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Retrieval of three North Sea reservoir sandstones for mineralogical, petrographical, and chemical characterization

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REPORT

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Title:
Retrieval of three North Sea reservoir sandstones for mineralogical, petrographical, and chemical characterization

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Summary:
The steady increase in concentration of CO_2 in the atmosphere owing to combustion of hydrocarbons is considered a major factor contributing to global warming. Storage of CO_2 as subcritical gas in depleted oil and gas reservoirs and deep aquifers is considered a viable mitigation for reducing the impact of global temperature increase as a consequence of increased atmospheric CO_2 (Hitcheon 1999, Bachu 2008). More knowledge is needed to be able to assess:

- the quantity of CO_2 trapped as minerals during CO_2 storage
- the amounts of major and trace elements which might be mobilized as ions during CO_2 storage, and
- how the mechanical strength of different reservoir rocks might be affected during storage of CO_2.

These assessments have to be based on careful sampling, detailed mineralogical, petrographical and chemical analyses of reservoir and cap rocks followed by comprehensive testing and geochemical modeling of possible chemical reactions taking place in the subsurface during injection and storage of CO_2.

This report presents the:
- criteria used in selecting the collected reservoir sandstones,
- the depositional environments or sedimentary facies of the sandstones,
- detailed descriptions of locations, stratigraphic positions, lithology and well-logs of the formations,
- procedure and equipment used for sampling,
- specific lists of requested and sampled intervals, and
- sketch of plans for laboratory work during 2012.

Keywords:

North Sea	Reservoir Sandstones	Core Samples
Åre Formation	Sognefjord Formation	Frigg Formation
Heidrun field	Troll field	Frigg field

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1 INTRODUCTION

The steady increase in concentration of CO_2 in the atmosphere owing to the combustion of hydrocarbons is considered a major factor contributing to global warming. The storage of CO_2 as subcritical gas in depleted oil and gas reservoirs and deep aquifers is considered a viable mitigation for reducing the impact of global temperature increase as a consequence of increased atmospheric CO_2 (Hitcheon 1999, Bachu 2008). As an example on the feasibility of storage, about 1 Mt CO_2/yr have been injected into the reservoir sands of the Utsira Formation in the Sleipner field over the past fourteen years (Eiken et al. 2011).

A pilot study performed in 2010 on six reference samples of resrvoir and cap rock interacting with CO_2 laden saline formation waters (Ojala 2010, Sæther and Ojala, 2010) needs to be refined to be able to assess:

- the quantity of CO_2 trapped as minerals during CO_2 storage
- the amounts of major and trace elements which might be mobilized as ions during CO_2 storage, and
- how the mechanical strength of different reservoir rocks might be affected during storage of CO_2.

These assessments should preferentially be done on samples collected in the rock formations which are potential targets of CO_2 storage in the future and kept under in situ conditions until analyses, testing and modeling of their behavior, although this might be an insurmountable challenge as these are:

- unloaded during the imposed large pressure reduction when removed from the sedimentary basin to the core laboratory
- very friable clastic sandstones consisting of mineral aggregates kept together by small amounts of naturally formed cement and difficult to transport or operate on without destructing their internal structure, and
- chemically affected by sea water and drilling mud which have intruded into the interstitial waters of the samples during retrieval.

Nevertheless, these assessments have to be based on careful sampling, detailed mineralogical, petrographical and chemical analyses of reservoir and cap rocks followed by comprehensive testing and geochemical modeling of possible chemical reactions taking place in the subsurface during injection and storage of CO_2.

This report presents the:

- criteria used in selecting the collected reservoir sandstones,
- the depositional environments or sedimentary facies of the sandstones,
- detailed descriptions of locations, stratigraphic positions, lithology and well-logs of the formations,
- procedure and equipment used for sampling,
- specific lists of requested and sampled intervals, and
- sketch of plans for laboratory work during 2012.

We ended up with three reservoir sandstones in four wells from three oil fields representing three distinctly different sedimentary facies in the Norwegian sector of the North Sea and Norwegian Sea (see Section 4 of this report).

Primo 2011 we were in communication with NPD (Riis pers. comm.) about the possibility of retrieving core samples of reservoir sandstones from four different sedimentary facies, including eolian, which was discarded since core material is not available in the Norwegian sector. The selection of representative formations from four wells in three fields was based on in which areas formations with these facies have been found and to what extent wells in these areas have been cored and are stored in NPDs repository. The amount of supplementary data generated on production properties was also of importance for the selection of these samples.

Based on these criteria we have selected three different types of reservoir sandstones which are potential target reservoirs for storage of CO_2 in the future because they might genetically exhibit favorable mechanical and mineralogical properties for sequestering supercritical CO_2.

The reservoir sandstones will be assessed with respect to content of aqueous mobile cations available for potential chemical reactions with injected CO_2. The sandstones will be subject to weak acid attack and detailed petrographical description.

The three sedimentary facies which were considered are:

A. Fluvial and estuarine channel sands,
B. Coastal and shallow marine deposits, and
C. Sands deposited by turbidity currents.

The proposed analyses and characterization of these samples will supplement similar investigations performed on sandstones considered as potential targets for CO_2 storage on Danish territory (Weibel 2010, Kjøller 2010) and is a necessary step of action before reactions between CO_2-laden formation waters and their mineral matrices can be assessed through geochemical modeling (Knauss et al. 2005, Portier and Rochelle, 2005, Rochelle et al. 2004).

The description of depositional processes and textural characteristics of each sedimentary sandstone facies which follows below is taken from Reineck and Singh (1973) and literature references cited in capital letters here are referred to there.

1.1 Fluvial and estuarine channel sands.

The term "channel sands" (also called "channelized sands") refers to sands having been deposited in fluvial channels whereas the term "channel pattern" refers to their configuration in planar view. The channel pattern reflects channel adjustment to channel gradient and cross-section, and seems to be strongly controlled by the amount of sediment load and its characteristics plus the amount and nature of discharge (Reineck and Singh, 1973). The channel pattern can be assigned as straight, braided, or meandering (Reineck and Singh, 1973 referring to LEOPOLD et al. 1964 and LEOPOLD AND WOLMAN 1957). There is a continuous gradation between one type of channel pattern and another.

Sediments deposited by rivers have been classified in several different manners. Geomorphologists tend to distinguish between vertical and lateral accretion. Lateral accretion results from lateral migration of the channel, resulting in redistribution of the available sediment. This process is active in point bars. Vertical accretion denotes vertical deposition and upward growth of the flood plain by deposition of sediment from suspension according to Stokes law. This classification is too simple and has the drawback that even lateral accretion results in vertical growth, and it is not always possible to distinguish the two.

