THE LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY (FORAMINIFERA) OF THE EARLY CRETACEOUS OF THE SOUTHERN NORTH SEA BASIN

by

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Sponsoring Establishment: Plymouth Polytechnic

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DECLARATION

This is to certify that the work submitted for the Degree of Doctor of Philosophy under the title "The Lithostratigraphy and Biostratigraphy (Foraminifera) of the Early Cretaceous of the Southern North Sea Basin" is the result of original work.

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

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This thesis, however, was completed during my registration as a part time research student at Plymouth while employed in the hydrocarbon exploration industry as a micropalaeontologist/stratigrapher (1982 to 1987).

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ABSTRACT

THE LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY (FORAMINIFERA) OF THE EARLY CRETACEOUS OF THE SOUTHERN NORTH SEA BASIN.

Stephen Crittenden

This thesis presents the results of a lithostratigraphical and biostratigraphical study, using foraminifera, of the Early Cretaceous strata in ten boreholes from the southern North Sea Basin (U.K. sector).

The boreholes have been subdivided lithostratigraphically, using ditch cuttings descriptions (315 samples) and wireline logs, within the schemes of the British and Dutch Geological Surveys. The lithostratigraphical subdivision has allowed correlation of the ten boreholes with each other and has enabled correlation with other boreholes further afield in the southern North Sea. It has been concluded that the Dutch Geological Survey scheme offers more scope for subdivision and correlation.

Each lithostratigraphical unit recognised has been dated biostratigraphically by the contained foraminiferal faunas present in ditch cutting samples from each interval. A total of 224 samples containing abundant specimens of foraminifera (approx 180 species) were examined from eight of the boreholes. Several genera/species were examined in some detail either because of taxonomic curiosity, or the need to illustrate their usefulness for biostratigraphy in the Early Cretaceous strata from the southern North Sea Basin. The benthonic species Osangularia schloenbachi (Reuss) has been discussed in great detail to illustrate both the biostratigraphical utility of the species and the confused and chequered taxonomic history of this species in the literature. The dating of the lithostratigraphical units has allowed the recognition of unconformities, hiatuses and periods of non-deposition in the succession.

The changes in the foraminiferal population through time have been interpreted in terms of palaeoenvironment; reflecting both the changes in water depth through Early Cretaceous times (associated with a global transgression trend coupled with minor stillstand and regressive phases) and the effects of an increasing faunal interchange with open oceanic areas and Tethys associated with the development of the North Atlantic.

The Albian - Aptian sections of the studied North Sea boreholes have been compared with sections in North West Europe. To assist those comparisons a full and detailed study was needed of the foraminiferal fauna from 30 samples of Early Aptian strata from the section at Atherfield Point, Isle of Wight. This resulted in the first published taxonomic account of the foraminiferal faunas of the Atherfield Clay (equivalent to Chale Clay member) type section. In addition a new species has been recognised, Lenticulina (Astacolus) atherfeldensis sp. nov., which is of stratigraphical importance. An additional study has been made of the foraminiferal faunas of the Barremian - Aptian "Urgonian facies" strata (15 samples) of Site 549, Leg 80 of the Deep Sea Drilling Project (Goban Spur, Western Approaches), the results of which assist in palaeogeographical/palaeoenvironmental reconstructions of the Early Cretaceous of North West Europe and North America and which show that a foraminiferal biozonal scheme erected on material from offshore Canada can be utilised in North West Europe.
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PART 1

INTRODUCTION
CHAPTER 1

INTRODUCTION

1.0 Introduction

In the available published literature there is little information on the Early Cretaceous strata of the Southern North Sea Basin (Mesozoic Basin). The small amount of information that has been published is the result of the search for hydrocarbons (see Chapter 2).

This thesis attempts to remedy the lack of information by a stratigraphical study of the Early Cretaceous strata in boreholes from the Southern North Sea Basin (U.K. sector blocks 44 and 49).

Several objectives for this thesis study were defined and are as follows:

A. Main objectives:

1) The lithostratigraphic subdivision of the borehole sections

2) The biostratigraphic subdivision of the boreholes by foraminifera

3) The chronostratigraphic subdivision of the boreholes

B. Secondary objectives:

4) Comparison of the Aptian age strata offshore with the onshore U.K.
v) A detailed foraminiferal study of the Aptian age Atherfield Clay s.s. (Chale Clay Member) of the Isle of Wight

vi) A discussion of the marine transgressions during Late Aptian and Albian times

vii) A discussion of the foraminiferal faunas recovered from strata of Barremian-Aptian age from DSDP Borehole 549 leg 80, Goban Spur

viii) A brief foraminiferal taxonomy of the fauna recovered from the studied sections

ix) A taxonomic study of Osangularia schoenbachi (Reuss, 1863)

x) A taxonomic discussion of Lenticulina (A.) atherfieldensis (Crittenden, 1983c)

xi) A discussion of the palaeoenvironment of Early Cretaceous times in North West Europe

These objectives, it was decided, could be answered by this thesis in a manner applicable to hydrocarbon exploration. The philosophy of this approach is defined in the following sections.

1.1 The Role of Biostratigraphy in Hydrocarbon Exploration

The main commercial task of a biostratigrapher employed in the hydrocarbon exploration industry involves the erection of lithostratigraphical, biostratigraphical and chronostratigraphical subdivisions of sedimentary sequences (Holland et al., 1978) and the determination of the palaeoenvironment of deposition (e.g. Billman & Scrutton, 1976). This task is achieved by micropalaeontological, palynological, visual
Fig. 1.1  BIOSTRATIGRAPHIC UTILITY OF CENOZOIC MICROFOSSIL GROUPS. (adapted from Billman + Scrutton, 1976)

NB: The environment range is not the range in which these groups are extant.
geochemical (kerogen type, spore colour, thermal maturity, vitrinite reflectance) and lithological studies of outcrop samples and borehole samples (ditch cuttings, sidewall cores, conventional cores) together with the integration of other geological data such as regional outcrop data (field maps, sections) seismic data, wireline log data, geological reports and published literature.

The biostratigrapher approaches his commercial role from two directions. Firstly, as a specialist he is aware of the utility of each fossil group used for age determination and palaeoenvironment analysis (e.g. Biswas, 1976) - See Fig. 1.1 For example, all biostratigraphers appreciate that the planktonic foraminifera are not the panacea for stratigraphic age determination or correlation (Crittenden, 1986).

Secondly, as a geologist he can compare, interpret and integrate biostratigraphical, palaeoenvironmental, lithostratigraphical and chronostratigraphical data and then integrate the data with the results of other exploration specialists' work (e.g. wireline logs, geochemical data). These data can be used to formulate a geological model for an area useful for exploration (Fig. 1.2).

The two directions of approach cannot be divorced from each other. The first provides the accurate raw data (taxonomic determination) needed for the second.

1.2 Functional Hierarchy

A. Initial Phases of Exploration

A biostratigrapher plays an important role in collating all lithostratigraphical and chronostratigraphical data available from published literature, traded data reports, from field mapping and sampling and from borehole data. The biostratigrapher may work with, and provide data for,
A. LITHOSTRATIGRAPHY
- Sedimentology/Petrology/Petrography.
  - Lithology
  - Wirelines log suites.
    - etc

B. BIOSTRATIGRAPHY
- Micropaleontology
- Palynology/visual Geochemistry data (spore colour, trinitite - reflectance)
- Palynofacies
- Calcareous nanofossils
- Macropaleontology
- Geochemistry data
  - etc

C. CHRONOSTRATIGRAPHY
- Radiometric dating

D. INTEGRATED STRATIGRAPHICAL INTERPRETATION / EVALUATION
  SEDIMENTARY / GEOLOGICAL HISTORY MODEL
  PALAEOENVIRONMENT / PALAEOGEOGRAPHY

SEQUENCE OF ANALYSIS A – D MAY BE APPLIED TO ONE WELL OR TO AN ASSEMBLAGE OF REGIONAL DATA.

Fig. 1.2

SIMPLIFIED STRATIGRAPHIC DATA UTILISATION PATHWAYS
other specialists such as the geophysicist, seismic stratigrapher, structural geologist, sedimentologist, geochemist or field/mapping geologist (Fig. 1.3).

The exploration team strives to predict and assess source rock potential, reservoir potential (permeability, porosity and effects of diagenesis etc), trapping potential (structural and stratigraphic), sealing potential, maturity and oil/gas generation, migration and leak off pathways (faults, unconformities etc) within a region.

The biostratigrapher in the initial stages of exploration also functions as a micropalaeontologist (or whichever group is his speciality) and analyses field samples to provide biostratigraphical age dating and palaeoenvironmental data.

In essence the prospectivity of an area is evaluated. The biostratigraphical input into the evaluation is very important as a sound stratigraphic framework is an essential base upon which to build and develop an area geological model.

B. Wellsite Stratigraphy

An important role for a biostratigrapher is as a micropalaeontologist/palynologist providing wellsite analysis on exploration wells as an aid, for example, in deciding the total depth of a well (to stop drilling), predicting the approach of a known overpressured horizon, determining casing points, determining the presence of faults, thrusts (repeated sections), correlating the drilled sections with nearby wells, or as a rapid means of providing a biostratigraphical age subdivision or palaeoenvironment for the drilled sequence useful for forward planning of
FIELD SECTIONS / OUTCROP DATA

WELL DATA

A B C D

A B C D

CORRELATED AND INTEGRATED TO GIVE DETAILED WELL AND OUTCROP ANALYSIS.

SEISMIC DATA

STRUCTURAL DATA

SEISMIC DATA

STRUCTURAL DATA

DETAILED BASIN / REGIONAL STRATIGRAPHIC ANALYSIS / MODELLING.

GEOCHEMICAL DATA

CONVENTIONAL CORE ANALYSIS DATA

PROSPECTIVITY POTENTIAL:
SOURCE ROCK
RESERVOIR ROCK
CAP / SEAL ROCK
STRUCTURAL TRAPPING
STRATIGRAPHIC TRAPPING
HYDROCARBON GENERATION

GENERATION OF PLAY CONCEPT AND PROSPECT LOCATION.

INTEGRATION OF EXPLORATION DATA FOR STRATIGRAPHIC MODELLING

Fig. 1.3
the next well location. Palynological studies can also provide additional, but very important, data for maturation (spore colour) and source rock (kerogen type) determination.

C. Laboratory Study

A very important role is to carry out a detailed laboratory study of the biostratigraphy and palaeoenvironment of the well section(s). This thesis is limited to an in-depth study of the lithostratigraphy and foraminiferal biostratigraphy of the Early Cretaceous strata from boreholes. An in-depth palaeoenvironmental/palaeogeographical study was not attempted.

D. Mature Phase of Exploration

The role of the biostratigrapher becomes more complex in the maturer phases of the exploration effort when the subtle stratigraphic trap becomes the target for the exploration drill. A sound stratigraphic knowledge coupled with detailed palaeoenvironmental and palaeogeographical models for the area being explored is an essential foundation if the hydrocarbon potential of an area is to be exploited to the full (Halbouty, 1982).

1.3 Cretaceous Strata Prospectivity

Rawson et al. (1978) emphasise that in North Sea hydrocarbon exploration, strata of Cretaceous age are not particularly prospective apart from the topmost carbonates (e.g. in the Dan and Ekofisk fields). This is a very short sighted statement in view of the lack of published data available on Cretaceous strata of the North Sea Basin. Perhaps the onshore U.K. is not prospective but only a brief perusal of the relevant literature will show that both oil and gas have been found in large
quantities in strata of Early Cretaceous age in Holland, Germany, France and the Southern North Sea Basin. For instance, hydrocarbons are present in strata of Early Cretaceous age in the Rijswijk oil province of Southern Holland and offshore the Netherlands.
CHAPTER 2

HISTORY OF PREVIOUS RESEARCH

2.0 Introduction

A comprehensive review of previous research on the Early Cretaceous of North West Europe would necessitate a discussion of all aspects of geology (e.g. ammonite biostratigraphy, lithological studies, sedimentological studies, micro-biostratigraphy, chronostratigraphy and lithostratigraphy). This would involve a vast amount of literature and such a review is far beyond the scope of this thesis.

The Early Cretaceous deposits present in the areas bordering the southern North Sea Basin contain ammonite faunas.

The stages of the Early Cretaceous are defined by ammonite faunas and some degree of correlation between the stratotypes and North West Europe (Boreal) has been attempted by "macro-fossil" workers (Rawson et al., 1978). Some of these stages and "standard biozones" have been established on Tethyan ammonite faunas and this poses problems when trying to identify these stages and biozones in Britain and other regions in the Boreal realm. However, attempts have been made with some success (Rawson, 1973; Owen, 1973; Casey, 1973; Thieuloy, 1973). Nevertheless, the problem of faunal provinciality is an important point to be borne in mind when dealing with microfaunas for worldwide correlation of the Early Cretaceous (e.g. Bartenstein, 1977b). This topic is discussed further in Chapters 7, 8, 10 and 11.

During the last fifty years there has been a steady flow of research directed toward an overall lithostratigraphy and foraminiferal biostratigraphy of the Early Cretaceous, calibrated by an ammonite biostratigraphy, in North West Europe. This
steady flow, mainly through the efforts of Helmut Bartenstein in West Germany, has resulted in a worldwide biostratigraphical correlation of the marine Early Cretaceous using index foraminifera species and faunas. However, even though the understanding of the Early Cretaceous in North West Europe has been increased by these studies, problems of Early Cretaceous stratigraphy, lithology and facies changes, and palaeogeography still need to be resolved.

This chapter discusses some of the relevant historical works which have been used in the present study. These works reflect the concentration of research on the most important Early Cretaceous outcrop areas of North West Europe.

It is inevitable that in a discussion of a history of previous research many published papers deal not only with the foraminifera but also with the lithology and sedimentology of the studied section. Indeed overlap is unavoidable, since a discussion of a foraminiferal fauna and an erected biostratigraphy is enhanced in value if lithostratigraphical details are published at the same time.

2.1 The stages of the Early Cretaceous (Boreal Province)

None of the standard Early Cretaceous stages has a stratotype in the British Isles and indeed the majority of the designated stratotypes lie in a different faunal province (Tethyan). The problems of correlating the Boreal Early Cretaceous successions with the standard Cretaceous stages have been discussed in the Cretaceous volume of the "Lexique Stratigraphique International" (ed. Hancock, 1972), the symposium volume "The Boreal Lower Cretaceous" (eds. Casey & Rawson, 1973) and in "A correlation of Cretaceous Rocks in the British Isles" (Rawson et al., 1978).

The occurrence of each stage onshore United Kingdom is fully discussed by Rawson et al. (1978).
A. **The Ryazanian**

This stage was erected by Sazonov (1951) for the interval between the Upper Volgian below and the Valanginian above, in the Ryazanian area south-west of Moscow.

The Ryazanian has been subdivided into two substages (Lower & Upper) and five biozones based upon ammonites (Casey & Rawson, Editors 1973; Casey, 1973; Rawson et al., 1978). The term Ryazanian is preferred for areas with a Boreal fauna, whilst the term Berriasian is employed for areas with a Tethyan fauna, although they are probably not exact time equivalents of each other.

B. **The Valanginian**

This stage, proposed by Desor (1854) is represented at its type locality of the Seyon Gorge, near Valangin (Valendis), Neuchatel, in Switzerland by shallow water deposits with a sub-littoral fauna. Ammonites are rare and poorly preserved. The Lyons Colloquium (Barbier & Thieuloy, 1965; Debelmas & Thieuloy, 1965) recommended that a Valanginian parastratotype should be erected based upon a section in the Vocontian trough in the région of the Hautes-Alpes. However, because of the Tethyan fauna of the stratotype, only limited correlations between Germany and France and between England and France can be made using ammonites (Kemper, 1973a; Rawson, 1973; Rawson et al., 1978). The use of foraminifera has been more successful (Moullade, 1966).

C. **The Hauterivian**

Again the stratotype of this stage is in Switzerland. Renevier (1874) designated a series of shallow water
deposits at Hauterive, near Neuchatel as the stratotype. It has been proposed (Debelmas & Thieuloy, 1965) that a parastratotype should be erected in the Salerans region (Hautes-Alpes) of the Vocontian trough of south-east France in order to overcome the rarity of ammonites at the stratotype. A very limited correlation may be made between Tethyan and Boreal regions and for both the Lower and Upper Hauterivian a Tethyan and Boreal ammonite biozonal scheme has been erected. The U.K. scheme (Rawson et al., 1978) compares well with the scheme of Kemper et al. (1974) for Germany.

D. The Barremian

Coquand (1861) mentioned sections at Barreme and Angles (Basses-Alpes, France) in his original designation but Busnardo (1965) has now designated the Angles roadside section as the stratotype. Again most work has been concentrated on the ammonite faunas and poor correlations have been established on this basis between England, Germany and south-east France (Rawson, 1973a; Rawson et al., 1978). Foraminiferal studies have met with more success (Moullade, 1966 and, for example, Bartenstein, 1977b).

E. The Aptian

d'Orbigny (1840) proposed that strata containing an Upper Neocomian fauna near the village of Apt (Basses-Alpes) in south-east France should be designated as the stratotype. The tripartite division of the French Aptian into the substages Bedoulian, Gargasian and Clansayesian (Toucas, 1888; Kilian, 1887; Breistroffer, 1949) is not used in Britain. In Britain a bipartite division into Lower and Upper Aptian is used (following Casey, 1961a).
This stage is readily recognised in Britain and easily correlated with sections in Germany and France (Rawson et al., 1978) but the Aptian microfauna of the British Isles is poorly known (see Chapter 12), (Crittenden, 1982b, 1983a, b, c, 1984a, b, 1987a,b).

F. The Albian

This stage was proposed by d'Orbigny (1842) for the interval between the Aptian and what is now termed the Cenomanian. The name is derived from the Roman name for the Aube (Alba).

In mainland Britain Albian strata are divided into three substages (Lower, Middle and Upper) and seven Ammonite biozones.

This stage has been the focus of much detailed research in the last decade by both micro- and macro-fossil workers (Price, 1975, 1976, 1977a, b; Carter & Hart, 1977; Hart, 1973 and Harris, 1982).

Each of the six stages of the Early Cretaceous are represented in the British Isles. They have all been studied in detail during the last 150 years by various authors but, due to poor exposure and lack of outcrop, some of the stages have been neglected in terms of published microfossil studies. A detailed historical discussion and investigation of the stage and biozonal nomenclature of the Early Cretaceous in the U.K. is not within the scope of this thesis, but reference may be made to Rawson et al. (1978) for further discussion.
2.2 Early Cretaceous Lithostratigraphy of the Southern North Sea Basin

To date there have been, to the author's knowledge, only three publications dealing specifically with the lithostratigraphy of the Mesozoic (and thus the Early Cretaceous) in the British southern North Sea Basin (Rhys, compiler 1974, 1975; Crittenden, 1982a). Burnhill & Ramsay (1981) and Deegan & Scull (compilers, 1977) have published some details of the Early Cretaceous lithostratigraphy of the British central North Sea Basin and the whole of the northern North Sea Basin, which are of importance to studies of the southern North Sea Basin while Hesjedal & Hamar (1983) have published details from the Norwegian sector of the Central North Sea. Jensen, Holm, Frandsen and Michelsen (1986) have more recently published a lithostratigraphic nomenclature for the Jurassic and Early Cretaceous of the Danish Central Trough.

This lack of published information on the British Southern North Sea is due to data restriction and the obvious need for the various operating oil exploration companies in the southern North Sea Basin not to release their proprietary information and lithostratigraphical schemes to competitors.

Apart from Crittenden (1982a) no detailed Early Cretaceous lithostratigraphical data have been published for the British southern North Sea Basin.

However, Nederlandsche Aardolie Maatschappij and Rijks Geologische Dienst - NAM & RGD (compilers, 1980) have published a detailed lithostratigraphical scheme for the Early Cretaceous of the Dutch southern North Sea Basin and onshore the Netherlands. This has been an invaluable aid in the formulation of this research.
Various authors in the two conference volumes on the North Sea (Woodland; ed., 1975 and Illing & Hobson; eds, 1981) have mentioned some details of Early Cretaceous stratigraphy in the southern North Sea which have been of some use in formulating a general overview but have served no part in the construction of the lithostratigraphical scheme proposed in Chapter 5 of this thesis (e.g. Johnson, 1975).

2.3 Early Cretaceous Foraminifera and Foraminiferal Biostratigraphy of North West Europe

In North West Europe Early Cretaceous marine sedimentary rocks adjacent to the southern North Sea Basin outcrop onshore only in relatively small scattered areas. This is possibly a reflection of the restricted Early Cretaceous palaeogeography and of the overlying transgressive Late Cretaceous and Tertiary strata.

The fact that most work has been concentrated on the Early Cretaceous foraminifera of North West Germany clearly demonstrates the importance of the oil exploration industry as a stimulus to academic and industrial research and the importance of foraminifera to oil exploration. To date the only published accounts on Early Cretaceous foraminifera from commercial boreholes in the British southern North Sea Basin have been by Crittenden (1983b; 1984a, b; 1987a, b).

A. North West Germany

Roemer (1839, 1841, 1842) pioneered the study of Early Cretaceous foraminifera in his studies on the now classic "Hils" area of Germany (Hannover district). Koch (1851) followed with his work on the "Hils" clay and Elligser Brink beds. Reuss, however, (1860a, b, 1862, 1863) was the first worker to attempt any sort of biostratigraphical palaeontology of the Early Cretaceous using foraminifera.
This is in contrast to his previous purely taxonomic studies (Reuss, 1844, 1846, 1851, 1854 & 1855).

There followed a marked lack of published work on the German Early Cretaceous foraminifera until a surge of activity commenced in the early 1930's. This is associated with the rise, in terms of military power, of Germany and the need to develop a self sufficiency in hydrocarbon resources. This resulted in the discovery and exploitation of the North German oil province.

Eichenberg's work (1931, 1933, 1934, 1935a, b) on the biostratigraphical use of foraminifera in oil exploration and on the taxonomy of the foraminiferal faunas of the Hauterivian, Barremian, Aptian and Albian stages was in response to the needs of the German oil exploration industry. Hecht's (1938) biostratigraphical classification of the North German Early Cretaceous was in direct response to the need for a quick and reliable method of correlating exploration boreholes. Hecht's work by itself is very limited as he uses a number for nomenclature below the generic level rather than a fully documented specific name. However, Bartenstein's revision (1952, 1962, 1965) of Hecht's (1938) work is an invaluable and very important contribution to Early Cretaceous micropalaeontology and microbiostratigraphy.

To date, Bartenstein has been the most prolific and active worker on the German Early Cretaceous in the post war period, publishing articles on the taxonomy, phylogeny and biostratigraphy of Early Cretaceous foraminifera (1948 - 1981). Numerous papers have also been co-authored by Bartenstein with various colleagues, dealing with the same variety of subject matter (e.g. Bartenstein & Bettenstaedt, 1962; Bartenstein & Brand, 1949, 1951; Bartenstein & Kaever, 1973; Aubert & Bartenstein, 1976).
Another prolific worker over the same period (geological and historical time) was Bettenstaedt (e.g. 1952, 1958, 1960, 1962, 1973, 1979) who has complemented the work of Bartenstein.

Other authors have also contributed to the knowledge of the German Early Cretaceous; occasionally as co-authors with either Bartenstein or Bettenstaedt (e.g. Bettenstaedt & Wicher, 1955; Bartenstein & Brand, 1949, 1951; Erhard, 1967; Grabert, 1959; Michael, 1966, 1967; Zedler, 1961).

One of the most interesting and important works is by Bartenstein & Kaever (1973) dealing with the Early Cretaceous foraminifera (& ostracoda) of the island of Heligoland. This has provided an important link between North West Germany, the southern North Sea Basin and Speeton on the east coast of England (Fletcher, 1966, 1973).

Later workers have illustrated the use (or misuse) of biometrics in foraminiferal taxonomy (e.g. Albers, 1952; Grabert, 1959; Bettenstaedt & Spiegler, 1975, 1980; Bettenstaedt, 1979).

More recently Price (1975, 1976 & 1977a, b) has discussed northern German Albian foraminiferal faunas in relation to the whole of North West Europe.

Foraminiferal studies of the German Early Cretaceous have proved to be the most prolific contributions to the available literature on North West Europe. The importance of this wealth of data for North Sea Basin studies cannot be over emphasised, especially the chapter in "Leitfossilien de Mikropalaeontologie" (Bartenstein &
Bettenstaedt, 1962) which has been recently revised by Bartenstein (1978a).

B. North-East England

Inland exposures of Early Cretaceous strata are very poor in north east England and work on foraminifera in strata of this age has consequently been sparse. Burrows, Sherborn & Bailey (1888, 1890) described and illustrated the foraminifera of the Red Chalk of Yorkshire, Norfolk and Lincolnshire. Lamplugh (1896) supplemented this work with a detailed lithological account of the Speeton Clay, Red Chalk and Carstone succession of northern England and recognised the diachronous nature of the lithological units. A paper, written by Sherlock (1914), which systematically described the foraminifera of the Speeton Clay, was, until the works of Khan (1962), Fletcher (1966) and Hart et al., (1981), the only paper to actually illustrate the fauna. Sherlock also recognised the possibilities of correlating the Speeton Clay fauna with the faunas present in the "Hils" clay of Germany, the Gault of Montcley and the Gault of Folkestone.

Bartenstein (1956) published a paper on the foraminifera of the Lower Tealby Clay of Lincolnshire (Nettleton Valley, south Humberside) from a single auger sample sent to him by Macfadyen (equivalent to the Hauterivian and the C beds of Speeton). The close similarity to the German fauna was recognised.

Khan (1962), in the first paper since that of Sherlock (1914), described the foraminiferal fauna from Speeton and compared it with the faunas in Germany. However, as noted by Fletcher (1966), Khan's lack of detailed knowledge of the section and imprecise location of the samples limits the value of his study.
Fletcher (1966) completed a Ph.D. thesis on the foraminiferal faunas of the D, C and Lower B beds (Ryazanian to Lower Barremian) from the Speeton section, Filey Bay, which has proved to be an extremely important contribution to the knowledge of the Early Cretaceous in North West Europe. Fletcher (1966) illustrated his fauna by excellent light photographs. This fauna has subsequently been re-photographed by Hart et al., (1981) using a scanning electron microscope. It was unfortunate that, due to the difficulties of collecting samples from the Speeton section, Fletcher (1966) did not extend his work to include the remainder of the B beds and the A beds.

Harris (1982) has illustrated and described some of the stratigraphically important foraminifera from the Upper A beds (mimicus marls) and the Red Chalk of the Speeton section at Filey Bay (Albian). Dilley (1969) discusses the fauna from the Greensand Streak (Early Albian) but to date there is no recently published work on the foraminifera from the Upper B beds and ewaldi beds (Late Barremian and Aptian) of the Speeton section.

Dilley & Kent (1968) and Dilley (1969) have described Late Aptian - Early Albian foraminiferal faunas from the Langton "Series" (Carstone Grit, Carstone Sands & Clays) at Melton (east Yorkshire) and Elsham (north Lincolnshire).

Harris (1982) has described the stratigraphically important foraminifera from the Red Chalk (Hunstanton Red Rock) at Hunstanton (Norfolk) and from various localities in Lincolnshire and Yorkshire including Melton and Speeton.
Fletcher (1966) listed the foraminiferal fauna from the North Forden G.I. borehole (British Petroleum, 1955) which penetrated circa 695 feet of Speeton Clay. Other borehole data from boreholes drilled in the Speeton area to test the presence of Lower Cretaceous strata have not been published (B.P. - G.2., G.3., F.1., boreholes and Shell - Speeton 1960, and West Heslerton 1960).

A minor publication by Hollis & Neaverson (1921) discussed the foraminifera from the Gault Clay from Ford in Buckinghamshire.

A study programme to rectify the inadequate data available on the foraminiferal faunas of the Early Cretaceous strata onshore north-east England, would in itself provide the basis of a Ph.D. thesis.

C. South East England

The initial Early Cretaceous deposits in south-east England are non-marine and the first fully marine faunas are encountered in the Aptian and Albian.

Chapman in a series of papers (1891–1898) described the foraminiferal fauna from the Gault Clay at Folkestone. Khan (1950, 1952) and Walters (1958) also described the foraminifera and biostratigraphy of the Gault Clay at Folkestone. These works provided a basis for the extensive studies of Hart (1973a, b), Price (1975, 1977a, b) and Carter & Hart (1977) on the foraminifera of the Albian of southern England. More recently Harris (1982) has made a further contribution to the study of Albian foraminifera in southern England and has made a comparison of previously published biostratigraphical zonations.
The marine Aptian of south-east England however, has been sadly neglected in terms of foraminiferal study.

Jaworski, in the late 1960's, failed to publish his research results (pers. comm.) on the Aptian foraminiferal fauna from the Atherfield Clay of southern England. This deficit in our knowledge is illustrated by the "Stratigraphical Atlas of Fossil Foraminifera" (Hart et al., 1981) by the lack of Aptian index foraminifera. Three publications however have made some progress toward rectifying this lack of published detail on the Aptian foraminifera of southern England (Crittenden, 1982b; 1983a, c).

D. Holland

A literature search revealed that some very important work on the foraminifera of the Early Cretaceous in the Netherlands has been published since 1940.

Ten Dam (1944, 1946, 1947, 1948a, b, 1949, 1950) has published a series of taxonomic and biostratigraphical studies on Early Cretaceous foraminifera from both borehole and outcrop sections. These faunas relate extremely well to the faunas present in the Early Cretaceous of Germany as well as to those in the U.K. and southern North Sea Basin.

More recently Fuchs and Stradner (1967) have detailed Early Albian foraminifera from a borehole in the province of South Holland (Delft 2) while Cottencon et al. (1975) briefly mention some index foraminifera species in the Valanginian and Hauterivian of boreholes in the provinces of North Holland and Groningen.
Price (1977a, b) has related the work of Fuchs and Stradner (1967) and of ten Dam (1950) to ammonite biozonal schemes and to his own proposed biozonal scheme for North West Europe.

All of these published works are of great importance for identification of the foraminifera and for delineating the Early Cretaceous strata in the southern North Sea Basin.

Northern France

A. d'Orbigny (1840, 1852) and Berthelin (1880) in a series of monographs, published the results of their studies on the foraminifera of the Gault Clay (Albian) of the Paris Basin. Since these works there has followed a wealth of published research on the Early Cretaceous foraminifera of the Paris Basin.

Marie (1938, 1939, 1941a-e, 1965) published a series of papers on the foraminiferal faunas from the Albian of the Aube and the Pas de Boulonnais. Bartenstein (1954) revised taxonomically the foraminifera discussed in Berthelin's Memoir (1880) on the foraminifera of Montcley. This provided the impetus for a revival of interest in the Early Cretaceous foraminifera of the Paris Basin.

Malapris-Bizouard (1965, 1967, 1974) and Magniez-Jannin (1965, 1967, 1968a, b, 1973, 1975, 1977) independently, together (1967) and with other authors (Magniez-Jannin & Rat, 1977) have been the most prolific workers on the Early Cretaceous (Barremian, Aptian, Albian) foraminifera of Northern France in recent years with not only in-depth taxonomic studies but also biostratigraphical studies on the fauna. Their work has been of exceptional value for the present study on the Early Cretaceous foraminifera of the southern North Sea Basin.
Baccaert (1973) published an important contribution on the planktonic foraminifera of the Upper Albian of Wissant and Pas de Calais. This prompted Price (1975, 1976, 1977a, b) to detail the biostratigraphical use of the planktonic, as well as the benthonic foraminifera of the Albian of the Aube and to relate the fauna to the rest of North West Europe.

Robaszynski, Amedro et al., (1980) have discussed in detail the biostratigraphy (micro and macrofauna) of the Aptian and Albian of Boulonnais. In their account there is a detailed history of previous foraminiferal research on the Early Cretaceous of northern France. Nevertheless, mention must be made of some of the more recent important publications which have proved invaluable during the compilation of this thesis. Harris's (1982) work, comparing and detailing previous biozonations for the Albian of southern England and France (Price, 1975, 1976, 1977a, b; Hart, 1973; Carter & Hart, 1977; and Magniez-Jannin, 1975) with his own, has proved to be of great value.

The work of Damotte & Magniez-Jannin (1973), has provided invaluable data to aid the identification of the foraminifera from the Early Aptian of the Isle of Wight.

It has been necessary in this subsection to restrict the discussion of research on the foraminifera of the Early Cretaceous to northern France. This area is geographically adjacent to the southern North Sea Basin.

The Early Cretaceous deposits of southern France also contain important foraminiferal faunas which have been discussed in the literature (e.g. Moullade, 1959, 1960a, b, 1966; Flandrin et al., 1962) and are important for identification purposes.
2.4 Radiometric dating of the Early Cretaceous

The Early Cretaceous lasted approximately from 135 million years B.P. to 100 million years B.P. Recently several attempts have been made to produce an acceptable time scale for the stages of the Early Cretaceous. Of especial note are the works of Casey (1964), Bandy (1967), Kauffman (1970) and van Hinte (1976). The stages discussed in this thesis are listed below, together with the radiometric dates proposed by van Hinte (1976):

<table>
<thead>
<tr>
<th>Ammonite Zone</th>
<th>Stage</th>
<th>Age M.Y.B.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cenomanian</td>
<td>100</td>
</tr>
<tr>
<td>7 biozones</td>
<td>Albian</td>
<td>107</td>
</tr>
<tr>
<td>7 biozones</td>
<td>Aptian</td>
<td>115</td>
</tr>
<tr>
<td>3 biozones</td>
<td>Barremian</td>
<td>121</td>
</tr>
<tr>
<td>8 biozones</td>
<td>Hauterivian</td>
<td>126</td>
</tr>
<tr>
<td>5 biozones</td>
<td>Valanginian</td>
<td>131</td>
</tr>
<tr>
<td>5 biozones</td>
<td>Ryazanian</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>Volgian</td>
<td></td>
</tr>
</tbody>
</table>

Van Hinte (1976) summarised and discussed the recent work on the problem of establishing an acceptable time scale for the Cretaceous but it is apparent that there is still a great deal of controversy and little agreement on an acceptable solution.

For instance, Lambert (1971) stated that the Cretaceous - Jurassic boundary may fall anywhere between -125 and -145 m.y.b.p. The controversial Albian/Cenomanian boundary is
discussed by van Hinte (1976) but despite the various estimates in the literature (Obradovich & Cobban, 1975; -95 or -94 m.y.b.p.; Rawson et al., 1978, -100 m.y.b.p.) Casey's (1964) figure is retained.

Radiometric data for the Early Cretaceous are scarce but van Hinte (1976) adequately sums up the available data in the formulation of his Cretaceous time scale.
CHAPTER 3

MATERIAL AND TECHNIQUES

3.0 Introduction

The material provided by Shell U.K. Exploration and Production Limited consisted of drill cuttings samples, sidewall core samples and wireline logs from the following boreholes:

44/2-1 Wireline logs: Sonic interval transit time
Gamma ray
Conductivity
Resistivity
Caliper
Cuttings samples (15) from 4850 to 5180 feet

49/10-1 Wireline logs: Sonic interval transit time
Gamma ray
Caliper
Cuttings samples (47) from 7010 to 7500 feet
Sidewall core sample (1) at 7255 feet

49/19-1 Wireline logs: Sonic interval transit time
Gamma ray
Caliper
32 slides of picked fauna from 2900 to 3350 feet
(from C.S. Harris, 1982, unpub., Ph.D.)

49/20-2 Wireline logs: Gamma ray
Formation density
Caliper
Cuttings samples (41) from 6500 to 7310 feet
Sidewall core samples (7) at 6732, 6900, 7070, 7097, 7177, 7242, 7282 ft.
49/24-1 Wireline logs: Gamma ray
Sonic interval transit time
Caliper
12 slides of picked fauna from 4260 to 4460 feet
(from C.S. Harris, 1982, unpub., Ph.D.)

49/24-3 Wireline logs: Gamma ray
Sonic interval transit time
Caliper
Cuttings samples (6) from 4840 to 5060 feet

49/24-4 Wireline logs: Gamma ray
Sonic interval transit time
Caliper
Cuttings samples (23) from 4700 to 4950 feet

49/24-12 Wireline logs: Sonic interval transit time
Caliper
Cuttings samples (25) from 4850 to 5340 feet

49/25-1 Wireline logs: Gamma ray
Sonic interval transit time
Caliper
Cuttings samples (46) from 6050 to 6970 feet

49/25-2 Wireline logs: Gamma ray
Sonic interval transit time
Caliper
Cuttings samples (50) from 6370 to 7400 feet

Total samples examined: 315

Further sidewall core descriptions were provided by Shell U.K. and are indicated in Chapter 6.
Additional material used is as follows:

The classic section in Britain of the marine Early Cretaceous at Speeton, Yorkshire, was sampled in order to provide comparative foraminifera from a section which has been studied extensively and dated by an independent biostratigraphy (e.g. Fletcher, 1966; Neale, 1969; Rawson et al., 1978) - 12 samples of approximately 0.5 kg. each.

The type locality of the Atherfield "Group" (Early Aptian) on the Isle of Wight was sampled and processed for foraminifera which were then identified for comparison with Aptian faunas from the southern North Sea. (This is presented in Chapter 12.) - 30 samples of approximately 1.5 kg. each.

The foraminifera in one sample of "Flammenmergel" from Brochterbeck, North West Germany were identified in order to provide a Late Albian fauna for comparative purposes. (Sample collected by Dr. H.W. Bailey & Prof. M.B. Hart.)

Borehole 549 from D.S.D.P. leg 80 in the Western Approaches (Goban Spur) cored an Early Cretaceous section. The Barremian/Aptian section was sampled and the contained foraminiferal fauna identified. (This is presented in Chapter 13.) - 15 samples.

Total samples examined: 58

Collections of Early Cretaceous foraminifera were examined at the following institutions for identification and comparison purposes.


4. Rijks Geologische Dienst, Haarlem, Holland; "in house" collection of European Early Cretaceous foraminifera; Hofker Collection; Ten Dam collection.


6. Collection of Early Aptian foraminifera from southern England of Mr. R.K.E. Jaworski, Cities Service (Europe-Africa) Petroleum Corporation; unpubl. research data.


Additional wireline log data for all of the published boreholes in the southern North Sea (U.K. Sector) were examined for Early Cretaceous strata. These data are housed in the Department of Energy Library, London.
3.1 Wireline Log Data

Wireline logs of each borehole were provided by Shell U.K. Exploration and Production Limited for correlation purposes. The main characteristics of each type of log provided are briefly discussed. Additional, and more detailed, information may be found in the manuals provided by the main wireline log service companies (Schlumberger, Dresser Atlas and Gearhart Industries).

All the wireline logs are the result of lowering a measuring and recording device down a borehole and the electric signals being recorded at the surface via a "wire line".

A. The Gamma Ray Log

This is a measurement of the natural radioactivity (in American Petroleum Institute units) of a rock formation. In sedimentary rocks this reflects the formation shale content. As radioactive elements tend to concentrate in clays and shales (20-60 API units), clean formations, such as sands, usually have a very low gamma ray response (10-20 API units). The gamma ray response is a function not only of the radioactivity and density of the formation but also of hole diameter since the borehole drilling fluid interposed between the counter and the formation absorbs gamma rays. The aspect of borehole diameter and out-of-gauge boreholes must be remembered when using the gamma ray response for correlation. Usually a caliper log is recorded on the same track as the gamma ray.

B. The Caliper Log

This is a wireline device which records the diameter of the borehole. This log reveals sections of the borehole which are under gauge, thus indicating swelling shales (or
an underbalanced drilling fluid), or overgauge thus indicating sections of the borehole which are "washed-out" e.g. sand sections, siltstone sections. The caliper log is important for the stratigrapher/micropalaeontologist as it can indicate sections of the borehole from where cavings are likely to have originated. The caliper log may also be used for correlation because it can be said to approximate a "weathering profile" log of the formations the bit has penetrated.

C. The Sonic Log

This is a recording, versus depth, of the time required for a compressional sound wave to traverse one foot of formation. The interval transit time, $\Delta t$, is the reciprocal of the velocity of the compressional sound wave and the value for a given formation depends on its lithology and porosity. Hard dense lithologies with low porosities give a low (fast) sonic response while soft porous lithologies give a high (slow) sonic response.

A porosity increase in a formation decreases the sonic velocity and correspondingly increases the $\Delta t$ value.

In conjunction with other logs (Gamma ray, Caliper, Formation density) the sonic response curve characteristics provide a good correlation tool and in some cases the $\Delta t$ value identifies a lithology, (e.g. sandstones, 55.5 - 51.1 $\Delta t$; Limestone, 47.6 - 43.5 $\Delta t$; shales, 50 - 100 $\Delta t$.)

D. Formation Density Log

This logging tool responds to the electron density (number of electrons per cubic centimetre) of the formation. This is related to the true bulk density which in turn
depends upon the density of the rock matrix material, the formation porosity, and the density of the pore fluid.

In this study this log was not very useful as a correlation tool as only one borehole was provided, by "Shell U.K.", with an F.D.C. log.

The detailed lithostratigraphical and correlation use of these wireline logs is discussed in the Lithostratigraphy Chapter of this thesis.

3.2 Samples

The samples used in this thesis are rotary borehole cuttings (commonly called "ditch cuttings"), sidewall core samples and standard onshore section samples (See Fig. 3.5).

A. Cuttings Samples

During the drilling of a borehole the formation is subjected to drill bit action and the crushed formation is released into the "mud stream" in the form of cuttings chips. The cuttings are carried to the surface, via the "annulus", by the drilling fluid (mud) which is then cleansed before being pumped down to the bit, via the ancillary equipment and drill pipe, to continue the cycle. Fig. 3.1 diagrammatically illustrates the complete drilling fluid circulation system used during drilling.

Cuttings always present problems for subsequent micropalaeontological analysis as they represent a mixture of the combined lithologies of a large section of the borehole. These problems depend on how the sample was drilled, how it was carried to the surface, and on how the sampling procedures at the surface were conducted. The processes and problems are briefly outlined in order to
Fig. 3.1
Diagrammatic illustration of the drilling fluid circulation system used in drilling.
Indicate how the sample quality may vary and thus affect conclusions drawn from lithological and micropalaeontological analysis.

Cuttings samples usually contain the following contaminants:

1) Cavings: These are cuttings from previously drilled intervals, rather than from the current interval, which have sloughed into the annulus from uncased higher sections of the borehole. They are usually large splintery fragments that are often concave or convex in cross-section (reflecting the borehole shape) and are lithologically identical with formations from higher sections of the uncased borehole. If cavings are found in large quantities they may indicate that a serious underbalanced drilling fluid condition existed or that rotation was too fast thereby causing the stabilisers of the drill string to catch on the side of the borehole.

11) Recycled cuttings: If cuttings are not efficiently removed from the drilling fluid at the shale shakers, desanders and desilters (see Fig. 3.1), they may be recycled through the drilling fluid system. Recycled cuttings may be recognised as small, abraded, rounded rock fragments in the sample.

Good cuttings sample quality is controlled by a number of factors:

a) Drilling fluid: The drilling fluid (mud) is very important as regards cuttings sample quality. The basic functions and
corresponding properties of a drilling fluid are:

1) To control subsurface pressures and to prevent caving (density - mud weight).

2) To remove cuttings from the borehole (viscosity).

3) To suspend cuttings when circulation is stopped (gel strength).

4) To cool and lubricate the drill bit and the drill string (oil and additive content).

5) To wall the borehole with an impermeable filter cake (filtrate - water loss).

6) To release the cuttings at the surface (viscosity and gel strength).

7) To help support the weight of the drill string and casing (density).

All of these functions are inter-related and good drilling fluid control is very important for sample quality as well as for safe drilling practice. The most important function of the drilling fluid for a stratigrapher/micropalaeontologist is to remove and to suspend the cuttings. The drilling fluid must carry the cuttings up the borehole annulus and suspend them when
circulation is stopped (e.g. to make a pipe connection). The most important factors involved in this function of the drilling fluid are:

1) Annular Velocity, that is:

$$\text{Pump Output (bbl/min)} \times \text{Annular Volume (bbl/ft)}$$

Usually this is maintained slightly higher than the largest cuttings slip velocity. Flow is maintained in a turbulent regime so as to keep the borehole clean.

2) Turbulent flow in the annulus is desirable for efficient cuttings removal.

3) Viscosity is the resistance that the drilling fluid offers to flow when pumped and it affects the ability of the drilling fluid to lift the cuttings out of the borehole.

4) Gel strength is the ability of the drilling fluid to develop as a gel when it stops moving so as to prevent cuttings and other solids in the drilling fluid from falling out of suspension.

In general, viscosity and gel strength should be low enough to allow cuttings to be removed at the shale shakers, desanders and
settling pits to prevent recycling and contamination.

b) Lag time: The lag time is the transit time between the bottom of the borehole, where the cuttings are generated by the drill bit, and the shale shakers where samples are collected. An accurate lag-time is essential for the precise depth location of each sample as it is "collected" at the surface. The lag time obviously changes with depth and because other factors also cause it to change it is imperative that the lag time is frequently checked and corrected during the drilling of a borehole.

A simple method of determining the lag time is to introduce a substance such as rice, barley, cellophane strips or lost circulation material (L.C.M., e.g. walnut shell chips) into the circulation system via the drill pipe at the surface when the "Kelly" is "broken off" during a "connection" and allowing the tracer to be pumped down the pipe, through the bit and back to the surface via the annulus. The tracer is then "picked up" on the shale shaker screen.

The number of strokes on the circulating pumps required to pump the tracer down the drill pipe and back up the annulus to the shale shaker is the circulation time. The lag time is the number of strokes after subtracting the number of pump strokes required to pump the tracer down the drill
pipe to the drill bit at the bottom of the borehole (i.e. the number of pump strokes required to displace the internal volume of the drill string).

Calcium carbide when placed as a tracer in the drill pipe will react with the water in the drilling fluid to form acetylene gas. This gas is recorded by the gas detector in the geological laboratory at the surface via a sensor (gas trap) at the shale shaker. This is easily the best method of calculating an accurate lag time. A carbide lag time takes into account variations in annulus diameter due to caving.

Calculating a lag time in pump strokes (rather than in minutes) takes into account pump efficiency, the times when the pumps are stopped (connections), and changes in pump rate.

A theoretical lag time calculation assumes that the borehole is exactly in gauge throughout which is not usually the case. It is a calculation of the time required to displace drilling fluid in an annulus of known inner and outer diameter. With variations in borehole size or casing size and when a tapered drill string is used (drill pipe and drill collars) separate calculations must be made for each annulus size.

Calculations of lag time do not take into account cuttings slippage, or cuttings
Fig 3.2

Shale shakers

vibrating mesh screen

sample catching point
elutriation, in the annulus. However, a borehole with good drilling fluid control will keep the error in lag time due to these two factors to a negligible amount.

Good drilling fluid control and accurate lag time calculations are extremely important for sample quality and it is essential that a stratigrapher/micropalaeontologist understands the problems involved when working with cuttings samples from a borehole.

c) Sample interval and sampling procedure: All drilling rigs have shaker screens for separating the cuttings from the drilling fluid when they reach the surface. The shaker screen (Fig. 3.2) provides the main collection point for sampling but if unconsolidated fine sands and siltstones are encountered they usually pass through the screens. These lithological components are extracted from the drilling fluid by desanders and desilters which provide another sample collection point (see Fig. 3.3).

A representative sample is taken at the shale shakers of the whole sample interval. A tray is usually placed at the end of the shale shaker screen to catch the cuttings. This tray is cleansed after every sample so that only cuttings of the relevant sample interval are contained within it. This, from the author’s own experience, reduces contamination and also ensures that a representative sample is collected.
Desander & desilter hydroclone arrays
However, it is also possible only to collect a sample off the shaker screen when the end of the sample interval is "up" across the shakers. This form of sampling is unsatisfactory as it does not truly represent the whole of the sample interval but is in reality a "spot sample".

Good sampling practices at the well site ensure good quality samples for the micropalaeontologist.

Samples are usually taken at specific depth intervals which will vary according to the drill rate and the rate at which samples can be caught and processed at the surface.

One extreme is during tophole (surface hole) drilling where a 300 feet per hour rate of drilling is not uncommon. Samples would be taken every 30 feet (i.e. every single or Kelly down). This is one sample every six minutes which, from personal experience, is at the limit of adequate and reliable "sample catching" and data analysis.

At greater depths where the formation is more consolidated the drill rate is slower and the sample interval is correspondingly less. At 100 feet in an hour drilling rate there is time to sample every 10 feet which again gives one sample every six minutes.

A representation of a borehole being drilled is illustrated in Figure 3.4 and portrays the concept of sample interval, lag time and
Diagrammatic illustration showing the relationship of actual depth to samples in the annulus to lag time.
sample catching. The annulus is the route by which the cuttings travel to the surface. The cuttings in the drill fluid represent a continuous column of lithological data moving up and out of the borehole.

When the bottom hole depth was 10,000 feet the total pump strokes counter was zeroed. The lag time was 4000 strokes and cuttings from that depth (newly drilled) started up the borehole. When a depth of 10,010 feet was reached the total pumpstrokes registered 1000. As this 10 feet of borehole was being drilled, the cuttings from this interval were released into the annulus. The bit continued to drill while the cuttings from this interval were travelling up the annulus in the drilling fluid. When the pumps had made 3000 more strokes the total pumpstrokes were 4000 and cuttings from the top of the interval (10,000 feet) began to pass over the shaker screen to fall into the sample tray. Cuttings collected in the tray after 5000 pumpstrokes (i.e. after 1000 pumpstrokes more) will be from the beginning of the next intervals (19,010 - 10,020 feet).

The same procedure was followed for successive samples though obviously the total pumpstrokes counter was not zeroed. The 10,010 - 10,020 feet sample started at 1000 strokes.

A lag time of 4000 pumpstrokes meant that 5000 strokes would be registered before the
top of that interval crossed the shale shaker. If that interval took 2000 pumpstrokes (i.e. total 3000 on the pumpstroke counter) to drill (a slower drill rate, or an increase in pump rate) the bottom of that interval (10,020 feet) will cross the shaker at 7000 pumpstrokes on the counter.

B. Sidewall Cores

Sidewall cores are the result of a coring method used in parts of the borehole where recovery by conventional methods was small or where conventional coring was not carried out during drilling.

The sidewall coring device, a chronological sample taker (C.S.T.), is lowered into the borehole on a "wireline cable" and a sample of the formation is taken at the desired depth. A hollow "bullet" is shot into and then pulled out of the side of the borehole. A gamma ray curve or other wireline log can be used to position the C.S.T. by direct log correlation. One gun usually has 30 bullets but 2 guns may be used hence up to 60 cores can be obtained in one "run". The sidewall cores are small (1 x 2 1/2 inches) and usually have a small amount of mudcake adhering to them.

It is usually assumed that sidewall cores provide an uncontaminated sample of formation for micropalaeontological analysis. However, from personal experience, microfossils can be entrained in the "mud" system and incorporated into the mudcake on the borehole wall and thus incorporated into the sidewall core as a contaminant. Sidewall cores have to be carefully scraped clean of mudcake before being processed in the usual
manner for microfossils.

Sidewall cores provide a sample of formation which is precisely located and are very important for micropalaeontological analysis.

C. Conventional Cores

Conventional cores are taken at the time of drilling by means of a specialised drill bit designed for that purpose (diamond core bit and barrel). When the core is retrieved at the surface it is wiped clean and sampled at various points. These "core chips" are then used for micropalaeontological analysis. None of the North Sea boreholes studied has a cored section through the Early Cretaceous. The only core material used in this thesis is from D.S.D.P. Leg 80, Site 549.

D. Onshore Section Samples

Samples from onshore sections were taken at precisely located intervals. At Atherfield the section was measured and samples of approximately 1.5 kilogrammes were taken every one metre. The section was first cleaned and samples as fresh as possible were collected.

Samples from the classic Speeton Clay section at Filey Bay were taken at points located by Prof. John Neale with reference to the detailed lithostratigraphy of Fletcher (1966, unpub., Ph.D.). Samples from the Speeton Clay weighed approximately 0.5 kg.
3.3 Sample Preparation

A. At the wellsite: The method of sample preparation at the wellsite of the cuttings samples studied is not precisely known. The cuttings samples were received in Plymouth already dried, labelled and sealed in plastic bags. The cuttings samples appeared to be unwashed and to represent a portion of the sample as it appeared over the shale shaker screens.

The side wall core samples were already washed, dried, sieved and picked for microfauna and only the picked microfauna was provided.

The conventional core samples had already been washed and broken down and only the unpicked residues were provided.

B. Sample processing and examination in the laboratory: All the samples were dried, weighed and described lithologically with reference to the A.A.P.G. Sample Examination Manual (Swanson, 1981).

Each sample from the wells studied for foraminifera was repeatedly washed through a 200 micron mesh sieve until clean of all clay particles. The residue was then dried and passed through a multi-storey nest of sieves (500 um, 250 um, 180 um, 125 um, base tray). Each sieve fraction was examined for foraminifera but only the 500 um, 250 um and 180 um sieve size fractions were picked (using a sable 000 brush, picking tray and binocular microscope), described and identified and used in the analysis. The complete foraminiferal fauna in these sieve size fractions was picked, placed in faunal slides and sorted into species.
3.4 Foraminiferal Analysis

Sophisticated statistical techniques are considered unnecessary. If performed, the results are invalid because of the inherent drawbacks of using cuttings samples. A simple planktonic/benthonic ratio method of comparing onshore sections and also for comparing the offshore boreholes was attempted. The results using the 500 μm, 250 μm and 180 μm sieve size fractions are tentative and are for correlation purposes, and for the recognition of "events" only. The author recognises and acknowledges fully the limitations of such a procedure when dealing with borehole cuttings samples but nevertheless bulk faunal changes can be recognised (Carter & Hart, 1977; Price, 1977a, b).

A simple biometric study was only performed on one species - Osangularia schloenbachi (Reuss), in order to indicate its true stratigraphical range. This is fully discussed in Chapter 16.

The foraminiferal faunas from each studied borehole and section studied were plotted in order of their first appearance downhole using the symbols provided by the "Shell standard legend" (see Chapter 7) to indicate their abundance or rarity (see Fig. 3.5).

3.5 Scanning Electron Microscope Photography

Before the specimens were photographed they were cleaned using a moist brush and water, dilute hydrogen peroxide, alcohol and xylene baths. The specimens were mounted on "stubs" using standard double sided clear adhesive tape. The glue on the clear adhesive tape was smoothed and thinned using xylene. The specimens, after careful mounting, were coated with 100 angstroms of gold using a Vacuum/Argon "Sputter" coater. This relatively easy mounting and coating procedure provided a "quiet" (black) background not prone to cracking and charging under the electron beam.
Fig. 3.5 SAMPLE EXAMINATION LEGEND

NF No Fauna

* 1 Specimen
/ 2 - 5 Specimens
O 6 - 20 Specimens
O 21 - 100 Specimens
□ 100 Specimens

□ Core Sample
▷ Sidewall Core Sample
○ Ditch Cutting Sample
◇ Surface sample, except Fig. 12.3
The specimens were photographed using either a Jeol J.S.M. 35C Scanning Electron Microscope or a Jeol T.20 Scanning Electron Microscope both with photographic attachments (in the Plymouth Polytechnic Electron Microscope Unit).
CHAPTER 4

THE GEOLOGICAL SETTING OF THE STUDY AREAS

4.0 Introduction

This section deals with the main study area in the southern North Sea Basin. The subsidiary study areas of the Goban Spur and the Isle of Wight are discussed in Chapters 12 and 13.

4.1 Overall Tectonic Setting

The tectonic setting and structural framework of the three study areas are illustrated in Fig. 4.1.

A. The Southern North Sea Basin

This is a regional name for the whole of the basin area south of the Mid-North Sea High and north of the London-Brabant Massif. It is bounded to the west by the Pennine High. The main Mesozoic structural element in this area is the structurally complex Anglo-Dutch Basin, situated to the south of the Mid-North Sea High, which trends from the Yorkshire coast south eastward into Holland. To the south it is structurally limited by the Dowsing Fault Zone which separates it from the East Midland Shelf and the London-Brabant Massif (Kent, 1975a, b). The Sole Pit Basin and the succeeding Sole Pit High occupy a north west - south west trending area north of the Dowsing Fault Zone (Glennie & Boegner, 1981).

The Texel - Ijsselmeer High in Holland separates the Central Netherlands Basin from the north-west German Basin and the Lower Saxony and East Netherlands Basins. The Central Netherlands Basin is separated from the West Netherlands Basin to the south by the structurally complex and narrow Zandvoort Ridge.
THE STRUCTURAL SETTING OF THE STUDY AREAS ON THE NORTH WEST EUROPEAN CONTINENTAL SHELF.
The Anglo-Paris Basin

This basin south of the London-Brabant Massif includes the Wealden Basin and the English Channel Basin. The whole region, which includes the subsidiary study area on the Isle of Wight, is structurally complex and consists of sedimentary depocentres (Allen, 1981; Casey, 1961; Stonely, 1982). The whole area within the U.K., onshore and offshore, is an area of active hydrocarbon exploration (Colter & Havard, 1981).

Western Approaches Basin

The Start-Cotentin High and Lizard-Brittany High separate the Anglo-Paris Basin from the Western Approaches Basin and the other complex Mesozoic basinal areas on the continental shelf to the west of the United Kingdom. This area has been described by Roberts et al., (1981) and other authors in Woodland (ed., 1975) and Illing & Hobson (eds., 1981) and is discussed further in this thesis in Chapters 11, 12 and 13.

Summary

The Mesozoic structures of North West Europe are a complex combination of basinal areas initiated during the Mesozoic and of basins inherited from the Palaeozoic.

Rhys (compiler, 1974), Deegan & Scull (compilers, 1977), Ziegler, P.A. (1975, 1981), Kent (1975a, b) and Roberts et al., (1981) as well as numerous other authors on the geology of the continental shelf of North West Europe (Woodland, ed., 1975; Illing & Hobson, eds., 1981) all mention numerous structures, basins, highs, and fault zones with, in most cases, duplication and overlap of
terminology and definition. This illustrates the complexity of the basinal evolution of North West Europe and the attempts of various exploration companies to establish their own geological terminology for the area.

4.2 Geological History of the North Sea

A detailed structural and geological history of the study area within the framework of North West Europe is not attempted. The main works consulted during the preparation of this study are Kent (1975a, b), Ziegler, P.A. (1975, 1981), Ziegler, W.H. (1975) and other papers in Woodland (ed., 1975) and Illing & Hobson (eds., 1981).

North West Europe has undergone a long and very complex geological evolution. Ziegler (1981) recognises four main stages of development during the Phanerozoic.

A. The Caledonian and Hercynian suturing of Pangea

B. The Permo-Triassic instability of the Pangean megacontinent

C. The Mesozoic opening of the central and northern Atlantic and the onset of the Alpine plate collision

D. The Cenozoic opening of the Norwegian - Greenland Sea, the Alpine Orogeny and the late orogenic collapse of the Alpine fold belt.

Selley (1981) has summarised the available data and reviews the development of the North Sea using Ziegler's (1981) framework as a model. This is outlined here.

The end of the Carboniferous Period marks the beginning of an important phase in the geological development of the North Sea.
Fig. 4.2

Schematic development of the North Atlantic during the Cretaceous.
(From Selley, 1981)
which continues to the present day. Instead of the European and Greenland-Laurentian plates suture being the important axis of geological development a phase of crustal tension heralded the formation of the Atlantic Ocean (see Fig. 4.2).

In a region to the north of the northern North Sea a major triple rift junction developed. During the Permian the rift floors were above sea level and were infilled by red conglomerates, sandstones and shales of a continental nature. Sporadic incursions of marine waters resulted in the deposition of evaporites, limestones and dolomites.

Plate separation and extension and subsidence of the rift floors ensued until a final invasion of the sea occurred during the Rhaetic. This marine sedimentation of mudstones, sands and limestones continued throughout the Jurassic. Coeval fault movements (collectively termed Cimmerian by some authors) occurred causing a number of features discernable in the stratigraphical record e.g. syn-sedimentary thinning, facies changes, and erosion of structural crests (termed Base Cretaceous Unconformity in this thesis) marks the culmination of this major phase of movement and a change from rifting to drifting. The succeeding Cretaceous sediments onlap the structural and stratigraphical units below the unconformity (Johnson, 1975). Active rifting and sea floor spreading occurred in the northern limbs of the triple-rift junction with the formation of the Norwegian Sea and opening of the North Atlantic. The Viking and Central Graben rift failed to become an active zone of sea floor spreading.

The Cretaceous was a period of relative structural quiescence but associated intervals of marine regression and transgression resulted in minor unconformities and periods of non-deposition. During the Early Cretaceous there were episodes of volcanic activity associated with sea floor rifting and spreading (Zimmerle, 1979).
Subsidence continued during the Cretaceous and Tertiary as shown by syn-sedimentary thickening into the centre of the North Sea Basin.

Significant structural movements during the Late Cretaceous resulted in the inversion of some sedimentary depocentres (Glennie & Boegner, 1981) e.g. the Wealden Basin; the West Netherlands Basin, the Sole Pit Basin. These movements, resulting in axes of inversion, were initiated in the late Early Cretaceous and progressed until the end of the Cretaceous and beginning of the Cenozoic (Laramide).

Late Cenozoic isopachs indicate that subsidence continued in the Viking and Central Grabens but as a closed intracratonic basin.

4.3 The Distribution and Regional Setting of Early Cretaceous Sediments in North West Europe

Throughout the Early Cretaceous there was an archipelago of changing proportions situated to the north of the main London-Brabant Massif, which extended from eastern England through Holland to North West Germany (Kemper, 1973a, b; 1979; Neale, 1973; Owen, 1979; Michael, 1979). The North Sea region was separated from the Tethys ocean in the south by a land mass extending from Ireland, through Wales and central England via the London-Brabant Massif across to the Rhenish Massif and Bohemia. Marine connections were to the north through the northern North Sea and thence to the proto-northern North Atlantic, and to the east through Germany and Poland. Intermittent marine influence probably extended across central southern England into the Wealden Basin via the Cambridgeshire-Bedfordshire straits (Kaye, 1963; Casey, 1963).

This archipelago region was part of a series of shallow water epicontinental shelf seas which fringed the southern edge of the
A. intermittent connection through the Western Approaches area.
B. intermittent connection through the Vocontian Trough area
C. Shallow epeiric sea with numerous island archipelagos, shoals, and narrow straits.

Fig. 4.3

Boreal ocean to the north (centred on the present day Arctic Ocean) and extended southward over parts of North America, northern Europe and Siberia (see Fig. 4.3 for a palaeo reconstruction). This broadly corresponds with the Boreal realm/province (zoogeographical) but includes marginal areas (North West Europe) which at times during the Early Cretaceous had Tethyan faunal influences (Price, 1976; Crittenden, 1982a, 1983a, b; Colin et al., 1981; Michael, 1979).

The Tethyan and Boreal Early Cretaceous seas were never completely separated even in phases of maximum regression (Berriasian/Ryazanian; Rawson, 1973) and a mixture of transient and more permanent sea ways existed along which faunas could migrate. However endemic benthonic foraminiferal faunas did exist in times of fewer connections (Kemper, 1973a, b, 1979).

In North West Europe the principal marine connections to the North Sea region were:

A. The Cretaceous North Atlantic seaway linking western Tethys with the Boreal Ocean via a narrow strait between East Greenland and the Scandinavian shield. This epicontinental seaway became a true ocean with the development of active sea floor spreading. This seaway provided Tethyan faunal links with the northern North Sea (marine currents, proto-Gulf stream?).

B. The Danish–Polish Furrow, which was an intermittent marine connection between the northern North Sea and north Tethys (Carpathians (Samuel & Salaj, 1966), Poland (Gawor-Biedowa, 1972), Rumania (Neagu, 1975)). This connection was presumed to be open to Germany during the Ryazanian, Valanginian and Hauterivian but was closed during the Barremian (Norling, 1981).
The Cambridgeshire-Bedfordshire Seaway was an intermittent marine connection during the major part of the earliest Cretaceous between the northern Boreal Ocean and the basin of deposition to the south of the London-Brabant Massif (Kaye, 1963). This seaway became a true connection during the Aptian and heralded the submergence, during the Albian, of the palaeoland masses which separated the northern and southern areas of deposition of the U.K.

The southern North Sea Basin belongs to a basin system which includes the northern North Sea, eastern England (Yorks, Humberside, Lincs. & Norfolk), the Netherlands, West Jutland, the north-west German Basin and regions further north such as Sweden (Norling, 1981) as well as the German Lower Saxony Basin (Kemper, 1973a, b, 1979). The Lower Saxony Basin was partially separated from the North Sea by an archipelago feature (Pompeckjs Swell) consisting of numerous islands, shoals, shallows, straits and bays (Kemper, 1973a, b, 1979).

From Valanginian to Middle Albian times only narrow connections existed between the North Sea and the Lower Saxony Basin (Kemper, 1973a, b, 1979) through the Pompeckjs Swell.

During Early cretaceous times the Mid-North Sea High probably acted in the same manner in restricting sea water circulation and faunal influences from the north.

Within the context of the distribution of Early Cretaceous sediments it is important to recognise the areas of non-marine sedimentation. South of a line from London to the northernmost tip of Denmark and from London to Northern Ireland non-marine and transitional marine sediments were deposited and are commonly overlain by marine sediments. The major areas of non-marine deposition seem to be intimately associated with the Early Cretaceous sea level low (Vail et al., 1977) and with areas of deposition near the continental margin of the spreading Atlantic...
Fig. 4.5 Sub-crop map beneath the Base Cretaceous Unconformity (from Fyfe et al., 1981)
ocean and shallow epicontinental sea areas. The detailed and complex geology of these "Wealden" basins of deposition is a result of repeated uplift and erosion of surrounding horsts (P. Allen, 1981). Within these "Wealden" sediments there are very rapid vertical and lateral facies changes coincident with advancement and recession of deltas. Numerous brackish marine incursions particularly in the Weald Clay and Upper Wealden of south east England foreshadow the Aptian transgression. Subsequently some of these areas become axes of inversion during the Late Cretaceous and Early Tertiary.

The Base Cretaceous Unconformity in the Southern North Sea Basin

The diachronous nature of this unconformity in the southern North Sea Basin is due to tectonic activity, salt diapirism and eustatic sea level changes (see Section 4.6). In this thesis a purely descriptive term - the Base Cretaceous Unconformity - is used and is derived from a knowledge of the local stratigraphy. An interpretive term such as Late Cimmerian Unconformity derived from a knowledge of regional stratigraphy and the basin evolution of north west Europe is not used. Cimmerian is a confusing term applied by a number of authors to a number of different periods of tectonic movement in the Mesozoic (Johnson, 1975). The terms Early, Middle and Late Cimmerian are usually imprecisely used. Generally Late Cimmerian refers to tectonism in the Late Jurassic and Early Cretaceous.

In the northern North Sea this distinctive basal Cretaceous event has been discussed by Johnson (1975). The same event is just as distinctive in the southern North Sea Basin (Fig. 4.4).

Tectonic uplift of the basin margins and a eustatic fall in sea level at the end of the Jurassic resulted in considerable erosion of the North Sea area. Continuous Late Jurassic - Early Cretaceous marine deposition in the southern North Sea Basin is restricted to a few isolated areas (Day et al., 1981; Rawson, 1973).
Fig. 4.6 Lap-out map of the Cretaceous in the study area

(from Fyfe et al., 1981)
Some marginal areas of North West Europe have a continuous sequence of Jurassic-Cretaceous deposits via paralic, non-marine, sedimentation (Wealden) e.g. the Weald (Casey, 1961), the West Netherlands Basin (Bodenhausen & Ott, 1981) and Sweden (Norling, 1981). Subsequent inversion tectonics and erosion has removed much of the strata from across the Jurassic-Cretaceous boundary in the study area (Sole Pit High). None of the studied boreholes has a continuous sequence.

Fyfe et al., (1981) discuss comprehensively the Base Cretaceous Unconformity as featured on seismic data. The subcrop map and lap out maps, for the unconformity, of Fyfe et al., (1981) are reproduced as Figs. 4.5 and 4.6.

These maps illustrate the Early Cretaceous overstepping onto the Early Jurassic in the western part of the Indefatigable area (Block 49) and, to the east of the same area, the Early Cretaceous overstepping on to progressively older Triassic formations. Overlap also occurs since the basal beds are variously pre-Aptian to Aptian-Albian in age.

The thickest Early Cretaceous sequences are in boreholes located in Cretaceous depositional centres. This is shown in Fig. 5.16 (from Glennie & Boegner, 1981). Boreholes located on pre-Cretaceous structural highs show attenuated Early Cretaceous sections, often with some of the basal sequence missing (see 49/24-3, Fig. 5.9).

The pattern of Cretaceous sedimentation has been strongly influenced by the pre-Cretaceous highs (horst blocks, fault blocks), and transgressions during the Early Cretaceous have resulted in Early Cretaceous sediments onlapping the highs. By Late Aptian times most of these structures had been covered (see section 4.6).
Structural outline of the British southern North Sea and the location of the study area on the north east flank of the Sole Pit High. (from Glennie & Boegner, 1981, hatchured areas are diapiric salt walls).
This structural/stratigraphical relationship of the Basal Cretaceous Unconformity is recognised in most of the boreholes drilled in the southern North Sea Basin (e.g. borehole 49/24-3 has Albian Red Chalk lying directly on Bunter Sandstone while borehole 49/20-2 has Speeton Clay/Vlieland Shale directly on Bunter Sandstone, Fig. 5.8).

4.5 Tectonic Setting of Block 49

Block 49 is situated on the north eastern flank of the Sole Pit High (inversion axis), (see Fig. 4.7).

The Sole Pit High came into being during the Cretaceous - earliest Tertiary as a result of structural inversion of a basinal area of deposition. It occupies a north west - south east trending area which is limited to the south west by the Dowsing Fault Zone, to the east by a combination of a steep synclinal flexure and a series of north northwest - south southeast trending en echelon faults (the Swarte Bank Hinge, Glennie & Boegner, 1981). The crest of the high has suffered erosion and the geological history from the Liassic onwards is not known. However, from a study of the flank areas it can be seen that the geological history of events differs from flank to flank.

Glennie & Boegner (1981) have noted the inherent differences between the two flanks. There was more or less continuous subsidence during the Mesozoic until a Late Cretaceous uplift on the southwest flank, (figs. 3c & 5a of Glennie and Boegner, 1981) while the north east flank had Mesozoic subsidence interrupted by a phase of Early Cretaceous uplift and erosion (Fig. 4.8). This uplift was easily demonstrated by Glennie & Boegner (1981) who studied the burial histories of a number of boreholes drilled on the two flanks of the Sole Pit High. The burial history for the three boreholes they studied on the north east flank are reproduced here (Fig. 4.8). Two of these boreholes (49/10-1 & 49/24-1) have been studied in this thesis.
Fig. 4.8

Burial histories of three boreholes from east of the Sole Pit area which show the Early Cretaceous phase of uplift. (from Glennie & Boegner, 1981)
Sea Levels during the Early Cretaceous

Sea level in North West Europe (and the rest of the world) at the beginning of the Cretaceous, after the eustatic fall in sea level at the end of the Jurassic (Vail et al., 1977; Hallam, 1978), was exceptionally low. Despite oscillations of sea level the overall trend during the Early Cretaceous was upward. A regional synchronicity of regressions and transgressions in North West Europe supports a eustatic model (Fyfe et al., 1981) but tectonic activity associated with the opening of the Bay of Biscay and the north Atlantic precludes comparison with the Goban Spur area.

During the Early Cretaceous, facies in the North Sea region were controlled by tectonic setting (local and regional), climate and availability of source material (Vail et al., 1980; Hancock & Kauffmann, 1979; Cooper, 1977).

Global changes of sea level plus regional and local tectonic events appear to have played a major part in the distribution and character of Early Cretaceous sediments in the North Sea Basin.

Various models have been proposed for relative changes and eustatic changes in sea level, both on a global scale and on a regional scale (Fig. 4.9). There is agreement on the major lowstands and highstands during the Early Cretaceous (Pitman, 1978; Sleep, 1976; Vail et al., 1980). These changes have been detailed and compared to the North Sea area by Vail et al., (1980), (see Fig. 4.9). Finer detail of the cycles of transgression/regression, such as published for the Jurassic, for the Early Cretaceous have not been released for publication (Vail et al., 1980).

Whether the model discussed by Vail et al., (1980) is applicable for the southern North Sea Basin is difficult to say from the
Global cycles of relative change of sea level during Jurassic-Tertiary time. Cretaceous cycles (hatched area) have not been released for publication.

### Table: Estimated Eustatic Changes of Sea Level

<table>
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Estimation of eustatic changes in sea level

(a) Pitman's (1978) and Pitman Hays' (1973) calculated sea level curve based on rates of sea floor spreading and volume of mid-ocean ridges.

(b) Pitman's (1977) curve from (a) overlain on global curve of relative changes of sea level.

(c) Best estimate of eustatic changes of sea level, calibrated from Pitman's (1977) curve.

Fig. 4.9

Cretaceous Sea Level curves (from Vail et al., 1980).
limited amount of data available. In the southern North Sea Basin eustatic changes may be very difficult to separate from apparent sea level changes caused by local tectonic and halokinetic activity.

4.7 Climate during the Early Cretaceous

From Figs. 4.3, 4.5 and 4.6 it can be seen that during the Early Cretaceous there were large areas of land. These areas were eroded and the resulting clastic detritus was deposited in a number of marine and non-marine depositional centres (P. Allen, 1981). Plant fossil evidence (e.g. Hughes, 1976) from onshore outcrop data and offshore borehole data suggests that there was lush vegetation on land areas adjacent to the North Sea Basin. This fact, coupled with large quantities of clastic detritus (coarse and fine grained), suggests that the climate was sufficiently seasonal (with high humidity, temperatures and rainfall) to allow erosion of the land areas (P. Allen, 1975, 1976, 1981 and Anderton et al., 1979). However, there is evidence that during the late Early Cretaceous (Upper Albian) the climate became more arid. This is perhaps associated with the rise in sea level, peneplanation of the land areas and changes in oceanic circulation associated with the development of the north Atlantic. The result was clear, shallow, semi-tropical seas with deposition of carbonate rich sediments (Eller, pers. comm.) in the southern North Sea area heralding the subsequent widespread chalk sea of the Late Cretaceous.
PART 2

ANALYSES
CHAPTER 5
LITHOSTRATIGRAPHY

5.0 Introduction

The ten boreholes used in this study were initially correlated using wireline log characters and the lithological description of the samples. From these data a correlation to other boreholes in the southern North Sea, onshore Netherlands and to onshore U.K. outcrop sections may be made. A further lithological/wireline log subdivision of the main units has also been attempted using discrete wireline log markers and this allows a finer correlation within the study area of Block 49 to be made.

