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A Foraminiferal Biostratigraphy of the Campanian and Maastrichtian Chalks of the United Kingdom.

Volume 1.

by

Anthony Swiecicki, B.Sc.

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

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Broad similarities have been noted between the British foraminiferal faunas of the Upper Cretaceous and those of wide areas of northern Europe, clearly placing Britain within the Transitional biogeoprovince . Palaeoecological study has indicated that marine conditions with normal salinities prevailed throughout the Campanian and Maastrichtian. Palaeotemperatures appear to have gradually declined throughout this time, with a short-lived warm phase in the latest Maastrichtian. Depths of deposition of the chalk are interpreted as having been between 150 - 250m., though greater depths probably prevailed in the North Sea basins. A transgressive phase is indicated for the Upper Campanian and a regressive phase for the Maastrichtian.

Plymouth Polytechnic,

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TEXT FIGURES

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ABSTRACT

The foraminiferal fauna from twenty-seven sections of Campanian and Maastrichtian chalk from both the onshore and offshore United Kingdom have been studied. In total, 160 species and subspecies belonging to 54 genera have been recorded and a complete revision of their systematics, with full synonomies and descriptions, has been given. The detailed stratigraphic distribution of these species has been studied and 65 species and subspecies of prime stratigraphic importance have been recognised and employed in the definition of a tripartite biozonal scheme based on planktonic foraminifera, Bolivinoides lineages and faunal assemblages respectively. This biozonal scheme has been accurately related to local rock units as well as to current macrofossil zonations. Correlation of all sections studied has been achieved by use of the proposed biozonal scheme.

Broad similarities have been noted between the British foraminiferal faunas of the Upper Cretaceous and those of wide areas of northern Europe, clearly placing Britain within the Transitional biogeoprovince. Palaeoecological study has indicated that marine conditions with normal salinities prevailed throughout the Campanian and Maastrichtian. Palaeotemperatures appear to have gradually declined throughout this time, with a short-lived warm phase in the latest Maastrichtian. Depths of deposition of the chalk are interpreted as having been between 150 - 250m., though greater depths probably prevailed in the North Sea Basins. A transgressive phase is indicated for the Upper Campanian and a regressive phase for the Maastrichtian.

CHAPTER 1

INTRODUCTION

The primary aim of the present research project has been to produce an accurate and practical foraminiferal zonation of the Campanian and Maastrichtian chalks both from onshore, and offshore, United Kingdom. However, an investigation of foraminiferal biostratigraphy cannot be pursued independently of the parallel studies of taxonomy and palaeoecology. The present study has clearly shown that biostratigraphic conclusions are only as valid as the taxonomy on which they are based, and that the distribution, and therefore the biostratigraphic application of any fossil group is strongly influenced by palaeoecological factors, a thorough understanding of which is necessary to the correct interpretation of biostratigraphy. Thus, while the present study is primarily of a biostratigraphic nature, considerable emphasis has been placed on a complete revision and clarification of the taxonomy of the foraminifera involved, together with a thorough study and interpretation of the palaeoecological factors controlling their distribution.

The application of foraminifera to the field of biostratigraphic correlation has been long recognised and documented, especially in respect to borehole material. Such studies have, in recent years, received a substantial impetus from both the Deep Sea Drilling Project and from the extension of the search for petroleum into offshore areas of the continental shelf. There has been a marked renewal of interest in the chalk both from an academic viewpoint, including the establishment of numerous national and international review bodies, and also from the commercial side, in view of its increasing importance in the fields of petroleum exploration and civil engineering. Despite this however, there has been relatively little work undertaken on the Foraminifera from the Campanian and Maastrichtian chalks of the United Kingdom.

To achieve the stated aims of the present project, the author has undertaken a highly detailed stratigraphic study of the foraminiferal fauna from many of the relevant localities in southern England and Norfolk (figs.1:1, 1:2) as well as from borehole material from the North Sea. This study has allowed the recognition of major faunal changes and the establishment of a refined foraminiferal zonal scheme. As noted previously, any biostratigraphic scheme is only as valid as the taxonomy on which it is based. There has however, been no major taxonomic revision of the British Upper Cretaceous foraminiferal fauna since the work of Barr (1962 MS.), and thus considerable emphasis has been placed on this aspect of the study , with full descriptions and synonomies being given for all species.

Though Foraminifera from the chalk of Britain were recorded in the nineteenth and early twentieth centuries (d'Orbigny 1842; Eley 1859; Jones 1872; Jones & Parker 1872; Wright 1886; Chapman 1892, 1894; Jukes-Brown & Hill 1904; Heron-Allen & Earland 1910), these early works generally gave only brief descriptions or merely faunal lists. At that time the full biostratigraphic significance of the Foraminifera was not readily appreciated. The concepts of foraminiferal biostratigraphy were first applied to the chalk faunas of England by Williams-Mitchell (1948), who undertook the biostratigraphic analysis of selected species of foraminifera from well cuttings in the Hampshire Basin, and surface samples throughout southern England. The results of this early work, though admittedly of a preliminary nature, have been largely confirmed by the present study. Barnard and Banner (1953) gave a detailed taxonomic and morphological account of the arenaceous foraminifera of the British chalk, whilst Barnard (1958, 1962, 1963, 1972) has undertaken taxonomic studies of

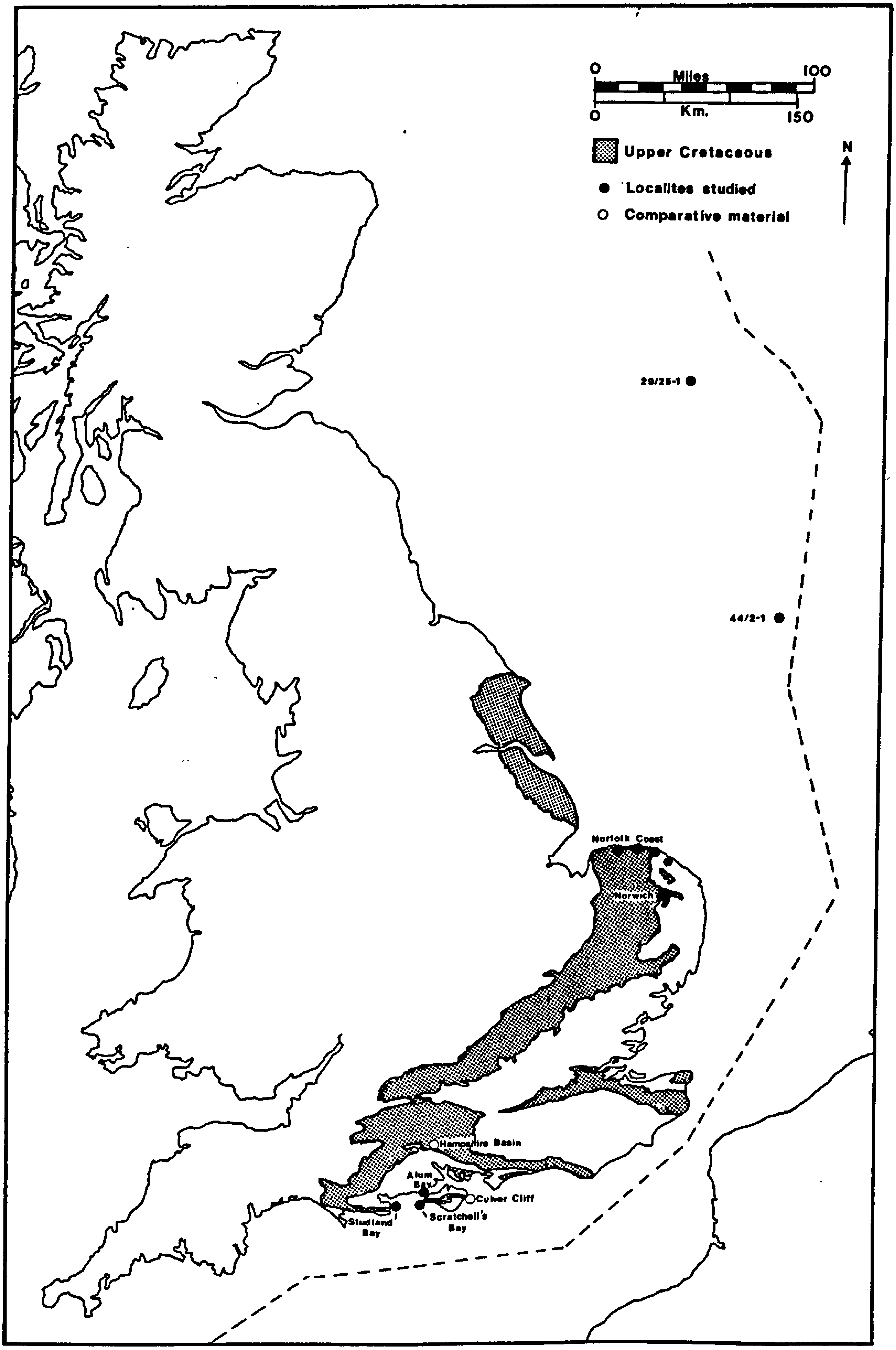


Fig. 1:1 Outcrops of Upper Cretaceous deposits onshore in the United Kingdom and locations of sections studied.

selected genera within the Lituolacea and Nodosariacea. All of these more recent papers have included some information on stratigraphic distributions. McGugan (1957, 1964) has described and figured foraminifera from the chalk and 'derived chalk' deposits of N. Ireland and has attempted a general correlation with faunas described from N.W. Europe. Barr (1962, 1966a) undertook a stratigraphic analysis of planktonic foraminifera and species of the genus Bolivinoides from selected horizons within the chalk of southern England. All the foregoing works have suffered however, in terms of their stratigraphic utility, from two major drawbacks, which have tended to confuse our knowledge of the detailed stratigraphic distribution of the chalk foraminifera, rather than clarifying the situation. Firstly, no systematic bed-by-bed analysis was undertaken, sample points generally being restricted to easily accessible horizons or those exhibiting softer lithologies. Secondly, all foraminiferal ranges were related to existing macrofossil zones. This second factor, in particular, has led to major discrepancies in the quoted ranges of many foraminiferal species. Such an approach does not, in the present author's opinion, provide the necessary stable reference framework for biostratigraphic analysis. A system of relating biostratigraphic data directly to local rock units as recommended by Holland et al (1978) has thus been employed. More recently, Hart and Carter (1975), Carter and Hart (1977a,b) and Bailey (1978 MS.) have undertaken detailed biostratigraphic analysis of foraminiferal faunas from the Albian to Santonian interval, referring biostratigraphic data directly to reference sections along the lines outlined herein.

Foraminiferal studies may also be utilized for the determination of palaeoecological data. Distribution patterns, numerical abundance and specific diversity of planktonic foraminifera may be governed by temperature, salinity, depth of water column, oceanic current patterns

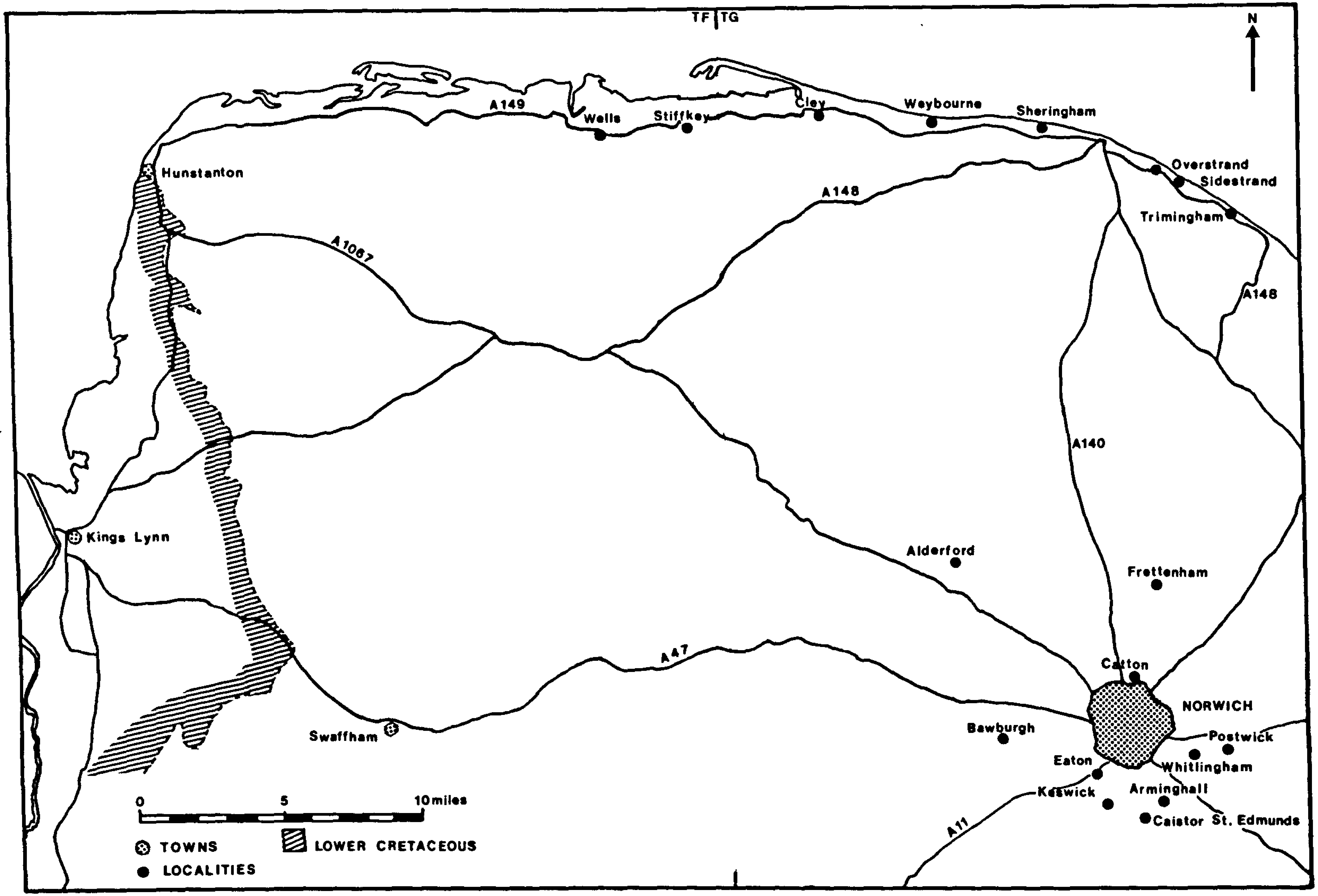


Fig. 1:2 Outcrop of Upper Cretaceous deposits in Norfolk and locations of sections studied.

and nutrient supply. In addition, benthonic foraminifera are also influenced by substrate, turbidity and sedimentation rates. The Campanian and Maastrichtian chalk of the British Isles was deposited under open marine conditions of normal salinity (Kennedy & Garrison 1975). Analysis of foraminiferal distribution patterns indicate that for much of the Campanian and Maastrichtian, southern England was part of the Transitional biogeoprovince of Scheibnerova (1971). Fluctuating abundances of planktonic foraminifera have lent support to the concept (Hancock 1975) of there being a series of transgressive and regressive events within the time span, though the magnitude of these events is difficult to gauge. Transgressive phases appear to have dominated the uppermost Campanian, whilst regressive phases are indicated for the Middle/Upper Campanian boundary and the Maastrichtian. Palaeoclimatological indications (see Chapter 8) suggest a general cooling trend from earliest Campanian times onward with a brief period of warming in the Upper Maastrichtian.

To achieve the stated aims of this research project, the author has undertaken the bed by bed lithological logging and sampling of nineteen major onshore sections from southern England and Norfolk, together with a comparative study of the foraminiferal faunas from spot samples collected from England, N.W. Germany, Denmark, Sweden, Belgium, Holland, France, and the U.S.A. In addition, material has been studied from well cuttings from boreholes in the North Sea basin which penetrated complete Campanian/Maastrichtian successions. Thus, sections studied cover an extremely wide geographical area. In total, over 700 samples have been collected and examined , and their total foraminiferal fauna analysed. From these, approximately 180,000 individual specimens of foraminifera have been isolated and examined, comprising 160 species and subspecies belonging to 54 genera. Of these, 65 have been found to be of major importance stratigraphically, and have been used to formally erect a tripartite foraminiferal biozonation based on planktonic foraminifera, Bolivinoides phylozones and assemblage biozones respectively. The biozonation produced has been referred to designated type sections and compared to available macrofossil biozonation schemes. Each of the major sections studied has been integrated into the biozonal scheme and many of the isolated chalk outcrops of Norfolk have been accurately correlated with the more extensive exposures of southern England. The applicability of the proposed zonal scheme to offshore material has also been rigorously tested.

CHAPTER 2

STRATIGRAPHY

2.1. Introduction

The lithostratigraphic term 'chalk' has been in use since the Middle Ages. D'Omalius d'Halloy (1842) first designated the 'terrains crétacés' and the system takes its name from the Latin 'creta' for chalk, which is its most distinctive rock type. In the early nineteenth Century, British and French geologists had reached a broad concensus of opinion concerning the lithostratigraphic subdivision of the Cretaceous System into:-

Chalk
Greensand
Gault
Wealden/Neocomian

D'Orbigny (1842, 1847) was amongst the first to formally subdivide the Upper Cretaceous chalks of N. W. Europe, erecting the Cenomanian, Turonian and Senonian stages, using a combination of lithostratigraphic and biostratigraphic data. Much of the earliest stratigraphic work on the Upper Cretaceous strata of France, such as that of d'Archiac (1836) and Coquand (1856), was largely of a lithostratigraphic nature. Coquand (1858) in a major study of the Upper Cretaceous stratigraphy of the Charente region of S.W. France, first designated the Coniacian, Santonian and Campanian stages, describing both their lithostratigraphy and biostratigraphy, and replacing his earlier numeric designations. In Holland, Dumont (1849) established the Maastrichtian stage.

There has been considerable debate as to the exact relationship between Coquand's three 'stages' listed above, and the Senonian of d'Orbigny. Various authors have considered Coquand's units either as substages of the Senonian stage (eg. Gignoux 1928), or stages within the Senonian sub-epoch (van Hinte 1965). There is now little doubt that the Senonian is largely co-extensive with the Coniacian to Campanian interval (Rawson et al 1978), though there is debate as to the exact stratigraphic extent of both Coquand's and d'Orbigny's units, even in their type regions. In addition, numerous authors (eg. Haug 1911; van Hinte 1965) have included the Maastrichtian as a subdivision of the Senonian, despite the fact that no equivalent of the Maastrichtian stage has been demonstrated in the type region of the Senonian. In order to maintain a consistent scale and to avoid adding to the already confused nomenclature of Upper Cretaceous stratigraphy, the present author has willingly complied with the recommendation made at the meeting of the International Subcommission on Cretaceous Stratigraphy at Münster(1978), that the use of the term 'Senonian' be allowed to lapse. Thus, in the present work the Campanian and Maastrichtian stages are taken to comprise the final two, independent, stages of the Cretaceous System.

2.2. The Campanian Stage.

As previously noted, this stage name was first employed by Coquand (1858) to replace his previously established numerical subdivision of the Upper Cretaceous of France. The Campanian stage (2nd. Stage or 'craie' with Ostrea vesicularis sensu Coquand 1856) was described from the Charente region of S.W. France and the only section which was described in detail from this stage was that situated at Aubeterre-sur-Dronne. This section has subsequently been accepted by most Cretaceous stratigraphers as the type section of the Campanian stage (van Hinte 1965, 1966a,b, 1967, 1979; van Gorsel

1973 ; Gohrian 1970, 1971; Rawson et al 1978).

The Aubeterre section also includes beds which were placed by Coquand in his Dordonian stage, which is now generally accepted as being equivalent to the Maastrichtian (van Gorsel 1973; Séronie-Vivien 1972). Arnaud (1877, 1878) substantially amended Coquand's original concepts of the Campanian and Dordonian, placing the base of the Dordonian at the first appearance of the larger foraminifera Orbitoides media and thus, as noted by Gohrian (1971), Séronie-Vivien (1972), Rawson et al (1978), a major part of the type section of the Campanian stage may be considered to be of Maastrichtian age.

Séronie-Vivien (1972), in recognition of this problem, rejected the Aubeterre section as the type locality of the Campanian stage and designated a number of sections near the valley of Né as parastratotypes. This designation has not been widely accepted however, and has been criticized by Rawson et al (1978) who noted that macrofossils were scarce and not distinctive in the parastratotypes. They also noted that the parastratotypes failed to resolve many of the problems related to the recognition of the base of the stage. Recent work by van Hinte (1968) and Colin (1974) has cast significant doubt on the identification, and consequent stratigraphic distribution of the genus Orbitoides as present at Aubeterre and thus on the precise position of the Campanian/Maastrichtian boundary.

Thus it may be seen that, despite considerable debate over a period of years, no consensus of opinion has emerged to date as to the exact nature and delimitation of the Campanian stage in its type area. It is with this situation in mind, that the Coniacian-Maastrichtian Working Party of the International Subcommission on Cretaceous Stratigraphy is actively engaged in debate and discussion of the problems relating to the definition and retention of the Campanian stratotype.

Problems are also encountered in correlating the type Campanian of the Charente region with the British Campanian, due to marked provincialization of many of the key macrofossil genera, the lack of aragonitic skeletal components in the chalk, and the problems of facies control on the distribution of the most stratigraphically important groups of benthonic organisms. There are indications (van Hinte 1965, 1966a, 1966b; Séronie-Vivien 1972) that the smaller benthonic foraminifera may fulfil a useful role in this area.

In the present study, the consensus of opinion, outlined in Special Report no.9 of the Geological Society (Rawson et al, 1978) regarding the limits, and subdivision, of the Campanian stage, has been followed. Thus, the base of the Campanian in the British Isles is placed at the base of the macrofossil biozone of Offaster pilula and the following macrofossil biozonation is recognised, utilizing a combination of belemnites and echinoides (Peake & Hancock 1961; Wood 1967; Rawson et al 1978).

Belemnitella mucronata

Gonioteuthis quadrata

Offaster pilula

The first of which has been subdivided into sub-biozones (Peake & Hancock 1961, 1970; Wood 1967) as indicated in T.fig. 2:1 . Study of the foraminiferal fauna from these macrofossil zones within N.W. Europe, together with comparison of the foraminiferal fauna described from Aubeterre (van Hinte 1965, 1966b,1967; Séronie-Viviene 1972), has led the author to conclude that no strata of Lower or Middle Campanian age are represented within the Aubeterre section, and thus no information regarding the base of the Campanian stage can be obtained from the stratotype. In view of this and the previously documented stratigraphic problems concerning the Aubeterre section, its retention as the stratotype of the Campanian must be seriously questioned.

2.3. The Maastrichtian Stage

Dumont formally erected the Maestrichtian stage in 1850 though he had earlier (1832) established the following lithostratigraphic subdivisions within the Upper Cretaceous of Limburg (Holland):-

Calcaire de Maestricht

Craie

These units Dumont (1850) later referred to the Système Maestrichtien and the Système Senonien respectively. There has been considerable debate as to which strata were included by Dumont (1850) in his new stage (see discussions Voigt 1956; Berggren 1964; Deroo 1966). The type locality was designated as the town of Maastricht and the Comité d'étude du Maastrichtian has fixed the stratotype as the section of the Tuffeau de Maastricht (= Maastricht Formation of van der Heide 1954; Felder 1975 = lithostratigraphic units Ma-Md of Uhlenbroek 1912) as exposed in the E.N.C.I. quarry at St. Pietersberg on the southern outskirts of Maastricht. Biostratigraphic evidence from both the macro- and microfaunal groups (Schmid 1959, 1967; Hofker 1966) has clearly demonstrated that thus defined, the type section includes only beds of Upper Maastrichtian age of current usage (Rawson et al 1978). Voigt (1956) and Berggren (1964) have discussed the different concepts of this stage which have been employed by Cretaceous stratigraphers. The most widely accepted definition of the base of the stage (Hiltermann 1952; Brotzen 1945; Voigt 1951, 1954; Jeletzky 1951; Birkelund 1957; Berggren 1960 , 1962a,b, 1964; van Hinte 1976; Rawson et al 1978) has extended Dumont's original concept downwards to include those beds below the Maastricht Formation which are characterized by the cephalopods Scaphites (Hoploscaphites) constrictus (Sowerby) and Belemnella lanceolata (Schlotheim). In this view, the Maastricht Formation is regarded as being a warm, shallow water detrial facies of local significance only. It is in this sense that the present author uses the term Maastrichtian stage. As recommended by the Maastrichtian Committee at the 22nd. Geological Congress in New Delhi, the stage name when used in this extended sense should be spelt with a double - a - in contrast to its original spelling and meaning sensu Dumont (1850) (see Meijer in discussion of Barr & Hammuda 1971). Thus defined, the base of the Maastrichtian stage coincides in N.W. Germany with the first appearance of the benthonic foraminifera Bolivinoides peterssoni Brotzen, Osangularia navarroana (Cushman) and Neoflabellina reticulata (Reuss) (Hiltermann & Koch 1955; Koch 1977). Within the British Maastrichtian the following macrofossil zones have been recognised (Rawson et al 1978).

Belemnella kazimiroviensis

Belemnitella junior

Belemnella occidentalis

Belemnella lanceolata

However, only the lanceolata zone and possibly the occidentalis zone have been recognised onshore in England and then only in erratic blocks within the glacial deposits of northern Norfolk. Structurally, these have been much complicated, both internally and externally, by glacial tectonics. Microfaunal evidence (Curry 1962, 1965; Andreieff et al 1975, and the present study) has indicated the widespread presence of a complete Maastrichtian chalk succession over large areas of the North Sea Basin.

Due largely to the considerable time gap which exists between the uppermost Cretaceous and lowest Tertiary deposits within the British Isles, few British geologists have been directly concerned with the delimitation of the top of the Cretaceous. However, this situation has been radically changed by the acquisition of considerable areas of strata within the North Sea Basin covering the Cretaceous/ Tertiary boundary. It is now widely accepted (Berggren 1964; Rawson et al 1978; Curry et al 1978) that the base of the Tertiary should be placed at the base of the Danian stage. This view upholds the conclusions of Forchhammer (1825) and refutes the ideas of Desor (1847) and d'Orbigny (1852), who considered the Danian as the youngest stage of the Cretaceous, apparently as a result of mistaken palaeontological evidence. The top of the Cretaceous System (= top of the Maastrichtian stage) is associated with the complete extinction of the Ammonoidea, Sauropterygia, Saurischia and Ornithischia (Rawson et al 1978) and the planktonic foraminiferal genera Globotruncana, Globotruncanella, Hedbergella and Rugoglobigerina. Belemnoidea, Inoceramidae, and rudists also became virtually extinct at this level (Hancock 1967). The causes of this massive faunal turnover at the end of the Cretaceous have been a matter of considerable debate, and almost as many hypotheses have been put forward as there have been papers written on the subject. A consideration of these is clearly beyond the scope of the present study, and the reader is referred to Worsley(1964), Berggren(1964), Tappan(1968)for useful discussions. All that may be stated at the present time is that it seems likely that a critical combination of palaeoecological factors (possibly including temperature, depth and nutrient supply) drastically reduced the primary productivity of the oceans, resulting in a major faunal turnover throughout the length of the long established Cretaceous food chains. What may be stated as fact is that the abrupt extinction of many elements of the characteristic Upper Cretaceous fauna marks one of the most readily recognisable biohorizons in Phanerozoic times.

2.4. Lithostratigraphy

Strata of Campanian and Maastrichtian age in the United Kingdom are almost completely represented by chalk. Chalk is a distinctive, pure biomicrite, composed largely of calcitic skeletal debris of planktonic marine algae, the coccolithophorids (Hancock 1976). Other important biogenic constituents include planktonic and benthonic foraminifera, ostracods, bryozoans and other minor faunal groups. In general, detrital clastic material is very rare in the Campanian and Maastrichtian chalks of England. The composition of the chalk clearly indicates that it is a pelagic sediment. However, this does not necessarily imply a deep water origin (Hakansson et al 1974). Indeed, its geological setting strongly argues against such a depositional environment. It seems likely that the chalk was deposited in a relatively shallow shelf sea, which covered most of N.W. Europe during the Cenomanian to Maastrichtian interval (see Chapter 9.). Though it is difficult to quantify actual depths of deposition (Chapter 8), most recent estimates (see review Hakansson et al 1974) consider the Campanian and Maastrichtian chalks to have been deposited at depths of 180m - 300m (Kennedy & Garrison, 1975) and the present study does not contradict these conclusions.

The distinctive chalk lithology owes much to its diagenetic potential and history. Coccolith debris is composed of low magnesian calcite (Thompson & Bowen 1969) and is thus stable at temperatures and pressures which are generally operational at shallow to moderate depths of burial. Thus chalk does not undergo significant pressure solution above depths of burial of 1000m (Hancock & Scholle 1975).

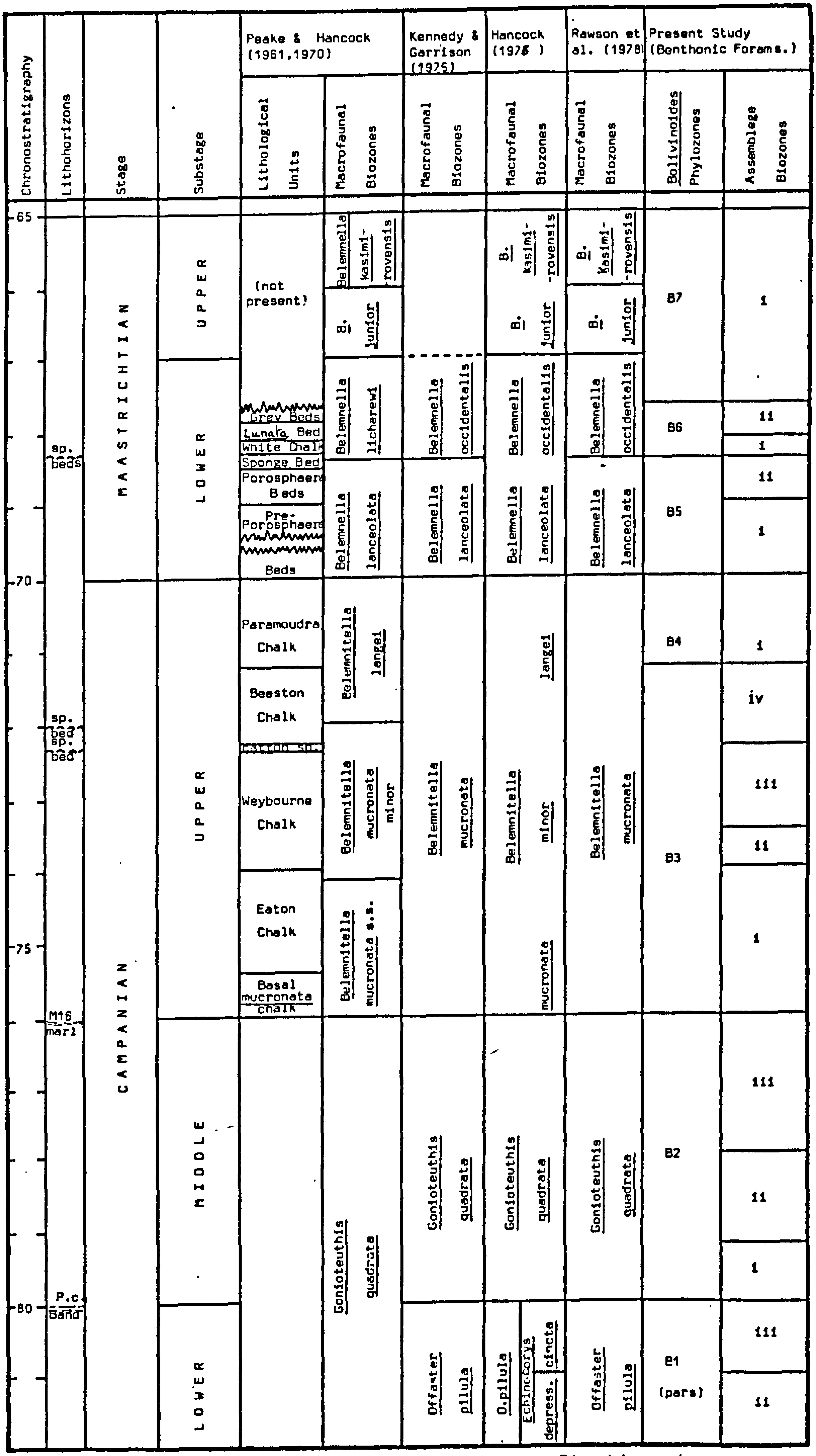


Fig.2:1 Campanian and Maastrichtian Stratigraphy.

Thus, the vast bulk of chalk studied from Norfolk and southern England has not suffered excessive diagenesis which could lead to greatly increased cementation, hardness, reduction in porosity and loss of microfossil content. In addition, the lack of significant quantities of aragonite in the chalk has also reduced the amount of calcite available for purposes of cementation. The result is that most of the chalks studied lack many of the early lithification features which hinder the micropalaeontological analysis of many shelf sea carbonates.

In N. Ireland, and to a lesser extent northern England, other factors, including increased geothermal and hydrothermal alteration (Scholle 1974) have produced very hard chalks with low porosity values, which has virtually excluded these areas from consideration within the present project. The chalk encountered in the North Sea is also a moderately hard limestone similar in many respects to the chalks of Yorkshire. In the North Sea, however, this alteration is almost entirely due to the increased depth of burial (Scholle 1974; Hancock & Scholle 1975).

In most areas the chalk is relatively poor in primary sedimentary structures, as a result of either a very uniform deposition with little or no current activity, or of almost complete bioturbation (Hakansson et al 1974). It is worthy of note that in general the effects of bioturbation are not readily apparent in the chalk; however, where minor differences in lithology are found, intense bioturbation is readily apparent. These include the ichnogenera Thalassinoides, Chondrites and Zoophycos. Other sedimentary features present in the chalk include hardgrounds and associated sponge beds. There are three noticeable levels of development of hardgrounds within the sections studied (Chapter 7), though the limited nature of stratigraphic coverage, particularly within the uppermost Campanian and Maastrichtian, renders delimitation of their geographical extent impossible. These three levels include the

Lower Campanian at Culver Cliff, Isle of Wight, the Catton Sponge Bed complex and the Sidestrand sponge beds. The first of these forms an extensive series of hardgrounds occupying much of the Lower Campanian succession of Culver Cliff. Despite their considerable stratigraphic extent they appear to be a local feature, as no trace of hardground development could be discerned at a comparable level in the Scratchells Bay section at the other end of the island. The second group includes a series of sponge beds in the Beeston and Weybourne Chalk lithostratigraphic units (Peake & Hancock 1961) in the chalk of Norfolk. These beds are generally of a red colour produced as a result of oxidation of synsedimentary disseminated pyrite associated with sponge debris (H. Ernst pers. comm.). They appear to cover a considerable geographic extent, as they can be detected also on the N. Norfolk coast, and hence have been used as regional lithostratigraphic marker horizons (Peake & Hancock 1961, 1970). Microfaunal differences, especially across the main Catton Sponge Bed, indicate that it may represent a considerable period of non-deposition. The final unit of hardgrounds and sponge beds are those exposed in the Sidestrand (East) platform. Kennedy and Garrison (1975) have undertaken considerable research into the development of hardgrounds within the chalk and have summarized the processes involved in their formation, as well as their stratigraphic distribution. Some, though by no means all, hardgrounds represent significant time gaps within the chalk succession, a factor which should be borne in mind when considering ranges of species.

Other common lithological factors of the chalk are the product of diagenetic alteration. These include the ubiquitous flints and common marl seams. The latter are particularly abundant in the Lower and Middle Campanian of the Isle of Wight. However, their morphology, relationship to bedding and development of flaser structures (Kennedy & Garrison 1975) and corroded microfauna indicate that they

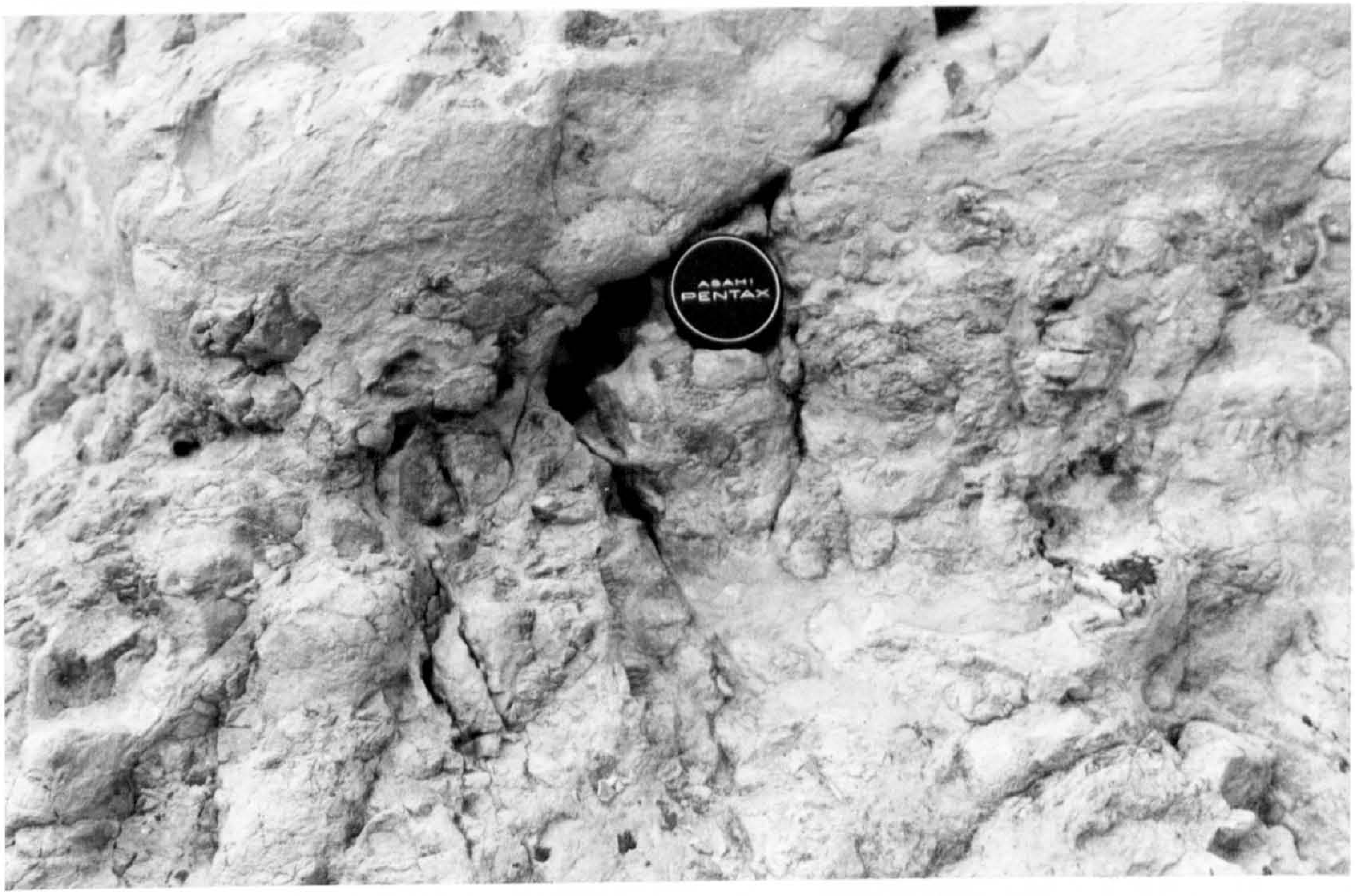
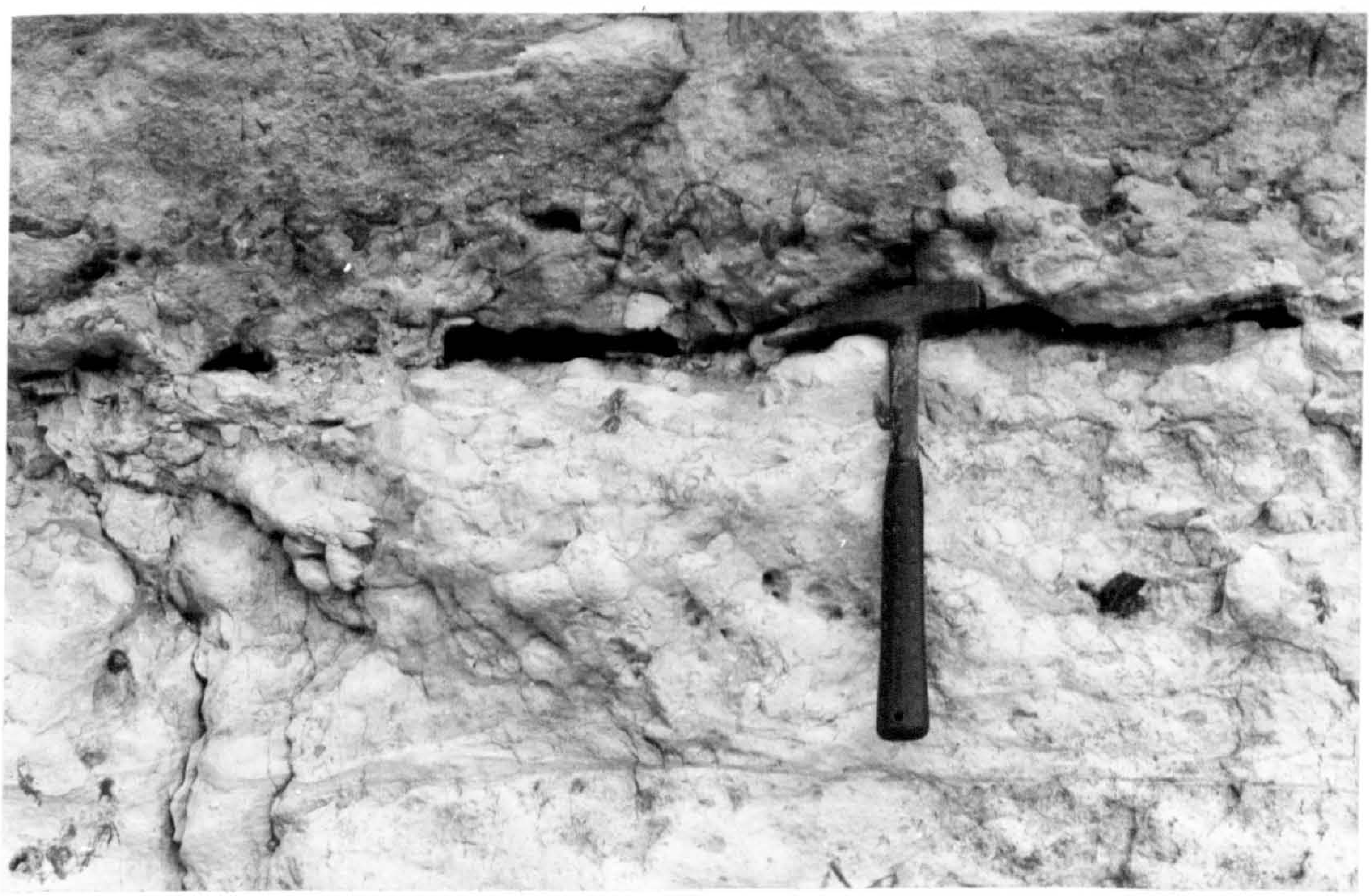


Fig. 2:2 Hardground development, Turonian, Beer, Devon.
2 views showing glauconitized and phosphatized hardgrounds, pebbles, and omission surfaces.



are in most cases secondary diagenetic features formed by the preferential solution of carbonate material. Notwithstanding this however, Hancock (1976) and Rawson et al (1978) have used a pair of marl seams - the Planoconvexa bed - as a lithostratigraphic marker for the Lower/Middle Campanian boundary in southern England. This lithostratigraphic horizon has been recognised by the present author in the Scratchell's Bay section, Isle of Wight.

Probably the most characteristic lithological feature of the chalk is the presence of flint. Flint occurs in rhythmic, nodular bands, late stage diagenetic infills along joints and more rarely as replacements of single macrofossils especially echinoids. The diagenesis and formation of flint has been a subject of considerable debate and controversy, and a thorough discussion of these problems is clearly beyond the scope of the present project. In recent years a growing consensus of opinion has evolved concerning the mechanisms and controls on the formation and development of flint (Siever 1962; Hakansson et al 1974; Wise and Weaver 1974; Bromley et al 1975), an outline of which is given below.

Flint is a dark, translucent form of chalcedonic quartz, commonly occuring in carbonate rocks. It has a conchoidal fracture and a grain size of 2-30μ. (Micheelsen 1966). The source of silica within the chalk is likely to have been from siliceous microfossils and sponge spicules. The present author has observed a marked inverse correlation between the density of flint bands and the abundance of siliceous sponge spicules within the Campanian chalk of southern England, which strongly indicates that they were at least a partial source of silica. Flint formation appears to have required considerable periods of time and is both an early and late stage diagenetic process. That this is so, is strongly evidenced by the complete absence of any flint in intraformational conglomerates eg. Maastrichtian of Ciply. The first stage of flint formation involves the precipitation of lepispheres of cristobalite around sites of organic decay where the solubility of silica is significantly lowered (Bromley et al 1975; Hakansson et al 1974). On deeper burial, i.e. during later diagenesis, the metastable cristobalite undergoes inversion to quartz and accretion of additional silica takes place. Sites of silica precipitation are strongly influenced by sites of organic decay and a close connection between nodular flint horizons and Thalassinoides burrow systems has been noted (Voigt & Hantzschel 1956; Bromley 1967; Kennedy & Garrison 1975). These deep burrow systems introduced organic rich material to depths within the sediment, close to the redox barrier, where almost all other organic material had been removed by the activities of burrowing organisms and aerobic decay. The chemical gradients thus produced controlled precipitation of silica and produced the rhythmic nodular flint horizons. At levels within the uppermost Campanian the extremely deep burrows of the (?)pogonophore Bathichnus paramoudrae acted as sites of silica precipitation, producing the gigantic 'paramoudra' or potstone flints so characteristic of the 'Paramoudra chalk' unit (Peake & Hancock 1961; Bromley et al 1975). Of particular interest to the chalk micropalaeontologist is the occasional occurrence of relatively uncompacted chalk ooze within the cavities of nodular flints. This "flint meal" often contains a rich microfaunal assemblage dominated by partially or wholly silicified foraminifera, which may yield valuable information on the microfaunal composition of the chalk sediment at an early stage in diagenesis. Flint meal faunas often contain a far higher percentage of planktonic foraminifera than does the surrounding chalk (Barr 1962 ; Bailey MS. 1978). Such results cast severe doubt on the validity of planktonic/benthonic ratios calculated for the 'normal' chalk and may well indicate that significant removal of the more fragile planktonic foraminifera has taken place by

Fig. 2:3 Loose flint, foreshore, Sidestrand. This large and distinctive flint, derived from flint band S (Peake & Hancock 1961) is pierced by a network of radiating cavities possibly representing an original burrow system.

Fig. 2:4 Flint band F9, Alum Bay. Cavernous flints containing 'flint-meal'.

a combination of diagenesis (Schlanger & Douglas 1974) and processing (see Chapter 3). It is also likely that such processes might introduce considerable bias into the ratios between keeled globotruncanas and non-keeled planktonics.

2.5. Chronostratigraphy

Two recent works have dealt exhaustively with the chronostratigraphy of the Cretaceous Period. That of Obradovich and Cobban (1975) utilized a combination of biostratigraphic and radiometric techniques in a detailed study of the Late Cretaceous of the Western Interior of North America. Van Hinte (1976) utilized biostratigraphic, radiometric and geomagnetic-reversal information from onshore and Deep Sea Drilling Project material on a world wide basis. Both schemes place the Cretaceous Tertiary boundary at 64/65 Ma, and the Campanian-Maastrichtian boundary at 70/71 Ma, thus giving a time span for the Maastrichtian of approximately 5 Ma. It should be noted that there is a marked discrepancy between the two schemes, with regard to the dating of the base of the Campanian. The reasons for this are not readily apparent, though it is of note that the restriction of the _Bolivinoides strigillatus_ biozone solely to the Upper Santonian by van Hinte (1976) is markedly at variance with the U.Santonian - L.Campanian range as determined by the present author. In view of this discrepancy, the chronostratigraphic scheme of Obradovich and Cobban (1975) has been followed herein. Thus the Campanian stage is taken as extending from 70/71 Ma to 82 Ma, ie. a time span of some 11 Ma. This data is incorporated in T. fig. 2:1.

CHAPTER 3

TECHNIQUES

3.1. Introduction

In any quantitative faunal study the techniques employed for sample collection, processing, analysis and data recording will have a significant influence on the results obtained. Thus, a thorough understanding and documentation of the various techniques available and employed is a necessity for comparison of results from different sources. Whilst it is desirable to investigate and utilize new techniques where these would lead to the acquisition of additional data, it is also important to maintain a degree of continuity of techniques to facilitate comparison of results. Several accounts have outlined techniques employed in the study of chalk foraminifera (Williams-Mitchell 1948; Barr 1962, 1966a; Owen 1970 MS.; Hart 1970 MS.,1973), and the techniques employed herein have drawn on their experience.

3.2. Sample collection

Samples averaging 0.5kg. in weight were collected from all onshore sections studied at a stratigraphic interval of 1m. and from as narrow a stratigraphic interval as was practical (about 10cm.). A stratigraphic interval of 1m. was selected as the optimum spacing to maximise stratigraphic resolution, whilst minimizing the effects of bioturbation (Berger & Heath 1968; Bromley et al 1974). Spot samples were also taken from horizons of distinct lithological change ie. above omission surfaces, from marly chalks and from 'flint meal'. Samples from borehole material were supplied as cuttings at 30ft. (9.14m.) intervals from well 29/25-1 and at 10ft. (3.05m.) from well 44/2-1, by Shell (U.K.) Exploration and Production Ltd. and Esso Exploration and Production. From onshore sections care was taken to adequately clean all samples before packing. This was especially important in many of the sections studied from Norfolk where the soft lithology resulted in considerable downwash of material. Notice was also taken at these sections both of periglacial action and ice tectonics, the former exemplified by the development of pseudo-intraformational conglomerates and ice wedges (e.g. foreshore exposures at Weybourne Hope (Grid Ref. TG. 110 438). Ice tectonics within many of the glacial erratic blocks of chalk along the North Norfolk coast have also resulted in folding and overthrusting, the detailed interpretation of which has had to be undertaken before samples could be collected and analysed (Chapter 4.).

3.3 Processing

Several methods for liberating foraminifera from chalk matrix have been described in the literature. Notable amongst these are the 'hydrogen peroxide' method (Barr 1962, 1966a; Owen 1970 MS.; Bailey 1978 MS.), 'white spirit' technique (Weaver 1978 MS.), glauber salt crystallization, and physical crushing (Bailey 1978 MS.). All of these were employed at an early stage in the present study in an attempt to elucidate the effects of the various processing techniques on the foraminiferal fauna obtained.

The processing technique employed on any given sample was a function of the physical properties of the sediment, these in turn being intimately related to its original composition and diagenetic history. As a general rule, it may be stated that the least destructive method consistent with obtaining a representative foraminiferal fauna was employed. In addition, as over 700 individual samples have been processed, the speed of processing technique was an important factor. Some techniques (ie. glauber salt crystallization), though yielding fractionally improved results, proved to be so time consuming that their use as a standard processing technique was not practicable.

For processing soft chalks, uncemented chalk oozes and marly chalks, the 'white spirit' method was employed, as this was by far the least destructive. This comprised the following steps :-

a) the cleaned sample was broken by hand into fragments some 3cm. across and dried thoroughly.

b) white spirit was then poured on to the sample until it was completely submerged. It was allowed to stand for 30 minutes.

c) the white spirit was then decanted, filtered and recycled.

d) water was then added to completely cover the sample, and it was then allowed to stand for up to 24 hours.

e) the resulting residue was thoroughly washed through a 75μ sieve to remove the bulk of the fine material, and dried.

The resulting breakdown of the chalk liberated an extremely rich foraminiferal fauna.

For chalks too hard to yield results by the above method, a technique of gentle physical crushing under water was employed. This proved to be the optimum technique for bulk processing of the chalk, being fast whilst not introducing excessive processing bias to the faunas obtained. The following steps were employed :-

a) the sample was first broken into small fragments (3cm. dia.), and dried thoroughly.

b) it was then covered by water for 24 hours and gently crushed piecemeal under water , in a mortar and pestle.

c) finally, the residue was washed through a 75 μ. sieve and dried.

Though the above may sound excessively harsh treatment, the overwhelming majority of chalk samples processed by this method yielded abundant, well preserved foraminiferal faunas, often with delicate morphological features preserved. In order to determine if any significant bias had been introduced into the faunas by processing techniques, a series of comparative tests were undertaken.

Several samples of chalk selected to display widely varying degrees of hardness and cementation were processed, using a variety of methods including those outlined above, glauber salt crystallization and hydrogen peroxide. The 'glauber salt' technique is widely accepted as producing a minimum physical force on foraminiferal tests (H. Ernst pers. comm.). Ratios between fragile planktonic and the more robust benthonic foraminifera were calculated as a means of assessing the faunal bias introduced within a given sample, and these have been tabulated overleaf.

From these preliminary results, certain indications may be drawn. Firstly, it would appear that where it is possible to utilize the 'white spirit' technique, this introduces the least bias into the fauna obtained, whilst the 'hydrogen peroxide' method introduced the most bias and corroded most of the specimens. Secondly, that the crushing technique, when applied to samples of chalk from the Lagerdörf quarries of N.W. Germany, introduces a significant processing

Sample	Hardness	% Planktonic/Benthonic Ratios (250 μ fraction)				Remarks
		W.S.	G.S.	Crush.	H_2O_2	
Tr.6	very soft	45	40	42.5	-	flint meal
OLM 4	mod. soft	40	-	-	-	
NP 3	soft	0	0	0	-	glacially tectonised
Tr.6	mod. soft	-	13	17.5	-	
CS 8	mod. soft	2	3	2	-	periglacial action
CS 7a	mod. soft	-	12	10	-	less periglacial action
Lag.2	mod. hard	-	24	2.3	-	processing effect
WNS 3a	hard	-	7	3.2	1.8	slight proc. effect
AB 81	hard	-	2	1.5	0.2	tectonically deformed

W.S.:'White Spirit'; G.S.:' Glauber salts '; Crush:crushing.

bias by selectively removing the more fragile species of planktonic foraminifera. Thirdly, that similar results arising from the use of the crushing technique cannot be demonstrated from the British chalk. The reasons for this apparent discrepancy may well vary from sample to sample (see Remarks above). It may be stated however, that chalk samples from the Campanian of Britain (excluding flint meal faunas) yielded consistently lower P/B ratios than the Lagerdörf chalks, regardless of processing techniques. The reasons for this may be sought in primary differences possibly resulting from different depths of deposition (Barr 1962; Flexer & Starinsky 1970), or in their diagenetic history. It appears possible that a combination of tectonic, periglacial and geothermal effects may well have selectively removed or fragmented many of the more fragile faunal elements within the British chalk . That this process may occur in deep sea chalks has been demonstrated by Schlanger and Douglas (1974).

If this is indeed the case, then the planktonic/benthonic ratios found in flint meal faunas may represent the closest approximation to those pertaining in the original chalk ooze. In conclusion, it may be stated that in general the different processing techniques employed introduce an insignificant faunal bias compared to the diagenetic bias already present in the British chalks.

3.4 Sample examination

The processed residue was split so that the portion used yielded a minimum of 350 foraminifera in the >250μ fraction. The split residues were dry sieved through a series of sieves measuring 1.75mm., 500μ, 250μ, 180μ and 125μ. Each sieve size was then completely examined for its faunal content, following the proceedure outlined by Hart (1970 MS., 1973; Hart & Carter 1975). The 250μ fraction was then completely picked, until a representative fauna had been obtained , and this was stored on a microfaunal slide. Extensive search was also made for any rare species missed in the first picking.

A similar technique was employed when dealing with the fine (ie. <250μ) sieve fractions, though only adult forms of species were stored and mounted. The fauna retained on the 250μ sieve generally includes the vast majority of adult forms, and it is this fraction which has been quantitatively analysed. Comparative studies were undertaken on the quantitative analysis of the finer sieve fractions which yielded closely comparable results. In view of the limited amount of additional information gained, and the time required, it was considered impractical to quantitatively analyse all of the finer fractions. It should be noted however, that the methods employed preclude a quantitative comparison with those (eg. Barr 1962) who dealt quantitatively with all size fractions.

3.5 Scanning Electron Microscopy

The Scanning Electron Microscope employed in the present study was a Joels 35C, newly installed in the Electron Microscopy Unit at Plymouth Polytechnic. Specimens to be photographed were cleaned using a 15% solution of Extran 100 laboratory detergent. They were then mounted on stubs using a variety of methods. Both 'Microstick' and 'Kodaflat' adhesives were used; the former proving unsatisfactory by its lack of adhesive strength; 'Kodaflat' thinned with xylene, whilst being far stronger, required extreme delicacy in its handling, as its high degree of solubility in the xylene made extreme caution necessary to avoid coating the specimens with a thin film of adhesive. This latter mounting medium also showed a tendency to develop polygonal cracks when subjected to 'sputter' coating. These tended to 'charge up' during S.E.M. examination. The method of mounting specimens finally developed, utilized a strip of narrow double-sided tape, the upper glued side of which was thinned using xylene. This mounting medium provided a 'quiet', ie. a black background, reduced cracking and charging and was convenient to handle. Mounted specimens were then 'sputter coated' with a 100 Å gold coating.

CHAPTER 4

SECTION DESCRIPTIONS

4.1. Introduction

In any study of the biostratigraphy of the Campanian and Maastrichtian stages within the United Kingdom, the list of potential localities is extensive. The studied sections have been selected to be stratigraphically extensive with as few breaks as possible. Also, the lithology should be one that will allow the separation of a representative foraminiferal fauna, and it is also an advantage if previous lithostratigraphic and macrofaunal studies have been undertaken. In addition, sections have been selected from as wide a geographical area as possible to enable rigorous testing of biostratigraphic information. All onshore localities were sampled at 1m. intervals and detailed lithological logs of all sections are given in Chapter 7. Localities studied in detail during the present project can be grouped into three geographic regions :-

a) Southern England

b) Norfolk

c) North Sea

4.2 Southern England

1. Scratchell's Bay, Isle of Wight. (Grid Ref. SZ 297 848)
This extensive section is located at the extreme western end of the Isle of Wight and is accessible only by boat. The chalk exposed in the bay comprises a series of steeply inclined beds dipping north-west. Beds exposed range from the *Micraster cortestudinarium* zone (Coniacian) to the lower *Belemnitella mucronata* zone (Upper Campanian). It is these latter beds which form the distinctive Needles Headland.

Fig.4:1 Composite view,Scratchell's Bay,Isle of Wight with the Needles lighthouse on the left (north).

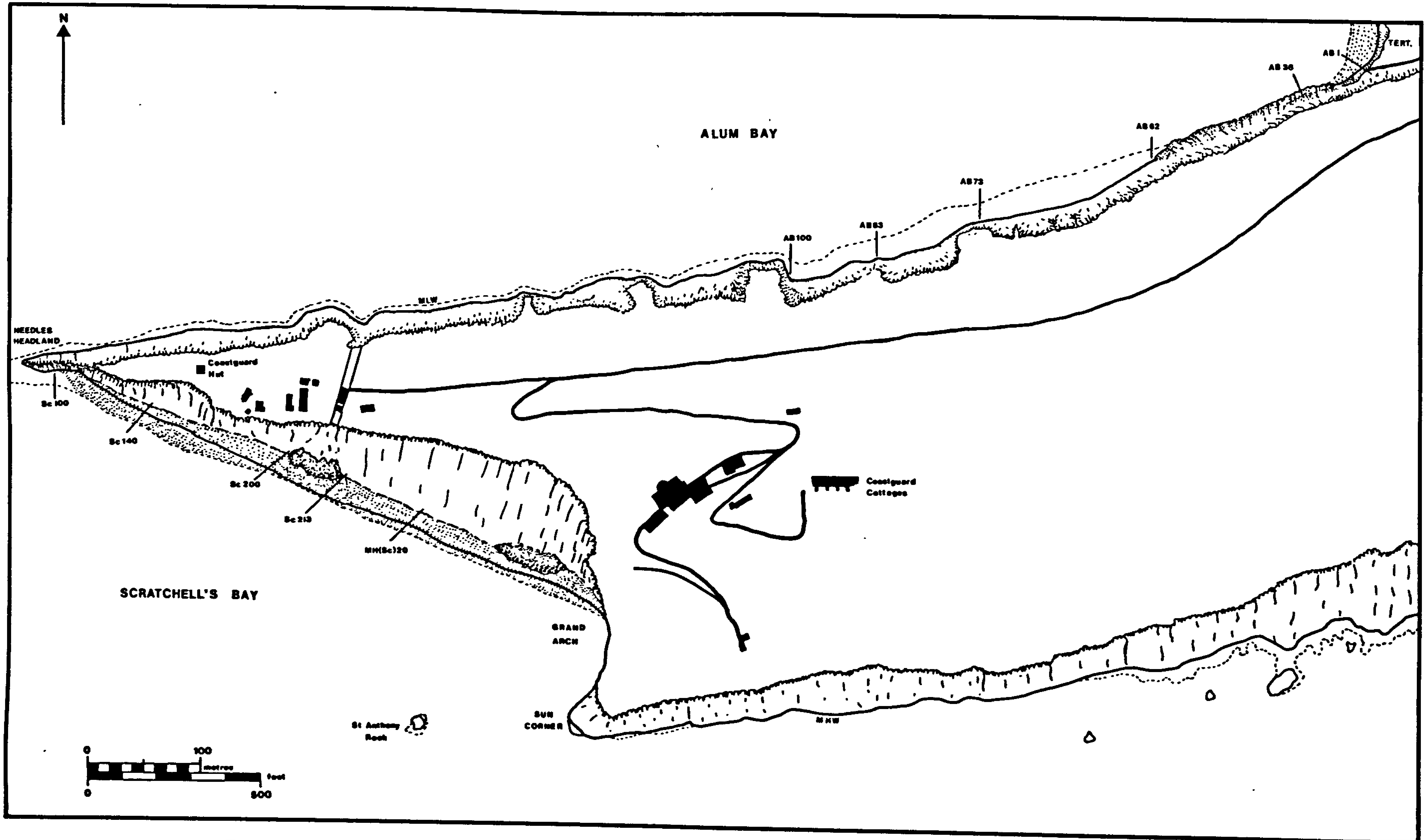


Fig.4:2 Plan view of the western end of the Isle of Wight showing key sample localities.

The lithostratigraphy and macrofauna have been described by Rowe (1908) and Brydone (1914). The base of the Campanian is here exposed towards the centre of the bay in a succession of chalk with numerous marl seams. The presence of the Upper Santonian guide fossil M. testudinarius, has been utilized to determine the top of the Santonian and a close correspondence was found to the lithostratigraphy detailed by Brydone (1914). Marl seams are common throughout the Lower and lowest Middle Campanian at this locality. Here the Lower Campanian macrofossil zone of Offaster pilula has been accurately delimited by use of Brydone's (1914) lithostratigraphic markers and measurements, together with supplementary collection of macrofauna made during the course of the present study and kindly identified by Mr. C. Wood (I.G.S). Here the zone of O. pilula is some 40m. thick. No equivalent features to the extensive hardgrounds developed at Culver Cliff at this stratigraphic level, have been found at Scratchell's Bay.

The uppermost part of the zone is partially covered by a major fall of chalk which appears to have resisted the effects of erosion at least since the turn of the century (Rowe 1908; Brydone 1914). The top of this zone is marked by a bed of chalk with abundant O. pilula enclosed within two well developed marl seams which may well correspond to the Planoconvexa bed (Kennedy & Garrison 1975).

The Lower Campanian is succeeded in Scratchell's Bay by approximately 60m. of Middle Campanian chalk belonging to the zone of Gonioteuthis quadrata. However, Mr. C.Wood has been unable to accurately determine the top of this zone on the basis of the macrofauna supplied and the figure is determined from Brydone's (1914) lithostratigraphic data, supported by the present microfaunal studies. Within the upper half of the Middle Campanian, marl seams become noticeably more rare, whilst flint bands increase in size. At this

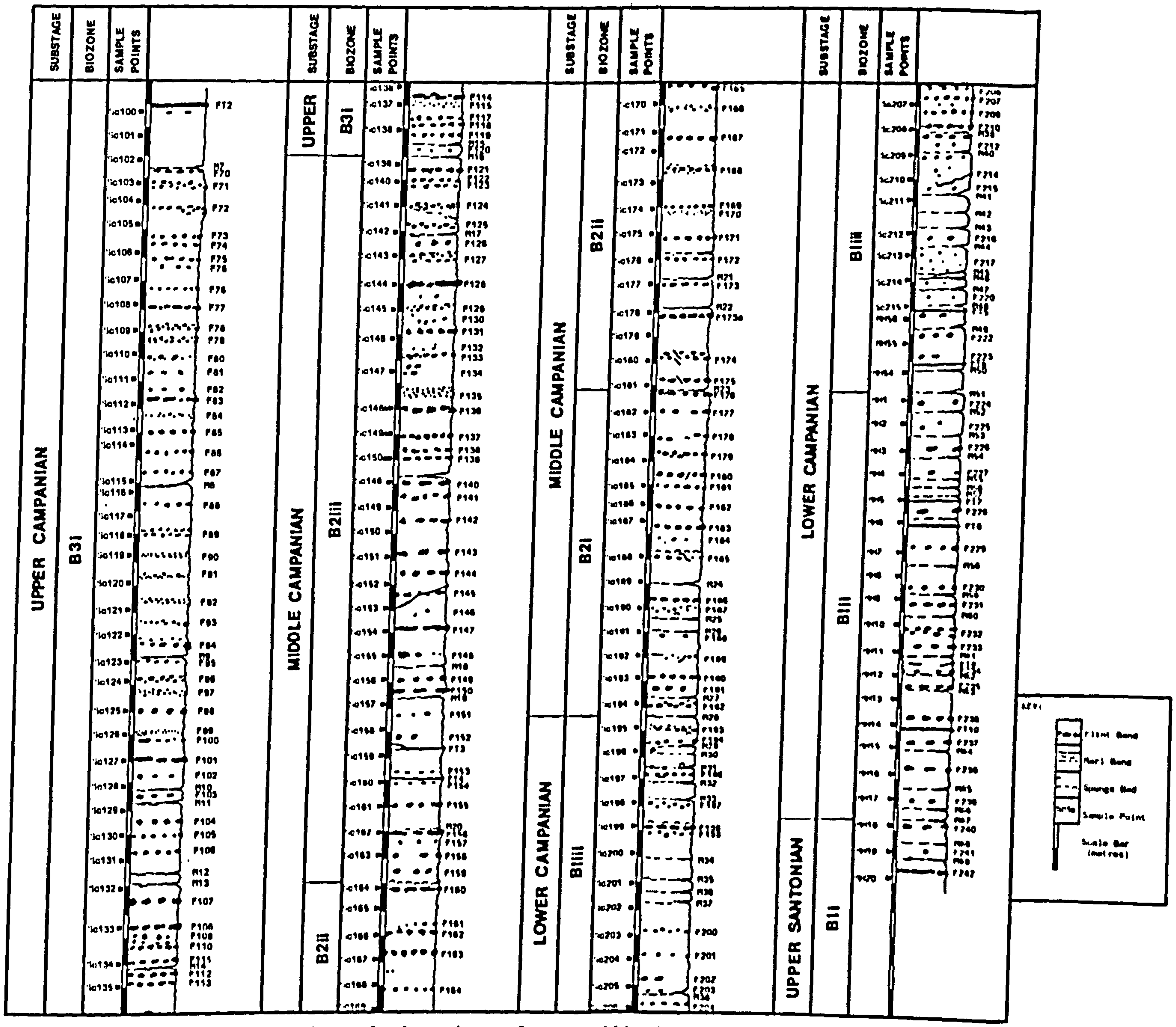


Fig.4:3 Lithostratigraphy and sample locations, Scratchell's Bay.

level also, two bands of yellow stained (phosphatized ?) chalk may be discerned high in the cliff. The junction between the Middle and Upper Campanian has been located at the base of a pair of prominent marl seams which are undoubtedly those recorded by Brydone (1914). However, the prominent fall of chalk mentioned both by Rowe (1908) and Brydone (1914) has been completely removed. At this point, the cliff is closely undercut with a much reduced storm beach and presumably increased current activity is responsible for the increased erosion in this area of the bay. Thus determined, the present author has recorded a combined thickness of 100m. (328 ft.) for the Lower and Middle Campanian which corresponds remarkably closely to the figure of 327 ft. given by Brydone (1914), and in sharp disagreement with the figure of 343 ft. of Rowe (1908). The Upper Campanian in Scratchell's Bay could only be logged up to the Needles Headland and the first prominent tubular flint on the headland has been taken as a useful lithological marker to mark the top of the section. Thus defined, some 39m. of Upper Campanian chalk have been recorded from Scratchell's Bay. This figure is markedly at variance with that given by Rowe (1908) of 196 ft. (=60m.). However as Rowe does not give lithological markers by which his placement of the zonal boundaries may be recognised, it is impossible to determine exactly what this measurement refers to . It should also be noted that Rowe's measurements are consistently higher than those obtained by Brydone (1914) and the present author. In addition, the considerable fall of chalk in this area may have led Rowe to overestimate the thickness of this unit. Such factors have led the present author to question the much quoted (Osborne White 1921) figure of the maximum thickness of the mucronata zone given by Rowe (1908). In the Upper Campanian of Scratchell's Bay marl seams again become moderately common. The most noticeable lithological feature however is the increasing induration of the chalk as one approaches the Needles. An estimate of 16m. (52.5 ft.) for the stratigraphic thickness of the Needles' Headland, determined from the 25" O.S. map of the area, compares closely with a measured thickness of 52 ft. by Rowe (1908). (Text figs 4:1 - 4:4)

2. Alum Bay, Isle of Wight. (SZ 300 850)

This extensive strike section is a stratigraphic continuation of the Scratchell's Bay section. It lies totally within the Upper Campanian, its upper surface representing an erosional contact with the overlying Reading Beds of Eocene age. The measured thickness of the accessible section was determined as 74m (243 ft.), which compares favourably with the 227 ft. (69m.) measured by Rowe (1908), particularly considering the presence of a major fall in the middle of the Bay. The chalk in Alum Bay becomes progressively less indurated towards the Tertiary contact. Marl seams become increasingly rare up the succession. Mid-way along Alum Bay a major fall has occurred. At this level, distinctive macrofaunal and microfaunal changes indicate the presence of the sub-biozone of Belemnitella mucronata minor, some 37.5m. of which are preserved in the Bay. From the measured sections detailed above, the total thickness for the mucronata chalk at the western end of the Isle of Wight has been determined as 129m.(=423 ft.), considerably less than the 475 ft. measured by Rowe (1908). The combined thicknesses for the whole of the Campanian are 229m. (= 751 ft.). (Text figs. 4:5, 4:6).

3. Studland Bay, Dorset. (SZ 045 824)

Only the topmost chalk from this extensive coastal section has been studied in any detail. The chalk at this level has been determined as Upper Campanian in age.

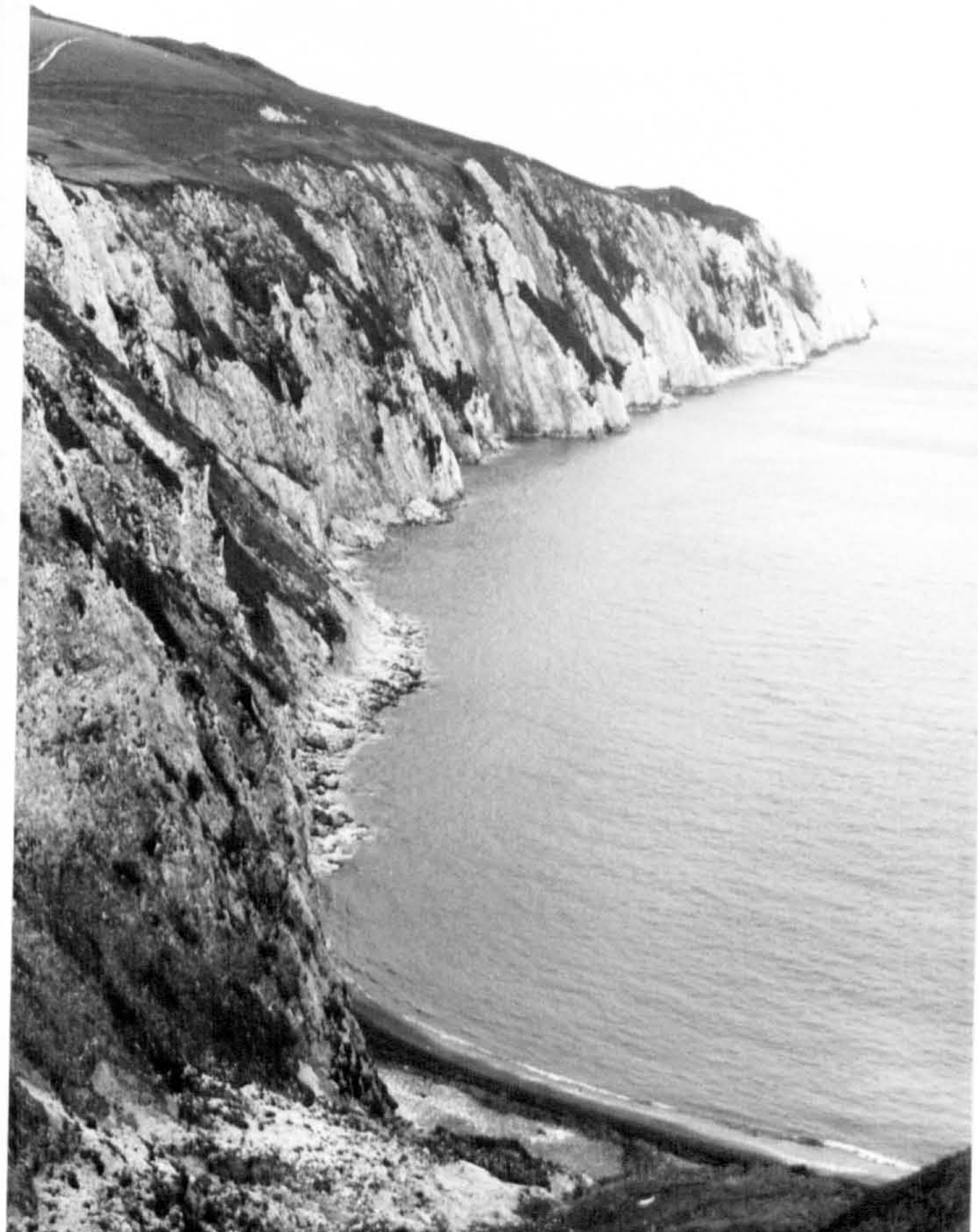


Fig. 4:4 Alum Bay, Isle of Wight.
This strike section is here viewed from the Cretaceous/Tertiary contact looking westwards to the Needles.