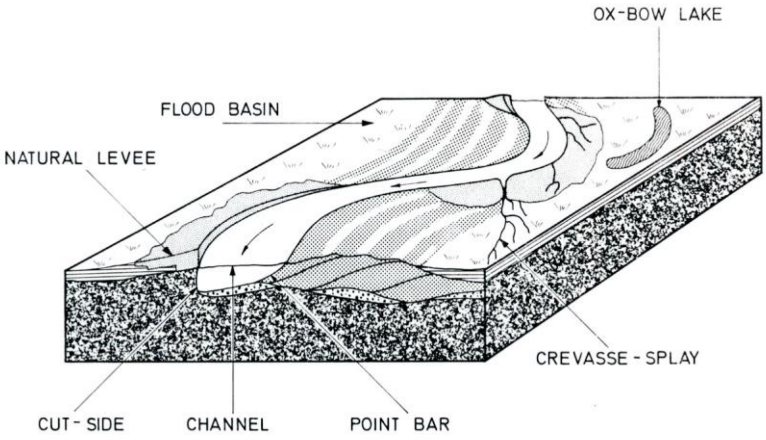

Figure 1. Block diagrammatic representation of various kinds of fluvial processes. After S*INGH 1972 (adapted from Reineck and Singh, 1973, Fig. 342, p. 23).*

For practical purposes, fluvially deposited sediments can be grouped into three major groups (Reineck and Singh, 1973, p. 230):

Fluvial deposits:

1. Channel deposits
2. Bank deposits
3. Flood basin deposits

The latter two are collectively referred to as "Flood plain deposits".

The characteristic features of various fluvial deposits such as "point bar deposits, "channel bar and braided river deposits", natural levee deposits", "crevasse splay deposits", "channel-fill deposits" , "flood basin" "flood plain deposits " and "alluvial fan deposits" are partially illustrated in Figure 1 and further covered in Reineck and Singh (1973, p. 231-263).

Channel sands with sealing caprocks are prevalent in deltas, where rivers meet large bodies of water, ie. lakes, the seas, the oceans. The most important factors for the development of a delta, are a large supply of sediments by streams and subsidence in the area of deposition. (Reineck and Singh 1973). The configuration of a delta is controlled by several factors (Reineck and Singh 1973, see also MORGAN 1979).

Factors controlling delta configuration:

1. Coastal morphology
2. Incoming waves
3. The degree of coastal transport of sediment in relation to the sediment transport by distributaries
4. Tidal range

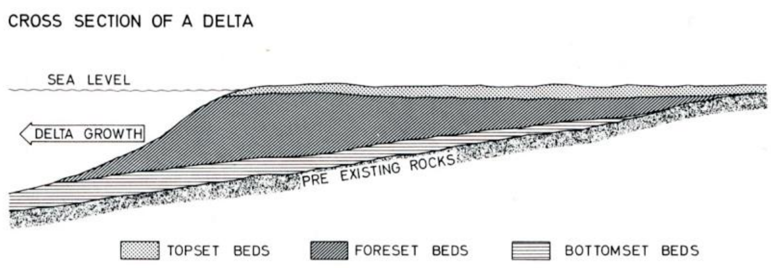

Figure 2. Schematic illustration of the construction of a delta body (adapted from Reineck and Singh, 1973, Figure. 388, p. 264).

A delta (Figure 2) can be divided into topset, foreset, and bottomset beds:

Topset beds of a delta are mainly made up of marsh depositis and delta-front silts and sands. River channel deposits and natural levee deposits are present together with crevasse splay deposits. These various sediments are associated with each other in a very complicated way and their lateral and vertical boundaries are both gradational and sharp.

Foreset beds are made up of pro-delta silty clays and rather coarse sand, silt and clay deposits formed off the major deltaic distributaries, including delta front gullies (Reineck and Singh, 1973 refers to SHEPARD 1956b).

Bottomset beds are made up of offshore clays under the influence of active deltas. In the Mississippi-delta such offshore clays are up to ten meters thick (Reineck and Singh, 1973, p. 265).

Marginal deposits are transitional deposits between bottomset deposits and deposits of the subsurface, which were deposited before the building of the delta. Unconformities are most common in sedimentary units deposited in ancient marginal-marine shelf environments. GRABAU (1913), in his book "Principles of Stratigraphy", established the concept of lithofacies relations used in the 3D subsurface mapping, in which an isopach map is made of each formation. The building up of deltas has taken place throughout history. However, the recognition of delta deposition in sedimentary basins may be very difficult, because for definite recognition of a delta, one also have to establish the regional variation in depositional environments. Economically, delta deposits are most important, since oil and gas are often associated with them (Reineck and Singh, 1973, p. 279).

1.2 Coastal sand and shallow marine deposits.

The hydrographic conditions on the shore and on the shelf are very different; so are the sediments and their characteristics (Figure 3). However, they are somewhat interrelated; the sediments of the shore change laterally into shelf sediments and in a prograding sequence coastal sediments follow on top of shelf sediments in a vertical succession. In a sense, the differentiation between coastal sand and shelf mud takes place in the rivers that bring sediment to the sea. Sand is transported mainly by rolling and saltation up to the shore line. Silt and clay is transported in suspension, by-passing the coastal sand and being transported into deeper parts, i.e. the shelf.

As a result of repeated transgressions and regressions of shallow seas in geologic times, an extensive record of ancient coastal and shelf sediments is present on the present-day continents. Together with deltaic sediments they probably compose a major part of sedimentary rocks.

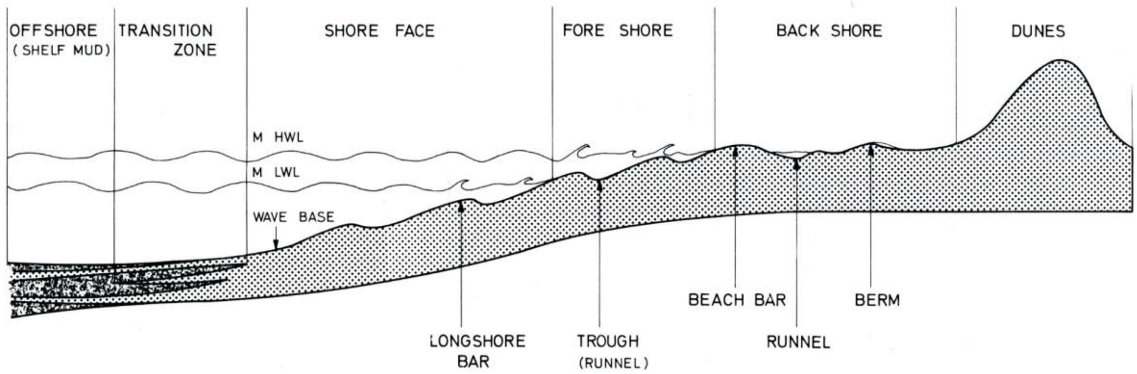

Figure 3. Schematic representation of the terminology of the various geomorphic units of a beach profile. Various geomorphic features of a beach as well as transition to shelf mud are shown. The terminology is mainly based on EMERY (1960) (adapted from Reineck and Singh 1973, Figure. 410, p. 28).

In general, one can recognize the following types of coasts (Reineck and Singh, 1973, p. 281):

1. Mainland coast
   Coasts with spit development
   Coasts with development of chenier
2. Barrier island coast
3. Coasts with cliffs
4. Coasts with sunken morphology (fjords etc.)
5. Coasts with bioherms of warm seas, e.g. coral reefs, i.e. coastal reefs and atoll.

