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STATOIL 15/9 - 14 NORWEGIAN NORTH SEA WELL:
BIOSTRATIGRAPHY OF THE INTERVALS
180m - 2537m AND 2945m - 3563m T.D.

by

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I

SUMMARY

1. The youngest sediments to be analysed from this well are claystones with interbedded sandstones, of Pleistocene age, which are assigned to the Nordland Group.
2. The Nordland Group, Utsira Formation, which predominantly comprises sandstones, overlies the sandstones and shales of the Hordaland Group of Early Miocene to Early Eocene age.
3. The Hordaland Group Frigg Formation sandstones pass down into the Rogaland Group.
4. The Rogaland Group, deposited during the Late Palaeocene, is represented by shales with minor tuffaceous shales, of the Balder Formation and shales of the Sele and Lista Formations.
5. The interval 2537m-2945m was not examined on instructions from the client.
6. The Late Cretaceous Chalk Group comprises limestones with thin argillaceous partings, of the Hod Formation, argillaceous limestones and calcareous shales of the Plenus Marl Formation which overlie limestones of the Hydra Formation.
7. Non-calcareous shales of the Rødby Formation and the lithologically variable Valhall Formation, both of the Cromer Knoll Group, were deposited during the Early Cretaceous.
8. An unconformity separates the Cromer Knoll Group from the Humber Group, resulting in the absence of sediments of Valanginian and uppermost Ryazanian age.

9. The Humber Group is represented by shales of the Kimmeridge Clay and Heather Formations which overlie an interbedded sequence of coals, shales and sandstones of the Hugin Formation. These sediments range in age from Ryazanian - Volgian to early Callovian.
10. A major unconformity separates the Hugin Formation, of early Callovian age at the oldest, from the Triassic sandstones and claystones.
11. The well terminated in claystones assignable to the Skagerrak Formation.

II

INTRODUCTION

This report summarises the results of the micropalaeontological, palynological and stratigraphic analyses which have been carried out on material received from the intervals 180m-2537m and 2945m-3563m T.D. from the Statoil 15/9-14 Norwegian North Sea Well under Project No. RRPS/823/A/10360.

The interval 2537m-2945m was not analysed on receipt of instructions from the client.

The following analyses were carried out:

Lithology: 410 ditch cuttings, 10 sidewall core and 7 core samples from the entire section.

Micropalaeontology: 152 ditch cuttings and 5 sidewall core samples from the intervals 180m-2537m and 2945m-3167m.

Palynology: 47 ditch cuttings, 8 sidewall core and 7 core samples from the interval 3048m-3563m T.D.

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 Larsen and Jaarvik (1981). The stratigraphic significance of the Rhaetian - Albian dinocyst zonation 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 Statoil with whom we have been associated during the course of this work.

Robertson Research staff involved in this study were:

Jim Fenton	-	Palynology
Dave Renshaw	-	Palynology
Alison Shaw	-	Lithostratigraphy
Rosemary Titterton	-	Micropalaeontology and Project co-ordinator

III

SUCCESSION

<u>Age</u>	<u>Tops</u>
Pleistocene	180m (top not seen)
Pliocene	600m
Late - Middle Miocene	930m
Early Miocene	1010m
Late Oligocene	1270m
Early Oligocene	1650m
Late - Middle? Eocene	1740m
Middle - Early? Eocene	1980m
Early Eocene	2363m
Late Palaeocene	2382m(log)
Interval 2537m-2945m	not examined
Late Cretaceous	2945m(top not seen)
	(Coniacian - Turonian 2963m
	(
Late Cretaceous	(Turonian 3017m
	(
	(Cenomanian 3074m(log)
	(Albian 3127.50m(log)
	(
	(early Albian - Aptian 3131m
Early Cretaceous	(3137m
	(
	(Barremian - Hauterivian 3140m
-----Unconformity-----	
Early Cretaceous - Late Jurassic	Ryazanian - Volgian 3176m(log)

	(Kimmeridgian? - Oxfordian	3211m(log)
	(
Late Jurassic	(early? Oxfordian - middle Callovian	3221m
	(
	(early Callovian	3254m

-----Unconformity-----

Triassic 3274m(log)-3563m T.D.

This breakdown has been achieved by the analysis of ditch cuttings, sidewall core and core piece samples. ISF/BHC/GR electric log information was made available.

Core depths quoted are uncorrected drillers depths.

IV

LITHOSTRATIGRAPHY

The lithostratigraphic nomenclature used in this report is taken from Deegan and Scull (1977) and Larsen and Jaarvik (1981).

Wireline logs (ISF/BHC/GR) were provided for use in this study. All but two of the lithological boundaries are based on log breaks.

LITHOSTRATIGRAPHIC UNITS

NORDLAND GROUP: 180m-1077.50m(log); Age: Pleistocene - Early Miocene.

Unassigned: 180m-926m(log); Age: Pleistocene - Pliocene.

The predominant lithologies between 180m and 324m are inferred from wireline log evidence to be claystones which are moderately soft, light olive grey, silty, and sandy with interbedded sandstones. The ditch cuttings samples contain only traces of claystone, most of which are assumed to have been washed out during the drilling process leaving fine to coarse sand, lithic fragments and shell debris. From 324m to 926m claystones are indicated by wireline logs but these sediments are still poorly represented in the ditch cuttings samples which contain predominantly fine to medium sand grains; pyrite rods occur sporadically below 390m. Sandy claystones are indicated on wireline logs between 675m and 700m and below 890m.

Utsira Formation: 926m(log)-1077.50m(log); Age: Pliocene - Early Miocene.

This unit consists of sandstone, represented in the ditch cuttings samples by very fine to coarse sand, with characteristically abundant shell fragments, pyrite rods and traces of glauconite. Minor argillaceous bands of olive grey, calcareous claystone occur intermittently throughout.

HORDALAND GROUP: 1077.50m(log)-2382m(log); Age: Early Miocene - Early Eocene.

Unassigned: 1077.50m(log)-2048m(log); Age: Early Miocene - Middle - Early ?Eocene.

