Modeling Challenges and Geological Uncertainty Quantification in a Pre-Salt Discovery, Brazil*

Rodrigo Zanao[1], Tacilaine Saciloto Real[1], Jose Luis Algibez Alonso[1], Pedro Bonillo Martinez[1], and Ricardo Perona Jimenez[1]

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Abstract

The pre-salt in Brazil is a new exploratory play in the South Atlantic Margin. Due to the fact that it is a new exploratory frontier, the quantity of data available is scarce and the associated uncertainty is proportionally inverse to the existing information. The present work is related to a geological 3D model of a recent pre-salt discovery located in Brazil. The uncertainties incorporated into the modeling process were quantified in three different steps: structural model, facies model and petrophysical model.

The objective of the Structural Model was to understand the uncertainty associated to Gross Rock Volume (GRV). Three scenarios were used considering different seismic interpretations and horizon picking for the three reservoir intervals. Structural model building involves challenges, as faults with high angles can generate deformed cells which cause problems in the flow simulation so distinct approaches were tried to minimize the problem. Three different facies model scenarios, FS1, FS2 and FS3, were created, varying the input data (reservoir probability cube and seismic facies maps) and assumptions. The porosity model used as input the statistical data delivered from the petrophysical interpretation and the Sequential Gaussian Simulation (SGS) to populate the model. For the saturation model, two scenarios were built: (Sw1) Archie derived, and (Sw2) Sw defined with NMR log. The permeability model was created using two different approaches: (K1) using Flow Units, and (K2) using SGS to populate KSDR permeability log of the well constrained by porosity.

As a result of the uncertainty related to the structural model, the GRV in the optimistic case is around 100% larger than the pessimistic case. For fault representation, the use of the stair-stepped method minimizes the number of deformed cells compared to the pillar fault representation. The facies model results allow ranking the most pessimistic (FS2) and the most optimistic (FS3) scenarios. Related to the Sw model, the Sw1 scenario shows more optimistic results than the Sw2. As a result of the analyses of permeability models, the K1 scenario shows lower values of permeability compared to the K2 scenario.

It was possible to quantify that the variation of the hydrocarbon-in-place between the most pessimistic and the most optimistic scenario is around 320%. Structural model uncertainty has the greatest impact in the volumetric results at this early stage of discovery.

AAPG ICE 2013

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Agenda

- Modeling Challenges
- Uncertainty Management
- Structural Uncertainty and Associated Challenge
- Facies Uncertainty
- Porosity Model
- Water Saturation Uncertainty
- Permeability Uncertainty
- Results
- Final Considerations

