Hydrocarbon potential of the Lower Carboniferous in the Dutch northern offshore

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Introduction

• Recent UK gas discoveries were made in Lower Carboniferous reservoirs; most prominently: Breagh.

• Is there potential for Lower Carboniferous fields in the Dutch offshore?

Presentation outline:
• Post-well analysis
• Reservoir potential
• Source& charge
• Closures
Take-home messages

• Lower Carboniferous present in most of the Dutch northern offshore
• A mature source rock is expected to be present
• Reservoir potential looks promising
• The play is virtually untested
• Significant closures exist at BPU level, also in open blocks
Early Carboniferous & Devonian

- Significant extension on the S flank of the Elbow Spit Platform
- No or little offset at Base Permian level
- Change in seismic facies across fault; faulting affects deposition

Seismic data courtesy Spectrum
A major Carboniferous/Devonian low is present north of the Elbow Spit Platform; in line with findings by Milton-Worssell et al. (2010) for adjacent UK sector. Lower Carboniferous deposits preserved!
A detailed structural framework was constructed for the Northern Dutch offshore.

More details available on our poster, which is on display today.
The Lower Carboniferous clastics play is established in the SNS, with fields producing from Namurian reservoirs and the Visean Breagh field.
Exploration history of the Lower Carboniferous in the Northern Dutch offshore

- **1972-1990**: wildcats, aiming to extend the Rotliegend play towards the north.
- **1990s**: Namurian in E12 (discoveries: Tulp/Lelie stranded fields).
- Last well penetrating the Lower Carboniferous was drilled in 1996.
- Only two wells had the Lower Carboniferous as primary target!

<table>
<thead>
<tr>
<th>Well</th>
<th>Spud year</th>
<th>Lower Carboniferous primary target?</th>
<th>Result</th>
<th>Stratigraphy</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>A11-01</td>
<td>1981</td>
<td>No (Rotliegend)</td>
<td>Dry</td>
<td>Devonian</td>
<td>X Placid</td>
</tr>
<tr>
<td>A14-01</td>
<td>1982</td>
<td>No (Rotliegend)</td>
<td>Gas Shows</td>
<td>Tournaisian</td>
<td>X X NAM</td>
</tr>
<tr>
<td>A15-01</td>
<td>1978</td>
<td>No (Zechst./Rotl.)</td>
<td>Gas Shows</td>
<td>Visean</td>
<td>X Placid</td>
</tr>
<tr>
<td>A16-01</td>
<td>1974</td>
<td>No (Zechstein)</td>
<td>Dry</td>
<td>Namurian</td>
<td>X Elf Petroland</td>
</tr>
<tr>
<td>B10-01 (DE)</td>
<td>1977</td>
<td>Unknown</td>
<td>Dry</td>
<td></td>
<td>X Amoco</td>
</tr>
<tr>
<td>B17-04</td>
<td>1990</td>
<td>Yes</td>
<td>Dry</td>
<td></td>
<td>X Arco</td>
</tr>
<tr>
<td>E02-01</td>
<td>1972</td>
<td>No (Wildcat)</td>
<td>Dry</td>
<td></td>
<td>X X NAM</td>
</tr>
<tr>
<td>E02-02</td>
<td>1990</td>
<td>No (Zechstein)</td>
<td>Dry</td>
<td></td>
<td>X Mobil</td>
</tr>
<tr>
<td>E06-01</td>
<td>1983</td>
<td>No? (Westphalian?, Rotliegend)</td>
<td>Dry</td>
<td></td>
<td>X X X ? NAM</td>
</tr>
<tr>
<td>E09-01</td>
<td>1990</td>
<td>No (Rotliegend)</td>
<td>Gas, high N&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
<td>X NAM</td>
</tr>
<tr>
<td>E12-02</td>
<td>1990</td>
<td>No (Westphalian?)</td>
<td>Dry? Shows?</td>
<td></td>
<td>X Conoco</td>
</tr>
<tr>
<td>E12-03 (Tulp)</td>
<td>1991</td>
<td>No (Westphalian)</td>
<td>Gas, high N&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
<td>X Elf Petroland</td>
</tr>
<tr>
<td>E12-04-S2 (Lelie)</td>
<td>1996</td>
<td>Yes</td>
<td>Gas, high N&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
<td>X Elf Petroland</td>
</tr>
</tbody>
</table>

*Used UK wells in study as well*
Well Results, Visean

- Only two wells had the Lower Carboniferous as their primary target; one focused on the Namurian, the other on the Lower Carboniferous in general.

<table>
<thead>
<tr>
<th>Well</th>
<th>Charge</th>
<th>Reservoir</th>
<th>Seal</th>
<th>Trap</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A14-01</td>
<td>Gas shows</td>
<td>Present</td>
<td>Doubtful (Epen Fm)</td>
<td>Absent (2D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>A16-01</td>
<td>No shows</td>
<td>Present</td>
<td>Present, thin</td>
<td>Probable (2D)</td>
<td>Negative/invalid</td>
</tr>
<tr>
<td>B10-01</td>
<td>No shows</td>
<td>Present</td>
<td>Present</td>
<td>Absent (2D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>E02-01</td>
<td>Doubtful shows</td>
<td>Present</td>
<td>Doubtful (Chalk)</td>
<td>Absent (3D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>E02-02</td>
<td>No shows</td>
<td>Present</td>
<td>Present, thin</td>
<td>Absent (3D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>E06-01</td>
<td>No shows</td>
<td>Present</td>
<td>Present</td>
<td>Doubtful (3D)</td>
<td>Invalid test</td>
</tr>
</tbody>
</table>
### Well Results, Namurian

