West Brae field:
- Started production in 1997
- 4D seismic survey acquired in 2007 to aid the identification of potential late stage development targets
- Late drilling campaign in 2010-2011

Presentation focus:
- Interpretation of the 4D seismic response
- Integration with the dynamic field behaviour for the Flugga reservoir
- Comparison of pre-drill models with well results
Presentation Outline

- Introduction
- West Brae Overview
- 4D seismic acquisition and interpretation
- Integrating the 4D results with dynamic modelling of the Flugga reservoir
- 2010 drilling campaign
- Conclusion
West Brae

- Two stacked turbiditic reservoirs:
  - Balder sandstone
  - Flugga sandstone

- Amalgamated units of massive unconsolidated sandstones:
  - 90% net-to-gross
  - 30% porosity
  - Darcy's permeability
  - Strong aquifer support

- Field production (2010):
  - Cumulative: 87 MMboe
  - Recovered: 45%
  - Water cut: 78%
Seismic acquisition:
- 1993 Baseline and 2007 Monitor 3D surveys (streamers)
- Same geometry, parallel processing
Pressure changes have little influence in West Brae

Mostly fluid response:
- Water replacing oil produces a hardening (e.g. water coning)
- Gas replacing oil generate a softening (e.g. gas coming out of solution – an effect of reservoir depletion – or gas coning)
4D Seismic Interpretation of the Flugga Reservoir

- In the Flugga reservoir, main 4D response is water rise caused by producing wells.

- No water rise in the NW of the field.

- Linear weak feature along the edge of the reservoir (“NW rise”).

- Uncertainties:
  - Detection/resolution limits (tuning of thin water layers or low water saturations sections).
  - Existence of NW rise as it fails to stand out.
No water rise in the NW of the field whereas:

- W8Z well producing since 2005
- Good reservoir properties in surrounding wells and along well path
Supporting Evidence of Compartmentalisation

- **W8 pilot hole**
  - Good sand
  - No water rise in 2005

- **16/7a-34Y appraisal**
  - No gas above field GOC level

![Diagram showing geological features and well locations](image-url)
Data Integration to the Dynamic Modelling

- History matching process indicated extensive barriers to fluid flow /pressure transmission were required
  - To be effective in high net-to-gross, high permeability reservoir

- Barrier types:
  - Faults: West Brae lies over a horst and major graben fault
  - Shale: shale drape or overbank shale of turbiditic complex
  - Combination of both
Data Integration to the Dynamic Modelling

- Numerous iterations of history matching
  - Determine geometries to reproduce 4D signal shape, while honouring production/pressure data

- Possible elements of scenarios:
  - Under seismic resolution rise or water saturations
  - NW rise feature is noise
  - W8Z toe not contributing
  - Faults or shales creating protection from water encroachment
  - Etc...
Base Case Model

3D view of West Brae pre-drill model

Flugga reservoir outline

Isolated compartment

Flugga reservoir outline

Interpreted oil-water contact

north
Objective of the Drilling Campaign

- Targets un-swept oil in the Flugga reservoir
- Pilot hole objectives:
  - Determine presence of gas
  - Determine water encroachment, test 4D data and interpretation
  - Understand compartmentalisation (pressure data)
  - Confirm reservoir quality
- 3 well path options depending on pilot results
Pilot Results

- Outcome of the pilot holes
  - Gas cap
  - Good reservoir properties
  - Water encroachment
  - No significant aquifer rise
  - Unswept compartment
  - Upper section depleted

- Decision to drill the horizontal in un-swept compartment
Horizontal Results

- Drilled through expected swept compartment and NW rise
- Penetrated un-swept compartment as planned
- Completed un-swept sections with sand screens equipped with Inflow Control Device, which strength against the flow diminishes towards the toe
- Wells confirmed base case scenario
Interpretation of the well results

Vertical exaggeration ×10

300m

Sand | Shale | Water | Oil

W8
W8Z
W9Z
W9
34Y

Swept and depleted: Upper Compartment
Sand unit produced by W8Z
Swept: Upper Compartment
Unswept: Lower Compartment
Unswept: isolated Compartment

W9Y
W9X

W9Z

Gas cap

Top Flugga

W8Z water cone

Mid-Shale

Aquifer

Isolated compartment

Upper Compartment

Lower Compartment
Conclusion

- Wells confirmed a complex model based on 4D image
- Importance of integrating all subsurface disciplines tightly
- 4D key tool for West Brae reservoir management
- 4D changed how reservoir was viewed
- Targets would not have been identified/drilled without 4D
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