Variable depth streamer technology for enhanced seismic interpretation

Gregor Duval*, Steven Bowman, Roger Taylor, Yves Lafet, Adrian Smith and Henning Hoeber
Introduction: why does the seismic interpreter need broadband data?

Benefits for interpretation of a wide range of geological settings:
- Tertiary silici-clastic reservoirs
- Chalk section
- Deep sub-BCU targets
Why does the seismic interpreter need broadband data?
Effects and benefits of increasing the bandwidth

Increasing high frequencies:
- 10-20Hz: Large side-lobes and broad central peak
- 10-25Hz
- 10-30Hz
- 10-35Hz: Sharper central peak

Increase low frequencies:
- 10-20Hz: Reduced side-lobes
- 5-20Hz
- 2-20Hz: Reduced side-lobes
Effects and benefits of increasing the bandwidth

Courtesy of Total, Cobalt and the Republic of Gabon
Effects and benefits of increasing the bandwidth

Courtesy of Total, Cobalt and the Republic of Gabon
CPI log showing thin/complex formations
Seismic synthetic model

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<th>Time/Depth (s)</th>
<th>T-Delay Velocity (v)</th>
<th>Log (log10 s/v)</th>
<th>Density</th>
<th>Impedance</th>
<th>Vp (s/t)</th>
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Conventional seismic synthetic

Conventional seismic data at well location

Broadband seismic synthetic

Diagram showing seismic data with different synthetic models.
Seismic synthetic model

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<th>Time/Depth (s)</th>
<th>TTI (Vp/Vs)</th>
<th>Log (v) (v/s)</th>
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Conventional seismic synthetic

Conventional seismic data at well location

Broadband seismic synthetic

Prominent side-lobe interfering with interpretation of conventional seismic data
Seismic synthetic model

Peaks and troughs fit better with well marker on broadband model.
**Seismic synthetic model**

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**Impedance**

- Obvious impedance gradient
- No impedance gradient
- Obvious impedance gradient

**Conventional seismic synthetic**

- Conventional seismic data at well location

**Broadband seismic synthetic**

NB: The low frequency component of broadband data give a better feel of the actual impedance gradients, which should in turn provide better seismic inversion results.
Interpretation of Tertiary siliciclastic reservoirs
Conventional – Interpretation of a gas reservoir
Broadband – Interpretation of a gas reservoir
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Conventional – Ip from AVO inversion
Broadband – Ip from AVO inversion

BroadSeis pre-stack inversion gives a more stable result:
1 – The GWC flat spot is better resolved
2 – Values of Ip within the gas column are more accurate and more homogeneous
Conventional – Tay fan imaging (zoomed)
Broadband – Tay fan imaging (zoomed)
Broadband filtered – Tay fan imaging

Bandpass filter applied: 10-40Hz – 50-70Hz to approximately match spectrum of Conventional data
Conventional – Tay fan imaging
Conventional – Low frequency Tay fan imaging

Bandpass filter applied: 0-4Hz – 6-10Hz
Broadband – Low frequency Tay fan imaging

Bandpass filter applied: 0-4Hz – 6-10Hz
Conventional – Tertiary channel interpretation

Mey channel
Broadband – Tertiary channel interpretation

Top Mey sandstone
Broadband – Tertiary channel interpretation

Top Mey sandstone
Conventional – Section through polygonal faults and contourites
Broadband – Section through polygonal faults and contourites
Conventional – Shallow section interpretation

Autopicking with waveform correlation tool on a wide window is noisy (spiky) on band limited data
Broadband – Shallow section interpretation

Autopicking works a lot better on Broadband data, less spiky
Interpretation of Chalk facies
Conventional – Well tie and Chalk interpretation
Broadband – Well tie and Chalk interpretation
This low impedance, marly interval correlates with the edge of a bright amplitude dissolution feature in the upper chalk section on the seismic data.
Conventional – Ekofisk/Maureen RMS amplitude map

Upper Chalk clay ponds and dissolution features
The chalk dissolution features (clay pools) are much better defined on broadband data.

The gray scale trends in the background highlight the regional facies variations: darker grays to the left are indicative of a marlier chalk section whereas light grays correspond to hard, carbonate-rich chalk.
A recent Chalk discovery: Orchid

3 May 2012

Trap Oil Group plc
("Trapoil" or the "Company")

Orchid Exploration Well (Licence P.1556 Block 29/1c)
Management Estimate Unaudited In Place Volumes to be Approximately 40mmbls

Trapoil (AIM: TRAP), the independent oil and gas exploration and appraisal company focused on the UK Continental Shelf ("UKCS") region of the North Sea, announces that further to the release of 23 April 2012 it has been advised by Summit Petroleum Limited ("Summit") that operations on the Orchid exploration well have reached their targeted depth.

