Application of Geosteering Technology for Real-Time Decision Making to Optimize Infill Drilling at West Brae, Central North Sea, UK

DEVEX 2012 – 9th May 2012 – Aberdeen AECC

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West Brae Stratigraphy

Two Tertiary stacked turbidite channel reservoirs:

- Balder Formation Sandstone
- Sele Formation Flugga Sandstone

- 90% Net to Gross
- 33% Porosity
- Several Darcy Permeability

2010/11 Drilling Campaign:
W10Y targeted Balder Sandstone
W9X targeted Flugga Sandstone
West Brae History

Reservoir
- High porosity sands with multi-Darcy permeability
- 22°API saturated oil
- Strong aquifer bottom drive recovery mechanism

Subsea Tie-back Development (1997 - 2010)
- 4 horizontal producers in Flugga, 3 horizontal producers in Balder, 1 Water Injector in Balder
- First oil October 1997
- Cumulative oil production 88 MMSTB at end Dec-2010
- Recovery factor of 43% at end Dec-2010
- Mature field in decline with 80% water cut, prior to 2010/11 drilling campaign
WPHZ Opportunity (W9X)

- Development well targeting un-swept oil in the Northwest of the Flugga channel. Based on interpretation of 4D seismic (acquired 2007, processed 2008).
Real Time Environment

- Offshore team:
  - Directional Drillers (2), MWD/LWD Engineers (3)
  - Marathon Wellsite Geologists (2)
- Onshore team:
  - Well Placement Engineers (2)
  - Marathon Subsurface (5) – Operations Geologist, Petrophysicist, Reservoir Engineer, Geophysicist, Subsurface Team Lead
- Petrel model used as tool for data integration to assist real time decision making
Well Placement Technology

– Bed Boundary Mapping

– Real-Time Density Images

– Azimuthal Measurements: GR/Dens
Pre-Drilling Feasibility Study

Density/Neutron Resistivity
Gamma Ray PeriScope Attn.
PeriScope Phase

Shale: Dark Brown
Sands: Yellow
Drilling W9Y

- Geometric drilling down to the reservoir sweet spot, through the depleted upper Flugga presenting a water leg above the mid shale, as anticipated from pilot holes results & 4D seismic interpretation (Eastern edge drive)

Shale: Dark Brown
Sands: Yellow
Drilling W9Y

- Geosteering in the sweet spot of the reservoir underneath the mid shale, avoiding sumps

Shale: Dark Brown
Sands: Yellow

Drilled trajectory
Planned trajectory
W9Y Overview

Geosteering decisions made

Wet Calibration

Tracking the overburden

Maintained till TD

Shale: Dark Brown
Sands: Yellow

Drilled trajectory

Planned trajectory

Density /Neutron
LWD Resistivity
Gamma Ray
Drilling sidetrack W9X

- Operational side-track, following well trajectory issue, to maximise footage in oil bearing sands and to explore reservoir extension towards the North of the field.

Shale: Dark Brown
Sands: Yellow

Geosteering decisions made

Into the oil bearing reservoir

Maintained till TD
Logs/pressures confirmed geological model and 4D interpretation.

Flugga more heterogeneous and compartmentalised than anticipated prior to 4D.

Well results were fed back into geomodel to evaluate further prospectivity for future infill drilling.
WPFZ Opportunity (W10Y)

- Development well targeting un-swept attic oil in the Sedgwick area of the Balder channel.
- Located down dip of existing producer V1, on shoulder of its water cone.
- Based on dynamic simulation and confirmed by interpretation of 2007 4D seismic.
- Optimised well path to be drilled toe up to maximise stand off to water.
Drilling W10Y

Shale: Dark Brown
Sands: Yellow

- Geosteering against Balder roof (unstable shale), drilling upwards. Avoiding to create sump at heel in structural hump.
Drilling W10Y

- Geosteering against Balder roof (unstable shale), closely following top reservoir structure. Avoiding to create sumps.

Shale: Dark Brown
Sands: Yellow

Density / Neutron
LWD Resistivity
Gamma Ray
Drilling W10Y

- Geosteering against Balder roof (unstable shale), drilling upwards following dipping top reservoir structure. Avoiding to create sumps.

Shale: Dark Brown
Sands: Yellow

Drilled trajectory
Planned trajectory

10 ft

- Density /Neutron
- LWD Resistivity
- Gamma Ray
W10Y Overview

Geosteering decisions made

Shale: Dark Brown
Sands: Yellow
3D Surfaces

Top Reservoir Shale Boundary

Drilled trajectory
Planned trajectory

Shale: Dark Brown
Sands: Yellow
Conclusions

Geosteering Success:
- Stay in the reservoir between the water bearing layers
- Stay in the reservoir below the shale roof

Drilling campaign was a success:
- Over 1,500 ft MD (Flugga) & 3,000 ft MD (Balder) net pay completed
- Field oil production more than doubled, with water cut down to ~55%
- Project contributed to extending field life by 3 years

Co-located team essential to success:
- Ease of access to resources for decision making
- Potential downtime & delays for decision making reduced
- Knowledge sharing across a range of disciplines
Acknowledgements

The authors would like to thank the management of Marathon Oil, the Brae group*, and Schlumberger for their continued support and for authorising to share this data.

*The Brae group partners are BP, TAQA Bratani, Centrica, JX Nippon and GDF Suez.

Thank you to Marathon subsurface colleagues, who have contributed to the success of this project: L. Ashman, F. Bacciotti, S. Buckner, R. Cameron, K. D’Amore, D. Eickhoff, A. McGeer, A. Schwab, A. Vitali.
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