

Review of Site Surveys, Store Fisker Banke area, Danish North Sea

Review of the Quaternary geology presented in
a series of Site Surveys in the southern
Store Fisker Banke area,
Danish North Sea

Peter Konradi



Review of Site Surveys, Store Fisker Banke area, Danish North Sea

Review of the Quaternary geology presented in
a series of Site Surveys in the southern
Store Fisker Banke area,
Danish North Sea

Peter Konradi

Contents

Review of the Quaternary geology presented in a series of Site Surveys in the southern Store Fisker Banke area, Danish North Sea	3
The Site Surveys	3
The Geology	3
The summary	5
General stratigraphy	5
Correlation	6
Remarks	6
References	7
Annex A	9
Site Survey: CECILIE-1	10
Site Survey: CONNIE-1	11
Site Survey: D-1x.....	12
Site Survey: ELNA-1.....	13
Site Survey: FRANCISCA-1	14
Summary: Site Survey FRIDA-1.....	15
Site Survey: L-1x	16
Site Survey: NINI-1	17
Site Survey: NINI-2	18
Site Survey: NINI-3.....	19
Site Survey: NOLDE-1.....	20
Summary: Site survey SANDRA-1	21
Summary: Site survey SANDRA-site A (alternative)	22
Summary: Site survey SANDRA-site C (alternative)	23
Summary: Site survey SIRI-1	24
Summary: Site survey SIRI-2	25
Summary: Site survey SIRI-3	26
Summary: Site Survey VANESSA-1	27
Annex B	28
Summery and comparison of the sites	

Review of the Quaternary geology presented in a series of Site Surveys in the southern Store Fisker Banke area, Danish North Sea

In the last years several hydrocarbon appraisal wells were drilled in the "Siri Fairway" area south-east of the Store Fisker Banke, Great Fisher Bank, in the Danish North Sea.

This trend started with Statoils hydrocarbon discovery at the SIRI-1 site in 1995.

A "Site Survey "or" Pre-drilling Hazard Survey" precedes the drillings. Copies of these reports to the operator are found in the Subsurface archive of the Geological Data Centre of GEUS. These reports include predictions of the expected geology at the drilling site and form the basis for the present report. The report concentrates on the Quaternary geology at the sites.

This report includes company reports registered at the Subsurface archive of the Geological Data Centre at GEUS by 1. December 2001.

The Site Surveys

Reports from the following sites are included in the present review (Fig. 1):

CECILIE-1,
CONNIE-1,
FRANCISCA-1,
FRIDA-1,
NINI-1, NINI-2 & NINI-3
NOLDE -1
SANDRA-1, SANDRA-alternative A & SANDRA-alternative C
SIRI-1, SIRI-2 & SIRI-3,
VANESSA-1

Less comprehensive studies were performed at the sites D-1 and L-1 about 30 years ago and are included in the present review.

A site survey at the ELNA-1 site from 1980 is also included.

A report on a survey the FLOKI-1 site, drilled in September 2000, was not found in the GEUS Subsurface Archive by December 2001. Nor was a site survey report on the SIRI-4 site, drilled in June 2001, but the area most probably is covered by the SIRI-3 site report.

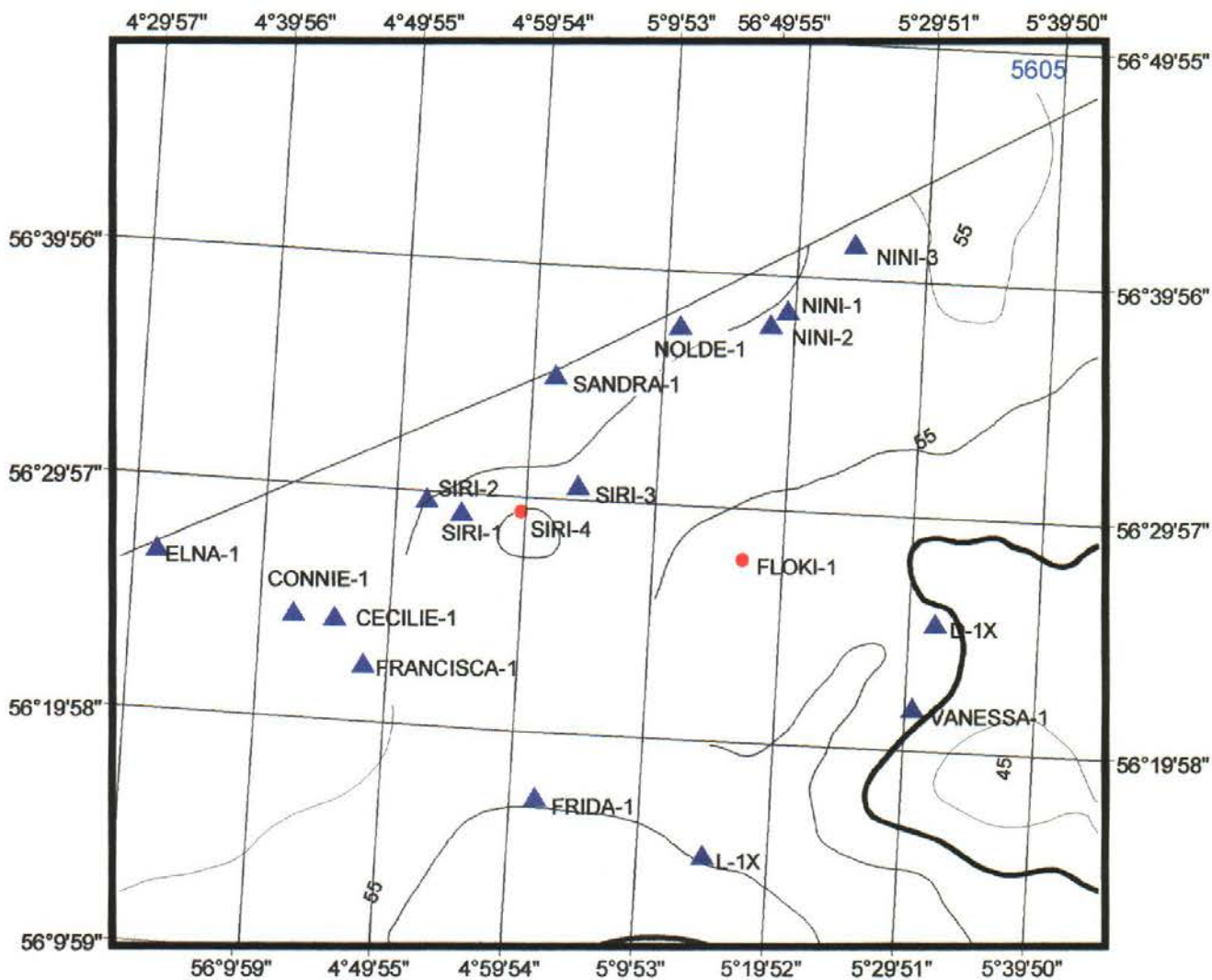
The Geology

The understanding of the geology at the sites is primarily based on interpretations of seismic investigations. At several sites this is supplemented by shallow vibrocores, gravity cores or sea bed sampling.