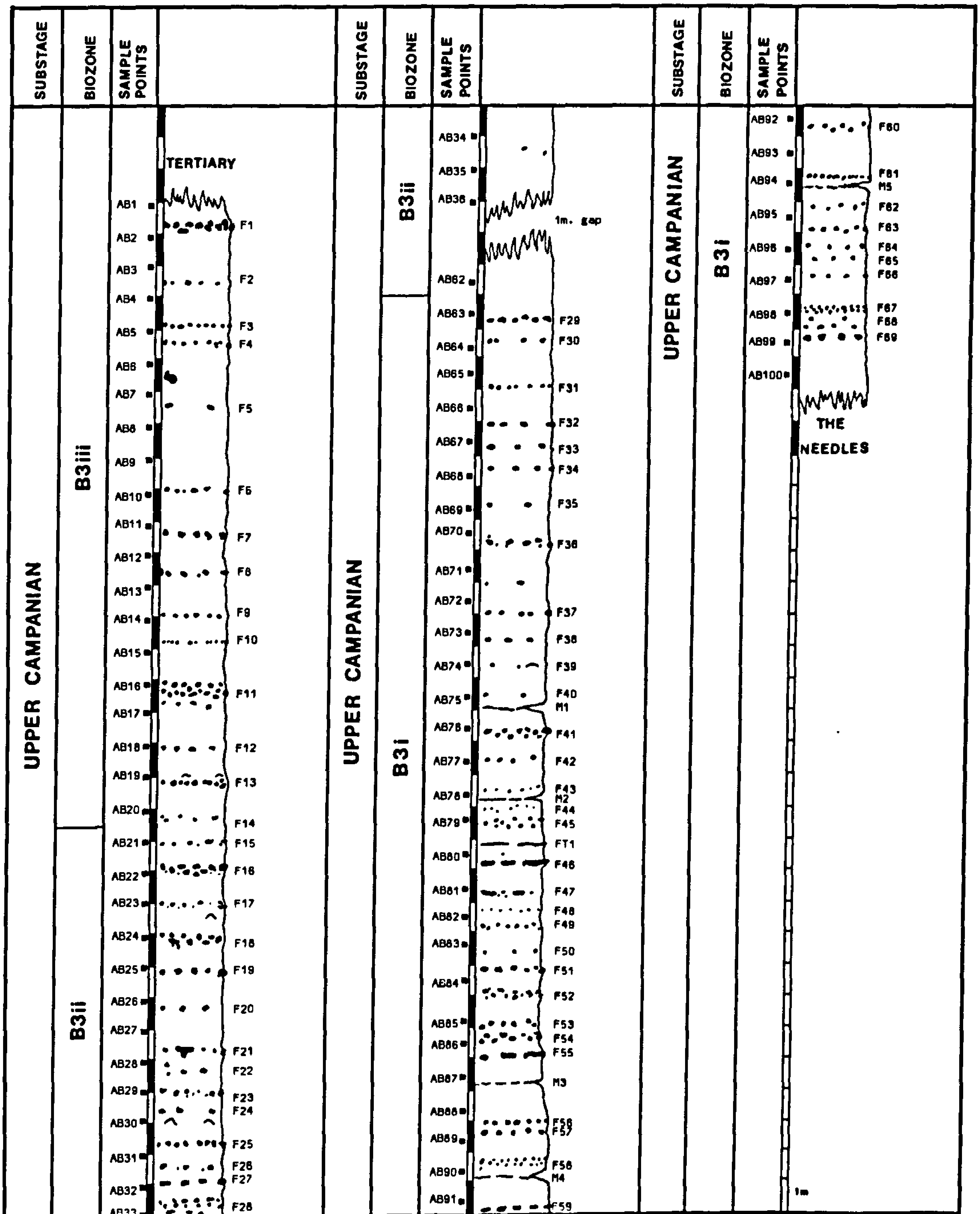


Fig.4:5 Lithostratigraphy and sample locations, Alum Bay.

Fig. 4:6 Cretaceous/Tertiary contact, Alum Bay, Isle of Wight.
The Upper Campanian chalk of biozone B3 iii is on the right (south) of the picture, here dipping northwards at approximately 75^{0} and being unconformably overlain by the Tertiary Reading Beds on the left.

4.3. Norfolk (Campanian localities)

The following localities have been listed in broadly stratigraphic order :-

1. Wells - next - the - Sea. (TF 928 429).

This is a working quarry situated on the south side of the A149 immediately east of the level crossing, south east of the village of Wells. This locality was mentioned by Peake and Hancock (1961, 1970), though no lithological section has ever been published. Peake and Hancock (1961) originally stated that the section exposed chalk of lower *quadrata* age and postulated a condensation or non-deposition of the *pilula* zone. They substantially revised this opinion in 1970, stating that the major part of the section exposes chalk of the *pilula* zone , whilst the lower *quadrata* zone is present towards the top of the section. They also noted the presence of a shallow monocline within the quarry and estimated that a total of 120 ft. (36m.) of chalk was present. In the present study, this structure was not found to be readily apparent and the maximum vertical section measuring 15m. was collected from the extreme eastern end of the quarry. Lithologically, the chalk from the lower levels was slightly grey and the chalk throughout was moderately hard. Large channels, some 20m. across, containing Pleistocene gravels can be seen at the very top of the quarry. (Text fig. 4:7).

2. Stiffkey Hall Farm (TF 975 428).

An abandoned quarry face in front of Hall Farm exposes some 11m. of relatively soft, buff chalk with bands of small, scattered flints common in the lower half of the section. No published section is available for this quarry, though Peake and Hancock (1961, 1970) have noted it, considering it to expose strata from " near the top of

Fig. 4:7 Chalk Quarry, Wells-next-the-Sea, Norfolk.
This working quarry exhibits large scale channels of Pleistocene gravel (Ai, Aii). The section studied was located at the rear of this quarry (B).

the *quadrata* zone." Mr. C. Wood (pers. comm.) has stated that he considers this section to be at a lower level than indicated by Peake and Hancock.

3. *Alderford Common* (TG 129 184).

Several small pits were recorded by Peake and Hancock (1961) on Alderford Common, 1 mile north of Attlebridge. One such section was found to expose some 4.6m. of soft white chalk with flint bands. The section is overlain by Pleistocene gravels and periglacial action appears to have affected the chalk as ice wedges are present, also many of the 'bedding' planes within the section are coated with a brown mud, presumably boulder clay. Peake and Hancock (1961, 1970) regarded this chalk as being of uppermost *quadrata* zone age.

4. *Bawburgh Pit* (TG 149 088).

This is an abandoned, degraded chalk pit, which is all but completely infilled. Almost 2m. of chalk was still observable (August 1975) with two flint bands. Mr. C. Wood (pers. comm.) considers the pit to expose chalk from near the top of the *quadrata* zone.

5. *Bowthorpe* (TG 176 092).

This degraded chalk pit was considered by Mr. C. Wood to possibly expose chalk from the basal *mucronata* zone. Studies of the section in August 1975 however, revealed the pit to be completely overgrown, and no chalk could be recovered.

6. *Cley* (TG 054 440).

Diligent searching within this completely infilled locality, situated on the A 149, revealed a single exposure of in situ chalk beneath the steps leading to the observation hut. Mr. C. Wood (pers. comm.)

considers this pit to be situated in basal mucronata chalk. Peake and Hancock (1961) considered that Cley perhaps formerly exposed chalk from their Eaton Chalk subdivision.

7. Drayton (TG 175 132).

This overgrown, but formerly extensive quarry is situated on the north side of Costessey Lane, half a mile south-west of the Red Lion public House. It was listed by Peake and Hancock (1970) as exposing chalk from the base of their Eaton Chalk member. Though the quarry still exposes a considerable thickness of chalk, access was refused by the present owners and enforced by a rather fierce dog ! The locality is included here, both as a note of its present condition and as a record of the hazards faced by geologists working in the remote corners of the globe.

8. Weybourne Hope to Old Hythe Gap (TG 110 438).

Discontinuous low chalk cliffs and foreshore exposures outcrop for 2 miles between Weybourne Hope and Old Hythe Gap, 1 mile west of Sheringham. These outcrops are the type locality of Peake and Hancock's Weybourne Chalk member. The amount of exposure is highly dependent on the state of the winds and tides. Peake and Hancock (1961) have published a synthetic succession of these coastal exposures which has been built up by long study of these outcrops, and which has proved invaluable in the field. Mr. C. Wood (pers. comm.) considers that the published section requires amendment between flint horizons O and P, where he has recorded approximately 5m. of chalk with additional flint courses. The present author's field investigations support this view and an amended synthetic section of this section is to be found in Chapter 7. Much of the chalk exposed here has suffered from periglacial action and is extensively brecciated, stained and split by ice wedges. The lowest flint horizon seen in the present study was Z, and this is coincident with a rust coloured sponge bed which Peake and Hancock consider to represent the junction between their Eaton and Weybourne Chalk members. Some 300m. west of Old Butts Gap, a course of spindly flints has been noted with associated occasional black manganese staining.

A total section of some 21.45m. of chalk has been recorded in the present study which compares favourably with the figure of 19.9m. (65 ft. 3in.) recorded by Peake and Hancock (1961), especially considering the nature of the exposures along this section. (Text fig. 4: 9).

9. <u>Keswick Quarry</u> (TG 212 048).

This working quarry exposes some 11m. of soft white chalk with flint bands. Some 3.5m. above the base of the section a band of black, manganese stained chalk with associated small scattered flints may be seen. Peake and Hancock (1961) considered this section to expose the upper part of their Eaton Chalk, and Mr. C. Wood (pers. comm.) is in agreement with this. Peake and Hancock (1970) substantially amended this view, largely on the basis of study of the echinoid fauna, they equated the Keswick section with the upper part of the Weybourne Hope exposures. Comparison of the two sections given in Chapter 7 reveals a close lithological correlation

10. <u>Eaton Golf Course</u> (TG 218 058).

Despite the locality name, this exposure does not come from the Eaton Chalk member of Peake and Hancock, but from stratigraphically higher levels. This section is located in a chalk pit on the edge of Eaton golf course and exposes some 4m. of soft white chalk with flint courses. The top of the section has been much affected by periglacial action.

11. Catton Grove (TG 229 109).

This classic locality, situated on the outskirts of Norwich, is rapidly becoming degraded and infilled with rubbish, and it proved impossible to collect from the lower levels. This section has been described in detail by Peake and Hancock (1961), who also gave a published section. The Catton Sponge Bed is located some 1.2m. below the top flint band. Peake and Hancock (1961) take this as the junction between the Weybourne Chalk and Beeston Chalk. Lithologically the chalk here is moderately soft, white with flint bands. Some 3m. below the Catton Sponge Bed, a flint horizon with black manganese stained chalk is present. The Catton Sponge Bed comprises a layer of some 30-50cm. thick, of indurated red stained chalk. Peake and Hancock (1970) have tentatively correlated this sponge bed with that occurring under the Lifeboat Station at Sheringham. Poor exposure in this area during the fieldwork season has not allowed the present author to test this hypothesis.

12. Sheringham to East Runton foreshore (TG 176 435).

There are discontinuous foreshore exposures from Sheringham to East Runton. However, during the field seasons available to the author, exposures were extremely poor and no synthetic section could be pieced together. C.Wood (pers. comm.) has noted that the succession is structurally complicated at the western end. The succession sampled includes sponge beds and hardgrounds and probably spans the upper Weybourne - lower Paramoudra Chalk interval (Peake & Hancock 1961, 1970; C.Wood pers. comm.). Sample localities are shown in Text fig. 4:8.

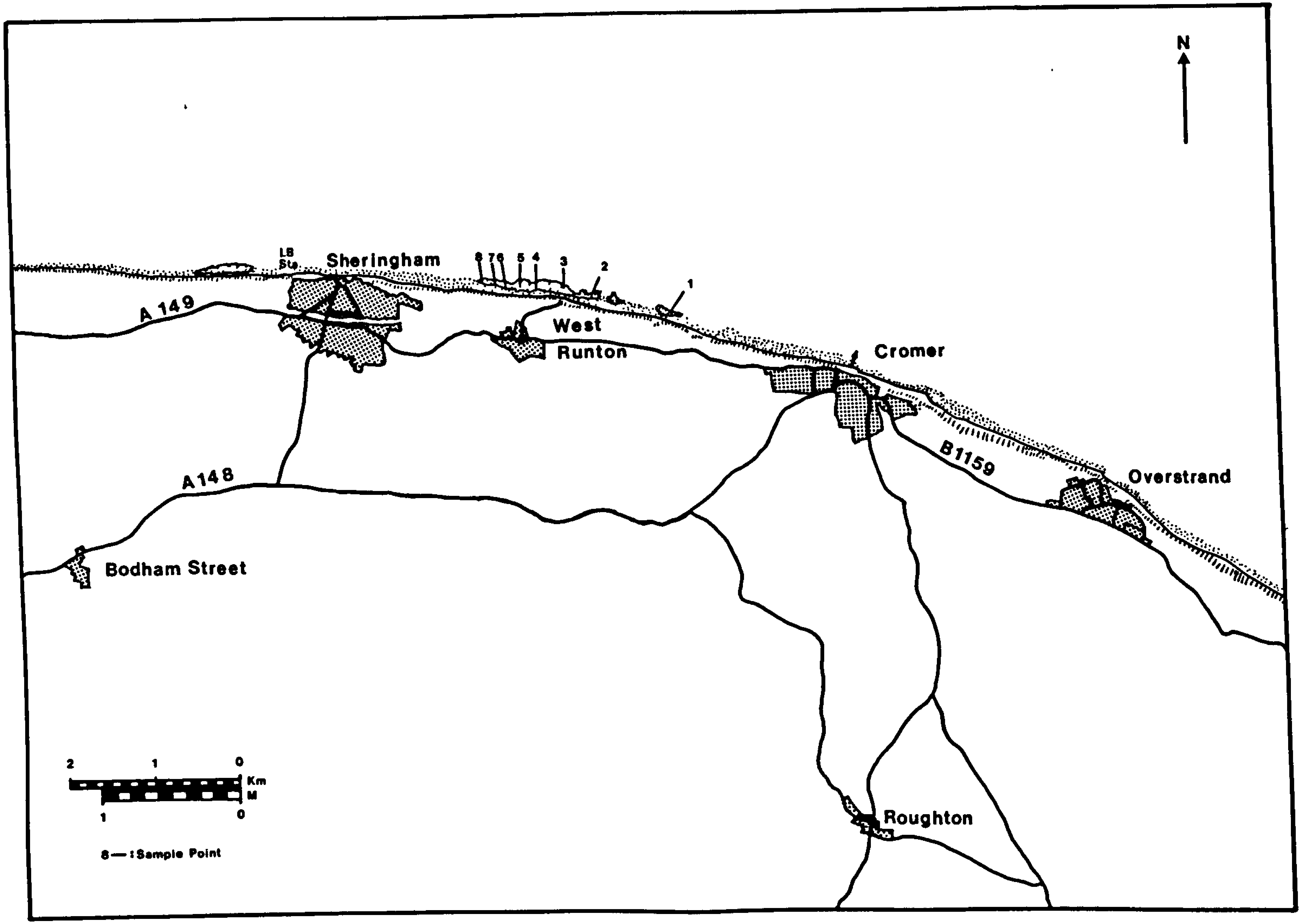


Fig.4:8 Sample locations, Sheringham, Norfolk.

13. Caistor St. Edmunds (Frettenham Lime Works Quarry)
(TG 239 047).

This working quarry exposes some 15.5m. of soft to extremely soft white chalk with numerous flint courses. In the middle of the section a major band of large flints with associated manganese staining is to be found, whilst at the top of this section, giant 'paramoudra' flints occur. The chalk succession is overlain by Pleistocene gravels, and several massive ice wedges are to be seen. This section exposes strata of Beeston Chalk age (Peake & Hancock 1961). The lowest levels sampled may lie only some 2-3 ft. above the Catton Sponge Bed horizon (Peake & Hancock 1970).

14. Arminghall Pit (TG 244 057).

This is an abandoned chalk pit close to the much larger Caistor St. Edmunds quarry. It exposes some 5m. of soft white chalk with horizons of small flints. The uppermost flint course contains occasional paramoudras. This quarry has not been recorded by Peake and Hancock, however, it is closely comparable to the upper levels of the Caistor quarry, both lithologically and faunally.

15. Frettenham Quarry (TG 245 171).

This formerly extensive quarry, situated some 200m. S.W. of the church, is now disused and largely overgrown. The best exposures occur in the deep water filled pits, though access is difficult. Approximately 5m. of soft grey/white chalk have been logged in the present study. There is some debate as to the exact stratigraphic position of this section amongst macrofossil workers. Peake and Hancock (1961) considered this quarry to expose strata of the Beeston Chalk member, but in 1970 regarded it as correlatable with the basal Paramoudra Chalk. Mr. C. Wood (pers. comm.) has stated that while the exact position is in doubt, it is definitely younger than the Caistor Quarry.

16. Whitlingham Pit (TG 268 078).

This section is on private land and somewhat difficult to locate. It is situated due south of Thorpe St. Andrew on the south side of the river. Permission to visit the site is obtainable from The Hall, Trowse Newton, and access is at a point just past the house where the river approaches the road. The pit is rapidly degrading and only some 4.2m. of chalk is visible. The chalk has been affected by periglacial action and is somewhat harder than is usual at these stratigraphic levels. Peake and Hancock (1970) regard this chalk as belonging to their Paramoudra Chalk member.

17. Postwick Riverbank (TG 2866 0800).

The classic chalk pit at Postwick Grove is now completely degraded and filled with rubbish, and no chalk was obtainable. However, samples of in situ chalk were recovered from the river bank directly opposite the pit and a further 200m. downstream. Mr. C. Wood (pers. comm.) considers that the chalk formerly exposed at Postwick Grove possibly exposed the Campanian/Maastrichtian boundary.

18. Pyramidata Reef, Overstrand (TG 25 40).

Located some 140m. west of the promenade at Overstrand is a mass of flints and extremely hard chalk containing abundant specimens of the distinctive *Echinocorys pyramidata*. Peake and Hancock (1970) believe these to be directly derived from a submerged outcrop directly beneath. They consider that the mass may represent a hardground developed at the level of the Campanian/Maastrichtian boundary. Chalk samples obtained as matrix infill from echinoid tests were processed, but proved to be too indurated to yield any identifiable microfauna which might have shed light on the recognition of the boundary.

4.4. Chalk Outcrops and Glacial Tectonics on the Norfolk Coast.

Before detailing sections of Maastrichtian age studied from Norfolk, an outline of Pleistocene ice movements in the region is included as these have profoundly influenced present day outcrop patterns. Between Sheringham and Mundsley on the North Norfolk coast many isolated masses of chalk may be seen, some of which reach a considerable size. Many of these masses may be seen to be completely enclosed within the till, whilst others are exposed only on the foreshore, and their relationship to the Pleistocene deposits is not readily discernible. In many cases the structure and internal stratigraphy of these masses are complex and difficult to determine, given the vagaries of exposure at any one time. However, over a hundred years of careful observation of the constantly changing patterns of exposure (Lyell 1840; Trimmer 1847; Reid 1882; Bonney & Hill 1905; Brydone 1906, 1908, 1909, 1937; Peake & Hancock 1961, 1970; Wood 1967) have produced a relatively clear understanding of the overall geometry and structure of most of the masses.

Many of these masses are completely enclosed within the till (Text fig. 4:10). There is also a complete gradation in scale from blocks little more than 1m. in height, showing clear evidence of having been transported within the till (Text fig. 4:11), to those over 300m. in length. These features, readily discernible in the field, provide overwhelming support for an origin as glacial erratics for all these diverse masses (Peake & Hancock 1961, 1970). Many of the larger masses, ie. Sidestrand, show a complex overfolding with shallow dipping northern limbs and vertical to overturned southern limbs (Text fig. 4:12), whilst others show one erratic piled on top of others. The latter mode is clearly illustrated by the Runton mass,

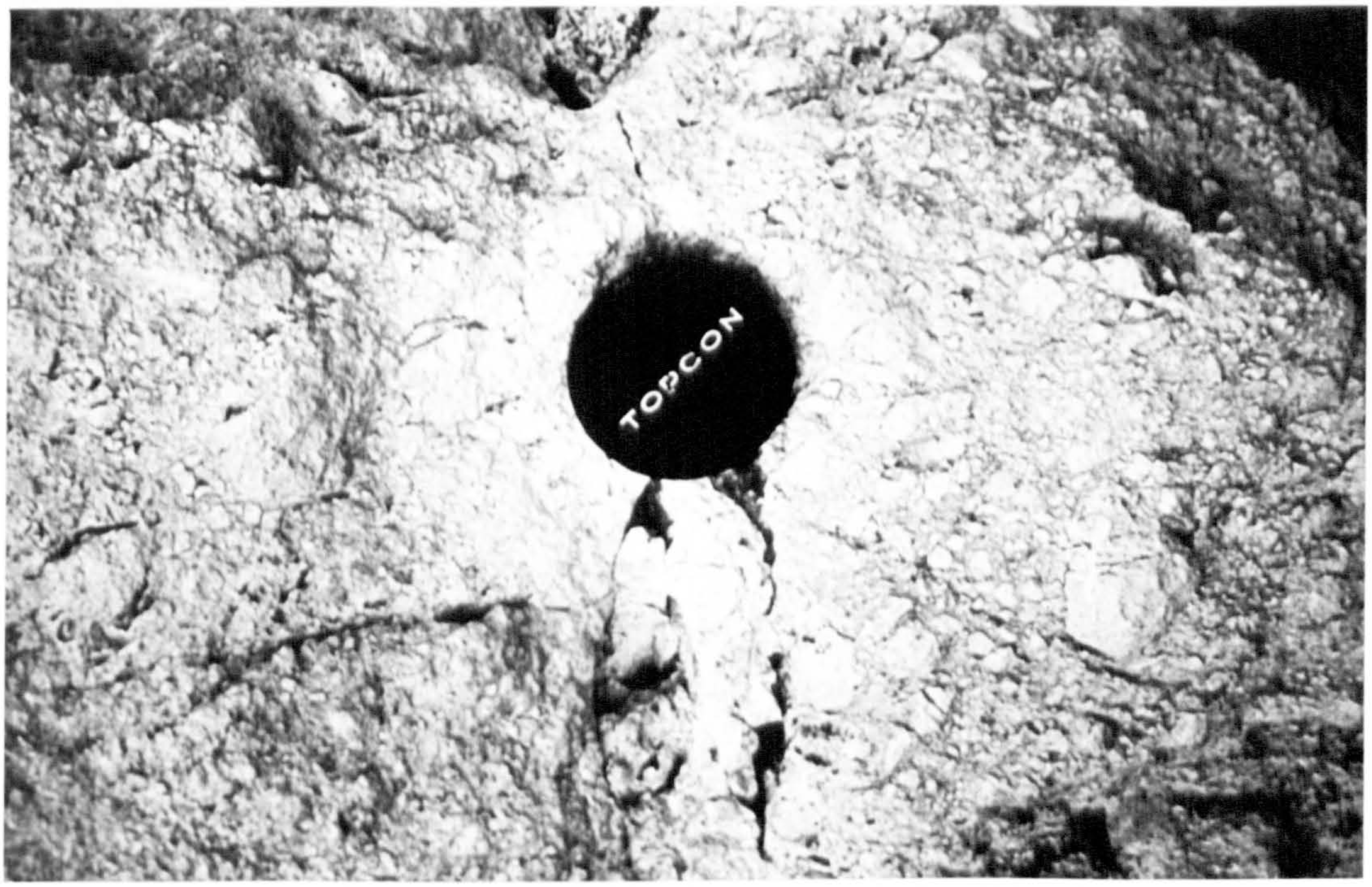


Fig. 4:9 Weybourne Hope, Norfolk. Chalk surface extensively shattered by the effects of periglacial action.

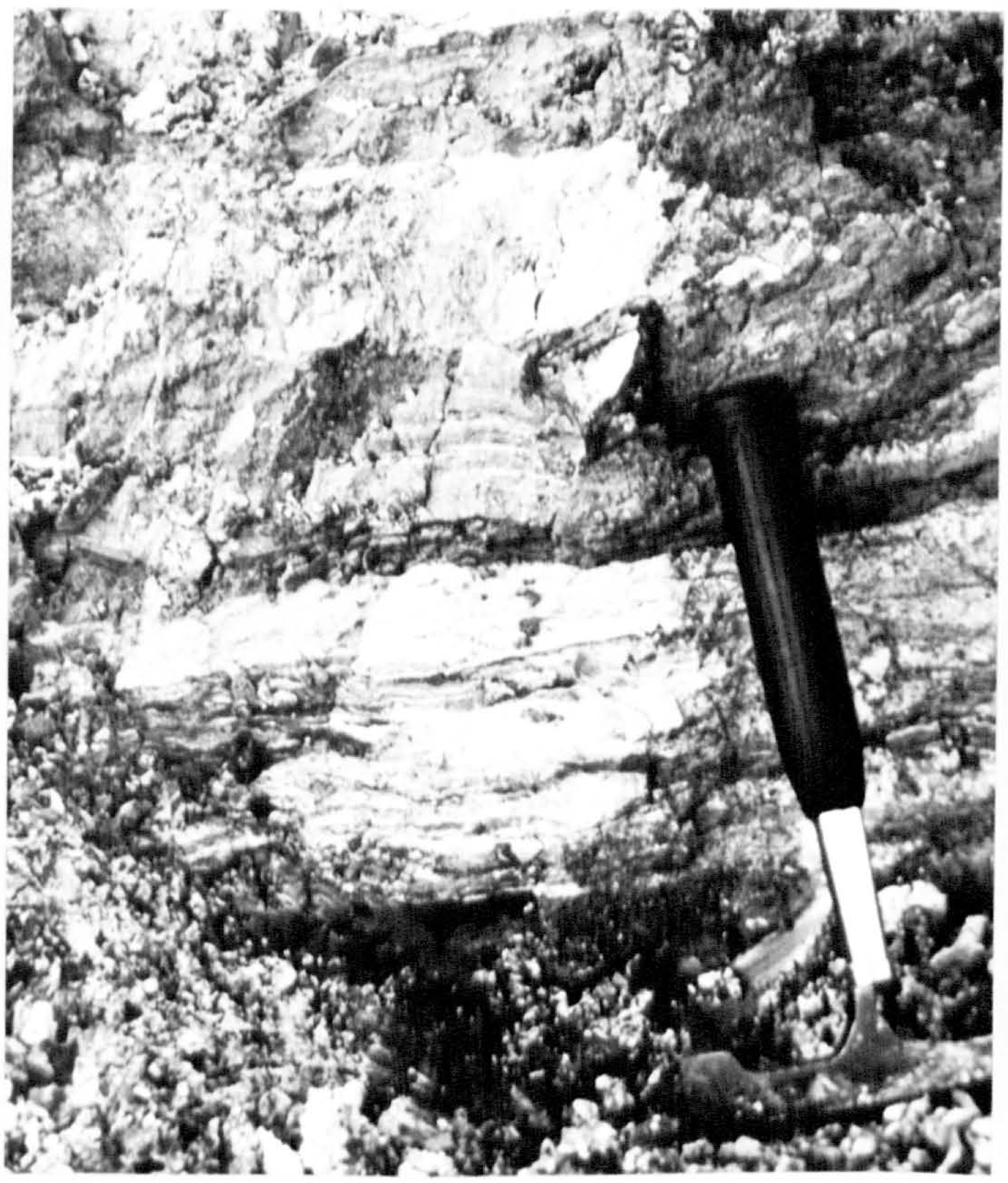


Fig. 4:10 Chalk/Till contact at the base of the Overstrand Lower Mass, showing extensive intermixing.

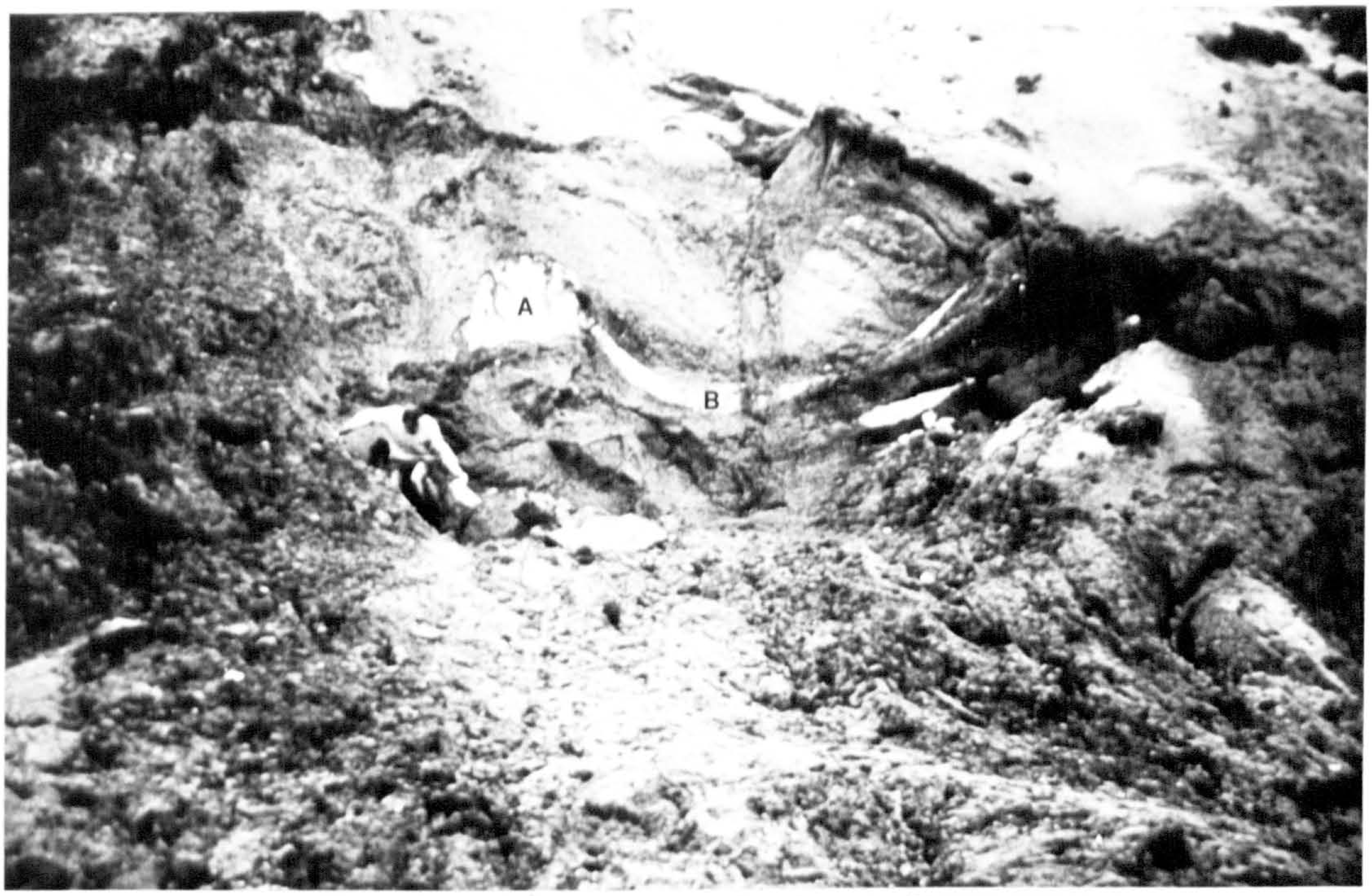


Fig 4:11 Overstrand Minor Mass. Small chalk mass may be seen to left of centre (A) completely surrounded by till. A drawn-out 'tail' of chalk may be seen (B).

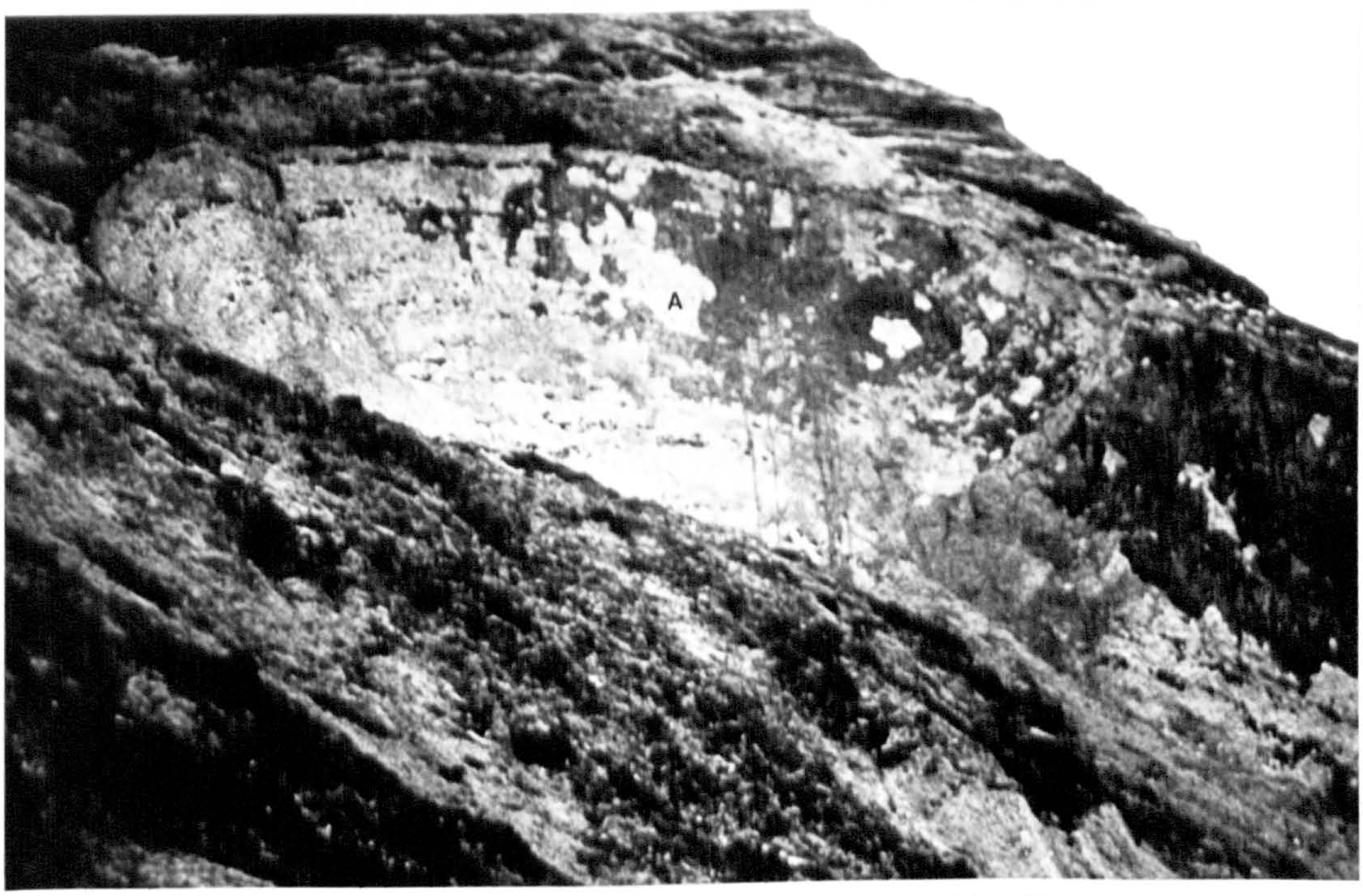


Fig. 4:12 Sidestrand erratic enclosed by till. The top of the chalk mass (A) and uppermost flint bands pick out overfolding on the extreme left.

Fig. 4:13 East Runton chalk erratics. A vertical series of overthrust chalk masses are exposed in the cliff. The lowest mass is clearly to be seen lying directly on glacial till.

where most of the successive erratic 'slices' are capped by Crag and are clearly delineated from one another (Text fig. 4:13). The Overstrand Lower Mass also shows frequent overthrusting (Text fig. 4:14), though this is not as readily discernible as that of the Runton erratics, being marked by a series of relatively thin marl bands containing Pleistocene gravel. The method of erosion of the chalk, and subsequent incorporation within the till, has been a subject of considerable debate (Reid 1882; Peake & Hancock 1961, 1970). It is now thought (N. Peake pers. comm.) that salt doming, possibly initiated as a result of increased loading due to the development of extensive Pleistocene ice sheets, raised the surface of the chalk in a number of places to a level where they could be eroded by surges within the ice sheet. Transport and deformation of the soft chalk as part of the bed load of a southerly moving ice sheet, and eventual deposition on the flanks of the positive Cromer Ridge, produced the outcrop pattern which we see today. Similar features have now been recognised over a wide area of N.W. Europe, including N.W. Germany and Scandinavia, notably at Møns Klint (Hakensson 1968). The fact that all the Norfolk chalk erratics investigated lie almost directly above in-situ chalk of a comparable stratigraphic horizon, strongly indicates that glacial transportation took place almost exactly along the line of strike of the chalk, thus indicating a possible source area in the direction of the Leman Bank area, where diapiric structures have indeed been recorded (Peake and Hancock pers. comm.).

The present author cannot overemphasise the need for a thorough understanding of the lithological and structural complexities of these chalk erratics, before any attempt is made at biostratigraphic analysis.

4.5. Norfolk (Maastrichtian localities)

1. Overstrand Hotel Lower Mass (TG 255 406).

This is by far the largest chalk mass to outcrop in the Overstrand area. In form, it is a roughly tabular body, some 100m. in length and 13m. high, occupying the cliff beneath the site of the former Overstrand Hotel. The centre of the mass is essentially horizontal, whilst at either end it is slightly uptilted giving it an overall concave aspect. The extreme western end of the mass exhibits a relatively accessible section of chalk some 13m. in height and with an apparent dip of 16.5^0 to the south. Close examination of this face reveals the presence of at least three marly layers containing quartz pebbles derived from the till. These have been interpreted as thrust planes. The maximum recorded thickness of any one thrust slice is 5.2m. The base of the mass was excavated and found to clearly rest on glacial clay. Flint bands are developed throughout the section. The uppermost thrust slice contains occasional paramoudra flints. Samples were collected at regular intervals throughout the section, in order to determine whether the sequence rperesented a repetition of a single horizon or an accumulation of stratigraphically distinct levels.

The stratigraphic position of the mass has been a matter of some considerable debate, which has not been aided by the general scarcity of macrofauna within the mass. Peake and Hancock (1961) considered the mass to be of uppermost Campanian age, whilst Wood (1967) stated that the mass possibly contained layers of both uppermost Campanian and Lower Maastrichtian chalk. Peake and Hancock (1970) later speculated that the entire mass might be of Lower Maastrichtian age, with the Campanian/Maastrichtian boundary being placed at the level of the underlying indurated Pyramidata reef. However, it must be noted that no examples of the characteristic Lower Maastrichtian belemnite, Belemnella lanceolata, have ever been recorded from this section.

Fig. 4:14 Overstrand Lower Mass, Norfolk.
This composite chalk erratic represents a repeatedly overthrust chalk succession. Major 'marly' horizons (A) represent the thrust planes. The Overstrand Upper Mass may be seen on the upper right (B).

Many of these features are illustrated in text figs. 4:10, 4:14.

2. Overstrand Minor Mass

This small erratic was observed by the present author within the till west of the preceeding localities. It consisted of a mass of white, soft chalk, approximately 1m. across, with an extensive drawn out 'tail'. No macrofauna was found at this locality (Text fig. 4:11).

3. Overstrand Hotel Upper Mass (TG 255 406).

This mass was originally described by Wood (1967). It outcrops within the till almost directly above the Overstrand Lower Mass. This section exposes some 3.3m. of yellow stained chalk, which appears to have been shattered by periglacial action. Three flint bands have been found within the mass. Wood (1967) has recorded the presence of Belemnella lanceolata from the mass, thus definitely assigning it to the Lower Maastrichtian. (Text fig. 4:14).

4. Sidestrand Western Mass (TG 255 404).

This complex series of folded and overthrust erratic blocks have been described and figured by Peake and Hancock (1961). Collection of this locality has been made with reference to the flint bands recorded by Peake and Hancock (1961, 1970). The chalk exposed is white and moderately soft, with occasional levels showing a grey mottled appearance. Peake and Hancock (1961) have divided the chalk succession exposed here into the Porosphaera Beds and the underlying Pre-Porosphaera Beds, and they have taken the highly distinctive flint horizon S to mark the boundary between the two. A thickness of some 4m . was measured for the Pre-Porosphaera Beds and approximately the same for the Porosphaera Beds. (Text fig. 4:12.).

5. Sidestrand Sponge Bed Platform (TG 255 404).

The sponge beds are now exposed on the foreshore only as a result of fortuitous combinations of tides and winds. The succession has been described in detail by Peake and Hancock (1961), and sample collection has been made with respect to their recorded sequence of beds. A total thickness of 2.8m. was measured extending from flint bands P to K. Lithologically the sponge beds represent a complex of erosion surfaces with marl bands and glauconite coated chalk nodules; a typical hardground complex (Kennedy & Garrison 1975). The chalk here is grey, with levels relatively rich in glauconite and pyrite and is indurated. Wood (1967) has recorded the first appearance of Belemnella occidentalis within the sponge beds and has tentatively placed the base of the eponymous zone at this level. (see discussion Chapter 7). Sponges, belemnites and echinoids are abundant at this level. (Text figs. 4:15, 4:16).

6. Trimingham (Little Marl Point) (TG 298 380).

Though Brydone recorded a large number of chalk masses from this area, this is the only one which has resisted the ravages of erosion to the present day. Peake and Hancock (1961), on the basis of many years study of these changeable exposures, have been able to correlate the Sidestrand Sponge Beds with the lowest levels at Trimingham; however, the present author has been unable to substantiate their conclusions on the basis of the current state of exposures. Peake and Hancock (1961) have also given a useful section of the Trimingham outcrop to which reference has been made in collection of samples. However, the present author has found discrepancies between this published section and the Little Marl Point outcrop, particularly with regard to the rapid thickening and thinning of some beds within the succession (Chapter 7). The lower levels of the outcrop are now (Peake and Hancock 1970)

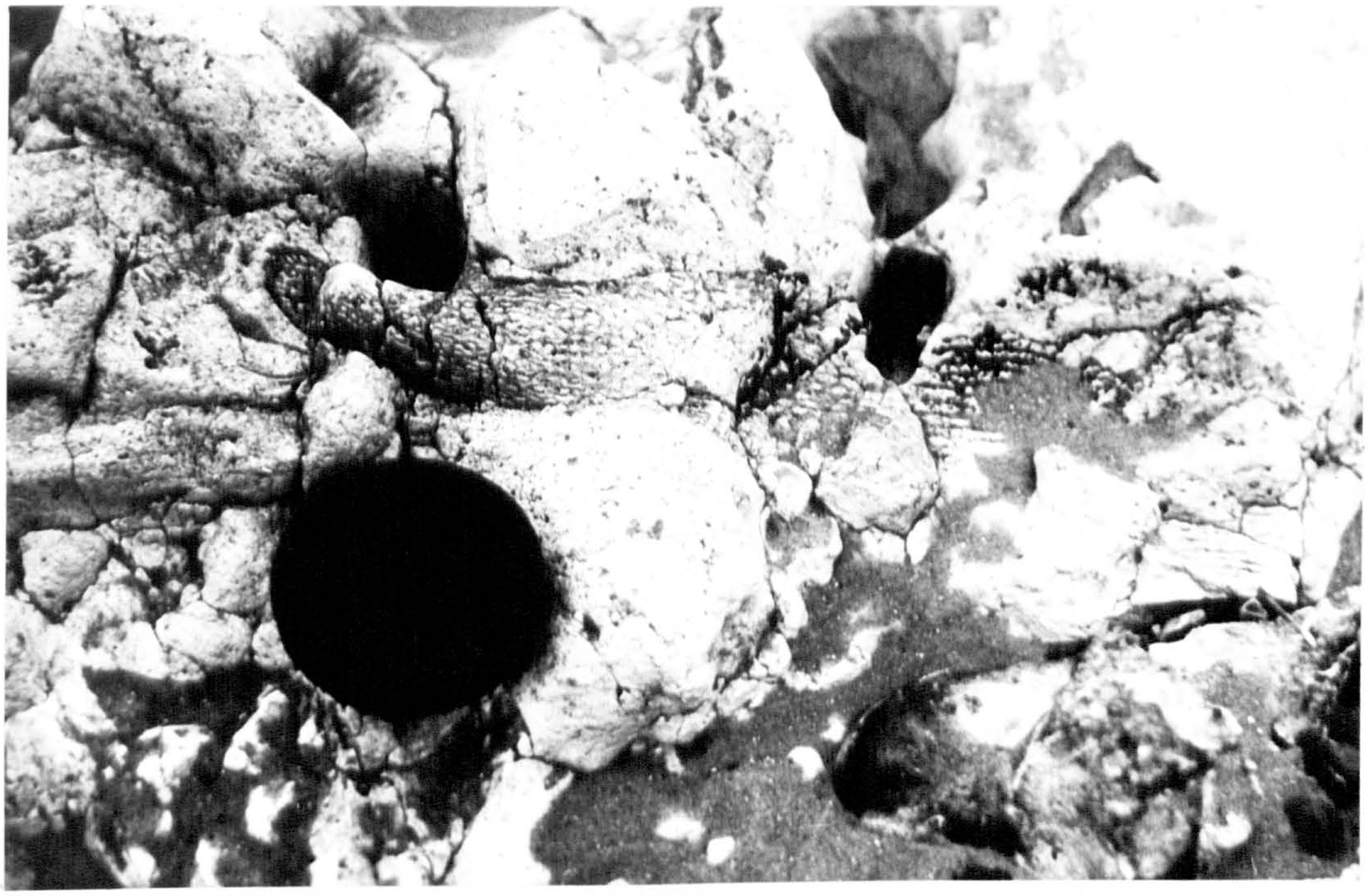


Fig. 4:15 'Ventriculitid' sponge, Sidestrand sponge Beds, Norfolk.

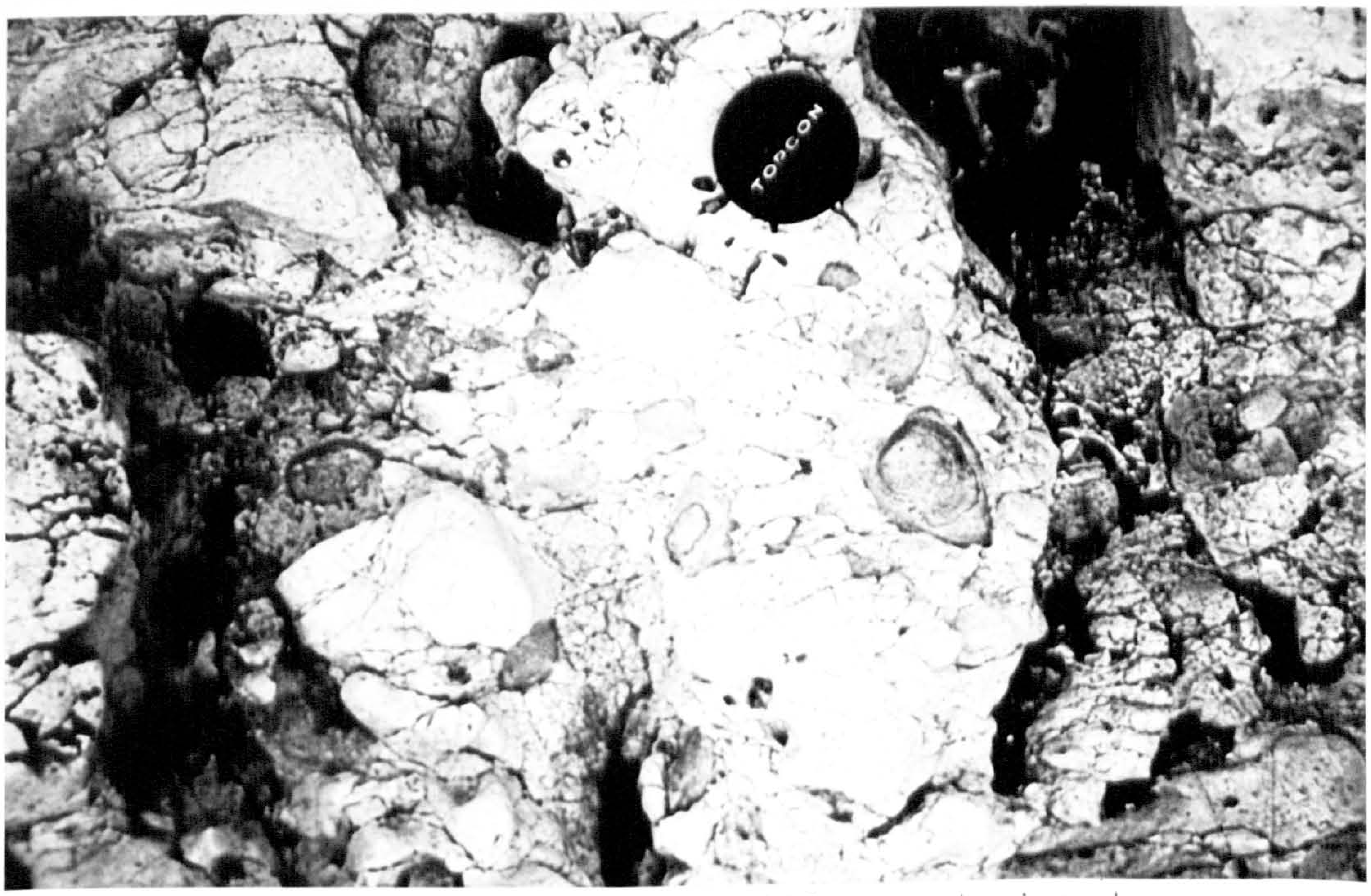


Fig. 4:16 Glauconitized chalk pebbles — horizon L (Peake & Hancock 1961).

Fig. 4:17 Trimingham erratic (Little Marl Point), Norfolk.

considered to belong to the upper levels of the Sponge Beds, with the prominent marl G marking their boundary with the overlying white chalk. Some 2.5m of Sponge Beds have been measured at Trimingham, with 1.5m of White Chalk overlain by 2.5m of White Chalk with abundant Ostrea lunata (Text fig. 4:17).

7. Marl Point Platform (Trimingham) (TG 294 384).
This chalk platform may still be exposed at certain times of the year. The chalk seen on the platform was grey but also contained O.lunata and thus could not be assigned to the Grey Beds s.s. (Peake & Hancock 1970).

4.6. North Sea Basin.

1. Well 44/2-1 (lat. 54° 55'N long. 2° 15'E).
This well is situated on the extreme southern flank of the Mid-North Sea High. It penetrated some 330 ft. (100m.) of Maastrichtian, and 1080 ft. (329m.) of Campanian chalks belonging respectively to the Tor and Hod Formations. Cutting samples have been provided from this well at 10 ft. (3m.) intervals.

2. Well 29/25-1 (lat. 56° 18'N long. 01° 51'E).
This well is situated on the flank of the Central Graben. It has been described by Rhys (1974) and Rawson et al (1978). It penetrated some 168m of Maastrichtian chalk and 92.5m of Campanian chalk assignable lithologically to the Tor and Hod Formations respectively, of the Chalk Group (Rhys 1974). The Hod Formation comprises "a thick sequence of white to light grey cryptocrystalline to microcrystalline hard limestones, which may become argillaceous or chalky in places" (Rhys 1974). Occasional pink horizons may be present. The Tor Formation comprises a series of white to light grey hard chalky limestones which may be more friable in places. Styolites may be developed at certain levels.

The boundary between the two formations may be difficult to place, though in general, the Hod Formation is a less pure carbonate and tends to have a slightly higher gamma ray response and lower velocity (Rhys 1974). The boundary between the two is gradational. In the material to hand from this well, the base of the Campanian was not recorded. Cutting samples have been provided from this well at 30 ft. (9.1m.) intervals.

CHAPTER 5

SYSTEMATIC DESCRIPTIONS

The classification used in this study follows that of Loeblich and Tappan (1964) in the Treatise of Invertebrate Palaeontology, Part C Protista and subsequently amended by the same authors (Loeblich and Tappan, 1974). Other taxonomic revisions considered necessary by the present author are discussed in the text.

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARINA Delage and Hérouard, 1896

Superfamily AMMODISCACEA Reuss, 1862

Family AMMODISCIDAE Reuss, 1862

Subfamily AMMODISCINAE Reuss,1862

Genus AMMODISCUS Reuss, 1862

Genotype Ammodiscus infimus Bornemann, 1874

Ammodiscus cretaceus (Reuss, 1845)

(Plate 1, fig. 1)

1845 Operculina cretacea Reuss, p.35, pl.13, figs. 64, 65.

1860 Cornuspira " (Reuss); Reuss, p.177, pl. 1, fig. 1.

1899 " " (Reuss); Egger, p. 18, pl.22, figs.1,2.

1925 " " (Reuss); Franke, p.7, pl.1, fig.5.

1928 " " (Reuss); Franke, p.16, pl.1, fig.22.

1929 " involvens (Reuss); Berry & Kelley, p.15, pl.1, fig. 15.

1932 " cretacea (Reuss); Sandige, p.271, pl.41, fig.22.

1934b Ammodiscus " (Reuss); Cushman, p.45.

1937 " " (Reuss); Loetterle, p.56, pl.10, fig.1.

1941 Ammodiscus cretacea (Reuss); Marie, p.18, pl.1, figs.5, 6.

1946 " cretaceus (Reuss); Schijfsma, pp. 26-28, pl.6, fig.1.

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

1946 " " (Reuss) var. rugosa Schijfsma, p.28, pl.6,fig.2

1953 " " (Reuss); Hagn, p.4, pl.1, fig.3.

1954 " " (Reuss); Frizzell, p.58, pl.1, fig.15.

1956 Involutina cretacea (Reuss); Said & Kenawy , p.120, pl.1, fig.4.

1957 Ammodiscus cretaceous (Reuss); McGugan,p.336, pl.34, fig.9.

1960 Involutina cretacea (Reuss); Takayanagi, p.67, pl.1, figs.10-12.

1960 " " (Reuss); Belford, p.22, pl.6, fig.1.

1962 Ammodiscus cretaceus (Reuss); Tappan, p.130,pl.30, figs.1, 2.

1963 " " (Reuss); Graham & Church, p.12, pl.1, fig.17.

1964 " " (Reuss); Olsson, p.1, pl.1, fig.1.

1966b " " (Reuss); Barr, p.495, pl.77, fig.2.

1966 " " (Reuss); Macfadyen, p.79, fig.2a.

1968 " " (Reuss); Sliter, p.42, pl.1, fig.8.

1969 " " (Reuss); Hanzlikova, p.19, pl.1, fig.5.

1969 " " (Reuss); Mello,p.41, pl.4, fig.3.

1972 " " (Reuss); Hanzlikova, p.34, pl.3, figs.1,9.

Description:Test free; discoidal, proloculus followed by an undivided, planispiral, tubular chamber, very slightly involute ; chamber increasing uniformly in size, with subcircular cross section in undistorted specimens; maximum number of whorls nine, commonly less; suture distinct, depressed; aperture simple opening at end of single chamber; wall finely agglutinated, calcareous particles with much calcareous cement; surface finely roughened.

Average diameter: 0.65mm. Average width: 0.08mm.

Remarks: Specimens encountered are distinguished by their relatively wide chamber, few whorls and large size. Some specimens show slight growth constrictions transversely, though rarely as well developed as those figured by Reuss (1860) on the holotype.

Occurrence: An almost cosmopolitan distribution has been recorded for this species, from strata of Albian to Maastrichtian age. In the present study recorded rarely throughout the Campanian and Lower Maastrichtian from onshore sections, much more common in borehole material from the North Sea ranging in addition throughout the Upper Maastrichtian.

Zonal range: B1ii - B7i

Ammodiscus parianus Hedberg, 1937

(Plate 1, fig.2.)

1937 *Ammodiscus parianus* Hedberg, p.666, pl.90, fig.3.

Description: Test free; planispiral extremely compressed, proloculus followed by undivided tubular chamber,coiling evolute; chamber increasing very gradually and uniformly, six to seven whorls; spiral suture distinct, only weakly depressed; aperture a simple opening at end of chamber, subcircular to subrectangular in outline; wall very finely agglutinated, having distinctive glassy appearance, composed predominantly of calcite cement; surface smooth.

Average diameter: 0.24mm. Average thickness: 0.04mm.

Remarks: The small size, compressed test and glassy appearance, all serve to distinguish this species. The proloculus is often broken, leaving a central hole in the test.

Occurrence:Originally described from the Middle Tertiary, Carapita Formation, of Venezuela, this species is encountered rarely in the Campanian and Maastrichtian of the North Sea, though whether as a downhole contaminant, or an indigenous species, or both, could not be conclusively determined. Elsewhere the species has been found rarely in the Middle and Upper Campanian on the Isle of Wight, but has not been found in Norfolk.

Zonal range: B2i - B3i, B7i

Genus ARENOTURRISPIRILLINA Tairov, 1956.

Genotype Arenoturrispirillina aptica Tairov & Kuznetsova, 1956

Arenoturrispirillina sp. A.

(Plate 1,figs.3, 4.)

1910 Spirillina limbata Brady; Heron - Allen & Earland, p.425, pl.9, figs.4, 5.

Description: Test free; low conical spire, proloculus followed by single tubular chamber coiling in a regular trochospire outline circular; chamber size increasing gradually and uniformly, forming 5 to 6 whorls; cross section subrectangular to rectangular, occasionally developing angular keels; spiral suture distinct, depressed; aperture simple opening at end of chamber; wall finely agglutinated, calcareous; surface finely roughened.

Average diameter: 0.66mm. Average thickness: 0.2mm.

Remarks:This species was referred to Spirillina limbata Brady by Heron - Allen and Earland (1910). Examination of their hypotypes by Barr (1962 MS) showed the present species to be distinct, bearing only a superficial resemblance to the Recent S.limbata. Barr (1962 MS) described this form as Ammodiscoides heronalleni sp. nov., but, this name has never been published. To avoid further proliferation of specific names for this form in manuscript it is herein left in open nomenclature. It is removed herein from the genus Ammodiscoides Cushman, 1901 as it does not show the change from trochospiral to planispiral growth, characteristic of this genus. It is placed in Arenoturrispirillina Tairov, 1956 on the basis of its low, regular trochospiral coil. There have been several references (e.g. Cushman, 1946; Hofker, 1959) to Cretaceous occurrences of Ammodiscoides turbinatus Cushman, 1909 originally described from the Recent, Gulf of Mexico. This latter species, the genotype of Ammodiscoides, lacks the regular trochospiral form of the present species and it is felt that revision of these Cretaceous references is required.

Occurrence: Rare specimens were found in the Campanian of the Isle of Wight. A single specimen was also found in the Lower Maastrichtian of Norfolk.

Zonal range: Blii - B5i

Superfamily LITUOLACEA de Blainville, 1825

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily SPIROPLECTAMMININAE Cushman, 1927

Genus SPIROPLECTAMMINA Cushman, 1927

Genotype Textularia agglutinans d'Orbigny var. biformis Parker & Jones, 1865

Spiroplectammina baudouiniana (d'Orbigny, 1840)

(Plate 1, figs.5,6,7.)

1840 Textularia baudouiniana d'Orbigny, p.46, pl.4, figs.29,30.

?1860 Textularia anceps Reuss; Reuss, p.234, pl.3, fig.2a,b.

1899 " baudouiniana d'Orbigny; Egger, p.24, figs, 10,11.

1917 Spiroplecta anceps (Reuss); Chapman, p.20, pl.2, fig.16, pl.12, fig.14.

1925 Textularia baudouiniana d'Orbigny; Franke, p.12, pl.1, fig.15.

1928 " " d'Orbigny; Franke, p.135, pl.12, fig.12.

1932 Spiroplectammina laevis (Roemer) var. cretosa Cushman, p.87, pl.11, fig.3.

1936 " " (Roemer) var. " Cushman; Jennings, p.12, pl.1, fig.2.

1937 Textularia baudouiniana d'Orbigny; Kalinin, p.13, pl.1, fig.1,2.

1940 Spiroplectammina laevis (Roemer) var. cretosa Cushman; Cushman, p.52, pl.9, fig.3.

1941 Textularia baudouiniana d'Orbigny; Marie, p.63, pl.2, fig.21.

1944 Spiroplectammina laevis (Roemer) var. cretosa Cushman; Cushman & Deaderick, p.329, pl.50, fig.6.

1946 " " (Roemer) var. cretosa Cushman; Cushman, pp.27-8, pl.6, fig.1-3.

non 1946 " baudouiniana (d'Orbigny); Cushman, p.27, pl.5, fig.12.

1946 Textularia " d'Orbigny; Schijfsma, p.30, pl.1, fig.2.

1951 Spiroplectammina " (d'Orbigny);Visser, pp.212, 213, pl.1, fig.1.

1953 Textularia " d'Orbigny; Barnard & Banner, pp.183-4, figs.5g,h,i.

1953 Spiroplectammina laevis (Roemer) var. cretosa Cushman; Hagn, p.9, pl.1, fig.10.

1954 " " (Roemer) var. cretosa Cushman; Frizzell, p.66, pl.4, figs.24a,b.

1957 " " (Roemer) var. cretosa Cushman; McGugan, p.337, pl.34, fig.8.

1957 Spiroplectammina baudouiniana (d'Orbigny); Hofker, pp.60-1, t.fig.57.

1959 _____"_____ laevis (Roemer); Hofker, p.371, fig.6.

1960 _____"_____ " (Roemer) var. cretosa Cushman; Belford, p.8, pl.1, figs.7-10.

1961 _____"_____ baudouiniana (d'Orbigny); Akimets, p.74, pl.1, fig.8,9.

1964 _____"_____ laevis (Roemer) var. cretosa Cushman; McGugan, p.939, pl.150, fig.3.

1964 Textularia baudouiniana (d'Orbigny); Subbotina, pl.25, figs.1-12.

1965 Spiroplectammina baudouiniana (d'Orbigny); Pozaryska, p.48, pl.2, fig.5.

1966 _____"_____ " (d'Orbigny); Hofker, p.20, pl.1, fig.12.

1966 _____"_____ laevis (Roemer); Hofker, p.32, pl.12, fig.5, pl.15, fig.17, pl.22, fig.79.

1968 _____"_____ " (Roemer); Sliter, p.46, pl.2, fig.9.

1969 _____"_____ " (Roemer) var. cretosa Cushman; Mello, p.44, pl.4, fig.7.

?1969 _____"_____ cretosa Cushman; Hanzlikova, p.21, pl.2, fig.8.

?1972 _____"_____ " Cushman; Hanzlikova, p.47, pl.10, fig.9.

1972 _____"_____ semicomplanata (Carsey); Hanzlikova, p.46, pl.10, figs.2-4.

1977 Textularia baudouiniana d'Orbigny; Villain, p.40, pl.3, figs.1,5.

Description: Test free; tapering, generally longer than broad, wedge - shaped; maximum width near apertural end, maximum thickness along median line; moderately compressed, periphery acute to sub - acute, margin entire to slightly lobate; cross section rhomboid. Microspheric forms show development of indistinct, initial, planispiral coil which is absent in megalospheric forms. Chamber arrangement is exclusively biserial after initial portion, with up to 18 pairs of chambers; chambers uninflated, much broader than high, increasing in size gradually to rapidly; sutures flush, indistinct, becoming slightly more distinct, depressed towards the margin, slightly curved and oblique; development of thickened chamber margins sometimes gives the appearance of indistinctly raised sutural ridges; aperture broad, narrow subrectangular slit, re-entrant at inner margin of last chamber; wall finely agglutinated, often showing distinct, elongate grooves, subparallel to the sutures; surface moderately rough.

Average height: 1.2mm. Average width: 0.6mm.

Remarks: Barr (1962 MS) noted the synonymous relationship between S. baudouiniana (d'Orbigny) and S. laevis (Roemer) var. cretosa Cushman, 1932 and this view has been followed herein, though final confirmation must await re-study of type material. As was also noted by Barr (1962 MS), d'Orbigny's original figure shows a well developed individual, which is more gradually tapering than most species of S. baudouiniana encountered in the British Campanian; however, examples can be selected (pl.1, fig.5) which have a very similar length/breadth ratio to the holotype. In the present species a wide degree of morphological variation is shown both in the tapering of the test and angularity of the margin; a similar wide range of variation has been illustrated by Subbotina (1964). In view of this, it is felt that revision of the relevant type material of the closely related forms S. anceps (Reuss), S. semicomplanata (Carsey) and S. laevis (Roemer) is required to elucidate their exact relationship to S. baudouiniana.

Occurrence: Originally recorded from the Upper Campanian of the Paris Basin, S. baudouiniana is found rarely in the Lower Campanian of the Isle of Wight. Occasional examples occur in the Middle and lower Upper Campanian. A marked increase in abundance occurs in the middle Upper Campanian. In Norfolk, S.baudouiniana occurs as a slightly more consistent and abundant member of the fauna in the Lower and Middle Campanian, and is abundant throughout the Upper Campanian and Lower Maastrichtian.

Zonal range: B1ii, B2i - B6ii

Genus BOLIVINOPSIS Yakovlev, 1891

Genotype Bolivinopsis capitata Yakovlev, 1891

Remarks: There has been considerable debate as to the status of the genus Bolivinopsis Yakovlev, 1891. This has been summarized in Loeblich & Tappan (1964), and their conclusions have been followed herein; however, attention should be paid to the statement of Frizzell (1943), concerning the difficulty in distinguishing between finely agglutinated calcareous tests and secreted calcareous ones. This is particularly true of foraminifera from the chalk where, as Schlanger & Douglas (1974) have clearly shown considerable fine-scale recrystallization of foraminiferal tests has occurred.

Bolivinopsis flexuosa (Reuss, 1860)

(Plate 1, figs.8,9.)

1851 Textularia articulata Reuss, p.45, pl.4, fig.14.

1860 ______"______ flexuosa Reuss; Reuss, p.235.

1892 Spiroplecta annectens Parker & Jones; Chapman, p.516. (list only)

?1899 ______"______"______ Jones; Egger, pl.14, figs. 48,49.

1934 Spiroplectoides flexuosa (Reuss); Cushman, p.41, pl.6, figs.14-18

1941 ______"______"______ (Reuss); Marie, p.180, pl.28, figs.265-272.

1953 <u>Spiroplectammina flexuosa</u> (Reuss); Hagn, p.12, pl.1, fig.9.

?1957 ______"______ "___ (Reuss); Hofker, pp.57-58, t.fig.52.

<u>Description</u>: Test free; elongate, compressed; initially distinct planispiral coil followed by long, narrow, biserial portion comprising up to 12 pairs of chambers, increasing extremely gradually so that test is almost parallel sided; chamber 2½ times as wide as high; test oval in cross section with sub-acute margins; sutures distinct, depressed, oblique. Characteristically, this species shows marked constrictions after every third or fourth pair of chambers; aperture low, narrow slit, slightly re-entrant at the inner margin of the last chamber; wall finely agglutinated, calcareous; surface smooth to finely roughened.

Average length: 1.4mm. (fragment). Average width: 0.36mm.

<u>Remarks</u>: Reuss (1860) renamed this species as its original name <u>T.articulata</u> was occupied by <u>T.articulata</u>,described by d'Orbigny from the Miocene beds of Baden near Vienna. Originally the species was defined on broken fragments and, although the vast majority of specimens found in the present study were also fragmented, rare complete specimens have been found from 'flint-meal' samples.

A large number of Upper Cretaceous and Lower Tertiary species have been defined in this genus, many of which appear to be extremely closely related, and a thorough study of the type specimens would seem desirable. The chief distinguishing feature of <u>B.flexuosa</u> is the regular, distinct, constrictions which are also responsible for the fragmentary nature of many specimens. The specimens of <u>Spiroplecta annectens</u> Parker & Jones sensu Chapman (1892), have been examined in the British Museum (Nat. Hist.), and were found to be conspecific with <u>B.flexuosa</u>. Material from Taplow, where Chapman recorded this form, has also commonly yielded B. flexuosa, which bears little resemblance to S. annectens (Parker & Jones, 1863.)

Occurrence: Originally described from the Upper Senonian Kreidemergel of Lemberg, Galicia. This species has been found in moderate abundance throughout the Campanian and Maastrichtian both from onshore sections and borehole material from the North Sea.

Zonal range: Blii - B7i

Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily VERNEUILININAE Cushman, 1911

Genus VERNEUILINA d'Orbigny, 1839

Genotype Verneuilina tricarinata d'Orbigny, 1840

Verneuilina münsteri Reuss, 1854

(Plate 1, fig.10.)

1845 Textularia triquetra (v. Münstr.) Reuss, p.39, pl.13, fig.77.

1854 Verneuilina münsteri (Reuss); Reuss, p.71, pl.26, fig.5.

1925 " " (Reuss); Franke, p.17, pl.1, fig.29.

1928 " triquetra (v. Münstr.) (Reuss); Franke, p.136, pl.12, fig.13.

1936 " limbata Cushman, p.2, pl.1, fig.2.

1937 " " Cushman; Cushman, p.12, pl.1, fig.21.

1956 Gaudryina " Said & Kenawy , p.123, pl.1, fig.23.

1957 Verneuilina " Cushman; McGugan, p.337, pl.34, figs.4-7.

1961 " münsteri (Reuss); Vasilenko, p.15, pl.1, fig.8.

1964 " " (Reuss); Martin, p.51, pl.3, fig.1.

1975 " " (Reuss); Robaszynski, in Colbeaux et al. p.19, fig.2.

Description: Test free; elongate, pyramidal; sharply triangular in cross section; chambers arranged triserially; rare geriontic specimens show tendency to biseriality in last pair of chambers; sides flat to slightly concave, angles of test sharp; 7 to 8 chambers on each face, distinct slightly inclined, uninflated, increasing rapidly and uniformly in size; sutures generally slightly raised, occasionally flush, limbate, curved; aperture small loop or slit shaped opening, at base of highly inclined apertural face; occasionally well preserved specimens show slight apertural lip; wall structure finely agglutinated, calcareous, with much calcareous cement; surface smooth.

Average height: 1.15mm. Average width: 0.6mm.

Remarks: This species is clearly distinguished by its distinct limbate sutures and sharp test edges. V.limbata Cushman 1936, and Gaudryina limbata Said & Kenawy 1956, are considered to lie within the range of variation of V. münsteri .

The genus Verneuilina d'Orbigny, 1839 is distinguished most readily from Gaudryina d'Orbigny, 1839 by its triserial chamber arrangement, as opposed to the initially triserial, later biserial arrangement of Gaudryina . The development of biserial chambers in occasional geriontic individuals of V.münsteri might suggest that the two genera are intergradational in character. Loeblich and Tappan (1964) in a review of this problem, noted that, although occasional specimens of Verneuilina may show biserial chamber arrangement, such a situation is abnormal. For this reason, the two genera are regarded as distinct. V.münsteri is placed within the genus Verneuilina on the basis of its predominantly triserial chamber arrangement, sharp test angles and finely agglutinated wall structure.

Occurrence: Originally described from the Turonian Planermergel of Luschitz. In the present study this species ranges in moderate abundance throughout the Campanian and Lower Maastrichtian both in the Isle of Wight and Norfolk. In the North Sea found rarely.

Zonal range: B1ii - B5ii

Genus GAUDRYINA d'Orbigny, 1839

Genotype Gaudryina rugosa d'Orbigny, 1840

Gaudryina rugosa d'Orbigny, 1840

(Plate 1, fig.11)

1840 Gaudryina rugosa d'Orbigny, p.44, pl.4, figs.20,21.

?1845 " " d'Orbigny; Reuss, p.38, p.12, figs.15,24.

pars1891 " " d'Orbigny; Beissel, p.69, pl.13, figs.30-33.

1899 " pupoides d'Orbigny; Egger, p.37, pl.4, figs.14,15.

non1899 " rugosa d'Orbigny; Egger, p.37, pl.4, figs.19,20.

1917 " " d'Orbigny; Chapman, p.21, pl.2, fig.21.

1925 " " d'Orbigny; Franke, p.14, pl.1, fig.19.

1928 " " d'Orbigny; Franke, p.141, pl.13, fig.2.

1937 " " d'Orbigny; Cushman, p.36, pl.4, figs.14-19, pl.5, figs.1,2.

1941 " " d'Orbigny; Marie, p.63, pl.2, figs.22,23.

1946 " " d'Orbigny; Schijfsma, p.32, pl.1, fig.6.

1951 " " d'Orbigny; Visser, p.217, pl.1, fig.6.

1953 " " d'Orbigny; Barnard & Banner, p.184, pl.9, fig.3. t.figs. 5t,u.

1953 " " d'Orbigny; Hagn, p.14, pl.1, fig.14.

non1954 " (Gaudryina) rugosa d'Orbigny; Frizzell, p.71, pl.5, fig.20.

1957 " rugosa d'Orbigny; Hofker, p.63-64, t.figs.59,60.

1960 Gaudryina rugosa d'Orbigny; Belford, p.13, pl.2, figs. 17-20.

1966 " " d'Orbigny; Hofker, p.19, pl.1, fig.2.

1966 " cretacea (Karrer); Hofker, p.20, pl.5, fig.14, pl.8, fig.15, pl.12, fig.12.

1972 " " (Karrer); Hanzlikova, p.51, pl.9, fig.9.

1977 rugosa d'Orbigny; Villain, p.41, pl.3, fig.8.

Description: Test free; initially triserial, pyramidal with rounded, trilobate cross section; later adult forms often develop distinct biserial portion, subrectangular to triangular in cross section. In the triserial stage the sides are initially flat, moderately and uniformly increasing in size, later lobate and rapidly flaring; in the biserial stage periphery distinctly lobate and gradually tapering; biserial portion representing 10-60 % of test; chambers distinct, initially uninflated, becoming inflated, rectangular, twice as wide as high in biserial portion; sutures distinct, initially flush, later depressed, curved and slightly oblique; apertural face subrectangular, aperture in triserial forms simple semi-circular loop, in biserial forms narrow rectangular slit in slight re-entrant in apertural face; wall coarsely agglutinated with calcareous cement; surface rough.

Average height: 1.4mm. Average width: 0.9mm.

Remarks: This species exhibits considerable variation in the development of a biserial portion. In the Lower Campanian, the tendency to biseriality appears to be less well developed than in the Upper Campanian. D'Orbigny (1840) originally described this form from the Upper Campanian of the Paris Basin, figuring a holotype with a well developed biserial portion. It seems likely that phylogenetically older populations, which do not show a marked tendency to biseriality, may have been confused with other species of the genera Gaudryina and Verneuilina. The hypotype of G.rugosa figured by Loeblich and Tappan (1964) more closely resembles d'Orbigny's original figure of G. pupoides d'Orbigny than that of G.rugosa d'Orbigny.

The generic position of this species clearly illustrates the difficulties involved in consistently distinguishing between species of the genera Gaudryina and Verneuilina on the basis of chamber arrangement alone. It is felt that the rounded test edges and coarse agglutination , together with the pronounced tendency to biseriality, all serve to place the present forms within the genus Gaudryina .