As previously announced, the 12½" hole section of the Orchid well bore was re-drilled as a mechanical side-track. The well has reached its target depth of 9,333ft Measured Depth Below Rotary Table ("MBRDT") or 8,609ft True Vertical Depth Sub Sea ("TVDSS"). The shallow secondary objective Andrew sandstones were not well developed over the top of the structure, but the deeper primary target Chalk zone had over 280ft of good oil shows. 100ft into the reservoir an influx into the wellbore of a small amount of fluid was encountered, which was safely controlled, and reported on the rig site to be oil. MWD logs completed over the Chalk interval confirm at least 50ft of net oil pay with average porosities of 30 per cent. and an average oil saturation of 47 per cent. Further log runs were obtained over this zone but these proved inconclusive as to the quality of the pay zone. Accordingly, following due consultation amongst the partnership group, where there are significant differences in materiality thresholds, the well will now be plugged and abandoned.

Analysis of the well data by Trapoil suggests that the Orchid well has penetrated 64ft of gross oil pay above a 235ft transition zone. Trapoil estimates that based on the current available data there are in place unaudited volumes of approximately 40mmbls which should potentially provide a commercial reserve. However, a second wellbore will be required to provide conclusive evidence of such potential. The partnership group will now consider their options for potential future additional drilling activities.

The partners in exploration licence P.1556 are Summit (45 per cent., operator), Valiant Exploration Limited (30 per cent.), Atlantic Petroleum UK Limited (10 per cent.) and Trapoil (15 per cent., of which 5 per cent. is carried and 10 per cent. is a paying interest).

Martin David, Technical Director of the Company, has reviewed and approved the technical information contained within this announcement in his capacity as a qualified person under the AIM Rules. Mr David holds a BSc degree in Geology from the University of London and has over 37 years’ experience in the oil industry.
Orchid as interpreted on conventional data

Principal Seismic: AHL (1991), Repro. 2010

P1556 Block 29/1c (Orchid)
- Block awarded 25th Round (2009)
- 1 Firm well
- 2,530m (8,300ft) to evaluate Palaeocene and Chalk
- Block 29/1c is located in the Central Graben, immediately north east of the Bittern field
- Principal prospect: Orchid - salt induced play with four-way dip closures mapped at Palaeocene Andrew Sandstone Member and Chalk Group (Ekofisk and Tor Formation) levels. Principal Risks: reservoir effectiveness, top seal (faulting)
- Well currently operating

Source: Trap Oil investor presentation
W-E regional seismic line with interpretation

- Orchid
- Salt-induced high
- West Central shelf
- Zechstein salt
S-N regional seismic line with interpretation

Salt-induced high
Orchid
Zechstein salt
W-E seismic line across Orchid

Phase reversal due to ‘soft’ response from the oil-filled chalk reservoir?

Flat-spot or porosity effect (or both)?
NE-SE arbitrary seismic line across Orchid

Central Orchid is offset by a large fault initiated due to uplift from the Zechstein salt below

Large salt diapir towards the NW
Orchid chalk reservoir as interpreted on broadband data

- TWT structure map
- Top Chalk amplitude map
- Minimum amplitude map directly below Top Chalk

Broadband data do not show amplitude dim in the central part of the field.
Interpretation of deep sub-BCU targets
Fault blocks interpretation using band-limited data

Cross fault correlation with multiple choices??
Any reflector can be correlated through faults
Fault blocks interpretation using broadband data

Cross fault correlation better understood
Uniqueness of the reflector correlation through faults
Conventional – Jurassic fault blocks interpretation
Broadband – Jurassic fault blocks interpretation
Broadband – Jurassic fault blocks interpretation
Conventional – Jurassic fault blocks interpretation
Conventional – Well synthetic, deep tie

NB: Well synthetic phase reversed for display purposes
This sub-BCU low frequency package is clearly visible on broadband seismic but not on conventional data, and it is replicated by a well seismic synthetic. This means that this is the genuine formation signature and that the low frequencies below the BCU are not coming from any kind of noise.
Summary – Benefits for qualitative interpretation

- BroadSeis data provide a broader frequency spectrum enabling the interpreter to:

  - Accurately interpret stratigraphy, thin beds and subtle structures – *benefit from the high frequencies*

  - Produce a clearer interpretation of deep targets (sub-BCU, sub-chalk, sub-basalt...) and large-scale and subtle facies variations – *benefit from the low frequencies*

  - Extract the ‘true’ seismic signature of the geological formations by reducing the wavelet side-lobes and sharpening its central peak – *benefit from the broad frequency range*
Broadband shallow imaging
Acknowledgments

- **CGG multi-client division** for permission to show these data examples
- **Steven Bowman, James Rigg and Steve Thompson** - interpretation of seismic data and images contribution
- **Vincent Durussel, Steve Hollingworth and their team** - seismic processing
THANK YOU!