A summary of the units and reflectors identified at the sites is found in Annex A.

Some of the reflectors are not discernible in all surveys and some of the units are not identified.

An abbreviated summary and comparison of the sites is found in Annex B.
 The following summary therefore is a "best fit", valid for most of the surveys.



Skala: 1:550000

0 4 8 Kilometers



GEUS

Kort fremstilling:
 GEUS/Lotte Møller/april 2002.

Figure 1. Well location map, western part of Danish North Sea, with sites mentioned in text indicated in blue triangles. Red dots indicate sites, where site survey reports are missing in the GEUS Subsurface Archive. Bathymetric data from Kort & Matrikelstyrelsen.

The summary

In the area the **seafloor** seems to be practically flat or shoaling slightly to the south-east. The sea bed is made up of silty, fine sand, in a few cases fine to medium sand, often with shell patches.

At all sites an upper unit, **unit 1**, of loose silty, fine sand is specified often with shells. This fine sand often becomes clayey in ~0.5-1 m depth and is followed by dense sand, with occasional clayey bands. The base of the unit is often specified to be a lag deposit.

Reflector 1, the base of unit 1, is mostly slightly undulating at 1.5 - 6 m below sea bed. In places it includes a shallow channel reaching down to 15 m below sea bed.

Unit 2 is often presumed to be stiff clay, mostly with silt and sand interbeds, or it is expected to be fine to medium sand. Internal channelling down to 50 m below sea bed is indicated.

The base of the unit, **reflector 2**, is an undulating erosional surface around 9 - 15 m below sea bed including channels down to ~50 m below sea bed.

Unit 3 is interpreted to be medium to fine sands with thin clays. Channelling events are indicated.

Reflector 3, base of unit 3, is a marked erosion surface around 35 - 40 m below sea bed with channels reaching down to 160 m below sea bed.

Unit 4 consists of channel fill sands with clay and includes lag deposits. The channels reach more than 300 m below sea bed and are eroded into the Neogene at the base of the Quaternary.

Reflector 4, the base of unit 4, is an undulating erosional surface at depth of 62 - 180 m below sea bed in places, or it is subhorizontal and difficult to discern from reflectors in lower part of unit 4.

Unit 5 is made up of well-layered sediments, probably mainly sand.

The **reflector 5**, at the base of this unit, is the **base Quaternary reflector**. It can at some sites be difficult to discern from reflectors in the lower, sandy part of unit 5 as well as from the upper part of the underlying sandy Neogene of supposed Upper Pliocene age.

General stratigraphy

The geological structures found in the area can best be correlated to the stratigraphy of the central North Sea established in the British sector north of 55° N (Stoker, Long & Fyfe 1985, emended by Gatliff et al. 1994). This geology is outlined below:

The youngest formation, **The Forth Formation**, is divided into two members. **The Whitethorn member** is made up of fine sand with moderate silt content, and its base is of erosional character. This member is of Holocene age. **The Fitzroy member** consists of soft to firm interlaminated silty clay, and often appears as channel fills. The base is irregular with sometimes deep erosive features. The age is Late Weichselian.

The Coal Pit Formation forms fill in channels cut in Saalian time. It consists of interbedded muddy sands and pebbly muds or sandy silts to very fine to fine sands. The base is irregular and erosional. The age is interpreted to be Late Saalian and Eemian to Early Weichselian.

The Fisher Formation consists of interbedded hard, overconsolidated clays and silty sands. It shows parallel subhorizontal reflectors with small intraformational channels. Up to 70 m thickness. The base is a distinct planar erosion surface. The age is suggested to be Saalian.

The Ling Bank Formation comprises dense silts and silty sands with interbeds of sand and clay. It is partly channel-fill. Possibly Cromerian Complex or Late Elsterian to Early Saalian in age.

The Aberdeen Ground Formation comprises hard silty muds interbanded with sands. The age is Lower Pleistocene and the uppermost partly Cromerian Complex to Elsterian.

Correlation

In the present area the unit 1 seems to compare to the Whitethorn member of the central North Sea stratigraphy. Some of the channel fills at the base of reflector 1 may represent the Fitzroy member.

The unit 2 is expected to represent the Coal Pit Formation.

The unit 3 is suggested to represent the Fisher Formation.

The unit 4 is suggested to represent the Ling Bank Formation.

The unit 5 is supposed to represent the Aberdeen Ground Formation.

The correlation is indicated in the Table below:

BGS central North Sea stratigraphy		Age	Present summary
Forth Formation	Whitethorn Member	Holocene	Unit 1
	Fitzroy Member	Late Weichselian	Channels at base of reflector 1
Coal Pit Formation		L Saalian ? E Weichs. ?	Unit 2
Fisher Formation		Saalian	Unit 3
PLing Bank Formation		L Elsterian ? E Saalian	Unit 4
Aberdeen Ground Formation		E Pleistoc. ? Cromerian	Unit 5

Remarks

In vibrocores delivered to GEUS by DONG E & P A/S from the NINI-2 and the NINI-3 site surveys laminated, dense, fine to very fine sand with disseminated fine organic particles is identified (Konradi and Czako 2002). This sand most probably forms part of unit 2 and is thought to compare to the Twente Formation of the southern North Sea (Cameron *et al.* 1989). The Twente Formation is of Weichselian age. The Twente Formation is also identified in the Dutch sector but not in the British sector of the central North Sea (Jeffery *et al.* 1990).

A rough correlation between the Formations established in Dutch sector and the British sector South of 55° and the British sector North of 55° is given in the table below (from Gatliff *et al.* 1994):

Dutch sector and British sector south of 55°	British sector north of 55°	
Nieuw Zeeland Gronden Formation	Forth Formation	Whitethorn Member
Elbow Formation		
Botney Cut Formation		Fitzroy Member
Twente Formation	Not identified	
Bolders Bank Fm. & Dogger Bank Fm.	Wee Bankie Fm. & Marr Bank Fm.	
Eem Formation	Coal Pit Formation	
Cleaver Bank Formation	Fisher Formation	
Egmond Ground Formation	Ling Bank Formation	
Yarmouth Road Formation	Aberdeen Ground Formation	

The survey at the proposed site 5605/13-C location (SANDRA alternative) is situated at the edge of major deep channel eroded from unit 4 into the Neogene. This channel is comparable to the channels mapped by Salomonsen (1995) and Huuse & Lykke-Andersen (2000). The present channel shows several generations of infill and also is expected to have a complicated history of channel infill. Comparable deep channels are also indicated at the NINI-1, NINI-2, NINI-3 and NOLDE-1 sites.

