# Robertson Research International Limited

Dr. W. W. McB. Brown (Chairman), Dr. H. R. Bichan (Managing Director) Dr. R. H. Cummings, R. J. Clint, R. W. Goldsmith, Dr. P. Ibbotson, R. W. L. Oldroyd, Dr. E. B. Wolfenden, Dr. A. J. Wright

'TY'N-Y-COED', LLANRHOS, LLANDUDNO, GWYNEDD LL30 1SA, UNITED KINGDOM.

TELEPHONE: (0492) 81811
CABLES: RESEARCH LLANDUDNO
TELEX: 61216 (AB Robres G)
FACSIMILE (GP. 3): 0492 83416


Your Reference..... Our Reference RSWN/ewt.

Mr. H. Ellingsve

Conoco Norway Inc.
P.O. Box 488
Finnestadveien 28
4000 Stavanger
Norway.

1st March 1984.

Dear Mr. Ellingsve,

Re: 7/8-3 Norwegian North Sea Well

Please find enclosed three copies of our Report No. 3049P/A, entitled Conoco Norway Inc. 7/8-3 Norwegian North Sea Well: Biostratigraphy of the Interval 210m-4320m T.D.

We would be grateful if you could acknowledge receipt of this report by signing one copy of the enclosed transmittal notice and returning it to us as soon as possible.

It has been a pleasure working for you and we look forward to continuing our association in the future.

Yours sincerely,

Dick Neville

R. S. W. NEVILLE
Senior Palynologist

for and on behalf of
Robertson Research International Limited



Enc.

ROBERTSON RESEARCH INTERNATIONAL LIMITED

REPORT NO. 3049P/A

# CONOCO NORWAY INC.
# 7/8-3 NORWEGIAN NORTH SEA WELL:
# BIOSTRATIGRAPHY OF THE INTERVAL 210m-4320m T.D.

by

R.W. JONES
C.P. MORTIMER
R.S.W. NEVILLE
A.J. SHAW
R. TITTERTON

PROJECT NO: RRPS/834/A/10077

Prepared by:

Robertson Research International Limited,
'Ty'n-y-Coed',
Llanrhos,
Llandudno,
Gwynedd LL30 1SA,
Wales,
U.K.

Prepared for:

Conoco Norway Inc.,
P.O. Box 488,
Finnestadveien 28,
4000 Stavanger,
Norway.

February, 1984

## CONTENTS



## APPENDICES



## FIGURES



## ENCLOSURE

## SUMMARY

1. The youngest sediments analysed are claystones with minor sandstones, which range in age from Pleistocene to Late - Middle Miocene and are assignable to the Nordland Group.

2. The Nordland Group rests conformably on the Hordaland Group, which ranges in age from Late - Middle Miocene to Early Eocene, and is composed of brown shales and claystones with traces of dolomite.

3. The Rogaland Group lies below the Hordaland Group; the contact between them is possibly unconformable. It consists of the Balder, Sele and Lista Formations which are respectively composed predominantly of grey silty and tuffaceous shales; grey laminated shales and grey shales with traces of limestone throughout.

4. The Montrose Group of Late to Early Palaeocene age is represented by the Maureen Formation which consists of calcareous claystones and limestones.

5. The Chalk Group which ranges in age from Early Palaeocene to Late Cretaceous, Cenomanian, consists mainly of limestone. There is an unconformity within the lower part and rocks of late Turonian age are absent.

6. The Cromer Knoll Group which conformably lies below the Chalk Group consists predominantly of limestones of Albian age which unconformably overlie a thin limestone of early Barremian - late Hauterivian age which in turn lie unconformably on deposits of early Valanginian age.

7. The oldest sediments of the Cromer Knoll Group range in age from early Valanginian to latest Ryazanian and comprise a sequence of shales, which conformably overlie the Boknfjord Group.

II

## INTRODUCTION

This report summarises the results of the micropalaeontological, palynological, nannofloral and stratigraphical analyses which have been carried out on material received from the section 210m-4320m T.D. from the Conoco Norway Inc. 7/8-3 Norwegian North Sea Well under Project No. RRPS/834/A/10077.

The following analyses were carried out:
Lithology: 495 ditch cuttings, 53 sidewall core and 32 core samples from the entire section.
Micropalaeontology: 324 ditch cuttings and 26 sidewall core samples from the interval 210m-3607m.
Palynology: 23 ditch cuttings, 31 sidewall core and 11 core samples from the interval 3415m-4320m T.D.
Nannofossils: 11 ditch cuttings and 15 sidewall core samples from the interval 2864m-3550m.

The basic breakdown obtained by these analyses has already been communicated by telex and telephone and forms the framework of factual information on which this report is based. A summary of the sequence penetrated in this well can be seen on pages 5 and 6.

All rock colour references in this report conform to the "Rock-Color Chart" distributed by the Geological Society of America. The lithological descriptions of the sidewall cores can be seen in Appendix 1 whilst those of the core samples occur in Appendix 2.

It should be noted that the lithostratigraphic terminology is taken from Deegan and Scull 1977 and Olsen and Strass 1982. The stratigraphic significance of the Ryazanian - Albian dinocyst zones is summarised in Appendices 3 and 4.

The prepared samples and recorded information are now filed and curated in the confidential records section of these laboratories.

We wish to acknowledge the continued co-operation and assistance received from the various members of Conoco Norway Inc. with whom we have been associated during the course of this work.

Robertson Research staff involved in this study were:

| | | |
|---|---|---|
| Paul Frame | - | Cretaceous and Jurassic micropalaeontology |
| Bob Wynn Jones | - | Cainozoic micropalaeontology |
| Chris Mortimer | - | Nannofossils |
| Dick Neville | - | Palynology and Project Co-ordinator |
| Alison Shaw | - | Lithologies |
| Rosemary Titterton | - | Cretaceous and Jurassic micropalaeontology. |

III

## BIOSTRATIGRAPHIC SUCCESSION

| Age | | Tops(in metres) KB |
|---|---|---|
| Pleistocene | | 210(top not seen) |
| Pliocene | | 450 |
| Late - Middle Miocene | | 800 |
| Early Miocene | | 1380 |
| Late Oligocene | | 1410 |
| Early Oligocene - Middle? Eocene | | 2330 |
| Middle - Early? Eocene | | 2520 |
| Early Eocene | | 2690 |
| ----------?Unconformity---------- | | |
| Late Palaeocene | | 2716.50(log) |
| Early Palaeocene | | 2864(SWC) |
| Late Cretaceous | ( latest Maastrichtian | 3023.50(log) |
| | ( late Maastrichtian | 3061 |
| | ( early Maastrichtian - late Campanian | 3282(SWC) |
| | ( early Campanian | 3340 |
| | (----------Unconformity---------- | |
| | ( early Turonian | 3348(log) |
| | ( Cenomanian | 3367(log) |

Continued.....

## BIOSTRATIGRAPHIC SUCCESSION (Continued)

| Age | | Tops(in metres) |
|---|---|---|
| | ( Albian | 3393(log) |
| | ( ---------- Unconformity ---------- | |
| | ( early Barremian - late | 3459(log) |
| Early Cretaceous | ( Hauterivian | |
| | ( ---------- Unconformity ---------- | |
| | ( early Valanginian | 3461(log) |
| | ( earliest Valanginian | 3580 |
| | ( latest Ryazanian | 3601 |
| Early Cretaceous - ?Late Jurassic | late Ryazanian - ?late Volgian | 3638.50(log) |
| ----------?Unconformity---------- | | |
| | ( late middle Volgian | 3691 |
| | ( ----------Unconformity---------- | |
| Late Jurassic | ( latest early Volgian | 3723.50(log) |
| | ( early Volgian | 3741.70(core) |
| | ( latest Kimmeridgian | 3758.10(core) |
| ----------Unconformity---------- | | |
| Triassic | | 3767(log) |
| Middle - Early? Triassic | middle Anisian - ?Skythian | 3972(SWC) |
| ----------?Unconformity---------- | | |
| Late Permian (Zechstein) | | 4237(log)-4320 T.D. |

This breakdown has been achieved by the analysis of ditch cuttings, sidewall core, and core samples. Wireline logs were provided by the client.

IV

## LITHOSTRATIGRAPHIC SUCCESSION

| Unit | Age | Tops (in metres) |
|---|---|---|
| Nordland Group | Pleistocene to Late - Middle Miocene | 210(top not seen) |
| Hordaland Group | Late - Middle Miocene to Early Eocene | 1310 |
| Rogaland Group | | |
| Balder Formation | Late Palaeocene | 2716.50(log) |
| Sele Formation | Late Palaeocene | 2757.50(log) |
| Lista Formation | Late Palaeocene | 2830(log) |
| Montrose Group | | |
| Maureen Formation | Late - Early Palaeocene | 2854(log) |
| Chalk Group | | |
| Ekofisk Formation | Early Palaeocene | 2870(log) |
| Tor Formation | latest - late Maastrichtian | 3023.50(log) |
| Hod Formation | late Maastrichtian - early Campanian | 3275(log) |
| Plenus Marl Formation | early Turonian | 3348(log) |
| Hidra Formation | Cenomanian | 3367(log) |
| Cromer Knoll Group | | |
| "Limestone Unit" | Albian | 3393(log) |
| Valhall Formation | early Barremian - late Hauterivian to latest Ryazanian | 3459(log) |

Continued. .....

## LITHOSTRATIGRAPHIC SUCCESSION (Continued)

| Unit | Age | Tops (in metres) |
|---|---|---|
| Boknfjord Group | | |
| Kimmeridge Clay Formation | late Ryazanian - late middle Volgian | 3638.50(log) |
| Vestland Group | | |
| Ula Formation | latest early Volgian - latest Kimmeridgian | 3723.50(log) |
| "Triassic Group" | | |
| Skagerrak Formation | Triassic | 3767(log) |
| Zechstein Group | Late Permian | 4237(log)-4320 T.D. |

V

## LITHOSTRATIGRAPHY

The lithostratigraphic nomenclature used in this report is based on Deegan & Scull 1977 and Olsen and Strass 1982. Wireline logs were provided between 210m and 4261m, and all but one of the lithostratigraphic boundaries are based on log breaks.

## LITHOSTRATIGRAPHIC UNITS

NORDLAND GROUP: 210m(top not seen)-1310m; Age: Pleistocene to Late - Middle Miocene.

This unit comprises a thick sequence of claystones with minor sandstones. The claystones are light olive grey to olive grey, locally sandy and weakly calcareous. Pyrite and shell fragments persist throughout, with traces of fine to coarse sand between 210m and 775m.

HORDALAND GROUP: 1310m-2716.50m(log); Age; Late - Middle Miocene to Early Eocene.

The upper boundary of this unit is based on the occurrence of glauconite in the ditch cuttings sample at 1310m, which may represent a regional hardground formed during the Middle Miocene. The characteristic brown shales and claystones of the Hordaland Group are recorded just below this depth, at 1340m. Traces of dolomite, representing stringers or concretions, are recognised below 1335m and are similarly typical of the Hordaland Group.

Brown and olive grey shales and claystones with dolomite and limestone stringers or concretions persist throughout this unit with traces of pyrite, calcite, siderite and shell fragments.

The basal section, between 2570m and 2716.50m(log) is lithologically distinctive. In this interval, greenish grey shales overlie greyish red, and waxy, greenish grey shales which contain traces of grey and white tuffaceous

shale. Pyrite, siderite and calcite are common accessories within this basal section.

ROGALAND GROUP: 2716.50m(log)-2854m(log); Age: Late Palaeocene.

Balder Formation: 2716.50m(log)-2757.50m(log).
This formation is delineated by a characteristic log signature and consists of shales which are moderately hard, subfissile, medium grey to dark greenish grey and greyish red to greenish grey, becoming medium grey to dark grey, locally silty and tuffaceous. Traces of pyrite, calcite and sphaerosiderite occur throughout.

Sele Formation: 2757.50m(log)-2830m(log).
The upper limit of this formation is marked by a log break corresponding to the occurrence in ditch cuttings samples of finely laminated shales. These shales are medium grey to dark grey and olive grey, and locally sandy with traces of greyish red shale between 2790m and 2800m.

Minor glauconitic limestone, fine grained sand and pyrite are recorded at the base of this unit.

Lista Formation: 2830m(log)-2854m(log).
The predominant lithology in this unit is shale, which is medium grey to olive grey and locally pyritic. Traces of limestone occur throughout this interval, consisting of thin stringers or concretions of pale brown, slightly argillaceous limestone between 2830m and 2845m, and white, brittle, locally sandy limestone at and below 2845m.

MONTROSE GROUP: 2854m(log)-2870m(log); Age: Late - Early Palaeocene.

Maureen Formation
The upper boundary of this unit is defined by a log break corresponding to the occurrence of calcareous claystones and limestones in ditch cuttings samples. The claystones are waxy, olive grey and micromicaceous, and the limestones are hard and white, locally sandy with chert.

CHALK GROUP: 2870m(log)-3393m(log); Age: Early Palaeocene - Late Cretaceous, Cenomanian.

Ekofisk Formation: 2870m(log)-3023.50m(log); Age: Early Palaeocene.
The predominant lithology within this formation is limestone which is moderately hard, white, and locally chalky. Chert is present below 2900m and the limestones are locally sandy below 2940m. Light olive grey dolomitic shales and dolomites are recorded between 2889m(log) and 2894.50m(log). Rare glauconitic sandstone occurs in the ditch cuttings sample at 2980m, within a sequence of white limestones which becomes slightly argillaceous and very light grey towards the base of the unit.

