



**欢迎Whitson教授莅临中海油研究总院**

**Welcome Professor Whitson to  
CNOOC Research Institute**

# Norwegian Oil & Gas Fields

## Technology Triumphs From Shallow-to-Deep Water

魏克海

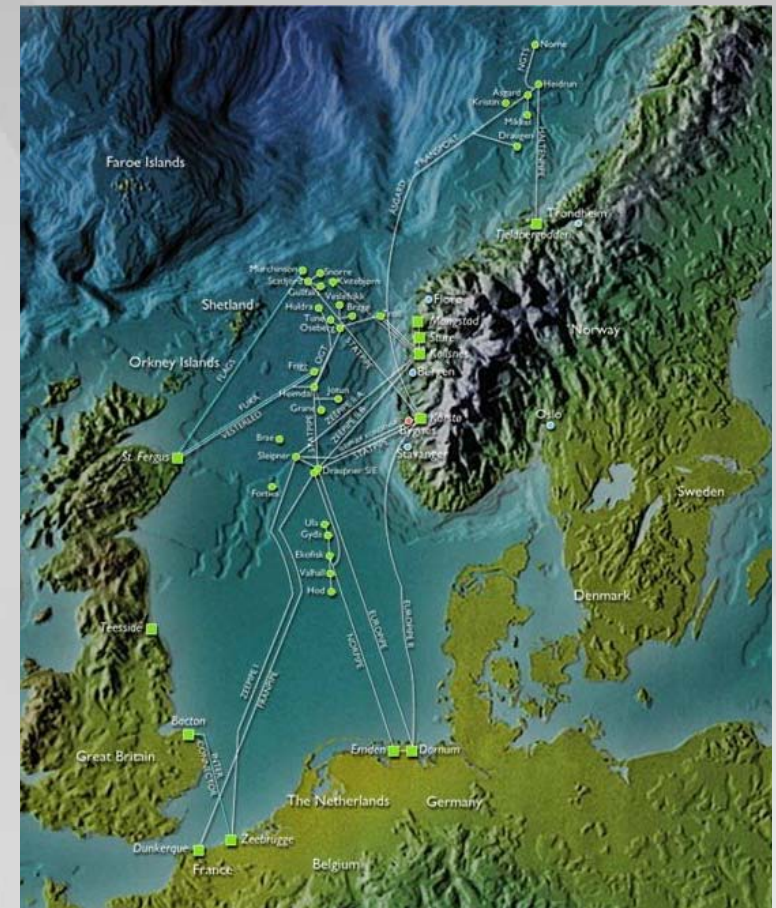
Curtis Hays Whitson

Professor (NTNU)

Founder (PERA & Petrostreamz)



April 8, 2010  
CNOOC – Beijing



# Background Check

- **1956-1974 : Oklahoma** (born & raised)
- **1974-1978 : Stanford U** (education)
- **1978-2010 : Norway** (problem-solving)

# Oklahoma

- **Small-time, big-time O&G industry**
  - Innovation pays
  - Rags-2-Riches (Phillips, Kerr-McGee)
  - Can't ain't in the dictionary
  - Keep your eyes open for opportunity
    - *Rig in The Netherlands (1962)*
    - *Rig in Bergen Norway (1977)*

# Stanford U

- **Learned how to learn**
- **Muz Standing**
  - PVT, PTA
- **Hank Ramey**
  - Gas engineering, PTA
- **Bill Brigham**
  - PTA, Well logging

# Achievements in Norway

- **Problem solving**

- Research (PVT, EOR, GC, IO) – NTNU & PERA
- Teaching (PVT, EOR, GC, Gas, DCA, RE & PE) – NTNU ([link](#))
- Consultancy (PVT, EOR, GC, IO)

- **Sharing thru publishing**

- Well Performance (IHRDC, Prentice-Hall)
- SPE Phase Behavior monograph
- Papers

- **Pillar collaboration**

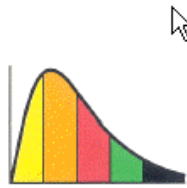
- Mike Golan
- Mike Fetkovich
- Aaron Zick
- Michael Michelsen
- Keith Coats

- **Founder**

- PERA
- Petrostreamz

# PERA

- **Founded 1988**
  - Curtis Whitson, professor dr.techn.
- **~15 employees & associates**
  - Seven PhD/MSc engineers and one office manager.
- **Worldwide consulting**
  - Compositionally-sensitive reservoir processes.
- **Software development**
  - Pipe-It (through Petrostreamz subsidiary).
  - EOS-based specialty software.



## PERA a/s

Petroleum Engineering Reservoir Analysts

Address:

Granaasveien 1, 3rd floor  
7048 Trondheim  
Norway

Phone: 47 7384 8080

Fax: 47 7384 8081

	Email	Office Phone	Mobile Phone	<a href="#">Petrostreamz</a> Associate
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Snjezana Sunjerga	<a href="mailto:sunjerga@pera.no">sunjerga@pera.no</a>	47 7384 8088	47 4060 9181	x
M. Faizul Hoda	<a href="mailto:hoda@pera.no">hoda@pera.no</a>	47 7384 8098	47 9222 0197	x
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Aleksander Juell	<a href="mailto:juell@pera.no">juell@pera.no</a>			x
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<b>PERA Associates</b>				
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Oleksandr Yakovlyev	<a href="mailto:oleks@petrostreamz.com">oleks@petrostreamz.com</a>	47 7384 8086	47 9889 7746	x
Gunnar Borthne	<a href="mailto:gubo@condev.no">gubo@condev.no</a>		47 9004 7888	x
Robert Mott	<a href="mailto:mott@pera.no">mott@pera.no</a>			



# PERA Consulting

- ADCO / ADNOC
- Anadarko
- Anadarko
- BP
- BHP
- Bunduq
- Burlington / LLE
- Chevron
- Cimarex
- ConocoPhillips
- Deminex
- DPC
- Ecopetrol
- Edison
- Encana (Cenovus)
- ENI
- Expro
- ExxonMobil
- Hess
- HLJOC
- JVPC
- Maersk
- Noble Energy
- Occidental (Oxy)
- OMV
- PDO
- Petrobras
- PetroCanada
- PetroSA
- PDVSA
- Preussag
- Qatar Petroleum
- ResLab
- Saudi Aramco
- Schlumberger
- Shell
- SINTEF Petroleum
- Statoil (Hydro)
- Total
- Unocal
- Vintage
- Wintershall
- RasGas

Active 2009-2010 projects

# PERA Consulting

- **Algeria**
- **Angola**
- **Australia**
- **Canada**
- **China**
- **Colombia**
- **Denmark**
- **Egypt**
- **Equatorial Guinea**
- **Ghana**
- **India**
- **Indonesia**
- **Iran**
- **Iraq**
- **Italy**
- **Libya**
- **Malaysia**
- **Netherlands**
- **Norway**
- **Oman**
- **Pakistan**
- **Phillipines**
- **Qatar**
- **South Africa**
- **Tunisa**
- **UAE**
- **USA**
- **Venezuela**
- **Vietnam**

Active 2009-2010 projects

# Chinese Connection

- **1980s**

- Zhongxiang Chen (dr.techn.)
- Yuanchang Qi (PhD)
- Hua Hu (PhD)

- **1990s**

- Tao Yang (post-doc, employee)
- Huiling Sun (MSc)