References

- Cameron, T.D.J., Schüttenhelm, R.T.E. & Laban, C. 1989: Middle and Upper Pleistocene and Holocene stratigraphy in the southern North Sea between 52° and 54° N, 2° to 4° E. *In*: Henriot J.P. & de Moor, G. (Eds.) *The Quaternary and Tertiary geology of the Southern Bight, North Sea*.
- Huuse, M. & Lykke-Andersen, H. 2000: Overdeepened Quaternary Valleys in the eastern Danish North Sea: Morphology and origin. *Quaternary Science Reviews* 19, 1233-1253.
- Gardline Surveys 1980: Chevron Oil Company of Denmark. ELNA site survey. July 1980. DGU Report File no 5463.
- Gardline Surveys 1995: Statoil Denmark A/S. 5604/20-A. Pre-drilling hazard survey. September 1995. Survey report. GEUS Report File no.13022.
- Gardline Surveys 1998: Statoil Efterforskning og Produktion A/S. Danish 5605/13-B {5605/13-2 (SANDRA-1)} site. Pre-drilling hazard survey. Survey report. GEUS Report File no. 15420.
- Gardline Surveys 1998: Statoil Efterforskning og Produktion A/S. Danish 5605/13-A Site. Pre-drilling hazard survey. Survey report. GEUS Report File no. 15536.
- Gardline Surveys 1998: Statoil Efterforskning og Produktion A/S. Danish 5605/13-C Site. Pre-drilling hazard survey. Survey report. GEUS Report File no. 15538.
- Gardline Survey Limited 2000: Dong Operatørselskab i-s. NINI-1 (5605/10-1) site survey. May 2000. Survey report. GEUS Report File no 17936

- Gardline Surveys Limited 2000: Clam Petroleum Danske BV, Danish Block 5605/23, VANESSA-1 Site Survey, May 2000, Survey Report. GEUS Report File no 17950.
- Gardline Surveys Limited. 2000: DONG Efterforskning og Produktion A/S. CECILIE & CONNIE Site Surveys. August - September 2000. Survey report. GEUS Report File no 18138 & 18139.
- Gardline Survey Limited 2000: Dong Efterforskning og Produktion A/S. NINI-2 site survey. Danish Block 5605/10. October 2000. Survey report. GEUS Report File no 18108.
- Gardline Survey Limited 2001: Dong Efterforskning og Produktion A/S, NINI-3 site survey, Danish Block 5605/10, November 2000, Survey report. GEUS Report File no 18109
- Gardline Surveys Limited. 2001: DONG Efterforskning og Produktion A/S. AUGUSTA-1 Site Survey. Danish Block 5604/22-5. January 2001. Survey report. GEUS Report File no. 18187.
- Gatliff, R.W., Richards, P.C., Smith, K., Graham, C.C., McCormac, M., Smith, N.J.P., Long, D., Cameron, T.D.J., Evans, D., Stevenson, A.G., Bulat, J. and Ritchie, J.D. 1994: The geology of the central North Sea. British Geological Survey. United Kingdom Offshore Regional Report.
- George Wimpey & Co., Limited, 1967: Gulf Oil Company of Denmark. Proposed oil rig locations in Danish concession area of the North Sea. Report on geophysical and sea bed sampling survey. DGU Report File no 279.
- Jeffery, D., Graham, C., Wright, S., Laban, C. and Schüttenhelm, R.T.E. 1990: Dogger. Sheet 55° N - 2° E. Sea bed sediments and Holocene geology. Holocene en oppervlakesedimenten. British Geological Survey and Rijks Geologische Dienst, 1:250.000 Series.
- Konradi, P. And Czakó, T. 2002: Geological description of vibrocores from the Nini-3 site, Store Fisker Banke, Danish North Sea, Danmarks og Grønlands Geologiske Undersøgelse, Rapport 2002/2.
- Salomonsen, I. 1995: Origin of deep buried valley system in Pleistocene deposits of the eastern Central North Sea. In: Michelsen, O. (Ed.), Proceedings of the Second Symposium on: Marine Geology - Geology of the North Sea and Skagerrak. Geological Survey of Denmark, Series C 12, 7-19.
- Seateam (UK) Limited 1996: Dansk operatørselskab i-s (Danop). SIRI-2 site survey. Danish continental shelf. Block 5605/20. Rig site survey. Final report GEUS Report File no 13353.
- Seateam (UK) Limited 1996: Dansk operatørselskab i-s (Danop). SIRI-3 site survey. Danish continental shelf block 5605/13. Rig site survey. Final report GEUS Report File no.13332.
- Seateam (UK) Limited 1997: Dansk Operatørselskab i-s (DANOP). Site Survey. North Sea Danish Sector. Site 5605/9-1. Survey report. GEUS Report File no.14023.
- Stoker, M.S., Long, D. & Fyfe, J.A. 1985: A revised Quaternary stratigraphy for the central North Sea. BGS Report 17,2.

Annex A

Site Survey: CECILIE-1

The CECILIE-1 site survey was conducted simultaneous with the CONNIE-1 site survey.

Position: 56° 24' 20.15" N 04° 45' 41.15" E

Site designation: 5604/20-5

Seabed: 61 m water depths, essentially flat, shoaling very slightly eastward, fine, silty sand.

Geology (seismic interpretation):

Unit 1: SAND, fine, silty, with clay and peat intercalation's, 1-10 m's thickness

Reflector 1: irregular surface at 4 - 10 m below seabed, with channel in eastern end, possibly gravel lag at base

Unit 2: CLAYS, stiff with silt interbeds, and SANDS with several channelling events with basal coarse lag deposits, 50 - 100 m thickness.

Reflector 2: undulating erosional surface down to 160 m below seabed

Unit 3: interbedded SANDS and CLAYS

Reflector 3: slightly undulating surface, at 180 - 188 m below seabed.

Unit 4: interbedded SANDS and CLAYS

Reflector 4: erosional surface at 334 m below seabed: base Quaternary, on gently, westerly dipping Plio-Miocene strata

Cores: 1 vibrocore at site location: 2.30 m of silty, fine sand, grey

1 vibocore between Cecilie and Connie sites: 0 - 4.1 m: silty, fine sand, grey with thin clay laminae

Source: Gardline Surveys Limited. 2000: DONG Efterforskning og Produktion A/S. CECILIE & CONNIE Site Surveys. August - September 2000. Survey report. GEUS Report File no 18138 & 18139.

02. May 2001

Peter Konradi

Site Survey: D-1x

Position: 56° 25' 29.7" N 05° 31' 52.2" E

Site designation: 5605/19-1

Seabed: ~54 m water depths, gently sloping to northwest, fine to medium sand, occasional shells.