5.1 Discussion of previous Lithostratigraphical Nomenclatures

During the last decade four major publications have proposed lithostratigraphical schemes for the Early Cretaceous in the British sector southern, central and northern North Sea Basin (Rhys, compiler, 1974, 1975; NAM & RGD, compilers, 1980; Deegan & Scull, compilers, 1977, see Fig. 5.1).

A further publication by Burnhill & Ramsay (1981) has discussed Middle Cretaceous lithostratigraphy, and the wireline log characteristics of each unit, of the U.K. central North Sea (as defined by Deegan & Scull, 1977, see Chapter 11).


Of the two schemes the lithostratigraphical subdivision of the Dutch sector is more detailed. This is perhaps a result of the greater economic importance in the Dutch sector of the Early
Fig. 5.1 Diagrammatic comparison of the Lower Cretaceous lithostratigraphic nomenclatures in the North Sea (from Rhys, 1974; Deegan & Scull, 1977; NAM & RGD, 1980 and Crittenden, 1982).

A is the Tezel Greensand Member. B is the Holland Greensand Member.
Fig. 5.2
Location of the studied boreholes in the southern North Sea Basin
Cretaceous with its reservoirs of hydrocarbons. The subsequent detailed exploration activity by oil companies to find and delineate the reservoirs has resulted in a large amount of available data. As yet the Early Cretaceous strata in the British sector of the southern North Sea have not been considered a prime economic target for hydrocarbon exploration and as a result a detailed lithostratigraphical subdivision has been considered less important.

The two independent schemes proposed for the southern North Sea Early Cretaceous are the result of an international boundary and not of geological differences. The boreholes from Block 49 (Fig. 5.2) of the British sector, from other blocks in the British and Dutch sectors and from onshore U.K. and Holland are used in this thesis to illustrate the compatibility of both the lithostratigraphical schemes and the relative ease with which one borehole may be correlated with another. The relevant Dutch sector boreholes are from NAM & RGD (1980), (see Figs. 5.3, 5.4 and 5.5).

The scheme proposed by Rhys (1974) is useful and has proved to be a base upon which to build and develop a lithostratigraphical scheme for the central and northern North Sea (Deegan & Scull, 1977).

The Dutch scheme (NAM & RGD, 1980) however, is well established and has been used as a viable hydrocarbon exploration tool by the Nederlandse Aardolie Maatschappij B.V. since 1949. The British scheme of Rhys (1974) has not been used extensively as an exploration tool in the British southern North Sea and its potential shortcomings and inadequacies have not been recognised but neither has the terminology become too entrenched in the literature (offshore areas).
5.2 The U.K. versus the Dutch Scheme in the Southern North Sea

Rhys (1974) subdivided the Early Cretaceous strata (Cromer Knoll Group) into three formations: Red Chalk Formation, Spetton Clay Formation and Spilsby Sandstone Formation. Rhys (1974) designated borehole 48/22-2 (Burmah) as the type section and borehole 49/24-1 (Shell/Esso) as a reference section (see Figs. 5.6 & 5.7).

NAM & RGD (1980) subdivided the marine Early Cretaceous strata of the Dutch sector into two formations: the Vlieland Formation and the Holland Formation, together forming the Rijnland Group. A further subdivision of the two formations into members distinguishes the Dutch scheme from the British scheme. The British scheme is also amenable to subdivision. In fact the same subdivisions as the Dutch scheme can be applied (see Figs. 5.7, 5.8, 5.9 and 5.10).

The Vlieland Formation is divided into the Vlieland Shale Member and a basal Vlieland Sandstone Member. However, in the West Netherlands Basin, a number of hydrocarbon bearing sandstone bodies are present in the Vlieland Formation and are each given member status. All of these sandstone bodies pinch out northwards into the Vlieland Shale Member and are in fact only present as east-west orientated lenses on the southern margin of the basin. These represent the gradual transgression of the Early Cretaceous Sea on to the London-Brabant Massif (Bodenhausen & Ott, 1981, see Fig. 5.11). The sandstone bodies present within the Vlieland Formation are probably represented in the British sector by thin sandstone intercalations within the Spetton Clay Formation. The Vlieland Sandstone Member is the Dutch equivalent of the Spilsby Sandstone Formation which apparently has a limited occurrence adjacent to the Lincolnshire and Norfolk coast (Glennie & Boegner, 1981). The Vlieland Formation is therefore represented in the British sector by the
Fig. 5.3 Composite log of a borehole in the Dutch sector of the southern North Sea to show the similarity to boreholes in the British sector. (From NAM & RGD, 1980)
**Fig. 5.4**

Composite log of a borehole in the Dutch sector of the southern North Sea to show the Upper Holland Marl (from NAM & RGD).
Fig. 5.5 Composite log of the Vlieland Oost - 1 well - reference borehole for the Rijnland Group (from NAM & RGD, 1980)
Speeton Clay Formation and Spilsby Sandstone Formation.

The Holland Formation (which lies above the Vlieland Formation) is subdivided into three distinct members in the Dutch southern North Sea: The Upper Holland Marl Member, the Middle Holland Shale Member and the Lower Holland Marl Member. A fourth member, the Holland Greensand, is present between the Lower Holland Marl Member and the Middle Holland Shale Member on the southern margin of the basin but it rapidly shales/thins out to the North and is not seen as such in Block 49. However, at or near the base of the Middle Holland Shale in the southern North Sea there is usually a thin basal sand/conglomerate or silty horizon (e.g. see 49/24-1, 4410 feet; and 49/24-12, 5060 feet; Figs. 5.8, 5.9 and 5.10).

The Holland Formation embraces part of the Speeton Clay Formation and all of the Red Chalk Formation of the scheme of Rhys (1974), (see 49/24-1, Fig. 5.7). The Upper Holland Marl Member seems to be, from wireline log and lithological evidence, directly equivalent to the Red Chalk Formation, while the Middle Holland Shale and Lower Holland Marl Members are both equivalent to the upper part of the Speeton Clay Formation (again from wireline log and lithological evidence). A comparison of the three boreholes illustrated by NAM & RGD (enclosure 24, 27 & 28, 1980; see Figs. 5.3, 5.4 and 5.5) with the boreholes from Block 49 shows the remarkable similarity and ease of correlation of the wireline log pattern and lithology of the Early Cretaceous strata across the southern North Sea Basin.

5.3 Lithostratigraphical Method

Wireline logs of boreholes, especially the gamma ray and sonic interval transit time, accurately reflect the lithology of the strata penetrated by the drill bit. However, the caliper log is used in borehole 49/24-12 and the F.D.C. log in borehole 49/20-2. This is because the gamma ray and sonic logs respectively were
BURMAH 48/22-2 WELL

Co-ordinates: 53° 15' 34" N
01° 22' 36" E

Scale 1:1,000

RED CHALK FORMATION
Mudstone, calcareous to slightly calcaeous, red brown with consistent small amounts of white to light grey mottling and lesser dark grey mottling.

SPEETON CLAY FORMATION
Mudstone grading to shale with depth, slightly calcareous (occasionally very calcareous), light brown to grey becoming predominately greyish olive green with depth, traces of glauconite, some shell fragments.

SHERWOOD SANDSTONE FORMATION
Sandstone, very fine to medium, colourless to grey white, unconformably with some cemented bands, sub-angular to sub-rounded, occasional nodules, brown to grey, green to bluish grey, firm to flaky.

JURASSIC
Kimmeridge Clay

Fig. 5.6

The Type Section of Rhys (1974) for the Lower Cretaceous of the British southern North Sea.
Fig. 5.8 Lithostratigraphical correlation of boreholes 49/20 - 2, 49/25 - 1, 49/25 - 2, and 49/24 - 12
Fig. 5.9 Lithostratigraphical correlation of boreholes 49/24 - 3, 49/24 - 4 and 49/24 - 1
Fig. 5.10 Lithostratigraphical correlation of boreholes 44/2 - 1, 49/10 - 1 and 49/19 - 1
Lithological control was provided by the cuttings and sidewall core samples. This control was adequate for the determination of the main lithological units but the accurate placing of the boundaries was aided by the gamma ray log response changes. Additional data were available for borehole 44/2-1 in the form of the resistivity and conductivity logs.

The boundaries of each lithostratigraphical unit are clearly distinguished on the logs. These boundaries do not represent isochronous surfaces but they are mappable and provide a method of rapid correlation and interpretation of the Early Cretaceous strata in the southern North Sea. However, a biostratigraphy based upon foraminifera does give further information and assists in a regional correlation and in the subsequent recognition of a chronostratigraphy. The sections in Block 49 have been dated by the author (see Chapter 8) but age per se has not been used as a criterion for defining any lithostratigraphical unit.

The Base Cretaceous Unconformity is the only unconformity recognised by the lithostratigraphy. Other unconformities can be recognised on micropalaeontological and geophysical criteria. For this reason no other unconformities are discussed in this chapter but will be mentioned in the biostratigraphical chapter (see Chapter 7).

The present author has favoured the formation concept - layer cake geological approach in identifying mappable lithological units in the studied boreholes and in the correlation of these "units" from one borehole to another. This approach recognises the vertical distribution of rock types rather than the concept of identifying laterally related genetic lithological units (facies), (Weimer, 1976). The lithological units defined are only used as lithological references and no time connotation is implied. For environmental interpretation, genetic lithological units have to be identified. Such units result from the
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Fig. 5.11
Sandstone tongues of the Vlieland Shale Member in the West Netherlands Basin (from NAM & RGD, 1980)
physical and biological processes operating within an environment at the time of sedimentation and are equivalent to the recognition of facies. The analysis of facies involves the prediction of lateral lithological changes in contemporaneous deposits.

Selley (1978) has discussed in some detail the use of wireline log and lithological data for subsurface facies analysis. This can be approached by a study of the five basic parameters which define a facies (Selley, 1978):

A. Lithology - data from logs, ditch cuttings and cores

B. Sedimentary structures - data from cores

C. Palaeocurrent analysis - data from the wireline log dipmeter tool

D. Palaeontology - microfossils from cuttings, sidewall cores and conventional cores

E. Geometry - this is the object of the whole exercise: to define the lateral and vertical extent of the facies unit. It is a result of A. to D., together with subsurface mapping utilising borehole and seismic data.

As a result of the limited nature of the data used in this thesis (B., C. and E. are not available) the application of the "lateral accumulation"/facies concept is difficult to apply. The only data available are from borehole information.

The boreholes have to be treated as vertical sections of changes of lithology (and time) which are then correlated laterally.

Wireline logs may be used for environmental interpretation. The gamma ray log reflects the clay content, and hence grain size in
Characteristic log motifs. From left to right: thinly interbedded sand & shale; an upward coarsening profile with abrupt upper sand/shale contact; a uniform sand with abrupt upper & lower contacts; & furthest right, an upward fining sand: shale sequence with an abrupt base.

None of these log patterns are diagnostic on their own. Coupled with data on the distribution of glauconite & carbonaceus detritus however, they define the origin of a number of sand bodies.
clastic sequences, but glauconite, zircon and micas may deflect the reading. Selley (1974, 1975, 1976, 1978), in an oversimplistic approach, expounds the uses of the gamma ray log in defining environmentally diagnostic vertical profiles of sediment grain size. However, the data available from the studied boreholes are not sufficient for a detailed or unequivocal analysis. For instance the determination of the glauconite content (marine indicator when autochothonous) and carbonaceous detritus (winnowing index) is hampered by the amount of caving present in the samples and is therefore not attempted (see Fig. 5.12).

The subsurface lithological units defined by NAM & RGD (1980) and by Rhys (1974) are practical nomenclatures. To prevent unnecessary proliferation of localised names it is felt that the subdivision of the British scheme (corresponding directly to the Dutch subdivisions) illustrated in this chapter should be left open and not formally named until further cooperation of oil companies and government institutions reaches an accepted agreement on terminology. Informally the present author uses a combination of the Dutch and British systems.

5.4 Lithostratigraphy and Correlation of the Studied Boreholes in Block 49

The Plenus Marl, because of its widespread occurrence in North West Europe (Jeffries, 1962, 1963; Carter & Hart, 1977), is used as the datum level for the correlation of the boreholes used in this thesis. In three of the boreholes illustrated (49/24-4, 49/24-1 and 49/24-1) the Plenus Marl is absent. This is related to the mid-Cretaceous disconformity as discussed by Carter & Hart (1977) and Burnhill & Ramsay (1981).
Fig. 5.13  TENTATIVE ELECTRIC LOG CORRELATION OF THE UPPER HOLLAND MARL (Gamma Ray)
A. Upper Holland Marl Member/Red Chalk Formation

Rhys (174) defines the Red Chalk Formation as "a mudstone, calcareous to slightly calcareous, red-brown, with consistent small amounts of white to light grey mottling and lesser dark grey mottling". This is identical to the Upper Holland Marl Member of NAM & RGD (1980). The carbonate content gradually increases toward the top of the unit which is reflected by a decrease in the gamma ray and an increase in the sonic velocity. The top is taken as a sudden sharp decrease in gamma ray response and an increase in sonic velocity at the base of the overlying chalk-marly limestone of the Chalk Group. The base of the unit is marked by an increase in gamma ray response and a decreased sonic velocity in the underlying unit.

This unit is recognisable over the whole of the southern North Sea Basin (and into the central North Sea Basin) and is mappable.

In block 49 it is easily recognised both by cuttings lithology and wireline log character. It varies in thickness e.g. 203 feet in 49/10-1 and 97 feet in 49/24-3.

A much finer lithological subdivision of the Upper Holland Marl Member/Red Chalk Formation is made possible by the use of the gamma ray and sonic log responses (see Fig. 5.13). In borehole 49/24-3 the gamma-ray response has a number of easily distinguished peaks which correspond to a slower sonic velocity (higher interval transit time). These represent clay rich horizons within the essentially marl formation. These peaks are labelled for convenience as A, B, C, D etc., from the top downward and are present in all of the studied boreholes in Block 49 as well as in some boreholes in the Dutch sector. They are cross correlated in the studied boreholes.
The wireline log characteristics of the Upper Holland Marl Member/Red Chalk Formation, offshore, show that this unit is mappable in the subsurface, but whether of member status (NAM & RGD, 1980) or formation status (Rhys, 1974) is open to debate.

Borehole 49/25-1 is designated by the author as the reference borehole for the Upper Holland Marl Member in the British southern North Sea Basin (Crittenden, 1982a).

B. Middle Holland Shale Member/Top Part of the Speeton Clay Formation

The grey-red brown marly shale Middle Holland Shale Member is recognised by its lower carbonate content when compared to the upper and lower members of the Dutch scheme and to the overlying Red Chalk Formation of the British scheme. Rhys (1974) did not formally recognise this unit though it is apparent on the borehole gamma ray and sonic logs of boreholes 49/24-1 and 48/22-2 (773 feet to 810 feet, see Figs. 5.7 and 5.8). This unit is also mappable in the southern North Sea Basin. It is recognised by a distinctive wireline log character: high gamma ray response and low sonic velocity response, when compared to the units above and below. The base commonly has a distinct negative "kick" in the gamma ray response and a corresponding increase in sonic velocity response, possibly marking a sandy or conglomerate basal bed. This marks an unconformity (e.g. borehole 49/24-1) and NAM & RGD (1980) use this to denote the "Albian transgression". This unconformity is not depicted on the borehole lithological correlation figures as it can only be delineated by biostratigraphical evidence. The basal sandstone/ conglomerate - siltstone bed is present in all of the studied boreholes. Even though the Middle Holland
Shale Member is recognised in the British sector it is not proposed here to formally name this unit as a member within the Speeton Clay Formation. Borehole 49/25-1 is designated by the author as the reference borehole for the Middle Holland Shale Member in the British southern North Sea Basin.

No finer subdivision or correlation of this unit was attempted for the boreholes in Block 49. However, the basal, or near base, unconformity is important and provides an important marker horizon which, as will be seen, is easily correlated with the onshore sections of the U.K.

C. Lower Holland Marl Member/Top Part of the Speeton Clay Formation

The Lower Holland Marl Member is a grey/red-brown calcareous mudstone/argillaceous limestone, shale. In the basal portion there are intercalated carbonaceous shale beds. The wireline log character makes it easily recognised: relatively low gamma ray response and a characteristic high sonic velocity log response. This unit is not present in borehole 49/24-1 but is well developed in boreholes 49/25-1, 49/25-2, 49/24-12, 49/20-2 and 48/22-2 (810 feet - 845 feet). In the Dutch sector this unit marks the base of the Holland Formation and overlies the Vlieland Formation. The basal contact is marked by the negative gamma ray log response suggesting an increase in carbonate content in the Lower Holland Marl Member as compared to the Vlieland Formation. According to NAM & RGD (1980) this boundary marks a slight but distinctive regional unconformity.

This unit is easily recognised and correlated across the whole of the southern North Sea Basin. The distinct
"belly" log motif of the gamma ray and sonic log response make it unmistakable.

Borehole 49/25-1 is designated as the reference borehole for the Lower Holland Marl in the British southern North Sea Basin.

It is logical to place the Lower Holland Marl Member, Middle Holland Shale Member and the Upper Holland Marl Member into the Holland Formation. They are all characterised by their carbonate content and are distinct from the underlying argillaceous-sandy Vlieland Formation. The Middle Holland Shale Member is interpreted as a more argillaceous phase between the calcareous members and is also characterised by red/grey mottling.

The Dutch (NAM & RGD, 1980) classification of the units would have to be revised in the British sector if the existing scheme of Rhys (1974) were to be used. Retaining the Red Chalk Formation and placing the Middle Holland Shale and Lower Holland Marl as members in the Speeton Clay Formation would be a possible solution.

D. Vlieland Shale Member/Speeton Clay Formation (pars)

The Vlieland Shale Member is a sequence of marine, grey/brownish grey-black shales which are slightly calcareous at the top and become greyish olive green, olive green-grey black with depth. There are traces of glauconite and interbeds of friable silty sandstones throughout. The Vlieland Shale Member is not present as such in borehole 49/24-1 if the Speeton Clay, as noted by Rhys (1974), is taken as the Middle Holland Shale Member. The base of the Vlieland Shale Member is delimited by either local basal sandstone beds (Spilsby Sandstone equivalent) or older formations (Triassic 49/24-1, as
Fig. 5.14
TENTATIVE ELECTRIC LOG CORRELATION OF THE VLIELAND FORMATION
dated by Shell U.K.). The top is formed by the base of the Lower Holland Marl Member and is characterised on wireline logs by a change to a lower gamma ray response and an increased sonic interval transit time. NAM & RGD (1980) regard the top as marking a disconformity. None of the studied boreholes in Block 49 have a thick basal sandstone but there are minor siltstones and sandstones intercalated in some sections, while 49/20-2 and 49/25-1 have sandier sections at their base.

E. **Vlieland Sandstone Member/Spilsby Sandstone Formation**

This forms a transgressive basal section to the Vlieland Formation and its age therefore varies (diachronous). It is a fine grained glauconitic sandstone containing lignite/carbonaceous particles and is present at the base of 49/20-2 and 49/25-1.

The Vlieland Formation is encountered only in six of the studied boreholes in Block 49. However, an informal log unit correlation may be made by using the gamma ray and sonic log motifs (see Fig. 5.14). The subdivision and correlation are tentative, as the data available are limited. It does indicate that with additional data a wireline log/lithological correlation and analysis of the Vlieland Formation would be possible.

The essentially splintery grey/black shale at the base of 49/20-2 and 49/25-1 had a distinct glauconitic, fine grained sandstone element when the cuttings samples were examined. The wireline log shapes are not exaggerated by "washing out" of the borehole wall above the unconformity/lithology change to the underlying Triassic sediments. This lithological change is well seen in borehole 49/20-2 where the cuttings samples from the underlying Triassic are a red-brown colour in contrast to the dark grey-black/olive green shales/mudstones/siltstones above.
Fig. The marine Ysseland Sandstone
Member north east of the Texel High
(From Cottonçon et al., 1975)

**GAMMA RAY LOG**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2447.5</td>
<td>Black shale.</td>
</tr>
<tr>
<td>2479</td>
<td>Fine to very fine green sandstones with ferruginous and argillaceous cement, Oolitic limestone.</td>
</tr>
<tr>
<td>2500</td>
<td>Fine and grey sandstones with black argillaceous cement.</td>
</tr>
</tbody>
</table>

*Stratigraphic and gamma logs of wells from the Harlingen, Zuidwol and Leeuwarden gas-fields.*
The basal sandstone/silt section (Z) in borehole 49/25-2 is a unit which has a higher clay content than in boreholes 49/25-1 and 49/2-2. The top contact of unit Z is quite pronounced. Above, the gamma ray pattern reveals a distinct cyclical series of coarsening-up sequences in 49/25-2 and 49/25-1. In 49/25-1 the top of unit V has a distinctly higher glauconite and very fine sandstone content than in the underlying units. There is an abrupt contact with unit U (Shale/mudstone). This coarsening-up motif has been noted by Cottencon et al., (1975), admittedly in much cleaner sands and in very much thicker sequences (75 metres), in boreholes through Early Cretaceous strata in the Netherlands. Cottencon et al., (1975) conclude that these sand bodies are the result of barrier island sandy sedimentation and partial reworking, which has formed transgressive sheet sands flanking the north of the Texel High (see log of Vlieland Oost-1, in Fig. 5.5, and see Fig. 5.15). In the Texel area the basal sands are Valanginian in age.

The Texel High constituted an emergent zone with the open sea located to the north. Sandy barrier islands were formed roughly parallel to the shore. This sequence of barrier bar deposits (coarsening-up, regressive motif on the gamma ray log), followed by a transgressive sequence (fining-up motif on the gamma ray log: units U, T, S) is seen in boreholes 49/25-1, 49/25-2 and 49/20-2. This represents the Early Cretaceous transgression across isolated emergent fault blocks (horsts), such as the Cleaver Bank uplift and the Mid-North Sea High, and the London-Brabant Massif. Halokinesis during the Early Cretaceous complicated the issue as salt structures pierced the overlying Mesozoic strata and are still major features in the southern North Sea (up to 40 km in length with a NW-SE trend, Ziegler, 1981). These structures provided areas of local uplift to form shallows and islands and possible sources of clastic material in the southern North Sea area (Bartenstein & Kaever, 1973).
Study area including boreholes with a basal Lower Cretaceous sand section

Yorkshire Basin area

Source area of clastics

Fig. 5.16 Isopach map (ft) of the Cromer Knoll Group in the British southern North Sea (from Glennie & Boegner, 1981)
The analagous Spilsby Sandstone Formation, which is assumed to be an area of coastal barrier sands (Casey, 1973. p. 214), has been mapped in the Sole Pit area of the southern North Sea by Glennie & Boegner (1981). They regard the probable source area of these sands as being within and to the east of, the Sole Pit area and that these sands were only deposited to the south west of Sole Pit (see Fig. 5.16, from Glennie & Boegner, 1981).

Additionally, there was the possibility of a supply of clastic material from the northern edge of the emergent Anglo-Brabant Massif to the south (Allen, 1981; Anderton et al., 1979). The high area to the north east of the Sole Pit area (the Cleaver Bank uplift) is another possible source area for the coarse clastics at the base of the Early Cretaceous in some of the boreholes in Block 49.

5.5 Summary

The British and Dutch lithostratigraphical schemes for the Early Cretaceous strata of the southern North Sea Basin are both applicable to the boreholes studied in Block 49 of the British sector. Both of the schemes enable a correlation of the boreholes within Block 49 and with other boreholes across the southern North Sea Basin, to be made.

At present the Dutch scheme offers more scope and finesse for correlation purposes because of its more subtle lithological subdivisions. These subdivisions can be recognised in the type borehole log sections of the British scheme and in the boreholes from block 49. They are however, as previously mentioned, left unnamed in the British sector boreholes.
CHAPTER 6

THE LITHOSTRATIGRAPHY OF THE STUDIED BOREHOLES
IN THE SOUTHERN NORTH SEA

6.0 Introduction

Each borehole is described lithologically and this information is discussed and related to the wireline log data. Some of the boreholes had only a limited amount of data available but in all cases a lithostratigraphical subdivision was possible. The boreholes are discussed in turn but in no particular order except that 49/25-1, being designated the reference borehole, is discussed first (Crittenden 1982a).
<table>
<thead>
<tr>
<th>Group</th>
<th>Forma</th>
<th>Gamma Ray</th>
<th>Sonic Log</th>
<th>Lithological Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.S.</td>
<td>Speeton Clay</td>
<td>400</td>
<td>40</td>
<td>Shale; dark grey, soft to firm, clay, argillaceous.</td>
</tr>
<tr>
<td>T.S.</td>
<td>Vlieland Shale</td>
<td>400</td>
<td>40</td>
<td>Sand: light brown, clear, unconsolidated; silt: light brown, clear, visible.</td>
</tr>
<tr>
<td></td>
<td>L. Holl. Marl</td>
<td>400</td>
<td>40</td>
<td>Marls; red brown, notched grey, firm to hard, fissile, occ. silty.</td>
</tr>
<tr>
<td></td>
<td>Middle Holl. Shale</td>
<td>400</td>
<td>40</td>
<td>Chalk; white, sub-rounded, angular, occasional V. f. sand stringers.</td>
</tr>
<tr>
<td></td>
<td>Upp. Holl. Marl</td>
<td>400</td>
<td>40</td>
<td>Sand; dark grey, clear, fine-graded, firm to hard.</td>
</tr>
</tbody>
</table>

Fig. 6.1 Composite log of borehole 49/25 - 1.
### Electric Log & Lithology

<table>
<thead>
<tr>
<th>Group</th>
<th>Depth (m)</th>
<th>Electric Log</th>
<th>Lithological Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>6100</td>
<td></td>
<td>CLAYSTONE; dark grey green, soft to firm.</td>
</tr>
<tr>
<td>Upper</td>
<td>8100</td>
<td></td>
<td>CHALK; white to pinkish grey, argillaceous.</td>
</tr>
<tr>
<td></td>
<td>9100</td>
<td></td>
<td>MARL; red brown, mottled grey, white, brown, firm to hard, sub fissile, occ. very chalky.</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td></td>
<td>SHALE / CLAYSTONE; grey, dark grey, occ. red brown, mottled, calcareous, glauconitic, micaceous, firm to hard, fissile, occ. silty.</td>
</tr>
<tr>
<td></td>
<td>1400</td>
<td></td>
<td>MARL; dark grey, green, soft, silty in part, grading to ARGILLACEOUS LIMESTONE; white grey, tree carbonaceous mat., chalky, grading to SHALE / MARL at base; dark grey, silty.</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td></td>
<td>SHALE / CLAYSTONE; dark grey, light grey, dark brown, occ. olive green, firm to hard, fissile, silty, calc., pyritic, glauconitic, silty in part, w/ occ. v. f. sand stringers.</td>
</tr>
<tr>
<td></td>
<td>1800</td>
<td></td>
<td>SAND; light brown, clear, uncon. friable, ang. - rnod., fine- crs., very argillaceous.</td>
</tr>
</tbody>
</table>

---

**Fig. 6.1 Composite log of borehole 49/25 - 1**
6.1 **Borehole U9/25-1 (Fig. 6.1)**

**Operator:** Shell/Esso

**Coordinates:** 53 deg 13' 10.1" N  
02 deg 49' 59.2" E

**Spudded:** 15 February, 1969

**Abandoned:** 20 April, 1969

**Kelly Bushing Elevation (above mean sea level):** 96 feet  
(29 metres)

**Water depth:** 104 feet (31 metres)

<table>
<thead>
<tr>
<th>Lithological Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys) (NAM &amp; RGD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Chalk /Upper Holland Marl</td>
<td>6184-6288 feet</td>
<td>104 feet</td>
</tr>
<tr>
<td>Speeton Clay /Middle Holland Shale</td>
<td>6288-6440 feet</td>
<td>152 feet</td>
</tr>
<tr>
<td>/Lower Holland Marl</td>
<td>6440-6520 feet</td>
<td>80 feet</td>
</tr>
<tr>
<td>/Vlieland Shale</td>
<td>6520-6922 feet</td>
<td>402 feet</td>
</tr>
<tr>
<td>Spilsby Sand-/Vlieland Sandstone</td>
<td>6922-6950 feet</td>
<td>28 feet</td>
</tr>
</tbody>
</table>
This borehole has been designated by the author (Crittenden, 1982a) as the reference section for the Dutch lithostratigraphical scheme (NAM & RGD, 1980) in the British Southern North Sea Basin.

The Plenus Marl at 6051-6053 feet provides a very good correlation datum with the other boreholes in Block 49.

The base of the Chalk/top of the Upper Holland Marl Member boundary is easily recognised at 6184 feet by the characteristic gamma ray and sonic log response and by the distinctive red brown marl lithology.

The top of the Middle Holland Shale Member at 6288 feet is marked by a pronounced change in sonic interval transit time and gamma ray response. This unit is characterised by the relatively high interval transit times and a marked negative peak in interval transit time at the base (6420 feet). This denotes a sandy basal horizon above the top of the Lower Holland Marl Member at 6440 feet.

The Lower Holland Marl Member in this borehole is easily recognised by the typical "belly" log motif of the gamma ray and sonic log responses. This motif is well developed in this borehole and is a characteristic of this member across the whole of the southern North Sea Basin. Essentially this member is a very argillaceous chalky limestone which grades up into a dark grey-green, soft marl and grades beneath into a carbonaceous, dark grey, silty marl with a sandy silty stringer at the base.

The underlying Vlieland Shale Member (6520-6922 feet) is distinguished by its log responses and the characteristic dark grey, olive green, dark brown shales and claystone sequence with occasional interbeds of siltstone and sand.
The Vlieland Sandstone Member at 6922-6950 feet is not so well developed as in some boreholes in the south eastern part of the British southern North Sea and in the West Netherlands Basin. The caliper log of this section (not depicted) indicates no "washing out" of the borehole which adds weight to the accuracy of the gamma ray response.

The Early Cretaceous section in this borehole is a typical development for the whole of the southern North Sea Basin though a thicker development of the Vlieland Formation is usually encountered in the Dutch sector.
**ELECTRIC LOG & LITHOLOGY**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FORMA</th>
<th>MBR</th>
<th>FORMA</th>
<th>GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.K.</td>
<td>R.C.</td>
<td>C.R.</td>
<td>R.H.M.</td>
<td>Rijnland</td>
</tr>
<tr>
<td>1000</td>
<td>1500</td>
<td>5000</td>
<td>7000</td>
<td>5000</td>
</tr>
</tbody>
</table>

**GAMMA RAY**

- API units: 80
- 5000

**SONIC LOG**

- ms ec/ft: 140
- 40

**LITHOLOGICAL DESCRIPTION**

- CLAYSTONE; dark grey, green - grey, firm to hard.
- CHALK; white to pinkish white hard.
- MARL; reddish brown, w/ trace grey - green clyst, trace white & pink chalk (caved).
- SAND; trace, v.f. grained, red stained.
- CLAYSTONE / MUDSTONE; green, grey, black.
- SILTSTONE; green - grey, red brown, w/ OOIDs, brown yellow.
- SANDSTONE; reddish brown, firm to friable, sucrosic, v.f. grain

N.B. All samples were very small and abundant cavings were present

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**Fig. 6.2 Composite log of borehole 44/2 - 1**
6.2 Borehole 44/2-1 (Fig. 6.2)

Operator: Shell

Coordinates: 54 deg 52' 38" N
02 deg 23' 35" E

<table>
<thead>
<tr>
<th>Lithological Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys) (NAM &amp; RGD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Chalk/Upper Holland Marl</td>
<td>5016-5068 feet</td>
<td>52 feet</td>
</tr>
</tbody>
</table>

The gamma ray and sonic log motifs at 4910 feet are characteristic of the Plenus Marl. This provides an excellent correlation datum with the other boreholes.

The top of the Red Chalk Formation/Upper Holland Marl Member is easily located at 5016 feet by the characteristic gamma ray log motif.

The log character of the section below this is extremely difficult to correlate with the other studied boreholes. There is obviously a condensed marginal sequence of Early Cretaceous strata present (from foraminiferal evidence, see Chapters 7 and 9). The borehole was drilled on the southern flank of the Mid-North Sea High; a Mesozoic structure which was aerially exposed during the Early Cretaceous. The exact thickness of the Early Cretaceous strata present in borehole 44/2-1 is extremely difficult to determine. The sample interval is variable (10 feet to 40 feet), the number of samples available for study was small (8 samples for 180 feet) and the exact sample size prior to washing was not very great (3 grammes to a maximum of 17 grammes in the sample from 5080 feet).
The cuttings lithology from 5010 feet to 5080 feet is a mottled grey-red-brown marl with traces of green-grey claystone (probably caved Plenus Marl), white and pink chalk and black flint (probably caved) and very fine grained sand.

The sample at 5080 feet is dominated by a mottled green, grey-black claystone/mudstone which is blocky and subfissile. The same lithology also dominates the sample at 5100 feet but the sample at 5110 feet has in addition a number of brown/yellow (iron stained pellicle) oolitic pellets and traces of a very fine grained reddish brown sandstone.

The sample at 5140 feet has the same lithological components together with fragments of white chalk and red brown claystone/marl.

It is very difficult to reconcile the wireline log pattern and lithology of borehole 44/2-1 to the Early Cretaceous sections of the other studied boreholes. The author has studied the wireline log patterns of other formations of different ages from examples in the stratigraphical volume of NAM and RGD (1980); especially that of the Sleen Shale Formation of the Altena Group (marine Rhaetian in age). The sonic log and gamma ray log character could be construed as being similar to the response of the same logs in the Sleen Shale Formation in boreholes K14-1 (NAM), which is the Dutch reference section of NAM and RGD (1980), and boreholes Emmen-7 (NAM), L2-1 (NAM), Nederweert-1 (Fina), Buurmalsen-1 (NAM), and Werkendam-2 (NAM) (see Figs. 6.3, 6.4, 6.5). The resistivity and conductivity logs of borehole 44/2-1 have been provided by Shell U.K. and their character does collaborate the possible reference of the section to the Sleen Shale Formation.

NAM and RGD (1980) place the Altena Group in the latest Triassic and the Early and Middle Jurassic (see text of Fig. 9. of NAM and RGD, 1980). The lowermost formation is the Sleen Shale
Fig. 6.3 Composite logs of boreholes offshore and onshore the Netherlands showing the Sleen Shale Formation (from NAM and RGD, 1980).
Fig. 6.4 Composite logs of boreholes offshore and onshore the Netherlands showing the Sleen Shale Formation (from NAM and RGD, 1980).
Location of boreholes with the Sleen Shale Formation

Fig. 6.5
Formation which is Rhaetian in age. It is a sequence of grey marine fossiliferous shales followed by brown shales (often with a considerable number of megaspores, NAM and RGD, 1980).

It is usually easily recognised on wireline logs by its relatively high gamma ray and low sonic velocity (high interval transit time) readings. NAM and RGD (1980) proposed no formal subdivision of this formation although they mention that locally a distinct sandstone bed within the shale sequence would allow a tripartite subdivision to be made. Rhys (1974) in his proposed southern North Sea nomenclature discussed the Winterton Formation (top Triassic, equivalent to the Rhaetian) in the type section borehole in the British sector of the southern North Sea (49/21-2). The Winterton Formation is divided into three by the presence of a Rhaetic Sandstone Member. This sandstone member is associated with the basin fringe of marine sedimentation. Unfortunately there is no sonic log for the type section borehole in the British southern North Sea Basin.

On lithological and wireline log grounds the author places (tentatively) the basal part of the studied section in borehole 44/2-1 in the Winterton Formation/Sleen Shale Formation of the Upper Triassic (Rhaetian in age) (see Fig. 5.10).
**Lithological Description**

**CLAYSTONE:** dark grey, firm to hard.

**CHALK:** white to pinkish white hard w/ marly partings.

**MARL:** reddish brown but w/ white, grey, brown mottled appearance in part, firm to hard.

**CLAYSTONE:** red brown, silty, calcareous, mod. hard, w/ light green speckles.

**CLAYSTONE:** red brown, silty, calcareous, soft, sub fissile

**CLAYSTONE:** as above but a very fine fissility present.

**MARL:** red brown, silty, calc., fissile, soft to hard, micaceous.

**SHALE / CLAYSTONE:** red brown, calc., soft to hard, micaceous, silty & sandy, tree light green claystone.

**SHALE / CLAYSTONE:** dark red brown, grey - dark grey, silty, sandy, calc., soft to hard, fissile, tree dark grey phosph. nodules.
6.3 Borehole 49/10-1 (Fig. 6.6)

Operator: Shell/Esso

Coordinates: 53 deg 42' 57.3'' N
02 deg 52' 00.6'' E

<table>
<thead>
<tr>
<th>Lithological Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys) (NAM &amp; RGD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Chalk /Upper Holland Marl</td>
<td>7132-7335 feet</td>
<td>203 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeton Clay /Middle Holland Shale</td>
<td>7335-7392 feet</td>
<td>57 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Lower Holland Marl/</td>
<td>7392-7495 feet</td>
<td>103 feet</td>
</tr>
<tr>
<td>Vlieland Shale</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Plenus Marl at 6995 feet provides an easily recognised datum level in this borehole.

The top of the Upper Holland Marl Member at 7132 feet is recognised by the characteristic increase of the gamma ray response coupled with the lithological change from white pink chalk to red brown marls. The whole of the unit is characterised by an irregular sawtooth gamma ray response.

The base of the Upper Holland Marl Member at 7335 feet is characterised by a slight but steady increase in the trend of the gamma ray response and a change to the red brown shale/claystone of the Middle Holland Shale Member.

The base of the Middle Holland Shale Member is delineated by a pronounced peak in sonic velocity (smaller interval transit time)
at 7392 feet. This denotes a silty sandy horizon which is a characteristic of the base of this unit according to NAM and RGD (1980), (see Fig. 5.3).

The Upper Holland Marl and Middle Holland Shale Members are easily recognised and correlated with the other boreholes in this study. However, lithological subdivision of the borehole below these two units is difficult. A correlation may be made between borehole L5-1 (NAM) and the lithological units present in 49/10-1, (see Fig. 5.3) but it is still a problem to distinguish the Lower Holland Marl and Vlieland Shale Members on either wireline log or lithological evidence.

The top of the Lower Holland Marl Member is apparently at 7392 feet, with its base at 7430 feet, and the Vlieland Shale Member beneath has its base at 7495 feet. In this case the base of the Lower Holland Marl Member is, from the nature of the sharp log break, probably an unconformity.

Alternatively the Lower Holland Marl Member may extend from 7392 feet to the Base Cretaceous Unconformity and would therefore appear to constitute a sequence of fining up cycles. There was no indication in this borehole of the dark bituminous shale/marl, characteristic of the Lower Holland Marl Member as defined by NAM and RGD (1980). The presence of a dark grey Vlieland Shale Member was not proven in the cuttings. Only the biostratigraphical analysis of the fauna within the cuttings will resolve the problem of the stratigraphical division of this borehole.
Fig. 6.7 Composite log of borehole 49/19 - 1
**ELECTRIC LOGS & LITHOLOGY**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FORHA</th>
<th>FORHA</th>
<th>FORHA</th>
<th>FORHA</th>
<th>GAMMA RAY API units</th>
<th>SONIC LOG 1 m/sec/ft</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>149</td>
<td>149</td>
</tr>
</tbody>
</table>

**LITHOLOGICAL DESCRIPTION**

- **CLAYSTONE;** Dark grey, green - grey, firm to hard.
- **CHALK;** White to white grey, firm to hard.
- **MARL;** Red brown, mottled grey white, brown, firm to hard.
- **CLAYSTONE;** Red brown, silty, calcareous, mod. hard, blocky, occ. subfissile.
- **SILTSTONE;** Red brown, argillaceous, sandy, uncons.
- **SILTY CLAYSTONE;** Red brown, grey brown, soft to hard, tree silt & sand.
- **SILTY CLAYSTONE;** Dark red brown grey - dark grey brown, calc., sandy in part, grading to marl in part.

Fig. 6.7 Composite log of borehole 49/19 - 1
6.4 **Borehole 49/19-1 (Fig. 6.7)**

Operator: Shell/Esso

Coordinates: 53 deg 20' 48.3" N
02 deg 45' 21.8" E

<table>
<thead>
<tr>
<th>Lithological Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys)</td>
<td>(NAM &amp; RGD)</td>
<td></td>
</tr>
<tr>
<td>Red Chalk /Upper Holland Marl</td>
<td>3000-3169 feet</td>
<td>169 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeton Clay /Middle Holland Shale</td>
<td>3169-3202 feet</td>
<td>33 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Lower Holland Marl</td>
<td>3202-3245 feet</td>
<td>43 feet</td>
</tr>
<tr>
<td>Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Vlieland Shale</td>
<td>3245-3270 feet</td>
<td>25 feet</td>
</tr>
<tr>
<td>Member</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

49/19-1 is an enigmatic borehole as it is difficult to correlate, by means of the wireline logs and lithology, with the other boreholes in Block 49. However, an excellent correlation may be made with borehole L5-1 (NAM) in the Dutch sector of the southern North Sea (Fig. 5.3).

The Plenus Marl provides the usual correlation datum at 2869 feet. Below this at 2952-2960 feet there is a gamma ray peak (positive) which indicates a marl horizon in the chalk.

The top of the Upper Holland Marl member is quite obvious from the wireline log response and lithology at 3000 feet. The base of the Upper Holland Marl Member is characterised by a marked change in log character at 3169 feet.
The Middle Holland Shale Member from 3169 feet to 3202 feet is a thin development but still quite distinctive in wireline log and lithological character and comparable to other boreholes in Block 49 with its marked basal siltstone/sandy horizon.

The Lower Holland Marl Member from 3202 feet to 3245 feet is comparable in wireline log character and lithology to the same Member in borehole L5-1 (NAM). It may be correlated with borehole 49/10-1 (Fig. 6.6) and the base of the unit may be an unconformity above the brown grey Vlieland Shale Member (3245-3270 feet). Where finer lithostratigraphical control is needed at the base of the Early Cretaceous section there is, unfortunately, a paucity of cuttings samples.
**ELECTRIC LOG & LITHOLOGY**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>PHQ</th>
<th>NAME</th>
<th>S.G.</th>
<th>2.0</th>
<th>P.D.C.</th>
<th>LITHOLOGICAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CLAYSTONE; dark green grey, firm to hard.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CHALK; white to pinkish white hard w/ marly partings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MARL; reddish brown but w/ white, grey, brown mottled appearance, firm to hard.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CLAYSTONE; red brown, firm to hard intercalations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SHALE / CLAYSTONE; med. brown grey and dark grey, firm to hard, sub fissile.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MARL / MUDSTONE; grey to grey brown, w/ green intercalations calcareous, tree carbonaceous.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SHALE / CLAYSTONE; dark grey, grey brown, firm to hard, fissile, all. calcareous, silty in part, glauconitic, pyritic.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SHALE / CLAYSTONE; generally as above but w/ tree v. fine and siltst. w/ glauconite &amp; pyrite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SANDSTONE; grey green light brown, unconsolidated, v.f. to med. grained, avg. to rudd</td>
</tr>
</tbody>
</table>

**Fig. 6.8 Composite log of borehole 49/20 - 2**
**Lithological Description**

- **CLAYSTONE**: dark green grey, firm to hard.
- **CHALK**: white to pinkish white hard w/ marly partings.
- **MARL**: reddish brown but w/ white, grey, brown mottled appearance, firm to hard. CLAYSTONE: red brown, firm to hard intercalations.
- **SHALE / CLAYSTONE**: med. brown grey and dark grey, firm to hard, sub fissile.
- **MARL / MUDSTONE**: grey to grey brown, w/ green intercalation calcareous, tree carbonaceous
- **SHALE / CLAYSTONE**: dark grey, grey brown, firm to hard, fissile, silty, calcareous, silty in part, glauconitic, pyritic.
- **SHALE / CLAYSTONE**: generally as above but w/ trace v. f. sand and siltst. w/ glauconite & pyrite.
- **SANDSTONE**: grey green light brown, unconsolidated, v.f. to med. grained, ang. to rndd.
6.5 Borehole 49/20-2 (Fig. 6.8)

Operator: Shell/Total

Coordinates: 53 deg 27' 26.056" N
02 deg 58' 15.124" E

<table>
<thead>
<tr>
<th>Lithostratigraphical Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys)</td>
<td>(NAM &amp; RGD)</td>
<td></td>
</tr>
<tr>
<td>Red Chalk /Upper Holland Shale</td>
<td>6592-6719 feet</td>
<td>127 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeton Clay /Middle Holland Shale</td>
<td>6719-6753 feet</td>
<td>34 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Lower Holland Marl</td>
<td>6753-6770 feet</td>
<td>17 feet</td>
</tr>
<tr>
<td>Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Vlieland Shale</td>
<td>6770-7060 feet</td>
<td>290 feet</td>
</tr>
<tr>
<td>Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spilsby Sand-/Vlieland Sandstone</td>
<td>7060-7080 feet</td>
<td>20 feet</td>
</tr>
<tr>
<td>stone Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Borehole 49/20-2 presented a problem for interpretation as the sonic log was not available for study. This borehole serves as a very good example of how a wireline log correlation may be erroneously applied unless care is taken to examine the cuttings and sidewall core lithologies.

The Plenus Marl is easily recognised by the characteristic gamma ray and sonic log motif (6502-6505 feet). The top of the Upper Holland Marl Member was placed correctly at 6592 feet. The
Diagram to show an erroneous Electric Log Interpretation.
correlation and placing of unit boundaries at deeper depths was
less straightforward.

The initial correlation using wireline log character is as Fig.
6.9 and would appear to agree very well with the other boreholes
in block 49. However, there appear to be two extra log units at
A and B. Upon closer examination of the cuttings lithology,
sidewall core lithology and an examination of the foraminiferal
content of the sidewall cores a revised correlation was made (see
Figs. 6.8, 5.8).

From approximately 6810 to 7110 feet the cuttings lithology has
increasing amounts of dark grey shale. Below 7110 feet the
cuttings lithology is a red/brown claystone. The sidewall core
sample at 7050 feet was barren of benthonic and planktonic
foraminifera; the sidewall core sample at 7070 feet had rare
foraminifera while the sidewall core sample at 7097 feet was
barren. All three of these sidewall core samples would be
expected to contain good diagnostic Early Cretaceous
foraminiferal faunas if the initial lithological and wireline log
correlation of Fig. 6.9 were correct.

After careful examination of the borehole cuttings samples and
consultation of the lithological subdivisions of the other
boreholes in block 49 a second lithological and wireline log
subdivision was made for borehole 49/20-2.

The log character at 7060 feet to 7080 feet is very misleading
and was originally interpreted as the Lower Holland Marl whereas
in actual fact it represents a basal sandier horizon of the
Vlieland Group - the Vlieland Sandstone Member. The formation
below is interpreted as the Bunter Sandstone/Claystone and the
gamma ray log pattern supports this interpretation as does the
red brown claystone lithology in the sidewall core sample at 7175
feet and the cuttings samples below 7110 feet. This explains
the significant lack of an Early Cretaceous foraminiferal fauna
in the samples below 7100 feet.
The Upper Holland Marl Member correlates extremely well with the other boreholes in Block 49 in terms of thickness, lithology and gamma ray motif.

The Middle Holland Shale Member at 6719 to 6753 feet however, is very much thinner than in the other studied boreholes, as is the Lower Holland Marl Member at 6753-6770 feet. This may indicate that the bases of these two Members are unconformities.

The Vlieland Shale Member compares very well with the other studied boreholes as does the basal Vlieland Sandstone Member.
**Fig. 6.10 Composite log of borehole 49/24 - 1**

### ELECTRIC LOGS & LITHOLOGY

<table>
<thead>
<tr>
<th>GROUP</th>
<th>PHYs</th>
<th>NDW</th>
<th>NDW &amp; RED</th>
<th>GAMMA RAY API units</th>
<th>SONIC LOG at m/sec/ft</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70000</td>
<td></td>
<td></td>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

- **Marl:** red brown, mottled grey, white, brown, firm to hard, sub fissile, occ. very chalky.
- **Shale / Claystone:** red brown, mottled grey, calcareous, trace micaceous, soft to hard, fissile, trace siltstone, dark red brown, firm.
- **Sand:** red stained - clear, angular to sub angular, fine to medium grain, unconsolidated, w/ trace phosphorus nodules.
MARL; red brown, mottled grey, white, brown, firm to hard, sub fissile, occ. very chalky

SHALE / CLAYSTONE; red brown, mottled grey, calcareous, tree micac., soft to hard, fissile, tree SILTSTONE, dark red brown firm.

SAND; red stained - clear, angular to sub rounded, fine to medium grain, unconsolidated, w/ trace phosphorus nodules.
6.6 Borehole 49/24-1 (Fig. 6.10)

Operator: Shell/EssO

Coordinates: 53 deg 16' 50" N
02 deg 41' 30" E

<table>
<thead>
<tr>
<th>Lithological Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys)</td>
<td>(NAM &amp; RGD)</td>
<td></td>
</tr>
<tr>
<td>Red Chalk / Upper Holland Marl</td>
<td>4243-4348 feet</td>
<td>105 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeton Clay / Middle Holland Shale</td>
<td>4348-4420 feet</td>
<td>72 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(pars)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This borehole is the reference borehole, designated by Rhys (1974), for the Cromer Knoll Group in the southern North Sea.

The absence of the Plenus Marl is perhaps associated with the Mid-Cretaceous disconformity of Carter & Hart (1977) and Burnhill & Ramsay (1981). The uniform nature of the chalk lithology is emphasised by the regularity of the gamma ray response. The irregularities of the sonic log are the result of alternations of soft and hard chalk.

The top of the Upper Holland Marl Member is readily picked out in the cuttings, and by the characteristic gamma ray and sonic logs of this unit, at 4243 feet.

The top of the Middle Holland Shale Member is easily recognised by the gamma ray and sonic log responses and cuttings lithology at 4348 feet. The base of this unit is marked by a sharp negative peak in the gamma ray and a corresponding sharp decrease...
in sonic interval transit time. An examination of the cuttings lithology reveals that this event is caused by a sandy, silty layer which probably represents the unconformity above the underlying Triassic sandstone.
GAMMA RAY API units

SONIC LOG at msec/ft

CLAYSTONE; dark grey, firm to hard.
CHALK; pink-white w/
MARL; brown-red, soft to firm.
MARL; reddish-brown but w/ white, grey, brown mottled appearance in part, firm to hard, sub-fissile.
### Lithological Description

<table>
<thead>
<tr>
<th>Group</th>
<th>Rhys</th>
<th>NAM &amp; RGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cromer Knoll-</td>
<td>Red Chalk</td>
<td></td>
</tr>
<tr>
<td>Upp. Holl. Marl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rijnland</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Gamma Ray
- API units 120
- 4000
- 4900

#### Sonic Log
- At m/s/ft

#### Electric Log & Lithology

**CLAYSTONE**: dark grey, firm
- reddish - brown mottled appearance in part,
- white, grey, brown

**MARL**: dark grey to hard,
- reddish - brown firm to hard, sub-fissile,
- white, grey, brown

**CHALK**: pink - white, firm to hard,
- brown - red, soft to firm,
- white, grey, brown

---

Map 6. 31 Composite Log of borehole 49/24 - 3
6.7 **Borehole 49/24-3 (Fig. 6.11)**

**Operator:** Shell/Essco

**Coordinates:** 53 deg 18' 40" N
02 deg 44' 57" E

<table>
<thead>
<tr>
<th>Lithological Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys) (NAM &amp; RGD)</td>
<td>(NAM &amp; RGD)</td>
<td></td>
</tr>
<tr>
<td><strong>Red Chalk /Upper Holland Marl</strong></td>
<td>4911-5008 feet</td>
<td>97 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Plenus Marl in this borehole provides a good correlation datum and is easily recognised by its gamma ray and sonic log response at 4839 feet.

The top of the Upper Holland Marl Member is easily picked at 4911 feet where the gamma ray response and sonic interval transit time both begin to increase.

The cuttings lithology in the three samples examined is the typical reddish-brown, mottled white grey, firm marl characteristic of this member in Block 49.
**LITHOLOGICAL DESCRIPTION**

**MARL; reddish brown, but w/ white, grey, brown mottled appearance in part, firm to hard, sub-fissile in part, occ. very chalky.**

**SHALE / CLAYSTONE; light green grey to med. grey, firm to hard, fissile, calc.**

**MARL; dark brown, grey, w/ trc fine to med. grain, red stn, uncons. Sand.**
6.8 Borehole 49/24-4 (Fig. 6.12)

Operator: Shell

Coordinates: 53 deg 19' 09.053" N
02 deg 42' 12.392" E

<table>
<thead>
<tr>
<th>Lithological Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys) (NAM &amp; RGD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Chalk /Upper Holland Marl</td>
<td>4724-4862 feet</td>
<td>138 feet</td>
</tr>
<tr>
<td>Formation, Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeton Clay /Middle Holland Shale</td>
<td>4862-4952 feet</td>
<td>90 feet</td>
</tr>
<tr>
<td>(pars) Member</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There is no Plenus Marl apparent in this borehole either from examination of the cuttings lithology or from the gamma ray or sonic log response. However above 4616 feet the sonic interval transit time response is variable and "saw tooth" in appearance which either represents hard and soft lithological changes or a fractured chalk lithology. An argillaceous content is not reflected by the gamma ray response. The absence of the Plenus Marl is probably associated with the Mid-Cretaceous disconformity of Carter & Hart (1977) and Burnhill & Ramsay (1981).

The top of the Upper Holland Marl Member is easily recognised at 4724 feet by the cuttings lithology (red brown marl) and the increase in gamma ray response when compared to the overlying chalk gamma ray response.

The close sample interval from 4724 feet to 4900 feet provides good lithological control for the Upper Holland Marl Member which has its base at 4862 feet.
The top of the Middle Holland Shale Member is picked by the start of a gradual increase in gamma ray response coupled with a marked increase in sonic interval transit time leading to an interval of relatively higher interval transit times. The lithology is characteristic of the Middle Holland Shale Member in Block 49 and is characterised in borehole 49/24-4 by a basal sandstone/siltstone. The large sample interval from 4900 feet to the base of the Early Cretaceous section precludes a detailed lithological analysis of the Middle Holland Shale Member in this borehole.
Fig. 6.13 Composite log of borehole 49/24 - 12

<table>
<thead>
<tr>
<th>Group</th>
<th>BRGS</th>
<th>FORM.</th>
<th>MBR</th>
<th>FORM.</th>
<th>RCD</th>
<th>Group</th>
<th>BRGS</th>
<th>FORM.</th>
<th>MBR</th>
<th>FORM.</th>
<th>RCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cromer Knoll</td>
<td>Red Chalk</td>
<td>Red Chalk</td>
<td>Middle Holland Shale</td>
<td>Upper Holland Marl</td>
<td>Blue Beds</td>
<td>Red Chalk</td>
<td>Red Chalk</td>
<td>Red Chalk</td>
<td>Red Chalk</td>
<td>Red Chalk</td>
<td></td>
</tr>
</tbody>
</table>

**ELECTRIC LOG & LITHOLOGY**

<table>
<thead>
<tr>
<th>CALIPER</th>
<th>SONIC LOG at msec/ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>4700</td>
<td></td>
</tr>
<tr>
<td>4800</td>
<td></td>
</tr>
</tbody>
</table>

**LITHOLOGICAL DESCRIPTION**

- **CLAYSTONE**: dark grey green, soft to firm.
- **CHALK**: white, pinkish white, grey, soft to hard.
- **MARL**: red brown, mottled grey white, brown, soft to firm, sub fissile in part.
- **CLAYSTONE / SHALE**: grey, brown grey, greenish, soft to hard, fissile, calcareous, locally silty, sandy at base.
- **MARL / MUDSTONE**: grey to grey brown w/ trace green, locally dark grey w/ carbonaceous mat.
- **ARGILLACEOUS LIMESTONE**: white grey, chalky grading at base to SHALE / MARL; dark grey, carbonaceous & silty.
- **SHALE / CLAYSTONE**: dark grey, light grey, dark brown, occ. olive green, firm to hard, fissile, sili. calc., pyritic, gleuconitic, silty in part, w/ occ. v.f. sand stringers.
Fig. 6.13 Composite log of borehole 49/24 - 12

<table>
<thead>
<tr>
<th>ELECTRIC LOG &amp; LITHOLOGY</th>
<th>LITHOLOGICAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALIPER</td>
<td>SONIC LOG at mseg/ft</td>
</tr>
<tr>
<td>140</td>
<td>40</td>
</tr>
</tbody>
</table>

CLAYSTONE; dark grey green, soft to firm.

CHALK; white, pinkish white, grey, soft to hard.

MARL; red brown, mottled grey white, brown, soft to firm, sub fissile in part.

CLAYSTONE / SHALE; grey, brown grey, greenish, soft to hard, fissile, calcareous, locally silty, sandy at base.

MARL / MUDSTONE; grey to grey brown w/ trace green, locally dark grey w/ carbonaceous mat.

ARGILLACEOUS LIMESTONE; white grey, chalky grading at base to SHALE / MARL; dark grey, carbonaceous & silty.

SHALE / CLAYSTONE; dark grey, light grey, "dark brown, occ. olive green, firm to hard, fissile, sl. calc., pyritic, glauconitic, silty in part, w/ occ. v.f. sand stringers.
Borehole 49/24-12 (Fig. 6.13)

Operator: Shell/Esso

Coordinates: 53 deg 11' 09.9" N
02 deg 42' 12.3" E

<table>
<thead>
<tr>
<th>Lithostratigraphical Unit</th>
<th>Interval</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rhys)</td>
<td>(NAM &amp; RGD)</td>
<td></td>
</tr>
<tr>
<td>Red Chalk /Upper Holland Marl</td>
<td>4760-4895 feet</td>
<td>135 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeton Clay /Middle Holland Shale</td>
<td>4895-5075 feet</td>
<td>180 feet</td>
</tr>
<tr>
<td>Formation Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Lower Holland Marl</td>
<td>5075-5160 feet</td>
<td>85 feet</td>
</tr>
<tr>
<td>Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Vlieland Shale</td>
<td>5160-5325 feet</td>
<td>165 feet</td>
</tr>
<tr>
<td>Member</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Borehole 49/24-12 initially posed a problem for wireline log and lithological correlation as only the sonic log and caliper log were available. The invaluable gamma ray log was not available. However, after the other boreholes had been subdivided and correlated, it became quite a straightforward exercise to correlate the sonic log response of 49/24-12 and to identify the major boundaries.

However, to subdivide these major lithological units is quite impossible without the gamma ray log.

The caliper log however mirrored, in some instances, the expected gamma ray response for each lithological unit. In fact it seems
to suggest a "weathering profile" of the drilled lithologies. This would be a function of the erosive action of the circulating drilling fluid in the borehole annulus. The harder, firmer lithologies would resist the erosive action while the softer unconsolidated horizons would "wash out".

The Plenus Marl is easily distinguished at 4590 feet and the top of the Upper Holland Marl Member at 4760 feet is picked on the sonic log response as there were no cuttings samples available to the author.

The base of the Upper Holland Marl Member is distinguished by cuttings lithology and by the characteristic sonic log motif for the interval. The basal siltstone sand horizon is very clear.

The Lower Holland Marl Member log motif depicts the characteristic "belly" shape while the underlying Vlieland shale log motif and cuttings lithology reflect the intercalated hard to firm nature of the lithologies. No basal sand could be recognised.
**Fig. 6.14 Composite log of borehole 49/25 - 2**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Gamma Ray API units</th>
<th>Sonic Log (msec/ft)</th>
<th>Lithological Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6400</td>
<td></td>
<td></td>
<td>Claystone; dark grey, greenish, soft to firm, subfissile.</td>
</tr>
<tr>
<td>6500</td>
<td></td>
<td></td>
<td>Chalk; white, grey, pinkish, soft to very hard.</td>
</tr>
<tr>
<td>6600</td>
<td></td>
<td></td>
<td>Marl; red brown, mottled grey, white, brown, soft to firm, subfissile in part.</td>
</tr>
<tr>
<td>6700</td>
<td></td>
<td></td>
<td>Claystone / Shale; grey, brown, dark grey, greenish, soft to hard, fissile, calcareous, locally silty, sandy at base.</td>
</tr>
<tr>
<td>6800</td>
<td></td>
<td></td>
<td>Marl / Mudstone; grey to grey brown w/ trace green, locally dark grey. Argillaceous Limestone; white to grey, chalky, soft, grading to Shale / Marl; dark grey, calcareous and silty.</td>
</tr>
<tr>
<td>6900</td>
<td></td>
<td></td>
<td>Shale / Claystone; dark grey, light grey, dark brown, occ. olive green, firm to hard, fissile to blocky, calcareous, pyritic, glauconitic, silty stringers, w/ occ. sand stringers, becoming non calc. w/ depth.</td>
</tr>
</tbody>
</table>
Fig. 6.14 Composite log of borehole 49/25 - 2

**LITHOLOGICAL DESCRIPTION**

- **CLAYSTONE**: dark grey, greenish, soft to firm, subfissile.

- **CHALK**: white, grey, pinkish, soft to very hard.

- **MARL**: red brown, mottled grey, white, brown, soft to firm, subfissile in part.

- **CLAYSTONE / SHALE**: grey, brown to dark grey, greenish, soft to hard, fissile, calcareous, locally silty, sandy at base.

- **MARL / MUDSTONE**: grey to grey brown with trace green, locally dark grey.

- **ARGILLACEOUS LIMESTONE**: white to grey, chalky, soft, grading to SHALE / MARL; dark grey, carbonaceous and silty.

- **SHALE / CLAYSTONE**: dark grey, light grey, dark brown, occ. olive green, firm to hard, fissile to blocky, calcareous, pyritic, glauconitic, silty stringers, with occ. sand stringers, becoming non calc. with depth.
6.10 Borehole 49/25-2 (Fig. 6.14)

Operator: Shell/Essco

Coordinates: 53 deg 11' 51.082" N
02 deg 51' 18.714" E

Lithological Unit | Interval | Thickness
---|---|---
(Rhys) (NAM & RGD)
Red Chalk /Upper Holland Marl : 6522-6651 feet : 129 feet
Formation Member
Speeton Clay /Middle Holland Shale : 6651-6800 feet : 149 feet
Formation Member
/Lower Holland Marl : 6800-6973 feet : 73 feet
Member
/Vlieland Shale : 6873-7392 feet : 519 feet
Member

The Plenus Marl at 6387 - 6389 feet provides a good correlation datum with the other boreholes in Block 49.

This borehole is very close to borehole 49/25-1 and the lithostratigraphical sequence is, as expected, very similar.

The top of the Upper Holland Marl Member is easily distinguished at 6522 feet by the wireline log response and by the change from a soft to hard white pink chalk to a distinctive red brown marl. The base of this unit is at 6651 feet where the lithology becomes shalier and darker in colour. The gamma ray and sonic log responses are characteristic of this unit but the basal siltstone sand is not so well developed as in other boreholes (see 49/25-1 for example).
The Lower Holland Marl Member is distinguished by its characteristic lithology and distinctive "belly" motif on the gamma ray and sonic log response from 6800 to 6873 feet. The base of this unit is slightly silty and sandy and this is shown by the gamma ray and sonic log response. This may represent a slight unconformity (see 49/25-1).

The Vlieland Shale Member is well developed in this borehole as an interval of dark grey-light grey, dark brown, green shale/claystones with occasional interbeds of sand and siltstone (6873-7392 feet). The Vlieland Sandstone Member is not present in this borehole.
CHAPTER 7
THE BIOSTRATIGRAPHY OF THE STUDIED BOREHOLES
IN THE SOUTHERN NORTH SEA

7.0 Introduction

Each lithological unit described from the studied boreholes yields a rich and varied foraminiferal fauna. These faunas provide a very valuable and useful method of correlation and subdivision which is a logical step toward establishing a chronostratigraphic subdivision of the Early Cretaceous strata of the studied boreholes (Holland et al., 1978).

The boreholes which have been examined for foraminifera are discussed in turn and the fauna is related to other faunas from other areas of North West Europe.

As an aid to the understanding of the offshore sequences of microfaunas a study was made of the surrounding onshore Early Cretaceous strata, as described in the literature, of the United Kingdom, the Netherlands and Germany (see Chapters 2, 4, 10, 11, 12). The majority of the Early Cretaceous outcrop sections in North West Europe have some bearing on the interpretation, biostratigraphical and lithostratigraphical, of the Early Cretaceous strata of the southern North Sea. For instance, the foraminiferal faunas are Boreal in character rather than Tethyan. Other areas, not necessarily Boreal in character, were also studied in terms of a literature survey, to aid identification of the foraminiferal fauna e.g., north and south France, Poland, Greenland, Norway, Canada, California (USA), Trinidad, Australia, North Africa; and data contained in the Deep Sea Drilling Project volumes were also examined.

In the author's opinion a thorough understanding of the onshore outcrop sequences surrounding the southern North Sea Basin
provides, in most cases, a sound foundation upon which to build an understanding of the events penetrated by the exploration drill offshore. Subsequently the offshore data helps in the further understanding and interpretation of the sequences encountered in onshore outcrop sections (see Chapters 10, 11, 12).

The major published articles which proved to be most useful for identification of the foraminiferal faunas studied are mentioned in the text dealing with each borehole (also see Section 7.11). These publications also gave some indication as to which genera and species were most useful for age determination. The foraminifera were identified, as far as possible, to species level. However some taxa were obviously long ranging, and of no biostratigraphic use for age dating purposes, and were therefore not identified to species level.

The work of Burnhill and Ramsey (1981) on the Mid-Cretaceous of the central and northern North Sea areas provides the only published biozonation scheme available for comparison from offshore United Kingdom. Their biozonal scheme, discussed later in this thesis (Chapter 10), is a result of comparisons made with the onshore section biozonal schemes published by Carter and Hart (1977), Price (1977a, b) and Fuchs (1967).

The publications by Crittenden (1983b, 1984a, b, 1987a, b), and the main conclusions presented in those papers, are a result of the work incorporated in this thesis.
Foraminiferal Range Charts of each Borehole studied

The foraminifera contained in the cuttings samples of each borehole studied are plotted in the order of their first appearance downhole (i.e. their apparent extinction level in each borehole). This is the conventional practice in the hydrocarbon exploration industry and alleviates, to some extent, the problem of caved faunas and downhole contamination from higher uncased intervals of the borehole.

The boreholes are discussed in the following order: those with the thinnest Early Cretaceous section are discussed first. A step by step biostratigraphic picture of the Early Cretaceous strata present in the studied boreholes is thus presented albeit in a non-conformist manner: youngest to oldest. Some sections are present in more than one borehole so reiteration of comments is inevitable. Albian and Aptian age strata are discussed in detail while pre-Aptian Early Cretaceous strata are discussed only briefly.
Lenticulina spp. unidentified
Arenobulimina chapmani
Flourerina intermedia
Arenobulimina frankei
Eggerellina mariae
Spiroplectinata complanata
Gnomospira gaultina group
Valvulineria spp. unidentified
Ammosphaeroidina minuta
Gavelinella intermedia group
Arenobulimina sabulosa
Lingulogavelinella albiensis
Lingulogavelinella ciri ciri
Marssonella trochaus
Tritaxia pyramidata
Gaudryina dividens
Falsogaudryinella sp.
Ammodiscus cretaceus
Paamosphaera sp.
Lenticulina (Marginulina) jonesi grp.
Lingulogavelinella sp.
Osangularia schloenbachii
Conorotalites bartensteini aptiensis /
Arenobulimina macfadyeni interceden
Gavelinella brielenisis

Hedbergella delrioensis plexus
7.2 Borehole 44/2-1 (Fig. 7.1)

The large sample interval, small size of the samples and lack of sidewall core or conventional core samples combine to cause difficulty in erecting a biostratigraphic subdivision for this borehole.

Samples 5,010 feet and 5,020 feet contained a sparse red-brown stained planktonic and benthonic foraminiferal fauna. The colouration is a characteristic of the faunas from the Upper Holland Marl Member. Sample 5,010 feet weighed 3 grammes and sample 5,020 feet weighed 1 gramme and it is concluded that both samples were of insufficient size for meaningful biostratigraphical conclusions to be made.

Sample 5,050 feet (3 grammes) contained a very sparse foraminiferal fauna.

Sample 5,080 feet (17 grammes) had a much more diverse foraminiferal fauna but unfortunately the majority were "caved" Late Cretaceous and Early Tertiary taxa. The sample was dominated by iron stained (pellicle) ooids which in some cases had a glauconite nucleus.

The following three samples downhole (5,100 feet, 8 grammes; 5,110 feet, 3 grammes; 5,140 feet, 15 grammes) contained an abundant "caved" Late Cretaceous and Early Tertiary foraminiferal fauna in addition to a very sparse red stained fauna characteristic of the Upper Holland Marl Member. In addition sample 5100 feet contained a light grey Late Albian foraminiferal fauna.

Sample 5180 feet was barren of foraminifera and consisted of mottled green, grey and red marly siltstones together with abundant caved lithologies (e.g. chalk).
Planktonic Foraminifera

The sparse planktonic foraminiferal fauna is dominated by the Hedbergella delrioensis (Carsey) - Hedbergella infracretacea (Glaessner) - Hedbergella brittonensis (Loeblich and Tappan) plexus. One specimen tentatively attributed to Hedbergella sp. cf. H. simplex (Morrow) in sample 5020 feet suggests a Late Albian - Cenomanian age (Robaszynski & Caron, 1979).

The planktonic foraminiferal fauna is considered to be in place in only the two upper samples: 5010 feet, 5020 feet and is characteristic of the Late Albian of North West Europe (Price 1977b, Carter and Hart, 1977).

Benthonic Foraminifera

The benthonic foraminiferal fauna in samples 5010 feet and 5020 feet is non-diverse and sparse but is important for dating the Early Cretaceous strata of this borehole. The occurrence of Arenobulimina sabulosa (Chapman), A. chapmani Cushman, A. frankei Cushman, Eggerellina mariae ten Dam and Flourensina intermedia ten Dam indicates according to Bartenstein (1976a, b, c, 1977, 1978a, b, 1979), Carter and Hart (1977), Price (1977a, b) and Harris (1982) strata of a Late Albian age. This Late Albian age assignment is supported by the occurrence of Gavelinella gr. intermedia (Berthelin), Gavelinella baltica Brotzen, Gavelinella ex. gr. cenomanica (Brotzen) and Valvulineria spp. which are recorded from Late Albian strata in North West Europe by various authors (e.g. Price 1977a, b; Magniez-Jannin, 1975).

The rare occurrence of Osangularia schloenbachii (Reuss) in sample 5010 feet is interesting. Its' first downhole consistent occurrence in the Early Cretaceous strata of the southern North Sea Basin usually indicates a Middle Albian to Late Aptian age (Crittenden, 1983b). It has been recorded rarely in Late Albian/Cenomanian strata in boreholes in the Dutch sector of the
southern North Sea and northern North Sea (Crittenden, 1983b; Burnhill and Ramsay, 1981).

The benthonic foraminiferal fauna in samples 5050 feet and 5080 feet is very sparse and non diverse. However the occurrence of *Tritaxia pyramidata* Reuss (5050 feet) and *Gaudryina dividens* Grabert (5080 feet) is important. *T. pyramidata* is indicative of Early Cenomanian to Albian and Late Aptian age strata in North West Europe while *G. dividens* is characteristic of strata of Early Albian to Aptian strata (Bartenstein, 1976b, 1978a, 1979). It is not possible to say whether the Early Cretaceous fauna is in place in these samples.

Sample 5100 feet contained an abundance of caved Late Cretaceous and Tertiary benthonic foraminiferal species. In place Early Cretaceous (or caved Early Cretaceous) species are sparse. The increase in number of *Glomospira* ex. gr. *gaultina* (Berthelin) is important and may be associated with similar increases seen towards the base of the Albian strata in nearby boreholes (49/24-1). This depth in borehole 44/2-1 is also the top occurrence of *Faisogaudryinella* spp. (*Uvigerinammina* sp. of authors). Sample 5100 feet contained an abundance of caved Late Cretaceous and Early Tertiary benthonic foraminifera species. In place Early Cretaceous (or caved) species are not common.

Sample 5140 feet has a more diverse benthic foraminiferal fauna and includes *Arenobulimina macfadyeni* (Cushman) and *Osangularia schoenbachii* (Reuss); species diagnostic of Middle to Early Albian age strata. The occurrence of *Gavelinella brielensis* (Malapris) suggests an Early Albian-Aptian age.

The presence of *Concorotalites bartensteini aptiensis* (Bettenstaedt) is interesting. The forms present in sample 5140 feet are the characteristically biconvex shape of this subspecies from the Middle and Lower Albian and Aptian Strata of north west Germany (Bartenstein and Bettenstaedt, 1962; Bartenstein 1978a).
and from the central and northern North Sea (Burnhill and Ramsay, 1981).

In an attempt to resolve the biostratigraphical subdivision of borehole 44/2-1 five samples 5080 feet, 5100 feet, 5110 feet, 5140 feet and 5180 feet) were subjected to palynological analysis.

Palynological Analysis

5080 feet

Dinoflagellates: Oligosphaeridium sp., Deflandrea sp. (caved), Spiniferites ramosus, Cribroperidinium sp., Mystichodinium voigtii, Palaeoperidinium complex, Dingodinium alberti.

Miospores: Classopolis torosus, Triporate pollen (caved), Bisaccate pollen (caved), Cyathidites sp., Cicatricosisporites sp., and Cingulizonates sp.

Kerogen: Inertinite rare
Vitrinite rare
Exinite/cutinite rare
Amorphous sapropel rare

Preservation: Poor to moderate

Age: Early Cretaceous, Aptian or older.
5100 feet

Dinoflagellates: Spiniferites ramosus and Cribroperidinium sp.

Miospores: Bisaccate pollen, Triporate pollen (caved), Perinopollenites elatoides and Lycopodium sporites.

Kerogen: Inertinite rare
Vitrinite rare
Exinite/Cutinite rare

Preservation: Poor

Age: ? Early Cretaceous

5110 feet

Dinoflagellates: Palaeohystrichophora infusorioides (caved), Palaeoperidinium pyrophorum (caved), Cleistosphaeridium sp. and Areoligeria sp. (caved).

Miospores: Bisaccate pollen, Triporate pollen (caved), Classopollis torosus, Cyathidites sp. and Gleicheniidites senonicus.

Kerogen: Inertinite rare
Vitrinite rare
Exinite/Cutinite rare
Amorphous sapropel rare

Preservation: Moderate

Age: Indeterminate
5140 feet


Microplankton:  *Microhystridium* sp. and *Veryhachium* sp.