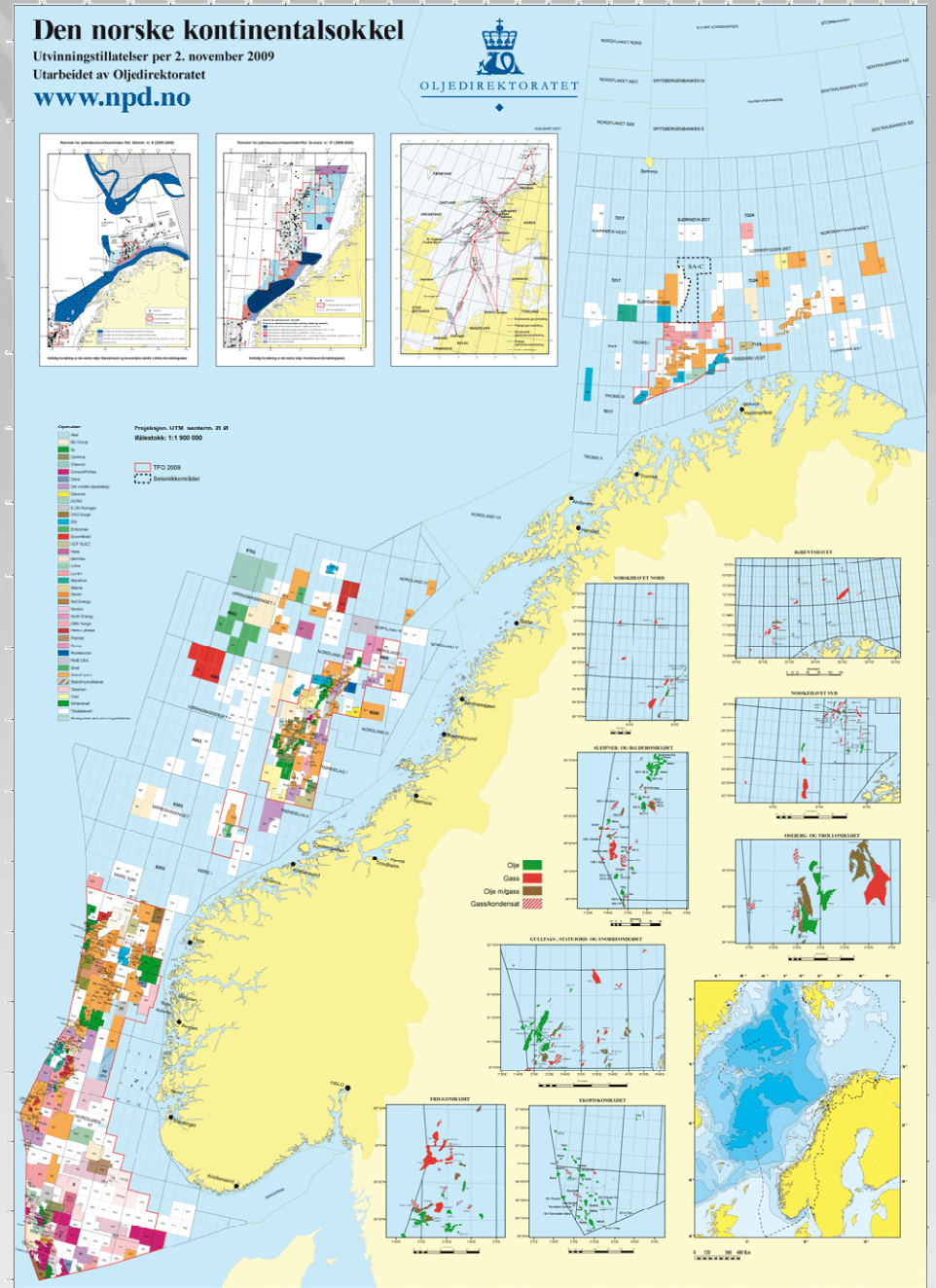
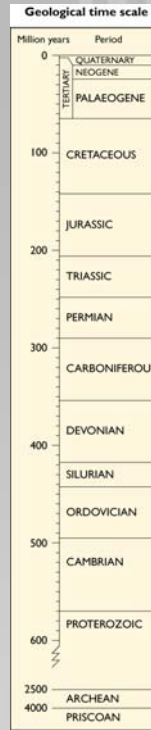
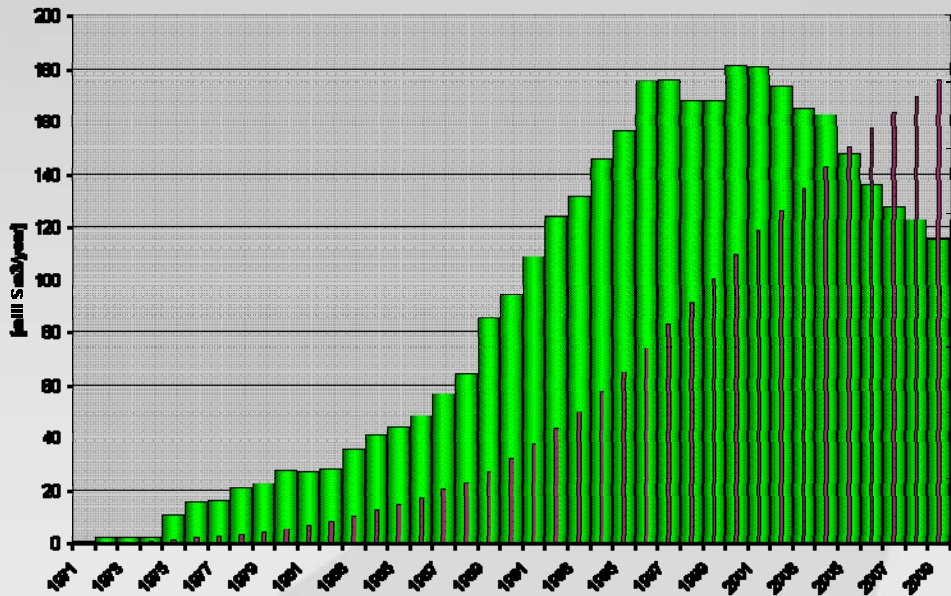
- **2000s**

- Nan Cheng (PhD)
- Huijuan Yu (MSc)

# Norwegian Petroleum Directorate

[www.npd.no](http://www.npd.no)

Norwegian continental shelf.  
Net production of oil per year. Complete history.



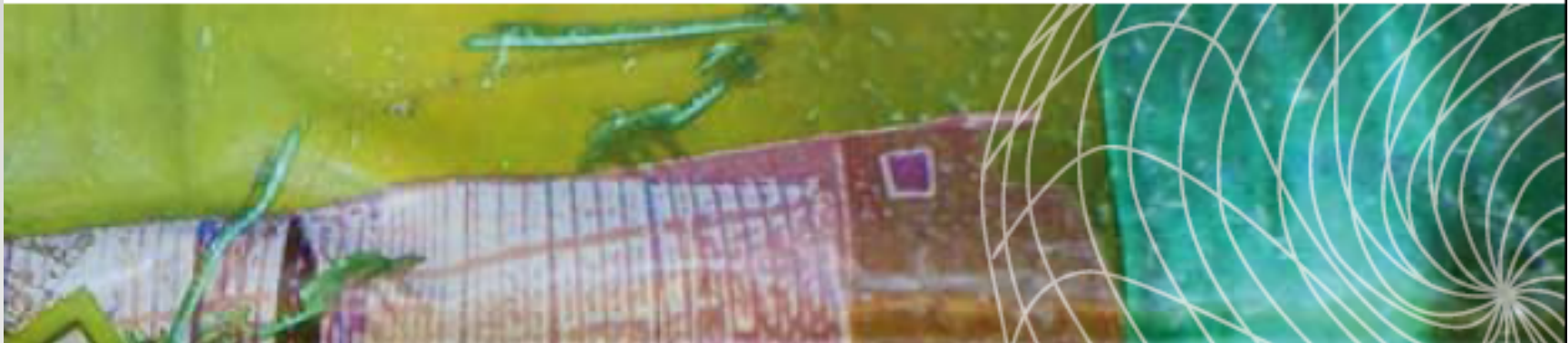
# www.npd.no

- **Facts**
- **Maps**
  - You name it, there's a high-quality map for it
  - GoogleEarth
- **Data**
  - Field production
  - Facilities, pipelines
  - Wells
  - Logs
  - Cores, Images, ...
- **Reports**

# FACTS

THE NORWEGIAN PETROLEUM SECTOR

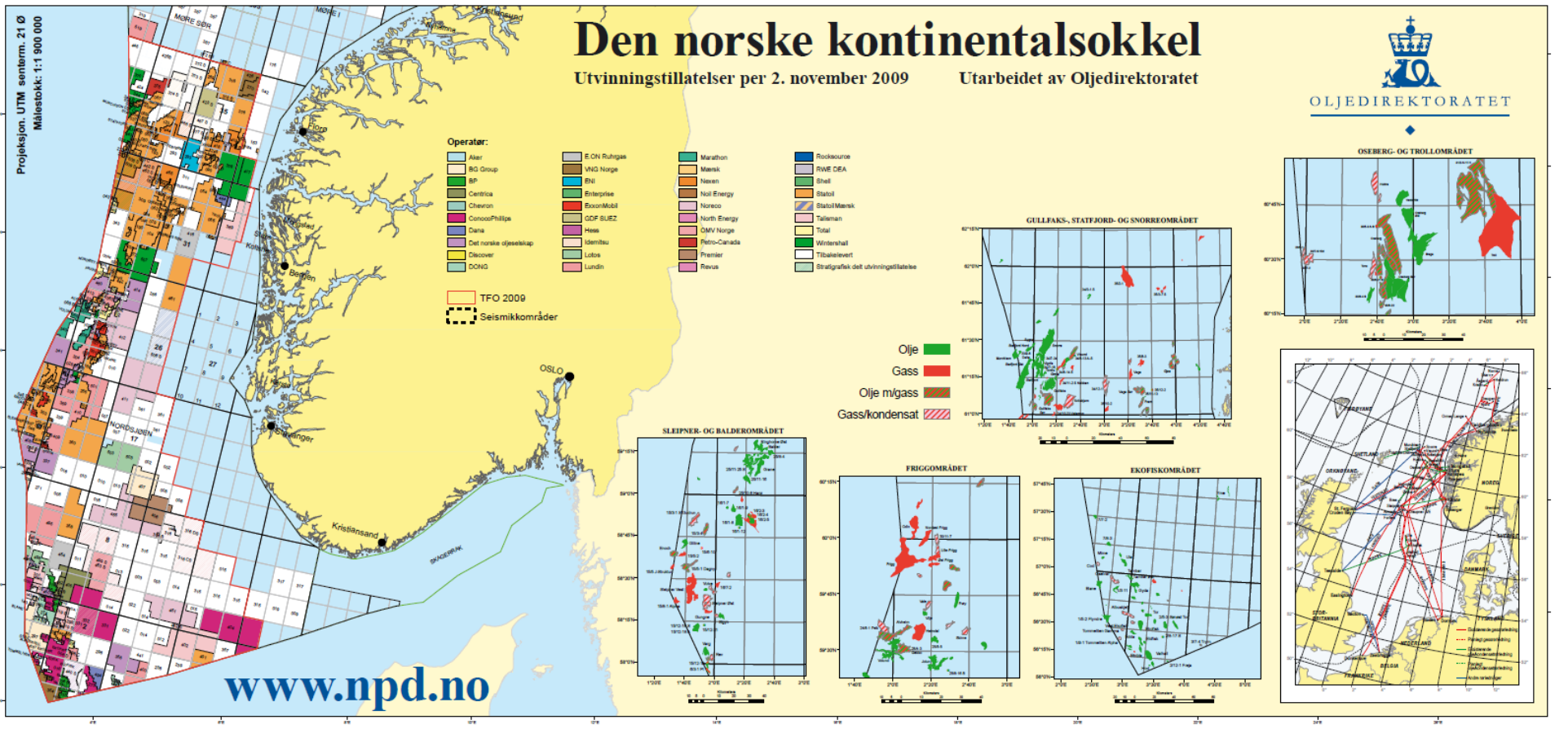
2009

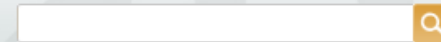


# Den norske kontinentalsokkel

Utvinningsstillatelser per 2. november 2009

Utarbeidet av Oljedirektoratet





Home / Maps / FactMaps on Google Earth

- ▶ FactMaps
- ▼ **FactMaps on Google Earth**
- ▶ Map of the NCS
- ▶ Two-way time map
- ▶ Order map

## FactMaps on Google Earth

**Some of the information available on the Norwegian Petroleum Directorate's (NPD's) FactMaps is also available on Google Earth.**

Like the FactMaps, this information is integrated into the NPD's FactPages, and is updated daily.

To use this service, Google Earth must be installed on the PC.

See box at right for further instructions.