Tor Formation: 3023.50m(log)-3275m(log); Age: Late Cretaceous, latest to late Maastrichtian.
This formation comprises a thick sequence of limestones which are white to very light grey, and locally chalky. Traces of sand and chert occur within the limestones in the upper part of the unit, down to 3180m. Rare calcareous shales are recorded at 3210m, and calcite and pyrite occur as traces throughout.

Hod Formation: 3275m(log)-3348m(log); Age: Late Cretaceous, late Maastrichtian - early Campanian.
The predominant lithology in the upper part of the formation is limestone which is moderate orange pink to pale red, slightly argillaceous and locally pyritic. Minor quantities of white to very light grey limestones are present, and these limestones predominate below 3315m.

Plenus Marl Formation: 3348m(log)-3367m(log); Age: Late Cretaceous, early Turonian.
This formation comprises an upper unit of limestones and sandy claystones which are pale red to greyish red and light grey, locally sandy, glauconitic and micaceous. The basal part of the formation, between 3357.50m(log) and 3367m(log), comprises shales which are medium grey to dark grey and non-calcareous and locally olive grey, silty, sandy, glauconitic, micaceous and highly calcareous.

Hidra Formation: 3367m(log)-3393m(log); Age: Late Cretaceous, Cenomanian.
The limestones comprising this unit are crystalline, and pinkish grey to very light grey, becoming locally sandy and glauconitic towards the base of the formation.

CROMER KNOLL GROUP: 3393m(log)-3638.50m(log); Age: Early Cretaceous, Albian - latest Ryazanian.

"Limestone Unit": 3393m(log)-3459m(log); Age: Early Cretaceous, Albian.
The upper section of this unit consists predominantly of limestones which are white to greenish grey, glauconitic, sandy and locally coarsely crystalline. These limestones become increasingly sandy, glauconitic and argillaceous, and grade locally into calcareous sandstones.

Minor argillaceous sandstones at 3457m(SWC) are friable, greyish red, very fine to fine grained, silty, micaceous, argillaceous and calcareous.

Valhall Formation: 3459m(log)-3638.50m(log); Age: Early Cretaceous, early Barremian - late Hauterivian to latest Ryazanian.
A thin limestone is delineated between 3459m(log) and 3461m(log), representing sediments of early Barremian to late Hauterivian age.

The lower section of this formation, below 3461m(log), comprises a sequence of shales and dolomitic shales. These sediments are moderately hard, locally greyish red to dusky red, micromicaceous and non-calcareous, becoming medium grey to dark grey and olive grey, locally dolomitic and locally pyritic. Traces of fine sand are recorded below 3577m, and light brown, sideritic limestone stringers or concretions occur below 3616m.

BOKNFJORD GROUP: 3638.50m(log)-3723.50m(log); Age: Late Jurassic, late Ryazanian - late middle Volgian.

Kimmeridge Clay Formation

This formation consists of shales which have a characteristic log signature, clearly delineating the upper boundary. The shales are subfissile, brownish black, micromicaceous and locally silty and calcareous. Traces of pyrite occur throughout and rare sand and glauconite are recorded at 3718m.

VESTLAND GROUP: 3723.50m(log)-3767m(log); Age: Late Jurassic, latest early Volgian - latest Kimmeridgian.

Ula Formation

This formation comprises sandstones which are olive grey to light grey and dark yellowish brown, very fine to medium grained, and glauconitic with shell debris and carbonaceous fragments. These sandstones are commonly oil stained, locally calcite cemented and locally argillaceous. Subordinate, brownish black, silty shales are indicated on wireline logs between 3726m(log) and 3730m(log).

"TRIASSIC GROUP": 3767m(log)-4237m(log); Age: Triassic

Skagerrak Formation

The upper boundary of this formation is based on a log break. The core piece at 3766m is considered to belong to this lithostratigraphic group, the depth discrepancy being due to the difference between drillers' and loggers' depths.

The predominant lithologies in this unit are sandstones and shales. The sandstones are friable to well cemented, pale red to moderate reddish brown, locally white to greenish grey, very fine to medium grained, locally highly micaceous and slightly argillaceous. The interbedded units of shales and claystones are slightly waxy, dark reddish brown to greyish red, locally light greenish grey to light grey, locally highly micaceous and sandy.

Subordinate dolomites and dolomitic shales are recorded between 3880m(log) and 3885m(log) and from 3930m(log) to 3956m(log). These sediments are light brown to light grey and crystalline, becoming medium grey, micaceous and locally silty.

Traces of anhydrite occur throughout in ditch cuttings samples and the sandstones are locally anhydritic (4169.70m (SWC)).

The claystones are calcareous, grading to argillaceous limestone in the sidewall core at 4233.20m.

ZECHSTEIN GROUP: 4237m(log)-4320m T.D.; Age: Late Permian.

The upper limit of this unit is defined by a sharp log break at 4237m, corresponding to the penetration of anhydrite. This lithotype is represented in ditch cuttings samples by traces only. Since wireline log information was not available below 4261m, lithological interpretations below this depth are based on ditch cuttings samples only. The predominant lithology below 4261m comprises dolomitic shales which are light to medium grey and locally micaceous, grading to argillaceous dolomite. Traces of anhydrite persist, and below 4302m the ditch cuttings samples contain red sand and shale, with traces of dolomite and anhydrite.

VI

# BIOSTRATIGRAPHY

## VI(1) CAINOZOIC

INTERVAL 210m-450m; PLEISTOCENE (top not seen)

Lithostratigraphic Unit:
Nordland Group (part).

Environment: marine, inner shelf.

The age of this interval is based on the following micropalaeontological criteria:

- the co-occurrence of representatives of the Elphidium incertum group and of the Nonion granosum/Protelphidium orbiculare group at 210m.
- the subsequent occurrences of bryozoan fragments at 290m and of the ostracod Rabilimis mirabilis at 330m.

MICROPALAEONTOLOGY

The presence at 210m of the nominate taxa indicates development of the Pleistocene Elphidium incertum group/Nonion granosum - Protelphidium orbiculare group Assemblage. The sparse, low diversity microfaunal associations suggest deposition in a high energy inner shelf environment. The occurrences of bryozoan fragments at 290m and of the ostracod Rabilimis mirabilis at 330m constitute potentially correlatable events.

INTERVAL 450m-800m; PLIOCENE

Lithostratigraphic Unit:
Nordland Group (part).

Environment: marine, inner to outer shelf, shallowing to inner shelf.

The upper limit and age of this interval are based on the following micropalaeontological criteria:

- the co-occurrence of Cibicides lobatulus var. grossa and Nonion affine at 450m.
- the subsequent occurrences of Bulimina marginata at 690m, Sigmoilina celata at 740m, Cibicides pseudoungerianus at 750m and Monspeliensina pseudotepida and Pullenia bulloides at 790m.

MICROPALAEONTOLOGY

The occurrence at 450m of the nominate taxa indicates penetration of the Pliocene Cibicides lobatulus var. grossa/Nonion affine Assemblage. The age assigned is corroborated by subsequent findings of a number of characteristic species listed above. The postulated palaeoenvironment remains essentially as for the overlying interval, but a slightly deeper environment is indicated over the lower half of the interval.

INTERVAL 800m-1380m; LATE - MIDDLE MIOCENE

Lithostratigraphic Units:
Nordland Group (part): 800m-1310m.
Hordaland Group (part): 1310m-1380m.

Environment: marine, outer shelf, shallowing to inner to outer shelf.

The upper limit and age of this interval are based on the following micropalaeontological criteria:

- the occurrence of Cibicides peelensis, Eponides umbonatus and Loxostomum sinuosum at 800m.
- the subsequent occurrences of Nonion boueanum at 840m, Angulogerina gracilis, Dentalina koninckí and Textularia decrescens at 890m, Globigerina praebulloides at 900m, Orbulina universa at 910m, Uvigerina hosiusi at 930m, Chilostomellina fimbriata at 960m, Coscinodiscus spp. and Hoeglundina elegans at 1040m, Pseudoclavulina sp. at 1070m, Spiroplectammina carinata at 1130m, Glomospira charoides at 1150m, Globigerina bradyi at 1160m, Elphidium inflatum and Globigerina angustiumbilicata at 1200m, Globigerina angustiumbilicata/aff. angulisuturalis transients at 1220m, Bolboforma metzmacheri at 1270, Litheliid sp.A and Bolboforma spiralis at 1330m and Bolboforma clodiusi at 1350m.

MICROPALAEONTOLOGY

The occurrence at 800m of the nominate taxa indicates joint development of the Cibicides peelensis and Loxostomum sinuosum/Eponides umbonatus Assemblages, both of Late Miocene age, at this depth. Three additional assemblages are recognised within the remainder of this interval: the Late - Middle Miocene Angulogerina gracilis Assemblage (below 890m) and the Middle Miocene Glomospira charoides/Bathysiphon spp./Pseudoclavulina sp. and Globorotalia scitula group/Globigerina angustiumbilicata Assemblages (respectively, below 1070m and 1200m). Several characteristic species corroborate the age assigned. The postulated palaeoenvironment for the Late Miocene and Angulogerina gracilis Assemblage Zone is inner to outer shelf. This is based on the dominantly calcareous benthonic foraminiferal associations therein, which are moderately rich and diverse. In contrast, the Middle Miocene would appear to have been

deposited in somewhat deeper waters subject to more open marine influences. Evidence for these views is provided by increasing proportions of agglutinating foraminifera in the Glomospira charoides/Bathysiphon spp./Pseudoclavulina sp. Assemblage, and of planktonic foraminifera in the Globorotalia scitula group/Globigerina angustiumbilicata Assemblage. Within the latter, the following sequence of species of the problematic (?algal cyst) genus Bolboforma was noted: B. metzmacheri at and below 1270m; B. spiralis at and below 1330m, and B. clodiusi at and below 1350m. The radiolarian species Litheliid sp.A, usually an Oligocene and Early Miocene indicator, was recorded at 1330m.

INTERVAL 1380m-1410m; EARLY MIOCENE

Lithostratigraphic Unit:
Hordaland Group (part).

Environment: marine, inner to outer shelf.

The upper limit and age of this interval are based on the following micropalaeontological criterion:

- the occurrence of Asterigerina staeschei at 1380m.

MICROPALAEONTOLOGY

Reliable evidence for an Early Miocene age is provided by the presence of the planktonic foraminifera Globigerinoides triloba, Sphaeroidinellopsis seminulina and Globorotalia zealandica caved into the underlying interval and of the calcareous benthonic form Asterigerina staeschei in situ at 1380m. The occurrence of the last named species indicates an inner to outer shelf environment of deposition. The occurrence of Sigmoilina schlumbergeri at 1390m and of Guttulina problema at 1400m is probably due to minor reworking of Oligocene sediments.

INTERVAL 1410m-2330m; LATE OLIGOCENE

Lithostratigraphic Unit:
Hordaland Group (part).

Environment: marine, outer shelf to upper bathyal shallowing to inner to outer shelf.

The upper limit and age of this interval are based on the following micropalaeontological criteria:

- the occurrence at 1410m of Globorotalia opima nana.
- the subsequent occurrences of Globigerina woodi at 1420m, Rotalia canui at 1430m, Asterigerina gürichi at 1440m, Globigerina ?ouachitaensis at 1470m, Dorothia sp.6 at 1510m, Karreriella cf. apicularis at 1520m, Uvigerina tenuipustulata at 1530m, Coscinodiscus cf. sp.1 at 1550m, Coscinodiscus sp.4 at 1740m, Sigmoilina schlumbergeri at 1750m, Coscinodiscus sp.13 at 1830m, Cyclammina amplectens at 1840m, Trochammina globigeriniformis at 1850m, Trochammina altiformis at 1860m, Coscinodiscus sp.5 at 1870m, Coscinodiscus sp.3 at 2080m, Cystammina sp. at 2090m, Baggatella cf. altiuscula at 2160m, Trochammina sp.X at 2300m and Elphidium latidorsatum at 2310m.

MICROPALAEONTOLOGY

An Oligocene age can be assigned to the sediments penetrated at 1410m on the basis of the recovery from the sample at that depth of Globorotalia opima nana. This is a planktonic foraminifer which ranges no higher than Zone P.22 of Blow 1979 (latest Oligocene). The age is substantiated by recognition of the Asterigerina gürichi/Guttulina problema Assemblage, the former nominate taxon occurring at and below 1440m, the latter caved into the underlying interval. This assemblage is believed to have been deposited under inner to outer shelf conditions. In contrast, the Sigmoilina schlumbergeri Assemblage (which occurs below 1750m) and the Trochammina globigeriniformis/Trochammina sp.X/Cystammina sp. Assemblage (which occurs below 1850m) are believed to have been deposited under outer shelf to upper bathyal conditions. Evidence for this is provided by the occurrence therein of substantial numbers of agglutinated foraminifera.

Within the Late Oligocene interval as a whole, the following sequence of diatoms was noted: Coscinodiscus cf. sp.1 at and below 1550m, C. sp.4 at and below 1740m, C. sp.13 at and below 1830m, C. sp.5 at and below 1870m and C. sp.3 at and below 2080m. Actinommid radiolaria (?Cenosphaera spp.) were first recorded at 1930m.

INTERVAL 2330m-2520m; EARLY OLIGOCENE - MIDDLE? EOCENE

Lithostratigraphic Unit:
Hordaland Group (part).

Environment: marine, outer shelf to upper bathyal.

