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WELL 34/10–16

NORWEGIAN OFFSHORE

STRATIGRAPHICAL/PALEONTOLOGICAL FINAL REPORT.

Project No.

1108

Stratigraphers

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Date

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CONTENTS

1. INTRODUCTION

This report presents the results of the stratigraphical and paleontological study of samples from Well 34/10-16, drilled by Statoil in the North Sea (Norwegian Offshore) in 1983.

The information presented here is based on the analyses of ditch samples collected at 3m intervals between 1,848m and 4,042m. No ditch samples were available over the intervals 3,168m-3,466m and 3,811m-3,829m but core chips were available in these intervals and have been incorporated into this study.

A total of one hundred and fifty-one samples (comprising 123 ditch cuttings and 28 core samples) have been analysed for palynology from the interval 2,049m to 4,042m.

This report is accompanied by the Stratigraphic Logs (Enclosure 1 and 3) and the Palynostratigraphic Log (Enclosure 2).

2. SUMMARY

1. The highest sample examined in this study (1,848m-1,851m) is a tuffaceous claystone of basal Eocene/Late Paleocene age.

2. The section between 1,848m-1,929m comprises tuffaceous claystones of basal Eocene-Late Paleocene age representing the 'Ash Series' (Balder and Sele Formations).

3. The Late and Middle Paleocene claystones of the Lista Formation(1,929m-2,073m) were deposited in a marine, outer sublittoral to bathyal environment. Interbeds of fine to coarse sand, which are present in the lower part of this interval (below c.1,977m), are interpreted as deep water mass-gravity deposits. Tuffaceous claystones recorded between c.2,031m-2,050m represent the 'Thanetian' volcanic episode. The Middle Paleocene rests unconformably on the Late Cretaceous (Late Maastrichtian).

4. The Shetland Group (2,073m-2,979m) is represented by Late Maastrichtian marly claystones with beds of chalky limestone, deposited in an outer sublittoral-bathyal environment influenced by open oceanic circulation, overlying Maastrichtian, Campanian, Santonian and Coniacian claystones with a microfauna dominated by agglutinating foraminiferids, deposited in a restricted outer sublittoral to bathyal environment. Numerous stringers of sandstone and siltstone occur in the Campanian-Santonian section between c.2,450m-c.2,720m and are interpreted as emplaced by mass-gravity mechanisms.

5. The Coniacian claystones of the Shetland Group rest unconformably at 2,979m on Albian claystones of the Cromer Knoll Group. The Cromer Knoll Group is very thin in this well, comprising mid-Albian to Late Aptian claystones and limestones (2,979m-2,991m), deposited in an outer sublittoral to upper bathyal environment, resting unconformably on Middle Barremian to Valanginian calcareous claystones and limestones (2,991m-c.3,015m) deposited in a well-oxygenated sublittoral environment.

6. There is an unconformity between the Early Cretaceous and the Late Jurassic. Valanginian claystones and limestones of the Cromer Knoll Group rest unconformably on dark grey to black claystones of the Kimmeridge Clay Formation (c.3,015m-3,027m). This thin representative of the Kimmeridge Clay Formation is dated as Portlandian, and was deposited in a marine, poorly oxygenated, sublittoral environment.

7. An unconformity extists between the Kimmeridge Clay Formation and the underlying Callovian to ?Late Bathonian marine, sublittoral limestones and claystones of the Heather Formation (3,027m-c.3,165m).

8. The Heather Formation rests unconformably on a sequence of interbedded sands, sandstones, claystones and coals of the Brent Formation (c.3,165m-3,478m). These sediments were deposited in a transitional, marginal marine to continental deltaic, lagoonal environment. The Brent Formation ranges in age from Early Bathonian to Early Bajocian (=Aalenian).

9. The Brent Formation rests at 3,478m on claystones of the Dunlin Formation (Drake Member). A thick Dunlin Formation (3,478m-3,798m) is present in this well. However, because of the use of a diamond drilling bit most of the fossil evidence has been destroyed and few of the regional markers are recognised. Thus detailed biostratigraphic analysis has not been possible. The Dunlin Formation was deposited in a marine, sublittoral environment.

10. The Statfjord and Cormorant Formations (3,798m-4,042m) in this well comprise a dominantly sandy sequence, with red claystones occurring below 3,970m. Hettangian/Rhaetian miospores were recorded in the ditch cuttings at 3,868m but no age-restricted palynomorphs or microfaunal taxa are recorded below this depth. A prominent and regionally consistent sideritic claystone horizon occurs at 3,917m. As no

definite Rhaetian fossils were recovered, the boundary between the Statfjord and Cormorant Formations is placed at the downhole increase in red claystones at c.3,994m, following discussions with Statoil geologists. The Statfjord and Cormorant Formations were deposited in marginal marine to continental environments.

3. STRATIGRAPHICAL SUMMARY

Interval. F.S.E.			Age.	Thickness.
1,848m	-	1,929m	Basal Eocene-Late Paleocene	81m
1,929m	-	2,049m	Late Paleocene	120m
2,049m	-	2,073m	Middle Paleocene	24m
---------- UNCONFORMITY ----------				
2,073m	-	2,130m	Late Cretaceous: Late Maastrichtian	57m
2,130m	-	2,361m	Late Cretaceous: Maastrichtian	231m
2,361m	-	2,778m	Late Cretaceous: Campanian-Santonian	417m
2,778m	-	2,952m	Late Cretaceous: Santonian	174m
2,952m	-	2,979m	Late Cretaceous: Coniacian	27m
---------- UNCONFORMITY ----------				
2,979m	-	2,982m	Early Cretaceous: Albian	3m
2,982m	-	2,991m	Early Cretaceous: Early Albian-Late Aptian	9m
---------- UNCONFORMITY ----------				
2,991m	-	2,997m	Early Cretaceous: Middle-Early Barremian	6m
2,997m	-	3,008m	Early Cretaceous: Hauterivian	11m
3,008m	-c.	3,015m	Early Cretaceous: Valanginian	c.7m
---------- UNCONFORMITY ----------				
c.3,015m	-	3,024m	Late Jurassic: Portlandian	c.9m
3,024m	-	3,027m	Late Jurassic: basal Portlandian	3m
---------- UNCONFORMITY ----------				
3,027m	-	3,045m	Late Jurassic: Late-Middle Callovian	18m
3,045m	-c.	3,165m	Late-Middle Jurassic: Early Callovian-?Late Bathonian	c.120m
---------- UNCONFORMITY ----------				
c.3,165m	-	3,324.65m	Middle Jurassic: Early Bathonian	c.159.65m
3,324.65m	-	3,457.66m	Middle Jurassic: earliest Bathonian-Bajocian	133.01m
3,457.66m	-	3,478m	Middle Jurassic: Early Bajocian (=Aalenian)	20.34m

cont .....