### INSTRUCTIONS

1. [Downloading and installing Google Earth](#)
2. [Installing the FactMaps in Google Earth](#)





## Current owner(s)

Business Area: [ORMEN LANGE UNIT](#)

## The field extends into

### Block(s) Production licence(s)

6305/4 [209](#)

6305/5 [209](#)

6305/7 [208](#)

6305/8 [250](#)

## Current operator(s)

### Company

[A/S Norske Shell](#)

## The NPDs reserve estimates as of 31.12.2009 (Norwegian share)

### Recoverable reserves

Oil	Gas	NGL	Cond.	Oil	Gas	NGL	Cond.
[mill Sm <sup>3</sup> ]	[bill Sm <sup>3</sup> ]	[mill tonn]	[mill Sm <sup>3</sup> ]	[mill Sm <sup>3</sup> ]	[bill Sm <sup>3</sup> ]	[mill tonn]	[mill Sm <sup>3</sup> ]
0.00	301.70	0.00	18.60	0.00	267.80	0.00	15.80

### Remaining reserves

## Net production of saleable products (Norwegian share)

NGL = butane + ethane + isobutane + propane + LPG + gasoline + NGL mix.

Condensate = Condensate.

Sm<sup>3</sup>o.e. = oil + gas + NGL + condensate.

### [Charts](#)

	Oil	Gas	NGL	Cond.	NGL	Sm <sup>3</sup> o.e.
	[mill Sm <sup>3</sup> ]	[bill Sm <sup>3</sup> ]	[mill tonn]	[mill Sm <sup>3</sup> ]	[mill Sm <sup>3</sup> ]	[mill]
<b>Total per jan.2010</b>	0.000000	35.689735	0.000000	2.870913	0.000000	38.560648
<b>2010</b>	0.000000	1.800511	0.000000	0.123103	0.000000	1.923614
jan.2010	0.000000	1.800511	0.000000	0.123103	0.000000	1.923614
<b>2009</b>	0.000000	20.781666	0.000000	1.645793	0.000000	22.427459
dec.2009	0.000000	2.131490	0.000000	0.162297	0.000000	2.293787
nov.2009	0.000000	2.031102	0.000000	0.152899	0.000000	2.184001

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; OLJEDIREKTORATET 04.04.2010
;
; Contents:
; Gross wellhead production (Norwegian share).
; Complete history.
;
; Unit of measure:
; Oil: mill Sm3
; Gas: bill Sm3
; Condensate: mill Sm3
; Sm3 o.e.: mill Sm3
; Water: mill Sm3
;
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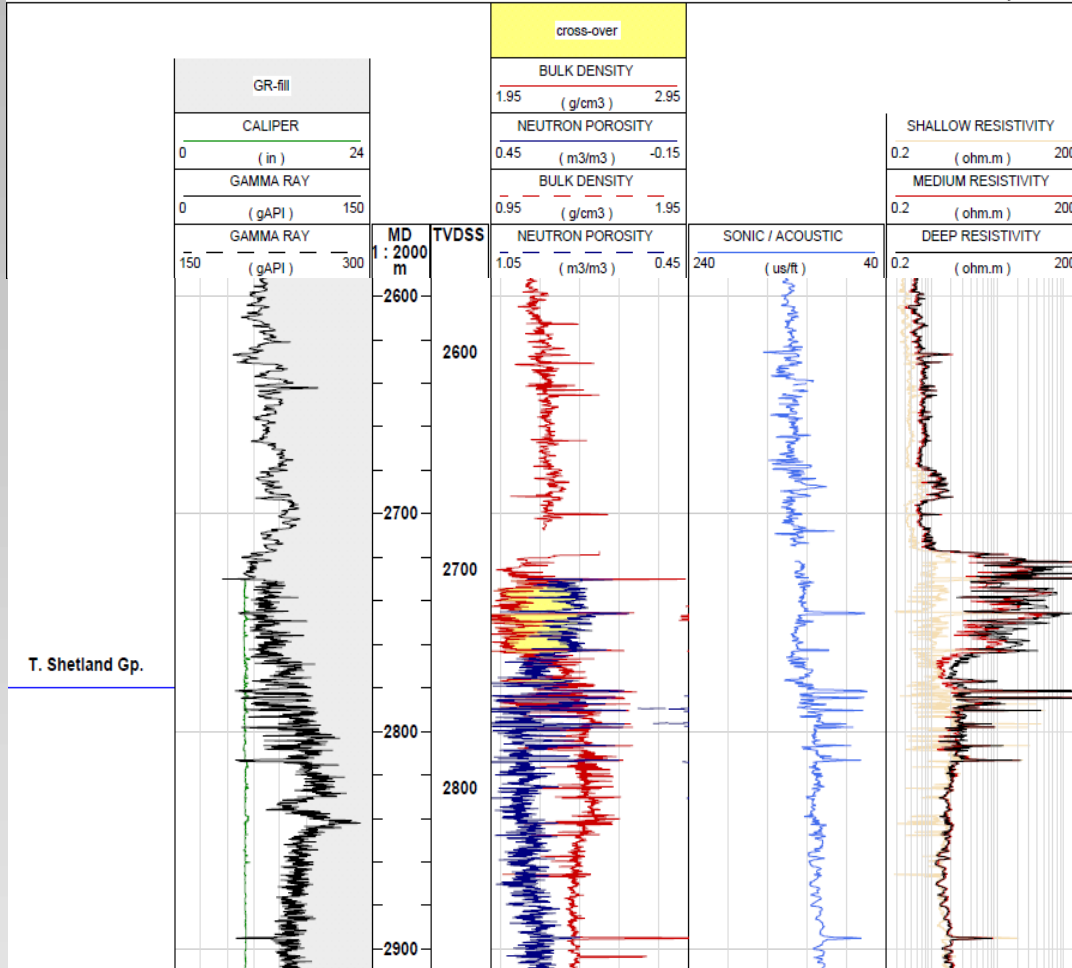
Every field, every month !

# Wellbore 6305/5-1

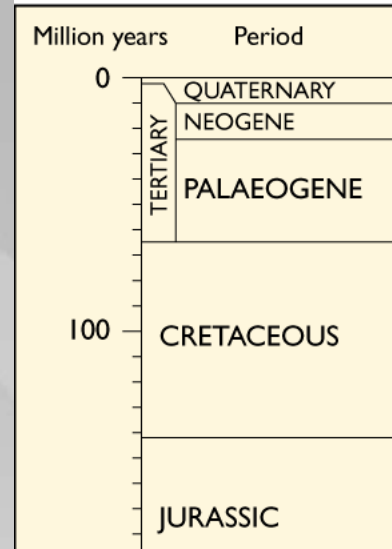


RKB 26 m

For more information see the NPD factpages at [www.npd.no](http://www.npd.no).



## Geological time scale



### 5.2 Oil stain and fluorescence

A summary of the observed shows is given in Table 5.1 below:

INTERVAL (mRKB)	SOURCE	LITHOLOGY	SHOWS DESCRIPTION
2730-2775	Core	Sandstone	Weak Petroliferous odour, no oil stain, 100% dull yellow direct Fluorescence, moderate blue white uniform blooming fluorescent cut, no visible cut, blue white - light yellow white fluorescent Residue, no visible Residue.
2775-2816.33	Core	Sandstone	Very weak - weak Petroliferous odour, no oil stain, weak dull yellow direct Fluorescence, weak blue white blooming fluorescent cut, no visible cut, white yellow fluorescent Residue, no visible Residue.
2786-2816.33	Core	Siltstone	No Petroliferous odour, no oil stain, no direct Fluorescence, weak - very weak blue white fluorescent cut, no visible cut, weak blue white - light yellow white fluorescent Residue, no visible Residue.
2792-2816.33	Core	Claystone	No Petroliferous odour, no oil stain, no direct Fluorescence, very weak blooming blue white fluorescent cut, no visible cut, very weak white - light yellow fluorescent Residue, no visible Residue.

## Field: ORMEN LANGE

### General information

Current activity status: PRODUCING

Discovery wellbore: [6305/5-1](#)

Discovery year: 1997

### Description [Norwegian](#)

### Development

Ormen Lange is a gas field located in the Møre Basin in the southern part of the Norwegian Sea. The sea depth in the area varies from 800 - 1 100 metres. The great sea depth has made the development very challenging and has resulted in development of new technology. The field is being developed in several phases with 24 wells from three subsea templates.

### Reservoir

The main reservoir consists of sandstones of Paleocene age in the Egga Formation, about 2 700 - 2 900 metres below sea level.

### Recovery strategy

The field is recovered by pressure depletion and, at a later stage, gas compression.

### Transport

The wellstream, which contains gas and condensate, is transported in two multiphase pipelines to the onshore facility at Nyhamna, where gas is dried and compressed before it is sent in the gas export pipeline, Langeled, via Sleipner R to Great Britain.

### Status

The gas production started from three wells in September 2007. A/S Norske Shell took over the operatorship from StatoilHydro 1 November 2007. The field is being produced with six wells, of these, three new wells were completed in 3rd quarter 2008. The onshore facility at Nyhamna can now produce at full capacity. A third subsea template will be installed in 2009.

## Current owner(s)

Business Area: [ORMEN LANGE UNIT](#)

## The field extends into

### Block(s) Production licence(s)

6305/4 [209](#)

6305/5 [209](#)

6305/7 [208](#)

6305/8 [250](#)

## Current operator(s)

### Company

[A/S Norske Shell](#)

## The NPDs reserve estimates as of 31.12.2009 (Norwegian share)

### Recoverable reserves

Oil	Gas	NGL	Cond.	Oil	Gas	NGL	Cond.
[mill Sm <sup>3</sup> ]	[bill Sm <sup>3</sup> ]	[mill tonn]	[mill Sm <sup>3</sup> ]	[mill Sm <sup>3</sup> ]	[bill Sm <sup>3</sup> ]	[mill tonn]	[mill Sm <sup>3</sup> ]
0.00	301.70	0.00	18.60	0.00	267.80	0.00	15.80

### Remaining reserves

## Net production of saleable products (Norwegian share)

NGL = butane + ethane + isobutane + propane + LPG + gasoline + NGL mix.

Condensate = Condensate.

Sm<sup>3</sup>o.e. = oil + gas + NGL + condensate.

