Integrated Uncertainty Workflows for Field Development Planning: Example from the Jackdaw Discovery*

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Abstract

Integrated static and dynamic uncertainty workflows are a powerful tool for quantifying subsurface risks and guiding decisions during field development planning. A multi-disciplinary workflow that incorporates geophysical, geological, and production uncertainties has been developed for the Jackdaw discovery, a High Pressure, High Temperature, gas-condensate field in the central North Sea. As a result of high well costs and the challenges of operating in extreme sub-surface conditions at depths approaching 19000 ft (5800 m), the exploration and appraisal programme, conducted between 2005 and 2012, was recognised as being unable to resolve various key uncertainties. In order to progress the development through the decision chain and provide key stakeholders with a robust, reasoned, and accurate resource range, a key element in evaluating overall value, the sub-surface team developed innovative approaches to dealing with and quantifying the key uncertainties. This workflow draws on a geological model built with PETREL with uncertainty parameters defined within MEPO. In addition to modification of geological and petrophysical parameters, each realisation runs additional nested workflows. The first of these nested workflows modify the structure of the grid to account for gross rock volume and seismic interpretation uncertainty. The second workflow automatically calibrates the generated static model to the available drill stem test data. Each model realisation is simulated with ECLIPSE, with results sent back to MEPO for statistical analysis and the generation of probability distribution curves for both GIIP and reserves. Sensitivity analysis reveals the key uncertainty on in place volumes in both the appraised and un-appraised fault blocks are the gas-water contacts. However recovery from the reservoir is largely controlled by abandonment pressure and permeability. The reservoir comprises a bimodal permeability system that is primarily controlled by depositional facies. High permeability turbidite or gravity flow deposits are found within a background of low permeability, bioturbated shelfal sand. The shelf sand facies has core measured permeabilities of 0.005–1 mD (air permeability). As a result of this low permeability, uncertainty around the Klinkenberg correction factor and vertical permeability can significantly impact recovery.

Integrated Uncertainty Workflows for Field Development Planning

Example from the Jackdaw Discovery

2nd June 2015

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Deepsea Metro I drillship
Offshore Tanzania

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Acknowledgements

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Agenda

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- Overview
- Uncertainties
  - What are the major uncertainties
  - Sector Modelling
  - Sensitivity Analysis
  - Full-Field Modelling
- Conclusions

Jackdaw Discovery

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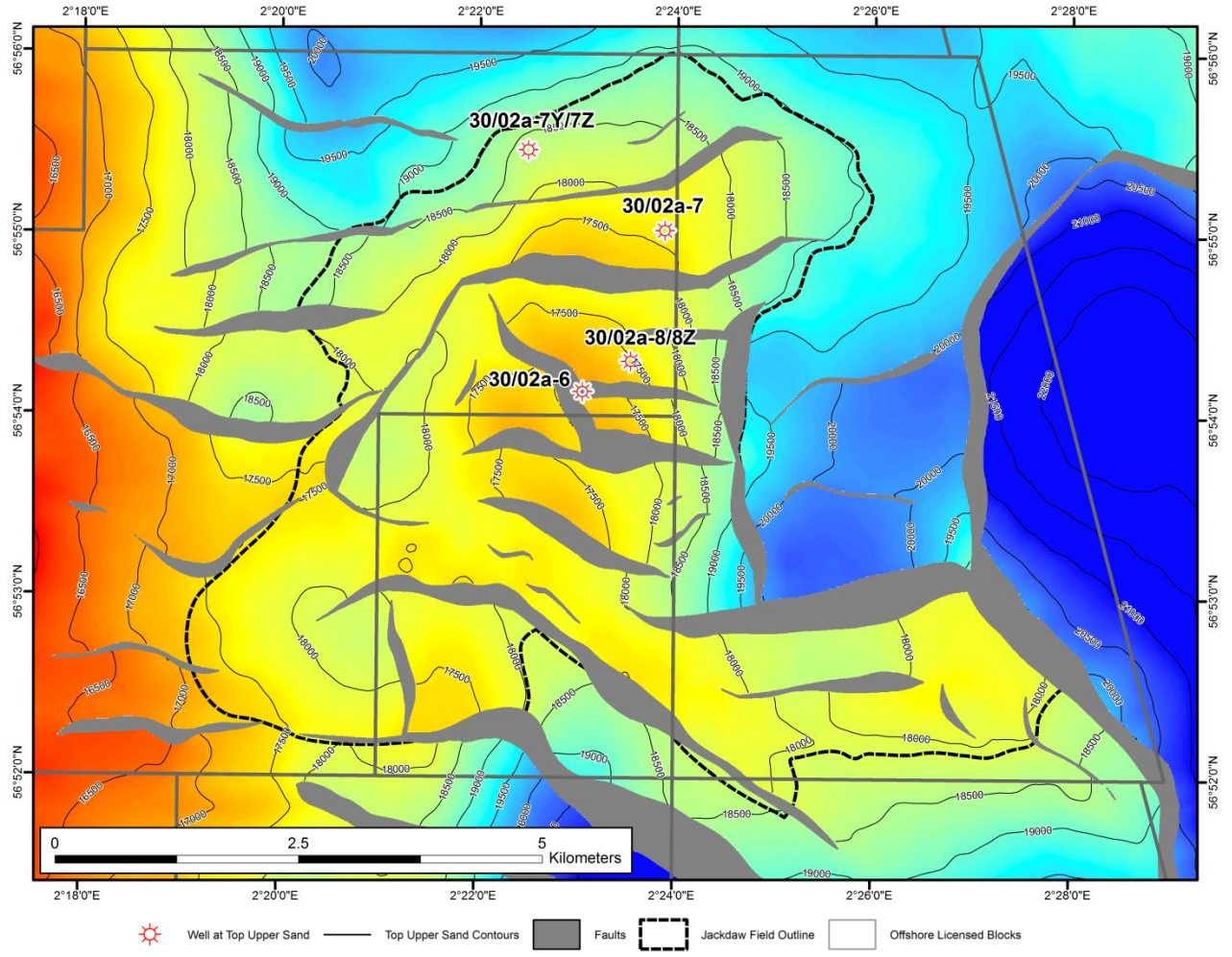

- Discovered 2005
- Appraised 2007-2012
- Well penetrations in 3 fault blocks
- -8z provides key datasets
  - DST
  - Core
- Reservoir
  - High permeability (10-500mD) Jurassic turbidites within background shelfal sand
  - 16900 psi
- Lean gas-condensate
  - 25-90 bbl/mscf
- Full-field recoverable volume
  - 140 – 280 mmboe