Modeling Challenges

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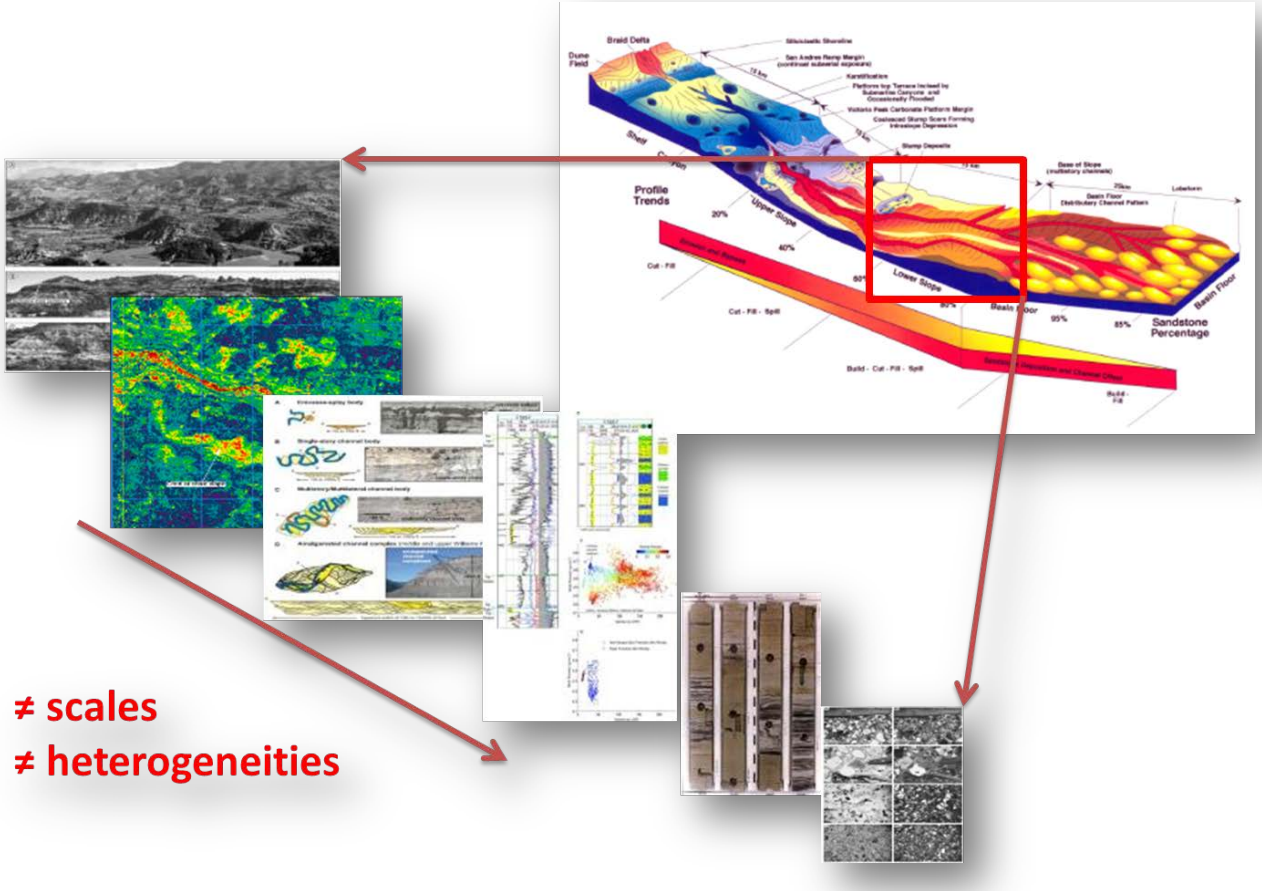
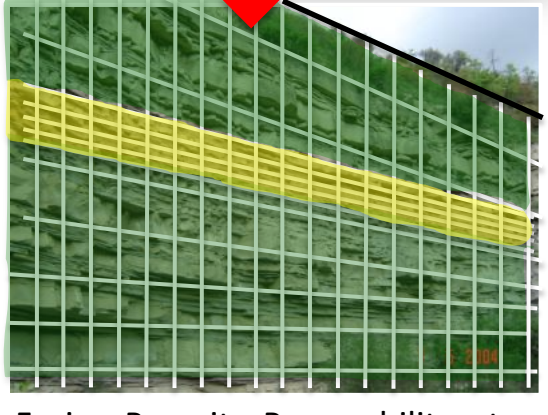


≠ scales
≠ heterogeneities

The Goal



Facies, Porosity, Permeability, etc.

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Uncertainty Management

Uncertainties are present during all the process!!

Reservoir Thickness?

Fluid contacts?

Time to Depth Conversion?

Seismic Data?

Compartimentation ?

Fault Transmissibility?

Seismic Interpretation?

Fractures ?