This group comprises a sequence of sandstones and shales with subordinate carbonate stringers or concretions. The shales are subfissile to blocky, often grading to claystone, light brownish grey to brownish grey and dusky yellowish brown, locally silty, sandy and weakly calcareous, with sponge spicules between 1077.50m(log) and 1172m. Traces of glauconite (from 1525m to 1800m) and sand (between 1525m and 2048m(log)) in the ditch cuttings samples are probably derived from the argillaceous sediments. Sideritic limestone, considered to represent stringers or concretions, occurs sporadically down to 2048m(log). Sand units are indicated on wireline logs between 1170m and 1190m and from 1260m to 1311m being represented in ditch cuttings by fine to medium grained, loose sand. At and below 1960m, the predominant lithology is shale which is slightly waxy, greenish grey and micromicaceous, becoming silty and sandy with minor, very fine to fine grained, white sandstone below 2005m.

Frigg Formation: 2048m(log)-2382m(log); Age: Middle - Early? Eocene to Early Eocene.

The upper boundary top of this formation is taken at the top of a thick sandstone unit which characteristically underlies green shales. The sandstone is white to light brown with fine to medium and rare coarse grains, locally with calcareous cement. An interval of greenish grey to olive grey shales, with minor sandy interbeds is recorded between 2099m and 2146m. The underlying sandstone down to 2195m contains traces of glauconite. The remaining interval consists of greenish grey to olive grey and brownish grey shale with stringers or concretions of dolomitic limestone and limestone, with traces of pyrite and sphaerosiderite. The basal part of this formation, from 2357m to 2382m, comprises shales which are slightly waxy, greyish red, greenish grey and medium grey, with traces of green, waxy claystone. These lithologies typically overlie Rogaland Group volcanics and traces of sandy tuff are observed at and below 2378m in ditch cuttings samples.

ROGALAND GROUP: 2382m(log)-2537m; Age: Late Palaeocene.

Balder Formation: 2382m(log)-2425m(log).

The predominant lithologies are shales which are subfissile, greyish red, greenish grey, medium grey and micromicaceous with pyrite and siderite. These shales are associated with minor tuffaceous shales which are light greenish grey (with light and dark blebs) and light to dark grey with faint laminations. The shales become predominantly medium grey below 2405m. The appearance of traces of sandy tuff at 2378m may be due to a difference between drillers and loggers depths, unless reworking into the basal part of the Frigg Formation is invoked.

Sele Formation: 2425m(log)-2484m(log).

This unit consists of shales which are weakly fissile, light to dark grey and locally finely laminated, becoming more fissile and predominantly medium grey below 2465m. Greyish red and greenish grey shales with associated tuffs persisting in the ditch cuttings samples are presumed to be caved.

Lista Formation: 2484m(log)-2537m.

The predominant lithologies in this formation are fissile to subfissile, medium grey shales with traces of brownish grey, silty shale at 2535m. Traces of siderite are considered to represent stringers or concretions. The base of this formation is not seen due to a sample gap between 2537m and 2945m (including the turbo-drilled interval).

Interval 2537m-2945m not examined on receipt of instructions from client.

CHALK GROUP: 2945m-3127.50m(log); Age: Late Cretaceous, Coniacian to Cenomanian from 2963m.

Hod Formation: 2945m-3045.50m(log); Age: Coniacian to Turonian from 2963m.

This interval consists of limestones which are hard to moderately hard, cryptocrystalline, locally chalky, white to very light grey, pinkish grey and locally argillaceous. Subordinate shales, which are light to dark grey, greenish grey and locally calcareous, probably represent thin argillaceous partings within the limestone. At and below 3025m the limestones become

microcrystalline with very fine grains of glauconite. This is a characteristic feature of the basal part of the Hod Formation.

Plenus Marl Formation: 3045.50m(log)-3074m(log); Age: Turonian.

The lithologies in this formation contrast sharply with the less argillaceous sediments above and below. They comprise argillaceous limestones which are light grey to dark grey, microcrystalline to cryptocrystalline, locally glauconitic and micaceous with traces of pyrite, grading to calcareous shale below 3072m.

Hidra Formation: 3074m(log)-3127.50m(log); Age: Cenomanian.

This formation consists of limestone which is white to light grey and pinkish grey, cryptocrystalline and locally chalky with subordinate calcareous shale which is medium grey to olive grey, slightly silty and micaceous.

CROMER KNOLL GROUP: 3127.50m(log)-3176m(log); Age: Early Cretaceous, Albian to Barremian - Hauterivian.

Rødby Formation: 3127.50m(log)-3131m; Age: Albian.

The predominant lithology in this formation is shale which is subfissile, medium grey to greenish grey and non-calcareous.

Valhall Formation: 3131m-3176m(log); Age: early Albian - Aptian to Barremian - Hauterivian.

The upper boundary of this formation is placed at 3131m on the occurrence, in the ditch cuttings samples, of shales which are subfissile, greyish red and non-calcareous. These shales persist to a depth of 3140m, where wireline log evidence indicates the predominant lithology to be argillaceous limestone which is light grey to dark grey, crystalline and slightly silty. Traces of pale reddish brown and medium grey, calcareous claystones are recorded below 3150m. At and below 3158m, calcareous shales become the predominant lithology, these shales are subfissile, light grey to dark grey and greyish red, with traces of olive grey, slightly silty, calcareous claystone at 3170m. Between 3172.50m and 3176m the lithology comprises a distinctive limestone which is cryptocrystalline, light olive grey to white and pinkish grey with pyrite spheroids.

HUMBER GROUP: 3176m(log)-3274m(log); Age: Early Cretaceous - Late Jurassic, Ryazanian - Volgian to early Callovian.

Kimmeridge Clay Formation: 3176m(log)-3211m(log); Age: Ryazanian - Volgian to Kimmeridgian? - Oxfordian.

The predominant lithology in this unit is shale which is weakly fissile and locally earthy, olive black to dark grey, slightly silty and locally weakly calcareous.

Heather Formation: 3211m(log)-3225.50m(log); Age: early? Oxfordian - middle Callovian.

The presence of this formation is inferred from wireline log evidence, where the shales become less "hot". Lithologies are represented in ditch cuttings samples by olive black to dark grey, silty shales which are similar to the sediments comprising the overlying Kimmeridge Clay Formation and may not represent the in situ lithology.

Hugin Formation: 3225.50m(log)-3274m(log); Age: early? Oxfordian - middle Callovian to early Callovian.