Interval.			Age.	Thickness.
3,478m	-	3,553m	Middle-Early Jurassic: Early Bajocian (=Aalenian)-Toarcian	75m
3,553m	-	3,751m	Early Jurassic: Toarcian-Pliensbachian	198m
3,751m	-	3,798m	Early Jurassic: Early Pliensbachian	47m
3,798m	-	3,868m	Early Jurassic: Sinemurian-Hettangian	70m
3,868m	-	4,042m L.S.R.	Early Jurassic- Late Triassic; Hettangian- Rhaetian	174m

4. STRATIGRAPHY:

4.1 1,848m-2,073m BASAL EOCENE AND PALEOCENE

Lithostratigraphy

Rogaland Group:

Balder Formation

1,848m-c.1,903m Claystone, grey and brown, silty, with abundant tuffaceous debris, coarse-grained at some levels. Red claystone is also present, but is presumed to be caved from a red claystone level which occurs regionally just above the 'ash-series'. Some sand, very fine grained, subangular, is present at 1,870m-1,872m, but may also be caved.

Sele Formation

c.1,903m-c.1,929m Claystone, dark grey, silty, laminated (samples between 1,923m-1,929m contaminated by cement).

Lista Formation

c.1,929m-c.1,977m Claystone, light grey and grey-green, silty; occasional beds of limestone, light grey to buff, argillaceous, micritic.

c.1,977m-c.2,031m Claystone, as above, but generally siltier and rather poorly sorted; sand, fine to coarse grained, subangular; limestone, light grey to buff, micritic.

c.2031m-c.2,049m Claystone, grey, silty; abundant tuffaceous debris.

c.2,049m-2,073m Claystone, grey, silty; slightly calcareous; glauconite present consistently below 2,058m.

Biostratigraphy:

1,848m-1,929m basal Eocene-Late Paleocene

This interval which corresponds to the Balder and Sele Formations is characterised by the presence (below 1,887m) of pyritised and siliceous specimens of the diatom Coscinodiscus sp. 1, which are diagnostic of the basal Eocene-top Paleocene interval which usually corresponds to the 'Ash Marker' (Balder and Sele Formations). Other fossils comprise rare arenaceous foraminiferids which are probably caved from the overlying Eocene sequence, and the planktic foraminiferid Globigerina gr. linaperta, probably caved from a level immediately above the 'ash series'.

1,929m-2,049m Late Paleocene

The top of this interval is defined by the downhole appearance of a microfauna of abundant agglutinating foraminiferids, including Bathysiphon, Recurvoides, Glomospira charoides, Rhabdammina gr. discreta and the characteristic large Paleocene specimens of Bolivinopsis spectabilis. This assemblage persists through the interval, with only minor variations. The diagnostic Paleocene species Trochammina aff. albertensis is recorded at 2,027m.

This assemblage is diagnostic of the Late Paleocene.

2,049m-2,073m Middle Paleocene

Microfauna: At 2,049m, the downhole appearance of large reticulate spherical/ovoid radiolaria is a marker event which is widespread in the North Sea and defines the top of a Middle Paleocene interval. Reticulate radiolaria occur throughout this interval, associated with an assemblage of agglutinating foraminiferids very similar to those in the overlying

interval. Rare specimens of planktic foraminiferids (Globorotalia cf. chapmani/compressa) are recorded at 2,058m.

Microflora: The first sample examined, at 2,049m, contains: Alisocysta margarita (common), A. circumtabulata and Eisenackia crassitabulata. This association indicates the penetration of Late Paleocene or older sediments. Palaeoperidinium pyrophorum, which is found commonly in this sample and in the sample at 2,064m, and also Ceratiopsis striata, are taxa normally considered to indicate an Early Paleocene (Danian) or older age. These taxa may range slightly above the top of the Early Paleocene, but the possibility of reworking cannot be excluded.

Extensive reworking occurs within the interval, especially in the sample at 2,049m where reworked dinoflagellate cysts include the Late Cretaceous taxon Trithyrodinium suspectum and the Early Cretaceous to Jurassic forms Endoscrinium pharo and Pareodinia ceratophora. Reworked miospores include the long-ranging Cretaceous to Jurassic/Triassic species Callialasporites dampieri, Classopollis torosus (common at 2,049m), Cerebropollenites mesozoicus and Ischyosporites variegatus.

Environment:

The 'Ash Series' was deposited in a marine, sublittoral or bathyal environment of uncertain depth, with tuffaceous debris derived from contemporaneous volcanism.

The underlying Late and Middle Paleocene sequence was deposited in an outer sublittoral to bathyal environment. The sand interbeds below 2,034m were probably deposited by gravity-flow mechanisms.

Comments:

Early Paleocene foraminiferid assemblages are absent, indicating that there is an unconformity between the Middle Paleocene and Late Maastrichtian.

The tuffaceous claystone in the lower part of the Late Paleocene probably is a representive of the 'Thanetian' volcanic episode.

