marls.

Neoflabellina sp.b

Pl. 18, Figs 10-12.

Description: Chambers increase gradually in size and are moderately inflated. Test is markedly compressed.

Occurrence: 93/2-1 14,15; ABC 10.

Remarks: The specimens recovered were poorly preserved.

Genus Pandaglandulina Loeblich and Tappan

Pandaglandulina sp.a

Pl. 18, Figs 13-16.

Description: Chambers are narrow with slight inflation towards their bases, this gives the test a "bullet-like" appearance.

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Occurrence: EGG 11; ABC 5.

<u>Remarks</u>: <u>P</u>. sp.a is very rare and forms a very low proportion of the the nodosariid population when it is present.

Genus <u>Planularia</u> Defrance in Blainville, 1824 Genotype Peneroplis auris Defrance in Blainville, 1824

Planularia? sp.a

Pl. 19, Fig. 1.

<u>Description</u>: The chambers are indistinct but appear to be of consistant size on addition.

Occurrence: WND 15; CBI 11; ABC 10.

Remarks: P? sp.a is very rare.

Genus <u>Vaginulina</u> d'Orbigny Genotype Nautilus legumen Linne, 1758

> Vaginulina costulata var.a Pl. 19, Figs 2-4.

1842 Vaginulina costulata Roemer, p.273, pl.7B, fig.3.

1966 Vaginulina costulata Roemer;Butt,p.173,pl.1,fig.ll.

1970 Vaginulina costulata Roemer; Owen, pp. 129-131, pl. 15, fig. 5.

<u>Description</u>: The test is broad with curved sides and thin raised sutures which are subtended at an angle of $40^{\circ}-50^{\circ}$ from the periphery.

Occurrence: WND 1,8-11,13,14; CBI 2,5,6,10-14; EGG 2,4,5,7-12,16; ABC 5,7.

<u>Remarks</u>: Some slight variation in the degree of broadness of the test is present.

Vaginulina costulata var.b

Pl. 19, Figs 5-7.

1970 Vaginulina costulata Roemer; Owen, pp. 129-131, pl. 15, figs 1-3.

<u>Description</u>: The test is very elongate, the chambers may not be completely in contact with all of the previous one giving the test a "stepped" appearance.

Occurrence: WND 7,12; CBI 3,5,10,11,13; EGG 2,4,8,10,11; ABC 8; BritOil 48/22-1 7,11,13.

Vaginulina costulata var.c

Pl. 19, Figs 8-10.

<u>Description</u>: The test is broad with strongly raised sutures. The peripheries are straight and the aperture is raised on a circular neck.

Occurrence: WND 6,10,13; CBI 9-11; EGG 1,2,5,8,11,16; ABC 9,10.

Vaginulina costulata var.d

Pl. 19, Fig. 11.

1970 Vaginulina costulata Roemer; Owen, pl.15, figs 6-7.

<u>Description</u>: The sutures are predominantly raised and aligned at an angle of 50 to the periphery. The chambers have, to a varying degree, short aligned striations.

Occurrence: WND 2; EGG 6; ABC 9.

Family Polymorphinidae d'Orbigny, 1839 Subfamily Polymorphininae d'Orbigny, 1839

Genus <u>Eoguttulina</u> Cushman and Ozawa, 1930 Genotype Eoguttulina anglica Cushman and Ozawa, 1930

Eoguttulina? sp.a Pl. 19, Fig. 12.

Description: The chambers show rapid expansion on addition.

Occurrence: WND 5,7; CBI 1,2,4; EGG 4.

Remarks: E? sp.a is extremely rare and the preservation of the

specimens is poor, thus little comment is possible.

Subfamily Ramulininae Brady, 1884

Genus <u>Ramulina</u> Jones and Wright, 1875 Genotype <u>Ramulina</u> <u>laevis</u> Jones and Wright, 1875

Ramulina aculeata (d'Orbigny), 1840

1840 Nodosaria (Dentalina) aculeata d'Orbigny,p.13,pl.1,figs 2-3.

The morphotypes figured under <u>R</u>. <u>aculeata</u> vary considerably (Cushman, 1936) with little apparent intergrading. Thus the morphotypes encountered in this study have been placed within the framework of <u>R</u>. <u>aculeata</u> but each separate one has been described.

Ramulina aculeata form a

Pl. 19, Figs 14-16.

1950 Ramulina fusiformis Khan, p.272, Pl.2, figs. 1-2.

1970 Ramulina fusiformis Khan; Owen, pp. 140–141, pl. 16, figs 10–12.

<u>Description</u>: The test is elongate with broad stolons. The test surface is variously ornamented with randomly positioned pustules.

Ramulina aculeata form b

Pl. 19, Figs 17-18.

1970 Ramulina aculeata (d'Orbigny); Owen, pp.139-140, pl.15, fig.9.

<u>Description</u>: Bulbous tests with randomly positioned pustules, the stolon opens out to form a wide neck.

Ramulina aculeata form c

Pl. 20, Fig. 1.

<u>Description</u>: Bulbous test with rapidly tapering stolons and coarse pustular ornament.

Ramulina aculeata form d

Pl. 20, Figs 2-3.

<u>Description</u>: Bulbous test with thin circular stolons which may be added obliquely to the line of the test.

Ramulina aculeata form e

Pl. 20, Fig. 4.

<u>Description</u>: Thin test with stolons formed by slight narrowing of the test. The ornament is poorly developed.

Ramulina aculeata form f

Pl. 20, Figs 5-6.

<u>Description</u>: The test is bulbous which gently tapers to wide stolons. The ornament is very coarse and randomly positioned. Occurrence of R. aculeata: BSA 7; CBI 2,3,5,9-11; EGG 4-6; ABC 1-3,5; BritOil 48/22-1 10,15.

Family Glandulinidae Reuss, 1860 Subfamily Glandulininae Reuss, 1860

Genus <u>Tristix</u> Macfadyen Genotype Rhabdogonium liasinum Berthelin, 1879

> Tristix excavatum (Reuss) Pl. 20, Figs 7-8.

1862 Rhabdogonium excavatum Reuss, p.91, pl.12, fig.8a-c.

1970 Tristix excavatum (Reuss);Hart,pp.167-168,pl.14,fig.11.

<u>Description</u>: The test is elongate with a slight tapering, the faces are flush or slightly concave.

Occurrence: CBI 4; EGG 3,10,13.

Subfamily Oolininae Loeblich and Tappan, 1981

Genus Oolina d'Orbigny, 1839

Genotype Oolina laevigata Galloway and Wissler, 1927

Oolina sp.a

Pl. 20, Figs 9-12.

<u>Description</u>: Test ovate to sub-ovate with the aperture on a large pronounced neck.

Occurrence: B.P. 93/2-1 4,5,7; BSA 7; ABC 3.

<u>Remarks</u>: The shape of the test varies slightly and there may be a micro-ornament on the test surface.

Superfamily Buliminacea Jones, 1875

Family Turrilinidae Cushman, 1927

Subfamily Turrilininae Cushman, 1927

Genus <u>Praebulimina</u> Hofker, 1953 Genotype Bulimina ovulum Reuss, 1844

Praebulimina sp.a

Pl. 20, Figs 13-16.

Description: The chambers are elongate and moderately bulbous with depressed sutures. The aperture is very small.

Occurrence: B.P. 93/2-1 5,8,9; SGQ 8,13. Remarks: All the specimens of P. sp.a were small.

> Superfamily Globigerinacea Carpenter, Parker and Jones, 1862 Family Heterohelicidae Cushman, 1927

Subfamily Guembelitriinae Montanaro Gallitelli, 1957

Genus <u>Guembelitria</u> Cushman Genotype <u>Guembelitria</u> <u>cretacea</u> Cushman, 1933

> <u>Guembelitria cenomana</u> (Keller) Pl. 21, Figs 1-10.

1935 <u>Guembelina cenomana</u> Keller,p.547-8,table 3,figs.13,14. 1940 Guembelitria harrisi Tappan,p.115,pl.19,fig.2a-b.

Occurrence: Goban Spur 6/2 70-72; 6/1 30-33; 5CCA; B.P. 93/2-1 4,6,8; BSA 7,8; SGQ 2,9,12,13,17,23; WND 2-5,7-15; CBI 2-5,7-11, 13,14,17; EGG 2,3,6-8,11-13; ABC 1,2,4,6.

<u>Remarks</u>: There is some variation in the development of the apertural lip with some forms exhibiting thicker more robust lips. The extent of pustule ornament is highly variable but in most forms it is absent on the last formed chamber. Keller incorrectly illustrates <u>G</u>. cenomanica on table 3, figures 13,14 as Reussia spinulosa.

Genus <u>Guembelitriella</u> Tappan

Genotype Guembelitriella graysonensis Tappan

Guembelitriella sp.a

Pl. 21, Fig. 11.

Description: The latter stage of randomly positioned chambers is

comprised of moderately inflating chambers. The ornamentation is the same as for <u>G</u>. <u>cenomana</u> and the early triserial stage is identical to the equivalent portion of test development of <u>G</u>. <u>cenomana</u>. <u>G</u>. sp. a occurs in a population of <u>G</u>. <u>cenomana</u> and thus may well be an aberrant or ecophenotypic variant of the latter.

Occurrence: SGQ 14; ABC 1.

Subfamily Heterohelicinae Cushman, 1927

Genus <u>Heterohelix</u> Ehrenburg, 1843 Genotype Spiroplecta americana Ehrenburg, 1844

Heterohelix globulosa (Ehrenburg)

Pl. 22, Figs 14-16.

1840 <u>Textularia globulosa</u> Ehrenburg,p.135,pl.4,figs 2b,4b,5b,7b,8b.
1967 <u>Heterohelix globulosa</u> (Ehrenburg);Pessagno,p.260,pl.87,figs
5-9,11-13.

Occurrence: Goban Spur 5/1 76-78; B.P. 93/2-1 11; SGQ 8; CBI 21, 22,24,26,32-36; EGG 33,34; ABC 21; AKS 1,12.

<u>Remarks: H. globulosa</u> is very close to <u>H. moremani</u> (Cushman) in that transitional forms exist within the heterohelixid population. These comprise forms with moderately inflated chambers and less pronounced depressed sutures.

Heterohelix moremani (Cushman)

Pl. 22, Figs 1-13.

1938 Guembelina moremani Cushman, p.10, pl.2, figs 1-3.

1967 Heterohelix moremani Cushman; Pessagno, pp.260-1, pl.89, figs 1-2.

<u>Occurrence</u>: Goban Spur 6/2 70-72, 26-29; 6/1 30-33;5/1 76-78, 7-10. B.P. 93/2-1 4,11; BSA 3-7; SGQ 2,3,7-9,10-21,23; WND 2-6,11-13,15, 16,21; CBI 1-5,7-14,16,17; EGG 2,3,5,7; ABC 1,3,4,6-12,14,21; AKS 1-4,6.

<u>Remarks</u>: <u>H</u>. <u>moremani</u> forms the bulk of the late Cenomanian heterohelixid population. The ornamentation varies considerably though much of the "heaviest" ornament may be due to post-depositional syntaxial overgrowth of calcite.

The heterohelixid population exhibits a progressive change in ornamentation (P1.22), the pre-OAE population shows random pustules that may be concentrated on single chambers or the earlier portion of the test. The post-OAE population yields morphotypes of <u>H. moremani and H. globulosa</u> but with varying degrees of costae. These consist of orientated lines of pustules to well-developed costae running the length of the test.

Family Planomalinidae Bolli, Loeblich and Tappan, 1957

Genus Globigerinelloides Cushman and ten Dam, 1948

Genotype <u>Globigerinelloides</u> <u>algeriana</u> Cushman and ten Dam, 1948.

<u>Globigerinelloides bentonensis</u> (Morrow) Pl. 23, Figs 1-5.

1934 <u>Anomalina bentonensis</u> Morrow,p.201,pl.30,fig.4a-b. 1977 <u>Globigerinelloides bentonensis</u> (Morrow);Carter and Hart, pp.27-8, pl.1,fig.11;pl.2,figs 19-20.

Occurrence: Goban Spur 6/2 70-72, 26-29; 50CA; B.P. 93/2-1 5; BSA 7; SGQ 17(?); WND 3,6,18,21-28; CBI 7; EGG 4,8-10,14. <u>Remarks</u>: The size of <u>G. bentonensis</u> varies, with the extremes illustrated (P1.22,Figs 1-5), this has been noted many times (reviewed Carter and Hart, 1977). The low numbers found means that little comment can be made on the relative merits of <u>G. caseyi</u> and G. bentonensis. Family Rotaliporidae Sigal, 1958

Subfamily Hedbergellinae Loeblich and Tappan, 1961

Genus <u>Favusella</u> Michael, 1973 Genotype <u>Globigerina</u> washitensis Carsey

> Favusella washitensis (Carsey) Pl. 25, Fig. 2.

1926 Globigerina washitensis Carsey, p. 44, pl. 7, fig. 10.

1985 Favusella washitensis (Carsey);Caron,p.45,fig.25,no.25,26a-b.

Occurrence: SGQ 6,7.

<u>Remarks</u>: <u>F. washitensis</u> was only recorded from Shapwick Grange Quarry and identified in thin section.

Genus <u>Hedbergella</u> Bronniman and Brown

Genotype Anomalina lorneiana d'Orbigny var.trocoidea

Gandolfi

The genus <u>Whiteinella</u> Pessagno has not been adopted in this study as many of the forms are of a transitional nature (<u>H</u>. <u>delrioensis</u> - <u>H</u>. <u>aprica</u> - "<u>H</u>". <u>archaeocretacea</u>) and many of the generic characters are not completely developed. In particular, the wide umbilicus and portici. Thus these forms have been designated under "Hedbergella".

"<u>Hedbergella</u>" <u>aprica</u> (Loeblich and Tappan) Pl. 23, Figs 6-8.

1961 Ticinella aprica Loeblich and Tappan, p.292, pl.4, figs 14-16.

1979 <u>Whiteinella aprica</u> (Loeblich and Tappan); Robaszynski and Caron, pp.157-160,pl.32,figs la-c,2a-c.

Occurrence: Goban Spur 5/2 13-17; 5/1 101-106, 76-78, 7-10; B.P. 93/2-1 12,14; BSA 9-13; SGQ 7-11,15-23; WND 2,4-12,22; CBI 3-5,7,9,10,19,20,22,24,32,33; EGG 5,8,9,11-17,19,20,28-31,34; ABC 2,3,5-14,16,21; AKS 1,2,3,4,6,7,10,12; BritOil 48/22-1 16-19. <u>Remarks: "H</u>". <u>aprica</u> is represented in the pre-OAE hedbergellid population but the specimens are smaller than <u>H. aprica sensu stricto</u> with a slightly higher trochospire. Post-OAE <u>H. aprica sensu stricto</u> is prevalent with a large umbilicus and low trochospire. "<u>H</u>". <u>aprica</u> is probably the precursor to "H". archaeocretacea (Pessagno).

"Hedbergella" archaeocretacea (Pessagno)

Pl. 23, Figs 9-12.

1967 <u>Whiteinella</u> archaeocretacea Pessagno,p.298,pl.51,figs 2-4; pl.54,figs 19-25;pl.100,fig.8.

1979 <u>Whiteinella archaeocretacea</u> Pessagno; Robaszynski and Caron, pp.161-168,pl.33,figs la-c,2a-c,3a-c;pl.34,figs la-c,2a-c. Occurrence: Goban Spur 5/2 13-17; 5/1 101-106, 76-78, 7-10; BSA 9-11; SGQ 15-17,19,20; WND 22; CBI 24,25,28,30,32-35; EGG 27,32-33; ABC 21; AKS 1-4,6,7,10,12; BritOil 48/22-1 19. <u>Remarks</u>: The development of "<u>H</u>". <u>archaeocretacea</u> from "<u>H</u>". <u>aprica</u> stock is rapid. The delicate portici are poorly preserved (if present in the first place). The ornament is comprised of randomly positioned pustules, though to some extent they are concentrated along the periphery.

Hedbergella delrioensis (Carsey)

Pl. 24, Figs 1-11.

1926 <u>Globigerina cretacea</u> d'Orbigny var. <u>delrioensis</u> Carsey,p.43.
1937 <u>Globigerina infracretacea</u> Glaessner,p.28.
1977 Hedbergella delrioensis (Carsey);Carter and Hart,p.35,pl.4,

figs 1-3.

Occurrence: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; 50CA; B.P. 93/2-1 1,6-15; BSA 1,2-8,10,11; SGQ 1,3,6-9,1-13,15-22; WND 1-12, 14,16; CBI 1-19; EGG 1-6,8-11,13,14,20,26; ABC 1-14,19,21; AKS 1,2,4,6; BritOil 48/22-1 1,4,5-7,11-13,15,16,19.

<u>Remarks</u>: <u>H</u>. <u>delrioensis</u> exhibits variability in chamber size, their rate of increase and ornament. In some individuals the ornament is concentrated on the umbilical surface of the first formed chambers of the last whorl. The pustules may be coalesced into thin stringers which are very broadly aligned parallel to the periphery. The density and distribution of pores varies but no systematic analysis has been undertaken. <u>H. delrioensis</u> forms the "middle" morphotype in the variability of the hedbergellid population (in terms of height of trochospire, test size and chamber shape).

> "Hedbergella" brittonensis Loeblich and Tappan Pl. 23, Figs 13-14.

1934 <u>Globigerina cretacea</u> d'Orbigny;Morrow,p.198,pl.30,figs 7,8, 10a-b.

1977 <u>Hedbergella brittonensis</u> Loeblich and Tappan;Carter and Hart, pp.31-2,pl.4,figs 13-15.

Occurrence: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; 5/1 7-10; B.P. 93/2-1 4,5,8; BSA 3-7; SGQ 8,11,15-17,19,20,23; WND 3,4,10; CBI 9-11,13,14,16; EGG 19,20,22,25,27,30; ABC 3-5,7,9,21; AKS 2,4,13; BritOil 48/22-1 5,10,12,13,16.

<u>Remarks: H. brittonensis</u> forms a minor part of the hedbergellid population when present. It exhibits considerable variation in size, but each sample population is consistant.

Hedbergella planispira (Tappan)

Pl. 24, Figs 12-14.

1940 Globigerina planispira Tappan, p. 12, pl. 19, fig. 12.

1977 <u>Hedbergella planispira</u> (Tappan);Carter and Hart,pp.36-37, pl.4,figs 4-6.

Occurrence: B.P. 93/2-1 2,4,5,9; SGQ 17,18; CBI 4,14; ABC 8,11,12; Britoil 48/22-1 2-10,12,13.

<u>Remarks</u>: <u>H</u>. <u>planispira</u> is not a constant part of the hedbergellid population but when it is present it forms a major part. This implies that <u>H</u>. <u>planispira</u> is an ecophenotypic variant of the standing hedbergellid stock possibly related to <u>H</u>. <u>delrioensis</u>.

Hedbergella simplex (Morrow)

Pl. 25, Fig. 1.

1934 <u>Hastigerinella simplex</u> Morrow,pp.198-199,pl.30,fig.6a-b.
1977 <u>Hedbergella amabilis</u> Loeblich and Tappan;Carter and Hart,
pp.29-30,pl.3,figs 22-23.

1979 <u>Hedbergella simplex</u> (Morrow); Robaszynski and Caron, pp.145-150,pl.29,figs la-c,2a-c,3a-c;pl.30,figs la-c,2a-c.

Occurrence: B.P. 93/2-1 3,4,5,7; BSA 6; WND 15,17,18,22; CBI 9-11,13,14,16; ABC 8.

<u>Remarks</u>: In a similar manner to <u>H</u>. <u>planispira</u>, <u>H</u>. <u>simplex</u> does not form a consistant component of the hedbergellid population and thus it may also be an ecophenotypic variant.

Genus Helvetoglobotruncana Reiss, 1957

Genotype Globotruncana helvetica Bolli

Helvetoglobotruncana helvetica (Bolli)

Pl. 25, Figs 11-14.

1945 <u>Globotruncana helvetica</u> Bolli,p.226,pl.9,figs 6-8,text-fig.1 (9-12).

1977 <u>Praeglobotruncana helvetica</u> (Bolli);Carter and Hart,pp.39-40, pl.3,figs 16-17.

1979 <u>Praeglobotruncana helvetica</u> (Bolli);Robaszynski and Caron, pp.39-42,pl.46,figs la-c,2a-c.

1985 <u>Helvetoglobotruncana</u> <u>helvetica</u> (Bolli);Caron,p.60,fig.30, nos.7.8a-c.

Occurrence: Goban Spur 5/1 76-78, 7-10; B.P. 93/2-1 15; SGQ 15, 16,19,23; CBI 36.

<u>Remarks</u>: The N.W. European <u>H</u>. <u>helvetica</u> is not as well developed in terms of size of test and flattening of the spiral surface as forms described from lower latitudes. This may be the result of it being towards the limit of its distribution.

Helvetoglobotruncana praehelvetica (Trujillo)

Pl. 25, Figs 3-10.

1960 Rugoglobigerina praehelvetica Trujillo,pp.340-341,pl.49,figs 6a-c.

1

1979 <u>Praeglobotruncana praehelvetica</u> (Trujillo); Robaszynski and Caron, pp.43-46, pl.47, figs ld, 2c.

1985 Helvetoglobotruncana praehelvetica (Trujillo);Caron,p.60,fig. 30,nos.9a-c,10a-c.

Occurrence: Goban Spur 5/2 13-17; 5/1 101-106,76-78,7-10; BSA 9, 11-13; SGQ 17,18; WND 19,21-26; CBI 23,24,27-32,35,36; EGG 23-26, 28-30,33; AKS 7-10,12.

<u>Remarks: H. praehelvetica</u> is thought to be the ancestor of <u>H</u>. <u>helvetica</u> (Bolli) (Hart and Bailey, 1979) with which the author agrees. Thus the differentiation between the two species is **equivocal**.

Genus Praeglobotruncana Bermudez

Genotype Globorotalia delricensis Plummer

Praeglobotruncana delrioensis (Plummer)

Pl. 26, Fig. l.