The upper limit and age of this interval are based on the following micropalaeontological and stratigraphical criteria:

- the occurrence at 2330m of Rotaliatina bulimoides.
- the subsequent occurrence at 2340m of Globigerina gortanii.
- the stratigraphical position of the section in relation to underlying positively dated Middle Eocene.

MICROPALAEONTOLOGY

The Rotaliatina bulimoides Assemblage, defined in terms of the total range of the nominate taxon and recognized between 2330m and 2350m, can be dated, by comparison with onshore sections and by inclusion of the planktonic foraminifer Globigerina gortanii (at 2340m), as Early Oligocene in age. The remainder of the interval represents a downhole continuation of the agglutinate dominated Trochammina globigeriniformis/Trochammina sp.X/Cystammina sp. Assemblage first recorded in the overlying Late Oligocene and perhaps extending down as far as the Middle Eocene, although the sidewall core at 2517m yielded no diagnostic Middle Eocene species. Both assemblages recognized within this interval indicate an outer shelf to upper bathyal environment of deposition.

INTERVAL 2520m-2690m; MIDDLE - EARLY? EOCENE

Lithostratigraphic Unit:
Hordaland Group (part).

Environment: marine, outer shelf to upper bathyal.

The upper limit and age of this interval are based on the following micropalaeontological and stratigraphical criteria:

- the occurrence at 2520m of Ammobaculites sp.1.
- the subsequent occurrences of Spiroplectammina spectabilis at 2560m and Spiroplectammina navarroana and Trochammina sp.C at 2595m(SWC).
- the stratigraphical position of the interval in relation to underlying positively dated Early Eocene.

MICROPALAEONTOLOGY

The recovery from the ditch cuttings sample at 2520m of Ammobaculites sp.1 indicates development, at and below this depth, of the Middle - Early? Eocene Ammobaculites sp.1/Verneuilina subeocaena/Spiroplectammina spectabilis Assemblage. This is subsequently confirmed by the finding at 2560m of Spiroplectammina spectabilis. Spiroplectammina navarroana and Trochammina sp.C, recognized in the sidewall core from 2595m, support the age assigned, the former further indicating proximity to the Middle/Early Eocene boundary. No positive Early Eocene was encountered until 2690m. The predominantly agglutinated nature of the microfaunal associations within this interval again indicates an outer shelf to upper bathyal environment of deposition.

INTERVAL 2690m-2716.50m(log); EARLY EOCENE

Lithostratigraphic Unit:
Hordaland Group (part).

Environment: marine, outer shelf to upper bathyal.

The upper limit and age of this interval are based on the following micropalaeontological criterion:

- the occurrence of Globigerina "triloculinoides" and G. linaperta at 2690m.

The Early Eocene may rest unconformably on the underlying Late Palaeocene.

MICROPALAEONTOLOGY

The occurrence of planktonic foraminifera, including Globigerina "triloculinoides" and G. linaperta at 2690m, permits recognition of Early Eocene deposits at and below this depth. The absence of planktonic foraminifera indicative of earliest Eocene deposits, together with regional considerations, tentatively suggests that a stratigraphical break separates this from the underlying Late Palaeocene interval.

INTERVAL 2716.50m(log)-2864m(SWC); LATE PALAEOCENE

Lithostratigraphic Units:
Rogaland Group;
Balder Formation: 2716.50m(log)-2757.50m(log),
Sele Formation: 2757.50m(log)-2830m(log),
Lista Formation: 2830m(log)-2854m(log).
Montrose Group (part);
Maureen Formation (part): 2854m(log)-2864m(SWC).

Environment: marine, outer shelf deepening to outer shelf to upper bathyal.

The upper limit of this interval is based on a log break at 2716.50m delineating the top of the Balder Formation.

The age of this interval is based on the following micropalaeontological criteria:
- the co-occurrences of Coscinodiscus sp.1 and C.sp.2 at 2720m(SWC).
- the subsequent occurrence of Spiroplectammina spectabilis (Palaeocene var.) at 2845m.

MICROPALAEONTOLOGY
The development of the Coscinodiscus sp.1 Assemblage to 2777m(SWC) indicates that the sediments encountered within the top part of this interval are Late Palaeocene in age. The remaining assemblages recognized are all consistent with this age. They are as follows: the Morphogroup A Assemblage, 2777m(SWC) - 2809m, comprising primitive astrorhizids such as Bathysiphon spp. and Hyperammina spp. (also found in the Coscinodiscus sp.1 Assemblage at 2720m(SWC); the Morphogroup B Assemblage, 2809m-2845m, containing additional lituolid taxa such as Haplophragmoides cf. walteri and Recurvoides spp.; the Morphogroup C Assemblage, 2845m-2854m, containing the textulariid Spiroplectammina spectabilis (Palaeocene var.) and also Paratrochamminoides spp., and the Calcareous Benthonics Assemblage, 2854m-2864m(SWC), containing nodosariids, polymorphinids and gavelinellids. With regard to the palaeoenvironment, it is postulated that

the transition from the Calcareous Benthonics Assemblage, through the Morphogroups C and B Assemblages, to the Morphogroup A Assemblage represent a phase of gradual deepening and restriction of bottom water circulation. As conditions so deteriorated, the availability of nutrients diminished, such that the eutrophic herbivorous feeders of the Calcareous Benthonics Assemblage became replaced by the progressively more oligotrophic passive deposit feeders of the Morphogroup C Assemblage, active deposit feeders of the Morphogroup B Assemblage and suspension feeders of the Morphogroup A Assemblage, the relationship between shell morphology and feeding strategy enabling recognition of this distinct trend. The Coscinodiscus sp.1 Assemblage contains abundant siliceous and pyritized diatom frustules, considered to be indicative of enrichment of surface waters in $SiO_2$ or CaO associated with vulcanism. An alternative model would require upwelling associated with a major rifting phase. Both would be equally plausible in view of the currently accepted nature of terminal Palaeocene events.

INTERVAL 2864m(SWC) - 3023.50m(log); EARLY PALAEOCENE

Lithostratigraphic Units:
Montrose Group (part);
Maureen Formation (part): 2864m(SWC)-2870m(log).
Chalk Group (part);
Ekofisk Formation: 2870m(log)-3023.50m(log).

Environment: marine, outer shelf.

The upper limit and age of this interval are based on the following micropalaeontological criteria:

- the occurrence of Globorotalia pseudobulloides, G. cf. compressa sensu Blow 1979 and Globigerina trivialis at 2864m(SWC).
- the subsequent occurrences of Globigerina aff. trivialis sensu Blow 1979 at 2926m and G. simplicissima at 2938m.

MICROPALAEONTOLOGY

Penetration of Lower Palaeocene sediments at 2864m is evidenced by the recovery from the sidewall core sample at this depth of the planktonic foraminifera Globorotalia pseudobulloides, G. cf. compressa sensu Blow 1979 and Globigerina trivialis, none of which ranges higher than Zone P.2 of Blow 1979 in the North Sea Basin. The subsequent recovery of the calcareous benthonic foraminifera Quadrimorphina allomorphinoides, Anomalinoides nobilis, A. velascoensis and Gavelinella beccariiformis (= G. vombensis of earlier RRI reports) is broadly consistent with the age assigned. The finding of Globigerina aff. trivialis sensu Blow 1979 at 2926m, and of G. simplicissima at 2938m permits recognition of the early Early Palaeocene Zone P.1 of Blow 1979 at and below the former depth. Characteristically, these forms exhibit a chalky mode of preservation. The development of a calcareous benthonic microfauna suggests normal marine conditions, the dominant families (nonionids and gavelinellids) further indicating an outer shelf setting. Strong open marine influences are implied by the strong planktonic element.

## VI(2) CRETACEOUS

### INTERVAL 3023.50m(log)-3061m; LATE CRETACEOUS, LATEST MAASTRICHTIAN

Lithostratigraphic Unit:
Chalk Group (part);
Tor Formation (part).

Environment: marine, outer shelf.

The upper limit is based on a log break at 3023.50m which defines the top of the Tor Formation.

The age is based on the following nannofloral and micropalaeontological criteria:

- the appearance of Late Cretaceous calcareous nannofossils, including abundant Arkhangelskiella cymbiformis and common Micula staurophora, at 3031m.
- the occurrence of Globotruncana contusa at 3046m.
- the occurrence of caved latest Maastrichtian restricted taxa Nephrolithus frequens and Lithraphidites quadratus at 3169m.

#### MICROPALAEONTOLOGY

Recovery of microfaunas from this interval is very poor and the majority of forms recorded is not-age diagnostic or caved Tertiary taxa. The occurrence of Brizalina incrassata incrassata at 3034m, however, confirms that Maastrichtian deposits have been penetrated and the occurrence of Globotruncana contusa at 3046m confirms a latest Maastrichtian age.

#### CALCAREOUS NANNOFOSSILS

A single ditch cuttings sample was examined from this interval and yielded a poor to moderately well preserved nannofloral assemblage characterised by Arkhangelskiella cymbiformis.

The appearance of abundant Arkhangelskiella cymbiformis and common Micula staurophora in association with such Late Cretaceous species as Prediscorphaera

cretacea and Kamptnerius magnificus at 3031m indicates that sediments of probable latest Maastrichtian age have been encountered at this depth, assigned to the Arkhangelskiella cymbiformis Subzone 1A. Some support for this age determination is provided by the occurrence of caved specimens of the latest Maastrichtian restricted taxa Nephrolithus frequens and Lithraphidites quadratus at 3169m. The presence of these species suggests that sediments belonging to the Nephrolithus frequens Subzone 1B are present in the well. Some Early Palaeocene caving is also noted over this interval.

INTERVAL 3061m-3282m(SWC); LATE CRETACEOUS, LATE MAASTRICHTIAN

Lithostratigraphic Units:
Chalk Group (part);
Tor Formation: 3061m-3275m(log),
Hod Formation: 3275m(log)-3282m(SWC).

Environment: marine, outer shelf.

The upper limit and age of this interval are based on the following nannofloral criteria:

- the appearance of Reinhardtites levis at 3061m.
- the subsequent appearance of Gartnerago obliquum at 3140m.

MICROPALAEONTOLOGY

Recovery from the hard Tor limestones is characteristically very poor. Occasional Late Cretaceous taxa were recorded within the interval, notably Inoceramus debris (3082m), Globigerinelloides asper (3140m), ?Bolivinoides draco draco (3214m) and ?Globotruncana marginata (3262m).

CALCAREOUS NANNOFOSSILS

The two ditch cuttings samples examined from this interval contained poorly preserved nannofloral assemblages dominated by Arkhangelskiella cymbiformis.

The appearance of the index taxon Reinhardtites levis at 3061m indicates that sediments of late Maastrichtian age have been penetrated at this depth, assigned to the Reinhardtites levis Subzone IC. The subsequent appearance of Gartnerago obliquum at 3140m allows the recognition of the Gartnerago obliquum Subzone ID, also of late Maastrichtian age.

INTERVAL 3282m(SWC)-3340m; LATE CRETACEOUS, EARLY MAASTRICHTIAN - LATE CAMPANIAN

Lithostratigraphic Unit:
Chalk Group (part);
Hod Formation (part).

Environment: marine, outer shelf.

The upper limit and age of this interval are based on the following nannofloral and micropalaeontological criteria:

- the appearance of Reinhardtites biperforatus, Phanulithus obscurus in association with common Micula staurophora at 3282m(SWC).
- the subsequent appearance of Helicolithus trabeculatus and Reinhardtites anthophorus at 3310m.
- the presence of a red stained microfauna, including Globotruncana cf. arca in the sidewall core at 3282m.
- the subsequent occurrence of common Rugoglobigerina/Archaeoglobigerina spp. (3286m), Globotruncana marginata (3310m) and Reussella szajnochae szajnochae (3310m).
- the appearance of Broinsonia parca at 3331m.

MICROPALAEONTOLOGY

The interpretation of the microfaunal evidence is hampered by the lack of information from the overlying interval due to the poor recovery of assemblages. At 3282m(SWC) there is a marked change in the microfaunal recovery, with a moderately rich assemblage which is strongly red stained being recorded. The presence of Globotruncana cf. arca in this assemblage indicates that the sediments are probably no younger than early Maastrichtian in age. The Rugoglobigerina/Archaeoglobigerina complex is common at 3286m. Such an increase is usually associated with the penetration of the early Maastrichtian, but this increase may be due to a change in facies giving better microfaunal recovery. If the age interpretation is correct, then the subsequent occurrence of Globotruncana marginata with Reussella szajnochae szajnochae at 3310m may indicate a late Campanian age. Nannofossil evidence strongly supports an early

Maastrichtian - late Campanian age assignment for this interval. Contradictory evidence is that the assemblages are strongly pink stained and contain Dorothia sp.1 (3282m(SWC)) and Tritaxia dubia (3286m). These species generally appear in the early Campanian, but have been recorded in younger sediments or may be reworked in this instance.

CALCAREOUS NANNOFOSSILS

The ditch cuttings and sidewall core samples, analysed from this interval yielded moderately to poorly preserved nannofloral assemblages characterised by Arkhangelskiella cymbiformis.

The appearance of Reinhardtites biperforatus in association with Phanulithus obscurus at 3282m(SWC) indicates that sediments are no younger than the Reinhardtites biperforatus Subzone 1F of early Maastrichtian age. However, the subsequent appearance of Helicolithus trabeculatus at 3310m suggests that sediments of an older late Campanian age have been penetrated at this depth, assigned to the Helicolithus trabeculatus Subzone 2B. Further general support for the age assigned to the interval is provided by the occurrence of Broinsonia parca at 3331m.