4.2 2,073m-2,979m LATE CRETACEOUS

Lithostratigraphy:

Shetland Group:

2,073m-c.2,450m Claystone, grey, calcareous; a few beds of limestone, light grey to white, chalky, near the top of the interval; passing down to less calcareous silty claystone, with thin beds of limestone, grey to buff, argillaceous. Pyrite is present throughout.

c.2,450m-c.2,585m Claystone, grey, very silty; with occasional stringers of siltstone and very fine sandstone; occasional beds of limestone, grey, micritic.

c.2,585m-c.2,720m Siltstone, grey; numerous stringers of sandstone, very fine grained, silty, calcareous.

c.2,720m-2,979m Claystone, grey, silty to very silty; occasional beds of siltstone in the upper part of the section. Thin stringers of limestone, grey, argillaceous, micritic.

Biostratigraphy:

2,073m-2,130m Late Maastrichtian

Microfauna: Abundant planktic and benthic foraminiferids are present throughout this interval. The top Maastrichtian is defined by the downhole appearance of abundant planktic foraminiferids, including Heterohelix spp., Pseudotextularia elegans, Racemiquembelina fructicosa, Globigerinelloides messinae and Globotruncana contusa. This assemblage is characteristic of the Late Maastrichtian.

Microflora: The downhole appearance of Spongodinium delitiense and Diconodinium firmum/arcticum at 2,079m indicates penetration of sediments of

Maastrichtian or older age. Trithyrodinium suspectum and Membranosphaera maastrichtia, which occur downhole at 2,094m and 2,109m respectively, also indicate penetration of Maastrichtian or older sediments.

The Jurassic to Triassic pollen Quadraeculina anellaeformis is found reworked at 2,124m.

2,130m-2,361m Maastrichtian

Microfauna: The top of this interval is defined by the downhole appearance of the calcareous benthic foraminiferid Reussella szajnochae. This is a regional marker event within the lower part of the Late Maastrichtian.

In the upper part of this interval, planktic and calcareous benthic foraminiferids are abundant, but they become less common downhole, and below about 2,250m, long-ranging agglutinating foraminiferids are dominant, including Pelosina sp., Rhabdammina sp., Bathysiphon sp. and Recurvoides sp.

The Maastrichtian planktic foraminiferid Abathomphalus intermedius is recorded between 2,286m-2,301m.

Microflora: Most of the taxa recorded higher up the well continue through this interval. Late Cretaceous palynomorphs of Maastrichtian and older age, which first appear downhole within this interval include the following; Aquilapollenites spp. (2,154m), Chatangiella spp. (2,169m), Odontochitina operculata (2,244m), Isabelidinium acuminatum (2,244m), Hexagonifera chlamydata (2,259m) and Spinidinium clavum (2,319m).

Reworked taxa occur frequently throughout this interval, including most of the taxa recorded in the overlying interval. Additional forms found reworked within this interval include the Jurassic and Triassic miospores Chasmatosporites spp. and Lycopodiacidites rugulatus.

2,361m-2,778m Campanian-Santonian

Microfauna: The top Campanian is defined by the downhole appearance of a limited suite of calcareous benthic foraminiferids, which includes Pseudogaudryinella capitosa (Tritaxia dubia), Reussella szajnochae (reappearance), and Dorothia truncata, associated with the planktic foraminiferid Globotruncana aff. arca. This fauna is regionally characteristic of the Late Campanian.

Below c.2,420m long-ranging agglutinating foraminiferids are dominant, and calcareous foraminiferids rare; from 2,550m scattered specimens of undiagnostic calcareous benthic foraminiferids occur, including Dentalina and Nodosaria.

In the sandy sequence between 2,585m-2,720m, and in the underlying claystones and siltstones down to 2,760m, microfossils are rare, and the microfauna is restricted essentially to scattered specimens of agglutinating foraminiferids, including Rhabdammina and Bathysiphon. Below c.2,760m, scattered calcareous benthic foraminiferids and planktic foraminiferids recur, including Globotruncana lapparenti (linneiana) gr. associated with fragments of the bivalve Inoceramus sp. From 2,772m Whiteinella baltica and Pseudogaudryinella capitosa occur. The assemblage in the interval below c.2,760m is more typical of the Santonian, although short-ranging species are not recorded.

Microflora: The assemblages from this interval are very similar to those in the overlying unit. The first downhole appearance of the association of the dinoflagellate cyst taxa Odontochitina costata and Palaeohystrichophora infusorioides, at 2,409m, indicates penetration of sediments of Campanian age. Other characteristic Late Cretaceous taxa which first appear downhole within this interval include Callaiosphaeridinium asymmetricum (2,364m), Chlamydophorella nyei (2,484m), Coronifera oceanica (2,512m), Dinogymnium cf. eucalaensis (2,544m), Xexascus ceratioides (2,574m) and Chatangiella niiga (2,619m).

2,778m-2,952m Santonian

Microfauna: The top definite Santonian is taken at the downhole appearance of lenticular reticulate radiolaria at 2,778m. This event, and the associated occurrence of calcareous benthic foraminiferids, planktic foraminiferids and common Inoceramus sp., are regionally characteristic of the Santonian. Characteristic benthic species in the interval 2,778m-2,880m include Pseudogaudrynella capitosa, Dorothia truncata and Eponides sp. Planktic foraminiferids comprise the long-ranging taxa Globotruncana gr. lapparenti and Whiteinella baltica.

Below 2,880m the diversity of the fauna decreases, and foraminiferids are presented mainly by rather poorly preserved agglutinants and long-ranging planktic foraminiferids. Globotruncana bulloides ('paraventricosa') is recorded from 2,841m.

Microflora: The assemblages from this interval are very similar to those higher up the well. Taxa which first appear downhole include Surculosphaeridium longifurcatum (2,859m), Cordosphaeridium truncigerum (2,919m) and Dorocysta litotes (2,919m). These palynomorphs are all characteristic of Late Cretaceous sequences.

2,952m-2,979m Coniacian

Microfauna: The downhole appearance of the planktic foraminiferid Marginotruncana marginata at 2,952m marks penetration of the Coniacian. The microfauna through this interval is poorly diversified, comprising long-ranging agglutinating foraminiferids, and at some levels frequent planktic foraminiferids which include consistent M. marginata, M. pseudolinneiana, Globotruncana bulloides and Whiteinella baltica.

