

GEOLOGICAL NOTE ON

F R I G G 1

(25/1-1x)

Boston

725.3

ELF NORGE A/S

Well: 25/1-1x FRIGG

Pertinent Data

Classification: New field wildcat

Area: Field 25 - Block 1 - Production licence 024

Location: Lat. 59° 53' 17.4" N SP 162
Long. 02° 04' 42.7" E of line 69205

Water depth: 101 m

KB elevation: + 24 m

Objective: To test the lower tertiary and Mesozoic

Results: Tested gas and oil in ^{Eocene}/Paleocene sands

Status: Plugged and abandoned, new field discovery wildcat

Total depth: 4570 m (KB)

Contractor: Neptune "Pentagone 81" (semi-submersible)

Date spudded: 30/3/71

At total depth: 6/7/71

Completed: 22/7/71

I. GENERAL

A) - Prospect geology and objectives

The Petronord 25/1-1 well is located in the tertiary graben which axis trends northerly and approximates the median line between Scottish and Norwegian waters.

- Reflection seismic surveys enabled to define structural closure in mesozoic and up in lower tertiary horizons -
- At C_1 reflector level, assumed to be the top of paleocene a large amoeboid feature is extending on blocks 25/1 and 25/2 upon 350 km^2 with a vertical closure of 180 m.
- Below at the C_2 , (top of upper cretaceous) M_1 , M_2 , (lower cretaceous, jurassic) horizons a North-South trending anticline underlies the median line stretching in the 25/1 and 10/1 blocks. It is more sharply defined at the M_2 level -
- The objective of this well was to test the hydrocarbon potential:
 - of the lower tertiary, as the C_1 structure was interpreted to be possibly a deltaic sand build-up -
 - and - of the jurassic sandstone in good structural position -

B) - Technical data -

- RKB - elevation + 24 m
- Water depth 101 m

Drilling and casing data

- Drilled 36" hole to 165 m. 30" guide set at that depth.
- Drilled 17 1/2 hole to 1846 m. 13 3/8 set and cemented at 1835,6 m.
- Drilled 12 1/4 hole to 2960 m. 9 5/8 set and cemented at 2950,3 m.
- Drilled 8 1/2 hole to 4062 m. 7" liner set at 4062 m. Then tied back.
- Drilled 5 1/2 hole to 4570 m. TD.

Drilling fluids -

- A sea water-LFC mud system was used down to TD.

Coring

- 6 mechanical cores were cut and recovered as follows:

K 1	1868 - 1877 m	66 %
K 2	1877 - 1895 m	19 %
K 3	1895 - 1910 m	66 %
K 4	2687 - 2696 m	95 %
K 5	2826 - 2843 m	100 %
K 6	2993 - 2997,5 m	100 %

- 64 sidewall cores were recovered out of four guns shot.

Logging

(see 1/5000 log)

Testing

- 9 wire line tests were conducted

- 1) 1973,5 m oil, gas and filtrate
- 2) 1927,5 m gas and filtrate
- 3) 1893,5 m gas and filtrate
- 4) 2471,0 m oil and filtrate
- 5) 2788,5 m dry
- 6) 3699 m dry
- 7) 3814 m dry, tool stuck
- 8) 2987 m dry
- 9) 2986,5 m dry, tool stuck

- A production test was carried through perforations between 1920 and 1928 m on gas bearing Frigg sands.

II. STRATIGRAPHY AND LITHOLOGY

The formations and divisions considered below are based on microfaunas and microfloras analysis and on petrographical and electrical correlations with surrounding wells -

1. Quaternary - Tertiary 101 - 2673 m (th. 2572 m)

1.1. Pleistocene - Miocene 101 - 731m (th 630 m) "Lignitic Series"-----

- A sea bed sample recovered by divers consists of a fine well sorted, micaceous sand -

- As the well was drilled without returns down to 490 m a sand and gravel lithology with minor clay interbeds

is inferred from the gamma-ray curve and a bit sample
Glacial boulder clay is also present in this interval -

Below 490 m down to 731 m heterometric quartz grains
and acid rocks debris make up this unit with some
lignitic clays and lumachellic stringers.