Kerogen:  Inertinite rare
Vitrinite rare
Exinite/Cutinite rare/common
Amorphous sapropel rare

Preservation:  Moderate to good

Age:  Triassic, Rhaetian.

5180 feet

Dinoflagellates:  All caved species

Miospores:  Caved bisaccate and triporate pollen
Kerogen: Inertinite rare (caved)
Vitrinite rare (caved)
Exinite/Cutinite rare (caved)

Age: Indeterminate

These palynological data provide some indication as to the age of the sediments but unfortunately can give no indication as to the subdivision of the Early Cretaceous interval.

Biostratigraphical (Foraminifera) Conclusions

From the lithological discussion of this borehole (Chapter 6) it was assumed that the base of the thin Albian - ?Aptian sequence was at 5068 feet. Below this depth a precise age assignment is not possible and there is no microfaunal or microfloral evidence to confirm the Rhaetic (?) age proposed by the lithostratigraphical analysis. The small size of the samples and abundant caving of fauna and flora confound and complicates any attempt at a refined biostratigraphic interpretation.

The presence of index foraminiferid species such as O. schloenbachii, A. macfadyeni, C. bartensteini aptiensis and G. brielensis in samples 5050', 5080', 5100', 5110' and 5140' should not be construed as in place but rather as caved from higher intervals. They have not been recorded (in some instances) from higher in the section because of lack of samples and the small sample size.

The samples beneath 5069 feet were examined for megaspores, a characteristic of the Rhaetian strata in North West Europe (see Simon & Brand, 1962) but none were found.

In conclusion the samples examined between 5010 feet and 5080 feet contain an Early Cretaceous, Late Albian to Aptian age fauna
and flora. Samples 5100 feet and 5110 feet are indeterminate in age though they do contain a caved Tertiary and Cretaceous fauna while the occurrence of Rhaetian strata (Winterton formation: Triassic) is confirmed by palynology at 5140 feet though the sample also contains a caved Tertiary and Cretaceous fauna.
Ammodiscus cretaceus
Glocospira gautlina group
Tritaxia pyramidata
Gaudryina dividens
Marsacella trochus
Eggerella marie
Arenobulimina-chapmani
Arenobulimina frankel
Arenobulimina edvards
Spiroplectina species
Haplophragmoides chapmani
Trochammina sp.
Quinquelocalina antiqua
Eoguillina species
Nodosariids - unidentified
Lenticulina species - unidentified
Dentalina species - unidentified
Lenticulina crassicosta crassicosta
Gavelinella Intermedia group -
Gavelinella baltica -
Gavelinella cenomanica -
Lingulogavelinella albiensis s.l.
Lingulogavelinella ciry inflata
Velvulinaria species - unidentified -
Arenobulimina sabulosa
Ammobaculites subcretaceus
Cribratina sp.
Hyperamminae gautline
Rectoangulina mutabilis
Dentalina distincte
Thurammina albinacs
Lingulogavelinella ciry ciry
Felsoguillina albiensis
Textularia chapmani -
Gaudryina grade
Vegulinina recta - broken
Ammosphaeroidina minute
Hedbergella simplex
Hedbergella delrioensis - plexus
Hedbergella brittonensis
Globigerinelloides bentonensis

Late Albian
Early Cretaceous
Chronostratigraphy

Cronmer Knoll
Red Chalk
Upp. Holl. Marl
Holland
Rijnland
Cretaceous Sandstone Formation

20-50
Core Lower Cretaceous Tertiary

50/20-50

5000
4000
3000
2000
1000
0

Depth in ft
Below KBE

Gama Ray
270 units

Rha
R.C.D.
R.A.M.
There is an incomplete coverage by ditch cuttings samples of the Early Cretaceous interval of this borehole. The three samples each contain a red brown stained foraminiferal fauna. This is a characteristic of the red brown calcareous mudstones which comprise the Upper Holland Marl Member (Red Chalk Formation equivalent) in block 49. A subtle change in the fauna is noted at 4980 - 5000 feet where the foraminiferal fauna is a dark reddish brown colour. This may be a colouration effect derived from the underlying Bunter Sandstone Formation.

**Planktonic Foraminifera**

The abundant planktonic foraminiferal fauna is dominated by the *Hedbergella delrioensis* (Carsey) - *Hedbergella infracretacea* (Glaessner) - *Hedbergella brittonensis* (Loeblich and Tappan) plexus. Members of this plexus became larger in size up the borehole section. This size increase has been noted by Price (1977a) and Carter and Hart (1977) in the Albian of North West Europe. Large high spired forms are attributable to *H. brittonensis* (=Whiteinella brittonensis of authors, e.g. Robaszynski and Caron, 1979) which is a characteristic species of the Late Albian and Early Cenomanian (Carter and Hart, 1977). Small high spired forms are attributable to *H. infracretacea*. Price (1977a) has discussed this plexus and its stratigraphical use in the Albian strata of North West Europe in some detail and it is not repeated here.

*H. simplex* (Morrow) is a Late Albian - Cenomanian species in North West Europe (Robaszynski and Carón, 1979) which probably evolved from the *H. delrioensis* plexus in the Late Albian.

*Globigerinelloides bentonensis* (Morrow) is an important index planktonic species as its occurrence in large numbers (flood horizons) is indicative of the Late Albian in North West Europe.
Floods of this species have been recorded from horizons in Late Albian sediments of southern England, the Central North Sea, northern France and Germany (Hart 1973; Carter and Hart, 1977; Price 1977b; Burnhill and Ramsay, 1981; Harris 1982). It is encountered rarely in the Middle Albian and it ranges into the Cenomanian. This species is not common in this borehole, only being found in the sample 4980 - 5000 feet. The planktonic foraminiferal fauna indicates a Late Albian age for the calcareous mudstones of the Upper Holland Marl Member (Red Chalk Formation) of borehole 49/24-3.

Benthonic Foraminifera

The benthonic foraminifera are diverse and numerous. Arenobulimina chapmani Cushman, A.frankel Cushman, A.advena (Cushman), A.sabulosa (Chapman), Eggerellina mariae ten Dam and Quinqueloculina antiqua (Franke) are, according to Bartenstein (1976a, b, c; 1977; 1978a, b; 1979), Carter and Hart (1977), Price (1977b) and Harris (1982), important members of the Late Albian benthonic foraminiferal fauna in North West Europe. This species association suggests a Late Albian age for the Upper Holland Marl Member (Red Chalk Formation). The diverse Arenobulimina spp. fauna and the absence of the Middle Albian species A.macfadyeni (Cushman) supports a Late Albian age. Walters (1958) recognised that Textularia chapmani Lalicker is a typically Late Albian species.

This Late Albian age assignment is supported by the occurence of a diverse gavelinellid fauna including Gavelinella cenomanica (Brotzen), G.baltica Brotzen, and G.ex.gr. intermedia (Berthelin) which are recorded together in the Late Albian of North West Europe by a number of authors (e.g. Price, 1977b; Magniez-Jannin, 1975). The lingulogavelinellid species substantiate the Late Albian age; L.cirvi inflata Malapris-Bizouard according to Magniez-Jannin (1975), indicates an uppermost Late Albian (Vraconian - dispar Zone) age in the Paris Basin.
Species of the *Spiroplectinata/Gaudryina* group were not present in sufficient numbers to enable a rigorous application of the phylogenetic scheme of Grabert (1959) to be made. However *S. complanata* (Reuss) is recorded from the Late Albian of North West Germany. *Gaudryina gradata* (Berthelin) is also considered to be of Late Albian/Cenomanian age.

**Biostratigraphical Conclusions**

The foraminiferal fauna recorded from borehole 49/24-3 indicates a Late Albian age for the Upper Holland Marl Member (Red Chalk Formation). The fauna shows an increase in arenaceous species downhole. The basal sample (2980-5000 feet) has a marked increase in the number of specimens of the *Glomospira* ex.gr. *gaultina* group. This is perhaps associated with the environment of deposition (shallow marine) - (see Crittenden, 1984a, b), and the "basal" Albian (be it Early or Middle) transgression. It is a facies event and is diachronous.

The sample 5030 feet - 5060 feet contained a sparse caved Early Cretaceous foraminiferal fauna.
<table>
<thead>
<tr>
<th>FORMn</th>
<th>GROUP</th>
<th>Rhyolite 1974</th>
<th>MBR</th>
<th>NAMa</th>
<th>RGD 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cromer Knoll</td>
<td>Spieston Clay</td>
<td>Rad Chalk</td>
<td>Chalk</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Rhyolite 1974</th>
<th>MBR</th>
<th>NAMa</th>
<th>RGD 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### EARLY CRETACEOUS

- **EARLY MIDDLE ALBIAN**
- **LATE ALBIAN**

#### CHRONOSTRATIGRAPHY

**Early Cretaceous Log of Borehole 49/24-1**

### Taxonomy

- *Lenticulina* spp., unidentified
- *Trinaxis* pyramidalis
- *Arenobilimina* frankii
- *Arenobilimina* chapmani
- *Eggerellina* mariae
- *Guinqueluculina* antiqua
- *Valvulineria* spp., unidentified
- *Gavelinella* intermedia group
- *Gavelinella cenomanica*
- *Rectiglandulina* mutabilis
- *Dorothy* filiformis
- *Lingulogavelinella* albilens
- *Ammobaculites* cretaceus
- *Glamospira* giultina group
- *Lingulogavelinella* ceryl ceryl
- *Ammoniacites* subcretacceus
- *Arenobilimina* macfadyeni
- *Marssonella* ozawa
- *Marssonella* trochus
- *Gaudryina* gradata
- *Hoeglundina* chapmani
- *Nodosaria* paupercula
- *Gaudryina* dividens
- *Gavelinella* baltica
- *Tristix* excavata
- *Felsogaudryinella* sp.
- *Haplophragmoides* nonioninoides
- *Reophax* minute
- *Gavelinella* breiensis
- *Gavelinella* berremiana

- *Hedbergella* delrioensis plexus
- *Hedbergella* planispira
- *Globigerinelloides* bentonensis
- *Hedbergella* simplex
This borehole, the reference borehole of Rhys (1974) for the British lithostratigraphical scheme, was discussed by Harris (1982) and by Crittenden (1984a). Harris (1982) only identified the foraminiferal species which he considered to be important index forms for the Albian. He concluded that the whole of the Early Cretaceous section in this borehole was probably Late Albian in age (Biozones 5a-6a of Hart, 1973; Biozones 711i - 9111 of Price, 1977b, top M.inflatum and S.dispar Ammonite Biozones).

The present author (Crittenden, 1984a, b) has re-examined the sieve fraction residues (washed samples) for lithology and foraminifera and the picked (unsorted) faunal slides of Harris. It is not known which sieve fractions were picked by Harris or whether he completely picked the sample clean of foraminifera. The range chart is accordingly presented with no indication of abundance.

There is an incomplete sample coverage of the Early Cretaceous strata of borehole 49/24-1. Due to the lack of samples, the Cenomanian/Albian boundary is not defined biostratigraphically but is picked lithologically at 4,243 feet (see Figs. 6.10 and 7.3). From other borehole evidence in the southern North Sea Basin the stage boundary lies either within the basal section of the overlying Texel Chalk (Chalk Group) or within the topmost part of the Upper Holland Marl Member (Red Chalk Formation). For convenience, a pragmatic approach is necessary and the electric log/lithological boundary may be taken as the Cenomanian/Albian boundary (e.g. Burnhill & Ramsay, 1981, fig. 4, borehole 24/1a-8). The first five downhole samples examined each contain a red brown stained foraminiferal fauna which is characteristic of the Upper Holland Marl Member. There is a marked colour change at sample 4340 - 4350 feet where specimens of Valvulinera spp., Gavelinella ex. gr. intermedia and A.macfadyenii are a grey-white colour quite distinct from the red brown above. This
is a reflection of the so-called "basal limestone" of the Upper Holland Marl recognised in other areas of the North Sea (pers. comm. C.J. Harlow, C.A. Burton).

A further but subtle colour change in the fauna is noted at 4390-4400 feet (and below) where the fauna is a dark reddish brown colour, different to the red brown above in the Upper Holland Marl Member. This is probably associated with the red Triassic sediments beneath (see section 7.3, borehole 49/24-3).

**Planktonic Foraminifera**

The planktonic foraminiferal fauna is dominated by the *H.delrioensis* - *H.infracretacea* - *H.brittonensis* plexus. Members of this plexus become larger in size "up" the borehole section through the Early Cretaceous. This size increase has been noted by Price (1977a) and Carter & Hart (1977) in the Albian of North West Europe. Large high-spired forms are attributable to *H.brittonensis* (=Whiteinella brittonensis of authors, e.g. Robaszynski & Caron, 1979) which is a characteristic species of the Late Albian and Early Cenomanian. Small, high-spired forms are attributable to *H.infracretacea*. Price (1977a) has discussed this plexus and its stratigraphical use in the Albian of North West Europe in some detail and it is not reiterated here.

*H.planispira* (Tappan) is a distinctive species and is found in North West Europe throughout the greater part of the Albian (Carter and Hart, 1977). Its topmost occurrence in the studied boreholes may be a local correlatable event.

*H.simplex* is a Late Albian - Cenomanian species in North West Europe (Robaszynski and Caron, 1979). In sample 4290-4300 feet this species is a distinctive light red brown colour and has probably caved from the unsampled topmost part of the Upper Holland Marl Member.
G. bentonensis is, as previously mentioned, a very important index species as its presence in large numbers (flood horizons) is indicative of the Late Albian (4280 feet and 4310 feet) in North West Europe.

The planktonic fauna indicates a Late Albian age for the Upper Holland Marl Member in this borehole and is very similar to Late Albian planktonic foraminiferal faunas recorded from onshore sections in North West Europe.

Benthonic Foraminifera

The benthonic fauna is both diverse and numerous and is important for indicating an age for the Early Cretaceous strata in this borehole.

The topmost five samples examined (all in the Upper Holland Marl Member) contain a fauna characteristic of the Late Albian e.g. A. frankelii, E. mariae, Quinqueloculina antiqua (Franke) and G. cenomanica (see borehole 49/24-3).

This age is supported by the occurrence of G. cenomanica, G. ex.gr.intermedia and Valvulineria spp. (including V. berthelini Jannin, V. loetterli (Tappan) and V. praestans Jannin) which are recorded in the Late Albian of North West Europe by various authors (Price 1977b; Magniez-Jannin 1975).

The colour change at 4340-4350 feet coincides with a faunal change; A. macfadyeni and Hoeglundina chapmani (ten Dam) are Middle Albian index species (first appearance downhole) in North West Europe (Carter and Hart, 1977; Price, 1977b; Harris, 1982). Other species have probably moved from higher up within the Upper Holland Marl Member e.g. Marssonella ozawai Cushman (latest Albian/Cenomanian species) and G. baltica (latest Albian/Cenomanian). This colour change and faunal change
coincides with the lithostratigraphical boundary between the Upper Holland Marl Member above and the Middle Holland Shale Member below.

The Middle Holland Shale Member in the borehole appears to be of Middle to Early Albian age.

Price (1977) indicates that an increase in the number of arenaceous benthonics and a corresponding decrease in calcareous benthonics and planktonic species, occurs in the Early Albian. *Haplophragmoides nonionoides* (Ruess), *G.ex.gr. gaultina* and *Reophax minuta* Tappan appear as a flood in sample 4390-4400 feet. This increase in agglutinated benthonics is a facies event and is probably associated with the diachronous "basal" Albian transgression (be it Early Albian or Middle Albian in age). This event is depicted by the lithology and wireline log character near the base of the Early Cretaceous sections in boreholes 49/24-1, 49/24-4 and 49/24-3, as a coarse clastic horizon (see Fig. 5.9).

Notable species absent from the fauna recovered from borehole 49/24-1 are *Osangularia schloenbachii* (Reuss), which in the southern North Sea Basin is a characteristic of the Late Aptian and Early to Middle Albian (Crittenden, 1983b) and *Conorboidea lamplughi* (Sherlock), a species characteristic of the Early and Middle Albian (Hart et al., 1981). A very important species which is used by various authors to denote the Early and Middle Albian in the North Sea is "*Globigerinelloides?" gyroindinaeformis Moullade* (Burnhill & Ramsay, 1981). This species was not found in the samples studied from borehole 49/24-1, and is not particularly common in the other studied boreholes from block 49. These three species probably owe their absence in borehole 49/24-1 to the small sample size and to the large sample interval (they are present in some of the other studied boreholes in block 49). *Gaudryina dividens* is a species recorded from the lowermost Middle Albian to the top Early Aptian of North West Europe.
by Bartenstein (1978b) and Grabert (1959). The specimens of G. dividens show an affinity to forms of the species illustrated by Grabert from the Late Aptian (Grabert, 1959).

It is unfortunate that where closer sample intervals are most needed at the base of the Middle Holland Shale Member there is a lack of samples. However the presence of Gavelinella brielensis Malapris-Bizouard together with G. barremiana Bettenstaedt would suggest the presence of Aptian age strata within the interval 4,400 – 4,420 feet. This is supported by the occurrence of G. dividens. More samples would help resolve the dating of the lower part of the Middle Holland Shale. In this borehole it is predominantly Middle Albian - Early Albian in age with probably a thin Late Aptian section toward the base from 4390 feet to 4420 feet above the Base Cretaceous Unconformity.

Biostratigraphical Conclusions

The nature of the samples (ditch cuttings) precludes a detailed dating of the studied section. The foraminiferal fauna is not referred to the biozonations of Hecht (1938), Hart (1973), Carter and Hart (1977) and Price (1977b). However, an age is assigned by comparison with the aforementioned authors' published works.

Both the planktonic and benthonic foraminiferal faunas in borehole 49/24-1 indicate that the Upper Holland Marl Member is Late Aptian in age and that the Middle Holland Shale Member is Middle to Early Albian in age (with perhaps a thin veneer of Late Aptian age sediments at the base).

The planktonic foraminifera are dominant in the Upper Holland Marl Member while the benthonic foraminifera are dominant in the Middle Holland Shale Member. This same relationship has been noted by Price (1977b) and Magniez-Jannin (1975) for the Albian strata of North West Europe.
**Fig. 7.4 Foraminiferal log of borehole 49/24 - 4**

<table>
<thead>
<tr>
<th>CHRONOSTRATIGRAPHY</th>
<th>EVENTS OBSERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**49/24-4**

**GAMMA-RAY**

- **Cm**
- **K**
- **U**
- **Th**

**HOLE**

- **ID**
- **INF**
- **FIN**
- **GROSS**
- **NET**
- **CLAY**

**CROSS-SECTION**

- **X**
- **Y**
- **Z**

[Graphical representation of the foraminiferal log and gamma-ray data]
There is good sample coverage of the Early Cretaceous strata of this borehole from 4730 feet to 4900 feet (every 10 feet). However, from 4900 feet to the base of the Early Cretaceous at c. 4955 feet the sample coverage is poor (2 samples) which is unfortunate as this is the interval where biostratigraphic control is most important for age dating.

Samples were examined from 4690 - 4700 feet to 4940 - 4950 feet. The foraminiferal fauna in the highest Early Cretaceous samples examined (downhole) is a light red/brown/pink colour (4720-4750 feet). This is a characteristic of the Upper Holland Marl Member in block 49 and is in stark contrast to the white coloured faunas of the overlying chalk. The fauna in sample 4760-4770 feet is a noticeably darker red brown colour which persists with the lighter coloured fauna as above down to 4810-4820 feet where the red brown again becomes darker and more intense. The next major change of colour is in sample 4840-4850 feet where the fauna is stained a deep red brown very different and distinct from the colour above. This colouration persists to 4890-4900 feet where the fauna is dominated by grey-brown and green stained taxa. A further but more subtle change is encountered in sample 4950 feet where the fauna is dark reddish brown and light grey in colour.

Planktonic Foraminifera

The planktonic foraminiferal fauna is abundant and dominated by the H.delrioensis - H.infracretacea - H.brittonensis plexus. This plexus dominates the fauna recorded from the Upper Holland Marl Member (Red Chalk Formation) in the interval 4720-30 feet to 4860 feet. The other species present are H.simplex, G.bentonensis and H.planispira (Tappan). The latter species is not common but is distinctive and present throughout the greater part of the late Early Cretaceous (Bartenstein, 1965; Carter and Hart, 1977; Price, 1977a; Harris, 1982). By comparison with
boreholes 49/24-3 and 49/24-1 (Crittenden, 1984a) the planktonic foraminiferal fauna indicates a Late Albian age for the Upper Holland Marl Member. The marked decrease in the planktonic fauna from 4860 feet coupled with the benthonic foraminiferal evidence suggests a Middle to Early Albian age to 4900 feet. The presence however of "Globigerinelloides"? gyroidaeformis Moullade at 4830-4840 feet is interesting. This species has been used by various authors to denote the Middle and Early Albian strata in the North Sea Basin. Its presence (1 specimen) at 4830-4840 feet would indicate a Middle Albian age at this depth while the single specimen recorded at 4890-4900 feet confirms a Middle-Early Albian age at that depth.

The occurrence of small, green coloured Hedbergella infracretacea at 4890-4900 feet is interesting and may be of local correlation value of Early Albian/Late Aptian age.

**Benthonic Foraminifera**

The benthonic foraminiferal fauna is both abundant and diverse and compares well with the faunas recorded from the Upper Holland Marl in boreholes 49/24-1 and 49/24-3. The interval 4730 feet to 4860 feet is interpreted as Late Albian in age and is characterised by an assemblage of arenobullimnids and gavelinellids usually associated with sediments of a Late Albian age in North West Europe (Price, 1977b; Carter and Hart, 1975). Other taxa indicative of a Late Albian age are E.marinae, Marssonella ozawai, Flourensina intermedia, Q.antiqua, T.pyramidata, Arenobullimina advena, T.chapmani, A.sabulosa and Vaginulina mediocarinata. The first downhole occurrence of Arenobullimina macfadyeni at 4820-4830 feet denotes the penetration of sediments of a Middle Albian age. This is associated with a dramatic increase in abundance of G.ex.gr.intermedia and is obviously a faunal facies change. The sample 4840-4850 feet contains the first downhole occurrence of Reophax minuta, Conorboides lamplughli and Osangularia
schloenbachl which are all considered index species for strata of Middle Albian age and older (Crittenden, 1982; Price, 1977a, b; Carter and Hart 1977). An increase in the abundance of Glomospira ex.gr.gaultina is also recorded in samples 4840-50 feet and 4850-60 feet. The top occurrence of G.dividens and Spiroplectinata lata indicates sediments of an Early Albian age (Grabert, 1959; Bartenstein op.cit) while the top consistent and common occurrence of G.dividens, Patellina sp., together with the top occurrence of Gaudryinella sherlocki and Conorotalites bartensteini aptiensis, associated with abundant Glomospira ex.gr.gaultina, are taken to indicate sediments of a Late Aptian age.

Biostratigraphical Conclusions

Sediments of a Late Albian age are present from 4720-30 feet to 4820-30 feet (top occurrence of A.macfadyeni). Middle Albian age sediments are present down to 4870-80 feet. Beneath this depth a pragmatic approach is used to arrive at a Late Aptian/Early Albian age, undifferentiated for the interval from 4870-80 feet to 4910-20 feet. A late Aptian age is indicated for the interval 4910-20 feet to the last sample examined at 4940-50 feet.

There is some degree of doubt involved in this age breakdown but the data available does not permit a finer solution. For instance, the interval 4820-30 feet to 4840-50 feet could be assigned to a Late Albian/Middle Albian age.

It is obvious that the Middle and Early Albian age sediments show condensation and minor discontinuities/hiatuses as is shown onshore (Owen, 1971a, b, 1975, 1979; Price, 1977a, b; Rawson & Riley, 1982). It is unfortunate however that only two samples were available for examination from the basal part of the Early Cretaceous sediments in this borehole.
**Fig. 7.5 Biostatigraphy of 49/19 - 1**

<table>
<thead>
<tr>
<th>Group</th>
<th>Rhys</th>
<th>Spenton Clay</th>
<th>Red Chalk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>Early</td>
<td>Middle</td>
<td>Late</td>
</tr>
<tr>
<td>Albian</td>
<td>Albian</td>
<td>To</td>
<td>Albian</td>
</tr>
</tbody>
</table>

**Group**
- **49/19-1**

**Chronostratigraphy**

<table>
<thead>
<tr>
<th>Time</th>
<th>Fauna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>Albian to Early Albian</td>
</tr>
<tr>
<td>Middle</td>
<td>Late Albian</td>
</tr>
</tbody>
</table>

**Facies**
- **Abundant L. ypsilobi**
- **Abundant L. reichardi**
- **Abundant L. rectangula**
- **Abundant L. byrnesi**

**Facies**
- **Early Albian**
- **Early Middle Albian**
- **Late Albian**

**Molluscs**
- **Lenticulina** spp.
- **Arenobuliminina chapmani**
- **Arenobuliminina preiskei**
- **Fluorescoina intermedia**
- **Hapalopilina phylloides**
- **Rhaphiellopsis antipolitana**
- **Spinolacina papyracea**
- **Erytrophoria dealata**
- **Hedbergella deltoidea**
- **Eliogobulinoides benisonensis**
- **Hedbergella spiculata**
7.6 Borehole 49/19-1 (Fig. 7.5)

This borehole was examined originally by Harris (1982) who identified only the foraminiferid species which he regarded as important Albian age indices. In addition he did not take into account lithological changes, wireline log characteristics, or caving. Harris concluded that the whole of the Early Cretaceous strata in this borehole was of Late to Middle Albian age. The reasons behind this are two fold:

A. Harris only identified Albian index forms. He ignored other species which if identified would have indicated an older age.

B. An Albian fauna (red brown stained) was present throughout the section as a result of abundant caving.

The washed residues of the samples used by Harris were re-examined and picked of foraminifera by the present author. The faunal slides of Harris were each re-sorted and the complete fauna identified.

The foraminiferal fauna is plotted in the order of species first appearance downhole and no attempt has been made to indicate abundance. The sieve size fractions and the quantity of sample Harris used is not known. In addition the lithological descriptions of the samples before preparation, made by Harris are inadequate for direct comparison with other boreholes.

In addition to incorrectly dating the whole of the Early Cretaceous section in this borehole as Late to Middle Albian in age, Harris assigned the section 2970 feet to 3310 feet to the Red Chalk Formation with 3310 feet being the top of the Speeton Clay Formation. In actual fact samples 3310 feet, 3340 feet and 3350 feet are within the Triassic and contain a caved Early Cretaceous fauna.
From the casing shoe (13 3/8 inches) at 2941 feet the hole was drilled using a 12 1/4 inch drill bit. The caliper log shows a consistent 14 inch hole diameter to 3140 feet and to 3250 feet a 15 inch hole is shown. Beneath 3250 feet to 3400 feet the caliper log shows a 14 inch diameter hole. The hole is persistently "out of gauge" and indicates that a large amount of caving has taken place.

Planktonic Foraminifera

The planktonic foraminiferal fauna is abundant and individuals increase in size "up" the borehole section examined.

The Hedbergella delrioensis plexus dominates the fauna with the larger specimens attributable to H. brittonensis being common in the uppermost section examined. The occurrence of H. simplex is interesting and indicates sediments of a Latest Albian/Early Cenomanian age (Carter and Hart, 1977). In the section examined it is caved. Globigerinelloides bentonensis is generally rare but appears as a flood in sample 3100 feet. This species, and its abundant occurrence has been recognised as being indicative of Latest Albian age sediments (Carter and Hart, 1977; Price, 1977a; Harris, 1982; Burnhill and Ramsey, 1981).

All the planktonic foraminiferids are stained a characteristic light red/brown colour; a feature of the Upper Holland Marl Member. Some of the smaller specimens of H. delrioensis, below 3200 feet are a dark brown/red colour and have a different preservational appearance to specimens in the interval above. H. planispira is recorded rarely throughout the section.

Benthonic Foraminifera

The arenaceous benthonic species are important as they provide very good indications of the age of the section. There is no

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foraminiferal evidence in this borehole for determining the position of the Cenomanian/Albian boundary.

The first three samples (above the Upper Holland Marl Member) contain a fauna characteristic of the Early Cenomanian and Late Albian. These species include *Arenobulimina chapmani*, *A.frankel*, *A.sabulosa*, *F.intermedia*, *M.ozawai* and *T.pyramidata*. The calcareous benthics *G.gr.intermedia*, *G.baltica*, *G.cenomanica* and *Valvulineria* spp. are important members of the fauna.

The benthonic foraminiferal fauna in the interval 3000 feet to the sample at 3150 feet is characteristic of the Late Albian in North West Europe (Price 1977a, b; Carter & Hart 1977). The rare occurrence of *Spiroplectinata annectens*, *S. complanata* and *S.bettenstaedti* indicates a Late Albian age though the species are according to Grabert (1959) most abundant in the Middle Albian. The first occurrence, down hole, of *Arenobulimina maofadyeni* is indicative of a Middle Albian age (3150 feet) and this age is substantiated by the abundant occurrence of *S.complanata* at 3180 feet (Grabert, 1959). There is a significant change in the fauna at 3200 feet, where there is a flood occurrence of *Glomospira ex. gr. gaultina*, *Reophax minuta* and *Gaudryina dividens*. There is a preservational change and the fauna is stained a dark brown/red colour. This coincides with a characteristic double spike in the interval transit time (base of the Middle Holland Shale Member). This fauna according to Price (1977a, b) is characteristic of the Early Albian and Late Aptian. The top occurrence of *Conorotalites bartenstein aptiensis*, *Verneuillnoides subfiliformis* at 3230 feet and, *Gaudryinella sherlocki* and *Gavelinella breiensis* at 3240 feet suggests an earliest Early Albian/Late Aptian age. The base of the Lower Holland Marl Member is at 3250 feet. There are no samples in the Vlieland Shale Member which is unfortunate.

The three samples at 3310 feet, 3340 feet and 3350 feet contain a diverse foraminiferal fauna; all caved from the interval above.
Some species have not been recorded from the overlying section possibly because i) samples are small sized, ii) lack of samples. The suggestion that a large amount of caving has taken place in this borehole is thus substantiated (cf. Harris op. cit.). The occurrence of age diagnostic species in these three samples does indicate or suggest the presence of Middle–Early Albian strata, Late Aptian and Early Aptian/Late Barremian age strata in the Early Cretaceous section above. *Osangularia schloenbachii* ranges from the Middle Albian to Late Aptian, *Lenticulina (S.) spinosa* is indicative of an Aptian age, *G.barremiana* is Earliest Aptian and Barremian in age, while *L. (L.) schreiteri* usually tops in the Earliest Aptian to Late Barremian (Bartenstein op. cit.).

**Biostratigraphical Conclusions**

Sediments of a Late Albian age are present from 3000 feet to 3150 feet. Middle to Early Albian age sediments are present to 3200 feet and Early Albian to Late Aptian sediments are present from 3200 feet to 3250 feet. Barremian sediments are probably present from 3250 feet to c. 3275 feet.

There are possible unconformities/discontinuities at c. 3200 feet, 3245 feet and 3275 feet.
**Fig. 7.6 Biostratigraphy of 49/10-1**

<table>
<thead>
<tr>
<th>Group</th>
<th>Shale</th>
<th>Top</th>
<th>MAX</th>
<th>MIN</th>
<th>TOPS</th>
</tr>
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<tbody>
<tr>
<td>C610</td>
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<td>C670</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### 49/10-1 Biostratigraphy

- **Lenticulina spp., unidentified**
- *Eponides marina*
- *Ammonitina charvoi*
- *Guillonia (Guillonia) group*
- *Guillonia belicia*
- *Palaeocymatina sp., unidentified*
- *Lingulopedinulina alliseria*
- *Arenicolitica eucanica*
- *Quinqueloculina antica*
- *Lingulopedinulina eucanica*
- *Polymerplithistea - unidentified*
- *Guadrycin gastrica*
- *Spirulinella pyriforme*
- *Pristiglandulina minitabilis / humilis*
- *Dreissella fitiformis*
- *Guillonia crenatia*
- *Ammonitina cavonum*
- *Denticula sp., unidentified*
- *Lingulopedinulina alta*
- *Arenicolitica alliseria*
- *Pseudodictyoceratina creata*
- *Pseudolenticulina arenitana*
- *Guadrycin recta*
- *Spirulinella complanata*
- *Guadrycin pyriformea*
- *Guadrycin discoides*
- *Arenicolitica mundicostata*
- *Nautiloides maximus*
- *Haplophragma spp., unidentified*
- *Pleurotomellina sp. c.*, *Triacidoma*
- *Vaginolina robusta*
- *Ischnopectenella sp.*
- *Dreissella trocha*
- *Lingulopedinulina sp., high spired*
- *Dreissella sp.*
- *Spirulinella sp. c.*
- *Armonitisina sp.*
- *Vaginolina cophica group*
- *Lenticulina (Lenticulina) hysterica*
- *Lenticulina (Hapalion) Jost group*
- *Amphirochitina minuta*
- *Phamoceras alliseria*
- *Ammonitina sp. e. unidentified*
- *Lenticulina (Hapalion) antelobata*
- *Conomuracites bentenensis optata*
- *Guadrycin breviseta*
- *Seephus acutovae*
- *Lenticulina (Saracenaria) spinosa*
- *Ceratites sp.*
- *Lenticulina (Planulina) complanata group*
- *Lenticulina (Hapalion) antelobata group*
- *Lenticulina (Saracenaria) broomi*
- *Lenticulina (Tentaculites) reticulata*
- *Spirulinella subfloridae*
- *Modoceras sp., unidentified*
- *Morphoceras subtrocha*
- *Triacidoma angusti*
- *Lenticulina (Lenticulina) qu'exchenei group*
- *Modoceras madisonian*
- *Gaudrycin flexirame*
- *Lenticulina (Hapalion) gravisetaea*
- *Vaginolina optatica*
- *Lenticulina (Saracenaria) festestia*
- *Lenticulina (Hapalion) reticulata*

- *Nebbergella simplex*
- *Pseudoceratites sp.*
- *Nebbergella deltoidea allusus*
- *Globigerinellidae bentenensis*
- *Nebbergella globospira*
- *Globigerinellidae pyriformis*
The sample coverage for this borehole is excellent from 7150 feet to 7500 feet (every 10 feet).

The foraminiferal fauna in the highest Early Cretaceous samples examined (downhole) is a light red/brown/pink colour (7150 feet - 7300 feet). This is a characteristic of the Upper Holland Marl Member in block 49: there is an element of caved fauna present readily identified by its chalk white colour. These specimens have not been logged. The colour of the foraminiferal fauna changes slightly in sample 7300 feet - 7310 feet to a pink/white/grey/red colouration. This colouration mix is also associated with a fauna caved from the overlying interval to sample 7360 feet - 7370 feet where there is a further colour change to a dark red brown. This colour persists to 7380 feet - 7390 feet. There are also traces of a light green claystone at this depth (7360 feet - 7370 feet to 7380 feet - 7390 feet) and in the sidewall core at 7210 feet (pers. comm. Shell U.K.). This imparts a greenish tint to elements of the foraminiferal fauna. The fauna beneath this depth is a light red/brown/pink and grey colour. At 7410 feet - 7420 feet to 7430 feet there is an influx of small red stained planktonic foraminifera (H. delrioensis = H. D11 of Hecht, 1938). Beneath 7430 feet - 7440 feet there is a grey white planktonic foraminiferal fauna in all samples to 7500 feet.

Planktonic Foraminifera

The planktonic foraminiferal fauna is numerous and diverse and dominated by the H. delrioensis - H. infracretacea - H. brittonensis plexus. This fauna is characteristic of the Upper Holland Marl Member in block 49 and individual size increases up the borehole section. The occurrence of H. simplex is indicative of latest Late Albian and Cenomanian age sediments (Carter & Hart, 1977). The presence of the genus
**Praeglobotruncana** is interesting as this genus is diagnostic of sediments of a latest Late Albian and Cenomanian age. **Globigerinelloides bentonensis** is generally not common but this species is recognised as indicating strata of a Late Albian age onshore northern Europe (Carter & Hart, 1977). In this borehole it is considered in place in the interval 7200 feet - 7210 feet to 7240 feet but is probably caved in samples beneath 7270 feet to 7410 feet. **H. planispira** is recorded as rare from 7240 feet - 7250 feet and is further evidence of a latest Early Cretaceous age for the section.

The occurrence of **Globigerinelloides** *gyroidinaeformis* from 7340 feet - 7350 feet to 7440 feet is interesting and denotes strata of a Middle to Early Albian age. It is rare in the samples studied (small size samples) and it may therefore be absent from the samples above by default (i.e. not caught in the sample). Its top recorded occurrence in this borehole may therefore not coincide with the top of Middle Albian sediments.

Red stained planktonics occur at 7410 feet - 7420 feet to 7430 feet and are referrable to the **H. delrioensis** group. They are quite small in size and equate with the **H. D11** horizon of Hecht (1938) = **H. delrioensis** of Bartenstein (1965). This important horizon is of earliest Late Aptian to Latest Early Aptian age in Germany. The white/grey coloured specimens of **H. infracretacea** - **H. aptiana** beneath (7430 feet - 7440 feet to 7500 feet) are important and may relate to the common occurrence of **H. delrioensis** in the Early Aptian and Late Barremian age strata of adjacent boreholes (this thesis) and of Heligoland (Bartenstein & Kaever, 1973). None of these deeper specimens in this borehole were strictly attributable to **H. aptiana** = **H. D9** of Hecht (1938).
Benthonic Foraminifera

The benthonic foraminiferal fauna is numerous and diverse and in the upper part of this borehole is comparable to the faunas recorded from the Upper Holland Marl in boreholes 49/24-3, 49/24-1 and 49/24-4. As a whole the faunal sequence from the first sample examined at 7140 feet - 7150 feet to the last at 7500 feet is very similar to the sequence in borehole 49/19-1. The fauna to 7250 feet is characterised by the common occurrence of Gavelinella intermedia group; rare specimens of G.baltica and G.cenomanica. This gavelinellid fauna according to a number of authors (e.g. Price, 1977a, b; Magniez - Jannin, 1975) indicates a Late Albian age when associated with the following benthonic species: Arenobulimina chapmani, A.franei, A.sabulosa, Eggerellina mariae and Q.antiqua.

Species of the Spiroplectinata/Gaudryina group were not present in sufficient numbers to enable a rigorous application of the scheme of Grabert (1959) to be made. However, the occurrence of G.gradata and rare S.complanata and S.annectens substantiates a Late Albian age to 7255 feet (swc).

The top downhole occurrence of A.macfadyeni and O.schloenbachii indicates the penetration of strata of a Middle Albian age (Carter & Hart, 1977) at 7255 feet (swc). Below this depth the rare but persistent occurrence of S.annectens and S.complanata substantiates a Middle Albian age. The occurrence of Conorboides lamplughii at 7300 feet - 7310 feet is further evidence for the penetration of strata of a Middle Albian age or older (Carter & Hart, 1977).

This fauna is characterised by an increase in the number and species diversity of the lenticulinid fauna, an increase in the gavelinellid fauna (number and diversity) and an increase in the numbers of the G. ex. group G. gaultina. These characteristics are according to Price (1977a, b) indicative of strata of an earliest Early Albian age in north west Europe. The top persistent occurrence of S.lata at 7360 feet - 7370 feet confirms an Early Albian age (Grabert, 1959). The rare specimens of Gaudryina dividens from 7310 feet to 7410 feet are similar to the earliest Early Albian to latest Late Aptian forms illustrated by Grabert (1959). At 7380 feet - 7390 feet an unconformity/hiatus/discontinuity is presumed to be present. This presumption is based on lithological evidence (dark red staining) and correlation with adjacent boreholes. The dark red stained interval may be an interval of condensation or of minor discontinuities (see 49/19-1).

The top occurrence at 7430 feet of specimens of Lenticulina (S.) spinosa confirms an Aptian age at that depth (see Bartenstein, op. cit. and the revised ammonite zonal scheme; see Chapter 11). The interval above from 7380 feet - 7390 feet to 7420 feet - 7430 feet is considered to be Early Albian to Late Aptian in age based on the benthonic foraminiferal evidence.

The benthonic foraminiferal fauna beneath 7430 feet is characterised by an increase in diversity and number of the lenticulinds and by an increase in the number of G.dividens. The presence of Gavelinella brielensis from 7410 feet - 7420 feet to 7500 feet indicates an Aptian to Barremian age for that interval. Barremian age sediments are indicated by the occurrence of L.(M.) reticulosa, L.(M.) gracillisma, L.(S.) forticosta, and L.(L.) ouachensis group from 7450 feet - 7460 feet to 7500 feet (Bartenstein, op. cit.). This is associated with an increase in the numbers of C.b. aptiensis which tend to grade towards C.b. bartensteini which does suggest the presence of Barremian age strata.
Biostratigraphical Conclusions

From a synthesis of the whole foraminiferal fauna the following biostratigraphic subdivision may be made. Sediments of a Late Albian age are present from 7140 feet - 7150 feet (first sample examined) to 7255 feet swc. Middle to Early Albian age sediments are present from 7255 feet to 7380 feet - 7390 feet. Early Albian to Late Aptian age sediments are present from 7380 feet - 7390 feet to 7420 feet - 7430 feet. Early Aptian? to Barremian age sediments from 7420 feet - 7430 feet to 7500 feet where the Early Cretaceous sediments overly unconformably sediments of a Permo-Trias age. There are unconformities/hiatuses - condensation horizons at 7390 feet and 7420 feet.
The sample coverage for the Early Cretaceous strata for this borehole is excellent from 4860 - 5340 feet.

The foraminiferal fauna to 4900 feet is stained a light red/brown/pink colour. This is a characteristic of the Upper Holland Marl Member.

The first grey coloured foraminiferal fauna is recorded in sample 4910 - 4820 feet and persists to sample 4970 - 4980 feet. In this latter interval very rare red stained foraminifera are present. The first downhole occurrence of green stained foraminifera occurs in sample 4910 - 4920 feet (*Hedbergella* spp.). Common green stained benthonic foraminifera occur in sample 4970 - 4980 feet (*Valvulineria* spp. among others).

Foraminifera in sample 4980 - 5000 feet are totally grey in colour. The fauna is sparse and totally dominated by agglutinating foraminifera.

The foraminiferal fauna from 5010 - 5020 feet is a very distinct green colour. This green coloured fauna persists to 5090 - 5100 feet where the foraminiferal fauna is dominated by brown red stained specimens.

From this depth to 5340 feet the faunal colouration is a mixture of grey, green, dark brown, black, light grey and white.

At 4910 - 20 feet there are very rare green stained planktonic foraminifera. Interval 5080 - 60 feet to 5090 - 5100 feet is dominated by rare to common green stained planktonic foraminifera.
Planktonic Foraminifera

Planktonic foraminifera of the *H. delrioensis - H. infracretacea - H. brittonensis* plexus are abundant in the four samples examined from 4850 - 60 feet to 4900 feet. The size of individuals increase on average "up" the borehole. This plexus dominates the fauna and is comparable to the same interval (Upper Holland Marl Member) in adjacent boreholes and all are stained a red/brown colour. *H. planispira* is not common but the specimens in sample 4900 - 20 feet are stained a green colour. This is coincident with the lithology change to the Middle Holland Shale Member.

Rare specimens of *H. planispira* occur in the interval 4850 - 60 feet to 4900 feet and are stained a red/brown colour. *H. planispira* is found in North West Europe throughout most of the Albian. Abundance levels may be events in the Albian important for correlation and event stratigraphy.

*Globigerinelloides bentonensis* is not common but its presence does indicate the presence of Late Albian age strata.

The rare occurrence of "*G."* *gyroidinaeformis* at 4900 - 20 feet indicates the presence of Middle to Early Albian age strata. Planktonic foraminifera are rare or absent from 4920 feet to 5050 - 60 feet. This is a characteristic of Middle to Early Albian strata in North West Europe (Price, 1977a, b).

Small green coloured specimens of *H. infracretacea* are recorded from 5060 feet to 5100 feet. They are common in sample 5050 - 60 feet (19 specimens) and 5070 - 80 feet (35 specimens), while in sample 5090 - 5100 feet specimens are rare (2). This planktonic occurrence is interesting as it denotes open oceanic connection, deeper water conditions and is of Early Albian/Late Aptian age and may be of use for local correlation (Middle Holland Shale Member).
Small, compressed, translucent/grey planktonic foraminifera, some specimens with a dull brown lustre, first occur downhole in sample 5100 - 20 feet. These specimens are attributable to *H. aptiana* Bartenstein. They are present in varying numbers to 5340 feet but are probably caved in the interval 5270 - 80 feet to 5340 feet. *H. aptiana* occurs with white coloured specimens of *H. infracretacea-delrioensis* in the interval 5130 - 40 feet to 5280 feet. This relates to the Late Barremian - Aptian interval of Germany and adjacent boreholes in the southern North Sea area (Bartenstein & Kaever, 1973).

The rare red specimens of *H. delrioensis-infracretacea* at 5160 - 70 feet and 5180 - 90 feet are probably caved from higher in the borehole. No red stained planktonics were recorded which could be attributed to the *H. D11* horizon of Hecht (1938). This may be a function of sample interval and/or sample size. A red stained benthonic foraminifera interval at 5090 - 5100 feet did not contain any red stained planktonics.

**Benthonic foraminifera**

The benthonic foraminiferal fauna is abundant and diverse and in the upper part of this borehole is comparable to the faunas recorded from the Upper Holland Marl Member in boreholes 49/24-3, 49/24-1, 49/24-4 and 49/10-1. In general the benthonic foraminifera sequence from the first sample examined at 4860 feet to the sample 4880 - 90 feet is characterised by the common occurrence of *Gavellinella intermedia* group; *G. baltica* and *G. cenuomanica*. This gavelinellid fauna, in association with the characteristic Arenobuluminid fauna, including *A. chapmani; A. frankei, A. sabulosa, and G. antiqua, S. mariae, S. bettenstaedti, S. papyracea, L. albiensis and L. ciryi ciryi* indicates, according to Price (1977a, b) and Magniez-Jannin (1975), a Late Albian age.
The top downhole occurrence of *Conorboidea lampiughii*, *Osangularia schloenbachii* with common *A. macfadyeni* at 4890 - 4900 feet indicates strata of a Middle Albian age (Carter & Hart, 1977). The numbers of the *G. intermedia* group increase downhole. However, the fauna beneath 4950 - 60 feet is dominated by arenaceous forms and is a characteristic of the Middle Holland Shale Member of earliest Middle to Early Albian age. The Lenticulinid fauna persists but the numbers of the gavelinellid and arenobuliminid fauna rapidly diminishes with depth. The first significant flood occurrence of *G. gaultina* at 4950 - 60 feet is also important as it is associated, as is the other faunal turnover, with the Early Albian of the Middle Holland Shale Member. The Middle Holland Shale Member in this borehole is of Middle to Early Albian age, but the top of the Early Albian cannot be positioned with precision. The increase in the arenaceous benthonics, as noted by Price (1977a, b), and noted in this thesis in other boreholes (e.g. 49/24-4) is facies related and is associated with the diachronous Albian transgression (Early Albian of Price op. cit.). This faunal change over at 4950 - 60 feet may be the top of the Early Albian strata. The top occurrence of *Textularia bettenstaedti* at 5000 - 5020 feet is taken to indicate Early Albian - Late Aptian age sediments. Coincidentally at this latter depth there is a log change on the caliper log and in the sonic log response.

The top occurrence of *L. (S.) spinosa*, together with abundant *G. ex. gp. gaultina*, persistent but still rare *T. bettenstaedti* and an increase in the number of *G. dividens*, at 5050 - 60 feet together with the top occurrence of *L. (M.) schloenbachii* and *L. (M.) foeda* is taken pragmatically as the top of definite Aptian sediments. This is substantiated by the reoccurrence of green stained planktonics (Aptian transgression). The actual top of the Aptian cannot be placed with certainty but falls within the interval 5000 - 20 feet to 5050 - 60 feet.
The fauna beneath 5050 - 60 feet is characterised by the top occurrences of V. recta, L. (S.) frankei, L. (M.) bettenstaedti, A. reophacoides and G. barremiana and is associated with red staining. The calcareous fauna content increases and the agglutinating fauna decreases in number. The number of G. dividens and Gavelinella brielensis increases and the species L. (S.) spinosa persists. This fauna is characteristic of the Aptian strata.

The top occurrence of C. b. aptiensis, N. zippei, and L. (L.) heiermanni at 5160 - 70 feet and L. (L.) ouachensis, L. (F.) crepidularis, F. hastata, F. didyma, C. b. intercedens, L. (L.) schreiteri, N. spectrum, V. neocomiensis plus an increase in the numbers of G. ex. gp. gaultina at 5180 - 90 feet is associated with an increase in total fauna number. This fauna indicates the penetration of strata of a (?Late) to Early Barremian age (Bartenstein & Bettenstaedt, 1962).

The faunal change at 5240 - 50 feet coupled with the top occurrence of C. b. bartensteini s.s., F. hannoverana, N. proboscidae, L. (A.) neopachynota, and the top occurrence of H. caracolla, G. richteri/praevidens, L. (L.) guttata at 5250 - 60 feet indicate the penetration of strata of ?earliest Barremian to Late Hauterivian age. The increase in the numbers of V. neocomiensis together with M. kummi/hauteriviana substantiates the age assignment.

Biostratigraphical conclusions

From a synthesis of the whole foraminiferal fauna the following biostratigraphic subdivision may be made.

Sediments of a Late Albian age are present from circa 4760 feet to 4880 - 90 feet. The higher depth is the formational boundary between the Cromer Knoll Group and the overlying Chalk Group.
No samples were made available for study across this boundary so the actual Cenomanian/Late Albian boundary could not be determined.

Middle to Early Albian age strata occurs from 4880 - 90 feet to 5000 - 5020 feet.

?Early Albian - Late Aptian sediments are present from 5000 - 5020 feet to 5050 - 5060 feet. Late - Early Aptian sediments are present from 5050 - 5060 feet to 5160 - 5170 feet. ?Late Barremian to Early Barremian sediments occur from 5160 - 5170 feet to 5240 - 50 feet.

?Early Barremian to Hauterivian sediments are present from 5240 - 50 feet to 5325 feet where the Early Cretaceous sediments overly unconformably sediments of a Permo-Triassic age.
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The sample coverage for this borehole is excellent from 6050 - 60 feet to 6960 - 70 feet (10 feet samples every 20 feet).

The highest samples from 6050 - 60 feet to 6150 - 60 feet comprise white chalk. The foraminiferal fauna in the highest Early Cretaceous samples examined (downhole) is a light red/brown/pink colour (6170 - 80 feet). This is a characteristic of the Upper Holland Marl Member in block 49. There is a caved Late Cretaceous fauna present which is readily identified by its chalk white colour. These specimens have not been logged. The fauna in the interval to 6270 - 80 feet is a red/brown/pink colour but in sample 6290 - 6300 feet there is a drastic colour change to a fauna which is dominantly light grey. This is associated with the "limestone" present at the base of the Upper Holland Marl/Red Chalk. There are a few species which are stained a light green colour (e.g. O. schloenbachii, Valvuliniera spp.). This colour change coincides with a lithological change from the Upper Holland Marl member to the Middle Holland Shale Member at 6290 feet. The fauna for the remainder of the section studied is a predominantly non descript grey-brown colour apart from a few horizons where influxes of red colouration (6460 feet, 6640 feet) and green colouration (6440 feet, 6460 feet) occur.

**Planktonic foraminifera**

The planktonic foraminiferal fauna is abundant and diverse and dominated by the *H. delrioensis* - *H. infracretacea* - *H. brittonensis* plexus. This fauna is stained red/brown and is characteristic of the Upper Holland Marl Member in block 49 and individual specimen size increases up the borehole section. The presence of the genus *Praeglobotruncana* is diagnostic of sediments of a latest Late Albian and Cenomanian age. *Globigerinelloides bentonensis* is not common but indicates strata of a Late Albian age (Carter & Hart, 1977) in the interval 6230 -
40 feet to 6290 - 300 feet. The occurrence of *H. planispira* (top at 6230 - 40 feet) is of local correlative importance and supports a latest Early Cretaceous age.

The planktonic fauna is a light grey colour from, and below, sample 6290 - 6300 feet. The planktonic fauna is sparse and monospecific beneath 6290 - 6300 feet to 6430 - 40 feet where the first occurrence downhole of *Hedbergella delrioensis* stained green is of local correlative importance of Early Albian to Late Aptian age.

The rare occurrence of "*Globigerinelloides*? gyroidinaeformis" in samples 6250 - 60 feet and 6270 - 80 feet denotes strata of a Middle to Early Albian age.

Red stained *Hedbergella delrioensis* of small size occur in sample 6450 - 60 feet and may equate with the *H. D11* horizon of Hecht (1938) which is of earliest Late Aptian to latest Early Aptian age.

Reddish grey lustre coloured specimens of *H. aptiana* beneath 6450 - 60 feet are important as they may relate to the common occurrence of *H. delrioensis* in the Early Aptian and Late Barremian age strata of adjacent boreholes and of Heligoland (Bartenstein & Kaever, 1973). However none of the specimens in this borehole are strictly attributable to *H. aptiana = H. D9* of Hecht (1938). They occur as a flood in 6490 - 500 feet. Clumps of white coloured *H. delrioensis* (*H. D11*) - *H. aptiana* (*H. D9*) occur in sample 6470 - 80 feet. This planktonic fauna is characteristic of the Early Aptian in northwest Germany (Bartenstein, 1965; Hecht, 1938; Bartenstein & Kaever, 1973; Bartenstein, 1978). The planktonic fauna decreases in number and importance beneath 6530 - 40 feet and only rare specimens are recorded - possibly as a result of caving, though planktonic foraminifera did exist in the pre-Aptian Early Cretaceous of North West Europe.
Benthonic foraminifera

The benthonic foraminifera are diverse and numerous. The arenobuliminid (A. chapmani, A. frankelii, A. advena, A sabulosa) and gavelinellid fauna (G. ex gr. intermedia, G. baltica, G. cenomonica) are, according to Bartenstein (op. cit.), Carter & Hart (1977), Price (1977a, b) and Harris (1982), important members of the Late Albian benthonic foraminiferal fauna in North West Europe. This species association together with L. cyri inflata indicates a Late Albian age for the Upper Holland Marl in this borehole.

The topmost occurrence of O. schloenbachi, A. macfadyeni and the glomospira gaultina group in the basal part of the Upper Holland Marl Member indicate the penetration of sediments of a Middle Albian age at 6270 – 80 feet. This is associated with an increase in the number of arenaceous foraminifera (Haplophragmoides spp., Trochammina spp.) and a decrease in individual size of the gavelinellid species.

The benthonic foraminiferal fauna to 6370 feet is characteristic of the Middle to Early Albian strata of North West Europe (Carter & Hart, 1977; Price, 1977a, b). The occurrence of C. lamplughi and V. mediocarinata indicate a pre Late Albian age. The topmost occurrence of G. dividens and S. lata is interesting as they have been used in Germany to indicate Early Albian sediments. In fact the boundary between the Upper Holland Marl and the Middle Holland Shale may be unconformable representing Late and Middle Albian age sediments above Early Albian with earliest Middle Albian sediments being absent. This tentative suggestion cannot be substantiated precisely by the available data.

The basal part of the Middle Holland Shale from 6370 feet down to 6450 – 60 feet (within the Lower Holland Marl) is of Early Albian
to Late Aptian age as indicated by the occurrence of *T. bettenstaedti* and a dramatic increase in the number of *G. ex. gr. gaultina*. The sandy/silty horizon at 6420 feet is assumed to be the lateral equivalent of the Holland Greensand Member and to represent the "basal" Albian transgression. The occurrence of *A. minuta, M. subtrochus, A. reophacoides, L. (M.) bettenstaedti, L. (M.) jonesi* group and the abundance of *H. concavus/nonioninoides* and *G. gaultina* characterise this interval.

A pragmatic approach could be taken and the conclusion made that the silty/sandy horizon at 6420 feet is in fact the base of the Albian (Lott, Ball & Wilkinson, 1985). This would indicate that the portion of the Middle Holland Shale Member beneath is Late Aptian in age.

The top occurrence of a red stained benthonic foraminiferal fauna together with *L. (S.) spinosa, G. brielensis, F. concinna, L. (M.) schloenbachi* and *L. (S.) forticosta* define the top of definite Aptian age sediments at 6450 feet. This is associated with an increase in the lenticulinid and the planktonic foraminiferal fauna as a result of a change in depositional regime: more carbonate. The occurrence of *C. b. aptiensis* and *L. (S.) frankei* at 6510 - 20 feet indicate Early Aptian age strata.

The wireline log features at 6520 feet probably represent an unconformity with Late? to Early Aptian age strata (6450 feet to 6520 feet) resting on Late to Early Barremian age strata (6520 feet to 6550 feet) beneath. The occurrence of *C. b. intercedens, V. robusta, M. kummi/hauteriviana, L. (L.) ouachensis* and *L. (L.) praegaultina* at 6520 - 6530 feet indicates the penetration of sediments of Late to Early Barremian age (Bartenstein & Bettenstaedt, 1962; Bartenstein 1978a). This is coincident with a marked lithological change to a dark grey, micaceous, fissile claystone (the Vlieland Shale Member).
The occurrence of *G. barremiana*, *C. b. bartensteini*, *G. sigmoicosta* and *V. neocomiensis* plus an influx of *G. ex. gr. gaultina* indicates an Early Barremian to Late Hauterivian age for the interval beneath 6550 - 60 feet (Bartenstein & Bettensaedt, 1962; Bartenstein, 1978a).

The foraminiferal fauna beneath this depth to the Base Cretaceous Unconformity have not been studied in detail. As a consequence this section has not been subdivided biostratigraphically using the foraminiferal faunas. Any such division would be tentative in the absence of i) collaborative data from calcareous nannoplankton analysis and palynological analysis ii) similar sections from nearby boreholes for comparison.

The foraminiferal fauna recorded, none the less, appears to be essentially Early Barremian and Hauterivian in aspect with perhaps Valanginian at the base.

Biostratigraphical conclusions

The development of the Early Cretaceous strata in this borehole is typical for block 49 of the southern North Sea. The biostratigraphical breakdown is as follows.

Strata of a Late Albian age are present from 6170 - 80 feet to 6270 - 80 feet. Strata of Middle Albian age though may commence at 6250 - 60 feet at the base of the Upper Holland Marl.

Strata of a definite Middle Albian to Early Albian age are present to 6370 - 80 feet (Middle Holland Shale) and overy an interval of Early Albian to late Aptian age (6320 - 80 feet to 6480 - 60 feet). This in turn overlies strata of ?Late Aptian to Early Aptian age (6450 - 60 feet to 6510 - 20 feet) - Lower Holland Marl.
The basal part of the Middle Holland Shale is therefore Early Albian to Late Aptian in age.

Strata of a ?Late Barremian to Early Barremian age are present from 6510 - 20 feet to c. 6560 feet. Strata between this depth are of ?Barremian to Hauterivian age.

Unconformities/hiatuses are present at the junction of the Upper Holland Marl and Middle Holland Shale (c. 6280 feet); at c. 6420 feet and at 6510 feet.
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Stratigraphische Tabelle

Revised chronostratigraphy in north west Germany, after Bartenstein, 1978a.
7.10 Biostratigraphical Methods

A. Benthonic Foraminifera

The value of benthonic foraminifera in the worldwide biostratigraphy of the Early Cretaceous is limited in the degree of zonal refinement possible. Biozonal schemes of a refined nature tend to have good local validity for correlation but have a lesser degree of worldwide applicability.

In a biozonal scheme utilising benthonic foraminifera the vertical ranges of the zonal species are never clearly defined but commonly overlap with stratigraphical older or younger zonal index foraminifera (see Figs. 7.9 & 7.10). This is coupled with the complication that the range of the index species usually differs between facies realms (Boreal and Tethys).

Benthonic foraminiferal assemblages have to be used for correlation and results in the erection of an ecostratigraphy as well as a biostratigraphy. As a result of the lack of diverse planktonic foraminiferal faunas in the Early Cretaceous of North West Europe (a facies and evolution control) benthonic faunas have to be used for correlation purposes. Tethyan and/or deeper water Early Cretaceous sediments in North West Europe do contain planktonic foraminifera but their specific diversity is low (Hart, 1980). Nevertheless some planktonic species can be used within a biozonal scheme (e.g. *Hedbergella* D9 and H. D11; see Fig. 7.11).

Benthonic foraminiferal faunas are facies controlled but it must be remembered that in some species the larval stage may be pelagic, hence their widespread distribution.
Fig 7.10

The stratigraphic distribution of Conorotellites bartensteini in the north-west German Lower Cretaceous (from Bettenstaedt & Brunton, 1962).


1. Gehäuse von Mittelungseiten rechteckig-gerundet, niedrig; die Umbilicalseite bildet mit der meisten gefärbten Spirealseite Winkel von 90° bis über 100°.

2. Rechteckig-gerundet, hoch.

3. Stumpfzwick, wobei die Seitenwand der Endkammer mit der Spirealseite noch einen rechten Winkel bildet, während die andere Seite schräg abfällt.

4. stumpfzwick, beide Seitenwände schräg abfallend.

5. Spitzkonisch-lachch.

6. Spitzkonisch-flach; Umbilicalseite glckenförmig; Spirealseite konvex; Rand schwach gekeilt.


Kurven a—c: Conorotellites bartensteini (HERRERSTAEDT 1932)
Kurven d—g: Conorotellites intercedens (DIETRICH-STEINER 1932)
Kurven h—i: Conorotellites apertus (HERRERSTAEDT 1932)

a) Flämische Ziegelsie Herrenboest bei Hannover (Typlokalität) — 224 Gehäuse.
b) Ziegelsie Herrenboest — 100 Gehäuse.
c) Ziegelsie Herrenboest — 100 Gehäuse.
d) Ziegelsie Herrenboest — 100 Gehäuse.
e) Ziegelsie Herrenboest — 50 Gehäuse.
f) Ziegelsie Herrenboest — 50 Gehäuse.
g) Ziegelsie Herrenboest — 50 Gehäuse.
h) Bohrung Georgsfeld 81, Kern 560—581,5 m. — 101 Gehäuse.
i) Bohrung Georgsfeld 81, Kern 575,5—577 m. — 117 Gehäuse.
j) Bohrung Georgsfeld 81, Kern 603,2—604,8 m (Typlokalität) — 118 Gehäuse.
k) Bohrung Georgsfeld 81, Kern 645—647,5 m. — 201 Gehäuse.
l) Bohrung Georgsfeld 49, Kern 911—938 m. — 38 Gehäuse.
m) Bohrung Georgsfeld 43, Kern 954—958 m. — 43 Gehäuse.
a) Bohrung Georgsfeld 53, Kern 116,5—120 m. — 106 Gehäuse.
b) Bohrung Georgsfeld 60, Kern 116,5—120 m. — 106 Gehäuse.
In North West Europe broad correlation from one area to another (e.g. Speeton to Heligoland to the Lower Saxony Basin) can be achieved by benthonic foraminiferal faunas (Fletcher, 1973). The resultant correlation is usually adequate for distinguishing stage subdivisions. A more precise and refined zonal scheme using benthonic foraminiferal faunas can be used for correlation within one particular area e.g. in the Lower Saxony Basin where events of a local rather than of a regional significance can be correlated from well to well.

B. Planktonic Foraminifera

Planktonic foraminifera are of particular value in biostratigraphy as they satisfy all the attributes for correlation.

i) preservable and identifiable

ii) their small size ensures their recognition in borehole cuttings

iii) widespread geographic distribution

iv) rapid migration

v) abundant

vi) rapid evolution and diversification

Modern planktonic foraminifera are considered to be cosmopolitan in their distribution. However, pronounced modifications of planktonic foraminiferal abundances and character are apparent (due to currents and other environmental factors) with latitude, with water depth and with salinity changes etc. (Bandy, 1960a, b). These
Verbreitung der Gattung Hedbergella in der Unterkreide nach Hecht 1938. —
Erläuterung der Ziffern:

<table>
<thead>
<tr>
<th>Ziffer</th>
<th>Globigerina</th>
<th>Unterkreide</th>
<th>Verbreitung der Hedbergella-Arten</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Globigerina</td>
<td>D 16</td>
<td>Hedbergella cf. deliriensis (CANSAY 1926).</td>
</tr>
<tr>
<td>9</td>
<td>Globigerina</td>
<td>D 9</td>
<td>Hedbergella aptana n. sp.</td>
</tr>
<tr>
<td>5</td>
<td>Globigerina</td>
<td>D 5</td>
<td>Hedbergella sp.</td>
</tr>
<tr>
<td>11</td>
<td>Globigerina</td>
<td>D 11</td>
<td>Hedbergella deliriensis (CANSAY 1926).</td>
</tr>
<tr>
<td>6</td>
<td>Globigerina</td>
<td>D 6</td>
<td>Hedbergella planispira (TAPPAN 1940).</td>
</tr>
</tbody>
</table>

(Die Verbreitung von Globigerina D 5 ist in Hecht's Tabellen nicht wiedergegeben.)

<table>
<thead>
<tr>
<th>Unterkreide</th>
<th>Zonen</th>
<th>Stratigraphische Verbreitung der Hedbergella-Arten</th>
</tr>
</thead>
<tbody>
<tr>
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<td>laetus, intermedius, densatus, mammillatum</td>
<td>M. Albian</td>
</tr>
<tr>
<td></td>
<td>regularis, tardifuscata, schrammeni, jacobii, nolani</td>
<td>L. Albian</td>
</tr>
<tr>
<td>Unter-Alb</td>
<td>schmidtii, clava</td>
<td>U. Aptian</td>
</tr>
<tr>
<td>Ober-Apt</td>
<td>deshayesi, bodei</td>
<td>L. Aptian</td>
</tr>
<tr>
<td>Unter-Apt</td>
<td>bidentatum, rude</td>
<td>M. Barr.</td>
</tr>
<tr>
<td>Ober-Barrême</td>
<td>sparsicostata, dendkmanni, elegans</td>
<td>U. Barr.</td>
</tr>
<tr>
<td>Mittel-Barrême</td>
<td>fuscostatum, saracinctum, strambeki</td>
<td>L. Barr.</td>
</tr>
<tr>
<td>Unt-Barrême</td>
<td></td>
<td>Haut.</td>
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</tbody>
</table>

Fig. 7.11

The distribution of the genus *Hedbergella* in the Lower Cretaceous of north-west Germany, after Bartenstein (1965) revision of Hecht (1938). With the revised north-west German chronostratigraphy of Bartenstein (1978).
details are discussed in some detail, with particular reference to Cretaceous planktonic foraminifera, by Bandy (1967).

Fossil planktonic foraminifera have long been recognised as valuable tools for correlation in Cretaceous and Tertiary strata (Bandy; 1964a, 1967; Stainforth et al., 1975) especially in the Tethyan faunal realm. As with modern faunas their abundance and distribution is modified by the effects of climatic/ecological controls. Their usefulness in the Boreal realm of the Early Cretaceous as correlation tools is therefore modified by the relationship of the various environmental controls to the distribution pattern of the planktonic foraminifera.

The southern North Sea Basin during the Early Cretaceous was part of the Boreal faunal realm and the low diversity of the planktonic foraminifera precludes a fine correlation and biozonal scheme. This is in sharp contrast to the planktonic foraminifera of the later Early Cretaceous (Aptian-Albian) in the Tethyan realm where their abundance and diversity makes them more amenable for biostratigraphic use (e.g. Longoria, 1974; Moullade, 1966; van Hinte, 1976).

However it must be remembered that the planktonic foraminifera as a group were at an early stage of evolution during the Early Cretaceous and consequently not diverse generically or specifically (Hart, 1980).

The earliest record of a true planktonic foraminifera is from the Bathonian (Middle Jurassic). Masters (1977) and Bandy (1967) have discussed the origin, development and phylogeny of the planktonic foraminifera. Until the Barremian, records of planktonic foraminifera are sparse. After the "mid" Barremian there ensued a rapid
diversification of the planktonic foraminifera (Masters, 1977). After the Aptian/Early Albian transgression there is an apparent adaptive radiation and increase in diversity of the planktonic foraminiferal faunas in southern England, northern France and the North Sea Basin within the Boreal realm which, despite the lack of some Tethyan index species (Burnhill & Ramsay, 1981; Price, 1977a, b; Carter & Hart, 1977) are very useful biostratigraphically. Recently Magniez-Jannin (1981) has recorded keeled planktonic foraminiferal faunas in the Late Albian sediments of southern England (Folkestone - Copt Point).

The increase in the number and diversity of the planktonic foraminifera in the late Early Cretaceous has been discussed by Carter & Hart (1977), Hart & Bailey (1979) and Hart (1980) in relation not only to changes in temperature but to changes in water depth in the North West European Early Cretaceous continental shelf sea. These authors suggest that the water depth of the epicontinental sea increased with time and that the progressive submergence of the London - Brabant Platform archipelago area during the Aptian and Albian provided faunal links and migration routes from Tethys in the south to North West Europe for deep water planktonic foraminifera. Therefore, the first occurrence (evolutionary) of certain species of planktonic foraminifera in shallow epicontinental seas is controlled by migration and water depth and is not an indication of evolutionary first appearance per se.

The philosophy governing the use of planktonic foraminifera as biostratigraphical tools is interesting and complex. However, a full discussion of this topic is beyond the scope of this thesis. Suffice to say that the
author recognises the many problems, drawbacks and restrictions inherent in the use of planktonic foraminifera as biostratigraphical tools (Stainforth et al., 1975; Crittenden, 1979, 1981, 1982b, 1986). Planktonic foraminifera are not the panacea for biostratigraphical correlation. Too many stratigraphers regard planktonic foraminifera as the ultimate tool for solving stratigraphical problems and assume that they are not affected by environmental factors. Relatively shallow epicontinental seas, where numerous bays, inlets, estuaries and islands abound exercise a profound effect on the distribution of planktonic foraminiferal faunas. This palaeoenvironmental scenario is envisaged for the Early Cretaceous sea of North West Europe. Facies changes associated with transgression/regression phases of the sea affect both benthonic and planktonic foraminiferal faunas. An additional point to remember is that high rainfall, associated high runoff and high freshwater discharge into the shallow marine environment inhibits the development of planktonic foraminiferal faunas.

The occurrence of certain planktonic species at certain levels in a stratigraphic sequence of shallow marine nearshore sediments is probably a product of local environment and will not indicate the species true stratigraphic range (either evolutionary first appearance or extinction) - (e.g. see the Atherfield Clay section - Chapter 12, and Crittenden, 1982b, 1983a and 1986).
### F. BETTENSTAEDT
#### LOWER CRETACEOUS

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**Fig 7.12.** The Worldwide Lower Cretaceous biostratigraphic scheme of Bettenstaedt (1955).
Bettenstaedt & Wicher (1955) at the 4th World Petroleum Congress proposed a worldwide correlation of the marine Early and Late Cretaceous strata by foraminifera. Their paper discussed in some detail the utility of foraminifera in biozonation and the different methods of approach employed by various micropalaeontologists and stratigraphers in solving taxonomic problems and correctly identifying species. Their biozonal scheme (Plate v) of stratigraphic ranges of Early Cretaceous foraminifera are related to stage boundaries defined prior to the revision of Bartenstein (1978a) and in consequence the ranges of their index foraminifera are now imprecise (Fig. 7.12). For example "Saracenaria" spinosa according to Bettenstaedt & Wicher (1955) became extinct in the Early Albian but according to Bartenstein (1978a) it became extinct in the Late Aptian.

Bettenstaedt & Wicher (1955) relied on a data base of research conducted mainly on material from north west Germany and included the biozonal scheme of Hecht (1938). The biozonal scheme of Hecht (1938) is a practical, easily used, industrial biostratigraphy of the Early Cretaceous strata of North West Germany. It is a classic of its kind (Fig. 7.13). As a scheme for comparison with other Early Cretaceous sequences in North West Europe it has severe limitations. A major limitation is Hecht's use of genus (now sadly outdated) and an alpha-numeric code for the index species he uses. Bartenstein's revisions (1952a, b, 1962, 1965) of Hecht's classification and terminology has partially solved the problem but a great deal of tiresome work is involved in relating the publications of Bartenstein to that of Hecht. In addition the stage and ammonite zonal boundaries of Hecht need to be revised in view of the later work of Bartenstein (1978a).
Fig. 7.13

The stratigraphy of the north west German Early Cretaceous (Hecht, 1938).
In 1962 Bartenstein and Bettenstaedt proposed a zonation of the Early Cretaceous strata of north west Germany which was essentially based on their own researches and the pioneering work of Hecht (1938). This biozonation scheme together with that of Hecht (1938) has been used extensively by stratigraphers working in the North Sea area. However it is apparent that few are aware of the major changes in the scheme made by Bartenstein (1978a) (Fig. 7.14 a & b).

The aforementioned biozonal schemes have been of paramount importance in the compilation of this thesis. However mention must be made of a number of other published biozonal schemes for North West European Early Cretaceous strata and of the more ambitious biozonal schemes proposed for the worldwide Early Cretaceous strata.

Bartenstein (1976a) proposed a foraminiferal biozonation of the Early Cretaceous of north west Germany and simultaneously applied it to Early Cretaceous sequences encountered in Trinidad, West Indies (Barremian to Albian). This work was aided by the earlier research of Bartenstein and colleagues on Trinidadian Early Cretaceous material (1957, 1966, 1973, 1977) (See Fig. 7.15).

Bartenstein (1976b) consolidated his research on a worldwide applicability of a biozonation by benthonic foraminifera (36 species) of the Early Cretaceous by including research results from both the Temperate (Boreal) and Tethyan realms of Europe and central America (Bartenstein, Bettenstaedt & Kovatcheva, 1971) (see Fig. 7.16). In a further publication the same year Bartenstein (1976c) incorporated additional Canadian research results to arrive at 35 index species (Fig. 7.17).

Bartenstein (1977b) presented a further amplification of his initial worldwide biozonal scheme and increased to 59 the number
Fig. 7.14a. Bartenstein's revision (1978a) of Bartenstein & Bettenscheidt (1962).

**Norwegische Unterkreide**

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<td>Ober- Hauter.</td>
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**ACTUAL ZONATION WITH AMMONITES**

According to papers by:
IN THE MAIN PUBLISHED BY:

BARTENSTEIN & DERTLI 1978.