Geology (seismic interpretation):

Unit 1: sand, fine to medium, occasional shells, ~7 m.

Reflector 1: undulating, ~10 - 15 m below seabed

Unit 2: thin clay

Reflector 2: erosional with channels, 10 - 20 m, max. 35 m

Unit 3: dense fine sand, 12 m

Reflector 3: erosional event, ~20 m, max. 40 m below sea bed

Unit 4:

Reflector 4: at base: erosional channel > 60 m

Dredge samples: 9 samples: sand, fine to medium with occasional shell fragments
1 sample: sand, fine to medium with pockets of clayey, sandy silt

Source: George Wimpey & Co., Limited, 1967: Gulf Oil Company of Denmark. Proposed oil rig locations in Danish concession area of the North Sea. Report on geophysical and sea bed sampling survey. DGU Report File no 279.

08. June 2001

Peter Konradi

Site Survey: ELNA-1

Position: 56° 25' 30" N 04° 32' 37.5" E

Site designation: 5604/19-1

Seabed: 62 m water depths, fairly flat, fine sand.

Geology (seismic interpretation):

Unit 1: fine sand

Reflector 1: 04 - 0.5 m below sea bed

Unit 2: finely banded clays and sands

Reflector 2: irregular horizon, 1.5 - 2 m below sea bed

Unit 3: stiff boulder(?) clay, includes channel structures and erosion surfaces,

Reflector 3: uncertain, ~60 m

Unit 4: marine clays with sand, subhorizontal indistinct reflectors

Reflector 4: distinct reflector ~210 m below sea bed, possible base Quaternary

Cores: 5 cores: penetration: <0.10 - 1.17 m:

0 - max. 0.61 m: sand, fine, occasional silty, shell debris

- 1.17 m: fine sand with clay bands and clay with bands of fine sand

Source: Gardline Surveys 1980: Chevron Oil Company of Denmark. Elna Site Survey.
July 1980. DGU Report File no. 5463.

30. May 2001

Peter Konradi

Site Survey: FRANCISCA-1

A tie-line to FRIDA-1 exists: little variation laterally, except for Quaternary channelling.

Position: 56° 22' 28.978" N 04° 48' 04.824"E

Site designation: 5604/24-1

Seabed: 59.5 m water depths, essentially flat, shoaling to the southeast, fine sands with small percentage of silt, clay and shells,

Geology (seismic interpretation):

Unit 1: SANDS, fine, with occasional shelly or gravelly pockets, possible gravel accumulations at base

Reflector 1: 3.5 - 8 m below seabed

Unit 2a: SAND, with possible gravel, 2 - 8 m thick

Reflector 2a: semi-continuous, undulating

Unit 2b: sand, with possible gravel, sign of reworking and channelling, 5 - 20 m thick

Reflector 2b: undulating nature with signs of erosion and channelling

Unit 3: SAND, 10 - 40 m thick, several internal channels with gravel, reworking,

Reflector 3: uneven, channelling at base,

Unit 4: SANDS with occasional clay, some internal erosional channels (with gravel), horizontal to subhorizontal reflectors, ~250 m thickness.

Reflector 4: ~302 m below seabed, base Quaternary, westerly dipping unconformity on Pliocene.

Cores: 5 vibrocores were recovered within 1 km of site location:

0.10 - 0.60 m top layer: slightly silty to clayey sand, fine and medium, with shells

- max. 3.75 m: sand, brown, fine or fine-medium, few shell fragments

Source: Seateam (UK) Ltd.1998: Dansk Operatørselskab i-s (DANOP). Digital/Analogue site survey. Danish continental shelf 5604/24-1. Survey report. GEUS Report File no.15476.

25. April 2001

Peter Konradi

Summery: Site Survey FRIDA-1

Position: 56°17' 14.264" N, 05°01'50.097" E

Site designation: 5605/21-2

Seabed: 55 m water depth, slightly silty, fine sand, shoaling slightly to the southeast.

Geology (seismic interpretation):

Unit 1: including seabed: silty fine sand with abundant shell

Reflector 1: at 7 m below sea bed.

Unit 1a: sand 1 - 2.5 m thickness, acoustically transparent

Reflector 1a: at 8.2 m below sea bed.

Unit 1b: sand, 1.5 - 5.5 m thickness, sub-horizontal internal reflectors

Reflector 1b: at 11.8 m below sea bed.

Unit 2: sand, 11 m thickness, sand with possible gravel, chaotic structure, internal reflectors, localised cross bedding

Reflector 2: at 23 m below sea bed.

Unit 3: sand with thin clay, chaotic structures with numerous small channels

Reflector 3: at 222 m below sea bed

Unit 4: marine sands and clay, 78 m thickness, horizontal to subhorizontal reflectors, Cromerian age

Reflector 4: at 300 m below sea bed: base Quaternary

Cores: Three gravity cores were taken within 100 m from site location.

Recovery: 0.25 - 0.50 m: silty, fine sand with abundant shell fragments

Source: Seateam (UK) Ltd. 1997: Dansk Operatørselskab i-s (DANOP), Digital/Analogue SiteSurvey, Danish Cotinental shelf 5605/21-2. GEUS Report File no 14722.

21. March 2001

Peter Konradi

Site Survey: L-1x

Position: 56° 15' 09.7" N 05° 14' 55.2" E

Site designation: 5605/21-1

Seabed: 59 m water depths, flat, silty, fine sand.

Geology (seismic interpretation):

Unit 1: sand, fine, silty, 5.5 m m.

Reflector 1: undulating, 6 - 13 m below seabed

Unit 2: dense sand

Reflector 2: faint reflector, ~ 30 m.

Dredge samples: 10 samples: sand, fine, silty with submarine life
1 sample: clayey, sandy silt with submarine life

Source: George Wimpey & Co., Limited, 1967: Gulf Oil Company of Denmark. Proposed oil rig locations in Danish concession area of the North Sea. Report on geophysical and sea bed sampling survey. DGU Report File no 279.

08. June 2001

Peter Konradi

Site Survey: NINI-2

Tie-line to NINI-1 exists.

The survey area borders on the NINI-1 site survey.

Position: 56° 37' 52.89" N 05° 17' 59.00" E

Site designation: 5605/10-2

Seabed: 59 m water depth, practically flat, silty, fine sand.