Jackdaw Discovery

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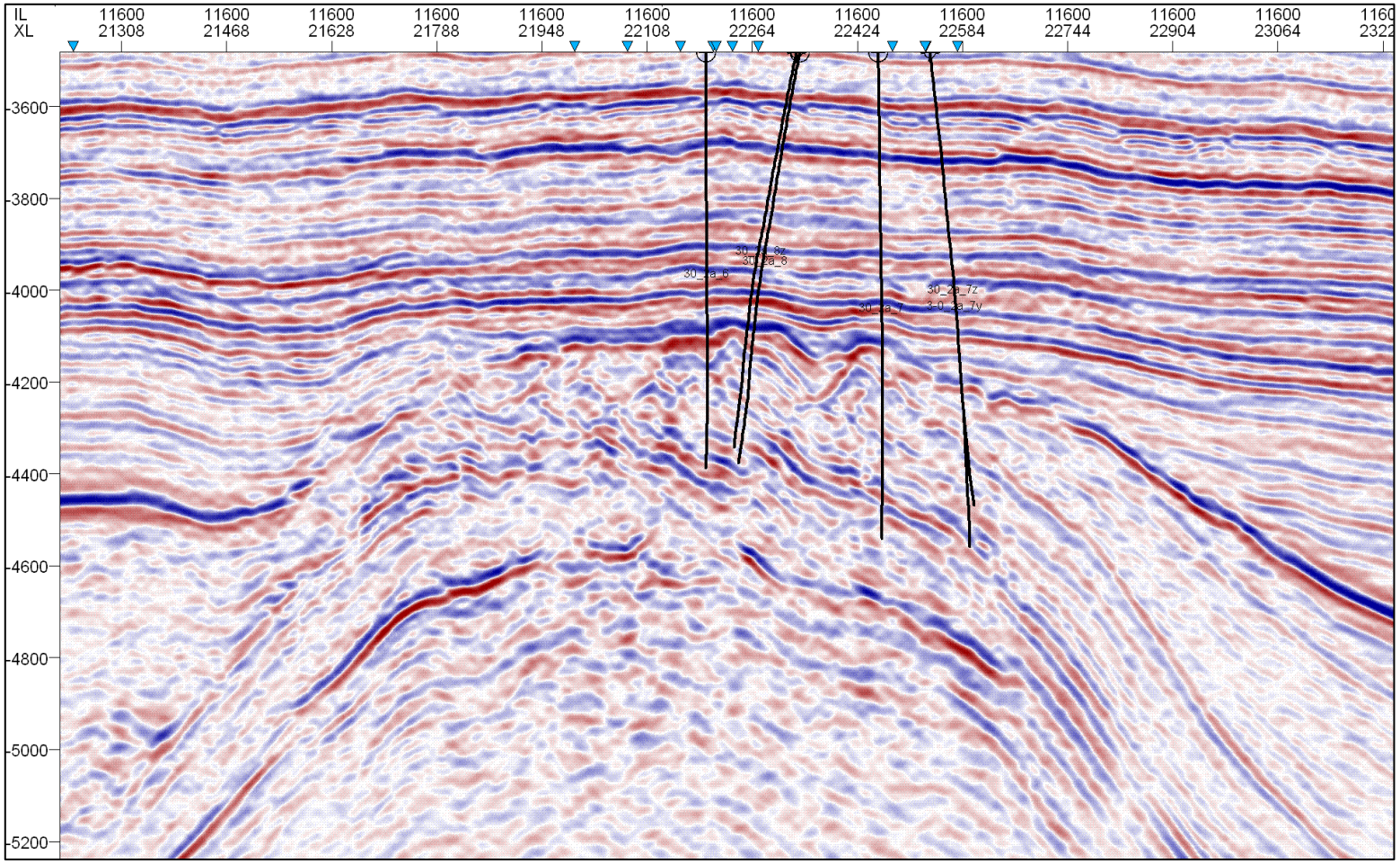

Cornerstone 3D data by permission CGGVeritas

Jackdaw Discovery

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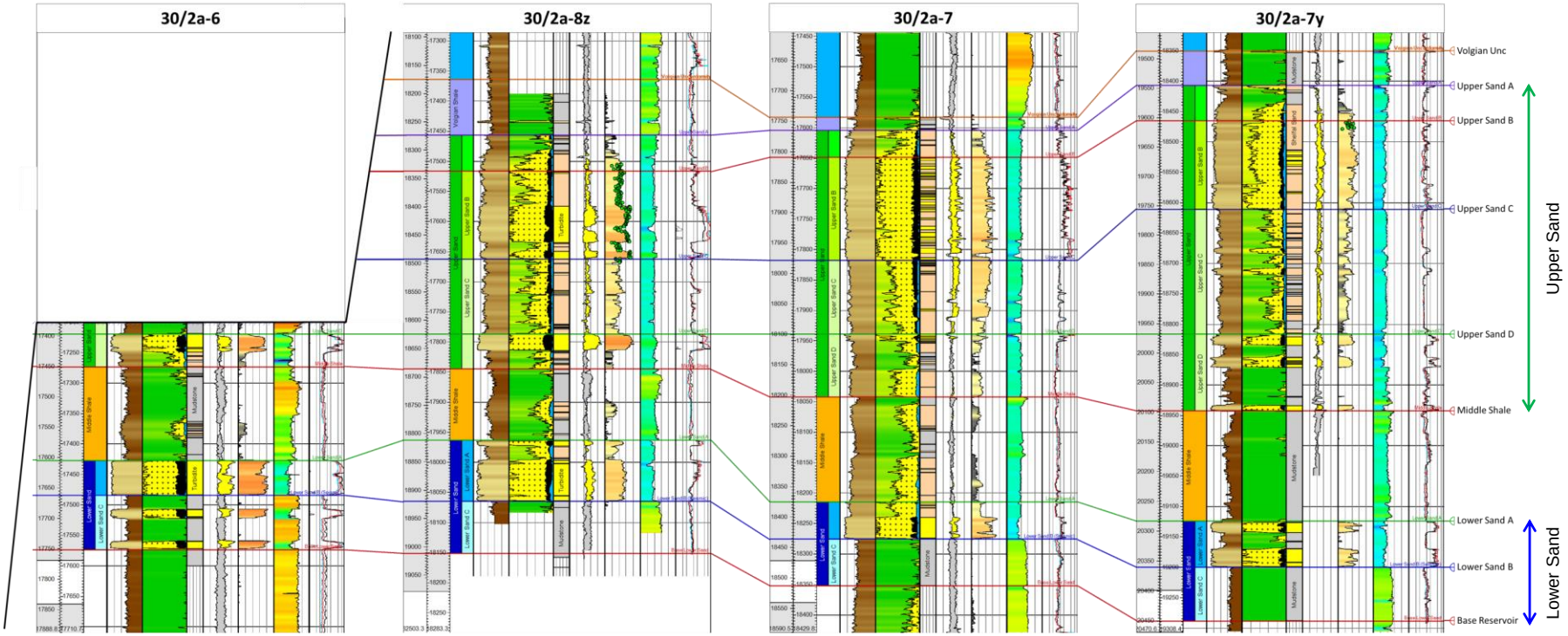