The sand body of coastal sand is usually tens of meters to several hundred meters broad, several kilometers long, and 10 to 20 m thick. Along its long axis a coastal sand might be cut across by river deltas, estuaries, bays, lagoonal outlets and tidal inlets. The lower boundary of a coastal sand body is usually uneven. This is because tidal inlets change their position by migrating laterally or because new tidal inlets are made by breaking through the coastal sand. Thus, below the coastal sand, broad filled-up tidal channels may be present. In a progradational sequence of the mainland beach, tidal flat and lagoon deposits are missing.

During sea-level regression (i. e. progradation), the following units in a vertical sequence is produced from top downwards/laterally:

1. Alluvium
2. Marshes peat and coal
3. Coastal sand
4. Transition zone
5. Shelf mud

During transgression, in a retrograde sequence, the arrangement is just the reverse (Reineck and Singh, 1973, p. 282 refers to OOMKENS 1967).

A typical beach (strand) on a sea coast can be divided into several units – sand, dunes, backshore, foreshore, and shoreface (Figure 3, see also Reineck and Singh, 1973, Fig. 462, p. 316), showing a vertical sequence with variation in sedimentary facies as a result of a prograding coast of Licola, Gulf of Gaeta, Italy).

1.3 Sands deposited by turbidity currents

A turbidity current denotes a high-density current flowing down a subaqueous slope, or spreading horizontally because suspended sediment gives it a higher density than the surrounding clear water. A sedimentary deposit resulting from the deposition of a turbidity current is called a turbidite deposit, or a turbidite (Figure 4).

Where ever two bodies of water of different densities are in contact with each other, the water body of higher density tends to flow and spread out below the dense one. Such density currents are well known in oceans, because of accompanying differences in temperature or salinity (Reineck and Singh, 1973, p.383).

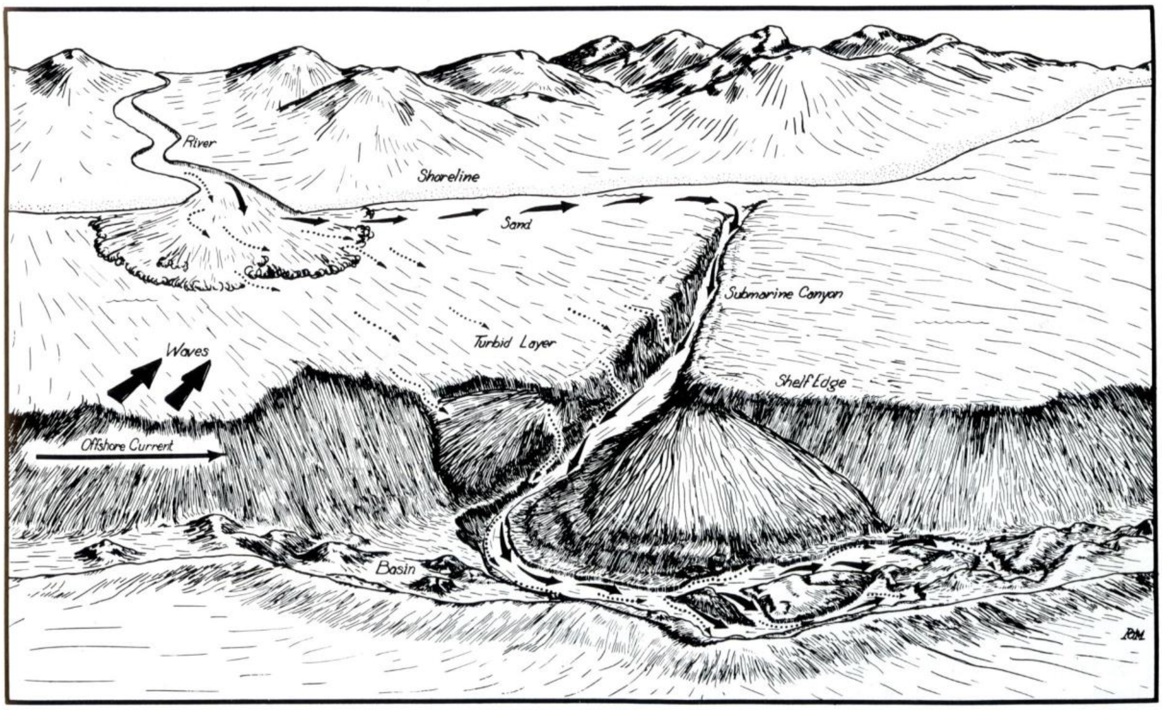

Figure 4. Schematic representation of the routes of transportation of sand (solid arrow) and mud (dotted arrow) from river mouth to deep-sea basin floor. After MOORE *1969 (adapted from Reineck and Singh 1973, Fig. 541, p. 379).*

The resulting turbidite deposit comprises graded bedding and current ripple laminated beds alternating with pelagic beds. There is a different fauna in the turbidite and adjacent pelagic beds. Besides, the sole markings are abundantly developed on the bottom of the sandy turbidite layers (Reineck and Singh 1973, p. 385).

BOUMA (1962) made a comprehensive study of ancient turbidites and developed a turbidite facies model, now known as the Bouma-sequence (Reineck and Singh 1973, Fig. 545, p. 383). An ideal, single turbidite sequence is made up of five units with specific sedimentary structures in the following chronological order from bottom to top in Figure 5:

Graded interval (T1).
Lower Interval of Parallel Lamination (T2).
Interval of Current Ripple Lamination (T3).
Upper Interval of Parallel Lamination (T4).
Pelitic Interval (T5).

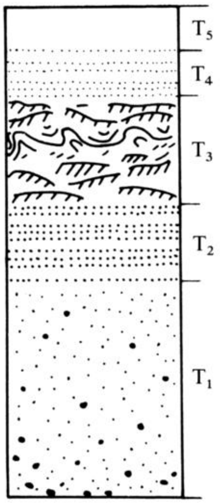

Figure 5. Schematic representation of turbidite facies model (Bouma sequence), showing five units each with characteristic sedimentary structures (after BOUMA 1964, in Reineck and Singh 1973, Fig. 545, p. 383).

BOUMA (1962) pointed out that this complete sequence has been found only in the thicker layers of flysch deposits. Usually the sequence is incomplete, and the topmost part, bottom part, or both are missing (Reineck and Singh 1973, p. 384).