In view of the micropalaeontological evidence only a general early Maastrichtian to late Campanian age can be assigned to the interval.

INTERVAL 3340m-3348m(log); LATE CRETACEOUS, EARLY CAMPANIAN

Lithostratigraphic Unit:
Chalk Group (part);
Hod Formation (part).

Environment: marine, outer shelf.

The upper limit and age of this interval are based on the following nannofloral criterion:

- the appearance of Eiffellithus eximius in association with Tranolithus orionatus at 3340m.

This interval rests unconformably on sediments of early Turonian age.

MICROPALAEONTOLOGY

A single ditch cuttings sample was analysed at 3346m. Only a few foraminifera were present, including Globotruncana marginata. No taxa diagnostic of the early Campanian were found in this sample.

CALCAREOUS NANNOFOSSILS

The ditch cuttings sample examined at 3340m contained quite a rich, moderately preserved, nannofloral assemblage.

The appearance of Eiffellithus eximius at 3340m indicates that sediments no younger than the unnamed Subzone 2C of early Campanian age are present at this depth. The appearance of Tranolithus orionatus at the same depth adds some support for a general Campanian age. Early Palaeocene and Late Cretaceous caving was also noted over this interval.

INTERVAL 3348m(log)-3367m(log); LATE CRETACEOUS, EARLY TURONIAN

Lithostratigraphic Unit:
Chalk Group (part);
Plenus Marl Formation.

Environment: marine, inner shelf.

The upper limit of this interval is based on a log break at 3348m which defines the top of the Plenus Marl Formation.

The age is based on the following nannofloral criteria:
- the appearance of Lithastrinus floralis and to a lesser extent Biscutum ellipticum at 3352m(SWC).
- the apparent absence of such species as Kamptnerius magnificus, Eiffellithus eximius, Ahmuellerella octoradiata and Quadrum gartneri in either of the sidewall cores at 3352m or 3365m.

MICROPALAEONTOLOGY

There is a further change in the microfaunas at and below 3352m(SWC) with a return to poorly preserved and impoverished assemblages; the majority of taxa recorded having caved. The occurrence of Stensioina praeexsulpta at 3353m is consistent with the early Turonian age assigned on nannofloral evidence.

CALCAREOUS NANNOFOSSILS

The two sidewall core samples analysed from this interval, yielded moderately preserved and, in the case of the sample at 3365(SWC), a relatively rich nannofloral assemblage dominated by Watznaueria barnesae.

The appearance of Lithastrinus floralis at 3352(SWC) suggests that sediments are no younger than Turonian age at this depth. However, the absence of such species as Kamptnerius magnificus, Ahmuellerella octoradiata and in particular Eiffellithus eximius and Quadrum gartneri at this level and the subsequent sidewall core sample at 3365m indicates that sediments are certainly no younger

than early Turonian in age at these respective depths. The appearance of Biscutum ellipticum at 3352m(SWC), a species which often seems to appear just above the Plenus Marl Formation in the Southern Norwegian North Sea Chalk Field Province, lends some further support for an early Turonian age determination. The subsequent occurrence of common Tranolithus orionatus at 3365(SWC), (a species which often becomes abundant in the Cenomanian) would also suggest close proximity to sediments of Cenomanian age. This, coupled with the presence of relatively common Lithastrinus floralis, a form which characteristically can become common in the Plenus Marl (from regional knowledge), adds confirmation for the early Turonian age assigned to the interval.

INTERVAL 3367m(log)-3393m(log); LATE CRETACEOUS, CENOMANIAN

Lithostratigraphic Unit:
Chalk Group (part);
Hidra Formation.

Environment: marine, inner to outer shelf.

The upper limit of this interval is based on the log break at 3367m which defines the base of the Plenus Marl Formation.

The age is based on the following nannofloral criterion:

- the appearance of Parhabdolithus angustus, Cribrosphaera primitiva, Parhabdolithus asper and Parhabdolithus achlyostaurion, in association with abundant Tranolithus orionatus and Broinsonia cf. enormis at 3382m(SWC).

MICROPALAEONTOLOGY

The in situ microfaunas continue to be very impoverished. No age-diagnostic taxa are present.

CALCAREOUS NANNOFOSSILS

The single sidewall core analysed from this interval yielded a rich, diverse and moderately preserved nannofloral assemblage dominated by Watznaueria barnesae and Broinsonia cf. enormis.

The appearance of Parhabdolithus achlyostaurion, Parhabdolithus asper, Parhabdolithus angustus and Cribrosphaera primitiva at 3382m(SWC) indicates that sediments of Cenomanian age have been encountered at this depth. However, the occurrence of Parhabdolithus asper at this horizon indicates that sediments are no younger than the Parhabdolithus asper Subzone 6C of middle Cenomanian age at this level. In view of this, and the presence of the late Cenomanian subzone marker species also in the sample, a late to middle Cenomanian age could be assigned to the interval 3367m to 3382m based on nannofloral evidence. However, in view of poor micropalaeontological evidence over this interval, and the fact that only a single sample was analysed for calcareous nannofossils, a general Cenomanian age has been preferred.

INTERVAL 3393m(log)-3459m(log); EARLY CRETACEOUS, ALBIAN

Lithostratigraphic Unit:
Cromer Knoll Group (part);
"Limestone Unit".

Environment: marine, inner to outer shelf.

The upper limit of this interval is based on a log break at 3393m which defines the top of the Cromer Knoll Group.

The age is based on the following nannofloral, palynological and micropalaeontological criteria:

- the appearance of common Cribrosphaera primitiva and Biscutum ellipticum at 3395m(SWC).
- the subsequent appearance of Tegumentum stradneri at 3442m.
- the apparent last stratigraphic downhole occurrence of Tranolithus orionatus at 3457m(SWC).
- the appearance in the ditch cuttings sample at 3436m of the dinocyst taxa Palaeoperidinium cretaceum and the Subtilisphaera perlucida/terrula group.
- the incoming of Glomospira gordialis and Uvigerinammina moesiana at 3454m.

This interval rests unconformably on sediments of early Barremian-late Hauterivian age.

MICROPALAEONTOLOGY

Microfaunal recovery throughout the majority of the interval is very poor. A change is not recorded until the base of the interval at 3454m. A red stained microfauna was recovered at this depth, predominantly comprising agglutinated foraminifera, including Glomospira gordialis and Uvigerinammina moesiana. This assemblage indicates a general middle Albian to Aptian age, which is consistent with the Albian age assigned on nannofloral criteria.

The sidewall core at 3457m is barren of a microfauna.

CALCAREOUS NANNOFOSSILS

The sidewall cores and ditch cuttings samples examined from this interval varied considerably in species diversity and preservation, with the ditch cuttings samples at 3409m and 3430m considered to be barren of in situ calcareous nannofossils.

The appearance of common Cribrosphaera primitiva and Biscutum ellipticum at 3395m(SWC) tentatively suggests that sediments of probable late Albian age have been penetrated. However, in view of the lack of any micropalaeontological or palynological evidence to support this tentative age assignment, this age determination must be viewed with some caution.

The first positive nannofloral evidence for penetration of sediments of Early Cretaceous age is provided at 3442m with the appearance of Tegumentum stradneri, indicating that sediments no younger than the Tegumentum stradneri Subzone 7B of middle Albian age are present at this depth. Further support for this age determination is subsequently provided at 3457m(SWC), with the last stratigraphic downhole occurrence of Tranolithus orionatus which, if in situ, would suggest that sediments are still no older than middle Albian in age at this depth.

A significant amount of both Tertiary and Late Cretaceous caving, which in some instances has considerably modified the nannofloral assemblages, was noted throughout this interval.

PALYNOLOGY

The ditch cuttings sample from 3415m yielded a palynoflora which consisted entirely of forms believed to be caved from the Tertiary. The sample from 3436m, although containing abundant caved Tertiary taxa, yielded single specimens of the dinocysts Palaeoperidinium cretaceum and the Subtilisphaera perlucida/terrula group. This association indicates that rocks of Early Cretaceous age, late Albian or older, have been penetrated. The sidewall core analysed from 3457m produced an unreliable assemblage, which indicated that drilling mud contamination had occurred.

INTERVAL 3459m(log)-3461m(log); EARLY CRETACEOUS, EARLY BARREMIAN - LATE HAUTERIVIAN

Lithostratigraphic Unit:
Cromer Knoll Group (part);
Valhall Formation (part).

Environment: marine, inner shelf.

This interval is defined by log breaks at 3459m and 3461m which mark a thin limestone unit.

The age is based on the following micropalaeontological and nannofloral criteria and regional knowledge.

- the occurrence of common Uvigerinammina moesiana, Pontocypris sp. and Marssonella cf. trochus at 3460m.
- the subsequent occurrence of caved Aulotortus (Spirillina) neocomiana (3539m), Patellina subcretacea (3562m) and Lenticulina ouachensis wisselmanni (3562m).
- the appearance of Micrantholithus hoschulzi at 3460m.

This interval rests unconformably on sediments of early Valanginian age.

MICROPALAEONTOLOGY

The presence of early Barremian - late Hauterivian limestones is indicated in the ditch cuttings sample at 3460m and in cavings. At 3460m, Uvigerinammina moesiana is common and occurs commonly as cavings below this depth, as do Marssonella cf. trochus, Lenticulina spp. and species of ostracods. These taxa indicate the development of the Calcareous benthonics/Ostracods Assemblage which suggests a general Barremian - Neocomian age. A more restricted early Barremian - late Hauterivian age is proposed on regional considerations and on microfaunal evidence caved lower in the section. Aulotortus (Spirillina) neocomiana (3539m), Patellina subcretacea (3562m) and Lenticulina ouachensis wisselmanni (3562m) all indicate an age no younger than early Barremian.

CALCAREOUS NANNOFOSSILS

The single ditch cuttings sample examined from this interval (3460m) consisted almost entirely of caved Late Cretaceous species.

However, the appearance of Micrantholithus hoschulzi at this depth (a species which has a reported stratigraphic top in the Aptian) would suggest that sediments are no younger than Aptian age at this horizon. However, from regional knowledge this species does in fact tend to appear (first downhole occurrence) at the top of the Barremian in the area. So its presence at 3460m, whilst not confirming the micropalaeontological evidence, does provide some tentative support for a Barremian or older age for the sample.

INTERVAL 3461m(log)-3580m; EARLY CRETACEOUS, EARLY VALANGINIAN

Lithostratigraphic Unit:
Cromer Knoll Group (part);
Valhall Formation (part).

Environment: marine, inner shelf.

The upper limit of this interval is based on a log break.

The age of this interval is based on the following palynological and nannofloral criteria:

- the appearance of the dinocyst Tubotureralla apatela in association with Muderongia simplex (tabulate var.), Phoberocysta neocomica and Sirmodinium grossii in the sidewall core at 3462m.
- The subsequent occurrences of Canningia compta at 3475m(SWC), the Muderongia crucis/tetracantha group at 3490m(SWC), Nelchinopsis kostromiensis and common Cleistosphaeridium sp. KE McIntyre and Brideaux 1980 at 3505m(SWC), Gochteodinia "robusta" at 3520m(SWC), Systematophora palmula and Dinocyst sp.1 at 3535m(SWC), Gochteodinia villosa multifurcata at 3550m(SWC) and Muderongia "pyknosa" in the ditch cuttings sample from 3562m.
- the appearance of common Cruciplacolithus salebrosus in association with Diazomatolithus lehmani, common Tranolithus gabalus and common Nannoconus sp. at 3475m(SWC).
- the subsequent occurrence of Corollithion silvaradion, abundant Cycagelosphaera margereli, abundant Cruciplacolithus salebrosus and ?Cruciplacolithus sp.1 at 3490m(SWC).

MICROPALAEONTOLOGY

The majority of forms, recorded in this section, is caved, principally from the overlying interval. Rare, in situ species are present, notably Lenticulina nodosa at 3472m and L. cf. nodosa at 3496m. The sidewall core samples at 3462m and 3505m were barren, the other sidewall core samples yielding poor assemblages of small, agglutinated foraminifera.

PALYNOLOGY

The sidewall core from 3462m yielded a very rich palynoflora dominated by Tertiary forms from drilling mud contamination. The presence, however, of the dinocysts Tubotubella apatela, Muderongia simplex (tabulate var.), Phoberocysta neocomica and Sirmiodinium grossii indicates that rocks of early Valanginian age have been penetrated. The assemblages throughout this interval are rich in dinocysts and include the typical forms Kleithriasphaeridium corrugatum, K. fasciatum, K. simplicispinum, Lagenorhytis delicatulus, Pseudoceratium "eopelliferum", P. pelliferum, Cassiculosphaeridia magna and Ctenidodinium elegantulum. Significant occurrences within this interval are Canningia compta, the Muderongia crucis/tetracanta group, M. "pyknosa", Nelchinopsis kostromiensis, common Cleistosphaeridium sp. KE McIntyre and Brideaux 1980, Gochteodinia "robusta", G. villosa multifurcata, Systematophora palmula and Dinocyst sp.1. The M. crucis/tetracantha group, recorded from 3490m(SWC) has a base in the late early Valanginian. The specimens of Oligosphaeridium diluculum from this interval are possibly present due to reworking, and there is evidence of definite reworking of sediments of Middle Jurassic to Late Triassic age, with records of Chasmatosporites spp. and Ovalipollis pseudoalatus.

The assemblages from this interval can all be assigned to the Tubotuberella apatela Dinocyst Subzone (IVB) of the Phoberocysta neocomica Dinocyst Zone (IV).