Jackdaw Discovery

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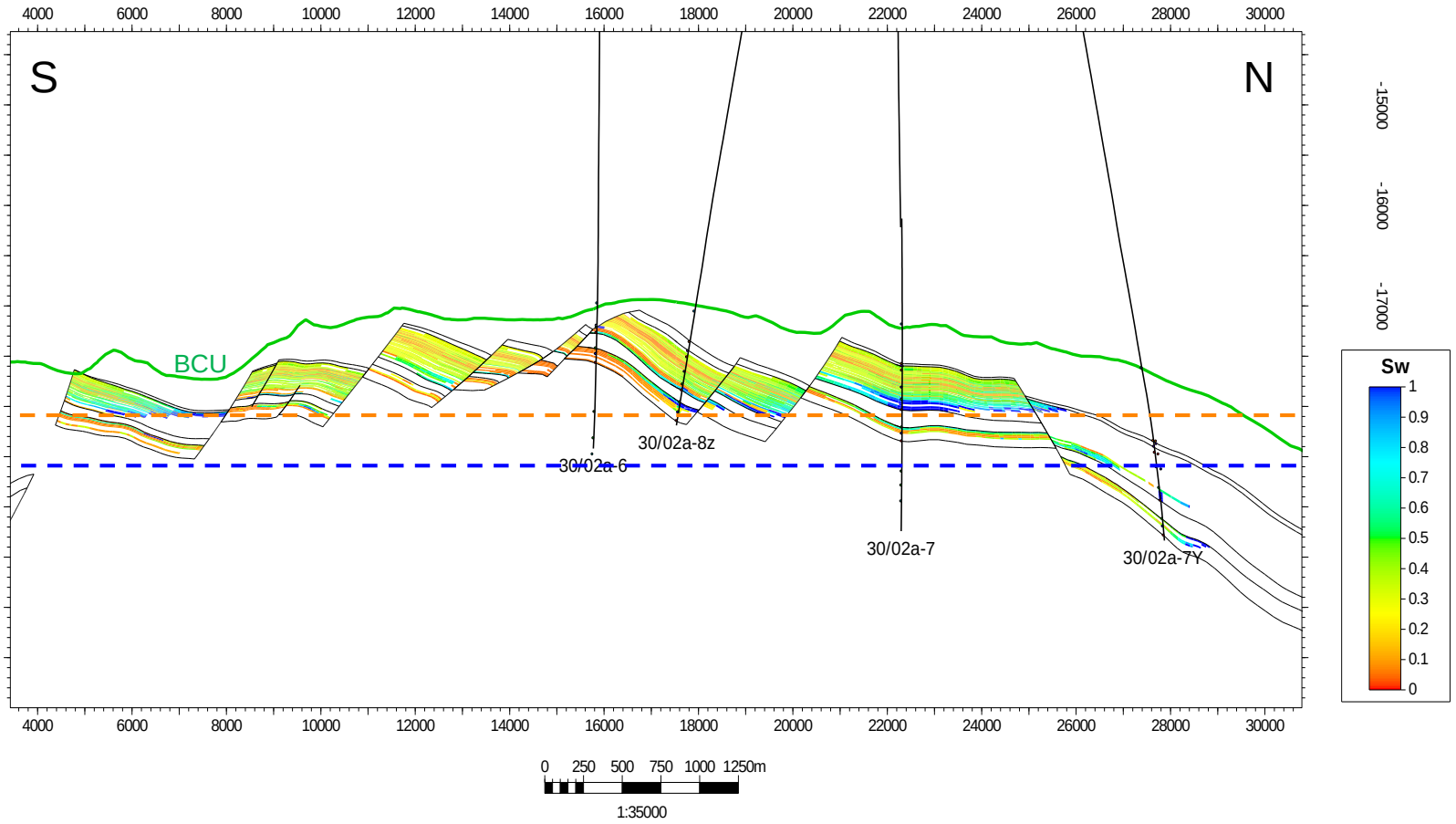

Key Uncertainties

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- Contacts
- GRV
  - Interpretation in southern portion of structure (the undrilled fault blocks)
  - Depth conversion
- Shelfal sand facies
  - Permeability
- Turbidite facies
  - Geometry and extent
  - Proportion away from well control
  - Permeability
- Sub-seismic faulting

How to model uncertainties

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- Sector models
  - DST matching and turbidite permeability
  - Turbidite stacking patterns
  - Sub-seismic faulting
  - Dynamic sensitivity analysis

- Full-field modelling
  - Integrated workflow
  - Petrel-MEPO link
  - Output to development decision tools

Timing and Resourcing

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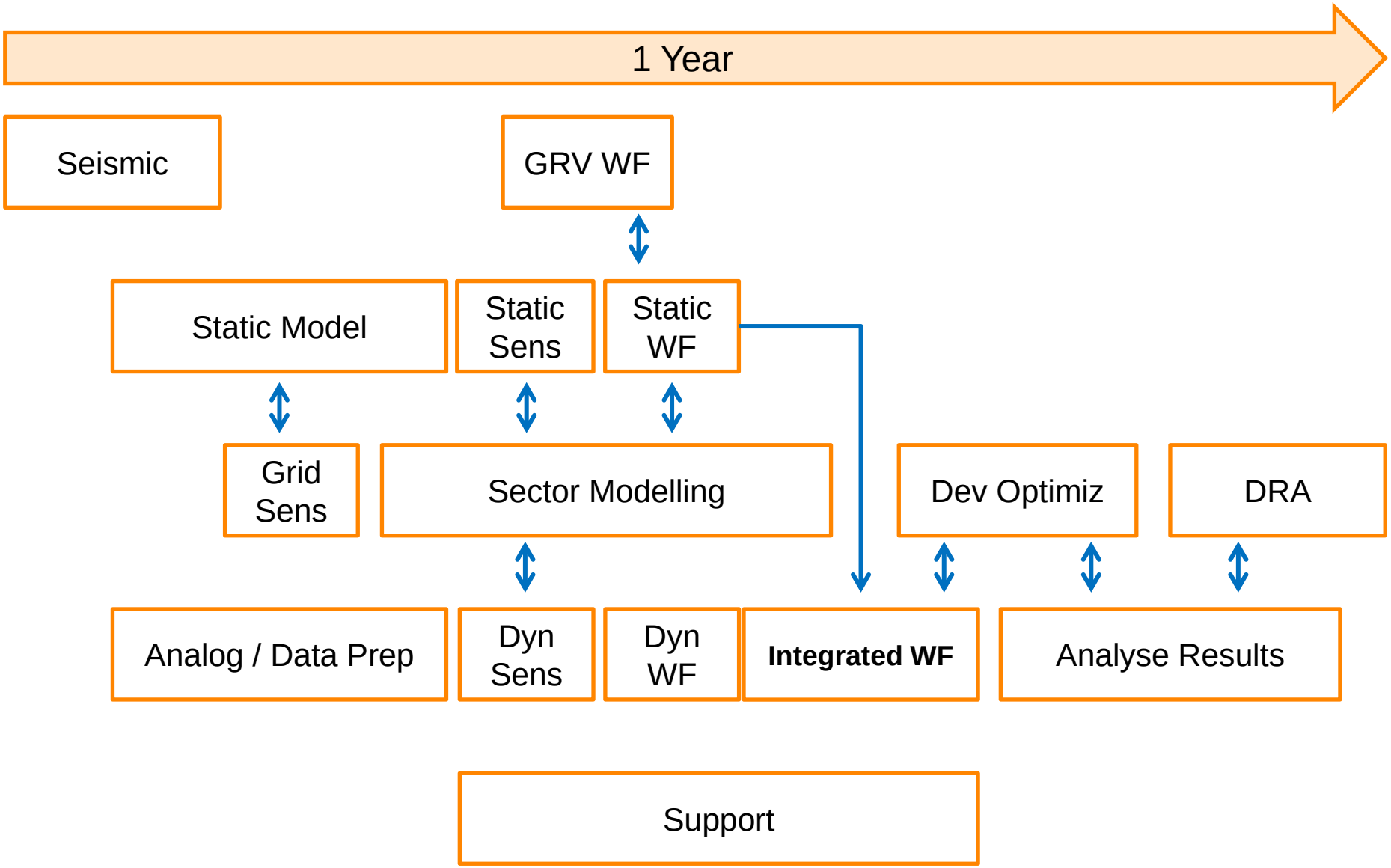

