Johan Sverdrup – Offshore Norway: The Story behind the Giant Sverdrup Discovery*

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Key Statements

Fewer wells have been drilled on the Norwegian Continental Shelf compared to the United Kingdom Continental Shelf, even though there is the same geological risk. Taxes are lower in the UK; there is an independent sector in the UK. The overall result is lower exploration in Norway.

John Sverdrup Discovery – Fourth Generation Exploration

- In the heart of the Central North Sea
- Located on the southern Utsira High (Haugaland High or Greater Luno Area)
- 40 km south of Grane
- Water depth of 115 m
- Reservoir depth of approximately 1900 m
- Avaldsnes Discovery
  - 100-400 million barrels of recoverable resources
  - Exceptional DST result gained confidence in the discovery
- Upside Potential
  - 200 km² of closure
  - Uncertainty of reservoir continuity and quality

Exploration and delineation drilling

The discovery well 16/2-6 was drilled in 2010; 6 delineation wells were drilled in 2011 unfolded the resource range. Delineation wells in 2012 will narrow the range; yet additional delineation wells will be needed in 2013.

Results to Date:

- Extremely good Volgian (Upper Jurassic) sandstone reservoir - 28% porosity; 10-40 darcy permeability
• Good underlying Upper to Middle Jurassic sandstone reservoir and weathered basement
• OWC varying between 1922 and 1935 m MSL

Main reservoir uncertainties
• Top reservoir depth reflecting velocity variations in overburden
• Thickness variation of extremely good reservoir versus good reservoir sand
• Reservoir wettability
• Variations in oil-water contacts
• Varying aquifer support

Subsurface Learning on the Southern Utsira High
Play concept in 2004 of thin Jurassic sands, with 40-50 m leg, over inlier basins and basement was proved in 2007 by Edvard Grieg; it also lowered the risk of Johan Sverdrup to P45%; Apollo proved the concept in 2010.

The main learning includes: (1) light under-saturated oil flanking saturated oil and gas discovery, (2) late migration of oil into Edvard Grieg and Johan Sverdrup, (3) extreme to very good reservoir quality of the Upper Jurassic sands, and (4) producible oil in weathered basement in Tellus and Luno South.

Seeing is Believing
The last years’ exploration effort by a diversity of subsurface focused companies demonstrates that the decline in discoveries was not subsurface-based.
To release the exploration potential, companies with a fact-based knowledge creation culture are needed:
Recycling is a Key Word in terms of licences, play models, wells and seismic, and people.
The story behind the Giant Johan Sverdrup Discovery
SIDETRACK

Smooth operator: Swedish junior Lundin has lofty dreams of taking the lead role on the giant Avaldsnes project

RYTIS DAUKANTAS
Discovered Resources in Norway 2001–2012
New Companies on the NCS in the Last Decade

- Statoil
- Eni
- Talisman
- Esso
- Con
- Det Norske
- Shell
- Marathon
- BG
- BP
- DONG
- Hess
- Chevron
- Lundin
- RWE-Dea
- Total
- Centrica
- PetroChina
- Nexen
- GDF
- Noreco
- VNG
- EON
- Idemitsu
- OMV
- Premier
- Rocksource

Legend:
- wells 2011
- wells 2010
- wells 2009
- wells 2000-2008
Production NCS 1971–2016

Source: NPD
NCS Production / Exploration Wells

Source: NPD
NCS Production / Exploration Wells + 10y

Source: NPD
Fewer Wells Drilled on the NCS Compared to UKCS

- Same geological risk
- Lower taxes in United Kingdom
- Independent sector in United Kingdom
- Lower exploration activity in Norway
Organic Growth Strategy

- Find oil with the drill bit - organic growth
- Leverage on organisational knowledge
- Portfolio synergy in relation to improved exploration and development
- Design yearly balanced exploration drilling portfolios in relation to
  - Frontier breakthrough
  - Growth
  - Mature tie-in
- Maintain production from existing and emerging developments
- Applying and developing data and fact-driven subsurface models, based on appreciation of the limitations of data, tools, methods and theories available at any time
- Applying new emerging technology and methods
- In the heart of the Central North Sea
- Located on the southern Utsira High
  (Also referred to as Haugaland High or Greater Luno Area)
- 40 km south of Grane
- Water depth: 115m
- Reservoir depth: ~1900m
The Greater Luno Area

or

Haugaland High

or

South Utsira High
Four operators since 1965

Limited exploration success
Greater Luno Area Technical Concept

- Jurassic sands deposited around the basement high
- Saturated hydrocarbon system
- Common oil water contact

Depositional Model

**Luno prospect**

**Southern Utsira High**

**PL338 (APA2004)**

**Ragnarock**

**Gas field/discovery**

**Oil field/discovery**

**Lundin Petroleum operator**

**Lundin Petroleum partner**
The Greater Luno Area

3D Seismic over Luno Prospect at time of application

3D Seismic over Luno Prospect today
Seismic Velocities Sub-BCU by use of Refraction Events