CALCAREOUS NANNOFOSSILS

The appearance of common Cruciplacolithus salebrosus in association with common Tranolithus gabalus at 3475m, both numerical acmes characteristic of sediments of early Valanginian age, indicates that sediments assigned to the Micrantholithus speetonensis Subzone IIB of early Valanginian age have been encountered. Some further support for this age assignment is provided by the subsequent appearance of Corollithion silivaradion, ?Cruciplacolithus sp.1 and abundant Cyclagelosphaera margereli (another numerical acme characteristic of deposits of early Valanginian age, from regional knowledge), at 3490m(SWC).

INTERVAL 3580m-3601m; EARLY CRETACEOUS, EARLIEST VALANGINIAN.

Lithostratigraphic Unit:
Cromer Knoll Group (part);
Valhall Formation (part).

Environment: marine, inner shelf.

The upper limit and age of this interval are based on the following palynological criterion:

- the appearance of Endoscrinium pharo and Surculosphaeridium sp.III Davey 1982.

MICROPALAEONTOLOGY

The microfaunal assemblages continue as in the overlying interval. Species of Lenticulina and agglutinated foraminifera, with common cavings, were recorded.

PALYNOLOGY

The ditch cuttings sample from 3580m produced a rich dinocyst-dominated palynoflora which includes forms such as Phoberocysta neocomica, Maduradinium? sp.A, Kleithriasphaeridium fasciatum, K. simplicispinum, Lagenorhytis delicatulus and Isthmocysta distincta. Of particular stratigraphic significance are the appearance of Endoscrinium phara and Surculosphaeridium sp.III Davey 1982. The presence of E. pharo indicates an earliest Valanginian age and assignment to the Endoscrinium pharo Dinocyst Subzone (IVC) of the Phoberocysta neocomica Dinocyst Zone (IV).

INTERVAL 3601m-3638.50m(log); EARLY CRETACEOUS, LATEST RYAZANIAN

Lithostratigraphic Unit:
Cromer Knoll Group;
Valhall Formation (part).

Environment: marine, inner shelf.

The upper limit and age of this interval are based on the following palynological criteria:

- the appearance in the ditch cuttings sample at 3601m of Dingodinium spinosum, Egmontodinium cf. expiratum, E. torynum, Cantulodinium sp.1 and Dinocyst sp.II, together with records of Oligosphaeridium diluculum which are considered to be in situ.
- the subsequent occurrence in the ditch cuttings sample at 3619m of Gochteodinia villosa and Gonyaulacysta sp.B Davey 1982.

MICROPALAEONTOLOGY

The single ditch cuttings sample analysed at 3607m was barren.

PALYNOLOGY

A very rich dinocyst-dominated palynoflora was recorded from the ditch cuttings sample at 3601m. The assemblage is dominated by Hystrichodinium pulchrum and Cleistosphaeridium spp.; other forms present including Dingodinium albertii, Ctenidodinium elegantulum, Systematophora palmula and Occisucysta tentoria. Of particular stratigraphical significance are the records of Dingodinium spinosum and Egmontodinium torynum together with E. cf. expiratum, Cantulodinium sp.1, Dinocyst sp.II and Oligosphaeridium diluculum. The latter is here considered to be in situ. Gochteodinia villosa and Gonyaulacysta sp.B Davey 1982 were first seen in the ditch cuttings sample from 3619m.

The presence of D. spinosum and E. torynum indicates a latest Ryazanian age and this interval can be assigned to the "?Prolixosphaeridium" torynum Dinocyst Subzone (VA) - Dichadogogonyaulax spp. Dinocyst Subzone (VB) of the Dingodinium spinosum Dinocyst Zone (V).

## VI (3) CRETACEOUS - ?JURASSIC

### INTERVAL 3638.50m(log)-3691m; EARLY CRETACEOUS - ?LATE JURASSIC, LATE RYAZANIAN - ?LATE VOLGIAN

Lithostratigraphic Unit:
Boknfjord Group (part);
Kimmeridge Clay Formation (part).

Environment: marine, inner shelf with anoxic bottom conditions.

The upper limit of this interval is based on a log break.

The age is based on regional knowledge and the general palynofloras recovered.

PALYNOLOGY

The upper limit of this interval is based on a log break, particularly well seen in the gamma-ray profile, which marks the top of the Kimmeridge Clay Formation. The top of this formation is regionally known to lie within the stenomphalus ammonite zone of the late Ryazanian (Rawson and Riley, 1982). The sidewall core from 3641m yielded an impoverished palynoflora, with evidence of drilling mud contamination, the in situ elements being rare prasinophycean algae and bisaccate pollen. The ditch cuttings sample analysed from 3661m yielded abundant amorphous kerogen, a feature typical of the Kimmeridge Clay Formation. In addition it yielded a rich and diverse palynoflora which is dominated by dinocysts, although the prasinophycean algal genus Pterospermella is fairly common. A similar assemblage was recovered from the ditch cuttings sample from 3681m. The dinocyst association recorded from these samples is typical of the early late Ryazanian and includes forms such as Oligosphaeridium diluculum, Canningia compta, Dingodinium spinosum, Stiphrosphaeridium dictyophorum and Gochteodinia villosa. There are no forms indicative of rocks of early Ryazanian or late Volgian age. The caliper on the wireline log over this interval does, however, indicate a major wash-out of the hole and the ditch cuttings samples recovered are therefore probably not representative of the in situ rocks and no

sidewall cores were taken. This interval has therefore been assigned an Early Cretaceous - ?Late Jurassic, late Ryazanian - ?late Volgian age. The assemblage can be attributed to the Dichadogonyaulax spp. Dinocyst Subzone (VB) - ?Systematophora spp. Dinocyst Subzone (VIC) of the Dingodinium spinosum Dinocyst Zone (V) - ?"Imbatodinium" villosum Dinocyst Zone (VI). A possible unconformity is proposed at the base of this interval because, although no palynomorphs indicative of an age older than late Ryazanian were recovered, the palynofloras are considered to be unrepresentative.

## VI(4) JURASSIC

### INTERVAL 3691m-3723.50m(log); LATE JURASSIC, LATE MIDDLE VOLGIAN

Lithostratigraphic Unit:
Boknfjord Group (part);
Kimmeridge Clay Formation (part).

Environment: marine, inner shelf with anoxic bottom conditions.

The upper limit and age of this interval are based on the following palynological criteria:

- the appearance of Ctenidodinium panneum and Glossodinium dimorphum in the ditch cuttings sample at 3691m.
- the subsequent occurrence of Hexagonifera jurassica at 3700m (ditch cuttings sample) and below, and of a caved specimen of Muderongia sp.A Davey 1979 in the ditch cuttings sample at 3721m(3726m approximately, when corrected to loggers' depth).

This interval rests unconformably on sediments of latest early Volgian age.

PALYNOLOGY

The ditch cuttings sample from 3691m produced a rich palynoflora which included the dinocysts Ctenidodinium panneum, Glossodinium dimorphum and Egmontodinium expiratum. The presence of C. panneum and G. dimorphum indicates that rocks of middle Volgian age have been penetrated. Further support for the age is provided by the occurrence of Hexagonifera jurassica in the ditch cuttings sample from 3700m and below and also of a caved specimen of Muderongia sp.A Davey 1979 in the ditch cuttings sample from 3721m (3726m approximately, when corrected to loggers' depth).

The absence of persistent and subsequently common Muderongia sp. A Davey 1979 indicates that only sediments of late middle Volgian age are present. If in situ, the association of Gochteodinia villosa with Egmontodinium polyplacophorum

in the mud-contaminated sidewall core from 3721.50m would indicate an age no older than the Dichadogonyaulax pannea Dinocyst Subzone (VIIA). This interval can be assigned to the Dichadogonyaulax pannea Dinocyst Subzone (VIIA) - Dichadogonyaulax culmula Dinocyst Subzone (VIIB) of the Muderongia sp.A Dinocyst Zone (VII).

INTERVAL 3723.50m(log)-3741.70m(core); LATE JURASSIC, LATEST EARLY VOLGIAN

Lithostratigraphic Unit:
Vestland Group (part);
Ula Formation (part).

Environment: marine, inner shelf.

The upper limit of this interval is defined on a log break.
The age is based on the following palynological criteria:

- the appearance of Oligosphaeridium pulcherrimum sensu Ioannides et al. 1977 in the ditch cuttings sample from 3721m (3726m approximately, when corrected to loggers' depth).
- the subsequent occurrence of Perisseiasphaeridium spp. in the sidewall core from 3724.50m and below.

PALYNOLOGY

The ditch cuttings sample from 3721m has an approximate depth of 3726m when corrected to loggers' depth since there is a five metre discrepancy between drillers' and loggers' depth indicated on the wireline log. The presence of Oligosphaeridium pulcherrimum sensu Ioannides et al. 1977 indicates that rocks of early Volgian age have been penetrated. There is also a marked increase in prasinophycean algae in this sample. The top of the interval has been drawn slightly higher, at 3723.50m, based on a log break. Further support for the age is provided by the occurrence of Perisseiasphaeridium spp. in the sidewall core from 3724.50m and below.

The assemblages from this interval can all be assigned to the Gonyaulacysta jurassica Dinocyst Subzone (VIIIB) of the Pareodinia murabilis Dinocyst Zone (VIII) and indicate a latest early Volgian age for this interval.

INTERVAL 3741.70m(core)-3758.10m(core); LATE JURASSIC, EARLY VOLGIAN

Lithostratigraphic Unit:
Vestland Group (part);
Ula Formation (part).

Environment: marine, inner shelf.

The upper limit and age of this interval are based on the following palynological criterion:

- the appearance of Gonyaulacysta longicornis together with a marked increase in the number of specimens of Oligosphaeridium pulcherrimum sensu Ioannides et al. 1977 in the core piece from 3741.70m.

PALYNOLOGY

The core piece analysed from 3741.70m yielded a microplankton-dominated assemblage which included common O. pulcherrimum sensu Ioannides et al. 1977 and G. longicornis, together with Ctenidodinium panneum, Perisseiasphaeridium spp, Glossodinium dimorphum and Egmontodinium ovatum. The core pieces examined from 3748.80m and 3752m yielded relatively impoverished microplankton-dominated palynofloras.

The incoming of G. longicornis, with a marked increase in the number of specimens of O. pulcherrimum sensu Ioannides et al. 1977, indicates that the assemblages in this interval can be assigned an early Volgian age and be attributed to the Egmontodinium polyplacophorum Dinocyst Subzone (IXA) of the Gonyaulacysta longicornis Dinocyst Zone (IX).

INTERVAL 3758.10m(core)-3767m(log); LATE JURASSIC, LATEST KIMMERIDGIAN

Lithostratigraphic Unit:
Vestland Group (part);
Ula Formation (part).

Environment: marine, inner shelf.

The upper limit and age of this interval are based on the following palynological criteria:

- the appearance of Palaeoperidinium paeminosum and Scriniodinium luridum in the core piece at 3758.10m.
- the subsequent appearance of Gonyaulacysta jurassica in the core piece at 3760.10m.
- the presence of P. paeminosum in the core piece at 3762.20m.

This interval rests unconformably on sediments of Triassic age.

PALYNOLOGY

The palynoflora obtained from the core piece at 3758.10m consists entirely of microplankton. The presence of the dinocysts Palaeoperidinium paeminosum and Scriniodinium luridum indicates that rocks of latest Kimmeridgian age have been penetrated. The core piece from 3760.10m yielded a palynoflora which included the dinocysts P. paeminosum, S. luridum, Ctenidodinium panneum and Perisseiasphaeridium spp. and the first occurrence of G. jurassica. The core piece from 3762.10m produced common microforaminiferal test linings and a specimen of P. paeminosum. The sample from 3766m, a core piece, proved to be barren and its lithology indicates that it belongs in the underlying Triassic interval. When its depth is corrected to a loggers' depth of approximately 3771m, it does in fact lie within the Triassic.

The presence of P. paeminosum throughout this section indicates that this short interval is of latest Kimmeridgian age, and the assemblages can all be attributed to the Scriniodinium luridum Dinocyst Subzone (IXB) of the Gonyaulacysta longicornis Dinocyst Zone (IX).

## VI(5) TRIASSIC

### INTERVAL 3767m(log)-3972m(SWC); TRIASSIC

Lithostratigraphic Unit:
"Triassic Group" (part);
Skagerrak Formation (part).

Environment: continental, fluviatile and lacustrine.

The upper limit of this interval is based on a log break.

The age assigned to this interval is based on the following criteria:
- the lithologies present.
- regional knowledge.
- the age of the underlying interval.
- very limited palynological evidence.

PALYNOLOGY

The core piece analysed from 3768.10m was barren and most of the sidewall cores were either barren, or only contained palynomorphs derived from drilling mud contamination. The single specimen of Apiculatasporites plicatus from the sidewall core at 3884.80m is probably recycled in the drilling mud. Rare dark bisaccate pollen may be in situ in the sidewall core from 3938.50m and a single specimen of the striate bisaccate pollen genus Striatoabieites was observed in the impoverished palynoflora from 3954m(SWC). The ditch cuttings samples examined from this interval yielded no age-diagnostic taxa, but some of the dark bisaccate pollen may be in situ.

The presence of a specimen of the genus Striatoabieites would support a Triassic age but it does also occur in Permian strata. The Triassic age assigned to this interval is based mainly on the lithologies present, regional knowledge and the age assigned to the underlying interval.