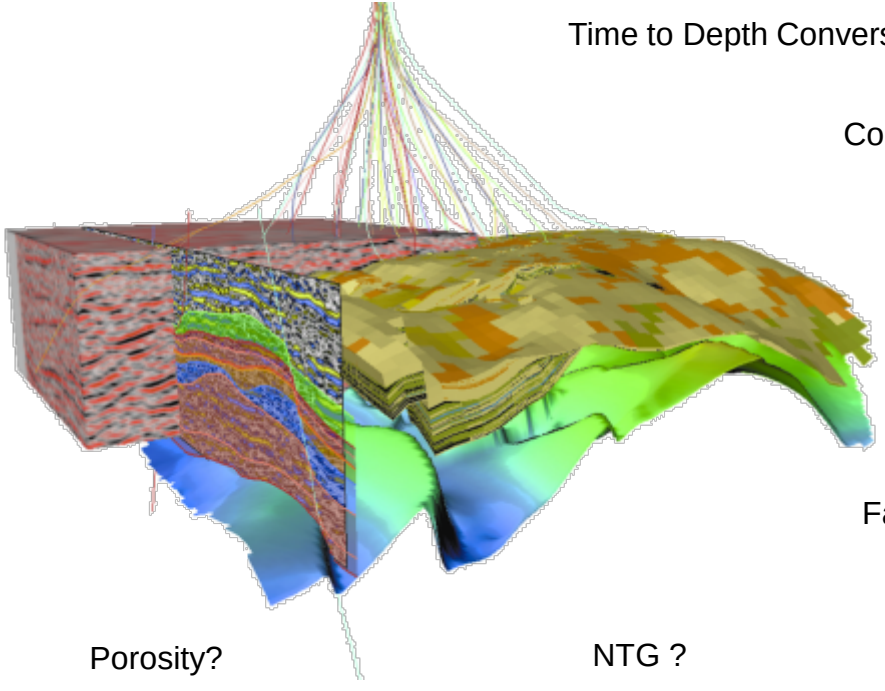
Water Saturation?

Permeability?

Facies Model?

Porosity?

NTG ?



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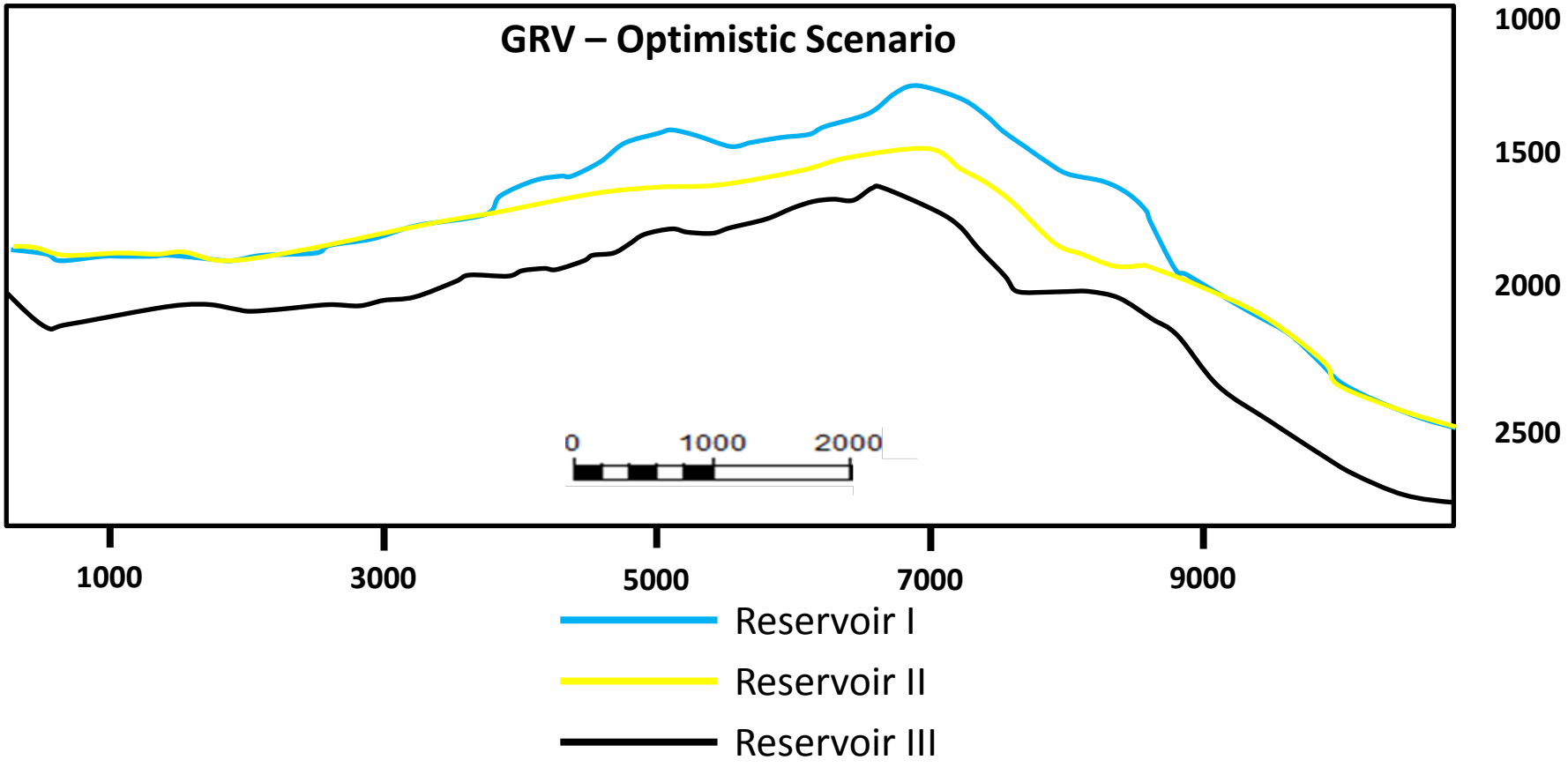
Structural Uncertainty and Associated Challenge