1931 Globorotalia delrioensis Plummer, p.199, pl.13, fig. 2a-c.

1977 Praeglobotruncana delrioensis (Plummer); Carter and Hart,

pp.38-39,pl.4,figs 22-24.

1979 <u>Praeglobotruncana</u> <u>delrioensis</u> (Plummer); Robaszynski and Caron, pp.29-32,pl.43,figs la-c,2a-c.

Occurrence: B.P. 93/2-1 1; SGQ 6.

Remarks: The differentiation of the species within Praeglobotruncana

based on the height of the trochospire (progressively increasing through <u>P. delrioensis - P. stephani</u> (Gandolfi) - <u>P. gibba</u> (Klaus)) has been shown to be fallacious Klaus, (1960), as intermediate forms are found between all three morphotypes. Unfortunately, Klaus did not illustrate the position of the forms against time, as such a treatment would have shown that the increase in the height of the spire (and size) was a developing feature within the moving population.

Praeglobotruncana gibba Klaus

Pl. 26, Figs 2-3.

1960 <u>Praeglobotruncana stephani</u> var. <u>gibba</u> Klaus, p. 306, text-fig.l. 1979 <u>Praeglobotruncana gibba</u> Klaus; Robaszynski and Caron, pp. 33-38, Pl.44, figs.la-c, 2a-c; Pl.45, figs.la-c. 2a-c.

<u>Occurrence</u>: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; SGQ 7. <u>Remarks</u>: <u>P. gibba</u> forms the end member of the <u>P. delrioensis</u> - <u>P.</u> <u>stephani</u> - <u>P. gibba</u> plexus. <u>P. gibba</u> has a restricted development across the Anglo-Paris Basin (see Chapter 7) and thus forms the least significant portion of the population.

Praeglobotruncana stephani (Gandolfi)

Pl. 26, Figs 4-10.

1942 Globotruncana stephani Gandolfi,p.130,pl.3,figs 4-5;pl.4,figs

36-37.

1977 <u>Praeglobotruncana stephani</u> (Gandolfi);Carter and Hart pp.40-41, pl.4,figs 16-21.

1979 <u>Praeglobotruncana stephani</u> (Gandolfi); Robaszynski and Caron, pp.47-50,pl.48,figs la-c,2a-b,3a-b.

Occurrence: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; B.P. 93/2-1 1,7,8,11; BSA 5-7; SGQ 7,8,12,15,16,19; WND 1-5,7,9-12,14,16-19; CBI 1-18; EGG 1-6,8-12,19; ABC 1,2,4-9,11,12; BritOil 48/22-1 9-16.

<u>Remarks:</u> <u>P. stephani</u> forms the middle morphotype in the <u>P</u>. <u>delrioensis</u> – <u>P. stephani</u> – <u>P. gibba</u> plexus. It is ubiquitous across the sections studied (Chapter 5) and thus forms the bulk of the praeglobotruncanid population.

Genus Dicarinella Porthault

Genotype Globotruncana indica Jacob and Sastry, 1950

Dicarinella algeriana (Caron)

Pl. 27, Figs 1-3.

1966 <u>Praeglobotruncana algeriana</u> (Reuz);Caron,pl.2,fig.5a-c.
1979 <u>Dicarinella algeriana</u> (Caron);Robaszynski and Caron,
pp.57-60,pl.50,figs la-d,2a-d.

Occurrence: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; 5CCA; 5/2 13-17;

5/1 101-106, 76-78, 7-10; B.P. 93/2-1 12; BSA 5-7; SGQ 8,14-16,19,20,23; WND 9,11,14-18,22,23,25,28; CBI 4,5,14-18,20,21, 25,26,32; EGG 5,9-14,19,20,30,31,33; ABC 3-8,10,11,21; AKS 1-5,8; BritOil 48/22-1 18.

<u>Remarks</u>: The differentiation of the early forms of <u>D</u>. <u>algeriana</u> from <u>P</u>. <u>stephani</u> is problematical as the development of the keels is very variable with many forms showing only two poorly differentiated keels.

Dicarinella hagni (Scheibnerova)

Pl. 27, Figs 4-10.

1962 Globotruncana hagni Scheibnerova,pp.219-221,text-fig.6a-c. 1979 Dicarinella hagni (Scheibnerova);Robaszynski and Caron, pp.79-86,pl.56,figs la-c,2a-c;pl.57,figs la-c,2a-d.

<u>Occurrence</u>: Goban Spur 6/2 70-72,26-29;6/1 30-33;5CCA; 5/2 13-17; 5/1 101-106, 76-78, 7-10; B.P. 93/2-1 5,7,8,10,12; BSA 7,12; SGQ 8, 14-16,19-21,23; WND 9,11,13-19,22,23; CBI 7-27; EGG 6,9,21,24,25, 28,31-33; ABC 3,6,7,9-14,21; AKS 2-12; BritOil 48/22-1 18,19. <u>Remarks</u>: <u>D. hagn1</u> exhibits variability in the shape of the chambers and the degree of spacing between the keels. The early forms have indistinct closely spaced keels.

Dicarinella imbricata (Mornod)

Pl. 27, Figs 11-12.
1950 <u>Globotruncana</u> <u>imbricata</u> Mornod, p. 589, text-fig. 5, 3a-d. 1979 <u>Dicarinella</u> <u>imbricata</u> (Mornod); Robaszynski and Caron, pp. 87-92, pl. 58, figs la-c, 2a-d; pl. 59, figs la-c, 2a-c.

<u>Occurrence</u>: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; 5CCA; 5/2 13-17; 5/1 101-106, 76-78, 7-10; SGQ 8,9,14-16,19-21; WND 9,11,13-19; CBI 7-10,13-17,25-27,36; EGG 6,12-15,27; ABC 10-12,14; AKS 2-5,8-10,12; BritOil 48/22-1 18,19. <u>Remarks: D. imbricata</u> is derived from <u>D. hagni</u> by the development

of offset keels.

Genus <u>Marginotruncana</u> Hofker, 1956 Genotype <u>Rosalina marginata</u> Reuss, 1845

Marginotruncana marginata (Reuss) Pl. 28, Figs 1-4.

1845 Rosalina marginata Reuss, p. 36, pl.8, figs 54a-b, 74a-b.

1979 <u>Marginotruncana marginata</u> (Reuss); Robaszynski and Caron, pp.107-114,pl.63,figs la-c,2a-d;pl.64,figs la-c,2a-d.

Occurrence: AKS 9,10,12.

<u>Remarks:</u> <u>M. marginata</u> is very rare in this study and the umbilical thickenings are poorly developed. The designation of <u>M. marginata</u> used is the one established by Robaszynski and Caron, 1979, though

there may well be some confusion in the neotype they adopted from Jirova (1956) between <u>M. marginata</u> and <u>M. canaliculata</u> (Reuss) (Bailey, 1978).

Marginotruncana sp. cf. <u>M. sigali</u> (Reichel) Pl. 28, figs. 5-8.

1950 <u>Globotruncana</u> (<u>Globotruncana</u>) <u>sigali</u> Reichel,pp.610-612, text-figs 5-6,pl.16,fig.7.

1979 <u>Marginotruncana sigali</u> (Reichel); Robaszynski and Caron, pp.141-146,pl.72,fig.la-c,2a-b;pl.73,fig.a-f.

Occurrence: SGQ 20; CBI 36.

<u>Remarks:</u> <u>M</u>. sp. cf. <u>sigali</u> is extremely rare in this study and the specimens small and poorly preserved which makes its identification problematical.

Subfamily Rotaliporinae Sigal, 1958

Genus Rotalipora Brotzen, 1942

Genotype Rotalipora turonica = Globorotalia cushmani

Morrow, 1934

The rotaliporid population shows variation in its relative percentage of the planktonic population across the sections studied. In addition, the relative dominance of the component species within the rotaliporid population and the size of specimens varies. This is detailed and discussed in Chapter 5.

Rotalipora appenninica (Renz)

Pl. 28, Fig. 9.

1936 Globotruncana appenninica Renz, p.13, text-fig.2.

1979 <u>Rotalipora appenninica</u> (Renz); Robaszynski and Caron, pp.59-64, pl.4, figs la-c, 2a-c, 3a-c; pl.5, figs la-c, 2a-c, 3a-c.

Occurrence: SGQ 7; BritOil 48/22-1 8.

<u>Remarks:</u> <u>R</u>. <u>appenninica</u> is rare and is only present from Shapwick Grange Quarry. The specimens were identified in thin section. The forms present show very poor keel development.

> Rotalipora cushmani (Morrow) Pl. 28, Figs 10-14.

Pl. 29, Figs 1-3.

1934 Globorotalia cushmani Morrow, p.199, pl.31, figs 2a-b, 4a-b.

1977 <u>Rotalipora cushmani</u> (Morrow);Carter and Hart,pp.41-44,pl.2, fig.18;pl.4.figs 7-9.

1979 <u>Rotalipora cushmani</u> (Morrow); Robaszynski and Caron, pp.69-74, pl.7, fig.la-c; pl.8, figs la-c, 2a-c.

Occurrence: Goban Spur 6/2 70-72, 26-29; 6/1 30-33; B.P. 93/2-1 1,6; BSA 1,4-7; SGQ 8; WND 1-13; CBI 1-13; EGG 1-5,8-12; ABC 1-10;

BritOil 48/22-1 11,13-16.

<u>Remarks:</u> <u>R</u>. <u>cushmani</u> forms the dominant part of the rotaliporid population and increasingly so into the Anglo-Paris Basin (see 5.14).

> Rotalipora deecki (Franke) Pl. 29, Figs 4-6.

1925 Rotalipora deecki Franke, pp.90-91, text-fig.7a-c.

1979 <u>Rotalipora deecki</u> (Franke); Robaszynski and Caron, pp.75-80, pl.9, figs la-c, 2a-c; pl.10, figs la-c, 2a-c.

<u>Occurrence</u>: Goban Spur 6/2 70-72, 26-29; 6/1 30-33. <u>Remarks</u>: <u>R</u>. <u>deecki</u> forms the minor portion of the rotaliporid population and significantly only from Goban Spur.

Rotalipora greenhornensis (Morrow)

Pl. 29, Figs 7-9.

1934 Globorotalia greenhornensis Morrow, p. 199, pl. 39, fig. 1.

1977 <u>Rotalipora greenhornensis</u> (Morrow);Carter and Hart,pp.44-45, pl.4,figs 10-12.

1979 <u>Rotalipora greenhornensis</u> (Morrow); Robaszynski and Caron, pp.85-90,pl.12,figs la-c,2a-c;pl.13,figs la-c,2a-c.

Occurrence: Goban Spur 6/2 70-72,26-29; 6/1 30-33; B.P. 93/2-1

7,8; BSA 5; WND 1-3,5,10-12; CBI 2,3,10; EGG 9; ABC 1,3,7,8; Britoil 48/22-1 15.

<u>Remarks:</u> <u>R. greenhornensis</u> decreases in influence as part of the rotaliporid population into the Anglo-Paris Basin (see 5.14).

Rotalipora sp. cf. <u>R.</u> reicheli Mornod Pl. 29, Fig. 10.

1950 <u>Globotruncana</u> (<u>Rotalipora</u>) <u>reicheli</u> Mornod,p.583,fig.5 (lVa-c),fig.6(l-6),pl.15,figs 2a-p,3-8.

1979 <u>Rotalipora reicheli</u> Mornod;Robaszynski and Caron,pp.99-106, pl.16,fig.la-c;pl.17,fig.la-c;pl.18,figs la-c,2a-c.

Occurrence: Shapwick Grange Quarry 5.

<u>Remarks:</u> <u>R</u>. sp. cf. <u>R</u>. <u>reicheli</u> is only present in thin section. The specimens are very low trochospired, with angular chambers and are poorly preserved thus their identification is problematical.

Superfamily Cassidulinacea d'Orbigny, 1839 Family Pleurostomellidae Reuss, 1860 Subfamily Pleurostomellinae Reuss, 1860

Genus <u>Pleurostomella</u> Reuss, 1860 Genotype Dentalina subnodosa Reuss, 1851

Pleurostomella subnodosa (Reuss)

Pl. 29, Figs 11-14.

1851 Dentalina subnodosa Reuss, p.24.

1964 <u>Pleurostomella</u> <u>subnodosa</u> (Reuss);Loeblich and Tappan,C275-276, pl.594,fig.la-b.

Occurrence: Goban Spur 5/1 101-106.

<u>Remarks</u>: The degree of inflation of the chambers on addition varies slightly, but the population from Goban Spur is of a consistant size.

Family Alabaminidae Hofker, 1951

Genus <u>Gyroidina</u> d'Orbigny Genotype Gyroidina orbicularis Cushman, 1927

Gyroidina sp.a

Pl. 29, Figs 15-16.

<u>Description</u>: The test increases moderately in size on chamber addition. The periphery is well-rounded in cross-section but in umbilical view there is a slight angle between chambers.

Occurrence: Goban Spur 6/2 70-72.

<u>Remarks</u>: <u>G</u>. sp.a is only found from Goban Spur and forms a very small part of the benthonic assemblage.

Family Osangulariidae Loeblich and Tappan, 1964

Genus <u>Gyroidinoides</u> Brotzen, 1942 Genotype <u>Rotalina nitida</u> Reuss, 1844

Gyroidinoides parva (Khan)

Pl. 30, Fig. 1.

1

1898 <u>Rotalina soldanii</u> d'Orbigny var. <u>nitida</u> Reuss;Chapman,pp.9-10, pl.2,fig.2a-c.

1970 Gyroidinoides parva (Khan); Hart, pp. 208-209, pl. 22, figs 5-7.

Occurrence: WND 4; CBI 7; ABC 2,5; BritOil 48/22-1 13,16.

<u>Remarks:</u> <u>G. parva</u> only forms a very small part of the benthonic population when present.

Family Anomalinidae Cushman, 1927 Subfamily Anomalininae Cushman, 1927

Genus <u>Gavelinella</u> Brotzen, 1942 Type species <u>Discorbina pertusa Marsson</u>, 1878

Gavelinella baltica Brotzen

Pl. 30, Figs 2-7.

1942 Gavelinella baltica Brotzen, p.50, pl.1, fig.7.

1977 <u>Gavelinella</u> <u>baltica</u> Brotzen;Carter and Hart,p.46,pl.1, figs 36-38.

Occurrence: B.P. 93/2-1 5; SGQ 3,6; WND 2,3,5,8,9,11; CBI 2,4-6, 9; EGG 1,2,4,6,8; ABC 1-3,5-8; BritOil 48/22-1 4.

<u>Remarks:</u> <u>G. baltica</u> is very distinctive and is usually noticeably larger than <u>G. cenomanica</u> (Brotzen) and <u>G. intermedia</u> (Berthelin) with which it occurs. It is derived in the early Cenomanian from <u>G. intermedia</u> (Carter and Hart, 1977).

Gavelinella berthelini (Keller)

Pl. 30, Figs 8-11.

1935 <u>Anomalina berthelini</u> Keller, pp.552-553, pl.3, figs 25-27.
1967 <u>Gavelinella berthelini</u> (Keller); Fuchs, p.336, pl.18, fig.8a-c.

Occurrence: B.P. 93/2-1 1-3,5-8,10-12,14,15; BSA 4,6,7,8,10-12; SGQ 8-18; WND 11,12,14,16-21; CBI 11-24,26-28,34-36; EGG 10-22, 24-26,28-34; ABC 2-4,6,7,9,11-21; AKS 1-9; BritOil 48/22-1 11,14-16,18-19.

<u>Remarks:</u> <u>G. berthelini</u> has a much larger boss than <u>G. reussi</u> (Khan) from which it is derived. These species form a more significant part of the gavelinellid population than alluded to by others (e.g. Hart and Swiecicki, 1987). <u>G. tourainensis</u> Butt is thought to be an ecophenotypic form of G. berthelini.

Gavelinella cenomanica (Brotzen)

Pl. 30, Figs 12-15.

1942 <u>Cibicioloides</u> (<u>Cibicides</u>) <u>cenomanica</u> Brotzen,p.54,pl.2, fig.2a-c.

1977 <u>Gavelinella cenomanica</u> (Brotzen);Carter and Hart,pp.46-47, pl.1,figs 27-28.

<u>Occurrence</u>: B.P. 93/2-1 1-3,5-9; BSA 3; WND 1-10; CBI 1-6,8-9; EGG 1,2,4-9; ABC 2-6,8; BritOil 48/22-1 1-3,5-8,11,13,14,16. <u>Remarks</u>: The degree of development of the umbilical rim is variable.

Gavelinella intermedia (Berthelin)

Pl. 31, Figs 1-3.

1880 <u>Anomalina intermedia</u> Berthelin, p. 67, pl.4, fig. 14a-b.
1977 <u>Gavelinella intermedia</u> Berthelin; Carter and Hart, p. 48, pl.1, figs 33-35.

Occurrence: Goban Spur 6/2 70-72; B.P. 93/2-1 1-8; BSA 3,4,6; SGQ 8; WND 1-11; CBI 1-6,8-10; EGG 1,2,4-9; ABC 1-11; BritOil 48/22-1 1,2,4-8,11-17.

<u>Remarks</u>: <u>G. intermedia</u> forms the major part of the pre-OAE gavelinellid population.

Gavelinella reussi (Khan)

Pl. 31, Figs 4-5.

1863 <u>Rosalina complanata</u> Reuss var. Reuss, p.86, pl.11, fig.3a-c.
1970 Gavelinella reussi (Khan); Hart, pp.213-214, pl.23, figs 7-9.

Occurrence: Goban Spur 6/2 70-72; B.P. 93/2-1 1-2; BSA 3,4; WND 1,3-13; CBI 1-12; EGG 1,2,4-11; ABC 1,3,4,6,10-14; BritOil 48/22-1 1-3,5,8,9,11-13,17.

Remarks: G. reussi is the ancestor of G. berthelini.

Genus <u>Lingulogavelinella</u> Malapris, 1965 Genotype <u>Lingulogavelinella</u> <u>albiensis</u> Malapris, 1965

Lingulogavelinella globosa (Brotzen)

Pl. 31, Figs 7-9.

1942 Anomalinoides globosa Brotzen, p.58, pl.2, fig.6a-c.

1977 <u>Lingulogavelinella globosa</u> (Brotzen);Carter and Hart,p.49, pl.1,figs 12-14.

Occurrence: B.P. 93/2-1 4,8,9,11,12,14; BSA 5-8,10-12; SGQ 8,9, 12-15,18; WND 1-7,10-16; CBI 1-3,5,7-19; EGG 6-20,28,31-34; ABC 3,6-9,11-AKS 4,8,9; BritOil 48/22-1 12,14.

<u>Remarks:</u> <u>L. globosa</u> shows a rapid increase in size and numbers after the extinction of <u>G. baltica</u>, <u>G. intermedia</u> and <u>G</u>. cenomanica.

Lingulogavelinella aumalensis (Sigal) Pl. 31, Figs 10-11.

1952 Anomalina aumalensis Sigal, p.27, text-fig.26.

1970 <u>Lingulogavelinella aumalensis</u> (Sigal);Owen,pp.200-201,pl.30, figs 10-12.

Occurrence: B.P. 93/2-1 10-12; WND 23-29; CBI 18,20,24,26,29,32,

35,36; EGG 23-25,32,34; AKS 12,13.

Incerti ordinis

Family Calicispherulidae Bonet, 1956

. .

Genus Pithonella Lorenz, 1902

Pithonella ovalis (Kaufmann) Pl. 31, Figs 12-13.

1865 Lagena ovalis Kaufmann,p.196-197,text-fig.107a-b.

1902 Pithonella ovalis (Kaufmann);Lorenz,pp.13-14,pl.9,fig.2.

1976 Pithonella ovalis (Kaufmann); Bein and Reiss, p.85, pl.1,

figs 3-8;pl.2,figs 1-6.

<u>Remarks: P. ovalis</u> is sporadically present but occurs in great numbers when present.

<u>Description</u>: Calcareous(?) spheres with chipped (striated) surface.

Pl. 31, Figs 14,15.

Occurrence: 93/2-1 1090'.

Remarks: The exact compostition has not been established. The

randomly oriented striae may well be post-depositional damage.

<u>Incertae</u> <u>cedis</u>

<u>Description</u>: Calcareous subconical protruberance formed by the cementation of small calcareous(?) grains.

Pl. 31, Fig. 16.

Occurrence: Abbots Cliff 9.

Remarks: It only appears in ABC9 but in large numbers (>30).

Chapter 5: Biostratigraphical implications, methods of basinal correlation and pre-Oceanic Anoxic Event palaeoenvironmental analysis.

5.1. Previous work.

Previous biostratigraphical studies of the Cenomanian and Turonian of southern England (Hart, 1970, 1982b; Owen, 1970; Carter and Hart, 1977), have integrated the planktonic and benthonic foraminifera. In addition, the European Working Group on Foraminifera has established a series of Cretaceous planktonic foraminiferal zones (Robaszynski and Caron, 1979). Comparison with the above has been made in this study.

5.2. The existance world-wide of organic-rich shales of late Cenomanian age is well documented (see Schlanger <u>et. al.</u>, 1987, for a recent review). This Cenomanian - Turonian Oceanic Anoxic Event is marked by a positive excursion in the \S 13C curve due to the preferential extraction of 12C by marine plankton whose organic components were not recycled because of enhanced organic carbon burial (Arthur <u>et al.</u>, 1987).

5.3. Goban Spur (Figures 3.1 and 5.1).

5.3(1). Lithostratigraphy.



The basal sedimentary sequence recovered from the Goban Spur (DSDP Leg 80), has been described by Graciansky <u>et</u> <u>al</u>. (1985). It comprises 4.1m of nannofossil chalk (Core 6; Figure 5.1), which underlies an unknown thickness of poorly recovered, partially laminated black shale, This, in turn, is overlain by a further 4.1m of nannofossil chalk (Core 5; Figure 5.1).

5.3(ii). §13C isotope curve.

