Oil production from Lower Cretaceous Chalk Play - the Valdemar Field, Denmark

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Centre for Oil and Gas

DHRTC Background

• The Centre is part of the Danish long-term national strategy on energy production.
• Collaboration between different Danish Universities (AAU, AU, GEUS, KU and DTU) and the Industry.

Objectives

• Research and innovation can identify and qualify innovative ways to enable increased oil and gas recovery in the Danish North Sea.
  • Reservoir Characterisation
  • Enhanced Oil and Gas Recovery Processes
  • Drilling and Production Technology Concepts
  • Production Facilities and Material Research and Design
• Attract and educate professionals to the industry.

Resources

• 1 billion DKK over 10 years, tax-deductible grant by Danish Underground Consortium (DUC).
• 50 years of data and interaction with DUC and other industries.
• Employees with many years of chalk expertise from the industry.
Research at DHRTC

AWF.1 Demo Model
Advanced Waterflooding
Pilot: Kraka, Dan & Halfdan

AWF.2 Demo Model
Advanced Stimulation Techniques
Pilot: Halfdan and Gorn

TRD.1 Demo Model
Tight Reservoir Development
Pilot: Valdemar Lower Cretaceous

CTR.1 Demo Model
Increase Water Injection Availability
Pilot: Dan and Halfdan

CTR.2 Demo Model
Enhanced Well Chemistry & Integrity

CTR.3 Demo Model
Extend Life of Potential Hub Structures
Introduction – Lower Cretaceous Play

Despite representing a widespread play in the Central North Sea, production from the Lower Cretaceous chalks is currently confined to the Valdemar Field and one single well in the Tyra Field. The Valdemar field has been producing for more than twenty years and yet significant risk and opportunities remain.

Thickness Lower Cretaceous Tuxen/Sola Formation;
Jakobsen et. Al. 2004

Mærsk, 2016
Sedimentation during the Early Cretaceous was strongly influenced by the tectonic evolution of the area.

The extensional tectonic regime of the Late Jurassic continued in the Early Cretaceous although with reduced sedimentation rates.

There was a slight shift from deposition concentrated along the Coffee Soil fault in the east to depo-centres also developing further to the west. Sediments accumulated in local depo-centres.

Finally the basin was inverted in Late Cretaceous creating anticlinal traps.
The Lower Cretaceous reservoir section is divided into the Sola Formation and the Tuxen Formation.

The section is composed of interbedded chalk, marly chalk, organic rich marlstones and marlstone.
The Valdemar Field

Field Information

Type: Complex inversion anticline
Discovery date: 1977 (Bo-1 well)
Field start-up: October 1993
Top reservoir: ~2200m
Formation: Tuxen/Sola Formation
Reservoir thickness: 95m
Net pay: 75m
Porosity: 15-35%
Permeability: Below 1mD

Field Volumetrics:

Area: 15 km2
In Place volumes: ~700MMstb
Recovery factor: 10-25%
Production (end 2017) ~80MMbbls (including Upper Cretaceous production; ENS 2017)

Production mechanism: Primary depletion and likely some addition of compaction

Figures and numbers from Millenium Atlas, 2004
The Valdemar Field

The Valdemar Field is produced from 16 horizontal wells and is today the fourth largest oil producing field in the Danish Underground Consortium (DUC).

- 9 producers in the North Jens area and 3 abandoned wells
- 7 producers in the Bo area
- Bo South undeveloped

- All wells are completed with sand propped frac’s
- Some zones acid stimulated.

- Valdemar wells are typically ~3000 meters in lateral. Sand propped frac’s are placed with a spacing of ~200 m.
- Traditional fracture designs placed just below 1,000,000 lbs. sand per zone.
The Lower Cretaceous reservoir is very different from the Upper Cretaceous Chalks (Ekofisk & Tor Formation). It is a lot more heterogeneous and permeabilities are much lower and the clay content is very high. Areas with good porosity are locally restricted.

Figures taken from GEUS, Geology, 2003
Reservoir Zonation

The reservoir section is divided into 16 different zones including the organic rich mudstone layers. The reservoir can be followed across the entire Valdemar Field with the help from biostratigraphy. The zonation is based on differences in porosity, permeability and clay content.