- Three scenarios considering different seismic interpretations and horizons picking for the Reservoir I, Reservoir II and Reservoir III horizons.

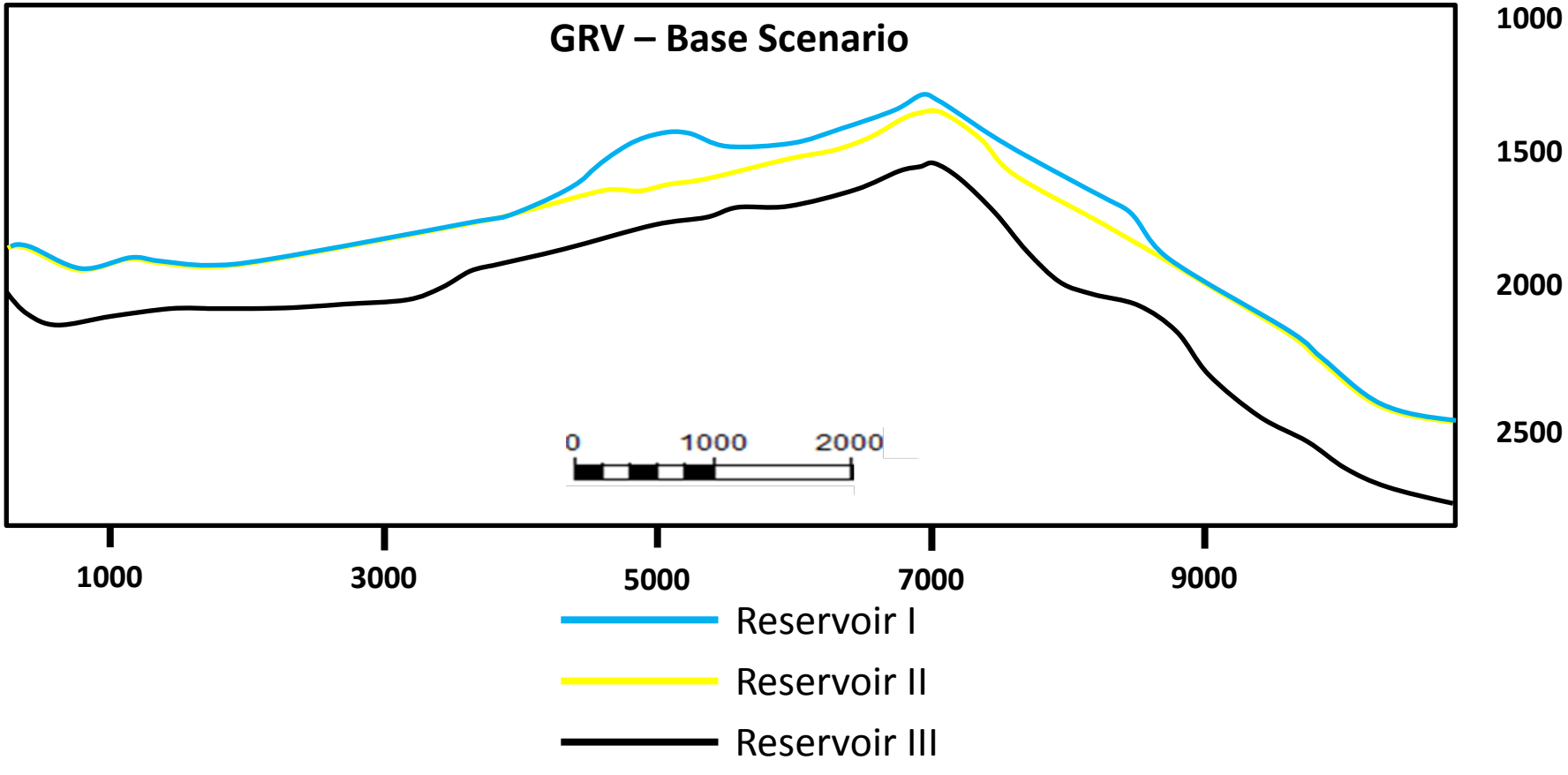
- The objective is handle with the associated uncertainty on GRV regarding the interpretation and seismic velocities field. The scenarios ranked on GRV are:

