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NORWEGIAN PETROLEUM DIRECTORATE

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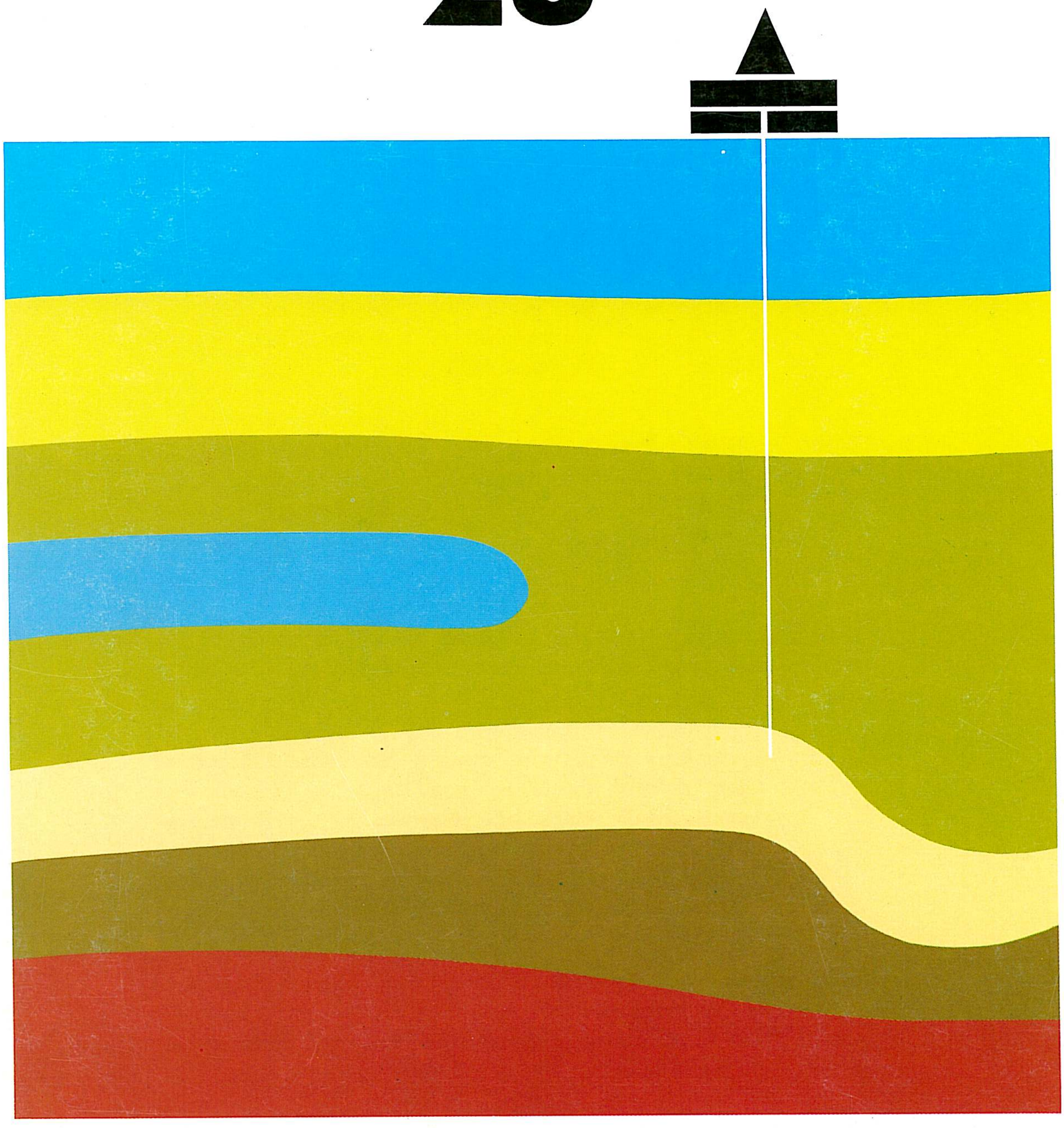

The Balder Area

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— maintain contact with scientific institutions and provide that material should be made available for companies and scientific institutions concerned to the extent possible pursuant to the regulation concerning confidential treatment of material forwarded by the licensees and in accordance with the decisions of the Ministry.

This is a part of the responsibility of the Resource Management Department in the Directorate and the present publication series is meant to partially fulfill this object. It is named NPD Papers and issued as consecutively numbered volumes.

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Preface

The Norwegian Petroleum Directorate has, among its duties, the responsibility for publication of releasable data connected to petroleum activities on The Norwegian Continental Shelf.
In this connection it has been decided to make a standardized description of drill bit cuttings as well as cores.
The sample descriptions are based on the «Standard Legend — Exploration and Production Department of the Royal Dutch/Shell group of companies». The Directorate much appreciates the Royal Dutch/Shell companies and A/S Norske Shell Exploration and Production's permission to use their legend.

The samples and the wire line logs from the herein described well are released to scientific institutions, companies and other interested organizations for futher studies. The material pertinent to the well can be examined in the Directorate. For practical reasons an application must be made in each case.
The application should state what material is to be examined, what kind of examination will be made, and the purpose of the studies. It should be addressed to:

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THE BLOCK SYSTEM FOR CONCESSIONS ON THE NORWEGIAN CONTINENTAL SHELF SOUTH OF 62°N

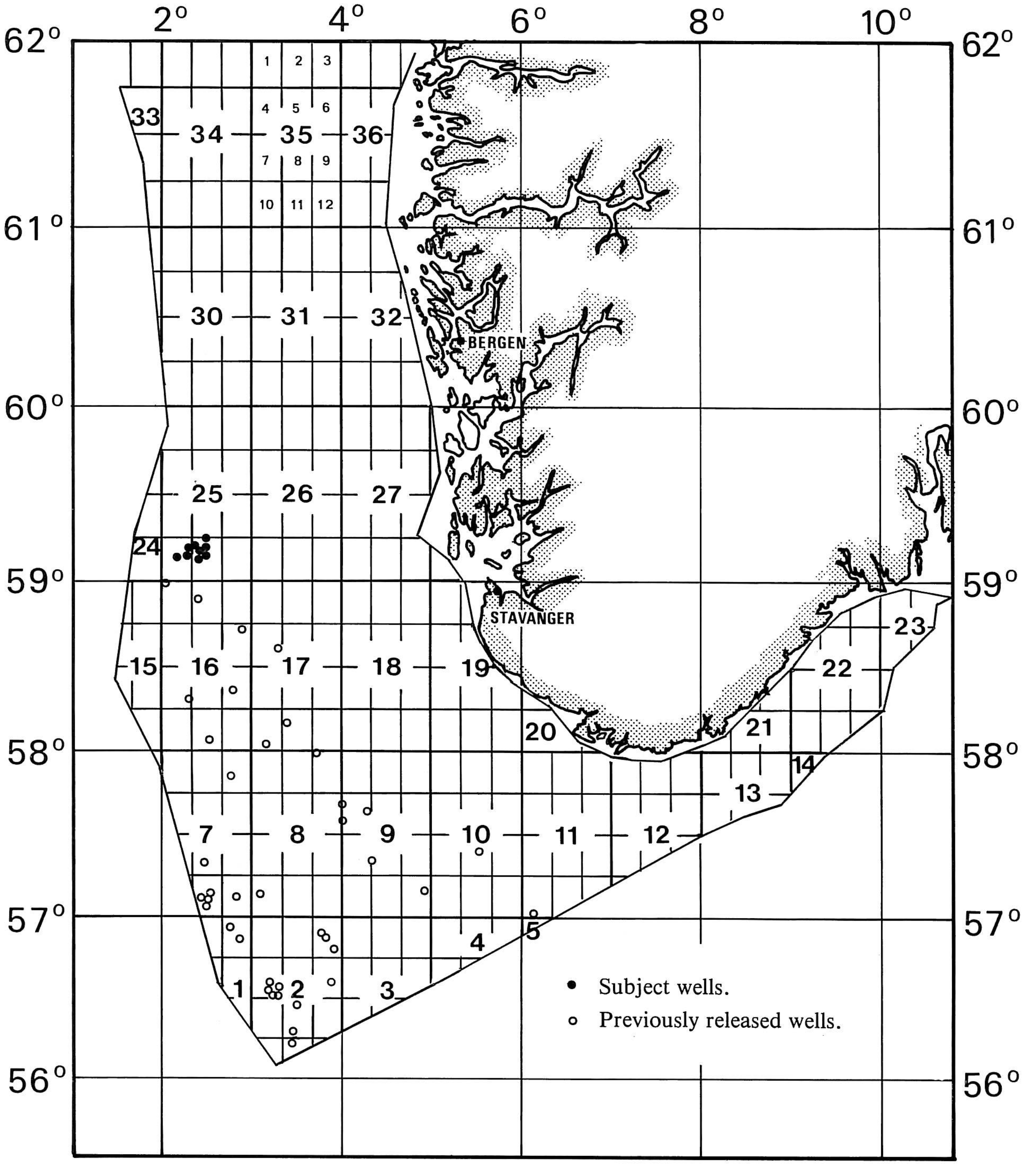


Fig. 1

Contents

The Balder Area

Introduction

This paper deals with the Balder Oil Field on the Norwegian Continental Shelf. The Balder Field is located mainly within block 25/11 and extends into block 25/10, Fig. 1. Esso Exploration Norway Inc. was awarded block 25/11 (licence 001) in 1965, and blocks 25/8 (licence 027) and 25/10 (licence 028) in 1969. Statoil has a 17 1/2% net profit interest in the 1969 concessions. The Balder structure was first tested by the second well on the Norwegian Continental Shelf, 25/11-1, drilled in 1966/67 (Myhre 1976a). This well encountered small amounts of oil in thin Paleocene sands. Two years later 25/10-1 revealed good oil shows in similar sands, and in 1970 well 25/8-1 discovered oil in equivalent sands in a separate structure north east of Balder.

The Balder structure turned out to be particularly complicated due to primary sedimentary variations as well as faulting and truncation. Concequently the Balder Oil Field was proved only by the seventh well on the structure, 25/11-5. By 1 January 1980 another three wells, 25/11-6, 25/11-7 and 25/11-8, had been drilled, but the question of commerciality of the field could still not be settled.

The first seven wells are presented in this paper together with 25/8-1 and 25/10-2 which were drilled on separate structures close to the Balder Field. The relative positions of the wells are shown in Fig 2.

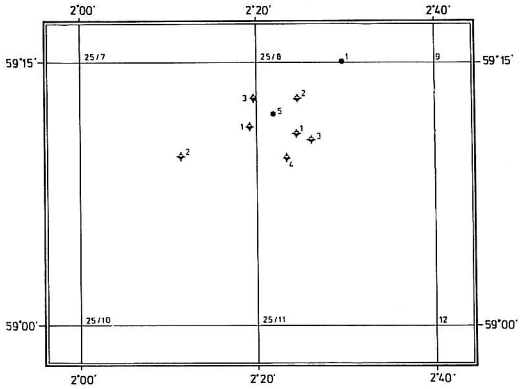


Fig. 2. The relative positions of the wells in the Balder area.