2 LOCATION OF SELECTED STRATIGRAPHIC FORMATIONS

In considering these three sedimentary facies, which constitute most of the reservoir sandstones in the Norwegian sector of the North Sea, we focused on getting samples from the following stratigraphic formations in four wells (i.e. two production wells and two exploration wells) within three different hydrocarbon fields, i.e. Heidrun, Troll, and Frigg as shown in Figure 6:

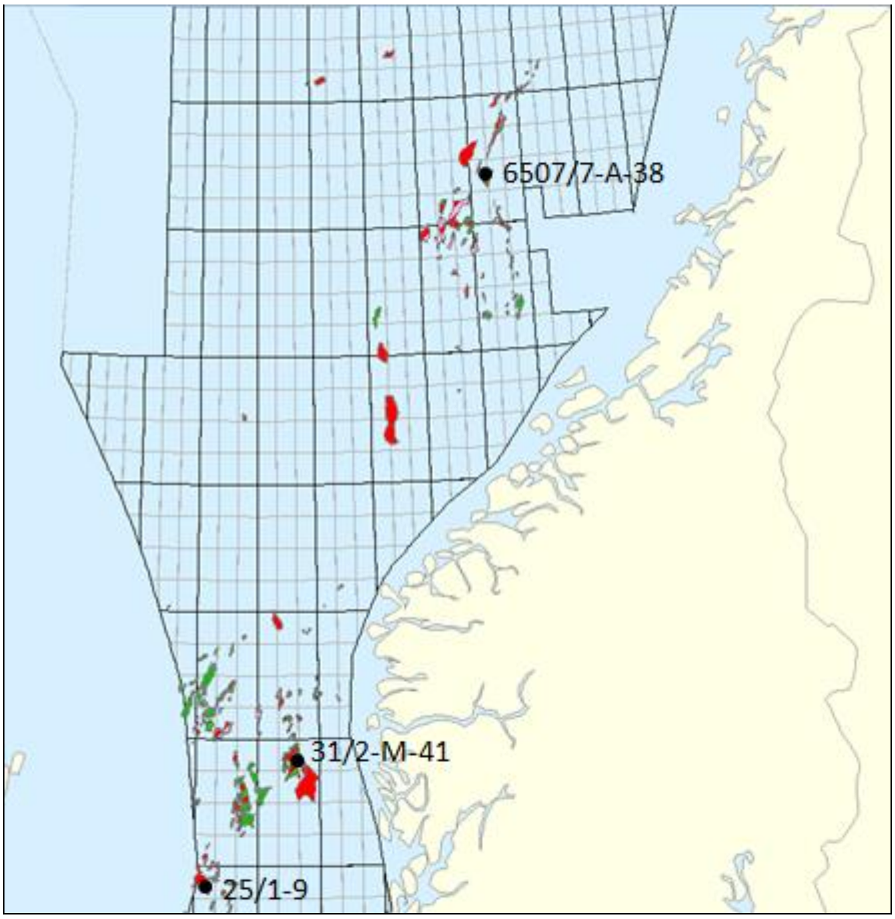

Figure 6. Map showing location of wells from which selected stratigraphic formations with reservoir sandstones in the North Sea – Norwegian sector were sampled.

2.1 Fluvial and estuarine channel sands: Åre Formation (Heidrun).

Figures 7 and 8 and the text below is sourced from NPD Bulletin No.4 (p.10):

Name:
From the Norwegian word for oar. This formation corresponds to the informal term Hitra formation ("the coal sequence or H1-1) together with the lower part of the Aldra formation (H1-2).

Well type section:
6507/12-1 (Saga Petroleum), coordinates 65 07'01.62"N 07 42'42.61" from 2920 m to 2412 m (Figure 7 in NPD Bulletin No.4). Two cores, 26.2 m recovery.

Well reference section:
6407/1-2 (Statoil), coordinates 64 47'50.61"N, 07 02'23.76"E, from 4548 m to 4221 m (Figure 8 NPD Bulletin No.4). No cores.

Thickness:
508 m in the type well. Generally between 300 m and 500 m.

Lithology:
Alternating sandstones and claystones are interbedded with coals and coaly claystones. The claystones are grayish or locally red brown and noncalcareous to very calcareous. The sandstones are grayish, very fine to coarse-grained and predominantly moderately to poorly sorted. The coals in the type well are dark brown to black, vitreous, brittle and locally pyritic.

Basal stratotype:
The base is defined directly underneath the lowermost coal bed identified on the sonic log. In the type well the resistivity log increases slightly and changes to a somewhat less nervous pattern at the transition into the Åre Formation.

Lateral extent and variation:
The formation is present in all areas drilled in the Haltenbanken –Trænabanken region but seismic data indicate that it is truncated in positive areas such as the Nordland Ridge. The upper part of the formation contains a laterally continuous mudstone interval; this has a generally uniform thickness, but thins slightly to the north.

Age:
Rhaetian to Pliensbachian.

Depositional environment:
Coastal plain to delta plain deposits with swamps and channels pass upwards into marginal marine facies. Individual coals can be up to 8 m thick. More proximal lithofacies contain less coal and coarser sandstones. Shallow drilling to the east shows conglomerates which are probably laterally equivalent to the Åre Formation (Bugge et al. 1984).

Correlation:
The formation is partially equivalent to the Statfjord Formation int the North Sea, to the combined upper Fruholmen, Tubåen and Nordmela formations int the Hammerfest Basin and to the Kap Stewart Formation of esstern Greenland. The Åre Formation has a lower sand content than the Statfjord Formation in the northern North Sea.

(Above text sourced from NPD BulletinNo.4, p. 10)