### [Charts](#)

	Oil	Gas	NGL	Cond.	NGL	Sm <sup>3</sup> o.e.
	[mill Sm <sup>3</sup> ]	[bill Sm <sup>3</sup> ]	[mill tonn]	[mill Sm <sup>3</sup> ]	[mill Sm <sup>3</sup> ]	[mill]
<b>Total per jan.2010</b>	0.000000	35.689735	0.000000	2.870913	0.000000	38.560648
<b>2010</b>	0.000000	1.800511	0.000000	0.123103	0.000000	1.923614
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<b>2009</b>	0.000000	20.781666	0.000000	1.645793	0.000000	22.427459
dec.2009	0.000000	2.131490	0.000000	0.162297	0.000000	2.293787
nov.2009	0.000000	2.031102	0.000000	0.152899	0.000000	2.184001

### Exploration wellbore(s)

Name	Entry date	Completion date	Drill permit	WB purpose	WB status	WB contents
<a href="#">6305/4-1</a>	2002.03.14	2002.06.03	1025-L	APPRAISAL	P&A	GAS
<a href="#">6305/5-1</a>	1997.07.27	1997.10.07	900-L	WILDCAT	P&A	GAS
<a href="#">6305/7-1</a>	1998.07.08	1998.08.30	932-L	APPRAISAL	P&A	GAS
<a href="#">6305/8-1</a>	2000.07.13	2000.09.08	978-L	APPRAISAL	P&A	OIL/GAS

4 wellbore(s)

### Development wellbore(s)

Name	Entry date	Completion date	Drill permit	WB purpose	WB status	WB contents
<a href="#">6305/5-B-1 H</a>			2817-P	PRODUCTION		
<a href="#">6305/5-B-2 H</a>	2007.02.10	2007.02.27	2624-P	PRODUCTION	PLUGGED	
<a href="#">6305/5-B-2 AH</a>	2007.02.28	2008.01.23	2939-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/5-B-3 H</a>	2008.07.17	2008.08.14	2625-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/5-B-4 H</a>			2818-P	PRODUCTION		
<a href="#">6305/5-B-5 H</a>			2819-P	PRODUCTION		
<a href="#">6305/5-B-6 H</a>	2008.12.08	2009.03.12	2626-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/5-B-7 H</a>	2008.11.08	2008.12.07	2627-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/5-B-8 H</a>			2820-P	PRODUCTION		
<a href="#">6305/5-M-2</a>	2006.08.05	2006.08.30	2749-P	OBSERVATION	PLUGGED	
<a href="#">6305/7-D-2 H</a>			3194-P	PRODUCTION		
<a href="#">6305/7-D-3 H</a>			3169-P	PRODUCTION		
<a href="#">6305/7-D-6 H</a>			3170-P	PRODUCTION		
<a href="#">6305/7-D-7 H</a>	2009.12.28	2010.01.24	3171-P	OBSERVATION	PLUGGED	
<a href="#">6305/7-D-7 AH</a>	2010.03.16		3172-P	PRODUCTION		
<a href="#">6305/8-A-1 H</a>			2821-P	PRODUCTION		
<a href="#">6305/8-A-2 H</a>	2006.02.04	2006.03.11	2610-P	OBSERVATION	PLUGGED	
<a href="#">6305/8-A-2 AH</a>	2006.03.12	2006.03.25	2611-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/8-A-3 H</a>	2006.03.26	2006.04.19	2621-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/8-A-4 H</a>	2009.01.25	2009.02.27	2822-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/8-A-5 H</a>	2008.12.24	2009.01.22	2823-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/8-A-6 H</a>	2006.04.20	2007.03.23	2622-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/8-A-7 H</a>	2006.07.11	2007.05.05	2623-P	PRODUCTION	PRODUCING GAS	
<a href="#">6305/8-A-8 H</a>			2824-P	PRODUCTION		

24 wellbore(s)



## Exploration wellbore: 6305/4-1

### General information

NPDID wellbore:	4441
Well name:	6305/4-1
Drilling operator name:	Norsk Hydro Produksjon AS
Geodetic datum:	ED50
Coordinates:	63° 34` 17.76`` N      5° 17` 55.93`` E
UTM coordinates:	7051501.85 N      614148.32 E
UTM zone:	31
Drilled in production licence:	<a href="#">209</a>
Area:	NORWEGIAN SEA
Discovery:	<a href="#">6305/5-1 ORMEN LANGE</a>
Field:	<a href="#">ORMEN LANGE</a>
Drill permit:	1025-L
Drilling facility:	<a href="#">SCARABEO 5</a>
Drilling days:	82
Wellbore entry date:	14.03.2002
Wellbore completion date:	03.06.2002
Original wellbore purpose:	APPRAISAL
Wellbore purpose:	APPRAISAL
Wellbore status:	P&A
Wellbore contents:	GAS
Discovery wellbore:	NO
Formation/age with hydrocarbons 1:	EGGA (INFORMAL) / PALEOCENE
Seismic location:	inline 4152 & x-line 5028
Kelly bushing elevation (KB) [m]:	25
Water depth [m]:	1004
Total Depth (MD) [m]:	2975
Final vertical depth (TVD) [m]:	2974
Max inclination [°]:	5.70
Bottom hole temperature [°C]:	84
Oldest penetrated age:	LATE CRETACEOUS

## Wellbore history

### General

The appraisal well 6305/4-1 is located in the north western part of the direct hydrocarbon indicator (DHI) area of the Ormen Lange Field, in the eastern part of block 6305/4 in PL209. There were three main objectives for the well, all having equal priority. The first objective was to reduce the risk of the worst-case scenario of reservoir compartmentalisation. The second objective was to address the potential slide risk due to reservoir drainage of the main production area, and the third objective was to reduce the risk of worst-case GIIP through improved knowledge on the hydrocarbon distribution. Further important objectives were to test the reservoir quality closer to the NW margin of the gas field as well as to acquire a new check point for geophysical, geological and petrophysical interpretations.

### Operations and results

The well was spudded on 16 March 2002 and reached a total depth of 2975 m in the Late Cretaceous Springar Formation. In general, the drilling conditions experienced in well 6305/4-1 are as predicted. The well was drilled with seawater and hi-vis pills to 1756 m and with KCl/polymer/glycol (Glydril) mud from 1756 m to TD. In tie-well 6305/5-1 problems with borehole instability was experienced in the Eocene deposits. No such problems were reported from well 6305/4-1, but loss of mud to the formation was experienced during the leak off test at 1749 m.

All drilling objectives were met. All logging and well test objectives were met. The well proved good reservoir quality in the Egga Reservoir Unit, which was thinner than prognosed. A Gas Down To situation was encountered in the lowermost Egga Formation. Isolated, overpressured water filled sands were found in the underlying units. Shows were recorded only in the reservoir section. A single day production test indicates dynamic sealing for parts of 3 of the 4 seismically interpreted faults, which surround the well location. One 60 ft core was cut in the Ooze section of the Brygge Formation from 1761 m to 1779 m (Core #1). Additional 3 x 60 ft cores were cut from 2769 m in the Egga reservoir sand to 2817.3 m. When Core # 3 was at rig floor it started to expand due to trapped gas. Approximately 1,5 - 2m of core came out of the inner barrel and partly disintegrated on rig floor. The upper part of the inner barrel contained therefore gaps between core pieces. As a result, the measured depths do not fit the actual depth of the reservoir for core # 3.

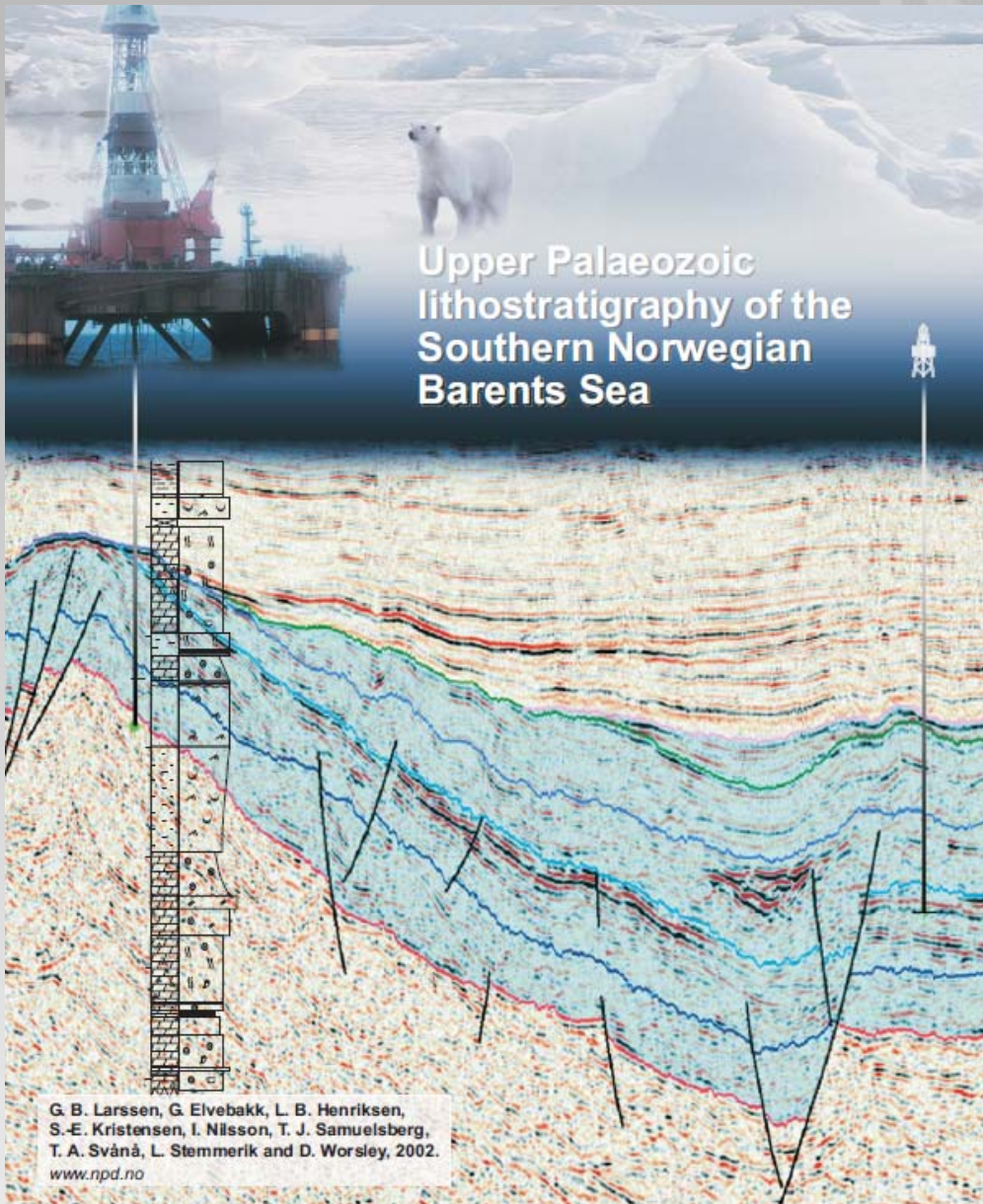
Formation temperatures using Horner plots were estimated at 2660 m and 2975 m giving 72°C and 84°C, respectively. This gives an average formation temperature gradient of 4.31°C / 100m TVD assuming 1.8°C at seafloor. It was prognosed a gradient of 4.4°C. The small discrepancy may be due to the uncertainty of the method used. The result was within the range of data from nearby wells. The average gradient may be further divided into one gradient of 4.52°C from seafloor to 2660 m and then one gradient of 3.81°C from 2660 m to 2975 m. However, the long marine riser is known to cool down the mud to such an extent that the use of only Horner plots to estimate the formation temperature becomes doubtful. The well was tested and a temperature of 86.9°C was estimated at 2783.5 m. This would give an average formation temperature gradient of 4.84°C / 100 m TVD, which is higher than prognosed. With a gradient of 4.84°C / 100 m TVD the BHST at TD (2975m) equals to 96.1°C. Eight MDT samples were taken in the Reservoir at 2788.8 m. All eight recovered gas. One MDT sample taken at 2811.1 m recovered water.