Sector Modelling – DST Matching

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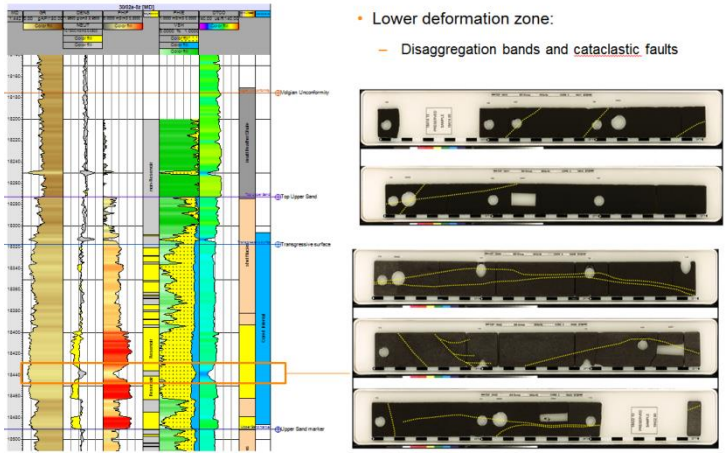
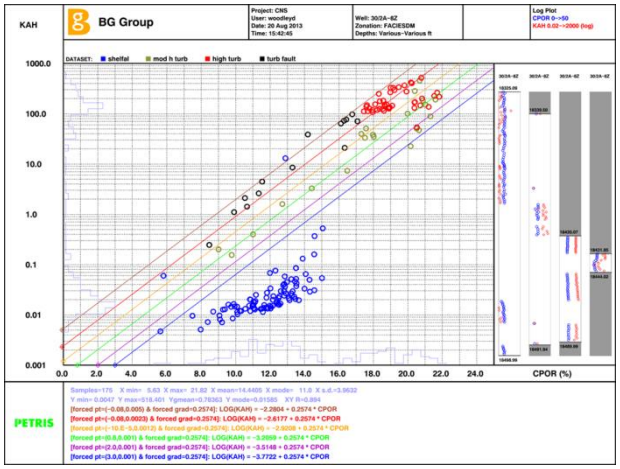
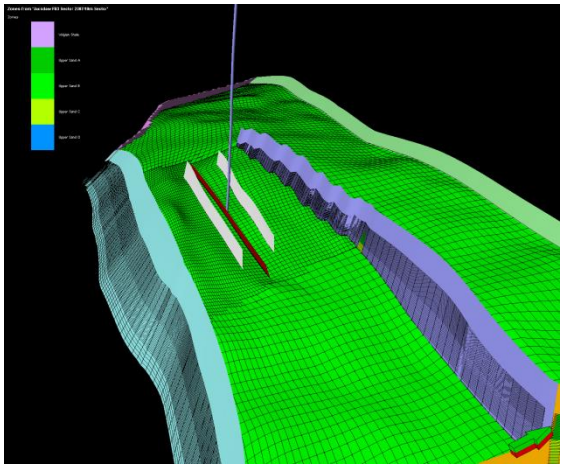
Static Inputs