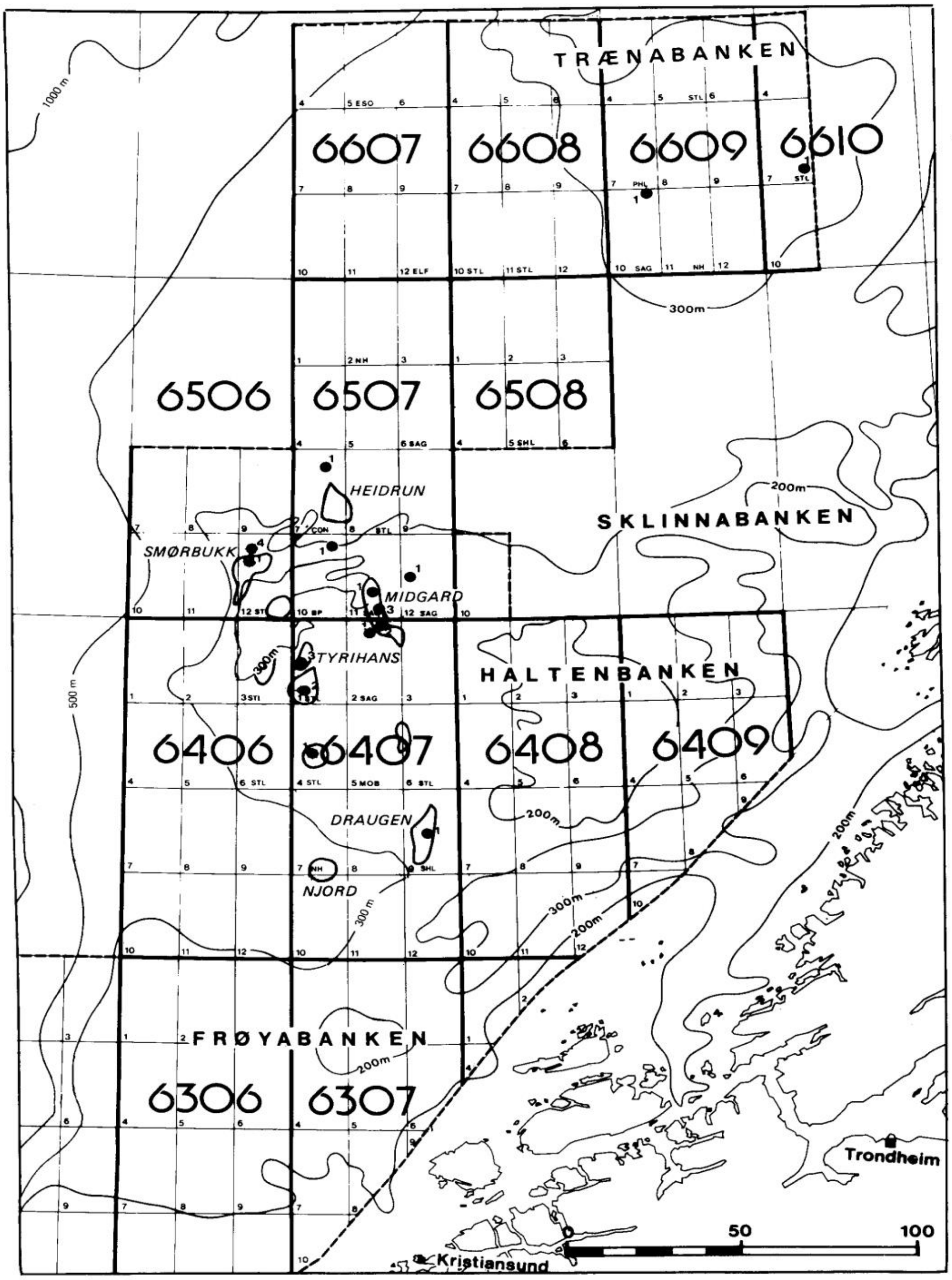

Fig. 4 Location of wells (black dots) used as type or reference sections in the Haltenbanken-Trænabanken area

Figure 7. Map of Haltenbanken-Trænabanken area (NPD Bulletin No.4, Fig. 4).

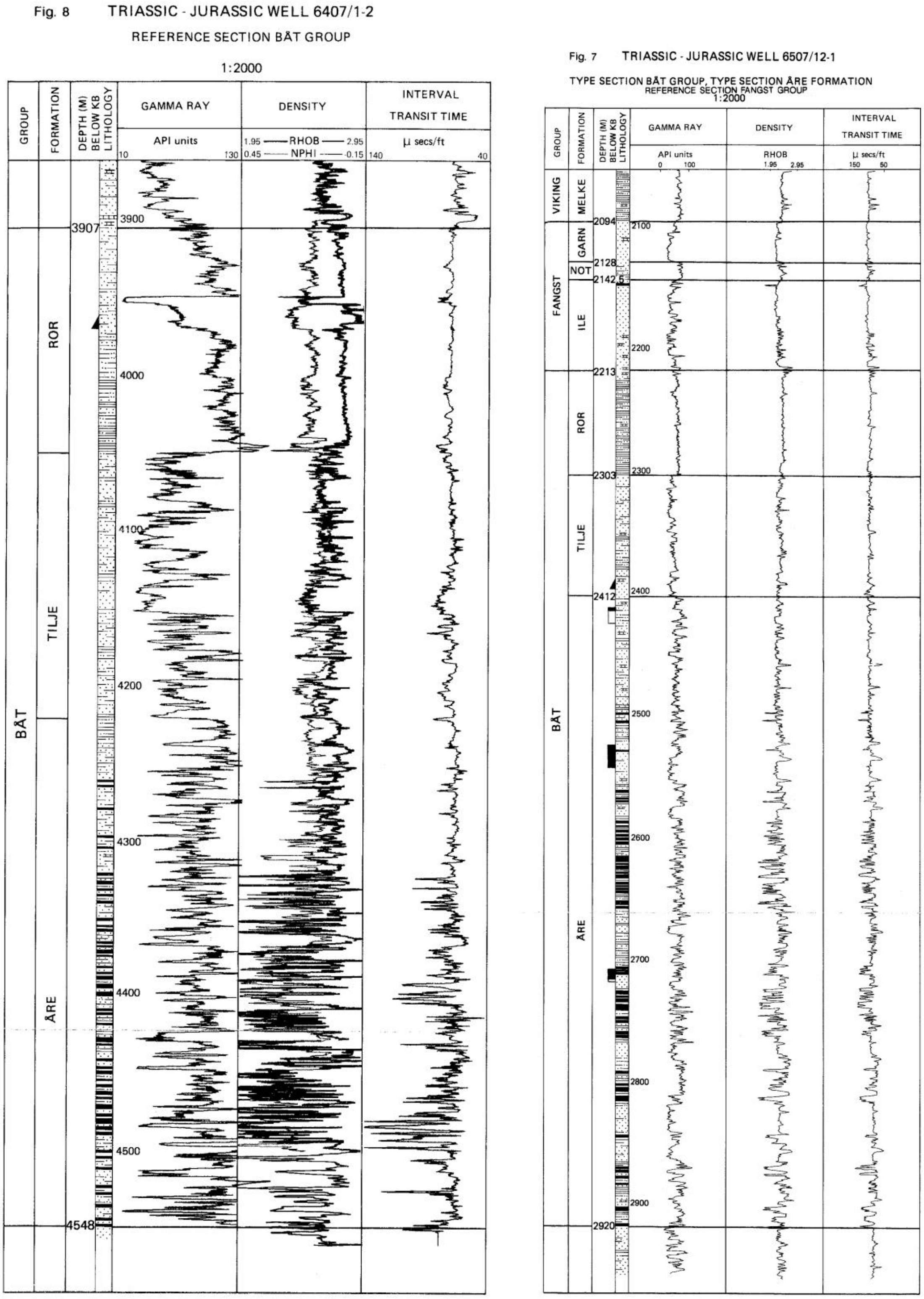

Figure 8. Well logs of reference/type section of Åre Formation for well 6407/1-2 (NPD Bulletin No.4, Fig. 8) and well 6507/12-1 (NPD Bulletin No.4, Fig. 7).

2.2 Coastal sand and shallow marine deposits: Sognefjord Formation (Troll).

Figures 9 and 10 and the text below is sourced from NPD Bulletin No.3 (p. 30):

Name:
After a fjord on the west coast of Norway, adjacent to the type area in Quadrant 31.

Well type section:
Norwegian well 31/2-1 (Shell), from 1440 m to 1531.5 m, coord N 60 46'19.16", E 03 33'15.87" (NPD Bulletin No.3, Fig. 21).

Well reference section:
None at present.

Lithology:
The formation consists of sandstones and sands, grey-brown in colour, medium to coarse grained, well sorted and friable to unconsolidated. Locally, the formation is weakly micaceous with minor argillaceous and carbonaceous beds. Bioclastic material and occasional cemented bands occur locally.

Boundaries:
The Sognefjord Formation has a gradational lower boundary due to the interdigitation of sandstones with the siltstones which form the upper part of the Heather F. The base is chosen immediately below the first continuous sandstone, often shown by reduction in gammaray intensity. The formation has a homogeneous "blocky" log motif in the lower half. The upper half comprises several cycles displaying "funnel-shaped" gamma ray log motifs coincident with coarsening upward sequences. The top of the formation is marked by a distinct lithological break into claystones or shales, which in the type well are the overlying Draupne Formation.

Distribution:
The Sognefjord Fm has only been clearly recognized in the Troll Field area, where it is the major reservoir interval.

Age:
Oxfordian to Kimmeridgian/Volgian.

Depositional environment:
The formation was deposited in a coastal-shallow marine environment.