The well was permanently plugged and abandoned after testing as a gas appraisal well on 2 June 2002.

### Testing

A production test was carried out, producing 1.87 mil Sm<sup>3</sup> gas and 153 Sm<sup>3</sup> condensate /day through a 80/64" choke at 135 bar.&





## Tropical Weathering in Norway

### The NGU - NPD Twin Project

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 2) Geological Survey of Norway (NGU), NO-7491 Trondheim

The Norwegian Petroleum Directorate and the Geological Survey of Norway (NGU) have launched a joint research and mapping project on deep weathering of basement rocks in Norway. The project involves mineralogical, chemical and petrophysical characterization of known occurrences of deep weathering, as well as development and testing of age dating techniques and geomorphological and geophysical mapping tools.

This poster highlights some of the on- and offshore sites in Norway we are already found deep weathering, and presents preliminary work.

Deeply weathered basement are preserved along fault and fracture zones (Fig 7.) onshore Norway in several localities (e.g.) ☆:

- Vesterfjell in northern Norway,
- Beitstad-Indersjøy area in mid Norway
- Stadlandet-Vågsøy in western Norway
- Lista in southernmost Norway
- Kjøse-Larvik area, south-eastern Norway

Three of the areas are located adjacent to offshore areas (Fig 1,2), one site is found close to seismic indications of Mesozoic deep weathering (Fig 6). The recognition of preglacial weathering in Scandinavia is not a new phenomena, but was not in focus for several decades in academia.

**Weathered basement found in well nr. 1 on the Norwegian Shelf!**

The Norwegian continental shelf is covered by post-Silurian sediments, overlying crystalline basement. NPD's Core Store contains all the cores taken offshore Norway. Of the more than 1200 exploration wells drilled by the petroleum industry, about 50 wells have reached basement. Even the first exploration well drilled, 8/3-1, terminated in deeply weathered basement. Figure 3 shows a possible DHI in a deeply weathered zone from western Norway.

**Deep weathering localities, Lista:**

A: corals with barren features.  
 B: corals with a high Mn and Fe content.  
 C: Core stones.

**Issues on deep weathering offshore Norway:**

- Possible lack of bottom seal in petroleum reservoirs, especially in the provinces Nordland VII, Troms II and offshore the Møre coast.
- Possible hydrocarbon migration route
- Importance for CO<sub>2</sub> storage and possible leakage problems in areas close to coast.
- Weathered basement could act as petroleum reservoir (Well 16/1-4 on Osira High proved gas condensate in brecciated, and probably weathered, basement, Fig 2).
- Our knowledge about deep weathering in the North Atlantic Petroleum Provinces is limited.

This project will provide new insight and may provide a new play model for hydrocarbon exploration.

**Fig. 3:** Seismic and geoseismic profile offshore Møre, NW-Norway. Indications of deep weathered basement is also found on fault blocks

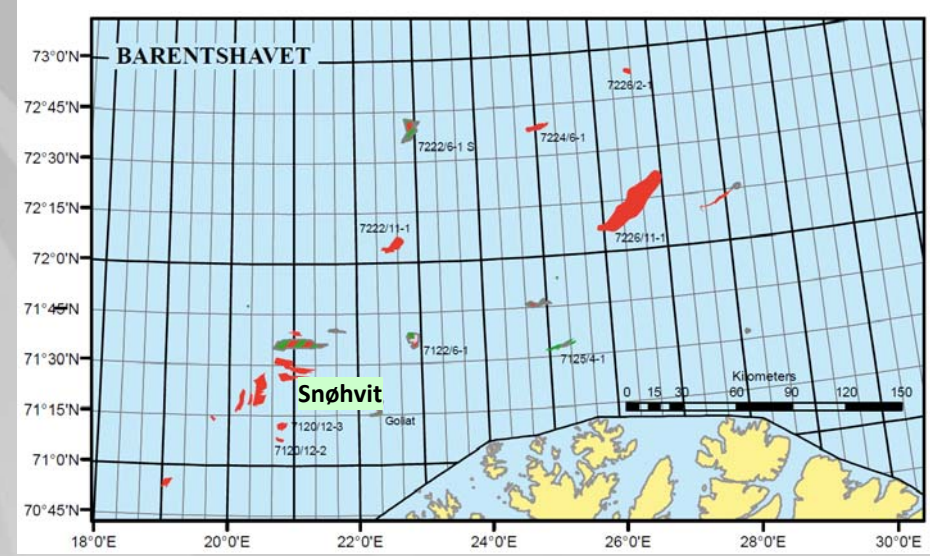
**Fig 5.** Ramak, Andøya geological profile (modified from Møller 2007)

**Onshore hydrocarbons**

Andøya in Nordland County, Northern Norway is one of the few sites onshore Norway that contains in-situ Mesozoic sediments (Fig 5.). These sediments were drilled for hydrocarbon exploration during the early 1970s. The drilling revealed deeply weathered basement underlying the Cretaceous and Jurassic sediments (Fig 4).

**Fig 6:** Indications of deeply weathered basement offshore Karmøy, SW-Norway.

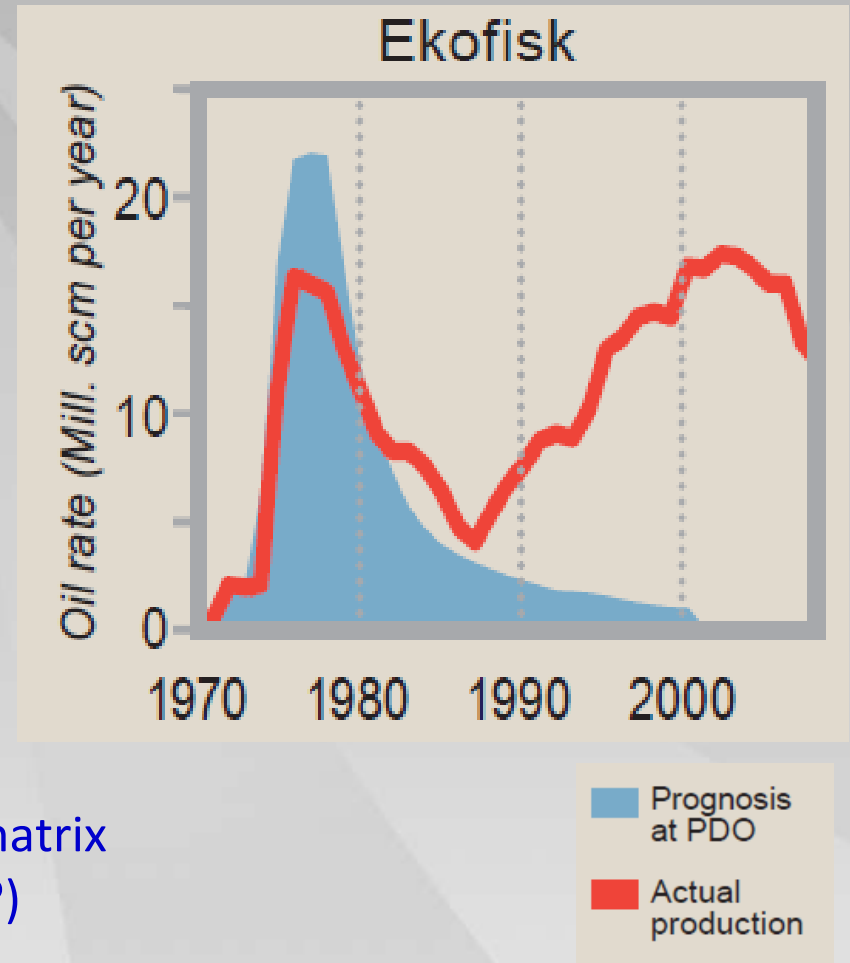
**Fig 7:** Estimated deeply weathered paleo-surface in the Juvøy area, SW-Norway. Note similarity between Fig 4, 6 (box) and 7.



**Norwegian  
fields we're  
going to take a  
look at ...**

# Ekofisk

- **Shallow water depth (70 m)**
- **Discovered 1969**
  - Initial production already in 1972!
  - 40 years and still going strong!
- **Giant (6 billion bbl , 8 Tcf) IFIPs**
- **Fractured chalk**
  - 30-40% porosity
  - 0.5-5 md matrix ; 0.5-100 md fracture-matrix
  - EOR (Water? HC-gas ? N<sub>2</sub>? Water? CO<sub>2</sub> ?)
  - Subsidence / Compaction
  - Modeling
- **Hugely successful waterflood**
  - Technology Triumph #1.