INTERVAL 3972m(SWC)-4237m(log); MIDDLE - EARLY? TRIASSIC, MIDDLE ANISIAN - ?SKYTHIAN

Lithostratigraphic Unit:
"Triassic Group" (part);
Skagerrak Formation (part).

Environment: continental, fluviatile and lacustrine.

The upper limit and age of this interval are based on the following palynological criteria:

- the appearance of Illinites kosankei and Protodiploxypinus cf. sittlerii with common Apiculatasporites plicatus in the sidewall core at 3972m.
- the subsequent occurrence of Lunatisporites noviaulensis var. mollis in the ditch cuttings sample at 4111m.

This interval rests unconformably on sediments of Late Permian age.

PALYNOLOGY

The sidewall core analysed from 3972m yielded a rich palynoflora which contained several Triassic palynomorphs in addition to dark bisaccate pollen of no age significance. The assemblage includes common Apiculatasporites plicatus, together with Illinites kosankei, Protodiploxypinus cf. sittlerii, Granisaccus decus, Verrucosisporites pseudomorulae, Striatoabieites aytugii, Protohaploxypinus sp., Lunatisporites spp. and indeterminate striate bisaccate pollen. Apiculatasporites plicatus occurs in several of the samples throughout this interval but the sidewall core from 4085m was barren, and that from 4233.20m contained only taxa derived from the drilling mud. The striate bisaccate pollen Lunatisporites noviaulensis var. mollis was recorded from the ditch cuttings sample at 4111m. Rare non-striate bisaccate pollen, which may be in situ, occur in some of the other samples treated from this interval and G. decus was recorded from 4111m and 4144.80m(SWC) and G. cf. decus from 4182m.

The presence of Granisaccus decus indicates the presence of Middle Triassic rocks of Ladinian - Anisian age. The occurrence, however, of Illinites kosankei, Protodiploxpinus cf. sittlerii and Apiculatasporites plicatus indicates a middle Anisian age at the youngest for the top of this interval. No taxa indicative of an early Anisian or Early Triassic age have been encountered. A Middle - Early? Triassic, middle Anisian - ?Skythian age has therefore been assigned to this interval.

## VI(6) PERMIAN

### INTERVAL 4237m(log)-4320m T.D.; LATE PERMIAN

Lithostratigraphic Unit:
Zechstein Group.

Environment: marginal marine with hypersaline episodes.

The upper limit of this interval is based on a log break.
The age is based on the following criteria:

- the appearance of anhydrite.
- the position of the interval.
- regional knowledge.

PALYNOLOGY

Five ditch cuttings samples were analysed from this interval. Most of the taxa recovered are caved from post-Triassic strata although a few forms have definitely caved from the Triassic interval. Some of the bisaccate pollen, including indeterminate striate forms and specimens assigned to the genera Lunatisporites, Striatoabieites and Protohaploxypinus, may be in situ, but even these may all have caved from the overlying Triassic sediments. No palynomorphs indicative of a Late Permian age have been recorded and the age is based on the lithologies present, the position of the interval, and our regional knowledge.

VII

## SELECTED REFERENCES


BARTENSTEIN, H. et al. 1962. Leitfossilien der Mikropäleontologie. Gebrüder Borntraeger, Berlin.

BERGGREN, W.A. 1971. Tertiary boundaries and correlations. In FUNNELL, B.M. & RIEDEL, W.R. (Editors), Micropalaeontology of the Oceans. Camb. Univ. Press.

BIRKELUND, T. & BROMLEY, R.G. (Editors). 1979. Cretaceous - Tertiary Boundary Events. Symposium I. The Maastrichtian and Danian of Denmark. University of Copenhagen.

BLOW, W.H. 1979. The Cainozoic Globigerinida. E.J. Brill. Leiden.

CARTER, D.J. & HART, M.B. 1977. Aspects of mid-Cretaceous stratigraphical micropalaeontology. Bull. Br. Mus. Nat. Hist. (Geol.) 29(1).

CHRISTENSEN, W.K. & BIRKELUND, T. (Editors). 1979. Cretaceous - Tertiary Boundary Events. Symposium II. Proceedings. University of Copenhagen.

CLARKE, R.F.A. 1965. British Permian saccate and monosulcate miospores. Palaeontology, Vol.8, Pt.2.

DAVEY, R.J. 1979. The Stratigraphic distribution of Dinocysts in the Portlandian (latest Jurassic) to Barremian (Early Cretaceous) of Northwest Europe. AASP. Cont. Series No. 5B.

DAVEY, R.J. 1982. Dinocyst stratigraphy of the latest Jurassic to Early Cretaceous of the Haldager No.1 borehole, Denmark. Danm. Geol. Unders., Series B, No.6.

DEEGAN, C.E. & SCULL, B.J. (Compilers). 1977. A proposed standard lithostratigraphic nomenclature for the Central and Northern North Sea. Rep. Inst. Geol. Sci., No. 77/25; Bull. Norw. Petrol. Direct., No.1.

DUXBURY, S. 1977. A palynostratigraphy of the Berriasian to Barremian of the Speeton Clay of Speeton, England. Palaeontographica, Abt. B, 160.

DUXBURY. S. 1980. Barremian phytoplankton from Speeton, East Yorkshire. Palaeontographica, Abt. B, 173.

FINSTAD, K.G. & SELLEY, R.C. (Editors). 1975. Proceedings, Jurassic Northern North Sea Symposium. Norwegian Petroleum Society.

FINSTAD, K.G. & SELLEY, R.C. (Editors). 1977. Proceedings, Mesozoic Northern North Sea Symposium. Norwegian Petroleum Society.

FISHER, M.J. 1972. A record of palynomorphs from the Waterstones (Triassic) of Liverpool. Geol. J. Vol.8, Pt.1.

FISHER, M.J. 1979. The Triassic palynofloral succession in the Canadian Arctic Archipelago. AASP. Cont. Series No. 5B.

GEIGER, M.E. & HOPPING, C.A. 1968. Triassic stratigraphy of the southern North Sea Basin. Phil. Trans. Roy. Soc. London, Ser. B, No. 790, Vol. 254.

GRADSTEIN, F.M. & BERGGREN, W.A. 1981. Flysch-Type Agglutinating Foraminifera and the Maastrichtian to Paleogene History of the Labrador and North Seas. Marine Micropaleontology, Vol. 6.

ILLING, L.V. & HOBSON, G.D. 1980. Petroleum Geology of the Continental Shelf of North-West Europe. Institute of Petroleum.

IOANNIDES, N.S., STAVRINOS, G. & DOWNIE, C. (1976) 1977. Kimmeridgian microplankton from Clavell's Hard, Dorset, England. Micropaleontology, Vol.22.

JENKINS, D.G. & MURRAY, J.W. (Editors). 1981. Stratigraphical Atlas of fossil foraminifera. British Micropalaeontological Society Series.

KEIZER, J. & LETSCH, W.J. 1963. Geology of the Tertiary of the Netherlands. Verhandelingen, Vol. 2, Pt. 2, (Trans. Jubilee Convention Pt.2)

KLAUS, W. 1964. Zur sporenstratigraphischen Einstufung von gipsführenden Schichten im Bohrungen. Erdöl-Z. Bohr-u. Fördertech. Vol. 80.

KOCH, W. 1977. Biostratigraphie in der Oberkreide und Taxonimie von foraminiferen. Geol. Jb., A, Vol. 38.

LARSEN, R.M. & JAARVIK, L.J. 1981. The geology of the Sleipner Field Complex. In: Norwegian Petroleum Society. Norwegian Symposium on Exploration (NSE '81), Bergen, September 14th-16th, 1981. Proceeding Paper No. NSE/15.

LORD, A.R. (Editor). 1982. A Stratigraphical Index of Calcareous Nannofossils. British Micropalaeontological Society Series.

MARTINI, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. Proc. 2nd Int. Conf. Planktonic Microfossils, Rome.

McINTYRE, D.J. & BRIDEAUX, W.W. 1980. Valanginian miospore and microplankton assemblages from the northern Richardson Mountains, District of Mackenzie, Canada. Geol. Surv. Can. Bull. No.320.

NORWEGIAN PETROLEUM SOCIETY. 1980. The sedimentation of the North Sea Reservoir Rocks.

OLSEN, R.C. & STRASS, I.F. 1982. The Norwegian - Danish Basin. N.P.D. Paper No. 31.

PERCH-NIELSEN, K. 1979. Calcareous Nannofossil Zonation at the Cretaceous/Tertiary Boundary in Denmark. Cretaceous - Tertiary Boundary Events. Symposium I. The Maastrichtian and Danian of Denmark. University of Copenhagen.

PERCH-NIELSEN, K. 1979. Calcareous Nannofossils from the Cretaceous between the North Sea and the Mediterranean. In: Aspekte der Kreide Europas. IUGS Series A, 6 (Stuttgart).

RASMUSSEN, L.B. 1974. Some geological results from five Danish exploration wells in the North Sea. Geol. Surv. of Denmark, III Series, No.42.

RAWSON, P.F. & RILEY, L.A. 1982. Latest Jurassic - Early Cretaceous Events and the "Late Cimmerian Unconformity" in North Sea Area. A.A.P.G. Bulletin Vol 66, No.12.

ROBASZYNSKI, F & CARON, M. 1979. Atlas de foraminiferes Planctoniques du Cretace Moyen (mer Boreale et Tethys). Cah. Micropaleont., Parts 1-2.

SHERLOCK, R.L. 1947. The Permo-Triassic Formations. A World Review.

SISSINGH, W. 1977. Biostratigraphy of Cretaceous Calcareous Nannoplankton. Geol. en Mijnb. Vol. 56.

SMITH, E.G. and WARRINGTON, G. 1971. The age and relationships of the Triassic rocks assigned to the lower part of the Keuper in north Nottinghamshire, north-west Lincolnshire and south Yorkshire. Proc. Yorks. geol. Soc. Vol. 38.

SORGENFREI, Th. & BUCH, A. 1964. Deep Tests in Denmark 1935-1959. Geol. Surv. of Denmark, III Series, No. 36.

THUSU, B. (Editor) 1978. Distribution of biostratigraphically diagnostic dinoflagellate cysts and miospores from the Northwest European Continental Shelf and adjacent areas. Cont. Shelf. Inst. Publ. No. 100.

TYSON, R.V. WILSON, R.C.L & DOWNIE, C. 1979. A stratified water column environmental model for the type Kimmeridge Clay. Nature, Vol. 277.

WOODLAND, A.W. (Editor). 1975. Petroleum and the Continental Shelf of North West Europe, Vol. 1. Geology. Institute of Petroleum.

ROBERTSON RESEARCH INTERNATIONAL LIMITED. 1975/1976. The Jurassic of North West Europe: Offshore Project.

ROBERTSON RESEARCH INTERNATIONAL LIMITED. 1977. The Inner Moray Firth Area of Scotland: Stratigraphy, Reservoir Rocks and Source Rock Potential of the Devonian to Lower Cretaceous Sediments.

ROBERTSON RESEARCH INTERNATIONAL LIMITED. 1979. Southern Offshore Norway: The Stratigraphy and Petroleum Geochemistry of the Jurassic to Tertiary Sediments.

ROBERTSON RESEARCH INTERNATIONAL LIMITED. 1980. Outer Moray Firth Area North Sea: The Stratigraphy and Petroleum Geochemistry of the Jurassic to Tertiary Sediments.

ROBERTSON RESEARCH INTERNATIONAL LIMITED. 1982. Southern Offshore Norway Phase Two Study: The Stratigraphy and Petroleum Geochemistry of the Jurassic to Tertiary Sediments.

ROBERTSON RESEARCH INTERNATIONAL LIMITED. 1983. The Danish North Sea Area: The Stratigraphy and Petroleum Geochemistry of the Jurassic to Tertiary Sediments.