(Above text sourced from NPD BulletinNo.3, p. 30)

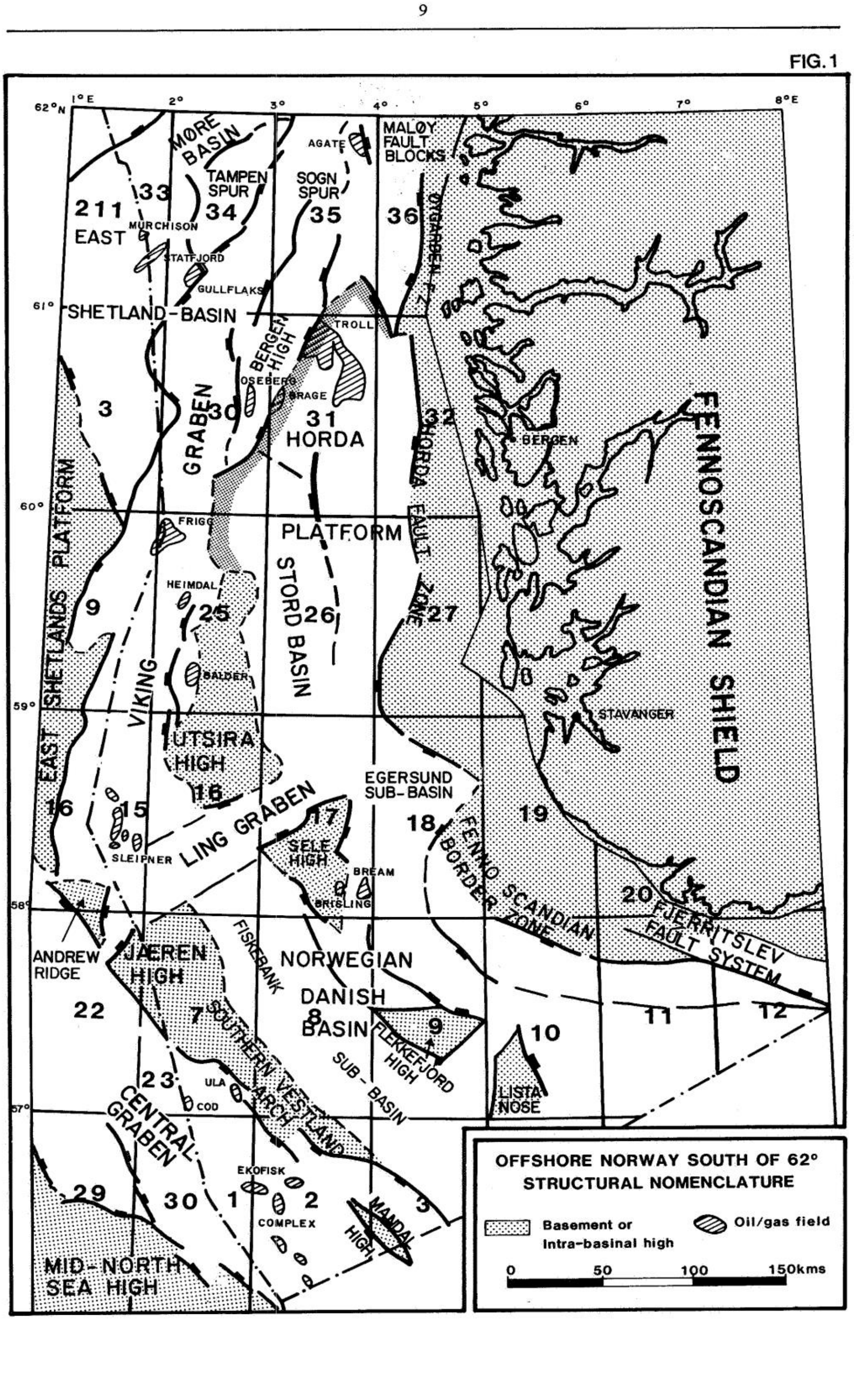

Figure 9. Map with block areas and structural nomenclature North Sea south of 62° north (NPD Bulletin No.3 Fig. 1, p. 9).

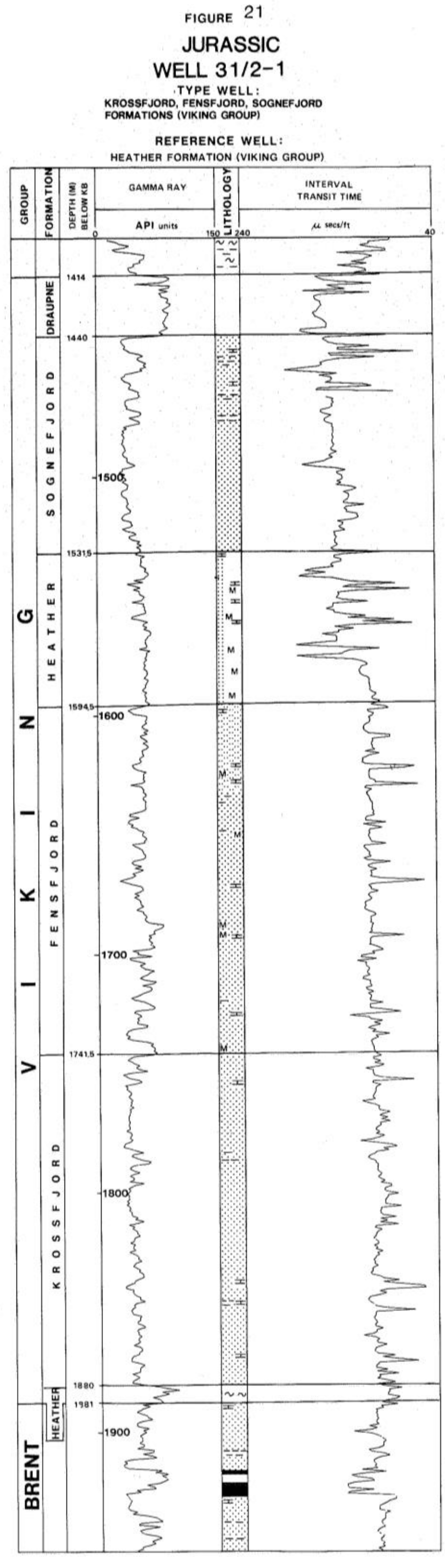

Figure 10. Reference well logs of Heather Formation with Sognefjord Formation above in well 31/2-1 (NPD Bulletin No.3 Fig. 21).

2.3 Sands deposited by turbidity currents: Frigg Formation (Frigg).

Figures 11 and 12 and text below is sourced from NPD Bulletin No.5, p.49.

Name:
Named by Deegan & Scull (1977) after a Norse goddess, the wife of Odin.

Well type section:
Norwegian well 25/1-1 from 2115 to 1836 m, coordinates N 56 53' 17.40", E 02 04' 42.70" (Figure 62). 42 m of cores (1868-1910 m).

Well reference section:
Norwegian well 30/7-6 from 1923 to 1783 m, coordinates N 60 29'29.82", E 02 03'26.14" (Figure 63). No cores.

Thickness:
The formation has a thickness of 279 m in the type well and 140 m in the reference well. A depocentre with maximum thickness of approximately 300 m lies in Norwegian block 25/1.