This formation comprises an interbedded sequence of coals which are black and vitreous, locally grading to carbonaceous shales, with shales and claystones which are fissile to blocky, dark grey to brownish black, silty and micromicaceous. These grade to, and are interbedded with, argillaceous sandstones and sandstones which are friable to well cemented, yellowish grey to dusky yellowish brown, very fine to fine grained, locally micaceous, grading to siltstones.

"TRIASSIC GROUP": 3274m(log)-3563m T.D.; Age: Triassic.

Skagerrak Formation:

The upper part of this unit between 3274m(log) and 3350m comprises a sequence of shales and claystones which are light brownish grey and greenish grey, silty and sandy, becoming predominantly greyish red to moderate reddish brown with rare greenish grey colouration below 3305m. These sediments are interbedded with thin sandstones, which are friable to well cemented, white and pinkish grey to light greenish grey, very fine to medium grained and locally highly micaceous. Sandstone becomes the predominant lithology at and below 3350m

represented in ditch cuttings largely by loose sand with minor argillaceous bands and traces of pyrite. Below 3428m the sand becomes fine to coarse with white, moderate orange pink and pale green grains; the proportion of coarse grains and pink and green grains increases below 3455m. The sequence becomes increasingly argillaceous with depth below 3285m and at 3542m, the predominant lithology is claystone. This is greyish red to moderate reddish brown, slightly silty and micaceous with sandy and silty bands, possibly representing a transition to the more argillaceous Smith Bank Formation.

BIOSTRATIGRAPHYV(1) QUATERNARY

INTERVAL 180m-600m; PLEISTOCENE (top not seen)

Lithostratigraphic Unit:

Nordland Group (part);

Unassigned.

Environment: marine, inner shelf.

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

- the occurrence of the Nonion granosum/Protelphidium orbiculare group, the Elphidium incertum group, Elphidium ustulatum and Elphidium asklundi in the sample 180m-190m.
- the subsequent occurrence of Globorotalia humerosa at 260m.

MICROPALAEONTOLOGY

In the youngest sample to be examined (180m-190m) the Elphidium incertum group/Nonion granosum/Protelphidium orbiculare group Assemblage is recognised by the presence of members of both groups. This assemblage indicates a Pleistocene age, which is substantiated by the occurrence of Elphidium ustulatum and E. asklundi in the same sample and of Globorotalia humerosa at 260m.

Within the upper half of the interval the assemblages are of moderate abundance and diversity and are dominated by calcareous benthonic foraminifera. Between 380m and 510m the microfaunas are poorly preserved, red stained and of low diversity. The microfaunas become particularly impoverished below 510m.

Reworked Palaeogene foraminifera were recorded between 260m and 300m and Late Cretaceous foraminifera at 280m.

V(2) TERTIARY

INTERVAL 600m-930m; PLIOCENE

Lithostratigraphic Units:

Nordland Group (part);

Unassigned: 600m-926m(log),

Utsira Formation : 926m(log)-930m.

Environment: marine, inner shelf.

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

- the occurrence of *Cibicides lobatulus* var. *grossa* at 600m.
- the subsequent occurrence of *Cibicides pseudoungerianus* at 870m and *Nonion* affine at 890m.

MICROPALAEONTOLOGY

At 600m there is a marked increase in abundance of the microfaunas. At this level the first occurrence of *Cibicides lobatulus* var. *grossa* indicates that sediments of Pliocene age have been penetrated. In the lower part of the interval, the incoming of *Cibicides pseudoungerianus* (870m) and *Nonion* affine (890m) confirms this age determination.

Although the microfaunas throughout the interval are of low diversity, *Cassidulina laevigata* and species of *Cibicides* and *Elphidium* are particularly abundant. The associations almost exclusively comprise calcareous benthonic foraminifera.

INTERVAL 930m-1010m; LATE - MIDDLE MIOCENE

Lithostratigraphic Unit:

Nordland Group (part);

Utsira Formation (part).

Environment: marine, inner to outer shelf.

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

- the occurrence of *Cibicides peelensis*, *Globigerina praebulloides* and *Nonion boueanum* at 930m.
- the subsequent occurrence of *Hoeglundina elegans* (950m) and *Eponides umbonatus* (970m).

MICROPALAEONTOLOGY

The incoming of *Cibicides peelensis*, in association with *Globigerina praebulloides* and *Nonion boueanum*, at 930m, defines the top of the Late - Middle Miocene in this well. The presence of *Hoeglundina elegans* (950m) and *Eponides umbonatus* (970m) within the interval, supports this age determination.

There is a marked increase in abundance and diversity of the microfaunas associated with the incoming of the *Cibicides peelensis* Assemblage. The microfaunas continue to be dominated by calcareous benthonic foraminifera but rare planktonic and agglutinating foraminifera also occur.

INTERVAL 1010m-1270m; EARLY MIOCENE

Lithostratigraphic Units:

- Nordland Group (part): 1010m-1077.50m(log);
 Utsira Formation (part).
Hordaland Group (part): 1077.50m(log)-1270m;
 Unassigned (part).

Environment: marine, inner to outer shelf.

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

- the occurrence of *Asterigerina staeschei* at 1010m.
- the subsequent occurrence of the ostracod *Thaerocythere bassiounii* (1030m) and the *Globorotalia scitula* group (1250m).

MICROPALAEONTOLOGY

The incoming of *Asterigerina staeschei* at 1010m is considered to define the top of the Early Miocene. *Thaerocythere bassiounii* (1030m) and the appearance of planktonic foraminifera of the *Globorotalia scitula* group (1250m) are also characteristic of the Early Miocene.

The samples at the top of the interval yielded diverse assemblages but the abundance and diversity of the microfaunas decrease downwell. Calcareous benthonic foraminifera remain the dominant element, although there is a significant increase in planktonic foraminifera at and below 1230m.

INTERVAL 1270m-1650m; LATE OLIGOCENE

Lithostratigraphic Unit:

Hordaland Group (part);

Unassigned (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 of *Asterigerina gürichi* at 1270m.
- the subsequent occurrence of *Sigmoilina tenuis* (1400m) and *Sigmoilina schlumbergeri* (1430m).