25/11-1 was drilled with the semi submersible rig Ocean Traveler (KBE 27m) and 25/11-5 with Drill Master (KBE 23m). The rest were drilled with the drilling vessel Glomar Grand Isle (KBE 10m). Pertinent data of the drilling history of the area are presented in Table 1.

The setting depths of the casing strings are shown in Table 2, and a generalized mud programme is presented in Table 3.

Drilling problems

25/8-1 was projected into metamorphic basement, but had to be terminated in probable Triassic sediments after unsuccessful fishing operations. 25/10-1 had to be sidetracked at 1 078 m due to an unrecovered fish. In the autumn the operations were laid down because of severe weather conditions, and an unintended sidetrack occurred at 1 664 m while re-entering the hole.

25/10-2 also sidetracked; unintentionally at 1 078 m while re-entering, and later at 1 074 m due to an unrecovered fish.

The rest of the wells were drilled with only minor problems.

Objectives and results

25/11-1 was drilled to test the general lithology down to basement. Based on its results, the only objective of the rest of the wells on the Balder structure was to test the development of the lower Tertiary sands. However, 25/11-5 also penetrated Mesozoic rocks and bottomed in the Triassic.
Well 25/8-1 intended to evaluate stratigraphic trapping on the northwest plunge on the Utsira High, and was terminated in sediments of probable Triassic age.

The structure on which 25/10-2 was drilled is downfaulted relative to the Balder structure, and possible middle Eocene sands, Danian carbonates and Mesozoic sands were considered prospective. 25/10-2 even penetrated unexpected Permian sediments, and ended in metamorphic basement, probably Silurian.
All objectives except the lower Tertiary sands proved water wet in the area. However, there were oil shows in probable Triassic sands and Permian dolomites, shales and conglomerates.
Produceable amounts of oil were found in Paleocene sands in the wells 25/8-1 and 25/11-5, and production tests were carried out. The oil is fairly heavy, with a gravity of approximately 0.9 g/cm^3. Formation interval tests were performed in all wells except 25/11-4. These tests were carried out in Paleocene, Jurassic, Triassic and Permian sections.
The test results are presented in Tables 4 & 5.

Available material

Wire line logs, ditch cuttings, wet samples and conventional cores from the wells are stored at the Norwegian Petroleum Directorate. Sidewall cores were also collected, but are in the possession of the operator. The logs are available in the scales 1:200 and/or 1:500, their depth coverages are given in Table 6.
The sampling intervals of the cuttings samples are given in Table 7.
The wet samples have been divided in two at the NPD, one half has been dried, the other half washed and dried, Table 8.
50 conventional cores were collected from the subject wells. They amount to a total of approximately 500 m, and are presented in Table 9 and in App. 1.

Geology

GENERAL

Lithological descriptions and wire line log interpretations made in the NPD have been used as the main basis for comments on environments of deposistion and lithostratigraphy.
The lithostratigraphic nomenclature used in the text and on the appended logs, is based on the joint work of the UK/Norwegian lithostratigraphic committees (Deegan & Scull 1977). The lithology is described in intervals according to lithostratigraphic groups.
Descriptions and classification of lithology are based on Shell's Standard Legend 1976 (Shell Internationale Petroleum Maatschappij B. V. 1976). The Legend is based on Wentworth's scale for grain size (Wentworth 1922) and Dunham's classification for carbonates (Dunham 1962).
Colours are described according to the Rock-Color Chart (Geol. Soc. Am. 1970) and are based on dry samples.

GEOLOGICAL SETTING

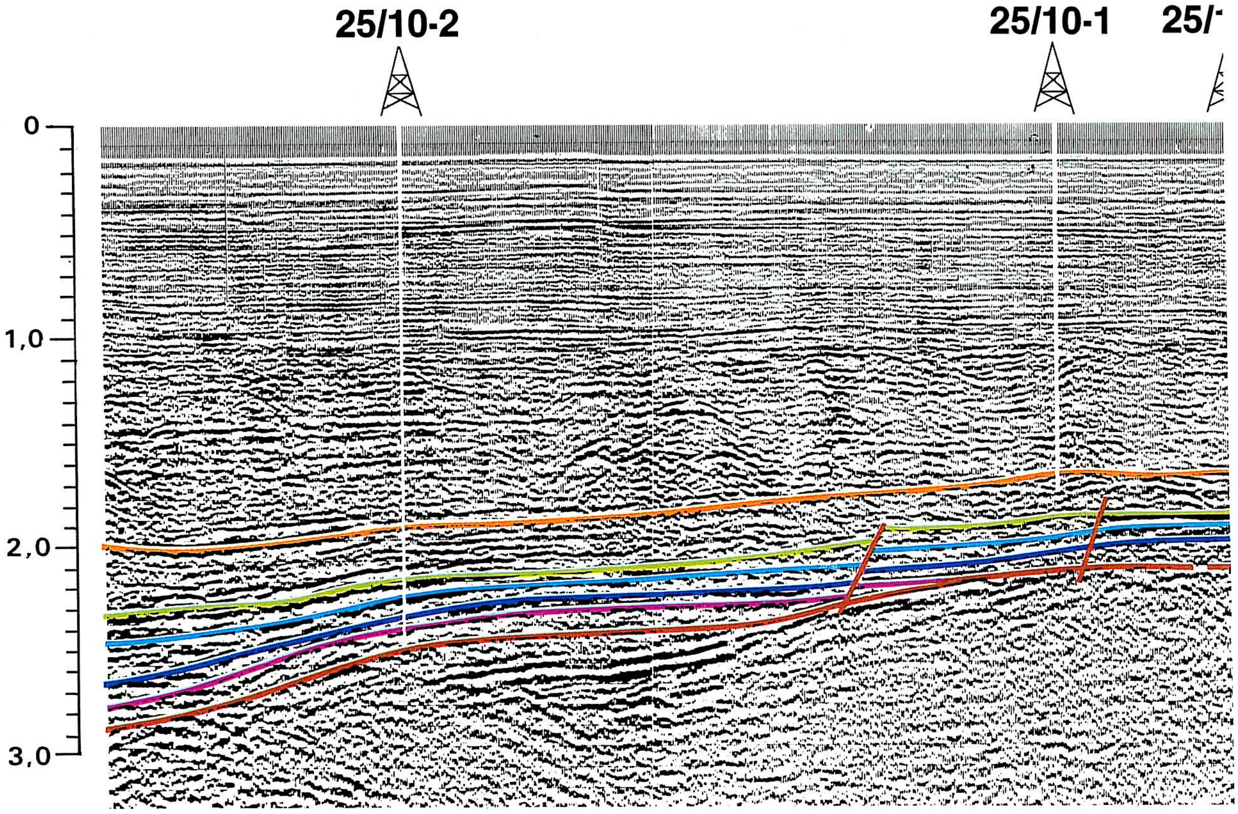
The Balder Oil Field is located on the north western flank of the Utsira High, which is a prominent basement high on the Vestland Arch. It lies in the margin of the Northern Zechstein Basin, and the Zechstein evaporites, which have created many hydrocarbon traps further south, are absent across the crest of the high (Myhre 1976 a & b), and only thinly developed on the downfaulted western flank as seen in well 25/10-2. The Balder Oil Field is built up by a stacked sequence of irregular Tertiary sand bodies which have been truncated and faulted. An interpreted seismic section through the field is presented in Figs. 3 & 4.

LITHOLOGY AND LITHOSTRATIGRAPHY

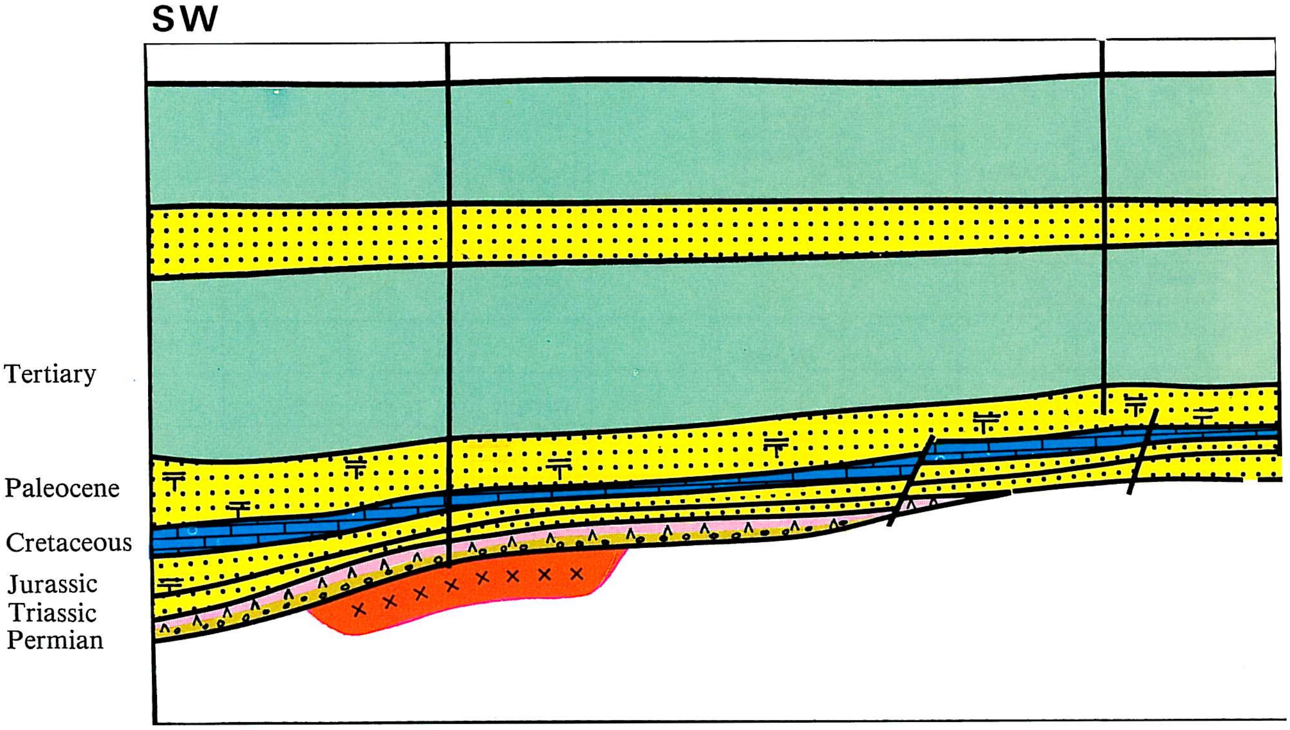
A sedimentological description of the lithostratigraphical units of the wells of the Balder area is summarized in the following. It is manly based on 25/8-1, 25/10-2 and 25/11-5 which have been described in detail for this paper. 25/11-1 has been described earlier (Myhre 1976 a). The logs of 25/10-2 and 25/11-5 are presented in App. 2 & 3. A correlation chart of the nine wells is shown in App. 4. The depth intervals of the different groups and formations are presented below.