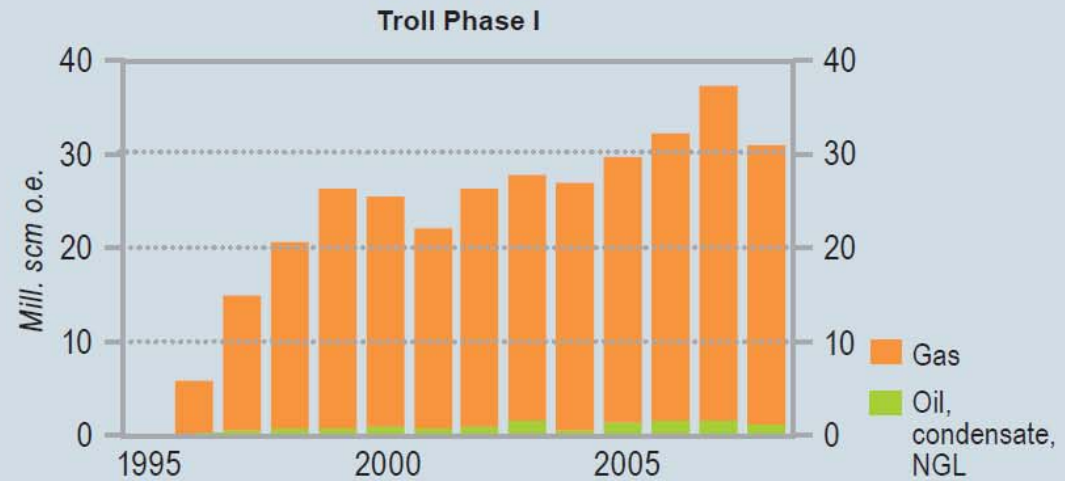


# Ekofisk

<b>Blocks and production licences</b>	Block 2/4 - production licence 018, awarded 1965	
<b>Discovered</b>	1969	
<b>Development approval</b>	01.03.1972	
<b>On stream</b>	15.06.1971	
<b>Operator</b>	ConocoPhillips Skandinavia AS	
<b>Licensees</b>	ConocoPhillips Skandinavia AS	35.11 %
	Eni Norge AS	12.39 %
	Petoro AS	5.00 %
	StatoilHydro ASA	0.95 %
	StatoilHydro Petroleum AS	6.65 %
	Total E&P Norge AS	39.90 %
<b>Recoverable reserves</b>	<b>Original:</b>	<b>Remaining as of 31.12.2008:</b>
	528.5 million scm oil	125.7 million scm oil
	156.1 billion scm gas	20.4 billion scm gas
	14.5 million tonnes NGL	2.2 million tonnes NGL
<b>Production</b>	<b>Estimated production in 2009:</b>	
	Oil: 212 000 barrels/day, Gas: 2.50 billion scm, NGL: 0.24 million tonnes	
<b>Investment</b>	Total investment is expected to be NOK 185.7 billion (2009 values)	
	NOK 139.5 billion have been invested as of 31.12.2008 (2009 values)	
<b>Operating organisation</b>	Stavanger	
<b>Main supply base</b>	Tananger	

# Troll

- **Moderate water depth (300 m)**
- **Discovered 1983**
  - Initial oil production already in 1996.
  - Earlier 4-well template TOGI project.
  - Hydro / Statoil split operatorship.
- **45 Tcf and 3+ billion bbl IFIP**
  - Shell valued “thin” oil = USD 0 initially!
  - >1 billion bbl already produced! (250-500 million bbl remaining)
  - Pioneering horizontal well and FPSO (1990) – [Technology Triumph #2.](#)
- **Untraditional Phased Development**
  - Initial (small) gas TOGI project.
  - Oil “rim” development.
  - Gas development.



## Troll

The Troll field lies in the northern part of the North Sea about 65 kilometres west of Kollsnes. The water depth in the area is more than 300 metres. The field has huge gas resources and one of the largest oil volumes remaining on the Norwegian continental shelf. Troll comprises two main structures: Troll Øst and Troll Vest, and roughly two-thirds of the recoverable gas reserves lie in Troll Øst. A thin oil rim underlies the gas throughout the Troll field, but so far only in Troll Vest is this oil zone of sufficient thickness to be commercial, 11 to 27 metres. In 2007, an oil column of 6-9 metres was proven in the northern part of Troll Øst. A test production of oil from this part of Troll started in November 2008. A phased development has been pursued, with Phase I recovering gas reserves in Troll Øst and Phase II focused on the oil reserves in Troll Vest. The gas reserves in Troll Vest will be developed in a future phase 3. The Troll licensees are conducting studies to plan for further development of the field. Troll was the largest producer of both oil and gas on the Norwegian continental shelf in the period 2000 – 2004.

# Troll I

<b>Blocks and production licences</b>	Block 31/2 - production licence 054, awarded 1979 Block 31/3 - production licence 085, awarded 1983 Block 31/3 - production licence 085 C, awarded 2002 Block 31/3 - production licence 085 D, awarded 2006 Block 31/5 - production licence 085, awarded 1983 Block 31/6 - production licence 085, awarded 1983 Block 31/6 - production licence 085 C, awarded 2002	
<b>Discovered</b>	1983	
<b>Development approval</b>	15.12.1986 by the Storting	
<b>On stream</b>	09.02.1996	
<b>Operator</b>	StatoilHydro ASA	
<b>Licensees</b>	A/S Norske Shell	8.10 %
	ConocoPhillips Skandinavia AS	1.62 %
	Petoro AS	56.00 %
	StatoilHydro ASA	20.80 %
	StatoilHydro Petroleum AS	9.78 %
	Total E&P Norge AS	3.69 %
<b>Recoverable reserves</b>	<b>Original:</b> 1330.7 billion scm gas 25.7 million tonnes NGL 1.6 million scm condensate	<b>Remaining as of 31.12.2008:</b> 995.0 billion scm gas 22.1 million tonnes NGL
<b>Production</b>	<b>Estimated production in 2009:</b> Gas: 28.7 billion scm, NGL: 1.08 million tonnes	
<b>Investment</b>	Total investment is expected to be NOK 81 billion (2009 values) NOK 62 billion have been invested as of 31.12.2008 (2009 values)	
<b>Operating organisation</b>	Bergen	
<b>Main supply base</b>	Ågotnes	

**Development:**

Troll Phase I has been developed with Troll A which is a fixed wellhead and compression facility with a concrete substructure. Troll A is powered by electricity supplied from land. An updated development plan involving the transfer of gas processing to Kollsnes was approved in 1990. Kollsnes was separated from the unitised Troll field in 2004, and the Kollsnes terminal is currently operated by Gassco as part of the Gassled joint venture. The gas compression capacity at Troll A was increased in 2004/2005. The Troll Oseberg Gas Injection (TOGI) subsea template is also located at Troll Øst. Gas was exported to Oseberg for injection. The TOGI decommissioning plan involving removal of the subsea template, was approved in 2005.

**Reservoir:**

The gas and oil reservoirs in the Troll Øst and Troll Vest structures consist primarily of shallow marine sandstones of the Sognefjord Formation. Part of the reservoir is in the Fensfjord Formation below the Sognefjord Formation. The reservoir is of Late Jurassic age. The field consists of three relatively large rotated fault blocks. The fault block to the east constitutes Troll Øst. Pressure communication between Troll Øst and Troll Vest has been proven. Previously, the oil column in Troll Øst was mapped to be 0-4 metres. A well drilled in 2007 proved an oil column of 6 - 9 metres in the Fensfjord Formation in the northern segment of Troll Øst. The reservoir depth at Troll Øst is about 1 330 metres.

**Recovery strategy:**

The gas in Troll Øst is recovered by pressure depletion.

**Transport:**

The gas from Troll Øst and Troll Vest is transported through two multiphase pipelines to the gas processing plant at Kollsnes. The condensate is separated from the gas, and transported by pipeline partly to the Sture terminal, and partly to Mongstad. The dry gas is transported in Zeepipe II A and II B.

**Status:**

A test production of oil from the northern part of Troll Øst started in November 2008. The licensees will consider development of this area when experience from the test production is available.



# Troll II

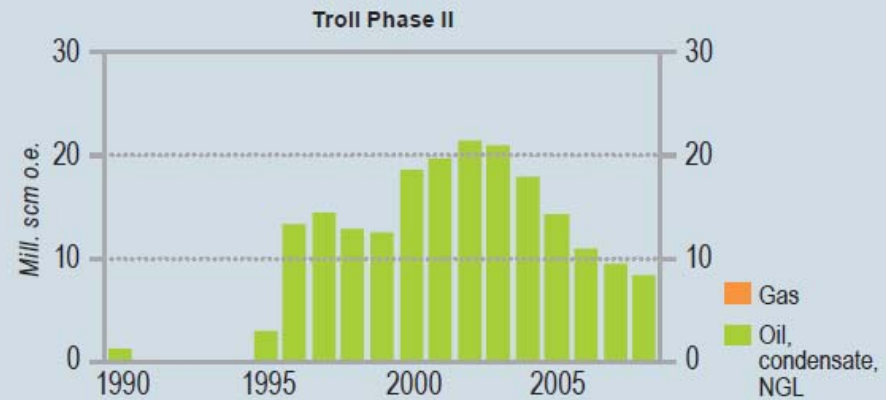
<b>Blocks and production licences</b>	Block 31/2 - production licence 054, awarded 1979 Block 31/3 - production licence 085, awarded 1983 Block 31/3 - production licence 085 C, awarded 2002 Block 31/3 - production licence 085 D, awarded 2006 Block 31/5 - production licence 085, awarded 1983 Block 31/6 - production licence 085, awarded 1983 Block 31/6 - production licence 085 C, awarded 2002	
<b>Discovered</b>	1979	
<b>Development approval</b>	18.05.1992 by the Storting	
<b>On stream</b>	19.09.1995	
<b>Operator</b>	StatoilHydro Petroleum AS	
<b>Licensees</b>	A/S Norske Shell	8.10 %
	ConocoPhillips Skandinavia AS	1.62 %
	Petoro AS	56.00 %
	StatoilHydro ASA	20.80 %
	StatoilHydro Petroleum AS	9.78 %
	Total E&P Norge AS	3.69 %
<b>Recoverable reserves</b>	<b>Original:</b> 244.5 million scm oil	<b>Remaining as of 31.12.2008:</b> 45.8 million scm oil
<b>Production</b>	<b>Estimated production in 2009:</b> Oil: 122 000 barrels/day	
<b>Investment</b>	Total investment is expected to be NOK 104.5 billion (2009 values) NOK 84.8 billion have been invested as of 31.12.2008 (2009 values)	
<b>Operating organisation</b>	Bergen	
<b>Main supply base</b>	Mongstad	

**Development:**

Troll Phase II has been developed with Troll B, a floating concrete accommodation and production facility, and Troll C, which is a steel-hulled, semi-submersible accommodation and production facility. The oil in Troll Vest is produced by means of several subsea templates tied back to Troll B and Troll C by flowlines. Troll Pilot, which was installed in 2000 at a depth of 340 meters, is a subsea facility which separates produced water prior to its re-injection into the reservoir. The Troll C facility is also utilised for production from the Fram field. The Troll C development was approved in 1997. There have been several PDO approvals in connection with various subsea templates at Troll Vest.