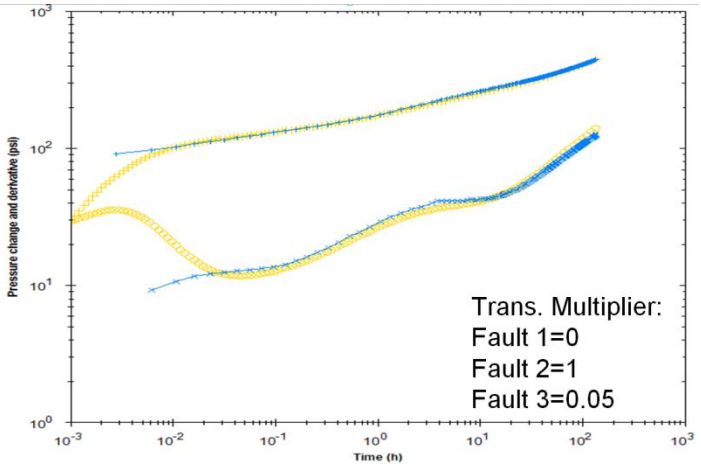




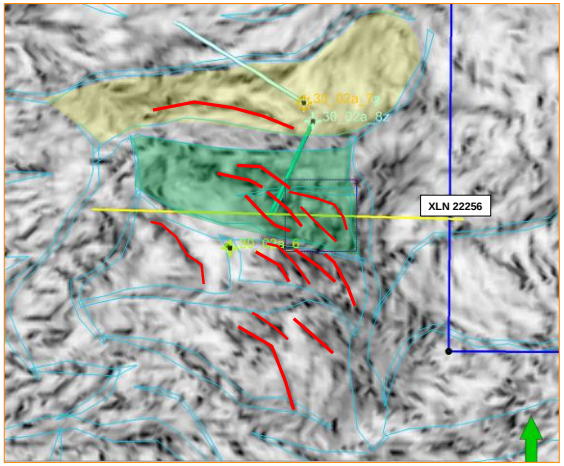
Sector with LGR

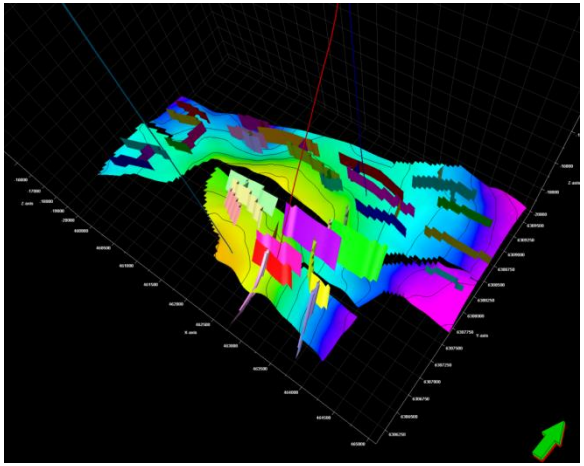


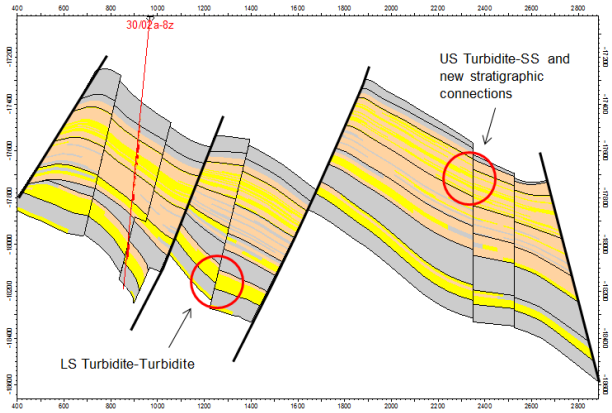
Best Match

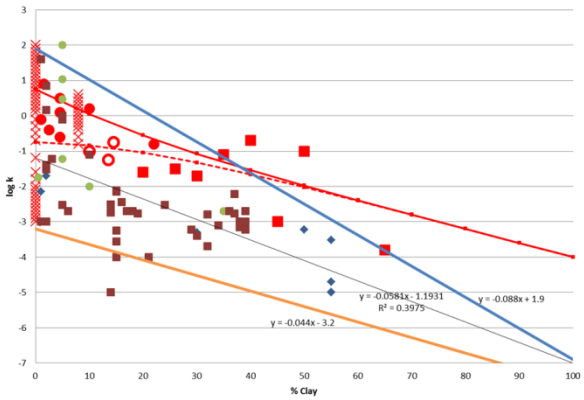


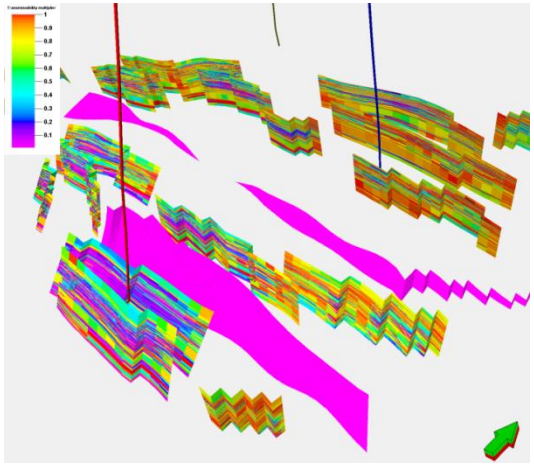
Sector Modelling – Sub-seismic Faulting

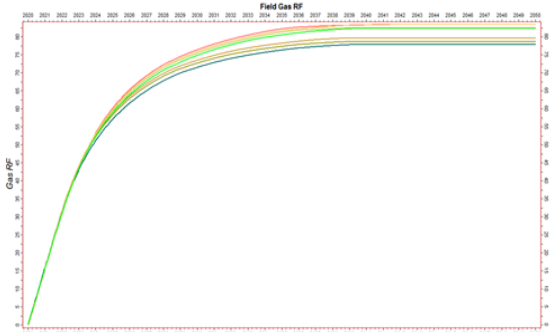




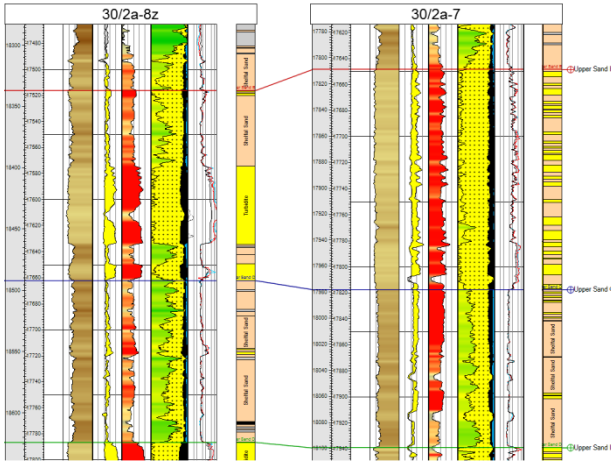


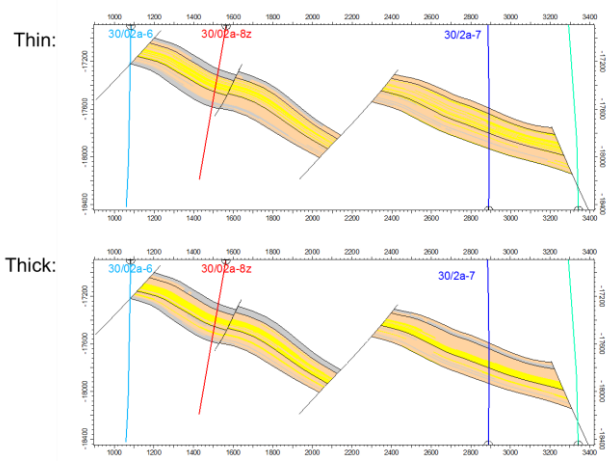




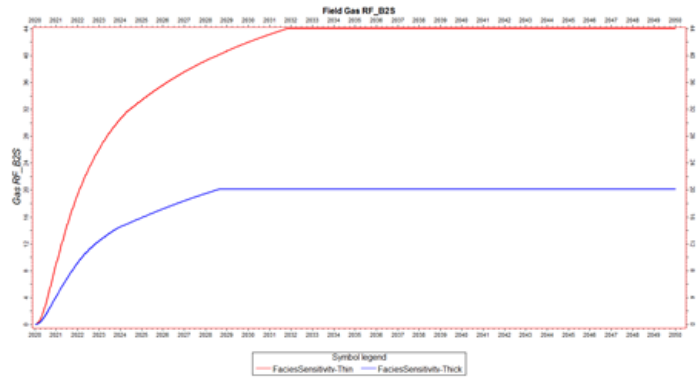


Sector Modelling – Turbidite Geometry

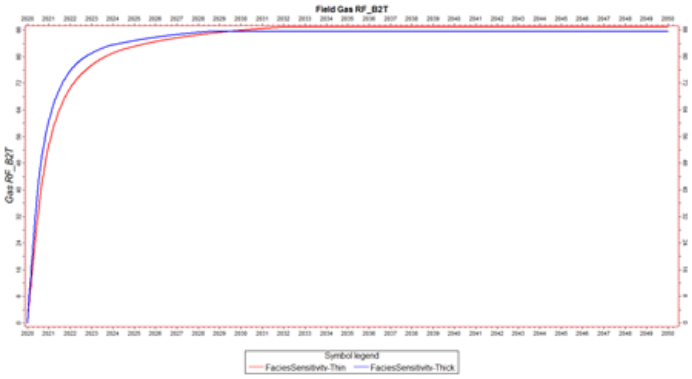




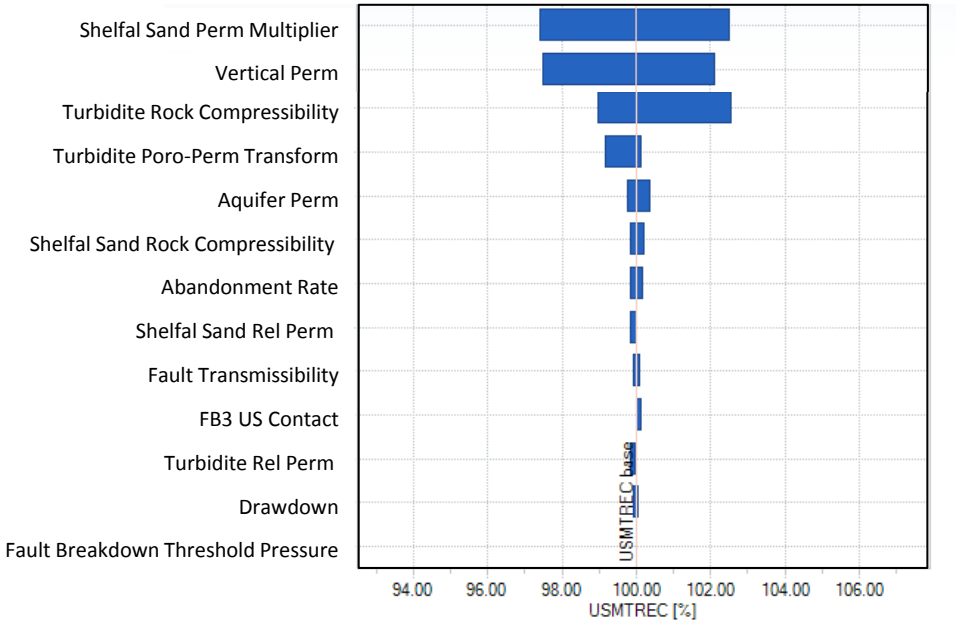
FB2 Shelfal Sands



FB2 Turbidite

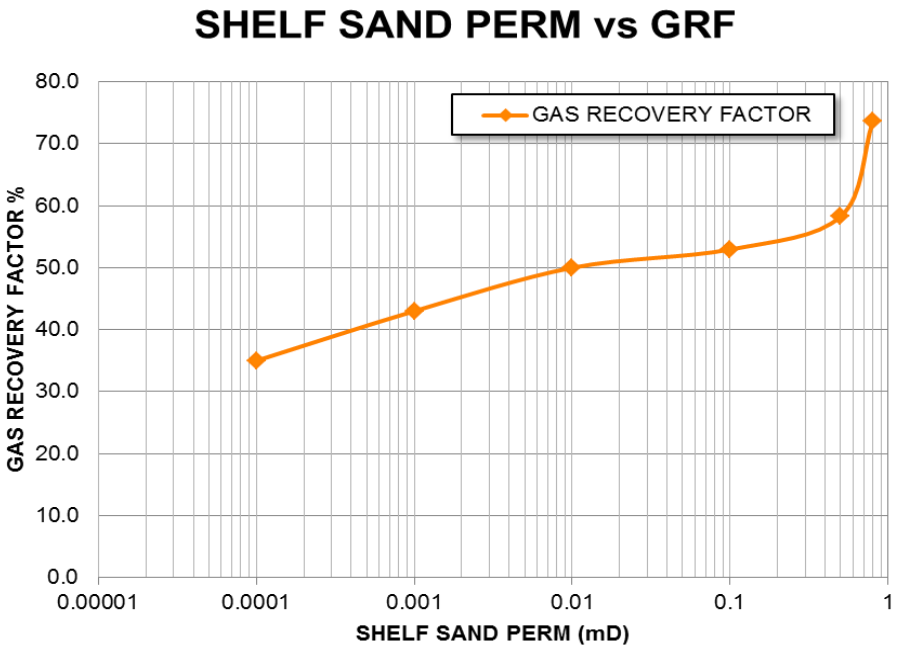


Sensitivity Analysis - Dynamic



- Undertaken using a reference case development strategy

- Range of ‘sensitivity’ used in full-field uncertainty workflows