Geology (seismic interpretation):

Unit 1: sand, fine, silty - fine to medium, 2 - >3.5 m's

Reflector 1: irregular erosional surface, including channel, at 2 - 8 m below sea bed, possibly lag

Unit 2: clayey or silty sands, 8 - 30 m thick

Reflector 2: undulating erosional surface partly indistinct, 6.5 - 15 m below sea bed

Unit 3: sand and clay, several channel features, with lag deposits,

Reflector 3: channels down to 100 m below sea bed

Unit 4: sand and clay

Reflector 4: weak reflector ~180 m below sea bed, possible base Quaternary

Cores: 1 vibrocore: 0 - 2 m: silty clay, sandy in upper 0.27 m, shelly
- 3.45 m: silty, fine sand, shelly with bed of .25 m of medium to coarse sand,
- 3.8 m: laminated fine and very fine sand, slightly silty

Source: Gardline Survey Limited 2000: Dong Efterforskning og Produktion A/S. NINI-2 site survey. Danish Block 5605/10. October 2000. Survey report. GEUS Report File no 18108.

Konradi, P. and Czakó, T. 2002: Geological description of vibrocores from the Nini-3 site, Store Fisker Banke, Danish North Sea. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2002/2, Appendix.

18. May 2001

Peter Konradi

Site Survey: NINI-3

Tie-line to NINI-1 exists.

Position: 56° 41' 32.03" N 05° 24' 12.33" E

Site designation: 5605/10-3

Seabed: 58 m water depth, practically flat, silt and sand, patches of gravelly, very shelly, fine to coarse sand, megaripples, $\lambda = 2 - 2.5$ m, $h = 0.16 - 0.26$ m, WSW - ENE crests.

Geology (seismic interpretation):

Unit 1: sand, fine, silty, change in shell/gravel content at ~1.5 m

Reflector 1: irregular erosional surface, <1 - 3.5 m below seabed, with channels below, possibly shelly, gravelly layer.

Unit 2: sand prone, ~ 3 - 6 m thick

Reflector 2: undulating erosional surface, partly indistinct, 4.5 - 9.5 m below sea bed, 2 channel features at base

Unit 3: sand and clay, several deep channel features, with lag deposits,

Reflector 3: base channeling unit, 70 m - 250 m b. sea bed, cutting into Neogene

Unit 4: subhorizontal reflectors, possible sand and clay

Reflector 4: unconformity 117 - 147 m below sea bed, possible base Quaternary

Cores: 4 vibrocores (comp.): 0 - ~0.35 m: clay, silty with toplayer of sand, fine-medium
- max. 2.10 m: sand, fine-medium-coarse, w. shells, occasional gravel at base
- 4.25 m: sand, fine and very fine, laminated, disseminated fine organic particles

1 vibrocore: 0 - 0.20 m: sand, fine
- 0.30 m: clay
- 4.60 m: sand, medium, shells

Source: Gardline Survey Limited 2000: Dong Efterforskning og Produktion A/S. NINI-3 site survey. Danish Block 5605/10. November 2000. Survey report. GEUS Report File no 18109.

Konradi, P. and Czakó, T. 2002: Geological description of vibrocores from the Nini-3 site, Store Fisker Banke, Danish North Sea. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2002/2.

01. June 2001

Peter Konradi

Site Survey: NOLDE-1

A tie line to the SIRI-2 site exists

Position: 56° 37' 37.872" N 05° 11' 01.989" E

Site designation: 5605/9-1

Seabed: 61 m water depths, essentially flat, shoaling to the south-east, clayey sand.

Geology (seismic interpretation):

Unit 1: CLAYS, soft, sandy and sand, dense, with clay bands, 4.3 - 11.5 m's

Reflector 1: irregular erosional surface at 3.5 - 8 m below seabed

Unit 2: SAND, dense, 8 - 30 m thick

Reflector 2: undulating erosional surface at 14 - 35 m below seabed

Unit 3: channel fill sediments of marine sand, above firm clays, interbedded with thin sands, above coarse sand grading into firm clays and sands, basal gravel lag deposit,

Reflector 3: irregular erosional surface, possibly base Saalian, north-east to south-west trending channel, base at 140 - 324 m below seabed, in part base Quaternary

Unit 4: channel infill of sand with gravel horizons, 0 - 220 m,

Reflector 4: erosional surface at 230 - 320 m below seabed into westerly dipping Pliocene: base Quaternary

Cores: 6 vibrocores were recovered:

0 - (max.) 0.19 m: clayey, fine to medium sand, dark olive

- (max.) 1.3 m: soft, silty clay with sandy laminae, shells, dark olive

- (max.) 2.6 m: silty, fine to medium sand, slightly shelly, dark olive

- (max.) 3.45 m: fine to medium sand, occasional slightly silty, few shells, yellowish

Source: Seateam (UK) Ltd. 1997: Dansk Operatørselskab i-s (DANOP). Site Survey. North Sea Danish Sector. Site 5605/9-1. Survey report. GEUS Report File no. 14023.

30. April 2001

Peter Konradi

Summary: Site survey SANDRA-1

Present survey is conducted simultaneously with SANDRA-A and SANDRA-C surveys

Tie-lines to SIRI-1 and to SIRI-3 exists, as well as to SANDRA-A and SANDRA-C.

Position: 56° 35' 13.6" N 05° 01' 34.8" E

Site designation: 5605/13-1

Seabed: 63 m water depth, predominantly flat, slightly shoaling to south and east, fine, silty sand to clayey sand.

Geology (seismic interpretation):

Unit 1: Sand, fine, silty, becoming clayey sand to soft clay at 0.5-1.0 m

Reflector 1: undulating, 1.5 - 3.0 m, channel: till 7.5 m below seabed

Unit 2: Presumed stiff clay, ~8 m

Reflector 2: unclear, 9 - 15 m below seabed,

Unit 3: Presumed dense medium to fine sand, ~ 17 m

Reflector 3: marked, erosion surface, undulating, 25 - 30 m below seabed

Unit 4: Channel fill sands, ~35 m, to east and south cutting into Neogene

Reflector 4: ~62 m below seabed

Unit 5: undisturbed, well layered mainly sand, slightly more clayey near base

Reflector 5: base Quaternary: 260 m - 300 m below sea bed, conformably on gently, westerly dipping Pliocene sands.

Cores: 2 vibrocores: VC2: 0 - 0.2 m: sand, silty, shelly
- 1.2 m: clay, silty, slightly shelly
- 1.32 m: gravel, sandy, slightly silty, slightly shelly
- 1.7 m: sand, slightly silty, few laminae of clayey silt

VC3: 0 - 0.3 m: sand, silty, slightly shelly
- 1.9 m: clay, sandy, slightly silty
- 2.1 m: sand, slightly silty, slightly shelly

Remark: Map of base Quaternary indicates depth of 190 m in NNE, 390 m in SSW (SW of SIRI-1 site), with channel features incised into top Neogene to 350 m.

Source: Gardline Surveys 1998: Statoil Efterforskning og Produktion A/S. Danish 5605/13-B Site. Pre-drilling hazard survey. Survey report. GEUS Report File no.15420.

