MAPPING OF PALEO RESIDUAL OIL ZONES ON THE NCS AND THE POTENTIAL FOR PRODUCTION BY CO$_2$-EOR

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PROZ – what and how

PROZ - RESIDUALLY TRAPPED OIL BELOW TRADITIONALLY DEFINED OIL WATER CONTACT (OWC)

- Residual saturation vary between 5 to 30 % (NCS)

from Trentham (2010)
PROZ – what and how

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THE OWC HAS MOVED OVER GEOLOGICAL TIME DUE TO

- Pressure/temperature change (uplift/subsidence)
- Leakage from trap
PROZ – what and how

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- Pressure/temperature change (uplift/subsidence)
- Leakage from trap
- Tilting of structure (Troll)
PROZ – how and where

WORLD
- 2012: 9 pilots producing 10 000 BOPD from PROZ intervals by CO$_2$-EOR in the US
- 2015: Seminole San Andreas Unit produces 10 000 BOPD from PROZ by CO$_2$-EOR (full field project)
- Studies performed in Canada and China
PROZ – how and where

**WORLD**
- 2012: 9 pilots producing 10 000 BOPD from PROZ intervals by CO$_2$-EOR in the US
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**NORWAY (NCS)**
- PROZ observed in a number of fields and wells
- NPD consider this oil unconventional (2011)
- CO$_2$ Storage Atlas (NPD 2014): PROZ extra resource that can be mobilised by CO$_2$.
- Best known PROZ is in Troll West oil Province (TWOP)

*from Statoil*
PROZ - Project

THREE YEAR PROJECT WITH STATOIL
MAIN OBJECTIVE
Present a first estimate of recoverable oil from paleo residual oil zones in Statoil oil and gas fields.

BASED ON
• Mapping of PROZ resources (Statoil operated fields)
• Characterisation of cores from target formations
• Fluid studies
• Core flooding tests with CO₂ to see how much of the oil that can be mobilised
• Reservoir simulations on generic models

WILL PRESENT RESULTS OF MAPPING, SIMULATIONS AND RESOURCE ESTIMATE
PROZ – Mapping NCS

MAPPING OF PROZ RESOURCES

- Screening more than 40 Statoil operated fields/assets
- Open available data from NPD Fact Sheets
  - No systematic recording of PROZ indicators in well reports
  - Examples: "residual oil", "oil shows"

### Table: OSEBERG Field

<table>
<thead>
<tr>
<th>Well</th>
<th>ROZ thickness</th>
<th>Associated with</th>
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<tr>
<td>30/6-15</td>
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<tr>
<td>30/6-7</td>
<td>20 m</td>
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### Table: OSEBERG SØR Field

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<th>ROZ thickness</th>
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<td>30/9-10</td>
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<td>30/9-14</td>
<td>&gt;100 m</td>
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<td>30/9-15</td>
<td>?</td>
<td></td>
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<tr>
<td>30/9-7</td>
<td>50 m</td>
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PROZ – Mapping NCS

MAPPING OF PROZ RESOURCES

- Screening more than 40 Statoil operated fields/assets
- Open available data from NPD Fact Sheets
- 20 Statoil operated fields have indications of PROZ

Alve
Fram
Glitne
Grane
Gullfaks
Gullfaks Sør
Heidrun
Heimdal
Huldra
Oseberg
Oseberg Sør
Skuld
Snorre
Snøhvit
Statfjord/nord/øst
Tordis
Troll
Tyrihans
Vega
Veslefrikk
**PROZ – Log interpretation**

**MAPPING OF PROZ RESOURCES**
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**LOG INTERPRETATIONS ON TROLL WELLS**

Average Oil Saturation in PROZ from 6 wells
- Between 14 and 22 %
  - This depends on assumed formation water conductivity and formation factor (Archie's equation)

Example: well 2-E-6H, \( R_w = 0.09 \)
PROZ – Simulations

MODEL
• Generic model with two wells (injector – producer)
  • Size – 1.4 by 0.8 km
  • Well distance – 1 km
  • Average thickness of model – 45 m
  • Grid resolution – 50 by 50 m

• Geology – shallow marine deposits (Tarbert Fm.)
  • From the SPE 10th comparative study

• Residual oil saturation for water flooding is 20%

• Paleo zone initialised with 15% oil
PROZ – Simulations

RESULTS
• Reservoir simulations on generic models
  • 30% of the oil in PROZ mobilised
  • Challenge is to achieve good sweep
PROZ – Simulations

RESULTS

• Reservoir simulations on generic models
  • 30 % of the oil in PROZ mobilised
  • Challenge is to achieve good sweep
  • Good local recovery where CO₂ has flowed

• Require large amounts of CO₂ (1.9 PV injected)

NEED TO BE SEEN TOGETHER WITH CO₂-EOR/STORAGE
PROZ - Simulations

GRAVITATIONALLY STABLE DISPLACEMENT TEST SIMULATION (CO₂ STORAGE)

- Initialise the model with only PROZ (15 % oil)
- Inject CO₂ from the top
  - Horizontal producer
  - 45 % recovery
  - Observe pushdown of oil
  - Requires targeted placement of long horizontal production wells
PROZ – Resource estimate

20 STATOIL OPERATED FIELDS
• Resource estimate in the order of 1000 MMSm³
• Approximately two times Johan Sverdrup!

BASED ON
• Mapping of PROZ resources (Statoil operated fields)
  • Thickness of PROZ
  • Areal fraction (little data)
• Reservoir parameters from literature (where available)
• Residual saturation is assumed low: 10 %

BETTER ESTIMATES SHOULD BE ACQUIRED!
• Need data from the oil fields
  • Well logs, core material, geological models

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<th>Fields</th>
<th>Area</th>
<th>Thickness</th>
<th>Saturation</th>
<th>Porosity</th>
<th>Bo</th>
<th>Eff. area</th>
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<tr>
<td></td>
<td>km²</td>
<td>m</td>
<td>Fraction</td>
<td>%</td>
<td>Rm³/Sm³</td>
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PROZ – Summary

• Large resources of unconventional PROZ oil exist on the NCS
• This oil can be mobilised by CO₂ flooding
• Recovery of PROZ must be seen in connection with CO₂ storage/EOR
• Produced oil and water will be replaced by CO₂
  • Oil reservoirs have demonstrated long term storage integrity

• Many fields/areas not covered in this study
  • Johan Sverdrup, Edvard Grieg, Barents Sea ....
Thank you for your attention.

Acknowledgement:
We wish to thank Statoil for funding the study and providing fluids, cores and logs.