The entire section is considered to be Coniacian in age, as no taxa restricted to Turonian or older sediments have been recorded.

Microflora: One sample at 2,964m was examined from this interval. All the age-diagnostic taxa continue through from the overlying intervals; though most are long-ranging Late Cretaceous (Maastrichtian to Late Turonian) forms, they are consistent with a Coniacian age at this depth.

Environment:

The Late Cretaceous was deposited in a marine, outer sublittoral to upper bathyal environment. The changing ratio of planktic to benthic foraminiferids through the section reflects the importance of oceanic water circulation. The dominance of agglutinating foraminiferids through much of the section indicates a restricted seafloor environment, and deposition probablybelow the carbonate compensation depth.

Comments:

Coniacian claystones rest unconformably on Albian claytones at 2,979m.

4.3 2,979m-c.3,015m EARLY CRETACEOUS

Lithostratigraphy:

Claystone, red and grey, calcareous; limestone, white, micritic (interpretation hindered by heavy caving).

Biostratigraphy:

2,979m-2,982m Albian

Microfauna: A faunal break at 2,979m is marked by the downhole appearance of abundant red-stained benthic foraminiferids. These include Recurvoides sp., Uvigerinammina bulimoides and Glomospira charoides. U. bulimoides (int. sp.) is a marker for the mid-Albian.

Microflora: No restricted Albian palynomorphs are present in the assemblage (2,979m) from this interval. The presence of Odontochitina costata and Palaeohystrichophora infusorioides, if in place and not caved, would indicate an age not older than Late Albian for this assemblage. However, as the lithologies are generally unfavourable for the preservation of palynomorphs, most of the taxa present are probably caved from higher up the well.

2,982m-2,991m Early Albian-Late Aptian

Microfauna: At 2,982m, the foraminiferids Pelosina spp., Gavelinella intermedia, Glomospirella gaultina and Verneuilinoides chapmani are recorded. The highest occurrence of V. chapmani is a marker for a level within the Early Albian; the interval from 2,982m-2,991m contains a microfaunal assemblage which ranges from Early Albian into the Late Aptian. There is no evidence for the existence of Early Aptian or Late Barremian sediments.

Microflora: No samples were examined from this interval.

2,991m-2,997m Middle-Early Barremian

Microfauna: At 2,991m the foraminiferids Gavelinella barremiana and Uvigerinammina sp. 1 are recorded. The co-occurrence of these species indicates a date within the Middle Barremian; G. barremiana ranges down to Middle Barremian, while U. sp. 1 ranges from Hauterivian to Middle Barremian. Associated foraminiferids include Marssonella kummi, Lenticulina guttata, and the ostracods Bairdia sp., Cytherella sp. and Pontocyprella sp., associated with abundant Inoceramus debris and echinoderm debris.

Microflora: No short-ranging Barremian taxa were recorded in the one assemblage at 2,994m, from this interval. As in the overlying Early Cretaceous intervals the lithology here is unfavourable for the preservation of palynomorphs; accordingly the taxa present in this assemblage are probably caved from higher in the well. Odontochitina operculata, if not caved, would suggest an age not older than Barremian at 2,994m, even though O.operculata has been recorded rarely from the latest Hauterivian.

2,997m-3,008m Hauterivian

Microfauna: The penetration of a Hauterivian section is indicated at 2,997m by the presence of Lagena hauteriviana and Lenticulina nodosa, associated with abundant Uvigerinammina moesiana.

Other foraminiferids occurring in this interval include Paalzowella sp. and Vidalina carpathica. These are typical of the carbonate-rich facies of the Early Cretaceous.

Microflora: No sample examined from this interval.

3,008m-c.3,015m Valanginian

Microfauna: The occurrence of the foraminiferid Trocholina sp. in this interval probably indicates the penetration of Valanginian. Other fossils present are long-ranging foraminiferids.

Microflora: One sample at 3,009m was examined from this interval. No in-situ age diagnostic taxa are present. Gardodinium trabeculosum, which does not range below the Hauterivian, is considered to be caved from higher up the well.

Environment:

2,979m-2,991m Marine, outer sublittoral to bathyal, restricted circulation.

2,991m-c.3,015m Marine, sublittoral.

Comments:

At c.3,015m Valanginian sediments of the Cromer Knoll Group age rest unconformably on the Kimmeridge Clay Formation, dated as Portlandian in age.

4.4 c.3,015m-3,027m LATE JURASSIC

Lithostratigraphy:

Kimmeridge Clay Formation

c.3,015m-3,027m Claystone, dark grey-black, 'bituminous', pyritic. Samples dominated by caving.

Biostratigraphy:

c.3,015m-3,024m Portlandian

Microfauna: The only inplace fauna is occasional fish debris. The samples contain abundant caved fossils.

Microflora: One sample at 3,018m was examined from this interval. The presence of Pterospermella aureolata and Pterospermopsis spp. combined with common amorphous sapropel is taken to indicate penetration of the Kimmeridge Clay Formation, which is regionally dated as Ryazanian to Kimmeridgian. The presence of Gochteodinia villosa, a Ryazanian to late Early Portlandian taxon, at 3,024m where it is presumed to be caved indicates that this interval is not older than Early Portlandian. As there is no indication of a disconformity in the Kimmeridgian Clay Formation and as there are only c.9m of sediments resting on basal Portlandian, it is considered that this interval is Portlandian in age.

3,024m-3,027m basal Portlandian

Microfauna: The co-occurrence of the radiolaria Lithostrobus sp. and Dictyomitra sp. within the Kimmeridge Clay Formation in the North Sea is characteristic of the Portlandian.

Microflora: The downhole appearance of Pareodinia mutabilis at 3,024m is taken to indicate penetration of sediments of basal Portlandian age. P. mutabilis ranges in age from basal Portlandian to Late Kimmeridgian.