Occurrence: Originally described from the Campanian of the Paris Basin, in the Isle of Wight this species is found rarely in the Middle Campanian and thence only sporadically until the base of the middle Upper Campanian, where it shows a slight increase in abundance. In Norfolk, it ranges in some abundance from the upper Lower Campanian to the Lower Maastrichtian. In the North Sea found rarely throughout the Campanian and Lower Maastrichtian.

Zonal range: B2i - B6ii

Gaudryina concinna (Reuss, 1845)

(Plate 1, figs.15,16.)

1845 Textularia concinna Reuss, p.109, pl.24, fig.54.

1854 " " Reuss; Reuss, p.71, pl.26, fig.6.

1860 " " Reuss; Reuss, p.233, pl.13, fig.1.

1928 " agglutinans d'Orbigny f. concinna Reuss; Franke, p.133, pl.12, fig.7.

1941 Gaudryina gradata Berthelin var. gracilis Marie, p.66, pl.3, fig.28.

1953 " concinna (Reuss); Barnard & Banner, p.185, pl.8, fig.8.

1953 " parallela (Reuss); Barnard & Banner, p.184, t.fig. 41.

1957 Gaudryina chapmani (Franke); Hofker, p.66, t.fig.66.

1966 " " (Franke); Hofker, p.68, pl.12, fig.23.

Description: Test free, elongate, initially rounded to sub-triangular; chambers arranged initially in four, triserial whorls, followed by several pairs of biserially arranged chambers, sometimes becoming loosely biserial; biserial portion occupying over $\frac{3}{4}$ of the test and occasionally develops slight axial twisting; chambers very gradually increasing in size so test is almost parallel sided; chambers becoming less embracing, more inflated, giving a slightly lobate periphery, biserial chambers initially wider than high, becoming higher than wide, subglobular; sutures indistinct flush, becoming distinct, slightly depressed; cross section subrectangular; aperture rounded, loop-shaped, interiomarginal to sub-terminal, basally constricted; wall finely to moderately coarsely agglutinated, largely calcareous with occasional spicular fragments; surface smooth to moderately roughened.

Average length: 0.84mm. Average width: 0.24mm.

Remarks: This species is distinguished from other members of the genus by its slender, almost parallel sided form and its chamber arrangement becoming loosely biserial. Barnard and Banner (1953) separated G. concinna from a form they referred to G. parallela (Reuss, 1860), by its greater size and less slender, more flaring form. G. parallela, however, was originally described by Reuss from the Gault of Germany whilst the form assigned to G. parallela by Barnard and Banner was restricted to the Campanian. It seems highly probable that the form described by Barnard and Banner should be considered a variety of G. concinna. This conclusion is in agreement with that reached by Barr (1962 MS).

Occurrence: Originally described from the Upper Senonian of Germany, found rarely both in Norfolk and the Isle of Wight, in the Middle Campanian, becoming slightly more abundant in the Upper Campanian and Lower Maastrichtian.

Zonal range: B2i - B5ii

Gaudryina faujasi (Reuss, 1862)

(Plate 1, figs. 12,13.)

1862 Textularia faujasi Reuss, p.320, pl.3, fig.9.

1937 Gaudryina " (Reuss); Cushman, p.39, pl.5, figs.17-20; pl.6, figs.1,2.

1942 " " (Reuss); Cushman & Deaderick, p.53, pl.9, fig.14.

1946 " " (Reuss); Cushman, pp.32-33, pl.7, fig.14.

1946 Textularia turris d'Orbigny; Schijfsma, p.31, pl.1, figs.1-3.

1951 " agglutinans d'Orbigny; Visser, p.213, pl.1, fig.2.

pars 1959 Gaudryina (Textularia) faujasi (Reuss) Hofker, p.370, fig.1.

1966 Textularia faujasi Reuss; Hofker, p.134, pl.19, fig.15, pl.22, fig.68, pl.29, fig.3, pl.33, figs.85,86, pl.35, fig.1, pl.37, fig.1, pl.40, fig.4.

1977 " " Reuss; Villain, p.40, pl.3, figs.4,7.

Description: Test free;broadly wedge shaped; chamber arrangement initially triserial , triangular in cross section often broken in the present material; major part of test biserial, gradually flaring, periphery broadly rounded, sides flat; cross section oval; chambers initially indistinct, becoming distinct towards aperture, horizontal, uninflated initially becoming slightly inflated , twice as broad as high, last two chambers domed terminally; sutures indistinct, obscured by coarse agglutination, becoming somewhat depressed, horizontal to slightly oblique; wall arenaceous, surface rough with short spicular projections; aperture semi-circular to subrectangular opening in slight re-entrant on the inner margin of the last chamber.

Average height: 0.68mm. Average width: 0.6mm.

Remarks: This species was found rarely in the present study and its full range of variation could not be determined. Specimens of G. partschi (Reuss) sensu Barnard & Banner (1953) deposited in the British Museum (Nat. Hist.) are similar morphologically though herein considered distinct, further study of full populations is needed to confirm this.

Occurrence: Originally described from the Maastrichtian of Maastricht, Holland. Very rare specimens found from the base of the middle Upper Campanian in the Isle of Wight. In Norfolk recorded rarely, ranging from the uppermost Middle Campanian through the Lower Maastrichtian.

Zonal range: B2iii, B3iii - B6ii

Gaudryina laevigata Franke, 1914

(Plate 1, fig.14.)

1914 Gaudryina laevigata Franke, p.431, pl.27, figs.1,2.

1928 " " Franke; Franke, p.142, pl.13, fig.3.

1936 " " Franke; Brotzen, pp.34, 35.

? 1951 " " Franke; Visser, pp.216-7, pl.1, fig.8.

1953 " " Franke; Hagn, p.14, pl.1, fig.16.

1956 " " Franke; Said & Kenawy, p.123, pl.1, fig.8.

1960 Gaudryina laevigata Franke; Belford, p.12, pl.2, figs.15,16.

1961 " " Franke; Vasilenko, p.16, pl.2, figs.5-7.

1964 " " Franke; McCugan, p.940, pl.150, figs.6-8.

1969 " " Franke; Hanzlikova, p.2, fig.2.

1972 " " Franke; Hanzlikova, p.52, pl.11, fig.2.

Description: Test free; initially triserial, later biserial, biserial portion occupying from 20 - 60 % of test; initially rapidly flaring, sides flat to slightly concave, edges subrounded, chambers indistinct and sutures indistinct flush; cross section initially triangular; biserial chambers inflated, distinct, slightly higher than broad, subglobular in side view; sutures distinct, depressed; cross section subovate to subquadrate; wall finely arenaceous; surface smooth; aperture very broad, low slit, re-entrant along inner margin of final chamber.

Average height: 0.9mm. Average width: 0.48mm.

Remarks: This species may easily be distinguished from G.rugosa by its inflated, almost globular biserial chambers, smooth surface, and broad low aperture. G.frankei Brotzen from the Santonian of Eriksdal is closely related but this may be distinguished, according to the original illustrations, by having a markedly shorter, less angular triserial portion; though in the original description (Brotzen 1936 p.35), the opposite relationship is described. As a result of this, it is quite probable that considerable confusion may exist in the literature between these two taxa. Indeed many North American authors (e.g. Cushman, 1946; Sliter, 1968) have figured hypotypes of G.laevigata which lack the distinctive subglobular biserial chambers of the European forms and these determinations require revision.

Occurrence: Found rarely in the Lower and Middle Campanian of the Isle of Wight. In Norfolk it is more commonly encountered throughout the Lower and Middle Campanian, but not in younger strata. Found also rarely in the North Sea material.

Zonal range: B1ii - B2iii

Genus MIGROS Finlay , 1939

Genotype Gaudryina medwayensis Parr, 1935

Migros schoendorfi Koch, 1973

(Plate 1, figs.17,18.)

1973 Migros schoendorfi Koch, pp.202-3, pl.18, figs.1-3.

Description: Test free, elongate, typically 3x as high as wide; moderately compressed; chamber arrangement initially comprising a short triserial portion of 2-3 whorls of indistinct chambers, followed by a biserial portion occupying 4/5 of the test; initial end bluntly pointed, test gently flaring, with narrow elliptical cross section; chambers moderately inflated, generally slightly higher than wide, slightly overlapping with a tendency to become irregularly and slightly loosely biserial giving the test an increasingly lobate periphery; sutures initially indistinct, flush, later distinct depressed, oblique and curved; aperture subterminal to terminal, high narrow, slightly sigmoid slit extending across over half the circumference of the final chamber and not in contact with the interiomarginal suture; wall moderately coarsely arenaceous; surface roughened.

Average height: 0.54mm. Average width: 0.24mm.

Remarks: M.schoendorfi is rare in the British Campanian and the full range of morphological variation within the population was indeterminable. The high, terminal slit-like aperture, and general form, appear to be characteristic of this species which was originally described from the mid- Santonian of Germany. This is the form described by Barr (1962 MS) as Gaudryinella wightensis sp.nov.

Occurrence: Rare, ranging from the basal Campanian to the top of the Upper Campanian. It has not been found in strata of Maastrichtian age.

Zonal range: Blii - B4i

Genus HETEROSTOMELLA Reuss, 1866

Genotype Sagrina rugosa d'Orbigny, 1840

Heterostomella rugosa (d'Orbigny, 1840)

(Plate 1, figs.19,20.)

1840 Sagrina rugosa d'Orbigny, p.47, pl.4, figs.31,32.

1850 " " d'Orbigny; d'Orbigny, p.283, no.1413.

? 1934 Heterostomella cuneata Sandidge; Dain, p.16, pl.1, fig.4.

1941 " rugosa(d'Orbigny);Marie, p.67, pl.3,fig.30.

1953 " " (d'Orbigny);Barnard & Banner, pp.196-7, pl.9, fig.4, t.fig.5a-f.

1957 Siphogaudryina cf. S. foveolata (Marsson); McGugan, p.333, pl.34, fig.10.

1957 " (Heterostomella) rugosa (d'Orbigny); Hofker, pp.71-72, t.fig.73.

1964 Heterostomella rugosa (d'Orbigny); Loeblich & Tappan, p.C269, fig.181, 2a,b.

1966 Siphogaudryina (Heterostomella) rugosa (d'Orbigny); Hofker, p.20, pl.1, fig.5.

Description: Test free; elongate, club shaped, initially triangular, chambers triserial; cross section triangular, later becoming irregularly rounded to subrectangular or triangular, last 1 or 2 pairs of chambers biserial, inflated, domed to flat, slightly overlapping; early chambers slightly obscured by ornament comprising irregular longitudinal costae along margins of chambers, which are fistulose to varying degrees; short median ridges may be developed in the quadrilateral stage, in the middle of the broadest faces; other irregularly constructed and positioned costae may also be developed; sutures initially obscured by ornament; aperture generally terminal at the end of short neck, position and shape somewhat variable, may be close to, though never touching, inner margin of final chamber, circular to crescentic slit in shape; wall quite coarsely arenaceous; surface rough initially, biserial chambers less so.

Average height: 0.65mm. Average width: 0.42mm.

Remarks: There is considerable variation in overall shape, length/breadth ratio, ornamentation and apertural position. Little of this variation shows any stratigraphic significance , though there is a tendency in the Lower Campanian for more elongate, less ornamented forms to give way to broader, more strongly ribbed forms in the Middle and Upper Campanian. A case could be made out for subdivision of the present species into chrono-subspecies, however, insufficient material has prevented such action being undertaken in the present study.

There is considerable confusion in the literature between H. rugosa and H. foveolata (Marsson, 1878). Both Cushman (1937) and Marie (1941) regarded these two species as closely related, whilst Barnard and Banner (1953) considered H. foveolata as falling within the range of morphological variation of H. rugosa.

Much of this confusion has arisen from the somewhat inadequate original figures of d'Orbigny (1840), which show few of the specific characteristics of H. rugosa. This situation was rectified when Loeblich & Tappan (1964), erected, and figured, a lectotype for H. rugosa . H. rugosa may be distinguished from H. foveolata by its larger, broader, more robust form and its stronger ornament which in adult forms shows a far greater tendency to form transverse ridges. The two forms are closely related and transitional forms were found in the Uppermost Campanian.

Occurrence: Originally described from the Campanian of the Paris Basin. In the Isle of Wight specimens of H. rugosa are extremely rare throughout the Campanian. A slight increase in abundance has been noted in the Upper Campanian in Alum Bay. In Norfolk the species is far more abundant, being a consistent component of the fauna, particularly in the Upper Campanian. It has not been found from strata of Lower Maastrichtian age.

Zonal range: B2, B3i - B4i

Heterostomella foveolata (Marsson, 1878)
(Plate 1, figs. 21,22.)

1878 Tritaxia foveolata Marsson, p.161, pl.3, fig.30.
1925 " " Marsson; Franke, p;19, pl.2, fig.3.
1928 " " Marsson; Franke, p.138, pl.12, fig.16.
1931a Heterostomella foveolata (Marsson); Cushman, p.301, pl.34, fig.8.
1937 " " (Marsson); Cushman, p.142, pl.20, figs. 12-16, 19.
1946 " " (Marsson);Cushman, p.42, pl.11, fig.11.
1953 " " (Marsson); Hagn, p.18, pl.1, fig.24.

1957 Siphogaudryina (Heterostomella) foveolata (Marsson); Hofker, p.72, t.fig. 74.

1966 " (") " (Marsson); Hofker, p.33, pl.4, fig.7, pl.12, fig.3, pl.14, fig.5.

1972 Heterostomella foveolata (Marsson); Hanzlikova, p.53, pl.11, fig.5.

1977 " " (Marsson); Villain, p.41, pl.3, fig.11.

Description: Test free; elongate, wedge shaped, sometimes slightly curved; initial portion distinctly triangular, triserial, and pointed; rapidly flaring, becoming irregularly rounded, with indistinct chambers; final chambers biserial, inflated, subglobular; chambers in lower portion indistinct, obscured by ornamentation of irregular pits and indentations; cross section rounded below biserial stage; sutures initially indistinct, obscured by ornament, in biserial stage distinct, depressed, curved; aperture terminal on short neck, generally circular to subcircular in centre of last chamber; wall coarsely arenaceous; surface rough.

Average height: 0.64mm. Average width: 0.37mm.

Remarks: This species appears to have arisen from H. rugosa (d'Orbigny) in the uppermost Campanian. Barnard and Banner (1953) considered that H. foveolata lay within the range of specific variation exhibited by H. rugosa, however, after extensive study of material from the Lower Maastrichtian, it is felt that the two forms can be distinguished both morphologically and stratigraphically. H. foveolata shows a much weaker, more irregular style of ornamentation, generally lacking the distinctly raised fistulose ridges of H. rugosa. It is also a smaller, slightly more slender form in which the last chambers tend to be more domed.

Occurrence: Originally described from the Maastrichtian chalk of the Isle of Rügen. Transitional forms between H. foveolata and the ancestral H. rugosa occur in the uppermost Campanian of Norfolk. H. foveolata has been recorded throughout the Lower Maastrichtian in the present study.

Zonal range: B5i - B6ii

Heterostomella gracilis Hofker, 1956

(Plate 1, figs. 23 - 25.)

? 1941 Heterostomella cf. minuta (Marsson); Marie, p.68, pl.3, fig.31.

1956b " gracilis, Hofker, p.64, fig.4.

1957 Siphogaudryina (Heterostomella) gracilis (Hofker); Hofker, p.73, t.fig.75.

1958b Heterostomella gracilis (Hofker); Hofker, p. B492, fig.46.

1966 Siphogaudryina (Heterostomella) gracilis (Hofker); Hofker, p.86, pl.14, fig.4.

Description: Test free, slender, elongate with subparallel sides; initially bluntly pointed or broadly rounded, rapidly flaring, triserial; major part of test subquadrangular to triangular in cross section; angles marked by fistulose ridges; last pair of chambers biserial, inflated, highly domed; fistulose angles may, in exceptionally well preserved individuals, show entire, carinate keels; chambers indistinct with exception of last pair; sutures also indistinct; later chambers show distinct, slightly depressed sutures; aperture terminal, circular to subcircular or occasionally even a crescentic hole at end of very short neck; wall finely agglutinated; surface moderately smooth.

Average height: 0.56mm. Average width: 0.25mm.

Remarks: This species is distinguished by its narrow, slender form, ornamentation restricted largely to the test angles and subquadrangular cross section. It appears to belong to the form described by Hofker (1956) as H. gracilis, though he records this as being restricted to the Upper Maastrichtian. Examination of topotypic material indicates that H. gracilis has a far greater stratigraphic range in the present material. Marie (1941) described a morphologically similar form from the Upper Campanian of the Paris Basin, which he referred to H. cf. minuta (Marsson, 1878). This form may be conspecific with H. gracilis, it differs from Tritaxia minuta Marsson in its broadly rounded initial end, development of fistulose ridges and subquadrate cross section.

Occurrence: H. gracilis has been found to range throughout strata of upper Upper Campanian and Lower Maastrichtian age. Rare.

Zonal range: B4i - B7i

Genus TRITAXIA Reuss, 1860

Genotype Tritaxia tricarinata Reuss, 1844

Tritaxia tricarinata (Reuss,1844)

(Plate 2, fig.1-3.)

1844 Textularia tricarinata Reuss, p.215.

1845 " " Reuss; Reuss, p.39, pl.8, fig.60.

1851 Verneuilina dubia Reuss, p.40, pl.4(5), fig.3.

1860 Tritaxia tricarinata (Reuss); Reuss, p.228, pl.12, figs.1,2.

1892 Tritaxia pyramidata (Reuss); Chapman, p.2, pl.11, fig.2.

1928 Clavulina angularis (d'Orbigny); Franke, p.140, pl.13, fig.1.

1928 Tritaxia tricarinata (Reuss); Franke, p.137, pl.12, fig.17.

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

1937 " tricarinata (Reuss); Cushman, p.25, pl.3, figs.16-25.

1949 " " (Reuss); Cuvillier & Szakall, p.20, pl.7, fig.7.

1953 " " (Reuss); Barnard & Banner, p.193,pl.8, fig.1a-e, t.fig.3a-j.

1953 " " (Reuss); Hagn, p.13,pl.1, fig.13.

1957 " " (Reuss); Hofker, p.67, t.fig.67.

1957 " dubia (Reuss); Hofker, p.67, t.fig.68.

1964 " tricarinata (Reuss); Loeblich & Tappan, p.C 272, fig.182, 5,6.

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

1966 " dubia (Reuss); Hofker, p.19, pl.1, fig.13, p. , pl.

1969 " tricarinata (Reuss); Hanzlikova, p. pl.2, fig.3.

1972 " " (Reuss); Hanzlikova, p.54, pl.11, fig.11.

Description: Test free, elongate, broadly triangular; test outline highly variable from subtriangular rapidly flaring with concave to flat sides, to an elongate, almost parallel sided form; shorter subtriangular form has rounded to sharp angles; chamber arrangement indistinct, triserial, occasionally terminated by short uniserial section; chambers low, sutures indistinct, flush to slightly depressed, curved; aperture central, terminal in larger elongate forms often encircled by broad lip which joins carinate edges; shorter triserial forms have non-terminal aperture, tending towards the inner edge of the final chamber; wall finely agglutinated, calcareous with much calcareous cement; surface smooth.

Elongate form: Average height: 0.58 mm. Average width: 0.38 mm.

Typical form: Average height: 0.46 mm. Average width: 0.40 mm.

Remarks: Barnard and Banner (1953) have illustrated the large range of variation shown by this species, by the use of acid-stripped specimens. These have clearly shown the transition from triserial to uniserial chamber arrangement.

Occurrence: Originally described from the Turonian Planermergel of Kostice, Bohemia. In the Isle of Wight, this species ranges throughout the Campanian, though it is rare, whilst in Norfolk it is found more frequently. In the North Sea material this species is found rarely, ranging throughout the Campanian and Maastrichtian.

Zonal range: Blii - B7i

Subfamily GLOBOTEXTULARIINAE Cushman, 1927

Genus ARENOBULIMINA Cushman, 1927

Genotype Bulimina preslii Reuss, 1846

Arenobulimina courta (Marie, 1941)

(Plate 2, fig.4.)

? 1851 Bulimina obesa Reuss, p.40, pl.4, fig.12, pl.5, fig.1.

1925 " " Reuss; Franke, p.26, pl.2, fig.24.

1928 " " Reuss; Franke, p.161, pl.14, fig.25.

pars 1937 Arenobulimina obesa Reuss; Cushman, pp.43-44, pl.4, fig.27 only

1941 Hagenowella courta Marie, p.43, pl.7, fig.68.

1953 " " " ; Barnard & Banner, p.202, t.fig.6j-o.

1953 Arenobulimina obesa Reuss; Hagn, p.20, pl.2, fig.10.

pars 1957 Ataxophragmium ovoideum (Marie); Hofker, pp.46-7, t.fig.35, non. t.fig.34.

pars 1977 Orbignyna variabilis (d'Orbigny); Villain, p.42, pl.3, figs.12-13, non. pl.3, fig.9.

Description: Test free; globular, low trochospirally coiled test of three to four whorls, initially may show slightly more rapidly expanding trochospire, though still obtuse, never pointed; chambers overlapping, inflated, markedly so in final whorl which forms about 2/3 of the test; mature specimens invariably show four chambers in final whorl of which the last chamber occupies almost half; internally simple, no partitions,sutures set in very distinct depressions; wall thick composed of moderately fine arenaceous particles set in calcareous cement; surface roughened; colour grey to markedly yellowish; aperture a simple elongate slit, to semicircular opening at junction of three sutures of final whorl and extending along the interiomarginal suture of the final chamber.

Average height: 0.65 mm. Average width: 0.50 mm.

Remarks: There has been considerable confusion as to the relationship between Bulimina obesa Reuss, 1851 and A. courta. Marie (1941) states that his species may be distinguished from B.obesa by being wider than high and by possessing oval chambers, as opposed to semicircular. These features are fairly variable, however, and study of type material is required to determine their exact relationship. The present specimens are included in A.courta as the original description and figures are closest to the present forms. Cushman (1937) studied topotypic material of B. obesa, but appears to have included more than one species in his concept (pl.4, figs.26,27.). Villain (1977) following closely Hofker's concept of trimorphism within several agglutinated foraminiferal genera, appears to have included forms herein referred to A.courta, within his concept of

Orbignyna variabilis (d'Orbigny).

Occurrence: Originally described from the Campanian of the Paris Basin. In the present study relatively common throughout the Campanian and Lower Maastrichtian. A.courta shows a marked increase in abundance in the highest levels (Upper Campanian) in the Isle of Wight, though this change is not so apparent in Norfolk. Found in the North Sea material ranging through the Campanian.

Zonal range: B1ii - B5i

Arenobulimina elevata (d'Orbigny, 1840)

(Plate 2, figs.5,6.)

1840 Globigerina elevata d'Orbigny, p.34, pl.3, figs.15-16.

? 1891 Haplophragmium inflatum Beissel, p.19, pl.4, figs.41-45.

1925 " subspherica Reuss; Franke, p.27, pl.2, fig.25.

1928 " " Reuss; Franke, p.161, pl.14, fig.24.

1941 Hagenowella elevata (d'Orbigny); Marie, p.42, pl.7, figs.66a-b,67.

1941 " subspherica (Reuss); Marie, p.42, pl.7, fig.66c-f.

1953 " elevata (d'Orbigny); Barnard & Banner, p.202, pl.8, figs.11a-d.

1953 Arenobulimina subspherica (Reuss); Hagn, p.22, pl.2, fig.11.

1957 Ataxophragmium subspherica (Marie); McGugan, p.333(list), pl.33, figs.11,12.

pars 1957 " trochoideum (Reuss); Hofker, pp.42-44, t.fig.30, non t.figs.28,29.

Description: Test free; high trochospire of four or five whorls, initially very broadly rounded, periphery lobate; chambers arranged in oblique spire, last whorl occupies ½ to 1/3 of test; chambers four per whorl, distinct, becoming strongly inflated, globular; increasing in size uniformly and rapidly; sutures distinct, curved, depressed; aperture variable in shape from narrow slit to broad loop, extending from junction of four sutures of final whorl, up the apertural face of the last chamber; internally chambers simple; wall finely arenaceous, surface finely roughened.

Average height: 1.3 mm. Average width: 1.1 mm.

Remarks: The simple chamber interiors, chamber arrangement, and apertural characteristics place this form firmly in the genus Arenobulimina. A.elevata shows a strong morphological similarity to A.courta (Marie,1941), differing in its markedly higher trochospire, and its larger size. There appears to have been considerable confusion in the literature between this form and Arenobulimina (?) subspherica (Reuss,1845) described from the Turonian Lower Plänerkalk, of Weisskirchlitz, Bohemia. The exact relationship of these two species is not clear and it is felt that study of type material is required. It is felt that all the forms found in the present study fall within the range of variation of A.elevata.

Occurrence: Originally described from the Campanian of the Paris Basin, this species was found rarely in the Lower and Middle Campanian, becoming increasingly abundant in the Upper Campanian and Lower Maastrichtian.

Zonal range: Bliii - B6i

Arenobulimina footei Jennings, 1936

(Plate 2, figs.7,8.)

1910 Bulimina ovata d'Orbigny; Heron-Allen & Earland, p.408, pl.6, fig.8.
1936 Arenobulimina footei Jennings, pp.13-14, pl.1, fig.9.

1947 Arenobulimina footei Jennings; Cushman, p.11, pl.1, fig.21.

1947 " " Jennings; Grekoff, p.4, pl.2, fig.6.

1951 " ovoidea Marie; Visser, p.218, pl.8, fig.2.

1977 " footei Jennings; Villain, p.41, pl.4, fig.1.

Description: Test free, elongate, initially bluntly pointed, becoming gradually flaring, almost subparallel in outline; apertural end rounded to slightly truncate; widest part close to apertural end, test $2\frac{1}{2}$ to 3 times as high as broad; chambers arranged in four to five whorls; initially three chambers per whorl, four in mature portion; chambers elongate, slightly inflated, oblique, uniformly and rapidly expanding; last chamber inflated, broadly rounded to flatter, vertically truncated; sutures distinct, depressed, curved; aperture interiomarginal moderately wide loop shaped opening, curved; wall finely to moderately arenaceous; surface smooth to moderately roughened, often marked by short grooves, arranged approximately parallel to the long axis of the test and especially prominent on the initial portion of the test; these possibly represent dissolution grooves of monaxial sponge spicules.

Average height: 0.64 mm. Average width: 0.30 mm.

Remarks: The original figures given by Jennings (1936) appear to be somewhat stylized, especially with regard to the spiral suture. It is possible, however, to find forms within the present population which compare favourably with the original figures. Marie (1941) described two species from the Upper Campanian of the Paris Basin, of broadly similar form to the present species, these being A.gutta and A.ovoidea, which were distinguished largely by the characteristic shape of their respective last chambers; as noted above, however, populations of A.footei show a considerable degree of variation in this feature and it is not inconceivable that the species erected by Marie may be conspecific with A.footei. A thorough revision of type material is required to determine their exact relationship. Specimens referred to Bulimina ovata d'Orbigny by Heron-Allen & Earland (1910) have been examined in the British Museum (Nat. Hist.) and found to be conspecific with the forms here referred to A. footei.

Occurrence: This species, originally described from the Lower Maastrichtian Mount Laurel Formation of New Jersey, occurs commonly throughout the Campanian and Lower Maastrichtian sections studied. In material from the North Sea it ranges also into the Upper Maastrichtian.

Zonal range: B1ii - B7i

Arenobulimina obliqua (d'Orbigny, 1840)

(Plate 2, fig.9,10.)

1840 Bulimina obliqua, d'Orbigny, p.40, pl.4, figs.7,8.

1928 " " d'Orbigny; Franke, p.156, pl.14, figs.11a,b.

1931b Arenobulimina obliqua (d'Orbigny); Cushman, p.36, pl.5, fig.5.

1934 " " (d'Orbigny); Dain, p.18, pl.1, fig.9.

1934 " " (d'Orbigny); Cushman & Parker, p.28, pl.5, figs.5,6.

1935 " preslii (Reuss); Keller, p.544, pl.1, figs. 5-6.

1937 " obliqua (d'Orbigny); Cushman, p.41, pl.4, figs.18-20.

1937 Bulimina " d'Orbigny; Marie, p.261.

1941 Arenobulimina " (d'Orbigny); Marie, pp.47,48, pl.4, figs. 34a-f.

1941 " conica Marie, pp.48,49, pl.4, figs. 35a-d.

1941 " sphaerica Marie, p.49, pl.4, figs.36a-e.

1941 " cytherea Marie, p.52, pl.4, fig.40a-c.

1946 " cf. cytherea Marie; Schijfsma, p.35, pl.1, fig.7.

1947 Arenobulimina obliqua (d'Orbigny); Grekoff, pp.496-7, pl.2, fig.10.

1947 " sphaerica Marie; Grekoff, p.499, pl.2, fig.13.

1947 " cytherea Marie; Grekoff, pp.493-4, pl.2, fig.5.

1953 " obliqua (d'Orbigny); Hagn, p.20, pl.2, fig.5.

1953 " cytherea Marie; Hagn, p.20, pl.2, fig.9.

1964 " obliqua (d'Orbigny); Krivoborskii (in Subbotina et al.) p.205, pl.33, figs.4-7.

1972 " " (d'Orbigny); Hanzlikova, p.56, pl.12, fig.16.

1977 " " (d'Orbigny); Villain, p.41, pl.4, fig.4.

Description: Test free; elongate, high conical trochospire, higher than broad, greatest breadth across final whorl, test initially acute; rapidly and uniformly increasing in size; three to four whorls; chambers elongate reniform, four to six in whorl, markedly oblique; last chamber large and slightly inflated, overlapping previous whorl strongly in most specimens; apertural face characteristically flat, often with slight apertural concavity; sutures moderately distinct, flush to slightly depressed, curved; aperture broad, curved interiomarginal loop; wall finely agglutinated with much cement; surface smooth; interior simple.

Average height: 0.68 mm. Average width: 0.55 mm.

Remarks: The present specimens are generally slightly less sharply conical than the original figures of d'Orbigny (1840). The overlapping, large, flat, final chamber is characteristic however, Marie (1941) has erected a suite of species which closely resemble A. obliqua differing only in their degree of tapering. In the present populations there is a great degree of variation shown in this character and it is felt that several of Marie's species as listed in the synonomy, can be included within the specific variation of A. obliqua.

Occurrence: An extremely abundant species, originally described from the Campanian of the Paris Basin and widely recorded from the Senonian of Europe. Found throughout the Campanian and Maastrichtian in all studied sections.

Zonal range: B1ii – B7i

Arenobulimina pseudorbignyi Marie, 1941

(Plate 2, fig.11.)

1937 Arenobulimina d'Orbignyi, Marie, p.261.

1941 " pseudorbignyi, Marie, p.50, pl.4, fig.37.

1946 " puschi (Reuss); Schijfsma, pp.35-6, pl.1, fig.8.

1947 " pseudorbignyi Marie; Grekoff, p.498, pl.2, fig.12.

pars 1961 Hagenowella chapmani (Cushman); Vasilenko, p.22, pl.4, fig.1, pl.3, fig.3.

? 1972 Arenobulimina pseudorbignyi Marie; Hanzlikova, p.56, pl.2, fig.17.

Description: Test free; elongate, high trochospiral, rapidly flaring; test outline varying from initially broadly rounded with subparallel sides to very rapidly flaring throughout and initially pointed; whorls three to five, each with three to four chambers; chambers broad, oblique, reniform, slightly inflated; last chamber inflated showing tendency to overlap previous whorl, may be vertically truncated or inclined; sutures distinct, slightly depressed, curved; aperture simple, relatively broad interiomarginal arch, bordered by thick semicircular lip; wall agglutinated; surface moderately rugose, sometimes having distinctly grooved appearance probably as a result of dissolution of monaxon sponge spicules; internally simple in majority of forms.

Average height: 0.53 mm. Average width: 0.42 mm.

Remarks: This robust species shows considerable variation in its rate of tapering. Its rough surface, aperture with thick bordering lip, and last chamber, with tendency to overlap previous whorls, are characteristic. Marie's original description records the presence of poorly developed internal partitions; these have been found only in a few specimens.

Occurrence: This species, originally described from the Upper Campanian of the Paris Basin, occurs rarely throughout the Campanian and Lower Maastrichtian in the studied sections. It shows a marked increase in abundance in the higher levels of the Upper Campanian exposed on the Isle of Wight.

Zonal range: B1ii - B5ii

Arenobulimina puschi (Reuss, 1851)

(Plate 2, fig.12.)

1851 Bulimina puschi Reuss, pp.37-38, pl.4, fig.6a,b.

1860 " " Reuss; Reuss, p.226.

? 1899 " " Reuss; Egger, p.53, pl.24.

1908 " " Reuss; Egger, p.23, pl.3, fig.3.

1928 " " Reuss; Franke, p.159, pl.14, fig,18,

1934 Arenobulimina puschi (Reuss); Cushman & Parker, p.30, pl.5, fig.18a,b.

1937 " " (Reuss); Cushman, p.42, pl.4, figs.22-25.

non 1946 " " (Reuss); Schijfsma, pp.35-36, pl.1, fig.8.

1947 " " (Reuss); Grekoff, pp.498-499, pl.2, fig.1.

1953 " " (Reuss); Hagn, p.22, pl.2, fig.8.

pars 1957 Ataxophragmium " (Reuss); Hofker, pp.44-5, t.fig. 31, nos. a,b,f,k. non.c,d,e,g-j.

Description: Test free; elongate, initially broadly rounded, gradually flaring; apertural end broadly rounded; greatest width near or slightly above mid-point of test, giving sub-fusiform outline; periphery slightly lobate; test 2 to 3 times as long as broad; whorls five or six, each consisting of three inflated to weakly inflated chambers, often giving the test a distinctly tri-lobed cross section; chambers almost as high as broad, subglobular; last chamber has tendency to overlap previous whorl, developing an almost uniserial habit; sutures distinct, depressed; aperture a narrow, moderately high loop extending from the interiomarginal position up the apertural face; wall coarsely arenaceous and the surface roughened, often obscuring chamber arrangement; young specimens are markedly less elongate though they maintain the characteristic triserial form and coarse agglutination.

Average height: 0.75 mm. Average width : 0.36 mm.

Remarks: This distinctive species is characterized by its triserial test and coarse agglutination.

Occurrence: A. puschi was originally described from the uppermost Cretaceous of Lemberg, Galicia, and has been widely recorded from the Upper Senonian of Europe. In Norfolk only found in strata of Upper Campanian and Lower Maastrichtian age, where it is moderately common. In the Isle of Wight very rare occurrences were recorded from the upper Middle Campanian. In material from the North Sea, found to range also throughout the Upper Maastrichtian.

Zonal range: B2, B3ii - B7i

Genus DOROTHIA Plummer, 1931

Genotype _Gaudryina bulletta_ Carsey, 1926

Remarks: The genus _Dorothia_ was erected by Plummer (1931) who distinguished it from _Gaudryina_ d'Orbigny by the presence of an initial trochospiral stage, comprising more than three chambers in the first whorl. Cushman (1933) erected the genus _Marssonella_ with _Gaudryina oxycona_ Reuss, 1860 as its genotype. This also possesses an initial trochospiral whorl composed of four or more chambers and is clearly very closely related to _Dorothia_. Trujillo (1960) placed _Marssonella_ in the synonomy of _Dorothia_ and this conclusion was followed by Loeblich & Tappan (1964).

The major problem concerning the exact status of these two genera is that the number of chambers in the initial whorl is highly variable between micro- and megalospheric individuals. After study of both type species, it is felt that other features such as the greater chamber inflation, height, and proportion of biserial test, serve to distinguish the genus _Dorothia_ from _Marssonella_. It is quite clear however, that the two genera are closely related, not only to one another, but also to the genus _Gaudryina_, and a separation of these genera into different subfamilies, as proposed by Cushman (1927-1937) and Loeblich & Tappan (1964), is an unnatural classification. In the present work both _Dorothia_ and _Marssonella_ are included within the subfamily Verneuilininae Cushman, 1911.

Dorothia pupa (Reuss, 1860)

(Plate 2, figs.13-15.)

1860 _Textularia pupa_ Reuss, p.232, pl.13, figs.4,5.

1870 _Gaudryina crassa_ Karrer, p.166, pl.1, fig.4.

? 1899 Textularia pupa Reuss; Egger, p.26, pl.2, fig.29.

1925 Gaudryina pupoides d'Orbigny; Franke, p.14, pl.1, fig.26.

1925 Textularia conulus f. pupa Reuss; Franke, p.11, pl.1,fig.12.

1928 " " f. " Reuss; Franke, p.132, pl.12, fig.5.

1928 Gaudryina pupoides d'Orbigny; Franke, p.143, pl.13, fig.7.

1931a " " d'Orbigny; Cushman, p.301, pl.34, fig.6.

1936 Dorothia plummeri Brotzen, p.36, pl.1, figs.6,8, t.fig.6.

1937 " pupa (Reuss); Cushman, p.78, pl.8, figs.22,24.

1937 Gaudryina pupoides d'Orbigny; Marie, p.261.

1941 " " d'Orbigny; Marie, p.65, pl.3, figs.24-27.

? 1941 " gradata Berthelin var. crassa Marie, p.66, pl.3,fig.29.

1953 Dorothia pupa (Reuss); Hagn, pp.25-6, pl.2, figs.19-22.

1953 " " (Reuss); Barnard & Banner, p.191, pl.8. figs. 3, t.figs.2i,4b,e.

1953 " " (Reuss) var. depressa, Barnard & Banner, p.191, pl.8, figs. 4a,b, t.figs. 4c.

1953 " " (Reuss) var. tenuis, Barnard & Banner, p.192, pl.8, fig.5, t.fig.4h.

1956 " " (Reuss); Said & Kenawy , p.128, pl.1, fig.53.

1957 " " (Reuss); Hofker, p.37, t.fig.21.

1960 " " (Reuss); Belford, p.19, pl.4, figs. 11-13.

1963 " " (Reuss); Graham & Church, p.18, pl.1, fig.7.

1964 " " (Reuss); McGugan, p.941, pl.150, figs.15,16.

1966 " " (Reuss); Hofker, p.20, pl.1, fig.1, pl.5, fig.17, pl.12, fig.14.

? 1966 " bulletta (Carsey); Hofker, p.87, pl.14, fig.3, pl.20, fig.19, pl.22, fig.73.

1968 " pupa (Reuss); Sliter, p.50, pl.4, fig.1.

1972 " " (Reuss); Hanzlikova, p.57, pl.12, fig.8, pl.13, figs.3,8.

? 1972 Dorothia bulletta (Carsey); Hanzlikova, p.57, pl.12, figs.4,9.
1977 " pupa (Reuss); Villain, p.43, pl.3, fig.6.

Description: Test free; conical, initially trochospiral, later biserial; cross section circular to slightly ovate; gradually and uniformly expanding; initial whorl of four to six chambers; rapidly expanding; initial whorls followed by six to ten biserially arranged chambers; gradually and uniformly expanding, often possessing an oval cross section; chambers slightly inflated, much broader than high and embracing; final pair of chambers show increase in inflation, being subglobular; sutures initially obscure, later,in biserial portion, distinct, nearly horizontal, flush to slightly depressed; aperture variable, generally extremely elongate, crescentic slit along inner suture of final chamber, may be more laterally constricted, arched slit; wall finely agglutinated; surface smooth.

Average height: 0.68 mm. Average width: 0.47 mm.

Remarks: Specimens have been compared with those hypotypes placed by Barnard & Banner in the British Museum (Nat. Hist.), numbers B.M. P41218, and were found to be conspecific. Topotype material and metatypes of D.bulletta (Carsey), deposited in the British Museum by Mrs. Plummer (B.M. no. P47555), were also examined and found to be distinct from any forms found in the present study. Those hypotypes identified by Hofker (1966) and Hanzlikova (1972) as D.bulletta, appear to be distinct from the American form and have been provisionally placed within the range of variation of D.pupa.

Occurrence: This species, originally described from the Senonian of Westphalia, Germany, has been found to range from the lowest Campanian to the upper Lower Maastrichtian.

Zonal range: B1ii - B6ii

Genus MARSSONELLA Cushman, 1933

Genotype Textularia trochus d'Orbigny, 1840

Marssonella trochus (d'Orbigny, 1840)

(Plate 2, figs. 16-19.)

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

1840 " turris d'Orbigny, p.46, pl.4, figs.27,28.

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

1899 Textularia trochus d'Orbigny; Egger, p.28, pl.14, figs.27,28.

1899 " turris d'Orbigny; Egger, p.29, pl.14, fig.29.

non 1899 Gaudryina oxycona Reuss; Egger, p.38, pl.4, figs.1,2.

? 1925 Textularia turris d'Orbigny; Franke, p.10, pl.1, fig.10.

? 1925 Gaudryina oxycona Reuss; Franke, p.15, pl.1, fig.20.

1928 Textularia trochus d'Orbigny f. typica Franke, p.130, pl.12, fig.2.

1928 " turris d'Orbigny; Franke, p.131, pl.12, fig.3.

? 1928 Gaudryina oxycona Reuss; Franke, p.143, pl.13, fig.8.

1929 " " Reuss; Cushman & Church, p.501, pl.36, figs.3,4.

1931a " " Reuss; Cushman, p.300, pl.34, fig.6.

1932 " " Reuss; Wickenden, p.205, pl.29, fig.3.

1932 " " Reuss; Sandidge, p.268, pl.41, figs.2,3.

1932 " " Reuss; Cushman & Jarvis, p.18, pl.5, figs.1,2.

1933b Marssonella oxycona (Reuss); Cushman, p.36, pl.4, fig.13.

1933 " " (Reuss); Cushman, pl.12, fig.7.

1933 " " (Reuss); Cushman, pl.8, fig.23.

1936 " " (Reuss); Jennings, p.14, pl.1, fig.11.

1937 " " (Reuss); Loetterle, p.59, pl.10, fig.7.

1937 " " (Reuss); Cushman, pp.56-59, pl.5, figs.27,29, pl.6, figs.3-12.

1943 Marssonella oxycona (Reuss); Frizzell, p.340, pl.55, fig.15.

1946 " " (Reuss); Keller, p.92, pl.1, fig.13.

1946 " " (Reuss); Schijfsma, p,38, pl.1, fig.12a,b.

1946 " " (Reuss); Cushman, p.43, pl.12, figs.3-5.

1951 " " (Reuss); Bandy, p.492, pl.72, fig.8.

1951 " " (Reuss); Visser,pp.218-9, pl.8, fig.3.

1952 " " (Reuss); de Civrien, p.257, pl.2, figs.15-16.

1953 " trochus (d'Orbigny); Barnard & Banner, p.204, t.figs. 5 o-s.

1953 " oxycona (Reuss); Hagn, p.23, pl.1, fig.28.

1953 " trochus (d'Orbigny); Hagn, p.24, pl.1, fig.30.

1954 " oxycona (Reuss); Frizzell, p.75, pl.6, fig.17.

1956 " " (Reuss); Said & Kenawy , p.127, pl.1, fig.48.

1957 " " (Reuss); Hofker, p.85, t.figs.86-90.

1957 " trochus (d'Orbigny); Hofker, pp.81-3, t.figs.82,83.

1957 " oxycona (Reuss); McGugan, pp.337-8, pl.33, fig.8.

1960 Dorothia " (Reuss); Trujillo, p.309, pl.44, fig.5.

1960 Marssonella " (Reuss); Belford, p.16, pl.4, figs.1-3.

1960 " " (Reuss); Takayanagi, pp.82-3, pl.3, fig.8.

1962 " " (Reuss); Schmid, p.322, pl.1, fig.5.

1963 " trochus (d'Orbigny); Barnard, p.44, t.figs.3a-q.

? 1963 " turris (d'Orbigny); Barnard, pp.42-3, t.figs.2a-h.

1963 " trochus (d'Orbigny); Graham & Church, p.21, pl.1, fig.6.

1964 " oxycona (Reuss); Martin, p.56, pl.3, fig.14.

1964 Dorothia oxycona (Reuss); Loeblich & Tappan, p.C275, fig.184,5a-c

1965 Marssonella oxycona (Reuss); Pozaryska, p.55, pl.2, figs.2,3.

1966 " " (Reuss); Hofker, p.35, pl.4, fig.8, pl.8, fig.16, pl.15, fig.6, pl.18, fig.33, pl.20, fig.20, pl.22, fig.70.

1966 Marssonella turris (d'Orbigny); Hofker, pl.1, fig.6.

1968 " trochus (d'Orbigny); Koch, t.fig.62.

1968 Dorothia oxycona (Reuss), Sliter, p.50, pl.3, fig.13.

1972 " trochus (d'Orbigny); Gawor- Biedowa, pp.30-1, pl.2, fig.4

1972 " turris (d'Orbigny); Gawor-Biedowa, pp.32-3, pl.2, figs.5,6.

1972 " oxycona (Reuss); Hanzlikova, p.57, pl.11, figs.8,10.

1973 Marssonella trochus (d'Orbigny); Koch, p.210, pl.18, figs.4,5.

1976 Dorothia " (d'Orbigny); Sliter, pl.1, fig.8.

1977 Marssonella oxycona (Reuss); Villain, p.43.

Description: Test free; conical, initially trochospiral becoming rapidly biserial; initially acutely pointed to broadly rounded; biserial portion varying between extremely rapidly flaring to gradually increasing with almost subparallel sides; cross section circular, occasionally ovate; initial trochospiral whorl contains four to five chambers, decreasing regularly until biserial; commonly ten pairs of biserially arranged chambers present; chambers relatively distinct, except initially, uninflated, horizontal, several times broader than high; sutures distinct, flush, occasionally slightly depressed, straight; aperture interiomarginal, broad, low slit in slight re-entrant in final chamber; final pair of chambers flat to slightly inflated; wall finely agglutinated; surface finely roughened.

Average height: 0.70 mm. Average width: 0.47 mm. ('oxycona form')

Remarks: There has been considerable confusion in the past concerning the three species M.trochus (d'Orbigny, 1840). M. turris (d'Orbigny, 1840) and M. oxycona (Reuss. 1860). From the present study it has been concluded that this is largely attributable to the fact that d'Orbigny erected his two species on specimens representing end members of one highly variable species. The picture was further confused when Reuss (1860) erected G. oxycona for more typical members of this same species. The moderately flaring '<u>oxycona</u>' variety is by far the most abundant, whilst the extreme forms, the rapidly flaring, '<u>trochus</u>' and gradually flaring '<u>turris</u>' are much more rarely encountered. A complete gradation in the degree of flaring of the test (the major distinguishing feature between these forms), has been observed in the present study and is illustrated in part in Plate 1, figs.16-19. As <u>M.trochus</u> (d'Orbigny, 1840) was the first specific name applied to this species, it is herein retained for the whole plexus, despite the unfortunate fact that it was erected on an extreme variant. It is felt that further study may possibly indicate that the variation present within this species is sufficient to allow the recognition of subspecies, viz. <u>M. trochus turris</u> and <u>M. trochus oxycona</u>, though it is unfortunate that such an arrangement, whilst taxonomically correct, places undue emphasis on the '<u>trochus</u>' form, which is most likely a rather late offshoot from the major, long ranging '<u>turris</u>' and '<u>oxycona</u>' forms.

Barnard's (1963) use of the trivial name <u>M.turris</u> for stratigraphically older forms ranging from the Cenomanian to Santonian is questioned on the grounds that <u>M.turris</u> was originally described from the Campanian.

<u>Occurrence</u>: This species originally described from the Campanian of the Paris Basin, is extremely common throughout the Campanian and Lower Maastrichtian in all the studied sections.

Zonal range: B1ii - B6ii

<u>Marssonella conoidea</u> (Marie, 1941)

(Plate 2, figs.21-23.)

1941 <u>Textularia conoidea</u> Marie, p.63, pl.2, fig.20.

1953 Textularia conoidea Marie; Hagn, p.11, pl.1, fig.8.

1963 Marssonella " (Marie); Barnard, pp.44-6, t.fig.4a-c.

Description: Test free; broadly conical, initially bluntly rounded; bullet-shaped; initially rapidly and uniformly expanding, later gently expanding, almost parallel sided; cross section circular; initial whorls obscure, trochospiral, containing three to five chambers, rapidly becoming biserial, this portion occupying 5/6 of the test; chambers low, flat, rounded peripherally, often ten to twelve pairs present; sutures distinct, depressed to slightly depressed, obscured in part by ornament; aperture broad interiomarginal slit, oval to subrectangular in shape, and often set in an extremely pronounced re-entrant in the final chamber; wall coarsely arenaceous with much spicular material, giving an extremely rough, spinose surface; spicular material often arranged in rings parallel to sutures.

Average height: 0.52 mm. Average width: 0.42 mm.

Remarks: The blunt, bullet-shaped test and characteristic spicular wall composition serve to distinguish this form from all other members of the genus. Its general form shows remarkably little variation, however, specimens in the lower Middle Campanian show a less pronounced spicular pattern and a more generally rugose surface possibly representing transitional forms between M. conoidea and M. trochus (d'Orbigny).

Occurrence: This species, originally described from the Upper Campanian of the Paris Basin, has been found in the present study only in Norfolk. It is moderately common from its first occurrence in the middle Mid-Campanian to the Campanian/Maastrichtian boundary, thereafter occurring sporadically in the lowest

Maastrichtian.

Zonal range: B2iii - B4i, B5i

Marssonella ellisorae Cushman,1936

(Plate 2, figs.20,24.)

1936 Marssonella ellisorae Cushman, p.44, pl.4, fig.11.

1937 " " Cushman; Cushman, p.60, pl.6, figs.19,20.

1946 " " Cushman; Cushman, p.44, pl.12, figs.8,9.

? 1957 " turris (d'Orbigny): Hofker, pp.83-85, t.figs.84,85.

1960 Dorothia ellisorae (Cushman); Trujillo, p.309, pl.44, fig.4.

1964 Marssonella " Cushman; McGugan, p.940, pl.150, fig.9.

1968 Dorothia " (Cushman); Sliter, p.49, pl.3, figs.12a,b.

1977 Marssonella " Cushman; Villain, p.43, pl.3, fig.3.

Description: Test free; elongate, sharply conical, initially acute, high trochospiral with four to five chambers, circular in cross section, trochospiral portion occupying approximately $\frac{1}{4}$ of test; sharp change to biserial chamber arrangement forming nearly parallel sided outline, rounded in cross section; chambers initially indistinct, low, broad, rounded on periphery, slightly inflated; initially rapidly expanding, abruptly becoming extremely gradually increasing; sutures distinct, initially flush, later slightly depressed; aperture low arch in re-entrant at base of final chamber; wall finely agglutinated; surface smooth, sometimes covered by irregularly arranged grooves, probably left by the dissolution of monaxon sponge spicules.

Average length: 0.59mm. Average width: 0.28mm.

Remarks: This species is fairly easily distinguished from other members of the genus by its slender form and sharp change to sub-parallel growth. In general form it approaches Gaudryina concinna (Reuss) from which it may be distinguished by its generally more robust form, uniform chambers, and circular cross section. Barnard (1963) refers to a tendency within M.trochus (d'Orbigny)"for long, narrow, almost cylindrical variants to occur abundantly at sporadic horizons". It is likely that this may well refer to individuals herein placed in M.ellisorae.

Occurrence: Originally described as being restricted to the Pecan Gap chalk. Sliter (1968) records its range as Turonian to Maastrichtian. In the present study it has been found in moderate numbers throughout the Campanian and lowest Maastrichtian.

Zonal range: Blii - B5i

Genus EGGERELLINA Marie, 1941

Genotype Bulimina brevis d'Orbigny, 1840

Eggerellina brevis (d'Orbigny, 1840)

(Plate 3, figs. 3,4)

1840 Bulimina brevis d'Orbigny, p.41, pl.4, figs.13,14.

1899 " " d'Orbigny; Egger, p.49, pl.15, figs.42,43.

1925 " murchisoniana d'Orbigny; Franke, p.27, pl.2, fig.22.

non 1925 " brevis d'Orbigny; Franke, p.25, pl.2, fig.18.

1928 " murchisoniana d'Orbigny; Franke, p.160, pl.14, fig.2.

1928 " trilobata Franke, p.161, pl.14, fig.26.

non 1928 " brevis d'Orbigny; Franke, p.157, pl.15, fig.12.

? 1934 " murchisoniana d'Orbigny; Cushman & Parker, p.29, pl.5, fig.7.

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

1941 Eggerellina intermedia (Reuss) var. globulosa Marie, p.33, pl.7, fig.69.

1941 ______"______ gibbosa Marie var. globulosa Marie, p.35, pl.7, fig.71.

1941 ______"______"______ Marie var. conica Marie, p.35, pl.7. fig.73.

1941 ______"______ ventricosa Marie, p.36, pl.7, fig.72.

1941 ______"______ ovoidea Marie, p.36, pl.7, fig.74.

? 1947 Bulimina brevis d'Orbigny; Cushman & Parker, p.79, pl.21, fig.3.

1947 Eggerellina intermedia (Reuss) var. globulosa Marie; Cushman, pp.18, 19, pl.3, fig.15.

1947 ______"______ brevis (d'Orbigny) var. conica Marie; Cushman, p.19, pl.3, fig.16.

1947 ______"______ gibbosa Marie var. conica Marie; Cushman, p.19, pl.4, fig.1.

1947 ______"______ gibbosa Marie var. globulosa Marie; Cushman, p.20, pl.4, fig.2.

1947 ______"______ ventricosa Marie; Cushman, p.20, pl.4, fig.3.

1947 ______"______ ovoidea Marie; Cushman, p.20, pl.4, fig.4.

1953 ______"______ gibbosa var. globulosa Marie; Barnard & Banner, p.203, pl.8, fig.12.

1953 ______"______ gibbosa var. conica Marie: Barnard & Banner, p.203, pl.8, fig.13.

pars 1957 Ataxophragmium trochoideum (Reuss); Hofker, pp.42-44, t.figs. 28,29, non.t.fig.30.

1964 Eggerellina brevis (d'Orbigny) conica Marie; Loeblich & Tappan, p.C277, fig.186, 6a,b.

1964 ______"______ intermedia (Reuss) globulosa Marie, Subbotina, p.207, pl.33, fig.8, pl.34, figs.1,2.

pars 1966 Ataxophragmium globosum (Hagenow); Hofker, p.33, pl.4, fig.10 only.

Description: This species exhibits distinct and well documented dimorphism and each form will be described independently.

i. Microspheric form: Test free, trochoid spire, conical outline, rapidly tapering, initially bluntly pointed to broadly rounded; test of three to four whorls; three chambers to each whorl except last which has only two to two and a half; final whorl shows greater inflation than earlier ones, distinctly overlapping, occupying over $\frac{1}{2}$ of the test; cross section distinctly trilobed occasionally bilobed; chambers initially indistinct, later distinct, inflated, subglobular; interior simple; sutures initially obscure, on final whorl distinct, depressed; aperture curved 'key-hole' shape often with distinct horizontal opening along interiomarginal suture and another larger virguline opening perpendicular to this, extending up apertural face of final chamber, may show extremely faint raised border; wall finely to moderately coarsely agglutinated with calcareous particles; surface smooth to slightly roughened.

Average height: 0.54 mm. Average width: 0.49 mm.

ii. Megalospheric form: Test free; subglobular, only slightly higher than wide, distinctly trilobed appearance, periphery lobate; outline variable depending on rapidity of trochospiral coil; test of two whorls, occasionally three; initial whorls extremely small represented only by short conical irregularity at base of extremely large final whorl; three chambers in final whorl, distinct, inflated, distinctly embracing, overlapping; final chamber semicircular in outline; interior simple; cross section trilobed; sutures in final whorl very distinct, depressed, slightly curved; aperture slightly curved slit extending up the apertural face, bordered by narrow indistinct lip; position of aperture variable, often central at junction of three sutures, but this varies with slight changes in the rate of trochospiral coiling; wall finely to moderately coarsely agglutinated, calcareous particles, with calcareous cement; surface generally smooth, occasionally slightly roughened.

Average height: 0.57 mm. Average width: 0.50 mm.

Remarks: E.brevis has had a somewhat confused history, despite the fact that d'Orbigny's type figures and description show all the characteristic features of this common species. In part, this confusion has been due to the variation in rate of coiling shown by this species, which governs the number of chambers visible from the summit, and the position of the aperture, features on which Marie (1941) erected a number of species. These species are all thought to fall within the range of specific variation of E.brevis.(see synonomy). Another problem has been the distinct dimorphism shown by this form. Microspheric forms have been referred to as Bulimina trilobata by Franke (1928) and to Eggerellina ovoidea, E.ventricosa and E.gibbosa var globulosa by Marie (1941), whilst the megalospheric forms have been recognised as E.gibbosa var. conica, E.brevis (d'Orbigny) var. conica and E. intermedia (Reuss) var. globulosa by Marie (1941). Rare specimens referable to all these various species and varieties have been found in the present study. Since Marie (1941) published his subdivision of this genus, many workers have referred the British forms in this morphological plexus to E.gibbosa var. globulosa Marie and E. gibbosa var. conica Marie (Barnard & Banner, 1953; Barr, MS.1962; Bailey,MS.1977). Marie (1941, p.33) considered that the distinctive feature of this species and its two varieties was an asymmetrical test, with only two chambers visible from the summit. Such a situation is extremely rare in the populations studied from the British Campanian, the more usual arrangement showing two and a half chambers when viewed from the summit. Thus the vast majority of the present forms cannot strictly be referred to E.gibbosa and its varieties, the specific characteristics of which are considered herein to lie within the range of specific variability of E. brevis.

Cushman (1934, 1946) recognised the species B. brevis d'Orbigny as a true buliminid, a pronouncement rejected by Marie (1941) and Loeblich and Tappan (1964). He also referred forms to this species from a markedly older stratigraphic level than the type horizon. It is felt that revision of these forms is required. In addition it is felt that in view of the wide range of morphological variation shown by this species, revision is also required of the closely related forms E. intermedia (Reuss, 1851) and E. (?) murchisoniana (d'Orbigny, 1840).

Occurrence: This species, originally described from the Campanian of the Paris Basin, ranges throughout the Campanian and Lower Maastrichtian, where it is moderately common.

Zonal range : B1ii - B7i

Subfamily ATAXOPHRAGMIINAE Schwager, 1877

Genus ATAXOPHRAGMIUM Reuss, 1860

Genotype Bulimina variabilis d'Orbigny, 1840

Ataxophragmium variabile (d'Orbigny, 1840)

(Plate 3, figs. 3,4)

pars 1840 Bulimina variabilis d'Orbigny, p.40, pl.4, figs.9-10, ?11, non.fig.12.

1845 " " d'Orbigny; Reuss, p.37, pl.8, figs.56, 76-7.

1891 Polyphragma variabile (d'Orbigny); Beissel, p.20, pl.4, figs.46-53.

1892 Bulimina variabilis d'Orbigny; Perner, pp.26-7, pl.13, fig.2.

1897 " " d'Orbigny; Perner, p.63, pl.7, figs.16,17.

1925 " " d'Orbigny; Franke, p.24, pl.2, fig.14.

1928 " " d'Orbigny; Franke, pp.155-6, pl.14, fig.9.

1931b Ataxophragmium variabilis (d'Orbigny); Cushman, p.38, pl.5, fig.6.

1934 " variabile (d'Orbigny); Cushman, p.28, pl.5, figs.2-4.

1936 " compactum Brotzen, pp.44-6, t.fig.8, pl.2, figs.3,10.

pars 1937 " variabile (d'Orbigny); Cushman, p.175, pl.21, figs.10,11,?13.

1941 Ataxogyroidina variabilis (d'Orbigny); Marie, p.56, pl.4, figs. 41,42, pl.5, figs.43,44,47.

1941 " cylindrica Marie, p.57, pl.5, fig.46.

1941 " ovoidea Marie, p.57, pl.5, fig.40.

1941 " concava Marie, p.58, pl.5, fig.45.

1941 " gibbosa Marie, p.58, pl.5, fig.49.

? 1946 " dufouri Schijfsma, p.37, pl.1, fig.9.

? 1946 " pseudoglobosa Schijfsma, p.37, pl.1, fig.11.

1947 " cylindrica Marie; Cushman, p.61, pl.6, fig.3.

1947 " ovoidea Marie; Cushman, p.62, pl.3, fig.9.

1947 " concava Marie; Cushman, p.62, pl.6, fig.2.

1947 " gibbosa Marie; Cushman, p.62, pl.6, fig.4.

1951 Ataxophragmium variabile (d'Orbigny); Noth, p.39, pl.5, fig.5.

1953 Ataxogyroidina variabilis (d'Orbigny); Barnard & Banner, pp.205-6, pl.9, fig.6, t.fig.7.

1953 Ataxophragmium variabile (d'Orbigny); Hagn, p.30, pl.2, fig.12.

1953 " compactum Brotzen; Hagn, p.29, pl.2, fig.14.

1957 Orbignyna sp. ; McGugan, pl.35, fig.33.

pars 1957 Ataxophragmium crassum (d'Orbigny); Hofker, p.39, t.fig.23-27.

pars 1957 " ruthenicum (Reuss); Hofker, pp.47-48, t.fig.37,38 c-g, non.t.fig.36,38a-d.

pars 1957 Orbignyna variabilis (d'Orbigny); Hofker, p.50, t.fig.40.

? 1960 Pernerina Redbankensis Olsson, p.8, pl.1, figs.22,23.

1961 Ataxophragmium compactum Brotzen; Vasilenko, p.26, pl.4, figs.4,6.

1964 " " Brotzen; Krivoborskii in Subbotina et al. p.214, pl.34, figs.6,7, pl.38, figs.5-9.

1964 " variabile (d'Orbigny); Loeblich & Tappan, pp.C283-4, fig.191,(1,2.)

1972 " compactum Brotzen; Hanzlikova, p.60, pl.13, fig.5.

1977 " " Brotzen; Jørgensen, p.313, pl.1, figs.4,5.

Description: Test free; loosely to tightly coiled helical spiral of two to three whorls, markedly overlapping; test subglobular to elongate; outline highly variable; chambers reniform, generally much broader than high; last chamber overlaps onto previous whorl; sutures flush to slightly depressed; apertural face often flat especially in young specimens, whilst geriontic individuals may possess overlapping, inflated last chamber; aperture highly variable, ranging from a simple semicircular opening on the inner margin of the final chamber to a very narrow, straight, elongate slit extending half way up apertural face; interior is most commonly simple, but some specimens show well developed internal pillars, especially in the final chamber; wall structure finely agglutinated, calcareous; surface generally smooth, occasionally slightly rugose.

Average height: 0.72mm. Average width: 0.62mm.

Remarks: Confusion has surrounded this species since it was first described (d'Orbigny 1840). This may, in part, be attributable to the highly stylized figures, which show a wide variation in form. In the text , also, d'Orbigny described the wide range of variation shown by this species, but, many later workers - including Marie (1941) and Loeblich & Tappan (1964) - have regarded d'Orbigny's figured types as including forms referrable to more than one genus. Loeblich & Tappan (1964) erected a lectotype based on d'Orbigny's figures (pl.4, figs. 9 & 10.) on the basis that he referred to this as a regular individual. Marie (1941), referring the other figured specimens to the genus Orbignyna, proposed Ataxogyroidina as a new generic name for the " regular individuals ", but as he designated Bulimina variabilis d'Orbigny as the type species, Ataxogyroidina is a junior synonym of Ataxophragmium.

The wide range of variation shown by this species has led some workers to subdivide the taxon, i.e. Brotzen (1936) and Marie (1941). As the new forms proposed by them have a similar stratigraphic range, and numerous intermediate forms between them and A.variabile occur, they are herein considered to lie within the range of its admittedly large specific variation. There has also been considerable confusion concerning the internal characters of this species. In his original designation of Ataxogyroidina (genotype B.variabilis) Marie (1941) stated that internal buttresses were more or less well developed near the suture lines. Although recognising the generic name Ataxogyroidina, Barnard & Banner (1953) stated that A. variabile had a simple interior and that the forms with internal partitions should be referred to juvenile specimens of Arenobulimina. As stated by Loeblich & Tappan (1964), this conclusion was directly contrary to features shown by the respective type species. In the present study, specimens from a single population, though often possessing simple interiors, occasionally show well developed internal supports as described by Marie. Following Gawor Biedowa (1969), Owen (MS. 1970) and Carter and Hart (1977), both Arenobulimina and Ataxophragmium are here regarded as possessing either simple or buttressed interiors, features which may well be ecologically or ontogenetically controlled and hence of less importance taxonomically than was considered by Loeblich & Tappan (1964). Such a situation therefore suggests that a revision of the taxonomic status of both these genera is required.

Occurrence: Originally described from the Campanian of the Paris Basin and widely recorded from the Senonian of Europe. A.variabile ranges throughout the Campanian and Lower Maastrichtian. It is common in all the studied sections.

Zonal range: Blii - B7i

Ataxophragmium crassum (d'Orbigny, 1840)

(Plate 3, figs. 7,8)

1840 Rotalina crassa d'Orbigny, p.32, pl.3, figs.7-8.

? 1928 Haplophragmoides crassa (d'Orbigny); Franke, p.171, pl.15, fig.16.

1941 Ataxogyroidina crassa (d'Orbigny); Marie, p.59, pl.6, figs.59-60.

1946 " " (d'Orbigny); Schijfsma, p.36, pl.1, fig.11.

1953 Ataxophragmium crassum (d'Orbigny); Hagn, p.29, pl.2, fig.13.

non 1957 " " (d'Orbigny); Hofker, pp.39-42, t.figs.22-27.

1964 Ataxophragmoides crassus (d'Orbigny); Subbotina, p.213, pl.34, fig.4, pl.36, figs.5-8, pl.37, figs.1-5, pl.38, figs.1-4.

1973 Ataxophragmium crassum (d'Orbigny); Koch, p.210, pl.18, fig.6.

Description: Test free; asymmetrical low trochospiral coil with a tendency to become planoconvex; two whorls composed of six chambers, embracing, evolute coil; chambers slightly inflated especially the last, distinct, somewhat obscured by surface agglutination, uniformly and moderately rapidly expanding, much higher than broad; last chamber overlaps previous whorl both dorsally and ventrally possessing pronounced lobes; interior simple; sutures indistinct flush to slightly depressed; apertural face flattened; aperture a characteristic broad subrectangular interiomarginal opening almost as high as wide; wall structure moderately coarsely arenaceous with siliceous grains set in a calcareous matrix; surface rugose occasionally showing randomly arranged longitudinal grooves as in A.rimosa (Marsson).

Remarks: It should be noted that the use of the trivial name " crassum" for this species of Ataxophragmium is based on the usage of Marie (1941). It is possible that d'Orbigny's (1840) reference to Rotalina crassa may have represented a truly calcareous, non-agglutinated form as it shows a spiral umbilical extension of the aperture, only examination of the relevant type material can determine this however.

This species is similar to A.mariae sp. nov. in general form. It may be easily distinguished, however, by its more rapidly expanding trochospire, its shorter, higher aperture, bordered by more pronounced lobes, and its more coarsely arenaceous test with rough surface. It differs from A.rimosa (Marsson, 1878) in its less well developed surface pattern of longitudinal grooves, its general form and its apertural characteristics.

Occurrence: This species has been found sporadically in the Upper Campanian both of Norfolk and the Isle of Wight.

Zonal range: B3ii - B4i

Ataxophragmium mariae sp. nov.

(Plate 3 , figs. 9,10)

Derivation of Name: In honour of P.Marie who first described this form.

1941 Ataxogyroidina globosa (von Hagenow); Marie, p.59, pl.5, figs.50-7.

pars 1966 Ataxophragmium globosum (Hagenow); Hofker, p.33, pl.4, fig.9. (non. pl.4, fig.10)

1977 " " (von Hagenow); Villain, p.43, pl.4, figs.2,3.

Diagnosis: A species of Ataxophragmium with a regular, low trochospiral chamber arrangement, tendency to planoconvex form, subrectangular, interiomarginal aperture and smooth surface.

Description: Test free; asymmetrical low trochospiral coil with a tendency to planoconvexity, occasional forms subspherical; two, occasionally three whorls, embracing, overlapping, evolute; chambers indistinct, moderately and uniformly increasing in size, may be slightly inflated, six per whorl, several times higher than broad; last chamber often overlaps previous whorl both dorsally and ventrally; sutures distinct, flush; apertural face flat, making angle of approximately 65° with previous whorl; aperture a deep, elongate, subrectangular slit along interiomarginal suture of last chamber, may show partial development of central lobe; interior most often simple, occasional forms show development of sutural buttresses; wall finely agglutinated with much calcareous cement; surface smooth.

Average height: 0.74 mm. Average width: 0.65 mm.

Remarks: Marie (1941) originally described this rather distinctive species of Ataxophragmium, noting in particular its characteristic form and aperture. However he referred it to Nonionina globosa Hagenow (1842), a form described, though never figured, from the Upper Cretaceous. Later workers, including Reuss (1861), Marsson (1878), Franke (1925, 1928), Cushman (1931), Schijfsma (1946) and Visser (1951), have all considered N.globosa to be calcareous, perforate, and it is herein considered to belong to the genus Gyroidinoides. The present form A. mariae is broadly similar in shape but its wall character and aperture serve clearly to distinguish it. Schijfsma (1946) noted the above situation and erected Ataxogyroidina pseudoglobosa and included forms referred by Marie to A. globosa in its synonymy. From his figures and descriptions, however, it is clear that A.pseudoglobosa Schijfsma, 1946 is not conspecific with Marie's species nor with the forms herein described, lacking as it does the characteristic form, aperture and smooth surface.

Occurrence: Ranging upwards from the base of the middle Upper Campanian on the Isle of Wight, where it is moderately common. In Norfolk found to range from the top of the middle Upper Campanian upwards. Rare to moderately frequent.

Zonal range: B3ii - B7i

Ataxophragmium rimosum (Marsson, 1878)

(Plate 3, figs. 11, 12)

1878 Bulimina rimosa Marsson, p.153, pl.3, fig.21.

1925 " " Marsson; Franke, p.23, pl.2, fig.13.

1928 " " Marsson; Franke, p.155, pl.14, fig.8.

1934 Ataxophragmium rimosum (Marsson); Cushman & Parker, p.32,pl.6, figs.3-5.

1937 Ataxophragmium rimosum (Marsson); Kalinin, p.23, pl.2, figs.20,21.

pars 1956c Orbignyna rimosa (Marsson); Hofker, p.16, fig. 3c, non. figs. 3a, 3b.

? 1964 Ataxophragmoides rimosum (Marsson); Subbotina, pl.39, figs.1-3, pl.40, figs.3-5, pl.41, figs.1-2.

1965 Orbignyna rimosa (Marsson); Pozaryska, p.59, pl.1, fig.3.

pars 1966 " " (Marsson); Hofker, p.87.

pars 1977 " " (Marsson); Villain, pp.42-3.

1977 Ataxophragmium rimosum (Marsson); Jørgensen, p.313, pl.1, figs.10,12.

Description: Test free; subspherical, tightly coiled in helical spiral; two or three whorls markedly overlapping; chambers obscured by ornamentation, wider than high; sutures flush; last chamber overlapping onto previous whorl, generally reniform inflated, occupying one third of test; apertural face flattened; aperture variable from simple semicircular opening on the inner margin of the final chamber to a narrow slit extending up apertural face; interior most often simple, sometimes developing partial buttresses along sutures; wall coarsely arenaceous; surface covered with very distinct grooves, occasionally in a subparallel arrangement and parallel to the test surface.

Average height: 0.60 mm. Average width: 0.60 mm.

Remarks: There is less variation in shape, chamber arrangement and apertural characteristics in this form than in A. variabile. The distinctive surface sculpturing serves to distinguish this species from all other members of the genus. The work of Jørgensen (1977), has indicated that the pattern of grooves may have developed by the dissolution of metastable monaxon sponge spicules. Both Jørgensen

(1977) and Loeblich & Tappan (1964), state that such agglutinated sponge spicules are common in both recent and fossil forms. Hofker (1956c) has taken this distinctive form of agglutination to be of specific value, and suggested that the present species is one form of a species exhibiting marked trimorphism and recognisable almost solely by its agglutinating habit. Such a species is stated to include forms commonly referred to the genera Ataxophragmium, Plectina and Orbignyna. Hofker regarded Orbignyna ovata Hagenow, 1842, as another ' form ' to be assigned to the present species. In the present study no'Plectina form' has been found, and the marked differences in the ranges of A. rimosum and O.ovata cast severe doubt on such a relationship. Thus the case for trimorphism in these two species is taken to be unproven. The generic assignment to Ataxophragmium is maintained.

Occurrence: Rare forms of this species have been found in the Upper Campanian, however, it only becomes abundant in the Lower Maastrichtian.

Zonal range: B3, B4, B5i - B7i

Genus ORBIGNYNA von Hagenow, 1842

Genotype Orbignyna ovata von Hagenow, 1842

Orbignyna ovata von Hagenow, 1842

(Plate 3, figs 13,14)

1842 Orbignyna ovata von Hagenow, p.573, pl.9, fig.26.

1861 Haplophragmium ovatum (von Hagenow); Reuss, p.328, pl.5, figs.8,9.

1878 Lituola ovata (von Hagenow); Marsson, p.171, pl.5, fig.40.

1925 Lituola ovata (von Hagenow) f.ruegensis Franke, p.82, pl.7, fig.5.

1928 " " (von Hagenow) f.ruegensis Franke, p.172, pl.15, fig.18.

1937 Orbignyna ovata von Hagenow; Cushman, p,180, pl.21, figs.23-29.

1941 " " von Hagenow var. ruegensis Franke; Marie, p.25, pl.1, fig.9.

1941 " " von Hagenow var. conica Marie, p.25, pl.1, fig.10.

1947 " " von Hagenow var. conica Marie; Cushman, p.63, pl.6, fig.5.

1953 " " von Hagenow; Barnard & Banner, p.200, pl.9, fig.7.

non 1956c " " von Hagenow; Hofker, p.16, fig.2.

1957 " " von Hagenow; McGugan, pl.34, fig.1-3.

pars 1957 " " von Hagenow; Hofker, pp.51-53, t.figs.42-45 non.t.fig.41.

1964 " " von Hagenow; Loeblich & Tappan, pp.C289-290, figs. 195-7.

non 1966 " " von Hagenow; Hofker, pp.34, 50, pl.4, fig.4, pl.7, figs.10-14.

pars 1977 " rimosa (Marsson); Villain, pp.42,43, pl.3, fig.10.

Description: Test free; early stage rounded, planispiral coil becoming more evolute until last chambers partially uncoiled, compressed; generally five to six planispirally coiled chambers followed in adult individuals by one or two uncoiled chambers; cross section subcircular; initial chambers overlap strongly on the inner coiled margin, uninflated, obscure, uniformly and quite rapidly expanding; internally divided by radial, vertical partitions;sutures initially indistinct, later distinct, depressed, curved, irregularly crenulate; apertural face weakly inflated, subcircular outline in uncoiled portion; aperture in depression, simple terminal pit, circular to elliptical; wall coarsely agglutinated including many longitudinal grooves, produced by the agglutination and subsequent dissolution of monaxon sponge spicules; surface extremely rough.