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<td>Ober- Hauter.</td>
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Guttaschel, Sarni, Bartenstein & Bettenscheidt.
Fig. 7.14b

Bartenstein's revision of Bartenstein & Bettenstaedt (1962).
<table>
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<tr>
<th>NW GERMANY</th>
<th>BOTH REALMS</th>
<th>TRINIDAD</th>
<th>MARIDALE</th>
<th>CUCHE</th>
<th>TOCO</th>
<th>FORMATION</th>
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<td>UPPER ALBAN (LOWER PART) TO LOWER ALBAN (UPPER PART)</td>
<td>Plesioschistella obtusa -- AND -- Gavellinella intermedia</td>
<td>Proeoglobotruncana rohri</td>
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<td>LOWER ALBAN (LOWER PART) TO UPPER APTIAN</td>
<td>Goudryina divinens -- AND -- Lenticulina (S.) spinosa</td>
<td>Planomalina maridalensis -- OR -- Biglabigerinella barri</td>
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<td>UPPER APTIAN (LOWER MOST P.) TO UPPER BARREM. (UPPER MOST P.)</td>
<td>Conorotalites aptiennis -- AND -- Lenticulina (A) tricarinella</td>
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<td>Epistomina caracolla,ornata -- AND -- Marssonella kummi</td>
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<td>ZONE</td>
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</tbody>
</table>

Fig. 7.15. Bartenstein's (1976a) Lower Cretaceous zonation of north-west Germany and Trinidad.
| U.J. BERRIAS | M. B. VALANGHAUTER BARREMI APTIAN ALBIAN U.C. ALBIAN | EAST CANADA AND NORTHWEST GERMANY |
|-------------|---------------------------------|---------------------------------
|             | Nodosaria recta                 | Nodosaria recta                 |
|             | Pseudobaculites novacostae      | Pseudobaculites novacostae      |
|             | Lingulina elongata              | Lent. (L.) gutata               |
|             | Lent. (L.) geosiphon           | Epistominus reticulatus         |
|             | Epistominus reticulatus         | Epistominus reticulatus         |
|             | Ex. sin. polyzoaellae          | Ex. sin. polyzoaellae          |
|             | Goniaspira intermedius         | Goniaspira intermedius         |
|             | Nodosaria recta                 | Nodosaria recta                 |
|             | Trachyceras magnificum          | Trachyceras magnificum          |
|             | Conanspira ornata              | Conanspira ornata              |
|             | Ex. sin. eugrapheigeri         | Ex. sin. eugrapheigeri         |
|             | Goniaspira polyzoaellae         | Goniaspira polyzoaellae         |
|             | Conanspira polyzoaellae         | Conanspira polyzoaellae         |
|             | Lent. (L.) nodose               | Lent. (L.) nodose               |
|             | Ammodiscus subcostatus         | Ammodiscus subcostatus         |
|             | Ostracodites polygonostigmatos | Ostracodites polygonostigmatos |
|             | Varvede, neoparacostata        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Epistominus reticulatus         | Epistominus reticulatus         |
|             | Epistominus reticulatus         | Epistominus reticulatus         |
|             | Conanspira ornata              | Conanspira ornata              |
|             | Ex. tenuispira                  | Ex. tenuispira                  |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Ep. eugrapheigeri              | Ep. eugrapheigeri              |
|             | Conanspira polyzoaellae         | Conanspira polyzoaellae         |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |
|             | Lent. (L.) eugrapheigeri        | Lent. (L.) eugrapheigeri        |

Legend:
- Tethyan facies realm of East Canada (--- upper line of respective species)  
- normal occurrence
- occurrence uncertain on account of caved material (in German "Nachfall") in deeper formations
- problematic occurrence in the East Canadian Lower Cretaceous according to deviation of occurrences of the respective species in North West Germany or North West Europe (Most important exploration areas with exploratory wells for Lower Cretaceous on the Atlantic continental margin of East Canada: Grand Banks offshore Newfoundland and Scotian Shelf offshore Nova Scotia) Northern temperate (--- boreal) facies realm of North West Germany (--- lower line of respective species)  
- normal occurrence
- occurrence uncertain, no sufficient proof

1) until now no systematic investigation and no taxonomic separation of respective species in the North West German Lower Cretaceous  
2) planktonic species  
3) partly (in the Berriasian and Lower Valanginian) proof of occurrence outside of North West Germany: in Britain, France and East Europe with marine deposits in the respective formations

Fig. 7.17.
Stratigraphic distribution of index foraminifera in the Lower Cretaceous of East Canada and north west Germany (Bartenstein 1976c)
Fig. 7.18a  Stratigraphic distribution of benthonic index Foraminifera in the northern hemisphere boreal and tethyan Lower Cretaceous. (from Bartenstein, 1977b)
Stratigraphic distribution of benthonic index foraminifera in the Lower Cretaceous of the northern hemisphere in its temperate (boreal) and tethyan (mediterranean) facies realms.

Upper line of respective species: o o o o Bulgaria and Rumania, tethyan facies realm.
* * * * only Rumania.

Central line of respective species: — — Central, North West Europe, North West Germany, boreal facies realm; and East Venezuela and Trinidad (interval only from Barremian to Albian), tethyan facies realm; and North California, boreal facies with transition marks to the tethyan facies realm, T T T only Trinidad and/or East Venezuela.

Lower line of respective species: — — East Canada offshore, tethyan facies, temporarily with transition marks to the boreal facies realm.

All of the lines: ? occurrence questionable.

The following Canadian species have been determined by P. Ascoli until October 1975, but so far without any publication: Conoceratulites barteniensis, Vagiinulina recta, V. gauliniana, Epitomina hechtii, Nederbergella heteroneta, Cavelinella sigmoidea, Trocholina inapplanata, Lenticulina edenbergi, L. lowdenii, L. saxonica, L. valanginiana, L. nodosa, Conobulites vallediesius, Marnotonella knuanni.

Remarks to selected species on table 2: Epitomina caracella = cross section (left specimen), E. oornis — ventral view (right specimen), Conobulites barteniensis = dorsal view (specimen below, left), C. vallediesius = cross section (specimen above).

Remarks to the time scale: According to a new Cretaceous time interpretation by J. E. van Hauw (1976) on the basis of presently available age data, the following two time scales are now under discussion:

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</table>

Upper line = this publication; lower line = Hauw (1976).

Fig. 7.18b.

Key to Bartenstein 1977b.
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<th>BERRIAS</th>
<th>VALANG.</th>
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(Neo) Troch. intragrap. paucigr.
(Neo) T. friburgensis ap籍iensa

Gaudryina hannoverana
Gaudryina shartochi

D.(M.) praesoycona [TETH]
D.(M.) oxycona

Spiroplectammina donii
Dor. (M.) hummi/hauterhixana
Dor. (M.) subrochus

Verruclingiades neocomiensis
Verruclingiades subfiliformis

Dorothy filiformis

Lenticulina (Sar.) frankei
Lenticulina (Sar.) faricosta
Lenticulina (Sar.) spinulosa

Epist. spinul. polyx [BOREAL]
Epist. spinul. spinul.
Epist. spinul. colonx [TETHIAN]

Gaud. reicheni [TETHIAN]
G. divinax & G. compacta

Spiroplectammina lata
S. annexens & S. complan.

Pleurostomella sp. B (n. subsp.)
P. obtusa
P. subnodosa
P. species A (n. subsp. ?)
P. species C (n. subsp. ?)
P. bulbosa
P. species
P. elongata

Gavetinopela cenomanica
G. berthelini
Gavelinella (Berth.) intermedia
G. ammonoides
G. (Lingulogav.) barremiana
G. (L.) sigmolecta

Conorotellina barretsteini
C. intermedii
C. spinulosa

Fig. 7.19.
Phylogenetic sequences of benthonic foraminifera in the Lower Cretaceous (from Bartenstein 1978b).
![Table showing the stratigraphic distribution of benthonic index foraminifers in the worldwide Lower Cretaceous.](image)

**Fig. 7.20a.** Stratigraphic distribution of benthonic index foraminifers in the worldwide Lower Cretaceous.

- **U.C. GEN.**
  - **BOREAL =** Planktonic foraminiferal.
  - **TETHYAN =** Distinct facies realm (does not occur in all facies realms).
  - **DORADO =** (Massone aux) Two different generic names according to differing nomenclatural interpretation, by the cited authors. The same is true of two different species names (e.g. *Camelites, badenianus, apthenia, falkencrbigenii*).

### U.C. GEN.

<table>
<thead>
<tr>
<th>U.C. GEN.</th>
<th>BERRIAS</th>
<th>VALANG.</th>
<th>HAUZIER</th>
<th>BARREM.</th>
<th>APTIAN</th>
<th>ALBIAN</th>
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<td><strong>DORADO</strong></td>
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</table>

- **V. necromantia** (as example for *Vermulinosides subflexiformis*)
  - Species name on the right side of the respective species and its distribution line = successor to the species.

- **D. filiformis** (as example for *Vermulinosides subflexiformis*)
  - Species name on the left side of the respective species and its distribution line = predecessor to the species.
<table>
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<th>U. J. TETIAN</th>
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<td>C. testisfera</td>
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<td>G. (1.) signiculata</td>
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<td>T. (1.) intermedia</td>
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Fig. 7.20b

- Northern (boreal) and sebayan (mediterranean), partly also southern facies realm.
- Only northern facies realm.
- Only sebayan facies realm.
- Beginning or ending of distribution uncertain.
- Occurrence also post-Campanian.

V. neocomiensis (as example for Verrucinoides subfiliformis)
Species name on the left side of the respective species and its distribution line = predecessor to the species.

D. filiformis (as example for Verrucinoides subfiliformis)
Species name on the right side of the respective species and its distribution line = successor to the species.

Phanomal = Phanomitic foraminifer.

BOREAL, TETHYAN = Distinct facies realm (does not occur in all facies realms).

Durobia (Marginella) Two different generic names according to differing nomenclatural interpretation by the cited authors. The same is true of two different species names (e.g. kummii, basanii).

(L.M.J.E.S.V) Subgenera of Lenticulina = Lenticulina, Marginulina, Seratella, Verrucinoides.
- All other abbreviations of genus (subgenus) names see the explanations in the text.
of index species or species groups of benthonic foraminifera valid for both Tethyan and Temperate realms (Venezuela, Trinidad, N. California, East Canada, Central & Northern Europe, Bulgaria and Rumania); see Fig. 7.18a, b.

The use of a phylogenetic sequence of benthonic foraminifera for a subdivision of Early Cretaceous strata and erection of a biozonal scheme was developed by Albers (1952), Bettenstaedt & Spiegler (1965, 1975), Grabert (1959), Kaever (1961) and Michael (1966). Their results were consolidated into a working scheme by Bartenstein (1978b); see Fig. 7.19.

Bartenstein (1979) amplified and consolidated previously published worldwide schemes into a definitive worldwide correlation biozonal scheme for the Early Cretaceous using 81 species and species groups of foraminifera (Fig. 7.20a, b).

The biozonation schemes of Bartenstein are important particularly for interregional correlation. They have been of invaluable help in the compilation of this thesis. However, for a more particular and finer stratigraphic breakdown of the various stages in the North West European Early Cretaceous various range charts and biozonations of a more parochial nature have been used (e.g. Price, 1977b; Carter & Hart, 1977; Harris, 1982; Bartenstein & Kaever, 1973; Bertram & Kemper, 1982; Hart et al., 1981) (Fig. 12.2).
CHAPTER 8

THE CHRONOSTRATIGRAPHY OF THE STUDIED BOREHOLES
IN THE SOUTHERN NORTH SEA

8.0 Introduction

Rhys (compiler, 1974, 1975), Deegan & Scull (1977), NAM & RGD (1980) and Hesjedal & Hamar (1983) assigned ages to their groups, formations and members of their respective lithostratigraphical schemes. The ages were determined by the study of the rich microfossil assemblages contained in the lithological units and by comparing them with those from onshore sections dated by microfossils, macrofossils and radiometric methods (van Hinte, 1976).

As is seen from Chapters 2 and 7 there is a great deal of published information available on the abundant foraminifera from the Early Cretaceous strata onshore North West Europe. The summary works of Bartenstein (op. cit. 1974 - 1979) have proved to be invaluable in determining the ages of the lithostratigraphical units defined in the southern North Sea.

8.1 Faunal Provinciality

At this point it is pertinent to mention briefly the phenomenon of faunal provinces and the complications involved in assigning chronostratigraphic ages to lithological units using foraminiferal faunas. The application of microfaunal biozones erected for the stages of the Early Cretaceous in the stratotype areas of southern France and Switzerland (Moullade, 1966) to the studied southern North Sea sections is difficult. The Boreal faunas of the southern North Sea area lack key planktonic taxa. However there are enough benthonic taxa in common between Tethyan and Boreal areas to enable reliable dating of the Early Cretaceous lithological units of the southern North Sea.
A full discussion of present day faunal provinciality and Early Cretaceous provinciality is beyond the scope of this thesis. A number of questions have to be asked however, the most important of which is: why have faunal provinces (geographical distinction of faunas) existed or did they exist at all during the Mesozoic era? There is a geographical distinction of faunas but this is probably a result of tectonic structures, sea level changes, sea depth, ephemeral and poor inter-oceanic connections acting as barriers to faunal migration, temperature (faunal provinces are broadly latitudinal), salinity, currents and drifts, freshwater runoff etc. Tethyan areas of deposition are poor in terriginous debris while Boreal areas have a higher terriginous content in sediments suggesting a further complicating factor important for faunal differentiation. Faunal provincialism is probably a result of the interaction of many limiting factors.

There are areas which have been subject to Tethyan and Boreal influences (Transition province of Price, 1976) such as the southern North Sea (Albian).

The faunal relationships between areas in the Boreal province may be confused by differences in taxonomic identification and classification by various authors. This confusion may be enhanced by differences in the preserved growth stages and in ecology rather than by real species distinction. Schelbnerova (1971, 1972, 1974) has discussed in some detail the problem of faunal provinciality and her work together with that of Pozaryska & Brochwicz-Lewinski (1975) gives an adequate insight to the subject. The subject is not discussed further in this thesis.

8.2 Palaeogeographic Setting

The palaeogeographic setting of the North Sea Basin has important implications for the Early Cretaceous foraminiferal fauna.
(Boreal) but the local variations in geography also exert a profound influence. For example the different lithological facies in the Lower Saxony Basin of Germany during the Early Cretaceous are characterised by distinct foraminiferal faunas (Kemper, 1973a, b, 1979).

Bartenstein & Bettenstaedt (1962) derived their foraminiferal biostratigraphy from the relatively shallow marine environment deposits of the oilfield region on the northern margin of the Lower Saxony Basin. Rapid facies changes in such an environment influence the local stratigraphic ranges of some species. This point has to be borne in mind when relating the biozonal schemes derived from the German region to similar schemes developed in the North Sea (see Section 4.3 & 7.11). However, the deposits of Albian-Aptian age in north Germany and Denmark are lithologically very similar to the marine sediments of the same age in Yorkshire, Lincolnshire and Norfolk. In particular it is interesting to note the similarity of the coarse deposits in Lincolnshire and Norfolk with the shoreline deposits in the Salzgitter area of south Hannover (see Chapters 10 & 11).

8.3 Upper Holland Marl Member = Red Chalk Formation

This lithological unit contains for the most part foraminiferal faunas characteristic of a Late Albian age.

The planktonic species are mostly long ranging but the association of *H.brittonensis* - *H.delrioensis* - *H.infracretacea plexus*, *H.planispira*, *G.bentonensis* and *H.simplex* suggests a Late Albian age as the same association has been recorded in Late Albian age sediments elsewhere in North West Europe (see discussion of each well in Chapter 7).

The benthonic foraminiferal assemblages from this lithological unit support unequivocally a Late Albian age. The recovered fauna is comparable to those recorded from Late Albian age strata onshore North Western Europe.
The details of the foraminiferal faunas and the reasons for assigning a Late Albian age to this unit are discussed in Chapters 7 and 11.

Foraminiferal evidence from the studied boreholes cannot provide a certain age for the top of this unit. In some instances the top of this lithological unit may be Early Cenomanian in age. In addition the age of the base of this unit varies from borehole to borehole. In some boreholes the base of this unit rests unconformably on strata of a Permo-Triassic age and the age of the basal part of the unit is Late Albian (49/24-3). In other boreholes there is a thicker sequence of strata assignable to this lithological unit and the basal portion can be dated by its contained foraminiferal fauna as Middle Albian age (49/25-1). It is not clear whether any borehole studied depicts a continuous sequence of strata through the lower lithostratigraphic boundary or whether the boundary is in all cases a disconformity. There may even be non-sequences within the lithological unit.

8.4 Middle Holland Shale Member = Speeton Clay Formation (pars)

The detailed foraminiferal biostratigraphy of this lithological unit has been discussed in the relevant borehole sections of Chapter 7 and in Chapter 11. This unit for the most part yields foraminiferal faunas of a Middle to Early Albian age comparable to those recorded from onshore sequences described in North West Europe.

The top of this unit appears to be eroded and the sonic log response shows a marked change from the overlying unit. The sediments of this unit contain a rich and varied foraminiferal fauna including age diagnostic taxa such as O. schloenbachi and G.? gyroidinaeformis. The remainder of the fauna are, for the most part, long ranging or non age diagnostic facies controlled taxa.
The basal part of this unit, as discussed in Chapter 11, section 11.3, is in some boreholes considered to be Late Aptian in age. The base of this unit is an unconformity/disconformity as illustrated and discussed in Chapter 11.

8.5 Lower Holland Marl Member = Speeton Clay Formation (pars)

The detailed foraminiferal stratigraphy of this interval is discussed in the relevant sections of Chapter 7 and in Chapter 11, section 11.3. This lithological unit is Aptian in age and is bounded above and below by unconformities/discontinuities.

8.6 Vlieland Shale Member = Speeton Clay Formation (pars)

The foraminiferal biostratigraphy of this unit has only been investigated in the boreholes 49/24-12, 49/25-1 and 49/10-1. There were no samples available for examination from the Vlieland Shale Member of the borehole 49/19-1. The two remaining boreholes discussed in this thesis, 49/20-2 and 49/25-2, were not considered in terms of their foraminiferal content of the Vlieland Shale Member. This lithological unit yields varied and rich foraminiferal faunas which by comparison with sections onshore in northern Europe indicate an age range of Barremian to Valanginian (see Chapter 7). This unit is of varying thickness and there may well be a number of minor disconformities, with missing sections, present within the unit.

8.7 Vlieland Sandstone Member = Spilsby Sandstone Formation

It has been demonstrated by various authors (Burnhill & Ramsay, 1981; Johnson, 1975; Fyfe et al., 1981; Day et al., 1981) that the base of the Early Cretaceous is diachronous in the North Sea area (see Chapter 4). The Early Cretaceous transgression ensured that the basal strata on the uneven 'Cimmerian' erosion surface becomes progressively younger towards the highs (compare
borehole 44/2-1 with borehole 49/25-1). Associated with this transgression in Europe are sand body depositional units which vary in age from Valanginian to Albian (e.g. Osning Sandstone, Kemper, 1973). These sand body deposits are discussed in Chapters 4 & 5. Boreholes 49/20-2, 49/25-1, 49/25-2(?) and 49/24-12 all display a sand body or sandier horizon at the base of the Early Cretaceous strata (Spilsby Sandstone Formation; 48/22-2, Fig. 5.6). Only borehole 44/2-1 has a sandstone body which could be comparable with that in borehole 48/22-2. This unit in the studied boreholes is Hauterivian to Valanginian in age.
CHAPTER 9

PALAEOENVIRONMENT OF DEPOSITION OF THE ALBIAN AND APTIAN STRATA
OF THE STUDIED BOREHOLES IN THE SOUTHERN NORTH SEA

9.0 Introduction

Palaeoenvironmental interpretations of fossil foraminiferal faunas depend upon their study and their comparison with analogous modern foraminiferal faunas in Recent sediments and environments. The inference is made that the environments were the same or similar. The distribution of modern foraminifera is closely related to water depth and other controlling ecological factors such as temperature, salinity, oxygen availability, nutrient supply, clastic sediment input, substrate and energy level within the marine and brackish marine environment (Phleger, 1951; Bandy, 1953, 1964; Murray, 1973; Boltovskoy & Wright, 1976; Douglas, 1979).

Empirical bathymetric models based upon modern distributions have often been applied to Cretaceous fossil assemblages to arrive at a palaeoecological reconstruction (e.g. Sliter & Baker, 1972). At present there is enough documented scientific research on the bathymetric distribution of modern day faunas to enable a precise bathymetric reconstruction for modern foraminiferal faunas to be made. Nevertheless our knowledge of the ecology, biology and distribution of modern day foraminiferal faunas is sparse in comparison to other microfaunal groups (e.g. ostracods).

These 'modern' studies have revealed the limitations and drawbacks of using foraminiferal faunas as bathymetric indicators. Factors such as water currents, turbidity flows, warm and cold water masses and nutrient supply, for example, modify in various ways the bathymetric distribution of foraminiferal faunas. These factors are very difficult to quantify in the fossil record. The adage that "the present is
the key to the past" is a tempting starting point for palaeoenvironmental reconstruction but such a simplistic approach for Early Cretaceous strata is untenable.

It is very difficult to define any modern analogues for the Early Cretaceous foraminiferal faunas and the subjective/empirical approach is probably based on false assumptions. Douglas (1979) summed up the situation thus: "The use of modern faunal concepts to interpret extinct fossil faunas rests on the assumption that modern distributional patterns are analogous to those of the past and that homeomorphs of modern species, and groups of species, had similar environmental adaptations".

The further back in time one goes the more invalid and indistinct the assumption becomes and the more imprecise and unscientific the palaeoenvironmental reconstructions become. The three main parameters, water depth, temperature and sea bottom conditions, which control the ecology of foraminifera are discussed briefly in the remainder of this section. The three parameters are closely interrelated and exert a profound influence on other parameters; salinity, oxygen availability, nutrient supply, clastic sediment supply, substrate and energy level which prevail in the marine environment. A simplistic approach as applied to foraminiferal faunas recovered from the fossil record is to attempt to relate the faunas to bathymetry only. In actual fact as many of the parameters as possible which effect the ecology of foraminifera and which can be measured should be taken into consideration.

**Water depth**

There is a relationship between the microfaunal content and the depth of deposition of a sediment and in terms of foraminifera has been identified in both recent (Grimsdale & Moorkhoven, 1955; Be, 1977; Phleger, 1951) and fossil (Bandy, 1953a, b; Carter & Hart, 1977; Price, 1976) settings.
The ratio of the numbers of planktonic to benthonic foraminifera has been used to estimate relative water depth at the time of deposition. In general the diversity of species and total individual number of planktonic foraminifera increases away from the shoreline while at the same time the relative numbers of benthonic foraminifera decreases (Murray, 1976). This is a general statement that broadly speaking is true. However, Parker (1948) shows that planktonic foraminifera such as Globigerina spp. require undiluted sea water to survive. Where large rivers dilute the coastal marine waters Globigerina spp. do not survive and do not by choice inhabit the nearshore waters and are not found as skeletal remains in near shore sediments. On the other hand beach sands of the Fiji Islands (Crickmay, Ladd and Hofmeister, 1941) are composed of Globigerina spp. tests because this species lives in waters undiluted by large rivers close to shore (Ellison, 1951).

Stehli & Creath (1964) have demonstrated in Upper Cretaceous sediments that the planktonic/benthonic ratio can be used to infer current circulation and to locate barriers to currents from the open sea. Their conclusions are corroborated by structural data.

Factors which increase the planktonic/benthonic ratio, besides sedimentation rate and solution, are lowered benthonic production and increased plankton production. Carter & Hart (1977) and Price (1977a, b) have used these ratios as a means of determining palaeoenvironment (water depth) and for correlation in the Albian sediments of northern Europe. The ratio gives a broad indication of water depth in normal marine shelf settings but cannot be used in extreme environments. Planktonic foraminiferal species depth preferences and habitats control their occurrence in sediments in relation to absolute water depth. As faunas spread across the continental shelf, deeper dwelling species are selectively eliminated (Bandy, 1956). This depth controlled reduction of
species has been described for mid-Cretaceous faunas (Sliter, 1972a, b), Late Cretaceous faunas (Hart & Bailey, 1979) and Cretaceous and Tertiary faunas (Hart, 1980). A good summary of planktonic foraminiferal ecology and water depth is provided by Lipps (1979).

The population of benthonic foraminifera in a sample may also be used to infer water depth as certain morphologies and species may be related to certain depth ranges (Natland, 1933; Douglas et al., 1976; Murray, 1976; Phleger, 1960; Murray, 1973; Boltovskoy & Wright, 1976; Bandy & Echols, 1964). This topic is complex but a good summary of modern scientific opinion is provided by Douglas (1979).

Temperature

Temperature is assumed to be responsible for the distributional limits of species and to control absolute species diversity with the more-diverse faunas occurring in warmer waters (Lipps, 1979). However such a simplistic approach to the distribution of modern faunas is untenable (Cifelli, 1971) and temperature per se does not control the distribution of species or species diversity. However temperature in conjunction with other controlling ecological factors may influence species distribution and species diversity in a general sense. For example the concept of water masses (identified by temperature, salinity and circulation) does explain planktonic foraminiferal fauna distribution patterns (Phleger, 1954): Arctic, subtropical and tropical faunas. Lipps (1979) discusses in detail and at length the ecological controls of planktonic foraminifera in modern oceans.

Benthonic foraminifera are widely distributed in all environments (estuarine to holomarine) and their distribution is controlled by many parameters. Temperature per se is not assumed to be of particular importance (Douglas, 1979) and is certainly not a single controlling parameter of benthonic foraminiferal distribution.
Bandy (1960a,b, 1964, 1967) describes the relationship between water temperature and the morphology of planktonic foraminifera. The modern distribution of keeled foraminifera is controlled by water depth and temperature (20 deg N - 20 deg S = 17 deg C isotherm). Such distribution patterns have been identified in the fossil record (Price, 1975, 1976; Carter & Hart, 1977).

The distribution of keeled planktonic foraminifera may be used to interpret in a very broad sense the palaeolatitude of a fossil fauna.

Substrate/Sea Bottom Conditions

The physical and chemical conditions prevailing in the bottom waters and substrate (to a depth of approximately a full centimetre), are important for the development of foraminiferal faunas. The conditions influence the abundance and diversity of foraminiferal life but also exert a considerable influence on the preservation of the test. Microfaunas collected from sediments deposited in anaerobic conditions/restricted bottom water circulation are characterised by an abundance of arenaceous foraminifera. However the rain of dead planktonic tests from the fauna living in the aerated surface waters contributes an important constituent to the total dead assemblage accumulating at the sea floor (Hart & Bigg, 1981). An important indication of environment is the almost total absence of calcareous benthonlcs from faunas associated with restricted bottom conditions. The preservation potential of the depositional environment of a foraminiferal fauna is very important. For example high/moderate energy environments will destroy all but the most robust foraminiferal test; deposition below the calcite compensation depth will destroy all calcite tests. Fragile tests will become crushed during diagenesis of soft sediments and post depositional diagenetic decalcification will destroy calcite tests. The interpretation of sea
Fig. 9.1. Palaeobathymetric scheme of Hedgepeth (1957)
bottom/substrate conditions in terms of the palaeoenvironment of a fossil foraminiferal fauna is not an easy task (see Chapters 12 & 15, this thesis).

9.1 Proposed Model for Palaeoenvironment Terminology used in this Thesis

The scheme of Hedgepeth (1957) (see Fig. 9.1) provides a convenient starting point and base for the construction of a palaeoenvironment subdivision for Early Cretaceous sediments. The scheme is bathymetric and fossil foraminiferal faunas can be related to it with modifications derived from the model of Shell Brunei, Shell Sabah and Shell Sarawak (see Fig. 9.2). Haig's (1979a, b) work relates the bathymetry model to an ecological model whereby, depending on circumstances, more than one ecological association can be characteristic of a certain water depth (see Fig. 9.3).

The major publications of Haig (1979a, b) are used in this thesis as a basis for palaeoenvironmental interpretation of the Aptian and Albian strata. Haig from his research and collation of available literature on worldwide mid-Cretaceous foraminiferal faunas recognises four major foraminiferal faunal associations (Fig. 9.4).

The four faunal associations, which appear to reflect major ecological units, can be recognised from the global distribution patterns of mid-Cretaceous (Late Barremian to Cenomanian) foraminifera.

Three associations are composed of benthonic species while the fourth comprises planktonic species.

The palaeoenvironments reflected by the benthonic associations are shallow land locked epicontinental seas (Ammobaculites association); open marine continental shelves (Marssonella
Fig. 9.2 Palaeobathymetric scheme for palaeoenvironmental analysis (from Shell Brunei)
association); and bathyal - hadal depths within geosynclinal troughs or the open ocean (Recurvoideas association).

The planktonic association occurs in all these settings.

The associations are discussed in turn and are illustrated in Figure 9.3 but are modified by Crittenden (this thesis).

The Ammobaculites association is a low diversity association characterised by abundant arenaceous foraminifera of a siliceous, rather than calcareous, wall composition (Ammobaculites, Saccammina, Millemmina and Trochammina) with the accompanying rotaline species being mainly very small unornamented species (Lenticulina, Epistomina and Valvulineria). This association according to Haig is extensively developed in shallow partially enclosed epicontinental seas in the northern and southern cool temperate belts of the late Early Cretaceous. Haig distinguished a number of biofacies within this association reflecting a more refined depth and/or salinity controlled division.

The Marssonella association is more diverse and is characterised by calcareous (cemented) agglutinated foraminifera (Marssonella, Gaudryina and Spiroplectinata) with abundant calcareous benthonic species (mostly rotaline; Valvulineria and Gavelinella). In general Haig recognised that this association was characteristic of open continental shelf seas and carbonate rich sediments but was also distinguished by a bathymetric zonation within it which was adapted from Sliter & Baker (1972).

The Recurvovoides association is characterised by siliceous agglutinating species. Calcareous benthonic species are usually absent. Haig (1979a) considered this association to indicate a very deep water palaeoenvironment.
A. AMMOCITES ASSOCIATION 3 subzones.
1 Nearshore very shallow water zone - Agglutinated assemblage
   Dominantly Textularine and Rotalline forms
   (nonionaceans turritinids & robertinaceans)
   Agglutinants similar to nearshore.
2 Inner sub littoral zone Dominantly Textularine forms
   Agglutinants similar to nearshore.
3 Outer sub littoral zone Dominantly buliminacean and robertinacean forms
   Agglutinants differ specifically from those in
   shallower zones.

B. MARSONELLA ASSOCIATION 5 subzones.
1 Inner shelf zone Dominantly nodosariids, polymorphinids and
   encrusting agg / calc species.
2 Outer shelf zone Diverse assemblages of agglutinants (though low
   in numbers) and nodosariaceans.
3 Upper slope zone Dominantly nodosariaceans but turritinids and Osangularia common
4 Middle slope zone Agglutinating species, turritinids and anomalinids.
5 Lower slope zone Agglutinating species mainly.

C. RECURVOIDES ASSOCIATION

Fig. 9.3. The foraminiferal associations of Haig (1979a) and their relationship to each other.
The planktonic association is of low diversity and dominated by Hedbergella species reflecting the early stage of evolutionary development of the planktonic foraminifera in the Early Cretaceous. The dominance of the genus Hedbergella, even in the Late Albian, reflects the northern temperate (Boreal) latitude of the Early Cretaceous North Sea. The morphological simplicity of the Hedbergella species reflects the epi-pelagic life style of the genus enabling it to inhabit the surface waters of the deep oceans, of the shelf seas, and within epicontinental seas. This association is found with all the other associations.

The remainder of this chapter discusses the palaeoenvironments of the Albian and Aptian strata represented by each lithological unit, and its contained foraminiferal fauna, in the studied boreholes. Most research workers who have published details of the foraminiferal faunas of the Early Cretaceous in North West Europe have made some attempt at palaeoenvironmental reconstruction (e.g. Hecht, 1938; Bartenstein & Kaever, 1973; Carter & Hart, 1977; Price, 1977a, b; Haig, 1979a, b; Hart & Bailey, 1979; Hart, 1980; Hart & Bigg, 1981; Crittenden, 1982a, b).

The palaeoenvironmental reconstruction is based on a combination of lithological/sedimentological and foraminiferal studies of each lithological unit. During the Albian and Aptian the southern North Sea was part of a large epicontinental sea. The sediments encountered in the studied boreholes are typical of a marine continental shelf setting and comprise mudstones/claystones, siltstones and minor sands and limestones. The whole area, from a study of the available literature, has a variety of sediments associated with the diverse sedimentary environments associated with an archipelago setting (Kemper, 1979). In this thesis no in-depth sedimentological study was performed. The foraminiferal faunas are typical of epeiric shelf seas but differences in composition permit subdivision of palaeoenvironment.
<table>
<thead>
<tr>
<th>CLIMATIC BELT</th>
<th>AMMERFICELUS ASSOCIATION</th>
<th>MALETIPSILA ASSOCIATION</th>
<th>ACCURVOIDS ASSOCIATION</th>
<th>PLANETOID ASSOCIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTHERN COOL-TEMPERATE (BOREAL)</td>
<td>extensively developed in shallow, land-locked epicontinental seas</td>
<td>&quot;larger&quot; foraminifera absent</td>
<td>no</td>
<td>assemblages of very low diversity dominated by <em>Hedbergella</em>. Keeled and cancellate forms generally absent</td>
</tr>
<tr>
<td>TROPICAL (TETHYAN)</td>
<td>locally developed in very shallow, brackish lagoons</td>
<td>&quot;larger&quot; foraminifera common, particularly in shallow shelf seas</td>
<td>faunal differentiation</td>
<td>assemblages of very low diversity, dominated by <em>Hedbergella</em>. Keeled and cancellate forms generally absent</td>
</tr>
<tr>
<td>SOUTHERN COOL-TEMPERATE (AUSTRAL)</td>
<td>extensively developed in shallow, land-locked epicontinental seas</td>
<td>&quot;larger foraminifera absent</td>
<td>known</td>
<td>assemblages of very low diversity, dominated by <em>Hedbergella</em>. Keeled and cancellate forms generally absent</td>
</tr>
</tbody>
</table>

Fig. 9.4

The climatic differentiation of Haig's foraminiferal associations during the early Cretaceous (from Haig, 1979a).
9.2 The Holland Formation

The Upper Holland Marl Member

The distinct red/red-brown sediments of this member are characterised by their increasing calcareous content (up-hole) perhaps reflecting 1) a decrease in clastic supply as the source areas were denuded and inundated by the Early Cretaceous transgression and 2) a temperature increase within the marine environment of the area. The red colouration may be the result of erosion of Devonian and/or Permo-Trias sediments or of slow deposition associated with oxidising conditions. The foraminiferal faunas recovered are dominated by calcareous benthonic species (abundant gavelinellids, lenticulnids and Valvulineria species) and by planktonic foraminifera (abundant hedbergellids). Common arenaceous species which characterise this member are: arenobulminids, Marssonella species, Spiroplectinata species and textularids. This assemblage is reminiscent of Haig's Marssonella association and Planktonic association. Further refinement suggests, according to the scheme of Haig (1979a, b) that the Late Albian sediments of the Upper Holland Marl Member of the southern North Sea were deposited in the inner to outer slope zones of an open marine shelf environment. A more precise interpretation of sea depth is not possible from the available data and any depth speculation is not indulged in this thesis (see Khan, 1950, who proposed 80 fathoms for the depth of the Upper Gault sea). The occurrence of bored nodosarid foraminiferids (sponge borings - Cliona sp., gastropod borings) suggests relatively shallow water depths (within the photic zone - less than 200m). The abundance of the foraminiferal genus Gavelinella indicates relatively shallow water (within the photic zone) as it has been suggested that this genus was epiphytal (on sea grasses) in a calcium carbonate rich marine environment (pers. comm. M.D. Brasier).
The Middle Holland Shale Member

The low to moderately calcareous claystones of this member contain a foraminiferal fauna which is very different to that of the overlying member. The planktonic and calcareous benthonic foraminifera are not so abundant or so diverse specifically. The arenaceous benthonic foraminiferal fauna increases in number downhole through this member while the planktonic and calcareous benthonic foraminifera decrease in number. The upper part of this member still has a fauna characteristic of the Marssonella association of Haig (upper to middle slope open marine environment). The occurrence of the calcareous benthonic O. schoenbachii, rare specimens of the planktonic foraminifera (simple Hedbergellids) and the continued presence of the genus Gavelinella (but smaller in size) indicate the upper to middle slope environment. Bottom conditions at some horizons in the higher part of the member may have been slightly restricted/anoxic as indicated by the absence of a calcareous benthonic fauna. The persistent occurrence however of a substantial agglutinating fauna, increasing in number downhole, indicates that bottom conditions were not totally stagnant. Locally, horizons of dark mudstones have a high Total Organic Carbon content (Burnhill, pers. comm.; Hesjedal & Hamar, 1983) which has important implications for source rock potential.

Price (1977b) calculated that approximately 85% of the microfauna during Early Albian times (basal part of this member if present as a complete unit) in North West Europe was composed of arenaceous species including Ammodiscus spp., and the Glomospira/Glomospirella spp. group and suggested an environment analogous with the present day Baltic Sea (semi-enclosed marine environment).

The scenario of numerous islets, bays, inlets, shoals, narrow straits and channels in the Early Albian North West European archipelago further accentuates the anoxic character of the
palaeoenvironment of deposition by restricting water circulation and connection to the open sea.

The foraminiferal fauna toward the base of this member comprises predominantly arenaceous benthonic foraminifera, very rare calcareous benthonic foraminifera and very rare planktonic foraminifera. This microfauna is reminiscent of Haig's (1979a, b) Recurviodes association suggesting deep water, lower slope to bathyal deposition. However as already indicated (Price, 1977b) this fauna is more probably a result of shallow, restricted circulation, marine deposition (Kemper, 1973). In addition it is difficult to envisage a deep water (lower slope - bathyal) setting for the southern North Sea during the Early and Middle Albian (Burnhill, pers. comm.)

The Lower Holland Marl Member

This member is in general thought to have been deposited under low energy conditions below the stormwave base in an open shelf environment. The relatively high carbonate content of the sediments indicates a high carbonate production regime (biogenic) and therefore indicates warm climatic conditions. The member has however a relatively high terriginous content indicating proximity to a land mass where subaerial erosion was taking place. The occurrence of good planktonic foraminiferal faunas at certain horizons indicates open marine connections.

In the latest Late Aptian (uppermost part of the member) the dark sediments contain predominantly arenaceous foraminifera adapted presumably to a poorly oxygenated marine environment.

In the middle part of this member (latest Early and early Late Aptian) calcareous benthonic foraminifera (and planktonics) are common and diverse; gavelinellids and hedbergellids (coeval with the ewaldi Marl and the Sutterby Marl).
Fig. 9.5. Cumulative percentage diagrams of boreholes 49/24 - 3 and 44/2 - 1

Borehole 49/24 - 3 Cumulative percentage diagram

Borehole 44/2 - 1 Cumulative percentage diagram
2. Increasing water depth is a measure of open sea conditions and the abundance of planktonic foraminifera is related to water depth.

3. The gross number of benthonic foraminifera is invariable and therefore provides a basis for judging the relative abundance of planktonic foraminifera.

Three boreholes only were analysed in terms of cumulative percentage diagrams. The results were inconclusive and showed little potential use and as a consequence diagrams for the other boreholes were not constructed. In terms of broad correlation and palaeoenvironment deduction potential this type of diagram may be of some use in block 49. However the use of cuttings samples as a raw starting point is not ideal and further sophisticated analyses were not attempted.

**Borehole 49/24-3 (Fig. 9.5)**

The sparse, crude data available from this borehole was sufficient to plot a cumulative percentage diagram which by comparison with Price (1977a, b) is characteristic of the Late Albian strata of North West Europe.

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>CALCARCEOUS</th>
<th>ARENACEOUS</th>
<th>TOTAL</th>
<th>PLANKTONIC TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>4900-20</td>
<td>30% (216)</td>
<td>12% (95)</td>
<td>42%</td>
<td>58% (425) 726</td>
</tr>
<tr>
<td>4940-60</td>
<td>31% (200)</td>
<td>17% (111)</td>
<td>48%</td>
<td>52% (340) 651</td>
</tr>
<tr>
<td>4980-5000</td>
<td>30% (87)</td>
<td>36% (103)</td>
<td>66%</td>
<td>34% (98) 288</td>
</tr>
</tbody>
</table>

The abundance of planktonic foraminifera decreases downhole while the abundance of arenaceous benthonic foraminifera increases downhole and the calcareous benthonic foraminifera remains relatively constant in number.
Borehole 44/2-1 (Fig. 9.5)

The cumulative percentage diagram for this enigmatic well was constructed primarily as an aid for correlation and subdivision of the Early Cretaceous strata. However the results are inconclusive and the extreme effects of caving render the resultant graph practically worthless. The only point worth noting is the characteristic increase of planktonic foraminifera in the Albian interval of the borehole.

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>CALCARCEOUS</th>
<th>ARENACEOUS</th>
<th>TOTAL</th>
<th>PLANKTONIC</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>4990</td>
<td>68% (22)</td>
<td>9% (3)</td>
<td>77%</td>
<td>22% (7)</td>
<td>32</td>
</tr>
<tr>
<td>5010</td>
<td>51% (77)</td>
<td>44% (67)</td>
<td>95%</td>
<td>5% (8)</td>
<td>152</td>
</tr>
<tr>
<td>5020</td>
<td>58% (97)</td>
<td>34% (57)</td>
<td>92%</td>
<td>7% (12)</td>
<td>166</td>
</tr>
<tr>
<td>5050</td>
<td>75% (21)</td>
<td>25% (7)</td>
<td>100%</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td>5080</td>
<td>63% (22)</td>
<td>37% (13)</td>
<td>100%</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>5100</td>
<td>56% (37)</td>
<td>44% (29)</td>
<td>100%</td>
<td>-</td>
<td>66</td>
</tr>
<tr>
<td>5110</td>
<td>58% (22)</td>
<td>42% (16)</td>
<td>97%</td>
<td>3% (1)</td>
<td>38</td>
</tr>
<tr>
<td>5140</td>
<td>60% (53)</td>
<td>32% (28)</td>
<td>92%</td>
<td>8% (7)</td>
<td>88</td>
</tr>
</tbody>
</table>

* All caved.

Borehole 49/24-12 (Fig. 9.6)

The raw data available from this borehole was sufficient to plot a detailed cumulative percentage graph.
Borehole 49/24-12 Cumulative percentage diagram.

Fig. 9.6. Cumulative percentage diagram of borehole 49/24 - 12
<table>
<thead>
<tr>
<th>DEPTH</th>
<th>CALCAREOUS</th>
<th>ARENACEOUS</th>
<th>TOTAL</th>
<th>PLANKTONIC</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>4860</td>
<td>44% (146)</td>
<td>25% (84)</td>
<td>69%</td>
<td>31% (104)</td>
<td>334</td>
</tr>
<tr>
<td>4870</td>
<td>48% (275)</td>
<td>12% (70)</td>
<td>60%</td>
<td>40% (228)</td>
<td>573</td>
</tr>
<tr>
<td>4880</td>
<td>49% (277)</td>
<td>18% (105)</td>
<td>67%</td>
<td>33% (187)</td>
<td>569</td>
</tr>
<tr>
<td>4900</td>
<td>50% (215)</td>
<td>21% (94)</td>
<td>71%</td>
<td>29% (127)</td>
<td>436</td>
</tr>
<tr>
<td>4920</td>
<td>48% (267)</td>
<td>30% (175)</td>
<td>78%</td>
<td>22% (128)</td>
<td>570</td>
</tr>
<tr>
<td>4940</td>
<td>44% (275)</td>
<td>41% (259)</td>
<td>85%</td>
<td>15% (94)</td>
<td>628</td>
</tr>
<tr>
<td>4960</td>
<td>36% (163)</td>
<td>63% (286)</td>
<td>99%</td>
<td>0.6% (3)</td>
<td>452</td>
</tr>
<tr>
<td>4980</td>
<td>36% (110)</td>
<td>63% (195)</td>
<td>99%</td>
<td>0.2% (5)</td>
<td>310</td>
</tr>
<tr>
<td>5000</td>
<td>39% (68)</td>
<td>61% (107)</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5020</td>
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<td>63% (159)</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5040</td>
<td>29% (120)</td>
<td>71% (308)</td>
<td>100%</td>
<td>0.13% (6)</td>
<td>434</td>
</tr>
<tr>
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<td>49% (167)</td>
<td>93%</td>
<td>7% (24)</td>
<td>340</td>
</tr>
<tr>
<td>5080</td>
<td>49% (156)</td>
<td>39% (128)</td>
<td>88%</td>
<td>12% (40)</td>
<td>324</td>
</tr>
<tr>
<td>5100</td>
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<td>36% (91)</td>
<td>99%</td>
<td>1% (2)</td>
<td>252</td>
</tr>
<tr>
<td>5120</td>
<td>35% (67)</td>
<td>64% (124)</td>
<td>99%</td>
<td>1% (2)</td>
<td>193</td>
</tr>
<tr>
<td>5140</td>
<td>23% (24)</td>
<td>69% (71)</td>
<td>92%</td>
<td>8% (8)</td>
<td>103</td>
</tr>
<tr>
<td>5155</td>
<td>25% (27)</td>
<td>72% (78)</td>
<td>97%</td>
<td>3% (3)</td>
<td>108</td>
</tr>
<tr>
<td>5170</td>
<td>53% (149)</td>
<td>41% (113)</td>
<td>94%</td>
<td>6% (16)</td>
<td>278</td>
</tr>
<tr>
<td>5190</td>
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<td>41% (136)</td>
<td>86%</td>
<td>14% (45)</td>
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<tr>
<td>5220</td>
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<td>40% (75)</td>
<td>95%</td>
<td>5% (9)</td>
<td>188</td>
</tr>
<tr>
<td>5250</td>
<td>28% (55)</td>
<td>65% (130)</td>
<td>93%</td>
<td>7% (14)</td>
<td>199</td>
</tr>
<tr>
<td>5260</td>
<td>67% (162)</td>
<td>32% (77)</td>
<td>99%</td>
<td>1% (3)</td>
<td>242</td>
</tr>
<tr>
<td>5280</td>
<td>56% (146)</td>
<td>39% (102)</td>
<td>95%</td>
<td>5% (14)</td>
<td>262</td>
</tr>
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<td>98%</td>
<td>2% (2)</td>
<td>127</td>
</tr>
<tr>
<td>5340</td>
<td>71% (110)</td>
<td>29% (46)</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The cumulative percentage plot for this borehole compares very well with the lithostratigraphic and biostratigraphic/chronostratigraphic subdivision.

The general increase in abundance of planktonic foraminifera through Albian time is easily recognised. The effects of caving are apparent through the Aptian and pre-Aptian sections by the
presence of a red coloured Red Chalk planktonic foraminiferal fauna. Minor peaks of abundance of planktonic foraminifera are associated with the upper part of the Aptian age section (early Late Aptian) and the Early Aptian and Barremian section.

The increases in the arenaceous foraminiferal faunas coincide with the Earliest Aptian and Early Albian anoxic environments. A further increase at 5220 feet - 5280 feet may reflect a possible anoxic phase during Hauterivian times.

The calcareous benthonics are numerous in the Albian section but a decrease in the Early Albian (masked by caving) reflects the anoxic-semianoxic environment at the sediment water interface. A marked increase in the Aptian section is a reflection of the increased calcium carbonate content of the sediment at that level.
PART 3

COMPARATIVE STRATIGRAPHY
CHAPTER 10

BRIEF STRATIGRAPHICAL COMPARISONS OF THE SOUTHERN NORTH SEA
STUDY AREA WITH NORTH WEST EUROPE

10.0 Introduction

A detailed discussion of the Early Cretaceous deposits onshore the UK and North West Europe is not within the scope of this thesis. Indeed such a project, if coupled with detailed microbiostratigraphical work, would form a research project in its own right. However, the southern North Sea Basin study area can be compared with, and correlated to, the onshore sections in a general manner using data from the available literature.

This chapter deals briefly with stratigraphical comparisons and correlation with the central and northern North Sea (10.1), with southern Norway (11.2), with southern Scandinavia (10.3) and with onshore UK sections (10.4). Chapter 11 discusses the Albian and Aptian stages and mention is made of important offshore and onshore sections in Holland and Germany.

This part of this thesis does not attempt to be a comprehensive survey but its aim is to confirm, by examples, the use of foraminiferal faunas as a correlation tool within an integrated approach to the stratigraphy of the Early Cretaceous of North West Europe. An indication of the large amount of literature available dealing with Early Cretaceous microbiostratigraphy in North West Europe is given in Chapters 2, 7 and 8. The bentonic and planktonic foraminiferal faunas from the southern North Sea Basin are typical of those from the Early Cretaceous in other areas of North West Europe.
| F. Unit | Gamma Ray API units | Lithol | Sonic Log ft | m/s 40 | 40 |
|---------|---------------------|--------|--------------|--------|
| G 4     |                     |        |              |        |    |
| G 3     |                     |        |              |        |    |
| G 2     |                     |        |              |        |    |
| G 1     |                     |        |              |        |    |
| H 3     |                     |        |              |        |    |
| H 2     |                     |        |              |        |    |
| H 1     |                     |        |              |        |    |
| R       |                     |        |              |        |    |

**Limestone**: white to light grey, hard to very hard, brittle, cryptocrystalline, chalky to part. traces of chert, pyrite, and glauconite.

**Limestone**: white, cream, light grey, brick red, hard to very hard, dense, cryptocrystalline; with **Mudstone**: red, green, soft.

**Mudstone**: dark brown to black, carbonaceous, calcareous, pyritic.

**Limestone**: white, red, brown, grey, hard to very soft, chalky becoming very argillaceous to very calcareous mudstone.

**Mudstone**: red, brown, grey, hard to soft moderately to very calcareous.

**Mudstone**: dark grey to dark brown, sometimes reddish, calcareous.

---

**Fig. 10.1** The lithostratigraphical subdivision of borehole 22/1 - 2a in the central North Sea
(from Burnhill & Ramsay, 1981)
The Risbey Formation is a grey, reddish brown marl and is probably equivalent to the Red Chalk Formation/Upper Holland Marl of the southern North Sea Basin.

The wireline log motifs (sonic and gamma ray) of the lithological units defined in the southern North Sea (block 49 this thesis; Crittenden, 1982; Rhys compiler, 1974; and NAM & RGD, 1980) may be tentatively recognised in the Norwegian borehole 2/11-1 (fig. 29, sheet K of Deegan & Scull, 1977). The Lower Holland Marl Member "belly" is recognisable at approximately 9700 feet while the unit above (but below the Risbey Formation) is equivalent to the Middle Holland Shale Member. The dating of these units (presumably by foraminiferal microbiostratigraphy) in the central North Sea boreholes corresponds, in terms of stage, to the southern North Sea.

However, borehole 29/25-1, upon close examination of the wireline log character and of the lithological descriptions given by Deegan & Scull (1977), does appear to have a log unit which exhibits reddening from 7410 feet (approx) which is the equivalent to the Risbey Formation. The stage assignment according to Deegan & Scull (1977) is Aptian. This cannot be verified by the present author.

Boreholes 22/1-2A and 21/1A-8 have been studied by Burnhill & Ramsay and their results have been published (1981). These two authors have published a detailed lithostratigraphy, microbiostratigraphy and chronostratigraphy of these boreholes in conjunction with a similar analysis of other boreholes in the central North Sea (see Figs. 10.1 and 10.2). Burnhill & Ramsay (1981) recognise the Risbey and Valhall Formations in borehole 22/1-2A.

According to Burnhill & Ramsay (1981) the Risbey Formation in the central North Sea is Late Albian to Early Cenomanian in age.
Fig. 10.2 Mid-Cretaceous foraminiferal zonation in the central North Sea (from Burnhill & Ramsay, 1981 - 21/1a - 8)
The foraminifera which Burnhill & Ramsay identify as defining the Late Albian are predominantly planktonic species and include *H. amabilis* (Loeblich & Tappan) (=*H. simplex* this thesis), *H. brittonensis*, *H. planispira* and *H. delrioensis*.

The foraminifera within the top part of the Réény Formation which define the Cenomanian stage (the *H. brittonensis* Biozone of Burnhill & Ramsay) are also present in the top Albian. The first downhole record of *G. bentonensis* defines the top of the local partial range biozone (*G. bentonensis* Biozone) which defines the top of the Albian according to Burnhill & Ramsay (1981). This illustrates the difficulty in defining the Albian/Cenomanian boundary in the Boreal regime of North West Europe by the use of foraminifera. The base of this biozone is defined by the first downhole occurrence of "*G.?*"*gyroidinaeformis*.

These data are in general accord with the foraminiferal fauna contained in the Red Chalk Formation/Upper Holland Marl Member and the Middle Holland Shale Member of the studied boreholes in the southern North Sea Basin. Exact biozonal correlation between the two areas is not possible as the total ranges of the index foraminifera vary from locality to locality. In addition it appears that the important genus *Arenobulimina*, species of which define the top Albian - base Cenomanian in the southern North Sea Basin are absent or very rare in the central and northern North Sea Basin. Of especial note is the use of *O. schloenbachii* by Burnhill & Ramsay (1981) as a marker species in the Late Albian and Early Cenomanian. In the southern North Sea Basin this species is only recorded consistently by the author in the Early to Middle Albian (see Chapter 14, and Crittenden, 1983).

The "*G.?*"*gyroidinaeformis* Biozone of Burnhill & Ramsay is dated Early to Middle Albian. It is present at the top of the Valhall Formation (Figs. 10.1 & 10.2). The fauna is similar in aspect.
to Early and Middle Albian faunas from the southern North Sea Basin.

No faunal data from pre-top Valhall Formation are available to the author (no published data) from the central and northern North Sea which precludes any attempt at further comparison with the southern North Sea Basin.

10.2 The Norwegian Sector of the Central North Sea Basin

A synthesis of Early Cretaceous lithostratigraphical schemes for the southern North Sea Basin has been discussed previously (Crittenden, 1982a, see Chapter 5). A comparison of the Dutch scheme (NAM & RGD, 1980) with the British scheme (Rhys, compiler 1974) concluded that the Dutch scheme offered more scope and finesse for correlation purposes. It was considered pertinent therefore to designate borehole 49/25-1 as the reference borehole for the Dutch lithostratigraphical scheme in the British sector of the southern North Sea (Crittenden, 1982a). In addition Crittenden made the comment that Deegan and Scull (1977) recognised units of formation status in the Cromer Knoll Group of the northern and central North Sea that were undefined because of data restriction.

Hesjedal & Hamar (1983) have since illustrated an Early Cretaceous lithostratigraphical scheme for the southern Norwegian central North Sea Basin which illustrates several formations within the Cromer Knoll Group. Hesjedal & Hamar (1983) presented a comparison and a general synthesis of the various lithostratigraphical schemes in use for the Early Cretaceous strata of North West Europe but omitted any discussion of the scheme of NAM & RGD (1980).

The Aptian to Early and Middle Albian age Sola Formation of Hesjedal & Hamar (1983) of the central Graben and Norwegian - Danish Basin of the North Sea would appear to be the time
Fig. 10.3 Lithostratigraphical correlation chart (from Hesjedal & Hamar, 1983)
equivalent of the Middle Holland Shale Member and part of the Lower Holland Marl. The Kopervik Formation would appear to be analogous to the Holland Greensand Member. The Utvik Formation (upper calcareous marls and shales and marly limestones) appears to be analogous to the calcareous claystone/clay limestone of the Lower Holland Marl. The other lithostratigraphic units identified by Hesjedal & Hamar (1983) are illustrated in Fig. 10.3.

To the best of the author's knowledge Hesjedal & Hamar (1983) have not formally published lithological descriptions, wireline log descriptions, or type sections for their lithological units. Considerable confusion may arise from the impropriety of erecting a lithostratigraphical scheme based upon an oral presentation (see Hesjedal & Hamar, 1981; in references in Hesjedal & Hamar, 1983). However this does not detract from the successful application of the very useful scheme to hydrocarbon exploration in the North Sea Basin.

All of the aforementioned lithostratigraphical studies (this chapter and Chapter 6) have aided the understanding of the geological development of the North Sea Basins during the Early Cretaceous. More detailed attention, due to hydrocarbon exploration, has been paid to the Early Cretaceous strata of the North Sea Basins and the various lithostratigraphical models proposed have progressed from the simplistic (e.g. Deegan & Soull, 1977) to the complex (NAM & RGD, 1980). This is the inevitable consequence of the acquisition of more and more data.

From a comparison of the lithostratigraphical schemes available it can be concluded that different areas of the North Sea region during the Early Cretaceous were characterised by broadly similar patterns of sedimentation. These patterns are the result of similar genetic processes and environments of deposition (Ziegler, 1982). The various basins and sub-basins within the North Sea region during the Early Cretaceous underwent the same
or very similar, stratigraphic development related to local
tectonics, halokinesis, and regional tectonics (e.g. associated
with the opening of the North Atlantic). This concept is
invaluable when assessing the possibility of hydrocarbon
accumulation (particularly stratigraphic plays) in the Early
Cretaceous strata of the whole of the North Sea region (i.e.
source rock potential, reservoir potential, trapping and sealing
potential and migration pathways).

10.3 Comparison with South East Scandinavia

The Early Cretaceous deposits studied from the southern North Sea
compare extremely well with those from the Danish - Scanian Basin
both lithologically and in terms of the contained foraminiferal
fauna (Brotzen, 1945; Norling, 1981; Hesjedal & Hamar, 1983;
see section 10.2 this chapter).

This section of the thesis briefly discusses the data available
in the literature on the Early Cretaceous deposits of the Danish
- Scanian Basin. This helps to develop an overall picture of the
Early Cretaceous in North West Europe. During the Early
Cretaceous the Danish-Scanian Basin, between the Scandinavian
Massif and the "Pompeckij Swell", formed an important marine
connection, permitting faunal interchange, between the central
North Sea Basin and Poland (Brotzen, 1945; Norling, 1981;
Christensen, 1974; Kemper, 1973a, b; - see Figs. 4.1 & 4.3) as
the Danish - Polish Furrow.

The depression between the Scandinavian Massif and the "Pompeckij
Swell" was filled with a great deal of fresh water/brackish water
"Wealden sediments" during the Ryazanian and Valanginian. These
sediments are comparable to the Wealden deposits of the U.K.,
Holland and Germany.

During the Valanginian however marine foraminiferal faunas are
recognised at certain horizons. These faunas of boreal aspect
Fig. 10.4 Ranges of diagnostic foraminifera in boreholes from southern Scandinavia (from Norling, 1983)
are associated with a marine transgression from the north (Brotzen, 1945). These marine occurrences (and contained faunas) in the upper horizons of the "Wealden deposits", and also those which terminate the "Wealden deposits" are discussed by Norling (1981). Norling also discusses the faunas from the Hauterivian, Barremian, Aptian and Albian sediments. Norling's data is from borehole material (see Figs. 10.4 & 10.5).

The picture of Early Cretaceous sedimentation on the Danish - Scanian Basin is similar to other areas in North West Europe, including the southern North Sea, and there is a complicated interplay of marine transgression and regression and local tectonics. From Norling's work it can be seen that only a few index species of foraminifera are needed to give an age subdivision to stage level. However Norling does not state whether he was aware of the changes made by Bartenstein (1978a) to the Early Cretaceous foraminiferal zonation of Bettenstaedt & Bartenstein (1962) and in addition does not indicate all the works he has used in order to arrive at his subdivision.

10.4 Comparison with onshore the United Kingdom

It is generally agreed that the key to the offshore in terms of lithostratigraphy, biostratigraphy and palaeogeography is often onshore outcrop data. However extension of the onshore outcrop Stratigraphical schemes is fraught with difficulty. The onshore schemes are very detailed whereas the inherent drawbacks of ditch cutting material and sidewall core material and the lack of conventional core material severely limit the detail with which an offshore lithostratigraphy, biostratigraphy and chronostratigraphy can be constructed. However, the recognition of lateral facies changes, facies bound microfaunas, diachronism and unconformities is aided by the study of the offshore boreholes and onshore outcrop data.
**Fig. 10.5** Ranges of diagnostic foraminifera from southern Scandinavia (from Norling, 1981).
The U.K. onshore area of marine Early Cretaceous strata outcrop nearest to block 49 is the counties of Yorkshire, Lincolnshire and Norfolk. This area is north of the Mesozoic London-Brabant palaeoland mass and comprises two main Early Cretaceous depositional areas; the Spilsby or Eastern Basin (Norfolk to East Yorkshire) and the Yorkshire Basin (Speeton area) north of the Market Weighton hinge.

The Spilsby/Eastern Basin, or the East Midlands Shelf of Kent (1975), was an area of shallow water sedimentation on a stable platform limited to the east and north by the Dowsing Fault line/Market Weighton hinge. Fringing this platform to the north was the Yorkshire basin and its south eastern extension the Sole Pit Trough. This trough was an area of deeper water sedimentation limited to the north by the Mid North Sea High and Ring-Købing-Fyn High. To the south of the London-Brabant Platform/palaeoland mass there was an essentially non-marine basin (until the Aptian; see Chapter 12 & 13). This basin maintained intermittent contact with the East Midlands Shelf by means of a narrow seaway which fringed the western margin of the massif (Cambs - Beds seaway). The London-Brabant Platform was in all probability a land mass of reduced topography in the later Early Cretaceous fringed by shallow bays, inlets, estuaries, islands and probably dissected by narrow, permanent to ephemeral, marine channels. The subsequent Aptian/Albian inundation of the area has obliterated any sedimentological evidence for such a scenario (Owen, 1979). Detailed correlation of the three depositional areas is difficult because of the rapidity, both laterally and vertically, of facies and faunal changes. However with the onset of more uniform deposition over the whole area, associated with the peneplanation of the adjacent land areas, and a rise in sea-level, post-Aptian correlation becomes easier. The Market Weighton Hinge (transgressed completely by the Red Chalk and its pebbly base) and the London-Brabant Platform were only completely inundated/transgressed during Albian times. However,
the continuous Albian outcrop from Yorkshire to Dorset reveals marked changes in thickness, zonal age and lithology; Red Chalk in the north, Gault Clay in the south and Greensands in the West. For further discussion see Chapter 11.

From the south of England one borehole section is discussed in this thesis. In the north of England a number of boreholes have penetrated Early Cretaceous strata (Gallois and Morter, 1982) in Norfolk and Lincolnshire. In Yorkshire a number of boreholes drilled by Shell and B.P. penetrated a substantial sequence of Early Cretaceous strata. No data was made available for this thesis apart from the faunal log of Fletcher (1963). No wireline log data is available and in Yorkshire neither the Speeton-1 (1960) or West Heslerton Borehole of Shell were electrically logged. No direct wireline log comparison of the Early Cretaceous section of northern England may be made with the offshore. The lithology and biostratigraphy of the Speeton section (Fletcher, 1966, 1973) and other Yorkshire and Lincolnshire and Norfolk sections does tempt a direct correlation with the southern North Sea borehole data. It is possible, but caution is needed as lateral facies changes may be pitfalls for the unwary trying to correlate facies controlled benthonic foraminifera (Lott et al., 1985, 1986).

The onshore sequence of the Lincolnshire and Norfolk Early Cretaceous is a far coarser grained and varied lithological sequence than that of Yorkshire and is characteristic of a basin margin analogous to the basin margin deposits of the south-west Netherlands Basin and of the German Basins (e.g. Osning Sandstone).

Correlation and comparison of the southern North Sea Basin Early Cretaceous sections to the onshore U.K. outcrops are detailed in Chapter 11, 12 and 13. Detailed reference is only made to the strata of Aptian and Albian age.
CHAPTER 11

STRATIGRAPHICAL COMPARISON OF ALBIAN AND APTIAN STRATA
OF THE SOUTHERN NORTH SEA BASIN TO SELECTED AREAS OF NORTH WEST EUROPE

11.0 Introduction

As has been stated in Chapters 1, 8 and 10 there are similarities between the Albian planktonic and benthonic foraminiferal assemblages of the southern North Sea Basin with those from other areas in North West Europe (Boreal Province).

Planktonic foraminifera are either rare or absent from Early Albian microfaunas in North West Europe (Price, 1977a, b; Harris, 1982) and this is true for the studied faunas from block 49. It is only in the Middle and Late Albian of the southern North Sea Basin and the remainder of North West Europe that planktonic foraminifera become significant (see Fig. 7.11). Hedbergellid species are dominant (Carter and Hart, 1977) and no specimens of *F. washitensis* (Carsey) were recorded from block 49.

Harris (1982) regards the distribution of this species to be facies controlled (shallow, inner sublittoral close to shore, or associated with shoal environments). It is not recorded from the deeper water Albian age sediments of block 49.

No larger, keeled (tethyan forms) planktonic foraminifera such as *Rotalipora appeninica* (Renz) were recorded from block 49 (see Magniez-Jannin, 1981; keeled planktonic foraminifera from the Late Albian of Folkestone). However rare specimens of *Praeglobotruncana* spp. were recorded in some sections from the southern North Sea (49/10-1); and central North Sea Basin (see Burnhill & Ramsay, 1981). The individual size of the planktonic foraminifera increases in size throughout the Albian - a fact noted by Price (1977 a, b).
Moullade (1966) described a tethyan species, 'Globigerinelloides?' gyroidinaeformis from the Middle to Early Albian of France. Burnhill & Ramsay (1981) record this species from the central North Sea Basin and use its presence as an indicator of sediments of an Early to Middle Albian age. It has not been recorded from onshore sections of Albian age strata in North West Europe. It occurs sporadically in the southern North Sea Basin boreholes studied in block 49, in the Middle Holland Shale Member (Early to Middle Albian) and rarely in the base of the Upper Holland Marl Member. It does not occur in sufficient abundance to be considered a reliable index species in the southern North Sea Basin (see van Hinte, 1976). It does occur in abundance in the central and northern North Sea areas where its presence is used to indicate reliably the presence of strata of a Middle Albian age (first downhole occurrence - Burnhill pers. comm.).

A planktonic species which is important in block 49 in strata of Albian age is Globigerinelloides bentonensis. Harris (1982) has summarised the stratigraphical importance of this taxon using data from Price (1977 a, b) and Carter & Hart (1977). It is an uncommon species in strata of Middle Albian and Early Cenomanian age but it occurs in floods at certain horizons in the Late Albian (see Burnhill & Ramsay, 1981).

The dominant planktonic foraminifera in the Late Albian of the southern North Sea Basin are members of the Hedbergella delrioensis plexus. This is true for Late Albian age faunas elsewhere in North West Europe (Carter & Hart, 1977; Price, 1977a, b; Harris, 1982; Burnhill & Ramsay, 1981).

The benthonic foraminiferal faunas of the Albian of North West Europe are extremely well documented (e.g. Carter & Hart, 1977; Hart, 1973; Price, 1977a, b; Harris, 1982; Magniez-Jannin, 1975; ten Dam, 1950; Gawor-Biedowa, 1969, 1972; Hecht, 1938). Biozonations of Albian strata, using the abundant and diverse
Fig. 11.1 The Lithostratigraphy of the Winterborne Kingston borehole

<table>
<thead>
<tr>
<th>Layer</th>
<th>GR</th>
<th>Lith.</th>
<th>Sonic</th>
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<tbody>
<tr>
<td>Lower Kimmeridge Clay</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lower Greensand</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Gault</td>
<td>324</td>
<td></td>
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</tr>
<tr>
<td>Upper Greensand</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glauconitic Marls</td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Chalk</td>
<td>242</td>
<td></td>
<td>lower</td>
</tr>
<tr>
<td>Plesus Marls</td>
<td>120</td>
<td></td>
<td>lower</td>
</tr>
<tr>
<td>Turon</td>
<td></td>
<td></td>
<td>lower</td>
</tr>
<tr>
<td>Lat. 50°46.30’N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long. 2°13.02’W</td>
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</tbody>
</table>

Cover interval

WINTERBORNE KINGSTON
benthonic foraminifera have been proposed by Hecht (1938), Walters (1958), Hart (1973), Carter & Hart (1977), Price (1977a, b) and Harris (1982) and can be applied with some success to Albian age sections in the southern North Sea Basin but only with some difficulty to Albian age sections in the central and northern North Sea areas (Burnhill pers. comm.).

11.1 Comparison of Albian Age Strata; Onshore U.K. with Block 49

Carter & Hart (1977, fig. 18) have correlated, lithologically and biostratigraphically, from outcrop and cored borehole data, the mid-Cretaceous strata (Carstone to the Plenus Marls) from Buckland Newton in Dorset to Hunstanton in Norfolk. They did not use any wireline log data. Their work can be used in conjunction with the Winterborne Kingston borehole (Fig. 11.1) to correlate the onshore Albian stratigraphy with the studied offshore boreholes in the southern North Sea Basin. These boreholes can then be correlated with boreholes in the Dutch sector of the southern North Sea Basin and onshore the Netherlands.

The biostratigraphical dating of the Early Cretaceous sections of the boreholes has been accomplished for the U.K. southern North Sea Basin by the present author; for the Dutch sector by N.A.M.; and for the Winterborne Kingston borehole by the Institute of Geological Sciences (now the B.G.S.). Precise palaeontological dating by microfauna of the Early Cretaceous strata of the Winterborne Kingston borehole and the Dutch sector boreholes is not available but never the less a lithological/wireline log correlation is possible. In any case Carter & Hart (1977), Price (1977a, b) and Harris (1982) have provided a wealth of data from adjacent outcrop onshore the U.K. The formations described in the Winterborne Kingston borehole are based upon Rawson et al., (1978) and Carter & Hart (1977). Colter & Havard (1981) have discussed this borehole in relation to the Wytch Farm Oilfield in Dorset.
Fig. 11.2
The correlation of the mid Cretaceous from Hunstanton to Buckland Newton showing the use of the Plenus Marls as a correlation datum (from Carter & Hart, 1977).

The Winterborne Kingston borehole (Lat 50° 46' 80" N, Long. 2 13° 02' W) provides a very good example, for a comparison with the offshore, of the wireline log responses of the lithological units which make up the Albian strata onshore (Fig. 11.1). This is despite the large distance of the Winterborne Kingston borehole from the southern North Sea Basin.

The Plenus Marl is an easily recognised horizon in the Winterborne Kingston borehole and provides a marker horizon and datum for any lithological/wireline log correlation. Unfortunately, this datum is absent in some of the studied boreholes (see 49/24-1). Carter & Hart (1977) have documented this datum across southern England from Buckland Newton in Dorset to Hunstanton in Norfolk (Fig. 11.2).

The Winterborne Kingston borehole has been drilled at the western end of the Early Cretaceous depositional basin (Wessex Basin or Southern Basin) in southern England where the Gault Clay and its sandy/conglomeratic base transgresses westwards over folded and eroded earlier Cretaceous and Jurassic strata. Regional outcrop data illustrate the transgression:

A. For example south of the London - Brabant Platform by the Lower Greensand, Carstone and the nodule beds at the base of the Gault Clay:

1) glauconitic sands of Early Albian age (mammilatum Biozone) at the base of the Gault Clay in the western outcrop of Early Cretaceous strata in Wiltshire and Buckinghamshire overlap onto Kimmeridge Clay.
11) The Carstone of the Isle of Wight is *mammilatum* Biozone in age and has a gradual junction with the overlying Gault Clay. The Lower Greensand of the Weald has a gradational junction with the Gault Clay and this junction is diachronous.

B. This important transgressive episode is represented north of the London-Brabant Platform:

1) In Yorkshire (Speeton) by the Greensand Streak (*regularis* Subzone of the *tardefurcata* Biozone; Dilley, 1969; Owen et al., 1968).

2) In central and southern Lincolnshire by the Carstone Grit or pebbly base of the Red Chalk where the grit is absent (Owen et al., 1968; Owen, 1972; Rawson et al., 1978).

This transgressive basal deposit in the Winterborne Kingston borehole lies unconformably on Lower Kimmeridge Clay. Morter (1982) regards the basement beds of the Lower Gault Clay in the Winterborne Kingston borehole to be *mammilatum* Biozone in age (345.24 - 345.55m) with earlier Albian (*kitcheni* Subzone), and perhaps Late Aptian, greensands beneath. The ostracod data (Wilkinson, 1982) from this borehole is inconclusive with regard to the age of the Early Cretaceous sediments above the Lower Kimmeridgian.

The sub-Gault Clay transgressive episode may be directly correlated to the 'basal' Albian event seen in boreholes in the southern North Sea Basin (e.g. see 49/24-1, c. 5520 ft). The transgression is marked by coastal onlap at the basin margin but, as is seen for some of the boreholes in block 49, the effects can be traced into basinal areas. Here silty sand and/or phosphatic nodule horizons represent periods of erosion or non deposition.
The wireline log pattern of borehole 49/24-1 is very similar to that of the Winterborne Kingston borehole. Borehole 49/24-1 has been drilled on a structural high/horst which during the Early Cretaceous underwent uplift and erosion (Glennie & Boegner, 1981) resulting in either the subsequent removal of, or non deposition of, pre-Albian Early Cretaceous sediments which was then followed by the deposition of an attenuated Albian sequence. From microfaunal evidence (this thesis) a relatively thin veneer of Albian age sediments (Early Albian/Late Aptian age at the base) has been deposited. This illustrates the onlap of Early Cretaceous sediments on to pre-Cretaceous structural highs as a result of the late Early Cretaceous marine transgression (associated with the development of the North Atlantic). The sub-Gault Clay transgressive episode is directly comparable and correlatable with the basal horizon of the Early Cretaceous strata of the Winterborne Kingston borehole. In turn this correlates with the Carstone Grit onshore Norfolk (Rawson et al., 1978) and to the basal Gault transgressive episode south and west of the London - Brabant Platform. The Gault Clay is the earliest Mesozoic unit known to extend across the Palaeozoic London - Brabant Platform (Owen, 1971) and represents a marked change in palaeogeography at this time.

Borehole 49/24-1 correlates lithostratigraphically and biostratigraphically extremely well with other boreholes in block 49 and in other areas of the southern North Sea Basin. The gamma ray and sonic logs of a number of boreholes show the same feature at or near the base of the Middle Holland Shale Member (see Crittenden, 1982a, figs. 3 - 4). This siltstone/sandstone horizon (phosphatic nodules) may be correlated with the greensand intercalations at the base of the Middle Holland Shale Member in the Netherlands offshore and onshore (NAM & RGD, 1980). These intercalations are thickest along the margin of the southern North Sea Basin and they rapidly shale out toward the depositional centers.
<table>
<thead>
<tr>
<th></th>
<th>Lower Holland Marl Member</th>
<th>Middle Holland Shale Member</th>
<th>Upper Holland Marl Member</th>
<th>Texel Greensand Member</th>
<th>Texel Chalk Formation</th>
<th>Aptian</th>
<th>Albian</th>
<th>Cenomanian</th>
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<tr>
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<td>Netherlands Basin</td>
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<tr>
<td>Interbedded Greensand</td>
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</table>

*Fig. 11.3*
In the West Netherlands Basin thicker developments of green, glauconitic, fine grained, basin margin sandstones and siltstones are termed the Holland Greensand Member (NAM & RGD, 1980) see Fig. 11.3. The Holland Greensand Member is Late Aptian to Early Albian in age in the Netherlands offshore and foraminiferal evidence suggests that the age range is valid for sandy horizons at the transgressive base of the Middle Holland Shale Member in some boreholes in the UK southern North Sea Basin (Crittenden, 1984a, b) see Fig. 11.3.