The total org.C curve from the Goban Spur shows a marked deflection (Arthur <u>et al.</u>, 1987), but it is not shown against a lithological log, thus its exact position cannot be illustrated.

5.3(iii). Macropalaeontological biostratigraphy.

No fragments of any macropalaeontological fauna were recorded (Graciansky et al., 1985).

5.3(iv). Foraminiferal biostratigraphy.

The presence of <u>R</u>. <u>cushmani</u> and <u>R</u>. <u>greenhornensis</u> in Core 6 (figure 5.1), is taken to confirm a late Cenomanian age for this part of the succession, while the occurrence of <u>H</u>. <u>praehelvetica</u> and <u>H</u>. <u>archaeocretacea</u> in Core 5 (Figure 5.1), indicates an early Turonian age (Graciansky <u>et al</u>., 1985; Hart, 1985, 1987b).

5.3(v). Foraminiferal assemblage.

The planktonic foraminiferal assemblage is dominated by rotaliporids (<u>R</u>. <u>cushmani</u> 45%; <u>R</u>. <u>greenhornensis</u> 15%; <u>R</u>. <u>deecki</u> 3%), with praeglobotruncanids/dicarinellids (29%) and hedbergellids (8%) comprising the remainder. The differentiation of the praeglobotruncanid and dicarinellid population is problematical as many of the forms are transitional. The planktonic assemblage shows little change in the relative proportion of these three populations prior to the OAE. During this interval the benthonic population forms a very small part (<2%) of the gross foraminiferal population. It is comprised of a limited assemblage which show a marked size consistancy within their respective populations (Figure 5.1).

The post-OAE population shows less consistancy in its overall composition. The lower samples (5CCA and $5\2 79-81$, Figure 5.1) yield low population numbers (<200 specimens). The specimens are pitted, indicating the effects of carbonate dissolution. Although the overlying population is constant (praeglobotruncanid/dicarinellid, 65-70% and hedbergellid 30-15%), the number of specimens contained in each sample varies considerably (>1,200 to <75). This implies that even though the number of specimens is small, it can still provide an accurate picture of the relative proportions of the

population. As in the pre-OAE population, the post-OAE benthonic foraminifera form a small percentage of the total (3-10%).

5.4. B.P 93\2-1 (Figure 5.2).

5.4(i). Lithostratigraphy.

The succession studied consists of 35m of chalk limestone overlain by 80m of hard chalk limestone, for which no detailed lithological logs or downhole logs were available. The seventeen samples comprised both sidewall core and ditch cuttings.

5.4(ii). 613C isotope curve.

There is no 8 13C isotope curve available from B.P 93\2-1 (Copestake, pers. comm.).

5.4(iii). Macropalaeontological biostratigraphy.

No macropalaeontological fauna was recorded from the interval under discussion (Williamson, 1979; Copestake, pers. <u>comm.</u>).

5.4(iv). Foraminiferal biostratigraphy.

The presence of <u>R</u>. <u>cushmani</u> and <u>R</u>. <u>greenhornensis</u> places samples 2-8 (Figure 5.2) within the top of R. <u>cushmani</u>

Arenobulimina advena	N 3 4000 7 8 W 6 0 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	9 •wc 1090-	10 swc1080		128Wc1080	1040 - 1 13 c 1050	15° 1030	Ţ
Eggereilina mariae Gavelinella berthelini Gavelinella cenomanica Gavelinella intermedia Gavelinella reussi	00000 00000 00000 000000 000000	0	0	0	0		00	
Haplophragmlum aequaleOLenticulina rotulata var. bOLenticulina rotulata var. cOMarssonella trochus var. turrisOTritaxla pyramidataOHerrescella trochus var. ovycona	00000	00	0	0	00	0	0	Fic
Marssonena trochus var. oxycona Nodosaria sp. a Pseudotextulariella cretosa Textularia chapmani Trochammina depressa Ataxophragmium depressum		0		0	0		00	gure 5.
Gyroidinoides parva Lingulogavelinella globosa Oolina sp. a Gavelinella baltica Praebulimina sp. a Ammodiscus protocours	°°°808	0		Q	0		0	2 Foran
Animiotascus ceretectus Plectina mariae Quinqueloculina sp. cf. Q. antiqua Marssonella trochus Eggerellina previs Arenobulimina presili	000 000 000	0	0	0	0			ninifera
Lingulogavelinella aumalensis Neoflabellina sp. b calcisphere ?		o			0	0	0 0 0	from I
Hedbergella delrioensis O Praeglobotruncana delrioensis O Praeglobotruncana stephani O Rotalipora cushmani O	~ 000 ~ 00	0	0	0 0	0	0	0 0	BP 93.
Hedbergella planispira Hedbergella simplex Dicarinella hagni Guembilitria cenomana Hedbergella brittonensis Heterohelix moremani Globigerinelloides bentonensis Rotalipora greenhornensis Marginotruncana sp. indet. Heterohelix globulosa Dicarinella algeriana "Hedbergella" aprica Helvetoglobotruncana sp. cf. H. hel	880000 8800000 0000000000	0	0	O	0		0	/2-1
	0 0 0			Ο	0		0 0 0 9	、
Pithonella ovalis			0					
30 20 Number of species					~			

i.z. and this is in agreement with Williamson (1979). Furthermore, the occurrence of benthonic species such as <u>G</u>. <u>cenomanica</u>, <u>G</u>. <u>intermedia</u> and <u>G</u>. <u>baltica</u> with forms of the <u>G</u>. <u>reussi</u> - <u>G</u>. <u>berthelini</u> plexus is consistant with this (Carter and Hart, 1977; also see 5.7-10). The <u>Marginotruncana</u> sp. <u>indet</u>. in sample 9 is probably caved. "<u>H</u>". <u>archaeocretacea</u> was not recorded but the presence of <u>H</u>. sp. cf. <u>helvetica</u> in sample 15 places that sample, at least, within the <u>H</u>. helvetica 1.z..

5.4(v). Foraminiferal assemblage.

The marked diversity change between samples 8-10 is consistant with the changes recorded onshore (see 5.5 -11), notably with the loss of <u>G. cenomanica</u>, <u>G. intermedia</u>, <u>G</u>. <u>baltica</u>, the <u>Eggerellina</u> population, <u>P. mariae</u> and the increased dominance of <u>L. globosa</u> and <u>G. berthelini</u> and the appearance of <u>A. preslii</u>. This interval contains the thin "calcareous mudstone" which is probably equivalent to the Plenus Marls which cover much of the Anglo-Paris Basin to the east (see 5.7-10). The gamma ray log was not available to investigate any possible deflection as exemplified by the offshore Plenus Marl Formation (Deegan and Scull, 1977).

5.5. Hooken Cliffs, Beer (Figures 3.2, 5.3-5).



0-0-0

0---0-0-0

0-0-0-0

0-0

dbergella'

obotruncene praeheli

Marssonella trochus var. oxycona

tricarinata var. jongmansi

archaeocretacea

Figure 5.3 Foraminifera from Hooken Cliffs

5.5(i). Lithostratigraphy.

The sequence examined comprises the upper 2.5m of the Beer Head Formation and the lower 2m of the Seaton Chalk Formation (Jarvis and Woodroof, 1984), and is locally the thickest representation. The Beer Head Limestone Formation consists of a number of well-indurated hardgrounds superimposed on detritus-rich limestones, the most prominent of which are used to delimit a number of members. The Humble Point Hardground, a massively indurated intraclastic nardground with a strongly phosphatized and glauconitized surface, marks the summit of the Little Beach Member. This is overlain by the Pinnacles Member: 2.3m of poorly indurated yellowish-grey glauconitic limestones with a weakly developed limonitic nodular hardground (Haven Cliff Hardground), at its summit, (op cit. Jarvis et al., in press).

The overlying Connett's Hole Member (the basal member of the Seaton Chalk Formation), has weakly indurated limestones at its base passing up into chalks containing little detritus. In all, thirteen samples were examined from this succession (Figure 5.3).

5.5(ii). 8 13C isotope curve.

The § 13C isotope (and oxygen isotope) curve (Figure 5.5) exhibits a marked excursion at the limonitic nodular hardground within the Pinnacles Member which is comparable



Figure 5.4 Details of foraminifera from Hooken Cliffs

with other late Cenomanian records (Arthur <u>et al.</u>, 1987), (see Figure 5.13 for detailed basin correlation).

5.5(iii). Macropalaeontological biostratigraphy.

The base of the Turonian in N.W. Europe is defined on ammonites and inoceramid bivalves, <u>Watinoceras</u> spp. and <u>Mytiloides</u> sp. cf. <u>M. opalensis</u> (<u>sensu Kaufman non Bose</u>), (Birkelund <u>et al.</u>, 1984). These have been recorded from immediately above the Haven Cliff Hardground (Wright and Kennedy, 1981), and thus it marks the base of the Turonian in S.E. Devon (Wright and Kennedy, 1981; Jarvis and Tocher, 1983; Jarvis and Woodroof, 1984; Jarvis <u>et al.</u>, in press). In addition, the assemblage also contains reworked ammonites of the Neocardioceras juddii zone (latest Cenomanian).

5.5(iv). Foraminiferal biostratigraphy.

The presence of <u>R</u>. <u>cushmani</u> (samples 1,4 and 5) and <u>R</u>. <u>greenhornensis</u> (sample 5), places these within the top of the <u>R cushmani</u> i.z., this in agreement with Hart (1970) and Carter and Hart (1977). The presence of "<u>H</u>". <u>archaeocretacea</u> (samples 9, 10, 11), places these within the <u>H</u>. <u>archaeocretacea</u> i.z. of Robaszynski and Caron (1979) which is in agreement with Hart and Weaver (1977), though they did not record any planktonics from the lowermost Connett's Hole Member.





5.5(v). Foraminiferal assemblage.

The foraminiferal assemblage (Figure 5.3) is impoverished compared to the basinal facies to the east (see 5.7-10), and the preservation of the specimens very variable, with many broken and exhibiting intense dissolution (particularly samples 3,6 and 8). The intense induration of some of the samples, especially those associated with hardgrounds, only permitted analysis of the foraminifera using thin sections. Thus no measurement of the relative proportions of each species was possible.

The foraminiferal assemblage is comparable to that recorded from a laterally equivalent sequence in a large isolated stack (the Pinnacles), by Carter and Hart (1977).

The foraminiferal assemblage shows a slight drop in diversity up the sequence (Figure 5.4), and a low specimen count for each sample except for one (sample 7), and this is due to an increase in the numbers of <u>H</u>. <u>delrioensis</u> with the appropriate change in the planktonic : benthonic ratio (Figure 5.4).

5.6. Shapwick Grange Quarry (Figures 3.3, 5.6).

5.6(i). Lithostratigraphy.

Shapwick Grange Quarry exposes the Upper Greensand, the Beer Head Limestone and the lower part of the Seaton Chalk

(Jarvis <u>et al</u>., in press). The Upper Greensand comprises 7m of yellow-light grey calcarenites which locally contain high proportions of quartz and glauconite sand. The sequence also contains prominent chalcedonic cherts at the base and in the middle of the sequence (Figure 5.6).

Two nodular hardgrounds with glauconitized surfaces occur in the succession. The lower one is found between the chert levels and the other forms the top of the Upper Greensand. The latter has been called the Small Cove Hardground in the comparable succession in the Beer area (Jarvis and Woodroof, 1984).

The Beer Head Limestone is strongly attenuated (60cm.), and two beds may be recognized. The lower one (25cm.) is comprised of intensely indurated light grey, quartz-rich micritic limestone. The structure of the bed is very complex, exhibiting many phases of sedimentation, bioturbation, cementation, reworking, mineralization, encrustation and boring (Jarvis <u>et al.</u>, in press). These characteristics are diagnostic of the Humble Point Hardground (top of the Little Beach Member) in severely attenuated successions (Jarvis and Woodroof, 1984; Jarvis et al., in press).

The Humble Point Hardground is overlain by 35cm. of strongly indurated nodular micrites containing occasional quartz sand. Its surface is uneven and has pebble intraclasts plastered upon it. This is representative of the Haven Cliff



Hardground which is the top of the Pinnacles Member (Jarvis and Woodroof, 1984; Jarvis <u>et al</u>., in press). The surface of the Haven Cliff Hardground marks the base of the Seaton Chalk.

The Seaton Chalk Formation (20m) consists of two moderately indurated hardgrounds at its base overlain by ~lm thick weakly developed rhythms of alternating poorly nodular and marly chalks. Nodular flints are associated with an omission suface developed 20m above the base of the Seaton Chalk Formation. The uppermost 6m of section consists of marly chalks including a second prominant semitabular flint and two weakly developed nodular hardgrounds. The sequence is comparable to the Connett's Hole Member (Jarvis and Woodroof, 1984; Jarvis et al., in press).

5.6(ii). <u>613C</u> isotope <u>curve</u>.

There are no isotope curves available for this section.

5.6(iii). Macropalaeontological biostratigraphy.

Shapwick has yielded many diverse and biostratigraphically important ammonite assemblages (Hamblin and Wood, 1976; Wright and Kennedy, 1981; Kennedy <u>et al</u>., 1982; Wright and Kennedy, 1984), that are usually associated with hardground surfaces.

An assemblage of Stoliczkaia dispar (d'Orbigny) and

species of <u>Callihoplites</u> and <u>Discohopilites</u> were recorded from the "Upper Greensand" (Hamblin and Wood, 1976), providing a definite late Albian <u>S</u>. <u>dispar</u> zone age for the top of the Upper Greensand, though the exact position of this fauna was not made against a lithological log. They were later positioned (Wood, in Hart <u>et al.</u>, 1979), 1.5m above the tabular cherts, placing them within the Small Cove Hardground. These anmonites are now thought to have come from Im above the tabular cherts from a fine sand unit just below the Small Cove Hardground (Wood, pers. comm.).

From immediately above the Humble Point Hardground (base of the Pinnacles Member), <u>Euomphaloceras euomphalum</u> (Sharpe) and <u>Calyoceras naviculae</u> (Mantell) have been recorded belonging to the early late Cenomanian <u>Calyoceras guerangeri</u> zone (Wright and Kennedy, 1981).

Ammonites of the latest Cenomanian <u>Neocardioceras</u> judii zone have been recorded as some of the intraclasts welded to the surface of the Haven Cliff Hardground (Wright and Kennedy, 1981; Kennedy et al., 1982).

An assemblage of earliest Turonian <u>Watinoceras</u> spp. occurs in the nodular hardground at the bottom of the Seaton Chalk.

5.6(iv). Foraminiferal biostratigraphy.

A foraminiferal study of the greensand yielded a very

poor fauna of <u>Patellina trochiformis</u> (Shacko), <u>Arenobulimina</u> <u>sp. cf. A. obliqua</u> (d'Orbigny), <u>Arenobulimina sp. cf. A.</u> <u>depressa</u> (Perner) and <u>Marssonella oxycona</u> (Reuss) from just below the chert beds (Hart <u>et al.</u>, 1979). The assemblage did not permit a finer biostratigraphical resolution than an Albian - Cenomanian age (op cit.).

The Small Cove Hardground has yielded <u>R. reicheli</u> and <u>Favusella washitensis</u> (Figure 5.6). The presence of the former indicates that part of the sediment within the hardground is of an early Cenomanian age (Robaszynski and Caron, 1979). In addition, its association with <u>F. washitensis</u> is comparable to other local clastic dominated sequences of early Cenomanian age, e.g. Wilmington (Hart, 1970; Carter and Hart, 1977; Hart, 1983). Thus it implies the Small Cove Hardground contains sediment of Pounds Pool Member equivalent even though it is not present as a unit at Shapwick.

The presence of <u>R</u>. <u>appenninica</u> within the Humble Point Hardground infers an early to middle Cenomanian age (Robaszynski and Caron, 1979) for part of that unit. The nodular hardground at the base of the Seaton Chalk yielded <u>T</u>. <u>tricarinata</u>, <u>G</u>. <u>berthelini</u> and <u>L</u>. <u>globosa</u>, a characteristic early Turonian benthonic assemblage (Owen, 1970; Carter and Hart, 1977; see 5.7-10). Also present are a small number of <u>G</u>. <u>intermedia</u> and <u>Rotalipora</u> <u>sp</u>. cf. <u>R</u>. <u>cushmani</u> which are characteristic of the Cenomanian. These specimens are very

poorly preserved and heavily pitted. The rotaliporids are neanic and this, coupled with their poor preservation, makes their identification problematical. These specimens are probably reworked.

These features of downworking through burrowing and reworking on top of the hardground surfaces causes intermixing of the fauna and thus negates against biostratigraphical resolution.

The presence of <u>H</u>. <u>helvetica</u> 12m from the base of the Connett's Hole Member, infers an early - middle Turonian age (Robaszynski and Caron, 1979). "<u>H</u>". <u>archaeocretacea</u> is not recorded from below the sample containing <u>H</u>. <u>helvetica</u> which may be the result of the poor recovery of such delicate planktonic species from highly nodular chalks such as those found at the base of the Connett's Hole Member.

5.6(v). Foraminiferal assemblage.

The foraminiferal assemblage, in keeping with Hooken Cliffs (5.5(v)), is very poor when compared to the diversity of the most basinal sections (5.8-11).

5.7. Introduction to the lithostratigraphy and biostratigraphy of the mid-Cretaceous Chalk facies of southern England.

The mid-Cretaceous lithostratigraphy of the Chalk

facies of the Anglo-Paris Basin in southern England has recieved much attention (Phillips, 1818, 1821; Jukes-Browne and Hill, 1903,1904; Jefferies, 1962; Hancock, 1976; Mortimore, 1986; Robinson, 1986). All workers recognized the Plenus Marl (Robinson, 1986), and for the purpose of this study, which only covers this short interval, one lithostratigraphic scheme has been adopted (see 3.4).

The studied interval covers the Abbots Cliff Chalk Formation (part), Plenus Marl Formation and the Dover Chalk Formation (part). Only the top of the former, the Chapel-le-Ferne Member is covered in this study and consists of bioturbated chalks with occasional marl seams. The base of the Plenus Marl Formation is marked by an erosion surface (Jefferies, 1962), the sub-Plenus erosion surface, and the overlying Plenus Marl Formation consists of eight distinct beds numbered 1-8, the relative thicknesses of which may vary. The Dover Chalk Formation consists of a variety of lithologies: white chalk, calcarenitic chalk, nodular chalk and intraclastic chalk with occasional flints. Well-developed marl seams occur throughout the Formation (Robinson, 1986). It consists of three members: the Shakespeare Cliff, Aycliff and Akers Steps Members. The Shakespeare Cliff Member may consist of very nodular chalks with incipient hardgrounds at its base (Melbourn Rock facies) (Robinson, 1986).

The Cenomanian - Turonian boundary is proposed on

ammonites as the base of the <u>Pseudaspidoceras flexuosum</u> zone (Birkelund <u>et al.</u>, 1984), although this is a tethyan form. In Europe, the appearance of a <u>Watinoceras coloradoense</u> zone ammonite assemblage is used (Wright and Kennedy, 1981; Kennedy <u>et al.</u>, 1982; Kennedy, 1984), although the subspecies <u>W</u>. coloradoense coloradoense (Henderson) is absent in Europe.

The associated inoceramid fauna is useful. The base of the <u>P. flexuosum</u> zone is marked by the appearance of <u>Mytiloides opalensis sensu</u> Kauffman <u>non</u> Bose in America and a widespread appearance of early <u>Mytiloides</u> throughout the Tethyan and Boreal realms (Kauffman <u>et al.</u>, 1977; Birkelund, 1984; Hancock, 1984). Thus, because of the poor ammonite records in the onshore basinal sections, the inoceramid faunal change is a good Turonian indicator (Jefferies, 1963; Kennedy and Wright, 1981; Woodroof, 1981).

The foraminiferal zones previously proposed (Williams-Mitchell, 1948; Carter and Hart, 1977), use an integrated benthonic and planktonic scheme. The latter is particularly well-suited to correlation of the more basinal facies of the Anglo-Paris Basin. This study covers the upper level of zone 13 and all of zone 14, <u>sensu</u> Carter and Hart, 1977. Zone 14 coinciding with the Plenus Marl Formation (op cit.). Carter and Hart (1977) did not consider the whole of the succession above the Plenus Marl Formation. Owen (1970), established a series of local planktonic assemblage zones through the Turonian based upon relative abundances and occurrence. These have been coupled with the international zones proposed by Robaszynski and Caron (1979), and combined with locally significant benthonic species (Hart, 1982b).

6% White Nothe (Figures 3.7, 5.7, 5.8).

5.8(i). Lithostratigraphy.

The sequence at White Nothe comprises 10m of the top of the Abbots Cliff Formation, 3.6m of the Plenus Marl Formation and 15m of the Dover Chalk Formation of which the first 1.5m is not exposed (Figure 5.7).

The Abbots Cliff Formation consists of lm-0.5m marl-marly chalk rhythms with their frequency increasing up the succession. There are occasional flints towards the base.

All eight beds (<u>sensu</u> Jefferies, 1963) of the Plenus Marl Formation are present, with beds 1-4 being well represented, comprising 2.5m of the 3.6m unit.

The base of the Dover Chalk Formation is not exposed. The overlying sequence is composed of thinly bedded nodular chalks with incipient hardgrounds passing into nodular chalk-marl rhythms the thickness of which varies from Ø.75m-1.75m. Nodular chalks become dominant towards the top of the sequence.

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5.8(ii). Sl3C isotope curve.

There is no $\,\delta 13 C$ isotope curve available for White Nothe.

5.8(iii). Macropalaeontological biostratigraphy.

The base of the <u>M</u>. sp. cf. <u>M</u>. <u>opalensis</u> zone appears to be 2.8m above bed 8 of the Plenus Marls (Woodroof, 1981).

5.8(iv). Foraminiferal biostratigraphy.

