Precise well placement in the Cygnus gas field

Ian Dredge – ENGIE E&P UK Limited
Executive summary

- The Lower Leman reservoir in the Cygnus gas field is highly layered with low vertical permeability.

- The use of multiple real-time data sources and actively geosteering the production wells has delivered well test rates that have been up to 50% better than pre-drill expectations.

- Clear lines of communication and collaboration between the subsurface team, onshore and offshore drilling teams have ensured the wells have been a success.

- The first five production wells that have been drilled will ensure the plateau production rate will be met.
Precise well placement in the Cygnus Gas field

Section 1
Introduction to the Cygnus development & Lower Leman reservoir geology in Cygnus

Section 2
Final appraisal well data – fine tuning the well placement strategy

Section 3
Geosteering in a faulted reservoir – 44/11a-B3

Section 4
Summary of the Cygnus development wells
Introduction to the Cygnus development & Lower Leman reservoir geology in Cygnus
Cygnus - A flagship development project

- Operated by ENGIE E&P UK Limited

- Cygnus is the UK’s largest Southern Gas Basin discovery for 30 years

- Estimated 2P reserves of 110mmboe

- First gas is targeted in Q3 of 2016
The Cygnus development

- First discovered in 1988 by the 44/12-1 well
- Licenses taken on by ENGIE E&P UK Limited and the field was appraised between 2006 and 2014
- The field is now being developed from two platform locations by an initial 10 wells
- At peak production it will produce enough gas to meet the needs of 1.5 million homes (5% of UK production).
Reservoir targets

- Cygnus has two reservoir targets:
  1. Permian, Lower Leman Sandstone Formation
  2. Carboniferous Ketch Formation (Westphalian C/D)
- Seven wells will target the Lower Leman Sandstone and three wells will target the Ketch reservoir

![Cygnus Reserves Split Diagram](Image)

Legend:
- **Leman 58%**
- **Ketch 42%**

(after Bailey J.B. et al, 1993)
Lower Leman paleogeography from core data

Reservoir Zonation

<table>
<thead>
<tr>
<th>Zone 5a</th>
<th>Zone 5b</th>
<th>Zone 4</th>
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<tbody>
<tr>
<td>44/11a-4</td>
<td>44/11a-B3</td>
<td>44/12a-A4</td>
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</table>

Zone 5b Paleogeography map

D. Pilling, 2015
Final appraisal well data – fine tuning the well placement strategy
The first well drilled from the Cygnus Alpha platform was the 44/12a-A4 pilot hole.

The well was cored and a pipe conveyed MDT Dual packer was run.

Decision required: to hydraulically stimulate the reservoir or complete with Stand Alone Sand Screens.

Three test stations taken, when combined with core analysis results showed that to deliver a non-frac well with the desired gas rates (50 mmscf/d) an actively geosteered well would have to be drilled through the interval around test station # 1 for the full horizontal section (3500ft MD).

This determined three intervals that had to be targeted T,M & B sands.

### 44/12a-A4 pilot hole data

- **Stn#1**: kh 77mDft
- **Stn#2**: kh 8mDft
- **Stn#3**: kh 6mDft
44/12a-A4Z well strategy

- 44/12a-A4Z planned to kick off from the A4 pilot hole at the 7” shoe in the Werranhydrit Fm.
- Land out the sidetrack in the Zone 5b section of the reservoir
- Azimuthally turn the well to drill parallel to strike and drill through a seismic attribute (*good correlation between acoustic impedance and reservoir quality*)
- Utilise an extensive set of LWD logs
  - Near bit GR
  - Near bit inclination
  - Azimuthal directional resistivity
  - Density/Neutron
  - Density images
44/12a-AZ results – Laterally consistent reservoir

- Well kept within a 9ft TVT interval for 3513ftMD
- The entire 6” hole was 4609ftMD and delivered 3818ftMD Net Pay
- The use of the Density log as a krigged property within the reservoir model proved to be a very useful geosteering tool along with the other LWD logs
- Helped to confirm the geological understanding of a highly layered but laterally consistent reservoir
Geosteering in a faulted reservoir – 44/11a-B3
• The 44/11a-B3 well had two significant faults zones predicted that would intersect the reservoir in the 6” section

• The exact fault pattern was unclear and presumed there would be more sub-seismic resolution faults

• Significant amount of well planning and Azimuthal directional resistivity pre-job modelling carried out
Due to anhydrite cementation there is a measurable resistivity contrast within Zone 5b in the 44/11a-4 offset well.