Tectonic rejuvenation and subsequent erosion of horsts and the basin margin is thought to have supplied the clastic material. Areas of reduced rates of supply of terrigenous clastic material, as to be expected in the centre of the basin, are marked by condensed and phosphatic nodule horizons (see 49/25-1 and 49/25-2). Superimposed upon the general picture of an eustatic rise in sea level associated with the development of the North Atlantic (Cooper, 1977; Ziegler, 1981) are more localised events associated with Early Cretaceous uplift (and halokinesis) and erosion in the southern North Sea Basin. Early Cretaceous uplift has resulted in various degrees of erosion before the resumption of sedimentation during the Albian over the whole area. Subsequently post Early Cretaceous events of uplift and erosion in the southern North Sea Basin have complicated the geological history (Glennie & Boegner, 1981).

The Gault Clay lies above the Lower Greensand equivalent in the Winterborne Kingston borehole. This dark blue/grey-green, silty, calcareous and fossiliferous Middle Albian mudstone-claystone is reputedly a low energy environment deposit laid down at some distance from the major source of supply of clastic terrigenous material (Gallois & Morter, 1982). The log pattern and lithology correlates in a broad sense with the Middle Holland Shale Member in boreholes 49/24-1 and L5-1 (NAM). However in borehole 49/24-1 the Gault Clay equivalent (the Middle Holland
### Fig. 11.4

The lithostratigraphical correlation of the Albian strata of the United Kingdom (after Rawson et al., 1978).

<table>
<thead>
<tr>
<th>STAGE</th>
<th>ZONE</th>
<th>SPEETON</th>
<th>CENTRAL &amp; SOUTHLINCS</th>
<th>NORFOLK</th>
<th>CAMBS &amp; BEDS</th>
<th>WILTS TO BUCKS</th>
<th>DEVON &amp; DORSET</th>
<th>ISLE OF WIGHT</th>
<th>THE WEALD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albian</td>
<td>L. mammillatum</td>
<td>RED CHALK c. 20 m.</td>
<td>RED CHALK 20 m.</td>
<td>RED CHALK 20 m.</td>
<td>RED CHALK 20 m.</td>
<td>RED CHALK 20 m.</td>
<td>RED CHALK 20 m.</td>
<td>RED CHALK 20 m.</td>
<td>RED CHALK 20 m.</td>
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<tr>
<td></td>
<td>L. loricatus</td>
<td>MINIMUM MARKS 20 m.</td>
<td>CHALK 20 m.</td>
<td>Gault 20 m.</td>
<td>Gault 20 m.</td>
<td>Gault 20 m.</td>
<td>Gault 20 m.</td>
<td>Gault 20 m.</td>
<td>Gault 20 m.</td>
</tr>
<tr>
<td></td>
<td>L. dentatus</td>
<td>GRIT 20 m.</td>
<td>CARSTONE 20 m.</td>
<td>CARSTONE 20 m.</td>
<td>CARSTONE 20 m.</td>
<td>CARSTONE 20 m.</td>
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</tr>
<tr>
<td></td>
<td>L. loricata</td>
<td>SAND &amp; CLAYS 20 m.</td>
<td>SAND &amp; CLAYS 20 m.</td>
<td>SAND &amp; CLAYS 20 m.</td>
<td>SAND &amp; CLAYS 20 m.</td>
<td>SAND &amp; CLAYS 20 m.</td>
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<td>SAND &amp; CLAYS 20 m.</td>
<td>SAND &amp; CLAYS 20 m.</td>
</tr>
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<td></td>
<td>M. jacobi</td>
<td>RED SANDS &amp; CLAYS 20 m.</td>
<td>WOBURN SANDS 20 m.</td>
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Winterborne Kingston
Shale Member) is a mottled reddish grey colour which heralds the
colouration of the overlying Red Chalk Formation/Upper Holland
Marl Member.

In the Winterborne Kingston borehole the Gault Clay grades upward
through siltstones to a sequence of colourless - white, medium -
 coarse, very glauconitic sandstones alternately hard and friable
according to the degree of calcite cementation. This Upper
Greensand is assumed to be the lateral equivalent (with a
 diachronous base) of the Red Chalk Formation/Upper Holland Marl
Member and the Upper Gault Clay. The coeval relationship of
these three units has been demonstrated by various authors and is
summarised in Rawson et al., (1978) see Fig. 11.4, and by Carter
& Hart (1977) see Fig. 11.2.

The Upper Greensand is a basin margin deposit as indicated by its
depositional outcrop pattern around the perimeter of the Early
Cretaceous depositional basin in the south and west of England.
The Upper Greensand is more prominent in the west and is presumed
to be a glauconitic marginal shelf sand that accumulated at or
about the limits of wave effectiveness around the basin margin.
The Gault Clay is a low energy shallow water deposit laid down
some distance from the source of supply of clastic terrigenous
material. The Red Chalk s.s. is a shallow water limestone
intensely bioturbated and highly condensed, onshore the UK and
was almost certainly deposited in the photic zone. Anderton et
al., (1979) erroneously state that the main area of Red Chalk
deposition coincides with the Market Weighton Horst and, also
erroneously, state that the Red Chalk was deposited in deep water
on a sea mount surrounded by even deeper water shales (Gallois &
Chalk passes laterally when traced southward in Norfolk (see
Rawson et al., 1978) into rhythmic bedded Upper Gault Clay
sediments that initially thicken southward and then thin as the
London - Brabant platform is approached and overstepped (Gallois
& Morter, 1982).
In the Winterborne Kingston borehole the Glauconitic Marl overlies the Upper Greensand. The Glauconitic Marl is a basin margin deposit and is analogous to the Texel Greensand and intercalated marl horizons at the base of the chalk sequence in the Netherlands (Fig. 11.3). The Glauconitic Marl is Early Cenomanian in age. It occurs above the Upper Greensand in Hampshire, Sussex and Kent but in the Chilterns grades into the Cambridge Greensand (Rawson et al., 1978). Hart & Carter (1977) have demonstrated the coevality of the Cambridge and Warminster Greensands and the Glauconitic Marl with its characteristic condensed and diachronous nature. They remark that the Albian-Cenomanian boundary is a complex junction which is almost transitional in some sections but is a marked hiatus in others. None of the studied boreholes has a clear lithological equivalent of the Glauconitic Marl at the base of the Cenomanian.

The Lower Greensand, Gault Clay, Red Chalk and Upper Greensand succession in southern and central England is far from being a complete unbroken sequence of Early to Late Albian sediments (Price, 1977b). There are numerous minor unconformities, planes of erosion, non-sequences and facies changes (Owen, 1971a, b, 1975, 1979; Gallois & Morter, 1982). These are a result of such factors as local and regional tectonism, sea bed relief, current scour and sea level changes. This is also true for Albian sediments in other areas of North West Europe (Price, 1977b; Kemper, 1973; Rawson & Riley, 1982). It is therefore prudent to bear in mind this onshore situation when assessing the stratigraphy of Albian strata in boreholes in the southern North Sea Basin. However these minor unconformities recognised onshore UK are not easily recognised offshore especially when dealing with ditch cutting samples. The Upper Holland Marl Member (Red Chalk Formation) - Middle Holland Shale Member (Speeton Clay pars) formational boundary is a transgressive event (see NAM & RGD, 1980; Rawson & Riley, 1982).
11.2 The "Basal Albian Transgression"

Tectonic instability during Aptian and Albian times had a pronounced effect on sedimentation, especially in marginal areas and adjacent to palaeohighs (e.g. local salt stock structures) of the North West European sedimentary basins. The product is a profusion of non-sequences, discordances and erosion horizons of local and regional importance which are all associated with phases of shallowing and deepening of the sea. The resultant numerous sedimentary facies (Kemper, 1973a, b) characteristic of the Aptian and Albian strata in North West Europe may be mapped and dated biostratigraphically to provide an approximation of palaeogeography and palaeogeographical changes through time (Gallois & Morter, 1982). However correlation difficulties are encountered as a result of facies variation which, as they are a result of palaeoenvironment, are concomitant with variation in the benthonic and planktonic foraminiferal fauna. The scarcity of planktonic foraminifera during Early and Middle Albian times, which precludes their use as accurate stratigraphical tools, and the abundance of benthonic foraminifera, particularly arenaceous forms, is undoubtedly facies related.

It would appear that a major "gross" transgression phase commenced in Late Aptian times (nutfieldensis? - jacobi - nolani Biozones) which progressed through the tardefurcata Subzone, the regularis Subzone and mammilatum Biozone of the Early Albian through to Middle and Late Albian times (see Fig. 4.9). Minor still stands, tectonic movement and minor regression/transgression events have resulted in polyphase events throughout this interval which make a precise geological history difficult to unravel (Crittenden, 1984a, b). Basinward a number of disconformities/unconformities/hiatuses may be recognised while across high areas these coalesce into what appears to be a single major break (see Fig. 5.9). By Middle to Late Albian times the major high areas in the region were inundated by the sea. (c.f. the Gault Clay and the London Brabant Platform). The recognition
of this transgression and associated coarser sedimentation at its base will be of paramount importance for the delineation of possible stratigraphic traps of hydrocarbons in the southern North Sea Basin. The reservoir would be the coarser clastic sediments associated with the transgression. The source of these clastics is discussed in Chapter 5. (see Fig. 5.16).

The Southern North Sea Basin

The boreholes 49/24-3, 49/24-4 and 49/24-1 (see Fig. 5.9) provide an excellent example of a lithostratigraphical and biostratigraphical correlation of Albian age strata in the southern North Sea Basin. These boreholes are located on Mesozoic structural highs/fault blocks which during latest Early Cretaceous times underwent uplift and erosion. The onlap of Early Cretaceous strata as a result of a marine transgression onto the highs is illustrated by these boreholes (Day et al., 1981). The transgression has resulted in the subsequent erosion or non deposition of either pre-Late Aptian/Early Albian strata or pre-Late Albian age strata (Glennie & Boegner, 1981) with in general an increasing hiatus toward the crest of the highs. The concept of the coalescence of unconformities across palaeostructural highs is thus demonstrated. The microfaunal evidence indicates that by comparison with other areas in north west Europe only a relatively thin veneer of Late Aptian age sediments are present in the three boreholes.

Lithostratigraphy

The lithostratigraphic subdivision and correlation of the three boreholes has been discussed and illustrated previously (Chapter 5; Crittenden, 1982, 1984a, b, 1987a, b; see Fig. 5.9). The gamma ray and sonic log/interval transit time logs from the boreholes in the UK sector of the southern North Sea Basin all display a similar feature toward or at the base of the Middle Holland Shale Member. This siltstone/sandstone phosphatic
Fig. 11.5 Boreholes Vlieland Oost - 1 and L5 - 1 (NAM) in the Dutch southern North Sea showing the lithostratigraphical scheme of NAM & RGD (1980)
nodule bed horizon can be correlated with the greensand intercalations present toward the base of the Middle Holland Shale Member in the Netherlands offshore (NAM & RGD, 1980). Boreholes Vlieland Oost-1 and L 5-1 (Fig. 11.5) in the Dutch sector illustrate the "basal Albian" Gault transgression as depicted by the sandy basal horizon of the Middle Holland Shale Member (Crittenden, 1982, 1984a, b) see Fig. 5.3 and 5.5.

**Biostratigraphy**

Careful microfaunal analysis provides accurate age dating for the Early Cretaceous strata of boreholes 49/24-1 and 49/24-4 and reveals the presence of an unconformity at the base of the Early Cretaceous strata. Permoto-Triassic sediments are overlain unconformably by a thin veneer of Late Aptian age strata, which in turn is overlain unconformably by an interval of Early to Middle Albian age strata.

In borehole 49/24-3 Late Albian age sediments (Upper Holland Marl Member) overlie unconformably the Bunter Sandstone. This suggests that the boundary between the Upper Holland Marl Member and the Middle Holland Shale Member is a disconformity/unconformity. The foraminiferal faunas indicate that the Upper Holland Marl Member is Late Albian in age and that the Middle Holland Shale Member is Middle to Early Albian in age and as suggested by Crittenden (1984a, b) at the base is Late Aptian in age. An examination of fig. 5.9 shows the diachroncity of the Early/Middle Albian transgression and its effect on the age and thickness of the Albian sediments across the "high" areas.

**Germany**

There is a wealth of useful, highly detailed and factual data on the Albian age strata of Germany available in the literature (see Chapter 2). These data provide a valuable insight into the development of Albian age strata in North West Europe and has a

Fig. 11.6 Profile through the Scheerhorn oilfield, about 35 km NNW of Bentheim (after Kemper, 1979)

The Aptian Belly motif as seen in the southern North Sea
direct consequence (or should have) and bearing on hydrocarbon exploration in the whole of the North Sea area. More importantly, Early Cretaceous exploration plays and concepts developed and pursued in Germany may be applicable to the North Sea Basin area. The "basal Albian" transgression is represented in Germany as a development of sands, silts, glauconitic sands and phosphatic pebble beds which lie at the base of the "mid-Cretaceous" (s.l.) section (usually basal Gault Clay or equivalent - see Kemper 1979, fig. 2).

The Scheerhorn Oilfield (Kemper, 1979, fig. 3) provides an excellent example of the "basal Albian" transgression and illustrates the onlap of strata onto structural high areas. The concept of unconformity coalescence and the magnitude of the hiatus (missing strata) increasing as the high is overlapped is also illustrated. Part of the figure of Kemper (1979) is reproduced as Fig. 11.6. The wireline log pattern of the boreholes is remarkably similar to wireline log patterns encountered over the same stratigraphical interval in the southern North Sea Basin and onshore UK (see Fig. 11.1).

Wireline log patterns and correlation diagrams from the Albian strata of Munsterland (Fig. 11.7) by Schuster & Wolburg (1962, 1963) illustrate very dramatically the "Albian" transgression and the coarser facies associated with the transgression (Osning Sandstone). This sandstone as a lithostratigraphic unit according to Kemper (1979) is a basin margin deposit of Early Valanginian to Albian age which flanks the northern margin of the Rhenanian Massif (cf. the Lower Greensand). These sands pinch out to the north toward the basin centre (a situation very similar to the sandstone tongues which flank the northern margin of the London - Brabant Platform in the West Netherlands Basin). Various correlation profiles of boreholes in the Munsterland area are shown in Figs. 11.8 - 11.11. The work performed by Schuster & Wolburg illustrates very nicely how the careful integration of micropalaeontology, lithostratigraphy, chronostratigraphy and
Fig. 11.7 The Albian strata of Munsterland, Germany; cross-section locations (from Schuster & Wolburg, 1962 & 1963)
palaeoenvironmental analysis is an important tool and technique in helping to unravel the geological history and in developing a basin evolution model of an area to aid hydrocarbon exploration.

The "Albian transgression" is a regional event in North West Europe which is important for the understanding of the pattern of basin evolution during Early Cretaceous times.

11.3 Aptian Lithostratigraphy and Biostratigraphy (foraminifera) of Block 49 in the Southern North Sea Basin (UK Sector)

This section discusses the recognition of Aptian age strata in the southern North Sea Basin in terms of lithostratigraphy and foraminiferal biostratigraphy. In order to present a clear picture some repetition is necessary of statements made in previous chapters (Chapters 5 and 6) and publications (Crittenden, 1984a, b, 1987a). The overall aim of this section is to contribute to the, at present, meagre knowledge of UK Aptian micropalaeontology and stratigraphy.

Strata of Aptian age in boreholes in block 49 of the UK southern North Sea Basin (Fig. 5.2) can be recognised by distinct lithological and wireline log characteristics (low gamma ray log response and low interval transit times of the same log response). This permits broad correlation with other boreholes in the southern North Sea (Crittenden, 1982a), the central North Sea, the Netherlands (e.g. L5-1, NAM & RGD, 1980) and with areas further afield such as Germany (e.g. Scheerhorn Oilfield, boreholes 146 and H1, Kempér, 1979) and Scandinavia (e.g. Dansk Nordsø E-1, I-1 and J-1, Rasmussen, 1978).

Lithostratigraphically strata of Aptian age comprise the whole of the Lower Holland Marl Member equivalent of the Holland Formation (Rijnland Group) as defined by NAM & RGD (1980) and in some boreholes includes the basal portion of the Middle Holland Shale Member equivalent. The "basal sand" horizon of the Middle
Fig. 11.8 Correlation by wireline logs (Rheine Z1 to Donar 5) to show the Albian transgression (from Schuster & Wolburg, 1963)
Holland Shale Member equivalent may be the lateral equivalent of the Holland Greensand Member (Figs. 5.1, 11.3). These lithostratigraphical units can be dated in gross terms by the contained foraminiferal faunas (Crittenden, 1984a, 1987a, b). Borehole 49/25-1 (Shell/Esso) is used to illustrate strata of Aptian age in the UK southern North Sea (see Chapters 6, 7 and 8).

Lithostratigraphy

Middle Holland Shale Member

This member, predominantly of Albian age, consists of grey-brown and green, micaceous claystones which are glauconitic and calcareous. It has a lower lime content than the lower and upper members of the Holland Formation. Near the base there is a thin sand or siltstone horizon containing rare phosphatic pebbles. The designated Dutch reference borehole (NAM & RGD, 1980), L5-1 (NAM) and the borehole Vlieland Oost - 1 each show a typical development of this member (Fig. 11.5). This member is well developed in borehole 49/25-1 of the study area (Fig. 5.8).

The coarser horizon at the base or toward the base of the unit is depicted by the reduced gamma ray and increased sonic log responses (c. 2384 metres in L5-1) and may be the lateral equivalent of the Holland Greensand Member of the West Netherlands Basin (Crittenden, 1984b). This interval may be the equivalent of the Carstone, Carstone Grit and the Greensand Streak in north-east England (Fig. 11.4).

The base of the Middle Holland Shale Member is not defined by NAM & RGD which can cause difficulty when attempting to use foraminiferal data for age dating the unit. Both boreholes L5-1 and Vlieland Oost - 1 show a similar log response which in Vlieland Oost - 1 (1645m - 1650 m) is interpreted as Lower Holland Marl by NAM & RGD (1980) and which in L5-1 (2380m -
Fig. 11.9 Neuenkirchen 2 to Jburg 2 (from Schuster & Wolburg, 1962)
2384m) is interpreted as the basal sand/siltstone of the Middle Holland Shale. The unit termed the Lower Holland Marl Member in Vlieland Oost - 1 may be the basal sand/siltstone of the Middle Holland Shale and represent the product of the "basal Albian" transgression (note the double point spike of the sonic log). This hypothesis, however, has not been confirmed or refuted by microfaunal analysis (by the present author) of these two boreholes. It is not clear where the base of this Member should be drawn; at the coarser horizon, if present, or beneath at the point where there is a pronounced log character change (lower gamma ray response and lower interval transit times). The latter case is taken by Crittenden 1982a - see Chapters 5 & 6.

Holland Greensand Member

NAM & RGD (1980) define this member in the West Netherlands Basin as a green, very glauconitic, fine grained sandstone to siltstone, present only along the southern margin of the basin which rapidly "shales out" to the north. According to NAM & RGD (1980) this member is not present in borehole L5-1. However the present author is of the opinion that the sandy/silty horizon at approximately 2380m - 2384m is the lateral equivalent of the Holland Greensand Member. The same unit may be recognised in boreholes 49/25-1 at c. 6425 feet, 49/25-2 at c. 6795 feet and 49/24-12 at c. 5060 feet (see Fig. 5.8).

NAM & RGD (1980) point out that the base of the Middle Holland Shale Member marks a pronounced transgression ("Albian transgression"). They include the thin coarse clastic beds denoting this transgression within the Middle Holland Shale Member rather than suggesting that they may be the lateral equivalent of the Holland Greensand Member. This same transgression may be seen in the Scheerhorn Oilfield (Fig. 11.6). In this oilfield the unconformity is pre-nolani-jacobi zone (Aptian age) in borehole H-1, but is of pre-tardefurcata zone (Early Aptian age) in borehole I46.
Fig. 11.10 Karl-Mahne 2 to Jburg 2 (from Schuster & Wolburg, 1962)
The exact position of these lithostratigraphic units and boundaries poses a problem when attempting to integrate the biostratigraphic data with the lithostratigraphic data. This is, as previously mentioned, further complicated by the nature of the samples (ditch cuttings) and sample interval.

**Lower Holland Marl Member**

This member is a grey and red-brown marl/calcareous claystone very argillaceous limestone with intercalated bituminous claystone beds. This member as recognised by Crittenden (1982a) is of Aptian age. The whole unit is characterised by a low gamma ray log response and low interval transit times which are displayed as a "belly" motif. This member is well developed in borehole 49/25-1 of the study area (Fig. 6.1). This member is coeval with the "tock facies" and "ewaldi kreide" of Helgoland, and the "fischsheifer" and "ewaldi marl" of north west Germany and the "ewaldi beds" of Speeton, UK (Bartenstein & Kaever, 1973; Kemper, 1973a, b & 1979).

**Biostratigraphy**

Aptian age dating by means of foraminifera is hindered by a number of factors.

A. Imprecise knowledge of both Aptian foraminiferal (benthonic and planktonic) faunas and the foraminiferal sequence across the Albian/Aptian boundary (Kent & Dilley, 1968) in the adjacent onshore UK and North West Europe (Crittenden, 1982b, 1983a,b,c, 1984a,b).

B. The geographical separation of the Albian and Aptian stratotypes in France (Rawson, 1983).
Fig 11.11 Weseke 1008 to Donar 5 (from Schuster & Wolburg, 1962)
C. The locations of the Aptian stratotypes are in different faunal provinces. They fall within the Tethyan realm in contrast to the Boreal/Transitional realm situation of the Early Cretaceous southern North Sea.

D. The material studied from the boreholes in block 49 are cuttings samples which hinders accurate biostratigraphical study (problems of caving, sample interval and lag time - see Crittenden, 1979). For this study there were no conventional core or sidewall core samples available for biostratigraphical analysis. A detailed discussion of the disadvantages of borehole ditch cuttings samples is given in Chapter 3. A stratigrapher, in order to acquaint him/herself fully with the problems, should ideally spend time at the wellsites calculating lag times and catching and preparing ditch cuttings samples for analysis. Even so, it is surprising how many stratigraphers do not actually appreciate how ditch cuttings are "caught" and thus cannot fully comprehend the disadvantages and drawbacks of using such samples for biostratigraphic analysis.

E. A very important consideration is the state of flux which exists in the erection of a foraminiferal biozonal scheme for the boreal Early Cretaceous strata of North West Europe. This situation was recognised by Bartenstein & Oertli (1977) who acknowledged the difficulties of comparing the stages of the Early Cretaceous in North West Europe as defined by ammonites, with a microfaunal subdivision. The division of the North West European Early Cretaceous by ammonites has been revised (e.g. Kemper; 1979a, b; Rawson, 1983). In consequence the standard Early Cretaceous biozonal scheme (foraminifera & ostracods) of Bartenstein and Bettenstaedt (1962) and the worldwide Early Cretaceous biozonal scheme (foraminifera)
of Barstenstein (e.g. 1976a, b, c) are in need of revision. The schemes are dominated by the use of benthonic foraminifera.

The revised Aptian and Albian stages in terms of their ammonite biozones have been compared by Bartenstein (1978a) with the foraminiferal biozones of Bartenstein and Bettenstaedt (1962). The ammonite biozone boundaries do not coincide with extinctions, new appearances or major differences in the foraminiferal fauna (Barstenstein & Kaever, 1973). To overcome this difficulty a complete revision of the Early Cretaceous index foraminiferal species and faunas is needed from samples of a section calibrated for a control by index ammonites (Bartenstein, 1978a).

As a result of these factors it is considered improper to assume that in all cases foraminiferal age dating from ditch cuttings can provide accuracy to the limits of an ammonite zone or subzone. However, the inability to provide an age in terms of an ammonite zone or subzone must not be construed as a failing of foraminiferal biostratigraphy. Equally the inability of ammonites to provide an age in terms of foraminiferal zones or subzones must also not be construed as a failure of ammonite biostratigraphy. Kemper (1973a, b) neatly sums up the problem - "micropalaentologists have created problems through their biostratigraphical method - by giving ammonite zonal names to microfossil assemblages without finding the nominate ammonites, instead of proposing an autonomous classification".

Middle Holland Shale Member

This member is assumed by NAM & RGD (1980) to be Early Albian in age. This is essentially correct as seen in boreholes in block 49. However, in the same boreholes studied in block 49 the foraminiferal fauna in the basal part of this member has an earliest Early Albian/Late Aptian character (Crittenden 1984a, b). The Albian/Aptian boundary therefore falls somewhere toward
the base of this member. This earliest Albian - latest Aptian age, from a synthesis of all the studied boreholes in block 49, is suggested by the association of the following key benthonic species: **Textularia bettenstaedti** Barstenstein & Oertli (=T. foeda Reuss of Eichenberg 1935, and Gaudryina D16 of Hecht, 1938), **Ammosphaeroidina minuta** Khan, **Gaudryina dividens** Grabert, **Guadryinella sherlocki** Bettenstaedt, **Conorotalites aptiensis** (Bettenstaedt), **Haplophragmoides concavus** (Chapman), **Verneuilinoides subfiliformis** Barstenstein, **Marssonella subtrochus** Bartenstein, **Glomospira ex. gr. gaultina** (Berthelin)-abundance, **Falsogaudryinella** spp. (=Uvigerinammina spp. of authors), **Patellina** sp., **Lenticulina (Saracenaria) spinosa** (Eichenberg), **L. (Marginulina) schloenbachi** (Reuss), **L. (M.) foeda** (Reuss), **Nodosaria obscura** (Reuss). The total fauna is dominated by arenaceous species which are usually crushed and deformed and is marked by a flood of G. ex. gr. gaultina. This fauna compares very well with that recorded by Kent and Dilley (1968) as Late Aptian - Early Albian in age from the Elsham clay of Lincolnshire UK.

The most reliable indication for a Late Aptian age is the co-occurrence of **T. bettenstaedti**, L. (S.) spinosa (top occurrence) and G. dividens (Barstenstein and Oertli, 1977) but equally the total fauna could be earliest Early Albian in age (Kent & Dilley, 1968; Crittenden, 1984a). The sample interval precludes precise biostratigraphic analysis of the basal part of this member in block 49 (see previous lithostratigraphical discussion).

The situation of the unconformities or unconformity at or near the Albian/Aptian boundary is complex and in some wells difficult to assess. The base of the Middle Holland Shale Member may be Early Albian in age as illustrated by borehole I46 (see Fig. 11.6) or Late Aptian in age as illustrated by borehole H1 (see Fig. 11.6).
This assumes that the boundary of the Middle Holland Shale Member and Lower Holland Marl Member is defined by the change to a consistent lower gamma ray response i.e. the top of the "ewaldi Mergel".

An incoming downhole of abundant green coloured specimens of Hedbergella infracretacea (e.g. 49/24-1 and 49/24-12, 5060') together with L. (S.) spinosa and G. dividens is suggestive of the earliest(?) Late Aptian (Barstenstein & Kaever, 1973). In some boreholes (e.g. 49/20-2) there is a flood of red coloured Hedbergella infracretacea (Hedbergella sp. D11, Hecht 1938) again in association with L. (S.) spinosa and G. dividens. By comparison with Heligoland this association is indicative of the earliest Late Aptian (Bartenstein & Kaever, 1973) and equated with the orange-red chalk of the upper ewaldi Kreide which is two metres thick in Heligoland (Kemper et al., 1974). This same flood of planktonics is noted by Bertram and Kemper (1982) in north west Germany. In some boreholes in block 49 the strata beneath the "Albian unconformity" is Early Aptian in age and the distinctive flood of H. infracretacea (H. D.11) is not observed (a result of erosion associated with a transgression or non deposition on highs).

**Lower Holland Marl Member**

This member in boreholes from block 49 is characterised by the following benthonic foraminiferal fauna: Ammobaculites reophacoides Bartenstein, G.sherlocki, G.dividens, M.subtrochus, Falsogaudrycinella spp., L.(M.) schloenbachi, L.(S.) spinosa, L.(A). subgaultina Bartenstein, C.aptiensis, Darbyella sp., G.brieiensis Malaprls, G. ex. gr. gaultina, Vaginulina sherlocki Reuss, and V.reideli Bartenstein and Brand plus abundant small, crushed agglutinants (including Recurvoides spp.).

This fauna is characteristic of the Early Aptian in north west Germany and Heligoland (Bartenstein 1976a, b, c; 1977; 1978a, b; 1979; Bartenstein and Kaever, 1973).
The abundance of *Hedbergella aptiana* Bartenstein 1965 (=*Hedbergella sp. D.9*, Hecht 1938) in the basal part of the Lower Holland Marl Member (49/24-12, 5100') by comparison with Helgoland and north west Germany provides evidence of an Early Aptian age (Hecht, 1938; Bartenstein & Kaever, 1973).
CHAPTER 12

THE FORAMINIFERA OF THE ATERFIELD CLAY FORMATION
(EARLY APTIAN) OF THE ISLE OF WIGHT, U.K.

12.0 Introduction

The onshore outcrop area of Aptian strata closest (in the UK) to
the southern North Sea Basin comprises the Counties of Yorkshire,
Humberside, Lincolnshire and Norfolk. Kaye (1963) has published
details of the ostracod fauna from the Aptian strata at Speeton
and from the Sutterby Marl of Lincolnshire (Kaye & Barker, 1965).
Kent and Dilley (1968) have recorded a Late Aptian - Early Albian
foraminiferal fauna from Elsham, Humberside.

The Sutterby Marl is Late Aptian in age but contains macrofaunas
of an Early Aptian age within phosphatic nodule beds (Casey,
1961; Rawson et al., 1978).

At Speeton the Aptian stage is represented (but thin) and
collection of samples from the section is difficult due to poor
exposure and slumping of the cliff section. The Aptian strata
(non-Greensand facies) comprises the upper part of the Upper B
Beds plus the ewald》Marls. There are, however, gaps in the
sequence, as reported by Rawson et al., (1978).

To date no account has been published detailing the foraminiferal
fauna from the Skegness Clay (Early Aptian) or the Sutterby Marl
(Late Aptian) of Lincolnshire. At Elsham, north Lincolnshire, a
supposed Late Aptian-Early Albian foraminiferal fauna has been
recorded by Kent & Dilley (1968) from the Elsham Clay above the
Elsham sandstone which includes: Ammosphaeroidina minuta Khan,
A.macfadyeni, D.gradata, E.mariae, G.dividens, G.tealbyensis
(=Falsogaudryinella tealbyensis), G. intermedia, G.eaglefordensis
(=G.bentonensis (Morrow)), Globorotalites aff. minuta (White),
H.aff. aptiana, H.infracretacea, H.planispira, M.oxycona and
T.chapmani.
Fig. 12.1

The fauna is similar to that found at the junction of the Red Chalk and underlying red marls and clays in the Fordon No. 1 (B.P.) well in East Yorkshire (Kent & Dilley, 1968). Kent & Dilley (1968), from unpublished research, state that the Sutterby Marl contains a microfauna similar to that of Elsham including many specimens of Conototalites aptiensis. A Sutterby Marl foraminiferal fauna has been examined by the author at the B.P. Research Laboratories, Sunbury-on-Thames (courtesy of the late Dr. Ron Walters) and includes: C.aptiensis, L.(A.)crepidularis, G.group intermedia, G.barremiana, N.sceptrum, N.pyramidalis, G.dividens and H.infracretacea (Slide F.C.D. 177, Dilley collection).

In general the Aptian of the onshore area of eastern England adjacent to the southern North Sea Basin is poorly exposed or thin thus explaining the lack of published data on the foraminiferal fauna.

The foraminiferal faunas from the Aptian strata of the southern province of deposition of the U.K. (i.e. south of the London-Brabant palaeoland mass) are equally not so well known (Cambridgeshire - Bedfordshire, the Weald - Isle of Wight, Dorset - Devon and Wiltshire - Buckinghamshire). Kaye (1965) has published details of the ostracod fauna from the Atherfield "Group" of the Isle of Wight but he did not describe the foraminiferal fauna. Hart (1973) and Hart & Carter (1975) and Hart et al., (1981) have published an analysis of the foraminiferal fauna of the Atherfield Clay sensu stricto from a borehole near Sevenoaks, Kent. The fauna was not detailed as a species list but it is both numerous and diverse (see Fig. 12.1). Jaworski (pers. comm. 1981) has collected a comprehensive and rich foraminiferal fauna from a number of boreholes through the Atherfield "Group" in Kent, Surrey and Sussex but his results are unpublished.
Fig. 12.2 Summary of the distribution of Cretaceous foraminifera onshore UK. (from Hart et al., 1981)

Red dots - species now known in the U.K. Aptian

Green dots - recorded by Hart et al., 1981

Species now known in the UK Lower Aptian
Casey's (1961) pessimistic reference to the Atherfield Clay (Early Aptian) of the Isle of Wight stating that "washed samples of the clay give a large sand residue almost barren of microzon" has not encouraged stratigraphers/micropalaeontologists to take an interest in foraminifera from the Early Aptian strata of southern England. Casey (1961) states that the Atherfield Clay of Kent (Leeds Church section) has a good fauna of microzoa.

A publication by Chapman (1894) describes, illustrates and comments on the correlation potential of a foraminiferal fauna consisting of 139 species and varieties from the Bargate Beds of Surrey (nutfieldensis Biozone). No depository is given. Taxonomically the fauna that Chapman described is in need of revision but it does include L. tricanella (= L. (A) crepidularia) and Patellina sp.

The foraminiferal fauna of the onshore U.K. Aptian strata is nevertheless poorly known. This is illustrated by the recently published index foraminifera range chart for the Cretaceous of the U.K. (Hart et al., in Jenkins & Murray, 1981) where only five benthonic species and one planktonic species are used to characterise the Aptian: G. brieiensis, G. barremiana, Conorboides lamplughi, H. chapmani, Nodobacularia nodulosa and Hedbergella infracretacea. The "apparent" faunal break at the top of the Barremian to the top of the Aptian is a direct result of the lack of published research on foraminiferal faunas from the Aptian strata of the U.K. (Fig. 12.2).

The "tops" or "apparent" extinction levels of many of the species recorded by Hart et al., (1981) as Early or "Mid" Barremian in age are misleading and are in fact the upper level (Middle B Beds) at which Fletcher (1966, 1973) ceased to collect data from the Speeton Clay section (Filey Bay, Yorkshire). In consequence Hart et al., (1981) had to rely on very sparse information gleaned from the literature with which to complete their foraminiferal range chart for the Aptian strata of the U.K. (e.g. Hart, 1973).
Fig. 12.3

Lithostratigraphy, ammonite biostratigraphy, and foraminifera range chart for the Atherfield "group", Atherfield Point, the Isle of Wight.

* L. (A.) atherfieldensis.

Atherfield Group = Atherfield Formation
Atherfield Clay = Chale Clay Member
The lack of interest in Aptian foraminifera has applied equally to both Aptian strata in the northeast of England (northern basin of deposition - Boreal) and in the south of England (southern basin of deposition - Transitional - Tethyan).

This chapter presents a foraminiferal analysis for a section of the Atherfield Clay Formation (Early Aptian) from the type locality on the Isle of Wight, describes the foraminiferal fauna, and discusses the importance of the total foraminiferal fauna for the interpretation of the Early Aptian palaeoecological and palaeogeographical setting of southern England (for additional discussion see Simpson, 1985).

12.1 Lithology of Section and Sampling

The onshore outcrop of Aptian strata is of a "Lower Greensand" facies on the Isle of Wight. Only occasional clays and marls are present, such as the Atherfield Clay s.s. (=Chale Clay Member of Simpson, 1985), which is a lithology expected to contain a reasonable microfauna. The Aptian and Early Albian strata in south-east England are grouped together as the Lower Greensand "Formation". The Atherfield "Group" is the basal unit of the Lower Greensand "Formation" and consists of the Perna Bed, the Atherfield Clay, the Lower Lobster Bed, the Crackers and the Upper Lobster Bed (Fig. 12.3) and rests disconformably at Atherfield on a thick series of fresh and brackish water sediments called the Wealden Beds.

The Atherfield Clay s.s. is Deshayesites forbesi Zone in age while the Perna Bed belongs to the Prodeshayesites fissicostatus Zone. Casey (1961) has described the Atherfield section and his ammonite biostratigraphy provides a documented macrofossil zonation which which to calibrate the foraminiferal fauna.

The section at Atherfield is a south-west facing (prevailing wind
direction) sea cliff which is highly weathered, fractured and slumped and is partially obscured by downwash.

Samples as clean and fresh as possible were collected and all the samples were processed in the laboratory in the normal manner and each sieve size fraction was examined for foraminifera. Only the fauna retained on the 500, 250 and 180 micron aperture sieves was studied in detail.

The samples (about 1 - 1.5 kgs each) were collected at approximately one metre intervals through the Perna Bed and Chale Clay Member by Dr A. Swiecicki and Dr M.B. Hart in the Spring of 1979 from the cliff section approximately 45 metres east of Atherfield Point. At this location the Perna Bed sandstone outcrops on the beach. Further samples were collected by Dr M.B Hart in the spring of 1981 and by the author and Mr M.D Bidgood in the summer of 1981 at the same locality through the complete Atherfield Clay section. Samples were also taken through the overlying Ferruginous Sands but were all barren of any microfauna. The section is illustrated in Fig. 12.4.

12.2 The Foraminiferal Fauna

The fauna is the earliest fully marine foraminiferal fauna, to the best of the author's knowledge, yet described from the Cretaceous of south east England.

Of the species of foraminifera recorded 28 are arenaceous benthonic species, 18 are calcareous benthonic species and 3 are planktonic species.

The taxonomy of the fauna is included in the taxonomic section of this thesis but it is illustrated at the end of this chapter (Arenaceous: Plates 12.1, 12.2; Calcareous: Plates 12.3, 12.4). The arenaceous benthonic fauna is mostly crushed and distorted while the calcareous benthonic fauna shows signs of
Fig. 12.6 THE LOWER CRETACEOUS OUTCROP OF SOUTHERN ENGLAND & NORTHERN FRANCE
etching, breakage, wear and replacement by pyrite. The planktonic fauna is a recrystallised calcite.

These phenomena of preservation, apart from recrystallisation, may be a result of the processing procedure in the laboratory or, more likely, a combination of decalcification of the strata by percolating ground water, distortion by compaction of the sediment during diagenesis, and post-mortem transport of the fauna (in the case of the calcareous fauna). The most distorted (depressed) and crushed faunas were from the fine clay sediments while the broken, etched and worn faunas were from the sandier sediments. The fauna is dominated by the Textulariinae (again perhaps an indication that the more delicate, fragile, calcareous specimens have been decalcified). The calcareous benthonic fauna consists predominantly of broken and etched robust species.

A superfamily percentage graph was constructed for the Atherfield Clay s.s. (=Chale Clay Member) using the faunal counts from each sample (Fig. 12.5). This method was used by Hart (1973) and Carter & Hart (1975, 1977) as a rapid analytical method useful for relatively local correlation and palaeoecological interpretation which proved to be ideal for correlating the Atherfield Clay s.s. of boreholes for the construction of the Sevenoaks-by-Pass (A21).

Jaworski has found the method to be extremely useful in correlating boreholes from the Aptian outcrop of the periphery of the Weald of south east England - a distance of some 70 kilometres. The graphical analysis chart from the Isle of Wight does not correlate at all with the chart from south east England (Hart & Carter, 1975) (See Fig. 12.1); the main difference being the lack of the Robertinacea in the Isle of Wight section.

The graphical analysis and range chart for the Chale Clay Member, Isle of Wight reveal an apparent cyclical pattern with the repetition of ecological facies characterised by the dominance of
Fig. 12.5 Foraminiferal analysis of the Chale Clay, from Atherfield Point, Isle of Wight
Nodosariacea (Storm events?) combined with a gradual increase in diversity of the fauna.

The fauna in the Perna Bed at the base of the section is very poor and consists only of broken and etched robust calcareous benthonic species. The increase in both diversity and specimen number is apparent throughout until at the top of the section the fauna decreases in number and diversity. The top five metres of the Chale Clay Member were not sampled as slumps concealed the section. This "tailing off" of the fauna may be a reflection of subtle changes in environment, conditions of deposition and lithology. The planktonic species are sparse and only amount to significance in one sample (sample 12). This is a reflection of environment; the area at this time being a semi-enclosed, shallow epicontinental sea. The macrofaunal and ostracod evidence points to an initial nearshore environment of relatively warm clear water with conditions becoming more open marine toward the top of the succession (periodic marine influence - storm action?), (Casey, 1961; Kaye, 1965). The complete fauna is reminiscent of the Ammobaculites Association of Haig (1979a).

Haig (1979a) distinguished a number of biofacies within the Ammobaculites Association reflecting a more refined depth and/or salinity controlled zonation. This separation of biofacies would be a useful exercise if combined with sampling and faunal analyses of other sections of Atherfield Clay on the Isle of Wight and in south east England (see Chapter 9). Foraminiferal faunas have been studied by the author in material from boreholes drilled through the Atherfield Clay s.s. in south east England (Jaworski, 1981, pers. comm.). The faunas are numerically larger and far more diverse than the fauna recorded from the Isle of Wight. The arenaceous faunas are essentially the same as that from the Isle of Wight except for the occurrence of a small Choffatella species (Choffatella sp. A., Jaworski - unpublished, Sandgate Borehole 3, sample 73/68) - a genus not recorded at Atherfield.
The rotaline fauna recorded by Jaworski (pers. comm.) from south east England, for example, is diverse and abundant and includes species neither previously recorded from the Aptian of the U.K. e.g. *L.(M.)schreiteri* (Eichenberg), *L.(S.)spinosa* (Eichenberg) and *L.(P.)crepidularis* (Roemer) (recorded as *L.tricarinella* (Reuss) from France by Magniez-Jannin (1973), nor by the present author from the Isle of Wight. Jaworski's faunas are from sub-surface sections.

All those rotaline species recorded from the Isle of Wight are present in south east England (Jaworski pers. comm.). Perhaps the Atherfield fauna from the Isle of Wight is a remnant fauna of a much more diverse fauna reduced in number by in-situ strata decalcification?

12.3 The Palaeogeographical Setting of the Early Aptian, Southern England

Various authors have proposed palaeogeographical models for the Early Cretaceous of southern England and northern France. There appears to be a variety of equally applicable models which would fit the known data (Allen, 1981; Kaye, 1966; Anderton et al., 1977; Hallam & Sellwood, 1976). Allen (1981) has most recently discussed this problem in his "Pursuit of Wealden Models". A full discussion of all the models proposed is beyond the scope of this thesis, as is the proposal of a new model, but a general synopsis is presented. With the availability of data from the Deep Sea Drilling Project boreholes and the eventual release of data from commercial exploration boreholes in the Western Approaches area perhaps in the future a more precise picture may be painted of the Early Cretaceous (Wealden and Marine) Aptian palaeogeography.

In the United Kingdom the Early Cretaceous sea of a northern basin was separated from a southern basin of deposition by the
London-Brabant land mass (Fig. 12.6). This barrier is assumed by most authors to have been only completely transgressed to give a true marine connection between the two basins in the Late Aptian (Parahoplites nutfieldensis Zone, Casey 1961). Prior to the Aptian the Anglo-Paris Basin, Western Approaches area and the Celtic Sea Basin are presumed to have been fluvio-deltaic-lacustrine environments (Wealden beds), (Allen, 1981; Colin et al., 1981). The Anglo-Paris Basin was bounded to the north by the London-Brabant land mass and to the south by the Armorican Massif. It is a matter of debate as to whether the Start-Cotentin High, or even the Lizard-Brittany High, separated this basin from the Western Approaches area to the west prior to Aptian times or whether pre-Aptian sediments have been removed by erosion from these highs (Fig. 12.7). However Lott et al., (1980) from borehole and seismic evidence (I.G.S. and D.S.D.P.) propose the existence of these highs at least during the Aptian and Early Albian. Further it is not known precisely whether the Western Approaches Basin s.s. prior to the Aptian did connect to the proto-North Atlantic and the Celtic Sea Basin (Allen 1981, fig. 16, A.B.C.). There was probably some intermittent marine influence from the northern basin to the southern basin, and probably from the west across the Start-Cotentin High to the southern basin, prior to the Aptian as attested by marine bands in the Wealden strata of southern England (Kaye, 1966; Anderton et al., 1979; Hallam & Sellwood, 1976, fig. 10.f.). According to Vail et al., (1977) sea levels at the beginning of the Early Cretaceous were exceptionally low but a global trend of rising sea levels followed with the subsequent marine connection of the southern basin and the northern basin taking place during the Late Aptian. With the proposed global rise in sea level the non-marine Wealden deposition gave way to marine sedimentation during the Early Aptian in the Anglo-Paris Basin. The Chale Clay Member represents this marine sedimentation and is the beginning of a major marine transgression which culminated in the eventual fully marine connection of the southern and northern basins of deposition. The sea advanced from the south across France, from
Fig. 12.7
Aptian to Cenomanian correlation in the south west Approaches. (from Lott et al., 1980).

1. IPD. BIOClastic LIMESTONE UNIT (late Albian)
2. 'SALAB' BIOClastic LIMESTONE UNIT (late Albian-early Cenomanian)
3. 'SALAB' SANDSTONE UNIT (late Albian-early Cenomanian)
4. Clayton BEds and CENOMANIAN LIMESTONE (late Albian-early Cenomanian)
5. UPPER GREENSAND (upper beds late Albian-early Cenomanian)
6. GAULT CLAY: upper beds (late Albian-early Cenomanian)

7. IPD. CARBONACEOUS MUdSTONE AND LIMESTONE (Aptian-early middle Albian)
8. 'SALAB' SANDY CARBONACEOUS CLAY UNIT (middle Albian)
9. FOXMOULD (sandstone late Albian-late Cenomanian)
10. UPPER GREENSAND: lower beds (late Albian-late Cenomanian)
11. GAULT CLAY: lower beds (late Albian-late Cenomanian)
12. GAULT CLAY AND CARSTONE (early-middle Albian)
13. LOWER GREENSAND (Aptian-early Albian)
14. Atherfield CLAY (early Albian)

DATUM BASE CHALK (except section A)
the proto-North Atlantic in the west (marine Barremian in the Western Approaches - Goban Spur area), and from the north around the western end of the London-Brabant land mass (Juignet, Reout & Destombes, 1973; Anderton et al., 1979; Colin et al., 1981; Lott et al., 1980; Evans et al., 1981), (Fig. 12.6). This transgression (diachronous) provided important tethyan faunal links with the Celtic Sea Basins, the Western Approaches region (Dupeuble, 1979), the Isle of Wight region and the Anglo-Paris Basin in the Early Aptian. This is in accord with the conclusions of various authors (e.g. Rawson, 1973; Middlemiss, 1973, 1979; Casey, 1971; Dilley, 1971) using various palaeontological data (e.g. Holocystis sp. coral in the Perna Bed) that the southern basin was Tethyan in aspect during the Early Cretaceous while the northern basin of the UK was Boreal in aspect. This point is also corroborated by the work of Michael in N.W. Germany. Michael's (1979) work shows that there was a marked Mediterranean benthonic fauna influx in the uppermost Valanginian/Early Hauterivian and in the Late Albian and Cenomanian. This is in contrast to the dramatic influx of Mediterranean benthonic faunas in the Aptian of south and south eastern England (see Fig. 12.8, from Michael, 1979, p. 310). Jaworski's record (pers. comm.) of Choffatella sp. and of Trocholina infragranulata Noth/paucigranulata Moullade from the south east England Aptian also indicates the tethyan aspect of the fauna (Sandgate borehole 3, RJ/73/68; Ide Hill borehole RJ/46/70).

12.4 The Implications of the Foraminiferal Fauna for Biostratigraphy

The total foraminiferal fauna is very similar, but smaller in number and less diverse to the Aptian faunas recorded by Damotte and Magniez-Jannin (1973) and Damotte et al., (1978) from the Paris Basin, and by Jaworski (pers. comm.) and Carter & Hart (1977) from south east England.
Fig. 12.8

Diagram from Michael (1979) to show the periodic migration of warm water Mediterranean benthonic faunas into the Boreal European Lower Cretaceous.
The fauna is typical of the Early Aptian of the Anglo-Paris Basin but some of the species are not confined stratigraphically to the Early Aptian. The principle recorded diagnostic species common to the Isle of Wight and France are:

Gaudryina dividens Grabert

Verneuilonoides subfiliformis Bartenstein

Textularia pulchella Magniez-Jannin

Citharina aff. sparsicostata (Reuss)

Gavelinella brielensis Malapris

Hedbergella infracretacea Glaessner (including H. aptiana Bartenstein)

Lenticulina (A.) atherfieldensis Crittenden (=L. (A.) humilis of Magniez-Jannin 1973)

Hoeglundina chapmani (ten Dam) = Epistomina chapmani (ten Dam)

Gaudryinella sherlocki Bettenstaedt

The faunas from south east England have species in common with faunas from France, Germany and the southern North Sea Basin which are absent in the fauna from the Isle of Wight, e.g. L. (P.) crepidularis (Roemer), L. (M.) schreitei (Eichenberg) and L. (S.) spinosa (Eichenberg).

Early Aptian faunas have also been recorded from other areas in north-west Europe. For instance Colin et al., (1981) have recorded a very similar fauna from the Aptian of the northern Celtic Sea Basin, offshore southern Ireland. Species of tethyan
origin which Colin et al., recorded are: Choffatella decipiens Schlumberger (also found in the Aptian of the Scotian Shelf; Ascoli, 1976) and Orbitolina sp. Other species recorded are: Gaudryina sp. cf. G. reicheli Bartenstein, Bettenstaedt & Bolli, Valvulineria gracilisima ten Dam, Lenticulina ex. gr. L. nodosa (Reuss), Lenticulina sp. cf. L. gaultina (Berthelin), Lenticulina (Vaginulina) humilis (Reuss) (= L. (A.) atherfieldensis Crittenden) and Epistomina chapmani ten Dam. Colin et al., (1981) recorded no planktonic species.

Early Aptian planktonic and benthonic faunas which display a tethyan affinity and are similar to the Isle of Wight faunas have also been recorded in D.S.D.P. boreholes drilled on the Continental Shelf in the Western Approaches (Leg 48, Dupeuble, 1979). The benthonic fauna from the Isle of Wight Atherfield "Group" section compares well with the worldwide zonation scheme of the Early Cretaceous, using benthonic foraminifera, proposed by Bartenstein (1976b, 1977 Figs. 1-2, 1979 tables 1-2 - see Chapter 7).

The fauna is similar to the Early Aptian faunas discussed by Bartenstein in his comparison of North West Germany and Trinidad (1976a), North West Germany and East Canada (1976c), and in his discussion of the Aptian benthonic faunas in the northern hemisphere (1977).

Bartenstein & Bolli (1977) described and illustrated the fauna from the Early Aptian of the upper part of the Cuche Formation in Trinidad (Leupoldina protuberans Zone) and the fauna from the Atherfield Clay s.s in the Isle of Wight is remarkably similar (a fact also noted by Fletcher (1973) for the Valanginian, Hauterivian, and Barremian faunas of Speeton, Yorkshire and Trinidad). The Isle of Wight Early Aptian fauna would be placed in the Gavelinella barremiana-Lenticulina nodosa Zone and the Marssonella ex. gr. oxycon-Trocholina ex. gr. infragranaulata-Choffatella decipiens Zone of Ascoli (1976) (see Chapter 13).
12.5 Summary

The Isle of Wight, Atherfield Clay Formation benthonic foraminiferal fauna may be placed in the Early Aptian and compares well with Early Aptian faunas known from other parts of the world. The planktonic foraminiferal fauna present also substantiates the age assignment and the intermediate position of the fauna between the tethyan and temperate regions. The total fauna from the Isle of Wight is an aid to distinguishing the Early Aptian in boreholes drilled in the southern North Sea Basin. The first downhole occurrences of large numbers of *Gavelinella brielenisis* (synonymous with *Gavelinella cf. barremiana* Bettenstaedt, senau Bartenstein and Bettenstaedt 1962), *Gavelinella barremiana* Bettenstaedt, *Lenticulina (S.) spinosa* ten Dam, *Hedbergella infracreataea* (stained green) (Glaessner), and a flood of *Hedbergella* species attributable to *H. aptiana* Bartenstein (*Hedbergella D9* of Hecht 1938, also present in the Atherfield Clay s.s. of south east England, Jaworski pers. comm.), are indicative of the earliest Late and Early Aptian in the southern North Sea (see Chapters 7, 8 and 11).

The total foraminiferal fauna is Early Aptian in character but some of the species are not chronostratigraphically restricted to the Aptian. This emphasises the concept of using index foraminiferal faunas rather than index species alone for microbiostratigraphy.
PLATE 12.1

Figure(s)

1, 2  Psammosphaera sp.; 1, lateral view (x 120), SCAC 8101, sample 17; 2, lateral view (x 90), SCAC 8102, sample 17.

3, 4  Lagenammina sp. 1.; 3, lateral view (x 100), SCAC 8103, sample 17; 4, lateral view (x 100), SCAC 8104, sample 17.

5, 6  Lagenammina sp. 2; 5, lateral view (x 100), SCAC 8105, sample 17; 6, lateral view (x 75), SCAC 8106, sample 17.

7  Ammodiscus cretaceus (Reuss, 1845); lateral view (x 200), SCAC 8107, sample 6.

8, 9  Glomospirella gaultina (Berthelin, 1880); 8, lateral view (x 100), SCAC 8109, sample 6; 9, lateral view (x 175), SCAC 8110, sample 6.

10  Reophax minutus Tappan, 1940; lateral view (x 50), SCAC 8111, sample 5.

11, 12, 13  Reophax scorpiurus Montfort, 1808; 11, lateral view (x 40), SCAC 8113, sample 5; 12, lateral view (x 50), SCAC 8114, sample 5; 13, lateral view (x 50), SCAC 8115, sample 5.

14  Millammina sp.; lateral view (x 80), SCAC 8116, sample 11.

15, 16  Haplophragmoides concavus (Chapman, 1892); 15, lateral view (x 100), SCAC 8117, sample 3; 16, lateral view (x 100), SCAC 8118, sample 3.

17, 18  Haplophragmoides nonioninoides (Reuss, 1863); 17, lateral view (x 100), SCAC 8119, sample 2; 18, lateral view (x 100), SCAC 8120, sample 2.

19, 20  Haplophragmoides aff. platus Loeblich, 1946; 19, lateral view (x 175), SCAC 8121, sample 6; 20, lateral view (x 100), SCAC 8122, sample 6.
PLATE 12.1 (continued)

21, 22 Haplophragmoides aff. globosa Lozo, 1944; 21, lateral view (x 100), SCAC 8123, sample 3; 22, lateral view (x 100), SCAC 8124, sample 3.

23 Ammobaculoides mutabilis Magniez-Jannin, 1973; lateral view (x 50), SCAC 8125.
**Figure(s)**


2, 3. *Ammobaculites subcretaceus* Cushman & Alexander, 1930; 2, lateral view (x 100), SCAC 8127, sample 2; 3, lateral view (x 75), SCAC 8128, sample 2.

4, 5, 6. *Ammobaculites obliquus* Loeblich & Tappan, 1949; 4, lateral view (x 100), SCAC 8129, sample 2; 5, lateral view (x 100), SCAC 8130, sample 2; 6, lateral view (x 100), SCAC 8131, sample 2.

7, 8. *Ammobaculites aff. reophacoidea* Bartenstein, 1952; 7, lateral view, (x 75), SCAC 8132, sample 7; 8, lateral view (x 100), SCAC 8133, sample 5.

9, 10. *Textularia minuta* Berthelin, 1880; 9, lateral view (x 100), SCAC 8134, sample 8; 10, lateral view (x 100), SCAC 8135, sample 15.

11, 12. *Textularia pulchella* Magniez-Jannin, 1973; 11, lateral view (x 75), SCAC 8136, sample 7; 12, lateral view (x 75), SCAC 8137, sample 5.


14, 15. *Trochammina aff. latai* Loeblich & Tappan, 1950; 14, umbilical view (x 100), SCAC 8140, sample 2; 15, umbilical view (x 100), SCAC 8141, sample 2.

16, 17, 18. *Trochammina sp.* 1; 16, umbilical view (x 100), SCAC 8144, sample 6; 17, spiral view (x 100), SCAC 8145, sample 6; 18, umbilical view (x 100), SCAC 8146, sample 6.

19, 20. *Gaudryina dividens* Grabert, 1959; 19, lateral view (x 50), SCAC 8147, sample 5; 20, lateral view (x 75), SCAC 8148, sample 5.

21. *Gaudryina gradata* Berthelin, 1880; lateral view (x 75), SCAC 8149, sample 12.
PLATE 12.2 (continued)

22, 23, 24, Gaudryinella aff. sherlocki Bettenstaedt, 1952; 22, 25 lateral view (x 100), SCAC 8150, sample 17; 23, lateral view (x 100), SCAC 8151, sample 17; 24, lateral view (x 100), SCAC 8152, sample 17; 25, lateral view (x 100), SCAC 8153, sample 17.

26 Verneuilinoides subfiliformis Bartenstein, 1952; lateral view (x 75), SCAC 8154, sample 12.
Figure(s)

1 Lenticulina (Lenticulina) gaultina (Berthelin); lateral view, (x 100), P.51168, sample 2.

2, 3, 4, 5 Lenticulina (Lenticulina) rotulata (Lamarck); 2, lateral view, (x 100), P.51169, sample 13; 3, lateral view, (x 75), P.51170, sample 13; 4, lateral view, (x 50), P.51171, sample 25; 5, aperture view showing pyrite infill, (x 50), P.51171; sample 25.

6 Lenticulina (Lenticulina) ex. gr. nodosa (Reuss); lateral view, (x 100), P.51172, sample 13.

7, 8, 9 Lenticulina (Astacolus) atherfieldensis Crittenden; 7, lateral view, (x 39), P.51173, sample 21; 8, lateral view, (x 52), P.51174, sample 18; 9, ventral view, (x 75), P.51174; sample 18.

10, 11, 16 Lenticulina (Marginulina) schloenbachi (Reuss); 10, lateral view, (x 100), P.51175, sample 20; 11, ventral view, (x 100), P.51175; 16, lateral view, (x 75), P.51176, sample 20.

12, 13 Lenticulina (Saracenaria) planiuscula (Reuss) 12, lateral view, (x 75), P.51178, sample 4; 13, ventral view, (x 110), P.51178, sample 4.

14, 15 Lenticulina (Marginulina) aff. parallela (Reuss); 14, lateral view, (x 75), P.51177; 15, ventral view, (x 75), P.51177.

17 Nodosaria harrisi (Vieaux); lateral view, (x 75), P.51179.

18, 19 Citharina aff. sparsicostata (Reuss); 18, lateral view, (x 50), P.51181; 19, lateral view, (x 50), P.51180.

20 Citharina aff. discors (Koch); lateral view, (x 50), P.51182.

21 Vaginulina sp.; lateral view, (x 50), P.51183.

22 Globulina sp; lateral view, (x 100), P.51184.
PLATE 12.4

Figure(s)

1, 2  Hedbergella hoterivica (Subbotina): 1, umbilical view, (x 100), P.51186, sample 20; 2, edge view, (x 100), P.51186, sample 20.

3, 4  Leupoldina cabri (Sigal): 3, oblique view, (x 180), P.51185, sample 4; 4, oblique view, (x 100), P.51185, sample 4.

5, 9  Hoeglundina chapmani (Dam): 5, edge view, (x 175), P.51189, sample 20; 9, ventral view, (x 100), P.51189, sample 20.

6, 7  Gavelinella barremiana (Bettenstaedt): 6, umbilical view, (x 100), P.51187, sample 13; 7, dorsal view, (x 100), P.51187, sample 13.

8  Gavelinella ex. gr. intermedia (Berthelin): umbilical view, (x 100), P.51188, sample 12.

10, 11, 12, 13  Lenticulina (A.) atherfieldensis Crittenden: 10, lateral view, (x 51), P.51190, sample 18; 12, close up of thickened suture and perforate chamber wall, (x 500), P.51190, sample 18; 11, lateral view, (x 52), P.51191, sample 21; 13, close up of aperture, (x 520), P.51191, sample 21.
CHAPTER 13

EARLY CRETACEOUS (BARREMIAN-APTIAN) FORAMINIFERA
FROM SITE 549, LEG 80, D.S.D.P.

13.0 Introduction

The aim of the Deep Sea Drilling Project (I.P.O.D.) Leg 80 was to investigate the geology of the Goban Spur, 250 kilometres south west of Ireland, on the western edge of the European continental shelf (Fig. 13.1). Four cored boreholes were drilled, using the drilling vessel Glomar Challenger, in the summer of 1981. Prof. M. B. Hart, Kim C. Ball and the author requested core samples, adequate for microfaunal analysis, of any Cretaceous sediments that were recovered. The samples would be provided by the on-board palaeontologists during the drilling of Leg 80. On completion of the voyage it was apparent that only one borehole, site 549, had penetrated strata of an Early Cretaceous pre-Albian age while all four penetrated Upper Cretaceous sediments. Fifteen samples were provided by Dr. Jacques Sigal, of the onboard scientific staff, from the Lower Cretaceous pre-Albian section of site 549, for analysis of the ostracod fauna. The samples had already been washed and dried and only had to be passed through a nest of sieves. All the ostracods contained on the sieve sizes greater than 180mu were picked and placed in faunal slides. The fifteen samples were in addition to 56 slides of picked ostracods, from 56 samples, from site 549 provided by Dr. Jacques Sigal for further study by Prof. M. B. Hart and the author. From the fifteen samples the complete foraminiferal fauna was picked (greater than 180mu) and placed on faunal slides. It was decided that the foraminifera would be identified in the hope that the fauna would show some comparisons and contrasts with the faunas from the author's main study area of the southern North Sea Basin.
Interpreted seismic profile from Goban Spur illustrating a reefal body. Note the very high interval velocity within the reefal body.

Fig.13.1
The location of site 549. (Map and seismic section from Masson and Roberts, 1981).
13.1 Geological Setting of Site 549

Site 549 is located near the seaward edge of a tilted block of Hercynian basement that underlies the Pendragon Escarpment. The continental margin south west of the United Kingdom is a series of tilted and rotated fault blocks thinly covered by undeformed sediments of Cretaceous and Tertiary age (Montadert et al., 1979; Roberts et al., 1981; Masson & Roberts, 1981). The throw of the bounding faults is down to the adjoining ocean basin (listric normal faults). They are the result of the rifting (prior to spreading) of Iberia and North America from western Europe which in the Bay of Biscay is assumed to have ceased in the early Aptian and slightly later in the Goban Spur area. Masson & Roberts (1981) have recognised from seismic data a number of carbonate build ups on the margin of the continental shelf (see Figs. 13.1, 13.2, 13.3 taken from Masson & Roberts, 1981). They are concentrated in the shallowest parts of the half grabens immediately behind and below the crests of tilted blocks, below the pre-Aptian unconformity. Carbonate build ups of the same type and in the same structural and geological setting have also been identified by Pastouret et al., (1974) and Montadert et al., (1979) in the Bay of Biscay in Formation 4 of D.S.D.P. sites 400A, 401 and 402 (see Fig. 13.4).

Site 549 was sited so as to investigate an apparent carbonate build up within a half graben. From seismic data it was postulated that a thick, shallow water, syn-rift sequence of Barremian sediments was present, upon Hercynian basement, containing a possible carbonate build up or reef structure (within Formation 4 of Montadert et al., 1979 - Formation Sequence H of D.S.D.P. Leg 80). The carbonate build ups may be related to the tectonic setting of the area (Masson & Roberts, 1981). They occur patchily on the break in slope along the edge of the shelf, and on the shelf itself. In the Goban Spur area Masson & Roberts (1981) state that evidence points to reef growth.
Fig. 13.2
Seismic profiles across the Goban Spur (from Masson and Roberts, 1981)
being contemporary with half graben subsidence and that the rate of reef growth has equalled the rate of subsidence. Reefal development was terminated in the Goban Spur area by the Aptian transgression associated with the development of the north Atlantic Ocean. The present water depth is in excess of 2000 metres (Site 549 - 2353.5 metres) as a result of the regional subsidence of the continental margin.

Bubb & Hatelid (1977) and Brown & Fisher (1980, pp 50 - 57, figs 26 - 31) discussed the criteria that may be used to identify reefs and carbonate banks on seismic profiles (Fig. 13.5). These criteria have been discussed by Masson & Roberts (1981) who have applied them to the recognition of the reefal bodies in the Goban Spur.

13.2 Foraminiferal Biostratigraphy of Site 549 (Plates 13.1 & 13.2)

The fauna from the fifteen samples is divisible into faunal associations which correlate nicely with the lithology changes in the section (see Fig. 13.6). These lithology changes are also indicated by the gamma ray log pattern. The gamma ray log and lithological descriptions are from an as yet unpublished D.S.D.P. data report of the onboard scientific party of Leg 80. The fauna is not adequate to give an unequivocal age but examination of further samples would of course enable a more precise determination. The faunas are all facies controlled and characteristic of the Barremian, but some of the species are not necessarily restricted to the Barremian in North West Europe (Bartenstein & Bettenstaedt, 1962). For example Lenticulina (P.) crepidularia (tricarinella of some authors), L. (M.) schreiteri (reticulosa, djaffaensis, of some authors), L. (M.) schloenbachii, L. (S.) frankeli, Gavelinella barremiana, Gaudryina dividens-compacta group (Tethyan according to Bartenstein 1977a) and Spiroleptinata lata are all recorded from the Early Aptian of North West Europe (Crittenden, 1982a, 1983a, b, 1984a, b, 1987a, b; Bartenstein & Bettenstaedt, 1962; Grabert, 1959). The
Interpreted seismic profile from the western Goban Spur. Note that the postulated reef now lies 4 s (two-way time) below sea-level, indicating considerable subsidence since the period of reef formation.

Interpreted seismic profile from the southern Porcupine Seabight, illustrating the 'mid-Cretaceous' erosion surface and its relationship to formation 3 of Montaderr et al. 1979.

**Fig. 13.3**

Seismic sections and map to show the distribution of reefs.

Distribution of reefs and the areal distribution of the 'mid-Cretaceous' erosion surface.
benthonic assemblage is quite diverse but small in the number of specimens.

The most abundant genus is Trocholina which totally dominates the assemblage in samples 61cc, 73/2, 74/1, 74/2 and 76/1. Taxonomically this genus is a problem as the species are long ranging and facies controlled which questions their use as reliable age indicators. Bartenstein (1978) discusses this genus and its phylogenetic development in the Lower Cretaceous. Specimens attributable to (Neo) Trocholina infragranulata Noth/(Neo) Trocholina paucigranulata Moullade as well as (Neo) Trocholina friburgensis Guillame & Reichel/(Neo) Trocholina aptiensis Jovcheva are present in site 549. This would suggest a Barremian/Early Aptian age according to Bartenstein (1978, figs. 1 and 2).

Choffatella decipiens Schlumberger (a typical tethyan species) is of Barremian/Aptian in age and is present on the Scotian Shelf (Ascoli, 1976), North Celtic Sea Basin Aptian (Colin et al., 1981) and from the Early Aptian of South East England (Jaworksi, unpublished research).

The Falsogaudryinella group has been used by various authors as index species in the Early Cretaceous of North West Europe (as Uvigerinammina, see Bartenstein, 1977). However according to Bartenstein (1981) the species of various authors are very difficult to separate and invariably members of both generations (microspheric and macrospheric) are present in the same population. Bartenstein (1981) has shown that different specific names have been erroneously applied to the microspherical and macrospherical generations of the same species. This can be seen in borehole 549 where long forms (microspheric) and short forms (macrospheric) are referable to F. tealbyensis (Bartenstein, 1956). This species is difficult to separate from F. moesiana (Neagu, 1965, including F. triangula of Fuchs, 1967) which is higher Early Cretaceous (Aptian to Albian)
Formation 1
(Sub-units 1a and b) Quaternary to Oligocene

Unconformity

Formation 2
Eocene to Late Cretaceous

Unconformity

Formation 3
Albian to Aptian

Unconformity

Formation 4
Syn-rift sediments
Middle Jurassic to Early Cretaceous

BASEMENT
Oceanic (Post Early Aptian only), Continental

Fig. 13.4
Sections penetrated in DSDP sites 400A, 401, and 402 (Montadert et al., 1979)
in range in the European boreal and tethyan facies. F. alta (Magniez-Jannin) is also easily confused but Bartenstein (1981) regards this as a junior synonym of F. tealbyensis. Bartenstein (1981) states that the stratigraphical value of this genus in the Early Cretaceous is doubtful because of the uncertainty of the taxonomic distinction of tealbyensis, alta (triangula) and moesiana at their different stratigraphical and geographical occurrences.

The Lenticulina species identified to species level indicate a Hauterivian/Barremian age but some of them are also found in the Early Aptian of North West Europe e.g. L. (P.) crepidularis, L. nodosa nodosa (See Aubert & Bartenstein, 1978) and L. (M.) schloenbachi (Crittenden 1982a; 1983a, b). L. (S.) frankel is a Barremian/Early Aptian marker (Bartenstein, 1979) and L. (M.) schreiteri is Hauterivian, Barremian and ?Early Aptian in its range (Bartenstein, 1979, as L. (M.) reticulosa/djaffaensis). The Lenticulina species not identified to species level are smooth long ranging forms of no stratigraphical importance.

Badly corroded specimens of Epistomina (or Hoeglundina?) hechti, Bartenstein, Bettenstaedt & Bolli, are present in sample 85cc. This species is characteristic of the "Middle" Barremian of north-west Germany, of the Early and "Middle" Barremian of Speeton Yorkshire (of a tripartite division), and of the Barremian of the North Celtic Sea Basin. This species is distinct from Epistomina ornata. It is assumed to be characteristic of shallow marine environments.

Conorotalites bartensteini (Bettenstaedt) and its three subspecies bartensteini, intercedens and aptiensis have been used by various authors to distinguish the Early, Middle and Late Barremian (or Early/Late of a bipartite division) and the Aptian. Only bartensteini and intercedens have been recorded with certainty at site 549 which therefore indicates a Barremian age only ("Middle") for the highest sample examined (55/2, 108-111
Fig. 13.5
Reef recognition from seismic profiles (Brown and Fisher, 1980).
cm). However some specimens are present in the topmost sample which are approaching the morphology of aptiensis. The age assignment of the section presumes that the age relationship of the facies controlled benthonic foraminifera which exists in North West Europe also applies to the same foraminifera species in the Goban Spur Early Cretaceous sediments. This difficult problem is discussed in the introductory chapters of this thesis but it is emphasised that the very important work of Bartenstein (1976a, b, 1977, 1978a, b, 1979) does seem to justify the worldwide correlation use of benthonic index foraminifera and faunas.

The benthonic foraminiferal fauna suggests that the section is no younger than the Late Barremian/Early Aptian and that the base of the section above the Hercynian basement is probably earliest Barremian. In the base of the section the fauna is very sparse and may even be Hauterivian in age as suggested by the ostracod fauna (Hart & Crittenden, 1985). However it is the present author's feeling that the topmost samples examined contain a fauna which is approaching that contained in the higher Barremian and Early Aptian (see following remarks on Ascoli, 1976). No further comment may be made as the present author did not examine samples above 55/2. According to foraminifera and nannofossil data (Sigal and Muller, pers. comm.) sediments of Barremian age are unconformably overlain by Albian sediments (Aptian missing). This Post-Rift unconformity may well correspond to the major Aptian sea level drop of Vail et al., (1977).

The planktonic foraminifera are small, badly preserved and not very common. They were not studied in detail but some of the specimens may be referable to Hedbergella hoterivica (Subbotina); a species with a Hauterivian, Barremian and Early Aptian range in North West Europe.

The total fauna shows some similarity to the faunas discussed by Magniez and Rat (1972) from the Aptian & Albian (Urgonian facies) of Northern Spain.
Fig. 13.6 Foraminiferal range chart of the Mid - Cretaceous section of DSDP 80, site 549

<table>
<thead>
<tr>
<th>Depth (m) (ft)</th>
<th>Q.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>650</td>
<td></td>
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<tr>
<td>700</td>
<td></td>
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<tr>
<td>850</td>
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<td>900</td>
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<td>950</td>
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<tr>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

**Lithology**

- Oliststones, red/yellow, calc., mass - only lam., sand., cras.
- Oliststones, calc./mass - only lam., sand., cras.
- Oliststones, calc./mass - only lam., sand., cras.
- Oliststones, calc./mass - only lam., sand., cras.
- Oliststones, calc./mass - only lam., sand., cras.
- Oliststones, calc./mass - only lam., sand., cras.

**Fauna Association**


**Data**

- 1
- 2
- 3
- 3a

**Key**

- 1
- 2
- 3
- 4
- 5
- 6
- 7

- Specimen < 100 u (less than 100 u)
13.3 Faunal Associations

A number of faunal associations may be recognised from the samples examined which correlate with lithology changes and the gamma ray log pattern. From the top of the Section downward they are:

A. Faunal Association 1

This is the Marssonella Association of Haig (1979a, b) and is characteristic of the middle to outer shelf, is fully marine and confined to carbonate rich sediments deposited in open seas bordering continents.

B. Faunal Association 2

This section is characterised by extremely poor core recovery. The lithology (grainstones) and fauna, which is dominated by large Trocholina, is of a high energy environment; reefal - perireefal in aspect. This association has not been discussed by Haig (1979a, b) in his analysis of Early Cretaceous foraminiferal faunas except to comment that larger foraminifera are tethyan in aspect (Dilley, 1971). This interval is probably a reworked, winnowed interval of carbonate detritus associated with the high energy of a carbonate bank.

C. Faunal Association 3

The lithology of interbedded calcareous and non-calcareous sandy mudstones (seen by gamma ray log pattern) plus the foraminiferal fauna indicates a shallow inner shelf (inner sublittoral) marine environment with perhaps a fresh water influence (brackish) - deltaic). This is the Ammobaculites Association of Haig (1979a, b). A true
shallow marine phase of deeper water aspect, characterised by a more diverse calcareous fauna, is present within this section:

1) **Sub-Association 3A**

This represents either a change in circulation at this time or an increase in water depth, though an influx of a deeper marine fauna caused by a storm event is a more plausible explanation. Further examples of this may be present in this section but lack of samples prevents a detailed study.