MICROPALAEONTOLOGY

The *Asterigerina gürichi* Assemblage of Late Oligocene age is recognised at 1270m with the incoming of the nominate species. At 1400m there is a marked change in the microfaunas, to assemblages dominated by agglutinating foraminifera, which is associated with the upper limit of the *Sigmoilina schlumbergeri* Assemblage. Associations characteristic of this assemblage, with common to abundant species of *Bathysiphon*, *Cyclammina* and *Haplophragmoides*, continue to the base of the interval.

INTERVAL 1650m-1740m; EARLY OLIGOCENE

Lithostratigraphic Unit:

Hordaland Group (part);

Unassigned (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 *Rotaliatina bulimoides* at 1650m.

MICROPALAEONTOLOGY

The upper and lower occurrences of *Rotaliatina bulimoides* define the limits of the *Rotaliatina bulimoides* Assemblage which indicates the presence of Early Oligocene sediments. The microfaunas continue to be dominated by agglutinating foraminifera, notably species of *Bathysiphon* and *Cyclammina*.

INTERVAL 1740m-1980m; LATE - MIDDLE? EOCENE

Lithostratigraphic Unit:

Hordaland Group (part);

Unassigned (part).

Environment: marine, outer shelf to upper bathyal.

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

- the recognition of the *Trochammina globigeriniformis*/*Trochammina* sp. X/*Cystammina* sp. Assemblage throughout the interval.
- the stratigraphic position (between Early Oligocene and Middle - Early? Eocene deposits).

MICROPALAEONTOLOGY

No age diagnostic forms were recovered from this interval although the presence of the *Trochammina globigeriniformis*/*Trochammina* sp. X/*Cystammina* sp.

Assemblage is consistent with the general Late - Middle? Eocene age assigned.

This age is based on the stratigraphic position of the interval between Early Oligocene and Middle - Early? Eocene sediments.

The microfaunal associations within this interval are moderate to high in abundance but of low diversity. Long-ranging agglutinating foraminifera are the dominant element, with species of *Bathysiphon* and *Cyclammina* being particularly abundant.

INTERVAL 1980m-2363m; MIDDLE - EARLY? EOCENE

Lithostratigraphic Units:

Hordaland Group (part);

Unassigned (part): 1980m-2048m(log),

Frigg Formation (part): 2048m(log)-2363m.

Environment: marine, outer shelf to upper bathyal.

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

- the occurrence of *Spiroplectammina spectabilis* at 1980m.
- the subsequent occurrence of *Ammobaculites* sp. 1 at 2000m.

MICROPALAEONTOLOGY

The incoming of *Spiroplectammina spectabilis* at 1980m defines the top of the *Ammobaculites* sp. 1/*Verneuilina subeocaena*/*Spiroplectammina spectabilis* Assemblage, with *Ammobaculites* sp. 1 appearing 2000m. Regional knowledge indicates that this assemblage is Middle - Early? Eocene in age.

Agglutinating foraminifera continue to dominate the microfaunas. The microfaunal associations are generally of moderate abundance and diversity but are impoverished between 2141m and 2237m.

INTERVAL 2363m-2382m(log); EARLY EOCENE

Lithostratigraphic Unit:

Hordaland Group (part);

 Frigg Formation (part).

Environment: marine, outer shelf to upper bathyal.

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

- the occurrence of members of the *Globigerina linaperta* group at 2363m.
- the recognition of the *Globigerina triloculinoides* Assemblage throughout the interval.

MICROPALAEONTOLOGY

Microfaunas characteristic of the *Globigerina triloculinoides* Assemblage are recognised at 2363m with the incoming of members of the *Globigerina linaperta* group and the subsequent influx of *Globigerina triloculinoides* at 2381m. This assemblage confirms the presence of sediments of Early Eocene age.

At 2381m the first downhole occurrence of the pyritised diatoms *Coscinodiscus* sp. 1 and sp. 2 is recorded. This is considered to be due to reworking of the underlying Late Palaeocene sediments or due to a discrepancy between drillers and loggers depths.

INTERVAL 2382m(log)-2537m; LATE PALAEOCENE

Lithostratigraphic Units:

Rogaland Group;

Balder Formation : 2382m(log)-2425m(log),

Sele Formation : 2425m(log)-2484m(log),

Lista Formation : 2484m(log)-2537m.

Environment: marine, outer shelf to upper bathyal.

The upper limit of this interval is based on a log break at 2382m which marks the top of the Balder Formation.

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

- the recognition of the *Coscinodiscus* sp. 1 Assemblage between 2390m and 2483m.
- the subsequent occurrence of *Labrospira pacifica* (2519m).

MICROPALAEONTOLOGY

The pyritised diatoms *Coscinodiscus* sp. 1 and sp. 2 are believed to be in situ between 2390m and 2483m, indicating a Late Palaeocene age. This age determination is confirmed by the subsequent occurrence of *Labrospira pacifica* at 2519m.

The microfaunas throughout the interval are of low diversity and abundance, being dominated by species of the agglutinating genus *Bathysiphon*.

V(3) CRETACEOUS

INTERVAL 2945m-2963m; LATE CRETACEOUS (top not seen)

Chalk Group (part);
Hod Formation (part).

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

- the stratigraphic position of the interval overlying sediments of Coniacian - Turonian age.
- the occurrence of Inoceramus debris (2954m).

MICROPALAEONTOLOGY

The two samples at 2945m and 2954m, taken at the base of the turbo-drilled section (2684m-2946m), did not yield any age restricted microfossils. A general Late Cretaceous age only can be assigned on the occurrence of Inoceramus debris (2954m) and the stratigraphic position of the interval.

INTERVAL 2963m-3017m; LATE CRETACEOUS, CONIACIAN - TURONIAN

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 micropalaeontological criteria:

- the occurrence of common actinommid radiolaria at 2963m.
- the subsequent occurrence of *Stensioina exsculpta*, *S. praeexsculpta*, *Globotruncana linneiana tricarinata* (2972m), *G. linneiana linneiana* (2981m) and *G. linneiana cf. coronata* (3008m).

MICROPALAEONTOLOGY

The incoming of common actinommid radiolaria at 2963m and the assemblage recovered at 2972m which includes *Stensioina exsculpta*, *S. praeexsculpta* and *Globotruncana linneiana tricarinata*, indicates a Coniacian - Turonian age. The subsequent occurrence of *Globotruncana linneiana linneiana* (2981m) and *G. linneiana cf. coronata* (3008m) provides confirmation of this age.