The presence of <u>R</u>. <u>cushmani</u> (samples 1-13), and <u>R</u>. <u>greenhornensis</u> (samples 1-3, 5, 10-12), places the lower part of the sequence, up to the top of bed 3 (Plenus Marls), within the top of the <u>R</u>. <u>cushmani</u> i.z.. "<u>H</u>". <u>archaeocretacea</u> is rare (samples 22, 26), and definitely places the early portion of the Dover Chalk Formation within the "<u>H</u>". <u>archaeocretacea</u> i.z.. Early forms of the <u>H</u>. <u>praehelvetica</u> – <u>H</u>. <u>helvetica</u> plexus also occur (samples 19, 21-26) in this interval.

5.8(v). Foraminiferal assemblage.

The numbers of the foraminiferal population recovered varies considerably across the interval (Figure 5.8) which is a result of the interaction of benthonic diversity, planktonic diversity and preservation.

Within the Abbots Cliff Chalk Formation (samples 1-9), the population varies around 150 specimens (minimum), and 340





specimens (maximum) per sample, but shows a marked drop at the summit of the unit (sample 9) to 105 specimens. The planktonic diversity remains constant but the benthonic diversity largely mirrors the population numbers. The planktonic : benthonic ratio shows a gradual decrease (through samples 1-8) but a slight increase at the top (sample 9). Within the planktonic population the rotaliporid component shows a steady decline (samples 1-4) with a small recovery (samples 5-7) and a complex change (samples 8 and 9). The praeglobotruncanid/dicarinellid population remains constant and no planktonic or benthonic species becomes extinct throughout.

The Plenus Marl Formation, in contrast, shows major changes in diversity, population numbers and the relative numbers of planktonic and benthonic specimens. Bed 1 shows a significant increase in numbers (550 specimens) with an increase in benthonic diversity, though there is a slight decline at the top of bed 1. The planktonic diversity remains the same as from the Abbots Cliff Chalk Formation but the planktonic : benthonic ratio is very high, with the planktonic population forming 80% of the total. Within the planktonic population the rotaliporid component is high (75%) but declines slightly through the bed. At the top of bed 1 <u>A</u>. <u>advena, D. gradata, G. cenomanica, G. intermedia, G. baltica</u>, T. macfadyeni, A. depressum and P. plana disappear. Through beds 2-8 the benthonic diversity declines as does the number of specimens recovered, from 340-120. The planktonic : benthonic ratio decreases up these beds with the planktonic population forming as little as 10% of the total population. Within the planktonic population, the decline in the rotaliporid component (started in bed 1) continues with <u>R</u>. <u>cushmani</u> disappearing at the top of bed 3. Unlike the Abbots Cliff Chalk Formation the praeglobotruncanid/dicarinellid component becomes the dominant component of the total population. The benthonic population becomes dominated by an assemblage of <u>L</u>. <u>rotulata</u> var.b , <u>G</u>. <u>berthelini</u>, <u>L</u>. <u>globosa</u> and <u>T</u>. <u>chapmani</u>, the latter disappearing in bed 7. The specimens from beds 4 to 8 show pitted tests indicative of dissolution, the intensity of which is most marked in the tests of the planktonic species.

The decline in the total number of specimens continues into the Dover Chalk Formation except for one sample (no. 22). At the base of the Formation, the population is totally dominated by benthonic specimens. There is a slight increase in the planktonic influence (samples 22 and 23), mainly dicarinellids, which accounts for the increased number specimens from these samples. There are not sufficient number of planktonic specimens to warrant a detailed breakdown of the population.

5.9. Compton Bay, Isle of Wight (Figures 3.6, 5.9, 5.10).

5.9(i). Lithostratigraphy.

The sequence comprises 9.75m of the Abbots Cliff Formation, the Plenus Marl Formation (4.2m) and 24.2m of the Dover Chalk Formation (Figure 5.9). The sequence dips steeply to the N.W. and is complicated by faulting in the Dover Chalk Formation (Text Plate 2).

The Abbots Cliff Formation consists of bedded chalk marl - marl rhythms of variable thickness, 0.5 - 2.0m, though mostly they are >lm. Intense bioturbation is discernable where there is sufficient lithological contrast.

The Plenus Marl Formation (Text Plate 2), is well-developed with all eight beds present. The sub-Plenus erosion surface is poorly developed compared to Eastbourne (5.10(i)) and Dover (5.11(i)).

The base of the Dover Chalk Formation is marked by 2m of pebbly hardgrounds with a minor detrital component of shell debris. Above this is a sequence of chalk marls with the occasional well-developed marl. At 6.5m above bed 8 there is a prominent discontinuous sponge-rich hardground. The sequence is incomplete (11.5m above bed 8) because of strong local faulting. Apart from the thin nodular hardgrounds at the base

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of the Dover Chalk Formation, it is considerably less nodular and pebbly than the sequences to the east, particularly Dover.

5.9(ii). 613C curve.

There is no δ 13C isotope curve available for this section.

5.9(iii). Macropalaeontological biostratigraphy.

The base of the <u>M</u>. sp. cf. <u>M</u>. <u>opalensis</u> zone is 3.1mabove the base of the Dover Chalk Formation (Woodroof, 1981).

5.9(iv). Foraminiferal biostratigraphy.

The presence of <u>R</u>. <u>cushmani</u> (samples 1-13), and <u>R</u>. <u>greenhornensis</u> (samples 2, 3 and 10), places the lower part of the sequence up to the top of bed 3 (Plenus Marls), within the top of the <u>R</u>. <u>cushmani</u> i.z.. "<u>H</u>". <u>archaeocretacea</u> appears in the basal beds of the Dover Chalk Formation (samples 21, 22, 24-26, 28, 30-32, 34-36), and places up to sample 36 within the "<u>H</u>". <u>archaeocretacea</u> i.z.. The presence of <u>H</u>. <u>helvetica</u> (samples 36, 37), places these within the <u>H</u>. <u>helvetica</u> i.z..

5.9(v). Foraminiferal assemblage.

The number of the foraminiferal population recovered varies considerably across the interval (Figure 5.10) which is a result of the interaction of benthonic diversity, planktonic

-Figure 5.10 Foraminiferal details from Compton Bay Isle of Wight



diversity and preservation.

Within the Abbots Cliff Chalk Formation (samples 1-8), the population varies around 140 specimens (minimum) and 360 (maximum) per sample, but the population shows an increase at the top of the unit. The planktonic diversity remains constant but the benthonic diversity mirrors the population numbers. The planktonic : benthonic ratio shows a gradual decrease up the sequence (samples 1-7) with a sudden increase at the summit (sample 8). Within the planktonic population, the rotaliporid component forms much less than 50% of the total population. It decreases at the base of the section (samples 1-4), shows a small recovery (samples 5, 6) and then a decrease at the summit (samples 7, 8). The praeglobotruncanid/dicarinellid population forms around 5-35% of the total population. Major changes occur in the hedbergellid population.

The Plenus Marl Formation, in contrast, shows major changes in diversity, population numbers and the relative numbers of planktonic and benthonic specimens. Bed 1 shows a significant increase in the numbers of specimens (~460), although it is declining towards the middle of the bed. The benthonic diversity, in contrast, increases through the bed. The planktonic diversity remains the same as for the Abbots Cliff Chalk Formation and the planktonic : benthonic ratio remains as high as for the top of the Abbots Cliff Chalk

Formation, with around 55% planktonics.

5.10. Eastbourne, Gun Gardens (Figures 3.5, 5.11, 5.12).

5.10(i) Lithostratigraphy.

The succession at Eastbourne is expanded compared to Dover (5.11(i)), White Nothe (5.8(i)) and the Isle of Wight (5.9(i)) (Jefferies, 1962; Carter and Hart, 1977; Woodroof, 1981). It comprises 10.5m of the top of the Abbots Cliff Chalk Formation, the Plenus Marl Formation (8.3m) and 37m of the Dover Chalk Formation. Although towards the top of the sequence part of the Dover Chalk Formation is inaccessible (Figure 5.11).

The Abbots Cliff Formation comprises $\langle \emptyset.5-1.0m$ chalk marl- marl rhythms which exhibit a high degree of bioturbation (Text Plate 1).

The Plenus Marl Formation is significantly thicker, at 8.3m, than to the east (Dover) and west (Compton Bay, White Nothe), with a prominent sub-Plenus omission surface.

The Dover Chalk Formation comprises 5-6m of slightly nodular chalks and marl seams at its base passing into marl chalks with prominent marl seams. Towards the top of the

154 õ 6 сņ Cen'omanian Abbots Cliff Chalk Plenus Maria 3 NG Capel-le-Ferne Member . 1 ŝ Ģ .. 1 -EGG8 -EGG9 -EGG1 FEGG2 -EGG11 -EGG3 -E004 -EGG5 -E0G6 -EGG10 -EGG12 000 Ammodiscus cretaceus 0 0 œ 0 Arenobulimina edvena 8 000 000 Dorothis gradata 008880 808880 808880 80 Gavelnelle baltica Figure Gavelhele cenomi 8 Gavelhelle Intermedie Gavelhelle roussi Lenticulina rotuista var. a 0 0 888 Lenticulina rotulata var. b 0 0 8 Marssonella trochus var. turris 0 0 **e 5.11 Foraminifera from E** 88 88 80 0 8 Plectina cenomana 0 Tritexia macfadyeni Tritexia pyramidata Vaginulina costulata form c 8 0 0 0 0 0 Arenobulimina sp. a 0 Frondicularia cordal 0 Marssonella trochus Marssonella trochus var. oxycona 0 0 8 Plectina.marine 8 0 88 Pseudospiropiectinata plana 0 0 00 Vaginulina costulata form a 800 0 Vaginulina costulata form b Dentalina sp. b Nodosala sp. a 00 80 0 8 0 0 Tristix excavatus 8 8 0 Eggereiline marine 0 0 Eoguttulina sp. a Ramulina aculoata Dentalina sp. c 800 0 Frondicularia sp. a 0 0 Quinqueloculina antiqua 800 Dentalina sp. a Lingulogavelinella globosa ∞ 0 0 0 0 Vaginulina costulata form d 00 Eastbourne Ataxophragmlum depressum Lenticulina rotulata var. c 0 88 8 8 8 8 Eggerellina brevis 000 000000 000 Marssonella sp. a 00 0000 0000 Textularle chapmani Astacolus sp. a Frondicularia gaultina 000 Gavelinella berthelini 0 0 Pandaglanduline sp. a Tricarinata tricarinata 0 ထာထ Hedbergelia delricensis Praegiobotruncana stephani 8 808 000000 8 8 8000 800 ∞ 000000 8 00000 8 Rotalipora cushmani 0 Guembilitria cenomana 0 8 Heteroheik: moremani "Hedbergella brittonensis" Giobigenholioides bentonensis Dicamella algeriana "Hedbergella aprica" 8888 0 0 8000 8 8 80 8000 0 8°. 8 Dicarinella hagni 0 Dicarinella Imbricata Rotalipore greenhomensis 0

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sequence there are very occasional locally developed incipient hardgrounds. These chalks are much more marly than the nodular, pebbly chalks of the Melbourn Rock facies at Dover (5.11(ii).

5.10(ii). 613C isotope curve.

There is no $\$ 13C isotope curve available for Eastbourne.

5.10(iii). Macropalaeontological biostratigraphy.

The <u>M.</u> sp. cf. <u>M. opalensis</u> zone appears 4m from the base of the Dover Chalk Formation (Woodroof, 1981). The expansion in the sequence is displayed by the inoceramid zones, here the <u>M.</u> sp. cf. <u>M. opalensis</u> zone is 18m thick whereas to the west it is 3m thick (Compton Bay) and to the east 4.8m thick (Dover op cit.). A detailed study of this fauna is in progress (by Gale and Wood, Gale <u>pers. comm.</u>).

5.10(iv). Foraminiferal biostratigraphy

The presence of <u>R</u>. <u>cushmani</u> (samples 1-5, 7-11) and <u>R</u>. <u>greenhornensis</u> (sample 8), places the lower part of the sequence up to the top of bed 3 (Plenus Marls) within the uppermost part of the <u>R</u>. <u>cushmani</u> i.z.. "<u>H</u>". <u>archaeocretacea</u> first appears in the basal levels of the Dover Chalk Formation (samples 20, 24, 30-32 and 34) and places up to sample 33 within the "<u>H</u>". <u>archaeocretacea</u> i.z.. <u>H</u>. <u>helvetica</u> appears in sample 33 and places the very top of the sequence within the <u>H</u>. <u>helvetica</u> i.z..

5.10(V). Foraminiferal assemblage.

The number of the foraminiferal population recovered varies considerably across the interval (Figure 5.12), which is a result of the interaction of benthonic diversity, planktonic diversity and preservation.

Within the Abbots Cliff Chalk Formation (samples 1-7), the population varies between 280 specimens (maximum) and 105 specimens (minimum) per sample. The planktonic diversity mirrors the population numbers. The planktonic : benthonic ratio decreases in the base of the sequence (samples 1-3), increases slightly again (samples 4-6) only to decrease sharply at the top of the unit (sample 7). Within the planktonic population the rotaliporid component forms much less than 50% of the total population. It decreases at the base of the section (samples 1-3), shows a small recovery (sample 4), then a decline (sample 5) to zero (sample 6) to recover at the summit of the unit, (sample 7). The praeglobotruncanid/dicarinellid population forms around 5-25% of the total population. Major changes occur in the hedbergellid population.

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The Plenus Marl Formation, in contrast, shows major changes in diversity, population numbers and the relative numbers of planktonic and benthonic specimens. Bed 1 shows a significant increase in the number of specimens (~440), although it declines towards the middle of the bed. Benthonic diversity decreases through the bed. The planktonic diversity continues level as from the Abbots Cliff Chalk Formation. The planktonic : benthonic ratio increases dramatically with over 80% planktonic specimens. Within the planktonic population, the rotaliporid component continues the increase started in the top of the Abbots Cliff Chalk Formation, rising to 60% of the total. At the top of bed 1 <u>G. baltica</u>, <u>D. gradata</u>, <u>T</u>. <u>macfadyeni</u>, <u>G. intermedia</u>, <u>P. mariae</u>, <u>A. depressum</u>, <u>G</u>. cenomanica all disappear.

Through beds 2-8 the benthonic diversity shows a steady decline, with major fluctuations, as does the total number of specimens from 320 to under 200. The planktonic : benthonic ratio decreases up the succession with the occasional anomalous increase: bed 6 (sample 14) and the bottom of bed 8 (sample 16). Within the planktonic population the rotaliporid component declines, with <u>R. cushmani</u> disappearing in the middle of bed 3 (sample 11). Unlike the Abbots Cliff Chalk Formation, the praeglobotruncanid/ dicarinellid component becomes the dominant proportion of the planktonic population. The benthonic population becomes

dominated by an assemblage of <u>L</u>. <u>rotulata</u> var.b, <u>G</u>. <u>berthelini</u>, <u>L</u>. <u>globosa</u> and <u>T</u>. <u>chapmani</u>. The specimens from bed 8 (samples 16,17) exhibit pitted tests indicative of dissolution.

The decline in the total number of specimens continues into the Dover Chalk Formation though the benthonic diversity shows a moderate recovery. The assemblage is dominated by benthonics with a low planktonic : benthonic ratio. The number of planktonic specimens recovered was generally very low and in many cases there were not sufficient specimens to warrant a detailed breakdown of the planktonic population. All the specimens exhibit pitted tests indicative of dissolution.

5.11. Dover (Figures 3.4, 5.13, 5.14, 5.15).

5.11.(i) Lithostratigraphy.

The succession comprises the top of the Abbots Cliff Chalk Formation, the Plenus Marl Formation (2.5m), and 22m of the Dover Chalk Formation (Figure 5.13).

The Abbots Cliff Chalk Formation consists of weakly rhythmic marly chalks of decimetere scale alternations of friable marl and indurated chalk (Jukes-Browne and Hill, 1903; Kennedy, 1969; Carter and Hart, 1977), though at the top the rhythms are very poorly developed and the spacing increased.

5 ö () 0 Cenomanian Turonian Plenus Maria Abbots Cliff Chalk Dover Chalk Fmt. 3 Capel-le-Ferne Member 1 Nu Shakespeare Cliff Member 1 đ AKS1 ABC4 -ABC2 AKSA ABC1 -ABC3 -AKS2 ABC5 ABCE **ABC19** AKS3 ABC7 ABC 16 Arenobulimina advena 0 0 ∞ Arenobulimina bulletta Dorothia gradata Eggerellina brevia 0000 800 Eggerellina mariae Gavelinella baltica Gavelinella intermedia 0000 လာတ် လာဝဏ္ဍာက်ကို လောင် Gavelinella reussi Lenticulina rotulata var. a 0000 ğo Öc 00 0000000 00 Lenticulina rotulata var. b 0 0 0 Marssonella trochus var. oxycona Marssonella trochus var. turris Ô സ്ത്ത 0 0 Plectina mariae Ramulina aculeata 000 0000 800 Tritaxia macfadyeni 00 Tritaxia pyramidata 80 Gavelinelle berthelini Gavelinelle cenomenica 0 0 ω Gyroldinoides parva Merssonella trochus 80000 0000 Atexophragmium depressum oraminifera from Dover Frondicularia gaultina 8 ന്ന് അമ്മാറ്റ്റാ Lingulogaveline la giobosa 0 O 0 -0 Nodosaria sp. a Ooline sp. a Ammodiscus cretaceus 000 88 0 Arenobulimina sp. a 0 Astacolus sp. a Dentalina sp. a Dentalina sp. b ∞ 000000 Frondicularia cordal Pandagiandulina sp. a Plectina cenomana Tritaxia tricarinata 00 Q Vaginulina costulata var. a Pseudospiropiectinata plana Vaginulina costulata var. b Vaginulina costulata var. c 8 8 Vaginulina costulata var. d Dentalina sp. c Marasonella sp. a 0000 Textularia chapmani 00000 Neofiebellina sp. a Ô Arenobulimina presili 0 1 Guembilitria cenomana 0000000 0 0 0 Guembilitriella sp. a 0 0000 Hedbergelle del Hoensis 00 000000 0 888 8 8 Heterohelix moremani 8 0 Praeciobotruncana stephani 8 Rotalipora cushmani n Rotalpora greenhomensk **000**00 "Hedbergels aprica" Dicarinella hagni Dicarinella algeriana 0 0 8 කිකී 800 8 Q 8 8 Hedbergelle brittonensis 0 'o Hedbergelle planispira Hedbergelle simplex ω Dicarinella Imbricata ∞o 88 8 8 8 "Hedbergelle archaeocretacea" Heterohelix globulosa Helvetogibotruncana praehelvetica 30 20 Number of species 10 ٥

20 25 30 0 Turonian Dover Chalk Fmt. Shakespeare Cliff Member 3 -AKSBO O -AKS5 00000 -AKS90 000 AKS6O -AKS 10 -AKS12 00 00 0 -AKST O AKS11 0000 0 -AKS13 00 000000 Figure 5.13 Foraminifera from Dover (cont.) Gavelinella berthelini Lenticulina rotulata var. a 8 0 00000 Lenticulina rotulata var. b Marssonalla trochus var. oxycona Marssonalla trochus var. tumis 0 8 0 000 Arenobulimina presili Marssonelle trochus Ammodiscus cretaceus Frondicularia gaultina Lingulogavelinella globosa 8 8 Ataxophragmlum depressum ð 8 Tritaxia tricarinata var. jongmansi Frondicularia sp. a Lingulogavelinella aumalensis 0 8 Lenticulina rotulata var. c 8 00000 Dicarinella algeriana Dicarinella hagni Dicarinella imbricata 0 0 0000 0 0 8 8000 8000 0 Hedbergelle aprica 8 0 Helvetoglobotruncana praehelvetica 800 Hedbergella archaeocretacea Hedbergella delrioensis 0 Heterohelix moremani Marginotruncana marginata 0 00 0 Heterohelix globulososa 0 "Hedbergella brittonensis" 15 10 Number of species 0

In addition, a small number of prominent marls are present.

The Plenus Marl Formation at Dover is the thinnest, at 2.5m, of the four onshore basinal sections studied (see 5.8(i), 5.9(i), 5.10(i)). The sub-Plenus erosion surface is well developed with the dark grey clay-rich marls infilling a suite of burrows (<u>Thalassinoides</u>, <u>Chondrites</u> and <u>Planolites</u>) within the underlying chalk marl. Beds 1-4, at 1.85m, are well represented, whilst beds 5, 6 and 8 are reduced.

The overlying Dover Chalk Formation shows a marked change in facies from the clay-rich marl of the Plenus Marls to highly nodular intraclast-rich chalks with well indurated hardgrounds in the basal 1.2m. This latter, the Melbourn Rock facies, is particularly well represented at Dover and contains abundant limonite-stained chalk pebble intraclasts and coarse calcarenite shell debris, particularly comminuted inoceramid and echinoderm tests. Further up the sequence the nodularity of chalks decreases and a few prominent marls are present.

5.11(ii). <u><u>§13C</u> isotope curve.</u>

The carbon stable isotope signature (Figure 5.14) shows a marked excursion in \$13C value through the Plenus Marl Formation and the Melbourn Rock facies of the Dover Chalk Formation. It shows a \$13C enrichment from the background level of 2.5-3 @/@@ (PDB) to a maximum of 4.6 @/@@ (PDB) in bed 8 of the Plenus Marl Formation. The enrichment shows a





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5.14 Isotope curves from Dover (cont.) more rapid ascent through the Plenus Marls than descent through the first 2m of the Melbourn Rock facies (Carson, pers. comm.).

5.11(iii). Macropalaeontological biostratigraphy.

The presence of a <u>Sciponoceras</u> fauna in the basal hardgrounds of the Melbourn Rock at Dover suggests that the hardgrounds lie within the uppermost Cenomanian <u>Neocardioceras</u> <u>d</u> judii zone (Wright and Kennedy, 1981). A <u>Watinoceras</u> fauna has been recorded from Merstham (op cit.) which indicates that the higher beds of the Melbourn Rock are within the Turonian <u>W</u>. <u>coloradoense</u> zone. In addition, Upper Cenomanian <u>Inoceramus</u> <u>pictus</u> Sowerby are common in the basal hardgrounds and <u>Mytiloides</u> appears immediately above them (Woodroof, 1981). Thus this inoceramid faunal change is used to define the base of the Turonian, at 2.3m above the top of bed 8, Plenus Marl Formation.