13.4 **Faunal Comparison with Offshore Eastern Canada**

It is interesting to note that prior to 200 million years ago (Late Triassic) the north Atlantic did not exist as an open ocean, and that the continental plates of North America, Greenland and Western Europe were joined together forming one land mass. From mid-Jurassic to mid-Cretaceous times (160 - 100 million years) the southern part of the north Atlantic Ocean developed with the separation of the continental blocks and the formation of oceanic crust. This process was in its preliminary stages in the north (proto-north Atlantic Ocean) during this time. Prior to plate separation a shallow shelf sea existed which followed the lines of a series of downfaulted graben troughs which had developed in response to the pre-rupture phase of tensional stress between the plates (rifting).

The close juxtaposition of eastern Canada and the Western Approaches/Goban Spur area during the Early Cretaceous is reflected in the similarity of the geology and the foraminiferal faunas of the two areas.

Ascoli (1976), in a comprehensive account of the Mesozoic-Cenozoic sediments of the Scotian Shelf and the Grand Banks area.
### Foraminifera Biozonation Scheme for the Offshore Eastern Canada

**Fig. 13.7**

<table>
<thead>
<tr>
<th>Age</th>
<th>Planktonic</th>
<th>Calcareous Benthonic</th>
<th>Arenaceous Benthonic</th>
<th>Ostracoda</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tuonian</strong></td>
<td>Globoconina heblica</td>
<td>2 Gavelinopsis turamensis</td>
<td>1 Lingulodinella turatica</td>
<td>Mesococcosaurus arenaceous</td>
</tr>
<tr>
<td></td>
<td>Precapitulites urayana</td>
<td></td>
<td></td>
<td>Marsupellula trigonis</td>
</tr>
<tr>
<td><strong>Cenomanian</strong></td>
<td>2 Rosalpina cashana</td>
<td>1 Rosalpina longihaplaenesis</td>
<td></td>
<td>Gavelinopora cenomanica</td>
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<tr>
<td></td>
<td></td>
<td>1 Rosalpina appenninica</td>
<td>1 Gavelinina intermedius</td>
<td>Gavelinopsis benedicti</td>
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<tr>
<td></td>
<td>1 Favusella washarius</td>
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<tr>
<td><strong>Albian</strong></td>
<td>Ticinella prasicialis</td>
<td>2 Lenticulina geiniti</td>
<td>1 Epistomina chapmanni</td>
<td>2 Haplophragmoides granatiferulcosa</td>
</tr>
<tr>
<td></td>
<td>Ticinella prismula</td>
<td></td>
<td></td>
<td>1 Pseudonubeculina neglecta</td>
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<tr>
<td><strong>Aptian</strong></td>
<td>Favusella aff. washiansis</td>
<td>2 Lenticulina nodosa</td>
<td>1 Gavelinella buschiana</td>
<td>1 Gavelinella nana</td>
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<tr>
<td></td>
<td></td>
<td>1 Epistomina hechtii</td>
<td>1 Gavelinella buschiana</td>
<td></td>
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<tr>
<td><strong>Barremian</strong></td>
<td>Caecassita heterntica</td>
<td>2 Planulina crepidula</td>
<td>1 Lenticulina gyrata</td>
<td>2 Verneuilinides neophacethos</td>
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<tr>
<td></td>
<td></td>
<td>1 Lenticulina saraica saracena</td>
<td>1 Pseudocyprinida tetra</td>
<td>Rehacythia gr. sphenacanthi</td>
</tr>
<tr>
<td><strong>Hauterivian</strong></td>
<td>Caecassita heterntica</td>
<td>2 Planulina crepidula</td>
<td>1 Lenticulina gyrata</td>
<td>1 Pseudocyprinida prina</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Lenticulina saraica saracena</td>
<td>1 Conorbodes valida</td>
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<tr>
<td><strong>Valanginian-Berriasian</strong></td>
<td></td>
<td>2 Lenticulina saraica buchicola</td>
<td>1 Conorbodes valida</td>
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</table>

Biozonation scheme for the offshore eastern Canada (Ascott, 1976).
(material from 60 boreholes), proposed a foraminiferal and ostracod zonal scheme for the Early Cretaceous (Fig. 13.7). Ascoli attempted a preliminary comparison with North West European, Trinidadean, Alaskan and worldwide zonal schemes (i.e. Bartenstein, 1976a, b, 1977, 1978a, b, 1979). There are obvious similarities of all areas worldwide with North West Europe, but this may be exaggerated by the prolific European literature from which most foraminiferal identifications are made. However, it does confirm Bartenstein's assumption that a worldwide benthonic foraminiferal zonation of the Lower Cretaceous is possible.

Ascoli's (1976) zones are:

A. **L. Saxonica saxonica** - **L. guttata** - **Planularia crepidularis** Zone

Age: Hauterivian - Early Barremian. This zone is difficult to compare with Europe but one zonal marker is present in site 549. The diagnostic fauna of this zone (see Fig. 13.8) compares well with the fauna found in the base of Site 549. However *L. (P.) crepidularis* is of Hauterivian and Barremian age in north Germany while *L. (M.) schreiteri*, usually assumed to be a Hauterivian marker, appears in the upper section of site 549 (Barremian) and is not confined to the Hauterivian in the southern North Sea.

B. **Epistomina ornata** - **Epistomina caracolla** - **Epistomina hechti** Zone

This is Barremian in age and comprises the remainder of the Early Cretaceous of site 549 (Sub-Albian). It compares extremely well with the faunas of the Barremian in north-west Europe. Some of the boreholes on the Canadian shelf have abundant *Trocholina ex. gr. infragranulata* and *Choffatella decipiens* (Ascoli, 1976, p. 222).
Fig. 13.8
Calcareous and Arenaceous benthonic foraminifera zonation scheme for offshore eastern Canada (Ascoli, 1976)

<table>
<thead>
<tr>
<th>&quot;AGE&quot;</th>
<th>CALCAREOUS BENTHONIC FORAMINIFERA ZONE</th>
<th>DIAGNOSTIC BENTHONICS</th>
<th>DIAGNOSTIC PLANKTONICS</th>
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<td>ALBIAN</td>
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<tr>
<td>BARREMIAN</td>
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<tr>
<td>HAUTERIVAN</td>
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<tr>
<td>VALANGIN-</td>
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<tr>
<td>BERRASIAN</td>
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</table>

Calcarius and Arenaceous benthonic foraminifera zonation scheme for offshore eastern Canada (Ascoli, 1976)
686) which also compares well with 549 but they are not restricted to this zone offshore Canada.

C. *L. nodosa* - *Gavelinella barremiana* Zone

This zone according to Ascoli is Aptian in age but contains specimens found in the upper part of the studied section of 549, viz. *Gavelinella barremiana*, *L. (L.) nodosa*, *Choffatella decipiens*, *Trocholina ex. gr. infragranulata*. These species are also found in the Barremian of North West Europe. The base of this zone may be present at site 549.

In any case this zone is very difficult to compare with Europe on the basis of the benthonic fauna.

Site 549 may also be zoned by Ascoli's (1976) arenaceous benthonic foraminifera zones.

D. The *Verneulinoides neocomiensis* - *Psuedocyclammina litius* Zone

This zone is Berriasian - Valanginian - Hauterivian - Barremian in age and the diagnostic benthonics are present in site 549.

E. The *Choffatella decipiens* - *Trocholina ex. gr. infragranulata* - *Marssonella ex. gr. oxycona* Zone

This zone is also present at site 549 and is Barremian - Aptian in age.

In essence the section at site 549 straddles the boundary between these two arenaceous benthonic zones and using both the arenaceous benthonic and calcareous benthonics zonal schemes it may be concluded that the section is predominantly Barremian in
age with perhaps Late Barremian/Early Aptian at the top of the section with perhaps uppermost Hauterivian sediments present at the base.

This exercise of comparing the two areas does again emphasise the truth of Bartenstein's assumptions but also highlights the difficulty of using facies controlled bentonic foraminifera for biostratigraphy with the object of relating such a scheme to a chronostratigraphy.

13.5 Summary

The sediments and foraminifera indicate a gradual deepening and increasing marine influence of the environment; beginning with a shallow inner shelf (littoral? to inner sub-littoral) and culminating in an open marine middle to outer shelf (outer sub-littoral) environment. Abundant plant debris and some clastic detritus suggests the proximity of land; perhaps a sub-aerial block of Hercynian basement?

This sequence of events is related to the changing palaeogeographical situation of the area in response to plate tectonic processes and establishment of the north Atlantic Ocean (see Fig. 4.2 in Chapter 4).

Prior to plate separation a shallow shelf sea existed which occupied a series of down faulted grabenal troughs which had developed in response to the pre-rupture phase of tensional stress between the plates (rifting). The Forcupine Sea Bight and the Rockall Trough represent failed attempts at plate separation (grabenal troughs) in the development history of the north Atlantic Ocean (Naylor & Mounteney, 1975, p. 36). The Celtic Sea Basins, Western Approaches Basin s.s. and English Channel Basin may also represent failed attempts of extension northwards of the spreading axis of the Atlantic ocean during the Late Jurassic and Early Cretaceous (Figs. 4.2, 13.9). These
The geology of the Western Approaches (after Masson & Roberts, 1981)

**Fig. 13.9**
failed attempts ensured that the British Isles became European in character rather than American.

Plate separation was achieved in the Bay of Biscay - Western Approaches area but this ceased in Aptian - Albian times (Roberts et al., 1981) as sediments of this age overly oceanic crust in the Biscay area. Uplift and rejuvenation of the surrounding land masses (e.g. Cornubia) resulted in the thick wealden deposits of the Celtic Sea Basins, Western Approaches Basin and the Weald Basin. This continental deposition was terminated by the major marine transgression, associated with ocean ridge formation and sea floor spreading, during the late Barremian and Aptian (Ziegler, P.A., 1981, p. 24; Montadert et al., 1979).
Figure(s)

1. Lenticulina (Marginulina) schreiteri (Eichenberg), side view, (x 75), No. S.C.G.S. 1, 56cc.

2. Lenticulina (Planularia) crepidularis (Roemer), side view, (x 90), No. S.C.G.S. 2, 61cc.

3. Lenticulina (Saracenaria) frankei (ten Dam), side view, (x 75), No. S.C.G.S. 3, 56cc.

4. Lenticulina (Astacolus) sp. aff. neopachynota Bartenstein & Kaever, side view, (x 40), No. S.C.G.S. 4, 56cc.

5. Polymorphinid, ?Guttulina sp. (x 75), No. S.C.G.S. 5, 81/2.

6. Valvulineria sp. umbilical view (x 150), No. S.C.G.S. 6, 56cc.


8. Hedbergella sp. aff. hoterivica (Subbotina), umbilical view; (x 75), No. S.C.G.S. 8, 55/2, 108-111.


10, 13. Trocholina aptiensis Jovcheva/Neotrocholina friburgensis Guillaume & Reichel; umbilical, (x 40), side view, (x 75), No. S.C.G.S. 11, 61cc.

11, 14. Trocholina infragranulata Noth/Trocholina paucigranulata Moullade; No. S.C.G.S. 12, 61cc, umbilical, (x 75); side view (x 75).

12, 15. Trocholina aptiensis Jovcheva/Neotrocholina friburgensis Guillaume & Reichel; umbilical, (x 75); side view, (x 75), No. S.C.G.S. 15, 61cc.
Figure(s)

16, 20  *Conorotalites bartensteini intercedens* (Bettenstaedt); side view, (x 150), umbilical view, (x 150), No. S.C.G.S. 17, 58/2, 37-40.

17, 18  *Conorotalites bartensteini intercedens* (Bettenstaedt); side view, (x 150); umbilical view, (x 150), No. S.C.G.S. 19, 58/2, 37-40.

19    *Conorotalites bartensteini bartensteini* (Bettenstaedt); side view, (x 75), No. S.C.G.S. 20, 55/2, 108-11.
PLATE 13.2

Figure(s)

1, 2  Conorotalites bartensteini intercedens/ aptiensis transition (Bettenstaedt). No. S.C.G.S. 21, 55/2, 108-111, side view, (x 150); dorsal view, (x 150).


4, 6  Epistomina hechtii Bartenstein, Bettenstaedt & Bolli, No. S.C.G.S. 23, 85cc, dorsal view, (x 75); No. S.C.G.S. 24, 85cc, umbilical view, (x 75).

5, 7  Gavelinella barremiana Bettenstaedt No. S.C.G.S. 25, 55/2, 108-111, umbilical view, (x 75); No. S.C.G.S. 26, 58/2, 37-40, umbilical view, (x 75).


13, 14  Tritaxia pyramidata Reuss, No. S.C.G.S. 32, 55/2, 108-111, side view, (x 75); No. S.C.G.S. 33, 61cc, side view, (x 75).

15  Gaudryina dividens (?) Grabert, No. S.C.G.S. 34, 61cc, side view, (x 75).


18  (?) Cyclammina sp., No. S.C.G.S. 37, 81/2, 8-10, side view, (x 30).
PLATE 13.2 (continued)

Figure(s)


Foraminiferal Faunas in the Pre-Albian Section

The fauna from the fifteen samples examined is adequate to distinguish three associations with one sub-association, viz. 1, 2, 3, 3a. These correlate nicely with the lithology changes in the section which is also reflected in the gamma ray log pattern.

The fauna is not really adequate to give a precise age though obviously examination of further samples would probably provide further data. The faunas are all facies related and characteristic of the Barremian but in my experience not necessarily restricted to the Barremian. For example L. (P.) crepidularis, L. (M.) schreiteri, L. (M.) schloenbachii, L. (S.) frankei, G. barremiana, G. dividens - compacta group and S. lata are all recorded from the Lower Aptian of north-west Europe. However Conorotalites bartensteini and its sub species bartensteini, intercedens and aptiensis have been used by various authors to distinguish the Lower, (Middle) and Upper Barremian and the Aptian. Only bartensteini and intercedens have been recorded together at site 549 therefore indicating a Barremian age only (Middle?) for the highest sample examined (55/2 108 - 111 cm).

Epistomina (or Hoeglundina) hechti in the UK and north west Germany is indicative of the Middle Barremian. The specimens from sample 85 cc are identical to specimens from Speeton, Yorks. Further discussion is incorporated into the accompanying diagram (see Fig. 13.6).
To sum up, the results of the examination of the foraminifera are: the whole of the studied section is no younger than the late Middle/early late Barremian. A precise age is not possible to determine.

The age of the base of the section (above the basement) is ?Lower/early Middle Barremian.
PART 4

TAXONOMY
CHAPTER 14

SYSTEMATICS OF THE STUDIED FORAMINIFERA

14.1 Introduction

The classification of the foraminifera used in this thesis follows that of Loeblich and Tappan (1964) and their later amendments (1974). This thesis is primarily of stratigraphic interest and is not intended to be an authoritative and detailed account of foraminiferal taxonomy. For brevity the synonymy, in most instances, consists of the first citation of the species in the literature plus one or two other important references. Where appropriate, reference to the Ellis and Messina catalogue has been made though this is not recorded in the synonymy listings. This is considered adequate for most species as they have been extremely well documented in readily available literature and there would be no point in reiterating here the philosophical discussion regarding their taxonomy. However, in some instances where there are points of contention, a fuller discussion is entertained.

This part of this thesis deals with the complete recorded foraminiferal fauna of the Early Aptian of the Atherfield "Group" of the Isle of Wight and the most important species, stratigraphically, from the Early Cretaceous of D.S.D.P., Leg 80, site 549. The foraminiferal fauna from the southern North Sea boreholes is dealt with by identifying to species level the important index species (mainly in the Aptian and Albian) and by identifying to generic level the other constituents of the fauna. This enables an appreciation of the faunas present at different depths, and of different facies, and their relationship to biostratigraphical age.

Identification has been achieved by comparison with known faunas, described in the literature, and with collections in other
institutions, from other areas of North West Europe.

The arenaceous and calcareous foraminifera from the Atherfield Clay a.e. (=Chale Clay Member) of the Isle of Wight are the subject of two papers (Crittenden, 1983, First International Workshop on Arenaceous Foraminifera, Amsterdam, September 1981; Crittenden, 1982a).

The taxonomy of Lenticulina (A.) atherfieldensis Crittenden has been published as a paper (Crittenden, 1983 - see Chapter 15).

The taxonomy of Osangularia schloenbachi (Reuss) has also been published (Crittenden, 1983 - see Chapter 16).

The illustrated specimens from these papers are deposited in the British Museum of Natural History, Palaeontology section. Their catalogue numbers are indicated in the plate description of each species.

Order FORAMINIFERA Eichwald, 1830

Sub-order TEXTULARIINA

Superfamily AMMODISCACEA Reuss, 1862

Family ASTRORHIZIADAE Brady, 1881

Subfamily HIPPOCREPININAE Rhumbler, 1895

Genus HYPERAMMINA Brady, 1878

Type species: Hyperammina elongata Brady, 1898

Hyperammina gaultina ten?Dam 1950
1966 Hyperammina gaultina ten Dam; Bartenstein, Bettenstaedt & Bolli: p. 137, pl. 1, figs. 6-13.

Remarks: A common species found usually as fragments. It is of no stratigraphical importance.

Family SACCAMMINIDAE Brady, 1884

Subfamily PSAMMOSPHAERINAE Haeckel, 1894

Genus PSAMMOSPHAERA Schultze, 1875

Type species: Psammosphaera fusca Schulze, 1875

Psammosphaera sp.

(Plate 12.1, Figures 1, 2)

Diagnosis: Test is badly compressed but presumed to be originally globular, free, single chamber, wall siliceous, finely agglutinated.

Remarks: The features of the test are not precise enough for accurate specific determination.

Dimensions of figured specimens (mm):

max. diameter

| SCAC 8101 | 0.25 | Isle of Wight, Aptian |
| SCAC 8102 | 0.21 | Isle of Wight, Aptian |

Occurrence: In the Atherfield "group" it is most abundant in samples 13 and 17 but occurs rarely in samples below. Psammosphaera sp. occurs rarely in samples
examined from the southern North Sea Basin. It has no stratigraphical significance.

Subfamily SACAMMININAE Brady, 1884

Genus LAGENAMMINA Rhumbler, 1911

Type species: Lagenammina laguncula Rhumbler, 1913

Lagenammina sp. 1

(Plate 12.1, Figures 3, 4)

Diagnosis: Test a single flask shaped chamber, medium grain size agglutinated material, with terminal aperture on a produced neck. Colour dark grey to black, caused by mafic grains.

Remarks: An abundant species in the Atherfield "group" but in most part compressed and distorted which precludes precise specific determination. This species appears similar to the form called Pelosina sp. by Hart and Carter (1975) from the Atherfield Clay of Sevenoaks, Kent. This species was not recorded from the southern North Sea material.

Dimensions of figured specimens (mm):

max. diameter

SCAC 8103 0.25
SCAC 8104 0.30

Occurrence: Occurs abundantly throughout the Atherfield "group" section.
\textit{Lagenammina} sp. 2

(Plate 12.1, Figures 5, 6)

\textbf{Diagnosis:} Test a single spherical shaped chamber, coarsely agglutinated with a terminal aperture on a produced neck. Colour light yellow-brown. No mafic material.

\textbf{Remarks:} A common species in the Atherfield "group" but compressed and distorted. Easily distinguished from \textit{Lagenammina} sp. 1 by colour and shape of test.

Dimensions of figured specimens (mm):

max. diameter

SCAC 8105 0.30
SCAC 8105 0.40

\textbf{Occurrence:} Abundant in most samples of the Atherfield "group" from sample 5 upward. This species was not recorded from the southern North Sea material.

\textit{Lagenammina} sp.

\textbf{Diagnosis:} Test a single chamber badly distorted and compressed. Colour light grey.

\textbf{Remarks:} A simple specimen only recorded from DSDP 80, Site 549, (Sample 58/2, 37-40 cm).

\textbf{Occurrence:} Rare and of no stratigraphical significance.
Genus *THURAMMINA* Brady, 1879

Type species: *Thurammina papillata* Cushman, 1910

*Thurammina albicans* Brady

1884 *Thurammina albicans* Brady: p. 323, pl. 37, figs. 2-7

1938 *Thurammina* Dl Hecht: pl. 24, figs. 118, 120

Remarks: This species is not very common in the studied samples but is quite distinctive. It has no stratigraphic use in the studied sections.

Family *AMMODISCIDAE* Reuss, 1862

Subfamily *AMMODISCINAE* Reuss, 1862

Genus *AMMODISCUS* Reuss, 1862

Type species: *Ammodiscus inflatus* Bornemann, 1874

*Ammodiscous cretaceous* (Reuss, 1845)

(Plate 12.1, Figure 7)

1845 *Operculina cretacea* Reuss; Reuss: p. 34, pl. 13, figs. 64-65

1950 *Ammodiscus cretacea* (Reuss), ten Dam: 6

Diagnosis: Discoidal, non-septate, planispirally enrolled tubular second chamber preceded by a small proloculus. Aperture is open end of tube. Only three whorls visible. Very finely agglutinated, smooth polished surface.
Remarks: Only one specimen was recovered from the Atherfield "group" (other specimens have been recorded from the locality by Bidgood, pers. comm. 1981) which is identical in all respects to specimens recovered from the Albian and Aptian of the studied North Sea boreholes. Specimens recorded as *Ammodiscus* sp. from the North Sea and DSDP leg 80 may belong to this species but bad preservation precludes precise identification.

Dimensions of figured specimens (mm):

max. diameter

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Diameter</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8107</td>
<td>0.14</td>
<td>Isle of Wight, Aptian</td>
</tr>
</tbody>
</table>

Occurrence: Rare in the Atherfield "group" of the Isle of Wight and in the samples from DSDP site 549 but common in the North Sea boreholes. Haig (1979a, b) has documented its occurrence in the *Marsnionella* and *Ammobaculites* Associations worldwide.

Genus GLOMOSPIRELLA Plummer, 1945

Type species: *Glomospira umbilicata* Cushman and Waters

*Glomospira/Glomospirella* ex. group *gaultina* (Berthelin, 1880)

(Plate 12.1, Figures 8 and 9)

1880 *Ammodiscus gaultinus* Berthelin: p. 19, pl. 1, figs. 3a - 3b

1962 *Glomospirella gaultina* (Berthelin); Tappan: p. 130, pl. 29, figs. 17 - 20

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1975 Glomospirella gaultina (Berthelin); Magniez-Jannin: p. 26, pl. 1, figs. 2 - 4

Diagnosis: A moderately sized species of Glomospira/ Glomospirella with the last two to four whorls planispirally coiled. The single tubular chamber is initially streptospirally coiled. Test is finely agglutinated and smooth.

Remarks: This species is indistinguishable from forms encountered in the Aptian and Albian of the North Sea Basin. There is an apparently strong variation, from forms which have irregular coiling of all the tube to forms which have only the initial portion irregularly coiled followed by a planispiral portion. All intermediates between these extremes occur at Atherfield, in the North Sea and DSDP site 549. Magniez-Jannin (1975) has noted the practice of authors in placing forms which differ in coiling type into different species. Further research is needed on this group but the author favours the idea of placing all variations into one genus and species until the problem is resolved. The Isle of Wight specimens are all deformed as are most of the specimens from the North Sea boreholes. The specimens recorded as G. irregularis (Grzybowski) group from DSDP site 549 should in fact be included in this species group (see Fig. 13.6).

Dimensions of figured specimens (mm):

max. diameter

SCAC 8109 0.27  Aptian, Isle of Wight

SCAC 8110 0.23  Aptian, Isle of Wight
Occurrence: Occurs throughout the Atherfield "group" section but most abundant in sample 6. Common in the North Sea boreholes and levels of abundance are stratigraphically important. The specimens from the Ammobaculites Association as noted by Haig (1980) are smaller with thinner walls than specimens from the Marssonnella Association.

Subfamily TOLYPAMMININAE Cushman, 1928

Remarks: A number of attached tests attributable to this subfamily, have been recorded from the North Sea material. In most cases the test is attached to large quartz grains.

Genus LITUOTUBA Rhumbler, 1895

Type species: Serpula filum Schmid, 1867

Lituotuba sp.

Remarks: One specimen only was found in the Atherfield "group section studied. This specimen was lost.

Superfamily LITUOLACEA de Blainville, 1825

Family HORMOSINIDAE Haeckel, 1894

Subfamily HORMOSININAE Haeckel, 1894

Genus REOPHAX Montfort, 1808

Type species: Reophax scorpifurus Montfort, 1808
Reophax minutus Tappan, 1940

(Plate 12.1, Figure 10)

1892a Hormosina globulifera (non Brady): Chapman: p. 326, pl. b, figs. 10a, b

1940 Reophax minutus Tappan: p. 94, pl. 14, figs. 4a - b

1950 Reophax minutus Tappan; Ten Dam: p. 6, pl. 1, fig. 3

Diagnosis: A small elongate, species of Reophax with four to seven chambers. Test is free, uniserial, straight or slightly curved.

Remarks: The specimens from the Atherfield "group" agree well with forms from the Early Cretaceous of the North Sea boreholes some of which are round in cross-section. Tappan's description (1940) states that this species is flattened, perhaps by compression. Both compressed and uncompressed specimens are present in the Atherfield Clay and in the Early Cretaceous of the North Sea.

Dimensions of figured specimen (mm):

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Max. length</th>
<th>Max. width</th>
<th>Age</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8111</td>
<td>1.15</td>
<td>0.32</td>
<td>Aptian</td>
<td>Isle of Wight</td>
</tr>
</tbody>
</table>

Occurrence: Sporadically throughout the Atherfield "group" section but most abundant in Samples 3 and 5 near the base of the section. This species occurs commonly throughout the North Sea sections. Certain levels of abundance are of stratigraphical
use in the Early Albian and Late Aptian (Price 1977b) and may reflect conditions of environment of deposition.

Reophax scorpiurus Montfort, 1808

(Plate 12.1, Figure 11, 12 and 13)

1808 Reophax scorpiurus Montfort: p. 332, text - fig. p. 330 (from Ellis and Messina).

1940 Reophax deckeri n. sp. Tappan: p. 94, pl. 14, fig. 3a-b

1980 Reophax deckeri Tappan; Haig: p. 99, pl. 2, figs. 12 - 15, pl. 9, fig. 7

Diagnosis: A test, with few chambers, with rapid increase in chamber size, wall coarsely agglutinated, siliceous and mafic grains, surface rough, aperture at end of broad neck.

Remarks: The wide variability of this species has been noted by Magniez-Jannin (1975) and is partly a result of deformation during fossilisation. Most types have three to four chambers which increase rapidly in size and have in some cases a circular cross-section. The majority of specimens from Atherfield, the North Sea and DSDP site 549 are compressed and distorted but show the characteristic features of the species. The variation noted by Dammote and Magniez-Jannin (1973) is also apparent in these areas: that is the variation in the arcuate arrangement of the chambers, size of the test, and in size of the initial chambers responsible for the pointed initial part of the test. The specimens, from

239
DSDP, site 549, of *Reophax* sp. were too distorted for specific determination.

Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Max. length</th>
<th>Max. width</th>
<th>Age</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8113</td>
<td>0.88</td>
<td>0.40</td>
<td>Aptian, Isle of Wight</td>
<td></td>
</tr>
<tr>
<td>SCAC 8114</td>
<td>0.88</td>
<td>0.46</td>
<td>Aptian, Isle of Wight</td>
<td></td>
</tr>
<tr>
<td>SCAC 8115</td>
<td>0.70</td>
<td>0.34</td>
<td>Aptian, Isle of Wight</td>
<td></td>
</tr>
</tbody>
</table>

Occurrence: Most abundant in the lower half of the Atherfield "group" section, rarely in the upper part and rare in DSDP site 549.

Sub-family CRIBRATININAE Loeblich & Tappan, 1964

Genus CRIBRATINA Sample, 1932

*Cribratina* sp.

Remarks: This species is recorded in the southern North Sea material as a fragment and is extremely rare and only found in the Albian in the studied boreholes.

Family RZEHAKINIDAE Cushman, 1933

Genus MILIAMMINA Heron-Allen & Earland, 1930

Type species: *Miliolina oblonga* (Montagu) var. *arenacea* Chapman, 1916
Miliammina sp.

(Plate 12.1, Figure 14)

Diagnosis: A finely agglutinated, smooth, light brown species of Miliammina.

Occurrence: A single specimen not identified to species level in sample 11 from the Atherfield "group".

Dimensions of figured specimen (mm):

max. length max. width

SCAC 8116 0.58 : 0.33

Family LITUOLIDAE de Blainville, 1825

Subfamily HAPLOPHRAGMOIDINAE Maync, 1952

Genus HAPLOPHRAGMOIDES Cushman, 1910

Type species: Nonionina canariensis d'Orbigny, 1839

Remarks: In most instances the recovered specimens of arenaceous foraminifera referred to the genus Haplophragmoides spp. are highly compressed and distorted and apertural characteristics are obscured. This precludes a precise generic determination and certainly precludes a specific determination. In the North Sea and the Atherfield "group" section on the Isle of Wight some attempt has been made to distinguish genera and species. However the group is long ranging in the Early Cretaceous and is consequently of very little
at stratigraphical importance. Abundance levels are important and may provide very local datums for correlation purposes.

*Haplophragmoides chapmani* Morozova, 1948

1975 *Haplophragmoides chapmani* Morozova; Magniez-Jannin: p 37, pl. 2, figs 1-4.

**Diagnosis:** A sub-globose species of *Haplophragmoides* with five to six chambers in the final whorl.

**Remarks:** This species has a similar range to *H. nonioninoides* and they are difficult to separate from each other. *H. chapmani* may in fact have evolved from *H. nonioninoides* in the Late Albian.

**Occurrence:** Long ranging in the Albian but particularly common in the Late Albian. It is of limited stratigraphical value.

*Haplophragmoides concavus* (Chapman, 1892)

(Plate 12.1, Figures 15 and 16)

1892 *Trochammina concava* Chapman: p. 372, pl. 6, fig. 14

1940 *Haplophragmoides concava* (Chapman); Tappan: p. 95, pl. 14, figs. 7a-c

1966 *Haplophragmoides concavus* (Chapman); Bartenstein, Bettenstaedt & Bolli: p. 138, pl. 1, figs. 64 - 71, 76 - 78.

**Diagnosis:** Test free, a subcircular lobate periphery with four and one half to five and one half chambers in the final whorl. Biumbilical with sutures slightly

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depressed, agglutinated, very fine arenaceous material.

Remarks: Magniez-Jannin (1975 p. 39) has discussed the generic affinities of this species and the present author follows her conclusion in placing the species in the genus *Haplophragmoides*. All the forms from the Atherfield "group" are deformed. Damotte and Magniez-Jannin (1973) remark on the variability and deformation of this species from the Paris Basin Aptian.

Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Max. diam</th>
<th>No. of chambers</th>
<th>Final whorl</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8117</td>
<td>0.31</td>
<td>6</td>
<td>Aptian, Isle of Wight</td>
</tr>
<tr>
<td>SCAC 8118</td>
<td>0.33</td>
<td>6</td>
<td>Aptian, Isle of Wight</td>
</tr>
</tbody>
</table>

Occurrence: Not very common in the Atherfield "group" section - found in only three samples. It is not very common in the boreholes recorded from the Southern North Sea Basin. However it is of no stratigraphical value and in most instances is included in the grouping *Haplophragmoides* spp.

*Haplophragmoides nonioninoides* (Reuss, 1863)

(Plate 21.1, Figures 17 and 18)

1863 *Haplophragmium nonioninoides* Reuss: p. 30, pl. 1, figs. 8a-b

1954 *Haplophragmoides nonioninoides* (Reuss); Bartenstein: p. 38
1975 Haplophragmoides nonioninoides (Reuss); Magniez-Jannin: p. 30, pl. 2, figs. 9 - 18, text figs. 11 - 12

Diagnosis: A large compressed species of Haplophragmoides with six to fourteen chambers in the last whorl.

Remarks: This species, first described from the Albian of Germany (Reuss, 1863), is more coarsely agglutinated than H. concavus and is composed of siliceous and mafic material. Magniez-Jannin (1975) has published a thorough study of this species from the Albian of the Paris Basin. She separated it into two forms, one typical of the Early Albian and the other of the Late Albian.

Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th>max. diam</th>
<th>nos. of chambers in final whorl</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8119</td>
<td>0.31 5</td>
</tr>
<tr>
<td>SCAC 8120</td>
<td>0.31 6</td>
</tr>
</tbody>
</table>

Occurrence: Abundant in the lower part of the Atherfield "group" section of the Isle of Wight (Aptian). It occurs commonly in the Albian strata of the Southern North Sea Basin and is of limited stratigraphic use.

Haplophragmoides aff. platus Loeblich, 1946

(Plate 12.1, Figures 19 and 20)

1946 Haplophragmoides platus Loeblich: p. 134, pl. 22, fig. 5
1973 Haplophragmoides aff. platus Loeblish; Damotte & Magniez-Jannin: p. 15, text fig. 6, pl. 2, figs. 1 - 3 1/2

Diagnosis: Small test, free, compressed; lobate periphery, evolute, six to seven and one half chamber's in the final whorl. Chambers rapidly increase in size. Test is siliceous, composed of fine quartz and mafic grains.

Remarks: As a result of the chamber number in the last whorl and the evolute form this species is very close to H. platus of Loeblich (1946). It is identical to forms illustrated by Damotte and Magniez-Jannin (1973) but distortion of the specimens make precise identification difficult.

Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th>max. diam</th>
<th>nos. of chambers</th>
</tr>
</thead>
<tbody>
<tr>
<td>in final whorl</td>
<td></td>
</tr>
<tr>
<td>SCAC 8121</td>
<td>0.25</td>
</tr>
<tr>
<td>SCAC 8122</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Occurrence: Common throughout the Atherfield "group" section. This species was not distinguished within the H. spp. group from the southern North Sea material.

Haplophragmoides aff. globosa Lozo, 1944

(Plate 12.1, Figures 21 and 22)

1944 Haplophragmoides globosa Lozo: p. 543, pl. 2, fig. 8, text fig. 16
1949 *Haplophragmoides globosa* Lozo; Loeblich & Tappan: p. 249, pl. 46, figs. 3a - b

1973 *Haplophragmoides globosa* Lozo; Damotte & Magniez-Jannin: p. 15, pl. 2, fig. 6, text fig. 5

**Diagnosis:** This species shows a large degree of variation in number of chambers in the last whorl. It is characterised by a sub-circular outline with a slightly lobate periphery. Test is finely agglutinated and is composed of quartz and mafic grains. Surface is smooth.

**Remarks:** This species is rare in the Atherfield "group" section. It resembles the form described by Damotte and Magniez-Jannin (1973). The form described by Lozo (1944) has more chambers in the final whorl (ten to twelve). The Atherfield "group" forms are deformed.

**Dimensions of figured specimens (mm):**

<table>
<thead>
<tr>
<th></th>
<th>max. diam</th>
<th>nos. of chambers in final whorl</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8123</td>
<td>0.31</td>
<td>5</td>
</tr>
<tr>
<td>SCAC 8124</td>
<td>0.27</td>
<td>5</td>
</tr>
</tbody>
</table>

**Occurrence:** Rare in the Atherfield section. This species was not distinguished from the *H. spp.* group in the southern North Sea material.
Subfamily CYCLAMMININAE Marie, 1941

Genus CYCLAMMINA Brady, 1879

Type species: *Cyclammina cancellata* Brady, 1879

*Cyclammina* sp

(Pl. 13.2, Fig. 18)

Remarks: This species was recorded from the studied material from the Urgonian facies of DSDP borehole 59, leg 80. Poor preservation precludes a specific determination. This genus has not been recorded from the Isle of Wight material or from the North Sea Early Cretaceous. This may be due to non-identification as after all very little attention has been paid to the arenaceous foraminifera having little stratigraphical utility. The genus *Cyclammina* is usually associated with deeper water environments.

Genus CHOFFATELLA Schlumberger, 1905

Type species: *Choffatella decipiens* Schlumberger, 1905

*Choffatella decipiens* Schlumberger

(Pl. 13.2, Fig. 17)

1977 *Choffatella decipiens* Schlumberger; Bartenstein & Bolli: p. 549, pl. 1, fig. 32.

Remarks: This is essentially a Tethyan species (see Chapter 12) which is not recorded from the North Sea
material. It has been recorded from the DSDP material from the Goban Spur. Jaworski (pers. comm.) records it from the Aptian of southern England and Colin et al. (1981) record it offshore Ireland from borehole material of Aptian age in the Celtic Sea.

Subfamily LITUOLINAE Blainville, 1825

Genus AMMOBACULOIDES Plummer, 1932

Type species: Ammobaculoides navarroensis Plummer, 1932

Ammobaculoides mutabilis Magniez-Jannin, 1973

(Plate 12.1, Figure 23, Plate 12.2, Figure 1)

1973 Ammobaculoides mutabilis Magniez-Jannin, in Damotte & Magniez-Jannin: p. 17, fig. 7, pl. 2, fig. 10 - 13

Diagnosis: A species of Ammobaculoides characterised by a lobate periphery, a well developed umbilicus in the spiral portion and an unenrolled stage which is very variable in proportion of biserial to uniserial chamber addition.

Remarks: This species was initially described from the Lower Aptian of the Paris Basin. The specimens from the Atherfield "group" are identical to the illustration and description of Magniez-Jannin's species.
Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Max. length</th>
<th>Nos. of chambers</th>
<th>Uniserial portion in coil</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8125</td>
<td>0.7</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>SCAC 8126</td>
<td>0.66</td>
<td>4</td>
<td>2 (broken)</td>
</tr>
</tbody>
</table>

Occurrence: Common in the lower part of the Atherfield "group" section. Occurs in sample 18 higher up the section. This species was not recorded in the material from the southern North Sea.

Genus AMMOCALCULITES Cushman, 1910

Type genus: Spirolina agglutinans d'Orbigny, 1846

Remarks: In most cases the present author has not attempted to distinguish the various species in this genus and has been content to 'log' either 'unidentified agglutinants' or Ammobaculites spp. This approach has been necessary due to preservation and the little importance of this group for age determination.

Ammobaculites parvispira ten Dam, 1950

1950 Ammobaculites parvispira ten Dam: p. 10, pl. 1, figs. 8a, b.

Remarks: This species is only distinguished in some of the boreholes from the southern North Sea. In most instances it has been recorded with the group 'unidentified agglutinants' or within Ammobaculites spp.
**Ammobaculites subcretaceus** Cushman & Alexander, 1930

(Plate 12.2, Figures 2 and 3)

1930 *Ammobaculites subcretaceus* Cushman & Alexander: p. 6, pl. 2, figs. 9 - 10

1949 *Ammobaculites subcretaceus* Cushman & Alexander; Loeblich & Tappan: p. 251, pl. 46, figs. 9 - 13

**Diagnosis:** A test of medium size consisting of an elongate, flattened portion close coiled, slightly evolute, with a rounded periphery. Eight to nine chambers in the coil which increase gradually in size as added followed by as many as four uniserial chambers which increase very little in diameter. Wall arenaceous of fine to medium sized quartz grains.

**Remarks:** There is a marked variability in the size of the coiled portion. Some forms have a small coiled part and others have a large coiled portion. The form from the Atherfield "group" is identical to the form described by Damotte & Magniez-Jannin (173) from the Paris Basin and to the form described, and illustrated by Loeblich & Tappan (1949) from the United States.

**Dimensions of figured specimens (mm):**

| SCAC 8127 | 0.45 | 0.25 | 0.23 |
| SCAC 8128 | 0.44 | 0.20 | 0.17 |
Occurrence: Occurs throughout the Atherfield Clay ss. section. This species is recorded sporadically from the material from the southern North Sea.

*Ammobaculites obliquus* Loeblich & Tappan, 1949

(Plate 12.2, Figures 4, 5 and 6)

1949 *Ammobaculites obliquus* Loeblich & Tappan: p. 250, pl. 46, figs. 4 - 5

1973 *Ammobaculites obliquus* loeblich & Tappan; Magniez-Jannin: p. 18, pl. 2, figs. 7 - 9

Diagnosis: A small species of *Ammobaculites* with a closely coiled early portion and an uncoiled later portion. Five to seven chambers in the involute initial portion followed by up to four uniserial chambers. Sutures in the uncoiled portion at an oblique angle, highest dorsally. Arenaceous, smooth surface, medium grains.

Remarks: The specimens from the Atherfield "group" are identical to the forms recorded by Damotte & Magniez-Jannin (1973). Most specimens are distorted and crushed. This species has not been distinguished in the southern North Sea material.
Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th></th>
<th>max. length</th>
<th>max. width</th>
<th>uniserial coil</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8129</td>
<td>0.40</td>
<td>0.32</td>
<td>0.20</td>
</tr>
<tr>
<td>SCAC 8130</td>
<td>0.43</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td>SCAC 8131</td>
<td>0.35</td>
<td>0.25</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Occurrence: Present throughout the Atherfield "group" section but most abundant in sample 2. This species was not identified in the samples from the southern North Sea.

Ammobaculites aff. reophacoidea Bartenstein, 1952

(Plate 12.2, Figures 7 and 8)


Diagnosis: A species of Ammobaculites with equal sized Reophax like added chambers. The initial coiled portion has seldom more than two or three chambers.

Remarks: This species has close affinities to A. reophacoidea but differs in the following aspect. The Reophax added portion chambers are not so large and are higher. The species is very similar to the species described as A. aff. reophacoidea by Magniez-Jannin (1973).
Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th></th>
<th>max. length</th>
<th>max. width</th>
<th>uniserial coil</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8132</td>
<td>0.50</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>SCAC 8133</td>
<td>0.66</td>
<td>0.2</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Occurrence: Rare, most common in sample 8 of the Atherfield "group" section.

Ammobaculites reophacoides Bartenstein, 1952


Diagnosis: A small elongate test with a small initial coil and two to four uniserial chambers. The small initial coil gives the test a Reophax like shape.

Remarks: Not uncommon in the North Sea boreholes throughout the studied section beneath the Albian. Commonly crushed and distorted and consequently in many instances is included in "Arenaceous foraminifera undifferentiated".

Occurrence: Of no stratigraphic importance in the North Sea boreholes.

Genus HAPLOPHRAGMIUM Reuss, 1860

Type species: Spirolina aequalis Roemer, 1841
**Haplophragmium inconstans erectum** Bartenstein & Brand, 1951

1962 *Haplophragmium inconstans erectum* Bartenstein & Brand;
Bartenstein & Brand: p. 254, pl. 17, pl. 35, fig. 12

**Remarks:** This is a large arenaceous foraminiferid. It is rare and its occurrence is ecologically controlled. It has only been recorded from the Valanginian to Hauterivian in north west Germany. It is of no real stratigraphical use in the studied material from the North Sea.

**Haplophragmium aff. aequale** (Roemer, 1841)

1938 *Haplophragmium* D. 13 Hecht: Taf. 15a, fig. 86 - 92

1952 *Haplophragmium aequale* Roemer; Bartenstein: p. 325, taf 1., fig. 2, taf. 2, figs. 17 - 26, taf. 3, figs. 1 - 6, taf. 6, figs. 6 - 8, taf. 7, figs. 1 - 2

**Diagnosis:** Initial portion is streptospirally coiled and followed by rectilinear chamber addition.

**Remarks:** The single specimen from the Atherfield "group" has been lost by the author but appeared very close to the description of *Haplophragmium aequale* of Bartenstein and recorded by him from the Upper Hauterivian to Lower Barremian of North-West Germany.

**Genus TRIPLASIA** Reuss, 1854

**Type species:** *T. murchisoni* Reuss, 1854
Triplasia cf. T. emslandensis Bartenstein & Brand, 1951

1962 Triplasia emslandensis Bartenstein & Brand; Bartenstein & Bettenstaedt: p. 263, pl. 35, fig. 20

Remarks: Deformed specimens similar to T. emslandensis are rare in the North Sea material. They are of no stratigraphical utility in this study.

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily TEXTULARIINAE Ehrenberg, 1838

Genus TEXTULARIA Defrance in de Blainville, 1824

Type species: Textularia sagittula Defrance, 1824.

Textularia chapmani Lalicker, 1935

1975 Textularia chapmani Lalicker; Magniez-Jannin: p. 54, pl. 3, figs. 1-9

Diagnosis: A medium sized species of Textularia. The chambers increase rapidly in size. (eleven to fifteen in number).

Remarks: This species is ubiquitous and is age diagnostic as it typically occurs in the Late Albian. Walters (M.S.) regarded it as a characteristic species of the Late Albian.

Occurrence: A common species in the Late Albian sections of the studied boreholes in the North Sea. This species was recorded from DSDP site 549 as T. sp. aff chapmani as the single specimen was broken.
Textularia bettenstaedti (Bartenstein & Oertli; 1981)

1962 Textularia foeda Reuss, 1846: Bartenstein & Bettenstaedt; p. 270, pl. 37, fig. 10; pl. 39, fig. 19.

1977 Textularia bettenstaedti, Bartenstein & Oertli; p. 15, figs. 1-4.


Diagnosis: A species of Textularia with characteristic agglutination of the walls with black "pyrite" grains, especially strongly accumulated at the lower edge of the chamber walls and in the sutural area - coal dust impression.

Remarks: The specimens recorded by Fletcher (1966, 1973) as T. foeda Reuss from the Speeton Clay are without doubt T. bettenstaedti. The remarks by Fletcher (1966) have been incorporated by Bartenstein & Oertli (1977) into their stratigraphical discussion of this species. Both Fletcher (1966) and Bartenstein & Oertli (1977) and Bartenstein (1981) have discussed in detail the taxonomic history and stratigraphic importance of this species. Price (1975) places specimens of this species erroneously into T. minuta despite the black speckled sutures.

Occurrence: Characteristic of the Early Albian, Aptian and Barremian in the studied boreholes for the southern North Sea. It is most characteristic of the Late Aptian and Early Albian.

Textularia minuta Berthelin, 1880

(Plate 12.2, Figures 9 and 10)
1880 Textularia minuta Berthelin: p. 26

1975 Textularia minuta Berthelin; Magniez-Jannin: p. 49, pl. 3, figs. 35 and 36

Diagnosis: A small species of Textularia.

Remarks: The specimens are all distorted and compressed making an appreciation of variation very difficult. Magniez-Jannin (1975) and Damotte and Magniez-Jannin (1973) have discussed the affinities of this form and its taxonomic history. This species is rare in the Atherfield "group" section studied but Bidgood (pers. comm.) has recorded rather more specimens from the same locality and horizon of sample 7.

Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Max. Length</th>
<th>Max. Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8134</td>
<td>0.38</td>
<td>0.24</td>
</tr>
<tr>
<td>SCAC 8135</td>
<td>0.39</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Occurrence: Present in three samples only; 6, 7 and 15. Recorded by Magniez-Jannin (1975) from the Albian and the Aptian of the Paris Basin (1973, op cit). It has limited stratigraphic use. It has not been recorded from the North Sea boreholes. Specimens recorded as T. sp. 1 from DSDP site 549 may be attributable to T. minuta.

Textularia pulchella Magniez-Jannin, 1973

(Plate 12.2, Figures 11 and 12)
1973 *Textularia pulchella* Damotte & Magniez-Jannin: p. 20, fig. 9, pl. 2, figs. 22 - 25

**Diagnosis:** A species of *Textularia* characterised by the lanceolate shape, pointed, small initial portion and slightly lobate sides initially, which became more lobate towards the last portion of the test. The test is finely agglutinated and has a large proportion of calcareous material.

**Remarks:** The specimens from the Atherfield "group" are identical to the species described and illustrated by Magniez-Jannin (1973, in Damotte & Magniez-Jannin) from the Paris Basin Aptian. The species is not common at Atherfield and the majority are broken and incomplete as well as distorted.

**Dimensions of figured specimens (mm):**

<table>
<thead>
<tr>
<th></th>
<th>max. length</th>
<th>max. width</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8136</td>
<td>0.46</td>
<td>0.25</td>
</tr>
<tr>
<td>SCAC 8137</td>
<td>0.55</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Occurrence:** Rare in the Atherfield "group: section of the Isle of Wight, but is most abundant in sample 5. This species has not been recorded from the North Sea boreholes.

Family TROCHAMMINIDAE Schwager, 1877

Subfamily TROCHAMMININAE Schwager, 1877

258
Genus TROCHAMMINA Parker & Jones, 1959

Type species: Nautilus inflatus Montagu, 1808

Remarks: A variety of crushed, deformed and small arenaceous foraminiferids have been recorded from the boreholes in the southern North Sea and collectively referred to as Trochammina spp. unidentified. In general, species recognition serves no stratigraphic purpose. However their occurrence and variation in number does, in some boreholes, provide information useful for palaeoenvironmental interpretation and local correlatable event stratigraphy. The species described below were recovered from the Atherfield "group" section.

Trochammina depressa Lozo, 1944

(Plate 12.2, Figure 13)

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

Diagnosis: Test small to medium in size, compressed; outline lobulate, margin rounded, five to seven chambers in final whorl, gradually increasing in size; sutures depressed. Wall siliceous.

Remarks: The Atherfield "group" specimens have a generally coarser surface texture than the type specimens.

Dimensions of figured specimens (mm):

max. diameter

SCAC 8139  0.70
Occurrence: Only abundant in sample 2 of the Atherfield section. Recorded by Haig in the Ammobaculites Association in Queensland, Australia (1980).

Trochammina aff. lattai Loeblich & Tappan, 1950

(Plate 12.2, Figures 14 and 15)

1950 *Trochammina lattai* Loeblich & Tappan: p. 11, pl. 2, fig. 6

Remarks: A small species of Trochammina which occurs abundantly in the Atherfield "group" section but due to distortion and compression is difficult to place specifically. It differs from *T. lattai* in having a less convex dorsal side and by having an arcuate chamber pattern on the dorsal side. It is similar to *T. depressa* Lozo but because of the preservation it is difficult to appreciate the affinity, if any, between the two forms. Indeed Haig (1980) places *T. lattai* in synonymy with *T. depressa*. The test is arenaceous, entirely siliceous and is slightly rugose in appearance.

The specimens from the Atherfield "group" are very similar to the forms illustrated and described by Magniez-Jannin (in Damotte and Magniez-Jannin 1973).

Dimensions of figured specimens (mm):

| SCAC 8140 | 0.41 |
| SCAC 8141 | 0.40 |
Occurrence: Most abundant at the base of the Atherfield "group" section but occurs sporadically throughout the section.

Trochammina sp. 1

(Plate 12.2, Figures 16, 17 ad 18)

Remarks: This species is described in open nomenclature even though it is common in the Atherfield "group" section. Preservation and distortion preclude the precise appreciation of the morphological variation and character of the species.

Diagnosis: Test is small, depressed, composed of two to two and one half whorls of five to seven chambers. Finely agglutinated, composed of mafic grains, quartz and calcareous material. Aperture is not visible due to preservation characteristics.

Dimensions of figures specimens (mm):

max. diameter

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8144</td>
<td>0.30</td>
</tr>
<tr>
<td>SCAC 8145</td>
<td>0.36</td>
</tr>
<tr>
<td>SCAC 8146</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Occurrence: Abundant throughout the Atherfield "group" section.

Genus AMMOSPHAERIDINA Cushman, 1910

Type species: *Haplophragmium sphaeroidiformis* Brady, 1884
Ammosphaeroidina minuta Khan, 1950a

1950a *Ammosphaeroidina minuta* Khan; p. 269, pl. 1, figs. 5a-c

1975 *Ammosphaeroidina minuta* Khan: Price; p. 25, pl. 3, fig. 1.

Remarks: This species is rare and 'tops' in the Early/Middle Albian of the studied boreholes in the southern North Sea. This species may in fact be not *Ammosphaeroidina* but be attributable to the genus *Gubkinella*.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily VERNEUILININAE Cushman, 1911

Genus FLOURENSINA Marie, 1938

Type species: *Flourensina douvillei* Marie, 1938

*Flourensina intermedia* ten Dam, 1950

1950 *Flourensina intermedia* ten Dam: p. 15, pl. 1, fig. 16

1977a *Flourensina intermedia* ten Dam; Price: p. 508, pl. 59, figs. 1-2

1977 *Flourensina intermedia* ten Dam; Carter & Hart: p. 7, text fig. 2

Diagnosis: A large, coarsely agglutinated species of *Flourensina* which is triangular in cross section.

Remarks: This very distinctive species was first recorded by ten Dam (1950) from the Late Albian of Holland.
It has been investigated thoroughly by Carter & Hart (1977) and Price (1977a).

Occurrence: This species is diagnostic of the latest Albian of the Anglo-Paris basin (Carter & Hart, 1977). It is found rarely in the North Sea material and is indicative of a Late Albian age (49/24-4).

Genus GAUDRYINA d'Orbigny in de la Sagra, 1839

Type species: Gaudryina rugosa d'Orbigny, 1840

Gaudryina dividens Grabert, 1959

(Plate 12.2, Figures 19 and 20: Plate 13.2, Fig. 15: Fig. 9-11
(as G. compacta))

1959 Gaudryina dividens Grabert: p. 9, pl. 1, figs. 3 - 5, pl. 2, figs. 16 - 30, pl. 3, figs. 53 - 59

Diagnosis: A species of Gaudryina with triserial, tri-biserial and uniserial chamber arrangement.

Remarks: The specimens from the Atherfield "group" agree very well with the species described and illustrated by Grabert (1959) and also agree well with the species described by Magniez-Jannin (in Damotte & Magniez-Jannin 1973) from the Aptian of the Paris Basin. The variation seen in the Atherfield "group" and North Sea borehole specimens is the development of either a small or large biserial portion. The triserial portion is usually small in the earliest Albian. All the tests recovered from the Atherfield "group" are deformed and partially formed of calcareous material. The specimens recovered from Aptian sediments in the
North Sea material have a test where the triserial and biserial portions are equal or nearly so.

Dimensions of figured specimens (mm):

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<th>max. length</th>
<th>max. width</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8147</td>
<td>0.66</td>
<td>0.24</td>
</tr>
<tr>
<td>SCAC 8148</td>
<td>0.56</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Occurrence: Relatively rare in the Atherfield "group" section. Most abundant in sample 5. This species is common in the earliest Early Albian and Late Aptian of the North Sea borehole material. The specimens in the DSDP 549 material were included in the G. dividens - G. compacta plexus. Specimens in the earliest Early Cretaceous have been referred to G. richteri/praedividens (see Grabert, 1959).

*Gaudryina gradata* Berthelin, 1880

(Plate 12.2, Figure 21)

1880 *Gaudryina gradata* Berthelin: p. 24, pl. 1, figs. 6a - c

1975 *Dorothia gradata* (Berthelin); Magniez-Jannin: p. 86, pl. 8, figs. 3-6, text fig. 38

Diagnosis: A large species of *Gaudryina* with inflated chambers and sub-parallel test margins; partially calcareous wall composition? Majority of test is biserial.

Remarks: As with *G. dividens* there have been problems in generic assignments. This has been discussed by
Dimensions of figured specimens (mm):

max. length max. width

SCAC 8149 0.52 0.21

Occurrence: A solitary specimen in sample 12 of the Atherfield "group" section. This species is not uncommon throughout the Albian of the studied North Sea boreholes. It is of limited stratigraphic importance.

Genus GAUDRYINELLA Plummer, 1931

Type species: Gaudryinella delrioensis Plummer, 1931

Gaudryinella sherlocki Bettenstaedt, 1952

(Plate 12.2, Figures 22, 23, 24 and 25)

1952 Gaudryinella sherlocki Bettenstaedt: p. 268, pl. 1, figs. 1 - 5

1938 Bigenerina D2 Hecht: pl. 9b, figs. 27-31

1962 Gaudryinella sherlocki Bettenstaedt; Bartenstein & Bettensaetd: p. 272, pl. 38, fig. 14

1973 Gaudryinella aff. sherlocki Bettenstaedt; Damotte & Magniez-Jannin: p. 22, fig. 13, pl. 3, fig. 12

Remarks: The specimens from the Atherfield "group" section agree in some respects with the form described by
Bettenstaedt (1952) but agree entirely with the form described and illustrated by Damotte & Magniez -Jannin (1973) from the Aptian of the Paris Basin. All the specimens from Atherfield are deformed which makes precise identification and appreciation of any variation difficult. The specimens are siliceous, with calcareous material and are white in colour. The forms from the North Sea boreholes are identical to the illustration of Hecht (1938) and Bartenstein & Bettenstaedt (1962).

Dimensions of figures specimens (mm):

<table>
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<th>max. length</th>
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<tbody>
<tr>
<td>SCAC 8150</td>
<td>0.39</td>
<td>0.12</td>
</tr>
<tr>
<td>SCAC 8151</td>
<td>0.38</td>
<td>0.15 broken</td>
</tr>
<tr>
<td>SCAC 8152</td>
<td>0.26</td>
<td>0.15</td>
</tr>
<tr>
<td>SCAC 8153</td>
<td>0.38</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Occurrence: Abundant in sample 17 and rare in sample 6 of the Atherfield "group". Its occurrence in the North Sea borehole, in association with other taxa, denotes Aptian age strata.

Genus SPIROPLECTINATA Cushman 1927

Type species: _Textularia annectens_ Parker & Jones, 1863

_Spiroplectinata annectens_ (Parker & Jones)

1959 _Spiroplectinata annectens_ (Parker & Jones); Grabert: p. 12-13

266
1975 *Spiroplectinata annectens* (Parker & Jones); Magniez-Jannin: p. 69, pl. 5, figs. 23-24

**Diagnosis:** A moderately sized, compressed, species of *Spiroplectinata*. Test initially triserial, later growth stages are biserial and finally uniserial. Variation is largely due to the length of the uniserial portion. This variability may be a product of microspheric and megalosphoric generations (Ten Dam, 1950; Magniez-Jannin, 1975).

**Remarks:** Grabert has demonstrated very elegantly the usefulness of the *Spiroplectinata* group for biostratigraphy in the Aptian and Albian of Germany. The present author upholds the species separation of Grabert but does consider it a distinct possibility that the "species" recognised by Grabert are members of a sexual trimorphic single species. *S. annectens* may be the microspheric form and *S. complanata* the megalospheric form.

**Occurrence:** Middle and Late Albian and Cenomanian. In the boreholes studied, this species is not common but where recorded does support the Late Albian age assignment.

*Spiroplectinata bettenstaedti* Grabert

1959 *Spiroplectinata bettenstaedti* Grabert: p. 15

**Diagnosis:** An elongate, agglutinated, triserial in early portion, later biserial and then uniserial, test. The biserial portion is predominant (80% of the test). Uniserial portion is rare.
Remarks: Grabert regards this species as common in the Middle Albian and earliest Late Albian. It does range into the Cenomanian. It may be part of a trimorphic single species - see above.

Occurrence: Not very common in the studied boreholes but where present does denote a Middle Albian or younger age.

**Spiroplectinata complanata** (Reuss)

1959 *Spiroplectinata complanata* (Reuss); Grabert: p. 14-15

Diagnosis: Triserial portion very small, becoming biserial and then uniserial. Uniserial portion one or two chambers. Biserial stage predominant.

Remarks: This species may be the megalospheric generation of the same species as *S. annectens*.

Occurrence: Latest Early Albian to earliest Cenomanian. Acme of occurrence in the Middle Albian. It is not very common in the boreholes studied.

**Spiroplectinata lata** Grabert

(Plate 13.2, Fig. 12)

1959 *Spiroplectinata lata* Grabert: p. 16, Taf. 1, Fig. 9, Taf. 2, fig. 31-35, fig. 60-76.

Diagnosis: A very distinct, short but broad species. Initially triserial but developed into a flaring biserial portion which has chambers rapidly increasing in size.
Occurrence: This species occurs in the Early Albian. It is not common in the studied boreholes from the North Sea. It is rare at DSDP site 549, leg 80.

Note: The phylogeny and development of the genus Spiroplectinata is discussed in detail in Grabert (1959). The relationship of this genus with Gaudryina is also discussed in Grabert (1959) - (See Fig. 7.9).

Genus TRITAXIA Reuss, 1860

Type species: Textularia tricarinata Reuss, 1844

Tritaxia pyramidata Reuss

(Plate 13.2, Figs. 13, 14)

1862 Tritaxia pyramidata Reuss: p. 32, 88, pl. 1, figs. 9a-c.

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

1975 Tritaxia pyramidata Reuss; Magniez-Jannin: p. 71, pl. 5, figs. 25-28

Diagnosis: A pyramidal, triserial, triangular cross-section, arenaceous test. 8-10 triserially arranged chambers. There is a tendency in large specimens to develop a very short uniserial stage.

Remarks: There is a wide range of variation in the test shape, test size and concavity of the test sides. Small specimens may be confused with Gaudryina dividentis. Magniez-Jannin (1975) has discussed the evolution of this species in the Albian.
Occurrence: Very common in the Albian and Cenomanian of Europe. Specimens are recorded for Pre-Albian strata (see DSDP site 549, leg 80). It is common in the Albian of the North Sea boreholes. It does range into the Aptian and pre-Aptian strata where it has been recorded by Fletcher (1966) as *T. singularis*.

Genus **UVIGERINAMMINA** Majzon, 1943

Type species: **Uvigerinammina jankoi** Majzon, 1943

**Uvigerinammina alta** Magniez-Jannin, 1975

1973 *Uvigerinammina* sp. Damotte & Magniez-Jannin: p. 23, fig. 14, pl. 3, figs. 9 - 11

1975 *Uvigerinammina alta* Magniez-Jannin: p. 77, pl. 6, figs. 1 - 11

Diagnosis: An elongate species of *Uvigerinammina* with five to ten chambers.

Remarks: This species was first described from the Albian of France by Magniez-Jannin (1975) and was also described from the Lower Aptian of the Paris Basin by Damotte & Magniez-Jannin (1973) as *Uvigerinammina* sp. All the specimens in the Atherfield "group" are distorted, crushed and pyritized.

Occurrence: Rare in sample 6 of the Atherfield "group".

Discussion: Bartenstein (1977) has discussed in detail the occurrence in the Early and Late Cretaceous of species of the genus *Uvigerinammina*. Bartenstein
erected the new genus *Falsogaudryinella* for Early Cretaceous forms (Valanginian to Early Cenomanian). Bartenstein (*op cit*) discusses the various species recorded by authors and the relationships that exist between them. In this thesis the abundances of the genus *Falsogaudryinella* at certain levels in the studied boreholes may be useful for event stratigraphy and correlation.

Bartenstein (1981) regards *F. moesiana* (Neagu, 1965) and *F. triangula* (Fuchs, 1967) as synonymous and essentially Middle to Late Albian in age (triangular in cross-section).

Bartenstein (1981) regards *F. tealbyensis* (Bartenstein, 1956) and *F. alta* (Magniez-Jannin, 1975) as synonymous or at least *F. alta* as a successor to *F. tealbyensis*. The range would be Valanginian to Late Albian (more rounded in section). Bartenstein regards the whole group in the Early Cretaceous as a genetic plexus and justifies the specific distinction of "forma" within the plexus on the basis of stratigraphic utility.

In this thesis no attempt has been made at specific determination but influxes and abundance events are useful for correlation in the Early Cretaceous sections in the boreholes from the southern North Sea. This genus is recorded in the North Sea boreholes as *Falsogaudryinella* spp. group. Specimens of *F. tealbyensis* (microspheric and macrospheric generations) are illustrated in Plate 13.2, Figs. 18, 20.
Genus VERNEUILINOIDES Loeblich & Tappan, 1949

Type species: Verneulina schizea Cushman & Alexander, 1930

Verneuilinoides subfiliformis Bartenstein, 1952

(Plate 12.2, Figure 26)

1952 Verneuilinoides subfiliformis Bartenstein: p. 308, figs. 2 - 3

1973 Verneuilinoides subfiliformis Bartenstein; Damotte & Magniez-Jannin: p. 25, pl. 2, figs. 29 - 31

Diagnosis: Test is narrow, elongate, gently flaring; numerous chambers, with broad rounded outline. Wall siliceous, surface smooth.

Remarks: The specimen from the Atherfield "group" section is very similar to the form described by Damotte & Magniez-Jannin (1973) from the Aptian of the Paris Basin. Haig (1980) places V. subfiliformis in synonymy with V. neocomiensis (Myatliuk, 1939). Bartenstein, however, (1978) has demonstrated the phylogenetic sequence of V. neocomiensis - V. subfiliformis - Dorothia filiformis and its importance for biostratigraphy in north-west Europe and worldwide. This sequence has been recognised in the North Sea Basin.

Dimensions of figured specimen (mm):

max. length max. width

SCAC 8154 0.56 0.13
Occurrence: It is recorded from DSDP site 549, Leg 80 and one specimen in sample 12 from Atherfield, but other specimens have been seen from the Atherfield section (Bidgood, pers. comm.). This species is age diagnostic in the North Sea boreholes, sensu Bartenstein's (1978) sequence in Albian - Aptian - Barremian - Late Hauterivian strata.

Verneuilinoides neocomiensis (Mjatliuk)

1937 Verneuilina D 5 Hecht: pl. 206, figs. 58-60; pl. 13a, fig. 45; pl. 136, fig. 3; pl. 14a, fig. 13; pl. 16a, figs. 70-71; pl. 18b, figs. 61-62; pl. 19b, figs. 73-74.

1939 Verneuilina neocomiensis Mjatliuk: p. 50.

1946 Verneuilina chapmani ten Dam: p. 572, pl. 87, fig. 8

Diagnosis: A narrow, elongate, trilobed in cross section test; triserial chamber arrangement in 7 or 8 rows.

Remarks: This species is very similar to V. subfiliformis but differs by being shorter and broader. The V. neocomiensis - V. subfiliformis - D. filiformis plexus is useful stratigraphically but are at certain levels difficult to distinguish. V. neocomiensis does extend into the Aptian and Albian, though not in great numbers, as an end member of the plexus/population. Commonly the specimens observed from the North Sea are twisted, bent and crushed.

Occurrence: Rare in Early Albian and Aptian, common in Barremian and older sediments in boreholes in the North Sea.

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Subfamily GLOBOTEXTULARIINAE, Cushman 1927

Genus ARENOBULIMINA Cushman, 1927

Type species: Bulimina presli Reuss, 1846

Remarks: This genus has been fully documented by Price (1977a, b) with respect to the occurrence and evolution of various species in the Albian of north west Europe.

More recently Harris (1982) has discussed the generic affinities of the group and the evolution of various species. In this thesis I have recorded a number of species which are useful stratigraphically. Most authors have accepted that the genus Arenobulimina is used, based on entrenchment in the literature (e.g. see Freig & Price, 1982).

Arenobulimina advena (Cushman)

1969 Arenobulimina advena (Cushman); Gawor-Biedowa: p. 86, pl. 8, figs. 1-4, test figs. 7, 8.

1977a Arenobulimina advena (Cushman); Price: p. 508, pl. 59, fig. 3.

Diagnosis: A large species with internal partitions visible in well preserved specimens. Trochospiral arrangement of chambers with the last 3 chambers forming over half the test size. This species has a distinct rounded outline.

Remarks: This species evolves from A. chapmani in the latest Albian.
Occurrence: This species is stratigraphically useful as it evolves in the latest Albian and ranges into the Cenomanian. This species forms a very important part of the latest Albian fauna in the North Sea boreholes.

**Arenobulimina chapmani** Cushman

1977 *Arenobulimina chapmani* Cushman; Carter & Hart: p. 15, pl. 1, fig. 4

1977a *Arenobulimina chapmani* Cushman; Price: p. 508, pl. 59, fig. 4

**Diagnosis:** A large subconical species of *Arenobulimina*. It is very abundant and forms the basic stock for all the other Late Albian species. It is less rounded and more tapered than *A. advena*.

**Remarks:** *A. chapmani* evolved from *A. macfadyeni* during the Middle Albian.

**Occurrence:** Very abundant in the Late Albian of the boreholes from the southern North Sea. It is diagnostic of a Late Albian age.

**Arenobulimina frankei** Cushman

1977a *Arenobulimina frankei* Cushman; Price: p. 508, pl. 59, figs. 5, 6, 9.

**Diagnosis:** A moderately sized species of *Arenobulimina* which is triangular in cross-section.

**Remarks:** This species was originally described from the Cenomanian of Poland by Cushman (1936).
Occurrence: Latest Albian and Cenomanian of North West Europe and is thus stratigraphically useful where found in the North Sea boreholes.

Arenobulimina macfadyeni Cushman

1950 Arenobulimina macfadyeni Cushman; ten Dam: 14

1975 Arenobulimina macfadyeni Cushman; Magniez-Jannin: p. 78, pl. 8, fig. 28

1977a Arenobulimina macfadyeni Cushman; Price: p. 510, pl. 59, figs. 7-8

1977 Arenobulimina macfadyeni Cushman; Carter & Hart: p. 15, pl. 2, Fig. 2

Diagnosis: A small species of Arenobulimina with a smooth surface and a very rounded appearance, evenly tapered.

Remarks: A very distinctive species.

Occurrence: This species occurs rarely in the Early Albian. It is diagnostic of the Middle Albian. Its topmost occurrence in the North Sea boreholes together with C. schloenbachi and C. lamplughi is taken as a reliable indicator for the penetration of Middle Albian sediments.

Arenobulimina sabulosa (Chapman)

1977a Arenobulimina sabulosa (Chapman); Price: p. 510

1977 Arenobulimina sabulosa (Chapman); Carter & Hart: p. 17, pl. 1, Fig. 2.
Diagnosis: A robust, coarsely agglutinated species of *Arenobulimina* which is quadrate in cross-section.

Remarks: This species is very easily confused with *F. intermedia*.

Occurrence: A widely distributed species in the "Gault Clay" of latest Albian age in North West Europe. It occurs rarely in the "Red Chalk" facies of the latest Late Albian in the studied North Sea boreholes.

Discussion: Other specimens of *Arenobulimina* recorded from the North Sea borehole material not assignable to any of the preceding species have been logged as *Arenobulimina* sp. The genus is most abundant in the Late Albian and forms a very important part of the total foraminiferal fauna.

Genus DOROTHIA Plummer, 1931

Type species: *Gaudryina bulletta* Carsey, 1926

*Dorothia filiformis* (Berthelin, 1880)

1975 *Dorothia filiformis* (Berthelin); Magniez-Jannin: p. 83, pl. 8, figs. 1-2

1977 *Dorothia filiformis* (Berthelin); Carter & Hart: p. 7, pl. 1, fig. 3

Diagnosis: A long slender species of *Dorothia* with an early trochospire followed by a biserial stage.

Remarks: This species forms the end member of the *V. neocomiensis* and *V. subfiliformis* lineage.
Occurrence: This species has an overall Aptian to Albian range but is most common in the Middle Albian.

Genus MARSSONELLA Cushman, 1933

Type species: Gaudryina oxycona Reuss, 1860

Marssonella Kummi (Zedler, 1961)

1961 Marssonella Kummi Zedler: p. 31, pl. 7, fig. 1

Diagnosis: Conical, subcircular in cross section test. Initially triserial and then biserial with chambers gradually increasing in size.

Remarks: A raid flaring later portion can give a distinct flanged appearance to some specimens. This species is distinguished from M. oxycona by being smaller and thinner. This species is part of the plexus of forms in the Early Cretaceous identified as M. kummi/hauteriviana.

Occurrence: Early Cretaceous. It is sporadic in occurrence in the North Sea material.

Marssonella subtrochus Bartenstein 1962

(Plate 13.2, Fig. 16)


Diagnosis: A flared conical species of Marssonella.

Occurrence: A flared species which is long ranging (Barremian to Turonian) and is probably a plexus end member of
M. trochus and its ancestor, M. kummi.

Marssonella trochus d'Orbigny

1965 Marssonella trochus (d'Orbigny); Neagu: p. 8, pl. 1, figs. 14-16

1975 Dorothea levis Magniez-Jannin: p. 87, pl. 8, figs. 7-17

Diagnosis: A subconical species of Marssonella.

Remarks: Strongly flared specimens attributable to this species occur in the Red Chalk facies of the UK and in the southern North Sea boreholes.

Occurrence: Rarely in the latest Late Albian.

Marssonella ozawai Cushman, 1936

1975 Dorothea oxycona Cushman; Magniez-Jannin: p. 91, pl. 8, figs. 18-23.

1977 Marssonella ozawai Cushman; Carter & Hart: p. 12, pl. 2, fig. 1.

Diagnosis: A large, elongate species of Marssonella with weakly depressed sutures. Coarsely agglutinated and initially a small triserial portion but majority of test biserial. Later stages of test almost subparallel.

Occurrence: Late Albian to Early Cenomanian in the studied boreholes.

Discussion: The species of Marssonella in the Early Cretaceous described by various authors are in need of
revision in terms of taxonomy and stratigraphic occurrence. All species have been interpreted in various ways by different authors. Poor preservation, ecological variants and difficulties of dealing with large variable populations have exacerbated the situation. The degree of variation in the rootstock in response to ecology may be the underlying factor governing the recognition of such a variety of "species" by different authors throughout the Early Cretaceous. As a result, their stratigraphical value is limited.

Genus EGGERELLINA Marie, 1941

Type Species: Bulimina brevis d'Orbigny, 1840

Eggerellina mariae ten Dam, 1950

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

1977 Eggerellina mariae ten Dam; Carter & Hart: p. 17, pl. 2, fig. 7

Diagnosis: A sub conical species of Eggerellina with inflated embracing chambers.

Remarks: This species is quite distinctive but is also quite variable in shape - short and pyramidal to long and narrow (Carter & Hart, 1977).

Occurrence: Late Albian and Cenomanian and therefore of stratigraphic importance in the boreholes from the southern North Sea.
Family PAVONITINIDAE Loeblich & Tappan, 1961

Sub-family PFENDERININAE Smout & Sugden, 1962

Genus PSUEDOTEXTULARIELLA Barnard in Barnard & Barnes, 1953

Type species: Textulariella cretosa Cushman, 1932

Pseudotextulariella cretosa (Cushman, 1932)

1977 Pseudotextulariella cretosa (Cushman); Carter & Hart: p. 23, pl. 2, fig. 12

Diagnosis: A very large subconical species of Pseudotextulariella with internal partitions.

Remarks: This species is closely related to the genus Marssonella, particularly M. ozawai and M. trochus. P. cretosa is related but possesses internal partitions.

Occurrence: Rare in the Late Albian of the studied boreholes. It is probably environmentally controlled in distribution.

Sub-order MILIOLINA Delage & Herouard, 1896

Superfamily MILIOLACEA Ehrenberg, 1839

Family NUBECULARIIDAE Jones, 1875

Subfamily SPIROLOCULININAE Wiesner, 1920

Genus SPIROLOCULINA d'Orbigny, 1826
Type species: *Spiroloculina depressa* Cushman, 1917

*Spiroloculina papyracea* Burrows, Sherborn & Bailey, 1890

1975 *Spiroloculina papyracea* Burrows, Sherborn & Bailey; Magniez-Jannin: p. 95, pl. 15, figs. 2-4

1977 *Spiroloculina papyracea* Burrows, Sherborn & Bailey; Carter & Hart: p. 24, pl. 1, fig. 6

Diagnosis: A medium sized, compressed species of *Spiroloculina*.