Average height: 0.89mm. Average width: 0.67mm.

Remarks: The similarity in the character of agglutination between this species and Ataxophragmium rimosum has led Hofker (1956c) to suggest the two are in fact different forms of the same species. Such an interpretation is not followed herein. (See remarks under A. rimosum). This species shows a marked increase in size up the stratigraphic column, culminating in a maximum in the lowest Maastrichtian.

Occurrence: Rare forms found in the Campanian, becoming especially common in the Lower Maastrichtian.

Zonal range: B3i - B7i

Genus VOLOSHINOVELLA Loeblich & Tappan, 1964

Genotype Lituola aequisgranensis Beissel, 1886

Voloshinovella aequisgranensis (Beissel, 1891)

(Plate 3 , figs. 15 - 17)

? 1840 Bulimina variabilis d'Orbigny, p.40, pl.4, fig.12, non.pl.4, figs. 9-11.

? 1886 Lituola aequisgranensis Beissel, p.138, no.fig.

1891 " " Beissel; Beissel, p.12, pl.3, figs.1-16.

1910 Haplophragmium inflatum (Reuss); Heron-Allen & Earland, p.405, pl.6, figs.4,8.

1928 Haplophragmium aequisgranensis (Beissel) f. typica Franke, p.172, pl.15, fig.22.

1937 Orbignyna aequisgranensis (Beissel); Cushman, p.182, pl.21, figs.31,32.

1941 " variabilis (d'Orbigny); Marie, p.26, pl.6, figs.61-65.

1951 " aequisgranensis (Beissel); Visser, p.221, pl.8, fig.5.

1953 " typica (Franke); Barnard & Banner, pp.200-201, pl.9, fig.8.

? 1953 " aequisgranensis (Beissel); Barnard & Banner, pp.199-200, pl.9, fig.10.

pars 1957 " " (Beissel); Hofker, pp.53-56, t.figs. 46a-c, 47-50, non.t.fig.51

1964 Voloshinovella " (Beissel); Loeblich & Tappan, p.C291, fig.198, 1-6.

pars 1977 Orbignyna variabilis (d'Orbigny); Villain, p.42, pl.3, fig.9 only.

Description: Test free; initially planispiral rapidly becoming loosely planispiral and then uniserial, uncoiled; broadly rounded initially; planispiral portion containing about six chambers, followed by two to three uncoiled chambers only slightly embracing; chambers in uncoiled portion increase only very slowly to give subparallel outline; cross section more or less circular; chambers drum-shaped, wider than high; sutures distinct, limbate, flush, oblique becoming nearly horizontal; distinct chamber overlap gives impression of depressed sutures; chambers becoming increasingly inflated so that apertural face generally domed; aperture terminal, simple irregular circular opening in central part of final chamber; chamber interiors with ten to fifteen radial, vertical partitions extending from periphery to fuse with a ring below aperture; wall finely to moderately coarsely arenaceous with calcareous cement; surface smooth to slightly roughened.

Average height: 0.70mm. Average width: 0.40mm.

Remarks: The uncoiled test, distinct linear sutures and smoother surface serve to distinguish this form from the closely related O. ovata; indeed a case could be made for the inclusion of this form within the genus Orbignyna. Loeblich and Tappan (1964) distinguished Voloshinovella solely by its uncoiling growth form and rounded cross section.

Many workers (eg. Beissel,1891; Franke, 1928 and Loeblich and Tappan, 1964), have either described or figured rapidly flaring conical varieties of this species, however, these forms have not been found in the present study. Barnard and Banner (1953), raised the 'typica' form of Franke (1928) to specific rank and used it to cover the present forms whilst retaining the trivial name 'aequisgranensis' for the conical, flaring forms. As Franke's 'typica' form is indeed typical of Beissel's original concept of the species O. typica is a junior synonym of V. aequisgranensis. It is possible that the 'conica' form is indeed a distinct species, in which case it is this name that should be raised to specific rank. No references to the work of Hofker (viz. 1956c, 1966) on the genus Orbignyna have been included in the synonymy of this form, as it is felt that his concept of the 'trimorphic' status of the genus together with the variety of species he recognised, necessitates revision before their exact relationship to the present form can be accurately determined. Marie (1941) recognised that d'Orbigny had included an Orbignyna like form in his original figures of Bulimina variabilis. (See remarks under that species). It is possible that that form should be included in the present species.

Occurrence: Common in the Isle of Wight, ranging upwards from the base of the middle Upper Campanian. In Norfolk the species has been found very rarely in the Upper Campanian and Lower Maastrichtian.

Zonal range: B3ii - B5ii

Suborder ROTALINA Delage & Hérouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Remarks: Initial study of members of the superfamily NODOSARIACEA has revealed the presence of approximately 68 species amd subspecies within the Campanian and Maastrichtian strata of the United Kingdom. These taxa commonly exhibit a wide range of morphological variation, often resulting in considerable taxonomic confusion. Their fragile nature and long stratigraphic ranges severely reduce their biostratigraphic potential. For these reasons, the author has herein considered only those taxa within the superfamily Nodosariacea of proven biostratigraphic value.

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIACEA Ehrenberg, 1838

Genus NEOFLABELLINA Bartenstein, 1948

Genotype Flabellina rugosa d'Orbigny, 1840

Neoflabellina rugosa rugosa (d'Orbigny, 1840)

(Plate 4, fig. 1)

1840 Flabellina rugosa d'Orbigny, p.23, pl.2, figs.4,5,7.

non 1845 " " d'Orbigny; Reuss, p.33, pl.8, figs.31-34, 68, pl.13, figs.49-53.

? 1858 " interpuncta von der Marck, p.53, pl.1, fig.5.

1910 Flabellina interpuncta von der Marck; Heron-Allen & Earland, p.422, pl.8, fig.5.

non 1910 ____"____ rugosa d'Orbigny; Heron-Allen & Earland, p.422, pl.8, fig.7.

1925 ____"____ interpuncta von der Marck; Franke, p.64, pl.5, fig.13.

non 1925 ____"____ rugosa d'Orbigny; Franke, p.64, pl.5, fig.12.

1928 ____"____ interpuncta von der Marck; Franke, p.92, pl.8, fig.17.

non 1928 ____"____ rugosa d'Orbigny; Franke, p.92, pl.8, fig.18.

non 1930b ____"____ " d'Orbigny; Cushman, pp.32-3, pl.4, fig.15.

non 1931a ____"____ " d'Orbigny; Cushman, p.307, pl.35, fig.10.

non 1931 ____"____ " d'Orbigny; Plummer, p.166, pl.12, fig.4.

non 1932 ____"____ " d'Orbigny; Sandidge, p.279, pl.42, fig.22.

1936 ____"____ " d'Orbigny; Brotzen, pp.107-8, t.fig.35.

1940 ____"____ caesata Wedekind, p.199, pl.9, figs.8-10.

1940 ____"____ sphenoidalis Wedekind, pp.196-7, pl.9, figs.16-23, pl.11, fig.5.

? 1940 ____"____ deltoidea mut. pachydisca Wedekind, p.186, t.figs.3,4.

1941 ____"____ rugosa d'Orbigny; Marie, p.137, pl.17, figs.193-4.

pars 1946 Palmula ____"____ (d'Orbigny); Cushman, p.83, pl.31, figs.9-16. non. fig.17.

1946 ____"____ " (d'Orbigny); Schijfsma, pp.48-50, pl.3, fig.4.

? 1953 Neoflabellina rugosa (d'Orbigny); Hagn, pp.57-60, pl.5, fig.12.

1954 ____"____ " (d'Orbigny); Pozaryska, p.261, fig.17.

pars 1954 ____"____ " (d'Orbigny); Frizzell, p.97, pl.12, fig.16, non. fig.15.

pars 1957 ____"____ " (d'Orbigny); McGugan, p.338, pl.31, figs.9-11, non.fig.8.

1957 ____"____ " (d'Orbigny); Hiltermann & Koch, p.274, t.fig.1, figs.7-14.

1958 ____"____ " (d'Orbigny); Witwicka, pl.8, fig.5, 1958 Neoflabellina rugosa (d'Orbigny); Bieda, pp27-8, t.fig.2.

1962 ______"__________"___ (d'Orbigny); Hiltermann, p.308, pl.48, figs.13-15.

1964 ______"__________"___ (d'Orbigny); McGugan, p.942, pl.150, figs.18,19.

1964 ______"__________"___ (d'Orbigny); Loeblich & Tappan, p.C522, fig.407-6.

1964 ______"__________"___ (d'Orbigny); Martin, p.72, pl.7, fig.9.

1968 ______"__________"___ (d'Orbigny); Sliter, pp71-2, pl.8, fig.21.

1972 ______"______ ex. gr. rugosa (d'Orbigny); Hanzlikova, p.71, pl.17, fig.7.

1975 ______"______ rugosa sphenoidalis (Wedekind); Koch, p.210, pl.1, fig.7.

? 1975 ______"__________"___ caesata (Wedekind); Koch, p.210, pl.1, fig.8

? 1977 ______"__________"__________"___ (Wedekind); Koch, p.46, pl.16, fig.3.

1977 ______"__________"___ sphenoidalis (Wedekind); Koch, p.45, pl.16, fig.2.

1977 ______"__________"___ (d'Orbigny); Koch, p.45, pl.16, fig.4.

Description: Test free; palmate, compressed, greatest width more or less close to the base, sides flattened, parallel, with angular to slightly carinate margins; initial end broadly rounded; chambers initially coiled, rapidly becoming uncoiled, chevron shaped, strongly overlapping, narrow, and of approximately constant width, increasing uniformly and moderately in size; sutures distinct, raised, thickened, slightly curved; aperture terminal, subcircular to circular, at end of short neck; wall calcareous, perforate; surface between raised sutures ornamented by one to two rows of, more or less, distinct raised papillae.

Average height: 1.1 mm. Average width: 0.5 mm.

Remarks: The slightly elongate, palmate form and raised papillate ornament are characteristic of this species. Cushman (1946), after a study of topotypic material, noted the synonymous relationship of N. rugosa rugosa and N. interpuncta (von der Marck, 1858). Wedekind (1940) erected a number of species, eg. N. caesata and N. sphenoidalis which are clearly closely related to N. rugosa rugosa, and Koch (1977) has recognised them as subspecies of N. rugosa. Loeblich and Tappan (1964) erected and figured a lectotype of N. rugosa, though they give little information as to its type horizon and locality; d'Orbigny (1840) originally described N. rugosa from the Lower and Upper Campanian of the Paris Basin. After consideration both of morphological and stratigraphic variation within this species the present author does not feel that the maintenance of N. rugosa caesata and N. rugosa sphenoidalis as subspecies is justified. N. rugosa rugosa may be distinguished from N. rugosa leptodisca Wedekind, 1940 by its more elongate form and less well developed ornament.

Occurrence: This fragile species occurs sporadically in the Lower, Middle and Upper Campanian both in the Isle of Wight and Norfolk.

Zonal range: B1ii - B4i

Neoflabellina rugosa leptodisca (Wedekind, 1940)

(Plate 4, figs. 2,3)

1932 Flabellina interpuncta von der Marck; Sandidge, p.279, pl.42, fig.21.

1940 " leptodisca Wedekind, p.200, pl.9, figs.11-15.

pars 1946 Palmula rugosa (d'Orbigny); Cushman, p.83, pl.31, fig.17, ? figs. 9-16.

1952 Neoflabellina rugosa leptodisca (Wedekind); Hiltermann, t.fig.3, figs.32-6.

pars 1954 Neoflabellina rugosa (d'Orbigny); Frizzell; p.97, pl.12, fig.15, non.fig.16.

1955 " " leptodisca (Wedekind); Hiltermann & Koch, p.354-5.

pars 1957 " " (d'Orbigny); McGugan, p.338, pl.31, fig.8, non.figs.9-11.

non 1972 " leptodisca (Wedekind); Hanzlikova, p.70, pl.17, figs.1,2.

? 1975 " rugosa leptodisca (Wedekind); Koch, p.210, pl.1, fig.6.

1977 " " " (Wedekind); Koch, p.45, pl.16, fig.1.

Description: Test free; broadly palmate to deltoid outline, compressed, greatest width close to base; sides flattened, parallel, with angular to carinate margins; initial end broadly rounded; chambers initially coiled, becoming rapidly uncoiled, strongly overlapping chevron shaped, narrow, of approximately constant width, increasing uniformly and moderately rapidly; sutures distinct, raised, slightly curved; aperture terminal, subcircular to circular on short neck; wall calcareous, perforate; surface between sutures strongly ornamented by two to three rows of distinct raised papillae, which may coalesce on the last chambers of the stratigraphically youngest forms into short ridges, perpendicular to the sutures.

Average height: 0.97 mm. Average width: 0.53 mm.

Remarks: N. leptodisca was originally described from the Upper Campanian of Westphalia, Germany (Wedekind, 1940), but has been regarded as a subspecies of N. rugosa by many later workers. N. rugosa leptodisca may be distinguished from N. rugosa rugosa by its broader palmate test, showing a tendency to become deltoid, and by its much more strongly developed ornament.

Occurrence: This form ranges throughout the Upper Campanian, where it is more abundant than *N.rugosa rugosa*. Transitional forms between *N.rugosa leptodisca* and *N. praereticulata* Hiltermann,1952 occur in the uppermost Campanian.

Zonal range: B3i - B4i

Neoflabellina baudouiniana (d'Orbigny, 1840)
(Plate 4, fig. 4)

1840 *Flabellina baudouiniana* d'Orbigny, p.24, pl.2, Figs.8-11.

1845 " " d'Orbigny; Reuss, p.32, pl.8, fig.36.

1910 " " d'Orbigny; Heron-Allen & Earland, p.422, pl.8, fig.4.

1925 " " d'Orbigny; Franke, pp.63, 65, pl.5, fig.15.

1928 " " d'Orbigny; Franke, p.94, pl.8, fig.16.

1940 " " d'Orbigny: Wedekind, pp.180-1, t.fig.2.

1954 *Neoflabellina* " (d'Orbigny); Pozaryska, pp.262-3, t.fig.10.

1957 *Palmula* " (d'Orbigny); Pozaryska, p.165, pl.27, fig.3.

1958 *Neoflabellina* " (d'Orbigny); Witwicka, pl.8, fig.1.

1958 " " (d'Orbigny); Bieda, pp. 26-7, t.fig.1.

1970 " " (d'Orbigny); Porthault, in Donze et al., p.54, pl.8, fig.6.

1970 " aff. *baudouiniana* (d'Orbigny); Porthault, in Donze et al., p.54, pl.8, fig.9.

Description: Test free; palmate to elongate, only slightly compressed, initially planispirally coiled, slowly becoming uncoiled; chamber shape arcuate, curved, becoming several times broader than high and moderately thick, with carinate edges; sutures distinct, raised, thickened and curved, initially may be formed of discreet elongate ridges rapidly coalescing into continuous ridges; aperture terminal, at end of distinct short neck; wall calcareous, perforate; surface between sutures generally smooth occasionally showing extremely sparsely distributed papillae.

Average height: 0.70 mm. Average width: 0.35 mm.

Remarks: Originally described from the Lower Campanian of the Paris Basin (Sens). This species shows a wide range of morphological variation. Geriontic (?) individuals often show a more elongate form with increased ornament. These forms were separated by Porthault (1970) as N. aff. baudouiniana. This species also shows considerable variation in the nature of sutural ridges, ornamentation and chamber shape.

Occurrence: Ranging throughout the Lower, Middle and lower Upper Campanian of the Isle of Wight and Norfolk.

Zonal range: Blii - B3i

Neoflabellina buticula Hiltermann, 1952

(Plate 4, fig. 5)

1952 Neoflabellina buticula Hiltermann, pp.53-5, fig.58.

1954 ______"__________"____ Hiltermann; Pozaryska, p.262, fig.19.

1955 ______"__________"____ Hiltermann; Hiltermann & Koch, p.373, pl.28, fig.10.

1958 Neoflabellina buticula Hiltermann; Witwioka, pl.8, fig.2.

1958 " " Hiltermann; Bieda, pp.31-2, t.fig.5.

1962 " " Hiltermann; Hiltermann & Koch, p.310, pl.50, fig.10.

1969 " " Hiltermann; Medizza, p.32, pl.2, fig.14.

1977 " " Hiltermann; Koch, p.53, pl.3, fig.58.

Description: Test free; palmate, often irregular, test only moderately compressed, greatest width towards base, sides flat with sharp carinate edges; initial end broadly rounded; chambers initially coiled becoming only gradually uncoiled, finally chevron shaped; increasing moderately and uniformly in size; chambers relatively broad and thick, slightly curved; sutures raised to slightly raised, slightly curved and irregular; aperture terminal, broad, subcircular at end of short neck; relict apertures irregular; wall calcareous, perforate; surface between sutures smooth, in initial coiled portion may show sparse, irregular papillate ornamentation.

Average height: 0.55 mm. Average width: 0.40 mm.

Remarks: The 'box-like' form, slowly uncoiling chamber arrangement, apertural characteristics and smooth test serve to distinguish this species.

Occurrence: Ranging throughout the middle and upper Upper Campanian, rare. Koch (1977) records a similar range from N.W. Germany, and Medizza (1969) records N.buticula from the Upper Campanian of Italy.

Zonal range: B2i - B3iv

Neoflabellina permutata Koch, 1977

(Plate 4, fig.6)

1962 *Neoflabellina* n. sp., aff. *numismalis* (Wedekind); Hiltermann & Koch, p.311, pl.50, fig.11.

1977 ________"________ *permutata* Koch, pp.55-6, pl.17, figs.1-3.

Description: Test free; broadly palmate, test somewhat compressed; greatest width towards mid-point of test; sides almost flat, parallel, with angular, carinate edges; initial end broadly rounded, keeled; chambers initially coiled, becoming uncoiled, chevron shaped, overlapping; increasing rapidly and uniformly in size; chambers relatively broad and strongly curved; sutures raised especially medianly, strongly curved;aperture terminal subcircular on short neck, relict apertures closed becoming markedly irregular in latest chambers; wall calcareous, perforate; surface between sutures ornamented by numerous somewhat irregular papillae.

Average height: 0.84mm. Average width: 0.62mm.

Remarks:The broadly palmate shape, gracefully curved outline, initial coil bordered by broad thickened keel and strongly papillate surface, all serve to distinguish this species from the morphologically similar *N. rugosa*. Koch (1977) recorded the species from the uppermost Campanian and Maastrichtian of N.W.Germany.

Occurrence: Rare, restricted to the Lower Maastrichtian in Norfolk.

Zonal range: ?B4i, B5i - B5ii

Neoflabellina praereticulata Hiltermann, 1952

(Plate 4, figs. 7,8)

1952 Neoflabellina praereticulata Hiltermann, p.53, t.fig.3, fig.37.

1954 " " Hiltermann; Pozaryska, p.260, fig.16.

1955 " " Hiltermann; Hiltermann & Koch, pp.371-2, t.fig.7a-e, pl.28, fig.11, pl.29, fig.9.

1956b " " Hiltermann; Hofker, p.80, figs.43,76,77.

1957 " " Hiltermann; Hofker, p.146, t.figs.171-2.

1957 " " Hiltermann: McGugan, p.338, pl.31, figs.3-7.

1957 " " Hiltermann; Pozaryska, p.161, pl.26, fig.9.

1958 " " Hiltermann; Bieda, pp.28-9, t.fig.3.

1960 " " Hiltermann; Belford, p.43, pl.12, figs.7,8, t.fig.2.

1962 " " Hiltermann; Hiltermann & Koch, p.308, pl.50, fig.12.

1977 " " Hiltermann; Koch, pp.57-8, pl.14, figs.11,12.

Description: Test free; palmate, compressed, greatest width close to base, sides flat, parallel with angular to carinate edges; initial end broadly rounded; chambers initially coiled, uncoiling rapidly, chevron shaped, strongly overlapping; increasing uniformly and moderately in size; sutures distinct, raised, slightly crenulated and curved; aperture terminal, subcircular on slightly elongate neck; wall calcareous, perforate; surface between sutures strongly ornamented by numerous short ridges perpendicular to sutures and irregularly subparallel, often not touching sutures; ornament on earliest chambers nodose.

Average height: 1.0mm. Average width: 0.55mm.

Remarks: This species is characterized by its markedly irregular reticulate ornament. On the earliest chambers, especially in stratigraphically older populations, the nodose, papillate ornament suggests that this species may be phylogenetically descended from N. rugosa leptodisca. Stratigraphically younger forms of N. praereticulata develop an increasingly regular reticulate ornament on all chambers eventually giving rise to N. reticulata (Reuss, 1851)

Occurrence: Ranging from the upper Upper Campanian to the lower Lower Maastrichtian. An identical range is recorded by Koch (1977) from N.W. Germany.

Zonal range : B3iv - B5i

Neoflabellina reticulata (Reuss, 1851)
(Plate 4, fig. 9)

1851 Flabellina reticulata Reuss, p.30, pl.2, fig.22.
1891 " favosa Beissel, p.49, pl.19, figs.25-28, pl.26, fig.28.
1899 " reticulata Reuss; Egger, p.107, pl.13, figs. 5-7.
1925 " " Reuss; Franke, p.64, pl.5, fig.14.
1927 Frondicularia reticulata (Reuss); Plummer, p.39, pl.2, fig.5.
1928 Flabellina reticulata Reuss; White, p.204, pl.28, fig.15.
1928 " " Reuss; Franke, p.93, pl.8, fig.19.
1930 " " Reuss; Cushman, p.32, pl.4, figs.18,19.
1932 " " Reuss; Cushman & Jarvis, p.37, pl.11, fig.15.
1935 " " Reuss; Cushman, p.87, pl.13, fig.19.

1940 Flabellina reticulata Reuss; Wedekind, pp.201-2, pl.11, figs.1-3.

1940b Palmula " (Reuss); Cushman, pl.20, fig.9.

1943 " " (Reuss): Cushman & Todd, p.60, pl.10, fig.23.

1946 " " (Reuss); Cushman, p.84, pl.31, figs.1-6.

1952 Neoflabellina reticulata (Reuss); Hiltermann, t.fig.3, figs.38-9.

1954 " " (Reuss); Pozaryska, p.259, fig.4.

1954 " " (Reuss); Frizzell, p.97, pl.12, figs.13,14.

1955 " " (Reuss); Hiltermann & Koch, p.371, t.fig.7f, pl.29, fig.10.

1957 " " (Reuss); Pozaryska, p.162, pl.26, fig.6.

1957 " " (Reuss); Hofker, p.146, t.fig.173.

1957 " postreticulata Hofker, p.147, t.figs.174-6.

1958 " reticulata (Reuss); Witwicka, pl.8, fig.4.

1958 " " (Reuss); Bieda, pp.30-31, t.fgi.4.

1962 " " (Reuss); Hiltermann & Koch, p.309, pl.50, figs.13,14.

1966 " " (Reuss); Hofker, p.70, pl.12, fig.32.

1968 " " (Reuss); Stenestad, pl.2, fig.13.

1969 Palmula " (Reuss); Mello, p.64, pl.7, fig.6.

1977 Neoflabellina " (Reuss): Koch, p.58, pl.14, figs.9,10.

1977 " " (Reuss); Villain, pp.49-50, pl.4, fig.12.

Description: Test free; palmate to deltoid, compressed, greatest width towards base, sides flat, parallel, with angular to carinate edges; initial end broadly rounded; chambers initially coiled but rapidly uncoiling, chevron shaped, strongly overlapping, increasing uniformly and moderately in size; sutures distinct, raised, slightly curved, crenulate; aperture terminal subcircular on a short neck; wall calcareous, perforate; surface between sutures strongly ornamented by numerous ridges perpendicular to, and often continuous across the sutures.

Average height: 1.1 mm. Average width: 0.60 mm.

Remarks: This species may be distinguished from its ancestor N. praereticulata by its more regular reticulate ornament extending to the earlier chambers. Cushman (1946) after study of topotypic material, concluded that N. favosa (Beissel, 1891) is conspecific with N. reticulata.

Occurrence: Originally described from the Maastrichtian of Lemberg, Galicia, this species has been found in moderate abundance in the Lower Maastrichtian of Norfolk, though not in the basal levels. Also found in the Lower and Upper Maastrichtian in material from the North Sea.

Zonal range: B5i - B7i

Neoflabellina suturalis (Cushman,1935)

(Plate 4 , fig.10)

1910 Flabellina rugosa d'Orbigny; Heron-Allen & Earland, p.422, pl.8, fig.7.

1925 " " d'Orbigny; Franke, p.64, pl.5, fig.12.

1928 " " d'Orbigny; Franke, p.92, pl.8, fig.18.

1930 " " d'Orbigny; Cushman, p.32, pl 4, fig.15.

1931a " " d'Orbigny; Cushman, p.307, pl.35, fig.10.

1931 " " d'Orbigny; Plummer, p.166, pl.12, fig.4.

1932 " " d'Orbigny; Sandidge, p.279, pl.42, fig.22.

1935 " suturalis Cushman, p.86, pl.13, figs.9-18.

1937 Palmula " (Cushman); Loetterle, p.28, pl.3, fig.5.

1940 Flabellina deltoidea Wedekind, pp.186,190,194, figs.3,4,6.

1942 Palmula suturalis (Cushman); Cushman & Deaderick, p.60, pl.13, fig.1.

1944 " " (Cushman); Cushman & Deaderick, p.334, pl.52, fig.5.

1946 Palmula suturalis (Cushman); Cushman, p.82, pl.32, figs.3-14.

1952 Neoflabellina "deltoidea" (Wedekind); Hiltermann, t.fig.3, figs.1-3.

1954 " suturalis (Cushman); Frizzell, p.98, pl.12, figs.17-18.

1956 " "deltoidea" (Wedekind); Hiltermann & Koch, p.37, fig.4, no,1-6, pl.1, fig.2.

1962 " " (Wedekind); Hiltermann & Koch, p.308, pl.48, fig.12.

1962 " " (Wedekind); Porthault, in Donze et al., pp.54-5, pl.8, figs.4,5.

pars 1969 " suturalis (Cushman); Ohmert, p.12, figs.17,18, 20-22,25,35-37, 51,56,57, 75,76,80,82,83,90-95,

pars 1969 " " cf. rostrata (Wedekind); Ohmert, p.15, fig.19.

pars 1969 " ovalis ssp. A.Ohmert, p.17, figs.5-8,10.11.

1975 " suturalis (Cushman); Koch, p.209, pl.2, fig.3.

1977 " " (Cushman); Koch, p.43, pl.16, fig.9.

Description: Test free; broadly rhomboid, compressed, initial planispiral coil rapidly becoming uncoiled, chevron shaped, broad; uniformly and quite rapidly expanding in size; sutures distinct, highly raised in well preserved specimens, curved; aperture terminal at end of short neck, relict apertures generally closed; wall calcareous, perforate; surface generally smooth, occasionally showing faint papillate ornament.

Average height: 0.83 mm. Average width: 0.50 mm.

Remarks: The broad, rhomboid form, smooth to only weakly ornamented surface and highly raised sutures lacking relict apertures, serve to distinguish this species.

Occurrence: Rare, fragmentary individuals referable to this species were found in the Lower Campanian both in Norfolk and the Isle of Wight.

Zonal range: Bliii - B2i

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushman, 1927

Subfamily TURRILININAE Cushman, 1927

Genus PRAEBULIMINA Hofker, 1953

Genotype Bulimina reussi Morrow, 1934

Praebulimina reussi (Morrow, 1934)

(Plate 4, figs. 13,14)

1844 Bulimina ovulum Reuss, p.215 (non B.ovula d'Orbigny, 1839)

1845 " " Reuss; Reuss, p.87, pl.8, fig.57, pl.13, fig.73, ? pl.8, fig.57.

? 1899 " " Reuss; Egger, pp.51-2, pl.15, fig.46.

1925 " brevis d'Orbigny; Franke, p.25, pl.2, fig.18.

? 1925 " ovulum Reuss; Franke, p.25, pl.2, fig.17.

? 1928 " " Reuss; Franke, p.157, pl.14, fig.14.

1928 " brevis d'Orbigny; Franke, p.157, pl.14, fig.12.

1931b " " d'Orbigny; Cushman, p.40, pl.5, fig.9.

1931b " murchisoniana d'Orbigny; Cushman, p.309, pl.35, fig.14.

1934 " ovulum Reuss; Cushman & Parker, p.29, pl.5, figs.10,11.

1934 " brevis d'Orbigny; Dain, p.36, pl.4, fig.4.

1934 " reussi Morrow, pp.195-6, pl.29, fig.2.

1935 " " Morrow; Cushman & Parker, p.99, pl.15, figs.8,10.

1936 " " Morrow; Jennings, p.31, pl.3, fig.20.

1936 Bulimina ovula Reuss; Brotzen, pp.125-7, t.fig.42, fig.9.

1936 " ventricosa Brotzen, pp.124-7, pl.8, fig.1, t.fig.42, figs.1-8.

1941 Buliminella ovulum (Reuss) var. hemicircularis Marie, p.202, pl.31, fig.296.

1941 " " (Reuss) var. triangularis Marie, p.202, pl.31, figs.298,299.

1941 Bulimina reussi Morrow; Cushman & Hedberg, p.95, pl.22, fig.30.

1943 " " Morrow; Frizzell, p.350, pl.57, fig.2.

1944 " " Morrow; Cushman & Deaderick, p.337, pl.53, fig.6.

1944d " " Morrow; Cushman, p.12, pl.2, fig.25.

1946 " " Morrow; Cushman, pp.120-1, pl.51, figs.1-5.

1947 " " Morrow; Cushman & Parker, p.84, pl.19, fig.31, pl.20, figs.1-5.

1951 " " Morrow; Visser, p.258, pl.2, fig.15.

1951 Praebulimina reussi (Morrow); Hofker, p.144.

1951 Buliminella ovula (Reuss); Hofker, p.123, figs.73,74.

1953 Praebulimina ovulum (Reuss); Hofker, p.27.

1953 Bulimina reussi Morrow; Hagn, p.78, pl.6, fig.21.

1954 " ovulum Reuss var. ovulum Reuss; Frizzell, p.115, pl.17, fig.2.

1956 " reussi Morrow; Said & Kenawy , p.143, pl.4, fig.15.

pars 1957 Praebulimina reussi (Morrow); Hofker, p.187-8, t.figs.227 nos.1-3, non. no.4,5.

1957 " ovulum (Reuss); Hofker, p.184.

1957 " ventricosa (Brotzen); Hofker, pp.184-6, t.figs.223,224.

1960 " ovulum (Reuss); Belford, p.64-5, pl.16, figs.7-9.

1961 Bulimina reussi Morrow; Vasilenko, pp.174-6, pl.38, figs.2a-b,7a-b

1964 Praebulimina reussi (Morrow); Loeblich & Tappan, p.C545, fig.428, 1-3

1964 Bulimina reussi (Morrow); Martin, p.88, pl.11, fig.9.

1968 Praebulimina reussi (Morrow); Sliter, p.85, pl.12, figs.1,2.

1972 " " (Morrow); Hanzlikova, p.77, pl.18, fig.16.

Description: Test free; ovate, only slightly longer than broad, cross section subcircular, greatest breadth above mid-line of test; chambers arranged in four to five whorls, triserial throughout, expanding rapidly and uniformly; initial chambers slightly inflated forming broadly rounded initial end in megalospheric forms, an acute point in microspheric forms which also tend to show a rapid increase in size between the penultimate and final whorl, which occupies half to four-fifths of the test;chambers becoming rapidly inflated, elongate, overlapping; sutures distinct, slightly depressed; aperture variable, a narrow terminal slit at inner margin of final chamber often with a distinct sub-terminal loop shaped extension, tooth plate present; wall calcareous, finely perforate; surface smooth.

Average height: 0.42mm. Average width: 0.34mm.

Remarks:Reuss' original name B. ovulum was a junior homonym of B. ovula d'Orbigny, 1839, a recent species described from South America. Morrow (1934) therefore proposed the name B. reussi for Reuss' species. Praebulimina ventricosa (Brotzen) is herein considered to fall within the range of variation of the present species.

Occurrence: This species occurs in the Lower Campanian of the Isle of Wight , in moderate abundance, though mostly restricted to the 180μ and 125 μ sieve fractions. In the Middle Campanian it becomes increasingly abundant and also larger,often occurring in in the 250 μ sieve fraction. It ranges just into the basal layers of the middle Upper Campanian. In Norfolk this species is notably more abundant and of larger size, ranging from the Lower Campanian to the top of the middle Upper Campanian, with very sporadic occurrences in the upper Upper Campanian.

Zonal range: B1ii - B4i

Praebulimina carseyae (Plummer, 1931)

(Plate 4, figs. 11, 12)

1910 Bulimina elegans d'Orbigny; Heron-Allen & Earland, p.409, pl.6, fig.11.

1926 " compressa Carsey, p.29, pl.4, fig.14.

1931 Buliminella carseyae Plummer, p.179, pl.8, fig.9.

1936 " " Plummer, Cushman & Parker, p.8, pl.2, fig.6.

1936 " hofkeri Brotzen, p.129, pl.8, fig.3, t.fig.45.

1937 " carseyae Plummer; Loetterle, p.58, pl.5, fig.10.

? 1941 Bulimina intermedia Reuss; Visser, p.257, pl.2, fig.14.

1941 Buliminella obtusa (d'Orbigny) var. inflata Marie, p.199, pl.30, fig.293, pl.31, fig.294.

1944d " carseyae Plummer; Cushman, p.12, pl.2, fig.24, p.93, pl.14, fig.10.

1946 " " Plummer; Cushman, p.119, pl.50, figs.17-20.

1947 " " Plummer; Cushman & Parker, p.58, pl.15, fig.8.

1953 " " Plummer; Hagn, p.78, pl.7, fig.1.

1954 " " Plummer; Frizzell, pp37-8, pl.16, figs.37,38.

pars 1957 " obtusa (d'Orbigny); McGugan, p.341, pl.32, figs7,8 non.figs.5,6.

1957 Praebulimina hofkeri (Brotzen); Hofker, pp.186-7, t.fig.225.

1957 " carseyae (Plummer); Hofker, p.192, figs.235-237.

1961 Buliminella " Plummer; Vasilenko, p.171, pl.38, figs.6,?14.

1962 Praebulimina " (Plummer); Tappan, p.186, pl.48, figs.11-15.

1964 Praebulimina carseyae (Plummer); Subbotina, p.267, pl.59, figs.1-11.

1964 Buliminella carseyae Plummer; Martin, p.88, pl.11, fig.11.

1966 Praebulimina " (Plummer); Hofker, p.58, pl.10, figs.94-5, 99-100, pl.20, fig.38, pl.24, fig.160.

1968 " " (Plummer); Sliter, p.83, pl.11, fig.16.

1969 " " (Plummer); Hanzlikova , p.30, pl.5, fig.5.

1972 " " (Plummer); Hanzlikova, p.76, pl.18, figs.6,14.

Description: Test free, ovate, twice as long as wide, initially bluntly pointed, greatest width close to mid-point of test, giving the test an overall subfusiform outline; cross section distinctly subrectangular; chamber arrangement four to a whorl in mature section, generally four whorls; chambers distinct, more or less inflated, elongate; sutures distinct, depressed, curved, especially spiral sutures which give mature specimens stepped appearance, due to marked increase in size between whorls; last chamber strongly overlapping onto previous whorl; apertural face of final chamber elongate, often flattened and forming approximate right angle to previous whorl; aperture variable, most commonly trilateral slit, subterminal, extending along interiomarginal suture often to the junction with the suture between preceeding two chambers, apertural depression pronounced; wall calcareous, finely perforate, surface smooth.

Average height: 0.77mm. Average width: 0.47mm.

Remarks: This species can be distinguished by its step-like outline, quadriserial chamber arrangement, and distinctly inflated chambers which give the test a subrectangular 'box-like' cross section.

Forms identified by Heron-Allen and Earland as *Bulimina elegans* d'Orbigny,1839 (described from the Recent of Rimini, Italy), have been examined by the author in the British Museum (Nat. Hist.), and found to be clearly conspecific with *P. carseyae* . *P. hofkeri* (Brotzen,1936) is also considered to lie within the range of specific variation of *P. carseyae*.

This species shows stratigraphically useful morphological variation throughout the sections under investigation. The earliest forms encountered in the Lower Campanian are generally much smaller, slender and with slightly less inflated chambers. Whilst in the Middle and Upper Campanian *P.carseyae* shows a marked increase in size and chamber inflation culminating in the Upper Campanian.

Occurrence: Moderately common in the Lower and Middle Campanian both in the Isle of Wight and Norfolk, though generally restricted to <250 μ sieve fractions. In the lower Upper Campanian they become increasingly common, generally occurring in the 250 μ sieve fraction. The species is abundant throughout the Upper Campanian, though only sporadic specimens have been found in the lowest Maastrichtian.

Zonal range: Blii - B5i

Praebulimina laevis (Beissel, 1891)

(Plate 5, figs.1,2)

1891 *Bulimina laevis* Beissel, p.66, pl.12, figs.39-43.

1936 *Buliminella laevis* (Beissel); Cushman & Parker, p.6, pl.2, fig.3.

non 1941 ______"______ *obtusa* (d'Orbigny) var. *laevis* (Beissel); Marie, p.199, pl.30, fig.293, pl.31, fig.294.

? 1941 ______"______ *guttiformis* Marie, p.200, pl.31, fig.295.

1947 ______"______ *laevis* (Beissel); Cushman & Parker, p.57, pl.15, fig.6.

1956 Buliminella laevis (Beissel); Said & Kenawy , p.142, pl.4, fig.6.

1957 Praebulimina laevis (Beissel); Hofker, p.190, t.fig.228g,h, t.figs.230-232.

1966 " " (Beissel); Hofker, p.37, ? pl.5, fig.27, pl.10, figs.70-72, 77,88.

Description: Test free, subfusiform, large, generally 2 to $2\frac{1}{2}$ times as long as wide, greatest width around the mid-point of test; initially bluntly pointed and rapidly flaring until final whorl, which is gradually flaring, almost parallel-sided and occupies two-thirds of the test; three to four whorls, four chambers to a whorl; chambers only very slightly inflated, if at all; sutures flush to very slightly depressed in earlier whorls, flush in final whorl; cross section subcircular; apertural face of final chamber markedly subterminal, not overlapping previous whorl; aperture variable, comma shaped, moderately wide slit set in distinct depression, some specimens showing extensions down the interiomarginal suture, may be bordered by an indistinct, thin lip; wall calcareous, finely perforate; surface smooth.

Average height: 0.71mm. Average width: 0.44mm.

Remarks: In his original figures, Beissel (1891) shows a wide range of morphological variation which may possibly have included more than one species. Both Cushman and Parker (1947) and Hofker (1966) have figured topotypic material which clearly shows the major characteristics of the present species. P. laevis displays a general morphological similarity to both P. carseyae and P. obtusa (d'Orbigny, 1840), with which it may have been confused in the past, eg. Marie (1941), Brotzen (1945). It may be distinguished from P. carseyae by its less well inflated chambers, less distinctly depressed sutures, and its more elongate, slender, regularly tapering outline; while it differs from P. obtusa in its more acute initial end, and far more elongate, slender form, with less inflated chambers.

Occurrence: Originally described from the Maastrichtian of Germany. Rare forms are found in the uppermost Campanian of Norfolk. It becomes increasingly and markedly abundant in the Lower Maastrichtian.

Zonal range: B4i - B6ii

Praebulimina obtusa (d'Orbigny, 1840)

(Plate 5, figs.3-5)

1840 Bulimina obtusa d'Orbigny, p.39, pl.4, figs.5,6.

non 1899 " " d'Orbigny; Egger, p.50, pl.15, fig.51.

1934 Buliminella obtusa (d'Orbigny); Cushman & Parker, p.28, pl.5, fig.1.

1936 " " (d'Orbigny); Cushman & Parker, p.6, pl.2, fig.1.

1936 " " (d'Orbigny); Brotzen, p.131, pl.8, fig.2.

1941 " " (d'Orbigny); Marie, p.197, pl.30, fig.290.

1941 " " (d'Orbigny) f. typica Marie, p.198, pl.30, fig.291.

1947 " " (d'Orbigny); Cushman & Parker, pp.56-7, pl.15, fig.4.

1946 " " (d'Orbigny); Schijfsma, p.80, pl.4, fig.9.

non 1951 " " (d'Orbigny); Visser, p.257, pl.2, fig.13.

1957 " cf. obtusa (d'Orbigny); McGugan, p.341, pl.32, fig.9.

pars 1957 " " (d'Orbigny); McGugan, p.341, pl.32, figs.5,6, non.figs.7,8.

1964 " " (d'Orbigny); McGugan, p.934, pl.150, fig.26.

1966 Buliminella obtusa (d'Orbigny); Barr, pp.499-500, pl.77, fig.3.

1977 " " (d'Orbigny); Villain, p.71.

Description: Test free, large, approximately twice as high as wide; two morphological variants appear to be present; the first is initially bluntly pointed, rapidly flaring, composed of four to five whorls, last whorl occupies approximately two-thirds of test; chambers four to a whorl and little inflated, sutures flush; the other variant is characterized by an extremely rapidly flaring series of initial whorls forming a broadly rounded initial end, These are followed by a more or less parallel sided final whorl, which may often occupy more than two-thirds of the test, this form is distinguished by being far more inflated. In both forms the cross section is subcircular; aperture relatively large loop-shaped opening set in depression, with a slight extension along the interiomarginal suture; apertural face of last chamber more or less distinctly overlapping previous whorl.

Average height: 0.92mm. Average width: 0.64mm. (inflated variety)

Remarks:This species has been confused with P. carseyae (eg. Barr 1962 MS.) It may be distinguished by its more regular inflated outline as opposed to the more slender, irregularly flaring P. carseyae which possesses chambers that are more inflated. P. obtusa may be distinguished from P. laevis with which it occurs in the lowest Maastrichtian, by its squatter, more inflated form. There appears to be a stratigraphically useful morphological trend within populations of P. obtusa with the much more inflated variety described above, replacing the less inflated variety within the lower levels of the middle Upper Campanian. Such a replacement is not felt sufficient justification to separate the two forms into distinct taxa at the present time, though further material may warrant the erection of chronosubspecies.

Occurrence: Originally described from the Campanian of the Paris Basin. In the Isle of Wight rare individuals are found in the uppermost Middle Campanian, ranging sporadically to the base of the middle Upper Campanian from whence it shows a dramatic increase, both in size and abundance. In Norfolk a remarkably similar series of events is to be found; here the species ranges throughout the middle and upper Upper Campanian and the lowest Maastrichtian. It has not been found in the upper Lower Maastrichtian.

Zonal range: B2iii, B3i-B5ii

Praebulimina parva (Franke, 1928)

(Plate 5, fig.6)

1928 Bulimina parva Franke, p.157, pl.14, fig.13.

1947 " " Franke; Cushman & Parker, pp.80-81, pl.19, fig.17.

non 1951 " " Franke; Visser, p.258, pl.2, fig.16.

Description: Test free; small, elongate, slender, fusiform in outline, two to three times as long as wide; chambers arranged in four whorls, triserial throughout, slightly inflated, elongate, overlapping, uniformly and moderately rapidly increasing; sutures distinct, slightly depressed; aperture subterminal trilateral slit; wall calcareous, finely perforate; surface smooth.

Average height: 0.42mm. Average width: 0.17mm.

Remarks: The small size and graceful, fusiform test, make this a highly distinctive species. Specimens referred to B. parva by Visser (1951) from the Maastrichtian of Holland, have been re-examined by Hofker (1966), and tentatively reassigned to P. carseyae. From the figured hypotype of Visser these forms fall outside the range of specific variation shown by P. parva in the present study.

Occurrence: In the Isle of Wight found sporadically ranging from the basal Campanian to the upper Middle Campanian, where it becomes increasingly rare. In Norfolk only very rarely found in the Lower Campanian.

Zonal range: B1ii - B2iii

Praebulimina pseudoacuta (Marie, 1941)

(Plate 5, figs.7,8)

1941 Bulimina pseudoacuta Marie, p.203, pl.32, fig.300.

Description: Test free; markedly elongate, subfusiform, gradually tapering; test three times as high as wide; chambers arranged in three to four whorls; chambers subquadrate, becoming markedly higher than broad, only slightly inflated; rapidly and uniformly increasing in size; sutures distinct, slightly depressed; aperture high, subterminal narrow slit, apertural lip may be present; wall calcareous, finely perforate; surface smooth.

Average height: 0.70mm. Average width: 0.27mm.

Remarks: The extremely elongate form and slightly inflated chambers, together with the subterminal aperture, serve to distinguish this species.

Occurrence: Originally described from the Belemnitella mucronata zone of the Paris Basin. This species has been found extremely rarely in the Middle and Upper Campanian of the Isle of Wight.

Zonal range: B2iii - B3ii

Genus PYRAMIDINA Brotzen, 1948

Genotype Bulimina ? curvisuturata Brotzen, 1940

Remarks: Loeblich and Tappan (1964) stated in their remarks on the genus Reussella Galloway, 1933 that:-

> "Upper Cretaceous species that have been previously referred to Reussella are here regarded as belonging to Pyramidina, differing in their less angular margin, finely perforate wall and simpler tooth plate."

In the present study however, not all members of this plexus of triserial, triangular forms are considered to be referable to Pyramidina Brotzen. Herein this genus is restricted to include only those species with less angular, subrounded margins with finely perforate wall structure. Species showing distinctive carinate, often spinose angles have been found in the present study in the Upper Cretaceous, in contradiction to the statement of Loeblich and Tappan (1964), and are referred to the genus Reussella.

Pyramidina minuta (Marsson, 1878)

(Plate 5, figs.9,10)

1878 Tritaxia minuta Marsson, p.162, pl.4, fig.31.

1925 " " Marsson; Franke, p.19, pl.2, fig.2.

1928 " " Marsson; Franke, p.138, pl.12, fig.19.

1937 Bulimina " (Marsson); Cushman, p.29.

1940 " marssoni Cushman & Parker, p.46, pl.8, fig.17.

non 1941 Heterostomella cf. minuta (Marsson); Marie, p.68, pl.3, fig.31.

1947 Bulimina minuta (Marsson); Cushman & Parker, p.81, pl.21, fig.4.

1964 Reussella minuta (Marsson); Subbotina, p.284, pl.62, figs.3-12.
non 1966 Tritaxia " Marsson; Hofker, p.49, pl.7, fig.4.

Description: Test free; elongate, small; initial end pointed, rapidly and uniformly expanding till widest point of test close to apertural end; test three times as high as wide; cross section triangular with rounded edges, sides flat to concave; test may show axial twisting; chambers triserial arranged in four to six whorls, indistinct, wider than high, uninflated becoming increasingly distinct, inflated; interior simple; sutures initially indistinct flush becoming increasingly distinct, depressed; aperture high loop shaped or narrow slit opening extending up apertural face of last chamber; wall calcareous, finely perforate; surface smooth.

Average height: 0.26mm. Average width: 0.11mm.

Remarks: There has been some confusion as to the generic status of this small, distinctive species. Cushman examined Marsson's types in Vienna in 1932 and concluded that they were referrable to the genus Bulimina d'Orbigny 1826, and not the agglutinated genus, Tritaxia. The calcareous, finely perforate wall structure, triangular test with rounded edge and high loop shaped aperture, place this species within the genus Pyramidina. P.prolixa (Cushman & Parker,1935) is a closely related form with a similar range, described from the U.S.A. Study of the relevant type material is necessary to determine the exact relationship of this form to P.minuta.

Occurrence: Ranging throughout the Lower Maastrichtian. Moderately common, both in Norfolk and North Sea material.

Zonal range : B5i - B6ii

Pyramidina rudita (Cushman & Parker, 1936)

(Plate 5, figs.11,12)

1935 Bulimina ornata (Egger); Cushman & Parker, p.97, pl.15, fig.4.

1936 " rudita Cushman & Parker, p.45.

1936 Reussella minima Brotzen, p.136, pl.8, fig.6.

1946 Bulimina rudita Cushman & Parker; Cushman, p.122, pl.51, fig.24.

1947 " " Cushman & Parker; Cushman & Parker, p.82, pl.19, fig.26.

1957 Reussella uvigeriniformis Hofker, p.217, t.figs.226-7.

1968 Pyramidina rudita Cushman & Parker; Sliter, pp.86-7, pl.12, fig.12.

Description: Test free; small, triserial; initial end bluntly pointed, gradually and uniformly expanding; cross section distinctly triangular; sides weakly convex, margins rounded; test twice as high as wide; chamber arrangement triserial in 5-6 whorls; chambers distinct, slightly inflated; sutures moderately distinct, weakly depressed, meeting on side in zig-zag line; aperture loop shaped opening generally extending up apertural face from basal position, occasionally subterminal; wall calcareous, finely perforate; surface, except for final chamber, highly ornamented, being covered by dense array of short pustules, decreasing slightly towards apertural end.

Average height: 0.24mm. Average width: 0.14mm.

Remarks; The highly developed rugose ornament is characteristic of this species. Sliter (1968) has suggested that P. minima (Brotzen, 1936) described from the Coniacian/Santonian of Eriksdal, Sweden, is conspecific with P. rudita. It is probable that P. rudita was derived from P. minima by the increased development of its pustulose ornament. In general form, P.rudita closely approaches Pseudouvigerina rugosa

Brotzen, 1945 described from the Maastrichtian of Denmark (Höllviken). P. rudita may be distinguished however, by its more coarsely pustulose ornament, rounded margins, and basal aperture, whilst Pseudouvigerina rugosa possesses a more finely hispid ornament, terminal aperture and faint traces of vertical marginal costae. P. rudita is generally restricted to sieve fractions $<250\mu$.

Occurrence: Originally described from the Taylor Formation of Texas, and recorded by Hofker from the Campanian of Holland and Germany. In the present study, this species has been found, rarely, in the upper Lower and Middle Campanian.

Zonal range: B1iii - B2iii

Pyramidina trigona (Chapman, 1892)

(Plate 5, figs. 13,14)

1892 Bulimina trigona Chapman, p.515, pl.15, fig.8.

1964 " " Chapman; Barr & Cordey, p.308, pl.49, figs.5-7.

Description: Test free; small, triangular, triserial, $1\frac{1}{2}$ times as high as wide; cross section triangular with broadly rounded edges and concave sides; initial end broadly rounded to pointed; chambers arranged in five to six whorls, inflated becoming subglobular; broadest portion near middle of test; sutures indistinct, initially slightly depressed, becoming flush; aperture loop shaped opening at inner margin of final chamber; wall calcareous, finely perforate; surface of initial end covered by subcircular pits, which may extend to cover up to two-thirds of the test.

Average height: 0.27mm. Average width: 0.17mm.

Remarks: This species is easily distinguished by its pitted surface, This is however, difficult to see unless the specimen is stained. In general outline P. trigona is very similar to P. triangularis (Cushman & Parker, 1935) from the Campanian of the U.S.A., though according to the original description P. triangularis possesses an initial ornament comprising short, irregular longitudinal ridges. It is possible that considerable confusion may exist in the literature between these two species. P. trigona is generally restricted to $<250\ \mu$ sieve fractions.

Occurrence: Originally described from the Upper Santonian phosphatic chalk of Taplow, England. This is a moderately common species ranging throughout the Campanian in the Isle of Wight. In Norfolk it ranges up to the upper Lower Maastrichtian, being commonest in the Upper Campanian. Also recorded rarely from North Sea material.

Zonal range: B1ii - B6ii

Family BOLIVINITIDAE Cushman, 1927

Genus BOLIVINA d'Orbigny, 1839

Genotype Bolivina plicata Cushman, 1911

Bolivina decurrens (Ehrenberg, 1854)

(Plate 5, figs. 15,16)

1854 Grammostomum decurrens Ehrenberg, p.22, pl.30, fig.17.

1878 Bolivina " (Ehrenberg); Marsson, p.156, pl.3, fig.24.

1899 " " (Ehrenberg); Egger, p.46, pl.16, figs.17,18.

1925 " " (Ehrenberg); Franke, p.20, pl.2, fig.6.

1927 " " (Ehrenberg); Cushman, p.88, pl.12, fig.4.

1928 " " (Ehrenberg); Franke, p.152, pl.14, fig.3.

1935 Bolivina decurrens (Ehrenberg); Cushman & Cambell, p.73, pl.11, fig.9.

1937 " " (Ehrenberg); Cushman, p.39, pl.5, figs,29,30.

1946 " " (Ehrenberg); Cushman, p.127, pl.53, figs.12,13.

1954 " " (Ehrenberg); Frizzell, p.117, pl.17, fig.24.

1957 " " (Ehrenberg); Hofker, p.232, figs.287,288c-e, 292d.

1958 " " (Ehrenberg); Bieda, pp47-8, t.fig.16.

1962 " " (Ehrenberg); Hiltermann & Koch, p.313, pl.51, figs.18,19.

1964 " " (Ehrenberg); Baranovskaya in Subbotina, p.297, pl.64, figs.13-19.

1966 " " (Ehrenberg); Hofker, p.39, pl.5, fig.40 pl.10, fig.76, 102, pl.12, fig.26

? 1968 " " (Ehrenberg); Sliter, p.87, pl.12, fig.16.

1969 " " (Ehrenberg); Mello, p.81, pl.9, fig.6.

1972 " " (Ehrenberg); Hanzlikova, p.79, pl.19, fig.3.

1972 " " (Ehrenberg); Bertels, p.338, pl.2, figs.1-4.

1977 " " (Ehrenberg); Villain, p.68, pl.5, fig.15.

1977 " " (Ehrenberg); Koch, p.59, pl.14, figs.7,8.

Description: Test free; elongate, slender, $3\frac{1}{2}$ times as long as wide, initially bluntly pointed, occasionally spinose, moderately rapidly and uniformly expanding; widest point of test close to apertural end; test compressed, margins subacute; chambers biserial throughout, initially indistinct becoming more distinct and slightly inflated, inclined, wider than high, with extensions of basal margin, producing a spinose periphery; sutures initially indistinct, becoming distinct slightly depressed, curved and inclined at angle of about 45° to long axis of test; aperture elongate, elliptical slit extending from the basal suture of final chamber to occupy a subterminal position; wall calcareous, finely perforate; surface smooth.

Average height: 0.51mm. Average width: 0.19mm.

Remarks: This widely recorded species is easily distinguished by its spinose periphery and slender form. It has been recorded from strata of Maastrichtian age though occasionally also from the uppermost Campanian.

Occurrence: Extremely rare in the Lower Maastrichtian of Norfolk, whilst more commonly found in North Sea material.

Zonal range: uppermost B4i - B7i

Bolivina incrassata Reuss, 1851

(Plate 5, figs. 17,18)

1851 Bolivina incrassata Reuss, p.45, pl.4(5), fig.13.

1899 " " Reuss; Egger, p. 45, pl.16, figs.4,5.

? 1899 " " Reuss var. lata Egger, p.46, pl.16, figs.8,9.

1925 " " Reuss; Franke, p.21, pl.2, fig.8.

1926b " " Reuss; Cushman, p.19, pl.2, fig.1.

1928 " " Reuss; Franke, p.153, pl.14, fig.6.

1929 " " Reuss; White, p.44, pl.4, fig.19.

1935 " " Reuss; Cushman & Cambell, p.73, pl.11, fig.10.

non 1941 " " Reuss var. limonensis Cushman; Marie, p.205, p.132, figs.303-5

1946 " " Reuss; Cushman, p.127, pl.53, figs.8-11.

1946 " " Reuss; Schijfsma, pp77-8, pl.6, fig.9.

1947 " " Reuss var. crassa Vasilenko & Myatliuk, p.203, pl.2, figs.3-5.

1949 Bolivina incrassata Reuss; Wicher, p.84, pl.5, fig.1.

1949 " " Reuss f. gigantea Wicher, p.85, pl.5, figs.2,3.

1951 " " Reuss; Bandy, p.510, pl.75, fig.5.

1951 " " Reuss; Noth, p.64, pl.9, fig.8.

1951 " " Reuss; Visser, p.260, pl.2, fig.10.

1954 " " Reuss; Frizzell, p.117, pl.17, fig.25.

1955 " " Reuss; Bettenstaedt & Wicher, p.502, pl.2, fig.16.

1955 " " Reuss gigantea Wicher; Bettenstaedt & Wicher, p.502, pl.2, fig.19.

1955 " " Reuss; Hiltermann & Koch, p.363, pl.28, figs.1,2, pl.29, figs.1,2.

1956 " " Reuss; Said & Kenawy , p.144, pl.4, fig.9.

1956 " " Reuss f.gigantea Wicher; Wicher, p.120, pl,12, figs.2,3.

1957 " " Reuss; McGugan, pp.340-1, pl.32, figs.1-4.

1957 " " Reuss; Hofker, p.228, t.figs.282-6, 291.

1958 " " Reuss; Bieda,pp.44-6, t.fig.15.

1959 " " Reuss; Eternod Olvera, p.79, pl.2, figs.17-18.

1960 " " gigantea Wicher; Hiltermann & Koch, p.75, pl.3.

1962 " " Reuss; Hiltermann & Koch, p.312, pl.51, fig.14,15.

1962 " " gigantea Wicher; Hiltermann & Koch, p.312, pl.51, figs.16,17.

1964 " " Reuss; McGugan, pp.942-3, pl.150, figs.22,23.

1964 " " Reuss; Baranovskaya, in Subbotina, p.300, pl.65, figs.1-7.

1964 " " Reuss; Martin, p.90, pl.11, fig.14.

1966 " " Reuss; Hofker, p.39, pl.5, fig.42, pl.10, figs.90,91.

1968 Bolivina incrassata Reuss; Sliter, p.88, pl.12, fig.14.

1968 " " gigantea Wicher; Sliter, p.88, pl.12, fig.15.

1968 " " " Wicher; Stenestad, pl.2, fig.14.

1969 " " Reuss; Hanzlikova, p.31, pl.5, figs.7,8.

1972 " " Reuss; Hanzlikova, p.80, pl.19, figs.5,6.

1972 " " Reuss; Bertels, p.336, pl.2, fig.5.

1972 " " crassa Vasilenko & Myatliuk; Hanzlikova, p.80, pl.19, fig.4.

1977 " pliata Carsey; Villain, p.68, pl.5, fig.16.

1977 " incrassata Reuss; Sliter, pl.5, fig.1.

1977 " " incrassata Reuss; Koch, p.54, pl.14, figs.5,6.

1977 " " crassa Vasilenko & Myatliuk; Koch, p.54, pl.14, figs.3,4.

1977 " " gigantea Wicher; Koch, pp.54-5, pl.14, figs.1,2.

Description: Test free; elongate, varying from slender form $3\frac{1}{2}$ times as long as wide to a robust, very elongate form up to $4\frac{1}{2}$ times as long as wide; occasional very stout forms occur only twice as high as broad; megalospheric forms are broadly rounded, very gradually expanding with almost parallel sides; microspheric forms are pointed and moderately uniformly expanding up to widest point of test, which is close to the apertural end; test compressed with subrounded margins, periphery entire, occasionally becoming slightly lobate in extremely elongate individuals; chambers numerous, commonly 8-12, slightly inflated, markedly inclined; sutures fairly distinct, slightly depressed, slightly curved, inclined at steep angle to length of test, may become very slightly limbate; aperture elongate, wide, ovate, highly inclined subterminal opening arising from interiomarginal suture of last chamber, extending up apertural face; wall calcareous, thick, very finely perforate; stouter and larger individuals may be covered with a dense, very sparsely perforate, calcite layer; surface smooth but in some individuals extremely fine longitudinal striations may be observed.

Average height: 1.0mm. Average width: 0.42mm. (Megalospheric form)

Remarks: The extreme range of variation shown by this species has long been a source of debate. Hofker (1966) regarded the various forms as different generations though he conceded that they showed slightly different stratigraphic ranges. Wicher (1949) , and Vasilenko and Myatliuk (1947) have all erected subspecies within B. incrassata, though these have been variously interpreted by later workers eg. Hanzlikova (1972), Hiltermann & Koch (1962), and Koch (1977). Such a situation has served rather to confuse the stratigraphic distribution of the various forms. Koch (1977) has figured an excellent series of S.E.M. photographs, which clearly show the three subspecies (with their micro- and megalospheric generations), as they occur both in N. Germany and in the present study. Comparison of range charts, however, shows major discrepancies, and such a situation was also noted by Sliter (1968), who recorded the subspecies B. incrassata gigantea Wicher, 1949, prior to the first occurrence of B. incrassata incrassata. This is completely the reverse stratigraphic sequence to that recorded from many other areas of the world. This situation led Sliter to speculate that ecological factors may strongly influence the stratigraphic distribution of these forms. The work of Lutze (1964) is of importance in this respect, showing that major morphological variation can occur within the genus Bolivina due to ecological controls. These results, together with the differing stratigraphical ranges recorded for the various subspecies of B. incrassata from various areas of the world, indicate that a description of the morphological variation shown within the population is preferable, at the present moment, to the formal recognition of subspecies.

Occurrence: Apart from one isolated individual found 1m. below the Catton Sponge Bed, this species is restricted to the upper Upper Campanian and Maastrichtian. Forms referable to B. incrassata s.s. and B. incrassata crassa sensu Koch (1977) are to be found throughout this range. Larger, stouter forms referable to B. incrassata gigantea sensu Koch (1977), were found only sporadically in the upper part of the Lower Maastrichtian, whilst they occurred in abundance in North Sea material of Upper Maastrichtian age.

Zonal range: B3iv - B7i

Genus BOLIVINOIDES Cushman, 1927

Genotype Bolivina draco Marsson, 1878

Bolivinoides draco draco (Marsson, 1878)
(Plate 5, fig.19)

1878 Bolivina draco Marsson, p.157, pl.3, fig.25.

1899 " " Marsson; Egger, p.47, pl.16, figs.14-16.

non 1925 " " Marsson; Franke, p.20, pl.2, fig.4.

1926b " rhomboidea Cushman, p.19, pl.2, fig.3.

1927 Bolivinoides rhomboidea (Cushman); Cushman, p.90, pl.12, fig.10.

1927b " " (Cushman); Cushman, p.158, pl.28, fig.12.

non 1928 Bolivina draco Marsson; Franke, p.151, pl.14, fig.2.

1929 Bolivinoides draco (Marsson); White, p.45, pl.5, fig.2.

1933 " rhomboidalis (Cushman); Cushman, pl.21, fig.9.

1940 " dorreeni Finlay, p.453, pl.63, figs.56-8.

1946 " rhomboidea (Cushman); Cushman, p.113, pl.48, fig.15.

1950 " draco draco (Marsson); Hiltermann & Koch, p.598, t. figs. 1-5, figs.52-54, 58-60,69,72-3.

1951 Bolivinoides draco draco (Marsson); Noth, p.63, pl.9, fig.10.

1954 ____ " ____ " ____ " ____ (Marsson); Edgell, p.73, pl.13, figs.1-3, pl.14, figs.1-3.

1954 ____ " ____ " ____ " ____ (Marsson); Pozaryska, p.253-4, t.fig.3.

1954 ____ " ____ " ____ " ____ (Marsson); Reiss, p.155, pl.29, figs.1-3

1954 ____ " ____ " ____ dorreeni Finlay; Reiss, p.153, pl.29, figs.4-7.

1955 ____ " ____ " ____ draco (Marsson); Hiltermann & Koch, p.371, tab.1.

1956 ____ " ____ " ____ " ____ (Marsson); Said & Kenawy , p.140, pl.3, fig.41.

1956 ____ " ____ " ____ dorreeni Finlay; Said & Kenawy , p.140, pl.3, fig.42.

1957 ____ " ____ " ____ draco (Marsson); McGugan, p.335(list), pl.32, fig.17.

1957 ____ " ____ " ____ (Marsson); Hofker, p.267, t.fig.321.

1957 ____ " ____ " ____ (Marsson); Montanaro-Gallitelli, p.145, pl.33, figs.14-16.

1961 ____ " ____ " ____ (Marsson); Vasilenko, pp.201-3, pl.41, fig.2, t.fig.21(6).

1962 ____ " ____ " ____ draco (Marsson); Hiltermann & Koch, p.318, pl.46, fig.18.

1963 ____ " ____ " ____ " ____ (Marsson); Hiltermann, p.222, pl.4, figs.16-19.

1963 ____ " ____ " ____ " ____ (Marsson); van Hinte, p.106, pl.14, fig.3.

1964 ____ " ____ " ____ " ____ (Marsson); Beckman & Koch, pp.45-6, pl.6, fig.24.

1964 ____ " ____ " ____ (Marsson); Loeblich & Tappan, p.C549-552, fig.435, 1,2.

1964 ____ " ____ " ____ (Marsson); Baranovskaya in Subbotina et al., p.294, pl.64, fig.9.

1965 Bolivinoides draco dorreeni Finlay; Martinez- Pardo, p.362, t.fig.3

1966 " " (Marsson); Hofker, p.73, pl.13, figs.34-6.

1968 " " draco (Marsson); Sliter, p.88, pl.12, fig.17.

? 1968 " " miliaris Hiltermann & Koch; Sliter, p.88, pl.12, fig.17.

1968 " " " (Marsson); Koch, p.654, t.fig.62.

1968 " " " (Marsson); Stenestad, pl.2, fig.3.

1969 " " " (Marsson); Medizza, p.23, pl.2, figs.1,2.

1970 " " (Marsson); Barr, p.646, pl.99, figs.2,3.

1972 " " (Marsson); Hanzlikova, p.81, pl.19, fig.10,11.

1977 " " (Marsson); Villain, p.69, pl.5, fig.13,

1977 " " (Marsson); Petters, p.1032, pl.1, fig.1.

1977 " " draco (Marsson); Koch, pl.12, figs.2-3.

1977 " " (Marsson); Govindan, ;.473, pl.2, fig.15, t.fig.10 n-o.

Description: Test free; rhomboidal, compressed with thickest part of test along median line and widest point generally more or less towards apertural end; margins sub-acute to acute often carinate, may become slightly lobate in upper portion of test; cross section elliptical to subfusiform; initial end bluntly pointed to broadly rounded, proloculus globular followed by 6-7 pairs of biserially arranged low chambers 3 times wider than high, slightly to moderately inclined, and slightly curved, becoming more overlapping; septa between chambers thick; sutures indistinct obscured by ornament, oblique; aperture wide loop shaped basal opening extending up the face of final chamber, bordered by a relatively indistinct lip and internally possessing a tooth plate; wall calcareous, perforate; surface covered by very strong ornament comprising on average four longitudinally elongated lobes on each chamber, perpendicular to sutures, more or less parallel and coalescing to form longitudinal costae extending over a number of chambers. These longitudinal costae converge and coalesce into two prominent vertical ribs bordering a median sulcus extending down the length of the test.

Average height: 0.47mm. Average width: 0.44mm.

Remarks: B. draco draco is distinguished from its ancestral subspecies B. draco miliaris Hiltermann & Koch, 1950, by its more regular rhomboid test and the fusion of ornamental lobes into ridges which coalesce to form the two prominent costae bordering the median sulcus. Following Beckmann & Koch (1964) and Barr (1970),the subspecies B. draco dorreeni Finlay, 1940, distinguished by its more prominent reticulate ornamentation, is thought to be intergradational with B. draco draco and thus a junior synonym possibly representing ecophenotypic variation within the population.

Occurrence; Transitional forms between B. draco draco and B. draco miliaris were found rarely in the uppermost Lower Maastrichtian in Norfolk.This subspecies is abundant in the Upper Maastrichtian of the North Sea.

Zonal range : B7i

Bolivinoides draco miliaris Hiltermann & Koch, 1950
(Plate 5, figs.20-22.)

1927 Bolivinoides decorata (Jones); Cushman, p.89, pl.12, fig.9.
1946 " " (Jones); Cushman, p.113, pl.48, figs.8,9.
1950 " draco (Marsson) miliaris Hiltermann & Koch; pp.604-6, t.figs.2-4, nos.32-34, 39-41,46-48, t.fig.5,no.39.

1954 Bolivinoides draco miliaris Hiltermann & Koch; Reiss, p.155, pl.28, figs.9-12,14.

1954 ___"___"___"___ Hiltermann & Koch; Pozaryska, p.254, t.fig.4.

1955 ___"___"___"___ Hiltermann & Koch; Hiltermann & Koch, p.365, t.figs.28,9.

? 1956 ___"___"___"___ Hiltermann & Koch; Said & Kenawy, p.140, pl.3, fig.40.

1957 ___"___cf. B.draco (Marsson); McGugan, pl.32, fig.16.

1957 ___"___ decorata (Jones); Sacal & Debrourle, p.14, pl.3, fig.21.

1958 ___"___ draco miliaris Hiltermann & Koch; Bieda, pp.44,45, fig.14.

1958 ___"___"___"___ Hiltermann & Koch; Witwicka, p.199, pl.9, fig.11.

1960 ___"___"___"___ Hiltermann & Koch; Hiltermann & Koch, p.72.

1961 ___"___ miliaris Hiltermann & Koch; Vasilenko, pp.200-1, pl.40, fig.4, pl.41, fig.1.

1962 ___"___ draco miliaris Hiltermann & Koch; Hiltermann & Koch, p.317, tab.19, pl.46, fig.9.

1963 ___"___"___"___ Hiltermann & Koch; Hiltermann, p.222, pl.4, figs.21-23.

1963 ___"___"___"___ Hiltermann & Koch; van Hinte, pp.106-7, pl.13, figs.7,8.

1964 ___"___"___"___ Hiltermann & Koch; Beckmann & Koch, pp.44-5, pl.6, figs.21-23.

1966 ___"___ miliaris Hiltermann & Koch; Barr, pp.234-5, pl.35, figs.4,5.

1967 Bolivinoides miliaris Hiltermann & Koch; van Hinte, p.256, pl.1, fig.4.

1968 ______"______ draco miliaris Hiltermann & Koch; Koch, p.654, tab.62.

1968 ______"______"__ miliares Hiltermann & Koch; Sliter, p.89, pl.13, fig.1.

1969 ______"______"__ miliaris Hiltermann & Koch; Medizza, pp.24-5, pl.2, fig.4.

1970 ______"______ miliaris Hiltermann & Koch; Barr, p.650, pl.99, fig.1.

1977______"______ draco miliaris Hiltermann & Koch; Koch, pp.56-7, pl.12, fig.4.

1977 ______"______ miliaris Hiltermann & Koch; Petters, p.1034, pl.1, fig.3.

1977 ______"______"______ Hiltermann & Koch; Govindan, p.472, t.figs. 10h,1-m.

Description: Test free; kite-shaped, outline rapidly expanding, compressed, thickest part of test along median line, widest point just above mid-point of test; margins subacute to acute; cross section almost rhomboid; initial end bluntly pointed; proloculus globular, followed by 7-8 pairs of biserially arranged chambers which are slightly inflated, 3 times as broad as high, oblique and slightly curved; sutures indistinct except at periphery, medianly obscured by ornament, oblique, slightly depressed and slightly curved; aperture loop shaped basal opening extending up apertural face of final chamber, occasionally bordered by an indistinct lip; internally possessing tooth plate; wall calcareous, perforate; surface strongly ornamented initially by small subcircular pustules, somewhat restricted to the median portion of the test and forming two well defined, discontinuous median rows bordering a median sulcus. On later chambers, ornament is less restricted medianly, comprising elongate, narrow lobes, generally three per chamber, perpendicular to the sutures and occasionally coalescing into ribs extending across more than one chamber.

Average height: 0.52mm. Average width: 0.45mm.

Remarks: B. draco miliaris is morphologically intermediate between B.decoratus (Jones, 1875) and B. draco draco. It is distinguished from B. decoratus by its shorter, more rhomboid outline, and by the highly characteristic development of two discontinuous median ridges. B. draco miliaris may be most readily distinguished from B. draco draco by the lack of continuous median ridges.

Occurrence: B. draco miliaris first appears, in some abundance, in the uppermost Upper Campanian together with B. sidestrandensis Barr, 1966. It is then found commonly throughout the Lower Maastrichtian. Rare transitional forms between B. draco miliaris and B. draco draco were noted in the uppermost samples from Trimingham (upper Lower Maastrichtian). B. draco miliaris is extremely common in material from the North Sea.

Zonal range : B4i - B6ii

Bolivinoides australis Edgell, 1954

(Plate 6, fig.1.)

1954 Bolivinoides decorata (Jones) australis Edgell, pp.71-2, pl.13, figs.5,6. pl.14, figs.5,6.

1955 Bolivinoides australis Edgell; Hofker, p.71, t.fig.c-o.

1958 " " Edgell; Hofker, pl.1, figs.11-14, pl.2, figs.18-23.

1958 " decorata australis Edgell; Bieda, pp.33-4, t.fig.7.

1959 " australis Edgell; Hofker, p.71, pl.13, figs.5,6.

non 1965 " " Edgell; Goel, p.82, pl.7, figs.14,15.

1966 Bolivinoides australis Edgell; Barr, pl.34, fig.1, pl.35, figs.1-3

1966 " " Edgell; Hofker, p.39, pl.5, figs.29-30, pl.10, figs.79-87, pl.13, figs.37-42

1969 " " Edgell; Hofker, t.fig.1(2).

? 1977 " sidestrandensis Barr; Sliter, pl.5, fig.4.

non 1977 " australis Edgell; Sliter, pl.5, figs.5-6.

Description: Test free; outline pyriform showing a slight tendency to become rhomboid in some individuals; 1½ times as high as broad, widest point towards apertural end; periphery subrounded, entire, becoming slightly lobate; initial end bluntly pointed, test rapidly and uniformly expanding; proloculus globular followed by 5-7 biserially arranged chambers which are slightly inflated, oblique, 3½ times as broad as high; sutures oblique, indistinct, obscured by ornament; aperture loop shaped, basal, extending up apertural face, subterminal; wall calcareous, perforate; surface ornamented, initially may be smooth, lower two-thirds of test covered by elongate lobes perpendicular to sutures, generally not extending over more than one chamber, 5-7 lobes per chamber.

Average height: 0.58mm. Average width: 0.41mm.

Remarks: B.australis show morphological characters intermediate between B. decoratus (Jones, 1875) and B. giganteus Hiltermann & Koch, 1950. It may be distinguished from its ancestor B. decoratus by its broader outline tending to subrhomboid, its uniform subcircular nodose ornament covering the initial two-thirds of the test, and by a greater number of ornamental lobes per chamber in the later chambers. As shown by Hofker (1958) this later feature undergoes a gradual change throughout the phylogenetic lineage B. strigillatus - culverensis - decoratus - australis - giganteus (t.fig.5:1).

B. australis may be distinguished from B. giganteus by its lack of ornamental lobes coalescing into long ridges and by lower average numbers of ornamented lobes per chamber; however the two are morphologically so close that a case could be made for considering B. australis as a subspecies of B. giganteus. In overall form B. australis may somewhat resemble B. draco miliaris which may be distinguished by its more acute periphery, more rhomboid outline, and median ornamental nodes aligned into two parallel median rows.