Raw shot gather

Initial Top Basement interpretation

Relative refraction velocities sub-chalk

Relative velocities sub-crop BCU

High Relative Velocities

Low Relative Velocities
Securing more acreage prior to drilling Luno exploration well

The Greater Luno Area
Two exploration wells fail to find Jurassic reservoir

Edvard Grieg South porous basement discovery
Edvard Grieg discovery

Catalyst to focus on eastern side of Haugaland High
- Identified Avaldsnes prospect extends into PL265

- Acquired a 10 percent interest in PL265
Oil Population Analysis Essential for Charge History

Oil Populations
- Anoxic
  - A: Draupne Fm
  - B/C: Draupne Fm
  - C: Draupne Fm
  - D: Draupne/Heather M Jur
  - G: Heather Fm
- Dysoxic

Map showing various oil populations and locations.
Avaldsnes Discovery

- 100-400 Million barrels recoverable resources
- Exceptional DST result gained confidence in the discovery

Upside Potential

- 200 km² of closure
- Uncertainty of reservoir continuity and quality
Johan Sverdrup - A New Giant in Norway

- 8 wells drilled to date on Johan Sverdrup
- Edvard Grieg
- PL338, PL265
- PL502
- PL501
- Geitungen - new exploration discovery
- 16/2-13S sidetrack currently drilling
- OWC -1922m
Edvard Grieg, Johan Sverdrup and Apollo (Cretaceous) contain under-saturated non-biodegraded oil

Main migration from 1.5 Ma to present day

Several glacial-induced tilting has redistributed the oil across the high
Middle Jurassic Sleipner Formation Palaeogeography

- Floodplain fines
- Peat swamp
- Fluvial channels
Middle Jurassic Hugin Formation Palaeogeography

Pulau Tarakan delta, eastern Borneo

- Floodplain fines
- Peat swamp
- Shoreface
- Fluvial channels
Upper Jurassic Draupne Formation Palaeogeography

Map showing offshore muds and gravity flow sands.

- Offshore muds
- Gravity flow sands
Exploration and delineation drilling:
- Discovered by well 16/2-6 in 2010
- 6 delineation wells in 2011 unfolded the resource range
- Delineation wells in 2012 will narrow the range
- Additional delineation wells will be needed in 2013

Results so far:
- Extremely good reservoir 28% porosity and 10-40 darcy permeability, Volgian reservoir sandstone overlying older Upper to Middle Jurassic good reservoir sandstone and weathered basement
- OWC varying between 1922 to 1935 m MSL

Main reservoir uncertainties:
- Top reservoir depth reflecting velocity variations in overburden
- Thickness variation of extremely good reservoir versus good reservoir sand
- Reservoir wettability
- Variations in oil-water contacts
- Varying aquifer support
**Play concept in 2004:**
- Thin Jurassic sands over inlier basins and basement with a saturated system with a 40-50 m oil leg and a common OWC over the whole high
- Potential stratigraphic traps fringing the high in the west and southwest

**Results in 2012:**
- Edvard Grieg proved the concept in 2007 and converted Johan Sverdrup to a low risk prospect (P45%)
- Apollo proved the concept in 2010

**Main learning:**
- Light under-saturated oil flanking saturated oil and gas discovery
- Late migration of oil into Edvard Grieg and Johan Sverdrup
- Extreme to very good reservoir quality of the Upper Jurassic sands
- Producible oil in weathered basement in Tellus and Luno South
The last years exploration effort by a diversity of subsurface-focused companies demonstrates that the decline in discoveries was not subsurface-based.

To release the exploration potential, companies with a fact-based knowledge creation culture are needed:
- Several integrated multicultural upstream companies
- Cash flow to test the new concepts
- Continuous balanced exploration is a must
- Play models must include, but not be limited by facts
- Investments in new technology
- Hard core data sampling is a must (DST has proved very valuable)
- Indirect data necessary, but never sufficient (core is core!)
- Understand the ambiguity of DTMT
- Integrate at highest possible entropy level
Recycling is a Key Word

Recycling licences
→ Utsira area licences are 4th generation exploration. Majors have been in the area from 1965

Recycle play models
→ Similar licence clusters have been established on NCS prior to drilling at inverted Jurassic high settings

Recycle wells and seismic
→ All relevant exploration wells are internally reinvestigated for biostratigraphic rezonation and hydrocarbon system analysis using newest technology available
→ Seismic is routinely reprocessed internally or externally for improved image. New data acquired where necessary.

Recycling people
→ Industry mergers and acquisitions like Saga/Hydro/Statoil provide recruitment base for opportunistic organisations getting the right people
→ Success is attractive
Summary - Seeing is Believing
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BOEs

BOEs may be misleading, particularly if used in isolation. A BOE conversion ratio of 6 Mcf : 1 Bbl is based on an energy equivalency conversion method primarily applicable at the burner tip and does not represent a value equivalency at the wellhead.
Thank You!

Piet Hein, Danish mathematician
“To know what thou knowest not is in essence omniscience”