Sensitivity Analysis - Static

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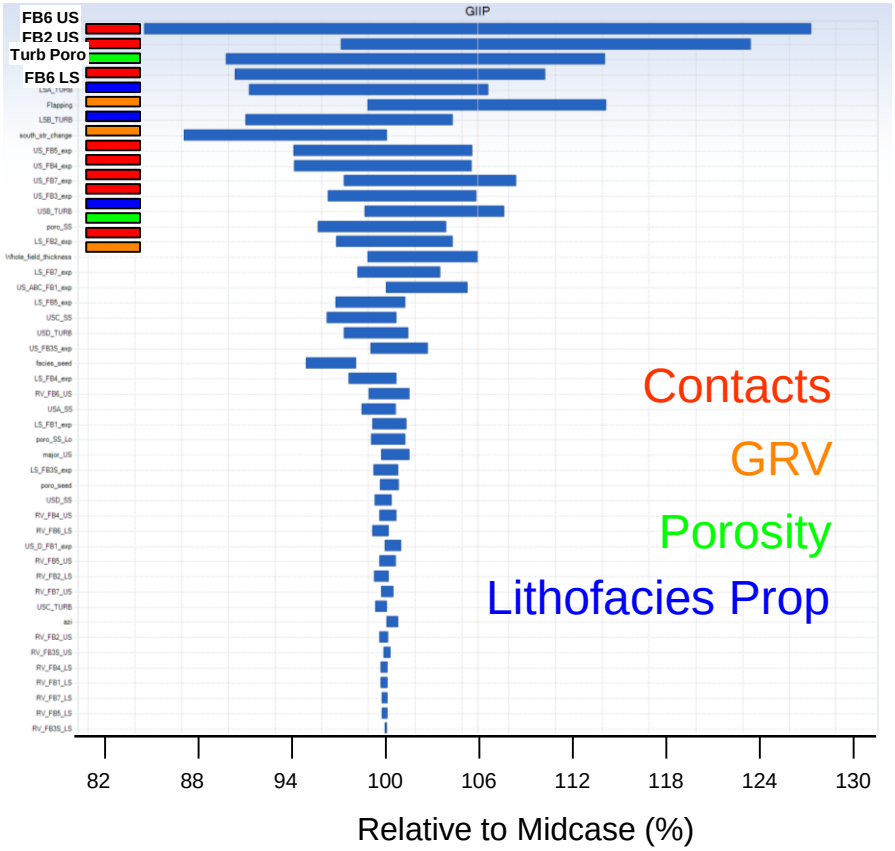

- GIIP uncertainty is largely controlled by contacts (GRV)
- Turbidite proportion and porosity also important (pore volume)

Full-field Integrated Workflow

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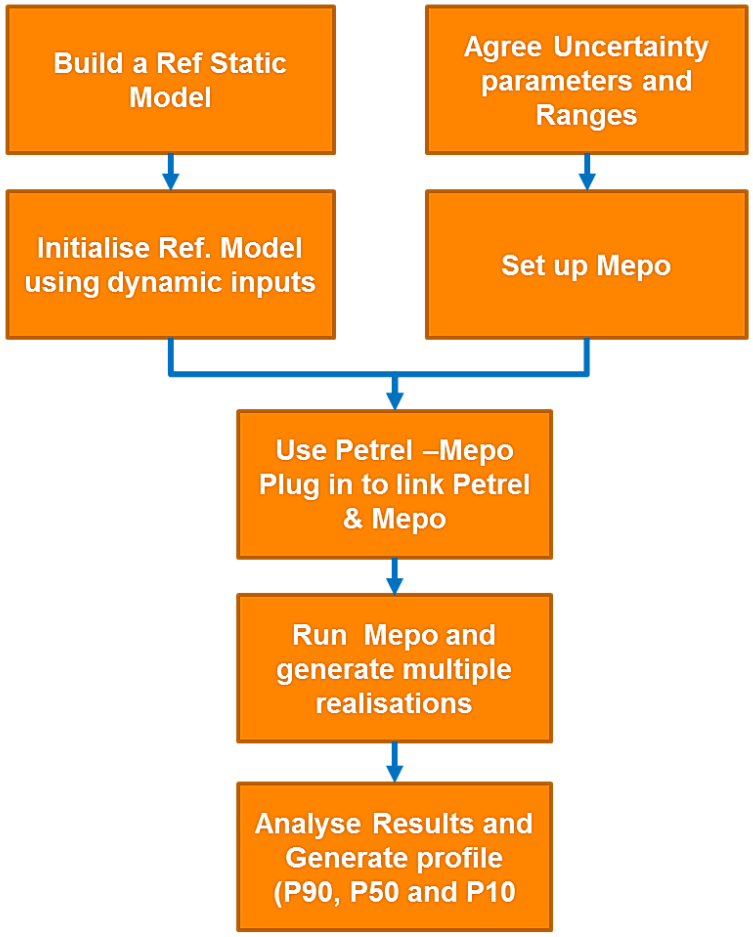
- Develop workflow and uncertainty parameters in Petrel
- Define uncertainty variable ranges and distributions in MEPO
- Use software link to initiate each model realisations with results sent back to MEPO
- Analyse results and generate profiles



The Workflow

Link to MEPO
- Uncertainty variables imported from generate MEPO Case

Nested GRV Workflows
- Depth Conversion
- Reservoir Thickness
- South Interpretation