- Only one well had the Namurian as primary target

<table>
<thead>
<tr>
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<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A11-01</td>
<td>Weak gas shows</td>
<td>Present</td>
<td>Present</td>
<td>Absent (3D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>A14-01</td>
<td>Gas shows</td>
<td>Present</td>
<td>Doubtful (Epen Fm)</td>
<td>Absent (2D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>A15-01</td>
<td>Gas in Zechstein (16% N₂)</td>
<td>Inconclusive</td>
<td>Lower Rotliegend volc.</td>
<td>Present</td>
<td>Negative</td>
</tr>
<tr>
<td>B17-04</td>
<td>Mature source rock in well</td>
<td>Tight</td>
<td>Present</td>
<td>Absent (2D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>E06-01</td>
<td>No shows</td>
<td>Only 17 m, possibly part of Yoredale.</td>
<td>Present</td>
<td>Doubtful (3D)</td>
<td>Invalid test?</td>
</tr>
<tr>
<td>E09-01</td>
<td>Present, 85% N₂</td>
<td>Inconclusive</td>
<td>Present</td>
<td>Inconclusive</td>
<td>Invalid test</td>
</tr>
<tr>
<td>E12-02</td>
<td>Gas shows</td>
<td>Probable</td>
<td>Present</td>
<td>Absent (3D)</td>
<td>Invalid test</td>
</tr>
<tr>
<td>E12-03</td>
<td>Present, 33% N₂</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
<td>Positive</td>
</tr>
<tr>
<td>E12-04</td>
<td>Present, 65% N₂</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Legend:
- Well Results Namurian
- Conclusion
  - Valid Positive Test
  - Valid Negative Test
  - Invalid Test
  - Well into pre-Permiian (NL)
  - DEAFAB area
  - International Border

Map of Well Results Namurian

2 June, 2016
Reservoir potential

- Lithological classification based on sonic and gamma ray logs.
- 7 Lithology types distinguished: Sand, Shaly sand, Shale, Marl, Carbonate, Coal. Igneous rocks marked manually.
- QC’d using composite logs, mudlogs, density, resistivity, spontaneous potential and caliper logs, and core descriptions.
- Applied to Lower Carboniferous in 13 NL, 9 UK and 2 DE wells.
Roughly coincides with the Yoredale Fm in the Elbow Spit High area.

Less shale and carbonates, more sand toward the N.
Well correlation, Visean, NL

More sand, more coal, less limestone & shale
Well correlation, Visean, UK

More sand, more coal, less limestone&shale
Well correlation, Namurian, NL

S  Lelie  Tulp

2 juni 2016

Coal  Sand  Shaly Sand  Shale  Marl  Carbonate
• Wells shown where the Lower Carboniferous subcrops the BPU.
• Averages for the first 100 m below the BPU.
• Breagh & Crosgan appear to be at the margin of the play; more sand further north.
Porosity & permeability data

- Same color coding as lithologies on well correlation panels.
- 6 NL wells, 2 UK wells.
- All data from Visean & Namurian.
- Intervals classified as sand have favourable reservoir characteristics.
Source Rock potential

**Coals**
- N-ward increase in coal content in Scremerston Fm.
- Yoredale Fm and Namurian also contain coal; up to 7.5 m encountered in wells.

**Potential additional source rocks**
- Namurian marine shales; potential in the S
- Lateral charge from Westphalian
- Bituminous limestones Yoredale
- Lateral migration from downthrown proven Posidonia Shale, Zechstein.
Coals in Lower Carboniferous north of the Elbow Spit Platform

- Lower Carboniferous is present north of the Elbow Spit Platform.
- Has a high contrast seismic facies.
Maturity - BPU below 3.0 km

- Basin modelling by TNO shows that Scremerston coals become mature at approximately 3 km burial.
- Region where Base Permian Unconformity is below 3 km is shown in figure.
- Coals are commonly located a few hundred metres below the BPU.
- Carboniferous expected to be in gas window in most of the area.
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- Region where Base Permian Unconformity is below 3 km is shown in figure.
- Coals are commonly located a few hundred metres below the BPU.
- Carboniferous expected to be in gas window in most of the area.
Lateral migration

- Carboniferous expected to be in gas window in most of the area.
- Lateral migration from kitchen areas may have charged areas located updip.
Positive indications for Palaeozoic source rocks

• Hydrocarbon shows also occur below the Posidonia & Kimmeridge Clay Fm.

• Shows also occur outside the extent of these source rocks.

Shows, below North Sea Group

Inventory of formations with source rock potential. Where formations overlap only the shallowest formation is shown.
Closures

• 20 structures at BPU level have been identified with a total P50 GIIP of ~75 BCM (unrisked). A subset of these structures is indicated on the BPU depth map (right).
• Closures also located in open blocks.
Example of a lead at BPU level: Kilimanjaro

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Namurian &amp; Visean clastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal</td>
<td>Silverpit shales &amp; Zechstein salt</td>
</tr>
<tr>
<td>Source</td>
<td>Scremerston coals</td>
</tr>
</tbody>
</table>
Example: Intra-Carboniferous structuration

- Significant structures, formed by Lower Carboniferous faults, combined with a younger Carboniferous fault trend.
- More information about the structural evolution of the area available on poster on display today.

Seismic data courtesy Spectrum ASA
Take-home messages

• Lower Carboniferous present in most of the Dutch northern offshore
• A mature source rock is expected to be present
• Reservoir potential looks promising
• The play is virtually untested
• Significant closures exist at BPU level, also in open blocks
Thank you for your attention

More information about the structural evolution of the area available on poster on display today.

More information? Contact us: exploration@ebn.nl

Acknowledgements:
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References:
TNO, 2014: Basin Modelling carried out for EBN.