In addition, the Turonian nannofossil marker <u>Quadrum</u> <u>gartneri</u> appears (sample 20, Figure 8.4) just above this level (Cooper, pers. comm.).

5.11(iv)). Foraminiferal biostratigraphy

The presence of <u>R</u>. <u>cushmani</u> (samples 1-10), and <u>R</u>. <u>greenhornensis</u> (samples 1, 3, 7 and 8), place the lower part of the sequence up to bed 3 (Plenus Marls) within the upper part of the <u>R</u>. <u>cushmani</u> i.z.. "<u>H</u>". <u>archaeocretacea</u> appears in the basal part of the Dover Chalk Formation (samples 21-25, 26, 27, 30, 31, 33), and places up to sample 35 within the "<u>H</u>". <u>archaeocretacea</u> i.z.. The presence of <u>H</u>. <u>helvetica</u> (samples 35, 36, 38-40) places these samples within the <u>H</u>. helvetica i.z..

5.11(v). Foraminiferal assemblage.

The number of the foraminiferal population recovered varies considerably across the interval (Figure 5.15), which is a result of the interaction of benthonic diversity, planktonic diversity and preservation.

Within the Abbots Cliff Chalk Formation (samples 1-6), the population varies between 310 specimens (maximum) and 55 (minimum) per sample. The planktonic diversity remains constant but the benthonic diversity largely mirrors the population numbers, with a marked drop in sample 4. The planktonic : benthonic ratio increases in the base of the sequence (samples 1-3), recovers and decreases (samples 4 and 5), to recover at the top of the unit (sample 6). Within the planktonic population the rotaliporid component forms much less than 50% of the total population. It decreases at the base of the sequence (samples 1, 2), decreases (sample 5) and recovers (sample 6). The praeglobotruncanid/dicarinellid





component remains constant and major changes occur in the hedbergellid population.

The Plenus Marl Formation, in contrast shows major changes in diversity, population numbers and the relative numbers of planktonic and benthonic specimens. Bed 1 shows an increase in the number of specimens (~250). The benthonic diversity declines through the bed. The planktonic diversity continues on the same level as from the Abbots Cliff Chalk Formation. The planktonic : benthonic ratio is high with around 75% planktonics. Within the planktonic population the rotaliporid component continues the increase started in the top of the Abbots Cliff Chalk Formation, rising to over 60% of the total. At the top of bed 1 <u>T. macfadyeni, G. baltica, A.</u> <u>advena, A. depressum, P. plana, R. greenhornensis, G. cenomana</u> and <u>G. intermedia</u> all disappear.

Through beds 2-3 the benthonic diversity shows a steady decline, as does the total number of specimens, from 190 to 40 with a slight increase in bed 4 (sample 11). The planktonic : benthonic ratio shows a sharp decrease and remains steady at around 75% of the total population. Within the planktonic population the rotaliporid population declines sharply, with <u>R. cushmani</u> disappearing in the middle of bed 3 (sample 10). Unlike the Abbots Cliff Chalk Formation, the praeglobotruncanid/dicarinellid component becomes the dominant portion of the planktonic population. The benthonic population

becomes dominated by an assemblage of <u>L</u>. rotulata var., <u>G</u>. <u>berthelini</u>, <u>L</u>. <u>globosa</u> and <u>T</u>. <u>chapmani</u>. The specimens from beds 4 to 8 show pitted tests indicative of dissolution, the intensity of which is most marked in the tests of the planktonic species.

The decline in the total number of specimens continues into the Dover Chalk Formation as does the benthonic diversity. The assemblage is dominated by benthonic taxa with a moderate planktonic : benthonic ratio. The number of planktonic specimens recovered was generally very low and in many cases there were not sufficient specimens to warrant a detailed breakdown of the planktonic population. All the specimens exhibit pitted tests indicative of dissolution.

5.12. BritOil 48/22-1. (Enclosure 1, Figure 5.16).

5.12(i). Lithostratigraphy.

The succession comprises some 66m of limestone of which approximately 62m is part of the Hildra Formation. The position of the Plenus Marl Formation is problematic and the gamma ray deflection is poor, probably occuring at around 126m downhole (Copestake, pers. comm.).

5.12(11). & 13C isotope curve.

There is no carbon isotope curve available for Brit0il



5.12(iii). Macropalaeontological biostratigraphy.

No macrofossils have been recorded from BritOil 48/22-1 (Copestake, pers. comm.).

5.12(iv). Foraminiferal biostratigraphy.

The first appearance downhole of <u>R</u>. <u>cushmani</u> occurs in sample 19 and thus the top of the <u>R</u>. <u>cushmani</u> i.z. is at 124m downhole.

5.12(v). Foraminiferal assemblage.

Only the sequence from the base of the <u>R</u>. <u>cushmani</u> i.z. has been studied in detail (samples 14-22). The number of specimens shows a steady decline from 180 (maximum) to 50 (minimum) per sample. The planktonic : benthonic ratio is low until sample 19 when the planktonics become dominant, forming at least 80% of the total population thereafter. Within the planktonic population the rotaliporid component is low, always less than 10%. <u>R</u>. <u>cushmani</u> disappears in sample 19. After sample 19 the praeglobotruncanid/ dicarinellid component becomes the dominant part of the planktonic population.

5.13. Carbon isotope curve and stratigraphy.

Carbon isotope curves have been used for correlation

of Cretaceous sediments by Scholle and Arthur (1980), Jenkyns (1985), Hilbrecht and Hoefs (1986) and Schlanger <u>et al</u>. (1987).

The carbon isotope curve at Beer Stone Adit (figure 5.5), shows a marked excursion, at the limonitic hardground within the Pinnacles Member, in the \$ 13C value from 2 0/00 (PDB) to just over 4 0/00 (PDB). The larger value from the chalk matrix, lower values provided by intraclasts contained within the hardground (Carson, pers. comm.).

The carbon isotope curve from Dover (Figure 5.14), shows an excursion through the Plenus Marl Formation from a background level of 2.5-3.0 0/00 (PDB) to a maximum of 4.6 0/00 (PDB) in bed 8 of that unit (Carson, <u>pers. comm.</u>). Thus the limonitic hardground at Beer is equivalent to at least the Plenus Marl Formation.

<u>G. intermedia</u> disappears at the top of bed 1 (Plenus Marls) and <u>R. cushmani</u> disappears in the base of bed 4. Their recovery from the top of the limonitic hardground at Beer, (sample 6), suggests intense reworking of material in the Beer Stone Adit sequence, which is also bourne out by the ammonites on the top of the Haven Cliff Hardground (5.5(iii)).

5.14. Rotaliporid population and eustasy.

The rotaliporids possess the "deep water" features (Hart, 1980a; Caron, 1983a; Hart, 1985; Hart and Ball, 1986) of

low trochospire, well-developed keels and supplementary apertures. Their distribution in the boreal realm is resticted (Carter and Hart, 1977). The rotaliporid population in the sections studied varies in its relative dominance within the planktonic population, the distribution of species and the size of the individuals within each population.

5.14(i). Relative dominance of rotaliporid population.

Within the total planktonic population the rotaliporid component varies. In Goban Spur, the rotaliporids consistantly form more than 60% of the total planktonic population. In contrast, in the basinal sections of the Anglo-Paris Basin, the rotaliporid component is variable and gradually decreases in its presence eastwards (through White Nothe, Isle of Wight, Eastbourne, Dover). In all these sections the rotaliporid component rises in bed 1 of the Plenus Marl Formation (Figure 5.17).

5.14(ii). Distribution of rotaliporid species.

<u>R. deecki</u> was only recorded from Goban Spur where it forms a very small part (3%) of the total planktonic population. <u>R. greenhornensis</u> is more prevalent, forming 15% of the total planktonic population at Goban Spur but it is more sporadically distributed in the Anglo-Paris Basin sections. <u>R. cushmani</u> is found in all sections until its



Figure 5.17 Planktonic population from selected sites

White Nothe

disappearance at the top of bed 3, Plenus Marl Formation (Figures 5.1, 5.17).

5.14(iii). Size of the R. cushmani specimens.

During ontogeny, extant planktonic foraminifera add chambers and progressively sink in the water column until the test is vacated during gametogenesis (Be <u>et al.</u>, 1966; Be and Anderson, 1976; Spindler <u>et al.</u>, 1979; Bé, 1980; Bé <u>et al.</u>, 1983). Thus the relative proportions of neanic to gerontic individuals of deeper water forms is a measure of depth. The greater the number of gerontics, the deeper the water.

> Text figure 5.1 Measured characteristics of X-rayed Rotalipora cushmani (Morrow)



For each sample the individuals of the <u>R</u>. <u>cushmani</u> population were measured (see section 2.6 for method). The parameters taken (Text Figure 5.1) were the maximum distance across the test from the penultimate chamber of the last whorl (b) and the maximum distance across the test from the first chamber of the last whorl (a). The last chamber was not measured because in some specimens it was slightly inclined






a:



a x 10 m.

Figure 5.22 X-ray of *R. cushmani* from Dover



umbilically and thus such a measurement would have produced a spuriously short width.

Goban Spur:

The <u>R</u>. <u>cushmani</u> population at Goban Spur shows a population with test sizes of up to $60-65 \times 10^{-5}$ m (figure 5.18). White Nothe:

Within the Abbots Cliff Chalk Formation (samples 1-9), the maximum test size is variable but just achieves a value greater than $50-53 \times 10^{-5}$ m. In bed 1 of the Plenus Marl Formation (sample 10 and 11), the maximum test size increases dramatically but decreases through beds 2 and 3 (Figure 5.19). Isle of Wight:

Within the Abbots Cliff Chalk Formation the maximum test size is variable and is rarely above $50-53 \times 10^{-5}$ m. In bed 1 of the Plenus Marl Formation the maximum test size increases to $59-63 \times 10^{-5}$ m and remains high in bed 2 but decreases very slightly into the top of bed 3 (Figure 5.20).

Eastbourne:

Within the Abbots Cliff Chalk Formation the maximum test size is variable but slightly more than in White Nothe, Isle of Wight and Dover. In bed 1 of the Plenus Marl Formation there is a significant increase in test size reaching a maximum of $60-63 \times 10^{-5}$ m. This high value is maintained through bed 2 but declines markedly in bed 3 (Figure 5.21). Dover: Within the Abbots Cliff Chalk Formation the maximum test size is variable but does not achieve a value greater than $40-42 \times 10^{-5}$ m. In bed 1 of the Plenus Marl Formation there is a modest increase to $40-42 \times 10^{-5}$ m which is maintained through bed 2 but declines sharply in bed 3 (Figure 5.22).

The four sections produce a composite picture with three main features:

(i) the water depth decreases from west to east.

(ii) the lower part of the Plenus Marl Formation, particularly bed 1, is a deep water facies.

(iii) the rate of change in water depth appears rapid marked by the sharp change in maximum test size.

A late Cenomanian transgression has been recognized on the Falklands Plateau (Sliter, 1976), in Poland (Marcinowski, 1974), in northwest Europe (Hancock and Kaufmann, 1979), on the Russian Platform (Naidin, 1983) and globally (Cooper, 1977; Matsumato, 1980; Morner, 1981; Vail <u>et al.</u>, 1977; Haq <u>et</u> al., 1987).

An increased sample resolution ffrom the Abbots Cliff Chalk Formation would permit a more detailed appraisal of any water depth changes. This approach would also permit the differentiation of phases within a planktonic foraminiferal biozone and also whether sea level changes are gradual (<u>sensu</u> Hancock and Kaufmann, 1979), or sharp (<u>sensu</u> Vail <u>et al.</u>, 1977).

5.15. Benthonic foraminifera: bathymetric considerations.

The limited distribution of certain genera across the shelf and onto the continental shelf of extant benthonic foraminifers has long been recognized (Bandy and Annal, 1957; Valentine and Mallory, 1965; Bandy and Chierici, 1966; Frerichs, 1970), and the Cretaceous bathymetric distribution of benthonic foraminifers (Sliter and Baker, 1972) of southern California show several features with increasing depth: increase in agglutinated foraminifera, lowering diversity and abundance.

Goban Spur, in contrast to the other sections, yielded a high rotaliporid component compared to the rest of the planktonic population including <u>R. cushmani</u>, <u>R. greenhornensis</u> and <u>R. deecki</u>, indicative of a deeper water assemblage (5.14).

The associated benthonic assemblage only forms 3% of the total population (5.3(v); Hart, 1987b), also indicative of a deeper water assemblage. The presence of any well-preserved calcareous forms infers that the assemblage has not been affected by the lysocline. It also shows several other differences from the other sections:

(i) a restricted diversity of <u>T. macfadyeni</u>, <u>L. rotulata</u>
 var. a, <u>G. reussi</u>, <u>G. intermedia</u>, <u>A. advena</u>, <u>N. sp.a</u>, <u>E</u>.

brevis, M. trochus, M. trochus var. oxycona, Pseudobolivina sp.a, Lagena sp.a, Gyroidina sp.a and Lenticulina sp.a. The last four species being restricted to Goban Spur.

(ii) all the forms show a low size variability.

Thus these features of low benthonic diversity and size variability, dominance of rotaliporids and high planktonic : benthonic ratio suggest a deep bathyal water assemblage. Chapter 6: The late Cenomanian Anoxic Event and the associated foraminiferal changes: Dover, a case study.

6.1. Introduction.

The late Cenomanian sea level rise (see 5.14), brought a high-stand on the continental shelf coupled with an expansion in the oxygen minimum zone (Jenkyns, 1980; Hart, 1985; Schlanger <u>et</u> <u>al</u>., 1987; Arthur <u>et al</u>., 1987): this adversely affected both the planktonic and benthonic foraminifera. The rise in the oxygen minimum layer may be positioned using the carbon isotope curve (Schlanger <u>et al</u>., 1987; Arthur <u>et al</u>., 1987; Arthur <u>et al</u>., 1987). The details of this change may best be discerned by looking at the most expanded section against the carbon isotope curve, for example Dover.

At Dover, (see 5.11 (ii)), the δ 13C enrichment occurs gradually through the Plenus Marl Formation, reaching its peak in bed 8, then slowly declining to its background level at 2.5m from the base of the Dover Chalk Formation (Figure 5.14).

The changes in the foraminiferal population characterized by lowering of diversity, extinction and dwarfism. The changes in the planktonic and benthonic populations are not coeval and are thus reviewed separately.

6.2. The late Cenomanian Anoxic Event and the benthonic taxa.

The benthonic assemblage shows a steady decrease in diversity (Figure 5.13) up the Plenus Marl Formation, together with

a change in species composition:

(i) at the top of bed 1, <u>G. baltica</u>, <u>G. intermedia</u>, <u>G. cenomanica</u>, <u>A. advena</u>, <u>P. plana</u>, <u>T. pyramidata</u>, <u>T. macfadyeni</u>, <u>P. mariae</u> become extinct.

(ii) through beds 2-8 the assemblage comprises M.
trochus, M. trochus var. turris, M. trochus var. oxycona, E.
mariae, E. brevis, L. rotulata var. a, L. rotulata var.b, G.
reussi, G. berthelini, L. globosa, Nodosaria sp.a, A. cretaceus,
Marssonella sp.a, T. chapmani and T. tricarinata.

Within the marssonellid population the dominant morphotype is <u>M. trochus</u> var. <u>turris</u> which is characterized by an equal rate of growth in width and height of new chambers, giving the test straight sides in side view. Also associated with this is the aberrant <u>M</u>. sp.a which is only found from beds 2-8 and the two basal hardgrounds of the Shakespeare Cliff Member.

Within the eggerellinid population <u>E</u>. <u>brevis</u> becomes dominant over <u>E</u>. <u>mariae</u>. The former is characterized by a squat test as opposed to the more elongate test of the latter. Thus, the smaller chamber growth indicative of <u>E</u>. <u>brevis</u> may represent a stunted form of E. mariae.

The only representative of the genus <u>Tritaxia</u> recorded from this interval is <u>T</u>. <u>tricarinata</u> which is subtriangular with triserial growth. This form is smaller than the tritaxid population from below of <u>T</u>. <u>pyramidata</u> and <u>T</u>. <u>macfadyeni</u> and thus may represent a dwarf ecophenotype of these forms.

The textularids first appear in bed 2 in this study with $\underline{\mathbf{T}}$. <u>chapmani</u>, the population of which shows a reduction in size through beds 2-8, though only one specimen shows a smaller height than it should for the number of chambers (Figure 4.1). Though dwarfism is not conclusive, the population does display a reduction in the number of specimens recovered and their size through beds 2-8.

Within the nodosarids, the assemblage is dominated by \underline{L} . <u>rotulata</u> var.a and \underline{L} . <u>rotulata</u> var.b, the former only being present to the top of bed 3. Though the number of specimens recovered decreased towards the top of bed 8, the specimen size remained consistant. Although <u>N</u>. sp.a was evident in bed 2, it was not recorded from the other beds.

The gavelinellid population shows a marked change with the dominance of the <u>G. reussi</u> - <u>G. berthelini</u> plexus. These characteristic forms with a flattened umbilical surface and a variably developed boss on the spiral surface are notably smaller than the <u>G. baltica</u>, <u>G. intermedia</u>, <u>G. cenomanica</u> population they replace. Coupled with <u>G. berthelini</u>, <u>L. globosa</u> becomes prevalent, though the spcimens of this species are slightly smaller in the last three beds of the Plenus Marl Formation.

(iii) through the Shakespeare Cliff Member (Dover Chalk Formation), the benthonic diversity remains low but does show a small recovery towards the top of the sequence. <u>A. preslii, T.</u> <u>tricarinata</u> var. jongmansi, <u>L. aumalensis</u> and <u>L. rotulata</u> var.<u>c</u> augment the benthonic assemblage well above the horizon where the

§13 C level returns to its background value. Thus although the oxygen depleted waters have receded, the benthonic assemblage shows a poor recovery.

Oxygen deficient benthonic foraminiferal assemblages have been recognized in the Devonian (Gutschick and Wuellner, 1983); in the Nigerian (Nyong and Ramanathan, 1985), the Brazilian (Mello <u>et</u> <u>al</u>. in press), and the English (Hart and Bigg, 1981) Cretaceous; in the Miocene and Pliocene of the Mediterranean (Katz and Thunell, 1984); in the Recent sediments of the southeastern Pacific Ocean (Ingle <u>et al</u>., 1980), and from Jurassic to Holocene levels (Bernhard, 1986).

Nyong and Ramanathan (1985), recorded a late Cenomanian anoxic benthonic assemblage of <u>Gavelinella</u> sp., <u>Gabonita</u> sp., and <u>Ammobaculites subcretacea</u> from the Calabar Flank, S.E. Nigeria. This shows some similarity with a limited fauna dominated by gavelinellids. The specimens were not illustrated or described so no detailed comparison of the gavelinellid populations is possible.

The late Cenomanian anoxic (Arthur <u>et al.</u>, 1987) benthonic assemblage (Hart and Bigg, 1981) from across the "Black Band" in Lincolnshire, (Engand), was very poor. Although the sequence is not as complete as Dover, the assemblage shows many similarities. <u>G</u>. <u>cenomanica</u> and <u>G</u>. <u>intermedia</u> disappear below the anoxic event, whilst <u>L</u>. <u>globosa</u> and <u>G</u>. <u>tourainensis</u> (= <u>G</u>. <u>reussi</u> - <u>G</u>. <u>berthelini</u> plexus) occur across it. The "Black Band" itself (the peak of the 813 C enrichment (Arthur <u>et al.</u>, 1987)), only yielded <u>A. cretaceus</u> (Hart and Bigg, 1981), although <u>Glomospira</u> sp., <u>T. chapmani</u> and <u>Haplophragmoides</u> sp. have also been recorded (Martinez-Rodriguez and Crump, 1987; Brasier, <u>pers. comm.</u>)

A Cenomanian anoxic benthonic assemblage from the Mancos Shelf (New Mexico) yielded <u>Gavelinella dakotensis</u>, <u>Neobulimina</u> <u>cadadensis</u>, <u>Dentalina basisplanata</u>, <u>Citharina kochii</u> and <u>Lenticulina</u> sp. (Bernhard, 1986). The tests were small to medium sized with little ornamentation on the nodosarids. This assemblage is similar to the one recorded at Dover with small <u>Lenticulina</u> spp. and <u>G. dakotensis</u>. <u>G. dakotensis</u> is very similar to <u>G. reussi</u> with a flattened test and a small boss on the spiral side.

From the Sergipe Basin, Brazilian margin, a late Cenomanian anoxic benthonic community comprised of <u>Lingulogavelinella</u> <u>thalmanniformis</u>, <u>G. berthelini</u>, <u>Dentalina</u> sp. and <u>Gabonella</u> spp. has been recorded (Mello <u>et al.</u>, in press). The <u>Gabonella</u> spp. and <u>L. thalmanniformis</u> exhibit dwarfism but the nodosarids show little size reduction and ornamentation (Koutsoukos, <u>pers. comm.</u>). This assemblage is very similar to the one recorded at Dover with smooth Lenticulina spp., G. berthelini and elongate nodosarids.

Thus the late Cenomanian anoxic benthonic community may be characterized by forms of the <u>G. reussi</u> - <u>G. berthelini</u> lineage, smooth <u>Lenticulina</u> spp. and <u>Nodosaria</u> spp. or <u>Dentalina</u> spp. with the addition of regional forms such as <u>L. globosa</u> and <u>Textularia</u> chapmani (Europe) and L. thalmanniformis and Gabonella spp. (South

Atlantic).

<u>G. reussi</u> is present in the pre-OAE fauna and proliferates rapidly into the form <u>G. berthelini</u> after the extinction of <u>G</u>. <u>baltica</u>, <u>G. cenomanica</u> and <u>G. intermedia</u>. Thus the <u>G. reussi</u> - <u>G</u>. <u>berthelini</u> plexus is probably tolerant of low levels of dissolved oxygen as is <u>Lenticulina rotulata</u> var.b which is also present in the pre-OAE fauna. In contrast, <u>Textularia chapmani</u> is only present during the anoxic event and may represent a specialist form tolerant of low levels of dissolved oxygen.