    - **Pessimistic Case**
    - **Base Case**
    - **Optimistic Case**

Structural Uncertainty and Associated Challenge



Structural Uncertainty and Associated Challenge



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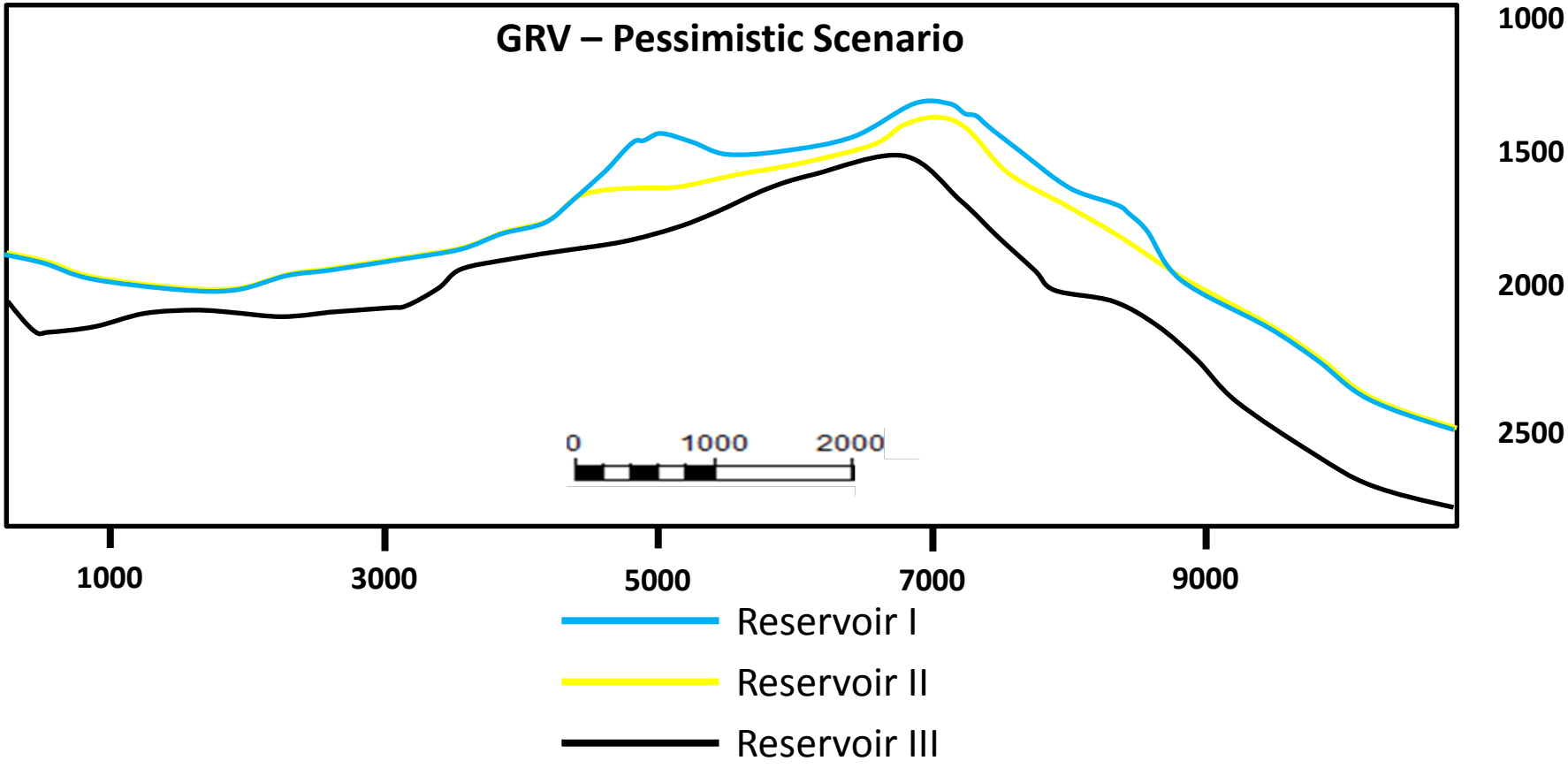