Goel (1965) figured specimens which he referred to B. australis that lack the broad form and characteristic ornamentation of B. australis as well as having a markedly different stratigraphic range. These specimens more closely resemble B. decoratus as does B. australis sensu Sliter (1977). Sliter also figures a specimen which he refers to B. sidestrandensis Barr, 1966. This specimen, though poorly preserved, has a much broader outline and lacks the distinctive fine regular ornament of B. sidestrandensis . Its general form suggests it may be closer to B. australis.

Occurrence: B. australis is found in the Lower Maastrichtian where it is quite rare. In the uppermost Lower Maastrichtian rare forms show a tendency towards B. giganteus. It has also been found rarely in North Sea material.

Zonal range: B5i - B5ii

Bolivinoides culverensis Barr, 1967

(Plate 6, figs. 5,6.)

1954 Bolivinoides decoratus (Jones) cf. delicatula Cushman; Edgell, p.71, pl.13, fig.7, pl.14, fig.7.

1955 " strigillatus (Chapman); Hofker, pl.1, fig.a.

1963 Bolivinoides sp., Hiltermann, p.209, pl.1, figs.2,3,7-9.

1966 " hiltermanni Barr, pp.229-30, pl.36, figs.7,8, pl.37, figs.1-3.

1967 " culverensis Barr, p.136.

1977 " " Barr; Petters, p.1031-2, pl.1, figs.10-12.

pars 1977 " decoratus decoratus (Jones); Koch, p.51, pl.12, fig.5.

pars 1977 " strigillatus (Chapman); Govindan, pp.469-70, t.fig.10c.

Description: Test free; elongate,initial end bluntly pointed, proloculus subglobular followed by 7-8 pairs of biserially arranged chambers; test moderately flaring, greatest width between mid-line of test and apertural end; chambers oblique, fairly distinct, somewhat obscured by ornament, 2-3 times as broad as high; sutures indistinct, oblique, slightly curved; cross section compressed,elongate ovoid, test edges subrounded; wall calcareous, perforate; surface ornamented by strongly raised broad elongate lobes, usually three per chamber, especially on last two pairs, lobes running perpendicular to the sutures occasionally coalescing with those of earlier chambers; initial portion of test much less ornamented, possessing faintly raised nodules generally restricted to the median portion of the test, faint median sulcus often developed; earliest two pairs of chambers often smooth with a thick calcite crust.

Average height: 0.43mm. Average width: 0.22mm.

Remarks: Barr erected this species to include those forms, found commonly in the Lower and Middle Campanian of the Isle of Wight, which represent a transitional morphospecies between the ancestral B. strigillatus (Chapman, 1892) and the descendant B. decoratus (Jones, 1875). B. culverensis may be readily distinguished from B. strigillatus by its broader, more markedly compressed test, and elongate oval cross section as opposed to the subcircular to slightly elliptical cross section of B. strigillatus, in addition, B. culverensis is generally larger and more rapidly flaring, giving it a higher length/breadth ratio, it also shows a more strongly developed ornamentation. Koch (1977 and pers. comm.) has not followed Barr's separation of the earlier B. culverensis from B. decoratus and considers that a broad classification of this phylogenetic lineage is necessary to avoid oversplitting. Despite this, he has suggested (pers. comm.) that the two groups are in general orthogenetically separable and that with a large population it is possible to separate them stratigraphically. The present material comprising several hundred specimens is considered large enough to achieve such a separation.

Occurrence: Transitional forms between B. strigillatus and B. culverensis occur sporadically in the upper Lower Campanian. B. culverensis occurs abundantly throughout the Middle Campanian for which it is a useful index, both in Norfolk and the Isle of Wight. It is exceedingly rare, however, in material from the North Sea.

Zonal range: B1iii - B2iii

Bolivinoides decoratus (Jones, 1875)

(Plate 6, figs.2-4.)

1875 Bolivina decorata Jones, (in Wright), pp.87, 96,97 (list).

1886 " " Jones; Jones (in Wright), p.330, pl.27, figs.7,8.

1910 " " Jones; Heron- Allen & Earland, pl.7, figs.1,2.

1926 " latticea Carsey, p.27, pl.4, fig.9.

1929 " decorata Jones; White, p.43, pl.5, fig.1.

1931 " " Jones; Plummer, p.181, pl.10, fig.10.

1932 Bolivinoides decorata (Jones); Sandidge, p.196, pl.19, fig.16.

1934 Bolivinoides decorata (Jones); Dain, pp33-4, pl.3, fig.34.

1938 " " (Jones); Cole, p.35, pl.4, fig.9.

1941 " " (Jones) f. typica Marie, p.188, pl.29, fig.279.

non 1946 " " (Jones); Cushman, p.113, pl.48, figs.8,9.

pars 1946 " " (Jones) var. delicatula Cushman; Cushman, p.113, pl.48, figs.11,12, non.10,13,14.

1948 Bolivina strigillata Chapman; Williams-Mitchell, p.106, pl.9, fig.3.

1950 Bolivinoides decorata decorata (Jones); Hiltermann & Koch, pp.606-10, t.figs.2-4, nos.17-25, 27-31, 35-38, 42-45.

1953 " " " (Jones); Hagn, p.74, pl.6, fig.22.

1954 " " " (Jones); Reiss, p.155, pl.28, figs.5-8.

1954 " regularis Reiss, p. 158.

pars 1954 " decorata latticeus (Carsey); Frizzell, p,112, pl.16, figs.18, non.fig.19.

non 1954 " " decorata (Jones); Frizzell, p.111, pl.16, fig.17.

? 1954 " " " (Jones); Pozaryska, pp.254-5, t.fig. 5.

1955 " " " (Jones); Hiltermann & Koch, p.365, pl.28, fig.4.

1955 " " (Jones); Hofker, t.fig.1,b.

1956 a " " decorata (Jones); Hofker, p.B207, fig.8.

pars 1957 " " " (Jones); McGugan, p.339, pl.32, figs.10, 13, ?14, 15, non.11,12.

1958 " " " (Jones); Pokorny, p.305, t.fig.6.

1958 " " " (Jones); Bieda, pp32,33, t.fig.6.

1958 " " " (Jones); Witwicka, pp.198-9, pl.9, fig.9.

1958 Bolivinoides decorata (Jones); Hofker, pl.1, figs.3-10.

1959 " " decorata (Jones); Bykova, pl.1, fig.2.

1961 " decoratus (Jones); Akimets, pp.188-9, pl.18, figs.17,18.

1961 " decorata decorata (Jones); Vasilenko, pp.189-90, pl.39, figs.8-10, t.fig.21(2a).

1962 " decoratus decoratus (Jones); Hiltermann & Koch, p.315, tab.19, pl.46, fig.7.

1963 " " (Jones); Kaptarenko-Chernousova et al., p.111, pl.25, fig.4.

1963 " " decoratus (Jones); Hiltermann, pp.198-207, pl.4, figs.6-14.

1963 " decorata decorata (Jones); van Hinte, p.105, pl.14, figs.1,2.

1964 " decoratus (Jones); Baranovskaya-Bulynikova in Subbotina, p.291, pl.64, figs.1-8.

1965 " ellipsodecorata Goel, p.81, pl.7, figs.13.

1965 " rhombodecorata Goel, p.80, pl.7, figs.9,10.

1965 " australis Edgell; Goel, p.82, pl.7, figs.14,15.

1966 " decorata decorata (Jones); Hofker, p.27, pl.3, fig.50.

1966 " " (Jones); Barr, pp.231-2, pl.34, figs.2-6, 12, pl.35, figs.6-9, pl.36, fig.1-5.

1966 " " (Jones); Barr, pp.500-1, pl.77, figs.4,5.

1969 " decoratus decoratus (Jones); Medizza, p.21, pl.1, fig.11.

1970 " cf. " (Jones); Barr, p.647, pl.100, figs.1-3, t.fig.5.

1972 " " (Jones); Hanzlikova, pp.80-1, pl.19, figs.7-9.

1977 " " (Jones); Villain, p.69, pl.5, fig.4.

1977 *Bolivinoides decoratus* (Jones); Petters, p.1032, pl.1, fig.2.

pars 1977 " " *decoratus* (Jones); Koch, p.51, pl.12, fig.6, non.fig.5.

? 1977 " *australis* Edgell; Sliter, pl.5; figs.2,3.

Description: Test free; elongate to kite- shaped outline; periphery subrounded, widest point of test varying between mid-line and apertural end; cross section compressed, elliptical; proloculus globular followed by 7-9 pairs of biserially arranged chambers, moderately distinct, oblique slightly inflated, uniformly and rapidly increasing in size; sutures oblique, curved, obscured by strong ornament; aperture narrow loop shaped opening extending up the apertural face from the base of the final chamber; wall calcareous, perforate; surface covered by strongly developed ornamental lobes, extending down the chamber face and often coalescing across two chambers, general direction of elongation perpendicular to sutures; ornament most strongly developed on the later chambers where 3-4 lobes occur on each chamber, initial portion of the test is much less ornamented, often only possessing irregular nodules.

Average height: 0.57mm. Average width: 0.35mm.

Remarks: After examination of type material Barr (1966a) erected and figured a lectotype of this species. The author has examined Barr's type material in the British Museum (Nat. Hist.) which is clearly conspecific with the forms described here. Cushman (1946) appears to have confused this species with *B. draco miliaris* Hiltermann & Koch, 1950, as his figures clearly show a form possessing a strongly rhomboidal test and pustulose ornament characteristic of *B. miliaris*. *B. decoratus* is a distinctive species within the *B. strigillatus* - *culverensis* - *decoratus* - *australis* lineage (t.fig. 5:1). It may be distinguished from its ancestral species B. culverensis by its more rapidly flaring test (and therefore greater length/breadth ratio) and its more highly developed ornament generally with a greater number of lobes per chamber. B. australis differs from B. decoratus in its generally wider, larger, more rapidly flaring outline with a greater development of ornamental lobes.

Goel (1965) appears to have oversplit this species and it is felt that B. ellipsodecorata Goel, B. rhombodecorata Goel and B. australis Edgell, sensu Goel, all lie within the range of morphological variation of B. decoratus The specimens of B. australis figured by Sliter (1977) from the Lower Maastrichtian of S.W. Atlantic lack the rapidly flaring test and advanced development of ornament characteristic of B. australis and appear morphologically identical with B. decoratus. Reiss (1954) erected B. regularis to include those forms from the Saratoga Chalk erroneously referred to B. delicatula by Cushman (1931). Barr (1966a) after examination of the holotype of B. regularis, considered this species to be conspecific with B. decorata, a view with which the present author agrees.

Occurrence: Transitional forms between B. culverensis and B. decoratus occur sporadically in the uppermost Middle Campanian. B. decoratus ranges, often abundantly, throughout the Upper Campanian where it is a useful index species in onshore sections. B. decoratus also occurs slightly less abundantly in the Lower Maastrichtian. This species has only been found rarely in material from the North Sea.

Zonal range : B3i - B5i

__Bolivinoides laevigatus laevigatus__ Marie, 1941

(Plate 6, fig.10)

1941 __Bolivinoides decorata__ (Jones) var. __laevigata__ Marie, p.189, pl.29, fig.281.

1952 __" " laevigata__ Marie; Hiltermann, p.63, t.figs.4,5.

1953 __" " "__ Marie; Hagn, p.75, pl.6, fig.23.

? 1954 __" compressa__ Reiss, p.156, pl.30, figs.1-3.

? 1954 __" praecursor__ Reiss, p.156, pl.30, figs.4-7.

1954 __"__ sp. Reiss, p.157, pl.29, fig.11.

1954 __" decorata laevigata__ Marie; Pozaryska, p.256, t.fig.9.

1955 __" laevigata__ Marie; Hiltermann & Koch, pp367-8, pl.27.

1958 __" decorata laevigata__ Marie; Witwicka, p.199, pl.9, fig.13.

1958 __" praecursor__ Reiss; Bieda, pp.41-2, t.fig.12.

1960 __" laevigata__ Marie; Hiltermann & Koch, p.72, tab.3.

1961 __" laevigatus laevigatus__ Marie; Vasilenko, p.197, pl.40, figs.2,3, t.fig.21 (7b).

1962 __" "__ Marie; Hiltermann & Koch, p.316, pl.51, fig.10.

1963 __" delicatulus__ Cushman; Graham & Church, p.51, pl.5, fig.24.

1963 __" laevigatus__ Marie; Hiltermann, p.213, pl.2, figs.6-10.

? 1965 __" praecursor__ Reiss; Goel, pp79-80, pl.7, fig.8.

1965 __" compressa__ Reiss; Goel, p.82, pl.7, fig.16.

1965 __" laevigatus__ Marie; Goel, p.83, pl.7, fig.19.

1966 __" laevigata__ Marie; Barr, p.237, pl.34, fig.7, pl.38, figs.1-5.

1968 __" laevigatus__ Marie; Sliter, p.89, pl.13, fig.2.

? 1970 Bolivinoides cf. laevigatus Marie; Barr, p.648.

? 1972 ______"______ delicatulus Cushman; Hanzlikova, p.82, pl.19, fig.12.

1975 ______"______ laevigatus Marie; Koch, p.209, pl.1, fig.3.

1977 ______"__________"_____ Marie; Petters, p.1033-4, pl.1, fig.4.

1977 ______"__________"_____ Marie; Koch, p.52, pl.13, fig.7.

Description: Test free; elongate, greatest breadth towards apertural end, periphery subacute; cross section compressed, flatly elliptical; initial end broadly rounded, globular proloculus followed by 7-9 pairs of biserially arranged chambers; chambers distinct only slightly inflated, 2 to 3 times as broad as high, inclined and curved; sutures distinct, slightly depressed, oblique and curved, becoming increasingly so towards the periphery; in the median area of the test obscured by ornament; aperture narrow loop shaped opening extending from basal suture up the apertural face, commonly bordered by a lip; surface weakly ornamented by circular to elongate nodes generally 2 to 3 per chamber and restricted to the median portion of the test.

Average height: 0.41mm. Average width: 0.22mm.

Remarks: This subspecies belongs to the group of weakly ornamented Bolivinoides including B. laevigatus prelaevigatus, B. peterssoni and B. palaeocenicus which are probably members of one phylogenetic lineage (t.fig. 5:1). Though originally described as a subspecies of B. decoratus, such a relationship is not felt to be the most likely. Reiss (1954) described two species from the Campanian of Israel, B. compressa and B. praecursor, both of which have ranges overlapping part of the range of B. laevigatus laevigatus . They are distinguished from each other by differences in ornamentation; B. compressa possessing circular nodes, whilst those of B. praecursor are elongate.

A complete gradation between these two ornamental characters was found in the present populations of B. laevigatus laevigatus. It is felt therefore that in view of the overall morphological and stratigraphic similarities of these three species, both B. compressa and B. praecursor fall within the range of variation of B.laevigatus laevigatus.

B. laevigatus laevigatus may be distinguished from its ancestral subspecies B. laevigatus praelaevigatus Barr, 1966 by its greater range of length/breadth ratio, commonly 1.5 - 2.0 in B. laevigatus laevigatus, compared with 1.9 - 2.3 in B. laevigatus praelaevigatus. B. laevigatus laevigatus is also commonly less compressed than its ancestor. Both subspecies are generally restricted to sieve fractions $<250\mu$.

Occurrence: Transitional forms between B. laevigatus laevigatus and B. laevigatus praelaevigatus are common in the lower Upper Campanian. B. laevigatus laevigatus ranges throughout the Upper Campanian, often in abundance. It is also found somewhat less commonly in the Lower Maastrichtian. It is quite common in material from the North Sea.

Zonal range : B3i - B5i

Bolivinoides laevigatus praelaevigatus Barr, 1966

? 1954 Bolivinoides watersi (Cushman); Reiss, p.156, pl.29, fig.8.

1961 ____"____ laevigatus Marie var. finitima Vasilenko, p.196, pl.40, figs.5,6,9.

1966 ____"____ praelaevigatus Barr, p.237, pl.38, figs.7-9.

1977 ____"________"____ Barr; Petters, p.1034, pl.1, figs.7,8.

Description: Test free; elongate, very gradually tapering, periphery subacute; cross section compressed, flatly elliptical; proloculus smooth, globular followed by 7-9 pairs of biserially arranged chambers which are twice as broad as high, generally uninflated, oblique and slightly curved; sutures distinct, especially near the periphery where they are flush, oblique and slightly curved; aperture a narrow loop shaped opening extending up apertural face; wall calcareous, perforate; surface weakly ornamented by circular to slightly elongate nodes, from 1-3 per chamber, restricted to the median portion of the test.

Average height: 0.40mm. Average width: 0.18mm.

Remarks: The present specimens have been compared with type material deposited by Barr in the British Museum (Nat. Hist.) and found to be clearly conspecific. Originally described as a distinct species ancestral to B. laevigatus. Barr recorded B. praelaevigatus as being restricted to the lower Upper Campanian. Many workers, however, eg. Koch (1977), have not recognised B. praelaevigatus but assigned specimens from the lower Upper Campanian to B. laevigatus . Barr originally distinguished B. praelaevigatus from B. laevigatus by its gretaer length/breadth ratio, ie. less expanding form, its smaller width and its smaller, more compressed test. All these features are variable however, and in the Upper Campanian, the two forms are difficult to distinguish. Indeed, Barr (1966a) himself notes that in the B. mucronata zone a complete gradation was observed between B. praelaevigatus and B. laevigatus. In the present study, as in that of Petters (1976), very elongate, weakly ornamented forms were found sporadically in beds of Middle Campanian age, which are readily separable from B. laevigatus from its type level in the Upper Campanian. It appears likely therefore, that Barr erected his species from levels where a transitional population was already present, hence the difficulties encountered by later workers in separating these two taxa. It is felt, however, that the differences between the two are not sufficient to warrant their separation into distinct species, and they are here distinguished as chrono-subspecies.

Cushman (1937, 1946) described and figured a species from the Lower Taylor Marl. Texas, which he named B.texana. This species has a very similar, weakly ornamented, elongate, compressed form to B. laevigatus praelaevigatus, and also a similar range. Beckmann and Koch (1964) figured topotypic specimens of B. texana however, which are more strongly ornamented and less compressed, closely resembling B. pustulatus Reiss, 1954. It is felt that further study of type material is required to determine the exact taxonomic status of B. texana, which, from study of the original figures alone, could prove to be conspecific with, and therefore a senior synonym of, B. laevigatus praelaevigatus.

Occurrence: B. laevigatus praelaevigatus occurs sporadically in the upper Middle Campanian and more commonly in the lower Upper Campanian. Transitional morphotypes between it and B. laevigatus laevigatus are common throughout the higher levels of the lower Upper Campanian. This subspecies is also encountered in North Sea material.

Zonal range: B2iii - B3i

Bolivinoides paleocenicus (Brotzen, 1948)

(Plate 6. figs. 12,13.)

1948 Bolivina paleocenica Brotzen, p.66, pl.9, fig.5.

1952 Bolivinoides paleocenica (Brotzen); Hiltermann, pp.61-3, figs.4,5.

1953 Bolivinoides paleocenica (Brotzen); Wicher, pp.16-7, t.fig.1, fig.5.

1954 ______"______"______(Brotzen); Reiss, p.157, pl.30, figs.9-11.

1955 ______"______"______ (Brotzen); Hiltermann & Koch, p.370, pl.27, figs.3-6.

1957 ______"______"______ (Brotzen); Hofker, p.253, fig.305.

1958 ______"______"______ (Brotzen); Bieda, pp.42-44, t.fig.13.

1958 ______"______"______ (Brotzen); Witwicka, p.201, pl.10, fig.14.

1962 ______"______paleocenicus (Brotzen); Hiltermann & Koch, p.317, pl.50, fig.15.

1963 ______"______"______ (Brotzen); Hiltermann, p.217, pl.3, fig.3.

1966 ______"______paleocenica (Brotzen); Hofker, p.39, pl.5, fig.33, pl.10, fig.75.

1968 ______"______paleocenicus(Brotzen); Stenestad, pl.2, fig.10.

1969 ______"______"______ (Brotzen); Medizza, pp.26-7, t.fig.5, no.2,3.

1970 ______"______"______ (Brotzen); Barr, p.650, t.fig.6, pl.99, fig.7.

1977 ______"______"______ (Brotzen); Koch, p.60, pl.13, figs.1-3.

1977 ______"______"______ (Brotzen); Govindan, pp470-2, pl.1, figs.9,10, t.fig.10i-k.

Description: Test free; rapidly expanding, kite-shaped, widest part of test above mid-line of test; initial end bluntly pointed; cross section extremely flat, compressed, periphery subacute; test almost as high as wide; periphery becoming distinctly lobate; chambers biserial, 6-7 pairs, uninflated, 2 to 3 times as wide as high, strongly oblique; sutures in median portion of test obscured by ornament, near the periphery, distinct, depressed, straight; aperture narrow loop shaped opening extending from basal position up apertural face; wall calcareous, perforate; surface, especially in median area, covered by raised network of intersecting narrow ridges.

Average height: 0.27mm. Average width: 0.22mm.

Remarks: This highly distinctive species, originally described from the Palaeocene of Sweden, has not previously been recorded from the U.K. It is characterised by its strongly compressed test, which is almost as wide as high, and by its network of raised ribs. It may possibly have been derived from an ancestral form close to B. peterssoni Brotzen, 1945, though no transitional forms were found in the present study. Restricted to sieve fractions $<250\mu$.

Occurrence: Moderately common in the upper Lower Maastrichtian, with a single specimen found in the top two metres of the lower Lower Maastrichtian. Also found rarely in material of Upper Maastrichtian age from the North Sea.

Zonal range : B6i - B7i

Bolivinoides peterssoni Brotzen, 1945

(Plate 6, fig. 11)

1945 Bolivinoides peterssoni Brotzen, p.49, pl.1, fig.10.
1953 " " Brotzen; Wicher, pp.14-15, t.fig.1,fig.3.
1954 " " Brotzen; Pozaryska, p.256, t.fig.8.
1954 " " Brotzen; Reiss, p.157, pl.30, figs.12-14.
1955 " " Brotzen: Hiltermann & Koch, pp.366-7, pl.28, figs.7,8.

1957 <u>Bolivinoides peterssoni</u> Brotzen; Hofker, p.253, t.fig.312.

non 1958 ______"______"______ Brotzen; Witwicka, p.200, pl.9, fig.12.

1960 ______"______"______ Brotzen; Hiltermann, p.72, tab.3.

1961 ______"______"______ Brotzen; Vasilenko, pp.198-9, pl.40, fig.8.

1962 ______"______"______ Brotzen; Hiltermann & Koch, p.317, pl.50, fig.16.

1963 ______"______"______ Brotzen; Hiltermann, p.213, pl.2, figs.1-3.

1966 ______"______"______ Brotzen; Barr, pp238-9, pl.38, fig.6.

1966 ______"______"______ Brotzen; Hofker, p.40, pl.5, fig.41.

1968 ______"______"______ Brotzen; Stenestad, pl.2, fig.2.

1969 ______"______"______ Brotzen; Medizza, pp27-28, pl.2, fig.3.

1970 ______"______"______ Brotzen; Barr, p.650, pl.99, fig.6.

1977 ______"______"______ Brotzen; Koch, p.59, pl.13, fig.6.

<u>Description</u>: Test free; compressed, elongate, $1\frac{1}{2}$ times as long as wide; periphery slightly lobate; initial end bluntly pointed; cross section flatly elliptical, periphery subacute; proloculus globular followed by 7-8 pairs of biserially arranged, slightly inflated chambers, oblique, twice as broad as high; sutures indistinct in median portion, obscured by ornament, towards the periphery sutures becoming increasingly distinct, oblique, relatively straight, slightly depressed; aperture narrow loop shaped basal opening, extending up apertural face of final chamber; wall calcareous, perforate; surface ornamented strongly in median portion by elongate nodes extending across chamber faces perpendicular to sutures; ornamentation decreases rapidly towards the peripheral areas.

Average height: 0.48mm. Average width: 0.28mm.

<u>Remarks</u>: This distinctive species, originally described from the Maastrichtian of Hölviken, may be distinguished from its probable

ancestor B. laevigatus laevigatus by its broader, markedly compressed form and ornament which is even more restricted to the median region.

Occurrence: Moderately common throughout the Lower Maastrichtian of Norfolk. It appears to be a useful index form for strata of Maastrichtian age. It is somewhat rare in material from the North Sea.

Zonal range: B5i - B7i

Bolivinoides pustulatus Reiss, 1954
(Plate 6, fig.9)

1954 Bolivinoides pustulata Reiss, p.156, pl.29, figs.9,10.

? 1957 " granulata Hofker, pp.250-1, t.figs.303, 310.

1962 " granulatus Hofker; Hiltermann & Koch, p. 316, pl.51, figs.8,9.

1963 " pustulata Reiss; Hiltermann, p.214, pl.2, fig.17.

1963 " granulata Hofker; Hiltermann, p.213, pl.2, figs.5,11,12.

1964 " granulatus Hofker; Beckmann & Koch, pp39-40, pl.5, figs.4-6.

1964 " texanus Cushman; Beckmann & Koch, pl.5, fig.7.

1965 " hiltermanni Goel, p.83, pl.7, figs.17-18.

? 1965 " pustulo-decorata Goel, p.80, pl.7, fig.11.

1966 " pustulata Reiss; Barr, p.236, pl.37, fig.4.

1972 " granulatus Hofker; Hanzlikova, p.82,pl.19, fig.13.

1975 " " Hofker; Koch, p.208, pl.1, fig.2.

1977 " " Hofker; Koch, p.52, pl.13, figs.8,9.

1977 " pustulatus Reiss; Petters, p.1034.

Description: Test free; elongate, outline varying from 2 to $2\frac{1}{2}$ times as high as broad, periphery subacute, only slightly lobate; initial end varying between bluntly pointed and broadly rounded; cross section elliptical to flatly elliptical; proloculus globular followed by 6-8 pairs of chambers, slightly inflated, gradually and uniformly increasing, oblique, indistinct; sutures indistinct, oblique, only slightly curved, depressed, obscured by ornament especially in median portion of test; aperture narrow loop shaped slit extending from base, up the apertural face of final chamber; wall calcareous, perforate; surface ornamented by numerous weakly raised, somewhat elongate pustules often merging with one another; ornament generally well developed on initial portion of test and not markedly restricted to the median area, generally 2-3 pustules present on later chambers.

Average height: 0.38mm. Average width: 0.20mm.

Remarks: S.E.M. photographs of B. pustulatus, supplied by Dr. R. Reiss, have been compared to material from Britain and are considered conspecific. Barr (1966a) noted the close morphological similarity between B. pustulatus and B. granulatus Hofker, 1957, and tentatively regarded the two as conspecific. Reiss (1954) originally noted the morphological similarity between his new species and B. texana Cushman 1937, which Reiss distinguished as having a much less ornamented form, especially initially, such a statement being in keeping with the type figures of B. texana. Beckmann and Koch (1964) figured a topotypic specimen which they determined as B. texana,which, unlike the original figures, showed an initial pustulose ornament, placing it within the range range of morphological variation of B. pustulatus.

It is felt that a re-study of type material of B. texana is required to determine its exact relationship to the morphologically similar B. pustulatus and B. laevigatus praelaevigatus.

B. pustulatus is closely related both to B. culverensis and B. laevigatus, which both occur in the British Campanian, but it may be distinguished by its characteristic pustulose ornament.

B. pustulatus is generally restricted to sieve fractions <250μ.

Occurrence: Moderately common ranging throughout the upper part of the Middle Campanian with sporadic occurrences in the basal Upper Campanian, in onshore sections. Rare in North Sea material.

Zonal range: B2ii - B3i

Bolivinoides sidestrandensis Barr, 1966

(Plate 14, fig.14)

1950 Bolivinoides decorata delicatula Cushman; Hiltermann & Koch, p.612, fig.5, nos.65-7.

1952 " " " Cushman; Hiltermann, pp.61, 63, t.figs.4,5.

1954 " " " Cushman; Pozaryska, pp.255-6, t.fig. 7.

pars 1957 " " (Jones); McGugan, p.339, pl.32, figs.11, 12, ?14, non.figs.10,13,15.

1958 " " delicatula Cushman; Witwicka, p.199, pl.9, fig.10.

1958 " delicatula Cushman; Bieda, pp.38-9, t.fig.10.

1960 " decorata delicatula Cushman; Hiltermann, p.72, tab.3.

1961 " delicatulus Cushman; Cushman; Vasilenko, pp.193-5, pl.40, fig.7.

1962 " decoratus delicatulus Cushman; Hiltermann & Koch, p.315, tab.19, pl.47, fig.5.

1963 " delicatulus regularis Reiss; Hiltermann, p.205, pl.3, figs.7,11,12.

1964 " " " Reiss; Beckmann & Koch, pl.5, fig.22.

1966 Bolivinoides sidestrandensis Barr, pp.239-241, pl.34, figs.10,11, pl.36, figs.69, pl.37, fig.6.

? 1972 " regularis Reiss; Hanzlikova, p.83, pl.14, fig.15.

1977 " delicatulus regularis Reiss; Koch, pp.58-9, pl.13, figs.4,5.

non 1977 " sidestrandensis Barr; Sliter, pl.5, fig.4.

1977 " " Barr; Petters, pp.1034-5, pl.1, fig.5.

Description: Test free; elongate, twice as high as wide, periphery entire, initial end bluntly pointed; proloculus globular followed by 7-8 pairs of biserially arranged chambers; rapidly and very uniformly increasing in size; greatest breadth close to apertural end; cross section flatly elliptical, edges subrounded to subacute; chambers distinct inflated, markedly oblique , slightly curved, twice as wide as high; sutures oblique, depressed, slightly curved generally obscured by ornament; aperture narrow loop shaped opening extending from base of apertural face of final chamber, bordered by a faint lip; wall calcareous, perforate; surface strongly ornamented by well defined, narrow, elongate and extremely regular, lobes extending across chambers, perpendicular to the sutures.

Average height: 0.50mm. Average width: 0.22mm.

Remarks: The present species has been compared with type material deposited by Barr in the British Museum (Nat. Hist.) and is considered clearly conspecific. There has been considerable taxonomic confusion between B. delicatulus Cushman, 1927, B. regularis Reiss, 1954, and B. sidestrandensis Barr, 1966. B. delicatulus was originally described from the Lower Tertiary Velasco Shale, Mexico, though later, Cushman (1946) extended this range to include forms from the Taylor and Navarro Formations in the Gulf Coast Region of the U.S.A. Amongst this latter group, Reiss (1954) separated those forms from the Saratoga Chalk as a distinct species, B.regularis, erecting one of Cushman's specimens (1931; pl.35, fig.13.) as holotype. This species is easily distinguished from B. delicatulus by its broader, more rapidly flaring form, and its more pronounced ornament. It also has a markedly different stratigraphic range. Barr (1966a), however, noted the strong morphological similarity between B. regularis and B. decoratus and after examination of the holotype of B.regularis tentatively suggested that the two were conspecific. This view is also held by the present author. B. decoratus (= B. regularis Reiss) differs from B. sidestrandensis by its much broader form, more rapidly flaring test and much broader ornamental lobes. B. delicatulus is distinguishable from B. sidestrandensis by its more elongate test and less regular ornament. Reiss (1954) also suggested that specimens figured by Hiltermann and Koch (1950, p.612, fig.5, nos.65-7) and Hiltermann (1952, pp.61, 63, t.figs.4,5) as B. delicatulus were conspecific with his species B.regularis and, following this, many references (eg. Koch, 1977) have referred this species to B. delicatulus regularis. This form is, in the present author's opinion, distinct from B. regularis (= B. decoratus) and is considered conspecific with B. sidestrandensis.

Sliter (1977) has figured a hypotype of B. sidestrandensis from the S.W. Atlantic. This specimen, however, shows a much broader test than is typical of B. sidestrandensis, and appears to lack the characteristic regular, fine ornament. The exact taxonomic position of this specimen is in doubt, however, owing to its poor state of preservation. Petters (1977) noted the occurrence of specimens of B. sidestrandensis which show a greater breadth than is normal, and though such forms are encountered in the present material, none approach the dimensions of the specimen figured by Sliter.

Occurrence: Moderately common, ranging from the uppermost Upper Campanian to the Lower Maastrichtian. Rare in material from the North Sea.

Zonal range: B4i - B6i

Bolivinoides strigillatus (Chapman, 1892)
(Plate 6, figs.7,8)

1892 Bolivina strigillata Chapman, p.515, pl.15, fig.10.
1937 Bolivinoides austiniana Cushman, p.104, pl.15, fig.10.
1946 " " Cushman; Cushman, p.112, pl.48.
non 1948 Bolivina strigillata Chapman; Williams-Mitchell, p.106, pl.9, fig.3.
1950 Bolivinoides " (Chapman); Hiltermann & Koch, pp.614-23, t.figs.2(1-19), 3(1-9), 5(10).
1954 " " (Chapman); Edgell, pp.70-1, pl.13, fig.8, pl.14, fig.9.
1954 " austinianus Cushman; Frizzell, p.111, pl.16, fig.16.
non 1955 " strigillata (Chapman); Hofker, pl.1, fig.a.
1958 " " (Chapman); Witwicka, pp.196-8, pl.9, fig.8.
1959 " " (Chapman); Bykova, pl.1, fig.1.
1960 " " (Chapman); Belford, p.61, pl.15, figs.14-18.
1961 " " (Chapman); Vasilenko, pp.186-8, pl.39, fig.7.
1962 " strigillatus (Chapman); Hiltermann & Koch, p.314, pl.48, figs.10-11.
1963 " strigillata (Chapman); Hiltermann, pp.209-10, pl.1, figs.12-14, 16, 18, 19, 24.
1964 " " (Chapman); Barr & Cordey, pp.308-9, pl.49, figs.1-3.

1965 Bolivinoides strigillatus (Chapman); Goel, p.79, pl.7, fig.6.

1966 ______"______ strigillata (Chapman); Barr, pp.228-9, pl.34, figs.8,9, pl.37, figs. 7-9.

1968 ______"______ strigillatus (Chapman); Bettenstaedt, p.346, t.fig.3.

1970 ______"______"______ (Chapman); Barr, pp.651-2, t.fig.7, pl.100, figs.6-7, t.figs.2,7.

1975 ______"______"______ (Chapman); Bettenstaedt & Spiegler, pp.221-233.

1975 ______"______"______ (Chapman); Koch, p.207, pl.1, fig.1.

1977 ______"______"______ (Chapman); Sliter, p.674, pl.5, figs.5,6.

1977 ______"______"______ (Chapman); Petters, p.1035, pl.1, fig.9.

1977 ______"______"______ (Chapman); Koch, pp.44-5, pl.12, figs.7-8.

pars 1977 ______"______"______ (Chapman); Govindan, pp.469-70, pl.1, figs.1-8, pl.2, fig.13, t.fig.10a,b,non.c.

Description: Test free; elongate, 2 to 3 times as long as broad, initially bluntly pointed; proloculus subglobular, later chambers gradually and uniformly expanding; widest portion of test very close to apertural end; periphery becoming very slightly lobate; cross section subcircular, only very slightly compressed; chambers arranged biserially throughout, 6-8 pairs; chambers indistinct, slightly inflated, wider than high, inclined; sutures indistinct, slightly oblique, obscured by ornament; aperture narrow loop shaped opening at inner margin of final chamber, with an indistinct lip extending up the apertural face; wall calcareous, finely perforate; surface ornamented by raised lobes extending the length of each chamber, only rarely fusing with lobes on younger chambers, the number of lobes per chamber varies between 2 and 3, less on earliest chamber where they are blurred into an even thickening of the test.

Average height: 0.50mm. Average width: 0.23mm.

Remarks: B. strigillatus, originally described from the Upper Santonian phosphatic chalk of Taplow, England, is the earliest recorded species of the genus and is distinguished by its small, gradually flaring test, less numerous ornamental lobes and its almost uncompressed subcircular cross section. Barr and Cordey (1964) re-examined Chapman's type material deposited in the British Museum (Nat. Hist.), and from this material erected a lectotype (P 44968). Both Chapman's and Barr and Cordey's material has been examined by the present author, as has topotypic material from Taplow, England. Barr (1966) erected the species B. hiltermanni (= culverensis) to represent transitional forms between B. strigillatus and B. decoratus found commonly in the Lower Campanian. Koch (1977 and pers. comm.) and Govindan (1977) amongst others, have not recognised B. culverensis Barr, 1967 and thus their concept of B. strigillatus and B. decoratus include forms referred herein to B. culverensis. Following Barr (1970) B. austiniana Cushman, 1937, originally described from the Upper Austin Chalk, is considered conspecific with B. strigillatus.

Occurrence: Moderately rare ranging throughout the Lower Campanian. Found also quite commonly in material from the North Sea.

Zonal range : Bli - Bliii

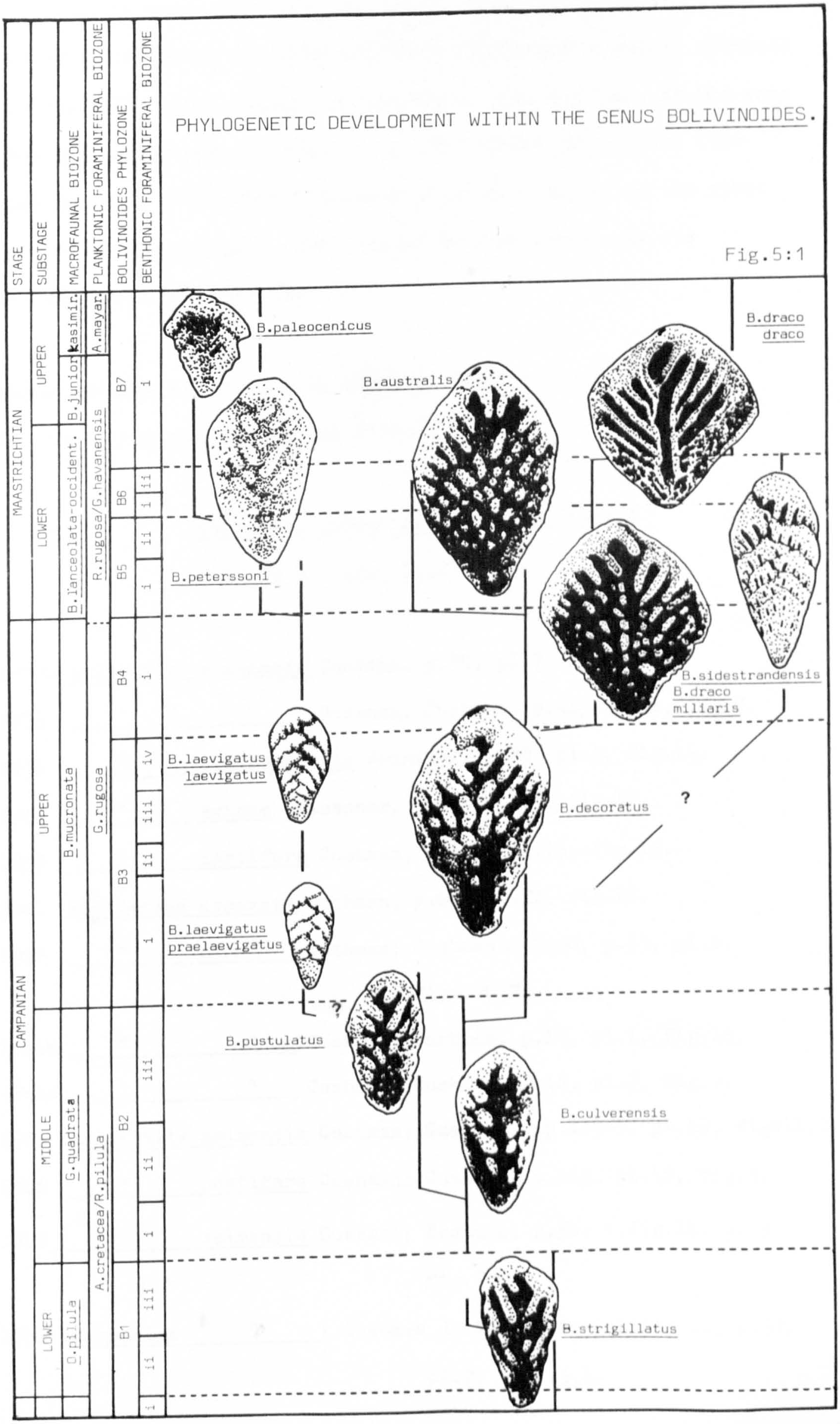
Notes on the Genus BOLIVINOIDES.

The genus Bolivinoides Cushman, 1927 has been widely recorded from strata ranging in age from uppermost Santonian to Palaeocene, and from a wide geographical area. The genus has been much studied, due largely to its value in correlation, both on a local and on an international scale. Its biostratigraphic value is due to rapid, and well documented evolution, together with widespread, almost cosmopolitan distribution. Species of Bolivinoides have been widely recorded from both Europe and North America, and from Russia, Libya, Israel, India and Australia, and similar sequences of evolutionary lineages have been found to occur apparently synchronously in all these areas. Species of Bolivinoides also appear to show a relatively wide degree of ecological tolerance, being recorded from a variety of different palaeoclimatic regimes.

The genus originated in the uppermost Santonian, the first recorded species being B. strigillatus. Even this ancestral species appears to show an almost world-wide distribution and synchronous appearance. From this ancestral B. strigillatus stock two major phylogenetic lineages evolved. The first lineage shows a distinct trend towards an increasingly compressed, subrhomboid test with acute margins, and becoming increasingly ornamented. This lineage includes B. culverensis, B. decoratus, B. australis and B. giganteus.

A second major evolutionary lineage, arising either directly from B. strigillatus (Hiltermann 1963) or, more probably, from B. culverensis exhibits a trend towards a more markedly compressed, poorly ornamented test and includes B. laevigatus praelaevigatus, B. laevigatus laevigatus, B. peterssoni and B. paleocenicus. Barr (1966a) suggested that B. laevigatus praelaevigatus was derived from B. pustulatus. A completely independent derivation direct from B. culverensis stock is also considered to be a possibility. Such a view is in accord with the findings of Petters (1977), concerning the evolution of pore characteristics within these species.

The phylogenetic lineage including B. draco miliaris and


PHYLOGENETIC DEVELOPMENT WITHIN THE GENUS BOLIVINOIDES.
Fig.5:1
STAGE
SUBSTAGE
MACROFAUNAL BIOZONE
PLANKTONIC FORAMINIFERAL BIOZONE
BOLIVINOIDES PHYLOZONE
BENTHONIC FORAMINIFERAL BIOZONE
MAASTRICHTIAN
CAMPANIAN
UPPER
LOWER
UPPER
MIDDLE
LOWER
B.kasimir.
B.junior
B.lanceolata-occident.
B.mucronata
G.quadrata
O.pilula
A.mayar.
R.rugosa/G.havanensis
G.rugosa
A.cretacea/R.pilula
B7
B6
B5
B4
B3
B2
B1
B.paleocenicus
B.australis
B.draco
draco
B.peterssoni
B.sidestrandensis
B.draco
miliaris
B.laevigatus
laevigatus
B.decoratus
?
B.laevigatus
praelaevigatus
?
B.pustulatus
B.culverensis
B.strigillatus

B. draco draco arose from B. decoratus stock in the uppermost Campanian and shows a pronounced tendency towards a squat, rhomboid outline with acute margins and heavily ornamented test. At the same time B. sidestrandensis appears in the British succession. This species shows little morphological similarity to any of the other species of Bolivinoides found in the British Isles, and its derivation is somewhat obscure.

Genus TAPPANINA Montanaro-Gallitelli, 1955

Genotype Bolivinita selmensis Cushman, 1933

Tappanina selmensis (Cushman, 1933)

(Plate 6, figs. 16,17)

1933b Bolivinita selmensis Cushman, p.58, pl.7, figs.3,4.

1936 " " Cushman; Cushman, p.419, pl.1, fig.7.

1936 " crawfordensis Jennings, p.28, pl.3, fig.14.

1937 " exiqua Glaessner, p.349, pl.2, fig.12.

1937 " costifera Cushman, p.105, pl.15, fig.15.

1940 Eouvigerina excavata Cushman, p.66, pl.11, fig.18.

1942 " " Cushman; Cushman & Todd, p.35, pl.6, figs.20,21.

1944b " " Cushman; Cushman, p.10, pl.1, fig.18.

1944c " " Cushman; Cushman, p.42, pl.7, fig.7.

1946 Bolivinita selmensis Cushman; Cushman, pp.114-5, pl.49, figs.1,2.

1946 " costifera Cushman; Cushman, p.115, pl.49, fig.3.

1948 " selmensis Cushman; Brotzen, p.56, t.fig.16, pl.9, fig.7.

1956 Tappanina " (Cushman); Montanaro-Gallitelli, p.37, pl.7, figs.3,4.

1956 Tappanina costifera (Cushman); Monatanaro-Gallitelli, p.37, pl.7, figs.5-7.

1957 " selmensis (Cushman); Montanaro-Gallitelli, p.147, pl.33, fig.21.

1962 Bolivinita exiqua Glaessner; Hiltermann & Koch, p.314, pl.51, fig.24.

1964 Tappanina selmensis (Cushman); Loeblich & Tappan, pp.C553-5, fig.435,4.

1965 " " (Cushman); Perlmutter & Todd, p.115, pl.2, fig.16.

1965 " " (Cushman); Pozaryska, p.102, pl.15, fig.9.

1969 " costifera (Cushman); Mello, p.74, pl.8, fig.9.

1977 Bolivinita exiqua Glaessner; Villain, p.70, pl.5, fig.8.

1977 Tappanina selmensis (Cushman); Koch, p.64, pl.17, figs.8,9.

Description: Test free; small, initially bluntly pointed, expanding only very gradually and uniformly; cross section rhomboid or rectangular; broad sides weakly concave, narrow sides convex or truncated, may be horizontally carinate; chambers distinct, biserially arranged, 4 to 6 pairs, increasing very gradually; earlier chambers flattened and compressed, may give way to chambers which are concave on the broad face and distinctly convex on the periphery, giving test sharply crenulated outline; carinate margin following long axis of chambers; sutures distinct, slightly curved, becoming more so, may be obscured by carinae; aperture narrow loop shaped opening at base of final chamber, with tooth plate; wall calcareous, finely perforate; surface moderately smooth.

Average height: 0.18mm. Average width: 0.10mm.

Remarks: This small, distinctive species may be distinguished by its horizontal carinae, which may degenerate into four longitudinal sutural costae. As may be seen from the synonymy, it has had a complex taxonomic history. Brotzen (1948), after extensive study of populations from the Maastrichtian, Danian and Palaeocene, concluded that Tappanina exiqua (Glaessner, 1937), T. costifera (Cushman, 1937) and T. crawfordensis (Jennings, 1936) were conspecific with T. selmensis (Cushman, 1933) . Brotzen also expressed doubt as to the validity of Eovigerina excavata Cushman. Montanaro-Gallitelli (1956) after study of the holotype of E. excavata, found that it was, in fact, a specimen of T. selmensis which possessed a broken last chamber simulating a phialine neck, thus confirming Brotzen's original suspicions. Montanaro-Gallitelli recognised T. costifera Cushman as distinct from T. selmensis . In the present study, the earliest sample containing T. selmensis also contains forms referable to T. costifera, and there appears to be intergradation between the two extremes. For these reasons, Brotzen's concept of one species exhibiting a wide morphological variation is followed.

Occurrence: This species occurs only in the 125 μ sieve fraction. It was found in the top 3 metres at Trimingham, and rarely in North Sea material of Upper Maastrichtian age.

Zonal range: B6ii - B7i

Family EOUVIGERINIDAE Cushman, 1927

Genus EOUVIGERINA Cushman, 1926

Genotype Eouvigerina americana Cushman, 1926

Eouvigerina aculeata (Ehrenberg, 1854)

(Plate 6, figs.17,18)

1854 Loxostomum aculeata Ehrenberg, p.22, pl.27, figs.21,22, pl.28, fig.26.

1892 Textularia serrata Chapman, p.515, pl.15, fig.7.

1910 Sagrina cretacea Heron-Allen & Earland, p.423, pl.8, figs.8-10.

1926 Eouvigerina americana Cushman, p.4,5, pl.1, fig.1.

1929 " cretacea (Heron-Allen & Earland); White, p.42, pl.4, fig.18.

1931b " americana Cushman; Cushman, p.45, pl.7, fig.11.

1932 " cretacea (Heron-Allen & Earland); Macfadyen, p. 493, pl.35, fig.23.

1933 " americana Cushman; Cushman, pl.26, fig.32.

1936 " " Cushman; Brotzen, pp.123-4, pl.9, fig.4.

1937 " aculeata Cushman; Loetterle, pp.36-7, pl.5, fig.9.

1941 " aspera (Marsson) var. laevigata Marie, p.193, pl.29, fig.284.

1941 " " (Marsson) var. denticulocarinata Marie, p.193, pl.29, fig.285.

1946 " americana Cushman; Cushman, p.115, pl.49, figs.4,5.

1948 " cretacea (Heron-Allen & Earland); Williams-Mitchell, pp.103-4, pl.9, fig.4.

1951 " " (Heron-Allen & Earland); Noth, p.63, pl.9, fig.16.

1951 " americana Cushman; Loeblich, pp.106, 109-10, pl.12, fig.9.

1954 " " Cushman; Frizzell, p.112, pl.16, fig.15.

1957 " " Cushman; Montanaro-Gallitelli, p.148, pl.34, figs.1-5.

1957 " aculeata (Ehrenberg); Hofker, pp.275-6, t.figs.327-8.

1957 " cretacea (Heron-Allen & Earland); Hofker, p.275, t.figs.329-330.

1957 " " (Heron-Allen & Earland); McGugan, pl.32, figs.20,21.

1960 Eouvigerina americana Cushman; Belford, p.63, pl.16, figs.3-6.

1964 " serrata (Chapman); Barr & Cordey, pp.307-8, pl.49, figs.8,9.

1964 " aculeata (Ehrenberg); Loeblich & Tappan, pp.C556-7, fig.440, 1-3.

1966 " cretae (Heron-Allen & Earland); Hofker, p.38, pl.5, fig.34, pl.13, fig.44.

1970 " aculeata (Ehrenberg); Porthault, in Donze et al, p.57, pl.8, fig.25.

1977 " cretacea (Heron-Allen & Earland); Villain, p.70, pl.5, fig.12.

Description: Test free; small, initially broadly rounded, gradually expanding; periphery serrate especially in later stages; chamber arrangement biserial; chambers distinct, uninflated becoming inflated, angular and truncate; cross section subrectangular; sutures distinct, initially flush becoming strongly depressed, curved; aperture terminal, circular to subcircular opening at end of neck surrounded by phialine lip; internally with tooth plate; wall calcareous, finely perforate; surface smooth to finely hispid.

Average height: 0.29mm. Average width: 0.15mm.

Remarks: The rather wide morphological variation shown by the present species has led to a rather confused taxonomic history. Barr and Cordey (1964), after examination of type material concluded that E. cretacea (Heron-Allen & Earland, 1910) is conspecific with E. serrata (Chapman, 1892). They also noted the morphological similarity of this species to E. americana Cushman, 1926, stating that the two might prove to be conspecific. Loeblich and Tappan (1964) recognised E. americana as a junior synonym of E. aculeata (Ehrenberg). After examination of type material housed in the British Museum

(Nat. Hist.) in the collections of Chapman (P4547), Heron-Allen & Earland (P48937), and Barr & Cordey (P44966), the present author considers all these species listed above to be conspecific.

Eouvigerina aculeata Cushman, 1933 is a junior homonym of the present species. The two forms are closely related, though, according to Cushman' original description his species may be distinguished by its "much less clear-cut" form and chambers which "are not so clearly sculptured". Further study is required to determine whether this species is also a junior synonym of E. aculeata (Ehrenberg).

The rarely recorded species E. aspera (Marsson, 1878), described from the Maastrichtian of the Isle of Rügen, is also closely related to the present species, differing from the present species by possessing fewer chambers and a slightly longer apertural neck.

Occurrence: E. aculeata has been found in moderate abundance in strata of Campanian and Lower Maastrichtian age. It is generally restricted to sieve fractions <250μ

Zonal range: B1ii - B5ii

Eouvigerina sp. A

(Plate 6, figs. 19,20)

1975 Eouvigerina elongata (Brotzen) n.ssp. Abu-Maaruf , pp.161-2, t.fig.13a.

Description: Test free; small, initially broadly rounded, bearing an apical spine in well preserved individuals; chambers arranged biserially, rapidly becoming loosely biserial and then irregularly uniserial; periphery only very slightly lobate; cross section circular not compressed, chambers inflated, subglobular, increasing uniformly and moderately in size and strongly embracing, generally 5-6 chambers present; sutures distinct, depressed to slightly depressed, curved, almost horizontal; aperture terminal, circular opening at end of short neck bordered by a distinct phialine lip; wall calcareous, finely perforate; surface finely hispid to densely pustulose.

Average height: 0.37mm. Average width: 0.12mm.

Remarks: This species was originally described and figured as an unnamed subspecies of Eouvigerina elongata (Brotzen, 1936). It differs from Brotzen's species, which was described from the Santonian of Eriksdal, Sweden, by having a pustulose surface ornament, an almost uniserial chamber arrangement, and uncompressed test, together with a distinct apertural lip. It is felt that these differences are sufficient to warrant the separation of this form as a distinct species. Cushman (1931) described E. hispida, a morphologically similar species from the Selma Chalk of the U.S.A. The present species appears to differ from E. hispida by possessing a more densely pustulose ornament and a well developed uniserial portion. E. sp. A also appears to have a distinct stratigraphic range, being restricted to the Lower Campanian whilst E. hispida ranges throughout the Campanian and Lower Maastrichtian. E. austinana Cushman, 1933 is also similar morphologically to E. sp. A and has a similar stratigraphic range. It may be distinguished by its compressed test and smoother surface.

Occurrence: Rare both in Norfolk and the Isle of Wight, restricted to the Lower Campanian. Abu-Maaruf (1975) recorded an almost identical range for this species from Germany.

Zonal range: Blii - Bliii

Eouvigerina sp. B

(Plate 6, figs. 21,22)

1899 Uvigerina gracilis Reuss; Egger, p.132, pl.15, figs.27, 30, 31.

1956a " " (Egger); Hofker, p. B214, fig.25.

1957 " " (Egger); Hofker, p.277, t.figs. 332?, t.figs. 333-4.

1966 " " (Egger); Hofker, p.38, pl.5, fig.32.

1977 " " (Reuss); Villain, p.70, pl.5, fig.11.

Description: Test free; small, initial end sharply pointed, bearing short spines; chambers arranged biserially rapidly becoming very loosely biserial; outline strongly lobate; chambers slightly inflated, rapidly becoming inflated, subglobular, only slightly higher than wide, generally 5-7 in number; cross section circular; sutures distinct, initially slightly depressed becoming distinctly depressed, almost straight, inclined; aperture terminal, circular opening at end of moderately long neck, bordered by a distinct phialine lip; internally possessing thin columellar tooth plate; wall finely perforate, calcareous; surface finely rugose, hispid.

Average height: 0.34mm. Average width: 0.12mm.

Remarks: Egger (1899) figured a species of Eouvigerina from the Upper Cretaceous which he referred to Uvigerina gracilis Reuss, 1851, originally described from the Eocene. The wide difference in stratigraphic occurrence, together with differences in morphology, strongly suggest that Egger's form is a distinct species. Possibly recognising this, Hofker (1956a,1957, 1966) subsequently referred the species to Eouvigerina gracilis (Egger) disregarding Egger's attributation of the species to Reuss.

E. sp.B. appears to be closely related to E. hispida Cushman, 1931b. The two both possess a hispid surface and apical spines. E. sp. B may be distinguished, however, by its more slender form and loosely biserial, to almost uniserial, chamber arrangement, which is more marked than in the American species, it also shows a more acute initial end. E. gracilis Cushman, differs from E. sp. B in its compressed test, chambers which are wider than high, and more marked differentiation into relatively long biserial, and short, loosely biserial sections.

Occurrence: Moderately common in the Lower Maastrichtian of Norfolk. Restricted to the 125μ sieve fraction.

Zonal range : B5i - B6ii

Eouvigerina (?) galeata (Vasilenko, 1961)

(Plate 6, figs. 23,24)

1961 Bolivinitella galeata Vasilenko, p. 206, pl.41, fig.7.

1975 ______"______"___ Vasilenko; Abu-Maaruf, p.187, t.fig.13b.

Description: Test free; elongate, 3-4 times as long as broad; periphery entire becoming slightly lobate; initial end bluntly rounded; test uniformly and gradually expanding; cross section subrectangular; chambers biserial, 10-14 in number, initially indistinct, uninflated, becoming distinct, inflated, strongly arched; carinate; initially carinae fused into longitudinal keels at the four margins of the test; sutures indistinct, later strongly arched, incised; aperture terminal, ovate, at end of short, broad neck, bordered by a phialine lip; wall calcareous, finely perforate ; surface finely roughened.

Average height: 0.30mm. Average width: 0.11mm.

Remarks: This distinctive species is easily distinguished by its elongate form, strongly arched chambers and apertural characteristics. It was originally referred to the genus Bolivinitella, recognised as a junior synonym of Loxostomum Ehrenberg, by Loeblich and Tappan (1964). However, the distinctive, strongly arched chambers, and the terminal aperture with a short neck and phialine lip, suggest in the present author's opinion, a relationship to the genus Eouvigerina. This generic determination must however, remain tentative, as the primary wall structure of this species was indeterminable due to secondary recrystallization,and no internal tooth plate was conclusively observed, though this may have been due to problems of preservation.

Occurrence: Originally described from the Santonian/Campanian of Southern Russia and recorded by Abu-Maaruf (1975) from the Lower Campanian (pilula/senonensis to conica/papillosa subzones) of Germany. In the present study it has been found in the Lower and lowest Middle Campanian both in Norfolk and the Isle of Wight.

Zonal range: B2ii - B2iii

Genus STILOSTOMELLA Guppy, 1894

Genotype Stilostomella rugosa Guppy, 1894

Stilostomella pseudoscripta (Cushman, 1937)

(Plate 6, fig . 25)

1937 Ellipsonodosaria pseudoscripta Cushman, p.103, pl.15, fig.14.

1946 " " Cushman; Cushman, p.135, pl.56, fig.9.

1956b Nodogenerina spinosa Hofker, p.69, pl.6, fig.26.

1956a Stilostomella " (Hofker); Hofker, p.B214, fig.29.

1957 " " (Hofker); Hofker, p.142, t.fig.164.

1963 Siphonodosaria sp. cf. S. paleocenica (Cushman & Todd); Graham & Church, p.55, pl.6, fig.10-12.

1966 Stilostomella spinosa (Hofker); Hofker, p.38, pl.5, fig.18, pl.18, fig.29.

pars 1968 " pseudoscripta (Cushman); Sliter, pp.90-1, pl.13, fig.6, non. fig.7.

1972 " " (Cushman); Hanzlikova, p.84, pl.20, fig.3.

1977 " " (Cushman); Sliter, pl.5, fig.7.

1977 " sagrinensis Bagg; Villain, p.47, pl.4, fig.11.

Description: Test free; small, elongate, uniformly and very gradually expanding; chambers 9-11, uniserial, rectilinear, inflated, initially globular, later may become pyriform; initial chambers spinose in well preserved individuals; sutures distinct, depressed, limbate; wall calcareous, finely perforate; surface finely spinose, with base of chambers coarsely spinose; aperture terminal, with small tooth, on broad indistinct neck surrounded by phialine lip.

Average height: 0.84mm. Average width: 0.14mm.

Remarks: Sliter (1968) noted that S. spinosa (Hofker, 1956) and S. pseudoscripta (Cushman, 1937) were conspecific. Sliter also stated however, that this species is morphologically intergradational with Siphogenerinoides plummerae (Cushman, 1940). However, no specimens referable to this latter species have been found in the present study.

Occurrence: This species has been found in moderate abundance both in the Upper Campanian and Lower Maastrichtian of Norfolk and of the

North Sea. Generally restricted to sieve fractions <250μ.

Zonal range: B4i - B7i

Family BULIMINIDAE Jones, 1875

Subfamily PAVONINAE Eimer & Fickert, 1899

Genus REUSSELLA Galloway, 1933

Genotype Verneuilina spinulosa Reuss, 1850

Remarks: The genus Reussella Galloway 1933 differs from Pyramidina by possessing sharply angled margins, coarsely perforate walls, and complex tooth plates (Loeblich & Tappan, 1964). Such forms occur commonly in the Upper Cretaceous contrary to the opinion of Loeblich and Tappan,(1964), who state that all Upper Cretaceous records of Reussella should be referred to Pyramidina.

Reussella kelleri Vasilenko, 1961

(Plate 7, figs. 1-3)

1935 Reussella aff. spinulosa (Reuss); Keller, p.550, pl.2, figs.9-11.

pars 1957 " pseudospinulosa Troelsen; Hofker, pp.212-3, t.fig.260, non.t.fig. 259.

1961 " kelleri Vasilenko, pp.176-8, pl.38, figs.3-5,12,13.

1975 " " Vasilenko; Robaszynski, p.19, fig.2.

? 1977 " pseudospinulosa Troelsen; Sliter, p.675 (list), pl.5, figs.8,11.

Description: Test free; elongate, triangular in cross section, often twisted, test margins typically acute, carinate, occasionally subacute; test $1\frac{1}{2}$ times as high as wide; initial end sharply pointed, may be spinose and carinate; rapidly and uniformly expanding, periphery slightly to distinctly lobate; chambers arranged triserially throughout in 4-6 whorls; chambers distinct triangular, inflated and strongly overlapping, producing lobate or spinose margin; sutures distinct, curved, often raised and limbate; aperture narrow straight slit extending, almost vertically, up the steeply inclined apertural face; a slight lip may be present and internally a tooth plate is developed; wall calcareous, perforate.

Average height: 0.46mm. Average width: 0.30mm.

Remarks: This species may be distinguished by its sub-angular, raised chambers margin and carinate, often slightly spinose periphery. The specimens from the S.W. Atlantic assigned by Sliter (1977) to *R. pseudospinulosa* Troelsen may be distinguished from Troelsen's species by their more elongate form, weakly spinose periphery and less angular margins. Sliter's specimens were found in strata of Santonian age, and it is possible that they belong to *R. kelleri* . As noted by Bailey (1978 MS.) specimens of this species from the Isle of Wight are typically carinate and possess limbate, slightly raised sutures, whereas those from Norfolk tend to be more elongate, with a lobate to spinose periphery and possess markedly raised sutures. In many of these features they are transitional to *R. szajnoche praecursor* de Klasz & Knipscheer, 1954.

Occurrence: Originally described from the Santonian of Southern Russia. Found in moderate abundance throughout the Lower Campanian both in Norfolk and the Isle of Wight.

Zonal range : B1ii - B1iii, rarely B2i

Reussella szajnochae szajnochae (Grzybowski, 1896)

(Plate 7, figs. 4-6)

1896 Verneuilina szajnochae Grzybowski, p.287, pl.9, fig.19.

1929 Bulimina limbata White, p.48, pl.5, fig.9.

1935 Reussella spinulosa (Reuss); Keller, p. 550, pl.11, figs.12-14.

1937 " pseudospinulosa Troelsen, p.260.

1944 " szajnochae californica Cushman & Goudkoff, p.59, pl.10, figs.3-5.

1945 " pseudospinulosa Troelsen; Brotzen, p.46, fig.6.

1946 Bulimina limbata White; Cushman, p.124, pl.52, fig.5.

1947 " " White; Cushman & Parker, p.87, pl.20, fig.19.

1951 Reussella szajnochae (Grzybowski); Noth, p.65, pl.7, fig.7.

1951 " " californica Cushman & Goudkoff; Noth, p.65, pl.7, fig.6.

1954 " " (Grzybowski); de Klasz & Knipscheer, pp.600-601, t.fig.1, figs.2?,3?, 4-7

1955 " " (Grzybowski); Bettenstaedt & Wicher, p.502, pl.2, fig.18.

? 1957 " " (Grzybowski); Hofker, p.214, t.fig.262.

1957 " truncata Hofker, p.263, t.fig.263.

1957 " pyramidalis Hofker, pp.215-6, t.fig.264.

1958 " szajnochae (Grzybowski); Pokorny, p.303, t.fig.9.

1959 " " californica Cushman & Goudkoff; Eternod Olvera, p.83, pl.3, figs.1,2.

1960 " " (Grzybowski); Belford, p.66, pl.16, figs.16-19, pl.17, figs.1-13.

1963 " " (Grzybowski); Graham & Church, p.53, pl.6, fig.9.

1964 " " (Grzybowski); Martin, p.91, pl.12, fig.4.

1968 Reussella szajnochae (Grzybowski); Scheibnerova, p.54, fig.9.

1968 Pyramidina pseudospinulosa (Troelsen); Stenestad, pl.2, fig.11.

1968 " szajnochae (Grzybowski); Sliter, p.87, pl.12, fig.13.

1969 Reussella " (Grzybowski); Hanzlikova, p.35, pl.6, fig.9.

1972 " " (Grzybowski); Hanzlikova, p.85, pl.20, figs.9-11.

1977 " " (Grzybowski); Sliter, p.675 (list), pl.5, figs.9-10.

Description: Test free; triangular, robust, twice as high as wide, occasionally twisted; cross section triangular; test margins sharp, serrate, spinose, not carinate; initial end sharply pointed, spinose; test expanding rapidly and uniformly; sides of test flat to slightly concave; chambers arranged triserially throughout, in 4-6 whorls; chambers distinct, low, broader than high, arched, slightly inflated, distinctly overlapping; sutures distinct, limbate, distinctly raised, carinate and projecting from test angles to form spines; sutures curved, arched; aperture elongate slit shaped opening, extending up the apertural face from the mid-point of the interiomarginal suture, bordered by a distinct raised lip; internally tooth plate developed; wall calcareous, perforate; surface smooth.

Average height: 0.51mm. Average width: 0.34mm.

Remarks: De Klasz and Knipscheer (1954) have outline the gradual phylogenetic development of this species throughout the Campanian and Maastrichtian. There has been some confusion in the literature between this species and R. pseudospinulosa Troelsen, 1937 from the Lower Maastrichtian of Møns Klint, Denmark. Topotypic material has been examined and R. pseudospinulosa falls within the range of morphological variation of R. szajnochae szajnochae. R. szajnochae szajnochae was originally described from clays of uncertain age encountered in boreholes near Wadowice, Poland (Hanzlikova, 1972).

Occurrence: This species occurs sporadically, but in some abundance, throughout the upper Upper Campanian. It has also been found rarely at certain horizons within the Upper Maastrichtian of the North Sea, but has not been found in the Lower Maastrichtian of Norfolk. It is moderately abundant in the Upper Campanian of the North Sea.

Zonal range : B3iv - B4i

Reussella szajnochae praecursor de Klasz & Knipscheer, 1954

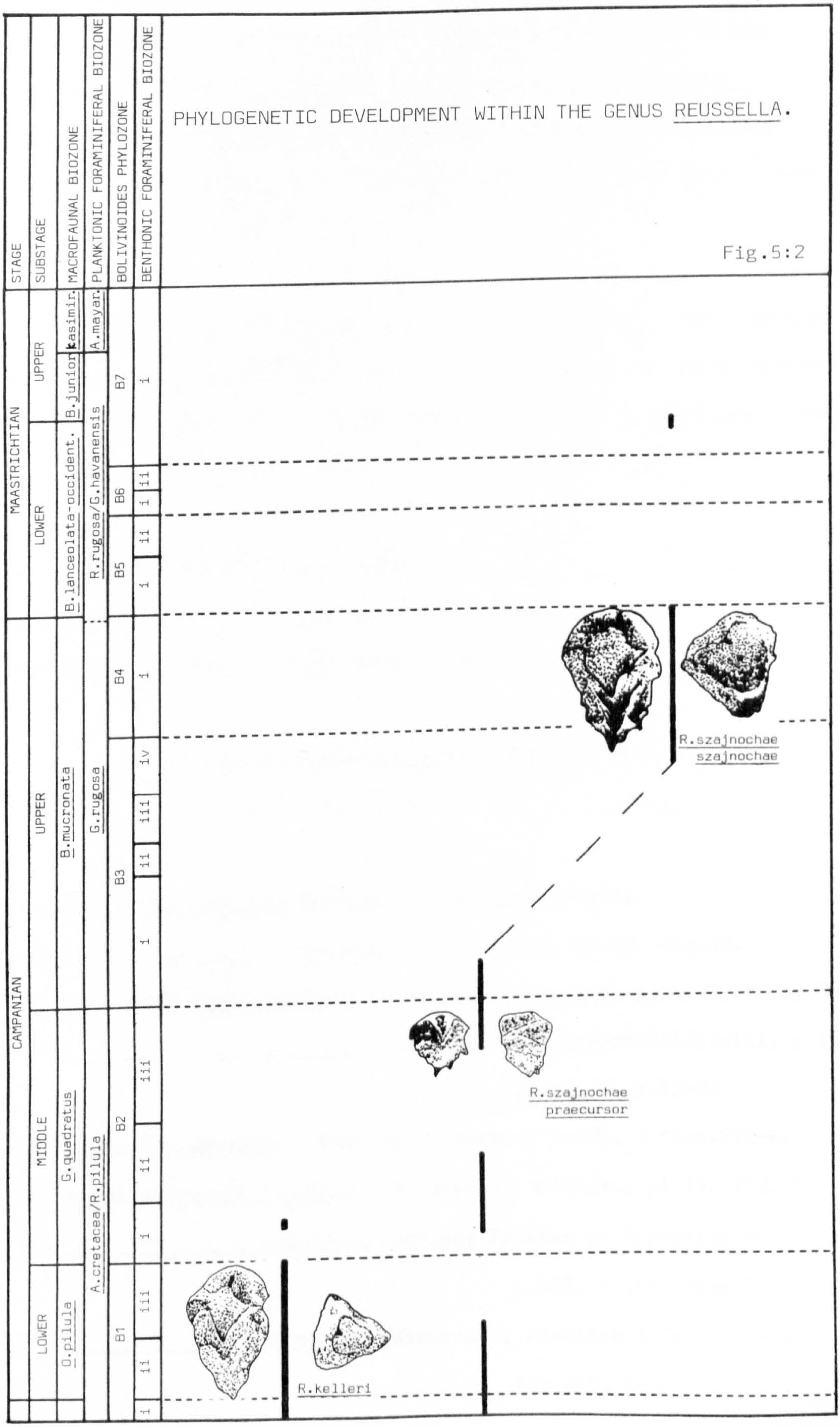
(Plate 7, figs. 7,8)

1954 *Reussella szajnochae* (Grzybowski) *praecursor* de Klasz & Knipscheer, pp. 603-4, t.fig.9(p.605), fig.1.

1957 " *pseudospinulosa* Troelsen; Hofker, pp.212-3, t.fig.259, non.t.fig.260

Description: Test free; small, triangular, varying from $1\frac{1}{4}$ to 2 times as high as wide; triangular cross section; test margins serrate, spinose; initial end sharply pointed, typically spinose, test expanding more or less gradually and uniformly; chambers triserially arranged throughout, 5-6 whorls; chambers distinct, arched, raised and extending beyond test angles in a series of spinose projections ; aperture slit shaped opening extending up apertural face from mid-point of interiomarginal suture; internally toothplate developed, externally a raised lip is distinguishable; wall calcareous, perforate; surface smooth.

Average height: 0.25mm. Average width: 0.21mm.



PHYLOGENETIC DEVELOPMENT WITHIN THE GENUS REUSSELLA.

Fig.5:2

Remarks: This species may be distinguished from R. kelleri by its smaller size, more spinose, generally non-carinate, test angles and by its distinctly raised, limbate sutures, bordering strongly overlapping chambers. This subspecies may be distinguished from R. szajnochae szajnochae by its much smaller size, less robust form and spinose appearance.

Occurrence: Found rarely in the Lower Campanian in both Norfolk and the Isle of Wight. Moderately abundant only in the lower half of the Middle Campanian of Norfolk. Restricted to sieve fractions $< 250\mu$.

Zonal range : B1ii - B2ii

Family UVIGERINIDAE Haeckel, 1894

Genus PSEUDOUVIGERINA Cushman, 1927

Genotype Uvigerina cristata Marrson, 1878

Pseudouvigerina cristata (Marsson, 1878)

(Plate 7, figs. 9,10)

1878 Uvigerina cristata Marsson, p.150, pl.3, fig.20.

1899 " " Marsson; Egger, p.132, pl.15, fig.55.

1945 Pseudouvigerina cristata (Marsson); Brotzen, pp.46-7, t.fig.8a,b.

1957 " " (Marsson); Montanaro-Gallitelli, p.151, pl.34, figs.19-22.

1957 Reussella cristata (Marsson); Hofker, p.220, t.figs.272-4.

1958 Pseudouvigerina cristata (Marsson); Witwicka, pl.10, fig.15.

1964 " plummerae Cushman; Freiman in Subbotina et al, p.287, pl.62, figs.15-18.

1964 " cristata (Marsson); Loeblich & Tappan, p.C568, fig.448, 1-3.

1966 Reussella cristata (Marsson); Hofker, p.38, pl.5, fig.36, pl.10, fig.97, pl.13, fig.47.

1968 Pseudouvigerina cristata (Marsson); Stenestad, pl.2, fig.4.

1969 " " (Marsson); Hanzlikova, p.36, pl.6, figs.7,8.

1972 " " (Marsson); Hanzlikova, p.86, pl.19, figs.18,19.

1977 " " (Marsson); Villain, p.71, pl.5, fig.5.

Description: Test free; elongate, 3 to 4 times as long as wide, initially bluntly pointed; cross section triangular; chamber arrangement triserial, in 4-5 whorls; chambers slightly inflated, overlapping, wider than high; chamber margins possessing distinct, widely spaced, double vertical costae; sutures distinct, initially slightly depressed becoming strongly depressed; aperture terminal or subterminal at end of more or less well developed short neck, occasionally bordered by lip; internal narrow columellar tooth plate present; wall calcareous, finely perforate; surface smooth to very finely hispid with a concentration of ornament between the vertical costae.

Average height: 0.49mm. Average width: 0.25mm.

Remarks: The widely spaced double costae are highly characteristic of this species. The apertural features show a tendency to fuller development of a short phialine neck with time. Such a development clearly suggests a phylogenetic link with P. plummerae Cushman, 1927 (see below). Specimens from the uppermost Campanian and Lower Maastrichtian generally represent a transitional population between these two species and a case could be made for separating out these early forms of P. cristata which possess the distinctive highly developed vertical costae but lack the well developed phialine neck, into a chronosubspecies. This species has been taken by many workers as a useful index form for the Maastrichtian. The record of this species from the Middle and lower Upper Campanian of the Isle of Wight (Barr 1962 MS) is considered to be erroneous.

Occurrence: P. cristata is found in Norfolk in the uppermost Upper Campanian ranging to the top of the Lower Maastrichtian. It is moderately common in strata of Maastrichtian age from the North Sea.

Zonal range: B3iv - B7i

Pseudouvigerina plummerae Cushman, 1927

(Plate 7, figs.11-13)

1927c Pseudouvigerina plummerae Cushman, p.115, pl.23, fig.8.

1931 ______ " ______ " ______ Cushman; Cushman, p.46, pl.7, figs.15, 16.

non 1931a ______ " ______ " ______ Cushman; Cushman, p.309, pl.35, fig.18.