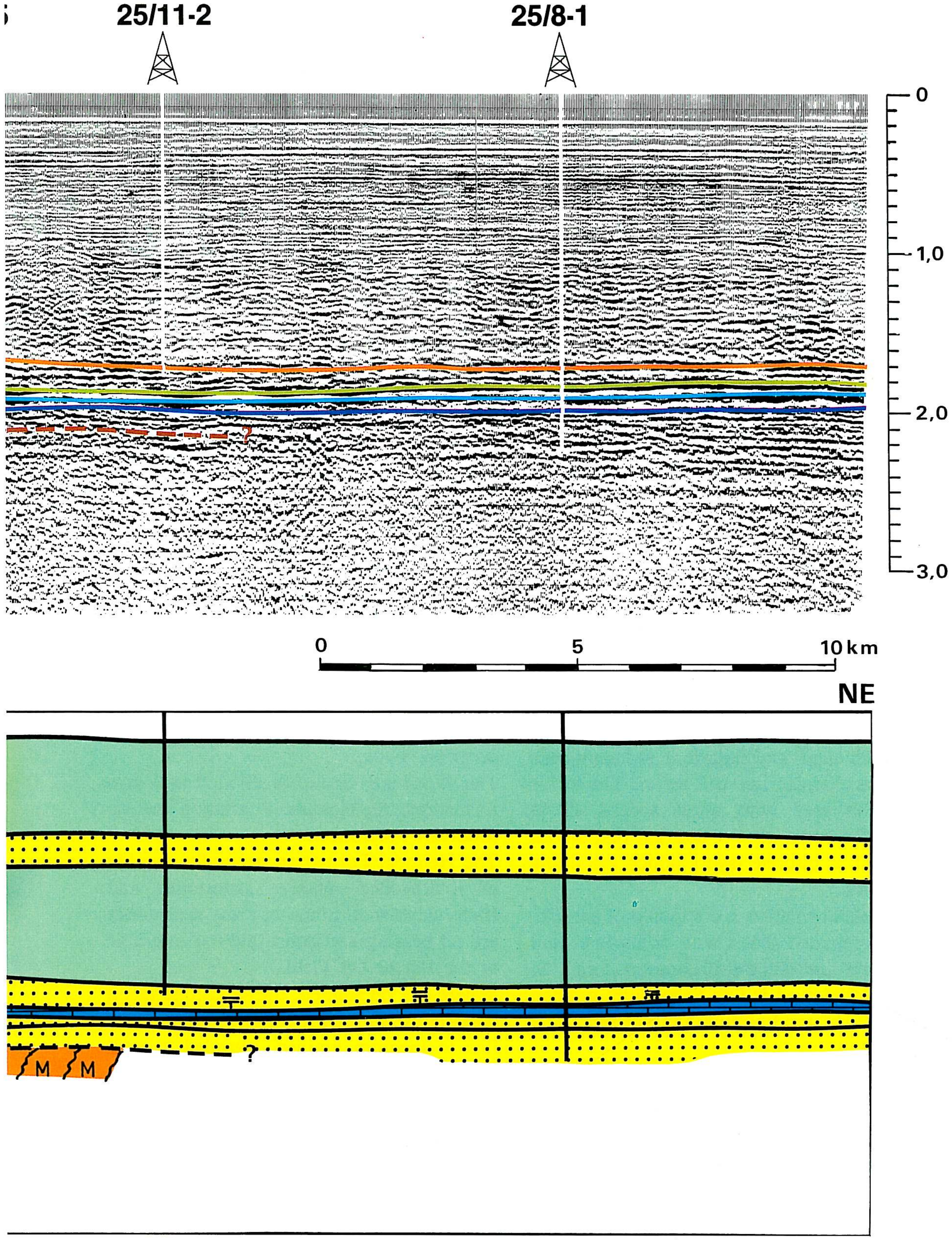
GROUP Formation	25/8-1	25/10-1	25/10-2	25/10-3	25/11-1	25/11-2	25/11-3	25/11-4	25/11-5
NORDLAND	Seafloor-970	Seafloor-908	Seafloor-1052	Seafloor-941	Seafloor-977	Seafloor-944	Seafloor-978	Seafloor-948	Seafloor-937
Utsira	607- 970	555- 908	505-1052	533- 941	613- 977	552- 944	622- 978	636- 948	562- 937
HORDALAND	970-1698	908-1664	1052-1935	941-1710	977-1702	944-1722	978-1707	948-1677	937-1668
ROGALAND	1698-1753	1664-1756	1935-2051	1710-1777	1702-1790	1722-1780	1707-1784	1677-1776	1668-1745
Balder	1698-1736	1664-1716	1935-1974	1710-1769	1702-1776	1722-1765	1707-1784	1677-1776	1668-1733
Sele	1736-1753	1716-1756	1974-2051	1769-1777	1776-1790	1765-1780			1733-1745
MONTROSE	1753-1845	1756-2091	2051-2384	1777-1919	1790-1892	1780-1823	1784-1852	1776-1874	1745-1915
Heimdal	1753-1845	1756-1960	2051-2384	1777-1919	1790-1892	1780-1823	1784-1852	1776-1874	1745-1915
Maureen		1960-2091							
CHALK	1845-1936		2384-2623		1892-1941		1852-1858	1874-1896	1915-1936
Ekofisk	1845-1853								
Tor			2384-2485						
Flounder			2485-2540						
Herring			2540-2623						
Plenus Marl	1915-1923				1921-1927				
Hidra	1923-1936				1927-1941				
CROM. KNOLL	1936-1981				1941-1980				1936-1950
HUMBER	1981-1987				1980-1987				1950-1955
Kimm. Clay	1981-1987				1980-1987				1950-1955
UNN. UPP. JUR.			2623-2680						
UNN. LOW. JUR.	1987-2152				1987-2072				1955-2087
TRIASSIC	2152-2606		2680-2893		2072-2392				2087-2163
Cormorant	2152-2332		2680-2708		2072-2249				
ZECHSTEIN			2893-3013						
Turbot Bank			2893-2962						
Halibut Bank			2962-3007						
Kupferschiefer			3007-3013						
ROTLIEGENDES			3013-3151						
BASEMENT			3151-3181		2392-2451				

Interpreted seismic record. Line: S 758, 1975.



Summary of interpreted seismic record and lithology. Index: See appendix 2.





25/11-2
25/8-1
0
1,0
2,0
3,0
0
5
10 km
NE
M
M
?

Nordland Group

The upper part of the Nordland Group is composed of light (olive) grey clay which becomes silty and sandy downwards. The lower part consists mainly of sand with clay interbeds. The sands are fairly clean quartz sands, very fine to very coarse grained, in general well rounded. Both glauconite and lignite are found.

The sands and the sandy clay above them belong in the Utsira Formation.

Hordaland Group

There is a conspicuous change in colour at the boundary to the Hordaland Group, which in the upper part is dominated by brownish grey clay In the lower part olive grey clay is more abundant. Near the base are found characteristic varicoloured shales in green, brown and red shades. Hard, crystalline, brownish limestone stringers are found throughout.

Rogaland Group

The Rogaland Group is subdivided into two formations, namely the Balder and Sele Formations.

The Balder Formation has a very heterogeneous lithology. It is composed of varicoloured greenish and brownish grey shales with sand- and limestone stringers besides the characteristic tuff layers. The tuff is greenish grey with white specks. Cores from the wells 25/8-1 and 25/10-1 reveal the tuff as discrete layers which are fining upwards.

The Sele Formation is composed of greyish, well laminated shales with occasional sand stringers and some tuffaceous material. In 25/8-1 the sand is fine to medium grained with fairly good sorting and porosity. It is oil stained.

A well preserved fish fossil was found in the Sele Formation in 25/10-2, Fig. 5. This species, which is related to smelts (Osmeroids), is the second most common species in the Danish Mo-clay (Bonde 1979).

Fig. 5. Fish fossil found in the Sele Formation in 25/10—2. This species, which is related to smelts (Osmeroids), is the second most abundant species in the Mo-clay.

The thin Sele Formation seems to be absent in the wells 25/11-3 and -4.

Montrose Group

The Montrose Group is divided into two formations, the Heimdal Formation and the Maureen Formation.

The Heimdal Formation generally consists of interbedded massive sandstones and shale/claystones. Some of these sandstones are oil bearing and constitute the reservoir of the Balder Oil Field.

Where not oil stained, the sandstone has a pale yellowish brown colour. It consists of fine to medium grained, rounded to well rounded quartz with minor amounts of feldspar and clay minerals. The sandstone is sorted to very well sorted and usually very friable.

The shale/claystone in the reservoir section

varies in colour from medium grey through dark greenish grey to brownish black. Plant debris is found in core 5 in well 25/8-1. Bioturbation is seen in some of the cores. The shale/claystone may occasionally be calcareous.
Underlying the Heimdal Formation the Maureen Formation is present in well 25/10-1. In the Balder area the Maureen Formation consists of interbedded shale and sandstone.
The sandstone is very fine to coarse grained, and poorly to well sorted. The shale is medium dark grey, silty and micaceous.
The wells 25/10-1, 25/10-3 and 25/11-2 were terminated in the Montrose Group.

Chalk Group

A very thin Chalk Group is found in the Balder Field. It is somewhat thicker in well 25/8-1, and particularly in the downfaulted 25/10-2.
The group consists of limestones with occasional intercalated shale beds. The limestones are mudstones and wackestones, in general white, but also pink or light grey. Accessories are chert, pyrite and glauconite. The intercalated shales are greyish red or brownish grey, more or less calcareous.
The Ekofisk, Tor, Flounder, Herring, Plenus Marl, and Hidra Formations have been identified in the Balder area. The wells 25/11-3 and 25/11-4 were terminated in the Chalk Group.

Cromer Knoll Group

The Lower Cretaceous sequence found in 25/8-1, 25/11-1 and 25/11-5 has tentatively been designated the Cromer Knoll Group. The logs of the three wells correlate very well within this sequence although it varies considerably in thickness.
The upper part is dominated by grey, red, brown and green shales, while white or light grey lime mudstones dominate in the lower part.
The Cromer Knoll Group is absent in 25/10-2.

Kimmeridge Clay Formation

The dark grey to brownish black, highly radioactive shale of the Kimmeridge Clay Formation is found in 25/8-1, 25/11-1 and 25/11-5, but is absent in 25/10-2.

Unnamed Upper Jurassic

In 25/10-2 the Chalk Group is underlain by a heterogeneous sequence which has been dated to be of Late Jurassic age (Robertson Research International Limited 1979). Mainly greyish red shales and siltstones are found together with white limestones and loose sands. The sands are fine to coarse grained, composed mainly of quartz, but feldspar is also abundant.
The serrated log patterns indicate that these mixed lithologies are finely interbedded. This sequence is found in 25/10-2 only.

Unnamed Lower Jurassic

In 25/8-1, 25/11-1 and 25/11-5 the Kimmeridge Clay Formation is underlain by a predominantly sandy sequence. It is probably time equivalent to the Statfjord Formation further north, but due to lack of well control it still seems premature to give it a lithostratigraphic name.
The upper part of the sequence is composed of poorly sorted, medium to very coarse grained sands with minor amounts of olive grey shale. These are underlain by varicoloured shales and claystones with some fine grained sandstone and limestone.
The lower part of the sequence contains medium to coarse grained sand and fine to medium grained, calcareous sandstone together with some varicoloured shales.
Some coal is seen throughout this sequence.