INTERVAL 3017m-3074m(log); LATE CRETACEOUS, TURONIAN

Lithostratigraphic Units:

Chalk Group (part);

Hod Formation (part): 3017m-3045.50m(log),

Plenus Marl Formation: 3045.50m(log)-3074m(log).

Environment: marine, outer shelf.

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

- the occurrence of questionable species of ?*Praeglobotruncana* cf. *stephani* at 3017m.
- the subsequent influx of *Praeglobotruncana* cf. *stephani* (3062m) and *Hedbergella delrioensis* (3071m).

MICROPALAEONTOLOGY

The appearance of a questionable species of ?*Praeglobotruncana* cf. *stephani* at 3017m suggests that sediments of Turonian age are present. The influx of *P.* cf. *stephani* at 3062m confirms this age determination. The influx of *Hedbergella delrioensis* (3071m) is consistent with this age determination. The microfaunas of the *Praeglobotruncana* cf. *stephani* Assemblage from this interval are characteristically impoverished and poorly preserved.

PALYNOLOGY

Relatively diverse microplankton dominated assemblages were recovered from the sidewall core (3048m) and ditch cuttings samples from within this interval. The assemblages are characterised by common to abundant specimens of the *Spiniferites ramosus* group, *Palaeohystrichophora infusorioides* and *Surculosphaeridium longifurcatum*. The ditch cuttings, however, are subject to considerable modification by, predominantly, Palaeocene cavings.

The presence of *Pseudoceratium turneri* and *Litosphaeridium siphoniphorum* in the sidewall core at 3048m, which have ranges of Cenomanian - late Albian, is considered to have resulted from drilling mud contamination, in view of the micropalaeontological and other palynological evidence. The presence of *Hystrichosphaeridium difficile*, at 3048m(SWC) and in a ditch cuttings sample at 3050m, reflects the presence of sediments no older than Turonian in age.

INTERVAL 3074m(log)-3127.50m(log); LATE CRETACEOUS, CENOMANIAN

Lithostratigraphic Unit:

Chalk Group (part);

Hidra Formation.

Environment: marine, inner to outer shelf.

The top of this interval is based on the log break at 3074m which marks the top of the Hidra Formation.

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

- the appearance of *Litosphaeridium siphoniphorum* at and below 3074m.
- the more consistent occurrence of *Hedbergella delrioensis* from 3083m.
- the occurrence of *Eggerelina mariei* (3086m) and *Gavelinella cf. baltica* (3092m).

MICROPALAEONTOLOGY

The penetration of the Hidra Formation of Cenomanian age is indicated by the log break at 3074m. The *Rotalipora/Hedbergella - Hedbergella delrioensis/Gavelinella cf. baltica* Assemblage is recognised at and below 3086m with the appearance of abundant, well preserved specimens of *Hedbergella delrioensis* and the subsequent occurrence of *Gavelinella cf. baltica* (3092m). This assemblage is characteristic of sediments of the Cenomanian. The presence of *Eggerelina mariei* (3086m) is consistent with this age determination.

PALYNOLOGY

Microplankton dominated palynofloras were recovered from the ditch cuttings and sidewall core analysed from this interval. The assemblages are characterised by the presence of *Litosphaeridium siphoniphorum* and *Palaeohystrichophora infusorioides*, together with persistent *Spiniferites ramosus* group.

Impoverished palynofloras were encountered in the lower part of the interval from 3116m. The presence of *Litosphaeridium siphoniphorum* at and below 3074m indicates the penetration of sediments no younger than Cenomanian in age.

INTERVAL 3127.50m(log)-3131m; EARLY CRETACEOUS, ALBIAN

Lithostratigraphic Unit:

Cromer Knoll Group (part);

Rødby Formation.

Environment: marine, inner to outer shelf.

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

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

- the general nature of the microfaunas.

MICROPALAEONTOLOGY

At 3128m there is a slight increase in diversity of the microfaunas with some selective pink staining. This, and the increase in numbers of well preserved *Hedbergella delrioensis*, indicate that sediments of Albian age are present at this depth.

PALYNOLOGY

A single ditch cuttings sample was analysed from this interval, yielding an impoverished, non-age diagnostic palynoflora.

INTERVAL 3131m-3137m; EARLY CRETACEOUS, EARLY ALBIAN - APTIAN

Lithostratigraphic Unit:

Cromer Knoll Group (part);

Valhall Formation (part).

Environment: marine, inner to outer shelf.

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

- the influx of agglutinating foraminifera at 3131m.
- the appearance of abundant "Lingulogavelinella" gyroidiniformis and Hedbergella planispira at 3131m.

MICROPALAEONTOLOGY

At 3131m there is a significant change in the microfaunas with an increase in agglutinating foraminifera, particularly species of *Recurvoides* and *Glomospira gordialis*, associated with abundant "Lingulogavelinella" gyroidiniformis and *Hedbergella planispira*. This association, and that in the sample at 3134m, are representative of the *Recurvoides*/*Glomospira* Assemblage of early Albian - Aptian age. Although the abundance of *H. planispira* is a feature which characterises the base of the Albian, it is probably due to caving from the basal part of the overlying interval. The majority of the microfossils are characteristically red stained with some white stained forms.

PALYNOLOGY

A sparse, non-age diagnostic palynoflora was recovered from the ditch cuttings sample at 3134m.

INTERVAL 3137m-3140m; EARLY CRETACEOUS, EARLY APTIAN

Lithostratigraphic Unit:

Cromer Knoll Group (part);

Valhall Formation (part).

Environment: marine, inner to outer shelf.

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

- an influx of species of Hedbergella, including H. infracretacea at 3137m.

MICROPALAEONTOLOGY

The influx of red stained species of Hedbergella and particularly the presence of H. infracretacea at 3137m are characteristic of the Hedbergella infracretacea Assemblage. This assemblage indicates that sediments of early Aptian age have been penetrated.

INTERVAL 3140m-3176m(log); EARLY CRETACEOUS, BARREMIAN - HAUTERIVIAN

Lithostratigraphic Unit:

Cromer Knoll Group (part);

Valhall Formation (part).

Environment: shallow marine, inner shelf.