## APPENDIX 1

## LITHOLOGICAL DESCRIPTIONS OF SIDEWALL CORES

| Depth (m) | Core No. | Recovery (mm) | Quality | Type of Analysis | Lithology |
|---|---|---|---|---|---|
| 2517 | 36 | 45 | good | M | CLAYSTONE: moderately hard, slightly waxy, olive grey to olive black, slightly micromicaceous and non-calcareous. |
| 2595 | 29 | 55 | good | M | CLAYSTONE: moderately hard, waxy, dark greenish grey, slightly micaceous, with traces of pyrite, non-calcareous. |
| 2643 | 28 | 30 | good | M | SHALE: moderately hard, subfissile, brownish black to olive black and slightly micromicaceous, non-calcareous. |
| 2697 | 27 | 50 | good | M | SHALE: moderately hard, waxy, greenish grey with minor pale red, micromicaceous with traces of pyrite, non-calcareous. |
| 2720 | 26 | frags | fair | M | SHALE: moderately hard, subfissile, medium grey to dark greenish grey and slightly micromicaceous, non-calcareous. |
| 2741 | 25 | frags | poor | M | CLAYSTONE: moderately soft, medium dark grey, slightly silty, ?tuffaceous, non-calcareous. |
| 2760 | 24 | frags | fair | M | CLAYSTONE: moderately soft, slightly waxy, olive grey, slightly micromicaceous, non-calcareous. |

| | | | | | |
|---|---|---|---|---|---|
| 2777 | 23 | frags | fair | M | CLAYSTONE: moderately soft, waxy, dark grey and slightly micromicaceous, non-calcareous. |
| 2828 | 22 | frags | fair | M | CLAYSTONE: moderately hard, slightly waxy, olive grey and micromicaceous, non-calcareous. |
| 2864 | 20 | frags | poor | M N | CALCAREOUS CLAYSTONE: moderately soft, waxy, olive grey, slightly micromicaceous and calcareous. Sample covered in drilling mud. |
| 2892 | 19 | frags | v. poor | M N | DOLOMITIC SHALE: moderately hard, light olive grey, micromicaceous and weakly calcareous. Sample covered in drilling mud. |
| 3022 | 18 | frags | fair | M N | LIMESTONE: moderately hard, crystalline, slightly chalky and very light grey. |
| 3140 | 17 | frags | fair | M N | LIMESTONE: moderately hard, chalky and white. |
| 3282 | 16 | frags | poor | M N | ARGILLACEOUS LIMESTONE: moderately hard, crystalline, greyish red, slightly argillaceous. Sample covered with drilling mud. |
| 3352 | 15 | frags | fair | M N | SANDY CLAYSTONE: moderately soft, greyish red, with very fine to fine sand grains, glauconite and mica, highly calcareous. |
| 3365 | 14 | frags | fair | M N | SANDY CLAYSTONE: moderately soft, olive grey, with silt and very fine sand, traces of glauconite and mica, highly calcareous. |
| 3382 | 13 | frags | fair | M N | ARGILLACEOUS LIMESTONE: moderately soft, olive grey, sandy, glauconitic and argillaceous. |

| | | | | | |
|---|---|---|---|---|---|
| 3395 | 12 | frags | v.poor | M N | GLAUCONITIC LIMESTONE: greenish grey to white. Sample covered with drilling mud. |
| 3457 | 8 | frags | fair | MPN | ARGILLACEOUS SANDSTONE: fairly friable, greyish red, very fine grained to silty, micaceous, argillaceous and highly calcareous. |
| 3462 | 7 | frags | fair | MP | CLAYSTONE: moderately hard, greyish red to dusky red, micromicaceous and non-calcareous. |
| 3475 | 6 | frags | fair | MPN | SHALE: moderately hard, subfissile, dark greenish grey to dark grey, slightly micromicaceous with traces of pyrite, weakly calcareous. |
| 3490 | 5 | frags | fair | MPN | SHALE: moderately hard, subfissile, olive grey to medium dark grey, weakly to moderately calcareous. |
| 3505 | 4 | frags | fair | MP | SHALE: moderately hard, subfissile, olive grey, micaceous and dolomitic. |
| 3520 | 3 | frags | fair | MPN | CLAYSTONE: moderately soft, waxy, olive grey and weakly calcareous. |
| 3535 | 2 | frags | fair | MPN | SHALE: moderately hard, subfissile, medium dark grey to olive grey, micromicaceous and weakly calcareous. |
| 3550 | 1 | frags | fair | MPN | SHALE: moderately hard, subfissile, medium dark grey, micromicaceous and weakly calcareous. |
| 3641 | 29 | frags | fair | P | SHALE: moderately hard, subfissile, brownish black, slightly micromicaceous and calcareous. |
| 3721.50 | 28 | frags | fair | P | SHALE: as 3641m. |

| | | | | | |
|---|---|---|---|---|---|
| 3724.50 | 27 | frags | fair | P | GLAUCONITIC SANDSTONE: fairly friable, olive grey to medium light grey, very fine to fine grained, glauconitic, slightly argillaceous with traces of mica and strongly calcareous. |
| 3728.80 | 25 | frags | fair | P | SILTY SHALE: moderately hard, weakly fissile, brownish black, micromicaceous with silt and fine sand, calcareous. |
| 3731 | 24 | frags | poor | | GLAUCONITIC SANDSTONE: friable, olive grey, very fine to fine grained, glauconitic, non-calcareous. Sample covered with drilling mud. |
| 3773 | 23 | frags | fair | P | SANDSTONE: friable, yellowish grey to light olive grey, very fine to fine grained, micaceous and slightly argillaceous, non-calcareous. |
| 3775 | 22 | frags | fair | | SANDSTONE: as 3773m. |
| 3783.50 | 21 | 30 | fair | P | CLAYSTONE: moderately hard, slightly waxy, dark reddish brown to greyish red, micromicaceous, non-calcareous. |
| 3815 | 20 | frags | fair | P | SILTY CLAYSTONE: moderately hard, slightly waxy, greyish red with light grey, silty and sandy and locally highly micaceous, non-calcareous. |
| 3833 | 19 | frags | fair | P | SILTY SHALE: moderately hard, fissile, greenish grey to locally greyish red, highly micaceous and silty, non-calcareous, locally grading to SILTSTONE. |

| | | | | | |
|---|---|---|---|---|---|
| 3843 | 18 | 25 | fair | P | CLAYSTONE: moderately hard, waxy, moderate reddish brown with traces of greenish grey, micaceous and slightly silty, non-calcareous. |
| 3884.80 | 17 | frags | fair | P | ARGILLACEOUS LIMESTONE: moderately hard, light olive grey, micaceous, grading to CALCAREOUS CLAYSTONE. |
| 3903.20 | 16 | 38 | fair | P | CLAYSTONE: moderately hard, slightly waxy, greyish red, micromicaceous, with traces of light grey, non-calcareous |
| 3925.40 | 15 | frags | fair | P | ARGILLACEOUS SANDSTONE: friable, pale reddish brown, very fine to fine grained, micaceous and slightly argillaceous, non-calcareous. |
| 3938.50 | 14 | frags | fair | P | ARGILLACEOUS DOLOMITE: moderately hard, medium grey, micaceous and silty, grading to DOLOMITIC CLAYSTONE. |
| 3954 | 13 | frags | fair | P | SILTY SHALE: moderately hard, subfissile, medium grey to medium dark grey, micaceous and silty, non-calcareous. |
| 3972 | 12 | frags | poor | P | SANDSTONE: soft, greenish grey, very fine to fine grained, highly micaceous and argillaceous, non-calcareous. Sample covered in drilling mud. |
| 4024.50 | 10 | 20 | fair | P | SILTY CLAYSTONE: moderately hard, dark reddish brown, silty, micromicaceous, non-calcareous. |
| 4059 | 9 | frags | fair | P | SANDSTONE: friable, moderate reddish brown, very fine to medium grained, slightly argillaceous, rare mica, non-calcareous. |

| | | | | | |
|---|---|---|---|---|---|
| 4085 | 8 | frags | fair | P | SILTY CLAYSTONE: moderately hard, moderate to dark reddish brown, highly micaceous and silty, non-calcareous. |
| 4144.80 | 7 | frags | fair | P | SILTY CLAYSTONE: as 4085m |
| 4147.40 | 6 | frags | fair | | SANDSTONE: friable, pale reddish brown to pale red, very fine to medium grained, slightly argillaceous, non-calcareous. |
| 4155.70 | 5 | frags | fair | P | SANDSTONE: fairly friable, moderate reddish brown, very fine to fine grained and slightly argillaceous, non-calcareous. |
| 4169.70 | 4 | frags | fair | P | SANDSTONE: as 4147.40m, slightly anhydritic. |
| 4198 | 3 | frags | fair | P | CLAYSTONE: moderately hard, moderately reddish brown, micromicaceous and slightly silty, non-calcareous. |
| 4233.20 | 2 | frags | fair | P | ARGILLACEOUS LIMESTONE: moderately hard, light olive grey, micaceous, grading to CALCAREOUS SHALE. |
| 4236.50 | 1 | frags | fair | | SILTY CLAYSTONE: moderately hard, moderate reddish brown, micaceous and silty, non-calcareous. |

KEY

M = Micropalaeontology
N = Nannofossils
P = Palynology
frags = Fragments

## APPENDIX 2

### LITHOLOGICAL DESCRIPTIONS OF CORE PIECES

| Depth (m) | Core No. | Type of Analysis | Lithology |
|---|---|---|---|
| 3731 | 1 | P | ARGILLACEOUS SANDSTONE: well cemented, olive grey, fine to medium grained, subangular grains, argillaceous, ?kaolinitic with streaks and lenses of carbonaceous material, non-calcareous. Oil stained. |
| 3732 | 1 | | ARGILLACEOUS SANDSTONE: as 3731m with macrofossil debris (calcite, belemnite fragments) and traces of glauconite. Oil stained. |
| 3733 | 1 | | ARGILLACEOUS SANDSTONE: well cemented, olive grey to light olive grey, medium, subangular grains, traces of glauconite, slightly argillaceous with rare carbonaceous particles, non-calcareous. Oil stained. |
| 3734 | 1 | P | ARGILLACEOUS SANDSTONE: well cemented, olive grey, fine to medium, subangular grains, glauconitic and slightly argillaceous with carbonaceous streaks, non-calcareous. Oil stained. |
| 3735 | 1 | | ARGILLACEOUS SANDSTONE: well cemented, olive grey, fine to medium grained with carbonaceous particles, rare glauconite, slightly argillaceous with macrofossil traces, non-calcareous. Oil stained. |
| 3737 | 1 | P | ARGILLACEOUS SANDSTONE: as 3735m. |
| 3738 | 1 | | SANDSTONE: well cemented, light grey to olive grey, fine grained with carbonaceous, argillaceous streaks, non-calcareous. |

| | | | |
|---|---|---|---|
| 3739 | 1 | | SANDSTONE: well cemented, light olive grey, fine to medium grained, glauconitic, kaolinitic, non-oil stained, rare mica, calcite cemented, with calcite macrofossil debris (bivalves). |
| 3739.60 | 2 | | SANDSTONE: well cemented, light olive grey to olive grey, fine to medium grained, slightly argillaceous, carbonaceous (patches and streaks), non-calcareous, locally oil stained. |
| 3740 | 2 | | SANDSTONE: well cemented, light grey, fine grained, glauconitic, kaolinitic, with calcareous cement. |
| 3740.38 | 2 | | SANDSTONE: as 3740m with carbonaceous streaks and slightly argillaceous. |
| 3740.40 | 2 | | SANDSTONE: well cemented, light grey to olive grey, fine grained, with carbonaceous streaks and rare mica, non-calcareous. |
| 3740.60 | 2 | | SANDSTONE: well cemented olive grey, fine to medium grained, glauconitic, slightly argillaceous (?kaolinitic - oil stained) and locally carbonaceous, non-calcareous. |
| 3741.30 | 2 | | SANDSTONE: well cemented, olive grey, fine grained, traces of glauconite and carbonaceous particles and slightly argillaceous, non-calcareous. |
| 3741.70 | 3 | P | ARGILLACEOUS SANDSTONE: well cemented, olive grey, very fine to fine grained with carbonaceous, argillaceous and micaceous streaks, oil stained and locally calcareous cemented. |
| 3743.70 | 3 | | ARGILLACEOUS SANDSTONE: as 3741.70m, but olive grey to dark yellowish brown. |
| 3745.10 | 3 | | ARGILLACEOUS SANDSTONE: as 3741.70m, with macrofossils (bivalves). |
| 3746.50 | 3 | | ARGILLACEOUS SANDSTONE: as 3741.70m. |

| | | | |
|---|---|---|---|
| 3748 | 3 | | ARGILLACEOUS SANDSTONE: as 3741.70m but rare carbonaceous material. |
| 3748.80 | 3 | P | ARGILLACEOUS SANDSTONE: as 3741.70m with lignite fragments and calcite macrofossil debris. |
| 3750 | 3 | | SANDSTONE: well cemented, brownish grey, fine to medium grained, angular to subangular grains, oil stained with argillaceous and carbonaceous laminae and macrofossil debris (bivalves). |
| 3751.50 | 3 | | CALCAREOUS SANDSTONE: well cemented, light grey, fine to medium grained with abundant macrofossil debris (calcite replaced, moderate brown), traces of lignite and rare galena and pyrite cements. |
| 3752 | 3 | P | ARGILLACEOUS SANDSTONE: well cemented, dark yellowish brown, very fine to fine grained, with carbonaceous particles and rare macrofossil debris, non-calcareous. |
| 3752.70 | 3 | | ARGILLACEOUS SANDSTONE: as 3752m. |
| 3754.50 | 3 | | ARGILLACEOUS SANDSTONE: as 3752m. |
| 3756.40 | 3 | | ARGILLACEOUS SANDSTONE: as 3752m. |
| 3758.10 | 3 | P | ARGILLACEOUS SANDSTONE: as 3752m. |
| 3760 | 3 | | SANDSTONE: well cemented, light olive grey to olive grey, fine to medium grained, slightly argillaceous, with carbonaceous particles, non-calcareous. Oil stained. |
| 3760.10 | 4 | P | SANDSTONE: well cemented, light olive grey, fine to medium grained, ?kaolinitic, locally oil stained, with carbonaceous streaks and patches. non-calcareous. |
| 3762.20 | 4 | P | SANDSTONE: well cemented, olive grey, very fine to fine grained, oil stained and slightly argillaceous, non-calcareous. |
| 3766 | 4 | P | SANDSTONE: well cemented, white to light greenish grey, very fine grained, highly micaceous, argillaceous with slickenside marks, non-calcareous. |

| | | | |
|---|---|---|---|
| 3768.10 | 4 | P | SANDSTONE: well cemented, light greenish grey, very fine grained, highly micaceous, ?kaolinitic, non-calcareous. |