16. May 2001 Peter Konradi

Summary: Site survey SANDRA-site A (alternative)

Present survey is conducted simultaneously with SANDRA-1 and SANDRA-C surveys

Tie-lines to SIRI-1, SIRI-3 and to SANDRA-1 exists.

Position: 56° 33' 37.6" N 05° 00' 05.9" E

Site designation: 54605/13-A

Seabed: 63 m water depth, practically flat, fine sand.

Geology (seismic interpretation):

Unit 1: Sand, fine, silty, becoming clayey sands to soft clay at 0.5-1.0 m, below ~2 m below sea bed: becoming medium to fine, loose to dense sands, 1.5 - 3 m

Reflector 1: undulating, 1.5 - 3.0 m below seabed

Unit 2: Presumed stiff clay, ~8 m thickness, with channel-like structure

Reflector 2: unclear, 9 - 12 m below seabed,

Unit 3: medium to fine, very dense sands, ~ 7 m thickness

Reflector 3: marked erosion surface, 20 - 30 m below sea bed, slightly undulating, channel feature to 70 m below sea bed

Unit 4: Channel fill sands, max. depth ~70 m,

Reflector 4: ~62 m below seabed, channelling into top Neogene in eastern part

Unit 5: undisturbed well layered mainly sand with some clay, slightly more clayey near base

Reflector 5: base Quaternary: 280 - 310 m below seabed, gently, westerly dipping on Pliocene sands.

Cores: 1 vibrocore: 0 - 0.22 m: sand, slightly silty, slightly shelly
- 1.8 m: silt and sandy silt, slightly shelly
- 2.53 m: silty, fine sand,

Source: Gardline Surveys 1998: Statoil Efterforskning og Produktion A/S. Danish 5605/13- A Site. Pre-drilling hazard survey. Survey report. GEUS Report File no.15536.

22. May 2001

Peter Konradi

Summary: Site survey SANDRA-site C (alternative)

Present survey conducted simultaneously with SANDRA-A and SANDRA-1 surveys

Tie-lines to SANDRA-1 exists.

Position: 56° 35' 02.6" N 05° 09' 57.9" E

Site designation: 54605/13-C

Seabed: 59 m water depth, essentially flat, slightly shoaling to south, fine, silty sand to clayey sand.

Geology (seismic interpretation):

Unit 1: Sand, fine, silty, becoming clayey sand to soft clay at 0.5-1.0 m, below ~2 m becoming medium to fine sand, 4.5 - 7.5 m thickness

Reflector 1: undulating, 4.5 - 7.5 m below seabed,

Unit 2: Presumed stiff clay, with small channelling events,

Reflector 2: unclear, 10 - 15 m below seabed,

Unit 3: Presumed very dense medium to fine sand, ~ 17 m thickness

Reflector 3: marked erosion surface, slightly undulating, 25 - 45 m below sea bed, channel feature to 75 m below sea bed

Unit 4: Channel fill sands, ~138 m thickness, several generations, two channel features cutting down into Neogene, to ~ 350 m below seabed

Reflector 4: ~ 150 m below seabed

Unit 5: undisturbed, well layered mainly sand, slightly more clayey near base

Reflector 5: ~ 230 - 240 m below sea bed, base Quaternary, strongly undulating with channel features from unit 4, till 350 m below sea bed, conformably on gently, westerly dipping Pliocene sands.

Cores: 1 vibrocore: 0 - 0.58 m: sand, slightly silty, slightly shelly
- 1.75 m: clay, slightly silty
- 2.58 m: sand, silty

Source: Gardline Surveys 1998: Statoil Efterforskning og Produktion A/S. Danish 5605/13- C Site. Pre-drilling hazard survey. Survey report. GEUS Report File no.15538.

23. May 2001
Peter Konradi

Summary: Site survey SIRI-1

A tie-line to ELNA-1 exists.

Position: 56° 29' 11.09" N 04° 54' 57.66" E

Site designation: 5604/20-1

Seabed: ~60 m water depth, flat, shoaling slightly to the south, consisting of sand, fine, loose, shelly patches

Geology (seismic interpretation):

Unit 1: Sand, slightly silty, few shells, thickness-1.5 - 5m, lag deposit at base.

Reflector 1: strong, 1.5 - 5 m below seabed, gravel and shells

Unit 2: several episodes of channelling, clay and minor sand lenses, gravel at base of channels.

Reflector 2: generally 30 - 100 m below seabed, max.: 225 m below sea bed

Unit 3: well layered clay with lignite? bed at 220 m

Reflector 3: 235 m below seabed, possible base Quaternary, dipping in westerly direction, unconformably on gently, westerly dipping Pliocene-Miocene

Cores: 2 vibrocores: 0 -1.65 m: fine sand, slightly silty, few shells, olive green - grey
- 1.75 m: gravel with shells and shell fragments
core catcher: firm clay, grey

Source: Gardline Surveys 1995: Statoil Denmark A/S. 5604/20-A. Pre-drilling hazard survey. September 1995. Survey report. GEUS Report File no.13022.

3. May 2001
Peter Konradi

Summary: Site survey SIRI-2

A tie-line to the SIRI-1 site exists.

Position: 56° 29' 41.20" N 04° 52' 10.40" E

Site designation: 5604/20-2

Seabed: ~60 m water depth, essentially flat, gently undulating, shoaling very gently to the southeast, sand, fine, silty, shelly patches.

Geology (seismic interpretation):

Unit 1: Sand, fine, silty, few shells, thickness 2 - 5m, basal gravel.

Reflector 1: inconsistent, 2 - 5 m's below seabed, undulating, caused by gravel and shells

Unit 2: firm clay and silty, fine sand, interbedded, ~70 m thickness, internal channelling, possible Forth Formation.

Reflector 2: persistent and weak, ~71 m below seabed.

Unit 3: firm clay interbedded with sand and lignite bands, internal erosion surfaces, possible Fisher Formation, thickness ~280 m

Reflector 3: 235 m below seabed, near base Quaternary, dipping in westerly direction, unconformably on gently, westerly dipping Plio-Miocene strata

Cores: 3 vibrocores: 0 - max. 2.32 m: fine sand, silty, few shells, pale grey-brown.

0.08 m: gravel, sandy, shelly, grey-brown

> 0.60 m: firm clay, very silty, slightly sandy, occasional silt pockets, grey-brown

Source: Seateam 1996: Dansk operatørselskab i-s (Danop). SIRI-2 site survey. Danish continental shelf. Block 5605/20. Rig site survey. Final report GEUS Report File no. 13353.