**Reservoir:**

The gas and oil in the Troll Øst and Troll Vest structures are found primarily in the Sognefjord Formation which consists of shallow marine sandstones of Late Jurassic age. Part of the reservoir is also in the underlying Fensfjord Formation. The field comprises three relatively large rotated fault blocks. The oil in the Troll Vest oil province is encountered in a 22–26 metre thick oil column overlain by a small gas cap, located at 1 360 metres depth. The Troll Vest gas province has an oil column of around 12-14 metres overlain by a gas column up to 200 metres in thickness. A significant volume of residual oil is encountered immediately below the Troll Vest oil column. In 2005 a minor oil discovery was made in the Jurassic Brent Group, located somewhat deeper than the main oil reservoir..



**Recovery strategy:**

The oil in Troll Vest is produced by means of long horizontal wells which penetrate the thin oil zone immediately above the oil-water contact. Here too, the recovery strategy is based primarily on pressure depletion, but this is accompanied by a simultaneous expansion of both the gas cap above the oil zone and the underlying water zone. In the Troll Vest oil province, some of the produced gas has been reinjected into the reservoir to optimise oil production. One important aspect of the strategy has been to recover the oil rapidly, since the volumes of oil that can be recovered will decrease as pressure drive declines at Troll Øst. For this reason, limits have been placed on the rates of gas production from Troll Øst.

**Transport:**

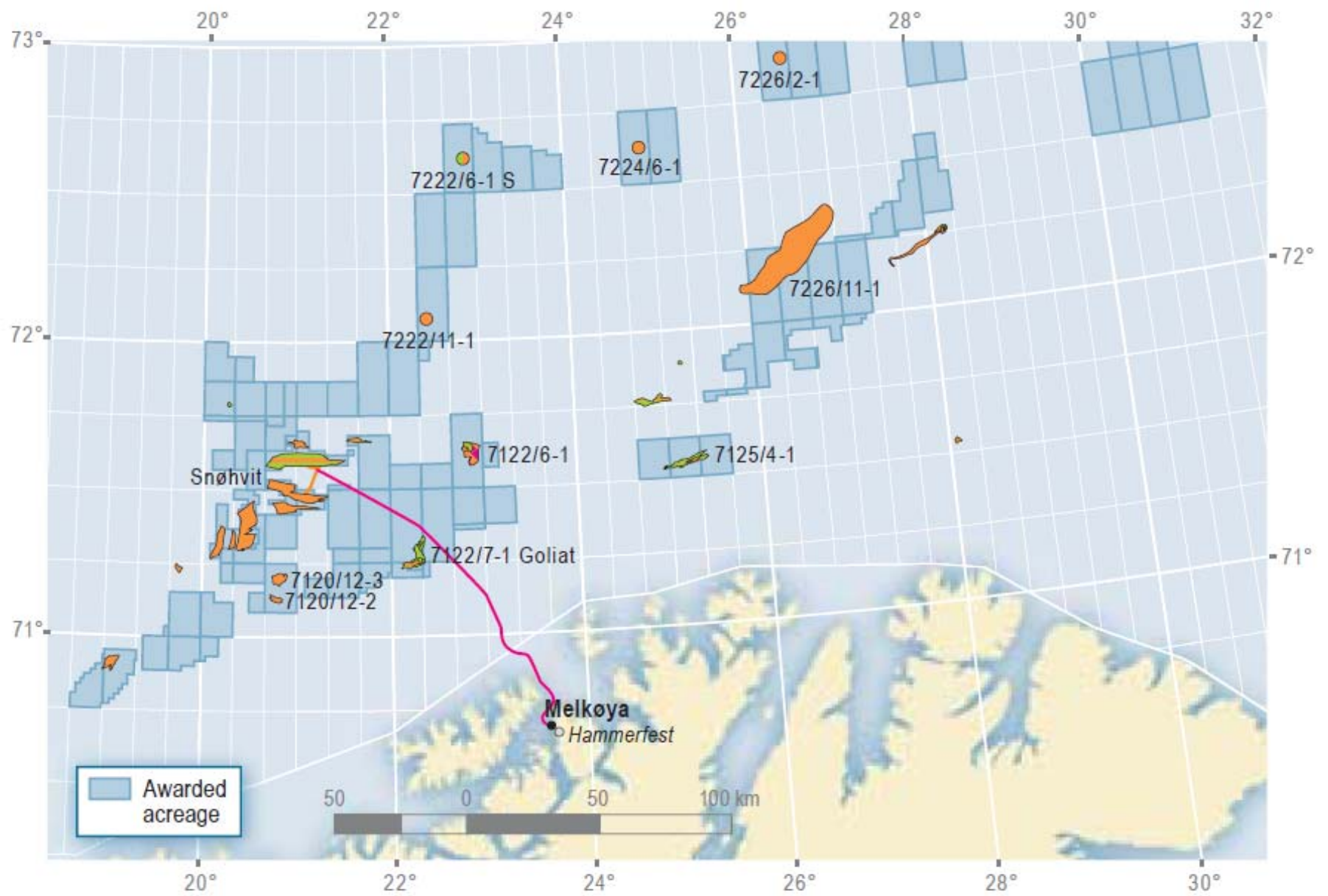
The gas from Troll Øst and Troll Vest is transported through two multiphase pipelines to the gas processing plant at Kollsnes. Condensate is separated from the gas and transported onwards by pipelines, partly to the Sture terminal, partly to Mongstad. The dry gas is transported through Zeepipe II A and Zeepipe II B. The oil from Troll B and Troll C is transported in the Troll Oil Pipelines I and II, respectively, to the oil terminal at Mongstad.

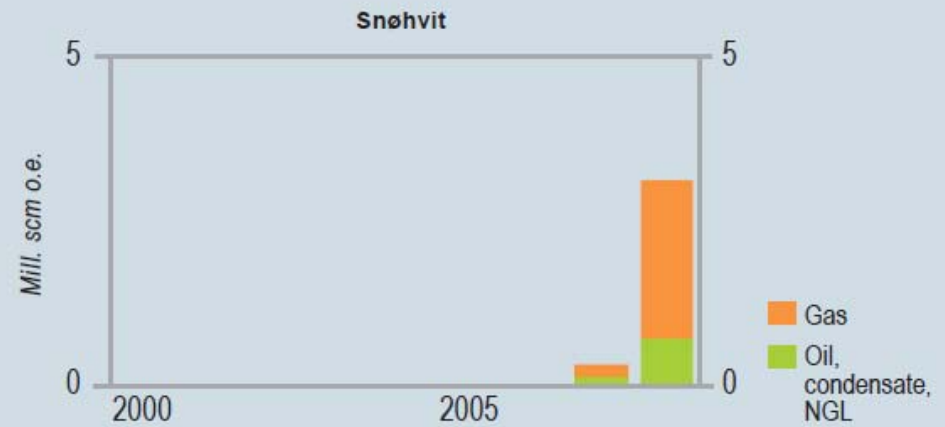
**Status:**

Drilling on Troll Vest with horizontal production wells from subsea templates continues with three mobile drilling facilities in activity. In total, more than 120 oil production wells have so far been drilled at Troll Vest. Over the last few years, decisions have been made every year to drill new production wells to increase the oil reserves in Troll, and there are still a number of wells in the drilling plan. Several multibranch wells have been drilled, with up to seven branches in the same well. In 2008 the licensees submitted a PDO which also included gas injection in Troll Vest. In addition, studies have been initiated with regard to water injection.

# Snøhvit

- **Moderate water depth (320 m)**
- **Discovered 1984**
  - Initial gas production in 2007.
- **Pressure depletion.**
  - 19 subsea production wells.
  - Subsea-to-land with 160 km multiphase pipeline.
  - CO<sub>2</sub> extraction and reinjection – 1 well (so far).
  - LNG transported to USA.





## Snøhvit

<b>Blocks and production licences</b>	Block 7120/6 - production licence 097, awarded 1984 Block 7120/7 - production licence 077, awarded 1982 Block 7120/8 - production licence 064, awarded 1981 Block 7120/9 - production licence 078, awarded 1982 Block 7121/4 - production licence 099, awarded 1984 Block 7121/5 - production licence 110, awarded 1985 Block 7121/7 - production licence 100, awarded 1984	
<b>Discovered</b>	1984	
<b>Development approval</b>	07.03.2002 by the Storting	
<b>On stream</b>	21.08.2007	
<b>Operator</b>	StatoilHydro ASA	
<b>Licensees</b>	GDF SUEZ E&P Norge AS Hess Norge AS Petro AS RWE Dea Norge AS StatoilHydro ASA Total E&P Norge AS	12.00 % 3.26 % 30.00 % 2.81 % 33.53 % 18.40 %

<b>Recoverable reserves</b>	<b>Original:</b> 160.6 billion scm gas 6.3 million tonnes NGL 18.1 million scm condensate	<b>Remaining as of 31.12.2008:</b> 158.1 billion scm gas 6.2 million tonnes NGL 17.5 million scm condensate
<b>Production</b>	<b>Estimated production in 2009:</b> Gas: 3.59 billion scm, NGL: 0.19 million tonnes, Condensate: 0.6 million scm	
<b>Investment</b>	Total investment is expected to be NOK 21.9 billion (2009 values)* NOK 9.0 billion have been invested as of 31.12.2008 (2009 values)	
<b>Operating organisation</b>	Harstad and Stjørdal	

*\*Total investment, including the land facilities, is expected to be 77.3 billion (2009 values).*

#### **Development:**

Snøhvit is located in the Barents Sea in the central part of the Hammerfest basin, at a sea depth of 310 - 340 metres. Snøhvit is a gas field with condensate and an underlying thin oil zone. The field comprises several discoveries and deposits in the Askeladd and Albatross structures in addition to Snøhvit. The approved PDO for the gas resources includes subsea templates for 19 production wells and one injection well for CO<sub>2</sub>.