Triassic

Sediments of Triassic age (or older) are found in 25/8-1, 25/10-2, 25/11-1, and 25/11-5. The upper part of the Triassic sequence has tentatively been designated the Cormorant Formation, while the lower part is still unnamed.

The Triassic sediments are characterized by reddish brown colours with only minor interbeds in green or grey.

In 25/8-1 the sediments are dominated by alternating shales, siltstones and very fine grained sandstones. Sandstones seem to be more abundant near the bottom of the well.

In 25/10-2 sands and sandstones dominate. The bulk of the interval is composed of loose, poorly sorted quartz sands underlain by shales and siltstones. The lower part of the interval consists of a well consolidated, poorly sorted, fine grained sandstone. Traces of sandstone with residual oil are found in the very upper part of the interval.

As described in NPD-paper No. 2, the Triassic sediments of 25/11-1 are composed of interbedded claystones, shales, siltstones and sandstones. A thick, argillaceous, well bedded sandstone sequence is suggested to be pre-Triassic in age (Myhre 1976 a).

The Triassic of 25/11-5 is dominated by shales and claystones with only traces of sandstone.

25/8-1 and 25/11-5 were terminated in the Triassic.

Zechstein Group

The Zechstein Group is found in 25/10-2 only. It has tentatively been subdivided into the Turbot Bank Formation, the Halibut Bank Formation and the Kupferschiefer Formation.

The Turbot Bank Formation is dominated by anhydrite with interbeds of dolomite and shale. The underlying Halibut Bank Formation is composed of interbedded shales and dolomites, and the basal Kupferschiefer Formation consists of a dark grey, carbonaceous and highly radioactive shale.

Rotliegendes Group

The Zechstein Group is underlain by a thick conglomerate which is thought to represent the Rotliegendes Group. The conglomerate is polymict with pebbles of quartz, feldspar, gneiss and amphibolite in a well cemented clayey or sandy matrix. The angular to subangular pebbles are up to 5 to 7 cm in diameter, Fig. 6.

Fig. 6. 25/10, core 9, 3020 m. Polymict conglomerate of probably Rotliegendes age.

Basement

25/10-2 and 25/11-1 bottomed in crystalline basement rocks.

In 25/10-2 the basement rock probably is plutonic. It is composed mainly of alkali feldspar, and thus best classified as a syenite. It is medium grained and highly crushed. Its dark greyish red colour is partly due to heavy staining by hematite. In 25/11-1 the basement is composed of schist and marble (Myhre 1976 a).

MICROPALEONTOLOGY OF WELL 25/11-4

The intention of this micropaleontological study is to give a review of the foraminiferal fauna and to establish a biostratigraphical and chronostratigraphical breakdown throughout one of the wells in the Balder Field.

Ditch cuttings samples from every 90' interval were washed and analysed according to standard laboratory treatment (Hilterman, 1958). Consolidated samples were treated with kerosene. In these cases the foraminifera were picked from the wash residues. All samples were washed through 1.0, 0.1 and 0.07 mm sieves. Only fractions greater than 0.1 mm have been analysed. Data relevant to the study are presented in App. 5.

The foraminiferal faunas in the analysed samples are strongly contaminated by caved specimens. This is a problem particularly in the upper part of the well, where the samples are heavily contaminated by Quaternary specimens. This contamination gradually decreases downward in the well.

The foraminiferal zonation

1350'—2100' *Elphidium excavatum — Cassidulina laevigata — C. crassa — Trifarina fluens zone*

The fauna consists almost entirely of calcareous benthonic foraminifera. The dominating species are *Elphidium excavatum* (Terquem) and *Cassidulina laevigata* d'Orbigny. Other common species are *Nonion barleeanum* (Williamson), *Cibicides lobatulus* (Walker & Jacob), *Trifarina fluens* (Todd), *Cassidulina crassa* d'Orbigny and *Buccella frigida* (Cushman). The lowermost sample of the interval shows an influx of *Bolivina pseudoplicata* Heron-Allen & Earland.

The fauna indicates a Recent to Pleistocene age.

2160'—2190' *Lagena costairregularis — Cassidulina laevigata var. pliocarinata — Globigerina zone*

The fauna consists of calcareous benthonic foraminifera (70%) and planktonic foraminifera (30%). The dominating species are *Cassidulina crassa, Trifarina fluens, Cassidulina laevigata* and *Cibicides lobatulus*. Other common species are the same as in the interval above. Planktonic species occurring in this zone are *Globigerina pachyderma* (Ehrenberg), *G. bulloides* d'Orbigny and *G. quinqueloba* Natland. *Lagena costairregularis* Toering & Voorthuysen, *Cassidulina laevigata* d'Orbigny var. *pliocarinata* von Voorthuysen, *Cibicides* aff. *rotundatus* Stshedrina and *C. scaldisiensis* ten Dam & Reinhold also occur in this interval.

The influx of planktonic species together with the occurence of *Cassidulina laevigata* var. *pliocarinata,* indicate penetration into Pliocene deposits.

2360'—2460' *Elphidiella hannai — Monspeliesina pseudotepida — Globorotalia crassaformis zone*

The fauna consists mainly of calcareous benthonic species. *Cassidulina laevigata, Elphidium excavatum, Cibicides lobatulus, Bolivina pseudoplicata, Trifarina fluens* and *Nonion barleeanum* dominate the fauna. These species are assumed to be caved and represent contamination from the samples above. Top-occurring species in this interval are *Siphotextularia sculpturata* (Cushman & ten Dam), *Dentalina konincki* Reuss, *Sagrina reticulata* (Cushman) *Mons-*

peliesina pseudotepida (Voorthuysen), *Elphidiella hannai* (Cushman & Hanna), *Nonion boueanum* (d'Orbigny), *Eponides umbonatus* (Reuss), *Cibicides* ex. gr. *dutemplei* (d'Orbigny) and *Globorotalia crassaformis* (Galloway & Wissler).

In the Netherlands several of the above mentioned species have their uppermost occurence in the Pliocene (Doppert 1980). These are *Siphotextularia sculpturata, Sagrina reticulata, Monspeliesina pseudotepida, Bulimina aculeata* Czjzek and *Dentalina konincki.*

2430'—2730' *Bulimina elongata — Asterigerina gürichi staeschei — Orbulina universa zone*

The three index species have their top-occurence in the upper part of this zone. *Sphaeroidina bulloides* d'Orbigny, *Uvigerina macrocarinata* (Papp & Turnovsky), *Angulogerina gracilis* (Reuss), *Stilostomella hirsuta* (d'Orbigny), *Uvigerina semiornata* (d'Orbigny), *Eponides nanus* (Reuss), *Nonion pompilioides* (Fichtel & Moll), *Elphidium hiltermanni* Hagn, *Nonion granosum* (d'Orbigny) and *Marginulina costata* Hosius, are all scarce and occur sporadically. However, in the terms of a general North Sea biostratigraphy, they are all representative for a Miocene age.

The occurence of *Orbulina universa* d'Orbigny, *Asterigerina güirichi staeschei* (ten Dam & Reinhold) and *Bulimina elongata* d'Orbigny, indicates a Middle Miocene age. Among the planktonic specimens are *Globigerina praebulloides* Blow, *G. angustiumbilicata* Bolli and *Globigerinita* cf. *naparimaensis* Brönnimann. The planktonic species are very rare, usually occurring as single specimens.

2790'—2910' *Loxostomum sinuosum — Protelphidium roemeri zone*

Two samples have been analysed from this interval. The fauna is very similar to the fauna above, except for the occurrence of *Loxostomum sinuosum* Cushman, *Gyroidinoides soldanii* d'Orbigny, *Protelphidium roemeri* (Cushman) and *Epistominella oveyi* (Bhatia). *Loxostomum sinuosum* often occurs in Middle Miocene deposits in the North Sea area, and often together with *Asterigerina güirichi staeschei.* Therefore, it is assumed that this zone also is referred to a Middle Miocene age.

2970' — 3180' *Barren*

The samples in this interval is almost barren of foraminifera. Due to the casing shoe situated at 3060', the samples contain only cement.

3240' — 3510' *Frondicularia seminuda — Valvulineria complanata zone*

The two index forms appear at the top of the zone together with *Alabamina tangentialis* (Clodius). In addition to these species, the fauna consists mainly of species observed in the *Loxostomum sinuosum — Protelphidium roemeri* zone. *Frondicularia seminuda* Reuss and *Valvulineria complanata* (d'Orbigny) are well known from Lower Miocene and Upper Oligocene deposits in Denmark (Kristoffersen 1972, Larsen & Dinesen 1959).

In the North Sea area these species also seem to be common in mid-Tertiary faunas. Because of a relatively poor *in situ* fauna, the zone is referred to a Late Oligocene to Early Miocene age.

3600'—3990' *Asterigerina güirichi — Turrilina alsatica zone*

The two index species *Asterigerina güirichi güirichi* (Franke) and *Turrilina alsatica* Andreae, are both rarely represented. No distinct influx of *A. güirichi güirichi* seems to occur, which is the case in other parts of

the North Sea area (Riise 1978) and parts of north west Europe.
The occurence of the species listed above, indicates an Oligocene age, probably lower part of Late Oligocene to Middle Oligocene. This is supported by the top-occurrence of *Eponides geinitzi* (Clodius), *Cibicides telegdi* Grossheide & Trunko, *Gyroidinoides angustiumbilicata* (ten Dam) and *Epistomina elegans* (d'Orbigny) which occur in this zone. Inside the *Asterigerina gürichi — Turrilina alsatica* zone, a distinct faunal break appears in the 3870'—3900' sample, which here is referred to as *Glomospira — Bathysiphon — Haplophragmoides* subzone. In this sample there is a very strong influx of agglutinated tests. This fauna is comparable with the agglutinated assemblages occuring from 4230' and downwards.

4050'—4170' *Gyroidinoides mamillata — Rotaliatina bulimoides zone*

The two index species *Gyroidinoides mamillata* (Andreae) and *Rotaliatina bulimoides* (Reuss) are rarely represented. In the North Sea area they usually occur in the lower part of the Oligocene section. *Rotaliatina bulimoides* is an established marker for the Middle Oligocene (Spiegler 1965). There is no distinct faunal change from the *Asterigerina gürichi — Turrilina alsatica* zone. This zone is referred to an Early to Middle Oligocene age.