There is a general relationship between feeding habits and test morphology (Jones and Charnonk, 1985) in extant benthonic foraminifera. In addition, their microhabitats have been recognized (Frankel, 1974; Severin, 1983; Kitazato, 1984; Corliss, 1985; Jones, 1986) within the sediment profile and this has been applied to fossil communities (Severin, 1983; Jones and Charnock, 1985). The assemblage from Dover may be characterized:

EPIFAUNAL: <u>Ammodiscus</u>, <u>Trochammina</u>, <u>Gyroidinoides</u>, Gavelinella, Lingulogavelinella, <u>Ramulina</u>, <u>Lenticulina</u>.

INFAUNAL: <u>Textularia</u>, <u>Eggerellina</u>, <u>Tritaxia</u>, <u>Ataxophragmium</u>, <u>Vaginulina</u>, <u>Dentalina</u>, <u>Plectina</u>, <u>Pseudospiroplectinata</u>, <u>Marssonella</u>, <u>Arenobulimina</u>.

6.3. The late Cenomanian Anoxic Event and the planktonic taxa.

The planktonic foraminifera show a gradual increase in diversity, reaching a peak at the top of bed 1, Plenus Marl Formation. There follows a steady decline through the succeeding beds of the Formation, reaching its nadir in the base of the Shakespeare Cliff Member: this clearly mirrors the δ 13C curve.

The peak in diversity at the top of bed 1 is coincident with the increasing water depth, (see 5.14). The rotaliporid component decreases with the rising oxygen minimum zone, finally disappearing at the top of bed 3, with <u>R. greenhornensis</u> disappearing before <u>R. cushmani</u> (Hart, 1985; Figure 5.13), at a § 13C value of $3.5 - 4.0 \ 0/00$ (PDB) which is below the maximum value of $4.0 - 4.5 \ 0/00$ (PDB) reached in bed 8. In the Muhlberg section (West Germany), <u>Rotalipora cushmani</u> disappears at a §13C value of $3.8 \ 0/00$ (PDB) (Hilbrecht and Hoefs, 1986). After the loss of the rotaliporids, the dicarinellids assume dominance but the number of specimens recovered becomes very low in bed 6 which remains the case through into the first 2m of the Shakespeare Cliff Member. The planktonic diversity slowly increases to reach its pre-OAE value.

There is no statistical difference between the empty tests of extant planktonic foraminifera in the basal anoxic waters of the Gulf of Mexico and the population in the overlying surface waters, although there may be some incipient dissolution of the spinose forms (Penrose and Kennet, 1979). Thus as the assemblage at Dover contains a hedbergellid population across the anoxic event, which are the thinnest walled planktonics, the assemblage is not

significantly altered by dissolution.

The evolutionary relationships are covered in Chapter 7.

Thus the sequence of foraminiferal changes may be shown (Figure 6.1) at punctuated intervals with the expansion in the oxygen minimum zone:

Bed 1: Plenus Marls (Figure 6.1 A). Rise in sea level, rich benthonic community and planktonic assemblage, O_2 minimum zone not affecting the shelf.

Bed 2: Plenus Marls (Figure 6.1 B). Benthonic community impoverished but planktonic community stable (with slight loss of rotaliporids). O_1 minimum zone upon the shelf but only affecting the basal waters.

Bed 4: Plenus Marls (Figure 6.1 C). Poor benthonic community and loss of rotaliporids. O minimum zone moved onto the shelf and part of the way up into the water column.

Bed 8: Plenus Marls (Figure 6.1 D). O₁ deficiency tolerant benthonic taxa established and very low planktonic count. O minimum zone expanded to its fullest extent up the water column.



Late Cenomanian Anoxic Event and the benthonic and Planktonic foraminifera



Late Cenomanian Anoxic Event and the benthonic and Planktonic foraminifera

Chapter 7: The late Cenomanian Anoxic Event and the evolution of the planktonic foraminifera.

The distribution of mid Cretaceous foraminifera in northwest Europe has been noted (Hart and Bailey, 1979), and the effect of oceanic anoxic events on foraminiferal evolution (Hart, 1980a; Caron, 1983a; Caron and Homewood, 1983; Hart, 1985; Hart and Ball, 1986; Arthur et al., 1987).

The rise in the oxygen minimum zone caused the extinction of the rotaliporids and initially the decimation of the planktonic population, with very low planktonic numbers recorded. The post OAE saw the re-establishment of the surviving taxa and a period of explosive evolution of forms adapted to capitalise on the deeper water niche vacated by the rotaliporids. The pre-late Cenomanian OAE foraminiferal population had developed through the Albian and most of the Cenomanian to produce well differentiated tripartite groups based upon test architecture of Hedbergella spp., Praeglobotruncana spp. (and some "early dicarinellids") and Rotalipora spp. (Figure 7.1). These three different morphotypes were adaptations to a progressively deeper water niche for gametogenesis (Hart, 1980a; Caron and Homewood, 1983), in the gerontic portion of their lifecycle (Figure 7.1). A consequence of a deeper water position for gametogenesis was a decrease in the frequency of gametogenesis. Thus the rotaliporids were the most susceptible to a rise in the oxygen minimum zone.

S.L. Hedbergella spp. Praeglobotruncana Rotalipora spp. SPP. thin walled, variable trochospire, small amount randomly Medium' thickness walls, low to high placed pustules trochospire, pustules -thin keels on umbilical periphery some increasing forms with thick-walled, biconvex depth to plano-convex, weakly developed supplementary apertures, two keels thick well developed early decreasing r. or gamerogenesis keels which thin dicarinellids to rise in Os minisusceptibility towards last-formed chambers inc. test mass

Pre late Cenomanian OAE foraminiferal populations and their ontology. ammended from Caron & Homewood (1983)

Figure 7.1

The extinction of the rotaliporids followed the pathway R. decki(?), then R. greenhornensis, then R. cushmani (Hart, 1985: see 6.3), R. deqki and R. greenhornensis being restricted to deeper water assemblages than R. cushmani. The pre-OAE globotruncanid population contains forms with two faintly developed keels (especially on the initial chambers of the last whorl) with a lower trochospire. On the demise of the rotaliporids, these forms rapidly increase in both numbers and keel definition, thus obtaining a more pronounced dicarinellid aspect. This population includes D. algeriana, D. hagni and D. imbricata, although the keels of the latter are only slightly offset around the whorl and are very close to the keel configuration of D. hagni. In addition, the differentiation of P. stephani and D. algeriana is problematical as in many cases the keels are poorly separated, if at all. Within the hedbergellid population there is a slight proliferation of forms with H. planispira, H. aprica and H. brittonensis increasing their numbers. Both praeglobotruncanids/dicarinellids and hedbergellids exhibit a sharp drop in numbers coupled with the continued gradual rise in the \$13C level (and rising oxygen minimum zone). With the waning of the &13C level there are four important developments:

(i) the appearance of "<u>H</u>". <u>archaeocretacea</u>. <u>H</u>. <u>archaeocretacea</u> is derived from the <u>H</u>. <u>aprica</u> group and is a rapid development: many of the specimens show poorly developed peripheral pustules and umbilical structures (Figure 7.2).

(ii) the appearance of <u>H</u>. <u>praehelvetica</u>. Some specimens within the <u>H</u>. <u>delrioensis</u> group during the anoxic event show very low trochospires, these develop with the waning of the anoxic event into the wider umbilical, trochospired form of <u>H</u>. <u>praehelvetica</u>. However, their absolute numbers are low (Figure 7.2).

(iii) further differentiation of the dicarinellids. Within the dicarinellid population the species-specific features become more acute. The <u>D</u>. algeriana stock show well separated and stepped keels. <u>D</u>. imbricata and <u>D</u>. hagni groups show a moderate increase in the size of the specimens, lower trochospires and an increase in the angle of the keels of the former (Figure 7.2).

(iv) the heterohelicid population. The pre-OAE heterohelicid population is dominated by the <u>H. moremani</u> group; with the waning of the oxygen minimum zone the more expanded chambered forms of the <u>H. globulosa</u> group appear derived from the former. In addition, nearly all the heterohelicid population is now striate, with variably developed thin costae on the tests. In some cases, these are concentrated on the first formed chambers of the test (Figure 7.2).

The proposed phylogenic relationships of mid-Cretaceous planktonic foraminifera have variously placed emphasis on such features as apertural position, height of the trochospire and the presence/absence of keel(s). Bandy (1961),

Figure 7.2



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placed much emphasis on the presence of keels and suggested that the rotaliporid group gave rise to the globotruncanids in the late Cenomanian and that H. helvetica was derived from P. delrioensis. In contrast, Neagu (1969), derived the globotruncanids from the praeglobotruncanids in the middle to late Turonian. Wonders (1980), agrees with this but states that only D. algeriana crossed the Cenomanian - Turonian boundary and that the hedbergellids gave rise to the whiteinellids. Similarly, Banner (1981), proposed that the praeglobotruncanids gave rise to the dicarinellids in the early Turonian. This, largely, was proposed by Caron (1983b), with the praeglobotruncanids being the ancestral stock of the dicarinellids and the whiteinellids deriving from the hedbergellids. In addition, she proposed that the helvetoglobotruncanids were an early Turonian offshoot of the hedbergellid stock.

This study proposes that the dicarinellids were derived from the praeglobotruncanids, in broad agreement with Neagu (1969), Wonders (1980), Banner (1981) and Caron (1983b), but that it occurred twice in the late Cenomanian.

The presence of the more specialist deep water rotaliporids prior to the OAE restrained the development of the praeglobotruncanid population. The formers' demise, with the rising oxygen minimum zone, facilitated rapid dicarinellid proliferation, both prior to the shallowest position of the zone and on its waning. Equally, the rapid appearance of "H". archaeocretacea was a deep water strategy. Its initial

success past the moving praeglobotruncanid / dicarinellid population may be due to the increased frequency of gamatogenesis of the surface-dwelling hedbergellids.

A common test morphology (Text-Figure 7.1) of low trochospire, peripheral test thickening (lines of pustules, 1-2 keels), and wide differentiated (supplementary apertures and infraliminal accessory apertures) umbilical regions is shown by <u>Rotalipora spp., H. archaeocretacea</u> and <u>Dicarinella</u> spp. This movement towards a keeled disc shape has several reprecussions for the test:

(i) increase in test mass.

(11) increase in surface area:volume ratio.

(iii) movement in the centre of gravity.

The physical analysis of empty tests of extant species shows that the co-efficient of resistance (Ø) increases as the test approximates more towards a disc (McNown and Malaika, 1950; Lipps, 1979). (The larger planktonic foraminifera are inappropriate for the application of Stokes Law, (Lipps, 1979)). The strategic secretion of calcite around the periphery in the form of keels shows several important features:

(i) it is remarkably consistant within a stablepopulation (Rotalipora spp.).

(ii) thicker, more substantial keel(s) on the initial chambers of the last whorl weakening progressively around the periphery.

The keels may possibly be the remains of concentrated spine bases which would result in an extended disc shape but with a much lower increase in overall test mass (Text Figure

7.1a). In addition, the thicker spines on the initial chambers of the last whorl would tend to maintain a regular overall outline in spiral view (Text Figure 7.1b).

Text figure 7.1(a)

Increase in test diametre with addition of spines

7.1(b) Smoothing of test outline in spiral view



This configuration would greatly increase the co-efficient of resistance (\emptyset), but only if the test were orientated perpendicular to the direction of motion of the test. There is no evidence of the orientation of the tests of extant foraminifera in the water column (Hemleben, <u>pers. comm.</u>). Whatever the physical interactions of the test and the sea water, the role of the ectoplasm has yet to be assessed properly. The increase in the surface area:volume ratio may cause transport problems of nutrients through the ectoplasm and endoplasm but the opening of the chambers to the umbilicus results in the minimal distance between the individual chambers and the ectoplasm, the so-called MinLOC (<u>sensu</u> Brasier, 1982, 1986). The development of supplementary apertures and infralaminal accessory apertures facilitates this. The latter may be a protective adaptation for the wide open umbilicus.

Chapter 8: Other faunal groups and the late Cenomanian Anoxic Event.

8.1. Introduction.

Some of the macrofaunal changes across the Cenomanian -Turonian boundary in England have been documented (Jefferies, 1963; Kennedy and Wright, 1981; Woodroof, 1981). Some microfaunal changes have been investigated (ostracods: Kaye, 1964; Weaver, 1981, 1982; dinoflagellates: Clarke and Verdier, 1967; nannoplankton: Crux, 1980, 1982) but several detailed studies are as yet unpublished (ostracods: Horne, <u>pers</u>. <u>comm</u>; dinoflagellates: Tocher, <u>pers</u>. <u>comm</u>.; nannoplankton: Cooper, pers. comm.).

8.2. Macrofaunal changes.

The macrofaunal assemblages found through the Plenus Marl Formation (Figure 8.1), as exemplified by Merstham, show several important features (Jefferies, 1963). The benthonic community exhibits a marked faunal change at the top of bed 1 and subsequent reduction in diversity through the successive beds (2-8), with a particularly low faunal count from the top of bed 3. In addition, there is no aragonitic macrofauna recorded from beds 4 to 8 (Jefferies, 1963), and the ammonite record is very poor (kennedy and Wright, 1981). This implies some dissolution of the fauna, also evident in the foraminifera tests (see 5.8(v), 5.9(v), 5.10 (v), 5.11(v)), and ostracod valves (see 8.3(i)). Although the degree of dissolution is not very intense: the presumably most susceptible thin walled



Figure 8.1 Macrofossil changes through the Plenus Marl Formation (after Jefferies 1963)

planktonic foraminifera are still preserved. The early Turonian benthonic fauna is characterized by only a small number of morphotypes, relatively small individual size and is dominated by suspension feeders such as <u>Orbirhynchia</u> and inoceramids (Woodroof, 1981).

8.3. Microfaunal changes.

(i) ostracods:

The ostracods from the Cenomanian of England have been described by Weaver (1981, 1982). The ostracod assemblage through the Cenomanian - Turonian succession at Dover is dominated by platycopids with the rest of the fauna comprised of podocopids (Figure 8.2) (Horne, pers. comm.). The former exhibit a drop in absolute numbers after bed 1 but not an appreciable drop in diversity. Their absolute numbers continue to decline through the successive beds (2-8) and only begin to recover about 1.5m above bed 8 of the Plenus Marl Formation (Horne, pers. comm.). In contrast, the podocopids show a dramatic decline in diversity through beds 1-8 of the Plenus Marl Formation, particularly at the tops of beds 1 and 4 (Figure 8.5, 8.6). These extinctions resulted in only three podocopids surviving into the overlying Dover Chalk Formation. The post-OAE ostracod population remains poor both in abundance and diversity well into the Dover Chalk Formation (Horne, pers. comm.). The durability of the platycopid population through the OAE in contrast to the podocopids may be due to their ontogenetic strategy of retaining meanics within the carapace for three instars prior to release into the



(after Jarvis et al. in press)

Figure 8.2 Ostracods from Dover(cont.)

(after Jarvis et al. inpress)





Figure 8.3 Dinoflagellates from Dover



Figure 8.3 Dinoflagellates from Dover(cont.)

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environment. A high proportion of <u>Cytherella</u> specimens in bed 4 and the higher parts of the Plenus Marl show dissolution effects, with valves displaying rough, etched surfaces in contrast to their normal smooth appearance.

(ii) dinoflagellates:

The dinoflagellate cysts across the Cenomanian -Turonian boundary have been investigated from the Isle of Wight (Clarke and Verdier, 1967). The dinoflagellate cyst assemblage from the late Cenomanian - Turonian succession at Dover (figure 8.3), exhibits a drop in diversity just below the sub Plenus erosion surface, recovering to its initial level in bed 3 of the Plenus Marl Formation (Tocher, <u>pers. comm.</u>) (Figure 8.5, 8.6). After bed 3, the diversity declines rapidly to zero at the top of bed 8. The dinoflagellate cysts reappear 3.5m above bed 8 and slowly recover in diversity to reach the pre-OAE level in the late Turonian (op cit.). The absence of cysts in the Melbourn Rock facies is probably not a preservational phenomenon but a true reflection of the devastation of the dinoflagellate encysting population (Tocher, <u>pers. comm.</u>), because their decline begins within the Plenus Marl Formation.

(iii) nannoplankton;

The nannoplankton population across the late Cenomanian - Turonian boundary succession at Dover shows a marked decline in beds 7 and 8 of the Plenus Marl Formation, with some extinctions at these levels (Figures 8.4, 8.5, 8.6). The diversity continues to decline to its lowest level in the



(after Jarvis et al. in press)


(after Jarvis et al. in press)

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Planktonic diversity (after Jarvis et al. in press)



Abundances from Dover Figure 8.6

et (after Jarvis

press)

2 al.

Microfossil abundance

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second incipient hardground of the Melbourne Rock facies (Dover Chalk Formation). The nannoplankton diversity rapidly increases after the waning of the OAE with the proliferation of several new species (Cooper, pers. comm.).

8.4. Overview.

The pattern of macrofaunal and microfaunal changes may be summarized sequentially as:

(i) Just below the sub-Plenus erosion surface-

loss of small number of dinoflagellate species.

(ii) bed 1, Plenus Marls-

high diversity of benthonic foraminifera, ostracods, benthonic macrofauna.

(iii) top bed 1-

extinction of some benthonic foraminifera, ostracods (podocopids), decline in macrofaunal diversity.

(1v) beds 2-3 -

poor benthonic macrofauna

continued decline in benthonic foraminifera.

(v) top bed 3-

extinction of rotaliporids

initial decline in dinofalgellate cyst diversity.

(vi) bed 4-

rapid decline in dinoflagellate cyst diversity continued decline in benthonic foraminifera and low ostracod diversity.

(vii) beds 5-8 -

planktonic and benthonic foraminifera, ostracods and dinoflagellates reach lowest diversities nannoplankton diversity begins decline macrofauna poor.

(viii) top bed 8-

§13C value reaches its peak
very low dinoflagellate numbers and diversity
planktonic and benthonic foraminifera diversities
low

ostracod diversity very low, limited benthonic macrofauna

- - (x) subsequent 20m of Dover Chalk Formation-

\$13C value quickly returns to background level
benthonic macrofauna and foraminifera,
ostracod diversities recover but to lower than
pre-OAE values

planktonic foraminiferal diversity recovers dinoflagellates reappear but with lower than pre-OAE diversity and abundance.

Thus it is evident that the rising oxygen minimum zone adversely affected the benthos prior to the deeper water planktonics (rotaliporids) and then subsequently the shallow water planktonics (praeglobotruncanids, hedbergellids, dinoflagellates and nannoplankton).

Chapter 9: Implications of the study.

9.1. Biostratigraphical implications.

The use of deep water planktonic foraminifera for biostratigraphy limits their use in onshore sections (e.g. Rotalipora spp, "H". archaeocretacea). In addition, the OAE means there is a gap between the extinction of the rotaliporids and the development of "H". archaeocretacea and this results in an unrefined biostratigraphic interval. The identification of biostratigraphically useful planktonic foraminifera in thin section from burrows within hardgrounds of attenuated sequences, such as Shapwick Grange Quarry (Chapter 5.6 (iv)), permits the dating of infilling events during the formation of these omission surfaces. Thus the detailed sampling of the burrow phases may allow the more accurate dating of the down-moved, though subsequently eroded, overlying sediment. The measurement of the size of tests within the rotaliporid population permits the analysis of eustatic changes across the Anglo-Paris Basin (Chapter 5.14 (iii)). Thus the detailed sampling of the sequences within the R. cushmani i.z. and the measurement of the specimens would provide data on the most subtle eustatic movements. These changes could be utilised to delimit the R. cushmani i.z..

9.2. The late Cenomanian "Event" and Mass Extinctions.

Major faunal turnovers (mass extinctions) have recieved

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much attention, notably the Cretaceous - Tertiary "event". A periodicity in extinction of 26 m.y has been recognized (Fischer and Arthur, 1977; Raup and Sepkoski, 1984; Raup, 1985; Sepkoski and Raup, 1986; Raup, 1987), with the late Cenomanian comprising one of these important "events". The idea of a meteor impact for the terminal Cretaceous faunal turnover (Alvarez et al., 1980), has led to the assertion of an extraterrestrial cause for the others (Raup, 1986), and the "Nemesis" death star to account for the regularity. This detailed late Cenomanian faunal study indicates that the extinction of marine biota depended on their relative niche with respect to the rise in the oxygen minimum zone. The very sequential nature of the extinctions, from benthonics (foraminifera, ostracods, macro-organisms) to deep water planktonics (rotaliporids), to shallow water planktonics (dinoflagellates then nannoplankton), argues heavily against the impact theory induced by the proximity of "Nemesis". The details of other Cretaceous faunal turnovers are not completely integrated but some conclusions may be drawn. In the Aptian, deep water planktonic foraminifera were not present but there were extinctions within the benthonic foraminiferal population (Hart et al., 1981), and the hedbergellids pass into the Albian. At the K-T boundary the benthonic foraminifera undergo extinctions and only the thin-walled "hedbergellid" population cross the boundary (Hart, 1981). In addition, the K-T boundary shows a marked drop in species diversity within the dinoflagellate cyst assemblage (Hansen, 1977), with only

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the cosmopolitan forms passing across the boundary (Tocher, <u>pers. comm</u>). Thus the similarities in the three events are apparent but the relative position of the faunal changes for each group need to be established.

9.3. Interpretation of the planktonic : benthonic ratios.

The ratio of planktonic : benthonic foraminifera may be utilised to make estimates of depths of deposition of sedimentary rocks (Grimsdale and Morkhoven, 1955). These have been used in the Cretaceous to map eustacy (Barr, 1961; Diver, 1968; Flexer and Starinsky, 1970; Hart and Carter, 1975; Bailey, 1978; Hart, 1980). Whilst P:B ratios are important and useful under stable marine conditions, the very poor post-OAE benthonic fauna (in all groups - macro-organisms, foraminifera and ostracods - Chapter 8.3(i) and 8.4), means that they must be used with caution during, at least, the early Turonian, to avoid spuriously deep water depth values.