Rebuild new structure
- Facies Modelling
- Property Modelling

Permeability Transforms

Saturation Height Functions

Define Fluid Models

Saturation Calculations

Set Completions

Fault Transmissibility
Rock Compressibility

Development Strategy

Nested DST Matching Workflow and Simulation

Model Simulation

Nested Workflows – GRV Uncertainty

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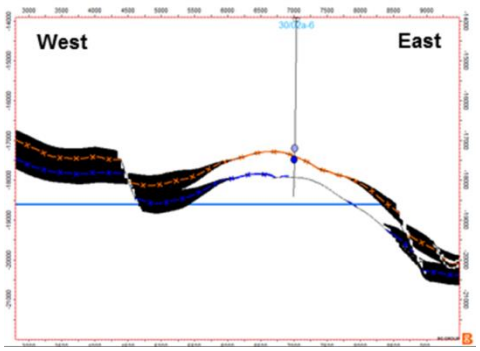
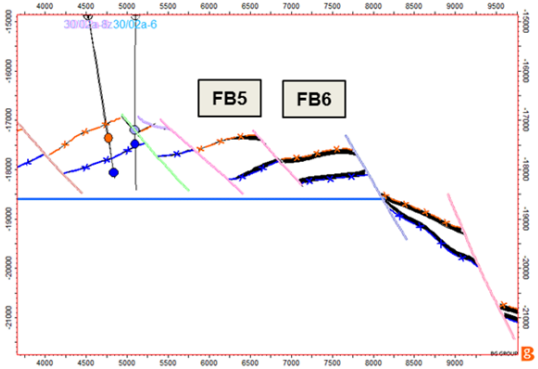
- Series of nested workflows combined to modify input datasets
- Variables ranges and distributions can be modified as required:

Uncertain	$Whole_field_thic	0	Uniform	Min	-0.1	Max	0.1				
Uncertain	$Flapping	0	Truncated nor	Mean	0	Std	250	Min	-250	Max	250
Uncertain	$south_str_chang	0	Uniform	Min	0	Max	100				

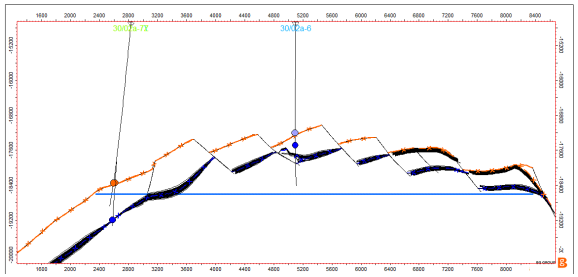
Depth Conversion off-structure



Southern Interpretation



Reservoir Thickness



- Results can be QC'ed via horizon exports, modifications maps, sensitivity tornado plots, volumetric histograms

Nested Workflows – GRV Uncertainty

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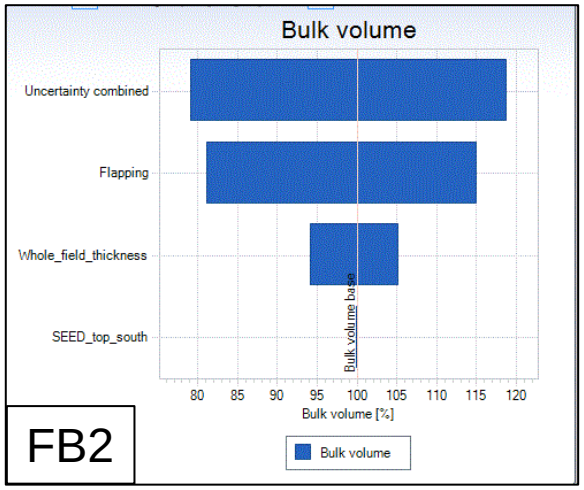
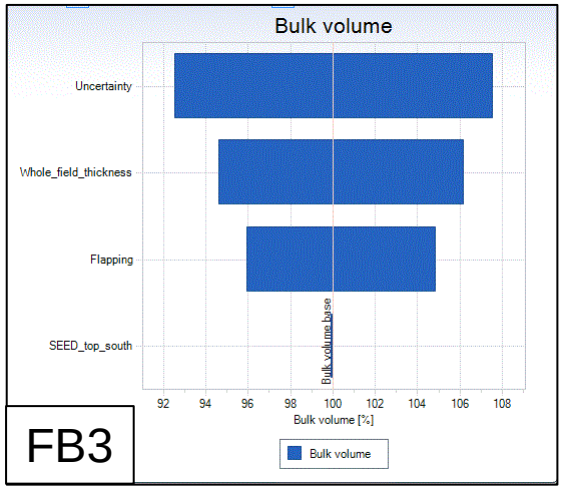
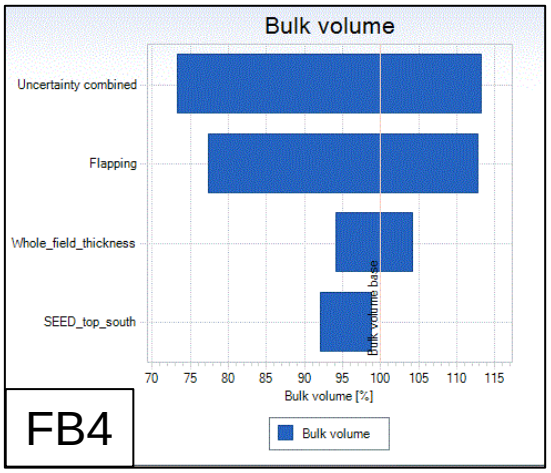


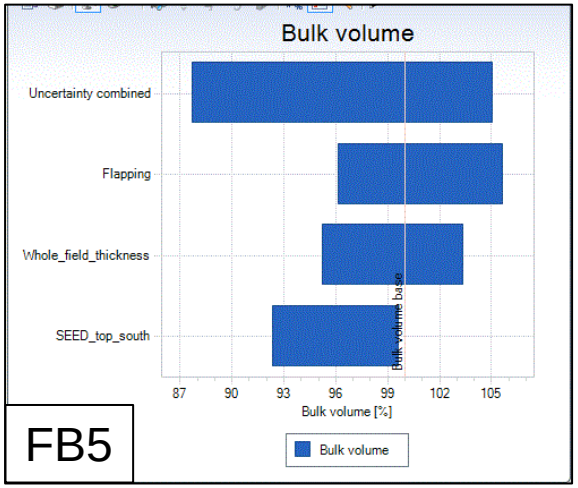
Principle effect – Flapping



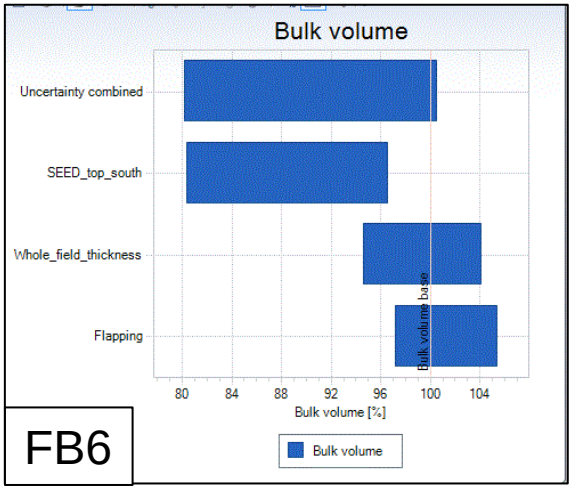
Very limited effects



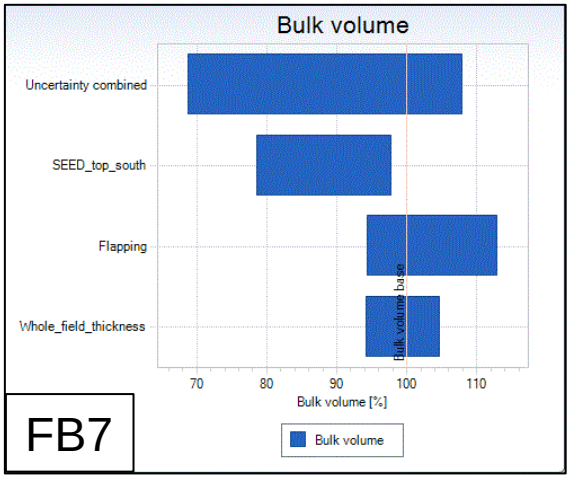
Principal effect flapping – western flank