Environment:

Marine, sublittoral, poorly oxygenated.

4.5 3,027m-c.3,165m LATE-MIDDLE JURASSIC

Lithostratigraphy:

Heather Formation

3,027m-3,036m Limestone, light brown; claystone, medium grey, micromicaceous, pyritic; trace sandstone, fine grained, angular.

3,036m-3,135m Claystone, medium grey to dark brown, often micromicaceous, pyritic, very fine organic fragments especially below 3,051m. Samples heavily contaminated by caving, especially below c.3,080m.

3,135m-3,165m As above, together with limestone, brown micrite, with very fine organic debris and at 3,165m some sand, fine grained, subangular.

Biostratigraphy:

3,027m-3,045m Late-Middle Callovian

Microfauna: The interval is characterised by the downhole appearance of Haplophragmoides sp. AH1 which ranges from the Middle Oxfordian to Callovian in the northern North Sea. The agglutinating foraminiferid Recurvoides cf. sublustris occurs at 3,030m; this taxon tops in the Late Callovian in this area.

Microflora: No short-ranging taxa are recorded from this interval. However, the presence of Gonyaulacysta scarburghensis, a Middle Oxfordian to Late Callovian taxon, at 3,048m where it is presumed to be caved, indicates that part of this interval is not older than Late Callovian in age.

3,045m-c.3,165m Early Callovian-?Late Bathonian

Microfauna: The top of this interval is taken at the downhole appearance of the ostracod 'Procytheridea cf. pseudocrassa' which regionally occurs in the Early Callovian.

Agglutinating foraminiferids are present throughout the interval and their occurrence may be of local significance in correlation.

Microflora: The assemblages from this interval are dominated by long-ranging Mesozoic miospores with subordinate Late to Middle Jurassic dinoflagellate cysts.

Mendicodinium groenlandicum is present to 3,054m; if in place, this indicates an age not older than latest Bathonian. Chytroeisphaeridia sp. 1 Davey occurs downhole between 3,051m and 3,066m, and if in place, indicates an age not older than Early Callovian. The dinoflagellate cyst Pareodinia evittii first appears downhole at 3,063m. This taxon is most characteristic of the Early Callovian to Bathonian.

None of the regional Early Callovian and Bathonian abundance marker levels were recognised in this well, possibly due to the poor sample quality.

Environment:

Marine, sublittoral, low energy, moderately well oxygenated.

Comments:

The absence of fossils of definite Bathonian age may be due to heavy caving through the lower part of the interval. An unconformity probably exists between the Heather and Brent Formations.

4.6 c.3,165m-3,478m MIDDLE JURASSIC.

Lithostratigraphy:

Brent Formation

Samples available from this interval comprise ditch cuttings between 3,165m-3,168m and 3,466m-3,478m; together with 34 core chips selected for analysis by Statoil geologists. Lithological descriptions of the core chips are given in Appendix 1.

The ditch cuttings comprise:

3,165m-3,168m Sand, fine to medium grained, occasionally coarse grained, angular-subrounded.

3,466m-3,478m Claystone and siltstone, dark grey, micromicaceous with organic debris; sandstone, white, very fine grained, angular; trace gravel at 3,472m.

The limits of the members within the Brent Formation (Enclosure 3) are based on petrophysical logs supplied by Statoil. Paleoservices Ltd. stratigraphers did not examine the complete cores.

The Members identified are:

3,165m-3,170m ?Tarbert/Ness Member
3,170m-3,398m Ness Member
3,398m-3,412m Etive Member
3,412m-3,478m Rannoch and ?Broom Members

Biostratigraphy:

c.3,165m-3,324m Early Bathonian

Microfauna: No microfauna is recorded from the ditch cuttings or core samples.

Microflora: The first sample examined from this interval, the core chip at 3,170.05m, contains numerous miospores including abundant Cyathidites spp., bisaccate pollen, Lycopodiumsporites spp. and Perinopollenites elatoides and common Cerebropollenites mesozoicus. This association of taxa is characteristic of the upper part of the Ness Member, which is regionally dated as Early Bathonian in age.

The remainder of the assemblages from this interval are very similar in composition with a slight marine influence indicated, at 3,227.30m, by the presence of rare microplankton (acritarchs).

3,324.65m-3,457.66m earliest Bathonian-Bajocian

Microfauna: No in place microfauna.

Microflora: The top of this interval is taken at the first downhole occurrence of Nannoceratopsis gracilis in the core chip at 3,324.65m. The presence of the dinoflagellate N. gracilis indicates an age not younger than earliest Bathonian. The assemblages between 3,324.65m and 3,393.62m are similar to those in the overlying interval. Below 3,393.62m three samples were examined for palynology; these contain a very impoverished assemblage which is regionally characteristic of samples from the lower part of the Brent Formation (Etive and Rannoch Members).

Comment:

As the palynological analyses over the Ness Member are restricted to selected core chips, the downhole appearance of Nannoceratopsis gracilis at 3,324.65m may not be its true top, which could be higher.

3,457.66m-3,478m Early Bajocian (=Aalenian)

Microfauna: No 'in-place' microfauna.

Microflora: Nannoceratopsis gracilis occurs commonly in the core chip at 3,457.66m. The downhole appearance of common N. gracilis is a palynological marker event which is regionally dated as Early Bajocian (=Aalenian).

Environment:

Transitional (marine-continental), marginal marine nearshore, and/or fluvial sands with deltaic, lagoonal clays and coals.

4.7 3,478m-3,798m MIDDLE-EARLY JURASSIC

Lithostratigraphy:

Dunlin Formation

Drake Member

3,478m-3,553m (top based on samples) Claystone and occasional siltstone, grey, micromicaceous; trace dolomite, brown. Chamosite pseudoolites are present at 3,478m.

Cook-Burton Members

3,553m-3,583m (top based on samples) Sand/sandstone fine to medium grained, angular-subangular, occasionally pyritic with pyrite coated sand grains at 3,517m; trace claystone, grey.