KEY

P = Palynology

APPENDIX 3

## RYAZANIAN–ALBIAN DINOCYST ZONATION

| GEOLOGICAL AGE | | | STANDARD AMMONITE ZONES | DINOCYST ZONATION: ZONES | DINOCYST ZONATION: SUBZONES |
|---|---|---|---|---|---|
| EARLY CRETACEOUS | Albian | late | *dispar* | *Ovoidinium scabrosum* OII | *Ovoidinium verrucosum* OIIA |
| | | | *inflatum* | | *Apteodinium grande* OIIB |
| | | | *cristatum* | | *Systematophora cretacea* OIIC |
| | | middle | *lautus* | | |
| | | | *loricatus* | | |
| | | | *dentatus* | | |
| | | early | *mamillatum* | | *Cauca parva* OIID |
| | | | *tardefurcata* | | |
| | Aptian | late | *jacobi* | *Dingodinium albertii* OI | *Aptea polymorpha* OIA |
| | | | *nutfieldensis* | | *Cyclonephelium tabulatum* OIB |
| | | | *martinioides* | | |
| | | early | *bowerbanki* | | |
| | | | *deshayesi* | | |
| | | | *forbesi* | | |
| | | | *fissicostatus* | | |
| | Barremian | late | *bidentatum* | *Sirmiodinium grossii* I | *"Astrocysta" cretacea* IA |
| | | early–mid | *rude-fissicostatum* | | *Doidyx anaphrissa* IB |
| | | | | | *Kleithriasphaeridium corrugatum* IC |
| | | | *rarocinctum* | | |
| | Hauterivian | late | *variabilis* | *Subtilisphaera terrula* II | *Adnatosphaeridium vetusculum* IIA |
| | | | *marginatus* | | *Canningia* cf. *reticulata* IIB |
| | | | *gottschei* | *"Oligosphaeridium" nannum* III | *Chlamydophorella trabeculosa* IIIA |
| | | | *speetonensis* | | |
| | | early | *inversus* | | |
| | | | *regale* | | *Kleithriasphaeridium simplicispinum* IIIB |
| | | | *noricum* | | |
| | | | *amblygonium* | | |
| | Valanginian | late | unnamed | *Phoberocysta neocomica* IV | *Muderongia extensiva* IVA |
| | | | *pitrei* | | |
| | | | *dichotomites* | | |
| | | early | *polyptychites* | | *Tubotuberella apatela* IVB |
| | | | *paratollia* | | *Endoscrinium pharo* IVC |
| | Ryazanian | late | *albidum* | *Dingodinium spinosum* V | *"? Prolixosphaeridium" torynum* VA |
| | | | *stenomphalus* | | *Dichadogonyaulax* spp. VB |
| | | | *icenii* | | |
| | | early | *kochi* | | *Cannosphaeropsis* sp. A VC |
| | | | *runctoni* | | |

* The Barremian/Hauterivian boundary should now be placed at the top of the *marginatus* Zone (Rawson, in press).

APPENDIX 4

# RHAETIAN–VOLGIAN DINOCYST ZONATION

| GEOLOGICAL AGE | | | STANDARD AMMONITE ZONES | DINOCYST ZONATION | |
|---|---|---|---|---|---|
| | | | | ZONES | SUBZONES |
| LATE JURASSIC | Volgian | late | *lamplughi* | *"Imbatodinium" villosum* VI | *Egmontodinium* sp. A VIA |
| | | | *preplicomphalus* | | *Kleithriasphaeridium* sp. A VIB |
| | | | *primitivus* | | *Systematophora* spp. VIC |
| | | | *oppressus* | | |
| | | middle | *giganteus* | *Muderongia* sp. A VII | *Dichadogonyaulax pannea* VIIA |
| | | | *gorei* | | *Dichadogonyaulax culmula* VIIB |
| | | | *albani* | | *Glossodinium dimorphum* VIIC |
| | | | *Epipallasiceras* sp. | | |
| | | | *rotunda* | | |
| | | | *pallasioides* | *Pareodinia mutabilis* VIII | *Gonyaulacysta pennata* VIIIA |
| | | | *Pavlovia* sp. | | *Gonyaulacysta jurassica* VIIIB |
| | | early | *pectinatus* | *Gonyaulacysta longicornis* IX | *Egmontodinium polyplacophorum* IXA |
| | | | *hudlestoni* | | |
| | | | *wheatleyensis* | | |
| | | | *scitulus* | | *Scriniodinium luridum* IXB |
| | | | *elegans* | | |
| | Kimmeridgian | | *autissiodorensis* | *Gonyaulacysta cladophora* X | |
| | | | *eudoxus* | | |
| | | | *mutabilis* | | |
| | | | *cymodoce* | | |
| | | | *baylei* | *Scriniodinium crystallinum* XI | *Leptodinium egemenii* XIA |
| | | | | | *Stephanelytron redcliffense* XIB |
| | Oxfordian | late | *pseudocordata* | *Scriniodinium galeritum* XII | *Scriniodinium oxfordianum* XIIA |
| | | | *decipiens* | | *Compositosphaeridium costatum* XIIB |
| | | | *cautisnigrae* | | |
| | | middle | *transversarium* | *Acanthaulax spinosissima* XIII | |
| | | | *plicatilis* | | |
| | | early | *cordatum* | *Wanaea digitata* XIV | *Gonyaulacysta areolata* XIVA |
| | | | *mariae* | | *Wanaea fimbriata* XIVB |
| | | | | | *Mendicodinium groenlandicum* XIVC |
| | Callovian | late | *lamberti* | *Polystephanephorus paracalathus* XV | *Kalyptea stegasta* XVA |
| | | | *athleta* | | *Nannoceratopsis pellucida* XVB |
| | | middle | *coronatum* | *Pareodinia ceratophora* XVI | *Dichadogonyaulax gochtii* XVIA |
| | | | *jason* | | *Wanaea acollaris* XVIB |
| | | early | *calloviense* | | *Gonyaulacysta filapicata* XVIC |
| | | | *macrocephalus* | | |
| MIDDLE JURASSIC | Bathonian | late | *discus* | | |
| | | | *aspidoides* | | |
| | | | *retrocostatum* | | |
| | | middle | *morrisi* | *Nannoceratopsis spiculata* XVII | |
| | | | *subcontractus* | | |
| | | | *progracilis* | | |
| | | early | *zigzag* | | |
| | Bajocian | late | *parkinsoni* | *Nannoceratopsis gracilis* XVIII | *Polysphaeridium deflandrei* XVIIIA |
| | | | *garantiana* | | |
| | | | *subfurcatum* | | |
| | | middle | *humphriesianum* | | |
| | | | *sauzii* | | |
| | | | *laeviuscula* | | |
| | | | *discites* | | |
| | | early | *concavum* | | |
| | | | *murchisonae* | | |
| | | | *opalinum* | | |
| EARLY JURASSIC | Toarcian | late | *levesquei* | | *Mancodinium semitabulatum* XVIIIB |
| | | | *thouarsense* | | |
| | | middle | *variabilis* | | |
| | | | *bifrons* | | "Sphaeromorphs" XVIIIC |
| | | early | *falciferum* | | |
| | | | *tenuicostatum* | | |
| | Pliensbachian | late | *spinatum* | | *Luehndea spinosa* XVIIID |
| | | | *margaritatus* | | |
| | | early | *davoei* | *Polysphaeridium langii* XIX | Unnamed subzone XIXA |
| | | | *ibex* | | |
| | | | *jamesoni* | | |
| | Sinemurian | late | *raricostatum* | | *Liasidium variabile* XIXB |
| | | | *oxynotum* | | |
| | | | *obtusum* | | |
| | | early | *turneri* | | Unnamed subzone XIXC |
| | | | *semicostatum* | | |
| | | | *bucklandi* | | |
| | Hettangian | | *angulata* | | *Dapcodinium priscum* XIXD |
| | | | *liasicus* | | |
| | | | *planorbis* | | |
| LATE TRIASSIC | Rhaetian | | | *Rhaetogonyaulax rhaetica* XX | |

## LITHOLOGIES

Clay

Shale/mudstone

Siltstone

Sand/sandstone, very fine to medium grained

Sand/sandstone, coarse grained to granules

Conglomerate (with sand matrix)

Conglomerate (without sand matrix)

Coal/lignite

Breccia

Limestone (undifferentiated)

Chalky limestone

Dolomitic limestone

Calcareous dolomite

Dolomite

Chert

Anhydrite/gypsum

Salt (halite)

Potassium salts

Concretions/nodules

Igneous rocks, undifferentiated

Basement, undifferentiated

Granite

### Qualifiers

Argillaceous

Silty/sandy

Pebbly

Carbonaceous

Calcareous

Dolomitic

Red sediments

### Accessories

Calcite . . . . . C

Ironstone/ferruginous deposits . . . . . Fe

Glauconite . . . . . Gl

Kaolinite . . . . . K

Phosphate . . . . . Ph

Pyrite . . . . . Py

Siderite/sphaerosiderite . . . . . S

Silica . . . . . Si

## GRAIN TYPES

Oolith

Fossils in general

Bioclastic debris

Mudflakes

## BIOSTRATIGRAPHIC SYMBOLS

Fossil Abundances

- Present . . . . . ○
- Common . . . . . ●
- Abundant . . . . . ■

Diagnostic forms . . . . . *

Caved forms . . . . . C

Reworked forms . . . . . R

Incoming of

Outgoing of

Unconformity/stratigraphic hiatus

Faulted boundary . . . . . F—F

Late . . . . . LT., lt.

Middle . . . . . M., m.

Early . . . . . EY., ey.

### Other symbols

Sample gap

Lost circulation material . . . . . lcm

Cement . . . . . cmt

Turbo drilling or diamond bit drilling . . . . . tu
(Samples unsuitable for good stratigraphic analysis)

Casing point

Core

Sidewall core

Sidewall core (analysed for biostratigraphy)

Sidewall core (no recovery)

**FIGURE 1 – Legend (edited from Robertson Research Standard Legend).**

ROBERTSON RESEARCH

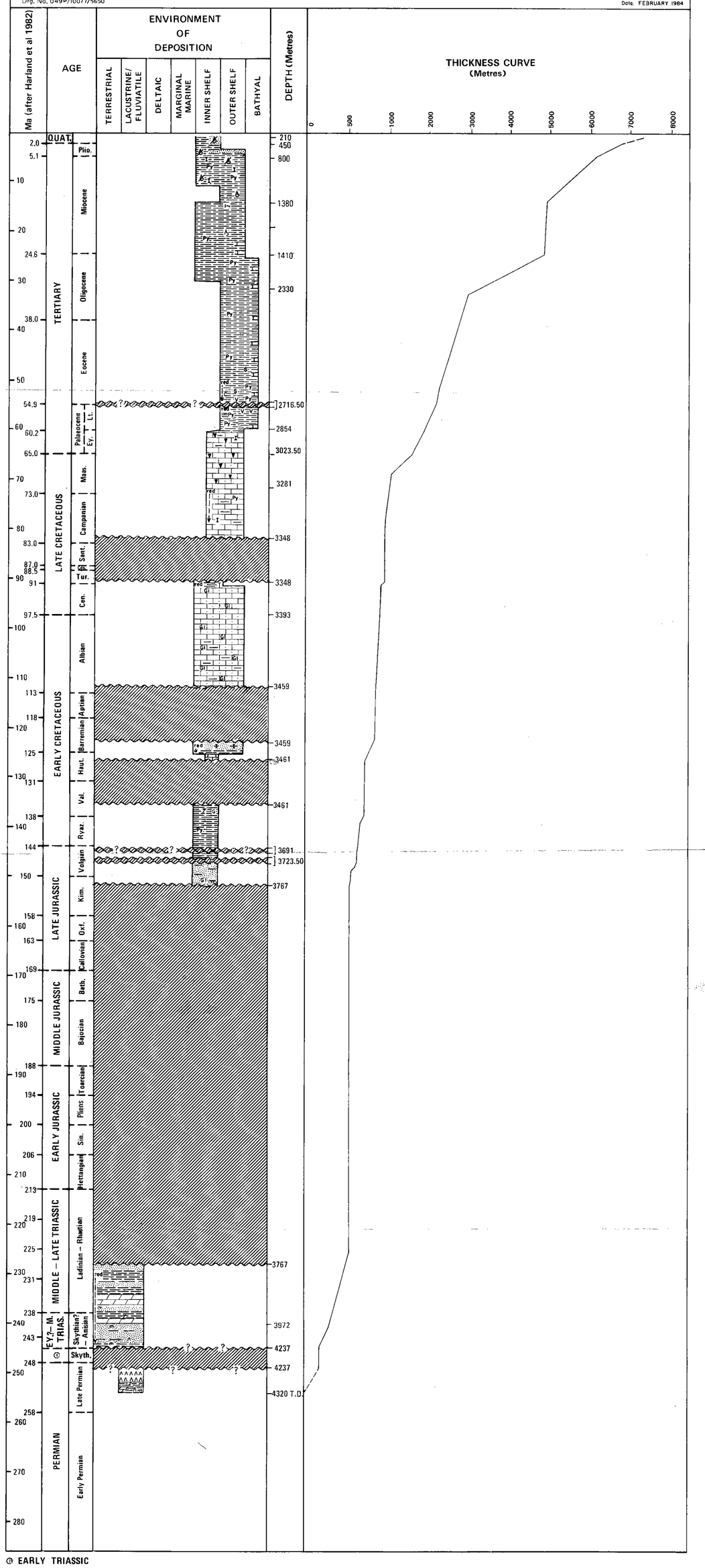
FIGURE 2
DEPOSITIONAL HISTORY

ROBERTSON RESEARCH INTERNATIONAL LIMITED

# CONOCO 7/8-3

Drg. No. 049P/10077/5650

Date. FEBRUARY 1984




① EARLY TRIASSIC