3. May 2001

Peter Konradi

Summary: Site survey SIRI-3

Position: 56° 30' 34.840" N 05° 03' 48.232" E

Site designation: 5605/13-1

Seabed: ~59 m water depth, predominantly flat, consisting of sand, occasional shells and shell fragments

Geology (seismic interpretation):

Unit 1: Sand with shells and basal gravel layer

Reflector 1: 2 - 4 m below seabed

Unit 2: clays with interbedded sand infill in two S - N striking channel features, Coal Pit Formation.

Reflector 2: generally 35 - 40 m below sea bed, channels to 160 m and 340 m respectively

Unit 3: stiff, pebbly clays, silts and sands with weak horizontal layering and dominant basal reflector, Fisher Formation

Reflector 3: ~100 - 100+ m below seabed, subhorizontal

Unit 4: stiff to hard clays with lenses and laminae of fine sand, horizontal reflectors, well layered, Aberdeen Ground Formation

Reflector 4: near base Quaternary: 270 - 290 m below seabed conformably on gently, westerly dipping shales.

Cores: 5 vibrocores: 3 shorter (10 -15 cm): sand, medium, poorly sorted, occasional shell fragments

core 4: 0 - 0.40 m: sand, fine to medium, occasional shells

core 5: 0 - 0.25 m: sand, medium to coarse, muddy, occasional shells and shell fragments

- 0.75 m: sand, fine, occasional shells and shell fragments

Source: Seateam 1996: Dansk operatørselskab i-s (Danop). SIRI-3 site survey. Danish continental shelf block 5605/13. Rig site survey. Final report GEUS Report File no.13332.

25 April 2001

Peter Konradi

Summary: Site Survey VANESSA-1

Position: 56° 21' 52.15" N 05° 30' 26.42" E

Site designation: 5605/23-1

Seabed: 54 m water depth, dips to the ESE with deepest trough in eastern part, silty sand, sand waves: $\lambda = 1$ m, h 0.5 m, direction ~WSW - ENE.

Geology (seismic interpretation):

Unit 1: silty sands, continuous parallel reflectors

Reflector 1: 0 till > 10 m dips to the W.

Unit 2: fine to medium sand, restricted penetration

Reflector 2: glacial channel, till ~50 m below seabed

Unit 3: interbedded sand and clay, coarse lag deposit at base.

Reflector 3: channel base at 91 m below sea bed in NE (channel shoulder?) to 268 m below sea bed in SW, possibly NNW - SSE direction,

below channel: gently SW dipping flat lying Nordland group sand
no reflector identified as base Quaternary

Vibrocores: descriptions at "cuts":

Core at Vanessa-1 position: at top: sand, fine to medium, occasional shell fragments
at 1 m: sand, fine to medium, clean
at 2 m: sand, fine, silty
at 3 m: sand, fine, silty
at 4.3 m (base): sand, fine to medium, shelly

Core at 600 m east of site position: at top: sand, fine to medium, clean
at 1.1 m: sand, fine, clean
at 2.2 m: sand, fine to medium, clean
at 3.4 m (base of core): sand, fine, clean

Source: Gardline Surveys 2000: Clam Petroleum Danske BV, Danish Block 5605/23, VANESSA-1 Site Survey, May 2000, Survey Report. GEUS Report File no 17950.

21 March 2001
Peter Konradi

Annex B

Site surveys, Store fisker Banke area, Danish North Sea: Review of water depth, sedimentologic units and reflectors					
Well name	CECILIE-1	CONNIE-1	D-1X	ELNA-1	FLOKI-1 (5605/18-1)
Site designation	5604/20-5	5604/19-5	5605/19-1	5604/19-1	5605/18-1
Position	56°24'20.15"N 04°45'41.15"E	56°24'28.31"N 04°42'30.42"E	56°25'29.7" N 05°31'52.2" E	56°26'53.13"N 04°31'43.44"E	56°27'48.6"N 05°16'47.1"E
water depth	61 m	61.5 m	~54 m	62 m	51 m
seabed	essentially flat	essentially flat	gentle slope to NW	fairly flat	
seabed sediment	fine, silty sand	silty, fine sand	fine to medium sand, o. shell	fine sand	
Year of drilling	2000	2000	1968	1985	2000
Unit 1	sand, fine, silty 1-10 m, irregular, channel 4-10 m below sea bed	sand, fine, silty 1-3 m, lag at base irregular surface 1-3 m below sea bed	sand, fine to medium, o.shell ~7 m undulating ~10 - 15 m below sea bed	fine sand subhorizontal 0.4 - 0.5 m below sea bed	
Reflector 1					
Unit 2	clays w. silt & sand 20-50 m, channels	clays w. silt & sand channels, 50-100 m	thin clay erosional w. channel 10 - 20 m, max. 35 m	finely banded clays and sands irregular horizon 1.5 - 2 m below sea bed	
Reflector 2					
Unit 3			12 m dense fine sand	stiff boulder(?) clay	
Reflector 3	undulating, erosional to 160 m below sea bed	undulating, erosional to 160 m below sea bed	erosional event, ~20 m max. 40 m below sea bed		
Unit 4	interbedded sands & clays undulating surface 180-188 m below sea bed	interbedded sands & clays slightly undulating, 180-195 m below sea bed	base erosional channel > 60 m	uncertain ~60 m	
Reflector 4					
Unit 5	interbedded sands & clays erosion surface, 334 m	interbedded sands & clays erosional, 334 m b. seabed		indistinct subhor. reflectors marine clays with sand distinct reflector, ~210 m	
Reflector 5	b Q. on w dipping Neogene	b Q. on w dipping Neogene		possible base Quaternary	
base Quaternary					
Remarks			no information on base Quaternary	biostratigrafic base Quaternary: ~ 340 m	no site survey report at 01.12.2001