9.4. Investigation of orbital forcing.

The recognition of orbital forcing as a mechanism for the formation of sedimentary\palaeontological cycles has developed over the last hundred years (Croll, 1875; Berger <u>et al.</u>, 1984). Cretaceous rhythms have recieved much attention (Barron <u>et al.</u>, 1985; Arthur <u>et al.</u>, 1986; Herbert and Fischer, 1986). For the optimal biotic changes the Cenomanian strata are more suitible for study since the OAE radically reduced the

benthonic diversity (foraminifera, ostracods, macro-organisms) found in most of the Turonian strata.

9.5. The pattern of onshore to offshore in the evolution of shelf communities.

Community trophic analysis of late Cretaceous shelf faunas indicates that major ecological innovations appeared in nearshore environments and then expanded outward across the shelf at the expense of older community types (Jablonski <u>et</u> <u>al</u>., 1983), due to the differential extinction rates of onshore as opposed to offshore clades, or from differential origination rates of new ecological associations or evolutionary novelties in nearshore environments (op cit.). The rising oxygen minimum zone would account for the extinctions of the specialist offshore species with the surviving nearshore forms evolving into the vacated niches on the waning of the oxygen minimum zone.

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Plate 1.

1.	Ammodisc	us cr	etaceus	(Reuss)
	lateral	view,	S6Q18,	x2ØØ

- 2. Ammodiscus cretaceus (Reuss) lateral view, ABC5, x100
- 3. Ammodiscus cretaceus (Reuss) lateral view, ABC5, x150
- 4. <u>Ammodiscus</u> <u>cretaceus</u> (Reuss) lateral view, ABCl4, x100
- 5. Ammodiscus cretaceus (Reuss) lateral view, ABC14, x150
- 6. Ammodiscus cretaceus (Reuss) lateral view, ABC19, x150
- 7. Ammodiscus cretaceus (Reuss) lateral view, ABCll, x100
- 8. Ammobaculites sp.a lateral view, CB1 2, x35
- 9. Haplophragmium aequale (Reuss) whole specimen, lateral view, CBl 5, x35
- 10. Haplophragmium aequale (Reuss) Initial coil of test, lateral view, CBI 5, x100
- 11. <u>Haplophragmium aequale</u> (Reuss) terminal chamber of test, apertural view, CBI 5, x100
- 12. <u>Haplophragmium</u> <u>aequale</u> (Reuss) terminal chamber of test, apertural view, CBl 5, x100
- 13. <u>Subbdelloidina</u> sp.a lateral view, CB1, x150
- 14. <u>Textularia</u> <u>chapmani</u> (Lalicker) side view, ABC9, x75
- 15. <u>Textularia</u> chapmani (Lalicker) apertural view, ABC9, x150


Plate 2.

1.	Textularia		apmani	(Lalicker)	
	lateral	view,	ABC9,	x100	

- 2. Textularia chapmani (Lalicker) apertural view, ABC9, x200
- 3. Textularia chapmani (Lalicker) lateral view, ABC9, x150
- 4. <u>Textularia</u> <u>chapmani</u> (Lalicker) lateral view, ABC9, x150
- 5. Textularia chapmani (Lalicker) apertural view, ABC9, x200
- 6. Textularia chapmani (Lalicker) apertural view, ABC9, x150
- 7. Textularia chapmani (Lalicker) lateral view, ABC9, x100
- 8. <u>Textularia</u> chapmani (Lalicker) close-up of aperture, ABC9, x350
- 9. <u>Textularia</u> <u>chapmani</u> (Lalicker) lateral view, ABC9, x100
- 10. <u>Textularia chapmani</u> (Lalicker) apertural view, ABC9, x200
- 11. Textularia chapmani (Lalıcker) apertural view, ABCl0, x200
- 12. <u>Textularia</u> chapmani (Lalicker) lateral view, ABC10, x200
- 13. Textularia chapmani (Lalicker) apertural view, ABC11, x150
- 14. <u>Textularia chapmani</u> (Lalicker) lateral view, ABCll, x100



Plate 3.

- <u>Textularia</u> <u>chapmani</u> (Lalicker) apertural view, ABCll, x200
 <u>Textularia</u> <u>chapmani</u> (Lalicker) lateral view, ABCll, x200
- lateral view, ABC11, x200
- 3. <u>Textularia chapmani</u> (Lalicker) apertural view, ABCl1, x150
- 4. <u>Textularia chapmani</u> (Lalicker) lateral view, ABCll, x150
- 5. <u>Textularia</u> <u>chapmani</u> (Lalicker) lateral view, ABCl3, x200
- 6. <u>Textularia</u> <u>chapmani</u> (Lalicker) apertural view, ABC13, x200
- 7. <u>Textularia chapmani</u> (Lalıcker) lateral view, ABCl4, x100
- 8. <u>Textularia</u> chapmani (Lalicker) apertural view, ABC14, x150
- 9. <u>Pseudobolivina</u> sp.a lateral view, Goban Spur 5\2 13-17, x100
- 10. <u>Pseudobolivina</u> sp.a apertural view, Goban Spur 5\2 13-17, x150
- 11. Trochammina depressa (Lozo) lateral view, B.P 93\2-1, 1116, x200
- 12. <u>Pseudospiroplectinata plana</u> (Gorbenko) lateral view, ABC7, x75
- 13. <u>Pseudospiroplectinata plana</u> (Gorbenko) lateral view, ABC7, x75
- 14. <u>Pseudospiroplectinata</u> <u>plana</u> (Gorbenko) lateral view, ABC7, x75
- 15. <u>Pseudospiroplectinata plana</u> (Gorbenko) close-up of initial coil, ABC7, x75

Plate 3 cont'd:

- 16. <u>Pseudospiroplectinata plana</u> (Gorbenko) lateral view, incomplete specimen, ABC8, x100
- 17. <u>Pseudospiroplectinata</u> <u>plana</u> (Gorbenko) close-up of aperture, ABC8, x350



Plate 4.

- 1. Tritaxia macfadyeni (Cushman) lateral view, Goban Spur 6\1 30-33, x100
- 2. Tritaxia macfadyeni (Cushman) lateral view, Goban Spur 6\1 30-33, x150
- 3. <u>Tritaxia</u> <u>macfadyeni</u> (Cushman) oblique apertural view, Goban Spur 6\1 30-33, x200
- 4. Tritaxia macfadyeni (Cushman) lateral view, Goban Spur 6\1 30-33, x150
- 5. Tritaxia macfadyeni (Cushman) lateral view, Goban Spur 6\1 101-105, x150
- 6. <u>Tritaxia</u> <u>macfadyeni</u> (Cushman) oblique apertural view, Goban Spur 6\1 101-105, x350
- 7. Tritaxia macfadyeni (Cushman) lateral view, Goban Spur 6\1 101-105, x150
- 8. Tritaxia macfadyeni (Cushman) close-up of test wall, Goban Spur 6\1 101-105, x500
- 9. Tritaxia macfadyeni (Cushman) lateral view, Goban Spur 6\1 101-105, x150
- 10. Tritaxia macfadyeni (Cushman)
 oblique apertural view, Goban Spur 6\1 101-105,
 x200
- 11. Tritaxia macfadyeni (Cushman) close-up of aperture, Goban Spur 6\1 101-105, x750
- 12. Tritaxia macfadyeni (Cushman) lateral view, ABC7, x50
- 13. Tritaxia macfadyeni (Cushman) lateral view, ABC7, x50
- 14. Tritaxia pyramidata (Reuss) lateral view, ABC6, x150
- 15. Tritaxia pyramidata (Reuss) lateral view, ABC6, x50

Plate 4 cont'd

16. Tritaxia pyramidata (Reuss) oblique apertural view, ABC6, x75



Plate 5.

- 1. Tritaxia tricarinata (Reuss) Reuss lateral view, ABC5, x150
- 2. Tritaxia tricarinata (Reuss) Reuss lateral view, ABC5, x150
- 3. Tritaxia tricarinata (Reuss) Reuss lateral view, ABC6, x150
- 4. Tritaxia tricarinata (Reuss) Reuss lateral view, ABC7, x150
- 5. Tritaxia tricarinata (Reuss) Reuss lateral view, ABC20, x200
- 6. Tritaxia tricarinata (Reuss) Reuss lateral view, ABC21, x150
- 7. Tritaxia tricarinata (Reuss) Reuss close-up of test wall, ABC21, x350
- 8. Tritaxia tricarinata var. jongmansı lateral view, AKS12, x75
- 9. Tritaxia tricarinata var. jongmansi lateral view, AKS9, x75
- 10. Tritaxia tricarinata var. jongmansi lateral view, AKSc, x75
- 11. Tritaxia tricarinata var. jongmansi lateral view, AKSc, x100
- 12. Tritaxia tricarinata var. jongmansı (incomplete specimen) lateral view, AKS H, x75
- 13. Tritaxia tricarinata var. jongmansı lateral view, AKS H, x75
- 14. Tritaxia tricarinata var. jongmansı lateral view, AKS11, x75

Plate 5 cont'd

15. <u>Tritaxia tricarinata</u> var. jongmansi lateral view, AKS9, x75



Plate 6.

- 1. Arenobulimina bulletta (Barnard and Banner) lateral view, ABCL, x100
- 2. Arenobulimina bulletta (Barnard and Banner) lateral view, ABCL, x100
- 3. Arenobulimina bulletta (Barnard and Banner) oblique apertural view, ABC1, x100
- 4. Arenobulimina bulletta (Barnard and Banner) close-up of aperture, ABC1, x200
- 5. Arenobulimina advena (Cushman) lateral view, ABC7, x100
- 6. <u>Arenobulimina advena</u> (Cushman) apertural view, ABC7, x100
- 7. <u>Arenobulimina</u> advena (Cushman) lateral view, ABC7, x75
- 8. <u>Arenobulimina</u> advena (Cushman) lateral view, ABC8, x100
- 9. Arenobulimina preslii (Reuss) lateral view, AKS7, x200
- 10. Arenobulimina preslii (Reuss) lateral view, AKS1, x200
- 11. Arenobulimina sp.a lateral view, ABC5, x200
- 12. Arenopulimina sp.a apertural view, ABC5, x150
- 13. Dorothia gradata (Berthelin) lateral view, ABC1, x150
- 14. Dorothia gradata (Berthelin) oblique apertural view, ABC1, x150



Plate 7.

- 1. <u>Marssonella</u> sp.a apertural view, ABC9, x200
- 2. <u>Marssonella</u> sp.a lateral view, ABC9, x100
- 3. <u>Marssonella</u> sp.a lateral view, ABC9, x100
- 4. <u>Marssonella</u> sp.a apertural view, ABC10, x200
- 5. <u>Marssonella</u> sp.a lateral view, ABC9, x100
- 6. <u>Marssonella</u> sp.a apertural view, ABC9, x200
- 7. <u>Marssonella</u> sp.a lateral view, ABC10, x150
- 8. Marssonella sp.a close-up of test wall, ABC10, x500
- 9. <u>Marssonella trochus</u> d'Orbigny lateral view, ABC9, x150
- 10. Marssonella trochus d'Orbigny close-up of test wall, ABC9, x500
- 11. Marssonella trochus d'Orbigny lateral view, ABC9, x100
- 12. <u>Marssonella</u> trochus d'Orbigny lateral view, ABC9, x150
- 13. <u>Marssonella trochus</u> d'Orbigny lateral view, ABC10, x150
- 14. Marssonella trochus d'Orbigny lateral view, ABC12, x200
- 15. Marssonella trochus d'Orbigny lateral view, ABC16, x200

Plate 7 cont'd

16. <u>Marssonella</u> trochus d'Orbigny lateral view, ABC20, x200



Plate 8.

- 1. <u>Marssonella</u> <u>trochus</u> d'Orbigny CBl 14
- 2. <u>Marssonella</u> <u>trochus</u> d'Orbigny WND 21
- 3. <u>Marssonella</u> trochus var. turris WND 1
- 4. <u>Marssonella</u> <u>trochus</u> var. <u>turris</u> WND 15
- 5. <u>Marssonella</u> <u>trochus</u> var. <u>turris</u> WND 25
- 6. <u>Marssonella</u> <u>trochus</u> var. <u>turris</u> WND 25
- 7. <u>Marssonella</u> trochus var. <u>oxycona</u> CBl 21
- 8. <u>Marssonella</u> trochus var. <u>oxycona</u> CB1 28
- 9. <u>Marssonella</u> trochus var. <u>oxycona</u> WND 23



Plate 9.

1.	Marssonella lateral view,	ABC10,	var. <u>turris</u> x150
2.	Marssonella lateral view,	ABC10,	var. <u>turris</u> x200
3.	<u>Marssonella</u> lateral view,	trochus ABC11,	var. <u>turris</u> x100
4.	Marssonella lateral view,	ABC14,	var. <u>turris</u> x150
5.	Marssonella lateral view,	ABC14,	var. <u>turris</u> x100
6.	Marssonella lateral view,	ABC14,	var. <u>turris</u> x150
7.	Marssonella lateral view,	ABC16,	var. <u>turris</u> x150
8.	Marssonella lateral view,	ABC20,	var. <u>turris</u> x200
9.	Marssonella lateral view,	ABC20,	var. <u>turris</u> x150
10.	Marssonella lateral view	w, ABC21	var. <u>turris</u> , x200
11.	Marssonella lateral view	w, ABC3,	var. <u>oxycona</u> x200
12.	Marssonella lateral view	, trochus ABC2,	var. <u>oxycona</u> x100
13.	Marssonella lateral view	trochus N, ABC2,	var. <u>oxycona</u> x200
14.	Marssonella lateral view	trochus ABC12	var. <u>oxycona</u> , x200

15. <u>Marssonella</u> trochus var. oxycona lateral view, ABC20, x200 Plate 9 cont'd

16. <u>Marssonella trochus</u> var. <u>oxycona</u> lateral view, <u>AKS12</u>, x150



Plate 10.

- 1. Eggerellina brevis (d'Orbigny) apertural view, ABC1, x200
- 2. Eggerellina brevis (d'Orbigny) lateral view, ABC2, x150
- 3. Eggerellina brevis (d'Orbigny) apertural view, ABC1, x100
- 4. Eggerellina brevis (d'Orbigny) lateral view, ABC1, x150
- 5. Eggerellina brevis (d'Orbigny) apertural view, ABC1, x200
- Eggerellina brevis (d'Orbigny) apertural view, ABC9, x150
- 7. Eggerellina mariae ten Dam lateral view, ABCL, x150
- 8. Eggerellina mariae ten Dam apertural view, ABCl, x200
- 9. Eggerellina mariae ten Dam close-up of aperture, ABCl, x500
- 11. Eggerellina murchisoniana (d'Orbigny) lateral view, ABC1, x200
- 12. Eggerellina murchisoniana (d'Orbigny) apertural view, ABCl, x200

PLATE 10

























Plate 11.

1.	Plectina	marı	ae (H	Franke)
	lateral	view,	ABC1	, x150

- 2. Plectina mariae (Franke) lateral view, ABC1, x100
- 3. <u>Plectina mariae</u> (Franke) lateral view, ABCl, x150
- 4. <u>Plectina mariae</u> (Franke) lateral view, ABC1, x150
- 5. <u>Plectina mariae</u> (Franke) oblique apertural view, ABC1, x200
- 6. <u>Plectina mariae</u> (Franke) oblique apertural view, ABCL, x200
- 7. <u>Plectina mariae</u> (Franke) oblique apertural view, ABC1, x150
- 8. <u>Plectina mariae</u> (Franke) oblique apertural view, ABCL, x200
- 9. Plectina mariae (Franke) close-up of initial portion of test, ABC1, x350
- 10. Plectina mariae (Franke) lateral view, ABC2, x150
- 11. <u>Plectina mariae</u> (Franke) close-up of test wall, ABC2, x350
- 12. <u>Plectina mariae</u> (Franke) lateral view, ABC2, x200
- 13. <u>Plectina</u> cenomana Carter and Hart lateral view, ABC5, x150
- 14. Plectina cenomana Carter and Hart oblique apertural view, ABC5, x200



Plate 12.

- 1. Ataxophragmium depressum (Perner) lateral view, ABC3, x200
- 2. Ataxophragmium depressum (Perner) apertural view, ABC3, x200
- 3. Ataxophragmium depressum (Perner) oblique apertural view, ABC6, x150
- 4. Ataxophragmium depressum (Perner) lateral view, ABC5, x150
- 5. Ataxophragmium depressum (Perner) lateral view, ABC7, x150
- 6. Ataxophragmium depressum (Perner) oblique apertural view, ABC7, x150
- 7. Ataxophragmium depressum (Perner) lateral view, ABC7, x150
- 8. Ataxophragmium depressum (Perner) lateral view, ABC7, x150
- 9. <u>Ataxophragmium depressum</u> (Perner) lateral view, ABC8, x150
- 10. Ataxophragmium depressum (Perner) lateral view, ABC8, x150
- 11. Ataxophragmium depressum (Perner) apertural view, ABC8, x150



Plate 13.

- 1. <u>Pseudotextulariella</u> <u>cretosa</u> Cushman BSA1
- 2. Pseudotextulariella cretosa Cushman apertural view, Britoil 48\22-1 490', x100
- 3. <u>Pseudotextulariella</u> cretosa Cushman lateral view, BritOil 48\22-1 490', x150
- 4. <u>Quinqueloculina</u> antiqua Franke lateral view, B.P 93\2-1 1108', x200
- 5. <u>Quinqueloculina</u> antiqua Franke lateral view, B.P 93\2-1 1090', x200
- 6. Nodosaria sp.a apertural view, ABC3, x350
- 7. <u>Nodosaria</u> sp.a lateral view, ABC3, x50
- 8. <u>Nodosaria</u> sp.a apertural view, ABC4, x500
- 9. Nodosaria sp.a lateral view, ABC4, x75
- 10. <u>Nodosaria</u> sp.a apertural view, ABC4, x350
- 11. Nodosaria sp.a lateral view, ABC4, x75
- 12. Nodosaria sp.a Lateral view, ABC8, x100
- 13. <u>Nodosaria</u> sp.a apertural view, ABC8, x350
- 14. Nodosaria sp.a lateral view, ABC11, x75
- 15. <u>Nodosaria</u> sp.a apertural view, ABC11, x350



Plate 14.

- 1. Astacolus sp.a lateral view, ABC5, x100
- Astacolus sp.a oblique apertural view, ABC5, x350
- 3. Dentalina sp.a lateral view, ABC5, x50
- 4. Dentalina sp.a oblique apertural view, ABC5, x350
- Dentalina sp.a oblique apertural view, ABC8, x500
- 6. <u>Dentalina</u> sp.a lateral view, ABC8, x75
- 7. Dentalina sp.b lateral view, ABC7, x75
- 8. Dentalina sp.b lateral view, ABC7, x75
- 9. Dentalina sp.b oblique apertural view, ABC7, x350
- 10. Dentalina sp.b lateral view, ABC8, x75
- Dentalina sp.b oblique apertural view, ABC8, x350
- 12. Dentalina sp.b lateral view, ABC8, x75
- Dentalina sp.b oblique apertural view, ABC8, x750
- Dentalina sp.b oblique apertural view, ABC8, x350
- 15. Dentalina sp.b lateral view, ABC8, x75

Plate 14 cont'd

- 16. <u>Dentalina</u> sp.c oblique apertural view, ABC9, x350
- 17. Dentalina sp.c lateral view, ABC9, x75
- 18. <u>Dentalina</u> sp.c close-up of test wall, ABC9, x750



Plate 15.

1.	Frondicu	laria	cordai	Reuss
	lateral	view,	ABC5,	x35

- 2. Frondicularia gaultina Reuss lateral view, ABC3, x35
- 3. Frondicularia sp.a lateral view, CBl 36, x35
- 4. Frondicularia sp.a lateral view, S6018, x100
- 5. Lagena sp.a lateral view, Goban Spur 5\1 30-33, x150
- 6. Lagena sp.a apertural view, Goban Spur 5\1 30-33, x150
- 7. Lenticulina ovalis (Reuss) lateral view, AKS6, x100
- Lenticulina ovalis (Reuss) apertural face, AKS6, x100
- 9. Lenticulina ovalis (Reuss) lateral view, AKS6, x100
- 10. Lenticulina rotulata var.a (Lamarck) lateral view, ABC1, x50
- 11. Lenticulina rotulata var.a (Lamarck) apertural face, ABCI, x75
- 12. Lenticulina rotulata var.a (Lamarck) close-up of aperture, ABC1, x350



Plate 16.

1.	Lenticulina rotulata var.a lateral view, ABC2, x150	(Lamarck)
2.	Lenticulina rotulata var.a apertural face, ABC2, x150	(Lamarck)
3.	Lenticulina rotulata var.a lateral view, ABC3, x100	(Lamarck)
4.	Lenticulina rotulata var.a apertural face, ABC3, x100	(Lamarck)
5.	Lenticulina rotulata var.a lateral view, AKS3, x100	(Lamarck)
6.	Lenticulina rotulata var.a apertural face, AKS3, x100	(Lamarck)

- 7. Lenticulina rotulata var.b (Lamarck) lateral view, ABC1, x100
- 8. Lenticulina rotulata var.b (Lamarck) apertural face, ABCL, x100
- 9. Lenticulina rotulata var.b (Lamarck) lateral view, ABC1, x150
- 10. Lenticulina rotulata var.b (Lamarck) apertural face, ABC1, x150
- 11. Lenticulina rotulata var.b (Lamarck) lateral view, ABC1, x150
- 12. <u>Lenticulina rotulata</u> var.b (Lamarck) apertural face, ABC2, x100


Plate 17.