Remarks: A species which is rare but characteristic of the Red Chalk and Gault Clay facies.

Occurrence: Very rare in the studied boreholes but it is characteristic of the Late Albian only.

Subfamily NODOBACULARIINAE Cushman, 1927

Genus NODOBACULARIA Rhumbler, 1895

Type species: *Nubecularia tibia* Jones & Parker, 1860

*Nodobacularia nodulosa* (Chapman, 1891)

1975 *Pseudonubeculina nodulosa* (Chapman); Magniez-Jannin: p. 96, pl. 15, fig. 2

1977 *Nodobacularia nodulosa* (Chapman); Carter & Hart: p. 24, pl. 1, fig. 5

Diagnosis: A test which is always fragmentary, particularly so in drill cuttings, composed of 2 - 3 chambers, joined by narrow tubes.

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Occurrence: Has a uniform distribution in the Early Cretaceous of north west Europe and is of no stratigraphic significance in the North Sea boreholes.

Sub-family QUINQUELOCULININAE Cushman, 1917

Genus QUINQUELOCULINA d'Orbigny, 1826

Type species: *Serpula seminulum* Linne, 1758

*Quinqueloculina antiqua* (Franke, 1928)

1975 *Quinquelocalina antiqua* (Franke); Magniez-Jannin: p. 97, pl. 15, figs. 5-9

1977 *Quinquelocalina antiqua* (Franke); Carter & Hart: p. 25, pl. 1, figs. 7, 8

Diagnosis: A small species of *Quinqueloculina*.

Remarks: A variable species ranging from a short/squat subtriangular and broad test to elongate and compressed. Price (1976) separated this species into two separate species with the same stratigraphic range.

Occurrence: Middle-Late Albian and Early Cenomanian of north west Europe. It is not uncommon in the Late Albian of the studied boreholes.

Sub-order ROTALIINA Delage & Herouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838
Remarks:

The study of the Nodosariidae is notorious for the problems posed for classification both generically (as *Lenticulina*, *Astacolus*, *Marginulina*, *Dentalina*, *Nodosaria*, etc.) and subgenerically. Magniez-Jannin (1975) has discussed this taxonomic problem in some detail with reference to whether the great morphological variation seen in the Nodosariidae should be placed at a generic or sub-generic level. In this study the material available was not sufficient to enable a full appreciation of the generic problems involved and in addition such a study does not constitute an objective of this thesis. The present author has followed the works of Bartenstein (see Bibliography) and Magniez-Jannin (1975) in the assignation of generic and sub-generic names. No taxonomic revision has been attempted by the present author. In some boreholes specimens have been logged as *Lenticulina* spp. unidentified, and/or as *Nodosariids* unidentified.

Genus *LENTICULINA* Lamarck, 1804

Type species: *Lenticulina calcar*, Linne 1758

*Lenticulina* (*Lenticulina*) *crassicosta crassicosta* (Eichenberg, 1933)

1950 *Saracenaria crassicosta* (Eichenberg); ten Dam: p. 25, pl. 2, figs. 10a-b.

Diagnosis: A generally small species of *Lenticulina*, with 7–11 chambers in the test. Marked by three frills/keels on each angle of the triangular, in cross section, test (laminae).
Remarks: Magniez-Jannin (1975) discusses this species (and subspecies) in great detail and remarks on its occurrence and diversity within the Middle and Late Albian of France.

Occurrence: Not common in the material from the North Sea. It is of no great stratigraphic importance.

*Lenticulina (Lenticulina) gaultina* (Berthelin, 1880)

(Plate 12.3, Figure 1)

1880 *Cristellaria gaultina* Berthelin: p. 49, pl. 3, figs. 15, 19

1967 *Lenticulina (Lenticulina) gaultina* (Berthelin); Fuchs: p. 293, pl. 11, figs. 4a – b

1973 *Lenticulina gaultina* (Berthelin); Magniez-Jannin: p. 28, pl. 3, fig. 31

1975 *Lenticulina/Lenticulina – Astacolus/gaultina* (Berthelin); Magniez-Jannin: p. 102, pl. 9, figs. 7 – 8, 10, text-fig. 44

Remarks: This species differs from *L. rotulata* (Lamarck) by the tendency of the last chambers to become higher, to unroll and become uniserial. Juveniles of the two species are particularly difficult to separate.

Occurrence: This species is not very common at Atherfield but it is found throughout the Albian in north-west Europe. Bartenstein (1976a, 1977) includes this species within his Lower Cretaceous benthonic index Foraminifera scheme as it is restricted to the Aptian and Albian stages. It is included in the
group *Lenticulina* spp. in samples from the North Sea boreholes as it has no real stratigraphic significance.

Dimensions of figured specimens (mm):

<table>
<thead>
<tr>
<th>max. diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAC 8155 (Sample 2) 0.5</td>
</tr>
</tbody>
</table>

*Lenticulina (Lenticulina) guttata* (ten Dam, 1946)

1946 *Planularia guttata* ten Dam: p. 574, pl. 88, fig. 2

1962 *Lenticulina (Lenticulina) guttata* ten Dam; Bartenstein & Bettenstaedt: p. 261, pl. 36, fig. 4, pl. 41, fig. 1.

Diagnosis: A very distinctive species of *Lenticulina* of intermediate size, compressed, keeled and characterised by limbate sutures each ornamented with raised pustules (guttiform). Tendency in some specimens for the last chambers to become uncoiled.

Remarks: Fletcher (1966) in his research discusses in detail the variation in this species to the extent of recognising four subspecies. In particular, *L. (L.) guttata* var. *eichenbergi* Bartenstein & Brand is considered to be a ecophenotypic variant.

Occurrence: Essentially *L. (L.) guttata* has a range of Valanginian to Late Aptian but according to Fletcher only *L. (L.) guttata* var. *eichenbergi* ranges above the Barremian. *L. (L.) guttata* S.L. in the Southern North Sea boreholes is only observed in strata of a Pre-Aptian age.
Lenticulina (Lenticulina) heiermanni Bettenstaedt, 1951

1938 Cristellaria D113, Hecht: pl. 17b, fig. 38

1962 Lenticulina (Lenticulina) heiermanni Bettenstaedt; Bartenstein & Bettenstaedt: p. 272, pl. 39, fig. 1

Diagnosis: Involute test of 10-11 chambers with raised limbate sutures, curved backwards toward peripheral margin. At the umbilicus is a clear raised calcite boss to which all sutures are fused. Ragged keel.

Occurrence: Only observed in samples from Pre-Aptian strata in the studied boreholes. It is of stratigraphic significance therefore and is apparently most abundant in the Early Barremian.

Lenticulina (Lenticulina) inaequalis (Reuss, 1860)

1950 Marginulina inaequalis Reuss; ten Dam: p. 22, pl. 2, fig. 3

Diagnosis: A very variable species of Lenticulina which is very similar to L. (M.) schloenbachi (Reuss).

Remarks: Magniez-Jannin (1975) has discussed in detail the variation, and occurrence, of this species in the Albian.

Occurrence: Not common in the material from the southern North Sea and of no real stratigraphical significance.

Lenticulina (Lenticulina) maridalensis Bartenstein & Bolli, 1973

1973 Lenticulina (A.) maridalensis Bartenstein & Bolli: p. 401, pl. 4, fig. 40

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1977 Lenticulina (A.) maridalensis Bartenstein & Bolli; Bartenstein & Bolli: p. 552, pl. 2, figs. 6-8

Remarks: This species is rare in the studied borehole material but is quite distinctive. It has no stratigraphical value except as indicative of Barremian to Albian age sediments. In fact this species may be an aberrant form of closely allied species. It has only been recorded by the present author because it is so distinctive.

Lenticulina (Lenticulina) ex. gr. nodosa (Reuss, 1863)

(Plate 12.3, Figure 6)

1863 Robulina nodosa Reuss: p. 78, pl. 9, fig. 6

1967 Lenticulina (Lenticulina) nodosa (Reuss); Michael: p. 34, pl. 3, figs. 8, 11

1974 Lenticulina (Lenticulina) nodosa (Reuss); Bartenstein: pp. 540-551, pl. 1, figs. 1-2; text fig. 6 (nodosa); pl. 1 figs. 3-17; pl. 2, figs. 5-6, 9-12, 16-17; text figs. 1-7, (nodosa nodosa); pl. 2, figs. 26-27; text figs. 1-2, 2-5, 7, (nodosa hulseana); pl. 2, figs. 26-29, text figs. 1-5, 7, (nodosa barremiana); pl. 2, figs. 7-8, 13-15, text figs. 1, 3, 6, (nodosa gibber).

1976 Lenticulina nodosa (Reuss); Ascoli: Fig. 27; pl. 4, fig. 4; pl. 14, fig. 6.

1976 Lenticulina Lenticulina nodosa (Reuss) group; Aubert & Bartenstein: pl. 1, figs. 1-21; pl. 2, figs. 1-22; pl. 3, figs. 1-8; pl. 4, figs. 1-8.
Remarks: Bartenstein (1974) and Aubert & Bartenstein (1976) have discussed fully the taxonomy and stratigraphical and worldwide distribution of the L. (L.) nodosa group. The material from the North Sea and the Atherfield "group" is too sparse to enable a "splitting" of the specimens into the various subspecies noted by the above mentioned authors. To place it into the new species Lenticulina (L.) kemperi Aubert and Bartenstein created for Aptian "forms" of the Boreal province would be incorrect.

Occurrence: This species is important stratigraphically in north-west Germany. Ascoli (1976) uses its first occurrence downhole to denote the Aptian on the Scotian shelf. However, Michael (1967) states that the L. (L.) nodosa group represents an iterative evolutionary modification of a smooth "lenticuline" rootstock (e.g. L. (L.) muensteri). Therefore, at successive geological times and in different geographical locations (worldwide) in the Lower Cretaceous "forms" (?)homeomorphs) attributable to the L. (L.) nodosa group have developed in response to similar ecological conditions. Ideally, each lineage arising from iterative evolution should be given a species name but in practice this is very difficult especially when dealing with borehole cuttings or when the age of the fauna of which the "form" is a member is not precisely known. Therefore these "forms" are of limited use to a stratigrapher but are useful in palaeoecological reconstruction.

Dimension of figured specimens (mm):

max. diameter

SCAC 8156 (Sample 13) 0.35
**Lenticulina** (*Lenticulina*) **praegaultina** (Bartenstein, Bettenstaedt & Bolli, 1957)

1957 *Lenticulina* (*Lenticulina*) **praegaultina** Bartenstein, Bettenstaedt & Bolli: p. 24, pl. 3, fig. 48; pl. 4, pp. 63-65.

Remarks: Only one specimen was found in the Atherfield "group". This species is characterised by a broad keeled periphery and transparent sutures which are continuous with a calcareous umbilical callus.

Occurrence: This species has a rare occurrence in the Barremian, Aptian and Albian worldwide. It is not common in the samples from the North Sea, the Atherfield "group" or in the samples from DSDP site 549, leg 80.

**Lenticulina** (*Lenticulina*) **rotulata** (Lamarck, 1804)

(Plate 12.3, Figures, 2, 3, 4, 5)


1973 *Lenticulina/Lenticulina/rotulata* (Lamarck); Magniez-Jannin: p. 27, pl. 3, figs. 23-28

1975 *Lenticulina/Lenticulina/rotulata* (Lamarck); Magniez-Jannin: p. 100, pl. 9, figs. 3a-b

Remarks: This species has a closed spire which is regular and a circular periphery which places it distinctively within the morphology of
"Lenticulina". It portrays a remarkable variation in a number of characters which have been discussed by Magniez-Jannin (1975). The specimens from the Atherfield "group" section display the same variation and could conceivably be "split" into a number of morphotypes (species ?) e.g. *Lenticulina subangulata* (Reuss, 1863, p. 74, pl. 8, fig. 7) and *L. macrodisca* (Reuss, 1863, p. 78, pl. 9, fig. 5). Magniez-Jannin (1975) recognises these forms plus others not seen at Atherfield, e.g. *L. roemerii* (Reuss, 1863, p. 75, pl. 8, fig. 9) and *L. secans* (Reuss, 1863, p. 214, pl. 9, fig. 7). *L. rotulata* is similar to *L. heiermanni* Bettenstaedt 1952.

**Occurrence:** This species has been recorded from the Albian and Lower Aptian of France (Magniez-Jannin, 1975). It has no stratigraphical importance as an index species but does illustrate the wide range of variation exhibited by a single species which previous authors have "split" into separate species. Specimens from the North Sea are included in *Lenticulina* spp.

**Dimensions of figured specimens (mm):**

max. diameter

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*Lenticulina (Lenticulina) saxonica* Bartenstein & Brand, 1951

1938 *Cristellaria* D107 Hecht: pl. 18b, figs. 43-49, pl. 22, figs. 28-30
1938 Cristellaria D86 Hecht: pl. 20b, figs. 16

1962 Lenticulina (Lenticulina) saxonica Bartenstein & Brand; Bartenstein & Bettenstaedt: p. 259, pl. 36, fig. 11

Diagnosis: A moderately sized, compressed and distinctly carinate, lenticulinid with limbate and raised sutures which may, or may not, meet at the centre. Keel is usually broken and jagged.

Occurrence: Usually taken to be of pre-Albian age and most abundant in the pre-Aptian (in Early Barremian), though in Germany is considered to 'top' in the Late Hauterivian.

Lenticulina (Lenticulina) schreiteri (Eichenberg, 1935)

(Plate 13.1, fig. 1)

1935 Elphidium schreiteri Eichenberg: p. 398, pl. 13, fig. 11.

1946 Vaginulinopsis reticulosa ten Dam: p. 574, pl. 88, fig. 4

Diagnosis: An elongate compressed test covered in a strong reticulate ornament: this ornament is less regular in the coiled portion than in the uncoiled portion of the test. The distinct keel on early chambers becomes very indistinct in later chambers.

Remarks: The variation in the degree and extent of ornamentation is quite marked from individual to individual and varies from a regular reticulate pattern to a very irregular pattern. Some authors still maintain that L. (L.) schreiteri should be separated from L. (L.) reticulosa. With this the
present author disagrees though such a separation was attempted hence in some boreholes from the North Sea, regular patterned specimens have been designated *L. (L.) reticulosa*.

**Occurrence:** A distinctive species in the Valanginian to Aptian strata of the North Sea boreholes. In the DSDP leg 80, site 549 borehole this species is referred to as subgenus (*marginulina*). This is incorrect.

*Lenticulina* (*Lenticulina*) *ouachensis* (Sigal, 1952)

1938 *Cristellaria D114* Hecht: pl. 22, figs. 34-37

1952 *Cristellaria ouachensis* Sigal: p. 16, fig. 10.

**Diagnosis:** A robust species of *Lenticulina* with a well developed keel and raised limbate sutures and a well developed ornate depressed umbilical area enclosed by a thin prominent rib. This umbilical area may be crossed by other ribs to divide it into two or three portions.

**Remarks:** Fletcher (1966) discussed this species and the three subspecies erected by Bartenstein, Bettenstaedt & Bolli (1957) - *L. (L.) ouachensis ouachensis*, *L. (L.) ouachensis wisselmanni* and *L. (L.) ouachensis multicella*. In the material from the North Sea all specimens are referred to as *L. (L.) ouachensis*.

**Occurrence:** Ranges in Europe from Late Hauterivian to Early Aptian. In the North Sea material it may be in place in Aptian strata (or could be reworked) but in most instances is taken to indicate strata older than Late Aptian in age.
**Lenticulina (Lenticulina) sternalis** type diademata

1975 *Lenticulina (Lenticulina) sternalis* type diademata (Berthelin); Magniez-Jannin: p. 101, pl. 9, figs. 1-2.

Remarks: This rather non descript species of *Lenticulina* has no stratigraphic value. Bartenstein in his revision of Berthelin's (1854) work grouped *L. sternalis* and *L. diademata* together as megalospherical and microspherical generations of the same species. This type of argument typifies the sort of taxonomic problem a stratigrapher has to contend with in his search for reliable biostratigraphic markers. This is really the only reason for identifying this species in this study.

Subgenus *ASTACOLUS* de Montfort, 1808

**Lenticulina (Astacolus) atherfieldensis** sp. nov.

(Plates 12.4, Figs. 10-13; 15.1, 15.2)

1973 *Lenticulina/Marginulina/humilis* (Reuss, 1863); Magniez-Jannin: p. 28, pl. 3, figs. 32-39: *non* Reuss 1863

1981 *Lenticulina (Vaginulina) humilis* (Reuss); Colin et al: p. 127; *non* Reuss 1863

1982 *Lenticulina/Marginulina/humilis* (Reuss, 1863); Crittenden: text fig. 3, *sensu* Magniez-Jannin 1973; *non* Reuss, 1863 in press

1983 *Lenticulina (Astacolus) atherfieldensis* Crittenden;

Description: Test free, elongate and laterally compressed; periphery angled; dorsal outline curved to nearly
straight. Initial chamber globular followed by 3 or 4 planispirally coiled, triangular shaped chambers forming half a whorl; uniserial chambers with oldest ones small and triangular; youngest chambers more wide than high and becoming parallel sided rather than triangular; increase in size as added; chambers inclined; last chamber pointed; chamber wall finely perforate. Sutures straight to slightly curved, oblique, elevated and thickened, non perforate. Aperture terminal and radiate at dorsal peripheral angle of last chamber.

Remarks: This species displays a wide variation in morphological character embracing the morphological "form" of L. (A.) humilis humilis, L. (A.) humilis praecursoria, and L. (A.) neopachynota especially in the degree of suture thickening and the presence of knot like thickenings of the dorsal peripheral margin to impart a "saw" like appearance to the dorsal periphery of some specimens. Test shape varies from a wide low test to a narrow high test and may correspond to "A" and "B" generation forms.

Occurrence: The new species is found in the Early Aptian of the Paris Basin, the Isle of Wight and the Celtic Sea. It has not been recorded by the present author from the southern North Sea or DSDP site 549.

Derivation of name: The species is named from the type locality of the Atherfield "group" section on the Isle of Wight. All specimens are deposited in the Foraminifera collections of the British Museum (N.H.) London.
Holotype: Plate 15.1, Fig. 2, Row C, e, Cat. number: P.51193

Length 0.85 mm, width 0.3 mm, thickness 0.10 mm, chambers 9

Paratypes: Plate 15.1, Fig. 2

Row A: a, Cat. number: P.51196
Length 0.55 mm, width 0.25 mm, thickness 0.15 mm, chambers 8
b, Cat. number: P.51197
Length 1.0 mm, width 0.4 mm, thickness 0.1 mm, chambers 12

Row B: a, Cat. number: P.51198
Length 0.6 mm, width 0.2 mm, thickness 0.13 mm, chambers 7
b, Cat. number: P.51199
Length 0.6 mm, width 0.25 mm, thickness 0.1 mm, chambers 8
c, Cat. number: P.51200
Length 0.4 mm, width 0.2 mm, thickness 0.08 mm, chambers 5

Row C: a, Cat. number: P.51201
Length 1.2 mm, width 0.5 mm, thickness 0.26 mm, chambers 12 (broken)
b, Cat. number: P.51202
Length 1.0 mm, width 0.5 mm, thickness 0.25 mm, chambers 12
c, Cat. number: P.51203
Length 0.9 mm, width 0.5 mm, thickness 0.20 mm, chambers 10 (broken)

d, Cat. number: P.51204

Length 0.85 mm, width 0.3 mm, thickness 0.18 mm, chambers 10

f, Cat. number: P.51205

Length 0.85 mm, width 0.3 mm, thickness 0.2 mm, chambers 12

g, Cat. number: P.51206

Length 0.55 mm, width 0.25 mm, thickness 0.18 mm, chambers 9 (broken)

h, Cat. number: P.51207

Length 0.5 mm, width 0.20 mm, thickness 0.15 mm, chambers 9

i, Cat. number: P.51208

Length 0.45 mm, width 0.20 mm, thickness 0.20 mm, chambers 10

j, Cat. number: P.51209

Length 0.50 mm, width 0.25 mm, thickness 0.15 mm, chambers 6 (broken)

The holotype and all the paratypes are from a single sample taken from the Atherfield "group" at the type section on the Isle of Wight: Sample 23 (see Fig. 12.3).

Type locality: Isle of Wight, Atherfield Point, United Kingdom

Type horizon: Lowermost Early Aptian (Atherfield "group") - Chale Clay Member
Lenticulina (Astacolus) cephalotes (Reuss, 1863)

1975 Lenticulina (Lenticulina-Marginulina) cephalotes (Reuss); Magniez-Jannin: p. 110, pl. 11, figs. 32-34, test fig. 49.

Remarks: This small distinctive species is encountered in the Albian of the North Sea boreholes. Magniez-Jannin (1975) included Cristellaria oligostegia of Reuss (1863) in synonymy. This species has a variable morphology probably due to environmental factors but has no real stratigraphical value. It may be related to L. (L.) maridalensis.

Lenticulina (Astacolus) neopachynota (Bartenstein & Kaever, 1973)

(Plate 15.1, Row B, (d))

1946 Vaginulinopsis pachynota ten Dam: p. 575, Taf. 88, Figs. 5-6

1973 Lenticulina (Vaginulinopsis) neopachynota nom. nov.
Bartenstein & Kaever: p. 223, Taf. 2, Fig. 25-27

Remarks: Rare in the studied borehole material from the North Sea but is usually taken to indicate strata of a Late Hauterivian age. For a fuller discussion see Chapter 15. L. (A.) sp. aff. neopachynota was identified and photographed from sample 56cc, DSDP site 549, leg 80. Poor preservation however precludes precise assignment.

Lenticulina (Astacolus) scitula (Berthelin, 1880)

1966 Lenticulina (A.) scitula (Berthelin); Bartenstein, Bettenstaedt & Bolli: p. 149, pl. 2, figs. 147-150
Remarks: A small distinctive but rare species of no stratigraphical value. It ranges from Barremian to Late Albian. It is similar to L. (M.) schoenbachi.

*Lenticulina* (Astacolus) *crepidularis/tricarinella* (Roemer, 1842).

(Plate 13.1, Fig. 2)

1842 *Planularia crepidularis* Roemer: p. 273, pl. 7B, fig. 4

1863 *Cristellaria tricarinella* Reuss: p. 68, pl. 7, fig. 9; pl. 12, figs. 2-4

1962 *Lenticulina* (Planularia) *crepidularis* (Roemer); Bartenstein & Bettenstaedt: p. 260, pl. 36, fig. 7

Remarks: This distinctive species is very common in the Early Cretaceous throughout Europe. Fletcher (1961) discusses this species in detail and the present author follows his argument in defining the species. It ranges from Late hauterivian, where it is most common, to Early and Middle Barremian strata, and to the Early Aptian where it is rare. It is present in the North Sea borehole material in samples which are pre-Aptian in age. However specimens of Early Aptian age have been recorded from borehole material in the south east of England (Surrey & Kent) by Jaworski (pers. comm.). Hart et al. (1981) record this species as an index of Jurassic to Early Aptian age.

Subgenus MARGINULINA d'Orbigny 1826

Type species: *Marginulina raphanus* d'Orbigny 1826

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Lenticulina (Marginulina) acuticostata (Reuss, 1863)

1863 Marginulina robusta Reuss: p. 63, pl. 6, figs. 5-6

1863 Marginulina acuticostata Reuss: p. 62, pl. 6, figs. 3a-b

1863 Marginulina aequivoca Reuss, p. 60, pl. 5, fig. 17

1863 Marginulina tenuissima Reuss, p. 61, pl. 5, fig. 18; p. 92, pl. 12, fig. 12

1975 Lenticulina (Marginulina) restricta Magniez-Jannin: p. 115, pl. 10, figs. 24-31, test fig. 51

Remarks: This diverse species "group" is quite common in the Albian material from the southern North Sea. Magniez-Jannin (1975) has discussed their fine stratigraphic use in the Albian of the Aube district of France. Her approval of "type" separation (see fig. 52 of Magniez-Jannin, 1975) is not followed in this thesis due to the nature of the samples (ditch cuttings/caved material). This species has therefore no real stratigraphical value in the North Sea material.

Lenticulina (Marginulina) bettenstaedti (Bartenstein & Brand, 1951)

1962 Lenticulina (Marginulinopsis) bettenstaedti Bartenstein & Brand; Bartenstein & Bettenstaedt: p. 267, Tab. 17, Taf. 36, fig. 6

Remarks: This species is not very common in the material from the North Sea boreholes. It is attributed an Early Hauterivian to Late Barremian range by Bartenstein & Bettenstaedt (1962) though in
borehole 49/24-12 its top occurrence is in Late Aptian - Early Albian strata. This species is characteristic of the Lower Holland Marl Member.

**Lenticulina (Marginulina) costulata** (Chapman, 1894)

1894C *Cristellaria costulata* Chapman: p. 649, pl. 9, fig. 10

**Remarks:** This species is very similar to *L. (M.) striatocostata*. It differs by having a well developed initial coil, by being smaller (in general). The two species co-exist and may even be end members of the same species. Stratigraphically this species is not important.

**Lenticulina (Marginulina) foeda** (Reuss, 1863)

1863 *Cristellaria foeda* Reuss: p. 64, pl. 6, figs. 11-12

1956 *Lenticulina (Marginulinopsis) foeda* (Reuss): Bartenstein; p. 516, pl. 2, figs. 57-58

**Diagnosis:** A small elongate test, circular in cross section. Surface of test strongly hispid, with a terminal aperture on a tubular neck. The intensity of ornament is variable. The hispidity of the test distinguishes this species from *L. (M.) gracillissima* which is smooth.

**Occurrence:** Rarely in the studied boreholes from the North Sea. It is encountered in the Aptian strata in boreholes 49/24-12 and 49/25-1. It is of some stratigraphic importance.
Lenticulina (Marginulina) gracillissima (Reuss, 1863)

1863 Cristellaria gracillissima Reuss: p. 64, pl. 6, figs. 9-10

Diagnosis: A small elongate test, circular in cross-section. Smooth test, no ornamentation. Otherwise identical to L. (M.) foeda.

Occurrence: Rarely in the studied North Sea boreholes. It is Early Aptian to Barremian to Hauterivian in age.

Lenticulina (Marginulina) jonesi group (Reuss, 1863)

1863 Marginulina jonesi Reuss: p. 61, pl. 5, figs. 19a-b

1975 Lenticulina/Marginulina/jonesi (Reuss); Magniez-Jannin: p. 125, pl. 10, figs. 34-35, test-fig. 57

Remarks: This species group is common in the Albian section of the studied boreholes from the North Sea. Magniez-Jannin (1975) has discussed in detail the taxonomic variability of this species. This species has no stratigraphical importance.

Lenticulina (Marginulina) aff. parallela (Reuss, 1863)

(Plate 12.3, Figs. 14, 15)

1863 Cristellaria parallela Reuss: p. 67, pl. 7, figs. 1-2

1973 Lenticulina/Marginulina/ aff. parallela (Reuss); Magniez-Jannin: p. 29, text-fig. 16.

Remarks: An elongate "lenticuline" species which is compressed, has 2-6 chambers in the enrolled stage,
with 3-5 in the uniserial stage, has an angular dorsal periphery, a compressed oval cross-section, and depressed slightly curved sutures.

Occurrence: Although very rare in the Atherfield "group" section studied this species appears very similar to that described by Magniez-Jannin (1973) from the Lower Aptian of the Paris Basin and to the illustrations of Reuss (1863).

Dimensions of figured specimens (mm):

max. diameter

SCAC 8162 (Sample 18) 0.63

Lenticulina (Marginulina) schloenbachi (Reuss, 1863)

(Plate 12.3, Figs. 10, 11, 16)

1863 Cristellaria schloenbachi m. Reuss: p. 65, pl. 6, figs. 14 - 15

1938 Cristellaria D 63 Hecht: pl. 6a, figs. 76 - 80

1973 Lenticulina Marginulina aff. schloenbachi (Reuss); Magniez-Jannin: p. 29, text-fig. 15

1981 "Lenticulina" schloenbachi (Reuss); Hart et al: p. 208, pl. 7.18, fig. 5

Remarks: This species is similar to Lenticulina Astacolus pachynota (ten Dam) (= L. (A.) neopachynota Bartenstein & Kaever 1973) but differs in lacking the limbate, elevated sutures and is not so laterally depressed.
Occurrence: Although occurring very rarely in the Atherfield "group" section its presence is important as it has been previously recorded in the U.K. only from the Upper Ryazanian to the Lower Barremian of Speeton. It occurs frequently in the North Sea boreholes. It has no stratigraphic importance as it ranges up through the Albian.

Dimensions of figured specimens (mm):

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Subgenus PLANULARIA Defrance in De Blainville, 1862

*Lenticulina (Planularia) complanata* (Reuss, 1845)

1975 *Lenticulina/Planularia/complanata* (Reuss); Magniez-Jannin: p. 151, Pl. 9, figs. 26-38, text fig. 83

Remarks: This typically Albian species is rare in the material from the southern North Sea. Its presence substantiates an Albian age but because of its sporadic and rare occurrence has no real stratigraphical value.

*Lenticulina (Saracenaria) planiuscula* (Reuss, 1863)

(Plate. 12.3, Figs. 12, 13)

1863 *Cristellaria planiuscula* m. Reuss: p. 71, pl. 8, fig. 15
1880 *Cristellaria planiuscula* Reuss; Berthelin: p. 53, pl. 3, fig. 25

1954 *Lenticulina planiuscula* (Reuss); Bartenstein: p. 46

1966 *Lenticulina (Astacolus) planiuscula* (Reuss); Bartenstein, Bettenstaedt & Bolli: p. 148, pl. 2, figs. 142 - 146

1973 *Lenticulina (Astacolus) planiuscula* (Reuss); Bartenstein & Bolli: p. 402

Remarks: A distinctive species which is not very common in the Atherfield "group" section. It has no real stratigraphical value.

Dimensions of figured specimens (mm):

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Subgenus *SARACENARIA* Defrance in De Blainville, 1824

*Lenticulina (Saracenaria) bononiensis* (Berthelin, 1880)

1880 *Cristellaria bononiensis* Berthelin: p. 55, pl. 3, fig. 23a-c

1975 *Lenticulina/Saracenarea/bononiensis* (Berthelin); Magniez-Jannin: p. 184, pl. 13, figs. 16-21

Remarks: This species is typical of the Albian sediments in north west Europe. It is a strongly variable species.

Occurrence: Not common in the studied material and of no real stratigraphical importance but is reported to be more common in the Middle and Late Albian.
Lenticulina (Saracenaria) bronni (Roemer, 1841)

1841 Planularia bronni Roemer: p. 97, pl. 15, fig. 14

Remarks: This is a ubiquitous species, though rare in the studied boreholes, of no real stratigraphical importance. It has been recorded by various authors throughout the Early Cretaceous.

Lenticulina (Saracenaria) frankei ten Dam, 1946

(Plate 13.1, Fig. 3)

1957 Lenticulina (S.) frankei ten Dam; Bartenstein, Bettenstaedt & Bolli: p. 33, pl. 3, fig. 60

1973 Lenticulina (S.) frankei ten Dam; Bartenstein & Kaever: p. 235, fig. 5

Occurrence: This rare, but distinctive triangular in cross section, species is a long ranging species: Hauterivian to Early Aptian. Its sporadic occurrence negates its use as a precise stratigraphical index species. It is part of the L. (S.) frankei - L. (S.) forticosta - L. (S.) spinosa phylogenetic sequence.

Lenticulina (Saracenaria) forticosta Bettenstaedt, 1952

1973 Lenticulina (Saracenaria) forticosta Bettenstaedt; Bartenstein & Kaever: p. 233, pl. 5, fig. 78

Occurrence: A very distinctive species of Early Barremian to Early Aptian age. Rare in the boreholes from the southern North Sea.
Lenticulina (Saracenaria) cf. L. (S.) jarvisi (Brotzen)

Astacolus jarvisi Brotzen: p. 57, pl. 3, fig. 5

Occurrence: A rare species of no stratigraphical importance. It does reflect the tendency, common to this genus, for various species to become uncoiled and assume a triangular cross-section at various stratigraphical levels.

Lenticulina (Saracenaria) spinosa (Eichenberg, 1935)

1966 Lenticulina (S.) spinosa (Eichenberg); Bartenstein, Bettenstaedt & Bolli: p. 151, pl. 3, figs. 238-242, 256-259

1973 Lenticulina (S.) spinosa (Eichenberg); Bartenstein & Kaever: p. 235, pl. 6, fig. 94

Remarks: A rare, but very distinctive species due to its triangular cross section and spinose inner angles of each chamber. It appears to have evolved/developed from the L. (S.) frantesi, L. (S.) forticosta lineage during the latest Barremian and Early Aptian.

Occurrence: Not common in the studied boreholes but nevertheless is a very useful index fossil. Its topmost occurrence invariably indicates strata of a Late Aptian age.

Genus DARBYELLA Bartenstein, 1956

Type species: Darbyella macfadyeni Bartenstein, 1956
Darbyella macfadyeni Bartenstein, 1956

1956 *Darbyella macfadyeni* Bartenstein: p. 517, pl. 2, fig. 51

1973 *Darbyella macfadyeni* Bartenstein; Bartenstein & Kaever: p. 228, pl. 3, fig. 51, pl. 4, fig. 52

Remarks: This distinctive small foraminiferid is rare in the North Sea material. It has been recorded from the Late Hauterivian of northern England. Its stratigraphical range in North West Europe is uncertain hence its stratigraphical utility in the North Sea material is uncertain but specimens are recorded throughout the studied sections. Some specimens have been assigned to *Darbyella* sp. The present author refers specimens to this genus though does agree with Loeblich & Tappan (1964) in regarding this genus as an abnormal asymmetrical form of the genus *Lenticulina*. Strictly speaking such aberrant forms should not be given distinct generic status.

Genus NODOSARIA Lamarck, 1812

Type species: *Nautilus radicula* Linne, 1758

*Nodosaria harrisi* (Vieaux, 1941)

(Plate 12.3, Fig. 17)

1941 *Nodosaria harrisi* Vieaux: p. 625, pl. 85, fig. 4

1973 *Lenticulina/Nodosaria/harrisi* (Vieaux); Magniez-Jannin: p. 33, pl. 4, figs. 12 - 13
Remarks: A species characterised by globular chambers separated by depressed sutures and by the high lamellar ribs; these are depressed as they cross the sutures and join together at the summit of the last chamber to form a small collar around the fine apertural neck.

Occurrence: This species is recorded from the Aptian and Albian of the Paris Basin (Magniez-Jannin 1973, 1975) and has no stratigraphical value.

Dimensions of figured specimen (mm):

max. length

SCAC 8166 (Sample 24) 0.6

Nodosaria obscura Reuss, 1845

1938 Nodosaria D53 Hecht: pl. 8a, figs. 17-18

1957 Nodosaria obscura Reuss; Bartenstein, Bettenstaedt & Bolli: p. 36, pl. 5, fig. 10, pl. 6, fig. 129

Remarks: This is a very variable but distinctive species which is identified by the dominant laminar costae and central tubular apertural neck. Nodosaria pyramidalis Koch differs by its eccentric apertural neck. It is of Early and Late Cretaceous age but in the samples from the studied boreholes is of ?Aptian and older age.

Nodosaria paupercula Reuss, 1845

1845 Nodosaria paupercula Reuss: p. 26, pl. 12, fig. 12
Remarks: A rare but non-descript species of no stratigraphic value. It is recorded throughout the Early Cretaceous.

Nodosaria proboscidea Reuss, 1861

1861 Nodosaria proboscidea Reuss: p. 7, pl. 1, fig. 6

Remarks: A rare non-descript, non-stratigraphically useful species. This species may be part of a plexus including N. obscura, N. harrisi and N. zippei.

Nodosaria pyramidalis Koch, 1851

1851 Nodosaria pyramidalis Koch: p. 173, pl. 24, fig. 8

1957 Marginulina pyramidalis Koch; Bartenstein, Bettenstaedt & Bolli: p. 34, pl. 5, fig. 100, pl. 6, fig. 132

Remarks: This species is very similar to N. obscura but differs in having an eccentrically placed apertural neck. The species has thin narrow costae over the whole test, and are easily damaged.

Occurrence: Rare in the studied boreholes but generally is pre-Aptian in age. It has therefore some stratigraphic significance.

Nodosaria sceptrum Reuss, 1863

1965 Nodosaria sceptrum Reuss; Neagu: p. 21-22, pl. 5, fig. 10

Remarks: This ubiquitous species ranges in North West Europe from Valanginian to Albian in age.
Nodosaria zippei Reuss, 1845

1950 Nodosaria zippei Reuss; ten Dam: p. 27

Remarks: A rare non age diagnostic but distinctive nodosariid.

Genus CITHARINA d'Orbigny in de la Sagra, 1839

Type species: Vaginulina (Citharina) strigillata Reuss, 1846

Citharina pseudostriatula Bartenstein & Brand, 1951

1956 Citharina striatula (Roemer); Bartenstein: p. 518, pl. 2, fig. 26, 28 (non striatula Roemer)

Remarks: A rare, small triangular active test, with a globular proloculus followed by six to twelve curving chambers. Longitudinal costae cover the test parallel to the ventral and dorsal margins and bifurcate distally.

Occurrence: In the North Sea material it is rare and is pre-Aptian in range and most likely pre-Barremian according to Bartenstein & Kaever (1973).

Citharina aff. sparsicostata (Reuss, 1863)

(Plate 12.3, Figs. 18, 19)

1863 Vaginulina sparsicostata m. Reuss: p. 50, pl. 4, fig. 4

1938 Vaginulina D25, D26, D28, Hecht: pl. 21, figs. 1-6a

1951 Citharina sparsicostata (Reuss); Bartenstein & Brand: p. 297, pl. 19B, figs. 45-46
1973 *Citharina* aff. *sparsicostata* (Reuss); Magniez-Jannin: p. 34, pl. 4, figs. 1-4

1981 *Citharina* *sparsicostata* (Reuss); Hart et al: p. 184, pl. 76, fig. 14

Remarks: The large compressed, triangular outline, keeled dorsal margin, limbate sutures and costate ornament characterise the specimens from the Atherfield "group" and place it specifically very close to *C. sparsicostata* (Reuss). Magniez-Jannin has reported an identical species from the Lower Aptian of France.

Dimensions of figured specimens (mm):

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*Citharina* aff. *discors* Koch, 1851

(Plate 12.3, Fig. 20)

1981 *Citharina* of. C. *discors* (Koch); Hart et al; p. 184, pl. 7.6, figs. 9, 10

Remarks: The compressed subtriangular test with 12-15 low broad chambers following an ellipsoidal proloculus coupled with the distinctly oblique sutures partially obscured by strong longitudinal costae place the specimen found at Atherfield very close to the species of Koch.
Dimensions of figured specimen (mm):

max. length  max. width

SCAC 8169 (Sample 4) 1.0  0.4

*Citharinella didyma* (Berthelin, 1880)

1975 *Citharinella didyma* (Berthelin, 1880); Magniez-Jannin: p. 213, pl. 14, fig. 10

Remarks: A single specimen from the Middle Albian of 49/24-12 is identical to the specimens illustrated by Magniez-Jannin (1975). It may be synonymous with *F. filocincta*. In this thesis this genus is separated from *F. didyma* by its stratigraphic appearance, the latter species appearing only in borehole 49/24-12 as a single specimen in the Barremian.

Genus *FRONDICULARIA* Defrance in d’Orbigny, 1826

Type species: *Frondicularia inversa* Reuss, 1844

Remarks: The genus *Frondicularia* is quite interesting taxonomically as many authors have either placed certain species in this genus or in the genus *Citharina*, or *Citharinella*. Further complication arises as similar equivocation has occurred regarding specific assignation. The group is very diverse in shape and ornament and appears to be a reflection of environment, stratigraphic age and megalospherical/microspherical generations. For instance Hecht identified a number of *Frondicularia* species, D6, D7, D9, D20, D22, which can all be
placed within the variability of one species, namely *Frondicularia concinna* Koch (see Fletcher, 1966).

**Frondicularia concinna** Koch, 1851

1967 *Frondicularia concinna concinna* Koch; Michael: p. 57, pl. 5, fig. 6

Remarks: A very variable species rare in the studied material from the North Sea. It is long ranging within the Early Cretaceous but in Helgoland and Germany is recorded only from the Late Hauterivian to Late Barremian. Despite this it is considered, due to its sporadic and rare occurrence to be of no real stratigraphic importance *per se*. However it is an important member of an assemblage and as such does provide supporting age evidence where it does occur. This species is very similar to *Frondicularia didyma* and may in fact be part of that plexus.

**Frondicularia didyma** Berthelin, 1880

Remarks: This species has been discussed under *C. didyma*. The generic distinction is purely due to stratigraphic reasons coupled with previous author usage (Bartenstein & Kaever, 1973). This species is recorded in well 49/24-12 only.

**Frondicularia filocincta** Reuss, 1863

1975 *Frondicularia filocincta* Reuss; Magniez-Jannin: p. 201, pl. 14, figs. 17-22, text fig. 108

Remarks: A variable species reputedly common in the Albian but rare in the studied borehole material. Has no real stratigraphic use.
Frondicularia cf. F. gaultina Reuss, 1860

1975 *Frondicularia gaultina* Reuss; Magniez-Jannin: p. 201, pl. 14, fig. 16

Remarks: Extremely rare specimens recorded from the North Sea material showed some similarity to the species of Reuss. No stratigraphical value.

Frondicularia hannoverana (Bartenstein, 1948)

1973 *Frondicularia hannoverana* (Bartenstein); Bartenstein & Kaever: p. 231, pl. 5, figs. 79-80

Remarks: This species is essentially Barremian in range in North West Europe. It is relatively large and quite distinctive. It is rare in the North Sea material.

Frondicularia hastata Roemer, 1842

1973 *Frondicularia hastata* Roemer; Bartenstein & Kaever: p. 226, pl. 3, fig. 40

Remarks: This is a large, distinctive, slim, spear shaped, unornamented species quite readily separated from the other species of *Frondicularia* in the studied material. It indicates, apparently, an Hauterivian-Barremian age. It is of limited use as it is rare in the North Sea material.

Frondicularia sp.

Remarks: A single, broken and badly preserved specimen was recovered from the Atherfield "group" section. The proloculus and last chambers were missing.
Genus VAGINULINA d'Orbigny, 1826

Type species: Nautilus legumen Linne, 1758

Vaginulina aptiensis Eichenberg, 1935

Vaginulina arguta Reuss, 1860

Remarks: This species differs from V. recta in its greater number of chambers (8-12). In the North Sea material it is not common but in north west Germany is used to indicate strata of Early Barremian to Late Albian age. It is a distinctive species, being long and thin.
Vaginulina Kochi Roemer, 1841

1952 Vaginulina Kochi Roemer; Albers: p. 89, pl. 5, fig. 2; text figs. 16-19

1962 Vaginulina Kochi Roemer; Bartenstein & Bettenstaedt: p. 261, pl. 36, fig. 5

Remarks: Morphologically this species is close to V. arguta Reuss but is smooth and lacks the prominent sutural ribs of V. arguta. It has been recorded rarely in the North Sea material and is thus of limited stratigraphical value. It has a stratigraphic range of Late Valanginian to Late Barremian in Germany but has been recorded through to the Albian by Price (1977a, b) and Magniez-Jannin (1975). Magniez-Jannin (1975) and Price (1977a, b) between them group V. kochi, V. truncata and V. striolata together with V. gaultina Berthelin, V. kochi and V. recta. This illustrates the taxonomic diversity of opinion in the literature about the genus Vaginulina in the Early Cretaceous of North West Europe probably because single specimens have been studied rather than whole populations.

Vaginulina mediocarinata ten Dam, 1951

1950 Vaginulina mediocarinata ten Dam: p. 36-37, pl. 3, fig. 3

Remarks: This species, in North West Europe, ranges throughout the Albian. However, in the North Sea material it is very rare but does provide supporting evidence for an Albian age. Carter & Hart (1977) regard it as typical of the late Albian "Gault facies".
**Vaginulina procera** Albers, 1952

1967 *Vaginulina procera* Albers; Michael: p. 54, pl. 5, fig. 19 (non fig. 20), pl. 14, fig. 2-5, 11, 18

1973 *Vaginulina procera* Albers; Bartenstein & Kaever: p. 230, pl. 4, figs. 65-66, 69-72, pl. 5, figs. 83-84

Remarks: This distinctive but uncommon species in the North Sea material (see illustrations of Bartenstein & Kaever, 1973) has an accepted range of Early Barremian to Early Aptian.

**Vaginulina recta** Reuss, 1893

1863 *Vaginulina recta* Reuss: p. 48, pl. 3, figs. 14, 15a-b

Remarks: This species ranges throughout the Albian. It is distinct but not very common in the studied boreholes. It is of very limited stratigraphical use.

**Vaginulina riedeli** Bartenstein & Brand, 1951

1951 *Vaginulina riedeli* Bartenstein & Brand: p. 295, pl. 19A, figs. 31-32

1962 *Vaginulina riedeli* Bartenstein & Brand; Bartenstein & Bettenstaedt: p. 262, table 17, pl. 35, fig. 21, pl. 38, fig. 4

Remarks: This species is diagnostic of the Late Valanginian in N.W. Germany. It is recorded in the Hauterivian of Speeton (Fletcher 1966). Its stratigraphic use is limited by the uncertainty of
its stratigraphic range but it would appear to be diagnostic of strata older than Barremian. \( V. \) weigelti Bettenstaedt is a closely related species.

**Vaginulina robusta** (Chapman, 1894)

1950 *Vaginulina robusta* (Chapman); ten Dam: p. 35, text fig. 3

1952 *Vaginulina robusta* (Chapman); Albers: p. 92, pl. 5, figs. 3-5

Remarks: A rare species in the North Sea material similar to \( V. \) *arguta* in appearance and also to \( V. \) *kochi*. Indeed some authors have placed *robusta* as a subspecies of \( V. \) *truncata* while some authors have placed \( V. \) *truncata* as a subspecies of \( V. \) *kochi*. This epitomises the taxonomic diversity of opinion existing in the identification of species within the genus *Vaginulina*. In France this species is Late Albian in age. In N.W. Europe this species has an accepted range of Early Barremian to Albian.

**Vaginulina striolata** Reuss, 1863

1863 *Vaginulina striolata* Reuss: p. 46, pl. 3, fig. 7

1967 *Vaginulina striolata* Reuss; Michael: p. 53, pl. 5, fig. 12, pl. 12, fig. 11, pl. 14, fig 17


Remarks: This species is rare in the studied borehole material from the North Sea. It is very similar to \( V. \) *arguta* but differs in possessing numerous costae. It has a stratigraphic range in N.W.
Europe of Late Valanginian to Late Albian. Magniez-Jannin (1975) places this species as a subspecies of *V. kochii* (Reuss).

**Vaginulina truncata** Reuss, 1863

1863 *Vaginulina truncata* Reuss: p. 47, pl. 3, fig. 9

Remarks: Price (1977a, b) regarded this species as ubiquitous in the Albian of N.W. Europe. Magniez-Jannin (1975) records this species as a subspecies of *V. kochii*. It is of little stratigraphical value in the studied borehole material from the southern North Sea.

**Vaginulina weigelti** Bettenstaedt, 1952

1967 *Vaginulina weigelti* Bettenstaedt; Michael: p. 55, pl. 6, fig. 4, pl. 13, fig. 4, pl. 14, fig. 7

1973 *Vaginulina weigelti* Bettenstaedt; Bartenstein & Kaever: p. 232, pl. 5, fig. 75, pl. 6, fig. 112

Remarks: A very distinctive species, characterised by a chamber form and arrangement like that of *Marginulina*. Michael (1967) records this species only from Barremian age sediments in north west Germany. It occurs in only one of the studied boreholes from the southern North Sea. This species may have evolved from *V. riedeli*.

**Vaginulina sp.**

(Plate 1, Fig. 21)
Remarks: The poor preservation of the single specimen found in the Atherfield "Group" precludes a precise specific determination. It is similar to V. kochi Roemer as it has a smooth test surface.

Dimensions of figured specimen (mm):

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Genus DENTALINA Risso, 1826

Type species: Nodosaria (Dentalina) cuvieri d'Orbigny, 1826

Dentalina communis (d'Orbigny, 1826)

1826 Nodosaria (Dentalina) communis d'Orbigny: p. 254

1973 Dentalina communis (d'Orbigny); Bartenstein & Bolli: p. 404, pl. 5, figs. 45-56

Remarks: This species is morphologically similar to the recent Dentalina communis as originally illustrated by d'Orbigny, 1840. It has no stratigraphical use. It is present in the studied North Sea boreholes and in the DSDP leg 50 site 549 borehole.

Dentalina distincta Reuss, 1860

1966 Dentalina distincta Reuss; Bartenstein, Bettenstaedt & Bolli: p. 153, pl. 3, figs. 203-204, 209, 217

Remarks: An uncommon species with no stratigraphical utility in this study.
Dentalina linearis (Roemer, 1841)

1966 Dentalina linearis (Roemer); Bartenstein, Bettenstaedt & Bolli: p. 153, pl. 3, fig. 205

Remarks: A rare species of no stratigraphical utility.

Dentalis spp.

Remarks: Most of the specimens of Dentalina recorded from the borehole material of the southern North Sea were not identified at species level. No stratigraphic utility would be gained by doing so. Consequently specimens were recorded in open nomenclature as Dentalina spp.

Genus LAGENA Walker & Jacob in Kanmacher, 1798

Type species: Serpula (Lagena) sulcata, Walker & Jacob, 1798

Lagena oxystoma Reuss, 1858

1951 Lagena oxystoma Reuss; Bartenstein & Brand: p. 318, pl. 10, fig. 331, pl. 13, fig. 354-356

1962 Lagena oxystoma Reuss; Bartenstein & Bettenstaedt: p. 255, pl. 35, fig. 8

Remarks: A very distinctive species of Lagena in the Early Cretaceous of North West Europe. It has a stratigraphical range of Valanginian to Aptian. Levels of abundance may be useful for correlation. This species was not recorded in sufficient numbers from the studied North Sea borehole material to be useful for correlation or for age determination.
Some specimens have been recorded in the North Sea borehole material as *L. cf. L. oxystoma*.

**Lagena app.**

Remarks: A number of specimens of Lagena have not been assigned to a species. They are not common and are of no stratigraphical use.

**Genus RECTOGLANDULINA Loeblich & Tappan, 1955**

Type species: *Rectoglandulina appressa* Loeblich & Tappan, 1955

*Rectoglandulina mutabilis* (Reuss, 1863)

1966 *Rectoglandulina mutabilis* (Reuss); Bartenstein, Bettenstaedt & Bolli: p. 154, pl. 3, figs. 231-235

Remarks: This is a relatively common and distinctive species, particularly in the Albian section of the studied boreholes. This species is short, wide and "stumpy" when compared to the larger, more chambered, slimmer *R. humilis* (Roemer, 1841).

*Rectoglandulina humilis* (Roemer, 1841)

1966 *Rectoglandulina humilis* (Roemer); Bartenstein, Bettenstaedt & Bolli: p. 155, pl. 3, figs. 246-247

Remarks: A relatively common and distinctive species which perhaps forms an end member of a plexus: *R. mutabilis* - *R. humilis*. In fact Magniez-Jannin (1975) places both of these two species together as *Pseudonodasaria humilis* (Roemer, 1841) and discusses this group in some detail. Some specimens have been recorded from the studied North Sea borehole material.
Sea material as *R. mutabilis/humilis*. An interesting point noted in this study is that many of the tests had boring holes in them; perhaps sponge borings - *Cliona* sp., or boreholes by gastropods preying on the foraminifera.

Subfamily LINGULININAE Loeblich & Tappan, 1961

Genus LINGULINA d'Orbigny, 1826

Type species: *Lingulina carinata* Cushman, 1913

*Lingulina* Loryi (Berthelin, 1880)

1966 *Lingulina loryi* (Berthelin); Bartenstein, Bettenstaedt & Bolli: p. 155, pl. 3, figs. 243-245.

Remarks: This distinctive species is rare in the studied material. It has no stratigraphic utility in this study.

Family POLYMORPHINIDAE d'Orbigny, 1839

Remarks: Polymorphinids of various types were observed in the North Sea material and DSDP material. Specimens with a fistulose development were common but of no correlation or biostratigraphical age potential. Such fistulose forms may be assignable to *Globulina prisca* (Reuss, 1863), a species common in the Albian of north west Europe (Magniez-Jannin, 1975).

Genus GLOBULINA d'Orbigny in de la Sagra, 1839

Type species: *Polymorphina (Globulina) gibba* d'Orbigny, 1826
Globulina sp.

(Plate 12.3, Fig. 22)

Remarks: Only one crushed specimen very similar to the species recorded by Bartenstein & Bolli (1977) from the Lower Aptian Cuche Formation of Trinidad as *Globulina prisca* (Reuss), was found in the Atherfield "group" section. Magniez-Jannin (1973) records *G. aff. lacrima* (Reuss) from the Aptian of the Paris Basin. Various *Globulina* species observed in the North Sea borehole material were not recorded as they have no stratigraphical utility.

Dimension of figured specimen (mm):

max. length

SCAC 8171 (Sample 21) 0.5

Genus EOGUTTULINA Cushman & Ozawa, 1930.

Type species: *Eoguttulina anglica*

Eoguttulina spp.

Remarks: A number of small specimens assignable to the genus *Eoguttulina* were recorded from the North Sea borehole material. No attempt was made at specific determination. In this study they have no stratigraphical use.

Genus RAMULINA Jones in Wright, 1875

Type species: *Ramulina Laevis*
Ramulina ex gr. R. aculeata (d'Orbigny)

Remarks: All specimens of Ramulina recorded in this study have been assigned to R. ex. gr. R. aculeata. There is a large amount of variation exhibited in the morphology of this group: globose forms to large branching types. Magniez-Jannin (1975) discusses the genus (Albian of the Paris Basin) in detail. In this study this genus has no stratigraphical utility but it is restricted in occurrence to the Albian.

Family GLANDULINIDAE Reuss, 1860

Genus: **Tristix** Macfadyen, 1941

Type species: *Rhabdogonium liasinum* Berthelin, 1879

**Tristix acutangula** (Reuss, 1863)

1966 **Tristix acutangula** (Reuss); Bartenstein, Bettenstaedt & Bolli: p. 157, pl. 3, figs. 266, 273-278

1975 **Tristix acutangula** (Reuss); Magniez-Jannin: p. 222, pl. 12, figs. 2-6

Remarks: This distinct, but variable, species is present throughout the Albian of the studied boreholes, but is not common. Its long narrow shape, arcuate sutures and non excavated sides distinguish it from *T. excavata* (Reuss). It is a characteristic species of the Albian according to Magniez-Jannin but does range throughout the Early Cretaceous.
Tristix excavata (Reuss, 1863)

1975 Tristix excavata (Reuss); Magniez-Jannin: p. 224, pl. 12, figs. 7-11

Remarks: This species is easily distinguished from T. acutangula by its excavated sides and its more rounded robust form. It is characteristic of the Albian strata but is found at other levels in the Early Cretaceous.

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushmañ, 1927

Genus PRAEBULIMINA Hoffer, 1953

Type species: Bulimina ovulum Reuss, 1844

Praebulimina elata Magniez-Jannin, 1975

1975 Praebulimina elata Magniez-Jannin: p. 235, pl. 15, figs. 39-43

Remarks: This distinctive species was first described by Magniez-Jannin (1975) from the Albian of the Paris Basin. It is rare in the North Sea borehole material and has no stratigraphical utility in this study. It does substantiate an Albian age where it does occur.

Superfamily DISCORBACEA Ehrenberg, 1838

Family DISCORBIDAE Ehrenberg, 1838
Genus VALVULINERIA Cushman, 1926

Type species: Valvulineria californica

Remarks: The genus Valvulineria is highly variable morphologically and its occurrence in the Early Cretaceous deposits of the Paris Basin has been extensively researched by Francoise Magniez-Jannin (Jannin 1967). Her observations are not repeated here. However, she does in 1975 admit the difficulty, in some instances, of separating the genera Valvulineria and Gyroidinoides. A discussion of this problem is beyond the scope of this thesis but it is in the present author's opinion that a thorough study is required of all the species of both genera occurring in the Early Cretaceous of North West Europe. It would appear that subtle specific distinctions will be useful stratigraphically on a very local scale.

Valvulineria parva Khan, 1950

1898 Rotalia soldarii d'Orbigny var nitida Reuss; Chapman: p. 9, pl. 2, figs. 2a-c

1950 Valvulineria parva Khan: p. 275, pl. 2, figs. 12-14, 19

Remarks: Magniez-Jannin (1975) separates this species into three subspecies within the Albian. This has not been attempted by the present author as caving precludes such practice. However, in some borehole material certain sub species could be distinguished but as no stratigraphical purpose would be served were not recorded. This "plexus" forms an important part of the Albian fauna and indeed does form likewise an important part of the Late Aptian/Early Albian fauna.
Valvulineria spp.

Remarks: This open nomenclature term has been used as a generic dustbin for all species in the Early Cretaceous of the studied boreholes. Within this group are such species as V. gracillima ten Dam, V. loetterlei (Tappan), Gyroidinoides nitida (Reuss), V. berthelin Jannin, V. angulata Magniez-Jannin, V. praestans Magniez-Jannin. Various horizons of abundance and paucity of this genus may prove, with further research, to be of correlation and stratigraphical use on a local scale (see Plate 13.1, Fig. 6).

Superfamily SPIRILLINACEA Reuss, 1862

Family SPIRILLINADAE Reuss, 1862

Genus SPIRILLINA Ehrenberg, 1843

Type species: Spirillina vivipara

Spirillina neocomiana Moullade, 1961

1961 Spirillina neocomiana Moullade: p. 213, pl. 1, figs. 6-8

(Plate 13.1, Fig. 7)

Remarks: This species is typically Hauterivian. In this study it is recorded from the DSDP Leg 80, site 549 material in the Barremian/Aptian. In this study it has no biostratigraphical use.

Genus PATELLINA Williamson, 1858

Type species: Patellina corrugata

329
Patellina spp.

Remarks: This curious foraminifera which is quite variable morphologically and is quite common at discrete levels within the Albian, Aptian and Barremian strata of the North Sea boreholes is worthy of further study. Its occurrence is environmentally controlled as it is associated with an increase in the calcareous content of the sediment (carbonate deposition environment) and with condensation levels in the sequences studied. Further study is warranted of the distribution of this species, in the Early Cretaceous of the North Sea. In particular, the association with carbonate and condensation horizons suggests that a comparison of the associated foraminiferal fauna - T. pyramidata group, Verneuilinoides species, Gaudryina species, Reophax species, Trocholina spp, gavelinellids, valvulinerids and Marssonella/Dorothia species - with the faunas recorded from the Barremian - Aptian Urgonion facies of southern Europe may be a worthwhile study. However such a study is beyond the scope of this thesis.

Superfamily GLOBIGERINACEA Carpenter, Parker & Jones, 1862

Family PLANOMALINIDAE Bolli, Loeblich & Tappan, 1957

Genus GLOBIGERINELLOIDES Cushman & ten Dam, 1948

Type species: Globigerinelloides algeriana Cushman & ten Dam, 1948

Globigerinelloides bentonensis (Morrow, 1934)

non 1927 Anomalina eaglefordensis Moreman: p. 99, pl. 16, fig. 9

330
1934 *Anomalina bentonensis* Morrow: p. 201, pl. 30, figs. 4a-b

1964 *Globigerinelloides caseyi* (Bolli, Loeblich & Tappan) Low: p. 122-123

1977 *Globigerinelloides bentonensis* (Morrow); Carter & Hart: p. 27, pl. 1, fig. 11; pl. 2, figs. 19, 20

**Remarks:** Carter & Hart (1977) have elegantly summed up the taxonomic position of this species. It is a distinctly Albian to Cenomanian species, having evolved from *G. blowi* (Bolli) in the Aptian. It is important in North West Europe as acmes of abundance in the Late Albian are correlatable events (Burnhill & Ramsay, 1981). In this study its occurrence is taken to indicate Late Albian sediments.

"*Globigerinelloides* gyroidinaeformis" Moullade, 1966

1966 "*Globigerinelloides* gyroidinaeformis" Moullade: p. 128, pl. 9, figs. 16-22

**Remarks:** The generic identity of this species is uncertain but the present author maintains the assignation of Moullade (1966). This very strongly involute, planospiral test, with four to five chambers in the last whorl which rapidly increase in size, is very distinct. It is, however, in the studied North Sea material, not very common but never the less its presence is very important. Its occurrence indicates or, in the presence of other foraminiferal evidence, substantiates, an Early Albian to Middle Albian age. A thorough study is needed of this species in the North Sea, in terms
of its taxonomy, its association with other foraminifera (palaeoenvironment), and its stratigraphical range.

Family SCHACKOINIDAE Pokorny, 1958

Genus LEUPOLDINA Bolli, 1958

Type species: Leupoldina protuberans Bolli,

Leupoldina cabri (Sigal, 1952)

(Plate 12.4, Figs. 3, 4)

1952 Schackoina cabri Sigal: pp. 20, 21 text-fig. 18

1959 Leupoldina protuberans Bolli: p. 277, pl. 2, figs. 1-13a

1966 Shackoina cabri Sigal; Salaj & Samuel: p. 165, pl. 7, figs. 5a-c

1977 Leupoldina cabri Sigal; Masters: p. 424, pl. 14, fig. 4; pl. 15, fig. 1

1977 Leupoldina protuberans Bolli; Bartenstein & Bolli: p. 559, pl. 3, figs. 15-17

1979 Schackoina cabri Sigal; Dupeuble: pl. 3, figs. 7, 8, 11-14

Remarks: Masters (1977) has discussed the taxonomic position of this genus and species and states that the phylogeny is unknown.

Occurrence: Only one specimen was found from the Atherfield "group" section but this species (as L.
protuberans) is used as an index species for the Early Cretaceous L. protuberans Zone of the Cuche Formation, Trinidad (topmost Late Barremian to base Late Aptian).

This species is also recorded from the D.S.D.P. Leg 48 (Sites 401 and 402) in the Bay of Biscay and implies a tethyan faunal link via the proto-north Atlantic to the Isle of Wight region during the Early Aptian.

This species was not recorded from the southern North Sea Basin.

Dimensions of figured specimen (mm):

max. diameter

SCAC 8172 (Sample 4) 0.4

Family ROTALIPORIDAE Sigal, 1958

Subfamily HEDBERGELLINAE Loeblich & Tappan, 1961

Genus HEDBERGELLA Bronnimann & Brown, 1958

Type species: Anomalina lorneiana d'Orbigny var. trochoidea Gandolfi, 1942

Remarks: This genus has had an interesting taxonomic history. Masters (1977) has discussed the practical problems associated with planktonic foraminiferal taxonomy while Price (1977a, b) has discussed the generic and specific taxonomic philosophy of the Hedbergellids in the Early Cretaceous of North West Europe. In actual fact
the apparent diversity of planktonic species in the Early Cretaceous strata of the North Sea region needs careful and thoughtful investigation. Too many workers have succumbed to the temptation to "lump" the specimens into "dustbin" generic and specific assignments. Indeed the present author uses this technique e.g. *H. delrioensis* - *infracretacea - brittonensis plexus*, but justifies such a procedure because 1) such a planktonic generic species study is beyond the scope of this thesis in terms of time available, and 2) not enough material is available for a full meaningful study. More material from onshore sections and boreholes elsewhere in the North Sea region are required.

**Hedbergella hoterivica** (Subbotina, 1953)

(Plate 12.4, Figs. 1, 2)

1953 *Globigerina hoterivica* Subbotina: p. 50, pl. 1, figs. 1-4

1959 *Globigerina kugleri* Bolli: p. 270, pl. 23, figs. 3-5

1976 *Caucasella hoterivica* (Subbotina); Ascoli: fig. p. 29; pl. 1, fig. 3

1976 *Hedbergella hoterivica* (Subbotina); Bartenstein: p. 256, fig. 1

1977 *Globigerina hoterivica* Subbotina; Masters: p. 460, pl. 22, figs. 1-3

Remarks: This small planktonic species is easily recognised by its quadrate shape and umbilical aperture. It is very variable in the size of the last four
chambers and in the height of the apertural arch. Masters (1977) and Gradstein (1978) discuss the taxonomy of this species. It is known from the Jurassic (Mid-Bathonian) to Mid-Aptian. Van Hinte (1976) restricts it to the Late Hau terivian. In the Atherfield "group" this species is rare but quite distinctive. This species has not been recorded by the present author from the southern North Sea boreholes. Specimens recorded from the DSDP material are referred to H. sp. aff. H. hoterivica (Plate 13.1, Fig. 8).

Dimensions of figured specimen (mm): max. diam.

SCAC 8173 (Sample 20) 0.3

Hedbergella delrioensis (Carsey, 1926) plexus

1977 Hedbergella delrioensis (Carsey); Carter & Hart: p. 35, pl. 4, figs. 1-3

1977 Hedbergella infracretacea (Glaessner); Carter & Hart: p. 35, pl. 3, figs. 18-20

1977 Hedbergella brittonensis Loeblich & Tappan; Carter & Hart: p. 31, pl. 4, figs. 13-15

Remarks: The present author accepts the approach of Carter & Hart (1977) in viewing these species as part of a plexus in Aptian and Albian sediments. For a fuller discussion please refer to their work. Harris (1982) also follows this approach. While Price (1977a, b) does agree with the plexus concept he does separate the end members as separate recorded species. In any population from the samples examined from the Albian of the North Sea
there is a full range from low spired H. delrioensis s.s. to high spired H. brittonensis. Indeed the low flat spired forms approach the appearance of H. planispira (Tappan). Small higher spired forms of H. delrioensis are herein referred to as H. infracretacea and are recognised as a separate species purely for taxonomic purposes and the recognition of earliest Albian and Aptian representatives of the plexus. Harris (1982) discusses this plexus in detail and it is not reiterated here.

Occurrence: This plexus is useful stratigraphically in the Albian and Aptian strata of the studied North Sea boreholes.

**Hedbergella infracretacea** (Glaessner, 1937)

1937 *Globigerina infracretacea* Glaessner: p. 28, text-fig. 1

1962 *Hedbergella infracretacea* (Glaessner) = *Globigerina* D11 Hécht 1938; Bartenstein: p. 129

1965 *Hedbergella* sp. = *Globigerina* D5 Hecht; Bartenstein: p. 348

1977a *Hedbergella aptiana* = *Globigerina* D9 hecht; Bartenstein: p. 347, text-figs. 3-6

1977a *Hedbergella infracretacea* (Glaessner); Price: p. 519, pl. 61, figs. 7-9

Remarks: Masters (1977 p. 454) places this species in the synonymy of H. delrioensis (Carsey) but both Price (1977) and Carter & Hart (1977) have upheld their separate identity while recognising that the two
"species" are end members of a complete range of variability (also see Harris, C. S., 1982, unpubl. Ph.D. thesis, Plymouth Polytechnic, C.N.A.A.)

Bartenstein (1962) originally named Globigerina D11 of Hecht (1938) as Hedbergella infracretacea but later (1965) changed this to H. delrioensis. Globigerina D9 (Hecht 1938) has been named by Bartenstein (1965) as H. aptiana but really could be placed within the range of variability of the H. infracretacea - delrioensis group. The paucity of material from the Isle of Wight favours this approach and Magniez-Jannin's (1973) illustrations (pl. 4, figs. 31-34) show a typical H. infracretacea (her "forme convexe" of H. infracretacea) and also (pl. 4, figs. 26-30) show a typical H. aptiana (her "forme plate" of H. infracretacea). H. aptiana is stratigraphically important as an index fossil in the Early Aptian of the southern North Sea Basin. For this stratigraphical reason in the southern North Sea boreholes both H. infracretacea and H. aptiana are separated from H. delrioensis. This "species" is rare in the Isle of Wight material and is also rare in the Atherfield Clay material of south-east England (Jaworski pers. comm.). The chronospecies - H. infracretacea and H. aptiana are characterised by colour and preservational changes in the studied boreholes (see Chapters 7 and 8). These preservational differences help reduce the problem of not being able to identify caved specimens.

Hedbergella planispira (Tappan, 1940)

1977 Hedbergella planispira (Tappan); Carter & Hart: p. 36, pl. 4, figs. 4-6
Remarks: This is a small and very distinctive species only found sporadically in the material studied from the southern North Sea. However its occurrence is significant as it is recorded only from the Middle and Late Albian sections of the studied boreholes. The relative abundance of this species may be of local correlative value. Its range does extend up into the Cenomanian. Not enough boreholes were studied to determine fully the stratigraphic significance of this species.

Hedbergella simplex (Morrow, 1934)

1977 Hedbergella amabilis Loeblich & Tappan; Carter & Hart: p. 29, pl. 3, figs. 22, 23

1981 Hedbergella simplex (Morrow); Hart et al: p. 204, pl. 7.16, figs. 6-8

Remarks: This is a distinctive species which includes H. amabilis in its synonomy. The chambers are globular, becoming radially elongated. This species is reputed to be Cenomanian and its presence in material from the southern North Sea material of Early Cretaceous age is either due to caving or are latest Late Albian precursor specimens of this species (elongate chambered H. delrioensis or H. planispira).

Genus PRAGLOBOTRUNCANA Bermudez, 1952

Type species: Globorotalia delrioensis Plummer, 1931
Praeglobotruncana cf. P. delrioensis (Plummer, 1931)

1977 Praeglobotruncana delrioensis (Plummer); Carter & Hart: p. 38, pl. 4, figs. 22-24

Remarks: This species is extremely rare in the studied material from the North Sea. It is important as the first evolutionary appearance of this species, developed from H. delrioensis, occurs in the latest Late Albian and earliest Cenomanian.

Praeglobotruncana spp

Remarks: This taxonomic grouping is used for a variety of rare specimens encountered in the latest Albian samples studied from the North Sea material. The specimens are probably caved from intervals higher up the borehole: Cenomanian - Turonian.

Superfamily CASSIDULINACEA d'Orbigny 1839

Family PLEUROSTOMELLIDAE Reuss, 1860

Genus PLEUROSTOMELLA Reuss, 1960

Type species: Dentalina subnodosa Reuss, 1851

Pleurostomella spp

Remarks: The lack of specimens from the North Sea material precludes a taxonomic/stratigraphic investigation of this genus in the Early Cretaceous of the southern North Sea. This genus is useful stratigraphically in the Early Cretaceous of North West Europe (Bartenstein, 1978b) particularly the
Albian (8 species). The specimens recorded from the North Sea material are grouped as *P.* spp.

Family INVOLUTINIDAE Butschli, 1880

Genus TROCHOLINA Paalzow, 1922

Type species: *Involutina conica* Schlumberger, 1898

Trocholina aptiensis Jovcheva/Neotrocholina friburgensis Guillame & Reichel

(Plate 13.1, Figs. 8, 9, 10, 12, 13, 15)

1966 *Trocholina* sp. aff. *friburgensis* Guillame & Reichel; Moullade: p. 61, pl. 6, figs. 1-3

1971 *Trocholina* aptiensis Jovcheva; Bartenstein, Bettenstaedt & Kovatcheva: p. 150, pl. 3, figs. 66-67.

1978a *Trocholina* aptiensis Jovcheva/Neotrocholina friburgensis Guillame & Reichel; Bartenstein: p. 22, fig. 1, fig. 2 (1).

Remarks: Taxonomic problems exist in the designation of *T. aptiensis* or *T. friburgensis*. The approach taken in this thesis is that of Bartenstein (1978b). *T. aptiensis*/*T. friburgensis* can be distinguished from *T. infragranulata* by fewer number of granules in the ventral side, 10-20, rather than 20-40. The stratigraphical range of Barremian to Early Aptian is important. *Trocholina* is rare in the North Sea Early Cretaceous (pers. comm. Burton, Harlow, Harris, King and personal observation). However its occurrence is important for palaeoenvironmental reasons as an equivalent of the "Urgonian Facies" may be present at certain horizons, and in certain
areas, of the North Sea. This will be the subject of further investigation by the present author.

The specimens recorded for DSDP site 549 are abundant and well preserved.

**Trocholina infragranulata Noth/Trocholina paucigranulata Moullade**

(Plate 13.1, Figs. 11, 14)

1971 *Trocholina infragranulata* Noth; Bartenstein, Bettenstaedt & Kovatcheva: p. 148

1978b *Trocholina infragranulata* Noth/Trocholina paucigranulata Moullade; Bartenstein: p. 22, fig. 1, fig. 2(1)

**Remarks:** A distinctive species which again is difficult to place specifically without more exhaustive study and research. It is important as an environmental indicator but its range is Berriasian to latest Early Aptian in North West Germany, and Albian in Bulgaria. It is only recorded in this study from the DSDP material.

The genus *Trocholina* in the Early Cretaceous is environmentally controlled — indicative of a reef environment (organic detrital sediments, oolitic sediments, marly limestones) associated with ostracods, crinoids, sponges, bryozoans, calcareous algae and corals. The variety of forms of *Trocholina*, which have been given specific status by various authors, are undoubtedly ecophenotypic variations.
Family ANOMALINIDAE Cushman 1927

Genus GAVELINELLA Brotzen 1942

Type species: Discorbina pertusa Marsson, 1878

Gavelinella baltica Brotzen, 1942

1977 Gavelinella baltica Brotzen; Carter & Hart: p. 46, pl. 1, figs. 36-38

Remarks: The evolutionary first appearance of this species is in the Late Albian (Carter & Hart, 1977; Price, 1977a). It differs from G. ex gr. G. intermedia in the inflation of the final three chambers of the last whorl.

Gavelinella barremiana Bettenstaedt, 1952

(Plate 12.4, Figs. 6, 7; Plate 16.5, Figs. 4, 5-7; Plate 13.2, Figs. 5, 7)

1938 Anomalina D11 Hecht: (pars), pl. 9b, figs. 55-58; pl. 10b, figs. 71-78; pl. 11b, figs. 48-49, pl. 12a, figs. 66-83

1952 Gavelinella barremiana Bettenstaedt: p. 275, pl. 2, fig. 26-29

Remarks: This is a distinctive species which displays little variation in morphology. It is distinguished from other species of Gavelinella by its large number of chambers in the last whorl (10-12) which all increase uniformly in size as added. The last chamber is commonly slightly more inflated, larger and more arcuate. The species evolves into G.
intermedia and transitional types can be found e.g. G. brielensis Malapris.