Lithology:
The formation consists of sandstones with some lenses and streaks of silty claystone. The sandstones are poorly consolidated, light brown, micaceous and carbonaceous, and very fine to medium, occasionally coarse grained. Some layers have a calcareous cement. Traces of glauconite are present. The silty claystones are green to grey and carbonaceous.

Basal stratotype:
The lower boundary normally shows a decrease in gamma-ray intensity and an increase in velocity from the Balder Formation into the Frigg Formation (Fig. 62 in NPD Bulletin No.5).

Characteristics of the upper boundary:
The top of the formation is placed where the sandstones give way to light grey to brown, occasionally green claystone of the Hordaland Group. The boundary is seen on logs as an increase in gamma-response and a decrease in velocity (Fig. 62 in NPD Bulletin No.5).

Distribution:
The Frigg Formation is found in the southwestern part of the quadrant 30, the northwestern part of quadrant 25, and in adjacent areas in the UK sector. The Frigg sands of the Beryl and Bruce Fields just extend into the Norwegian sector at about 59 30'N.

Age:
Early Eocene.

Depositional environment:
The Frigg Formation was deposited as submarine fans, by gravity flows. The mode of deposition led to the formation varying in thickness over short distances. The source was the East Shetland Platform to the west.

(Above text sourced from NPD Bulletin No.5, p.49)

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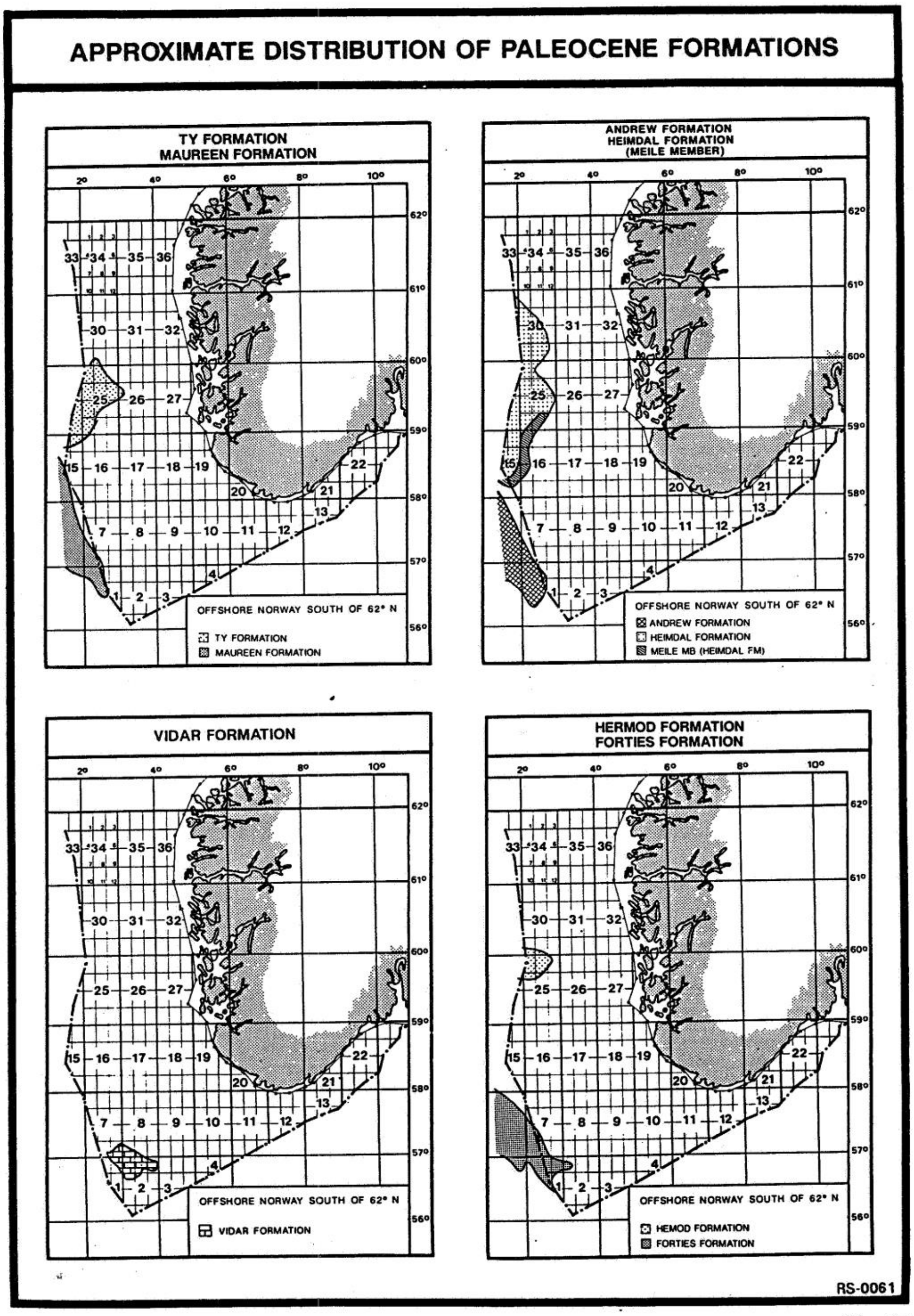

Fig. 47

Figure 11. Map with block areas and approximate distribution of Paleocene formations in North Sea south of 62° north latitude (NPD Bulletin No.5 Fig. 47).

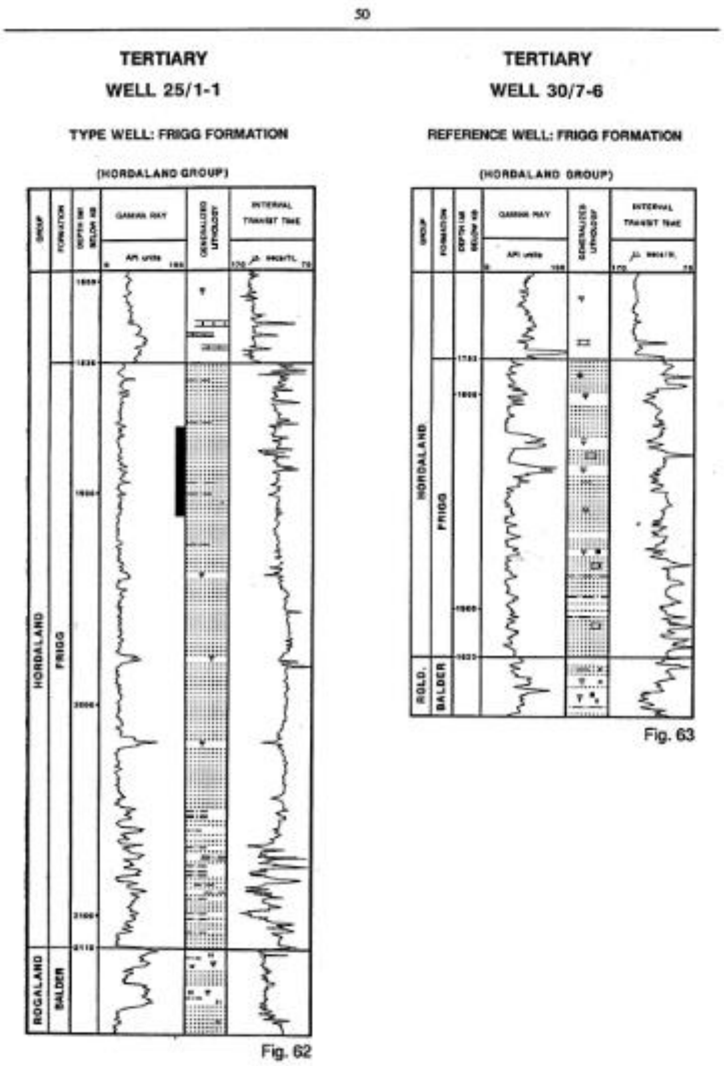

Figure 12. Frigg Formation type logs in well 25/1-1 (NPD Bulletin No.5, Fig. 62). and reference well logs in well 30/7-6 (NPD Bulletin No.5, Fig. 63).