Long horizontal wells are designed to target the layers of best reservoir quality. Completion with sand propped frac's to connect different layers and to connect across the Munk Marl.
Challenges

The recovery factor for the Lower Cretaceous has so far been **relative low and uneven** across the Valdemar Field area.

STOIIP is currently expected more or less the same, but **North Jens is today prognosed to recover twice as much oil as the Bo area**.

Another challenge is the rather limited **fundamental understanding** of the Lower Cretaceous marly chalk reservoir compared to the more clean Upper Cretaceous chalk.

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**Mærsk, 2016**
Opportunities

It is believed that research can help/complement with:

- Bridging the gap between North Jens area & Bo area (understand well performance)
- Decisions on how to expand into Bo South
- Increasing ultimate recovery of both the North Jens and the Bo area
- Unlocking further Lower Cretaceous potential
Hypotheses (DHRTC currently working with)

- **Natural and induced fractures** can increase productivity, compaction and sweep in the Lower Cretaceous
- Better understanding of the **Reservoir Quality distribution** can improve OIIP estimates and guide new development projects
- **Compaction/subsidence** is an important contributor to drive mechanism
- **Gas Injection** can help produce longer and more in Lower Cretaceous reservoirs
Challenges:
How do we position new wells in optimal ways? How do we develop new areas?
Can we get a better at predicting the permeability multipliers that are needed in our reservoir models to be able to history match?

Ongoing Research:
- Dynamic tectonic evolution of the greater Valdemar area – assessing the stress field and modelling of the deformation intensity > **better fracture models**
- Test the capabilities of a geomechanically driven Discrete Fracture Network (DFN) model
- Tailored processing schemes for optimized imaging based on seismic signals
Reservoir Quality distribution

Challenges:
Property modelling is not well aligned with current facies/geological model. Difficult to predict properties away from wells into undeveloped areas. Uncertainties on OOIP.

Ongoing Research:
• A quantified link between depositional processes/environments and reservoir properties
• Understanding the fundamental control on the distribution of clay minerals
• Models to predict reservoir heterogeneity from un-cored sections using cuttings – better database
• Spectral decomposition as a tool to de-risk (reservoir thickness, contacts etc.)
Challenges:
Do our reservoir models predict compaction correctly?

Ongoing Research:
- Updated Lower Cretaceous Rock Mechanical database (new cleaning methods)
- Understanding the effect of depletion with respect to fracturing and pore collapse – QC against 4D
- Effect of mineralogy and degree of cementation on rock mechanics properties
- Effect of water flooding – water weakening
Challenges:
Uncertainties on relative permeability properties. Uncertainties on the PVT in Valdemar. Uncertainty on recovery gain that can be expected from gas injection.

Ongoing Research:
- Estimation of increased recovery with gas injection using different injection gases
- Improved characterisation of the relative permeability parameters
- Important to understand the drivers for an economic business case
The Sola and Tuxen Formation is **widely distributed in the Norwegian and Danish sectors**. In the Norwegian sector it is developed in the Central Graben and in parts of the Norwegian-Danish Basin.

Looking at NPD there are 81 wells listed that have penetrated the Tuxen Formation. None of the wells had Tuxen as a target. Even more wells penetrated the Sola Formation.

Thickness varies between 1-100m for the Tuxen Formation and 20-200m for the Sola Formation.

Examples:

- 1/3-8 with shows in Sola Formation
- 2/11-1 reference well for Sola Formation – no shows
- 2/11-7 shows reported from Limestones in Lower Cretaceous
- 2/6-2 reference well for Tuxen Formation – tight water bearing
Getting the Lower Cretaceous into play

Despite representing a widespread play, production from the Lower Cretaceous chalks is currently confined to the Valdemar Field and one single well in the Tyra Field in Denmark.

The Valdemar field has been producing for more than twenty years and yet significant risk and opportunities remain.

The Sola and Tuxen Formation is also widely distributed in the Norwegian sector and could be an opportunity.

At DHRTC we believe that Research and Innovation in close cooperation with the Industry can help identify and qualify innovative ways to enable increased oil and gas recovery from the Lower Cretaceous reservoir.

Thank You
For Your Attention