4230'—4530' *Cyclammina challinori Spirosigmoilinella sp. 1 zone*

The faunas in the whole interval 4230'—6120', are dominated by agglutinated foraminifera. The high ratio of calcareous foraminifera shown in the chart (App. 5) is due to caving. The interval is supposed to include sediments of a Paleocene, Eocene and possible Oligocene age. A few generas and groups are common throughout the interval. These are *Bathysiphon* group, *Ammodiscus, Glomospira, Haplophragmoides, Recurvoides, Cyclammina. Cribrostomoides* and *Trochammina*. The interval has been subdivided into zones based on the occurrence of arenaceous species which are supposed to have biostratigraphical importance. These species mostly occur in small numbers in the samples. Long ranging Early Tertiary species like *Haplophragmoides walteri* (Grzybowski), *Cystammina pauciloculata* (Brady), *Ammodiscus incertus* (Orbigny), *Glomospira charoides corona* Cushman & Jarvis and *Cyclammina placenta/cancellata* group occur in most samples throughout the interval.
The *Cyclammina challinori — Spirosigmoilinella* sp. 1 zone is the uppermost zone in this agglutinated foraminiferal interval. In addition to the index species, *Cyclammina challinori* Haynes and *Spirosigmoilinella* sp. 1, the following species occur in the zone: *Haplophragmoides walteri, Cystammina pauciloculata, Ammobaculites spp.* and sporadically *Trochammina* cf. *subvesicularis* Homola & Hanzlikova, *T. globigeriniformis* (Parker & Jones) and *Cyclammina placenta/cancellata* group. *Turrilina brevispira* ten Dam, *Bulimina ovata* d'Orbigny and *Polymorphinids* occur in the zone. Usually these forms occur in Early Eocene to Late Paleocene deposits in the North Sea area, in this zone, however, they represent reworking. The zone is assumed to be of a Late Eocene or possibly Oligocene age.

4590'—4890' *Glomospira charoides corona — Trochammina cf. subvesicularis — Ammolagena clavata zone*

The fauna is quite similar to the one above. *Glomospira charoides corona* and *Ammolagena clavata* (Jones & Parker) occur sporadically and have their uppermost occurrence in this zone. *Trochammina* cf. *subvesicularis* is common throughout the zone. Other species are *Karreriella* cf. *apicularis*

(Cushman), *Trochamminoides irregularis* White and *Trochammina globigeriniformis*, all with relatively low frequency. *Bathysiphon* fragments are frequent. The zone is assumed to be of a Late to Middle Eocene age.

4950'—5340' *Cystammina pauciloculata — Haplophragmoides kirki — Spiroplectammina cf. spectabilis zone*

The index species, *Cystammina pauciloculata, Haplophragmoides kirki* Wickenden and *Spiroplectammina* cf. *spectabilis* (Grzybowski), have their maximum occurrence in this zone. *S.* cf. *spectabilis* is reported to be a diagnostic Early Eocene marker, but has also been found in younger sediments in parts of the North Sea. A few tests of *Spirosigmoilinella* sp. 2 and *Trochamminoides coronatus* (Brady) are observed. The zone is of a Late to Middle Eocene age.

5340'—5700' Cyclammina amplectens zone

Cyclammina amplectens Grzybowski is frequent in this zone. This species is usually abundant in sediments of Early to Middle Eocene age (Bieda 1969).
Coscinodiscus sp. 1 and *C.* sp. 2 occur in the lower part of this zone. A marked influx of these diatoms in the lower Eocene in the North Sea area, is probably associated with chemical changes in the sea water due to volcanic activity.
The zone is supposed to be of a Middle to Early Eocene age.

5750'—5850' *Barren*

The two samples in this interval contain about 95% cement. Only a few foraminifera have been recorded.

5910'—6120' *Spiroplectammina cf. spectabilis — Ammodiscus incertus — Coscinodiscus sp. 1 zone*

Green stained radiolarians and non-pyritized *Coscinodiscus* sp. 1 occur in this zone. This assemblage is typical in the uppermost part of the Paleocene in the Viking and Central graben. *Lenticulina cultrata* Montefort and *Rzehakina epigona* (Rzehak) occur sporadically in this zone. These species are reported from sediments of Late Paleocene age. Diagnostic planktonic foraminifera have not been found.

6120'—6222' *Globoconusa daubjergensis — Anomalina velascoensis zone*

The fauna is heavily contaminated by agglutinated foraminifera, which are caved from the interval above. The *in situ* fauna is dominated by planktonic specimens.
Subbotina triloculinoides (Plummer), *Globorotalia pseudobulloides* Plummer, *G. compressa* (Plummer), *Nordsoeina* sp. and *Chiloguembelina* sp. are registered. Benthonic species like *Gavelinella vombensis* (Brotzen), *Anomalina velascoensis* Cushman, *Anomalinoides* cf. *acuta* (Plummer), *Dorothia bulletta* (Carsey), and *D. oxycona* (Reuss) have been found. The occurrence of *Globoconusa daubjergensis* (Brönnimann) may indicate that the lower part of Danian is present (Bang 1978). The well bottoms in Danian limestone. Zonation of this limestone has not been possible.

Paleoenvironment

The whole section represents marine sedimentation. The upper part indicates a shelf environment, while the section dominated of arenaceous foraminifera may indicate an outer shelf to bathyal environment.

DISCUSSION

Two of the wells in the Balder area, 25/10-2 and 25/11-1, reached the crystalline basement. The Caledonides of Norway and Scotland are linked across the northern

North Sea, and a radiometric dating of the schist in 25/11-1 revealed an age of approximately 450 m.y. (Frost et al. 1980). The syenite in 25/10-2 was probably formed in association with the Caledonian folding activity. The granitic gneisses on the Utsira High proper, as seen in the nearby wells 16/2-1 and 16/5-1, possibly represent medium grade metamorphic rocks of Caledonian age.

The conglomerate above the basement in 25/10-2 is barren. A similar conglomerate was found in 17/4-1, which was drilled south east of the Utsira High (Olsen 1978). This has by Deegan and Scull (1977) been referred to the Rotliegendes Group, which is said to be extensive in the Norwegian North Sea, missing only on local highs. Therefore the conglomerate in 25/10-2 has been interpreted to be of Lower Permian, Rotliegendes age, although a Devonian or Carboniferous age cannot be excluded. Devonian conglomerates are well known onshore Norway and Scotland, and Carboniferous sands are found in the Piper Oil Field 150 km south west of the Balder Field (Williams et al. 1975).

The extremely poor sorting and the angularity of the pebbles and sand grains indicate a very short distance of transport, so the sediments were probably flushed down from the Utsira High, which seems to have been emergent during the Early Permian.

The thin, highly radioactive shale and the good hundred metres of interbedded shale, dolomite and anhydrite overlying the Rotliegendes in 25/10-2 are interpreted to constitute the Zechstein Group.

The radioactive shale is believed to be the Kupferschiefer Formation, which is widespread, although very thin (Deegan & Scull 1977). The Kupferschiefer Formation is also found in the Norwegian wells 8/3-1 (Myhre 1975), 17/4-1 (Olsen 1978) and 7/3-1 (Strass 1979). The sapropelic nature of the sediment indicates deposition in a low energy environment under stagnant conditions.

The interbedded sequence of shale, dolomite and anhydrite represents a marginal development of the Zechstein evaporites. The northern extention of the Zechstein basin is not yet well known, and it is possible that the marginal development in 25/10-2 is a local phenomenon near the Utsira High, not really related to the northern limit of the Zechstein sea.

There is no lithostratigraphic term for the marginal development of the Zechstein in the Norwegian sector. However, the log patterns of this sequence correlate so well with the type well, UK 15/26-1, that the British terms, Halibut Bank and Turbot Bank, have been used tentatively.

The deposition of the Zechstein evaporites is cyclic, and carbonate and anhydrite represent the early stage in each cycle (Taylor & Colter 1975). It is suggested that the marginal development may represent the lower part of the Zechstein only, with a regional unconformity to the Triassic (Deegan & Scull 1977).

Zechstein is absent in 25/11-1, which was drilled structurally higher than 25/10-2, and in the wells on the Utsira High proper, even the lower parts of the Mesozoic are missing.

The sandy section above the Zechstein in 25/10-2 does not contain recognizable palynomorphs, but is believed to be of Triassic age due to its stratigraphic position and the continental character of the sediments. Thick sequences of red, continental sediments of probable Triassic age are also found in the wells 25/8-1 and 25/11-1. A marked log break within each of these sequences has been interpreted to represent an unconformity, and the lower part of the section has been suggested to be pre-Triassic in age (Myhre 1976 a).

In an attempt to verify this, 25/8-1 was examined for palynological content by S. J.

Log correlations of the Mesozoic section in Balder. The lower part of the Triassic in 25/10—2 is correlated with sections in 25/8—1 and 25/11—1 which previously have been designated Permo-Triassic or Pre-Triassic.