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

- the occurrence of the ostracod *Pontocyprella mandelstami* at 3140m.
- the increase in numbers of calcareous benthonic foraminifera (3140m).
- the appearance of *Uvigerinammina moesiana* (3143m).
- the subsequent appearance of *Gonyaulacysta kostromiensis*, in association with *Sirmiodinium grossii* and *Pseudoceratium pelliferum* in a ditch cuttings sample at 3170m.

MICROPALAEONTOLOGY

Microfaunal associations characteristic of the Calcareous Benthonics/Ostracods Assemblage of Barremian - Neocomian age are recognised at 3140m, and throughout the interval, with the incoming of ostracods and an increase in numbers of calcareous benthonic foraminifera, particularly species of *Lenticulina*. The occurrence of the ostracod *Pontocyprella mandelstami* (3140m) and *Uvigerinammina moesiana* (3143m) supports the Barremian - Hauterivian age for this interval.

PALYNOLOGY

Microplankton dominated palynofloras were recovered from the ditch cuttings samples from this interval. The sidewall core at 3141m is considered to be subject to drilling mud contamination, mainly from the Late Jurassic, while the sidewall core at 3170m contains a poor non-age diagnostic palynoflora.

The assemblages from the ditch cuttings are characterised by the occurrence of the *Spiniferites ramosus* group and common to abundant undifferentiated bisaccate pollen. Associations within the ditch cuttings at 3146m and 3158m indicate a general Early Cretaceous age. The ditch cuttings sample at 3170m, however, yielded a rich and diverse microplankton dominated assemblage with the appearance of common specimens of *Sirmiodinium grossii* and

Pseudoceratium pelliferum; the latter feature, on regional criteria, indicating a Hauterivian age. A Hauterivian age is confirmed by the simultaneous occurrence of *Gonyaulacysta kostromiensis*, a dinocyst considered to be stratigraphically restricted to deposits of Hauterivian age.

Reworking of Callovian to Ryazanian age is indicated by the presence of single specimens of *Gonyaulacysta jurassica* and *Gochteodinia villosa*.

V(4) CRETACEOUS - JURASSIC

INTERVAL 3176m(log)-3211m(log); EARLY CRETACEOUS - LATE JURASSIC, RYAZANIAN - VOLGIAN

Lithostratigraphic Unit:

Humber Group (part);

 Kimmeridge Clay Formation.

Environment: marine, inner shelf with anaerobic bottom conditions and possible water stratification.

The top of this interval is based on a log break at 3176m which marks the top of the Kimmeridge Clay Formation.

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

- the appearance of *Dingodinium spinosum*, in association with *Canningia* sp. A, in the sidewall core at 3179.30m.
- an influx of amorphous kerogen at 3179.30m(SWC).
- the subsequent appearance of a questionable specimen of *Oligosphaeridium pulcherrimum sensu Ioannides et al.* at 3206m.

PALYNOLOGY

Microplankton dominated assemblages were recovered from this interval. The assemblages are characterised by the presence of leiospheres and *Pterospermella* spp. The appearance of *Dingodinium spinosum*, in association with *Canningia* sp. A at 3179.30m(SWC) indicates the penetration of Ryazanian - late Volgian sediments. The subsequent occurrence of a questionable specimen of *Dichadogonyaulax pannea*, in a ditch cuttings sample at 3182m, may indicate the presence of sediments no younger than middle Volgian, whilst at 3206m a questionable specimen of *Oligosphaeridium pulcherrimum sensu Ioannides et al.* tentatively suggests the penetration of early Volgian sediments. Regional considerations suggest that this interval is probably at least as old as middle Volgian in age. The questionable specimen of *O. pulcherrimum sensu Ioannides et al.* tentatively suggests, if in situ, the presence of deposits no younger than early Volgian in age.

An influx of amorphous kerogen at 3179.30m(SWC) indicates the penetration of sediments attributable to the Kimmeridge Clay Formation, this evidence is further supported by information from wireline logs.

A hiatus may be present at the base of this interval, being reflected by a marked log break, resulting in the absence of some deposits of early Volgian and Kimmeridgian ages. Due to the paucity of age diagnostic taxa, however, no positive palynofloral evidence has been encountered.

V(5) JURASSIC

INTERVAL 321m(log)-322m; LATE JURASSIC, KIMMERIDGIAN? - OXFORDIAN

Lithostratigraphic Unit:

Humber Group (part);

Heather Formation (part).

Environment: marine, inner shelf with anaerobic/dysaerobic bottom conditions progressively established.

The top of this interval is defined on a log break.

The age of this interval is based on the following palynological evidence:

- the presence of *Scriniodinium luridum*, in association with *Gonyaulacysta jurassica* and common specimens of microforaminiferal test linings in a sidewall core at 3219m.
- a questionable specimen of *Scriniodinium crystallinum* at 3219m(SWC).

PALYNOLOGY

One ditch cuttings sample and a sidewall core were analysed from this interval. The ditch cuttings sample at 3218m yielded a relatively impoverished microplankton dominated assemblage which includes specimens of *Oligosphaeridium pulcherrimum* sensu Ioannides et al., this, if in situ, suggests an age no older than Kimmeridgian. No age diagnostic forms indicating the presence of older sediments were encountered at this level.

The sidewall core at 3219m yielded a relatively diverse, palynoflora. Miospores include common undifferentiated bisaccates and *Cerebropollenites mesozoicus*. The appearance of *Gonyaulacysta jurassica* and *Scriniodinium luridum*, in association with common microforaminiferal test linings, indicate the penetration of Kimmeridgian - Oxfordian sediments. A questionable specimen of *Scriniodinium crystallinum* may indicate the presence of sediments no younger than early Kimmeridgian in age, whilst the occurrence of a single specimen of *Glossodinium dimorphum* suggests an age no older than mid Oxfordian, Subzone (XIIB). Regional considerations suggest that the palynofloras recovered from

this interval may be no younger than Oxfordian in age, although on the evidence seen a Kimmeridgian age at the youngest cannot be excluded.

INTERVAL 3221m-3254m; LATE JURASSIC, EARLY? OXFORDIAN - MIDDLE CALLOVIAN

Lithostratigraphic Units:

Humber Group (part);

Heather Formation (part): 3221m-3225.50m(log),

Hugin Formation (part): 3225.50m(log)-3254m.

Environment: non marine, deltaic - marginal marine to inner shelf (in upper part).