1932 ______ " ______ " ______ Cushman; Sandidge, p.197, pl.19, figs.9-11.

1936 ______ " ______ " ______ Cushman; Cushman, p.419, pl.1, fig.13.

1938 ______ " ______ " ______ Cushman; Cole, p.35, pl.4, fig.8.

1944 ______ " ______ " ______ Cushman; Cushman & Deaderick, p.337, pl.53, fig.4.

1946 ______ " ______ " ______ Cushman; Cushman, pp.116,117, pl.49, figs.14, 16 ?, 17.

1951 ______ " ______ cretacea Cushman; Bandy, p.513, pl.75, fig.13.

1954 ______ " ______ plummerae Cushman; Frizzell, p.113, pl.16, figs.32,33.

non 1964 ______ " ______ " ______ Cushman; Freiman in Subbotina et al, p.287, pl.62, figs.15-18.

1968 Pseudouvigerina plummerae Cushman; Sliter, p.91, pl.13, fig.11.

Description: Test free; small, elongate, 3 to 4 times as high as wide; initially pointed, widest point of test towards apertural end; test rapidly and uniformly expanding; cross section triangular; chamber arrangement triserial, in 4-5 whorls; chambers distinct, slightly inflated; margins of test subrounded possessing two weakly developed, closely spaced, vertical, crenulated costae, generally restricted to the lower two-thirds of test; sutures distinct, depressed; aperture subterminal to terminal, loop shaped to subcircular opening, occasional specimens show extension of final chamber to form rudimentary neck; wall calcareous, finely perforate; surface possessing fine tuberculate ornament.

Average height: 0.33mm. Average width: 0.16mm.

Remarks: This species, originally described from the Pecan Gap Chalk of Texas, closely resembles P. cristata as noted by Cushman (1927). It may be distinguished by its distinctly weaker, closely spaced, vertical costae and poorly developed apertural neck. It would appear that Barr's (1962 MS) record of P. cristata from the Middle Campanian of the Isle of Wight should be referred to P. plummerae.

Occurrence: Ranging from the middle Lower Campanian to the upper Upper Campanian in moderate abundance.

Zonal range: B1ii - B3iv

Pseudouvigerina rugosa Brotzen, 1945

(Plate 7, figs.14,15)

1945 Pseudouvigerina rugosa Brotzen, p.47, pl.1, fig.7.

1957 Reussella rugosa (Brotzen); Hofker, pp.218-9, t.figs. 268-270.

1966 " " (Brotzen); Hofker, p.38, pl.5, fig.31.

Description: Test free; elongate, triangular, initially bluntly pointed, occasionally developing axial twisting; chamber arrangement triserial, last chamber terminal, 4-6 whorls present; chambers distinct, slightly broader than high, final chamber drawn out, forming a rudimentary neck; cross section triangular, margins subacute, sides concave; sutures distinct, weakly depressed; aperture subterminal to terminal, circular to elliptical opening at end of drawn out final chamber; wall calcareous, finely perforate; surface finely hispid, especially pronounced along chamber margins, where fine traces of two vertical costae are present.

Average height: 0.26mm. Average width: 0.14mm.

Remarks: This distinctive species has here been reassigned to the genus Pseudouvigerina, on the basis of its non-carinate chamber margins, which show traces of two vertical costae, and its terminal aperture. P. rugosa shows a gross morphological resemblance to Pyramidina rugosa from which it may be distinguished by its less robust test, more markedly concave side, apertural characteristics, and subacute margins,

Occurrence: Originally described from the Lower Maastrichtian of Denmark (Höllviken) and recorded by Hofker from the Maastrichtian of Holland and N. W. Germany. In the present study this species has been found in great abundance in the top 3m. (White Chalk + O.lunata),Trimingham.

Zonal range: B6ii - B7i

Superfamily DISCORBACEA Ehrenberg, 1838

Family DISCORBIDAE Ehrenberg, 1838

Subfamily CONORBININAE Hofker, 1954

Genus CONORBINA Brotzen, 1936

Genotype _Conorbina marginata_ Brotzen, 1936

Conorbina cf. _marginata_ Brotzen, 1936

(Plate 7, figs.16-18)

1936 _Conorbina marginata_ Brotzen, p.141-2, pl.10, fig.5.

1964 " " Brotzen; Loeblich & Tappan, p.C575, fig.453, no.1.

Description: Test free; planoconvex trochospiral, bluntly conical; chambers arranged in 4-6 whorls; on spiral side early whorls indistinct, uniformly expanding, evolute; ventral side flat to slightly concave, involute; periphery circular with distinct thin keel; chambers uninflated, crescentic, increasing uniformly in size, number per whorl 6-7; sutures flush limbate, curved, dorsally, ventrally sutures distinct, radial, slightly curved, flush to depressed; aperture low slit at base of final chamber, almost totally obscured by short projecting flap; wall calcareous, perforate; surface smooth.

Average diameter: 0.26mm. Average thickness: 0.14mm.

Remarks: This species is extremely rare and it has not been possible to ascertain its full range of morphological variation. _C._ cf. _marginata_ differs from the figured holotype by being more highly convex dorsally and by having a less lobate periphery. Figured topotypes of Loeblich and Tappan (1964) show some variation in these features however.

Occurrence: C. marginata was originally described from the Lower Senonian of Eriksdal, Sweden. C. cf. marginata was found sporadically throughout the Middle and Upper Campanian of England, where it is generally restricted to sieve fractions $<250\mu$.

Zonal range: B2i - B3iv

Conorbina sigmoidalis (Schijfsma, 1946)

(Plate 7, figs.19-21)

1946 Discorbis sigmoidalis Schijfsma, pp.83-4, pl.4, fig.12.

Description: Test free; low trochospiral, plano-convex to biconvex; chambers arranged in 2 to $2\frac{1}{2}$ whorls; dorsal side moderately convex, evolute; ventrally, only weakly convex, involute; periphery in umbilical view slightly lobate, in side view subacute; dorsally chambers crescentic, strongly overlapping, only slightly inflated, increasing in breadth as added; ventrally chambers strongly curved, becoming increasingly inflated, 4-7 visible in final whorl, increasing uniformly in size; final chamber showing slight development of tenon with a distinct anterior lobus; sutures distinct, dorsally strongly curved, limbate, flush becoming weakly depressed, ventrally depressed, curved, nearly radial; aperture slit at inner margin of final chamber extending ventrally from umbilicus into the distinct anterior lobus, bordered by thin lip; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.31mm. Averege thickness: 0.15mm.

Remarks: This species is placed in the genus Conorbina on the basis of its apertural form and chamber arrangement. It lacks the characteristic chamber flaps of Discorbis Lamarck, 1804. C. sigmoidalis is characterised by its ventrally inflated chambers and distinct anterior lobus. C. transuralensis (Morozova, 1959) from the Danian of the Crimea is morphologically very similar to C. sigmoidalis and examination of type material is required to determine their exact relationship. This species was wrongly referred to Discorbis binkhorsti , a species restricted to the uppermost Maastrichtian and Danian, by Barr (1962 MS).

Occurrence: Originally described from the Hervian (Campanian) of southern Limburg, Holland. This species is rare in the Campanian and Lower Maastrichtian of England. It is generally restricted to sieve fractions <250μ.

Zonal range: Blii - B5i

Genus NEOCONORBINA Hofker, 1951

Genotype Rosalina orbicularis Terquem, 1876

Neoconorbina scanica (Brotzen, 1936)

(Plate 7, figs.22,23)

1936 Discorbis scanica Brotzen, pp.149, 150, pl.10, fig.3.

Description: Test free; moderate to high trochospire, concavo-convex; chambers arranged in 3-4 loosely coiled whorls; dorsal side moderately to strongly convex, evolute; ventral side involute, markedly concave; periphery rounded in side view, subovate to subcircular in umbilical view; chambers curved, reniform, overlapping, inflated dorsally; initially 5 chambers per whorl reducing to $2\frac{1}{2}$ to 2 in final whorl; ventrally chambers inflated, elongate, crescentic with final chamber often occupying over half the final whorl; final chamber clearly showing large protruding flap bordered by two re-entrant lobes; sutures distinct dorsally, depressed, strongly curved, oblique , ventral sutures moderately distinct, slightly depressed, curved; aperture opening into large umbilical depression, extending below projecting flap, covered by later chambers to form intercameral opening; supplementary apertures in other re-entrant lobes remain open; wall calcareous; surface smooth.

Average diameter: 0.42mm. Average thickness: 0.37mm.

Remarks: The apertural characteristics, loose coiling and moderate to high trochospire all serve to distinguish this species. *N. scanica* does not show the characteristic chamber flaps of the genus *Discorbis* Lamarck, 1804 and is here placed in the genus *Neoconorbina* on the basis of its apertural characteristics.

Occurrence: Originally described from the Lower Senonian of Eriksdal, Sweden, this species is found rarely in strata of Campanian age both in Norfolk and the Isle of Wight.

Zonal range: B2i - B4i

Neoconorbina cf. *sulcata* (Roemer, 1841)
(Plate 7, figs.24-26)

1841 *Rotalia sulcata* Roemer, p.97, pl.15, fig.20.

non 1863 " " Roemer; Reuss, p.85, pl.11, fig.2.

1951 *Conorbina* " (Roemer); Visser, pp.261-2, pl.5, fig.13.

1966 *Neoconorbina sulcata* (Roemer); Hofker, p.139, pl.20, fig.44.

Description: Test free; irregular trochospiral, concavo-convex;

chambers arranged in 2-3 whorls; dorsal side, low to moderately convex, evolute; ventral side involute, markedly concave; periphery subrounded in side view, in umbilical view irregularly subcircular; chambers crescentic, strongly overlapping, increasing in breadth as added dorsally; ventrally chambers slightly inflated, crescentic with strongly developed flap, chambers 3-4 per whorl; sutures distinct, dorsally strongly curved, limbate, flush to slightly raised, ventrally depressed, curved, occasionally undulating; aperture umbilical opening below posterior re-entrant lobe and extending under flap, covered by later chambers to form intercameral opening, supplementary apertures occurring in the other re-entrant lobes which remain open; wall calcareous; surface smooth.

Average diameter: 0.35mm. Average thickness: 0.13mm.

Remarks: The characteristic apertural arrangement and concavo-convex form distinguish this species. Hofker (1966) described the present species from the Maastrichtian of Holland, whilst noting that his assignment to N. sulcata (Roemer, 1841) was only tentative, due to the poor quality of the original figures. The present forms differ from the figured holotype by being markedly less convex dorsally, however, the poor quality of these illustrations make an exact determination impossible.

Occurrence: Found rarely in the Campanian both in Norfolk and the Isle of Wight. It is generally restricted to sieve fractions <250μ.

Zonal range: B1iii - B4i

Subfamily BAGGININAE Cushman, 1927

Genus VALVULINERIA Cushman, 1926

Genotype Valvulineria californica Cushman, 1926

Valvulineria lenticula (Reuss, 1845)
(Plate 8, figs.1,2)

1845 Rotalia lenticula Reuss, p.35, pl.12, fig.17.

1860 " " Reuss; Reuss, p.221.

1899 Discorbina lenticula (Reuss); Egger, p.166, pl.18, figs.22-4.

1925 Anomalina " (Reuss); Franke, p.87, pl.7, fig.15.

1928 " " (Reuss); Franke, p.183, pl.16, fig.11.

1936 Valvulineria " (Reuss); Brotzen, pp.151-3, pl.11, fig.5, t.fig.54,55.

non 1941 Ceratobulimina lenticula (Reuss); Marie, pp.226-7, p.35, figs.326-8.

1957 Valvulineria " (Reuss); Hofker, pp.380-1, t.fig.425.

1957 " " (Reuss); Harris & McNulty, pp.866-7, pl.97, figs.1-5.

1960 " " (Reuss); Belford,p.75, pl.20, figs.3-10.

1961 " " var. lenticula (Reuss); Vasilenko, p.43, pl.8, fig.1.

1973 " " (Reuss); Koch, p.211.

1977 " " (Reuss); Sliter, pl.6, figs.1,4.

Description: Test free; low involute trochospiral coil of 3 whorls, biconvex ; periphery broadly rounded; chambers indistinct, very weakly inflated ventrally, uniformly and gradually increasing in size, generally 7 chambers in final whorl; sutures indistinct initially, becoming distinct, ventral sutures, straight to slightly curved, flush becoming slightly depressed between last 2 or 3 chambers; dorsal sutures flush, slightly curved, spiral suture distinct becoming depressed in later stages; aperture narrow slit along inner margin of final chamber, bordered by thin lip; umbilicus covered by a distinct projecting apertural flap; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.35mm. Average thickness: 0.20mm.

Remarks: This species is closely related to V. plummerae Loetterle (1937), which Vasilenko (1961) regarded as a subspecies of V. lenticula. V. lenticula may be distinguished by being less compressed and having fewer chambers. V. laevis Brotzen, originally described from the Palaeocene of Sweden, is also closely related and may well be phylogenetically descended from V. lenticula from which it is distinguished by its greater number of chambers (commonly 9-10).

Occurrence : Originally described from the Turonian Plänermergel of Bohemia. Brotzen (1936) recorded the range of this species as Turonian to Santonian. In the present study it is found in moderate abundance in the Lower and Middle Campanian, both in Norfolk and the Isle of Wight, and rarely also in the Upper Campanian and Maastrichtian.

Zonal range: B1ii - B5ii

Valvulineria mariei Vasilenko, 1961

(Plate 8, figs.3,4)

1941 Ceratobulimina lenticula (Reuss); Marie , pp.226-7, pl.35, figs.326-8.

1961 Valvulineria mariei Vasilenko, p.45, pl.8, fig.3.

Description: Test free; trochoid, planoconvex to slightly biconvex, dorsally much flattened, ventral side convex to subconical, involute; periphery in end view sharply angled; chambers arranged in 3 whorls, only slightly inflated, 7 to 8 in final whorl, expanding uniformly and fairly rapidly; last chamber peripherally somewhat flattened whilst umbilically highly domed; ventral sutures distinct, curved, flush becoming slightly depressed; dorsal sutures markedly curved, oblique, flush indistinct, spiral suture ventrally distinct, slightly depressed; aperture narrow slit along inner margin of final chamber, bordered by narrow lip; umbilical area covered by distinct projecting apertural flap; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.43mm. Average thickness; 0.23mm.

Remarks: The planoconvex test, angular periphery and characteristically domed final chamber, all serve to distinguish this species. V. undulata Belford (1960) possesses a similar gross morphology but is distinguished by its characteristic, strongly undulating sutures. V. mariei was described as V. barnardi sp. nov. by Barr (1962 MS), although this name was never published.

Occurrence: Originally described from the Campanian/Maastrichtian of the Caspian Sea region and recorded by Marie (1941) from the Upper Campanian of the Paris Basin. In Norfolk found in the Middle and Upper Campanian, and Lower Maastrichtian, moderately common throughout this range. In the Isle of Wight also found rarely in the Lower Campanian.

Zonal range: B1ii - B6ii

Family EPONIDIDAE Hofker, 1951

Genus EPONIDES De Montfort, 1808

Genotype Nautilus repandus Fichtel & Moll, 1798

Eponides beisseli Schijfsma, 1946

(Plate 8, figs.5,6)

1946 Eponides beisseli Schijfsma, p.84, pl.4, fig.13.

1951 " " Schijfsma; Visser, p.271, pl.8, fig.14.

1956a " " Schijfsma; Hofker, p.B222, t.fig.46.

1957 " " Schijfsma; Hofker, p.382, t.fig.427.

1966 " " Schijfsma; Hofker, p.77, pl.13, fig.56.

1966 " " forma primativa Hofker, p.43, pl.6, fig.57.

1977 " " Schijfsma; Villain, pp.60-1, pl.8, figs.10-12.

1977 Gyroidinoides beisseli (Schijfsma); Sliter, pl.10, figs.3-6.

Description: Test free; biconvex trochospiral, dorsal side moderately to highly convex, ventral side generally less convex; in plan view periphery circular, occasionally slightly lobate, in side view subrounded to subacute; chambers dorsally indistinct covered by calcareous layers, only chambers of final whorl visible, final whorl overlapping previous whorls dorsally, chambers 6-7 per whorl, twice as broad as high; ventrally only chambers of final whorl visible, distinct, triangular, uninflated, last pair becoming weakly inflated; sutures dorsally indistinct except between chambers of final whorl, slightly oblique, curved, flush to slightly depressed, slightly limbate; ventral sutures, rectilinear, slightly depressed; aperture distinct narrow slit along inner margin of final chamber extending from the umbilical region to the periphery, ventrally bordered by a thick, distinct lip; wall thick, calcareous; surface smooth.

Average diameter: 0.64mm. Average thickness: 0.50mm.

Remarks: This species is characterised by its inflated, biconvex form, aperture bordered by a thick lip and sutures which are oblique, curved dorsally and rectilinear ventrally. *E. biconvexa* Marie, 1941 has a similar outline but with rectilinear sutures dorsally and curved sutures ventrally. Hofker (1966) has described a stratigraphic variation in this species from less globular forms with subangular margins (forma *primativa*) to more inflated forms. Villain (1977) regarded Hofker's "forma *primativa*" as a juvenile form of no stratigraphic significance and this later view has been supported by the present study.

Occurrence: Originally described from the Hervian Greensand (Campanian) of Holland, and found in the upper Upper Campanian and Lower Maastrichtian of Norfolk.

Zonal range: B3iv - B5ii

Eponides biconvexa Marie, 1941

(Plate 8, figs.7,8)

1941 *Eponides biconvexa* Marie, p.224, pl.34, fig.324.

1953 " " Marie; Hagn,p.89,pl,7, fig.19.

1961 " *biconvexus* Marie; Vasilenko, p.84, pl.14, figs.4,5. t.fig.13.

Description: Test free; biconvex trochospire of 3-4 whorls, dorsal side moderately convex, ventral side less convex; periphery in plan view circular, slightly lobate, from side subacute to acute;

chambers indistinct dorsally except for final whorl which comprises 6-8 rectangular chambers, uniformly and gradually increasing in size, evolute; ventrally only chambers of last whorl visible, 6-8 slightly inflated, triangular, curved; sutures indistinct dorsally, in final whorl, flush to slightly depressed, limbate, linear; ventrally distinct, slightly depressed, curved; umbilicus filled with small umbilical boss of clear calcite; aperture narrow slit along inner margin of final chamber, bordered ventrally by broad, distinct lip; wall calcareous, perforate; surface smooth.

Average diameter: 0.40mm. Average thickness: 0.24mm.

Remarks: This species is characterised by its biconvex test, and sutures which are curved ventrally, and rectilinear dorsally. The small umbilical boss appears to be a relatively constant feature. This species may be distinguished from *E. beisseli* which has a similar form by its smaller, less robust test, umbilical boss, and gracefully curving ventral sutures.

Occurrence: Originally described from the Upper Campanian of the Paris Basin, this species has been found rarely in the Upper Campanian both in Norfolk and the Isle of Wight.

Zonal range: B3i - B3iv

Eponides concinna Brotzen, 1936

(Plate 8, figs.9,10)

1936 *Eponides concinna* Brotzen, p.167, pl.12, fig.4.

1961 " *concinnus* var. *concinna* Brotzen; Vasilenko, p.79, pl.13, figs.4,5,8,9, t.fig.12, nos.1-4.

1961 Eponides concinnus var. plana Vasilenko, p.79, pl.13, figs.6,7, t.fig.12, nos.5-8.

1966 " cf. " Brotzen; Barr, p.505, pl.79, fig.2.

Description: Test free; plano-convex to biconvex, dorsal side flat to weakly convex, ventral side moderately convex; periphery in umbilical view circular, slightly lobate, in side view acute to subacute; chambers indistinct dorsally arranged in 3 whorls, uninflated, crescentic, curved, 7-10 in final whorl; ventrally only chambers of final whorl visible, slightly inflated, curved, triangular to crescentic, gradually and uniformly increasing in size; sutures indistinct dorsally, oblique, straight to slightly curved, flush, ventrally sutures slightly depressed, curved, radiate; umbilicus varying from open, narrow to closed, filled with umbilical boss of clear calcite; aperture narrow slit along inner margin of final chamber extending from umbilicus to periphery, bordered ventrally by a lip; wall calcareous, finely perforate, umbilical boss non perforate; surface smooth.

Average diameter: 0.29mm. Average thickness: 0.17mm.

Remarks: This species shows a wide morphological variation both in the number of chambers in the final whorl and the presence and size of an umbilical boss. Vasilenko (1961) has erected varieties based largely on the development of an umbilical boss which he found to have some stratigraphic significance. In the present study the most common form possesses a well developed umbilical boss (E. concinnus var. plana sensu Vasilenko), however, forms without any umbilical boss have been found throughout the stratigraphic range of the species and no formal significance has been placed on the development of this boss.

Occurrence: Originally described from the Lower Senonian of Eriksdal, Sweden, this species has been found in moderate abundance in the Lower and lowest Middle Campanian of the Isle of Wight, and sporadically throughout the Middle and Upper Campanian. In Norfolk it was found rarely throughout the Lower and Middle Campanian; it was not found, however, in the uppermost Campanian or Lower Maastrichtian.

Zonal range: B1ii - B3iii

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus CIBICIDES De Montfort, 1808

Genotype Cibicides refulgens De Montfort, 1808

Cibicides beaumontianus (d'Orbigny, 1840)

(Plate 8, figs.11,12)

1840 Truncatulina beaumontiana d'Orbigny, p.35, pl.3, figs.17-19.

1851 " convexa Reuss, pp.36-7, pl.3, fig.4.

1878 " lobatula (d'Orbigny); Marsson, p.167, pl.18, fig.38.

1899 " convexa Reuss; Egger, p.149, pl.18, figs.25-7.

1917 " " Reuss; Chapman, p.45, pl.11, fig.105.

1928 " beaumontiana d'Orbigny; Franke, pp.176-7, pl.16, fig.6.

1934 Cibicides " (d'Orbigny); Brotzen, p.61.

1936 " excavata Brotzen, pp.189,190, pl.13, figs.7,8.

1941 " beaumontiana (d'Orbigny); Marie, pp.249-250, pl.37, figs.352-4.

1946 " excavata Brotzen; Schijfsma, pp.100-1, pl.6, fig.7.

1948 " " Brotzen; Williams-Mitchell, p.103, pl.9, fig.6.

1954 " (Cibicides) excavatus excavatus Brotzen; Vasilenko, pp.131-2, pl.20, figs.1-3.

1956a Cibicides beaumontianus (d'Orbigny); Hofker, p.B218, fig.37.

1957 " excavatus Brotzen; Hofker, pp.93,94, t.fig.96.

1957 " beaumontianus (d'Orbigny); Hofker, pp.94-5, t.fig.97.

1957 " " (d'Orbigny); McGugan, p.344, pl.32, fig.24.

1960 " excavatus Brotzen; Belford, p.111, pl.34, figs.12-16.

1961 " (Cibicides) excavatus Brotzen; Vasilenko, p.132, pl. 26, figs.1-3.

1961 " (") beaumontianus (d'Orbigny); Vasilenko, p.132, pl.26, fig.4, pl.27, fig.1.

1966 " beaumontianus (d'Orbigny); Hofker, p.51, pl.13, fig.66.

1966 " " (d'Orbigny); Barr, pp507-8, pl.79, fig.4.

1969 " excavatus Brotzen ; Hanzlikova, p.53, pl.14, fig.4.

1972 " " Brotzen; Hanzlikova, p.117, pl34, figs.2,3.

1977 " beaumontianus (d'Orbigny); Villain, p.62, pl.9, figs.1-3.

Description: Test free or attached; plano-convex to biconvex or enrolled, with 2-3 whorls; shape and chamber arrangement widely variable reflecting the object to which specimen was attached; dorsal side commonly flat to concave, evolute; ventral side strongly to moderately convex, involute; chambers ventrally strongly inflated, subglobular; periphery in umbilical view irregularly lobate, in side view acute to broadly rounded; 5-9 chambers in final whorl, fairly rapidly increasing in size; dorsal sutures indistinct generally flush, ventral sutures distinct, depressed; aperture semicircular opening at base of final chamber extending back along dorsal side spiral suture; wall calcareous, coarsely perforate ventrally; surface smooth to slightly roughened.

Average diameter: 0.30mm. Average thickness: 0.26mm.

Remarks: This species exhibits a wide range of morphological variation reflecting the surface to which it was attached. When this surface was flat a typical plano-convex form resulted as illustrated by d'Orbigny (1840),but occasional specimens have been found wrapped around echinoid spines, resulting in a tightly coiled form as illustrated by Bailey (1978 MS) as C. beaumontianus var. A. It is felt that C. excavata Brotzen (1936) described from the Lower Senonian of Eriksdal, Sweden, falls within the range of variation of C. beaumontianus. The results of the present study do not support the conclusions of Hofker (1957) who regarded C. excavatus as being distinct from C. beaumontianus both morphologically and stratigraphically.

Occurrence: Originally recorded from the Upper Campanian of the Paris Basin (Meudon). This species has been found in moderate abundance throughout the Campanian and Maastrichtian.

Zonal range: B1ii - B6ii .

Cibicides bosqueti (Reuss, 1862)

(Plate 8, figs.13-15)

1862 Rosalina bosqueti Reuss, p.316, pl.3, fig.1.

1925 Discorbina " (Reuss); Franke, p.92, pl.8, fig.13.

1928 " " (Reuss); Franke, p.190, pl.18, fig.13.

1951 Gavelinella " (Reuss); Visser, p.266, pl.5, fig.8.

? 1957 Cibicides subbosqueti Hofker, pp95-6, t.figs.98-101.

1958b " compressus Hofker, p.B490, fig.41.

1966 " bosqueti (Reuss); Hofker, p.87, pl.13, figs.67, pl.17, fig.58, pl.19, fig.45, pl.23,fig.115, pl.27. fig.29, pl.30, fig.11, pl.35, fig.4, pl.38, fig.42.

1966 Cibicides compressus Hofker; Hofker, p.117, pl.18, fig.22, pl.24, fig.135, pl.27, fig.28, pl.30, fig.9.

1977 " bosqueti (Reuss); Villain, p.62, pl.10, figs.7-9.

Description: Test free or attached; plano-convex, generally compressed, spiral side flat to slightly convex; evolute, umbilical side slightly convex, may possess small umbo, chambers indistinct, flattened may become slightly inflated, sutures indistinct,irregularly curved, slightly depressed; periphery in umbilical view irregularly elongate, subcircular, in side view subacute bordered by imperforate peripheral band; 7-9 chambers in final whorl, rapidly increasing in size; aperture low interiomarginal arch extending slightly onto spiral side along spiral suture; wall calcareous; surface smooth.

Average diameter: 0.33mm. Average thickness: 0.19mm.

Remarks: The compressed, smooth, rapidly expanding test is highly characteristic of this species though its overall shape is strongly influenced by the surface to which it had been attached. In general form, C. bosqueti approaches G. multipunctata (Bandy, 1951). It may be distinguished, however, by its smaller number of chambers and simple aperture without the umbilical chamber extensions and initially raised sutures of the latter.

Occurrence: Recorded by Hofker (1966) from the Craie tigrée (mid Cr 3c) of Maastricht to the Danian. In the present study found rarely in the upper Lower Maastrichtian of Norfolk.

Zonal range : B5ii - B7i

Cibicides ribbingi Brotzen, 1936

(Plate 8, figs. 16-18)

1936 *Cibicides ribbingi* Brotzen, pp.186-9, pl.13, figs.5,6, t.figs.67-8.
1946 " *ribbingae* Brotzen; Schijfsma, pp. 101-2, pl.6, fig.6.
1948 " *ribbingi* Brotzen; Williams-Mitchell, p.103, pl.9, fig.5.
1956 " *megaloperforatus* Said & Kenawy, p.155, pl.7, fig.13.
1960 " *ribbingi* Brotzen; Belford, p.11, pl.34, figs.17-20.
1969 " *ribbingae* Brotzen; Hanzlikova, p.53, pl.14, fig.4.
1972 " *ribbingi* Brotzen; Hanzlikova, pp.116-7, pl.34, fig.4.
1973 " " Brotzen; Koch, pp.211-2.

Description: Test attached; plano-convex, dorsal side flattened, ventral side weakly convex, outline highly variable, irregularly lobate in umbilical view, in side view acute; chambers distinct, 5-7 in last whorl, ventrally weakly inflated, broadly flattened; dorsal sutures flush, indistinct, ventral sutures slightly depressed, straight, radial; umbilicus shallow; aperture a slit on the inner margin of final chamber extending slightly along dorsal spiral suture towards umbilicus; wall calcareous, ventrally coarsely perforate; surface smooth.

Average diameter: 0.55mm. Average thickness: 0.16mm.

Remarks: The extremely flattened plano-convex test is highly characteristic of this species. Barr (1966b) regarded this species as a phenotypic variant of *C. beaumontianus* . This conclusion is not upheld in the present study as no transitional forms between the two species were found. Bailey (1978 MS.) has recorded slightly different stratigraphic ranges for the two species.

Occurrence: Originally described from the Lower Senonian of

Eriksdal, Sweden. In the present study found rarely throughout the Campanian and Lower Maastrichtian from onshore sections studied.

Zonal range: Blii - B5ii

Family PLANORBULINIDAE Schwager, 1877

Genus PLANORBULINA d'Orbigny, 1826

Genotype Planorbulina mediterranensis Cushman, 1915

Planorbulina cf. cretae (Marsson, 1878)

(Plate 8, figs.19,20)

1878 Acervulina cretae Marsson, p.171, pl.5, fig.39.

1969 Planorbulina " (Marsson); Bignot & Larsonneur, p.34, t.figs.1-7, pl.2, figs.4-6, pl.3, figs.1-7, (full synonomy).

Description: Test attached or free; commonly irregularly spherical, occasionally hemispherical, reflecting surface of attachment; chamber arrangement irregular,involute, chambers distinct, inflated, low, irregular, elongate, strongly overlapping; sutures distinct, depressed; aperture single slit opening at base of chamber, later chamber may possess two or more low arched openings along base; wall calcareous, very coarsely perforate.

Average diameter: 0.74mm.

Remarks: The present specimens differ form P.cretae in their distinctly spherical form and more irregular, elongate, strongly overlapping chambers. Whether such differences are of taxonomic or ecological significance could not be determined however. In view of the differences in stratigraphic occurrence, together with the morphological differences outlined above, the present specimens are only tentatively referred to *P. cretae*.

Occurrence: *P. cretae* has been reported from strata of Maastrichtian age from Holland, W. Germany and the Isle of Rügen. In the present study, *P.* cf. *cretae* has been found in moderate abundance in the uppermost Middle and lowest Upper Campanian of the Isle of Wight.

Zonal range: B2iii - B3i

Superfamily GLOBIGERINACEA Carpenter, Parker & Jones, 1862

Family HETEROHELICIDAE Cushman, 1927

Subfamily HETEROHELICINAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1843

Genotype *Spiroplecta americana* Ehrenberg, 1844

Heterohelix complanata (Marie, 1941)

(Plate 9, figs.1-3)

1941 *Gümbelina complanata* Marie , p.184, pl.28.

1969 *Heterohelix* cf. *complanata* (Marie); Stenestad, pp.657-8, t.fig.11.

Description: Test free; small, moderately and uniformly expanding, moderately compressed; chamber arrangement biserial throughout, widest point close to apertural end; chambers 10-12, low, broader than high, becoming reniform, moderately inflated; sutures distinct, inclined, straight, weakly depressed; margin weakly lobate; cross section narrow, bi-lobed, subrectangular; aperture low arch on inner margin of final chamber with lateral flanges; wall calcareous, perforate; surface weakly striate, decreasing slightly towards apertural end.

Average height: 0.24mm. Average width: 0.15mm.

Remarks: This species may be distinguished from H. striata (Ehrenberg, 1840) by its more compressed, weakly striate test, and broader, reniform chambers. Stenestad (1969) has described specimens, referred to this species, which are half the size of the holotype. In the present author's opinion, such specimens lie within the range of morphological variation shown by H. complanata.

Occurrence: This species was originally described from the Campanian of the Paris Basin and has been recorded also from the Upper Campanian and Lower Maastrichtian of Denmark. In the present study, it was found in moderate abundance in the uppermost Campanian and Maastrichtian, both in Norfolk and in material from the North Sea.

Zonal range : B3iv - B7i

Heterohelix striata (Ehrenberg, 1840)

(Plate 9, figs. 4-6)

pars 1840 Textularia striata Ehrenberg, p. 135, pl.4, figs.1,2,3, non.9.

1899 Gümbelina " (Ehrenberg); Egger, p.33, pl.14, figs.5-7, 10, 11, 37-39.

1936 " " (Ehrenberg); Brotzen, p.118, t.figs. 39, 40, pl.9, fig.1.

1938b " " (Ehrenberg); Cushman, p.8, pl.1, figs.34-40.

1941 " globulosa (Ehrenberg) var. striatula Marie, p.182, pl.28, figs.273-5.

1946 " striata (Ehrenberg); Schijfsma, p.74, pl.4, fig.6.

1946 " " (Ehrenberg); Cushman, p.104, pl.45, figs.4,5.

1948 " " (Ehrenberg); Kikoine, p.19, pl.1, fig.7.

1951 " " (Ehrenberg); Bandy, p.510, pl.75, figs.8,9.

1953 Pseudoguembelina striata (Ehrenberg); Bronnimann& Brown, p.154, t.fig.6.

1957 Gümbelina striata "gruppe" Hofker, pp.418-421, t.figs.476-7.

1962a Heterohelix " (Ehrenberg); Berggren, p.21, pl.6, figs.1-5.

1964 " " (Ehrenberg); Martin, p.85, pl.11, fig.1.

? 1965 " " (Ehrenberg); Takayanagi, pp. 198-9, pl.20, fig.4.

1966 Gümbelina " (Ehrenberg); Hofker, pp.31, 64, 79, pl.3, fig.68, pl.33, fig.76, pl.34, fig.105.

1967 Heterohelix " (Ehrenberg); Bandy, pp.23-4, t.fig.12, no.9.

1967 " " (Ehrenberg); Pessagno, p.264, pl.78, figs.3-7, pl.98, fig.16.

1968 " " (Ehrenberg); Sliter, p.96, pl.13, fig.13.

1969 " " (Ehrenberg); Stenestad, pp.653-4, t.fig.7.

1969 " " (Ehrenberg); Hanzlikova, p.40, pl.7, figs.13-17, 24-28.

1969 " " (Ehrenberg); Douglas, p.159, pl.11, figs.4,7,8.

1972 " " (Ehrenberg); Hanzlikova, p.93, pl.23, figs.14-18.

1973 " " (Ehrenberg); Smith & Pessagno, p.19, pl.3, figs.8-11, pl.4, figs.1-4.

1974 " " (Ehrenberg); Kassab, pp.86-7, pl.1, figs.9-12.

1977 " globulosa (Ehrenberg); Villain, p.72, pl.13, fig.6.

1977 " " (Ehrenberg); Petters, p.175, pl.1, figs.11,12.

non 1977 " striata (Ehrenberg); Petters, p.175, pl.1, fig.6.

non 1977 " " (Ehrenberg); Masters, pp.356-8, pl.3, figs.2,3.

Description: Test free; small, moderately and uniformly expanding, slightly compressed; chamber arrangement biserial, occasionally with initial planispiral coil; widest point close to apertural end; chambers 10-12, globular to subglobular; sutures distinct, depressed; margin becoming strongly lobate; cross section bi-lobed, ovate; aperture moderately high arch on inner margin of final chamber with small lateral flanges; wall calcareous, perforate; surface covered by quite strongly developed discontinuous striations.

Average height: 0.19mm. Average width: 0.12mm.

Remarks: The synonomy given above may be far from complete, as there has been considerable taxonomic confusion surrounding both this species and the closely related H. globulosa (Ehrenberg, 1840). Several authors, notably Brotzen (1936), Berggren (1962) and Stenestad (1969) have discussed the relationship between H. striata and H. globulosa. Both were originally described in syntypic series from Denmark, Poland, England, France and Egypt. Cushman (1938), after study of the Ehrenberg collection in Berlin, concluded that H. globulosa could be distinguished from H. striata by its non striate surface. Pessagno (1967) formally designated figure 5b (Ehrenberg , 1840) of H. globulosa as lectotype, with Meudon, France, as the type locality, and illustrated hypotypes from the Taylor Formation, U.S.A. with extremely fine striations. Pessagno (1967) suggested that these two species might represent extreme morphological variants of a single species. In the present study, all specimens, when examined by S.E.M., were found to possess well developed, discontinuous costellae and thus have been placed in H. striata. Masters (1977) has presented a study of the taxonomy of the Heterohelicidae and considered that the designation by Pessagno (1967) of a lectotype figure, without concurrent re-examination and re-illustration of Ehrenberg's specimens, was " premature and pointless ". Masters (1977) has figured a specimen which he placed in H. striata, which differs from the lectotype by possessing coarser, more continuous costae and a broader, higher aperture. It is clearly not conspecific with H. striata.

Occurrence: H. striata was found in moderate abundance throughout the Campanian and Maastrichtian.

Zonal range: B1ii - B7i

Genus PSEUDOTEXTULARIA Rzehak, 1891

Genotype Cuneolina elegans Rzehak, 1891

Pseudotextularia elegans (Rzehak, 1891)

(Plate 9, figs.7,8)

1891 Cuneolina elegans Rzehak, p.4.

pars 1895 Pseudotextularia varians Rzehak, p.217, pl.7, fig.1, non.figs.2,3.

pars 1890 Guembelina acervulinoides Egger, p.36, pl.14, figs.14?. 15, 16, non.figs.17,18,20-22.

pars 1899 " fructicosa Egger, p.35, pl.14, figs.25,26, non.figs.8,9. 24.

1936 Pseudotextularia elegans (Rzehak) f. typica Glaessner, pp.99-101, t.fig.1, pl.1, figs.1,2.

1951 " " (Rzehak); Noth, pp.61-62, pl.7, figs. 15-17.

1966 " " (Rzehak); Willie-Janoschek. p.121, pl.8, fig.10.

? 1967 " " (Rzehak); Pessagno, pp.268-9, pl.75, figs.12-17.

pars 1968 " " (Rzehak); Sliter, p.98, pl.14, figs. 13-14, non.fig.15.

pars 1969 " " (Rzehak); Brown, pp.47-54, t.figs.9-10. non. t.figs.13,14, pl.2, fig.4, pl.3, figs.2,3.

pars 1972 " " (Rzehak); Hanzlikova, p.95, pl.24, fig. 10, figs. 11-12, non. fig.8.

non 1973 " " (Rzehak); Smith & Pessagno, pp.30-31, pl.9, figs.5-15, pl.10, figs.2-6.

1973 " deformis (Kikoine); Smith & Pessagno, pp.29-30, pl.9, figs.1-4, pl.10, fig.1.

1977 Pseudotextularia elegans (Rzehak); Koch, p.65, pl.15, figs.5,6.

1977 " " (Rzehak); Masters, pp.383-6, pl.6, figs.3-4.(full synonomy)

Description: Test free; chamber arrangement biserial throughout; rapidly expanding, periphery entire, becoming weakly lobate; widest point of test close to apertural end; chambers distinct, 7-10 pairs, moderately inflated, slightly wider than high, twice as thick as wide; sutures initially flush becoming distinct, depressed, straight, horizontal, aperture low, broad, interiomarginal arch bordered by narrow imperforate lip and with distinct lateral flanges; wall calcareous, perforate; surface strongly ornamented by moderately coarse vertical costae, continuous to irregularly discontinuous over chamber surface.

Average height: 0.40mm. Average width: 0.22mm.
Average thickness : 0.25mm.

Remarks: The general form and coarse costae are highly characteristic of this species. Masters (1977) has undertaken a thorough study of this species, and his conclusions have been followed in the present study. Numerous authors have considered the possibility that the predominantly biserial P. elegans and the multi-chambered Planoglobulina brazoensis Martin may represent different life stages of a single species. Brown (1969) concluded that the two were to be considered variants of a single species on the basis of their morphological similarities and their synpatric and isochronous distribution. Evidence has since accumulated (Hanzlikova 1972, Masters 1977) that the two are not strictly isochronous. In the present study only P.elegans has been found, further indicating that the two taxa are not entirely synpatric. Thus the case for considering them as distinct species is supported by the present study.

Occurrence: Masters (1977) recorded this species from the Maastrichtian, whilst Koch (1977) has recorded it as restricted to the Upper Maastrichtian of Germany. In the present study, this species has been found in samples of uppermost Maastrichtian age from the North Sea.

Zonal range: Upper B7i; A. mayaroensis biozone.

Family PLANOMALINIDAE Bolli, Loeblich & Tappan, 1957

Genus GLOBIGERINELLOIDES Cushman & Ten Dam, 1948

Genotype G. algeriana Cushman & Ten Dam, 1948

Globigerinelloides aspera (Ehrenberg, 1854)

(Plate 9, figs. 9-11)

1854 Phanerostomum asperum Ehrenberg, p.23, pl.30, fig.26

non 1854 Rotalia aspera Ehrenberg, p.24, pl.27, figs.57-58, pl.28, fig.42, pl.31, fig.44.

1891 Rotalia aspera Ehrenberg; Beissel, p.73, pl.14, figs.1-6.

1892 Globigerina aequilateralis (Brady); Chapman, p.517, pl.15, fig.14.

1910 " " (Brady); Heron-Allen & Earland, p.424, pl.8, figs.11,12.

1936 Globigerinella aspera (Ehrenberg); Brotzen, p.170, pl.13, fig.2.

1946 " " (Ehrenberg); Schijfsma, pp. 94-6, pl.6, fig.8.

1951 " " (Ehrenberg); Bandy, p.508, pl.75, fig.3.

1957 Globigerina " (Ehrenberg) f. plana Hofker, pp. 414-8, t.figs.473-4.

1960 Globigerinella " (Ehrenberg); Belford, p.91, pl.25, figs.4-6.

pars 1962 Planomalina messinae (Brannimann); Berggren, pp.44-9, t.fig.7, nos.1-5, non.6-8.

1962 " aspera (Ehrenberg); Barr, pp.561,563, pl.69, fig.4.

1962 Planomalina aspera (Ehrenberg); Barr, pp.561,563, pl.69, fig.4.

1963 " (Globigerinelloides) aspera (Ehrenbenberg); van Hinte, p.97, pl.12, figs.2a,3.

1963 Globigerinella aspera (Ehrenberg); Graham & Church, pp.64-5, pl.7, fig.17.

1964 Globigerinelloides aspera (Ehrenberg); Barr & Cordey, p.309.

1964 Planomalina aspera (Ehrenberg); Martin, p.84, pl.10, fig.7.

1967 Globigerinelloides aspera aspera (Ehrenberg); Bandy, p.12, t.fig.5, no.8.

1967 " asperus (Ehrenberg); Pessagno, pp.274-5, pl.60, figs.4,5.

1967 " prairiehillensis Pessagno, pp.277-8, pl.60, figs.2,3, pl.83, fig.1, pl.90, figs.1-2, pl.97, figs.3,4.

1968 " aspera (Ehrenberg); Barr, pp.313-4, pl.37, fig.6.

pars 1968 " messinae (Bronnimann); Sliter, p.99, pl.15, fig.3, non.fig.5.

1972 " aspera (Ehrenberg); Hanzlikova, p.98, pl.25, fig.1.

non 1977 " volutus (White); Petters, pl.2, fig.8.

1977 " aspera (Ehrenberg); Villain, p.72, pl.13, figs.4,5.

Description: Test free; planispiral coil of 2 to 3 whorls with 6 to 7 chambers in final whorl; bi-umbilicate, partially evolute; chambers inflated, spherical, expanding moderately rapidly in size; periphery lobate; sutures distinct, depressed, radial; aperture low broad, equatorial arch bordered above by a distinct lip, relict apertures and apertural flaps moderately well developed; wall calcareous, perforate; surface finely papillate.

Average diameter: 0.38mm. Average thickness 0.11mm.

Remarks: This species was originally described in syntypic series from North America and the Isle of Rügen. The original description, lacking both a holotype and a type locality, has led to much taxonomic confusion, indeed doubt has even been expressed as to whether Ehrenberg's species is a planispiral or trochospiral form (Pessagno 1967, Masters 1977). Pessagno (1967), in an attempt to clarify the taxonomic status of this species, designated a lectotype of P. asperum, stating that this individual is definitely planispiral with an equatorial aperture. However, the value of erecting such a lectotype without an accompanying re-examination and illustration is questionable. In addition, as Pessagno did not designate a type horizon his separation of the stratigraphically younger populations as G. prairiehillensis sp. nov. is here considered premature.

Occurrence: G. aspera is moderately common throughout the Campanian and Maastrichtian sections studied.

Zonal range : B1ii - B7i

Globigerinelloides cf. bollii Pessagno, 1967

(Plate 9, figs.12,13)

1967 Globigerinelloides bollii Pessagno, pp.275-6, pl.62, fig.5, pl.81, figs.7-8, pl.97, figs.1-2, pl.100, fig.3.

Description: Test free; partially evolute planispiral coil of 2-3 whorls, final whorl with 6-7 chambers, uniformly and gradually increasing in size as added, initially subspherical later becoming ovate; periphery lobate, outline in apertural view compressed; sutures distinct, depressed, radial, straight to slightly curved; umbilicii wide, shallow; primary aperture moderately high equatorial arch bordered by a thin lip; relict apertures and flaps moderately well developed; wall calcareous, perforate; surface smooth.

Average diameter: 0.23mm. Average thickness: 0.10mm.

Remarks: This species may be distinguished from *G. aspera* by its smooth surface, ovate chambers and more compressed test. It most closely resembles *G. bollii* Pessagno described from the Upper Taylor Marl, Texas. The present specimens differ from the figured type however, by possessing more strongly curved, ovate chambers.

Occurrence: *G. bollii* was originally described as ranging throughout the *G. calcarata* zonule (uppermost Campanian) of Texas. *G. cf. bollii* has been found in the present study only in the Maastrichtian & uppermost Campanian of Norfolk and the North Sea. It is generally rare.

Zonal range: B4i – B5i

Globigerinelloides multispina (Lalicker, 1948)
(Plate 9, figs.14-16)

1948 *Biglobigerinella multispina* Lalicker, p.5, pl.92, figs.1-3.
1956a *Globigerinella biforaminata* Hofker, p.53, t.figs.2,5.
1956b *Globigerina* " (Hofker); Hofker, p.76, pl.9, figs.68a-c, pl.10, figs.71a-c.
1957 *Biglobigerinella multispina* Lalicker; Bolli, Loeblich & Tappan, p.24, pl.1, figs.11-12b.
1960 " *biforaminata* (Hofker); Olsson, p.44, pl.8, figs.7,8.

pars 1962 Planomalina (Globigerinelloides) messinae (Bronnimann); Berggren, pp.44-6, pl.8, figs.4,6,8, non fig.7, t.fig.6, nos.2,5, non. nos.1,3,4,6, t.fig.7, nos.6,7,8, non. nos. 1-5.

1962 " multispina (Lalicker); Barr, pp.563-4, pl.69, fig.5.

1962 Biglobigerinella multispina Lalicker; Herm, p.53, pl.3, fig.8.

1963 Planomalina (Globigerinelloides) messinae biforaminata (Hofker); van Hinte, p.102, pl.12, fig.4.

1964 Globigerinelloides messinae (Bronnimann); Olsson, pp.174-6, pl.7, figs.6-8.

1964 Biglobigerinella multispina Lalicker; Loeblich & Tappan, p.C656, fig.526 nos.4,5.

1964 " " Lalicker; Subbotina, p.253, pl.54, fig.10

1967 Globigerinelloides " (Lalicker); Pessagno, pp.276-7, pl.70, figs.1-2, pl.82, figs.10-11, pl.91, figs.1-2.

pars 1968 " messinae (Bronnimann); Sliter, p.99, pl.15, figs.5, non. fig.3.

1969 " " (Bronnimann); Hanzlikova, p.45, pl.12, figs.1-3.

1969 Biglobigerinella biforaminata (Hofker); Mello, p.95, pl.2, figs. 3-5.

1969 Globigerinelloides multispina (Lalicker); Douglas, pp.161-2, pl.9, fig.6.

1972 " " (Lalicker); Hanzlikova, p.99, pl.25, figs.2-4.

1973 " " (Lalicker); Smith & Pessagno, pp.38-9, pl.13, figs.1-11.

1977 " abberanta (Netskaya): Masters, pp.401-3, pl.8, figs.3-5, pl.9, figs.1,2.

1977 Globigerinelloides multispina (Lalicker); Rodriguez, p.378, pl.1, fig.5.

Description: Test free; planispiral, partially evolute coil of 2-3 whorls, final whorl with 5-6 chambers, final chamber elongated at right angles to direction of coiling or separate, paired chambers; test biumbilicate; chambers inflated, globular except for final 1 or 2, which are characteristically abberant; periphery lobate; sutures distinct depressed, radial; last chamber possessing high, arched, widely spaced pair of apertures bordered by distinct lips, forms with paired final chambers have single aperture on each final chamber; wall calcareous, perforate; surface finely papillate.

Average diameter: 0.33mm. Average thickness: 0.30mm. (biserial form)

Remarks: This species is characterised by its paired final chambers. The genus Biglobigerinella Lalicker is not considered a valid taxonomic unit as the development of biserial chambers within species of the genus Globigerinelloides occurred during the Cretaceous, both in Aptian and Campanian times. As the Aptian "biglobigerine" forms are not considered to be phylogenetically related to those of the Campanian, the presence of biserial chambers within the genus Globigerinelloides is here regarded as of specific value only. G. biforaminata Hofker is here regarded as an immature growth stage of G. multispina as broken examples of the latter clearly possess a "biforaminata" stage and in addition the two are isochronous and synpatric in their known distribution. Masters (1977) in a valuable discussion of the genus Globigerinelloides has noted that G. abberanta (Netskaya, 1948) may be a senior synonym of G. multispina, though this may only be proven by study of type material. The present author disagrees with Masters'(1977) claim that most references to G. aspera are synonymous with G. multispina, though the two are closely related phylogenetically, they are not isochronous over their known range. It seems likely that G. multispina arose from G. aspera stock in the middle Lower Campanian.

Occurrence: G. multispina is moderately common throughout most of the Campanian and Maastrichtian, though apparently absent from the basal Campanian. Forms with paired final chambers are much more commonly encountered in strata of Upper Campanian and Maastrichtian age, whilst forms with paired apertures only predominate in the rest of the Campanian.

Zonal range: B1iii - B7i

Family HEDBERGELLIDAE Loeblich & Tappan, 1961

Genus HEDBERGELLA Bronnimamm & Brown, 1958

Genotype Anomalina lorneiana d'Orbigny var. trochoidea Gandolfi, 1942

Hedbergella holmdelensis Olsson, 1964

(Plate 9, figs.17-19)

1964 Hedbergella holmdelensis Olsson, pp.160-1, pl.1, figs.1,2.

1964 " planispira (Tappan); Olsson, pp.161-2, pl.1, figs.4,5.

1967 " ? homedelensis Olsson; Pessagno, p.283,

1967 " planispira holmdelensis Olsson: Bandy, pp.10-11, t.fig.4, no.4.

pars 1968 " holmdelensis Olsson; Sliter, p.100, pl.15, fig.8, non.fig.6.

1969 " " Olsson: Douglas, p.166, pl.9, figs.7-9.

1977 " " Olsson; Sliter, p.542, pl.2, figs.1-4.

Description: Test free; small, low trochospiral, nearly planispiral coil, compressed; outline subcircular, moderately lobate; periphery rounded; chambers arranged in $2\frac{1}{2}$ to 3 whorls, 5-6 in final whorl; chambers subspherical, inflated becoming ovate; sutures straight, radial, depressed on umbilical side, gently curved, depressed spirally; aperture low interiomarginal arch, umbilical-extraumbilical in position and bordered by well developed thin lip; relict apertures open into quite narrow, deep umbilicus; wall calcareous, finely perforate; surface finely hispid.

Average diameter: 0.20mm. Average thickness: 0.11mm.

Remarks: This species is closely related to H. planispira (Tappan) from which it undoubtedly evolved, probably in the Lower Senonian. H. holmdelensis may be distinguished from H. planispira by its more elongate chambers, less compressed form and finely hispid surface. It in turn gave rise to H.(?) monmouthensis by a reduction in the number of chambers and a marked increase in chamber inflation.

Occurrence: H. holmdelensis was originally described from the Lower Maastrichtian Mt. Laurel Formation of New Jersey. Sliter (1968) recorded this species from the Campanian and Lower Maastrichtian of California. In the present study H. holmdelensis has been found sporadically throughout the Campanian and Lower Maastrichtian.

Zonal range : Bliii - B6i

Hedbergella (?) monmouthensis (Olsson, 1960)

(Plate 10, figs. 1,2)

1960 Globorotalia monmouthensis Olsson, p.47, pl.9, figs.22-24.

1962 Praeglobotruncana (Hedbergella) monmouthensis (Olsson); Berggren, pp.37-41, pl.8, figs.1-3, t.fig.5,nos.1-5.

1964 Hedbergella monmouthensis (Olsson); Olsson, p.161, pl.1, fig.3.

1967 Globotruncanella monmouthensis (Olsson); Pessagno, p.374, pl.61, figs.1-3.

1967 Hedbergella planispira monmouthensis (Olsson); Bandy, p.11, t.fig.4, no.5.

1969 " monmouthensis (Olsson); Hanzlikova, p.45, pl.12, figs.4,5.

1969 " " (Olsson); Douglas, pp.167-8, pl.9, fig.4.

? 1972 " " (Olsson); Govindan, p.173, pl.2, figs. 11-13.

1972 " " (Olsson); Hanzlikova, p.101, pl.26, figs.3,4.6.

1973 Globotruncanella monmouthensis (Olsson); Smith & Pessagno, p.61, pl.27, figs.7-9.

1977 Globigerina " (Olsson); Masters, pp.466-7.

1977 Hedbergella monmouthensis (Olsson); Sliter, p.542, pl.3, figs.1-3.

Description: Test free; low trochospiral coil; outline subcircular, distinctly lobate; periphery rounded; umbilicus distinct, moderately narrow and deep; spiral side flattened, umbilical side convex; chambers inflated, subspherical, commonly five in final whorl, increasing rapidly in size as added, and arranged in 2½ to 3 whorls; sutures on umbilical side depressed, radial,slightly curved to straight, those of spiral side radial, slightly curved, depressed; aperture moderately high umbilical-extraumbilical arch, bordered by a distinct lip, relict apertures open to umbilicus beneath moderately well developed portici; wall calcareous, finely perforate; surface pustulose.

Average diameter: 0.33mm. Average thickness: 0.19mm.

Remarks: This distinctive species possibly evolved from H. holmdelensis in the Lower Maastrichtian, by a reduction in the number of chambers and an increase in chamber inflation. Pessagno (1973) considered H. monmouthensis to belong to the genus Globotruncanella on the basis of the fragile tegillum found in well preserved specimens. In the present material no such umbilical structure has been found and the species has been tentatively retained in the genus Hedbergella.

Occurrence: H. monmouthensis was originally described from the Redbank Formation of New Jersey (Middle Maastrichtian). Smith and Pessagno (1973) have recorded the species as ranging throughout the upper Middle and Upper Maastrichtian of Texas. In the present study this species was found onshore only in the uppermost beds of Trimingham and in material of Upper Maastrichtian age from the North Sea.

Zonal range : B6ii - B7i

Family GLOBOTRUNCANIDAE Brotzen, 1942

Subfamily GLOBOTRUNCANELLINAE Maslakova, 1964

Genus GLOBOTRUNCANELLA Reiss, 1957

Genotype Globotruncana citae Bolli, 1951, (=Globotruncana havanensis Voorwijk, 1937)

Globotruncanella havanensis (Voorwijk, 1937)

(Plate 10, figs.3,4)

1937 Globotruncana havenensis Voorwijk, p.195, pl.1, figs.25,26,29.

1951 " citae Bolli, p.197, pl.35, figs.4-6.

1955 " " Bolli; Gandolfi, p.51, pl.3, fig.11.

1956 Rugotruncana havenensis (Voorwijk); Bronnimann & Brown, p.552, pl.22, figs.4-6.

1956a Marginotruncana citae (Bolli); Hofker, p.334, fig.25.

1956b " " (Bolli); Hofker, p.79, fig.72.

1957 Globotruncana (Globotruncana) citae Bolli; Edgell, p.111, pl.1, figs.13-15.

1960 " (Rugotruncana) havanensis Voorwijk; Pessagno, p.103.

1960 " citae Bolli; Hofker, p.225, t.fig.20a-c.

1962 Praeglobotruncana havanensis (Voorwijk); Berggren, pp26-30, pl.7, fig.1.

1963 Globotruncanella " (Voorwijk); van Hinte, pp.94-6, pl.11, figs4,5, pl.12, fig.1, ?pl.10, fig.3.

1964 Globotruncana havanensis Voorwijk; Loeblich & Tappan, p.C662, fig.529 no.3.

1967 Praeglobotruncana havanensis havanensis (Voorwijk); Bandy, p.18, t.fig.10 no.11.

1967 Globotruncanella " (Voorwijk); Pessagno, p.373, pl.84, figs.1-3.

1968 Globotruncana " Voorwijk; Sliter, p.103-4, pl.17, fig.1-2.

1969 " " Voorwijk; Funnel et al, pp.32-3, pl.4, figs.4-6, t.fig.16a-c.

1969 Globotruncanella " Voorwijk; Douglas, p.190, pl.10, fig.3.

1971 Praeglobotruncana citae (Bolli); Postuma, pp.70-1, pl.28, figs.1-7.

1972 Globotruncana havanensis (Voorwijk); Hanzlikova, pp.105-6, pl.29, figs.2-5.

1977 " " (Voorwijk); Masters, pp.569-570, pl.45, figs.4,5,?6.

1977 Globotruncanella havanensis (Voorwijk); Rodriguez, pp.356-8, pl.45, figs.3-6.

1977 " " (Voorwijk); Koch, p.61, pl.7, figs.9,10

1977 Globotruncanella havanensis (Voorwijk); Sliter, p.542, pl.10, figs.1-6.

Description: Test free; compressed, low trochospiral coil, spiro-convex; outline lobate; periphery acute to subacute, may possess imperforate peripheral band; chambers distinct 4-5 in final whorl, compressed only weakly inflated, petaloid; sutures distinct, on umbilical side radial, slightly curved, depressed, on spiral side sutures strongly curved, flush to weakly depressed; umbilicus narrow, moderately deep; aperture high umbilical-extraumbilical arch, opening into umbilicus which may be covered by delicate tegilla with infralaminal accessory apertures; wall calcareous, finely perforate; surface hispid, occasionally coarsely spinose initially.

Average diameter: 0.26mm. Average thickness: 0.16mm.

Remarks: The thin, compressed test, lobate periphery and depressed non-beaded sutures are highly characteristic of this species. G. havanensis possibly evolved from 'hedbergellid' stock in latest Campanian times by the compression of the test and fusion of umbilical flaps to form a delicate tegillum. The phylogenetic lineage evolving from G. havanensis to Abathomphalus mayaroensis (Bolli) has been widely documented (Berggren, 1962, Pessagno, 1967).

Occurrence: This species has been widely recorded from strata of latest Campanian and Maastrichtian age. In the present study G. havanensis has been found in moderate abundance throughout the Maastrichtian.

Zonal range : uppermost B4i - B7i ;

R.rugosa /G. havanensis - A. mayaroensis biozones

Genus ABATHOMPHALUS Bolli, Loeblich & Tappan, 1957

Genotype Globotruncana mayaroensis Bolli, 1951

Abathomphalus mayaroensis (Bolli, 1951)

(Plate 10, figs. 8-10)

1951 Globotruncana mayaroensis Bolli, p.198, pl.35, figs.10-12.

? 1955 " " Bolli; Gandolfi, p. 18, pl.1, fig.2.

1956 Rugotruncana " (Bolli); Bronnimann & Brown, pp.553-4, pl.22, figs.10-12.

1957 Abathomphalus " (Bolli); Bolli, Loeblich & Tappan, p.43, pl.11, fig.1.

1957 Globotruncana (Globotruncana) planata Edgell, p.115, pl.4, figs.7-9

non 1958 " mayaroensis Bolli; Witwicka, p.225, pl.18, fig.36.

1962 Praeglobotruncana (Praeglobotruncana) mayaroensis (Bolli); Berggren, pp.32-6, pl.7, fig.3.

1964 Abathomphalus mayaroensis (Bolli); Loeblich & Tappan, p.C663, fig.529, no.5.

1967 " " (Bolli); Pessagno, p.372, pl.92, figs.4-9, pl.95, fig.5.

1967 Globotruncana " (Bolli); Bandy, p.20, t.fig.9,no.3.

1969 Abathomphalus " (Bolli); Hanzlikova, p.47, pl.9, figs.7-8

1969 " " (Bolli); Funnell et al, pp.26-7, pl.2, figs.5-7.

1971 " " (Bolli); Cita & Gartner, pl.1, fig.3, pl.4, fig.1.

1971 Globotruncana " Bolli; Postuma, p.50, pl.19, figs.1-7.

1972 Abathomphalus " (Bolli); Hanzlikova, p.114, pl.32, figs.5-6,? fig.4.

1976 " " (Bolli); Wright & Apthorpe, p.240, pl.2, figs. 13-14.

1977 Abathomphalus mayaroensis (Bolli); Rodriguez, pp.373-6, pl.47, figs.3,4.

1977 Globotruncana " Bolli; Masters, pp.591-3, pl.48, figs. 1-5.

Description: Test free; low trochospiral coil, spiral side weakly convex, umbilical surface typically concave umbilically; outline subcircular, moderately lobate; periphery truncated, subparallel with a moderately widely spaced, weakly developed, beaded, double keel; chambers distinct, 5-6 in final whorl, arranged in 2½ to 3 whorls, chambers subtriangular on umbilical side, becoming slightly arched, on spiral surface crescentic; sutures on umbilical surface straight, radial, depressed, on spiral surface crescentic, raised, slightly beaded; umbilicus shallow, covered by tegilla with infralaminal accessory apertures; primary aperture interiomarginal, extraumbilical; wall calcareous, perforate; surface finely hispid.

Average diameter: 0.48mm. Average thickness: 0.12mm.

Remarks: A. mayaroensis, the type species of the genus Abathomphalus, is homeomorphic with the double-keeled species of Globotruncana (Berggren, 1962). As noted by Bolli, Loeblich and Tappan (1957), A. mayaroensis is distinguished by its shallow umbilicus and interiomarginal extraumbilical aperture, lacking the wide deep umbilicus with a sharply angled rim and delicate tegilla of Globotruncana. Pessagno (1967) also noted that the double keels of A. mayaroensis are entirely radial, hyaline and are not strengthened by ultra-hyaline accretions as in the genus Globotruncana. For these reasons, the placing of A. mayaroensis within the genus Globotruncana by Masters (1977) is rejected. The evolutionary lineage Globotruncanella havanensis - Abathomphalus intermedius - A. mayaroensis has been widely documented (Berggren 1962, Pessagno 1967) and has been substantiated by the present study.

Occurrence: A. mayaroensis has been widely recorded from, and is an index fossil for, the Upper Maastrichtian. In the present study A. mayaroensis has been recorded in moderate abundance in material of Upper Maastrichtian age from the North Sea.

Zonal range: A. mayaroensis biozone

Abathomphalus intermedius (Bolli, 1951)

(Plate 10, figs.5-7)

1951 Globotruncana intermedia Bolli, pp.197-8, pl.35, figs.7-9.

1955 " " intermedia Bolli; Gandolfi, pp.48-9, pl.3, fig.8.

? 1956 Rugotruncana " (Bolli); Bronnimann & Brown, p.553, pl.22, figs.13-15.

1962 Praeglobotruncana (Praeglobotruncana) intermedia (Bolli); Berggren, p.31, pl.7, fig.2.

1967 Globotruncana intermedia Bolli; Bandy, p.19, t.fig.9, no.2.

? 1969 Abathomphalus " (Bolli); Funnel et al, p.27, pl.2, figs.8-18, t.fig.10.

1969 Praeglobotruncana intermedia (Bolli); Hanzlikova, p.46-7, pl.9, figs.5-6, ? fig.4.

1972 Abathomphalus intermedia (Bolli); Hanzlikova, p.113, pl.32, ? figs.1,2, fig.3.

1977 Globotruncana " (Bolli); Masters, pp.576-8.

1977 Abathomphalus " (Bolli); Rodriguez, pp.370-3, pl.47, fig.1, ? fig.2.

Description: Test free; low trochospiral coil, spiral side weakly convex, flattened to weakly concave umbilically; outline subcircular, moderately lobate; periphery weakly truncate to subacute with two closely spaced, weakly developed keels; chambers distinct, weakly inflated subtriangular on umbilical side, subpetaloid spirally, arranged in $2\frac{1}{2}$ to 3 whorls with 4-5 chambers in final whorl; sutures depressed, straight,radial ventrally, dorsally curved, raised, beaded; umbilicus shallow covered by tegillum; aperture low interiomarginal, extraumbilical opening; wall calcareous, perforate; surface pustulose.

Average diameter: 0.30mm. Average thickness: 0.11mm.

Remarks: This species, as noted previously, is intermediate between Globotruncanella havanensis and A. mayaroensis. It differs from the former by its less lobate periphery, subacute to truncate margin and keel development.

Occurrence: A. intermedius was originally described from the Upper Maastrichtian of Trinidad. In the present study A. intermedius has been found in moderate abundance in material of Upper Maastrichtian age from the North Sea.

Zonal range: B7i

Subfamily GLOBOTRUNCANINAE Cushman, 1926

Genus GLOBOTRUNCANA Cushman, 1926

Genotype Pulvinulina arca Cushman, 1926

Globotruncana arca (Cushman, 1926)

(Plate 10, figs.11-13)

1926b Pulvinulina arca Cushman, p.23, pl.3, fig.1.

1927b Globotruncana arca (Cushman); Cushman, p.169, pl.28, fig.15.

non 1931 " " (Cushman); Cushman, p.59, pl.11, fig.6.

non 1931b " " (Cushman); Plummer, pp.195-8, pl.13, ?fig.8, non. figs.7,9,11.

non 1936 " " (Cushman); Jennings, p.37, pl.4, fig.14.

1937 " " (Cushman); Glaessner, pp.36-7, pl.1, fig.10.

1951 " " (Cushman); Bandy, p.509, pl.75, fig.1.

1951 " (Globotruncana) arca (Cushman); Noth, pp.77-8, pl.8, fig.5.

1953 Globotruncana arca (Cushman); Hagn, p.97, pl.8, fig.11.

pars 1955 " " arca (Cushman); Gandolfi, pp.63-4, pl.5, figs.2,3, non.fig.4.

1956 " " (Cushman); Bronnimann & Brown, pp.539-40, pl.23, figs.10-12.

1957 " " (Cushman); Bolli, Loeblich & Tappan, pp.44-5, pl.11, figs.6-11.

pars 1957 " " (Cushman); Edgell, pp.110-1, pl.3, figs.4-6. non. fig. 13-15, non.pl.1, figs.10-12.

1958 " " (Cushman); Bieda, p.61, t.fig.14.

1959 " " (Cushman); Banner & Blow, pl.3, fig.5.

1960 " leupoldi Bolli; Olsson, p.50, pl.11, fig.1-3.

1962 " arca (Cushman); Barr, p.567, pl.69, fig.8.

1962 " " (Cushman); Herm, pp. 65-6, pl.7, fig.3.

1962 " (Globotruncana) arca (Cushman); Berggren, pp.49-51, pl.9, figs.1,2.

1963 " (") " (Cushman); van Hinte, pp.80-1, pl.6, fig.4,?fig.2.

1964 " arca (Cushman); Martin, p.79, pl.9, fig.4.

1964 " " (Cushman); Olsson, pp.162-3, pl.4, figs.1-3.

1964 " " (Cushman); Loeblich & Tappan, p.C662, fig.529, nos.1-2.

1965 Globotruncana arca (Cushman); Takayanagi, pp.209-211, pl.22, fig.6, pl.23, figs.1-2.

1965 " " (Cushman); van Hinte, p.20, pl.2, fig.3, pl.3, fig.3.

1966 " " (Cushman); Douglas & Sliter, pp.107-8, pl.2, figs.6-7.

1967 " " (Cushman); Pessagno, pp.321-3, pl.79, figs.5-8, pl.90, figs.6-8, pl.96, figs.7-8,17.

1968 " " (Cushman); Sliter, pp.101-2, pl.15, figs.9-10.

1969 " " (Cushman); Douglas, p.176, pl.9, figs.1-3, pl.10, figs.4-7.

1971 " " (Cushman); Postuma, p.18, pl.3, figs.1-7.

1971a " " (Cushman); El-Naggar, pl.5, figs.g-i, j-l.

1972 " " (Cushman); Hanzlikova, p.102, pl.26, figs.11-13, pl.27, fig.1.

1972 " " (Cushman); Barr, p.18, pl.6, fig.6.

1972 " " (Cushman); Govindan, p.175, pl. 4, figs.1-6.

1973 " " (Cushman); Sliter, pl.2, figs.8-10.

1973 " " (Cushman); Smith & Pessagno, pp.43-4, pl.18, figs.1-6.

1977 " " (Cushman); Masters, pp.536-540, pl.38, figs.1, 2,4.

1977 " " (Cushman); Rodríguez, pp.237-246, pl.26, figs. 2-3, ?pl.26, fig.4.

Description: Test free; moderately large, biconvex; outline subcircular, moderately lobate; periphery truncated by two well developed beaded keels; chambers distinct, inflated, $5\frac{1}{2}$ to 7 in final whorl, increasing gradually in size as added, subpetaloid dorsally; sutures distinct dorsally, curved, raised, beaded, on umbilical side curved, beaded; umbilicus wide, deep, bordered by pronounced beaded umbilical shoulder; primary aperture interiomarginal, umbilical, covered by tegillum with infralaminal and intralaminal accessory apertures; wall calcareous, perforate; surface smooth.

Average diameter: 0.50mm. Average thickness: 0.24mm.

Remarks: This species is characterised by its robust biconvex test, quite widely spaced, heavily beaded keels and 6-7 chambers in the final whorl.

Occurrence: Cushman originally described G. arca from Mexico, probably from strata of Upper Maastrichtian age (Smith & Pessagno, 1973). In the present study G. arca was found rarely in strata of Upper Campanian and Lower Maastrichtian age.

Zonal range: B3ii - B6i

Globotruncana bulloides bulloides (Vogler, 1941)

(Plate 10, figs.14-16)

1936 Globotruncana ventricosa White; Brotzen, pp.171-7, pl.13, fig.4.

1941 ______"______ linnei (d'Orbigny) subsp. bulloides Vogler, p.287, pl.23, figs.32-29.

1945 ______"______ lapparenti bulloides Vogler; Bolli, pp.231-2, t.figs, 17,18, pl.9, fig.12.

1946 Rosalinella marginata (Reuss); Schijfsma, pp.97-8, pl.7, fig.10.

1951 Globotruncana lapparenti bulloides Vogler; Bolli, pp.190, 194, fig.1.

1953 ______"______ marginata (Reuss); Hagn, pp.93-4, pl.8, fig.10, t.figs.10,11.

1955 ______"______ bulloides bulloides Vogler; Gandolfi, p.32, pl.1, fig.91.

1957 ______"______ marginata (Reuss); Edgell, p.114, pl.2, figs.4-6.

1958 Globotruncana lapparenti bulloides Vogler; Bieda, pp.58-9, t.fig.23.

1958 " " " Vogler; Witwicka, pl.17, fig.31.

1960 " " " Vogler; Belford, pp.97-8, pl.28, figs.7-13.

1961 " paraventricosa (Hofker); Vasilenko, pp.151-4, pl.33, fig.1.

1962 " lapparenti bulloides Vogler; Herm, pp.84-5, pl.6, fig.6.

1962 " " " Vogler; Pessagno, p.360, pl.6, figs.13,14.

1962 " marginata (Reuss); Barr, pp.574-5, pl.70, fig.3, pl.72, figs.7-8.

1962 " culverensis Barr, pp.569-70, pl.71, fig.1.

1962 " paraventricosa (Hofker); Hiltermann & Koch, p.331, pl.49, figs.6-7.

1963 " (Globotruncana) marginata (Reuss); van Hinte, pp.83-5, pl.7, fig.2, pl.8, figs.3-4.

1964 " paraventricosa (Hofker); Martin, p.81, pl.10, fig.4.

1965 " marginata (Reuss); van Hinte, p.23, pl.1, fig.2.

1967 " bulloides Vogler; Pessagno, pp.324-6, pl.64, figs.15-17. pl.67, figs.1-3.

1967 " linneiana bulloides Vogler; Bandy, p.19, t.fig.9,no.1.

1969 " marginata (Reuss); Douglas, pp.182-3, pl.8, fig.5, ?fig.4.

1969 " " (Reuss); Douglas & Rankin, pp.203-7, figs.14,15.

1970 " bulloides Vogler; Porthault, in Donze et al, p.83, pl.11, figs.20-22.

1971 " " Vogler; Postuma, pp.20-1, pl.4, figs.1-7.

1977 " " Vogler; Rodriguez, pp.296-303, pl.35, figs.1-2.

1977 Globotruncana paraventricosa (Hofker); Koch, p.39, pl.4, figs. 1-4.

Description: Test free; low trochospiral coil, biconvex; outline subcircular, moderately lobate; periphery truncated by two well developed keels; chambers distinct, inflated dorsally and ventrally, 5-7 in final whorl, increasing slowly to quite rapidly in size as added, subpetaloid dorsally; sutures distinct, curved, raised, beaded on spiral side, distinct, slightly curved, weakly depressed on umbilical side, with weakly raised, beaded keels; umbilicus moderately wide, deep; primary aperture interiomarginal,umbilical , covered by tegillae with intralaminal and infralaminal accessory openings; wall calcareous, perforate; surface smooth to finely roughened umbilically.

Average diameter: 0.52mm. Average thickness: 0.23mm.

Remarks: This species may be conspecific with and therefore a senior synonym of, G. praeventricosa (Hofker), although the illustrations and type description of the latter are inadequate for a definitive statement. G. bulloides has been confused in the past with Marginotruncana marginata largely due to the fact that G. bulloides was originally described from thin section, and thus no information concerning its external morphology was available. This situation was partially rectified by the comparative thin section studies undertaken by Pessagno (1967) on three dimensional specimens and his evaluation of G. bulloides is followed here. Jirova (1956) selected a neotype of M. marginata from the type locality of the Plänermergel from Luznice. This latter species clearly belongs to the genus Marginotruncana sensu Robaszynski & Caron (1979), possessing an umbilical extraumbilical primary aperture and less well developed tegilla. These latter features together with less well developed keels serve to distinguish M. marginata from G. bulloides and thus the suggestion (Masters, 1977) that the two are conspecific is here rejected.

Occurrence: G. bulloides was originally described from the Upper Cretaceous of the East Indies. In the present study it has been found to range, often in abundance, throughout the Campanian.