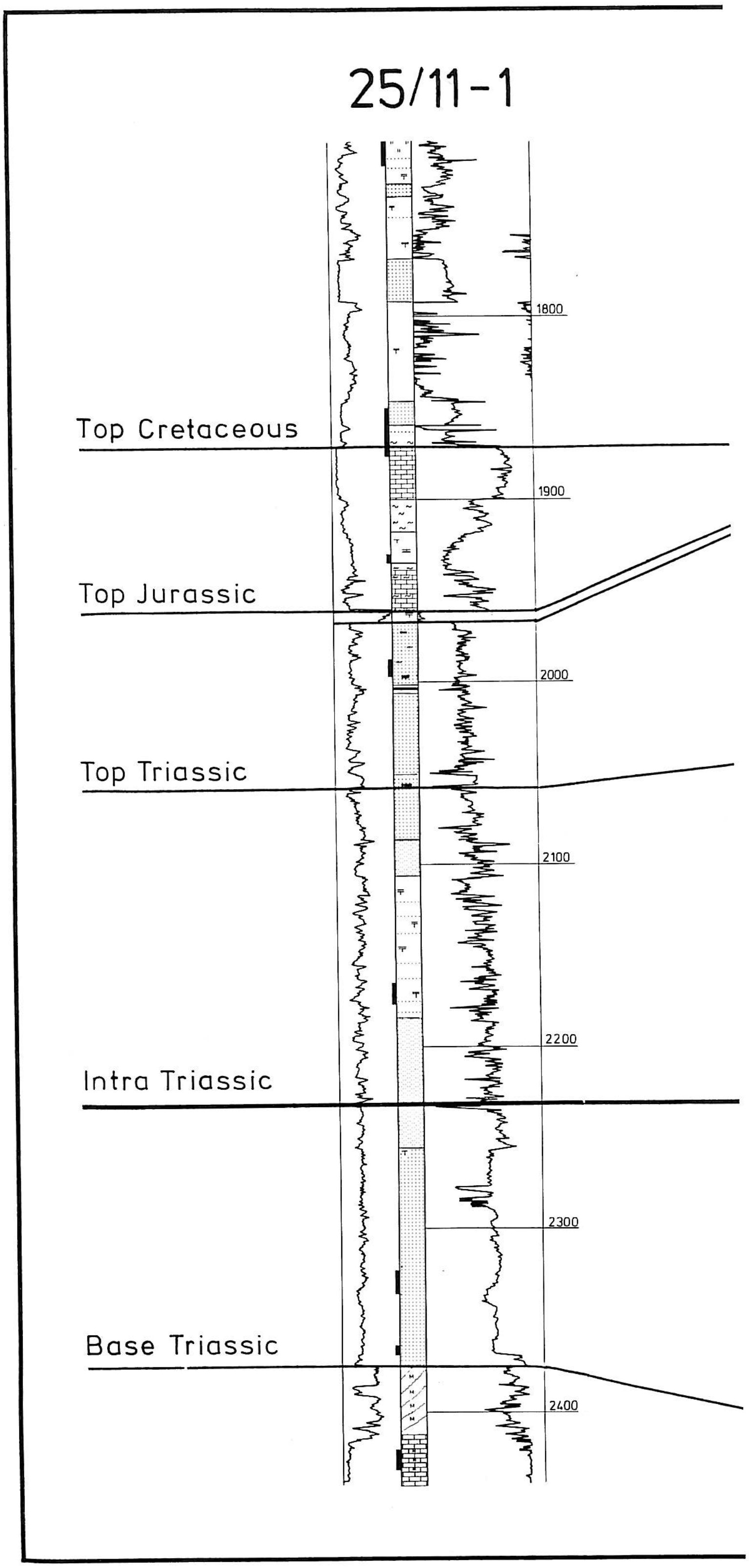
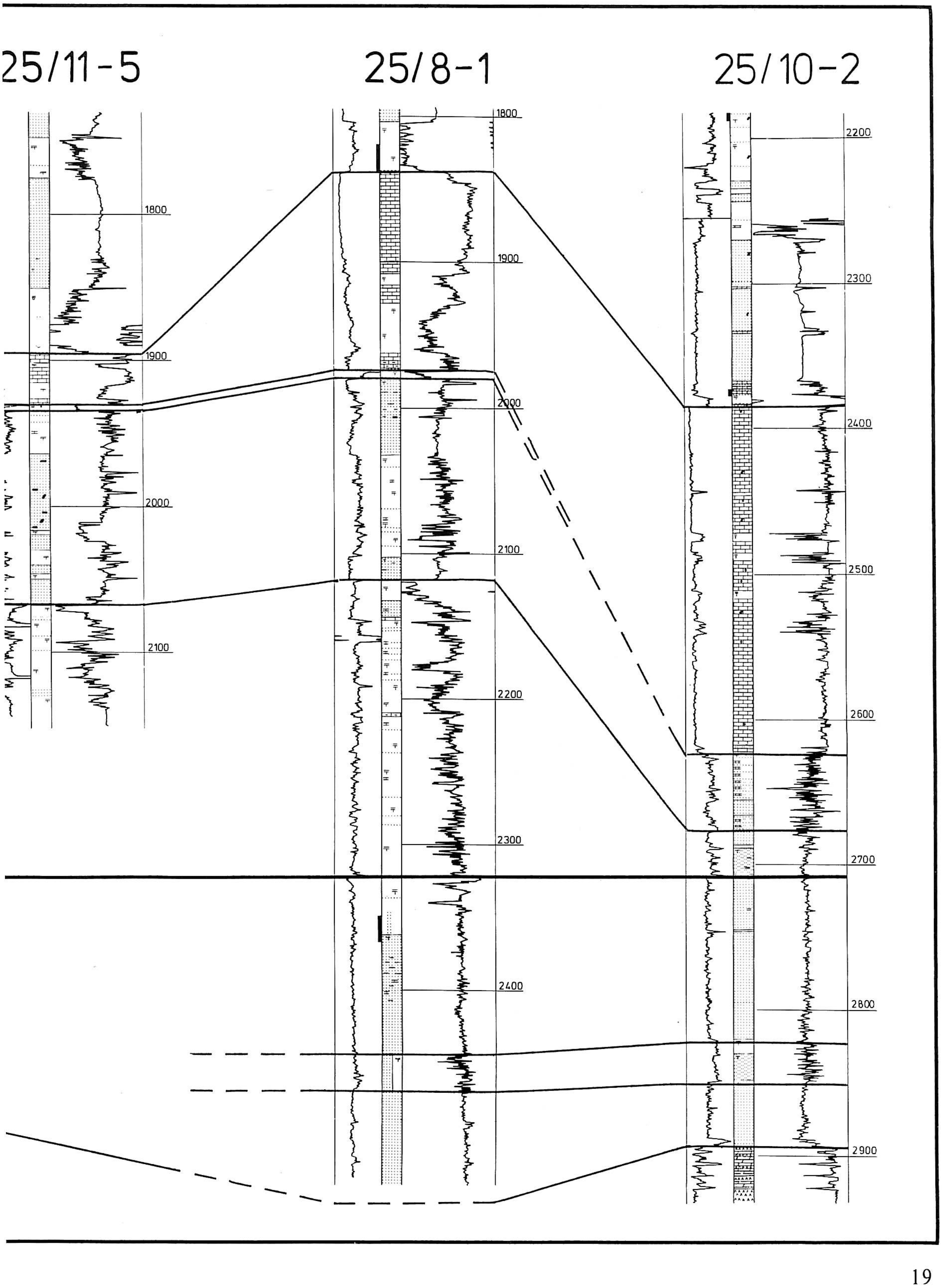


Fig. 7


25/11-5
25/8-1
25/10-2
1800
1900
2000
2100
1800
1900
2000
2100
2200
2300
2400
2200
2300
2400
2500
2600
2700
2800
2900

Morbey, Bio-Strat Consulting, but no taxa older than Late Triassic was found. However, the samples were poor, and this dating cannot be regarded as conclusive.

On the other hand, Fig. 7 shows that fairly good log correlations can be made on the presumption that the entire section is Triassic like in 25/10-2, and with the restricted data available, the latter interpretation is preferred.

Well 25/11-5 was drilled approximately 70 metres into the Triassic. Its logs correlate well with those of 25/8-1.

Due to the intermediate geographical position of the Balder Field relative to the Central and Northern North Sea it is difficult to fit the Triassic into the lithostratigraphical nomenclature of Deegan & Scull (1977). As the overlying Lower Jurassic sequence probably can be correlated with the Statfjord area (Wiik Jacobsen pers. comm.), it seems natural to use the northern nomenclature also for the Triassic. However, only the upper part of the Triassic has been defined in the Northern North Sea, the lower part is still unnamed. In the subject wells the upper part of the Triassic, consisting of alternating sands and shales, has been designated the Cormorant Formation, while the lower part of more massive sands is unnamed.

Micropaleontological datings and log correlations show that Lower Jurassic sediments are present in the wells 25/8-1, 25/11-1 and 25/11-5. As mentioned above, this sequence can be correlated with the Statfjord Formation. It can be subdivided into three subunits, which can be designated upper sand unit, middle shale and sand unit, and lower sand unit (Wiik Jacobsen pers. comm.). All three units are present in 25/8-1, the lowermost two are found in 25/11-5, while only the lower sand unit is present in 25/11-1. There is no equivalent to the Dunlin Formation in the Balder area. The change in lithology indicates a transition from continental environment in the Triassic to paralic in the Lower Jurassic. The alternating sand/shale ratio reflects variable energy of deposition.

According to Ziegler (1977) an uplifting of structural highs took place in the Middle Jurassic, and the Utsira High probably emerged. This is reflected by the absence of Middle Jurassic sediments and the erosion of parts of the Lower Jurassic.

During the late Middle Jurassic and early Late Jurassic a transgressive phase commenced. In the Kimmeridgian the Viking Graben was further developed, and thick shale series rich in organic material were deposited over most of the Central North Sea (Ziegler 1977). This dark, radioactive shale, which is designated the Kimmeridge Clay Formation, is of Volgian to Ryazanian (late Kimmeridgian to Berriasian) age in well 25/8-1 (Robertson Research International Limited 1979). The Kimmeridge Clay Formation is absent in 25/10-2. In this well sediments of Volgian age are developed as alternating shales, siltstone, limestone and loose sands, and do not fit into the existing nomenclature system.

The Late Kimmerian tectonic phase near the transition between the Jurassic and the Cretaceous gave rise to a marked block faulted submarine relief. The Utsira High seems to have been uplifted at this time as only late Early Cretaceous sediments are found in the Balder area.

Micropaleontological analyses of the Cretaceous sediments, which have been carried out at the NPD, indicate that sedimentation recommenced in the Barremian in the Balder area, Fig. 8.

The Late Cretaceous and earliest Tertiary (Danian) were characterized by sedimentation of lime mud, and the pure limestones with occasional shale intercalations belong in the Chalk Group.

The logs of 25/8-1, 25/11-1 and 25/11-5 correlate very well within this interval,

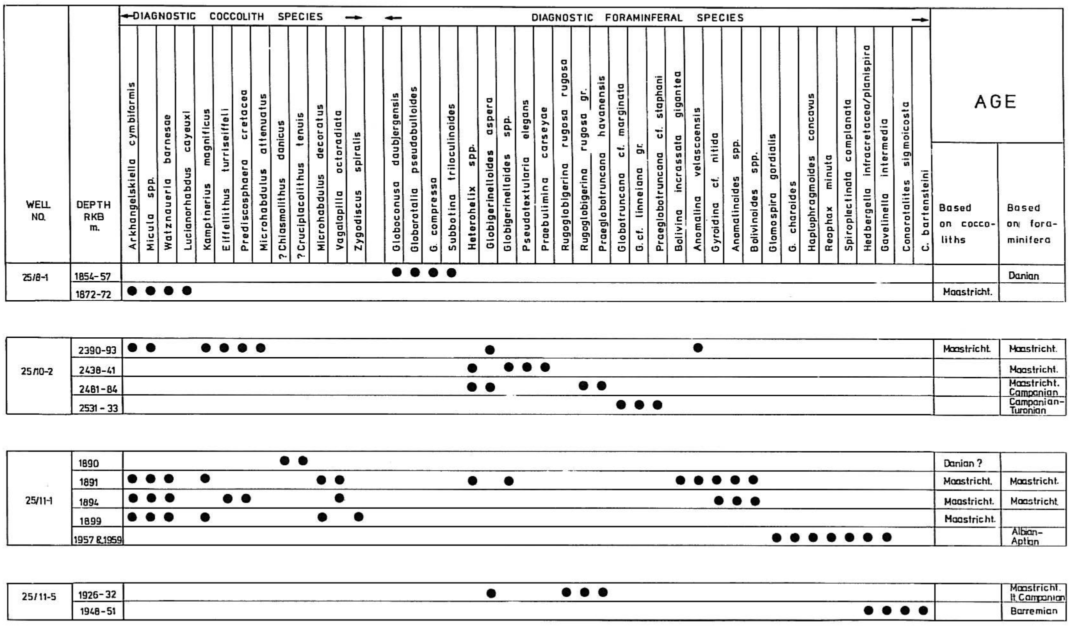


Fig. 8 *Registrations of Cretaceous microfossils in the Balder Area.*

while the logs of 25/11-2 are quite different. Micropaleontological analyses indicate that the three former wells contain only the upper parts of the Chalk Group, while in the latter also the middle and possibly the lower parts are present. In 25/10-2 the Chalk Group has been subdivided into the Herring, Flounder and Tor Formations. Danian microfossils have been found in the very upper part of the Chalk Group in 25/8-1 and 25/11-1 but the characteristic log patterns of the Ekofisk Formation can be distinguished in well 25/8-1 only.