- 1. Lenticulina rotulata var.b (Lamarck) apertural face, ABC3, x100
- 2. Lenticulina rotulata var.b (Lamarck) lateral view, ABC3, x100
 - 3. Lenticulina rotulata var.b (Lamarck) apertural face, B.P 93\2-1 1120', x200
- 4. Lenticulina rotulata var.b (Lamarck) lateral view, B.P 93\2-1 1120', x200
- 5. Lenticulina rotulata var.b (Lamarck) lateral view, AKS1, x200
- 6. Lenticulina rotulata var.b (Lamarck) apertural face, AKS1, x200
- 7. Lenticulina rotulata var.b (Lamarck) lateral view, AKS2, x150
- 8. Lenticulina rotulata var.b (Lamarck) apertural face, AKS2, x150
- 9. Lenticulina rotulata var.b (Lamarck) apertural face, AKS2, x150
- 10. Leenticulina rotulata var.b (Lamarck) lateral view, AKS2, x200
- 11. Lenticulina rotulata var.b (Lamarck) apertural face, AKS7, x150
- 12. Lenticulina rotulata var.b (Lamarck) lateral view, AKS7, x150
- 13. Lenticulina rotulata var.c (Lamarck) lateral view, B.P 93\2-1 1120', x100
- 14. Lenticulina rotulata var.c (Lamarck) apertural face, B.P 93\2-1 1120', x100



Plate 18.

- Lenticulina sp.a lateral view, Goban Spur 5\2 13-17, x200
- Lenticulina sp.a close-up of apertural face, Goban Spur 5\2 13-17, x750
- 3. Lenticulina sp.a apertural face, Goban Spur 5\2 13-17, x200
- 4. Marginulina sp.a lateral view, B.P 93\2-1 1090', x150
- 5. Marginulina sp.a oblique apertural view, B.P 93\2-1 1090', x500
- 6. <u>Marginulinopsis</u> acuticostata (Reuss) lateral view, BritOil 48\22-1 490', x200
- 7. <u>Marginulinopsis</u> acuticostata (Reuss) apertural view, Britoil 48\22-1 490', x350
- 8. <u>Marginulinopsis</u> acuticostata (Reuss) lateral view, BritOil 48\22-1 490', x200
- 9. <u>Neoflabellina</u> sp.a lateral view, ABClØ, x75
- 10. Neoflabellina sp.b lateral view, B.P 93\2-1 1090', x200
- 11. Neoflabellina sp.b oblique apertural view, B.P 93\2-1 1090', x350
- 12. Neoflabellina sp.b close-up of aperture, B.P 93\2-1 1090', x750
- Pandaglandulina sp.a lateral view, ABC4, x100
- 14. Pandaglandulina sp.a apertural view, ABC4, x350
- 15. Pandaglandulina sp.a lateral view, ABC4, x100
- Pandaglandulina sp.a apertural view, ABC4, x350



Plate 19.

1. Planularia? sp.a

lateral view, ABC10, x100

- 2. Vaginulina costulata Roemer form a lateral view, ABC7, x50
- 3. Vaginulina costulata Roemer form a lateral view, of aperture, ABC7, x200
- <u>Vaginulina</u> costulata Roemer form a lateral view of initial portion of test, ABC7, x200
- 5. <u>Vaginulina</u> costulata Roemer form b lateral view, ABC8, x50
- 6. <u>Vaginulina costulata</u> Roooemer form b lateral view, ABC9, x50
- 7. <u>Vaginulina costulata</u> Roemer form b lateral view, ABC9, x50
- 8. Vaginulina costulata Roemer form c lateral view, ABC7, x75
- 9. Vaginulina costulata Roemer form c close-up lateral view of aperture, ABC7, x150
- 10. Vaginulina costulata Roemer form c close-up lateral view of aperture, ABC9, x75
- 11. Vaginulina costulata Roemer form d oblique lateral view, ABC8, x50
- 12. Eoguttulina? sp.a lateral view, CBl 1, x150
- 13. <u>Ramulina</u> <u>aculeata</u> (d'Orbigny) form a lateral view, ABC1, x100
- 14. <u>Ramulina aculeata</u> (d'Orbigny) form a lateral view, ABC3, x150
- 15. <u>Ramulina</u> <u>aculeata</u> (d'Orbigny) form a close-up of test wall, ABC3, x350

Plate 19 cont'd.

- 16. Ramulina aculeata (d'Orbigny) form a lateral view, ABC8, x200
- 17. <u>Ramulina aculeata</u> (d'Orbigny) form b lateral view, ABC1, x150
- 18. <u>Ramulina</u> <u>aculeata</u> (d'Orbigny) form b oblique apertural view, ABC1, x200



Plate 20.

1.	Ramulina aculeata lateral view, ABC3,	(d'Orbigny) x100	form c
2.	Ramulina aculeata lateral view, ABC5,	(d'Orbigny) x150	form d
3.	Ramulina aculeata lateral view, ABC5,	(d'Orbigny) x150	form d
4.	Ramulina aculeata lateral view, ABC9,	(d'Orpigny) x75	form e
5.	Ramulina aculeata lateral view, AKS11,	(d'Orbigny) x150	form f
6.	Ramulina aculeata lateral view, AKSIL	(d'Orbigny) x200	form f
7.	Tristix excavatum lateral view, CBI 4	(Reuss) x50	
8.	Tristix excavatum apertural view, CBl	(Reuss) 4, x100	
9.	Oolina sp.a lateral view, ABC3,	x200	
10.	Oolina sp.a oblique apertural v	iew, ABC3,	x200
11.	Oolina sp.a lateral view, ABC3	, x200	

- 12. <u>Oolina</u> sp.a oblique apertural view, ABC3, x200
- 13. Praebulimina sp.a lateral view, B.P 93\2-1 1035', x500
- 14. Praebulimina sp.a Initial portion of test, B.P 93\2-1 1035', x500

Plate 20 cont'd

- 15. Praebulimina sp.a lateral view, B.P 93\2-1 1035', x500
- 16. <u>Praebulimina</u> sp.a oblique apertural view, B.P 93\2-1 1035', x500



Plate 21.

- 1. <u>Guembelitria</u> cenomana (Keller) lateral view, Goban Spur 6\1 124-126, x750
- 2. <u>Guembelitria</u> <u>cenomana</u> (Keller) lateral view, Goban Spur 6\1 124-126, x750
- 3. <u>Guembelitria</u> cenomana (Keller) last portion of test, Goban Spur 6\l 124-126, x1000
- 4. <u>Guembelitria</u> <u>cenomana</u> (Keller) lateral view, ABCl, x750
- 5. <u>Guembelitria</u> <u>cenomana</u> (Keller) lateral view, ABC1, x750
- 6. <u>Guembelitria cenomana</u> (Keller) last portion of test, ABC4, x750
- 7. <u>Guembelitria</u> <u>cenomana</u> (Keller) lateral view, ABC4, x500
- 8. <u>Guembelitria</u> <u>cenomana</u> (Keller) lateral view, ABCL, x500
- 9. <u>Guembelitria</u> <u>cenomana</u> (Keller) lateral view, ABCL, x500
- 10. <u>Guembelitria</u> cenomana (Keller) lateral view, AKS2, x750
- 11. <u>Guembelitriella</u> sp.a lateral view, ABC1, x500



Plate 22.

- 1. Heterohelix moremani (Cushman) lateral view, Goban Spur 6\1 124-126, x500
- 2. Heterohelix moremani (Cushman) lateral view, Goban Spur 6\1 124-126, x750
- 3. Heterohelix moremani (Cushman) lateral view, Goban Spur 6\1 124-126, x500
- 4. <u>Heterohelix</u> moremani (Cushman) oblique apertural view, Goban Spur 6\l 124-126, x500
- 5. <u>Heterohelix</u> moremani (Cushman) close-up of initial portion of test, Goban Spur 6\1 124-126, x1500
- 6. <u>Heterohelix</u> moremani (Cushman) lateral view, ABC1, x350
- 7. Heterohelix moremani (Cushman) lateral view, ABCL, x500
- 8. Heterohelix moremani (Cushman) lateral view, ABC1, x350
- 9. Heterohelix moremani (Cushman) lateral view, ABC4, x750
- 10. Heterohelix moremani (Cushman) lateral view, ABC4, x500
- 11. Heterohelix moremani (Cushman) lateral view, ABC20, x500
- 12. Heterohelix moremani (Cushman) lateral view, ABC21, x750
- 13. Heterohelix moremani (Cushman) lateral view, AKS1, x500
- 14. Heterohelix globulosa (Ehrenburg) lateral view, ABC20, x750
- 15. <u>Heterohelix globulosa</u> (Ehrenburg) lateral view, AKS8, x350

Plate 22 cont'd

16. Heterohelix globulosa (Ehrenburg) close-up of ornament, AKS8, x1000



Plate 23.

- 1. <u>Globigerinelloides bentonensis</u> (Morrow) umbilical view, ABC4, x500
- 2. <u>Globigerinelloides</u> <u>bentonensis</u> (Morrow) spiral view, ABC4, x500
- 3. Globigerinelloides bentonensis (Morrow) umbilical view, Goban Spur 6\1 70-72, x500
- 4. <u>Globigerinelloides bentonensis</u> (Morrow) apertural view, Goban Spur 6\1 70-72, x500
- 5. <u>Globigerinelloides</u> bentonensis (Morrow) spiral view, Goban Spur 6\1 70-72, x500
- 6. "Hedbergella" aprica (Loeblich and Tappan) umbilical view, SGQll, x200
- 7. "Hedbergella" aprica (Loeblich and Tappan) spiral view, SGQl1, x200
- 8. "Hedbergella" aprica (Loeblich and Tappan) EGG23
- 9. "Hedbergella" archaeocretacea (Loeblich and Tappan) umbilical view, SGQ15, x200
- 10. "Hedbergella" archaeocretacea (Loeblich and Tappan) apertural view, SGQ15, x200
- 11. "<u>Hedbergella</u>" <u>archaeocretacea</u> (Loeblich and Tappan) spiral view, SGQ15, x200
- 12. "<u>Hedbergella</u>" <u>archaeocretacea</u> (Loeblich and Tappan) CBl 26
- 13. "Hedbergella" brittonensis (Loeblich and Tappan) SGQ15
- 14. "Hedbergella" brittonensis (Loeblich and Tappan) WND 15



Plate 24.

- 1. Hedbergella delrioensis (Carsey) apertural view, Goban Spur 5\1 7-10A, x200
- 2. Hedbergella delrioensis (Carsey) close-up of aperture, Goban Spur 5\1 7-10A, x500
- 3. <u>Hedbergella delrioensis</u> (Carsey) umbilical view, Goban Spur 5\1 7-10A, x200
- 4. <u>Hedbergella</u> <u>delrioensis</u> (Carsey) spiral view, Goban Spur 5\1 7-10A, x150
- 5. <u>Hedbergella delrioensis</u> (Carsey) oblique peripheral view, Goban Spur 5\1 7-10A, x200
- 6. Hedbergella delrioensis (Carsey) umbilical view, Goban Spur 5\1 7-10A, x200
- 7. <u>Hedbergella</u> <u>delrioensis</u> (Carsey) close-up of umbilical area, Goban Spur 5\1 7-10A, x500
- 8. <u>Hedbergella</u> <u>delrioensis</u> (Carsey) spiral view, Goban Spur 5\17-10A, x200
- 9. Hedbergella delrioensis (Carsey) peripheral view, ABC1, x200
- 10. Hedbergella delrioensis (Carsey) close-up of periphery, ABCl, x350
- 11. <u>Hedbergella</u> <u>delrioensis</u> (Carsey) SGQ6
- 12. Hedbergella planispira (Tappan) oblique spiral view, B.P 93\2-1 1035', x200
- 13. Hedbergella planispira (Tappan) spiral view, B.P 93\2-1 1035', x200
- 14. Hedbergella planispira (Tappan) umbilical view, B.P 93\2-1 1035', x200



Plate 25.

- 1. Hedbergella simplex (Morrow) BSA 10
- 2. <u>Hedbergella</u> washitensis (Casey) SGQ6
- 3. Helvetoglobotruncana praehelvetica (Trujillio) spiral view, B.P 93\2-1 1030', x200
- 4. Helvetoglobotruncana praehelvetica (Trujillio) oblique apertural view, B.P 93\2-1 1030', x350
- 5. <u>Helvetoglobotruncana</u> praehelvetica (Trujillio) close-up of periphery, B.P 93\2-1 1030', x750
- 6. <u>Helvetoglobotruncana</u> praehelvetica (Trujillio) BSA 11
- 7. <u>Helvetoglobotruncana</u> praehelvetica (Trujillio) CB1 17
- 8. <u>Helvetoglobotruncana</u> praehelvetica (Trujillio) CBl 31
- 9. <u>Helvetoglobotruncana</u> <u>praehelvetica</u> (Trujillio) CB1 26
- 10. <u>Helvetoglobotruncana</u> <u>praehelvetica</u> (Trujillio) EGG 25
- 11. <u>Helvetoglobotruncana</u> <u>helvetica</u> (Bolli) AKS11
- 12. Helvetoglobotruncana helvetica (Bolli) spiral view, B.P 93\2-1 1090', x200

Plate 25 cont'd.

- 13. <u>Helvetoglobotruncana</u> <u>helvetica</u> (Bolli) peripheral view, B.P 93\2-1 1090', x200
- 14. <u>Helvetoglobotruncana helvetica</u> (Bolli) oblique peripheral view, B.P 93\2-1 1090', x350



Plate 26.

- 1. <u>Praeglobotruncana</u> <u>delrioensis</u> (Plummer) SGQ7
- 2. <u>Praeglobotruncana</u> gibba Klaus SGQ7 Little Beach Member
- 3. Praeglobotruncana gibba Klaus apertural view, Goban Spur 6\1 30-33, x150
- 4. <u>Praeglobotruncana stephani</u> (Gandolfi) SGQ7 Pinnacles Member
- 5. Praeglobotruncana stephani (Gandolfi) spiral view, Goban Spur 6\1 30-33, x200
- 6. <u>Praeglobotruncana</u> stephani (Gandolfi) apertural view, Goban Spur 6\1 30-33, x200
- 7. Praeglobotruncana stephani (Gandolfi) umbilical view, Goban Spur 6\1 30-33, x200
- Praeglobotruncana stephani (Gandolfi) spiral view, Goban Spur 6\1 30-33, x150
- 9. <u>Praeglobotruncana</u> <u>stephani</u> (Gandolfi) peripheral view, Goban Spur 6\1 30-33, x200
- 10. Praeglobotruncana stephani (Gandolfi) spiral view, Goban Spur 6\1 30-33, x200



Plate 27.

- 1. Dicarinella algeriana (Caron) umbilical view, Goban Spur 5\1 76-78, x150
- 2. Dicarinella algeriana (Caron) apertural view, Goban Spur 5\1 76-78, x200
- 3. Dicarinella algeriana (Caron) spiral view, Goban Spur 5\1 76-78, x110
- 4. Dicarinella hagni (Scheibnerova) spiral view, Goban Spur 5\1 76-78, x150
- 5. Dicarinella hagni (Scheibnerova) apertural view, Goban Spur 5\1 76-78, x100
- 6. Dicarinella hagni (Scheibnerova) close-up of keels, Goban Spur 5\1 76-78, x350
- Dicarinella hagni (Scheibnerova) apertural view, Goban Spur 5\1 76-78, x200
- 8. Dicarinella hagni (Scheibnerova) spiral view, Goban Spur 5\1 76-78, x150
- 9. Dicarinella hagni (Scheibnerova) CBl 34
- 10. <u>Dicarinella hagni</u> (Scheibnerova) WND28
- 11. Dicarinella imbricata (Mornod) peripheral view, Goban Spur 5\1 76-78, x200
- 12. Dicarinella imbricata (Mornod) spiral view, Goban Spur 5\1 76-78, x200



Plate 28.

- 1. <u>Marginotruncana</u> <u>marginata</u> (Reuss) umbilical view, AKS10, x150
- 2. <u>Marginotruncana</u> <u>marginata</u> (Reuss) apertural view, AKSIØ, x200
- 3. <u>Marginotruncana marginata</u> (Reuss) spiral view, AKS10, x200
- 4. <u>Marginotruncana marginata</u> (Reuss) spiral view, AKS10, x150
- 5. <u>Marginotruncana</u> sp. cf. <u>M</u>. <u>sigali</u> (Reichel) spiral view, AKS12, x100
- 6. <u>Marginotruncana</u> sp. cf. <u>M. sigali</u> (Reichel) apertural view, AKS12, x150
- 7. <u>Marginotruncana</u> sp. cf. <u>M.</u> <u>sigali</u> (Reichel) spiral view, AKS12, x100
- 8. <u>Marginotruncana</u> sp. cf. <u>M. sigali</u> (Reichel) peripheral view, AKS12, x150
- 9. Rotalipora appenninica (Reuz) SGQ7
- 10. Rotalipora cushmani (Morrow) umbilical view, Goban Spur 6\1 30-33, x150
- 11. Rotalipora cushmani (Morrow) apertural view, Goban Spur 6\1 30-33, x150
- 12. Rotalipora cushmani (Morrow) spiral view, Goban Spur 6\1 30-33, x150
- 13. Rotalipora cushmani (Morrow) spiral view, Goban Spur 6\1 30-33, x150
- 14. Rotalipora cushmani (Morrow) umbilical view, Goban Spur 6\1 30-33, x150



Plate 29.

- 1. <u>Rotalipora</u> <u>cushmani</u> (Morrow) BSA 6
- 2. Rotalipora cushmani (Morrow) CBl 10
- 3. Rotalipora cushmani (Morrow) WND 11
- 4. Rotalipora deecki (Franke) umbilical view, Goban Spur 6\1 30-33, x100
- 5. Rotalipora deecki (Franke) apertural view, Goban Spur 6\1 30-33, x200
- 6. Rotalipora deecki (Franke) spiral view, Goban Spur 6\1 30-33, x150
- 7. Rotalipora greenhornensis (Morrow) Umbilical view, Goban Spur 6\1 30-33, x150
- 8. Rotalipora greenhornensis (Morrow) apertural view, Goban Spur 6\1 30-33, x150
- 9. Rotalipora greenhornensis (Morrow) spiral view, Goban Spur 6\1 30-33, x150
- 10. Rotalipora sp. cf. reicheli Mornod S60.5
- 11. <u>Pleurostomella</u> <u>subnodosa</u> (Reuss) lateral view, Goban Spur 5\2 13-17, x150
- 12. Pleurostomella subnodosa (Reuss) close-up of aperture, Goban Spur 5\2 13-17, x150
- 13. <u>Pleurostomella</u> <u>subnodosa</u> (Reuss) lateral view, Goban Spur 5\2 13-17, x100
- 14. Pleurostomella subnodosa (Reuss) close-up of aperture, Goban Spur 5\2 13-17, x500

Plate 29 cont'd

- 15. <u>Gyroidina</u> sp.a apertural view, Goban Spur 6\1 30-33, x350
- 16. <u>Gyroidina</u> sp.a lateral view, Goban Spur 6\1 30-33, x350



Plate 30.

1.	Gyroidinoides	parva	(Kahn)
	lateral view,	ABC2,	x200

- 2. <u>Gavelinella baltica</u> Brotzen oblique apertural view, ABC2, x150
- 3. <u>Gavelinella</u> baltica Brotzen lateral view, ABC1, x100
- 4. <u>Gavelinella</u> <u>baltica</u> Brotzen lateral view, ABC2, x100
- 5. <u>Gavelinella</u> <u>baltica</u> Brotzen oblique apertural view, ABC2, x100
- 6. <u>Gavelinella</u> <u>baltica</u> Brotzen close-up of test wall, ABC2, x500
- 7. <u>Gavelinella</u> <u>baltica</u> Brotzen lateral view, ABC2, x150
- 8. <u>Gavelinella berthelini</u> (Keller) apertural view, ABC12, x200
- 9. <u>Gavelinella berthelini</u> (Keller) umbilical view, ABCl2, x200
- 10. Gavelinella berthelini (Keller) oblique apertural view, ABC13, x200
- 11. Gavelinella berthelini (Keller) lateral view, ABC14, x200
- 12. <u>Gavelinella</u> <u>cenomanica</u> (Brotzen) lateral view, ABC1, x150
- 13. <u>Gavelinella cenomanica</u> (Brotzen) oblique apertural view, ABC4, x150
- 14. <u>Gavelinella</u> cenomanica (Brotzen) lateral view, ABC4, x100

Plate 30 cont'.

15. <u>Gavelinella cenomanica</u> (Brotzen) close-up of umbilical thickening, ABC4, x200



Plate 31.

- 1. <u>Gavelinella</u> intermedia (Berthelin) lateral view, B.P 93\2-1 1050', x200
- <u>Gavelinella</u> intermedia (Berthelin) apertural view, B.P 93\2-1 1050', x200
- 3. <u>Gavelinella intermedia</u> (Bethelin) apertural view, B.P 93\2-1 1050', x350
- 4. <u>Gavelinella</u> reussi (Kahn) lateral view, ABC4, x200
- 5. <u>Gavelinella reussi</u> (Kahn) apertural view, ABC4, x200
- 6. <u>Gavelinella</u> reussi (Kahn) lateral view, ABC4, x200
- Lingulogavelinella globosa (Brotzen) apertural view, SGQ8, x200
- 8. Lingulogavelinella globosa (Brotzen) lateral view, SGQ8, x150
- 9. Lingulogavelinella globosa (Brotzen) lateral view, SGQ8, x200
- 10. Lingulogavelinella aumalensis (Sigal) oblique apertural view, AKS15, x200
- 11. Lingulogavelinella aumalensis (Sigal) lateral view, AKS15, x200
- 12. <u>Pithonella</u> <u>ovalis</u> (Kauffmann) AKS8, x750
- 13. Pithonella ovalis (Kauffmann) AKS7, x750
- 14. Calcareous (?) sphere B.P 93\2-1 1090', x350
Plate 31 cont'd.

- 15. Calcareous (?) sphere B.P 93\2-1 1090', x1000
- 16. Cemented calcareous (?) spines ABC9, x100