3,583m-3,625m Extremely poor samples, comprising drilling artifact only due to use of diamond bit.

Amundsen Member

3,625m-3,793m (top based on logs due to poor samples) Extremely poor samples. Drilling artifact only due to use of diamond bit.

3,793m-3,798m Sand/sandstone, fine-medium grained, angular to subangular; claystone, grey, possibly caved.

Biostratigraphy:

3,478m-3,553m Early Bajocian (=Aalenian)-Toarcian

Microfauna: The downhole appearance of agglutinating foraminiferids is regionally characteristic of the Drake Member. The presence of the foraminiferids Nodosaria regularis and Haplophragmoides kingakensis and the ostracod Camptocythere foveolata gr. suggests that the upper part of the interval is Early Bajocian (=Aalenian) in age.

Microflora: The distinctive dinoflagellate cyst Parvocysta nasuta first appears downhole at 3,511m. This taxon indicates an age within the range Early Bajocian (=Aalenian) to Late Toarcian. Calliala-sporites dampieri is present in the sample at 3,511m-3,514m and also indicates an age not older than Late Toarcian.

3,553m-3,751m Toarcian-Pliensbachian

Microfauna: The age of this interval is inferred by the dated sequences above and below; no microfauna was recorded because of the use of a diamond drilling bit.

Microflora: No short-ranging taxa are present in the assemblages from this interval. The samples generally contain sparse assemblages of palynomorphs dominated by long-ranging Mesozoic miospores with rare microplankton. Nannoceratopsis gracilis, which occurs in the ditch samples down to 3,724m, indicates an age not older than Late Pliensbachian (if in place and not caved). However, because of the use of a diamond bit all the taxa present may be the result of caving from the overlying intervals.

Comment:

No regionally diagnostic Early Toarcian microfaunal or microfloral markers were recognised in this well, which could suggest a possible unconformity somewhere within the top of this interval and the base of the overlying interval. However, this may be due to the sample quality.

3,751m-3,798m Early Pliensbachian

Microfauna: The interval is dated by the presence of a single ostracod (Ogmoconcha amalthei gr.) at 3,751m. This is typical of the Early Pliensbachian in this area.

Microflora: No short-ranging palynomorphs are present in this interval. All the taxa continue through from higher up the well.

Environment:

3,478m-3,553m Marine, inner sublittoral, low energy.

3,553m-3,798m Marine, inner sublittoral to possibly littoral in part.

Comments:

Dating through much of this interval is less precise than in the Dunlin elsewhere in this area because of the extremely poor samples.

4.8 3,798m-4,042m L.S.R. EARLY JURASSIC-LATE TRIASSIC

Lithostratigraphy:

Statfjord-Cormorant Formations

See Appendix 1 for lithological descriptions of core samples between 3,812.10m and 3,825.56m.

Ditch cuttings:

Sample quality extremely poor through this interval.

3,798m-3,811m Sand/sandstone, fine to medium grained, angular to subangular, and possibly caved claystones, grey, and coal, black.

3,811m-3,829m No ditch samples.

3,829m-3,937m Sand/sandstone, fine to medium grained, angular to subangular and occasional claystone and siltstone, grey with coaly debris.

3,937m-3,943m Claystone, brown grey, slickensided, sometimes sandy and sideritic; sand and grey claystone as above.

3,943m-3,970m Sand, fine to coarse, angular to subangular, poorly sorted; with claystone, grey-brown, especially at 3,964m.

3,970m-3,988m Sand, as above; with trace claystone, red/purple, mottled, grey-brown and pale grey, occasionally sandy and micaceous.

3,988m-4,042m L.S.R. Dominantly drilling artifact due to use of diamond drilling bit. Probably sands and clays as above, more red claystone at 3,994m. Dominantly red drilling artifact at 4,024m.

Biostratigraphy:

3,798m-3,868m Sinemurian-Hettangian

Microfauna: No in place microfauna.

Microflora: This interval is poorly defined palynologically and is dated by its stratigraphic position between better dated sections. Most of the taxa present were recorded in the overlying intervals. The core chips between 3,812.10m and 3,825.56m generally contain rare, long-ranging miospores except for Cerebropollenites mesozoicus in the sample at 3,825.39m which indicates an age not older than Hettangian.

Comments:

Dating of this interval based on the dated sequences above and below. A Sinemurian age for the top of the Statfjord Formation is based on regional evidence.

3,868m-4042m L.S.R. Hettangian-Rhaetian

Microfauna: No in place microfauna.

Microflora: The first downhole in-situ occurrence of Taeniaesporites rhaeticus is at 3,868m. T. rhaeticus is characteristically a Rhaetian taxon, but does occasionally occur within the Hettangian and even more rarely in the Sinemurian.

The presence of T. rhaeticus in the two samples at 3,868m and 3,898m combined with the absence of definite Rhaetian taxa is considered sufficient evidence to indicate penetration of sediments of Hettangian or older age at 3,868m.

Kraeuselisporites reissingeri appears downhole at 3,868m;this taxon is most characteristic of sediments of Hettangian and Rhaetian age but it has a total stratigraphic range of Early Sinemurian to Rhaetian.

The samples from this interval have moderately diverse assemblages of possible in-situ palynomorphs, but as the samples are generally heavily contaminated by caving many (if not most) of these records may be the result of caving.

There is no palynological evidence in this well to confirm the penetration of sediments older than Hettangian in age.

Environment:

3,798m-3,937m Marine to transitional; high energy sand deposition with claystone and coal debris deposited in a nearshore and/or fluvial environment.

3,937m-4,042m Continental; high energy fluvial deposition of sand and lower energy deposition of overbank claystones.

The level with abundant sphaerosiderite at 3,937m is a regionally consistent correlatable event, although it is probably diachronous.

Comments:

Dating of the lower part of this interval is imprecise because of the poor quality of the samples. Regionally a Rhaetian age can be assigned to the lowest part of the Statfjord and the upper part of the Cormorant Formations. The top of the Cormorant Formation may be at the increase in red claystones at c.3,994m.