#### **Reservoir:**

The reservoirs contain gas, condensate and oil in Lower and Middle Jurassic sandstones of the Stø and Nordmela formations. The reservoir depth is approximately 2 300 meters.

#### **Recovery strategy:**

The recovery strategy is pressure depletion. The development does not comprise recovery of the oil zone.

**Transport:**

The unprocessed wellstream, containing natural gas inclusive CO<sub>2</sub>, NGL and condensate, is transported through a 160 kilometres long pipeline to the facility at Melkøya for processing and export. The gas is processed and cooled down to liquid form (LNG) at Melkøya. The CO<sub>2</sub> content in the gas is separated at Melkøya and sent back to the field and reinjected in a deeper formation. LNG is shipped to the market.

**Status:**

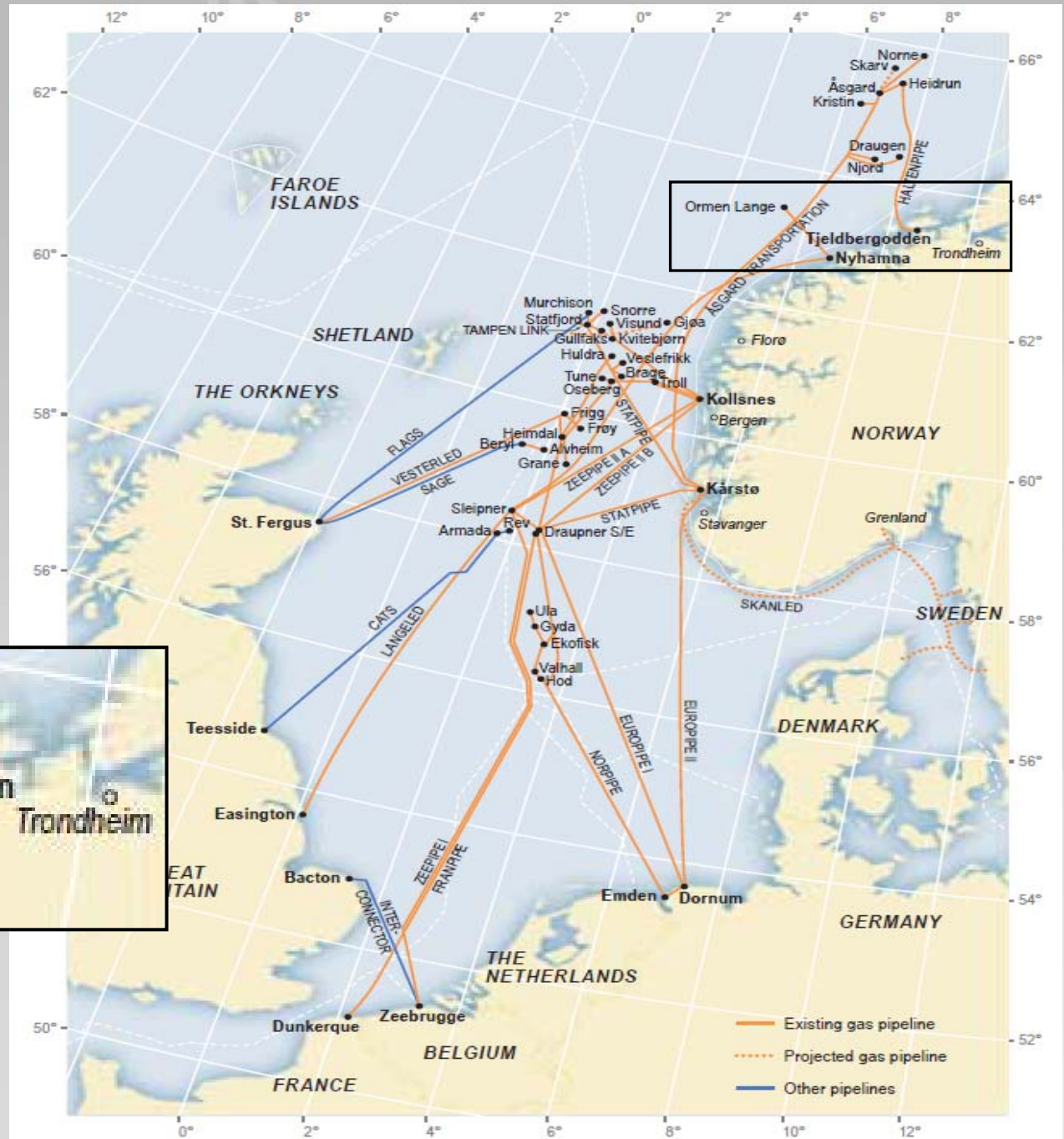
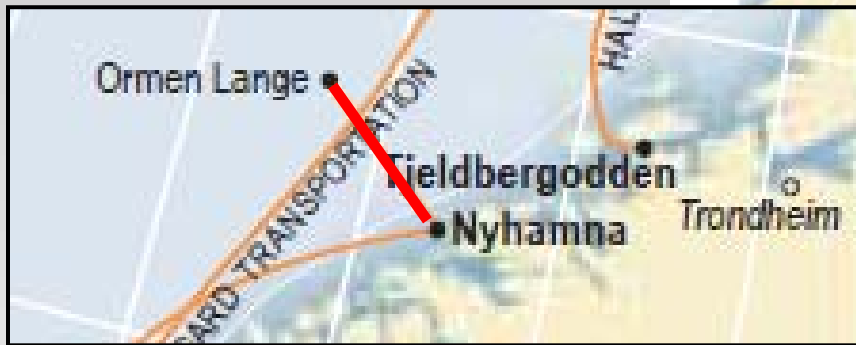
In the summer of 2007, an appraisal well was drilled in the western part of the field in order to collect more information from the oil zone. The well results showed that there was no basis for development of the oil zone. The production at Snøhvit started in the autumn of 2007. The LNG facility at Melkøya was closed down from November 2007 to January 2008 due to technical problems. An approximately eight weeks audit shut-down was carried out in the summer of 2008. The Melkøya facility is now producing at some reduced capacity.

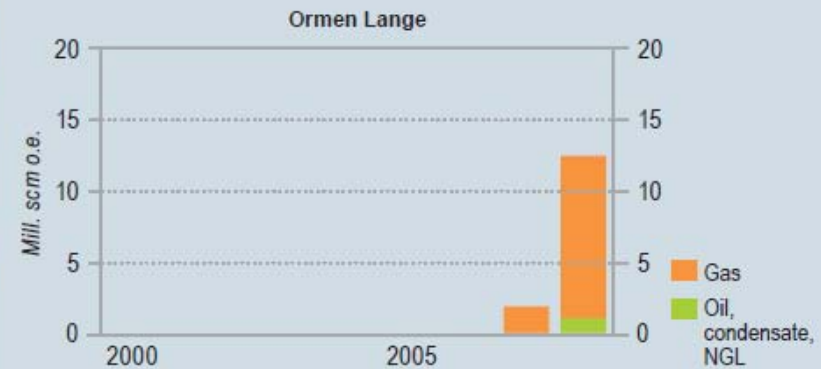


# Ormen Lange

- **Deepest water depth (850-1100 m)**
- **Discovered 1997**
  - Initial gas production in 2007.
  - Hydro (now Statoil) operated pre-production.
  - Shell operates production.
- **Pressure depletion.**
  - 24 subsea production wells.
  - Subsea-to-land with 2 x 120 km multiphase pipelines.
  - 1200 km gas pipeline from Norway(land) to UK.
  - Potential need for subsea compression in future.

# Norwegian Gas Pipeline Network





## Ormen Lange

<b>Blocks and production licences</b>	Block 6305/4 - production licence 209, awarded 1996 Block 6305/5 - production licence 209, awarded 1996 Block 6305/7 - production licence 208, awarded 1996 Block 6305/8 - production licence 250, awarded 1999	
<b>Discovered</b>	1997	
<b>Development approval</b>	02.04.2004 by the Storting	
<b>On stream</b>	13.09.2007	
<b>Operator</b>	A/S Norske Shell	
<b>Licensees</b>	A/S Norske Shell	17.04 %
	DONG E&P Norge AS	10.34 %
	ExxonMobil Exploration & Production Norway AS	7.23 %
	Petro AS	36.48 %
	StatoilHydro ASA	10.84 %
	StatoilHydro Petroleum AS	18.07 %
<b>Recoverable reserves</b>	<b>Original:</b> 394.7 billion scm gas 28.5 million scm condensate	<b>Remaining as of 31.12.2008:</b> 381.6 billion scm gas 27.4 million scm condensate
<b>Production</b>	<b>Estimated production in 2009:</b> Gas: 16.93 billion scm, Condensate: 1.53 million scm	
<b>Investment</b>	Total investment is expected to be NOK 64.3 billion (2009 values)* NOK 21.4 billion have been invested as of 31.12.2008 (2009 values)	
<b>Operating organisation</b>	Kristiansund	

**Development:**

Ormen Lange is a gas field located in the Møre Basin in the southern part of the Norwegian Sea. The sea depth in the area varies from 800 - 1 100 metres. The great sea depth has made the development very challenging and has resulted in development of new technology. The field is being developed in several phases with 24 wells from three subsea templates.

**Reservoir:**

The main reservoir consists of sandstones of Paleocene age in the Egga Formation, about 2 700 - 2 900 metres below sea level.

**Recovery strategy:**

The field is recovered by pressure depletion and, at a later stage, gas compression.

**Transport:**

The wellstream, which contains gas and condensate, is transported in two multiphase pipelines to the onshore facility at Nyhamna, where gas is dried and compressed before it is sent in the gas export pipeline, Langeled, via Sleipner R to Great Britain.

**Status**

The gas production started from three wells in September 2007. A/S Norske Shell took over the operatorship from StatoilHydro 1 November 2007. The field is being produced with six wells, of these, three new wells were completed in 3rd quarter 2008. The onshore facility at Nyhamna can now produce at full capacity. A third subsea template will be installed in 2009.

# Ormen Lange – location