- These coastal thick deposits are showing a strong
continental influence.

1.2. "Brown clays group" 731 - 1778 m
(th. 1047 m) - Oligocene - Upper Eocene -

- a) 731 - 1165 m Upper-middle Oligocene

Greenish-brown soft slightly silty clay characterizes
this unit.

Medium to coarse grained, glauconitic sands are present
and water-bearing between 876 and 918 m followed by
hard microcrystalline limestone stringers between
937 and 914 m.

- b) 1165 - 1778 m. Lower Oligocene - Upper and middle Eocene

This very monotonous section consists of soft, gumbo
type brown clay - with hard beige dolomite nodules and
stringers, more frequent below 1257 m.

A thin interbed of water-wet sand exists between
1310 and 1312 m - Pyrite is common throughout -
This unit is dated Lutetian by palynology below 1630 m.

1.3. 1778 - 1836 m. Green clay member -
Lower Eocene (Cuisian).-----

Apple green soft pyritic clay marks the top of this unit and is followed by brown red silty shale below 1830 m.

1.4. 1836 - 2050 m - Frigg formation

This exceptional reservoir consists in four main sand bodies separated by metric clay partings:

- a) 1836 - 1938 m (102 m)
- b) 1941 - 1976 m (35 m)
- c) 1980 - 2017 m (37 m)
- d) 2019 - 2050 m (31 m)

These sands are clean, loose, grey to beige with angular to subrounded grains, poorly sorted with a few dissiminated coarse grains - micas and lignitic particles are abundant throughout. A few metric streaks of hard sandstones with a white calcareous cement are present in the upper 50 m of this formation.

The shale partings are grey to dark grey, lignitic, fissile - Ripple marks and small cross-bedding associated with graded cycles of about 5 m thick were observed on the cores cut between 1868 and 1910 m.

Porosities of these sands are very high averaging 35, 40 % in the upper unit decreasing to 30 % below, with related permeabilities of serveral darcies -

The two uppermost sand bodies were deposited during lower Eocene (Palynological zone Nt II b) and the other two are dated Paleocene (upper Nt II a zone). Rapid deposition in a shallow water, high energy environment, with sediment transport from west to east, is indicated by the dipmeter interpretation of these levels.

1.5. 2050 - 2115 m (65 m) upper sand-shale member

Fine medium sands and grey-green shales in sedimentary cycles of 5 to 10 m make up this member. They are considered to represent small channels and bars of a deltaic fringe with alternating east to west and west to east sediment transportation.

1.6. Tuffitic-zone 2115 - 2218 m (103 m)

A thick homogenous sand body from 2150 to 2195 m (45 m) is the main point of this zone and is comprised between two levels of shale with volcanic ashes and calcareous sandstone stringers. A large diatom (*Coscinodiscus* Sp - 1) is characteristic of these levels enriched with silica.

The middle sand unit presents a mixture of two populations: large rounded frosted grains and clear subangular smaller ones well sorted, and shows a sediment transport from NNE to SSW.

1.7. "Cod Formation" 2218 - 2390 m (172 m)

Sand medium to coarse, sometimes, very coarse is the main lithology of this thick unit. Some minor metric stringers of calcareous sandstone and dark grey-green shale partings occur throughout. They are interpreted as a sandblanket, foresetting on a slope NNW to SSW in rapid deposition and under a greater water depth than the Frigg formation.

A good palynological marker is given by the species *Wetziellela*. D. 361 (Lower Nt II a zone) occurring at the top of this reservoir and associated with other forms characteristic of Paleocene.

1.8. 2390 - 2497 m (107 m) Lower sand-shale member

- a) 2390 - 2470 m: shales grey-green pyritic with thin sandy limestone and sandstone stringers are followed by:
- b) 2470 - 2497 m (27 m) sands medium to coarse, subrounded, glauconitic, layered in three main beds. On the dipmeter they appear as distributary fronts with transport from NW to SE.