Occurrence: This species is found in the Middle and Late Barremian and the Early Aptian of north west Europe. It is stratigraphically useful in the studied North Sea material.

Dimension of figured specimen (mm):

max. diameter

SCAC 8174 (Sample 13) 0.4

Gavelinella brielensis Malapris-Bizouard, 1974

1973 Gavelinella sp. Magniez-Jannin: p. 40, pl. 4, figs. 23-25

1974 Gavelinella brielensis Malapris-Bizouard: p. 19, pl. 1, figs. 11-16

1981 Gavelinella brielensis Malapris-Bizouard; Hart et al: p. 192, pl. 7.10, figs. 6-8

Remarks: This species seems to be the ancestral form of G. intermedia and is similar to G. cf. barremiana Bettenstaedt sensu Bartenstein & Bettenstaedt 1962.

Occurrence: In the U.K. this species is found in the Early Aptian Atherfield Clay of Kent. It has not been recorded from the north of England although specimens of Gavelinella brielensis are common from the Early Aptian of the southern North Sea Basin.
Gavelinella cenomonica (Brotzen, 1942)

1977 Gavelinella cenomonica (Brotzen); Carter & Hart: p. 46, pl. 1, figs. 27, 28

Remarks: The marked upstanding spiral rim/ridge around the inner margin of the chambers distinguishes this species from G. intermedia from which this species developed in the Late Albian. This species is stratigraphically important in the southern North Sea material because of its evolutionary appearance for, where it occurs, it substantiates a Late Albian age.

Gavelinella ex. gr. intermedia (Berthelin, 1880)

(Plate 12.4, Fig. 8; Plate 16.5, Figs 13, 14)

1977a Gavelinella intermedia (Berthelin); Price: p. 516, pl. 60, figs. 7, 8

1981 Gavelinella intermedia (Berthelin); Hart et al: p. 194, pl. 7.11, figs. 7-9

Remarks: This species has had a chequered history in the literature but Price (1977a, b) adequately sums up the main points of controversy. Specimens attributable to this group are extremely rare in the Atherfield section on the Isle of Wight but very common in the North Sea material. The umbilical boss varies from large to absent. It is the most abundant species in the Late Albian. Species with a large umbilical boss are variety A.
Occurrence: Essentially an Albian-Cenomanian species although ancestral species are present in the Aptian. The whole Gavelinella group in the Early Cretaceous of the North Sea is in need of further study and revision.

Dimension of figured specimen (mm): max. diam.

SCAC 8175 (Sample 12) 0.3

Gavelinella rudis (Reuss, 1863)

1863 Anomalina rudis Reuss: p. 87, pl. 1, fig. 7

Remarks: This species is small and of no real stratigraphical importance. It has only been recorded from a few of the studied boreholes. Carter & Hart (1927) regard this as a primitive early form of G. baltica in the Late Albian.

Gavelinella *sigmoicosta* ten Dam, 1948

(Plate 16.5, Figs. 1, 2, 3)

1948 Anomalina sigmoicosta ten Dam: p. 189, pl. 32, figs. 23-24

1962 Gavelinella (?) *sigmoicosta* (ten Dam); Bartenstein & Bettenstaedt: p. 271, pl. 37, fig. 6: pl. 38, fig. 12

Remarks: A very distinctive planoconvex test. The dorsal side is flat showing only the last coil clearly. The ventral side is very convex with a deep umbilicus. The seven to nine chambers in the last coil are sigmoidal and the sutures on the dorsal side are raised, thickened and sigmoidal. The
last chamber is higher, more inflated than the preceding chambers. This species is important stratigraphically as it is confined in North West Europe to the Late Hauterivian and Early Barremian.

Genus LINGULOGAVELINELLA Malapris, 1965

Type species: Lingulogavelinella albiensis Malapris, 1965

Lingulogavelinella albiensis S.L. Malapris, 1965

1965 Lingulogavelinella albiensis S.L. Malapris: p. 140, pl. 4, figs. 5-8

1967 Lingulogavelinella albiensis biconvexa Malapris: p. 130, pl. 1, figs. 1-2: pl. 2, figs. 2, 3, 4, 5

Remarks: Malapris (1965, 1967) has adequately researched the lingulogavelinellids and gavelinellids (1974) of the Paris Basin. However, to date there has been no exhaustive study of these genera in the Early Crétaceous of the North Sea. These genera are extremely diverse in the Aptian and Early and Middle Albian. In this thesis specimens of L. albiensis have been identified in the borehole material and in some instances the two subspecies L. albiensis albiensis and L. albiensis biconvexa have been identified.

The stratigraphical utility of this species is not certain, and will remain so until an exhaustive study has been carried out on North Sea material.

Lingulogavelinella ciryi S.L. Malapris, 1967

1967 Lingulogavelinella ciryi n. sp. Malapris: p. 136, pl. 1, figs. 17a, b, c
1967 *Lingulogavelinella ciryi* n. subsp. Malapris: p. 137, pl. 1, figs. 16-19, pl. 2, figs. 16-20

1967 *Lingulogavelinella ciryi* inflata n. subsp. Malapris: p. 139, pl. 1, fig. 20; pl. 2, figs. 21-22

Remarks: Malapris (1967) has adequately summed up the stratigraphic use of this species and subspecies in the Albian of the Paris Basin. Their use in the North Sea is limited as there is a lack of information/published data on this species from North Sea boreholes. *L. ciryi inflata* is a latest Late Albian indicator while *L. ciryi ciryi* is abundant in the Early and Middle Albian. This species is always evolute while *L. cibicidoides* is involute.

*Lingulogavelinella cibicidoides* Malapris, 1965

1967 *Lingulogavelinella cibicidoides* Malapris; Malapris: p. 135, pl. 1, figs. 14-15; pl. 2, fig. 14-15

Remarks: This species of Middle and Early Albian age is involute and easily distinguished from the *L. ciryi* group. The dorsal side has a small hyaline umbilical boss. Only in a few borehole samples was this species identified. In other boreholes they were recorded with *Lingulogavelinella* spp. A detailed, in depth study of the genus would not only make an interesting study but would provide a means of stratigraphic division of the Aptian and Albian strata. Such a study is beyond the scope of this thesis however.

Other specimens of *Lingulogavelinella/Gavelinella* spp. show a morphology which suggests an attachment
made of life — Sea grasses, cf. Cibicides spp. at the present day.

Note: The genera Lingulogavelinella and Gavelinella in the studied boreholes are abundant in the Late Aptian, Early Albian, Middle Albian and Late Albian. Levels of abundance, evolutionary first occurrences and extinction levels plus diversity differences suggest that they are amenable to study and the formulation of an event stratigraphy. The size of specimens increase uphole — Aptian to Albian.

Family OSANGULARIIDAE Loeblich and Tappan 1964

Genus OSANGULARIA Brotzen 1940

Type species: Osangularia lens Brotzen 1940

Osangularia Schloenbachi (Reuss 1863)

(Plate 16.1, Figs. 1-17; Plate 16.2, Figs. 1-13; Plate 16.3, Figs. 1-10; Plate 16.4, Figs. 1-19; Plate 16.5, Figs 8-12, 6)

(?1863 Rotalia schloenbachi Reuss, p. 84, pl. 10, fig. 5

1938 Planulina D5 Hecht, pl. 2a, row I & II, p. 13

1950 Planulina schloenbachi (Reuss); Ten Dam, p. 55, pl. 4, figs. 7a-7b

1962 Discorbis minimus Vieux; Flandrin, Moullade & Porthault: p. 220, pl. 3, figs. 7, 8, 9, 10

(?)1965 Planulina schloenbachi (Reuss): Neagu, p. 32, pl. 8, figs. 3a-c

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1966 *Eponides utaturensis* Sastry & Sastri: p. 292, pl. 19, figs. 6a-c

1966 *"Osangularia"* sp. aff. *brotzeni* (Gandolfi): Moullade, p. 77-79, pl. 1, fig. 9-11, text fig. 2.

(?)1966 *Discorbis wassoewizi* Salaj & Samuel: non Djaffarov & Agalarova, p. 141, pl. 36, fauna 8, fig. 5; pl. 37, fauna 9, fig. 5; text fig. 6

1966 *Osangularia schloenbachi* (Reuss): Fuchs, p. 335, pl. 19, figs. 3a-c

1969 *Osangularia schloenbachi* (Reuss): Dilley, p. 321

1970 *Osangularia californica* Dailey: p. 108-109, pl. 13, figs. 3, 4

non 1972 *Gavelinella (Gavelinella) schloenbachi* (Reuss): Gawor-Biedowa, p. 129-131, pl. 16, figs. 2a-c

1973 *Osangularia californica* Dailey: p. 77, pl. 13, figs. 4a, b, c

1974 *Osangularia utaturensis* (Sastry & Sastri): Scheibnerova, p. 714, pl. 4, figs. 27, 28; pl. 5, figs. 1-9; pl. 11, figs. 4a-c, 5a-c

1975 *Planulina schloenbachi* (Reuss): Price, pl. 13, figs. 8a-b, pl. 14, figs. 1a-b

1976 *Planulina schloenbachi* (Reuss): Price, p. 634-635, pl. 1, figs. 7-8
1976 **Osangularia utaturensis** (Sastry & Sastri): Sliter, p. 519, pl. 13, figs. 4, 5

1978 **Osangularia utaturensis** (Sastry & Sastri): Scheibnerova, p. 140, pl. 4, figs. 5, 6, 7

1978 **Osangularia utaturensis** (Sastry & Sastri): Gradstein, p. 676, pl. 7, figs. 5-12

1979 **Osangularia utaturensis** (Sastry & Sastri): Dupeuble, pl. 2, figs. 12-14

1981 **Osangularia utaturensis** (Sastry & Sastri): Burnhill & Ramsay, p. 254

non 1981 **Gavelinella schloenbachi** (Reuss): Edwards, p. 402, pl. 56, figs. 10-12

1981 **Osangularia utaturensis** (Sastry & Sastri): Scheibnerova, fig. 4, f, g, h, fig. 5, a-g

1981 **Osangularia utaturensis** (Sastry & Sastri): Haig,

Description: Test free, multilocular, very low trochospiral coil; either equally biconvex, or spiral side slightly more convex than the umbilical side; some specimens may be distinctly planoconvex while rare specimens have a concave umbilical side; periphery is bluntly acute, to acute and sub-lobate to lobate in outline. Chambers, except last, almost flat to moderately inflated, with generally 10-12 in the final whorl (some specimens have as little as 8 or 9 in the final whorl) and gradually increase in size as added; Crescentic in shape; all chambers are visible in the 2 1/2 to 3 whorls on the spiral
side (evolute); only chambers of final whorl visible on the umbilical side (involute); last chamber is commonly larger and more inflated than the previous chambers. Sutures distinct, oblique, straight to slightly curved initially, becoming strongly curved in later chambers on both umbilical and spiral sides; all sutures thickened and raised and meet at the margin to form elevated acute Keels. Wall calcareous; perforate; smooth; layers of non perforate secondary calcite on sutures; distinct calcareous boss (both umbilical and spiral in some specimens). Aperture distinct V-shape; interiomarginal slit at base of final chamber which then bends obliquely up the apertural face to become a small arcuate comma-shaped slit.

Variation: There are a variety of edge-view test shapes ranging from:

(i) equally biconvex,

(ii) spiral side more convex than umbilical side,

(iii) planoconvex (umbilical side flat),

(iv) rare specimens possessing a concave umbilical side and convex spiral side.

Dupeuple (pers. comm) also notes this variation in specimens from D.S.D.P. site 400A and regards it as a characteristic of the species.

There is also a variation in the extent and thickness of the secondary calcite along the sutures. The flatter specimens have very little or no secondary calcite thickening along the
sutures on either spiral or umbilical sides and the periphery is more lobate. This contrasts to the more inflated specimens which have an abundance of secondary calcite thickening and a more rounded periphery.

The variation in these characters is thought to be an expression of sexual dimorphism and/or the response of the foraminiferid to slight differences in living conditions (substrate, water depth, temperature, salinity etc). The presence or absence of an umbonal calcite boss (umbilical side) is a non-specific character. All the observed variation in test morphology of the specimens from the southern North Sea is to be expected in a normal population of one species and does not warrant the "splitting" of the population into two or more species.

Remarks: The umbilical boss of calcite present in some specimens is reminiscent of the feature found in Gavelinella intermedia (Berthelin) variety A. (Plate 16.5, Fig. 14) as described by Price (1977) from the Albian of north-west Europe. The sometimes inflated, crescentic last chamber in some specimens is reminiscent of Gavelinella sigmoicosta ten Dam (Plate 16.5, Figs. 1-3) and the dorsal and ventral views of this last chamber are reminiscent of Gavelinella barremiana (Bettenstaedt) (Plate 16.5, Figs. 4-7). However the aperture places the specimens from the southern North Sea in the genus Osangularia Brotzen 1940. The specimens from the studied boreholes (see Fig. 16.2) are present both in a red chalk/marl lithology and in a grey/ green clay/marl/shale lithology.
Genus **CONOROTALITES** KAEVER, 1958

Type species: Globorotalites bartensteini aptiensis Bettenstaedt, 1952

**Conorotalites bartensteini bartensteini** (Bettenstaedt, 1952)

**Conorotalites bartensteini intercedens** (Bettenstaedt, 1952)

**Conorotalites bartensteini aptiensis** (Bettenstaedt, 1952) Group

1962 **Conorotalites bartensteini bartensteini/bartensteini intercedens/bartensteini aptiensis** group; Bartenstein & Bettenstaedt: p. 275-278, pl. 37, fig. 1, fig. 2, fig. 3. Text fig. 22

Remarks: The above three subspecies have been described as separate, but closely related, species or as in this thesis as subspecies of one species. They have a total range in the Early Cretaceous of Early Albian to Early Barremian. These subspecies are very useful stratigraphically in the North Sea material and in North West Germany. This species group has been recorded from England, according to Bartenstein & Bettenstaedt (1962, p. 277), and Bettenstaedt (1952) regards the specimens recorded as *Pulvinulina reponda* by Sherlock (1914, pl. 19, fig. 14) as representative of the species **Conorotalites bartensteini**. Fletcher (1966, 1973) has not recorded this species from the Speeton Clay.

These three subspecies are discussed briefly as a group as it has been shown that they evolve from one another (Bartenstein & Bettenstaedt, 1962). As a consequence there are problems of separation of individuals within the evolutionary series (see
Fig. 7.10). The gross population has to be examined for a full appreciation.

*C. b. bartensteini*: Early Barremian to earliest Late Barremian

*C. b. intercedens*: Middle Barremian to Late Barremian

*C. b. aptiensis*: Late Barremian to Early Albian (rare)

This species is useful in the North Sea material and in the samples from the DSDP Leg 80, site 549 borehole.

Superfamily ROBERTINACEA Reuss, 1850

Family CERATOBULIMINIDAE Cushman, 1927

Subfamily CERATOBULIMINIDAE Cushman, 1927

Genus CONORBOIDES Hofker in Thalmann, 1952

Type species: *Conorboides mitra* Hofker, 1951

*Conorboides lamplughi* (Sherlock, 1914)

1914 *Pulvinulina lamplughi* Sherlock: p. 290, pl. 19, fig. 16

1977 *Conorboides lamplughi* (Sherlock); Carter & Hart: p. 50, pl. 1, figs. 21-23

Remarks: A rare, but distinctive species, which is age diagnostic. Its occurrence supports an Early to Middle Albian age (Price, 1977a, Carter & Hart,
1977). Its first downhole occurrence in the North Sea borehole material in association with other species, such as O. schloenbachi indicates the occurrence of strata of Middle - Early Albian age. However, it has been recorded in strata as old as Late Hauterivian by Fletcher (1966).

Subfamily EPISTOMININAE Wedekind, 1937

Remarks: The various species of Epistomina and Hoeglundina are irregularly distributed in the Early Cretaceous of North West Europe. There has been in the literature much discussion of these genera, and species, at various times, have been assigned to either genus. A taxonomic discussion of these genera is not considered pertinent to this thesis and the present author uses the generic assignment as noted in the most important references (e.g. Carter & Hart, 1977) and in the Treatise. Fletcher (1966) discusses in detail the classification of the subfamily Epistomininae.

Genus EPISTOMINA Terquem 1883

Type species: Epistomina regularis Terquem 1883

Epistomina hechti Bartenstein, Bettenstaedt & Bolli, 1957

(Pl. 13.2, Figs. 4, 6)

1957 Epistomina (Protzenia) hechti Bartenstein, Bettenstaedt & Bolli: p. 46, pl. 7, fig. 170

Remarks: This small species is difficult to distinguish from H. chapmani, particularly as the specimens from the DSDP borehole and the North Sea boreholes are badly
preserved. Fletcher argues that H. chapmani differs by having raised sutures and depressed chambers in the early whorls. However this is a very variable feature and does not really serve as a true distinguishing character. A thorough study of type material of both species would resolve this problem. However E. hechti is considered to be characteristic of pre-Aptian age strata and to be particularly common in Early Barremian sediments of North West Europe.

Epistomina ornata Roemer, 1841

1962 Epistomina (Brotzenia) ornata (Roemer); Bartenstein & Bettensteadt: p. 264, pl. 35, fig. 17, pl. 38, fig. 6

Remarks: This is a distinctive species, but rare, in the North Sea material. The ornamentation is variable in its development. It is abundant in the Hauterivian in North West Europe but does occur rarely in Early Barremian sediments.

Genus HOEGLUNDINA Brotzen, 1949

Type species: Rotalia elegans d'Orbigny 1826

Hoeglundina caracolla (Roemer, 1841)

1962 Epistomina (Hoeglundina) caracolla caracolla (Roemer); Bartenstein & Bettenuestaedt: p. 260, pl. 35, fig. 13

Remarks: This species is not common in the North Sea material and tests are often corroded and/or pyritised. It is apparently a useful species from the Late Ryazonian to Early Barremian and occurs in flood occurrences in the Late Hauterivian
(Fletcher, 1966). This sporadic occurrence in North Sea material is probably due to palaeoenvironment and the affects of diagenesis but it is useful as an age indicator.

_Hoeglundina chapmani_ (ten Dam 1948)

(Plate 12.4, Figs. 5, 9)

1948 _Epistomina chapmani_ ten Dam: p. 166, pl. 1, fig. 5

1950 _Epistomina chapmani_ ten Dam; ten Dam: p. 53, pl. IV, fig. 6

1973 _Epistomina chapmani_ ten Dam; Magniez-Jannin: p. 41

1975 _Epistomina chapmani_ ten Dam; Magniez-Jannin: p. 274, pl. 16, figs. 1-3

1977 _Hoeglundina chapmani_ (ten Dam); Carter & Hart: p. 51, pl. 1, figs. 18-20

1981 _Hoeglundina chapmani_ (ten Dam); Hart _et al._: p. 206, pl. 7.17, figs. 3-5

Remarks: This species is obviously related to _H. caracolla_ (Roemer) and _Epistomina hechtii_ Bartenstein, Bettenstaedt & Bolli, both of which are recorded from the Speeton Clay of north east England (Fletcher, 1966). The specimens from the Atherfield "group" are distinguishable from _H. caracolla_ but are difficult to distinguish from _E. hechtii_. Hofker's generic classification of the epistominids appears to be invalid (Cordey 1963, Loeblich & Tappan, 1964).
Occurrence: In the U.K. this species is extant from the Lower Aptian to the lowermost Upper Albian and is common in the Atherfield "group" Section. It has not been recorded from the North Sea material.

Dimensions of figured specimen (mm):

max. diameter

SCAC 8176 (Sample 20) 0.35
15.0 Introduction

The repeated occurrence of a lenticuline morphology attributable to the L. (A.) humilis (Reuss) "group" throughout the Early Cretaceous has resulted in a different specific name being given to the same morphology at various stratigraphic levels. This has caused great difficulty when attempting to name a species within the "group" for unless the stratigraphical level is known the appropriate specific name cannot be applied. This approach is obviously unsatisfactory from a biostratigraphical point of view.

A species which is very similar and perhaps related to the L. (A.) humilis "group" is L. (A.) nodosa barremiana Michael from the "Middle" Barremian of north west Germany. Bartenstein (1974) has discussed the relationship of the L. (A.) nodosa (Reuss) "group" to the L. (A.) humilis "group" as both are recorded to display a similar form of test sculpture, stratigraphical range and geographical occurrence. A similar evolutionary sequence has been suggested for both groups (Bartenstein, 1974; Aubert & Bartenstein, 1976).

15.1 Specimens from the Atherfield Clay Formation

From the type section of the Atherfield Clay Formation of the Isle of Wight, UK specimens of the L. (A.) humilis "group" from a single spot sample have been illustrated by S.E.M. photographs. From the displayed morphological variation the component species which make up the L. (A.) humilis "group" may be recognised (see Plate 15.1).
A. **Lenticulina (Astacolus) humilis praecursor** Bartenstein & Brand 1951, *sensu* Bartenstein (1974, pl. 2, fig. 18) as per row A, (a), in Plate 15.1.

B. **Lenticulina (Astacolus) humilis** (Reuss 1863), *sensu* Bartenstein (1974, pl. 2, figs. 19-20, neotype for the species). This species is included with C.

C. **Lenticulina (Astacolus) humilis humilis** (Reuss 1863), *sensu* Bartenstein (1974, pl. 2, fig. 21) as per Row B, (a), in Plate 15.1.


and forms similar to

E. **Lenticulina (Astacolus) nodosa barremiana** Michael 1967, *sensu* Bartenstein (1974, pl. 2, figs. 28, 29) as per Row B, (b) in Plate 15.1.

A specimen of *L. (A.) neopachynota* from the southern North Sea Basin is illustrated (Plate 15.1, Row B, (d)) and is similar to the species from Atherfield. This specimen has been compared with ten Dam's (1946) holotype of *L. pachynota* (F. 811) in the Rijks Geologische Dienst, Haarlem, the Netherlands.

The morphological variation displayed within one sample by a single population which embraces some of the "forms" attributable to the members of the *L. (A.) humilis* "group" strengthens the present author's view that iterative evolution, parallel evolution and phyletic evolution all play a complex role in the phylogeny of the *Lenticulina* genus as a whole.
Possible evolutionary pathways for the development of *L. (A.)*

Possible Phyletic Evolution

A – E Possible Phyletic Evolution

---

Possible derived from *Lenticulina major* in the Jurassic

**L. (A.) h. praecursoria**

**L. (A.) h. humilis**

**L. (A.) neopachynota**

**L. (A.) nodosa barremiana**

**L. (A.) atherfieldensis**

---

Fig. 15.1
For example, *L. (L.) major* (Bornemann) originally described from the Lias (and from the Lower to Upper Lias of the UK by Copestake & Johnson, 1981, table 6.4.1), but also described from the Callovian, Oxfordian and basal Kimmeridgian of the UK (Coleman, 1981, pl. 6.2.3, fig. 11; Shipp & Murray, 1981, pl. 6.3.3, figs. 12, 13), morphologically resembles species of the *L. (A.) humilis* "group". This conforms to the view that the morphological characteristics of the foraminiferal faunas of the Early Cretaceous were established during the Jurassic. This can be exemplified by other *Lenticulina* species such as *L. (A.) tricarinella* (Reuss) from the Bajocian to Oxfordian, which is morphologically identical to *L. (A.) crepidularia* (Roemer) of the Early Cretaceous (compare Shipp & Murray, 1981, pi. 6.3.3, figs. 20, 21 with Hart et al., 1981, pl. 7.20, figs. 11, 12 and with Coleman, 1981, pl. 6.2.3, figs. 14, 15, 16).

Bailey (1978, unpublished Ph.D. thesis - CNAA - Plymouth Polytechnic, and in Hart et al., 1981, pl. 7.25, fig. 7) figures *Vaginulinopsis scalariformis* Porthault, from the Coniacian and Lower Santonian of the UK which closely resembles members of the *L. (A.) humilis* "group" (see Plate 15.1, Row D, (c)). Magniez-Jannin (1975) has recorded an *L. aff. humilis* from the Albian of the Paris Basin.

These examples may all represent iterative evolution in response to a particular environment, of a similar morphology (?homeomorphs), from a smooth lenticuline rootstock such as *L. (L.) muensteri*. The situation may be more complex in that the morphology evolves either by a process of parallel evolution not from a common smooth lenticuline rootstock (i.e. a plexus), or may represent straight forward phyletic evolution.

A combination of all three methods is a possibility (Fig. 15.1). Aubert & Bartenstein (1976) suggest phylogenetic decline or periodic migrations of new stock from tethyan to boreal areas (or
<table>
<thead>
<tr>
<th>VALANGINIAN</th>
<th>HAUTERIVIAN</th>
<th>BARREMIAN</th>
<th>APTIAN</th>
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<td>LOWER Upper</td>
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- L. (A.) humilis
- L. (A.) humilis humilis
- L. (A.) h. praecursoria
- L. (A.) neopachynota

- L. (A.) atherfieldensis
- L. (A.) h. praecursoria
- L. (A.) cf. neopachynota (cf. pachynota of Fletcher)
- L. (A.) neopachynota (pachynota of Fletcher)

A Northwest Germany - after Bartonstein 1974
B Speeton, Yorks. - after Fletcher 1973, amendments after Bartonstein 1974
vice versa) are possible mechanisms which explain the repeated stratigraphic occurrence of the same morphology within the L. (A.) nodosa group. These mechanisms could also apply to the L. (A.) humilis group. A phylogenetic sequence in one area, such as north west Germany, constructed from a known stratigraphy (vertical sequence of facies changes calibrated by an ammonite biostratigraphy) may be very different from any other area where the facies changes with time have been different. Therefore at geologically different times and in geographically different areas of the Early Cretaceous world similar "forms" could have developed. To use these forms as stratigraphical index fossils, other than in a very restricted sense, e.g. a basin, is not justified but they are of use within an inter-regional correlation scheme using complete foraminiferal faunas. Further as emphasised by Aubert & Bartenstein (1976, p. 21) the stratigraphical range of the different morphological types in the L. (A.) nodosa group differs depending upon the faunal realm inhabited (Boreal, Austral or Tethyan). The application of the appropriate specific name to the morphology is dependent upon knowing the stratigraphical position of the sample from which the specimen came. Ideally each "form" arising from iterative evolution should be given a species name but in practice this is very difficult especially if dealing with borehole cuttings.

15.2 Specimens from the Speeton Clay Section, Filey Bay

This difficulty of applying the correct specific name is exemplified by Bartenstein (1974) in his description of Fletcher's (1973) reported occurrences of members of the L. (A.) humilis "group" from the Speeton Clay section in Yorkshire. Bartenstein (1974) amends the specific names of Fletcher's work on the basis of stratigraphical age only as Fletcher did not publish a description or figure his three species (see Fig. 15.2). The succession of species in Yorkshire then agrees very well with that in north west Germany. The illustrations in Fletcher's research (1966, unpublished) show the variation of
morphology expected within the L. (A.) humilis "group".

Plate 6, figs. 16 - 18, L. (A.) pachynota (Dam) from Bed D2E (Late Valanginian). The stratigraphical position suggests, following Bartenstein's reasoning, that this specimen should be called L. (A.) humilis praecursoria. This specimen (H.U. 23.C.22) has been examined by the present author who agrees with Bartenstein's conclusion.

Plate 7, figs. 3 - 5, H.U. 23.C.24, bed D2E L. (A.) pachynota
figs. 6 - 8, H.U. 23.C.25, bed D2E L. (A.) cf. pachynota
fig. 9, H.U. 23.C.27, bed D4A2 L. (A.) pachynota
fig. 10, H.U. 23.C.1, bed D4A2 L. (A.) pachynota

The stratigraphical position (Late Valanginian) of these specimens would suggest that they should be called L. (A.) humilis praecursoria if Bartenstein's reasoning is followed.

Plate 7, figs. 12 - 14, H.U. 24.C.2, bed LB4B, L. (V.) humilis praecursoria (lower Barremian). This specimen, if Bartenstein's reasoning is followed should be called L. (A.) neopachynota.

Fletcher did not illustrate a specimen of L. (A.) pachynota from the latest Hauterivian and Early Barremian (1973, fig. 3). All the specimens were examined in the collection at Hull University by the present author though complete foraminiferal faunas from Fletcher's research were not available. The renaming of Fletcher's specimens by Bartenstein appears to be justified but it must be noted that the range of morphology of L. (A.) humilis praecursoria and L. (A.) neopachynota are almost identical and very difficult to distinguish. Indeed Bartenstein (1974) places L. (A.) cf. pachynota of Fletcher (1973, figs. 1 - 2) in the synonymy of L. (A.) humilis praecursoria and questionably in the synonymy of L. (A.) humilis neopachynota. This emphasises the uncertainty of the identification of the correct species at the Early and Late Hauterivian boundary where L. (A.) humilis
Bartenstein & Brand 1951
Pl. 15, figs. 126-127

Bartenstein & Hauser 1963
(two forms)
Illustrated neotype

Bartenstein & Kaever 1973
Pl. 88, figs. 5-6
Illustrate neotype of the
new nom. nova

L. (A.) humilis acutuscula

L. (A.) humilis

L. (A.) acutuscula

sutures distinct, often thickened sutures, with knot-like thickenings on the peripheral margin (saw-like protrusions)

sutures, no dorsal knots

no conspicuous lamellose sutures, no dorsal knots

Fig. 15.3

the lower Cretaceous.
of the species making up the L. (A.) humilis Group. in
Trace drawings of the original illustrations of the holotypes
}

Rühs 1963
PI. 6, figs. 5-6

Bartenstein & Kaever 1973
Illustrate neotype of the
new nom.nova

Incidentally Hart et al., (1981) record the range of L. (A.) humilis praecursoria as latest Ryazanian to Early Barremian at Speeton (figs. 7.16, 7.5, 7.6, 7.7) while in the text the range is recorded as Valanginian to Hauterivian (op. cit., p. 222) and L. (A.) cf. pachynota sensu Fletcher and L. (A.) pachynota sensu Fletcher are not recorded at all (Hart et al., 1981). This reduces the value of including L. humilis praecursoria as an index species for the Early Cretaceous (in Hart et al., 1981). Bartenstein (1974) states that L. (A.) humilis praecursoria evolved into L. (A.) humilis humilis and that L. (A.) neopachynota either evolved from L. (A.) humilis humilis or evolved in the Hauterivian from a different species close to L. strombecki (Reuss, 1863) or to L. grata (Reuss, 1863). This is the justification for retaining L. (A.) neopachynota as an independent species rather than as a subspecies of L. (A.) humilis (see Fig. 15.3).

15.3 Conclusion

The stratigraphical distance between L. (A.) humilis humilis and L. (A.) neopachynota and the specimens in the Early Aptian of the Isle of Wight suggests that the latter should be regarded as a new species. This new species is either the result of an iterative development from the same smooth rootstock species in the Aptian, or the result of parallel evolution from a different smooth lenticuline rootstock (i.e. a plexus, see Fig. 15.1). A third possibility is that it has evolved from the L. (A.) neopachynota lineage.

The name L. (A.) atherfieldensis is proposed for the Aptian development of a morphology attributable to the L. (A.) humilis
"group" in the Atherfield section of the Isle of Wight, in the Bois du Perchois borehole of the Paris Basin (Damotte & Magniez-Jannin, 1973) and in the Celtic Sea Basin off Southern Ireland (Colin et al., 1981). The associated faunal evidence (this thesis, and Crittenden, 1982a, b) suggests a shallow, warm water nearshore, perhaps brackish, environment in the Early Aptian of the Isle of Wight. This environment may have favoured the fecundity and abundance of this new species. Bartenstein (1974) and Bartenstein & Aubert (1976) have discussed the taxonomy, morphology, stratigraphical range and geographical distribution of the L. (A.) humilis "group" and it is not repeated here.
PLATE 15.1

*Lenticulina (A.) atherfieldensis* Crittenden (1983), Atherfield "Group"

Row A. Fig. a, x 100, no. P.51196

Fig. b, x 50, no. P.51197

Row B. Fig. a, x 75, no. P.51198

Fig. b, x 75, no. P.51200

Row C. Fig. a, x 50, no. P.51201

Fig. b, x 50, no. P.51202

Fig. c, x 50, no. P.51203

Fig. d, x 50, no. P.51204

Fig. e, x 50, no. P.51193, Holotype

Fig. f, x 50, no. P.51205

Fig. g, x 50, no. P.51206

Fig. h, x 50, no. P.51207

Fig. i, x 50, no. P.51208

Fig. j, x 50, no. P.51209

Row D. Fig. a, x 35, no. P.51210


Row B. Fig. d, x 75, no. P51192

*Vaginulinopsis humilis praecursoria* Bartenstein & Brand, Speeton Clay, Speeton, Yorks. From: Hart *et al.*, 1981, pl. 7.25, fig. 6.

Row D. Fig. b, x 75

*Vaginulinopsis scalariformis* Porthault, Upper Chalk, Quidhampton, Wilts. From: Hart *et al.*, 1981, pl. 7.25, fig. 7.

Row D. Fig. c, x 30
Lenticulina (A.) atherfieldensis Crittenden (1983), Atherfield "Group"

Fig. a, x 39, P.51173, sample 21, lateral view.) from publication on
Fig. b, x 52, P.51174, sample 18, lateral view.) Atherfield Clay
Fig. c, x 75, P.51174, sample 18, ventral view.)
Fig. d, x 52, P.51191, sample 21, lateral view.
Fig. e, x 520, P.51191, sample 21, close-up of the aperture.
Fig. f, x 51, P.51190, sample 18, lateral view.
Fig. g, x 500, P.51190, sample 18, close-up of thickened suture and perforate chamber wall.
Fig. h, x 100, P.51194, sample 4, internal structure.
Fig i, x 100, P.51195, sample 4, internal structure.
CHAPTER 16

TAXONOMIC DISCUSSION OF OSANGULARIA SCHLOENBACHI (REUSS)

16.0 Introduction

From a study of the literature it appears that the generic and specific status of this species has been confused. Most workers have referred it to Planulina schloenbachi (Reuss, 1863). There are also many misconceptions about its stratigraphical range and geographical distribution. This chapter attempts to clarify the situation by reference to specimens from the southern North Sea Basin and to specimens provided by other workers from localities worldwide.

Deposition of types: Hypotypes illustrated in this chapter are deposited in the British Museum (Natural History), London. The index numbers allocated to the specimens are given in the plate descriptions. Additional material is housed in the author's collection in the Department of Geological Sciences, Plymouth Polytechnic.

16.1 Taxonomic Discussion

Hecht's (1938) Planulina D5 (plate 2a, row I-II) of the regularis Zone of the Early Albian of North West Germany appears identical to the specimens from the southern North Sea, although Hecht's photographs do not show the aperture well enough for direct comparison. Bartenstein (1965), in his revision of Hecht's work, refers this species to Planulina schloenbachi (Reuss 1863, p. 84, pl. 10, fig. 5) but did not indicate whether he compared Hecht's species with Reuss's material or topotype material. The specimens from the southern North Sea have been compared with specimens of "Planulina" schloenbachi (Reuss) in the collection of Shell Internationale Petroleum Maatschappij, Den Haag and found to be identical. The specimens in the "Shell" collection
were originally compared with Hecht's and Bartenstein's (1965) collections (Senckenberg Museum, Frankfurt am Main). The Shell collection was examined by the author and it was agreed that the generic determination of the species should be *Osangularia* (specimens from Delft 2 borehole of Early to Middle Albian age, and Tubergen 1 borehole of Albian age).

Ten Dam (1950) recorded a species called *Planulina schloenbachi* (Reuss, 1863) from the basal Albian (Zone A, ten Dam) of the eastern Netherlands (Winterswijk area). His illustrations are line drawings (Fig. 16.1) but they compare well with specimens from the Early and Middle Albian of the southern North Sea. Ten Dam's illustration does not show the form of the aperture clearly but his specimens have been examined by the present author in the Rijks Geologische Dienst, Haarlem, the Netherlands, and Slide F. 681 contained specimens identical to those from the southern North Sea (with incidentally the note, "determined by Hofker") including the *Osangularia* aperture. Other specimens determined by Hofker were also examined (F. 1308 Albian). Hofker noted the variation in morphology displayed by this species as specimens with a more convex spiral side are designated a variety.

Ten Dam (1950) states that his species is distinct from species described as *Planulina schloenbachi* (Reuss) by Kalinin (1937) from the Senonian of Baktygaryn (USSR) and from species described as *Planulina* ex. gr. *wuellersdorfi* by Dain (1934) from the Senonian of Djaksibai (USSR). Ten Dam also distinguished his species from *Planulina schloenbachi* (Reuss) sensu Cushman and Jarvis (1929) from the Upper Cretaceous of Trinidad.

Flandrin *et al.*, (1962) illustrated by stylised line drawings an Early Albian species from Drome, southern France, which appears superficially similar to the species from the southern North Sea. Their species shows sexual dimorphism in the degree of convexity of the dorsal side and they refer it to *Discorbia minimus* Vieaux, 1941 "forme A" and "forme B". Unfortunately they did
Fig. 16.1

Trace drawings of figures of Osangularia schloenbachi (Reuss) as illustrated by various authors, to show the degree of confidence that may be placed in stylised line drawings.

1a—c: Rotalia schloenbachi Reuss, 1863, pl. 10, fig. 5.
2a—b: Planulina schloenbachi (Reuss); Ten Dam, 1950, pl. 4, figs. 7a—b.
3a—c: Planulina schloenbachi (Reuss); Neagu, 1965, pl. 8, figs. 3a—c.
4a—b: DiscorbisAquaticus Djaifar & Agalarova, 1949, sensu Salaj & Samuel 1966, text-fig. 6a—b, p. 141.
5. "Osangularia" sp. aff. brozeni Gandolfi, sensu Moullade, p. 77—79, text-fig. 2.
6a—c: Planulina schloenbachi (Reuss), Fuchs 1967, pl. 19, Figs. 3a—c.
7a—c: Eponides ussurensis Sastri & Sastri 1966, pl. 16, 19, figs. 6a—c.
8a—b: Discorbis minimus Vieaux, 1941, sensu Flandrin et al. 1965, pl. 3, figs. 7, 8, 9, 10.
not illustrate the nature of the aperture (see Fig. 16.1). However Moullade (1966) in his Doctoral thesis (Vol. 1, pp. 77 - 79, text-fig. 2, pl. 7, figs. 9-11) places Discorbis minimus, sensu Flandrin et al., in synonymy with "Osangularia" sp. aff. brotzeni (Gandolfi, 1942). He described this species from the Early and Middle Albian of the "Fosse Vocontienne", south east France. Moullade described "Osangularia" sp. aff. brotzeni as being very variable, convex-concave to biconvex, with the dorsal side evolute, flat or domed, and the ventral side involute, rarely concave but usually slightly convex, with an umbilical depression. The sutures are strongly arcuate. Moullade remarks that this "form" recalls the morphology of Gavelinella barremiana Bettenstaedt. He concluded that his "form" was similar to a number of species described by Reuss (1863, Rotalia schloenbachi, Rotalia umbonella etc.), but states that the imprecise descriptions and figures of Reuss (1863) preclude a definite conclusion. Moullade has compared some specimens provided by the author from the southern North Sea (borehole 49/24-12) with his Osangularia sp. aff. brotzeni and agrees that they are very similar (pers. comm. Moullade). Moullade's text figure (Figure 16.1) of Osangularia sp. aff. brotzeni has only 8-9 chambers in the last whorl but it does compare well with the illustration of Hecht (1938). Moullade also records Osangularia sp. aff. brotzeni in other parts of Tethys and also in D.S.D.P. North Atlantic cores of Albian age; Legs 11, 14, 41, 43, 44, 47b, 48, 50 (Guerin and Moullade, 1980) together with forms he refers to as Osangularia c.f. californica Dailey 1970.

Dr. Anne Fortuin of the Vrije Universiteit, Amsterdam, in his research on the Aptian-Albian of southern France has collected specimens of a foraminiferid referable to Osangularia sp. aff. brotzeni Gandolfi sensu Moullade from the section at Col du Palluel (studied by Moullade) and from a section at Vergons. Dr. Fortuin has kindly provided specimens of his material and agrees that it is identical to the species from the southern North Sea Basin. Fortuin refers the species to Osangularia c.f. californica Dailey 1970.
Neagu (1965, pl. 8, Fig. 3a-c) illustrated by line drawing a species he calls Planulina schloenbachi (Reuss 1863, p. 84, pl. 10, fig. 5) from the Middle Albian of Rumania. There is no descriptions but he has Ten Dam's (1950) Planulina schloenbachi in synonymy. Neagu's drawing (fig. 16.1) shows 9 chambers in the last whorl in spiral view and 10 in umbilical view. There is an umbilical calcite boss present. It is not clear whether there are thickened sutures or perforate chamber walls present. The aperture is depicted as an interiomarginal slit at the base of the last chamber. The chamber arrangement and suture pattern agree well with Ten Dam's illustration but an examination of Neagu's hypotype (LPB 5086, University of Bucharest) would be needed in order to determine the actual character of the test morphology. The associated fauna and stratigraphical age of Neagu's species does suggest the likelihood that it is the same as the species studied from the southern North Sea Basin but until an examination of Neagu's material is carried out the writer prefers to include Planulina schloenbachi sensu Neagu only tentatively in synonymy.

Salaj and Samuel (1966) in their work on the West Carpathian Cretaceous refer to a foraminiferid called Discorbis wassoewizi Djaffarov and Agalarova, 1949, as occurring in the Late Aptian and Early, Middle and Late Albian of Eastern Europe. Their stylised line drawing (text fig. 6, p. 114) of the species appears similar to the studied species from the southern North Sea Basin except that only (Fig. 16.1) an interiomarginal, extra-umbilical aperture is depicted. However in plate 36, fauna 8, fig. 5, their light photograph illustration appears identical to the species from the southern North Sea in spiral view, and to Hecht's (1938) photographic illustrations. In ventral view the
aperture is not clear. Specimens of *Discorbis wassoewizi* Djaffarov and Agalarova sensu Salaj and Samuel have been provided by Dr Salaj (pers. comm.) from sample 38, locality Povazska Bystrica, from the Lower Gargasian (c.f. Salaj and Samuel, 1966, plate 37, fauna 9). Upon close examination and comparison with the species from the southern North Sea Basin (Plate 16.1, Fig. 9, compared to Plate 16.4, Fig. 1) it is concluded that the specimens of Salaj and Samuel are very similar if not identical. However the specimens provided by Salaj (Plate 16.4, Figs. 1-10, 14, 15) are badly preserved and do not show the aperture characteristics. The specimens provided by Salaj (op. cit.) appear to be similar to *Osangularia insigna secunda* Dailey 1970 (Plate 16.3, Figs. 11-15, 20, 21) except that the sutures in the latter species are not so recurved and the chambers not so crescentic as in the former species. Therefore *Discorbis wassoewizi* sensu Salaj and Samuel is only tentatively placed in synonymy with the southern North Sea species. Some authors though, do identify a species as *Discorbis wassoewizi* in the southern North Sea Basin and suggest that it is probably the same as *Osangularia/Planulina schloenbachi* (Reuss) sensu ten Dam. Further, the same authors regard it as a good marker for the Early Albian - Late Aptian in the Dutch sector of the southern North Sea Basin.

Fuchs (1967) records a *Planulina schloenbachi* (Reuss) from the Albian of a borehole at Delft (Delft, Zuid-Holland, W. Netherlands, N.A.M.). His illustration (Fig. 16.1) is stylised and shows an aperture with just an interiomarginal slit and no areal comma-shaped aperture on the apertural face of the last chamber. However Shell Internationale Petroleum Maatschappij, Den Haag, have provided specimens of *Planulina schloenbachi sensu* Fuchs from borehole Delft 2 (N.A.M.) and they are identical to the species from the southern North Sea and should be called *Osangularia schloenbachi* (Reuss) (cf. Hecht, 1938; Bartenstein, 1965), see Plate 16.2, Figs. 4-6.
Dilley (1969) recorded Osangularia schloenbachi (Reuss) from the Melton Carstone of Melton Pit, Yorkshire, U.K. (Early Albian, associated Foraminiferida and Brachiopoda fauna). Dilley's collection at the laboratories of the British Petroleum Company, Sunbury-on-Thames, was examined by the author and slide FCD 313 (Dilley, 1969) had two well preserved specimens identical in all respects to the studied species from the southern North Sea Basin. Dilley (1969) mentions the presence of Osangularia schloenbachi (Reuss) at Speeton in the stratigraphical interval of the Greensand Streak and immediately overlying red marls (bed A4 and basal A3) but remarks on its absence from the Albian Elsham Clays of Lincolnshire. Shell internationale Petroleum Maatschappij, Den Haag, have provided specimens of Osangularia schloenbachi (Reuss) from the Speeton borehole (Pl. 16.5, Figs. 8, 12, 16) and they are identical to the specimens of Dilley (1969), of Fuchs (1967), and to the species from the southern North Sea Basin.

Gawor-Beidowa (1972) records a Gavelinella (Gavelinella) schloenbachi (Reuss) from the Late Albian to the lowermost Turonian of Poland. She remarks on Reuss's (1863) very schematic illustration. Her species also depicts sexual dimorphism (alternation of generations) as Gawor-Biedowa recognises "A" and "B" forms. She places Discorbis minimus Vieaux in synonymy. The description and illustration of Gawor-Biedowa's species differs morphologically and stratigraphically from all the "forms" discussed in this paper. Gawor-Biedowa has kindly provided specimens of her Gavelinella (Gavelinella) schloenbachi (Reuss, 1863) from Lodz borehole 4a (Late Albian) (pers. comm.). The specimens have been examined by scanning electron microscopy and no trace of an "Osangularia" aperture could be found. The specimens have an interiomarginal aperture bordered by a narrow lip and even though there are similarities in morphological appearance the species is not the same as the studied species from the southern North Sea Basin, Speeton, Melton, Delft 2, the eastern and western Netherlands and south east France (Plate 16.4, Figs. 11-13, 16-19).
Price uses Planulina schloenbachi (Reuss) as indicative of the Transitional faunal province (between Tethyan and Boreal) in the Middle and Late Albian of Europe. He attempts to demonstrate its use in north-west Europe for illustrating the concept of a mobile Tethyan/Boreal province interface during the Middle and Late Albian with the westernmost limit of the species being the Netherlands. Price's illustrations (unpub. Ph.D. Thesis, 1975, Univ. London, Pl. 13, Figs. 8a-8b; Pl. 14, Figs. 1a-1b and 1976, Pl. 1, Figs. 7-8) appear identical to the specimens of Osangularia from the southern North Sea. Price's material has been studied by the author at University College London (Micropalaeontology Laboratory, courtesy of Professor Tom Barnard) and his specimens are referable to the genus Osangularia and are identical to the species from the southern North Sea Basin.

Burnhill and Ramsay (1981) record Osangularia schloenbachi (Reuss) from the Late Albian and earliest Cenomanian (their Globigerinelloides bentonensis Zone and Hedbergella brittonensis Zone) of the central North Sea. Burnhill regards Planulina schloenbachi (Reuss), ten Dam 1950; Planulina schloenbachi (Reuss), Neagu 1965; Planulina schloenbachi (Reuss) Price 1975, 1976; as conspecific. Burnhill identifies Osangularia schloenbachi by:

A. thick non-perforate sutures on both sides of the test
B. coarse pores, particularly on the dorsal surface
C. "tight" coiling with very crescentic chambers
D. often but not always biconvex.

Burnhill (pers. comm.) has examined specimens from the southern North Sea Basin and agrees that they are Osangularia schloenbachi. Some specimens from the central North Sea are illustrated in this study by courtesy of T.J. Burnhill and B.P. Petroleum Development Ltd., Aberdeen (Plate 16.2, Figs. 1-3).
Dailey (1970) described three species and one subspecies of *Osangularia* from the Early Cretaceous of California.

*Osangularia occidentalis*, Early Aptian to Early Albian

*Osangularia californica*, Early Aptian to top Albian

*Osangularia insigna insigna*, very top Albian to top Cenomanian

*Osangularia insigna secunda*

Dailey (pers. comm.) has provided the author with topotype material of the above species and subspecies (except *O. insigna insigna*). They have been examined by the author using a scanning electron microscope (Plate 16.3, Figs. 6-9, 11-21) and *O. californica* is referable to *O. schloenbachi*. The other species are not referable to *O. schloenbachi*.

Scheibnerova (1974, 1978) regards *O. californica* Dailey (1970 p. 108-109, Pl. 13, figs. 3-4) as a junior synonym of *O. utaturensis* (Sastry and Sastri, 1966) after comparing topotypes of Dailey's species with *O. utaturensis*. Sastry and Sastri (1966) described their species from the Upper Albian of the Utatur Formation, Trichinopoly district, Madras, India as *Eponides utaturensis* but Scheibnerova believes that there is little doubt as to its identity as an *Osangularia* despite the poor illustration and description of Sastry and Sastri (Fig. 16.1). The present author has not studied the type material or topotype material of *Eponides utaturensis* Sastry and Sastri.

Scheibnerova's illustrations of *O. utaturensis* (1974, Pl. 5, figs. 1-9, S.E.M. photographs; pl. 11, figs. 4a-c, 5a-c, line drawings; 1978, pl. 4 figs. 5, 6, 7, S.E.M. photographs; 1981, fig. 4, f., g., h: figs. 5, a-g, S.E.M. photographs) show dimorphism and are identical to the *Osangularia* specimens from the southern North Sea (c.f. Fortuin op. cit.). The ventral umbilical plug of *Osangularia californica* as described by Dailey
(op. cit.) is only present in some of the specimens illustrated by Scheinberova from the Albian of D.S.D.P. leg. 27. Burnhill (pers. comm.) regards Eponides utaturensis Sastry and Sastri, Osangularia californica Dailey, Osangularia utaturensis (Sastry and Sastri) of Scheinberova and Osangularia schloenbachi (Reuss) as conspecific.

Gradstein (1978) describes, as a particularly common species, Osangularia utaturensis from Late Aptian and Middle to Late Albian sediments on the Blake nose plateau of D.S.D.P. leg 44. Gradstein remarks that O. utaturensis may be the same as O. sp. aff. brotzeni of Moullade (1966) (c.f. Fortuin op. cit.). Gradstein's illustrated specimens closely resemble the species described by Scheinberova and the species studied from the southern North Sea Basin and display the same variation in degree of convexity and peripheral outline.

Dupeuble illustrates Osangularia utaturensis from hole 400A of D.S.D.P. leg 48 (Bay of Biscay) but does not describe the species. His S.E.M. illustrations are clear enough to see that the species is without doubt identical to the species studied from the southern North Sea Basin. Dupeuble (pers. comm.) has kindly provided specimens from hole 400A, leg 48 and they are illustrated here (Plate 16.2, Figs. 7-10, 14).

Scheinberova (pers. comm.) regards the problem of generic and specific determination of the studied species from the southern North Sea Basin as being mainly a result of confusion in the literature. Specimens of O. utaturensis from D.S.D.P. leg 26, (258-18cc) were kindly provided by her and are illustrated in this paper (P. 16.3, Figs. 1-5, 10). They are identical to O. californica and are within the range of variation of the species discussed from the southern North Sea Basin.

In a recent paper, Edwards (1981) argues that the species originally described by Reuss (1863) from the Albian is a
Gavelinella and that in the Senonian several stratigraphically significant lineages arose from a Gavelinella schloenbachi (Reuss) ancestor. Edwards illustrates a species he calls Gavelinella schloenbachi (Reuss) (from the upper B. mucronata Zone, Upper Campanian, Mours, Northern France) which is undoubtedly a Gavelinella (cf. remarks of ten Dam). In his synonymy he includes a work of Vassilenko and Myatliuk (1947) of the U.S.S.R. but none of the works on the Albian (apart from Reuss) even though the species was originally described from the Albian of Germany.

Numerous other workers have reported the occurrence of Osangularia species in the Early Cretaceous from various parts of the world (e.g. Luterbacher 1975, O. californica, N.W. Pacific. D.S.D.P. leg 32, site 305; Sliter 1976, O. utaturensis, S.W. Atlantic D.S.D.P. leg 36, sites 327A and 330; Sigal 1979, Osangularia utaturensis (Sastry & Sastri); p. 321, pl. 3 fig. 21-22; Hussey 1980, Osangularia utaturensis (Sastry & Sastri); pl. 3, fig. 17, Tanzania; Haig 1981, Osangularia utaturensis (Sastry & Sastri), Papua New Guinea. Surprisingly O. schloenbachi (Reuss) has not been recorded from the Early Cretaceous strata of Trinidad.

16.2 Summary

The keystone of the taxonomic discussion is the correct generic status of Reuss's specimens of Rotalia schloenbachi from the "minimusthon von Rohrenstoffen in nordwestlichen Theile des Sommerholzes bei Kniestedt", North Germany. (Middle Cretaceous - oberer Gault = Middle Albian, see Kemper 1973).

A. Is/are the forms described by Reuss (1863) an Osangularia or a Gavelinella? A revision of his material is needed but no depository of his material is given or known (Kemper in a personal communication thinks the original locality of Reuss's material is not now open). The stratigraphical
horizons and geographical locations of Reuss are uncertain as he did not collect the material himself (pp. 6, 7, 9, 15). Kniestedt is in the Salzgitter area and Price (1975, unpublished thesis) from samples in this area, has recorded a "form" he calls Planulina schloenbachii (=Osangularia op. cit.) from the Gault Clay of Finkenkuhle near Salzgitter Bad in the Lower Saxony Basin which is Eupholites latus Zone, (nitidus and daviesi Subzones), in age. (Price, sample No. 5340, equivalent to the minimus Clay and Greensand in old stratigraphical terms, Kemper 1973).

B. If Reuss's specimens are not Osangularia then the trivial name schloenbachii may not be used for the Osangularia species studied and described in this paper. It would be an error to use Reuss's species as the type. If Reuss's species is truly a Gavelinella then the specimens of Gawor-Biedowa (1972, op. cit.) and Edwards (1981, op. cit.) may well be the same as Reuss's.

C. The species of Burnhill, Dailey, Sastry and Sastri, Scheinberova, Fuchs, Dilley, Fortuin, Moullade, Price ten Dam, and Hecht are considered to be conspecific and, in the present author's opinion, the same as Reuss's species. Therefore the present author refers the species from the Early and Middle Albian of the southern North Sea to Osangularia schloenbachii Reuss.

16.3 The Occurrence of Osangularia Schloenbachii in Borehole 49/24-12

This borehole serves a good example of the stratigraphical distribution of Osangularia schloenbachii in the Early Cretaceous of the southern North Sea Basin (see Fig. 16.2). The first downhole occurrence of this species is in the sample interval 4880 feet - 4900 feet where 7 well preserved red coloured specimens occur. This sample interval, according to
Fig. 16.2
The distribution of *Osangularia schloenbachi* (Reuss) in borehole 49/24-12.
lithostratigraphical studies and correlation with other boreholes in the southern North Sea straddles the boundary between the Upper Holland Marl Member (Red Chalk Formation) and the Middle Holland Shale Member (top part of the Speeton Clay Formation). This is the approximate boundary between the Late Albian and Middle Albian (see Fig. 16.2) according to biostratigraphical (Foraminiferida) age dating. Red coloured specimens also occur in sample interval 4900 feet - 4920 feet and then appear no more except as "cavings". In sample interval 4960 feet - 4980 feet the species appears for the first time stained a green/grey/yellow colour and correlates with the lithology change from the Upper Holland Marl Member to the Middle Holland Shale Member. A simple biometric diagram equating number of chambers in the last whorl against depth and max diameter against depth was constructed (Fig. 16.3). An obvious relationship may be seen to depth 5040 feet and then the relationship breaks down and the specimens recorded are fewer. It is assumed that specimens in samples beneath 5040 feet - 5060 feet are "caved". However, by other evidence, such as lithostratigraphy and biostratigraphy, this is approximately the boundary (unconformity) between the Middle Holland shale Member and the Lower Holland Marl Member. The specimens become progressively larger (increasing diameter) and the maximum number of chambers in the last whorl progressively increases through Albian times.

The raw data for the specimens of *O. schloenbachi* in Borehole 49/24-12 are tabulated below:

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Diameter (mm)</th>
<th>No. of Chambers</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>4900</td>
<td>0.35</td>
<td>11</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>9</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>11</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>11</td>
<td>Red</td>
</tr>
</tbody>
</table>
Fig. 16.3 A plot against depth of number of chambers, and diameter of

chambers in last whorl.

Sample Interval: Chambers in Last Whorl

Depth Below KBE

Colour

Red

Green Grey

Red

Average number of chambers in last whorl

Maximum number of chambers in last whorl

Average diameter

Maximum diameter

Specimen Number

Maximum number of chambers in last whorl

Average diameter

Maximum diameter

Specimen Number

0.30

0.25

0.20

0.15

0.10

0.05

0.00
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4920</td>
<td>0.45</td>
<td>11</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>9</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
<td>11</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
<td>10</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>9</td>
<td>Red</td>
</tr>
<tr>
<td>4980</td>
<td>0.40</td>
<td>9</td>
<td>Light green/grey/yellow</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
<td>10</td>
<td>Light green/grey/yellow</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>9 (deformed)</td>
<td>Light green/grey/yellow</td>
</tr>
<tr>
<td>5000</td>
<td>0.40</td>
<td>9</td>
<td>Green/grey</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>10 (deformed)</td>
<td>Green/grey</td>
</tr>
<tr>
<td>5020</td>
<td>0.30</td>
<td>9 (very plano- convex, dorsal boss)</td>
<td>Green/grey</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>9 (pyritised)</td>
<td>Green/grey</td>
</tr>
<tr>
<td>5040</td>
<td>0.35</td>
<td>8</td>
<td>Light green/yellow</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>8</td>
<td>Light green/yellow</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>8</td>
<td>Light green/yellow</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>9</td>
<td>Light green/yellow</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>9</td>
<td>Light green/yellow</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>8</td>
<td>Light green/yellow</td>
</tr>
<tr>
<td>5060</td>
<td>0.35</td>
<td>9</td>
<td>Light green/grey/yellow</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>10</td>
<td>Light green/grey/yellow</td>
</tr>
<tr>
<td>5100</td>
<td>0.45</td>
<td>10</td>
<td>Light green/grey/yellow</td>
</tr>
</tbody>
</table>

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Further statistical analyses were not attempted as such techniques would be invalidated by the imprecise data base (inadequate number of specimens, effect of caving, small samples, the numbers of specimens not being representative of a true parent population). Initially it was assumed that all the specimens recorded from 49/24-12 represented a true parent population. This assumption is incorrect.

The occurrence of O. schloenbachi in the other studied boreholes substantiates its use as a marker for the Early and Middle Albian of the southern North Sea but due to the difficulty of identifying the Aptian by foraminifera faunas it may well be in place in the Lower Holland Marl (Aptian) and the basal Middle Holland Shale may be Aptian in age.

16.4 Stratigraphical Range

The Osangularia species studied from the southern North Sea is a cosmopolitan species known from the Aptian and Albian in Boreal and Tethyan Early Cretaceous sediments (Figure 16.4).
Fig. 16.4

In the southern North Sea Basin it is characteristic of Middle Albian and Early Albian/Late Aptian sediments as defined by the contained foraminiferal fauna. However as documented by Burnhill and Ramsay (1981) in the northern North Sea and central North Sea it is also recorded in the Late Albian (as a biconvex heavily calcified form). Some workers have also recorded rare specimens of *O. schloenbachi* from the latest Late Albian of the southern North Sea (biconvex heavily calcified form). The present author however has not seen any species attributable to *O. schloenbachi* in the Late Albian of the boreholes studied from the southern North Sea Basin.

It is well known that benthonic Foraminifera are facies controlled and influenced by various ecological variables (e.g. temperature, substrate etc). This may explain the wide range of variation in test morphology of the species and the variation in stratigraphical range as recorded by various authors. A more detailed study may reveal ecologically disjunct subspecies or variants of the species characteristic of the five faunal provinces worldwide and/or of different facies. This species has been recorded from Earliest Cenomanian to Late Albian through Middle and Early Albian to Latest Aptian strata in various localities throughout the world.

A list of some of the ranges of this species in Europe as cited in the available literature and from data provided by Shell Petroleum Maatschappij in the Hague is presented below.

<table>
<thead>
<tr>
<th>Period</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early-Late Albian</td>
<td>Nyons 3 &amp; Dieulefit 2 sections, France</td>
</tr>
<tr>
<td></td>
<td>(Flandrin, Moullade &amp; Porthault, 1962)</td>
</tr>
<tr>
<td>Early Albian</td>
<td>Melton Carstone; Greensand Streak; basal A3 marls, Speeton; North East England (Dilley, 1969)</td>
</tr>
<tr>
<td>(regularis Subzone)</td>
<td></td>
</tr>
<tr>
<td>Middle-Late Albian</td>
<td>Tubbergen-1 well, East Netherlands (Shell)</td>
</tr>
</tbody>
</table>

380
Early-Middle Albian Delft-2, West Netherlands (Shell)

Albian Speeton-1 borehole, North East England (Shell)

Middle-Late Albian Various sections North West Europe (Price, 1976)

Early-Middle Albian Leg 48, DSDP, Site 400A (Dupeuble, 1979)

Early-Middle Albian Leg 48, DSDP, Site 402A (Dupeuble, 1979)

Early Albian East Netherlands (ten Dam, 1950)

Late Albian-Earliest Cenomanian Central North Sea boreholes, Witch Ground Graben (Burnhill & Ramsay, 1981)

Early Albian Germany - mittleland Kanal (Hecht, 1938)

16.5 Geographical Distribution

Osangularia schloenbachi appears from the literature to be essentially Austral and Boreal in its distribution. This is a reflection of the available data in the literature and also a reflection of where most research has been carried out (i.e. North West Europe, see Fig. 16.4). Bartenstein's work (1976a, b, c, 1977, 1978, 1979) emphasises the worldwide distribution of Early Cretaceous benthonic index foraminiferida and the distribution of Osangularia schloenbachi corroborates this fact for the Aptian and Albian. Fig. 16.4 shows the known distribution of O. schloenbachi depicted on a palaeomagnetic
plate reconstruction map for the Albian. It is essentially subtropical (Transitional Boreal/Tethyan) in its distribution but there was probably a faunal continuum across the equator. Evidence for this is lacking however due to the paucity of published research on the Early Cretaceous smaller benthonic foraminifera of the Cretaceous tropical and equatorial areas. Due to orogenic activity, and plate movements, many shelf deposits of Early Cretaceous age originally deposited at equatorial latitudes (usually of carbonate facies) have been intensely folded and metamorphosed or subducted, (Mesozoic and Tertiary orogenic belt areas) thus destroying the evidence.

The worldwide occurrence of similar benthic foraminifera faunas characteristic of similar facies/environments emphasis the peculiar environmental and geographical situation and interconnection, of the epicontinental seas during the Early Cretaceous. *O. schloenbachi* is a facies fossil and as such is characteristic of similar environments at different times and different latitudes in the upper Early Cretaceous (from Aptian to top Albian). However in the southern North Sea it is characteristic of Middle to Early Albian strata.

16.6 **Simple Dimensional Comparisons of Specimens of Osangularia schloenbachi (Reuss) and Allied Forms from Localities Worldwide**

The raw measurements of specimens of *O. schloenbachi* are tabulated below:

<table>
<thead>
<tr>
<th>Localities Worldwide</th>
<th>Diameter (mm)</th>
<th>No. of Chambers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in Last Whorl</td>
<td></td>
</tr>
<tr>
<td>DSDP Leg 48, Site 400A</td>
<td>0.45</td>
<td>11</td>
</tr>
<tr>
<td>65.2, 42-46</td>
<td>0.43</td>
<td>9</td>
</tr>
<tr>
<td>Dupeuble</td>
<td>0.36</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>0.28</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>0.36</td>
<td>10</td>
</tr>
<tr>
<td>Location</td>
<td>Value 1</td>
<td>Value 2</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Col du Palluel (sample F324), France</td>
<td>0.41</td>
<td>9</td>
</tr>
<tr>
<td>Anne Fortuin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vergons (sample F127), France</td>
<td>0.34</td>
<td>8</td>
</tr>
<tr>
<td>Anne Fortuin</td>
<td>0.34</td>
<td>9</td>
</tr>
<tr>
<td>France</td>
<td>0.36</td>
<td>9</td>
</tr>
<tr>
<td>0.23</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>0.32</td>
<td></td>
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<td>0.16</td>
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<td>0.23</td>
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<tr>
<td>Speeton-1 borehole, UK</td>
<td>0.30</td>
<td>11</td>
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<tr>
<td>Shell I.P.M.</td>
<td>0.32</td>
<td>10</td>
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<tr>
<td>Delft-2 (652m - 661m), Holland</td>
<td>0.36</td>
<td>9</td>
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<td>0.30</td>
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<td>DSDP 26, site 258 18cc</td>
<td>0.39</td>
<td>9</td>
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<tr>
<td>Scheibnerova, pers. comm.</td>
<td>0.45</td>
<td>10</td>
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<td>0.41</td>
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<td>10</td>
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<tr>
<td>Povazska Bystrica, sample 38, West Carpathians</td>
<td>0.34</td>
<td>10</td>
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<td>Salaj &amp; Samuel, pers. comm.</td>
<td>0.36</td>
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<tr>
<td>0.36</td>
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California Budden Canyon, 0.34 10
locality D3474. 0.32 10
Dailey, 1970, pers. comm. 0.28 10
Reuss 1863, 0.42 10
measurements from drawing

These measurements give the variation in size and number of chambers in the last whorl. Further and more sophisticated statistical analyses were not performed. A useful exercise would be to collect sufficient numbers of specimens of \( O. \) schloenbachi from Germany and to conduct a statistical analysis on a parent population.

16.7 Conclusion

Boltovskoy in 1965 stated that no confidence can be placed in the real identity of the corresponding species in comparing lists of species containing identical names. Figures and descriptions may be compared but ideally the type material needs to be examined.

In this chapter a great deal of material has been examined from locations worldwide to try and assess the degree of concensus in defining and recognising \( O. \) schloenbachi. A too narrow concept of the species is a serious problem and the plates show the wide degree of morphological variation expressed by Osangularia schloenbachi. A micropalaeontologist is trying to classify a dead test and usually the probable soft body, life history, and ecology are ignored. The result is an overload of synonyms. It is appreciated that a stratigrapher/micropalaeontologist has a different concept of the species which will usually be narrow and very different to that of a zoologist. No credence can be given to a new species created on the basis of minor differences in ornamentation, umbilical bosses, secondary calcite deposition or degree of convexity of the test and for this reason no attempt is
made to "split" the species. The studied species from the southern North Sea is referred to Osangularia schloenbachii (Reuss, 1863) by the present author as the main problem of the correct identity of Reuss's species is still not resolved beyond doubt. An attempt has been made however.
Osangularia schloenbachi (Reuss)

Southern North Sea

Figure(s)

1, 2, 3 49/24-4 (4880 ft.) no. P.51211, spiral x 100, edge x 140, umbilical x 140.

4, 8 49/10-1 (7390 ft.) no. P.51212, umbilical x 100, edge x 100.

5, 6, 7 49/24-4 (4880 ft.) no. P.51213, spiral x 100, oblique umbilical x 180, umbilical x 150.

9, 10, 11 49/24-12 (4900 ft.) no. P.51214, spiral x 100, umbilical x 100, edge x 100.

12, 18 49/10-1 (7390 ft.) no. P.51215, spiral x 100, close up of spiral side to show non-perforate thickened sutures x 250.

13, 14, 15 49/24-12 (4920 ft.) no. P.51216, spiral x 100, edge x 100, umbilical x 100.

16, 17 49/10-1 (7390 ft.) no. P.51217, umbilical x 100, edge x 100.
Osangularia schloenbachi (Reuss)

Figure(s)

1, 2, 3 B.P. 21/1a-10 (2765m), Rodby Formation, late Albian (Globigerinelloides bentonensis local partial range Biozone), Central North Sea. Supplied by T.J. Burnhill. Spiral x 164, edge x 164, umbilical x 164.

4, 5, 6 Delft 2 borehole, the Netherlands, no. P.51218. Spiral x 117, edge x 190, umbilical x 110.

Osangularia utaturensis (Sastry & Sastri)

D.S.D.P. Leg 48, Site 400A, Core 65, Section 2, 42 - 46 cm.

Figure(s)

7, 8, 9 No. P.51219. Spiral x 100, edge x 100, umbilical x 100, close up of last chamber to show suture thickening and perforate chamber wall x 182.

10 Umbilical x 100.

Osangularia sp. aff. brotzeni (Gandolfi) sensu Moullade

Sample F 127, Vergons, Southern France, coll. by Dr A. Fortuin.

Figure(s)

11, 12, 13 No. P.5120. Spiral x 100, no. P.51221, edge x 100, umbilical x 100.
Osangularia utaturensis (Sastry & Sastri)
D.S.D.P. Leg 26, Site 258, 18cc.

Figure(s)
1, 2, 3 No. P.51222. Spiral x 100, edge x 100, umbilical x 100.
4, 5, 10 No. P.51223. Spiral x 100, edge x 100, umbilical x 100.

Osangularia californica Dailey
Topotype specimens. Budden Canyon Formation, northern edge of Dry Creek (see page 91, Dailey 1973) Locality D 3474.

Figure(s)
6, 7, 8 No. P.51224. Spiral x 100, edge x 175, umbilical x 100.
9 No. P.51225. Umbilical x 100.

Osangularia insigna secunda Dailey
Topotype specimens, (see Dailey 1973) Locality D 3501.

Figure(s)
11, 12, 13, 14 No. P.51226. Spiral x 120, close up of aperture x 175, edge x 110, umbilical x 110.
15, 20, 21 No. P.51227. Spiral x 100, umbilical x 110, edge x 100.

Osangularia occidentalis Dailey
Topotype specimens, (see Dailey 1973) Locality D 3580.

Figure(s)
16, 17 No. P.51228. Spiral x 175, edge x 175.
18, 19 No. P.51229. Edge x 230, umbilical x 175.
**PLATE 16.4**

*Discorbis wassoewizi* Djaffarov & Agalarova *sensu* Samuel & Salaj 1966.

Sample no. 308, Povazska Bystrica, Carpathians, Rumania.

**Figure(s)**

1, 2, 3  No. P.51230. Spiral x 100, edge x 175, umbilical x 100.

4, 5, 10 No. P.51231. Spiral x 100, edge x 190, umbilical x 100.

6, 7, 8  No. P.51232. Spiral x 100, edge x 175, umbilical x 100.

9, 14, 15 No. P.51233. Spiral x 100, umbilical x 175, edge x 175.

*Gavelinella (Gavelinella) schloenbachi* (Reuss) *sensu* Gawor Biedowa Lodz 4a borehole, Poland, Upper Albian.

**Figure(s)**

11 No. P.51234. Umbilical x 100.

12 No. P.51235. Edge x 175.

13, 16, 17 No. P.51236. Umbilical x 100, spiral x 100, edge x 100.

18, 19 No. P.51237. Umbilical x 200, edge x 200.
Gavelinella sigmoicosta ten Dam
Speeton Clay, Filey Bay section, C1 beds, Hauterivian.

Figure(s)
1, 2, 3 No. P.51238. Spiral x 100, edge x 100, umbilical x 100.

Gavelinella barremiana (Bettenstaedt)
Southern North Sea, 49/24-12, (5340 ft).

Figure(s)
4 No. P.51239. Umbilical x 100.
5, 6, 7 No. P.51240. Spiral x 100, edge x 100, umbilical x 100.

Osangularia schloenbachi (Reuss)
Shell Speeton 1 borehole

Figure(s)
8 No. P.51241. Spiral x 100.
12, 16 No. P.51243. Edge x 175, umbilical x 100.

Osangularia sp. aff. brotzeni (Gandolfi) sensu Moullade
Col du Palluel, southern France, coll. by Dr A. Fortuin, Sample F 324.

Figure(s)
9, 10, 11 No. P.51242. Spiral x 100, edge x 100, umbilical x 100.

Gavelinella intermedia (Berthelin)
Southern North Sea 49/10-1 (7120 ft)

Figure(s)
13 No. P.51244. Spiral x 100.

Gavelinella intermedia var A. (Berthelin)
Southern North Sea 49/10-1 (7160 ft)
PLATE 16.5 (continued)

Figure(s)

14 No. P.51245. Spiral x 100.

Lingulogavelinella albiensis s.l. Malapris

Figure(s)

15 No. P.51246. Umbilical x 100.
PART 5

CONCLUSIONS
CHAPTER 17

CONCLUSIONS

17.1 General Comments

The results of the analyses and the main conclusions drawn are discussed within the preceding sections of this thesis. This chapter briefly comments upon the main objective achievements.

The objectives of this thesis, as set out in Chapter 1, have been answered by the lithostratigraphical, biostratigraphical and chronostratigraphical subdivision of the studied boreholes. The main result is a foraminiferal biostratigraphy of the Early Cretaceous strata (Albian and Aptian mainly) of block 49. A brief taxonomic section discusses the majority of the foraminiferal fauna but particular attention has been paid to O. schloenbachi and L. (A.) humilis.

The relationship between the lithostratigraphical, biostratigraphical and chronostratigraphical subdivision is discussed in the preceding chapters of this thesis.

The data obtained from the offshore boreholes have been used to compare and contrast onshore UK sequences of Early Cretaceous strata to offshore sequences with especial attention being paid to the Albian and Aptian age strata. Particular attention has been paid to the Early Aptian strata of the Isle of Wight and to the Barremian-Aptian strata of DSDP leg 80, site 549.

The importance of an integrated stratigraphic approach has been stressed throughout this thesis and emphasis has been placed upon the important role that foraminiferal biostratigraphy plays in hydrocarbon exploration.
17.2 Suggestions for Further Research

This thesis only "scratches the surface" in terms of the Early Cretaceous stratigraphy of the southern North Sea Basin and, in order to achieve a better and fuller understanding, additional detailed research and analysis is essential. Many more boreholes, both offshore and onshore, from the UK and the Netherlands need to be examined in terms of: lithostratigraphy, micropalaeontological biostratigraphy, (foraminifera and ostracods), palynological and calcareous nannoplankton biostratigraphical studies, and chronostratigraphy. In particular, a thorough taxonomic study of the foraminiferal faunas of the Early Cretaceous is essential if a more refined foraminiferal biostratigraphy is to be developed. Material from boreholes throughout the North Sea region need to be examined. Specific taxonomic studies have been suggested in the taxonomic sections of this thesis but include: Gavelinellids and Hedbergellids. These data need to be supplemented by the results of sedimentological and source rock and thermal maturity geochemical studies.

The results of such studies will be of importance for the search for hydrocarbons in the Early Cretaceous strata of the whole of the North Sea region.
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APPENDIX

PUBLISHED PAPERS BASED ON THIS THESIS


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