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

- the appearance of *Adnatosphaeridium aemulum* at 3221m.
- the subsequent appearance of large specimens of *Verrucosisporites* spp. and *Kraeuselisporites "hyalinus"* at 3228.61m(core).
- the occurrence of *Dichadogonyaulax stauromatos* at 3233.22m(core).

PALYNOLOGY

This interval may be divided into two distinct units, the upper is characterised by predominantly marine assemblages. The appearance of several specimens of *Adnatosphaeridium aemulum* at 3221m suggests, on regional criteria, the presence of sediments of early Oxfordian age. Any positive evidence for the presence of early Oxfordian was not encountered, however. *Adnatosphaeridium aemulum* reaches its numerical acme in deposits of early Oxfordian age. The lower unit (below 3225.50m(log)) of the interval contains miospore dominated assemblages, characterised by undifferentiated bisaccates, *Deltoidospora* spp., *Cerebropollenites mesozoicus* and *Araucariacites australis*. The appearance of large *Verrucosisporites* spp. and *Kraeuselisporites "hyalinus"* in a core sample at 3228.61m indicates the penetration of Callovian sediments. The subsequent occurrence of *Dichadogonyaulax stauromatos* at 3233.22m(core) represents the penetration of sediments of late Callovian age, equivalent to the *Mendicodinium groenlandicum* Subzone (XIVC). At 3242m a questionable specimen of *Neoraistrickia gristhorpensis* indicates the presence of middle Callovian sediments.

The Oxfordian/Callovian boundary cannot be accurately located, however, regional knowledge suggests the possibility that this boundary may coincide with the Heather/Hugin formational boundary (at 3225.50m(log)).

INTERVAL 3254m-3274m(log); LATE JURASSIC, EARLY CALLOVIAN

Lithostratigraphic Unit:

Humber Group (part);

Hugin Formation (part).

Environment: marginal marine - non-marine, deltaic.

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

- the appearance of abundant *Nannoceratopsis pellucida* at 3254m.
- the subsequent occurrence of numerous *Valensiella* spp. in a sidewall core at 3261.30m.

PALYNOLOGY

Palynofloras recovered from this interval range from samples dominated by rich and diverse microplankton assemblages to those containing diverse miospore assemblages. The trend is for samples to reflect stronger terrestrial influences downhole.

The appearance of abundant *Nannoceratopsis pellucida*, which is a regional event marking the top of the early Callovian, occurs at 3254m. The subsequent occurrence of numerous *Valensiella* spp. is also associated with sediments of early Callovian age. The core piece at 3271.25m contains a rich and diverse microplankton assemblage which includes abundant *Deltoidospora* spp., common *Cerebropollenites mesozoicus* and common undifferentiated bisaccates.

Common to abundant *Pareodinia ceratophora*, together with numerous specimens of *Valensiella* spp., in a sidewall core at 3261.30m represent an early Callovian assemblage of marginal marine origin. This is an event of regional significance, which may be of correlative value.

A single specimen of *Nannoceratopsis gracilis* occurs at 3254m indicating the reworking of Middle - Early Jurassic sediments.

(V)6 TRIASSIC

INTERVAL 3274m(log)-3563m T.D.; TRIASSIC

Lithostratigraphic Unit:

"Triassic Group";

Skagerrak Formation.

Environment: terrestrial, lacustrine/fluviatile.

The upper limit of this interval is defined on a log break. The age is based on lithological criteria.

PALYNOLOGY

In view of the lithologies encountered within this interval and the fact that the core sample at 3285.28m was barren of palynomorphs, the assemblages recovered from the ditch cuttings are considered to result from caving.

GEOLOGICAL HISTORY

TRIASSIC

The oldest sediments examined are claystones which are considered to have been deposited in an arid, terrestrial, fluvio-lacustrine environment. The increasing amount of sand deposited, is possibly a result of the rejuvenation of source areas.

EARLY - MIDDLE JURASSIC

ABSENT; due to either non-deposition or deposition with subsequent erosion.

EARLY CALLOVIAN -
EARLY? OXFORDIAN

The early Callovian transgression is indicated by the resumption of sedimentation in a marginal marine environment. Interbedded coal seams, carbonaceous shales, shales and sandstones were deposited, probably in a deltaic or offshore bar complex environment close to a palaeoshoreline. A gradual increase in water depth to inner shelf conditions resulting from the regional early Oxfordian transgression led to the subsequent deposition of shales.

KIMMERIDGIAN? - OXFORDIAN
TO RYAZANIAN

The deposition of shales continued in an inner shelf environment. However, stratification of the water column resulted in the deposition of the Kimmeridge Clay Formation under anaerobic bottom conditions.

VALANGINIAN

ABSENT; sedimentation probably ceased during the regional Valanginian tectonic phase.

HAUTERIVIAN - ALBIAN

The Hauterivian transgression resulted in a shallow inner shelf environment being established, in which calcareous claystones and argillaceous limestones were laid down. Water depth increased, during the early Aptian transgression, to inner to outer shelf conditions in which deposition of shales continued to the Albian.

CENOMANIAN - CONIACIAN

Limestones accumulated in outer shelf seas with little terrigenous input. However, during the Turonian an influx of terrigenous material is indicated by the deposition of argillaceous limestones of the Plenus Marl Formation.

SANTONIAN - DANIAN

Not examined.

LATE PALAEOCENE -
EARLY OLIGOCENE

By the Late Palaeocene outer shelf to upper bathyal depths had been established due to basinal subsidence. Continual subsidence and deposition led to the accumulation of a thick sequence of shales of the Rogaland and Hordaland Groups. Tuffaceous shales were deposited at the end of the Palaeocene during tectonic events associated with North Atlantic rifting. During the Middle - Early? Eocene an influx of terrigenous material is indicated by sandstones of the Frigg Formation.

LATE OLIGOCENE -
PLEISTOCENE

There was an overall decrease in water depth throughout with a decrease in subsidence resulting in the gradual infilling of the North Sea Basin. Inner to outer shelf conditions prevailed in the Late Oligocene and Early Miocene, shallowing to the inner shelf seas of the Plio-Pleistocene. Predominantly argillaceous sediments were deposited, with shelly sands of the Utsira Formation being deposited during the Miocene. The increase in arenaceous material at the top of the Pleistocene is probably due to the incoming of sands of a glacial origin.