1.9. 2497 - 2672 m (175 m) Lower-shale member

Dark grey-greenish silty shale becoming more compacted and carbonated below 2595 m is the dominant component of this member. A few shaly limestones and buff microcrystaline dolomite stringers are present throughout mostly in the lowest part.

This section is dated lowermost Paleocene - Danian and Danian certain, below 2575 m by palynology.

(zones Nt I a and b)

2. Cretaceous 2672 - 4100 m (1528 m)

An almost complete disappearance of the chalk facies, thick argillaceous sequences and absence of ante-Albien strata are typical of this well.

2.1. Maestrichtian 2672 - 2979 m (307 m)

Palynozone NC 9 Divided in two lithological members:

2.1.1. 2672 - 2826 m (154 m)

Shales calcareous, pyritic, grey to dark grey with interbeds of limestones, whitish to buff, hard, up to 10 m thick, are the two lithologies for this unit. A detritic episode of sandstone: medium grained with a calcareous cement but with good reservoir qualities occurs between 2696 and 2710 m (14 m). The first three meters (72-75 m) made of bioclastic limestone with bryozoa and shell debris, may represent a small remnant of the Danian limestone.

Silicified zones, vertical fractures and stylolitic joints are noticeable in the limestones.

2.1.2. 2826 - 2979 m (153 m)

This member is composed of shale: dark grey to black, micaceous and pyritic, with some worm tubes and shell debris (Inoceramus) a thin limestone bed (4 m) is present at 2880 m.

A marked change in clay composition exists at the top of Cretaceous strata where the montmorillonite typical of the tertiary, gives way to an Illitic-montmorillonitic complex. A decompaction gradient on sonic log in this lower member is noteworthy.

2.2. 2979 - 3580 m (601 m) Campanian-Coniacian

This is a very monotonous section of shale of the same type. A thin limestone (4 m) vuggy and rubefied followed by some metric stringers of grey mudstone with hard grounds marks the top of this unit.

Below 3413 m the shale is becoming more carbonated and compacted, this depth being the limit between Campanian (NC 8) and lower Senonian comanian (NC 7 palynozone).

2.3. 3580 - 3995 m (415 m) Turonian-Cenomanian

The same type of sediments make up this interval, however, with some enrichment in carbonate content, following cyclic gradients. Intercalations of mudstone limestone occur at

3644 - 3663 m

3697 - 3716 m

3808 - 3819 m

3882 - 3892 m

3930 - 3938 m

Palyнологical and nanofossils results indicate a Turonian age down to 3697 m a transition zone Turonian upper Cenomanian down to 3808 m and a Cenomanian age below.

2.4. 3995 - 4100 m (105 m) Albian ?

This section of dark grey undercompacted shale in continuity with the above unit is mostly azoic with only small microfossils indicative of Albian.

3. Jurassic 4100 - 4570 m (470 m) (TD)

3.1. Shaly Jurassic 4100 - 4556 m (456 m)

Due to the lack of precise datations the jurassic top has been set at 4100 m on log evidence. Three members can be distinguished in this sequence:

3.1.1. 4100 - 4203 m (103 m)

Undercompacted dark grey shale with a few dolomitic

limestone stringers at the top compose this member. A few ostracods indicate a jurassic age (Oxfordian ?) for this section.

3.1.2. 4203 - 4280 m (77 m) Radioactive shale

This member very typical on electrical logs is made of a fissile black very radioactive (250 API) oil shale dated oxfordian by palynology.

3.1.3. 4280 - 4556 m (276 m)

Dark grey pyritic and calcareous shale with numerous dark buff dolomite stringers in the upper portion made up this member. Datation results indicate a range from oxfordian. to Dogger - Upper Lias - for these strata.

3.2. Jurassic sand 4556 - 4570 m TD (\approx 14 m)

Only the very top of this formation has been penetrated due to a violent kick of the well and a following fish.

Milky and clear, medium angular quartz grains were observed in the cuttings with some amounts of sandstone pyritic with siliceous and argilaceous cement.