Site surveys, Store fisker Banke area, Danish North Sea: Review of water depth, sedimentologic units and reflectors					
FRANCISCA-1 5604/24-1 56o22'28.98"N 04o48'04.82"E	FRIDA-1 5605/21-2 56o17'14.26"N 05o01'50.10"E	L-1X 5605/21-1 56o15'9,7" N 05o14'55,2" E	NINI-1 5605/10-1 56o38'31.02"N 05o19'15.44"E	NINI-2 5605/10-2 56o37'52.84"N 05o17'59.00"E	NINI-3 5605/10-3 56o41'32.03"N 05o24'12.33"E
59.5 m essentially flat fine sands 1998	55 m sl. shoaling to SE silty, fine sand 1997	59 m flat silty fine sand 1970	59 m flat silty fine sand 2000	59 m rather flat silty, fine to medium sand 2000	57 - 58 m rather flat silty sand, megarippled & 2000
sands w. shells gravel at base slightly undulating 3.5-8 m below sea bed	silty fine sand abundant shells 7 & 12 m below sea bed subhorizontal reflector	sand, fine, silty 5.5 m undulating 6 - 13 m below seabed	sand, fine, silty grading to fine to medium, 2 - > 3.5 m erosional incl. channel 2 - 8 m below seabed	silty fine to medium sand & dense sand w. gravel ill defined <1 - 6 m below seabed	silty sand w. shell/gravel shelly, gravelly layer <1 - 3 m below seabed
sand w. possible gravel 5-20 m, undulating semi-continuous	11 m sand w. gravel chaotic structure at 23 m below sea bed	dense sand faint reflector ~30 m	clay with sand 8 - 30 m erosional surface 5 - 18 m below seabed	fine sand, clayey or silty uneven erosion, w. lag 6.5 - 15 m below seabed	slightly silty clay undulating 4.5 - 9.5 m below seabed
sand w. gravel, channels 5-20 m, channels uneven, channels	sands w. thin clay numerous channels at 222 m below sea bed		sand and clay, channeling channel base at 110 m below sea bed	channeling event till 75 m below seabed erosional surface	channeling event erosional surface till 55 m below seabed
sands w. clays, channels ~250 m	sands & clay 78 m		sand and clay, channeling channel base into Neogene at 380 m below sea bed		
unconformity, ~302 m west dipping on Neogene	~300 m below sea bed b Q. on w dipping Neogene		ill defined ~ 180 m below seabed	channeling event to 265 m below seabed ill defined reflector (PK) 170-180 m, base Quater.(?)	channeling event till 200 m below sea bed slightly w. dipping (PK) 120 - 150 m, base Quat.(?)
		no information on base Quaternary	reflector 5 is base Quaternary(?)		second channel event reaches intounderlying Neogene

Site surveys, Store fisker Banke area, Danish North Sea: Review of water depth, sedimentologic units and reflectors			
NOLDE-1 5605/9-1 56°37'37.87" N 05°11'01.99"E	SANDRA-1 5605/13-1 56°35'13.6"N 05°01'34.8"E	SANDRA-alternative site A 5605/13-A 56°33'37.6"N 05°00'05.9"E	SANDRA-alternative site C 5605/13-C 56°35'02.6"N 05°09'57.9"E
61 m flat, shoaling to se clayey sand 1997	63m flat, shoaling to e & s silty, fine sand 1997	63 m practically flat, fine sand 1998	59 m essential flat, sl. shoal. to S silty, fine sand to clayey sand 1998
clay, sandy & sand irregular erosional 3.5 - 8 m below sea bed	sand, fine to soft clay 1.5 - 2.5 m undulating, w. channels 1.5 -3.0 m, max. 7.5 m	sand, fine, silty to soft clay 1.5 - 3 m undulating 1.5 -3.0 m	sand, fine, silty to soft clay 4.5 - 7.5 m thick undulating 4.5 - 7.5 m
sands 8 - 30 m	presumed stiff clay ~8 m unclear 9 - 15 m below seabed	presumed stiff clay, with channel structures, ~8 m unclear 9 - 12 m below seabed	presumed stiff clay, with small channel events, ~8 m unclear 10 - 15 m below seabed
undulating, erosional 14-35 m below sea bed	presumed medium-fine sand ~17 m marked erosion surface 25-30 m, max. 75 m bsb.	medium-fine, v. dense sand ~ 17 m sl. undul. mark. eros. surface 20-30 m, max. 70 m bsb.	medium-fine, v. dense sand ~17 m sl. undul. mark. eros. surface 25-45 m, max. 75 m bsb.
sand & clay & lag channel fill irregular erosional channel 140 - 320 m below sea bed	channel fill sands ~35 m, channels to > 300 m ~62 m below seabed	channel fill sands ~70 m, channels to > 300 m ~62 m below seabed	channel fill sands ~138 m, 2 channel features, ~150 m bsb. max. 350 m
sand w. gravel, channel fill 0 - 220 m erosional, 230 - 320 m bsb. b Q. on w dipping Neogene	well layered mainly sand 190 - 390 m bsf, max. 350m b Q. on w dipping Pliocene	well layered mainly sand 280 - 310 m bsf, max. 350m b Q. on w dipping Pliocene	well layered mainly sand undisturbed 230 - 240 m bsf, max. 350m b Q. on w dipping Pliocene
Refector 4 is possib. base Saalian	extensive map of base Quaternary with base Unit 5 channels (including SIRI-1 & SIRI-3)		

Site surveys, Store fisker Banke area, Danish North Sea, review of water depth, sedimentologic units and reflectors				
SIRI-1 5604/20-1 56°29'11.09"N 04°54'57.66"E	SIRI-2 5604/20-2 56°29'41.20"N 04°52'10.40"E	SIRI-3 5605/13-1 56°30'34.84"N 05°03'48.23"E	SIRI-4 5604/20-6 56°29'21"N 04°59'33"E	VANESSA-1 5605/23-1 56°21'52.15"N 05°30'26.42"E
60 m flat, shoaling to s fine sand, shelly patches 1995	60 m essentially flat, shoal'g to se fine, silty sand w. shel patch. 1996	59 m flat sand w. varying shells 1996	60 m 2001	54 m dipping to se to trough silty sand, w. sandwaves 2000
sand, slightly silty, few shells, gravel/shells at base, 1.5-5 m undulating, strong 1.5 - 5 m bsb.	sand fine, silty, shells, gravel 2 - 5 m undulating, inconsistent, 2 - 5 m bsb. of gravel/shells	sand w. shells, basal gravel 2 - 4 m below sea bed		silty sand, parallel reflectors irregular, dipping to w 0 - > 10 m
clays w. sand, sev. channels	interb. clay & silty, fine sand intern. channelling, ~70 m	clays w. interbedded sands in channel feature		fine to medium sand glacial channel till ~50 m below sea bed
irregular 30-100 m, max. 225 m bsb.	persistent, weak ~71 m bsb.	35 - 40 m below sea bed channels: 160 & 340 m resp.		interbedded sand & clay lag at base
layered clay, lignite(?) at 220	clay w. sands & lignite, erosion surfaces, ~280 m	pebbly clays, silts & sands dominant, subhorizontal ~100 - >100 m bsb.		channel erosion surface 91 m (shoulder) - 268 m bsb.
235 m, base Quaternary, on unconf. W dipping Neogene	235 m, b Q. unconformably on W dipping Neogene	clays w. lenses of sand horizontal reflectors 270 - 290 m, base Quat. on conform. W dipp. Neogene		sand & clay prone gently w dipping flat reflectors
	Unit 2 is possible Forth Fm. Unit 3 is possible Fisher Fm.	Unit 2 is possible Coal Pit Formation Unit 3 is possible Fisher Formation Unit 4 is possible Aberdeen Ground Fm.		Unit 4 is supposed to be Nordland Group PK: possibly Aberdeen Ground Fm. base Quaternary not identified