Principal effects negative, but not large – interpretation uncertainty main contribution



Principal effects negative – interpretation uncertainty



Principle effect – interpretation uncertainty

Geographically distributed uncertainty

Nested Workflows – DST Matching

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Mepo

Enter uncertain parameters in mepo and define distribution function and ranges

1

Petrel

Build petrel workflow with includes both static and dynamic uncertainty parameters

2

Mepo

Generate realisations of the uncertain parameters in mepo, and send to Petrel

3

Petrel

Run the petrel-mepo plugin in petrel to generate a static realisation based on the data received from mepo

4

Petrel RE

Perform DST matching and calibrate the model based on the derived multiplier

5

Petrel RE

Update generated static realisation in step 4 and export case to eclipse cluster

6

Mepo

The result of the eclipse run are sent to mepo

7

Mepo

Select from the reserves distribution the cases to be carried forward (P10, P50 & P90).

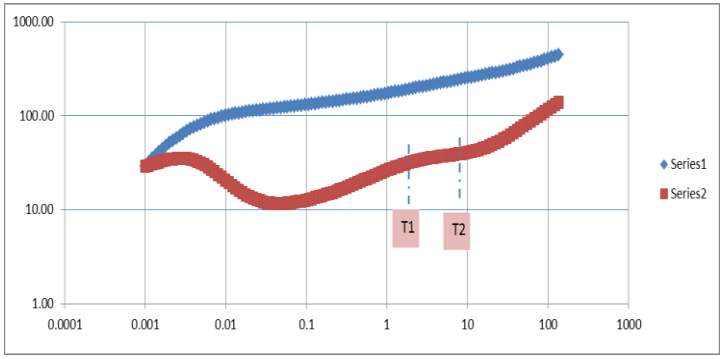
8

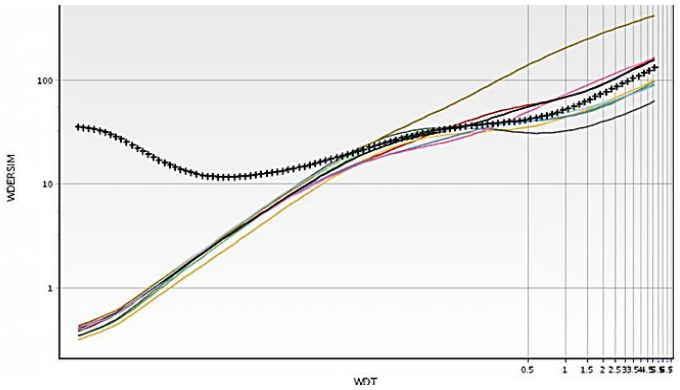
Economies and facilities options screening

9

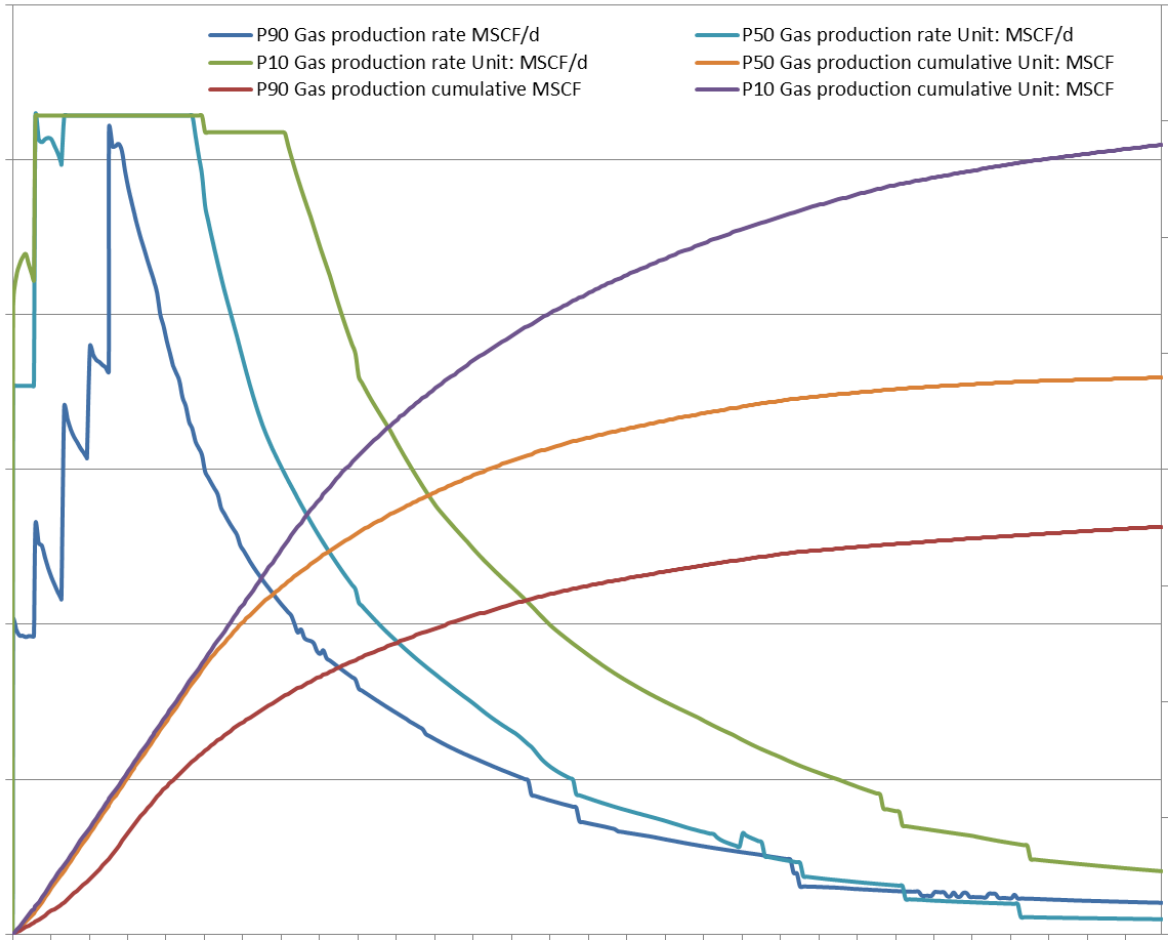
DRA (Decision Risk Analysis)

10





Probabilistic Output



- Results of ~1000 model realisation and simulation cases were extracted from MEPO
- Cases screened to meet static and dynamic GIIP/Reserves criteria
- Appropriate probabilistic profiles selected

Summary

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- A combination of sector models, sensitivity analysis and full-field modelling has been used to quantify a range of subsurface uncertainties which are largely derived from sub-optimum datasets

- Range of outcomes centered around a base case
  - Appropriate for drilled fault blocks?
  - Deterministic models for QC

- What about the surprises?
  - Obviously difficult to model
  - Will they help make a development decision?

- Range of modelling profiles can then be used in other decision-based tools. BG employs Decision Risk Analysis (DRA) to help optimise development plan.