Zonal range : B1ii - B4i

Globotruncana bulloides austinensis Gandolfi, 1955

(Plate 11, figs. 1-3)

1955 Globotruncana marginata austinensis Gandolfi, p.29, pl.1, fig.6.

1964 " aff. gagnebini Tilev; Olsson, pl.4, fig.6.

1967 " austinensis Gandolfi; Pessagno, pp.323-4, pl.82, figs.12-15, pl.94, fig.9.

? 1970 " " Gandolfi; Porthault, in Donze at al, pp.84-5, pl.11, figs.23-5.

1977 " " Gandolfi; Rodriguez, pp.303-4, pl.35, fig.4.

Description: Test free; low trochospiral coil, umbilicoconvex; outline subcircular, weakly lobate; periphery truncated by two closely spaced keels following periphery of final whorl; chambers distinct, moderately inflated spirally, strongly convex umbilically, 4-6 chambers in final whorl; sutures distinct, depressed, slightly curved, beaded on umbilical surface, depressed, curved on spiral surface; umbilicus deep; primary aperture umbilical, covered by tegilla with intralaminal and infralaminal accessory apertures; wall calcareous, perforate; surface smooth to finely hispid.

Average diameter: 0.47mm. Average thickness: 0.23mm.

Remarks: As noted by Pessagno (1967) this taxon is closely related to, and intergradational with, G. bulloides ss. It may be distinguished from the latter by its highly convex umbilical surface, almost planiform spiral side, and by the position of the double keels, which are often not as strongly developed as in G. bulloides ss.

Occurrence: This taxon was originally described from the Colon Formation of Colombia. In the present study it has been found in moderate abundance in the Upper Campanian.

Zonal range: B3ii - B4i

Globotruncana fornicata Plummer, 1931.

(Plate 11, figs.4-6)

1931 Globotruncana fornicata Plummer, pp.198-9, pl.13, figs.4,5.6.

1936 ___"___"___ Plummer; Jennings, p.37, pl.4, fig.13.

1946 ___"___"___ Plummer; Cushman, p.149, pl.61, fig.19.

1948 ___"___"___ Plummer; Cita, pp.153-4, pl.3, fig.8.

1951 ___"___"___ Plummer; Noth, p.77, pl.8, fig.18.

1952 ___"___"___ Plummer; Sigal, pp.35-6, t.fig.39.

1953 ___"___"___ Plummer; Hagn, p.98, pl.8, fig.8.

1953 ___"___"___ Plummer; Subbotina, pp.184-5, pl.8, figs.3-5.

1955 ___"___"___ fornicata Plummer; Gandolfi, p.40, pl.2, fig.2.

1955 ___"___"___ manaurensis Gandolfi, p.41, pl.2, fig.1.

1958 ___"___"___ Plummer; Bieda, pp.61-3, t.fig.25.

1958 ___"___"___ Plummer; Witwicka, pp.220-1, pl.17, fig.32.

1960 ___"___"___ Plummer; Takayanagi, p.135, pl.10, fig.3.

1961 ___"___"___ Plummer; Vasilenko, pp.154-6, pl.33, fig.3.

1962 Globotruncana fornicata Plummer; Barr, pp.570-1, pl.69, fig.6, pl.72, figs.1, ?2.

1962 ______"______"______ Plummer; Herm, pp.78-9, pl.7, fig.2.

1963 ______"______"______ Plummer; Graham & Church, pp.63-4, pl.7, fig.14.

1963 ______"______"______ Plummer; van Hinte, p.61, pl.1, figs.1-2, pl.20, fig.3.

1964 ______"______"______ Plummer; Olsson, pp.165-6, pl.2, figs.3,4, pl.3, figs.7,8.

1965 ______"______"______ Plummer; van Hinte, pp.21-3, pl.1, fig.1, pl.2, fig.1.

1965 ______"______"______ Plummer; van Hinte, p.83, pl.1, fig.6.

1965 ______"______"______ Plummer; Takayanagi, pp.214-5, pl.24, fig.4.

1966 ______"______"______ fornicata Plummer; El-Naggar, p.105-8, pl.13, figs.5-6.

1967 ______"______"______ Plummer; Pessagno, pp.338-341, pl.63, figs.1-9, pl.80, figs.7-9, pl.96, figs.3-4 (full synonomy).

1968 ______"______"______ Plummer; Sliter, p.103, pl.16, figs.5-7.

1969 ______"______"______ Plummer; Douglas, p.179, pl.7, fig.6.

1971 ______"______"______ Plummer; Postuma, pp.16-17, pl.12, figs.1-7.

1972 ______"______"______ Plummer; Hanzlikova, p.106, pl.28, figs.6-7.

1974 ______"______"______ manaurensis Gandolfi; Herb, pl.7, figs.15-16.

1977 ______"______"______ Plummer; Masters, pp.564-6, pl.44, figs.4-6.

Description: Test free; trochospiral, spiral side weakly to moderately convex, umbilical side weakly convex; margins angular, truncated by two well spaced keels; coiling predominantly dextral; chambers distinct, 4-5 in final whorl; on involute umbilical side chambers elongate, subrectangular, on evolute dorsal surface chambers narrow, elongate, crescentic; sutures raised, beaded, arched on spiral surface, raised beaded, strongly curved umbilically; umbilicus narrow, deep, covered by tegilla with intralaminal and infralaminal openings; primary aperture interiomarginal, umbilical; wall calcareous, perforate; surface smooth, on spiral side initially pustulose.

Average diameter: 0.42mm. Average thickness: 0.18mm.

Remarks: *G. fornicata* may be distinguished by its moderately convex spiral side and elongate, crescentic, chambers. Pessagno (1967) examined the holotype of *G. fornicata manaurensis* Gandolfi, and concluded that the latter is conspecific with *G. fornicata*.

Occurrence: *G. fornicata* was originally described from the upper Taylor Marl (Campanian) of Texas. In the present study, it was found in moderate abundance throughout the Campanian, both in onshore and offshore sections.

Zonal range: B1ii - B4i

Globotruncana contusa patelliformis Gandolfi, 1955

(Plate 11, figs.7,8)

1955 *Globotruncana contusa patelliformis* Gandolfi, pp.54-5, pl.4, fig.2.

1963 " (*Globotruncana*) *plicata caliciformis* Vogler; van Hinte, p.64, pl.3, fig.2.

1966 " *contusa patelliformis* Gandolfi; El-Naggar, pp.93-5, pl.8, fig.1.

1973 " *patelliformis* Gandolfi; Smith & Pessagno, pp.50-1, pl.21, figs.6-8.

1977 " " Gandolfi; Rodriguez, pp.222-6, pl.23, figs.2-3 (full synonomy).

Description: Test free; trochospiral, with deep umbilicus, strongly spiroconvex; outline subcircular, weakly lobate; periphery truncated by two closely spaced double keels; chambers indistinct, 5-7 in final whorl, spirally elongate, crescentic, on umbilical surface chambers elliptical; sutures distinct, strongly curved, weakly raised, beaded on spiral side, slightly curved, radial, depressed; umbilicus narrow, deep; primary aperture interiomarginal umbilical; wall calcareous, perforate; surface rugose.

Average diameter: 0.57mm. Average thickness: 0.41mm.

Remarks: This subspecies may be distinguished from *G. contusa contusa* (Cushman) by its smaller size, circular periphery and lack of pronounced plications.

Occurrence: Rare specimens belonging to this species were found in Upper Maastrichtian material from the North Sea.

Zonal range: Upper B7i

Globotruncana hilli Pessagno, 1967

(Plate 11, figs.9-11)

1967 *Globotruncana hilli* Pessagno, pp.343-4, pl.64, figs.9-14, 21-23, pl.94, fig.1, pl.97, fig.7.

1969 " " Pessagno; Douglas, p.180, pl.7, figs.7-8.

1973 " " Pessagno; Sliter, pl.3, figs.4-6.

1977 " " Pessagno; Rodriguez, pp.304-6, pl.37, figs.1-3.

Description: Test free; small, low trochospiral coil, almost planiform both spirally and umbilically; outline subcircular, moderately lobate; periphery truncated in later stages of final whorl by widely spaced, double keel; earlier chambers non truncate, subglobular, occasionally with weakly developed dorsal keel, later chambers elongate, subrectangular ventrally, petaloid dorsally, slightly imbricate; chambers distinct, inflated, $4\frac{1}{2}$ to $5\frac{1}{2}$ in final whorl; sutures strongly curved, beaded, depressed dorsally, ventrally depressed, radial, straight to weakly curved, weakly, if at all, beaded; umbilicus moderately wide and deep; primary aperture interiomarginal, umbilical, covered by tegilla with intralaminal and infralaminal accessory apertures; wall calcareous, perforate; surface finely spinose especially initially.

Average diameter:0.35mm. Average thickness: 0.17mm.

Remarks: This small, distinctive species is characterised by its almost planiform test, finely hispid surface and globular initial chambers. Pessagno (1967) postulated the derivation of this species from G. linneiana by an enlargement of the latter's 'Archaeoglobigerina' stage and the restriction of its double keel to the anterior of the test. Rodriguez (1977) has also raised the possibility of its derivation from G. bulloides.

Occurrence: G. hilli was originally described from the Taylor Formation of Texas, and has been recorded from strata of Upper Campanian and Lower Maastrichtian age. In the present study, it was found only in the Upper Campanian, for which it appears to be a useful index form.

Zonal range: B3iv - B4i

Globotruncana linneiana (d'Orbigny, 1839)

(Plate 11, figs.12,13)

1839 Rosalina linneiana d'Orbigny, p.110, pl.5, figs.10-12.

pars 1918 " " d'Orbigny; de Lapparent, pp.1-17, t.fig.2g, non. figs. 2a-f, h-n.

1941 Globotruncana linnei typica (d'Orbigny); Vogler, p.286, pl.23, figs.12-22.

1945 " lapparenti lapparenti Brotzen; Bolli, p.230, pl.9, fig.11, t.fig.1, nos.15, ?16.

1951 " canaliculata (Reuss); Bandy, p.509, pl.75, fig.2.

1956 " linneiana (d'Orbigny); Bronnimann & Brown, pp.540-2, pl.20, figs. 13-17, pl.21, figs.16-18.

1957 " (Globotruncana) cf. lapparenti Brotzen; Edgell, pl.1, figs.4-6.

1961 " linneiana (d'Orbigny); Graham & Clark, p.113, pl.5, fig.11.

1962 " lapparenti lapparenti Brotzen; Herm, pp.82-4, pl.6, fig.2.

1962 " (Globotruncana) lapparenti linneiana (d'Orbigny); Pessagno, p.360, pl.3, figs.7-9.

1962 " linneiana linneiana (d'Orbigny); Barr, pp.571-2, pl.69, fig.7, pl.72, fig.5.

1963 " (Globotruncana) linneiana linneiana (d'Orbigny); van Hinte, pp.75-8, pl.5, figs.1-2, t.fig.14.

? 1965 " linneiana (d'Orbigny); van Hinte, p.23, pl.1, fig.3.

1967 " " linneiana (d'Orbigny); Bandy, p.19, t.fig.8, no.11.

1967 " " (d'Orbigny); Pessagno, pp.346-9, pl.72, figs.1-4, 7-9, pl.79, figs.11-13.

1968 Globotruncana linneiana (d'Orbigny); Sliter, p.104, pl.17, figs.3-4.

1969 " " (d'Orbigny); Douglas, p.181-2, pl.3, fig.1.

1971 " lapparenti Brotzen; Postuma, p.48, pl.18, figs.1-7.

1971 " linneiana (d'Orbigny); Cita & Gartner, pl.1, fig.6.

1971 " " (d'Orbigny); El Naggar, pl.7, figs.g,j-m.

1972 " " (d'Orbigny); Barr, pp.21-2, pl.9, fig.2.

non 1972 " " (d'Orbigny); Hanzlikova, pp.107-8, pl.29, figs.6-7.

1973 " " (d'Orbigny); Sliter, pl.3, figs.7-9.

1976 " " (d'Orbigny); Wright & Apthorpe, p.239, pl.1, figs.8,11.

1976 " lapparenti Brotzen; Wright & Apthorpe, p.239, pl.1, figs.12-13.

1977 " " Brotzen: Masters, pp.579-583, pl. 46, fig.4.

non 1977 " linneiana (d'Orbigny); Masters, pp.583-5, pl.46, figs.3,5,6.

1977 " " (d'Orbigny); Rodriguez, pp.258-263, pl.29, figs.4-5, pl.30, figs.1-2.

Description: Test free; low trochospiral coil, planiform test both dorsally and ventrally; outline subcircular, weakly lobate; periphery acutely truncated by wide double keel; chambers distinct, arranged in $2\frac{1}{2}$ to $3\frac{1}{2}$ whorls, with 5-7 chambers in final whorl, chambers increasing gradually in size as added, petaloid dorsally, elongate, subrectangular ventrally; sutures distinct, raised, beaded curved dorsally, raised, beaded, curved with distinct beaded umbilical shoulder, ventrally; umbilicus wide, moderately shallow; primary aperture interiomarginal, umbilical, covered by tegilla with intralaminal and infralaminal accessory openings; wall calcareous, perforate; surface smooth to finely hispid.

Average diameter: 0.45mm. Average thickness: 0.18mm.

Remarks: D'Orbigny (1839) originally described and figured this species from Recent beach sands in Cuba containing redeposited Upper Cretaceous foraminifera. His figures, though styalized, showed a specimen which might have possessed radial,depressed,ventral sutures. Brotzen (1936) noted that the syntypic suite of specimens referred to G. linneiana by de Lapparent (1918) should be considered as a new species, G. lapparenti, which he distinguished from G. linneiana by their sigmoidal ventral sutures. However, Bronnimann and Brown (1956), in erecting a neotype for G. linneiana, clearly illustrated a specimen with raised, beaded, sigmoidal ventral sutures, which in all likelihood was the form described by Brotzen as G. lapparenti. Brotzen (1936) had not designated a holotype for G. lapparenti, but referred to a syntypic suite of specimens undoubtedly representing more than one species (Pessagno, 1967). Bolli (1945) was the first author to illustrate specimens which he referred to G. lapparenti. These specimens are clearly conspecific with the neotype of G. linneiana. However, Pessagno (1967) , whilst in agreement with the foregoing, recognised G. lapparenti as a distinct species, formally designating as lectotype the thin section illustrated in t.fig. 2n (de Lapparent, 1918). This species he distinguishes from G. linneiana by its narrower keels and a more inflated final chamber with a pronounced beaded umbilical rim. As noted by Masters (1977) this latter feature might indicate that G. lapparenti Brotzen sensu Pessagno, is a junior synonym of G. tricarinata Quereau, 1893, though as the types of both are thin sections, this cannot be conclusively proven.

Masters (1977) has illustrated a specimen which he placed in G. linneiana that possesses distinctly depressed radial, ventral sutures and is clearly not conspecific with the neotype of G. linneiana selected by Bronnimann and Brown. Therefore his contention that G. canaliculata (Reuss) is a junior synonym of G. linneiana is invalid.

Occurrence: G. linneiana was found rarely in the present study, ranging throughout most of the Campanian.

Zonal range: B1ii - B3iv

Globotruncana plummerae Gandolfi, 1955

(Plate 12, figs.1-3)

1955 Globotruncana fornicata plummerae Gandolfi, p.42, pl.2, figs.3,4.

1963 " (Globotruncana) fornicata plummerae Gandolfi; van Hinte, pp.63-4, pl.3, fig.1.

1966 " fornicata cesarensis Gandolfi; El-Naggar, pp.103-5, pl.13, figs.?3, 4, pl.14, fig.6.

1966 " " globulocamerata El-Naggar, pp.108-9, pl.14, figs.1, 2, ?pl.13, fig.1.

1967 " plummerae Gandolfi; Pessagno, pp.351-2, pl.66, figs. 3-8.

1973 " " Gandolfi; Smith & Pessagno, p.51, pl.21, figs.9-11.

1977 " " Gandolfi; Rodriguez, pp.232-4, pl.36, figs.1-2.

Description: Test free; low trochospiral coil; dorsally low to moderately convex, ventrally weakly inflated; outline subcircular to subquadrate, weakly lobate; periphery subrounded to subacute, truncated by prominent double keel; chambers distinct, arranged in 2 to 2½ whorls, with 4, rarely 5 chambers in final whorl; chambers increasing rapidly in size as added, those of final whorl dorsally elongate, crescentic, inflated on umbilical surface, chambers distinctly elongate, subrectangular, weakly inflated; sutures depressed, strongly curved dorsally, occasionally weakly beaded, sutures on umbilical surface depressed, slightly curved, radial; umbilicus moderately narrow, deep; primary aperture interiomarginal, umbilical covered by tegilla with intralaminal and infralaminal accessory apertures; wall calcareous, perforate; surface rugose especially initially.

Average diameter: 0.33mm. Average thickness: 0.22mm.

Remarks: This species may be distinguished by its elongate, inflated chambers, with those of the final whorl increasing rapidly in size as added. It is probable that G. plummerae arose either from G. fornicata by an increase in the inflation of the chambers, or from G. bulloides bulloides by a reduction in the number of chambers and their concomitant elongation.

Occurrence: G. plummerae was originally described from the Colon Formation of Columbia. In the present study it has been found in moderate abundance in the Upper Campanian both from onshore and offshore samples.

Zonal range: B3ii - B4i

Globotruncana rugosa (Marie, 1941)

(Plate 12, figs.4-6)

1941 Rosalina rugosa Marie, pp.240-1, pl.36, fig.340.

1953 Globotruncana rugosa (Marie); Hagn, pl.8, fig.13.

1961 " " (Marie); Vasilenko, p.159, pl.35, fig.3, pl.36, fig.1.

? 1962 " " (Marie); Barr, pp.576-7, pl.71, fig.3.

Description: Test free; small robust, moderately high trochospiral coil; outline subcircular, moderately lobate; periphery truncated by two prominent, widely spaced keels; chambers distinct, arranged in

2½ to 3 whorls, with 6-7 chambers in final whorl; chambers inflated, petaloid dorsally, elongate subrectangular on umbilical surface; dorsal sutures distinct, curved, raised, beaded, sutures on ventral surface slightly curved, weakly beaded, occasionally depressed; umbilicus moderately wide, deep; primary aperture interiomarginal, umbilical, covered by tegilla with intralaminal and infralaminal accessory apertures; wall calcareous, perforate; surface rugose dorsally and initially rugose ventrally.

Average diameter: 0.40mm. Average thickness: 0.24mm.

Remarks: The original illustrations of this species are highly styalized, though they do show the major morphological features which serve to distinguish this species, e.g. moderately convex, rugose, dorsal surface, ventrally elongate chambers and raised, beaded keels. The forms identified as G. rugosa by Barr (1962) appear to differ from the holotype in their more elongate chambers, and the less spiroconvex nature of the test. The present author favours the derivation of this species from G. bulloides (= G. paraventricosa Hofker) as indicated by Vasilenko (1961). The species G. churchi Martin, 1964, described from the Campanian of California has many morphological features in common with the present species and study of the relevant type material might prove the two to be conspecific.

Occurrence: G. rugosa was originally described from the Upper Campanian of the Paris Basin. In the present study it has been found in moderate abundance throughout the Upper Campanian.

Zonal range: B3i - B4i; G. rugosa biozone.

Globotruncana ventricosa White, 1928

(Plate 12, figs.7-9)

1928 Globotruncana canaliculata var. ventricosa White, p.284, pl.38, fig.5.

non 1931 " " ventricosa White; Plummer, p.199, pl.13, fig.10.

non 1936 " ventricosa White; Brotzen, pp.171-7, pl.13, fig.4, t.fig.63.

1946 " " White; Cushman, p.150, pl.62, fig.3.

1955 " lobata de Klasz, p.43, pl.7, fig.2.

1957 " (Globotruncana) paraventricosa (Hofker); Edgell, p.114, pl.1, figs.1-3.

1957 " ventricosa White; Bolli, p.57, pl.13, fig.4.

1960 " " White; Belford, pp.98-9, pl.29, figs.5-11.

non 1961 " " White; Graham & Clark , p.112, pl.5, fig.9.

1962 " cf. " White; Barr, pp.577-8, pl.71, fig.2.

1963 " " White; van Hinte, p.86-7, pl.7, fig.3.

1966 " " White; Douglas & Sliter, p.115, pl.3, fig.1.

1967 " " White; Pessagno, pp.362-4, pl.75, figs. 21-6, pl.79, figs.9-14, pl.95, figs.10-11, pl.99, fig.2.

1967 " " White; Bandy, p.20, t.fig.9, no.9.

1968 " " White; Barr, p.319, pl.40, fig.3.

pars 1968 " " White; Sliter, p.107, pl.18, fig.7, non.fig.8.

1969 " " White; Douglas, p.188, pl.7, figs.1-3.

1971 ______ " ______ " ______ White; Postuma, p.64, pl.26, figs.1-7.

1971 ______ " ______ " ______ White; Cita & Gartner, pl.4, fig.2.

1972 ______ " ______ " ______ White; Barr, pp.25-6, pl.8, fig.6.

1972 ______ " ______ " ______ White; Hanzlikova, p.113, pl.31, figs.5-7.

1972 ______ " ______ " ______ White; Caron, p.555, pl.2, fig.3.

non 1973 ______ " ______ " ______ White; Sliter, pl.4, figs.1-3.

1976 ______ " ______ " ______ White; Wright & Apthorpe, p.240, pl.2, figs.8,9.12.

1977 ______ " ______ " ______ White; Masters, pp.614-5, pl.55, figs.1-3.

1977 ______ " ______ " ______ White; Rodriguez, pp.265-272, pl.31, figs.2-3, pl.32, figs.1-2.

Description: Test free, robust; low trochospiral coil, dorsal side flat to weakly convex centrally, ventrally convex; outline subcircular, moderately lobate; periphery truncated by two closely spaced heavily beaded keels positioned close to the dorsal margin; chambers distinct, arranged in 2½ to 3 whorls with 6-7 chambers in final whorl, which increase gradually in size as added; chambers flattened, petaloid dorsally, inflated, highly convex, subrectangular ventrally; sutures on spiral side curved, raised, heavily beaded, those on umbilical side weakly depressed, curved, occasionally finely beaded; umbilicus deep, bordered by beaded umbilical shoulder; primary aperture interiomarginal, umbilical, covered by tegilla with intralaminal and infralaminal accessory apertures; wall calcareous, perforate; surface initially rugose, later smooth.

Average diameter: 0.35mm. Average thickness: 0.27mm.

Remarks: This distinctive species is characterised by its robust, almost planoconvex test and closely spaced double keels. The specimens described as G. cf. ventricosa by Barr (1962) were stated to differ from typical specimens of G. ventricosa by possessing fewer chambers and a more rugose surface. Such variation is within the range shown by tototypic specimens (Pessagno, 1967).

Occurrence: G. ventricosa was originally described from the Upper Campanian of Mexico, and has been widely recorded from strata of Campanian age. In the present study, it has been found sporadically throughout the Middle and Upper Campanian.

Zonal range: B2iii - B3iv

Genus ARCHAEOGLOBIGERINA Pessagno, 1967

Genotype Archaeoglobigerina blowi Pessagno, 1967

Archaeoglobigerina cretacea (d'Orbigny, 1840)

(Plate 12, figs.10-12)

1840 Globigerina cretacea d'Orbigny, p.34, pl.3, figs.12-14.

1936 Globotruncana globigerinoides Brotzen, p.177, pl.12, fig.3, pl.13, fig.3.

1941 Globigerina cretacea d'Orbigny; Marie, p.234, pl.36, fig.335.

1946 Rosalinella globigerinoides (Brotzen); Schijfsma, pp.96-7, pl.7, fig.9.

1951 Globotruncana " Brotzen; Noth, p.76, pl.5, fig.4.

1953 " " Brotzen; Hagn, pp.94-5, pl.8, fig.9.

1956 " saratogaensis (Applin); Bronnimann & Brown, pp.544-5, pl.21, figs.1-3.

1957 " (Globotruncana) globigerinoides Brotzen; Edgell, pp.112-3, pl.21, figs.13-15.

1958 " globigerinoides Brotzen; Bieda, pp.65-6, t.fig.27.

1960 Globotruncana cretacea (d'Orbigny); Banner & Blow, pp.8-10, pl.7, fig.1.

1961 Globigerina " (d'Orbigny); Hofker, pl.1, figs.15-17.

1962 Globotruncana " (d'Orbigny); Barr, pp.567-9, pl.69, fig.9.

1963 " (Globotruncana) cretacea (d'Orbigny); van Hinte, pp.85-6, pl.6, fig.3.

1965 " cretacea (d'Orbigny); van Hinte, p.21, pl.3, fig.1.

1967 Rugoglobigerina cretacea (d'Orbigny); Bandy, p.21, t.fig.10, no.1.

1967 Archaeoglobigerina cretacea (d'Orbigny); Pessagno, pp.317-8, pl.70 figs.3-8, pl.94, figs.4-5.

1969 Globotruncana cretacea (d'Orbigny); Douglas & Rankin, pp.200-3, t. t.fig.12.

1970 Archaeoglobigerina cretacea (d'Orbigny); Porthault in Donze et al, pp.539-40, pl.9, fig.17.

1972 Globotruncana cretacea (d'Orbigny); Hanzlikova, p.108, pl.28, figs.3-5.

1977 " " (d'Orbigny); Masters, pp.551-5, pl.41, figs.3,4, pl.42, fig.1.

1977 Archaeoglobigerina cretacea (d'Orbigny); Rodriguez, pp.72-7, pl.4, figs.1,2.

1979 " " (d'Orbigny); Robaszynski & Caron, pp.173-6, pl.80, fig.1.

Description: Test free; low trochospiral coil of 2½ to 3 whorls; outline subcircular, moderately lobate; periphery weakly truncated, initially rounded; chambers distinct, inflated, subglobular, weakly compressed dorso-ventrally, increasing gradually and uniformly in size as added, with weakly developed faint keels bordering a raised imperforate band; sutures radial, straight, depressed on umbilical side, depressed, nearly radial on spiral side; umbilicus broad, deep, covered by tegilla with infralaminal and intralaminal accessory apertures; primary aperture umbilical; wall calcareous, finely perforate; surface hispid.

Average diameter: 0.42mm. Average thickness: 0.20mm.

Remarks: Globigerina cretacea d'Orbigny, is referred to the genus Archaeoglobigerina on the basis of its non-truncate, globular chambers and radial depressed sutures on the umbilical side. Banner and Blow (1960) erected and figured a lectotype of this species which, for the first time, revealed the presence of weakly developed keels.

Globotruncana globigerinoides Brotzen, which was distinguished from A. cretacea by the presence of a weak double keel, is thus clearly a junior synonym of the present species.

Occurrence: A. cretacea was originally described from the Campanian chalk of St. Germain in the Paris Basin. In the present study, it has been found, often in great abundance, ranging throughout the Campanian, and rarely in the lowest Maastrichtian.

Zonal range: B1ii - B4i, rarely lowest B5i

Genus RUGOGLOBIGERINA Bronnimann, 1952

Genotype Globigerina rugosa Plummer, 1927

Rugoglobigerina rugosa (Plummer, 1927)

(Plate 12, figs.13-15)

1927 Globigerina rugosa Plummer, pp.38-9, pl.2, fig.10.

1931 " " Plummer Plummer, pp.194-5.

1952 Rugoglobigerina rugosa rugosa (Plummer); Bronnimann, pp.28-33, t.figs, 11-13.

1953 " " " (Plummer); Hamilton, p.227, pl.30, figs.1-3.

1955 Globotruncana (Rugoglobigerina) rugosa rugosa (Plummer); Gandolfi, p.72, pl.7, fig.6.

1957 Rugoglobigerina rugosa (Plummer); Bolli, Loeblich & Tappan, p.43, pl.11, fig.2.

non 1957 " " (Plummer); Edgell, pp.116-8, pl.4, figs. 10-12.

1960 " " rugosa (Plummer); Olsson, p.50, pl.10, figs.16-18.

1962 " " (Plummer); Pessagno, p.350, pl.5, fig.13.

1962 " " rugosa (Plummer); Herm, p.60, pl.3, fig.2.

pars 1962 " " (Plummer); Berggren, pp.71-5, pl.11, figs.1-2, ?fig.4, non. figs.3,5

1963 Globotruncana (Rugoglobigerina) rugosa (Plummer); van Hinte, p.92, pl.11, fig.1-2, ?fig.3.

pars 1964 Rugoglobigerina rugosa (Plummer); Olsson, p.173, pl.7, ?fig.4, non.figs.2,3,5.

1964 " macrocephala Bronnimann; Olsson, p.172, pl.6, fig.9.

non 1964 " rugosa (Plummer); Martin, p.83, pl.10, fig.6.

1964 " " (Plummer); Loeblich & Tappan, p.C663, fig.530, no.3.

1967 " " (Plummer); Pessagno, pp.366-367, pl.75, figs.2-3, pl.101, figs.8-9.

1967 " " (Plummer); Bandy, p.22, t.fig.10, no.6.

1968 " " (Plummer); Sliter, p.108, pl.19, fig.2.

? 1971a " (Rugoglobigerina) rugosa (Plummer); El-Naggar, pl.5, fig.a-c.

1971b " (") badryi El-Naggar, pp.482-3, pl.14, figs.2,5,9,10, pl.16, figs.1,3,7, ?figs.4,5,11.

1971b " (") browni El-Naggar, pp.484,5, pl.17, figs.2-3,5-6,8.

1971b Ruglobigerina (Rugoglobigerina) rugosa (Plummer); El-Naggar, pp.492-4, pl.1, figs.1-11, pl.2, figs.1-12, pl.3, figs.1-16, pl.4, figs.1-16, pl.8, figs.4,5.

1971 ______"______ rugosa (Plummer); Postuma, p.90, pl.39, figs.1-7.

1972 ______"______"______ (Plummer); Hanzlikova, p.116, pl.33, figs.5-6.

1972 ______"______"______ (Plummer); Barr, p.30, pl.9, fig.7, pl.10, fig.4.

1973 ______"______"______ (Plummer); Smith & Pessagno, pp.58-60, pl.25, figs.1-4.

1977 ______"______"______ (Plummer); Masters, pp.622-6, pl.56, figs.1,4,5, pl.57, figs.1,2

1977 ______"______"______ (Plummer); Rodriguez, pp.82-6, pl.4, figs.5-7.

Description: Test free; low trochospiral coil of $2\frac{1}{2}$ to 3 whorls; outline subcircular, moderately lobate; periphery rounded; chambers distinct, inflated, subglobular, $4\frac{1}{2}$ to 6 chambers in final whorl, increasing uniformly and rapidly in size as added; sutures distinct, depressed, radial,straight to slightly curved; umbilicus moderately wide, deep, covered by tegilla with intralaminal and infralaminal accessory apertures; primary aperture interiomarginal, umbilical; wall calcareous, perforate; surface of each chamber ornamented with meridional pattern of discontinuous ridges or costellae.

Average diameter: 0.37mm. Average thickness: 0.18mm.

Remarks: Intraspecific variation occurs in populations of R. rugosa with respect to the number of chambers per whorl, and degree of development of meridional ornament. R. rugosa may be distinguished from its cogenors by its low trochospiral coil, rapidly expanding chambers and moderately large umbilicus. As noted by Pessagno (1967) and Masters (1977) it is probable that R. macrocephala ornata Bronnimann, R.rugosa pennyi Bronnimann, R. badryi El-Naggar, and R. browni El-Naggar all represent intraspecific variants of R. rugosa.

It is probable that R. rugosa evolved directly from Archaeoglobigerina cretacea in the uppermost Campanian, as numerous transitional forms have been encountered in the present study. The extension of the range of R. rugosa down into the Santonian and its derivation from " Globigerina " delrioensis Carsey, as proposed by Masters (1977) is here rejected, as Masters has clearly included at least two readily distinguishable species within his concept of R. rugosa (see Remarks: R. (?) pilula).

Occurrence: R. rugosa was originally described from the uppermost Corsicana Formation (Middle Maastrichtian), Milam County, Texas. In the present study it has been found in great abundance in material of uppermost Campanian and Maastrichtian age from Norfolk and the North Sea .

Zonal range: Uppermost B4i - B7i; R. rugosa/G. havanensis to A. mayaroensis biozones.

Rugoglobigerina milamensis Smith & Pessagno, 1973
(Plate 13, figs.1-3)

1957 Rugoglobigerina rugosa (Plummer); Edgell, pp.116-8, pl.4, figs. 10-12.

pars 1962 " " (Plummer); Berggren, pp.71-5, pl.11, figs.3,5, non. figs.1,2,4.

pars 1964 " " (Plummer); Olsson, p.173, pl.7, figs.3,?4, non. figs.2,5.

pars 1966 Rugoglobigerina rotundata Bronnimann; Douglas & Sliter. p.116, pl.1, fig.5, non.figs.2,6.

pars 1972 ______"______ pennyi Bronnimann; Hanzlikova, p.114, pl.33, figs.1,3, non. fig.2.

1973 ______"______ milamensis Smith & Pessagno, pp.56-7, pl.24, figs.4-7

? 1976 ______"______ pilula Belford; Wright & Apthorpe, p.240, pl.2, fig.10.

1977 ______"______ rotundata Bronnimann; Sliter, p.543, pl.11, figs.1-3.

Description: Test free; high trochospiral coil, test strongly spiroconvex; outline subcircular, moderately lobate; periphery broadly rounded; chambers distinct, inflated, subglobular, arranged in 2½ to 3 whorls, 5-6 chambers in final whorl, increasing moderately rapidly in size as added, those of final whorl increasing only gradually; sutures distinct, depressed, radial, straight to slightly curved; umbilicus large, subrectangular, deep; primary aperture interiomarginal, umbilical, covered by tegillum with intralaminal and infralaminal accessory apertures; wall calcareous, perforate; surface of each chamber covered by meridional pattern of rugosities.

Average diameter: 0.38mm. Average thickness: 0.28mm.

Remarks:This species has had a confused taxonomic history both before and after its formal recognition by Smith and Pessagno (1973). It may be distinguished from R. rugosa by its high trochospiral coil, and from R. rotundata by its higher trochospiral coil, larger umbilicus, well developed meridional ornament and lack of axially elongate chambers.

Occurrence: R. milamensis was originally described from the Corsicana Formation of Milam County, Texas. In the present study, this species has been found in moderate abundance in the Maastrichtian of Norfolk and the

North Sea.

Zonal range: B5i - B7i

Rugoglobigerina (?) pilula Belford, 1960

(Plate 13, figs.4,5)

1960 Rugoglobigerina pilula Belford, pp.92-3, t.fig.6, pl.25, figs.7-13.

1967 ________"________tradinghousensis Pessagno, pp.367-8, pl.64, figs. 1-8.

1969 ________"________pilula Belford; Douglas, p.175, pl.6, figs.8-9.

1970 ________"________"____ Belford; Porthault in Donze et al, pp.68-9, pl.9, figs.21-23.

1972 ________"________"____ Belford; Hanzlikova, p.115, pl.33, fig.4.

1973 ________"________"____ Belford; Sliter, p.173, pl.4, figs.7-9.

? 1976 ________"________"____ Belford; Wright & Apthorpe, p.240, pl.2, fig.10.

1977 ________"________"____ Belford; Sliter, p.542, pl.10, figs.7-9.

1977 ________"________tradinghousensis Pessagno; Masters, pp.626-7, pl.58, figs.1,3.

Description: Test free; small,moderate to high trochospiral coil; outline subcircular, weakly lobate; periphery rounded; chambers inflated, subglobular, arranged in 2½ to 3 whorls, with 4-6 chambers in final whorl; sutures distinct, radial, depressed, straight to slightly curved; umbilicus small, deep; primary aperture interiomarginal, umbilical; wall calcareous, perforate; surface of earlier chambers covered by meridionally arranged rugosities decreasing in strength as chambers added.

Average diameter: 0.24mm. Average thickness: 0.15mm.

Remarks: This species may be distinguished from *R. rugosa* by its smaller size, smaller, deeper umbilicus, higher trochospire and weakly developed rugosities. It may be distinguished from *R. milamensis* by its smaller size, smaller umbilicus and weakly developed rugosities, and from *R. rotundata* by its lack of axially elongate chambers. It is possible that this species is not closely related to the other 'rugoglobigerines', and its meridionally arranged rugosities may be an example of homeomorphism. Masters (1977) has described the stratigraphic range of *R. tradinghousensis* (= *R. pilula*) as Santonian to Maastrichtian, and has stated that this species is the only member of the genus which is high spired. He seems to have been unaware of the description of *R. milamensis* Smith & Pessagno (1973), and it would appear likely that he has included forms referable to *R. milamensis* in his concept of *R. tradinghousensis*.

Occurrence: This species was originally described from the Santonian and basal Campanian beds of the Toolonga Calcilutite, Australia. It has been found in low abundance in the Lower and Middle Campanian both in Norfolk and the Isle of Wight.

Zonal range: B1i - B2iii; *R.*(?) *pilula*/*A. cretacea* biozone.

Rugoglobigerina rotundata Bronnimann, 1952

(Plate 13, figs.6,7)

1952 *Rugoglobigerina rugosa rotundata* Bronnimann, pp.34-6, pl.4, figs.7-9, t.fig.15,16.

1955 *Globotruncana (Rugoglobigerina) rotundata rotundata* (Bronnimann) Gandolfi, p.70, pl.7, fig.2.

1956 *Kuglerina rotundata* (Bronnimann); Bronnimann & Brown, p.557.

non 1966 Rugoglobigerina rotundata Bronnimann; Douglas & Sliter, p.116, pl.1, figs.5,6.

1967 " " Bronnimann; Pessagno, pp.365-6, pl.65, figs.1-4, pl.68, figs.1-3.

1967 " rugosa rotundata Bronnimann; Bandy, p.22, t.fig.10, no.5.

1969 " " (Plummer); Dupeuble, p.157, pl.4, fig.11.

1969 " rotundata Bronnimann; Funnell et al, p.37, pl.5, figs.7-9, t.fig.21.

1971 " " Bronnimann; Postuma, p.88, pl.38, figs.1-7

1971b " (Rugoglobigerina) rotundata Bronnimann; El-Naggar, pp.491-2, pl.10, fig.3.

1972 " rotundata Bronnimann; Barr, p.30, pl.10, fig.3.

? 1973 " " Bronnimann; Smith & Pessagno, p.58, pl.24, figs.8-11.

non 1977 " " Bronnimann; Sliter, p.543, pl.11, figs.1-3.

1977 " " Bronnimann; Masters, pp.621-2.

Description: Test free; moderately low trochospiral coil of 2½ to 3 whorls, final chambers often ventrally displaced and axially elongate, giving test subspherical form; outline subspherical, weakly lobate; periphery rounded; chambers somewhat indistinct, initially subglobular, later axially elongate, 5-6 chambers in final whorl, increasing moderately in size as added; sutures depressed, radial, straight on umbilical side, slightly curved; umbilicus moderately narrow, deep; primary aperture interiomarginal, umbilical; wall calcareous, perforate; surface pustulose with weakly developed meridional pattern.

Average diameter: 0.36mm. Average thickness: 0.28mm.

Remarks: The axially elongate chambers, subspherical test, moderately narrow umbilicus and weakly developed meridionally arranged rugosities, serve to distinguish this species. R. rotundata has been confused in the past with R. milamensis, from which it may be distinguished by its chamber shape, narrower umbilicus and lower trochospiral coil.

Occurrence: Originally described from the Guayaguayare Beds (Upper Maastrichtian) of Trinidad, this species has been found rarely in material of Upper Maastrichtian age from the North Sea.

Zonal range: Upper B7i

Superfamily CASSIDULINACEA d'Orbigny, 1939

Family PLEUROSTOMELLIDAE Reuss, 1860

Subfamily PLEUROSTOMELLINAE Reuss, 1860

Genus PLEUROSTOMELLA Reuss, 1860

Genotype Dentalina subnodosa Reuss, 1860

Pleurostomella subnodosa (Reuss, 1860)
(Plate 13, figs.8,9)

1860 Pleurostomella subnodosa Reuss, p.204, pl.8, fig.2.
1891 " " Reuss; Beissel, p.64, pl.12, figs.30-38.
1899 " " Reuss; Egger, p.48, pl.16, figs.27,28.
1910 " " Reuss; Heron-Allen & Earland, p.411, pl.11, fig.3.
1925 " " Reuss; Franke, p.22, pl.2, fig.11.
1928 " " Reuss; Franke, p.129, pl.11, fig.28.
1929 " " Reuss; White, p.53, pl.5, fig.15.
1932a " " Reuss; Cushman, p.341, pl.51, figs.9-11.
1938 " " Reuss; Cole, p.35, pl.4, fig.7.
1944d " " Reuss; Cushman, p.13, pl.2, fig.29.

1946 Pleurostomella subnodosa Reuss; Cushman, p.132, pl.5,, figs.1-9.

1953 ______"______"____ Reuss; Hagn, pl.7, fig.5.

1954 ______"______"____ Reuss; Frizzell, p.120, pl.18, fig.6.

1957 ______"______"____ Reuss; McGugan, p.341.

1960 ______"______"____ Reuss; Trujillo, p.345, pl.50, fig.7.

1964 ______"______"____ Reuss; Loeblich & Tappan, pp.C725-6, fig.594 no.1.

1966 ______"______"____ Reuss; Hofker, p.40, pl.5, fig.28, pl.12, fig.30.

1968 ______"______"____ Reuss; Sliter, p.110, pl.19, fig.10.

1977 ______"______"____ Reuss; Villain, p.51.

1977 ______"______"____ Reuss; Sliter, pl.6, figs.8,9.

Description: Test free; elongate, initially biserial, later alternating uniserial, cuneate; chambers slightly inflated, initially indistinct, becoming distinct and increasing in height as added; sutures initially indistinct, becoming distinct, oblique, depressed and slightly limbate, becoming less oblique; aperture subterminal ovoid opening, covered by projecting hood on one side and possessing 2 small basal teeth and an internal tube; wall calcareous, finely perforate; surface smooth.

Average length: 0.61mm. Average width: 0.16mm.

Remarks: The chamber arrangement and aperture are highly characteristic of this species.

Occurrence: Originally described from the Upper Cretaceous of Westphalia, Germany. In the present material found to range sporadically throughout the Campanian and Lower Maastrichtian.

Zonal range: B1ii - B5ii

Genus ELLIPSOIDELLA Heron-Allen & Earland, 1910

Genotype Ellipsoidella pleurostomelloides Heron-Allen & Earland, 1910

Ellipsoidella pleurostomelloides Heron-Allen & Earland, 1910

(Plate 13, fig 10)

1910 Ellipsoidella pleurostomelloides Heron-Allen & Earland, p.415, pl.10, figs.1-11, pl.11, figs.1,2.

1964 " " Heron-Allen & Earland; Loeblich & Tappan, p.C728, fig.594, nos.6,7.

Description: Test free; elongate, initial chambers cuneate, biserially arranged, rapidly becoming uniserial; gradually tapering, may be slightly curved; chambers weakly inflated, increasing in height as added; cross section circular; proloculus globular followed by up to 2 pairs of biserially arranged chambers, then a rectilinear series of 4-7 uniserial chambers; sutures distinct, depressed, oblique to horizontal, may be slightly limbate; aperture terminal transverse slit bordered by an overhanging lip, internal tube present; wall calcareous finely perforate; surface smooth.

Average length: 0.52mm. Average width: 0.16mm.

Remarks: The transverse slit-like aperture with strongly overhanging lip appears to be characteristic of this species. As was illustrated by Heron-Allen and Earland (1910) considerable morphological variation exists in the gross outline of the test. Loeblich and Tappan (1964) designated a lectotype for this species (P.41662) and this has been examined in the British Museum (Nat. Hist.), and found to be identical with the present specimens.

Occurrence: This species was originally described from chalk meal in a loose flint from the foreshore of Selsey Bill, Sussex. Though not in situ the fauna described strongly suggests that the type horizon of this species lies within the Upper Campanian. In the present study this species was found sporadically throughout the Campanian and Lower Maastrichtian.

Zonal range: B1ii - B5i

Ellipsoidella gracillima (Cushman, 1933)

(Plate 13, fig.11)

1933a Nodosarella gracillima Cushman, p.64, pl.17, fig.14.

1934 " sp. Morrow, p.197, pl.29, figs.2,3.

1944d " gracillima Cushman; Cushman, p.13, pl.2, fig.32.

1946 " " Cushman; Cushman, p.134, pl.55, figs.19-21.

1951 " " Cushman; Noth, p.68, pl.9, fig.4.

1954 Ellipsoidella " (Cushman); Frizzell, p.120, pl.18, fig.11.

1968 " " (Cushman); Sliter, pp.110-1, pl.19, fig.12.

1977 " " (Cushman); Sliter, pl.7, fig. 3.

Description: Test free; elongate, slender, slightly tapering; cross section circular; initial chambers biserial, later uniserial, rectilinear; chambers distinct, inflated, higher than broad in uniserial stage; sutures distinct, depressed, horizontal in uniserial portion, curved, oblique in biserial stage; aperture subterminal to terminal, slit, bordered by a moderately high, hooded lip, lacking teeth but possessing an internal tube; wall calcareous, finely perforate; surface smooth.

Average length: 0.73mm. Average width: 0.13mm.

Remarks: The initial biserial chamber arrangement and slit-like aperture lacking teeth, place this species within the genus Ellipsoidella. The relatively high, slightly hooded lip gives the aperture an outline superficially similar to that of the genus Pleurostomella. These apertural characteristics together with its elongate, slender form, serve to distinguish it from E. pleurostomelloides.

Occurrence: Originally described from the upper Austin chalk, Texas. In the present material ranging sporadically throughout the Campanian.

Zonal range: B2i - B4i

Subfamily WHEELERELLINAE Petters,1954

Genus BANDYELLA Loeblich & Tappan, 1962

Genotype Pleurostomella greatvalleyensis Trujillo, 1960

Bandyella cf. greatvalleyensis (Trujillo,1960)

(Plate 13, figs.12,13)

1960 Pleurostomella cf. subnodosa Reuss; Geroch, pl.8, fig.5.

1960 ______"______ greatvalleyensis Trujillo, p.345, pl.50, figs.5,6.

1964 ______"______ ______"______ Trujillo; Martin, p.74, pl.8, fig.2.

1964 Bandyella greatvalleyensis (Trujillo); Loeblich & Tappan, p.C730, fig.598 no.2.

1968 ______"______ ______"______ (Trujillo); Sliter, p.111, pl.19, fig.11.

1969 ______"______ ______"______ (Trujillo); Hanzlikova, p.55, pl.15, fig.1.

1972 ______"______ ______"______ (Trujillo); Hanzlikova, p.119, pl.35, fig.1.

Description: Test free; moderately large, robust; initially rapidly flaring, broad; chambers triserially arranged, later biserial, cuneate; greatest width near base of test; cross section circular; chambers inflated, increasing in height as added; commonly only 2-3 in uniserial portion; sutures distinct initially curved, limbate, later becoming oblique, depressed and only weakly limbate; aperture an elliptical opening at the top of a large elongate depression in the final chamber, subterminal possessing a basal bifid tooth; wall calcareous; surface smooth.

Average length: 0.47mm. Average width: 0.20mm.

Remarks: This species is placed in the genus Bandyella on the basis of its initial triserial chamber arrangement and 'pleurostomellid' aperture. It may be easily distinguished from P. subnodosa by its broader, squatter, more robust form, initial chamber arrangement and distinct limbate sutures. Few specimens have been found and the complete range of morphological variation cannot be assessed. This species closely resembles B. greatvalleyensis in its general form though it appears to lack the small 'T' shaped aperture of the holotype. Sliter (1968) has figured a specimen of B. greatvalleyensis which possesses aperture characteristics which closely correspond to those of the present specimens. While noting certain differences between his specimens and those of the holotype, with regard to chamber inflation and size, Sliter (1968) stated that his forms "closely resemble some unfigured paratypes". In view of the differences between the U.K. forms and the holotype, however, the British specimens are left in open nomenclature.

Occurrence: Originally described from the Campanian of California. In the present study found in moderate abundance in the lowest Maastrichtian.

Zonal range : Basal B5i

Family CAUCASINIDAE Bykova, 1959

Subfamily FURSENKOININAE Loeblich & Tappan, 1961

Genus CORYPHOSTOMA Loeblich & Tappan, 1962

Genotype Bolivina pliata Carsey, 1926

Coryphostoma pliata (Carsey, 1926)

(Plate 13, figs. 14,15)

1926 Bolivina pliata Carsey, p.26, pl.4, fig.2.

1931 Loxostoma pliatum (Carsey); Plummer, p.182, pl.10, figs.5-7.

1931b " " (Carsey); Cushman, p.51, pl.8, fig.9.

1932 " " (Carsey); Sandidge, p.363, pl.31, fig.22.

1936b " " (Carsey); Cushman, p.419, pl.1, fig.10.

1936 " " (Carsey); Jennings, p.31, pl.3, fig.23.

1937 " " (Carsey); Cushman, p.169, pl.20, figs.1-4.

1937 " " (Carsey); Loetterle, p.61, pl.11, fig.1.

1941 " " (Carsey); Cushman & Hedberg, p.95, pl.23, fig.1.

1941 Bolivina incrassata (Reuss) var. limonensis Cushman; Marie, p.205, pl.32, figs.305-6.

1943a Loxostoma pliatum (Carsey); Cushman & Todd, p.67, pl.11, fig.26.

1944c " " (Carsey); Cushman, p.93, pl.14, fig.15.

1944 " " (Carsey); Cushman & Deaderick, p.338, pl.53, fig.13.

1946 " " (Carsey); Cushman, p.130, pl.54, figs.10-14.

? 1951 Virgulina tegulata (Reuss); Visser, p.259, pl.2, fig.11.

1951 Loxostomum pliatum (Carsey); Bandy, p.505, pl.75, fig.7.

1954 " " (Carsey); Frizzell, p.118, pl.17, fig.38.

1957 Bolivina pliata (Carsey); Hofker, pp. 226-7, t.figs.278-9.

1957 " hiltermanni Hofker; Hofker, p.234, t.figs.289,292.

pars 1964 Bolivina pliata (Carsey); Baranovskaya-Bulynikova in Subbotina p.301, pl.66, figs.1-3, non.p.65, fig.9.

1964 Coryphostoma pliata (Carsey); Loeblich & Tappan, p.C733, fig.600, no.8.

1966 Bolivina pliata (Carsey); Hofker, p.26, pl.3, fig.53.

1966 " hiltermanni Hofker; Hofker, p.73, pl.18, fig.27.

1968 Coryphostoma pliatum (Carsey); Sliter, p.112, pl.19, fig.13.

1969 " pliata (Carsey); Hanzlikova, p.56, pl.15, fig.5.

1972 " " (Carsey); Hanzlikova, p.129, pl.35, fig.5.

1972 " " (Carsey); Bertels, p.350, pl.3, fig.13.

1977 " pliatum (Carsey); Sliter, pl.7, fig.7.

1977 Bolivina pliata (Carsey); Villain, p.68, pl.5, fig.16.

Description: Test free; elongate, slightly compressed, almost parallel sided, occasionally slightly twisted, $3\frac{1}{2}$ to 5 times as long as wide; periphery becoming slightly lobate, subrounded; cross section ovate; 7 to 12 pairs of chambers, biserially arranged with a marked tendency to become loosely biserial in later stages, initially chambers twice as wide as high, oblique, later becoming reniform, increasing only gradually in size; sutures distinct,initially straight, oblique, becoming slightly sigmoid, depressed, may be weakly limbate in later stages; aperture subterminal to terminal subcircular opening, bordered by an indistinct lip, internally possessing a tooth plate; wall calcareous; surface smooth.

Average length: 0.52mm. Average width: 0.12mm.

Remarks: This species may be distinguished by its narrow elongate form, chambers tending to become reniform and loosely biserial and its terminal to subterminal aperture.

Occurrence: This species was originally described from the Navarro Formation of Texas. In the present study it ranges from the mid-Upper Campanian to the Lower Maastrichtian. It becomes increasingly abundant in strata of Lower Maastrichtian age though generally restricted to sieve fractions $<250\mu$.

Coryphostoma limbosa (Cushman, 1931)
(Plate 13, figs.16,17)

1931b Loxostoma pliatum (Carsey) var. limbosum Cushman, p.52, pl.8, fig.10.

1937 " " (Carsey) var. " Cushman; Cushman, p.170, pl.20, fig.5.

1943a " " (Carsey) var. " Cushman; Cushman & Todd, p.67, pl.11, fig.27.

1946 " " (Carsey) var. " Cushman; Cushman, p. 131, pl.54, fig.15.

1954 Loxostomum pliatum (Carsey) var. " Cushman; Frizzell, p.118, pl.17, fig.37.

1956a Bolivina limbosa (Cushman); Hofker, p.B218, fig.38.

1957 " pliata var. limbosa (Cushman); Hofker, p.227, t.figs. 280-1.

pars 1964 " " (Carsey); Baranovskaya-Bulynikova in Subbotina, p.301, pl.65, fig.9, non.pl. 66, figs.1-3

pars 1969 Coryphostoma limbosa (Cushman); Hanzlikova, p.56, pl.15, fig.3, non.figs.2,4.

1972 " " (Cushman); Hanzlikova, p.120, pl.35, fig.3,4.

Description: test free; elongate, initially rounded, moderately to gradually tapering, almost parallel sided, periphery becoming slightly lobate; cross section broadly ovate; test occasionally slightly twisted; 8 to 10 pairs of chambers biserially arranged, initially indistinct, rectangular, oblique, later becoming slightly reniform; sutures flush, limbate, oblique, becoming sigmoid; aperture terminal to subterminal subcircular opening, bordered by indistinct lip and possessing internal tooth plate; wall calcareous, moderately thick; surface smooth.

Average length: 0.58mm. Average width: 0.18mm.

Remarks: This species was originally described as a variety of C. pliata from which it may be distinguished by its larger size, more robust, less compressed test and limbate sutures.

Occurrence: Originally described from the Selma chalk of Navarro age from the U.S.A., C. limbosa was found in moderate abundance in the Lower Maastrichtian of Norfolk.

Zonal range: B5i - B6ii

Coryphostoma aff. selmaensis (Cushman, 1931)

(Plate 13, figs.18,19)

? 1931b Bolivina tenuis Marsson var. selmaensis Cushman, p.49, pl.8, fig.6

1953 Loxostoma selmaensis (Cushman); Wicher, p.14, pl.1, fig.2.

1961 Bolivina (loxostoma) selmaensis Cushman; Hofker, pp20-2, figs.1-7.

1962 Loxostoma selmaensis (Cushman); Hiltermann & Koch, p.313, pl.47, fig.6.

1966 Bolivina " Cushman; Hofker, p.154, pl.24, figs.144, 157.

1977 Loxostoma " (Cushman); Koch, pp.63-4, pl.13, fig.11.

Description: Test free; $1\frac{1}{2}$ to 2 times as high as broad; strongly compressed; greatest thickness of test along median line; periphery acute, keeled; initial end broadly rounded; chambers arranged biserially throughout, oblique, twice as wide as high, later chambers rapidly becoming much higher than wide, chambers slightly inflated, distinct; sutures distinct, oblique, curved, depressed; aperture subterminal to terminal, subcircular opening, detached from basal suture of final chamber, internally possessing tooth plate; wall calcareous, finely perforate; surface smooth, translucent.

Average length: 0.43mm. Average width: 0.25mm.

Remarks: This highly distinctive species is characterised by its broadly rounded initial end, keeled periphery, chambers rapidly increasing in size as added, and subterminal aperture. It is placed in the genus Coryphostoma on the basis of its terminal aperture and tooth plate. This species has been widely recorded from Europe. Bolivina selmaensis Cushman was described from the Upper Cretaceous Selma chalk, U.S.A. While resembling the European species in general outline, Cushman's species was originally described and figured as possessing a subacute margin, chambers much broader than high, and being initially ornamented by fine longitudinal costae. In the present author's opinion, these features clearly serve to distinguish Cushman's species from the European forms referred to it. Until a thorough examination of type material can be made, however, the present species is left in open nomenclature.

Occurrence: This species has been recorded by Koch (1977) as ranging from the upper Lower Maastrichtian to the Maastrichtian/Danian boundary in Germany. In the present study found rarely in material from the North Sea of Upper Maastrichtian age.

Zonal range: B7i

Coryphostoma voigti (Brotzen, 1936)

(Plate 14, figs.4,5)

1936 *Loxostomum voigti* Brotzen, pp.133-135, t.fig.46, pl.9, fig.8.

1937 *Loxostoma* " Brotzen; Cushman, p.170, pl.20, fig.19.

Description: Test free; elongate, moderately tapering, slightly twisted; 3 to 4 times as long as wide; periphery slightly lobate becoming markedly lobate; cross section ovate; 7 to 10 pairs of chambers biserially arranged, becoming loosely biserial, initially weakly inflated, oblique, becoming markedly inflated, reniform; sutures distinct, initially flush, rapidly becoming depressed,sigmoid; aperture elongate subterminal to terminal slit, may possess indistinct lip; wall calcareous, finely perforate; surface smooth.

Average length: 0.50mm. Average width: 0.14mm.

Remarks: This species is placed in the genus *Coryphostoma* on the basis of its apertural characteristics and chamber arrangement. It may be distinguished from *C. pliata* by its more robust, less compressed form, chambers which are more inflated and becoming reniform at an earlier stage, and by its elongate, loop shaped aperture as opposed to the more nearly terminal subcircular aperture of *C. pliata*. It is possible that the two are phylogenetically related.

Occurrence: Originally described from the Santonian/Coniacian of Eriksdal, Sweden, this species has been found rarely in the Middle Campanian both in the Isle of Wight and Norfolk.

Zonal range: B2ii - B2iii

Family LOXOSTOMIDAE Loeblich & Tappan, 1962

Genus LOXOSTOMUM Ehrenberg, 1854

Genotype Loxostomum subrostratum Cushman, 1927

Loxostomum eleyi (Cushman, 1927)

(Plate 14, figs.1-3)

1859 Textularia obsoleta Reuss; Eley, p.202, pl.8, fig.11, p.195, pl.11, fig.11.

1927a Bolivinita eleyi Cushman, p.91, fig.11.

1931c " " Cushman; Cushman, p.39, pl.5, fig.8.

1932a " " Cushman; Cushman, p.338, pl.51, fig.7.

1936 " " Cushman; Brotzen, pp.122-3, pl.9, fig.5, t.fig.41

1941 Bolivinitella eleyi (Cushman); Marie, pp.190-1, pl.29, fig.282.

1941 " " (Cushman);var. polygonalis Marie, p.191, pl.29, fig.283.

1946 Bolivinita " Cushman; Cushman, p.114, pl.48, figs.18-20.

1946 Bolivinitella " (Cushman); Schijfsma, pp.72-3, pl.6, fig.10.

1948 Bolivinita " Cushman; Williams-Mitchell, p.103, pl.9,fig.1.

1953 " " Cushman; Hagn, pp.76,103, pl.6, fig.10.

1954 " " Cushman; Frizzell, p.112, pl.16, fig.23.

1957 Siphogaudryina (Bolivinitella) eleyi (Cushman); Hofker, p.75-6, t.figs.77,78.

1957 Bolivinitella eleyi (Cushman); Montanaro-Gallitelli, p.150, pl.34, figs.14-17.

1960 " " (Cushman); Belford, p.62, pl.15, figs.20,21.

1963 " " (Cushman); Graham & Church, p.51, pl.5, fig.25.

1964 " " (Cushman); Martin, p.91, pl.21, fig.3.

1964 Loxostomum " (Cushman); Loeblich & Tappan, p.C736, fig.603, 2-5.

1965 Bolivinitella eleyi (Cushman); Pozaryska, pp.102-3, pl.15, fig.2.

1966b " " (Cushman); Barr, pp.502-3, pl.77, fig.6.

1968 Loxostomum " (Cushman); Sliter, p.112, pl.20, fig.2.

1969 Bolivinitella " (Cushman); Hanzlikova, p.57, pl.15, fig.8.

1970 " " (Cushman); Porthault in Donze et al, pp.56-7, pl.8, fig.24.

1972 Loxostomum " (Cushman); Hanzlikova, p.121, pl.35, fig.8.

1977 " " (Cushman); Villain, p.69.

1977 " " (Cushman); Sliter, p.675, pl.7, fig.8.

Description: Test free; elongate, compressed, initially bluntly pointed; periphery entire, carinate, becoming slightly lobate; test 4 times as high as wide; cross section elongate, subrectangular; chambers biserial throughout, initially low, broad, compressed, uninflated, becoming more strongly overlapping and arched in upper portion of test; broadest sides of test flat to concave; final chambers becoming loosely biserial, occasionally uniserial; chamber edges bordered by 4 longitudinal carinae,especially marked initially; sutures distinct, limbate, flush to raised; aperture terminal, more or less elongate oval slit, often bordered by a distinct lip; wall calcareous, granular, perforate; surface smooth.

Average length: 0.53mm. Average width: 0.15mm.

Remarks: This small, distinctive, species has been widely recorded from Senonian strata. In the present study it is generally restricted to sieve fractions $<250\mu$.

Occurrence: L.eleyi ranges throughout the Campanian on the Isle of Wight, often in considerable abundance. In Norfolk it shows a marked decrease in abundance in the upper Upper Campanian and was not found in the Lower Maastrichtian.

Zonal range: B1ii - B3iv, rarely B4i

Superfamily NONIONACEA Schultze, 1854

Family NONIONIDAE Schultze, 1854

Subfamily CHILOSTOMELLINAE Brady, 1881

Genus QUADRIMORPHINA Finlay, 1939

Genotype <u>Valvulina allomorphinoides</u> Reuss, 1860

<u>Quadrimorphina allomorphinoides</u> (Reuss, 1860)

(Plate 14, figs.6,7)

1860 <u>Valvulina allomorphinoides</u> Reuss, p.223, pl.11, fig.6.

1925 <u>Discorbina " </u> (Reuss); Franke, p.91, pl.8, fig.11.

1926a <u>Discorbis " </u> (Reuss); Cushman, p.606, pl.20, figs.18,19, pl.21, fig.26.

1928 <u>Discorbina " </u> (Reuss); Franke, p.189, pl.18, fig.7.

1931c <u>Valvulineria " </u> (Reuss); Cushman, p.43, pl.6, fig.2.

1931b <u>" " </u> (Reuss); Cushman, p.53, pl.9, fig.6.

1936 <u>" " </u> (Reuss); Brotzen, p.153, pl.11, fig.1, t.fig.56.

1939 <u>Quadrimorphina " </u> (Reuss); Finlay, p.325.

1941 <u>Valvulineria " </u> (Reuss); Cushman & Hedberg, p.96, pl.23, fig.9.

1946 <u>" " </u> (Reuss); Cushman, p.138, pl.57, fig.6, ?fig.7.

1949 <u>Quadrimorphina " </u> (Reuss); Cushman & Todd, p.69, pl.12, figs.10-12.

1953 <u>" " </u> (Reuss); Hagn, p.90, pl.8, fig.17.

1957 Allomorphina allomorphinoides (Reuss); Hofker, pp.198-9, t.figs.243-4.

1960 Quadrimorphina " (Reuss); Belford, pp.87-8, pl.24, figs.9-12.

1960 " " (Reuss); Trujillo, p.330, pl.47, fig.15.

1962 " " (Reuss); Hillebrandt, p.89, pl.6, fig.24.

1964 Gyromorphina " (Reuss); Kuzninz in Subbotina , p.303, pl.66, figs.6-11.

1964 Quadrimorphina " (Reuss); Loeblich & Tappan, p.C744, fig.611, no.6a-c.

1966 Allomorphina " (Reuss); Hofker, p.40, pl.6, fig.43, pl.10, fig.93.

1968 Quadrimorphina " (Reuss); Sliter, p.114, pl.20, fig.7.

? 1972 " " (Reuss); Hanzlikova, p.123, pl.35, fig.16.

Description: Test free; biconvex trochospiral; spiral side partially evolute, umbilical side involute, earlier whorls not visible; outline trilobate, irregularly rounded; periphery broadly rounded; chambers moderately distinct, inflated, 4-5 in final whorl, final chamber large, occupying approximately $\frac{1}{2}$ the test; sutures indistinct, flush, radial; aperture umbilical, broad low arch along inner margin of last chamber, covered by a distinct flap.

Average diameter: 0.25mm. Average width: 0.16mm.

Remarks: This distinctive species is characterized by its large final chamber and well developed apertural flap.

Occurrence: Q. allomorphoides was found rarely throughout the Campanian and Lower Maastrichtian.

Zonal range: B1ii - B5i

Quadrimorphina trochoides (Reuss, 1845)

(Plate 14, fig. 8)

1845 Globigerina trochoides Reuss, p.36, pl.12, fig.22.

1851 " " Reuss; Reuss, p.37, pl.3, fig.5.

1928 Valvulina " (Reuss); Franke, p.162, pl.15, fig.2.

1931b Bulimina " (Reuss); Cushman, p.48, pl.7, fig.20.

1932 Allomorphina " (Reuss); Cushman & Jarvis, p.49, pl.15, fig.13.

1937 Eggerella (?) " (Reuss); Cushman, p.46, pl.5, figs.1,2.

1941 Allomorphina " (Reuss); Marie, p.230, pl.35, fig.331.

1944d Eggerella (?) " (Reuss); Cushman, p.4, pl.1, fig.14.

1946 Allomorphina " (Reuss); Cushman, p.145, pl.60, fig.7.

1946 Eggerella (?) " (Reuss); Cushman, p.43, pl.12, fig.2.

1953 " " (Reuss); Hagn, p.23, pl.1, fig.27.

non 1969 Eggerella (?) " (Reuss); Hanzlikova, pl.4, fig.7.

1977 Allomorphina " (Reuss); Sliter, pl.8, fig.2.

Description: Test free; initially acute, later inflated, margins rounded; initial chamber arrangement indistinct, 4 uninflated, rapidly expanding chambers in high trochospire; later triserial; final whorl composed of 3 inflated, subglobular chambers, occupying 4/5 of test, abrupt change in size and degree of inflation of chambers between penultimate and ultimate whorls; cross section bilobed; sutures initially indistinct flush, becoming distinct, slightly depressed, curved; aperture narrow transverse slit along inner margin of final chamber, bordered by a distinct thin lip; wall calcareous, perforate; surface smooth.

Average height: 0.34mm. Average width: 0.27mm.

Remarks: This small, highly distinctive species is characterised by its high trochospire, subglobular chambers in the final whorl, and narrow transverse slit-like aperture. The generic status of Q. trochoides has been much debated. Cushman (1931b) thought this species possessed a calcareous perforate wall structure and referred it to the genus Bulimina. Several authors have considered the wall structure to be calcareous agglutinated, and placed this species tentatively in the genus Eggerella, indeed in a single publication Cushman (1946) described this species twice, referring it both to Allomorphina and Eggerella. The present specimens possess a recrystallized wall structure, only superficially resembling an agglutinated calcareous structure. Loeblich and Tappan (1964) in a revision of the genera Allomorphina and Quadrimorphina stated that species possessing trochospiral tests should be placed in the genus Quadrimorphina .

Hanzlikova (1972) in a discussion of the taxonomic relationship between Q. trochoides and the agglutinated species Valvulina bullata Brotzen, 1936 concluded that the two were closely allied, if not identical, and may represent individual growth stages of a single species. Apart from fundamental differences in wall structure Q. trochoides possesses a narrow transverse slit-like aperture as opposed to the high arch and valvuline tooth of V. bullata.

Occurrence: This species has been found sporadically throughout the Campanian and Lower Maastrichtian in the studied sections.

Zonal range: B1ii - B7i

Subfamily NONIONINAE Schultze, 1854

Genus PULLENIA Parker & Jones, 1862

Genotype Nonionina bulloides d'Orbigny, 1846

Pullenia quaternaria (Reuss, 1851)

(Plate 14, figs.9,10)

1851 Nonionina quaternaria Reuss, p.34, pl.2, fig.13.

1928 Pullenia quinqueloba (Reuss);Franke, p.194, pl.18, fig.13.

1936b " quaternaria (Reuss); Cushman, p.74.

1943b " " (Reuss); Cushman & Todd, pp.2-3, pl.1, figs.1-4.

1951 " " (Reuss); Visser, p.283, pl.2, fig.21.

1953 " " (Reuss); Hagn, p.90, pl.8, fig.18.

1957 " " (Reuss); Hofker, pp. 430-1, t.fig.486.

Description: Test free; planispiral, involute coil, with 4-5 chambers in final whorl, test moderately compressed; outline subcircular, weakly lobate; periphery broadly rounded; chambers triangular, slightly curved, increasing gradually and uniformly; final chamber extending down to cover umbilicus on either side; sutures distinct, slightly curved, flush becoming weakly depressed; aperture low interiomarginal slit, extending almost from umbilicus to umbilicus, bordered by a thick imperforate band; apertural face moderately low; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.44mm. Average thickness: 0.35mm.

Remarks: P.quaternaria is characterized by its moderately compressed test, curved sutures, and low apertural face. Rare individuals with a more markedly lobate periphery may resemble P. jarvisi Cushman, from which they may be distinguished by their lack of pronounced umbilical depressions.

Occurrence: Originally described from the Upper Cretaceous of Lemberg, P. quaternaria was found in moderate abundance in the upper Middle Campanian to Maastrichtian of all onshore sections.

Zonal range : B2iii - B7i

Pullenia reussi Cushman & Todd, 1943

(Plate 14, figs.11,12)

1943b Pullenia reussi Cushman & Todd, pp.4-5, pl.1, figs.10-13.
1951 " " Cushman & Todd; Visser, p.284, pl.2, fig.22.
1953 " " Cushman & Todd; Hagn, p.91, pl.8, fig.19.
1956 " " Cushman & Todd; Said & Kenawy, p.156, pl.7, fig.22.
1960 " " Cushman & Todd; Belford, p.90, pl.24, figs.19-21.

Description: Test free; adult test subspherical, planispiral, involute coil of 4-5 chambers in final whorl; outline circular; periphery very broadly rounded; chambers triangular, slightly curved, gradually and uniformly increasing in size as added; sutures flush, very slightly curved, aperture low interiomarginal slit extending almost from umbilicus to umbilicus; apertural face low; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.32mm. Average thickness: 0.30mm.

Remarks: This species may be distinguished from P. quaternaria by its smaller, almost spherical test. Juvenile specimens of P. reussi possess a slightly more compressed test.

Occurrence: Originally described from the Upper Cretaceous of Mersch, near Hamm, Germany, P. reussi has been found in moderate abundance in the Upper Cretaceous and Lower Maastrichtian of Norfolk.

Zonal range: B3iv - B7i

Family OSANGULARIIDAE Loeblich & Tappan, 1964

Genus OSANGULARIA Brotzen, 1940

Genotype Osangularia lens Brotzen, 1940

Osangularia cordieriana (d'Orbigny, 1840)

(Plate 14, figs. 13,14)

1840 Rotalina cordieriana d'Orbigny, p.33, pl.3, figs.9-11.

1899 " " d'Orbigny; Egger, p.158,pl.20, figs.16-18.

1941 Pulvinulinella cordieriana (d'Orbigny); Marie, p.228, pl.35, figs.329, 330.

1945 Parrella cordieriana (d'Orbigny); Brotzen, pp.56,57.

1957 Osangularia " (d'Orbigny); Hofker, p.389, t.fig.433.

1961 Parrella " (d'Orbigny); Vasilenko, p.95, pl.15, figs.7-8, t.fig.14,nos.9,10.

1963 " sp.cf. cordieriana (d'Orbigny); Graham & Church, p.59, pl.7, fig.4.

1964 Osangularia sp.cf. " (d'Orbigny); McGugan, p.946, pl.152, fig.2.

1964 " cordieriana (d'Orbigny); Martin, p.102, pl.15, fig.2.

1968 " " (d'Orbigny); Sliter, p.118, pl.21, fig.9.

1972 " " (d'Orbigny); Hanzlikova, p.127, pl.36, fig.12.

non 1977 " " (d'Orbigny); Sliter, pl.9, figs.1-3,6.

? 1977 " whitei (Brotzen); Sliter, pl.9, figs.4,5.

Description: Test free; trochospiral, biconvex, biumbonate, spiral side evolute, generally somewhat more convex than umbilical; periphery in umbilical view circular, margin acute, commonly slightly carinate; chambers arranged in 3 to 4 whorls, initially obscure, on involute umbilical side chambers distinct, 8-10 in final whorl, uniformly and gradually increasing in size, sub-triangular in outline; umbilical side possessing pronounced, raised umbilical boss of clear calcite; umbilical side sutures distinct, limbate, straight to slightly curved, oblique, flush becoming slightly depressed between final chambers; spiral side sutures obscure in early whorls, becoming distinct, flush, limbate, oblique and curved; aperture narrow oblique slit along base of final chamber on umbilical side, and thence forming "V" shaped bend at oblique angle up apertural face, often two parts of aperture may be separate, one interiomarginal and one areal; wall calcareous, finely perforate ; surface smooth.

Average diameter: 0.38mm. Average height: 0.21mm.

Remarks: This species is characterised by its almost equally biconvex, biumbonate test and its slightly carinate margin. It may be distinguished from the closely related, and stratigraphically older, O. whitei (Brotzen) by its more robust, thicker test and more pronounced umbilical boss. It may be distinguished from O. navarroana (Cushman) by its far less well developed peripheral keel. It appears highly likely that these species are phylogenetically related(text fig. 5:3). The form described by Sliter (1977) as O. cordieriana from the S.W.Atlantic is more convex umbilically than spirally and certainly falls outside the range of morphological variation shown by O. cordieriana in the present study. The species Sliter (1977) assigns to O. whitei is tentatively assigned to the synonomy of O. cordieriana as it possesses a biconvex test and distinctly raised umbilical plug.

Occurrence: This species was originally described from the Campanian of the Paris Basin (St. Germain). Transitional forms between this species and O. whitei (Brotzen) have been found sporadically in the Lower

Campanian. O. cordieriana is moderately abundant throughout the Campanian and lowest Maastrichtian.

Zonal range: Bliii - B5i

Osangularia polycamerata (Vasilenko, 1961)

(Plate 14, figs. 15,16)

1961 Parrella whitei (Brotzen) var. polycamerata Vasilenko, p.92, pl.15, ? fig.1, figs.2-3.

? 1977 Osangularia cordieriana (d'Orbigny); Sliter, pl.9, figs.1-3,6.

Description: Test free; planoconvex to weakly biconvex trochospire; umbilical side strongly convex possessing a large, raised calcite boss, spiral side flattened to weakly convex; outline circular in umbilical view, periphery subacute, carinate; chambers arranged in approximately 3 whorls; spiral side evolute, chambers uninflated, those of earlier whorls indistinct, becoming distinct, curved; umbilical side involute 10-12 chambers of final whorl visible, earliest chambers indistinct, becoming distinct, curved, subtriangular; sutures distinct, flush, limbate, oblique and slightly curved, those of umbilical side may become weakly depressed between the final chambers; aperture narrow "V" shaped slit, which may be separated into distinct interiomarginal and areal segments; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.30mm. Average height: 0.22mm.