The above observations show a marked difference between well 25/10-2 and the rest of the wells in the Balder Area. There is a large gap in 25/10-2, as the Kimmeridge Clay Formation, the Cromer Knoll Group and probably the lower part of the Chalk Group are missing. The western flank, where 25/10-2 is situated, probably had been downfaulted relative to the high by late Kimmerian times. Therefore it is difficult to explain the gap as a result of erosion, and easier to imagine that this section has been faulted out, although this cannot be confirmed by the available seismic sections.

Sharp deflections on the logs at the top of the Chalk Group are indicative of an unconformity. This is possibly within the Danian in the Balder area, but at the base of the Danian further north (Mudge 1979). This unconformity is related to renewed tectonism which led to erosion of the basin margins. The erosion entailed a change from a carbonate to a clastic sedimentary regime, with deposition of alternating clay and sand in deep water.

The Maureen Formation, which is of Danian age, has been identified in well 25/10-1 only. Danian microfossils have been found above the chalk also in other wells, but it has not been possible to state whether they are *in situ* or reworked, and the entire sequence between the chalk and the tuff has been designated the Heimdal Formation.

As mentioned in the lithology chapter, the reservoir sandstones of the Balder field lie in the Heimdal Formation. The most characteristic properties of the reservoir sand-

stone are the very good sorting and the incomplete cementation. Fig. 9 shows a contour map of the top of the reservoir (Skjold 1980). The reservoir sandstone is thought to be a deep sea submarine fan consisting of up to 100 m thick lobes draped with hemipelagic shales.
The East Shetland platform must have been the source for the sediments. An outbuilding foreset wedge of clastic sediments was deposited during the Paleocene and Eocene on the shelf of the East Shetland platform (Ziegler 1978). This foreset wedge was the source area for high density turbidity currents which supplied the Viking graben and the surrounding deep sea with sands.
At the end of the Paleocene, when the reservoir sands were deposited, most of the Viking graben must have been filled in.
When triggered at the top of the slope of the East Shetland Platform, the turbidity currents had an easterly direction. Reaching the deep sea basin, the material was deposited in an environment of high energy erosion and deposition, resulting in a north south orientation of the sand lobes, Fig. 9.
The shale/sandstone boundaries are very clearly defined on the GR log. Both the logs and the description of the cores and cuttings samples indicate that the reservoir sandstone is clean and well sorted. Skjold (1980) assumes that this is caused by sorting of the sediment prior to the final transport and deposition.
The reservoir parameters of the Balder field are in general very good: The porosity ranges from 30 to 36 %, the water saturation from 7 to 20 %, and the permeability from 1 to 10 darcies (Skjold 1980). The oil/water contact is from the resistivity logs found to be at about 1760 m below sea level.
The tuffaceous Sele and Balder Formations overlie the reservoir. They are related to the volcanic activity at the transition between Paleocene and Eocene. 25/11-1 is chosen as the type well for the Balder Formation (Deegan & Scull 1977).
Since the Eocene, the North sea has been subjected to regional subsidence (Ziegler 1977) with deposition of the low energy sediments of the Hordaland Group. In the vicinity of the Utsira High this was interrupted in the middle to late Miocene when the sands of the Utsira Formation were deposited. Glauconite and carbonaceous material give evidence of a marine, near shore environment. Further subsidence gave rise to deposition of the clays of the rest of the Nordland Group.

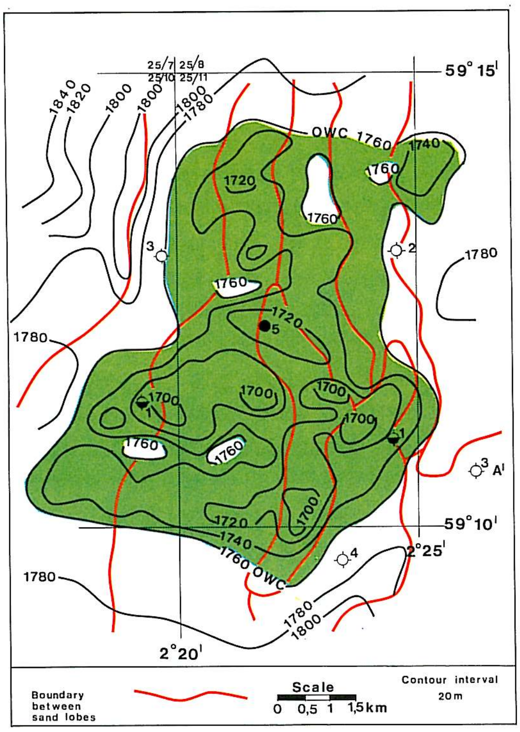


Fig. 9. Countour map of the top of the reservoir in the Balder Oil Field.

Summary

The Balder Oil Field is situated on the north western flank of the Utsira High, which is a prominent basement high on the Vestland Arch. The basement is composed of metamorphic and igneous rocks of Caledonian age.

A conglomerate of probable Rotligendes age, flushed down from the high, is found in the deepest well, 25/10-2, only. Zechstein is also found in 25/10-2 and has a marginal development of shales and dolomites.

Triassic is represented by thick sequences of continental deposits, overlain by paralic sediments of Lower Jurassic age. An interbedded sequence of sands, shales and limestones of Late Jurassic age is found in 25/10-2 only. The dark, radioactive Kimmeridge Clay is thinly developed in the area. The Cretaceous is also thinly developed, with shales, marls and limestones.

In the early Tertiary the sedimentation turned to a clastic regime, and the reservoir sands were deposited as a deep sea submarine fan. The Tertiary is dominated by low energy, marine sediments, except for the Miocene marine sands of the Utsira Formation.

Summary chart

The main rock types and depositional environments as seen in the Balder area.

Stratigraphic classification			mill. years	Rock type (not represented)	Sedimentary environments and geological events
QUATERNARY			0		
TERTIARY	PLIOCENE				
	MIOCENE			Clay Sand	Marine
	OLIGOCENE			Clay	Marine
	EOCENE		50		
				Tuff	Volcanic activity
	PALEOCENE			Sand, shale	Marine
		DANIAN			
CRETACEOUS	LATE	MAASTRICHTIAN			
		CAMPANIAN			
		SANTONIAN		Limestone	Open marine
		CONIACIAN			
		TURONIAN			
		CENOMANIAN	100		
	EARLY	ALBIAN		Marl	
		APTIAN		Shale	Marine
		BARREMIAN		Limestone	
					Transgression
		HAUTERIVIAN		(not represented)	Non deposition/erosion
		VALANGINIAN		(not represented)	
JURASSIC	LATE			Shale, siltstone, sandstone, limestone	Marine
			150		Transgression
	MIDDLE			(not represented)	Non deposition/erosion
					Regression
	EARLY			Sand, shale	Marine
					Transgression
TRIASSIC	LATE		200	Sandstone, siltstone, shale	Continental
	MID.				
	EAR		230		Regression
PERMIAN	LATE			Anhydrite, dolomite, shale	Marginal evaporitic
					Transgression
	EARLY			Conglomerate	Continental
CARBONIFEROUS			300	? (not represented)	
DEVONIAN			350	? (not represented)	
SILURIAN			400	Syerite, schist, marble	Caledonian orogeny

Chronostratigraphy after: F. W. B. van Eysinga, 3rd Edition, 1975.

TABLES

DRILLING HISTORY

Table 1

Drilling permit No.	Well No.	Location	Drilling period	Days on well	Total depth, TD, m	Formation at TD
2	25/11-1	59°10'53. "N, 02°24'49, "E	19.10.66-18.11.66, 14.04.67-09.06.67	88	2460	Silurian
32	25/10-1	59°11'21.98"N, 02°19'14.37"E	04.08.69-16.10.69, 09.07.70-03.08.70	100	2091	Paleocene
36	25/8-1	59°15'02.19"N, 02°29'38.18"E	28.04.70-03.07.70	67	2606	Triassic
43	25/10-2	59°09'38.37"N, 02°11'38.09"E	05.08.70-25.08.70, 02.05.72-08.07.72	89	3181	Silurian
45	25/10-3	59°12'58.96"N, 02°19'41.98"E	27.08.70-13.09.70	18	1919	Paleocene
47	25/11-2	59°13'01.59"N, 02°24'35.06"E	13.09.70-24.09.70	12	1823	Paleocene
48	25/11-3	59°10'36.19"N, 02°26'19.06"E	25.09.70-14.10.70	20	1858	Paleocene
49	25/11-4	59°09'38,77"N, 02°23'25.08"E	15.10.70-20.11.70	37	1896	Paleocene
106	25/11-5	59°12'10.25"N, 02°21'51.83"E	03.04.74-08.05.74	36	2163	Triassic

CASINGS

Table 2

Well No.	Depth to casing shoe, m — Casing diameter, inches: 30	20	13 3/8	9 5/8	7
25/8-1	162	390	1330	1881	—
25/10-1	161	380	1245	1369	—
25/10-2	164	397	1032	2259	—
25/10-3	173	386	386	942	—
25/11-1	179	363	1233	—	—
25/11-2	175	—	388	945	—
25/11-3	161	—	389	848	—
25/11-4	179	384	—	948	—
25/11-5	181	—	397	1397	1890

MUD PROGRAMME

Table 3

Mud type	Interval, m: 25/8-1	25/10-1	25/10-2	25/10-3	25/11-1	25/11-2	25/11-3	25/11-4	25/11-5
Seawater/Gel	138-378	134-997	130-396	144-402	181-370	140-175	137-396	137-188	Drispac from approximately
Seawater/Spersene/XP-20/Salinex	378-1310	997-1747	396-1036	402-951	370-2459	175-945	396-960	188-963	1000 to 1400 m. Lignosulphonate/
Fresh water/Spersene/XP-20	1310-2619	1747-2091	1036-3181	951-1921		945-1823	960-1856	963-1896	Gel/Sea water 1400 m to TD

Table 4

PRODUCTION TESTS

Well No.	Depth RKB, m	Choke	Recovery: Oil, m^3	Gas, m^3	GOR, m^3/m^3	Oil density, g/cm^3
25/8-1	1755-1762	1"	429	9,965	23.2	0.93
25/11-5	1750-1765	open	635	29,283	46.1	0.91