REFERENCES

FISHER, M.J. and DUNAY, R.E. 1981. Palynology and the Triassic/Jurassic boundary. Rev. Palaeobot. Palynol., 34:129-135.

APPENDIX 1

Lithological description of core chips received

P = Palynological analyses

M = Micropaleontological analyses

DEPTH	CORE	ANAL.	LITHOLOGY
3,170.05-.10m	1	P M	Claystone, dark grey, shaly with thin laminae of siltstone.
3,175.20-.25m	1	P	Siltstone, grey, micaceous. Several argillaceous laminae of silt; lens of fine sand cemented by pyrite.
3,177.57-.62m	2	P M	Claystone, very silty, grey, lenses of very fine sand cemented by pyrite.
3,198.63-.67m	3	P	Coal, black, with woody debris.
3,207.45-.51m	3	P	Sandstone, very fine, well sorted, partly calcite-cemented (nodular).
3,218.21-.26m	4	P	Coal, black, woody, interbedded with siltstone, very micaceous.
3,221.53-.59m	4	P	Siltstone, grey, micaceous, cross-laminated, with vertical burrows. Lignitic debris.
3,227.70-.75m	4	P	Siltstone, grey, micaceous, with partings and lenses of clay, some vertical burrows (?roots).

3,227.30-.31m	5	P M	Claystone, grey, silty, with lenses, flasers and partings of silt.
3,253.30-.36m	6	P M	Claystone, grey, conchoidal fracture, woody debris, silt laminae. Root traces, micaceous.
3,242.00-.07m	5	P M	Claystone, black, highly sapropelic, partially conchoidal, fracture and pyrite.
3,260.12-.18m	6	P M	Claystone, grey, silty, micromicaceous, irregular partings and lenses of silt.
3,263.08-.15m	7	P	Coal, black, woody, interbedded debris with siltstone, cross-laminated, very micaceous.
3,277.96-3,278.01m	7	P M	Claystone, grey, tough, conchoidal fracture, pyrite.
3,295.30-.36m	8	P M	Claystone, grey-brown, waxy fracture, lignitic debris, slickensided.
3,300.58-.63m	9	P M	Claystone, light grey, numerous thin laminaeof silt, micaceous; occasional organic debris.

3,305.90-.97m	9	P M	Claystone, light grey, very silty, unbedded, small ?sideritic nodules and plant debris, micromicaceous.
3,315.55-.60m	10	P M	Claystone, grey, silty, interbedded with silt, cross laminated, fine organic debris, micaceous.
3,324.65-.70m	11	P M	Claystone, grey, silty; numerous lenses and partings of silt.
3,333.18-.23m	11	P	Sandstone, very fine, laminated with siltstone, cross-laminated micromicaceous.
3,334.81-.86m	11	P	Coal, black, woody, with ferns, soft.
3,345.80-.84m	12	P	Sandstone, very fine to siltstone, well-sorted, argillaceous laminae with large plant fragments. Finely laminated, highly micaceous, cross laminated.
3,350.54-.59m	13	P M	Claystone, light grey-brown, silty, with roots, very fine mica.
3,362.18-.22m	14	P	Interbedded sandstone, very fine and siltstone with lignitic debris.

3,366.36-.40m	15	P	Siltstone, light grey-brown, conchoidal fracture and claystone, micromicaceous, occasional plant debris.
3,370.98-3,371.02m	16	P M	Claystone, dark grey-brown, shaly, plant debris.
3,375.50-.56m	16	P M	Claystone, grey, conchoidal fracture, woody debris.
3,382.30-.34m	17	P M	Claystone, light grey, shaly, some plant debris.
3,393.56-.62m	18	P M	Claystone, light grey, shaly, occasionally very fine mica.
3,410.10-.14m	19	P	Sandstone, very fine, well sorted, very micaceous, laminae.
3,423.00-.05m	20	P	Sandstone, very fine, well sorted, clean, light brown, some white matrix.
3,440.18-.22m	21	P	Sandstone, very fine, well sorted, micaceous, laminae.
3,457.66-.70m	22	P	Sandstone, very fine to argillaceous siltstone interbedded with claystone, very micaceous, shaly laminae.

3,465.71-.75m	22	P	Siltstone, micaceous, cross-laminated and dark grey, very micaceous claystone.
3,812.10-.15m	23	P	Sandstone, very fine with coaly laminae and white matrix.
3,816.14-.20m	23	P	Sandstone, laminated, white, fine-medium, mica and pyritic with black coaly sandstone.
3,817.57-.61m	23	P	Sandstone, as above.
3,822.30-.34m	23	P	Sandstone, very fine, with coaly laminae.
3,825.39-.44m	23	P	Laminated sandstone, fine, white, micaceous flasered coal.
3,825.50-.56m	23	P	Sandstone, fine occasional medium, slightly calcareous, micaceous, with laminae of pyrite and coal.

SEDIMENTARY HISTORY©

CLIENT: STATOIL

WELL NO: 34/10-16
NORWEGIAN OFFSHORE

FIGURE: 1

DATE: JUNE 1983

PROJECT NO: 1108

ANALYST: R.W.M. J.B.K. C.K.