Remarks:This species may be distinguished by the plano-convex to slightly biconvex outline and large,raised umbilical boss. Originally described as a variety of O. whitei (Brotzen, 1936) the highly convex umbilical outline as opposed to the distinctly flattened umbilical surface of Brotzen's species must cast doubt as to any close phylogenetic relationship between these two species. This, together with their distinct stratigraphic ranges has led the author to elevate this variety to specific rank. It is possible that O. polycamerata is more closely related to O. cordieriana than O. whitei, as both show a pronounced umbilical boss. Sliter (1977) described a species from the Campanian of the S.W.Atlantic which he referred to O. cordieriana. The figured specimen possesses a highly convex umbilical side and appears to be conspecific with O. polycamerata.

Occurrence: This species was originally described from the Santonian/Campanian (B. strigillatus zone) of S.W. Russia. In the present study O. polycamerata was found sporadically but often in abundance in the Lower and Middle Campanian both in Norfolk and the Isle of Wight.

Zonal range: B1iii - B2iii, rarely B3i

Osangularia navarroana (Cushman, 1938)

(Plate 15, figs.1,2)

1938 Pulvinulinella navarroana Cushman, p.66, pl.11, fig.5.

1946 " " Cushman; Cushman, p.144, pl.60, fig.1.

1954 Pseudoparrella " (Cushman); Frizzell, p.126, pl.19, fig.9.

1957 Osangularia lens Brotzen; Hofker, p.390, t.fig.434.

1961 Parrella navarroana (Cushman); Vasilenko, p.97, pl.16, figs.1-3, t.fig.14, nos.11,12.

1962 Osangularia cordieriana navarroana (Cushman); Hermanni, p.280, pl.19, figs.2-4.

1977 " " " (Cushman); Koch, pp.60-1, pl.6, figs.6,7.

1977 Epistominella nana (Reuss); Villain, pp.61-2, pl.8, figs.1-3.

Description: Test free; generally equally biconvex; umbilical side possessing a moderately raised calcite boss; outline circular, periphery acute bordered by distinct wide keel; chambers generally arranged in $2\frac{1}{2}$ whorls; spiral side evolute, early whorls obscure, chambers uninflated indistinct, curved; 10-12 chambers on the umbilical side uninflated, sub-triangular; sutures distinct, limbate, flush, oblique, slightly curved; aperture narrow "V" shaped slit typical of genus, occasionally separated into distinct interiomarginal and areal openings; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.50mm. Average height: 0.22mm.

Remarks: The biconvex test and distinctly keeled margin serve to distinguish this species from the closely related O. cordieriana. Villain (1977) described and figured specimens which he referred to Epistominella nana (Reuss), a species originally described from the Tertiary. Villain's hypotypes are considered conspecific with the present species. Osangularia lens (Brotzen, 1940), a species originally described from the Danian of Sweden, has been confused with the present species by Hofker (1957). O. lens may be distinguished by its more robust form, being more convex umbilically than spirally and lacking the well developed keel of O. navarroana.

Occurrence: Originally described from the Kemp Clay, Texas. In the present study found in moderate abundance throughout the Lower Maastrichtian of Norfolk.

Zonal range: B5i - B7i

Osangularia whitei (Brotzen, 1936)

(Plate 15, figs.3,4)

1936 Eponides whitei Brotzen, pp.167-9, pl.12, figs.7,8.

1936 " " var. intercedens Brotzen, p.167, pl.12, fig.6.

1945 Parella " (Brotzen); Brotzen, p.57.

pars 1961 " " var. whitei (Brotzen); Vasilenko, p.91, pl.14, fig.5, t.fig.14, no.1, non.2,3.

? 1977 Osangularia whitei (Brotzen); Sliter, pl.9, figs.4,5.

Description: Test free; planoconvex to biconvex, neither side strongly convex, may possess small,flush umbilical boss; outline circular to slightly ovate, becoming lobate; periphery subacute, slightly carinate; chambers arranged in 3 whorls, uniformly and rapidly increasing in size; chambers on the spiral side indistinct, uninflated, oblique, curved , subtriangular; umbilical side, involute, 7-8 in final whorl, subtriangular, becoming slightly inflated; spiral side sutures moderately distinct, limbate, strongly oblique, straight to slightly curved, flush, umbilical side sutures distinct, limbate, flush becoming depressed, straight to slightly curved; aperture typical "V" shaped slit characteristic of the genus, may be separated into distinct interiomarginal and areal openings; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.36mm. Average height: 0.16mm.

Remarks:Brotzen (1936) originally failed to note the distinctive apertural characteristics which firmly place this species within the genus Osangularia. O. whitei may be distinguished from the closely related O. cordieriana by its more compressed, less inflated form and


PHYLOGENETIC DEVELOPMENT WITHIN THE GENUS OSANGULARIA.
Fig.5:3
STAGE
SUBSTAGE
MACROFAUNAL BIOZONE
PLANKTONIC FORAMINIFERAL BIOZONE
BOLIVINOIDES PHYLOZONE
BENTHONIC FORAMINIFERAL BIOZONE
MAASTRICHTIAN
CAMPANIAN
UPPER
LOWER
UPPER
MIDDLE
LOWER
B.junior
kasimir.
B.lanceolata-occident.
B.mucronata
G.quadrata
O.pilula
A.mayar.
R.rugosa/G.havanensis
G.rugosa
A.cretacea/R.pilula
B7
B6
B5
B4
B3
B2
B1
i
ii
i
i
ii
i
iv
iii
ii
i
iii
ii
i
iii
ii
i
O.navarroana
O.cordieriana
O.polycamerata
?
O.whitei

by the lack of a pronounced umbilical boss, It also possesses fewer chambers in the final whorl, umbilical sutures which become more strongly depressed, and a periphery which shows a tendency to become lobate. Within the present study specimens with a flat umbilical side (var. intercedens Brotzen), and those with slightly convex umbilical sides, possessing a small boss occur together and grade into one another, and for this reason have not been formally separated.

Occurrence: This species was originally described from the Santonian of Eriksdal, Sweden. Vasilenko (1961) recorded this species as having a similar range to Bolivinoides strigillatus ie. Santonian/ Lower Campanian. In the present study this species was encountered abundantly in the Lower , and rarely in the Middle Campanian.

Zonal range: Blii - B2i

Genus GLOBOROTALITES Brotzen, 1942

Genotype Globorotalia multisepta Brotzen, 1936

Globorotalites conicus (Carsey, 1926)

(Plate 15, figs.5,6)

1926 Truncatulina refulgens var. conica Carsey, p.46, pl.4, fig.15.

1931 Eponides micheliniana (d'Orbigny); Plummer, p.192, pl.14, fig.11.

1942 Globorotalites n.sp. Brotzen, p.31.

pars 1946 Globorotalia micheliniana (d'Orbiny); Cushman, p.152, pl.63, fig.3 (non.fig.2.)

1954 Globorotalites conicus (Carsey); Frizzell, p.130, pl.20, fig.31.

1956 " " (Carsey); Said & Kenawy, p.47, pl.4, fig.43.

1956a " multisepta (Brotzen); Hofker, p.B210, fig.15.

non 1957 " conicus (Carsey); McGugan, p.343, pl.34, figs.13,14.

non 1960 Globorotalites conicus (Carsey); Belford, p.100, pl.30, figs.8-13.

non 1965 " " (Carsey); Goel, pp.105-6, pl.2, figs.3,7.

1966 " multisepta (Brotzen); Hofker, p.27, pl.3, fig.55.

non 1977 " conicus (Carsey); Sliter, pl.9, figs. 7,8.

Description: Test free; plano-convex trochospiral; spiral side flat to slightly concave, umbilical side convex, moderately high, conical, with broad, deep, pseudo-umbilicus, periphery in umbilical view circular. becoming lobate; periphery in side view acute, carinate with imperforate keel; chambers distinct, angular, slightly inflated, conical, 6-7 in final whorl; sutures on spiral side indistinct flush, strongly oblique, straight to only slightly curved, sutures on umbilical side indistinct flush to slightly depressed, radiate to slightly sigmoid; aperture narrow elongate interiomarginal slit along margin of final chamber; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.50mm. Average height: 0.35mm.

Remarks: This species may be distinguished from the closely related G. micheliniana (d'Orbigny, 1840) by its lower, wider form and broad, deep pseudoumbilicus. It is generally more lobate in outline and possesses a distinct keel. It may be distinguished from G. hiltermanni Kaever, 1961 by its plano-convex form and wider pseudoumbilicus.

Occurrence: Originally described from strata of Campanian age from Texas, G. conicus has been found sporadically but occasionally in great abundance in the Upper Campanian of Norfolk.

Zonal range: B3ii - B4i

Globorotalites hiltermanni Kaever, 1961

(Plate 15, figs.7,8)

1946 Gyroidina micheliniana (d'Orbigny); Schijfsma, p.87, pl.5, fig.2.
1957 Globorotalites conicus (Carsey); McGugan, p.343, pl.34, figs.13-14
1957 " multiseptus (Brotzen); Hofker, pp.408-9, t.figs.467-9.
1961 " hiltermanni Kaever, pp.418-9, pl.20, fig.1.
1965 " meudonensis Goel, pp.99-100, pl.1, fig.1.
pars 1972 " michelinianus (d'Orbigny); Hanzlikova, p.128, pl.33, fig.7 (non.fig.8).

Description: Test free; biconvex trochospire of 1½ to 2½ whorls, spiral side generally slightly less convex than umbilical, both only weakly convex, umbilical area generally covered though in rare instances a small shallow pseudoumbilicus may be present; outline circular, periphery acute slightly keeled; chambers indistinct spirally especially in earlier whorls, those of last whorl strongly curved, crescentic, 7 to 9 chambers visible on umbilical side, indistinct becoming slightly inflated; sutures on umbilical side also indistinct flush or weakly depressed, radial, curved, those on spiral side slightly limbate, strongly oblique, flush; aperture narrow, elongate, interiomarginal slit with distinct murus reflectus; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.57mm. Average height: 0.35mm.

Remarks: The almost equally biconvex test, and closed umbilicus characterise this species. The specimens described by McGugan (1957) as G. conicus was examined by Kaever (1961) and considered to belong to the present species. G. multiseptus (Brotzen) sensu Hofker (1957) from the Upper Campanian of N.W. Germany and Holland is also considered conspecific with G. hiltermanni, which differs from the Santonian G. multisepta (Brotzen, 1936) in possessing a closed umbilicus and more markedly biconvex test. G. meudonensis Goel, 1965, described from the Upper Campanian of the Paris Basin, is almost certainly conspecific with G. hiltermanni.

Occurrence: Originally described from the upper Upper Campanian of Germany, this species is found abundantly in the upper Upper Campanian of Norfolk.

Zonal range: B3iv - B4i

Globorotalites micheliniana (d'Orbigny, 1840)

(Plate 15, figs.9,10)

1840 Rotalina micheliniana d'Orbigny, pp.31-2, pl.3, figs.1-3.
1899 Rotalia " (d'Orbigny); Egger, p.155, pl.20, figs.1-3
1941 Gyroidina " (d'Orbigny); Marie, p.222, pl.34, fig.323.
pars 1946 Globorotalia " (d'Orbigny); Cushman, p.153, pl.63, fig.2 , non.fig.3.
1948 Globorotalites micheliniana (d'Orbigny); Dam & Magne, pp.223-4, t.fig.8a-c.
1953 " " (d'Orbigny); Hagn, p.100, pl.8, fig.4.
1957 " " (d'Orbigny); Hofker, p.405, t.figs.460-6.
1961 " " (d'Orbigny); Kaever, pp.409-412, pl.18, fig.3, pl.19, fig.1, pl.20, fig.5; pl.21, figs.1,2.
1961 " " (d'Orbigny); Vasilenko, p.58, pl.10, figs.1,2.

1965 Globorotalites micheliniana (d'Orbigny); Goel, p.100, pl.1, fig.2.

pars 1972 " " (d'Orbigny); Hanzlikova, p.128, pl.37, fig.8 ,non.fig.7.

1977 " " (d'Orbigny); Villain, p.56, pl.9, figs. 4-6.

Description: Test free; plano-convex,trochospiral; spiral side evolute commonly flat, though earlier, central whorls may show convex outline, umbilical side involute, steeply conical generally showing no pseudoumbilicus though occasional forms develop a small, narrow pseudoumbilicus; outline circular, periphery acute to subacute, slightly keeled; 6 to 7 chambers in final whorl, indistinct, uninflated, angular, conical; spiral side sutures indistinct, flush, curved, oblique; umbilical side sutures moderately distinct, flush becoming slightly depressed, radial, slightly curved; aperture narrow elongate interiomarginal slit, may be bordered by slight lip and with a moderately well developed murus reflectus; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.56mm. Average height: 0.39mm.

Remarks: G. micheliniana has had a very long and confused history. This trivial name has been applied to a wide variety of species of Globorotalites from the Upper Cretaceous both of Europe and North America. The synonomy given makes no claim to be complete and includes only those references which describe forms in every way identical to the holotype. Goel (1965) has further complicated the taxonomy of G. micheliniana , having recognised 27 new species of Globorotalites within the uppermost Turonian to Upper Campanian interval, several of which might be better retained as morphological variants of the present species. There has been some contention in the past as to the nature of the umbilical region in G. micheliniana. D'Orbigny (1840) originally stated that this species lacked a pseudoumbilicus though on examination of type material Barr (1962 MS) and Goel (1965) both found specimens which showed a small pseudoumbilicus. Such a situation is also seen in the populations of this species from the U.K. The present author is of the opinion that such variation is not of specific value in this instance.

G. micheliniana may be distinguished from G. conicus by its markedly higher, more conical outline, less distinctly keeled periphery and lack of a wide deep pseudoumbilicus.

Occurrence: Originally described from the Upper Campanian of the Paris Basin (St. Germain and Meudon) and England, G. micheliniana has been found in abundance from the basal Campanian to the base of the upper Upper Campanian both in Norfolk and the Isle of Wight.

Zonal range: B1ii - B3iii.

Genus GYROIDINOIDES Brotzen, 1942

Genotype Rotalia nitida Reuss, 1844

Gyroidinoides nitida (Reuss, 1844)

(Plate 15, figs.11-13)

1844 Rotalina nitida Reuss, p.214.

1845 " " Reuss; Reuss, p.35, pl.8, fig.52, pl.12, figs.8,20.

1891 Rotalia umbilicata var. nitida (Reuss); Beissel, p.71, pl.14, figs.14-19.

1925 " soldani f. nitida (Reuss); Franke, p.89, pl.8, fig.3.

1928 " " f. " (Reuss); Franke, p.187, pl.18, fig.1.

1934 Gyroidina nitida (Reuss); Morrow, p.197, pl.30, fig.1.

1936 " " (Reuss); Brotzen, pp.157-9, pl.11, fig.3, t.fig.58.

1941 " aff. nitida (Reuss); Marie, pp.220-1, pl.34, fig.319.

1941 " umbilicata (d'Orbigny); Marie, p.219, pl.34, fig.318.

1942 Gyroidinoides nitida (Reuss); Brotzen, p.19, figs.6,3.

1943 Gyroidina " (Reuss); Frizzell, p.351, pl.57, fig.6.

1946 " " (Reuss); Cushman, p.140, pl.58, fig.5.

1946 " " (Reuss); Schijfsma, p.85, pl.5, fig.1.

1957 " umbilicata (d'Orbigny); McGugan, p.342, pl.33, fig.4.

1957 Gyroidinoides nitida (Reuss); Hofker, pp.393-5, t.figs.437-440, 444.

? 1957 " octocamerata Hofker, pp.396-9. t.figs.442-3, 447-451.

1964 " nitida (Reuss); Loeblich & Tappan, p.C753, fig.615 no.6.

1966 " " (Reuss); Hofker, p.27, pl.3, fig.62, pl.11, figs.112-3.

? 1966 " octocamerata Hofker; Hofker, p.40, pl.19, fig.44.

1968 " nitidus (Reuss); Sliter, p.121, pl.22, fig.7.

1972 " " (Reuss); Hanzlikova, p.129, pl.37, fig.9.

1973 " " (Reuss); Koch, p.212.

1977 " nitida (Reuss); Villain, pp.56-7, pl.10, figs.1-3.

Description: Test free; trochospiral,plano-convex to biconvex; spiral side generally weakly convex, evolute,occasionally flat, umbilical side strongly convex, involute; periphery broadly rounded; chambers arranged in 3 to 3½ whorls, 7 to 8 chambers in final whorl; sutures on spiral side initially indistinct, flush, may become slightly depressed, straight to slightly curved, radial, spiral suture initially flush becoming distinct, depressed; umbilical side sutures distinct depressed close to umbilicus, towards periphery becoming flush, straight, radial; aperture narrow elongate slit along inner margin of final chamber, may be bordered by thin lip; umbilicus small open, may be partially covered by small chamber flaps extending into umbilical region; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.41mm. Average height: 0.30mm.

Remarks: This species shows a wide range of morphological variation, however, the subglobular form and narrow umbilical depression partially obscured by chamber flaps are distinctive. There has been considerable discussion in the literature as to the relationship between this species and G. umbilicata (d'Orbigny, 1840). From the type figures, d'Orbigny's species is a much compressed form lacking the distinctive umbilical chamber extensions of G. nitida. Within the present populations of G. nitida occasional less globular specimens do occur and it is possible that these two species are synonymous. Final determination of this point must await restudy of relevant type material.

Occurrence: G. nitida occurs in abundance throughout the Campanian and Lower Maastrichtian.

Zonal range: B1ii - B6i.

Family ANOMALINIDAE Cushman, 1927

Genus ANGULOGAVELINELLA Hofker, 1957

Genotype Discorbina gracilis Marsson, 1878

Angulogavelinella bettenstaedti Hofker, 1957

(Plate 15, figs.14-16)

1957 Angulogavelinella bettenstaedti Hofker, pp.367-8, t.figs. 421-2.

1972 ________"________________"_____ Hofker; Hanzlikova, p.130, pl.38, fig.6.

Description: Test free; trochospiral, lenticular, biconvex; spiral side evolute,less strongly convex than umbilical; small, deep umbilicus present; outline circular, periphery acute with non porous keel; chambers arranged in 2 to 3 whorls, uniformly and regularly increasing in size, chambers uninflated, oblique, strongly curved, crescentic, 8 to 10 in final whorl; spiral side sutures distinct, strongly curved, limbate, flush, umbilical side sutures distinct, raised, limbate, strongly curved; aperture high interiomarginal arch with narrow lip, extending slightly along spiral suture onto the umbilical side and partially covered by subtriangular umbilical chamber flap; wall calcareous, perforate on umbilical side, non perforate on the spiral side; surface smooth.

Average diameter: 0.44mm. Average height: 0.19mm.

Remarks: This species is distinguished from A. gracilis (Marsson, 1878) by its spiral side being less convex than the umbilical side and by its raised limbate umbilical side sutures.

Occurrence: Originally described from the Upper Campanian and Lower Maastrichtian of N.W. Germany and Holland, Hanzlikova (1972) recorded A. bettenstaedti from the Lower Maastrichtian of Moravia. In the present study this species occurs in a flood within the Lower Maastrichtian Sponge Beds at Sidestrand, Norfolk.

Zonal range: B6i

Genus GAVELINELLA Brotzen, 1942

Genotype Discorbina pertusa Marsson, 1878

Gavelinella pertusa (Marsson, 1878)

(Plate 16, figs.4-6)

1878 Discorbina pertusa Marsson, p.166, pl.4, fig.35.

1891 Rosalina ammonoides Reuss; Beissel, p.75, pl.16, figs.1-5.

1925 Anomalina pertusa (Marsson); Franke, p.86, pl.7, fig.16.

1928 " " (Marsson); Franke, p.182, pl.17, fig.4.

1940 Anomalina (?) pertusa (Marsson); Brotzen, p.29.

1941 Discorbis lorneiana (d'Orbigny) var. pertusa (Marsson); Marie, p.217, pl.34, fig.316.

1942 Gavelinella pertusa (Marsson); Brotzen, pp.41-3, pl.1, figs.1,2, t.fig.1.

pars 1946 Anomalina ammonoides (Reuss); Cushman, p.154, pl.63, fig.11, non.fig.10.

1948 Gavelinella pertusa (Marsson); Brotzen, pp.75-6, figs.4-6, t.fig.20.

? 1951 " " (Marsson); Visser, p.226, pl.5, fig.7.

1953 " " (Marsson); Hagn, pp.83-4, pl.7, fig.14.

1956a " " maastrichtensis Hofker, p.B216, fig.34.

1956e " " (Marsson); Hofker, p.107, t.fig.3a-c.

1957 " " (Marsson); Hofker, pp.291-2, t.figs.345-6.

1957 " " var. maastrichtensis Hofker, p.293-4, t.figs.347-8.

non 1957 Anomalina " (Marsson); McGugan, pl.33, fig.1.

1964 Gavelinella " (Marsson); Loeblich & Tappan, p.C759, fig.621 no.5.

1966 " " (Marsson); Hofker,p.27, pl.3, fig.57, pl.6, fig.60

non 1977 Gavelinella pertusa (Marsson); Villain, p.57, pl.10, figs.10-12.

1977 " lorneiana (d'Orbigny) "à omblic large" Villain, p.58, pl.11, figs.1-3.

Description: Test free; low plano-convex trochospiral coil of $2\frac{1}{2}$ to 3 whorls; spiral side flat to weakly convex, partially evolute, ventral side convex, involute with wide, deep umbilicus; outline circular, slightly lobate, periphery rounded to subacute; chambers distinct, gradually and uniformly increasing in size, becoming weakly inflated, 9 to 12 chambers in final whorl; spiral side sutures flush to slightly depressed; sutures bordered anteriorly by thickened imperforate ridges giving more or less distinct ribbed appearance; aperture interiomarginal slit bordered by a distinct thin lip, aperture extending into umbilicus, small subtriangular chamber flaps extending a short distance into the wide open umbilicus; wall calcareous, coarsely perforate; surface smooth.

Average diameter: 0.43mm. Average height: 0.19mm.

Remarks: The broad open umbilicus is characteristic of this species. The low chamber ridges anterior to the sutures are reminiscent of those shown by G.lorneiana (d'Orbigny, 1840) with which it has been confused (e.g. Villain, 1977). However, G. lorneiana never possesses such a wide, open umbilicus, whilst showing a much greater development of chamber ridges.

Occurrence: Originally described from the Lower Maastrichtian of Rügen, this widely recorded species was found in moderate abundance throughout the studied sections.

Zonal range: Blii - B7i

Gavelinella complanata (Reuss, 1851)

(Plate 16, figs.1-3)

1851 Anomalina complanata Reuss, p.36, pl.3(4), fig.3.

non 1945 Cibicides " (Reuss); Brotzen, p.55, pl.2, figs.4,5.

1969 Gavelinella supercretacea Hanzlikova, p.303, t. figs. 359a-h,363-4.

1972 " " Hanzlikova; Hanzlikova, p.132, pl.39, fig.6.

Description: Test free; compressed, low trochospiral coil; spiral side weakly concave, partially evolute; umbilical side weakly convex, with broad, shallow umbilicus, involute; outline circular; periphery subacute to acute, keeled; chambers distinct, 12-13 in final whorl, weakly inflated; anterior chamber margins imperforate; sutures distinct, flush to weakly depressed, limbate, strongly curved; aperture low interiomarginal slit bordered by indistinct lip, extending into umbilicus under subrectangular chamber flaps; wall calcareous, coarsely perforate; surface smooth.

Average diameter: 0.46mm. Average height: 0.16mm.

Remarks: The compressed, keeled test, numerous chambers and shallow umbilicus, characterize this species. G. supercretacea Hanzlikova, 1969 is here considered to lie within the range of morphological variation of G. complanata.

Occurrence: G. complanata was originally described from the Senonian chalk of Lemberg. In the present study it has been found in moderate abundance in the upper Upper Campanian and Lower Maastrichtian of Norfolk.

Zonal range: B3iv - B6ii

Gavelinella lorneiana (d'Orbigny, 1840)

(Plate 16, figs.7-9)

1840 Rosalina lorneiana d'Orbigny, p.36, pl.3, fig.20-22.

1899 Anomalina " (d'Orbigny); Egger, p.152, pl.18, figs.7,8.

1925 " clementiana (d'Orbigny); Franke, p.85, pl.7, fig.12.

1928 " " (d'Orbigny); Franke, p.179, pl.16, fig.9.

non 1928 " lorneiana (d'Orbigny); Franke, p.181, pl.17, fig.3.

non 1936 " " (d'Orbigny); Brotzen, p.178, pl.12, figs.1,2.

1941 Discorbis " (d'Orbigny) f. typica Marie, p.216, pl.33, fig.314.

1941 " " (d'Orbigny) var. costulata Marie, p.216, p.216, pl.34, fig.315.

pars 1946 Anomalina clementiana (d'Orbigny); Cushman, p.155, pl.63, fig.13, non.fig.12.

1953 Pseudovalvulineria lorneiana (d'Orbigny); Hagn, p.82, pl.7, fig.12.

1964 Gavelinella lorneiana (d'Orbigny); Loeblich & Tappan, p.C759, fig.621 no.6.

non 1966 " " (d'Orbigny); Hofker, p.41, pl.16, fig.57, pl.18, fig.36.

1977 " " (d'Orbigny) var."à omblic étroit" Villain, p.58, pl.11, figs.4-6.

Description: Test free; low trochospiral coil of 2½ to 3 whorls; spiral side flat to weakly concave, partially evolute, ventral side convex, involute with narrow umbilicus; outline circular becoming slightly lobate; periphery broadly rounded to subacute with occasional development of imperforate peripheral band; chambers distinct, weakly inflated, gradually and uniformly increasing in size, 8 to 10 chambers in final whorl, anterior chamber margins bearing distinct, raised, imperforate, curved ribs, somewhat better developed ventrally than spirally and decreasing in strength as chambers added; sutures on spiral side flush becoming slightly depressed, initially obscured by thickened chamber margins, on umbilical side sutures flush becoming weakly depressed initially obscured by thickened imperforate ribs; aperture low interiomarginal slit bordered by an indistinct lip and extending into the umbilicus where it is covered by subtriangular imperforate chamber flaps, which merge with the imperforate chamber thickenings and occupy much of the umbilical region; wall calcareous, coarsely perforate, where not covered by thickened imperforate layer; surface smooth.

Average diameter: 0.51mm. Average height: 0.23mm.

Remarks: The well developed, imperforate chamber ribs and narrow umbilicus are highly characteristic of this species. Considerable taxonomic confusion has surrounded this species due to the ommission of these features from the illustration of the holotype (d'Orbigny, 1840). This situation was clarified by the erection of a lectotype by Loeblich and Tappan (1964). Owing to the confused taxonomic history prior to this however, it is impossible to give a full synonomy for this species.

Occurrence: G. lorneiana was described from the Upper Campanian of the Paris Basin (St. Germain and Meudon). In the present study this species has been found abundantly throughout the Lower, Middle and lower Upper Campanian. It has not been found in strata of uppermost Campanian nor Maastrichtian age.

Zonal range: B1ii - B3ii

Gavelinella monterelensis (Marie, 1941)

(Plate 16, figs.10-12)

1941 Anomalina monterelensis Marie, p.243, pl.37, fig.342.

non 1946 " " Marie; Schijfsma, p.100, pl.6, fig.5.

1954 " (Pseudovalvulineria) monterelensis Marie; Vasilenko, p.108, pl.16, figs.5,6.

1956a Gavelinopsis menneri (Keller); Hofker, p.B210, fig.16.

1957 " " (Keller); Hofker, pp.333-4, t.figs. 385-6.

1958 Anomalina (Brotzenella) monterelensis (Marie); Vasilenko in Bykova et al, p.52.

1964 Gavelinella monterelensis (Marie); Loeblich & Tappan, p.C759, fig.621,7.

1966 Gavelinopsis " (Marie); Hofker, p.29, pl.3, fig.60.

1972 Gavelinella " (Marie); Hanzlikova, p.131, pl.39, fig.3.

1977 Gavelinopsis " (Marie); Villain, p.59, pl.7, figs.1-3

Description: Test free; moderately large, biconvex low trochospiral coil of $2\frac{1}{2}$ to 3 whorls; biumbonate, umbilical boss distinct, raised, moderately large; spiral side boss, distinct, broad, low; chambers numerous, 12-14 in final whorl, strongly curved becoming distinctly inflated; periphery in umbilical view circular, becoming weakly lobate, in side view acute to subacute, possessing indistinct imperforate keel; sutures distinct, limbate, depressed, curved, spiral suture distinct; aperture moderately high interiomarginal arch bordered by a thin lip and extending into umbilicus along spiral suture, partially covered by backward pointing, subtriangular chamber flaps; wall calcareous, finely perforate; surface smooth.

Average diameter: 0.48mm. Average thickness: 0.18mm.

Remarks: The subtriangular flaps extending from the umbilical chamber margins, and biconvex test, place this species within the genus Gavelinella, as noted by Loeblich and Tappan (1964).

Occurrence: G. monterelensis was originally described from the Upper Campanian of the Paris Basin. This species is moderately common throughout the Upper Campanian both in Norfolk and the Isle of Wight, and appears to be a useful index for strata of this age.

Zonal range: B3i - B4i

Gavelinella multipunctata (Bandy, 1951)

(Plate 16, figs.13-15)

1945 Cibicides complanata (Reuss); Brotzen, p.55, pl2, figs.4,5.
1951 Planulina multipunctata Bandy, pp.506-7, pl.74, fig.9.
1960 " " Bandy; Olsson, p.55, pl.12, figs.22-24.
1968 Gavelinella sandidgei (Brotzen); Sliter, pp.124-5, pl.23, figs.7-8.

Description: Test free; low trochospiral, compressed, plano-convex, weakly biumbonate test; umbilical side flattened to slightly concave, involute, umbilical boss small, flush; spiral side convex, with low, raised boss; partially evolute; chambers distinct, uninflated, becoming moderately inflated, 9-11 in final whorl, strongly curved, increasing rapidly and slightly irregularly in final whorl; outline circular becoming lobate; sutures on spiral side indistinct, curved, limbate, flush, those on umbilical side limbate, slightly elevated becoming weakly depressed; periphery subacute with imperforate peripheral band, umbilical surface coarsely perforate; aperture low, interiomarginal arch bordered by a broad lip and extending into umbilicus along spiral suture, relict lips project into umbilical region; wall calcareous; surface smooth.

Average diameter: 0.45mm. Average height: 0.20mm.

Remarks: The plano-convex, biumbonate test, subacute periphery, and strongly curved sutures are characteristic of this species. Brotzen (1945) described this form from the Maastrichtian of Höllviken, erroneously referring it to G. complanata (Reuss, 1851). G. multipunctata lacks the acutely keeled periphery, wide, shallow umbilicus and subrectangular chamber flaps of G. complanata, it also has fewer, less regular chambers. Sliter (1968) referred this species to G. sandidgei Brotzen, a species originally described from the Santonian of S. Sweden, which, though bearing a gross morphological resemblance, may be distinguished from G. multipunctata by its far less compressed spiral side. Sliter also suggested that Cibicidina californica Bandy, 1951 represented a different stage in the life cycle of G. multipunctata. No forms referable to C. californica were found in the present study however, and the suggestion must be questioned.

Occurrence: G. multipunctata was originally described from the Campanian/Maastrichtian of California. In the present study this species has been found in moderate abundance in the uppermost Campanian and Lower Maastrichtian of Norfolk.

Zonal range: B3iv - B7i

Gavelinella stelligera (Marie, 1941)

(Plate 17, figs.1-3)

1941 Planulina stelligera Marie, p.245, pl.37, fig.344.

non 1951 Gavelinella " (Marie); Visser, p. 267, pl.8, fig.10.

1953 " " (Marie); Hagn, p.82, pl.7, fig.13.

Description: Test free; low compressed trochospiral coil of 2½ to 3 whorls; spiral side distinctly flattened to slightly concave, partially evolute; umbilical side weakly convex, involute, with broad shallow depression surrounding umbilicus which is almost completely filled by chamber flaps; outline circular, periphery rounded to subacute; chambers distinct, uninflated, curved, gradually and uniformly increasing in size as added, 12 to 13 chambers in final whorl, on spiral side chamber margins imperforate, thickened anterior to sutures, giving appearance of series of oblique, curved ribs; on umbilical side thickened chamber margins more distinct than on the spiral side, extending into the umbilicus, merging into irregular, subtriangular chamber flaps which increase in size as chambers added, whilst the thickened ribs decrease rapidly so that final chamber has distinct flap with no thickened rib; sutures indistinct, curved, flush; aperture narrow interiomarginal slit bordered by indistinct lip and extending into umbilicus beneath chamber flap; wall calcareous, coarsely perforate on umbilical side between ribs; surface smooth.

Average diameter: 0.46mm. Average height: 0.12mm.

Remarks: The broad, curved, imperforate ribs and compressed test are characteristic of this species. The form referred to this species by Visser (1951) from the Maastrichtian of the Netherlands was re-examined by Hofker (1966) and reassigned to G. simplex (Brotzen, 1948).

Occurrence: G. stelligera was originally described from the Upper Campanian of the Paris Basin. In the present study this species has been found abundantly in the Lower and Middle Campanian, but only very rarely in the lower Upper Campanian.

Zonal range: B1ii - B2iii, rarely B3i - B3iii

Gavelinella thalmanni (Brotzen, 1936)

(Plate 17, figs. 4-6)

1936 Cibicides thalmanni Brotzen, pp.190-1, pl.14, fig.7.

1956 Anomalina (Gavelinella) sculptilis Hiltermann & Koch, p.38, t.fig.6, pl.3, fig.3.

non 1957 Gavelinella clementiana (d'Orbigny) var. thalmanni (Brotzen); Hofker, pp.295-6. t.fig.358.

1961 Anomalina (Pseudovalvulineria) thalmanni (Brotzen); Vasilenko, p.119, pl.22, figs.2,3.

1962 Gavelinella sculptilis Hiltermann & Koch; Hiltermann & Koch, p.319, pl.48, fig.2.

1966b " thalmanni (Brotzen); Barr, pp.506-7, pl.48, fig.1.

1973 " " (Brotzen); Koch, p.213.

1977 " " (Brotzen); Koch, p.41, pl.2, figs.1-3.

Description: Test free; flat, almost planispiral, trochospire consisting of $2\frac{1}{2}$ to 3 whorls; umbilical side distinctly flattened, occasionally concave, involute with narrow, shallow umbilicus partially filled with imperforate chamber flaps, spiral side concave, partially evolute with wide, moderately deep depression exposing previous whorl; outline circular, periphery rounded, imperforate; chambers numerous, distinct, uninflated, 11 to 12 in final whorl, uniformly and gradually increasing in size as added, on umbilical side chambers possess broad, imperforate thickened bands anterior to the sutures, radiating from umbilicus and merging with imperforate peripheral band, on spiral side chambers indistinct ornamented by series of radial imperforate ribs and irregular papillae; sutures indistinct, radial, straight flush to slightly depressed; aperture moderately high interiomarginal arch extending from periphery into shallow umbilicus, bordered by a slight lip which merges into the umbilical chamber flap; wall calcareous, coarsely perforate especially on umbilical side between imperforate bands; surface rough.

Average diameter: 0.29mm. Average thickness: 0.14mm.

Remarks: The concave, partially evolute, spiral side may on cursory inspection, be confused with the broad, deep umbilicus of G. pertusa, although the apertural position clearly distinguishes between them. The flattened sides and irregular nodose ornament are highly characteristic of this species.

Occurrence: Originally described from the Santonian of southern Sweden, Koch, (1977) records the range of G. thalmanni as Coniacian to Lower Campanian. In the present study G. thalmanni ranges in moderate abundance throughout the Lower and Middle Campanian and into the lower Upper Campanian in the Isle of Wight. In Norfolk found only in the Lower and Middle Campanian.

Zonal range: B1ii - B3ii

Notes on the "clementiana plexus".

Within the genus Gavelinella there exists a plexus of closely related species which are characterized by their convex, ornamented spiral surfaces and flattened to weakly convex umbilical surfaces, which generally possess an umbilical boss or distinct chamber flaps; the spiral side ornament of raised sutures and irregular nodes developed by most species of the plexus may be secondarily covered by a smooth calcitic layer. This "plexus" of forms reached their acme in the Campanian and they are amongst the most abundant species encountered in the present study. Several phylogenetic lineages may be traced within this plexus and these have been illustrated (text fig. 5:4). The "clementiana plexus" is named after the most widely known member of the group G. clementiana (d'Orbigny, 1840), and in addition the plexus includes G. cristata brotzeni (Goel, 1965), G. cristata cristata (Goel, 1965). G. ussakensis (Vasilenko, 1961) and G. trochus (Goel, 1965). Their distinctive morphology and close phylogenetic relationships may well warrant their separation into a distinct subgenus.

Gavelinella cristata brotzeni (Goel, 1965)
(Plate 17, figs.7-9)

? 1961 Anomalina (Pseudovalvulineria) clementiana var. clementiana (d'Orbigny); Vasilenko, p.121, pl.22, fig.4.

1965 Pseudovalvulineria brotzeni Goel, p.135, pl7, fig.2.

Description: Test free; trochospiral coil, outline circular, becoming slightly lobate, periphery rounded; spiral side evolute, strongly convex early whorls obscure, umbilical side flat to very weakly convex, involute; 9-11 chambers in final whorl, distinct, curved, uninflated, becoming weakly inflated, increasing gradually and uniformly in size; umbilicus filled with slightly raised calcite boss; sutures on umbilical side distinct, curved, initally distinctly raised and thickened, especially around umbilical boss, where a series of nodes are developed, later sutures becoming slightly depressed; spiral side covered centrally by highly raised, irregular ornament, final whorl visible; chambers distinct, curved; sutures raised, thickened, strongly curved, may become flush slightly depressed between final chambers; aperture low narrow interiomarginal slit, with distinct lip, extending from periphery towards umbilicus, wall calcareous; coarsely perforate on umbilical side; surface rough.

Average diameter: 0.43mm. Average thickness: 0.26mm.

Remarks: The raised sutures and highly raised, irregular spiral side ornament characterise this species. The species described by Vasilenko, from the Santonian of S. Russia, as Anomalina (Pseudovalvulineria) clementiana var. clementiana (d'Orbigny) is probably referable to this species, though the spiral side ornament is less high than is usual in populations of this species from the British Isles. The species referred to G. cf. clementiana (d'Orbigny) by Bailey (MS 1978) is undoubtedly G. cristata.

Occurrence: This species was originally described from the basal Campanian of the Paris Basin. Bailey (MS 1978) recorded this species from his Assemblage Zone F (Upper Santonian). In the present study G. cristata brotzeni was recorded in moderate abundance from the Lower Campanian both in Norfolk and the Isle of Wight, and sporadically from the basal Middle Campanian.

Zonal range: B1ii - B1ii, rarely basal B2i

Gavelinella cristata cristata (Goel, 1965)

(Plate 17, figs.10-12)

1965 Pseudovalvulineria cristata Goel, p.134, pl.8, fig.1.

1965 " hofkeri Goel, p.138, pl.10, fig.2.

1970 Gavelinella cristata (Goel); Bignót & Assadian, pl.1, figs.4,5,6.

pars 1977 " clementiana (d'Orbigny); Koch, p.46, pl.2, figs.4-5 non.fig.6.

Description: Test free; low trochospiral coil, outline circular, periphery rounded; spiral side evolute, weakly convex, early whorls indistinct, obscured by ornament; umbilical side weakly convex, involute; umbilicus filled with irregular calcite boss; chambers 9-10 in final whorl, distinct, on umbilical side curved, uninflated, becoming weakly inflated, chambers on spiral side strongly curved; sutures distinct, on umbilical side initially thickened, raised, with calcite node at umbilical end, later becoming depressed; on spiral side sutures raised, thickened, strongly curved, in later chambers becoming less raised to flush; aperture low interiomarginal slit, bordered by a distinct lip, extending from periphery towards umbilicus, covered by distinct subtriangular chamber flaps; wall calcareous coarsely perforate on umbilical side.

Average diameter: 0.46mm. Average thickness: 0.24mm.

Remarks: This subspecies may be distinguished from the nominal species by its flatter spiral side, less pronounced spiral ornamentation and reduced number of raised sutures on the umbilical side. There is some degree of variation in all these features, however, and intermediate forms between these two subspecies can be found in the Lower Campanian. Koch (1977) has, using a wide species concept, included these early members of the *G. clementiana* lineage within *G. clementiana*. *G. cristata cristata* may be distinguished from *G. clementiana* by its convex spiral side and stronger development of ornamentation.

Occurrence: This subspecies was originally described from the Lower Campanian of the Paris Basin and recorded as being restricted to the uppermost Santonian and Lower Campanian. In the present study it was found in abundance in the Lower Campanian and sporadically in the lower Middle Campanian of Norfolk and the Isle of Wight.

Zonal range: B1ii - B1iii, rarely B2i

Gavelinella clementiana clementiana (d'Orbigny, 1840)

(Plate 18, figs.4-6)

1840 Rosalina clementiana d'Orbigny, p.37, pl.3, figs.23-5.

non 1925 Anomalina " (d'Orbigny); Franke, p.85, pl.7, fig.12.

non 1928 " " (d'Orbigny); Franke, p.179, pl.16, fig.9.

1941 Discorbis " (d'Orbigny); f. typica Marie, p.213, pl.33, fig.312.

1941 " " (d'Orbigny) var. rugosa Marie, p.213, pl33, figs.310-311.

1941 " " (d'Orbigny) var. costata Marie, p.214, pl.33, fig.313.

1946 " " (d'Orbigny); Schijfsma, pp.81-2, pl.4, fig.11.

non 1946 Anomalina " (d'Orbigny); Cushman, p.155, pl.63, figs.12,13

1953 Gavelinella " (d'Orbigny); Hagn, p.84, pl.7, fig.11.

1957 " " (d'Orbigny); Hofker, pp.294-7, t.figs. 350-352.

1957 Anomalina pseudoexcolata Kalinin; McGugan, pp.343-4, pl32, fig.22.

non 1961 " (Pseudovalvulineria) clementiana var. clementiana (d'Orbigny); Vasilenko, p.121, pl.22, fig.5.

pars 1966 Gavelinella clementiana (d'Orbigny); Hofker, p.27, pl.3, fig.61 non.fig.59.

non 1977 " " (d'Orbigny); Koch, p.46, pl.2, figs.4-6.

1977 " " (d'Orbigny); Villain, p.58, pl.11, figs.7-9.

Description: Test free; low trochospiral coil; outline circular, may become distinctly lobate; periphery broadly rounded; spiral side flattened may be weakly concave, evolute,though early whorls obscured by ornament; umbilical side weakly convex, involute, with narrow umbilicus filled with small calcite boss; chambers distinct, 8-10 in final whorl, uninflated sometimes becoming distinctly inflated, curved; sutures on spiral side variable, generally raised initially, thickened, becoming distinctly depressed, curved, oblique; sutures on umbilical side initially raised, radial, curved, with calcite node at umbilical end, becoming flush or slightly depressed; aperture low, interiomarginal slit, bordered by a distinct lip and extending from periphery into umbilicus, covered by subtriangular chamber flaps; wall calcareous, coarsely perforate on umbilical side.

Average diameter: 0.51mm. Average thickness: 0.22mm.

Remarks: The flat to concave spiral side distinguishes this species from G. cristata cristata, with which it might be confused. G. clementiana clementiana shows considerable variation in the development of spiral side ornamentation. The stratigraphically oldest specimens are generally smaller, more compressed and have continuous raised spiral side sutures. These forms are closest to d'Orbigny's original figure of Rosalina clementiana, and were described under the variety name 'costata' by Marie (1941). Later forms become increasingly larger and possess more distinctly concave spiral sides, more inflated final chambers and irregular spiral side ribs. These later forms were assigned by Marie (1941) to the varieties 'typica' and 'rugosa'. These varieties are thought to be within the range of specific variation of G. clementiana clementiana, as they possess the same stratigraphic range and numerous intergradational forms occur.

Occurrence: G. clementiana clementiana was originally described from the Upper Campanian of the Paris Basin and England. In the present study this species was found in moderate abundance in the Upper

Campanian of the Isle of Wight, whilst in Norfolk it was also found rarely in the upper Middle Campanian.

Zonal range: rarely B2iii. B3i - Lower B4i

Gavelinella clementiana laevigata (Marie, 1941)
(Plate 18, figs.7-9)

1941 Discorbis clementiana (d'Orbigny) var. laevigata Marie, p.212, pl.33, fig.209.

1954 Anomalina (Pseudovalvulineria) clementiana (d'Orbigny) var. laevigata Marie; Vasilenko, p.92, pl.10, fig.2.

1961 " (") clementiana (d'Orbigny) var. laevigata (Marie); Vasilenko, p.121, pl.22, fig.5.

pars 1966 Gavelinella clementiana (d'Orbigny); Hofker, p.27, pl.3, fig.59, non. fig. 61.

? 1972 " laevigata (Marie); Hanzlikova, p.131, pl.39, fig.1.

Description: Test free; low trochospiral coil; outline circular, lobate; periphery broadly rounded; spiral side concave, evolute though early whorls obscured; umbilical side convex, involute, narrow umbilicus completely covered by large, overlapping apertural flaps; chambers distinct, 8-10 in final whorl, becoming distinctly inflated; sutures on spiral side distinct in final whorl, oblique, depressed, on umbilical side initially may be flush or slightly raised, rapidly becoming depressed; aperture interiomarginal arch bordered by a distinct lip and extending from the periphery beneath the pronounced chamber flaps into the umbilicus; wall calcareous, coarsely perforate on umbilical side; surface smooth.

Average diameter: 0.54mm. Average thickness: 0.31mm.

Remarks: This chrono-subspecies may be distinguished from G. clementiana clementiana by its unornamented, concave spiral side, depressed spiral side sutures, greater chamber inflation and markedly well developed chamber flaps. The specimen figured as G. laevigata by Hanzlikova (1972) lacks the distinctly depressed sutures and well developed chamber flaps of this subspecies, and is probably not conspecific.

Occurrence: This subspecies was originally described from the Upper Campanian of the Paris Basin. In the present study, it was found in moderate abundance only in the upper Upper Campanian. Transitional forms between this subspecies and G. clementiana clementiana were frequently encountered in the Upper Campanian.

Zonal range: B3iv - lower B4i

Gavelinella trochus (Goel, 1965)
(Plate 18, figs.1-3)

1965 Gavelinopsis trochus Goel, pp.140-1, pl.10, fig.1.
1972 Gavelinella involutiformis (Hofker); Hanzlikova, p.131, pl.38, fig.9.

Description: Test free; large, moderately high trochospiral coil; umbilical side weakly convex, involute, spiral side strongly convex, evolute; outline circular, periphery broadly rounded, imperforate; umbilicus occupied by large raised calcite boss; chambers on spiral side indistinct, all except last obscured by smooth thick calcite layer; last chambers moderately distinct, weakly inflated, curved ; sutures on this side only visible between last chambers, flush occasionally weakly depressed., chambers on umbilical side distinct, 10-14 in final whorl, curved, uninflated becoming weakly inflated, sutures curved initially thickened, raised, merging with umbilical boss, becoming slightly depressed; aperture narrow low, interiomarginal slit bordered by distinct lip and extending from periphery into umbilical area, beneath triangular chamber flap; wall calcareous, coarsely perforate on umbilical side; surface on spiral side smooth.

Average diameter: 0 61mm. Average thickness: 0.39mm.

Remarks: The highly convex, smooth spiral side is characteristic of this species. Anomalina (Pseudovalvulineria) cayeuxi (Lapparent) subsp. mangyschlakensis Vasilenko, 1961, has a remarkably similar gross morphology though it shows a more highly conical spiral side. Study of the relevant type material is required to determine if these two taxa are conspecific. G. trochus Goel, appears to have developed from G. usakensis Vasilenko, 1961, by a progressive increase in the convexity of the spiral side.

Occurrence: Originally described from the Upper Campanian of the Paris Basin, this species has been found sporadically in the Middle Campanian, and in moderate abundance in the lower Upper Campanian in the Isle of Wight. G. trochus has not been found in Norfolk.

Zonal range: rarely B2ii - B2iii, B3i - basal B3iii

Gavelinella usakensis (Vasilenko, 1961)

(Plate 17, figs.13-15)

1961 Anomalina (Pseudovalvulineria) clementiana (d'Orbigny) var. usakensis Vasilenko, p.122, pl.23, fig.1.

? 1965 Pseudovalvulineria glabra Goel, p.138-9, pl.9, fig.1.

pars 1977 Gavelinella clementiana (d'Orbigny); Koch, p.46, pl.2, fig.6, non. figs.4,5.

Description: Test free; low to moderate trochospiral coil, outline circular, becoming slightly lobate, periphery rounded; spiral side moderately convex, evolute but with earlier whorls indistinct, obscured by a thickened, smooth calcite layer; umbilical side weakly convex with small umbilical boss, involute; chambers distinct, 9-10 in final whorl, uniformly and gradually increasing in size, uninflated becoming weakly inflated, slightly curved; sutures on umbilical side distinct, initially flush or slightly raised, later depressed; sutures on spiral side flush becoming depressed, curved; aperture low interio-marginal slit bordered by distinct lip, extending from periphery to umbilicus, where it is covered by distinct subtriangular chamber flaps; wall calcareous, coarsely perforate on umbilical side.

Average diameter: 0.50mm. Average thickness: 0.25mm.

Remarks: This species may be distinguished by its low to moderately convex spiral side which is smooth, and by its depressed sutures especially on the spiral side. This species appears to have arisen from G. brotzeni cristata stock by the reduction of the spiral side ornament, and the development of depressed sutures. G. vombensis (Brotzen, 1945) may be closely related to G. usakensis. The figured types of G. vombensis differ from the present species by lacking the pronounced umbilical boss and the moderately convex spiral side.

Occurrence: This species was originally described from the Campanian of southern Russia. In the present study transitional forms between G. usakensis and G. cristata cristata occur at the level of the Lower/Middle Campanian boundary in the Isle of Wight. G. usakensis


PHYLOGENETIC DEVELOPMENT WITHIN THE GENUS GAVELINELLA
fig.5:4
STAGE
SUBSTAGE
MACROFAUNAL BIOZONE
PLANKTONIC FORAMINIFERAL BIOZONE
BOLIVINOIDES PHYLOZONE
BENTHONIC FORAMINIFERAL BIOZONE
MAASTRICHTIAN
CAMPANIAN
LOWER
MIDDLE
UPPER
O.pilula
G.quadrata
B.mucronata
B.lanceolata-occident.
B.junior
kasimir.
A.cretacea/R.pilula
G.rugosa
R.rugosa/G.havanensis
A.mayar.
B1
B2
B3
B4
B5
B6
B7
i
ii
iii
iv
G.clementiana laevigata
G.clementiana clementiana
G.trochus
G.usakensis
G.cristata brotzeni
G.cristata cristata

is found in moderate abundance throughout the Middle Campanian of the Isle of Wight, it was not found in the samples studied from Norfolk.

Zonal range: B2i - B3i

Notes on the Taxonomic status of the "voltziana plexus".

Within the Campanian and Maastrichtian strata of the United Kingdom, there exists a group of closely related species which are characterized by their biumbonate tests with imperforate peripheral band, and primary aperture bordered by more or less well developed chamber flaps. The "*voltziana* plexus" includes the species *Gavelinella voltziana* (d'Orbigny, 1840), *G. denticulata* (Marie, 1941) *G. eriksdalensis* (Brotzen, 1936), *G. bembix* (Marsson, 1878) and *G. involuta* (Hofker, 1957).

This plexus has been referred, in recent years, to a variety of genera including *Cibicides*, *Gavelinella*, *Anomalina (Brotzenella)* *Cibicidoides* and *Gavelinopsis*. In view of this evident taxonomic confusion, a brief review of the possible affinities of the group is offered here. The genus *Gavelinopsis* was included in the superfamily - Discorbacea by Loeblich and Tappan (1964). Members of the genus *Gavelinopsis* possess a radial monolamellar wall structure. *Anomalina* (*Brotzenella*) was considered cogeneric with, and hence a junior synonym of, *Gavelinella* by Loeblich and Tappan (1964). The genus *Cibicides* may be similar in gross morphology to members of the plexus; major differences however, occur in the lack of umbilical chamber flaps and umbilical boss. *Cibicides* possesses a calcareous, radial wall structure. Species of the genus *Gavelinella* possess a test with umbilical chamber flaps imperforate peripheral bands, and may also possess biumbonate tests. They have a calcareous granular wall structure.

From the above, it is obvious that the determination of the wall structure of members of this plexus is required, before a definite generic assignment can be made. Unfortunately, as was noted by Reiss (1959) and Schlanger and Douglas (1974), most foraminiferal tests from the Upper Chalk have undergone fine scale recrystallization, resulting in a secondary, heterogeneous granular wall structure. The species of the "voltziana plexus" cannot therefore be definitely assigned generically.

These species have been tentatively assigned to the genus Gavelinella, though later study of unrecrystallized material may indicate that they are more correctly referable to the genus Gavelinopsis.

Gavelinella bembix (Marsson , 1878)

(Plate 18, figs.10-12)

1878 Discorbina bembix Marsson, p.167, pl.5, fig.37.

1899 Rotalia " (Marsson); Egger, p.155, pl.20, fig.29.

1925 " " (Marsson); Franke, p.90, pl.8, fig.5.

1928 " " (Marsson); Franke, p.188, pl.17, fig.10.

? 1941 Cibicides " (Marsson); Marie, p.248, pl.37, figs.350-1.

? 1953 " " (Marsson); Hagn, p.101, pl.8, fig.22.

1954 " (Cibicidoides) bembix (Marsson); Vasilenko, p.155, pl.27, figs.3,4.

1956e Gavelinopsis bembix (Marsson); Hofker, p.101, fig.15.

1956a Gavelinopsis bembix (Marsson); Hofker, p.B228, fig.69.

1957 " " (Marsson); Hofker, pp.330-333, t.figs.383-4, ?t.figs.380-2.

1966 " " (Marsson); Hofker, p.42, pl.6, figs.58,59.

1969 Gavelinopsis bembix (Marsson); Hanzlikova, p.36, pl.17, fig.2.

1972 " " (Marsson); Hanzlikova, pp.86-7, pl.20, fig.12.

Description: Test free; small, plano-convex trochospiral; umbilical side flat occupied by large, broad, flattened boss; spiral side highly convex, conical occupied by distinct, raised clear calcite boss; on umbilical side chambers distinct, numerous, curved, 10-12 in number, on spiral side distinct, curved becoming slightly inflated; periphery in umbilical view circular, in end view sharply acute, possessing distinct imperforate keel; sutures distinct, curved becoming depressed; aperture low interiomarginal arch bordered by indistinct lip and extending a short distance on to the umbilical side, obscured by umbilical boss; wall thin, calcareous, finely perforate; surface smooth.

Average diameter: 0.44mm. Average thickness: 0.25mm.

Remarks: This species was regarded by Villain (1977) as being a juvenile stage of Gavelinella sp. Though there are marked similarities between this species and juveniles of G. voltziana , for instance in their small size and sharp keels, this interpretation is rejected. G. bembix may be distinguished by its small size, generally ½ that of C. voltziana, by its sharply keeled, plano-convex test, low,broad umbilical boss and more numerous chambers. The last two characteristics are not found in juvenile stages of C. voltziana. C. bembix has, in addition, a distinct stratigraphic range.

G. minimalis (Schijfsma, 1946), described from the mid-Campanian, Hervian Greensand of the Netherlands, has often been regarded as synonymous with G. bembix (eg. Hofker, 1957, 1966) , such an interpretation is not followed herein. It appears, from the present study, that G. bembix developed from G. eriksdalensis (Brotzen, 1936), This latter species, described from the Santonian of Sweden, shows a progressive increase in the height of the spiral side boss, and in the degree of planoconvexity, throughout the Campanian; no specimens of G. eriksdalensis from the Campanian possess the degree of planoconvexity or the large, flat umbilical boss which is so characteristic of G. bembix. It appears likely that G. minimalis represents a form transitional between G. eriksdalensis and G. bembix. Due to the rarity of these transitional forms, G. minimalis is not formally recognised in the present study.

Occurrence: G. bembix was originally recorded from the Maastrichtian of Rügen. In the present study it was found in moderate abundance in the upper Lower Maastrichtian of Norfolk.

Zonal range : B5i - B7i.

Gavelinella denticulata (Marie, 1941)

(Plate 19, figs.1-3)

1941 Cibicides voltziana (d'Orbigny) var. denticulata Marie; p.248, pl.37, figs. 348, 349.

1951 " involuta (Reuss); Visser, p.290, pl.6, fig.4.

? 1953 " " (Reuss); Hagn, p.101, pl.8, fig.21.

1957 Gavelinopsis complanata (Reuss); Hofker, pp.324-9, t.figs.372-4.

1966 " " (Reuss); Hofker, p.29, pl.3, fig.58, pl.11, fig.129.

Description: Test free; moderately large, biconvex trochospiral; biumbonate, chambers 9-10 in final whorl; umbilical side often slightly less convex than spiral side; chambers on umbilical side inflated becoming distinctly so curved, umbilical side umbo occupied by a slightly raised calcite boss; sutures on umbilical side generally distinct, broad, initially raised, commonly limbate and thickened, curved, sutural ridges may merge to form raised spiral ridge bordering spiral suture and joining umbonal boss, later sutures depressed, curved; spiral side convex; chambers initially distinct, only weakly inflated on spiral side, becoming slightly more inflated, distinct; spiral side umbo generally occupied by small calcite boss; spiral side sutures indistinct, flush, becoming depressed, curved; periphery in umbilical view circular, very weakly lobate, in end view subacute with imperforate peripheral band; aperture low arch along base of apertural face of final chamber, equatorial, bordered by distinct lip extending back along spiral suture; wall calcareous, granular, coarsely perforate on umbilical side, peripheral band imperforate, spiral side indistinctly and finely perforate, smooth.

Average diameter: 0.45mm. Average thickness: 0.25mm.

Remarks: This species was originally described as a variety of C. voltziana (d'Orbigny, 1840), in the present study it is regarded as a distinct species, as no intergradational forms were observed. G. denticulata is distinguished from G. voltziana by its biconvex test and initially thickened umbilical side sutures. Gavelinopsis complanata (Reuss) sensu Hofker (1957) is considered conspecific with C. denticulata , on the basis of biconvexity of test and sutural characteristics.

Occurrence: G. denticulata was originally described from the Upper Campanian of the Paris Basin. In the present study G. denticulata was found abundantly throughout the Upper Campanian and Lower Maastrichtian.

Zonal range: B3i - B7i

Gavelinella eriksdalensis (Brotzen, 1936)

(Plate 19, figs. 4-6)

Remarks: Brotzen (1936) erected *Cibicides* (*Cibicidoides*) without designating a type species. Later (1942) he elevated this subgenus to generic rank and designated *Cibicides eriksdalensis* as type species. Prior to this however, Thalmann (1939) formally erected *Cibicidoides*, with the Recent species *Truncatulina mundula* Brady, Parker and Jones, 1888, as type species. This action rendered Brotzen's use of the generic name *Cibicidoides* a nom. nud. as noted by Loeblich and Tappan (1964).

The present author considers that the cogeneric status of *T. mundula* and *C. eriksdalensis* has not been adequately proven. The Recent *T. mundula* lacks the distinctive apertural characteristics of the Cretaceous species. It may well be that a new genus is required for the Cretaceous forms. For the present, *C. eriksdalensis* is tentatively referred to *Gavelinella*, on the basis of its biumbonate test, apertural characteristics, and imperforate peripheral band.

1936 *Cibicides eriksdalensis* Brotzen, pp.193-4, t.fig.69, pl.14, fig.5.

? 1941 " *bembix* (Marsson); Marie, p.248, pl.37, figs.350-1.

1942 *Cibicidoides eriksdalensis* (Brotzen); Brotzen, p.21, t.fig.7, no.1.

1945 " " (Brotzen); Brotzen, pp.54-5.

1953 *Cibicides (Cibicidoides) eriksdalensis* Brotzen; Hagn, p.101, pl.8, fig.23.

1957 *Gavelinopsis eriksdalensis* (Brotzen); Hofker, p.322, t.figs. 370-1.

1960 *Anomalinoides* " (Brotzen); Belford, p.108, pl.34, figs.1-11.

1961 Cibicides (Cibicidoides) eriksdalensis (Brotzen); Vasilenko, p.139, pl.28, figs.4-5.

? 1968 Gavelinella eriksdalensis (Brotzen); Sliter, p.123, pl.23, fig.6.

non 1977 Gavelinella eriksdalensis (Brotzen); Sliter, pl.12, fig.4.

Description: Test free; small, biconvex to almost plano-convex, umbilical side generally flattened or weakly convex, spiral side moderately to strongly convex; biumbonate, umbilical boss small, flat, spiral side boss small, moderately raised; chambers on spiral side indistinct, 9-10 visible in final whorl, uninflated becoming weakly inflated, chambers on umbilical side initially indistinct becoming distinct, inflated, curved, becoming sharply sigmoid; outline slightly lobate, circular; periphery sharply keeled; sutures on spiral side indistinct,flush, limbate becoming weakly depressed, umbilical side sutures distinct, initially flush to slightly raised, limbate, curved, becoming depressed, sigmoid; aperture low interiomarginal arch bordered by thin lip and extending into umbilicus along spiral suture, covered by subtriangular lobes extending from the umbilical chamber edges; wall calcareous, finely perforate, somewhat more coarsely perforate umbilically; surface finely roughened.
Average diameter: 0.36mm. Average thickness: 0.16mm.

Remarks: Brotzen (1936) originally noted and figured the wide range of morphological variation shown by this species in its degree of biconvexity and umbonal development. A similar range of variation has been noted in the present study. Despite this, the small, sharply keeled test and sharply sigmoid umbilical side sutures are characteristic of this species. Sliter (1968) recorded a species which he refers to G. eriksdalensis from the Upper Campanian of California. His hypotypes however, appear to be far more robust, lacking the sharply sigmoid sutures of G. eriksdalensis. Sliter (1977) also records G. eriksdalensis from strata of Coniacian to Maastrichtian age from the S.W. Atlantic, though rather inadequately illustrated this also appears not to belong to the present species, being more coarsely perforate and lacking the distinct subtriangular chamber flaps.

Occurrence: Originally described from the Coniacian/Santonian of Eriksdal, S. Sweden, this small species is moderately common in the Lower and Middle Campanian, rare in the Upper Campanian both in Norfolk and the Isle of Wight.

Zonal range: B1ii - B2iii, rarely B3i - B4i

Gavelinella involuta Hofker, 1957
(Plate 19, figs.7-9)

1946 Anomalina monterelensis (Marie); Schijfsma, p.100, pl.6, fig.5.
1957 Gavelinella involuta Hofker, p.315, t.figs.356-7.

Description: Test free; moderately large, plano-convex trochospiral of 3-4 whorls; biumbonate, spiral side boss distinct, slightly raised, dorsal umbo small, weakly raised; 9-10 chambers in final whorl, curved, slightly inflated; outline circular; periphery rounded to subacute; sutures on umbilical side indistinct, flush to slightly depressed, curved, spiral side sutures very distinct, limbate, raised, thickened, curved, merging along spiral suture into thickened calcite rim, final suture may be depressed especially in stratigraphically younger populations; aperture moderately high interiomarginal arch extending on to spiral side along spiral suture, partially covered by short projecting calcite ridges extending out from thickened spiral sutures; wall calcareous, coarsely perforate on spiral side, finely perforate on umbilical side; surface smooth.

Average diameter : 0:37mm. Average thickness: 0.20mm.

Remarks: Stratigraphically younger populations of this species show a tendency to decrease the sutural thickening on the spiral side, so that the later sutures are depressed. G. involuta is phylogenetically related to both G. denticulata and G. voltziana (d'Orbigny, 1840).

Occurrence: Originally recorded from the Campanian Hervian Greensand of Limburg, this species was found by Hofker in the Campanian of N.W. Germany and Holland. In the present study, G. involuta was found in moderate abundance in the upper Middle and lower Upper Campanian. Transitional populations between this species and G. denticulata are common in the Upper Campanian.

Zonal range: B2iii - B3i

Gavelinella voltziana (d'Orbigny, 1840)

(Plate 19, figs.10 - 12)

1840 Rotalina voltziana d'Orbigny, p.31, pl.2, figs.32-4.

1899 " " d'Orbigny; Egger, p.159, pl.22, figs.26-8.

1925 Truncatulina voltziana (d'Orbigny) f. constricta Hagenow; Franke, p.84, pl.7, fig.8.

1928 " constricta Hagenow; Franke, p.178, pl.16, fig.3.

? 1928 " voltziana (d'Orbigny); Franke, p.177, pl.16, fig.7.

1934 Cibicides spiropunctatus Galloway & Morrey; Dain, p.48, pl.5, fig.53.

1935 " " Galloway & Morrey; Keller, p.553, pl.3, figs.15-17.

? 1936 " padella Jennings, p.40, pl.5, fig.6.

1937 Planulina voltziana (d'Orbigny); Kalinin, p.56, pl.8, figs.118-120.

1940 Cibicides " (d'Orbingy); Brotzen, p.24, pl.7, fig.3.

1941 " " (d'Orbigny) f. typica Marie, pp246-8, pl.37, figs.345-7.

1945 " " (d'Orbigny); Brotzen, pp.54,55.

1946 " " (d'Orbigny); Schijfsma, pp.102-3, pl.5, fig.6.

1956 " (Cibicidoides) voltziana (d'Orbigny); Vasilenko, p.154, pl.25, figs.3,4.

1957 " voltziana (d'Orbigny); McGugan, p.344, pl.32, fig.23.

1957 Gavelinopsis " (d'Orbigny); Hofker, pp.336-7, t.figs.367, 387, 388, 393.

1957 " ventricosa Hofker, pp.337-8, t.fig.389.

1961 Anomalina (Brotzenella) menneri Keller; Vasilenko, p.126, pl.24, fig.2, pl.27, fig.1.

? 1964 " voltziana (d'Orbigny); McGugan, p.946, pl.152, pl.1.

1965 " " (d'Orbigny); Pozaryska, pp.136-7, pl.28, fig.4.

1966 Gavelinopsis " (d'Orbigny); Hofker, pp.29, 42, pl.3, fig.63, pl.6, fig.56, pl.11, fig.124.

1977 " " (d'Orbigny); Villain, pp.59-60, pl.7, figs.4-6.

Description: Test free; large, trochospire of 3-4 whorls; plano-convex, spiral side more strongly convex, involute, with moderate to large calcite boss; umbilical side flat, may possess small raised central boss; outline circular to weakly lobate; periphery subacute; chambers distinct, dorsally slightly inflated, 9-11 in final whorl, gradually and uniformly increasing in size; umbilical side sutures flush, slightly limbate becoming depressed, distinct, radial, may be slightly curved, spiral side sutures indistinct flush, becoming slightly depressed, curved; aperture interiomarginal broad, low arch, extending on to umbilical surface along depressed spiral suture, and bordered by thick lip; wall calcareous, coarsely perforate with imperforate periphery; surface smooth.

Average diameter: 0.53mm. Average thickness: 0.29mm.

Remarks: The large, plano-convex test and more or less prominent calcite bosses, are characteristic of this species. The figures of the holotype show a form which is more acutely angled than most of the specimens of G. voltziana found in the British Campanian. Gavelinopsis ventricosa Hofker, 1957 was distinguished from G. voltziana by its greater development of calcite bosses. In view of the wide range of variation shown in the size of these features G. ventricosa is here considered conspecific with G. voltziana.

Occurrence: Originally described from the Upper Campanian of the Paris Basin (Meudon, St. Germain) and England, this species is abundant in the Upper Campanian and Lower Maastrichtian of all onshore sections studied.

Zonal range: B3i - B6ii

Genus STENSIOINA Brotzen, 1936

Genotype Rotalia exsculpta Reuss, 1860

Stensioina exsculpta gracilis Brotzen, 1945

(Plate 20, figs.1-3)

1945 Stensioina exsculpta var. gracilis Brotzen, p.52, pl.1, fig.15.

non 1957 " gracilis (Brotzen); Hofker, p.347, t.figs.396-7.

1957 " exsculpta var. aspera Hofker, pp.349-350, t.figs.401-3.

1957 " " var. " mut. infirma Hofker, pp.350-1, t.fig.404.

1958 Stensioina exsculpta gracilis Brotzen; Pokorny, p.307, t.figs.13,14.

non 1962 " " " Brotzen; Hiltermann & Koch, p.324, pl.49, figs.13,14.

1962 " " (Reuss); Hiltermann & Koch, p.325, pl.49, figs.15-18.

1968 " " gracilis Brotzen; Trümper, p.26, pl.9, fig.2, pl.10, figs.1-3, pl.11, figs.1,2,5, pl.12, figs.9,10.

1970 " gracilis Brotzen; Porthault in Donze et al., p.60, pl.8, figs.20,21.

1972 " exsculpta gracilis Brotzen; Hanzlikova, p.135, pl.40, figs.3-5.

1977 " " " Brotzen; Koch, p.44, pl.11, figs.5-8.

Description: Test free; biconvex trochospire of $2\frac{1}{2}$ to 3 whorls; outline circular, occasionally weakly lobate; periphery acute, keeled; spiral side moderately to highly raised, evolute; umbilical side weakly convex, involute, with narrow umbilicus partially filled by irregular network of chamber flaps, only last of which is well developed, subtriangular; chambers distinct, curved, 10-12 in final whorl, uninflated becoming weakly inflated, distinctly flattened on spiral surface, increasing uniformly and gradually; sutures on umbilical side distinct, radial, slightly curved, flush becoming slightly depressed, limbate, on spiral side sutures strongly elevated, spiral suture also elevated, thus forming irregular reticulose pattern; aperture low interiomarginal opening bordered by indistinct lip and extending into umbilicus beneath chamber flap; wall calcareous, coarsely perforate; surface smooth ventrally covered with fine nodose ornament between spiral sutures dorsally.

Average diameter: 0.41mm. Average thickness: 0.18mm.

Remarks: The raised trochospiral coil, resulting in a markedly biconvex test and sharply keeled margin are characteristic of this subspecies.

Occurrence: This subspecies was originally described from the Santonian of Höllviken, and has been widely recorded from the Santonian and Lower Campanian of Europe. In the present study, this subspecies has been found, often in abundance, in the Lower and Middle Campanian. It is markedly less abundant in the Isle of Wight, than in either Norfolk or North Sea material.

Zonal range: B1ii - B2iii

Stensioina granulata incondita Koch, 1977

(Plate 20, figs.4-7)

1962 *Stensioina labyrinthica* Cushman & Dorsey; Hiltermann & Koch, p.326, pl.51, figs.4-7.

1977 *" granulata incondita* Koch, pp.38-39, pl.10, figs.1-3.

Description: Test free; biconvex to almost plano-convex trochospire of $2\frac{1}{2}$ to 3 whorls; outline circular, periphery subacute to rounded, with broad, imperforate band; spiral side flat to slightly raised, evolute; umbilical side strongly convex, involute with narrow umbilicus filled by sutural ridges and chamber flaps, only the last of which is well developed, subtriangular; chambers distinct, curved, 11-12 in final whorl, uninflated, distinctly flattened on spiral surface, increasing gradually and uniformly; sutures on umbilical side distinct, curved, limbate, flush to slightly raised; on spiral side sutures slightly raised and much thickened, especially spiral suture, area between sutures covered with irregular granular ornament; aperture low interiomarginal opening, bordered by an indistinct lip and extending into the umbilicus beneath chamber flap; wall calcareous, coarsely perforate ventrally; surface rough dorsally.

Average diameter: 0.43mm. Average thickness: 0.24mm.

Remarks: This species is easily distinguished from *S. exsculpta gracilis* by its highly domed umbilical side, subrounded periphery, and granular ornament. This subspecies is closely related to *S. granulata perfecta* Koch, 1977, from which it may be distinguished principally by its less well developed granular ornament and much thickened spiral suture.

Occurrence: Originally described from the Lower Campanian of Germany, this subspecies was found in moderate abundance in the Lower Campanian and more rarely in the Middle Campanian of all studied sections. Transitional forms between this subspecies and *S. pommerana* were found in the upper Lower Campanian.

Zonal range: B1ii - B2iii

Stensioina pommerana Brotzen, 1936

(Plate 20, figs.8-10)

1936 *Stensioina pommerana* Brotzen, p.166.

1941 " " Brotzen; Marie, p.218, pl.34, fig.317.

1945 " " Brotzen; Brotzen, p.51, pl.1, fig.14.

1951 " " Brotzen; Noth, p.71, pl.9, fig.12.

1953 " " Brotzen; Hagn, p.89, pl.8, fig.2.

1956 " *esnehensis* Nakady; Hofker, p.74, pl.8, fig.54.

1957 " *pommerana* Brotzen; Hofker, p.352-3, t.figs.407-8.

1957 " " var. *juvenilis* Hofker, p.351-2, t.figs.405-6.

1957 Stensioina altissima Hofker, p.353-4. t.figs. 409,410.

1961 " pommerana Brotzen; Vasilenko, p.67, pl.11, fig.6.

1962 " " Brotzen; Hiltermann & Koch, p.327, pl.51, figs.11-13.

1966 " " Brotzen; Hofker, p.30, pl.3, fig.65, pl.11, fig.126.

1966 " altissima Hofker; Hofker, p.42, pl.6, fig,53, pl.11, fig.125, pl.14, fig.86.

1966 " esnehensis Nakady; Hofker, p.122, pl.19, fig.47.

1968 " pommerana Brotzen; Trümper, p.14, pl.4-7, fig.12.

1972 " " Brotzen; Hanzlikova, p.135, pl.40, figs.6,7.

1977 " " Brotzen; Koch, p.51, pl.11, figs.1-4.

1977 " " Brotzen; Villain, pp.58-9, pl.11, figs.10-12.

1977 " " Brotzen; Sliter, pl.13, figs.6,7.

Description: Test free; plano-convex trochospire of 2½ to 3 whorls; outline curcular, periphery acute; spiral side flattened, evolute; umbilical side involute, strongly convex, domed, with umbilical region completely covered by large irregular chamber flap; chambers distinct, curved, uninflated becoming weakly inflated, distinctly flattened on spiral surface, increasing gradually and uniformly in size as added; sutures on umbilical side distinct, flush to slightly depressed, limbate, radial, slightly curved; on spiral side sutures distinctly raised, elevated, as is spiral suture, producing a slightly irregular reticulose network, surface between sutures granular; aperture low interiomarginal arch bordered by thick lip, extending into umbilicus below chamber flap; wall calcareous, coarsely perforate ventrally; surface roughened dorsally.

Average diameter: 0.48mm. Average thickness: 0.22mm.

Remarks: This species may be distinguished by its domed outline, angled periphery and large well developed umbilical chamber flap. It may well have developed from the S. granulata lineage (Koch, 1977). Transitional forms between S. granulata incondita and S. pommerana were found in the Lower Campanian.

Occurrence: This widely recorded species has been found in abundance in the Middle and Upper Campanian and Maastrichtian of all studied sections. Transitional forms between this species and S. granulata incondita were found in moderate abundance in the upper Lower Campanian of the Isle of Wight.

Zonal range : Bliii - B7i