FORMATION INTERVAL TESTS

Table 5

Well No	Test No.	Depth RKB. m	Recovery: Fluids, 10^3 cm^3	Recovery: Gas, Sm^3
25/8-1	1	1757	8.5 oil, 23.0° API + 1.5 water	0.20
»	2	1783	20 water 1/2 0.5 mud	
»	3	1760	16.5 oil, 20.0° API + 0.5 mud	0.38
25/10-1	1	1789	13 water + 2 probably mud filtrate	
»	2	1778	11 water + 2 contam. mud filtrate	
»	3	1760	Failure	
»	4	1761	4 oil, 22°API + .2 mud. Seal fail. after 8 min.	0.11
»	5	1746	Failure	
»	6	1746	8.25 oil, 21.2°API + 3.5 gas cut mud	0.27
»	7	1701	1 oil + 15 oil cut mud. Almost instant seal failure	
»	8	1701	Failure	
»	9	1701	Failure	
»	10	1702	Failure	
»	11	1931	Failure	
»	12	1931	Failure	
25/10-2	1	2697	Oil scum + 5.5 water + 0.25 mud	
»	2	2702	9.75 water + 0.25 mud	
»	3	2690	8 water + 0.25 mud	
»	4	2685	8 mud	
»	5	3016	Failure	
25/10-3	1	1751	Failure	
»	2	1752	0.9 oil, 26°API + 2.3 gas and oil cut mud. Seal failure after 8 min.	0.05
25/11-1	1	1755	6 oil + 1 mud	0.32
»	2	1777	7 oil + 1 mud	0.53
»	3	2196	20 water + mud	
»	4	2007	20 water + mud	
»	5	1801	18.5 water + mud	
»	6	1873	9 water + mud	
25/11-2	1	1761	Failure	
»	2	1729	Failure	
»	3	1761	Failure	
»	4	1729	6.9 oil + 3.25 oil and gas cut mud	0.33
25/11-3	1	1744	0.3 mud. Seal fail. after 3 min. Tight formation.	
»	2	1817	Failure	
»	3	1740	0.3 mud. Very tight formation	
»	4	1783	Failure	
25/11-5	1	1742	Mud-scum of oil. Leak in hydraulic system	0.34
»	2	1744	4.55 oil, 23.5°API + 2.27 filtr. + 0.76 mud	0.03
»	3	1718	Traces of oil and filtrate + 1.9 mud	

AVAILABLE LOGS, DEPTHS IN M

Table 6

Log \ Well	25/8-1	25/10-1	25/10-2	25/10-3	25/11-1	25/11-2	25/11-3	25/11-4	25/11-5
GR	123- 382 1615-1867	123- 380	134- 397 2191-2259	136-1916		137- 945	141- 948	137- 947	150- 397
GR/BHC	390-2541	380-1382	397-3184	942-1916	180-2457	945-1819	948-1854	947-1883	397-2162
IES	390-2548	380-2090	397-3184	942-1918	362-2462	945-1823	949-1857	947-1885	
FDC	1329-2546	380-1074 1369-2090	1032-3184	942-1918	610-2461	945-1822	948-1857	947-1886	1398-2152
MLL-ML-C	390-1917	380-1074 1369-2090							
LL-7					362-2459				
DLL									397-2152
SNP			2258-3184						
CNL									1164-1859
CDM	390-2547	380-1074 1367-2093	1031-2173 2257-3183						
CAL	389-1345	268-1063	397-1043		1232-1718				
CBL						141- 919			
CCL									1676-1860
Mud	405-2604	386-2091		402-1920	370-2459	405-1823	402-1856	406-1896	190-2164
TS	21- 353					157- 922			198-1837

DITCH CUTTINGS

Table 7

Well No.	Sple. interval, m	Depth interval, m
25/8-1	9 1,5-3	415-1430 1430-TD
25/10-1*	9 3-6	386-1130 1130-TD
25/10-2**	3-9 3-6	397-2130 2130-TD
25/10-3	9-18 3-6	402-1670 1670-TD
25/11-1	6-9 3-6	153-1720 1720-TD
25/11-2	6-9	405-TD
25/11-3	9	402-TD
25/11-4	6-9	405-TD
25/11-5	3-9 3-6	192-1920 1920-TD

* Overlap due to side track 1064-1539 and 1664-1707 m

** Overlap due to side track 2139-2365 m

WET SAMPLES

Table 8

Well No.	Sple interval, m	Depth interval, m
25/8-1	3	2408-TD
25/10-1	10 3-6	1664-1728 1728-TD
25/10-2	3-9 3-6	397-2130 2130-TD
25/10-3	3-9	640-TD
25/11-1	no wet samples	
25/11-2	6-9	405-TD
25/11-3	9	402-TD
25/11-4	3-9	411-TD
25/11-5	3-9 3-6	192-1920 1920-TD

CONVENTIONAL CORES

Table 9

Well No.	Core No.	Interval, m	Rec. %	Lithology	Epoch
25/8-1	1	1677-1885	100	Clst	Eocene
	2	1724-1741	100	Sh, Tf	Paleocene
	3	1741-1759	100	Sh, Sst	Paleocene
	4	1759-1772	89	Sh, Sst	Paleocene
	5	1772-1790	100	Sst, Sh	Paleocene
	6	1829-1847	83	Clst	Paleocene
	7	2359-2377	90	Sst	?Triassic
25/10-1	1	1665-1682	67	Sh	Eocene
	2	1682-1692	97	Sh, (Sst, Tf)	Paleocene
	3	1692-1708	100	Sh, Tf, (Sst)	Paleocene
	4	1708-1721	100	Sh, Tf	Paleocene
	5	1721-1734	81	Sh	Paleocene
	6	1734-1739	100	Sh, Sst	Paleocene
	7	1739-1743	100	Sh, Sst	Paleocene
	8	1743-1747	100	Sh	Paleocene
	9	1731-1745	76	Sh, Sst	Paleocene
	10	1745-1758	74	Sh, (Sst)	Paleocene
	11	1758-1768	94	Sst, Clst	Paleocene
	12	1768-1786	100	Sst, Sh	Paleocene
	13	1786-1804	100	Sst, (Sh)	Paleocene
25/10-2	1	1975-1989	96	Sh, Sltst, (Tf)	Paleocene
	2	1989-2005	100	Sh, (Sst)	Paleocene
	3	2012-2028	92	Sh, (Sst)	Paleocene
	4	2028-2046	92	Sh, (Sst)	Paleocene
	5	2084-2102	90	Sst	Paleocene
	6	2102-2119	100	Sst	Paleocene
	7	2183-2191	81	Sst, Clst	Paleocene

Well No.	Core No.	Interval, m	Rec. %	Lithology	Epoch
25/10-2	8	2374-2378	100	Clst, Sst, (Ls)	Paleocene
	9	3007-3014	100	Clst, (Cgl)	Zechstein
	10	3014-3023	77	Cgl	Rotliegendes
	11	3023-3038	100	Cgl	Rotliegendes
	12	3038-3050	95	Cgl	Rotliegendes
	13	3050-3052	75	Cgl	Rotliegendes
	14	3177-3181	9	Syenite	Basement
25/10-3	1	1753-1768	100	Clst, (Tf, Sst)	Paleocene
25/11-1	1	991-1000	20	Cgl, Clst	Miocene
	2	1097-1105	0		Oligocene
	3	1105-1109	53	Clst/Sltst	Oligocene
	4	1727-1736	70	Sh/Clst, (Sst, Tf)	Paleocene
	5	1736-1742	74	Sh/Clst, Sst	Paleocene
	6	1742-1746	43	Sh/Clst, (Sst)	Paleocene
	7	1877-1889	69	Sst, Sh, (Ls)	Paleocene
	8	1889-1904	100	Ls, (Sh)	Paleocene
	9	1957-1961	100	Sh, Mrl	Cretaceous
	10	2014-2023	70	Sst, (Sh)	Jurassic
	11	2187-2198	100	Sst, Sltst, Clst	Triassic
	12	2350-2363	100	Sst	?Triassic
	13	2391-2395	85	Schist	Basement
	14	2448-2459	89	Marble	Basement
25/11-2	0				
25/11-3	0				
25/11-4	0				
25/11-5	1	1723-1725	100	Sh, Clst	Paleocene

Abbreviations

ab = above
abn = abundant
amr = amorphous
ang = angular
Anhd = Anhydrite
arg = argillaceous
Bar = Barremian
Bc = Breccia
bd = bedded
becom = becoming
BHC-Sonic = Bore Hole Compensated — Sonic Log
BHP = Bottom Hole Pressure
BHC-C = Bore Hole Compensated Sonic with Caliper Log
Biot = Biotite
Biv = Bivalve
bl = blue
Bld = Boulders
blk = black
Blm = Belemnite
brit = brittle
brn = brown
CAL = Caliper
Calc = Calcite
calc = calcareous
carb = carbonaceous
Cbl = Cobbles
CBL = Cement Bond Log
CDM = Continuous Dipmeter
Cgl = Conglomerate
Chk = Chalk
Chl = Chlorite
Cht = Chert
Cl = Clay
cl = clayey
Clst = Claystone
cmt = cement
col = colour(ed)
cont = contorted
conv = convolute
crs = coarse
crm = cream
csg = casing
DIR = Directional log
distr = distribute(ion)
dk = dark
dns = dense
Dol = Dolomite
dol = dolomitic
DLL = Dual Laterolog
dsk = dusky
Ech = Echinoid
f = fine
FDC = Formation Density log
fib = fibrous
filt = filtration
fis = fissile
fl = floor
Fld = Feldspar
frag = fragment
fri = friable
Foram = Foraminifera
Fos = Fossils
Gast = Gastropod
glac = glacial
Glc = Glauconite
glc = glauconitic
Gn = Gneiss
gn = green
Gran = Granules
gran = granular
GR = Gamma Ray log
Gr = Granite
grd = graded
grns = grains
Gvl = Gravel
gvl = gravelly
gy = grey
Gyp = Gypsum
h = horizontal
hd = hard
HDT = High Resolution Dipmeter
hom = homogeneous
IES = Induction Electrical Survey
ig = Igneous
Ill = Illite
incr = increasing
intbd = interbedded
irreg = irregular
Kaol = Kaolin
KB = Kelly Bushing
Kimm = Kimmeridgian
lam = laminated
LCM = Lost Circulation Material
Lig = Lignite
lig = lignitic
lith = lithic
LL = Laterolog
lns = lens
lse = loose
lt = light
m = medium
matr = matrix
met = metamorphic
mdst = mudstone
mic = micaceous
mid = middle
ML-C = Microlog — Caliper
MLL-C = Microlaterolog — Caliper
mod = moderate
Mrl = Marl
mrl = marly
mtl = mottled
Musc = Muscovite
NL = Neutron Log
nod = nodular
n.s. = no sample
o = oil
occ = occasional(ly)
olv = olive
orng = orange
pa = pale
Pbl = Pebble
pel = pellet
Pelc = Pelecypod
pkst = packstone
pk = pink
plast = plastic
Pleist = Pleistocene
por = porosity, porous
ppg = lb/gallon
predom = predominant
pres = pressure
psi = lb/sq.in
purp = purple
Pyr = Pyrite
pyr = pyritic
Qtz = Quartz
qtz = quartzitic
rec = recovery
red = red(dish)
Rk = Rock
rnd = rounded
S = Sand
s = sandy
sc = scattered
Sch = Schist
sec = second
sft = soft
Sh = Shale
Si = Silica
Sid = Siderite
Sks = Slickenside
Slt = Silt
slt = silty
Sltst = Siltstone
SNP = Sidewall Neutron Porosity
sph = sphericity
spic = spicules
SRS = Seismic Reference Survcy
srt = sorted
Sst = Sandstone
stnd = stained
strgs = strings
Styl = Stylolite
suc = sucrose(ic)
surf = surface
text = texture
TD = Total Depth
Tf = Tuff
tf = tuffaceous
tot = total
trsl = translucent
trsp = transparent
TS = Temperature Survey
v = vertical
visc = viscosity
vn = vein
vy = very
w = with
wkst = wackestone
wh = white
xln = crystalline
yel = yellow

Examples of quantitative expressions: (for sand)
(s) — slightly sandy, s — moderately sandy, $\underline{s}$ — very sandy

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