Other wells in Cygnus have <1 Ohm.m contrast.

Allowed for pre-job Azimuthal Resistivity modelling.

**44/11a-4 offset data and pre-job resistivity modelling**

- Target interval: 2.6Ω res contrast
14/11a-B3 Geosteering decisions

- Fourteen geosteering instructions made during the well, several instructions issued early due to variations in Silverpit cycles
- Final three geosteering instructions given to cut back through stratigraphy and cross cut good sands
44/11a-B3 Image log interpretation & TST Calculation

- Density images through the Lower Leman reservoir have been of a relatively high resolution
- Allowed for fault identification and drilling polarity

- The resolution of the image logs allowed for real-time TST calculations to be made
- 6 Significant faults encountered with throws up to 5ft
- 21 other high angle features encountered

- Decision to cut back up stratigraphy accessed the best reservoir quality and gave good stratigraphic control
Utilising all the logs in real-time has allowed the Lower Leman production wells to be placed in the best layers of the reservoir. No single data source can provide the answer when geosteering, they should be used in combination. Azimuthal directional resistivity has proven to be effective in a reservoir with low resistivity contrast.
Cygnus Leman well results summary
The key to successful geosteering for ENGIE

**Effective Planning:**
Geosteering Guidelines issued (max doglegs, inclinations etc.).
Onshore and offshore Geosteering briefings held.
Service company Well Placement Team fully engaged with planning.
RT Communications clarified and agreed with all stakeholders
Extensive T&D modelling conducted including dummy geosteering manoeuvres.

**Execution:**
24/7 Aberdeen & London Collaboration rooms / Ensco 80

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44/11a-B3 Land-out and Geosteering Organogram

<table>
<thead>
<tr>
<th><strong>Enresco 80</strong></th>
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<tbody>
<tr>
<td>WSG (Contact Point)</td>
<td>Drilling Supervisor*</td>
</tr>
<tr>
<td>DD / LWD</td>
<td></td>
</tr>
</tbody>
</table>

24/7 Well Team (Hrs) #
- Ops Geol (Focal Point) : KS 07:00-19:00 / NH 19:00-07:00
- Geoscientists : ST / RC / AK / ID (See Rota)
- SLB Well Placement : 06:00-18:00 / 18:00-06:00
- Drilling : SR / MS / AY

**Sub-Surface Support**
- Management
- Res Eng
- Petrophysics
- Geophysics
- PT

**IT Support**

**Completions**

* Land-out / geosteering requests will be within the agreed, pre-defined happy/surprise log, in line with these rules will need GR/ESC approval.

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Summary

- Despite a low vertical permeability reservoir with thin productive layers, the use of multiple real time data sources and careful planning has delivered highly productive wells in the Cygnus field.
- The Cygnus Lower Leman development wells that have been drilled and completed successfully will help to maximise productivity in the Cygnus field along with the successful Carboniferous wells already drilled.

- **44/11a-B5**
  - Flowed at a constant rate of 83.5MMscf/day (72/64” choke)

- **44/11a-B3**
  - Flowed at a constant rate of 84.5MMscf/day (80/64” choke)

- **44/11a-B2 (planned)**

- **44/11a-B4 (planned)**

- **44/12a-A4Z**
  - Flowed at a constant rate of 76 MMscf/day (64/64” choke)

- **44/12a-A3Z**
  - Flowed at a constant rate of 93MMscf/day (76/64” choke)

- **44/12a-A2**
  - Flowed at a constant rate of 96.1MMscf/day (76/64” choke)
Any questions?

ENGIE E&P UK Limited subsurface team

centrica energy

bayerngas