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APPENDIX 1

SIDEWALL CORE DESCRIPTIONS

Depth	Rec.	Qual.	Type of Analysis	Lithology
3048m	Frag.	Fair	M P	<u>ARGILLACEOUS LIMESTONE</u> : moderately soft, light grey to light olive grey, microcrystalline, glauconitic, micaceous.
3082.40m	Frag.	Fair	M P	<u>CALCAREOUS CLAYSTONE</u> : moderately hard to soft, slightly waxy, medium grey, with glauconite grains, silty, micaceous, calcareous.
3141m	Frag.	Poor	M P	<u>ARGILLACEOUS LIMESTONE</u> : hard, medium dark grey to dark grey, cryptocrystalline, slightly silty.
3170m	Frag.	Fair	M P	<u>CALCAREOUS CLAYSTONE</u> : moderately soft, light olive grey to light grey, slightly silty, strongly calcareous.
3179.30m	Frag.	Fair	M P	<u>SHALE</u> : soft to moderately soft and firm, subfissile, earthy, olive black, slightly silty and micromicaceous (very weakly calcareous).
3219m	Frag.	Fair	P	<u>SHALE</u> : as 3179.30m.
3239.30m	Frag.	Fair	P	<u>SANDSTONE</u> : friable, white to yellowish grey, very fine to fine grained, subangular, micaceous, silty (non-calcareous), grading to <u>ARGILLACEOUS SANDSTONE</u> : friable, pinkish grey to light brownish grey, very fine to fine grains, with mica and carbonaceous fragments, argillaceous. Also thin bands of <u>SANDY SHALE</u> : moderately soft, subfissile, slightly waxy, dusky yellowish brown, silty, sandy and micaceous.

3261.30m	15mm+	Fair	P	<u>SANDSTONE</u> : friable, pinkish grey with dark bands (light brownish grey), very fine grained, with mica, fine carbonaceous particles and argillaceous bands.
	Frag.			
3337m		Fair		<u>SHALE</u> : soft, subfissile, greenish grey, micaceous with very fine sand and rare fine, light brown quartz grains.
	Frag.			
3560m	18mm	Good		<u>CLAYSTONE</u> : soft, moderate reddish brown, micromicaceous.

KEY

M = Micropalaeontology

P = Palynology

Frag. = Fragments

Qual. = Quality

Rec. = Recovery

APPENDIX 2

CORE PIECE DESCRIPTIONS

Depth	Core No.	Type of Analysis	<u>Lithology</u>
3228.56m-3228.61m	1	P	<u>SILTY CLAYSTONE</u> : hard, dark grey to brownish black, micromicaceous, silty, non-calcareous.
3231.27m-3231.30m	1	P	<u>SILTY CLAYSTONE</u> : as 3228.56m-3228.61m, with thin, discontinuous lenses of <u>CLAYSTONE</u> : hard, brownish black, and <u>SANDSTONE</u> : hard, medium grey, very fine grained, argillaceous, micaceous, grading to <u>SILTSTONE</u> : (flaser bedding).
3233.15m-3233.22m	1	P	<u>SANDSTONE</u> : hard, yellowish grey, very fine grained micaceous, grading to <u>SILTSTONE</u> : as 3231.27m-3231.30m, with <u>SILTY CLAYSTONE</u> : and <u>CLAYSTONE</u> : as 3231.27m-3231.30m, but strongly bioturbated.
3267.56m-3267.61m	2	P	<u>CARBONACEOUS SHALE/COAL</u> : hard, subfissile, greyish black, highly carbonaceous shale, with lenses and rootlets of hard, vitreous, black coal.
3271.20m-3271.25m	2	P	<u>SILTSTONE</u> : hard, olive grey, micromicaceous, with black carbonaceous rootlets and fragments of plant debris.
3275.72m-3275.76m	2	P	<u>MICACEOUS SILTSTONE</u> : moderately soft, fissile, light grey, rare very fine sand, highly micaceous, bioturbated with burrow consisting of <u>MICACEOUS SANDSTONE</u> : moderately hard, very light grey, very fine grained, micaceous.

3285.23m-3285.28m

2

P

SANDSTONE: hard, light greenish grey, very fine grained (subangular to subrounded) with rare dark grains concentrated in laminae (probably heavy minerals), showing cross bedding.

KEY

P = Palynology

APPENDIX 3

RYAZANIAN-ALBIAN DINOCYST ZONATION

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

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

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

LITHOLOGIES

Clay		Calcareous dolomite	
Shale/mudstone		Dolomite	
Siltstone		Chalk	
Sand/sandstone, very fine to medium grained		Chert	
Sand/sandstone, coarse grained to granules		Anhydrite	
Conglomerate (with sand matrix)		Salt (halite)	
Conglomerate (without sand matrix)		Potassium salts	
Coal/lignite		Concretions/nodules	
Breccia		Igneous rocks, undifferentiated	
Limestone (undifferentiated)		Basement, undifferentiated	
Dolomitic limestone		Granite	

Qualifiers

Argillaceous	
Silty/sandy	
Pebbly	
Carbonaceous	
Calcareous	
Dolomitic	
Red sediments	

GRAIN TYPES

Oolith	
Fossils in general	
Bioclastic debris	
Mudflakes	

Other symbols

Sample gap		
Lost circulation material		lcm
Cement		cmt
Turbo drilling or diamond bit drilling (Samples unsuitable for good stratigraphic analysis)		.tu
Casing point		
Core		
Sidewall core		
Sidewall core (no recovery)		

Accessories

Calcite . . . . .	.C
Ironstone (ferruginous) . . . . .	.Fe
Glaucinite . . . . .	.Gl
Kaolinite . . . . .	.K
Phosphate . . . . .	.Ph
Pyrite . . . . .	.Py
Siderite/sphaerosiderite . . . . .	.S
Silica . . . . .	.Si

BIOSTRATIGRAPHIC SYMBOLS

Fossil Abundances	{	Present	○
		Common	●
		Abundant	■
Diagnostic forms		*	
Caved forms . . . . .		.C	
Reworked forms . . . . .		.R	
Incoming of			
Outgoing of			
Unconformity/stratigraphic hiatus			
Late . . . . .		.LT., lt.	
Middle . . . . .		.M., m.	
Early . . . . .		.EY., ey.	

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