PALEOSERVICES
Unit 15, Paramount Industrial Estate,
Sandown Road,
Watford, WD2 4UR, England

KEY:

- Missing section
- Volcanics
- Open marine circulation
- Transgressive Unit
- Restricted circulation
- Regressive Unit
- Mainly coarse clastics (sand)
- Mainly fine clastics (silt, clay)
- Carbonates
- Evaporites

AGE M.Y

RELATIVE CHANGES OF SEA LEVEL* (Rise ← 0.5 → Fall)

SERIES / STAGE

PALEO MARKERS: MICROFLORAL | MICROFAUNAL

ENVIRONMENT: CONTINENTAL | TRANSITIONAL | MARINE (SUBLITTORAL: INNER, OUTER | BATHYAL: UPPER, LOWER)

WELL DEPTH (METRES)

AGE M.Y	SERIES	STAGE
0	PLEISTOCENE	
2	PLIOCENE	
5	MIOCENE	LATE
10		MIDDLE
15		EARLY
20		
25	OLIGOCENE	LATE
30		EARLY
35		
40	EOCENE	LATE
45		MIDDLE
50		EARLY
55	PALEOCENE	
60		
65	MAASTRICHTIAN	
70	CAMPANIAN	
75		
80	SANTONIAN	
85	CONIACIAN	
90	TURONIAN	
95	CENOMANIAN	
100	ALBIAN	
105		
110	APTIAN	
115	BARREMIAN	
120	HAUTERIVIAN	
125	VALANGINIAN	
130	BERRIASIAN / RYAZAN	
135	PORTLANDIAN	
140	KIMMERIDGIAN	
145	OXFORDIAN	
150	CALLOVIAN	
155		
160	BATHONIAN	
165	BAJOCIAN	
170	AALENIAN	
175	TOARCIAN	
180	PLIENSBACHIAN	
185	SINEMURIAN	
190	HETTANGIAN	
195	RHAETIAN	
200	NORIAN	

Present sea level

Coscinodiscus sp.1

Reussella szajnochae
P. elegans
Radiolaria
Bolivinopsis spectabilis

Marginotruncana marginata
Radiolaria
P. capitosa

Recurvoides sp.
Uvigerinammina bulimoides

V. chapmani

U. sp.1

Trocholina sp.1

Paeodinia mutabilis
Pterospermella aureolata
common sapropel

Lithostrobus sp.
Dictyomitra sp.

Recurvoides cf. sublustris
Procytheridea cf. pseudocrassa

N. gracilis (common)
Nannoceratopsis gracilis
Cyathidites spp. (abundant)

Taeniaesporites rhaeticus
Parvocysta nasuta

Camptocythere foveolata gr.

SECTION ABOVE 1848m NOT STUDIED

1848
1929
SANDS EMPLACED BY GRAVITY FLOW
2073
2 - 3 m.y. ±
2073
2361
SAND EMPLACED BY GRAVITY FLOW
2778
2952
2979
15 - 20 m.y. ±
2979
5 m.y. ±
2991
2991
CROMER KNOLL
2997
3008
c.3015
5 - 8 m.y. ±
c.3015
KIMMERIDGE CLAY
3027
10 - 12 m.y. ±
3027
HEATHER
c.3165
3 - 5 m.y. ±
c.3165
NESS
BRENT
3478
DRAKE
COOK
DUNLIN
3498
STATFJORD
CORMORANT
L.S.R.
4042

(Turbo drilled)

STATOIL	ANALYSTS: C.K. J.B.K. R.W.M.	PROJECT No: 1108	DATE: JUNE '83	ENCLOSURE No: 2

WELL 34/10-16

MIDDLE PALEOCENE - VALANGINIAN

Norwegian offshore

PALYNOSTRATIGRAPHIC LOG

SCALE 1:500

PREPARED BY
PALEOSERVICES
UNIT 15, SANDOWN ROAD, WATFORD WD2 4UB ENGLAND.

LEGEND

CLAY/CLAYSTONE
F M C SANDSTONE
LIMESTONE
SHALE
CONGLOMERATE
CHALK
MARL CALCAREOUS SHALE
VOLCANICS LAVAS/TUFFS
DOLOMITE
SILTSTONE/SILT
UNDIFFERENTIATED BASEMENT
SALT
F M C SAND
NO SAMPLES
ANHYDRITE/GYPSUM
MEGAFOSSILS
G GLAUCONITE
MICA
CHERT
S SIDERITE
CORES
PYRITE
LIGNITE/COAL
SIDEWALL CORES
PS POOR SAMPLES

Boundary
Unconformity
T.D. (Total depth)
Partial or interrupted sequence
F.S.R. First sample received
L.S.R. Last sample received

FOSSILS AND ACCESSORY MINERALS
Abundant
Common
Rare
Abundant
Common
Rare
FOSSILS IN SIDEWALL CORES
PETROGRAPHICAL ANALYSIS

Depth	Lithology	Cores/Side-wall cores	Kerogen	Palynological analyses	Microplankton	Spores and Pollen	Depths	Significant floral events	Significant lithological horizons	Environment	Formation	Group	Age

METRES

SEE ENCLOSURE 3 PORTLANDIAN – RHAETIAN
N.B. Valanginian sediments rest unconformably on Portlandian at c.3015.

STATOIL	ANALYSTS R.W.M. J.B.K	PROJECT No 1108	DATE JUNE '83	ENCLOSURE No 3

WELL 34/10-16

JURASSIC-TRIASSIC

Norwegian offshore

STRATIGRAPHIC LOG

SCALE 1:500

(Metric)

PREPARED BY
PALEOSERVICES
UNIT 15, SANDOWN ROAD, WATFORD WD2 4UB ENGLAND.

LEGEND

CLAY/CLAYSTONE — SANDSTONE (F M C) — LIMESTONE
SHALE — CONGLOMERATE — CHALK
MARL-CALCAREOUS SHALE — VOLCANICS LAVAS/TUFFS — DOLOMITE
SILTSTONE/SILT — UNDIFFERENTIATED BASEMENT — SALT
SAND (F M C) — NO SAMPLES — ANHYDRITE/GYPSUM
MEGAFOSSILS — GLAUCONITE (G) — MICA
CHERT — SIDERITE (S) — CORES
PYRITE — LIGNITE/COAL — SIDEWALL CORES
P.S. POOR SAMPLES

Boundary
Unconformity
T.D. (Total depth)
Partial or interrupted sequence
F.S.R. First sample received
L.S.R. Last sample received

FOSSILS AND ACCESSORY MINERALS
Abundant
Common
Rare

Abundant / Common / Rare — FOSSILS IN SIDEWALL CORES

PETROGRAPHICAL ANALYSIS