3 APPLICATION PROCESS PRECEEDING COLLECTION OF CORE SAMPLES

Based on this research we submitted an application for the release of sample material from one well, alternatively two, located within the A) Heidrun (channel sands), B)Troll (shallow marine/coastal sands), and C) Frigg (turbiditic sands):

The application sent September 28, 2011, to the NPD is shown below (quotation in Norwegian):

> "SØKNAD OM UTTAK AV PRØVEMATERIALE FOR MINERALOGISK OG KJEMISK KARAKTERISERING
>
> Som en del av BIGCCS-prosjektet, søkes herved om å få ta ut fem til sju prøver à inntil 25 cm^3 fra hver av følgende tre brønner/brønnområder:
>
> A) 6507/7-A38 (Heidrun), intervall 2750-2833 m. Alternativt 6507/7-A27.
> B) 31/2-M41 (Troll), intervall 1497-1564 m, alternativt 31/2-D10H, intervall 1502-1563 m.
> C) 25/1—A14 (Frigg), hele intervallet kan være aktuelt for prøvetaking (54 m), alternativt 25/1-9.
>
> Resultatene av undersøkelsene vil bli rapportert til Oljedirektoratet.
> Sent/Sign: Ola M. Sæther,
>
> Forsker Ola M. Sæther, Ph. D.
> NGU
> 7491 Trondheim
>
> Epost: ola.sather@ngu.no
> Tlf.: +47-7390400/4372
> Fax: +47-73921620
> Mob.: +47-95842061"

In a later email (dated 17/10-2011) this request was delimited further by specifying the following core sample intervals within each well which would be targeted for sample retrieval:

Brønn 31/2-D10H:
1) 1535-1539m
2) 1549-1554m
3) 1558-1563m

Brønn 31/2-M41:
1) 1520-1525m
2) 1528-1533m
3) 1546-1551m

Brønn 6507/7-A38:
1) 2764-2768m
2) 2829-2833m
3) 2833-2837m
4) 2837-2841m
5) 2841-2845m

Brønn 25/1-9:
1) 2059-2063m
2) 2064-2067m
3) 2078-2083m
4) 2093-2097m
5) 2098-2102m

4 EQUIPMENT USED AND SAMPLES COLLECTED

On November 9 and 10, 2011, Ola M. Sæther and Bjørn W. Wissing travelled to NPD in Stavanger to sample the permitted intervals. Our contact person was Odd Kristiansen who had pulled the cores from wells 31/2-D10H and 31/2-M41 (Troll field), 6507/7-A38 (Heidrun), and 25/1-9 (Frigg). He gave us access to the sawing room and tripod (for photography) and provided us with basic supplies and wrapping paper and bubble-plastic. In addition we had brought:

Pre-numbered labels
Knife
Handlens
Ruler
Aluminium wrapping foil
Cotton
Small plastic bags
Plastic beakers (100ml) with yellow lids
Glad-plastic wrapper
Flash-light
Camera

We were soon made aware of the fact that some of the sandstones are very friable and prone to disaggregation. This forced us to be extra careful in cutting out the samples within the given intervals using a clean knife in the cores and minimizing the use of water during sawing. The samples were air-dried before individual wrapping with cellophane-wrap and storing them in plastic beakers as one piece with size about 2 x 5 cm (for thin-section preparation) and three pieces, each with size about 1 cm^3 (for chemical analyses).

The following samples were collected in the following chronological sequence (number indicates depth below sea bottom in meters with one decimal followed by weight in grams):

Tuesday 9/11-2011 @0930-1130 (collected from well 25/1-9 from Frigg field):

1) 2059.6 – 118
2) 2065.6 – 108
3) 2079.5 – 90
4) 2093.6 – 135
5) 2098.6 – 121
6) 2094.4 – 82

Tuesday 9/11-2011 @1200-1430 (collected from well 6507/7-A38 from Heidrun field):

7) 2767.4 – 108
8) 2832.7 – 123
9) 2832.4 – 138
10) 2837.3– 117
11) 2842.5 – 116

Wednesday 10/11-2011 @0855-1045 (collected from well 31/2 – D10H from Troll field):

12) 1537.6 – 83
13) 1552.4 – 120
14) 1552.2 – 90

Wednesday 10/11-2011 @0955-1045 (collected from well 31/2 – M41 from Troll field):

15) 1519.5 – 92
16) 1528.3 – 86
17) 1548.1 - 124

The samples were transported as part of regular luggage in a hard-shell suitcase.

5 LABORATORY WORK PLANNED FOR 2012

We plan to assess the potential mobilization of cations in aqueous solutions under weak acid attack of these sampled reservoir sandstones to mimick potential chemical reactions which may take place when CO_2 is injected into the interstitial porewaters of these formations. This will be done in batch mode with a contact-time of less than one hundred hours. The results will be compared to those obtained by 7N HNO_3 acid extraction and detection will be done by ICP-AES. It is assumed that this will yield a maximum estimate of cations which are leachable in weak acid. This work will be performed during the first five months of 2012.

Furthermore we plan a comprehensive petrographic analysis on polished thin sections using transmitted light. The thin sections of the rocks will be impregnated with blue epoxy for quantification of porosity and its texture in 2D. Half of each polished section will be stained for easy recognition of carbonates (calcite, dolomite, etc.). A modal analysis will be performed for mineralogical quantification. More specific mineralogy and paragenetic relations between minerals will be assessed by investigation of polished thin-sections using a scanning electron microscope (SEM). This includes quantification of types of quartz and feldspar minerals. X-ray diffraction (XRD) spectrograms will be generated to identify qualitatively and semi-quantitatively minerals present in bulk samples. This work will be carried out during the first eight months of 2012.

Table 1. Work plan for 2012.

Task	**Number of samples**	**Period**
Weak acid attack	Maximum 17	Jan 2012
Chemical analyses	Maximum 17	Feb 2012
Calculations/Assessments	Maximum 17	April-May 2012
TS preparations	Maximum 17	Jan 2012
TS petrographic descriptions	Maximum 17	Mar 2012
TS modal analysis	Maximum 17	April-May 2012
SEM mineral characterization	Maximum 17	Jun-Aug 2012
Reporting	All	Sept-Oct 2012

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