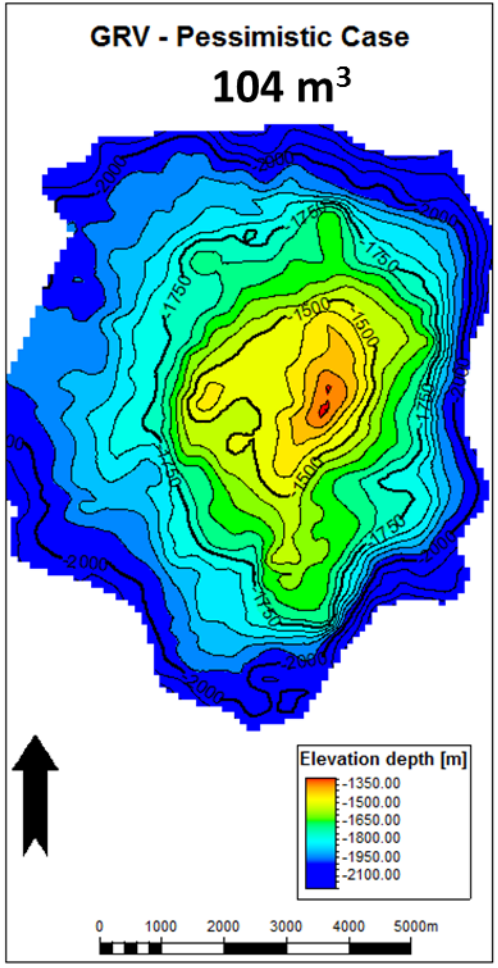
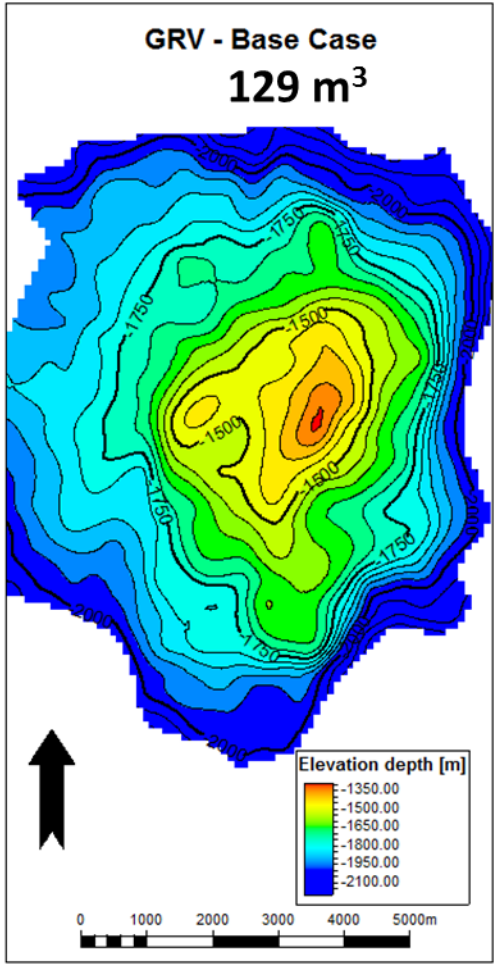
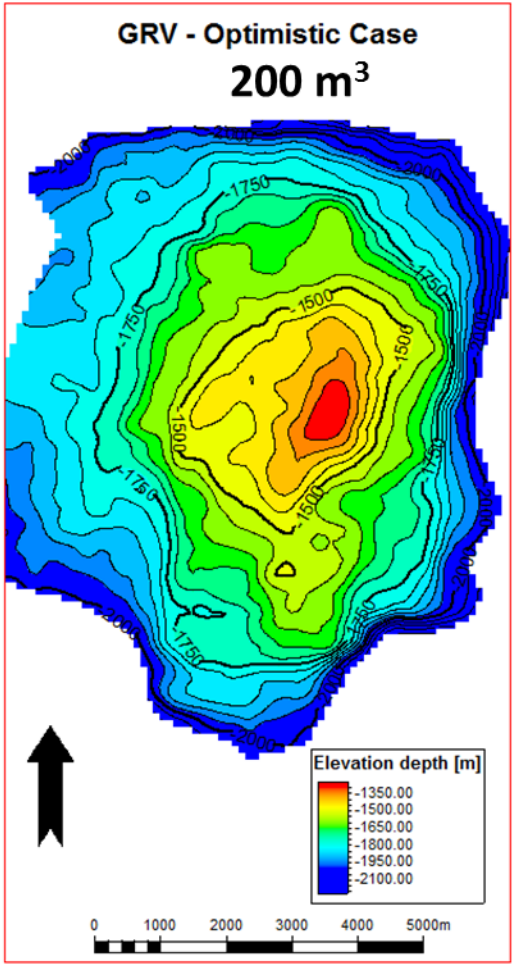


Structural Uncertainty and Associated Challenge







*Volumes normalized to 200m^3

Structural Uncertainty and Associated Challenge

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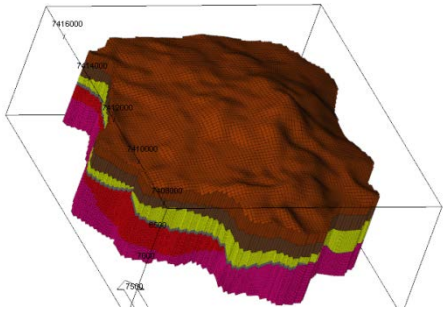
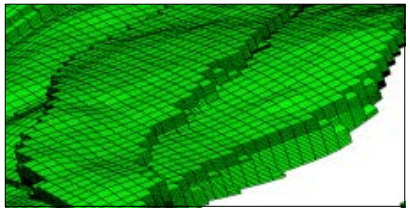
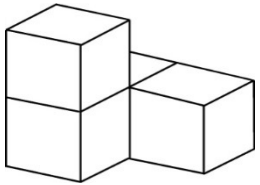
The Ideal

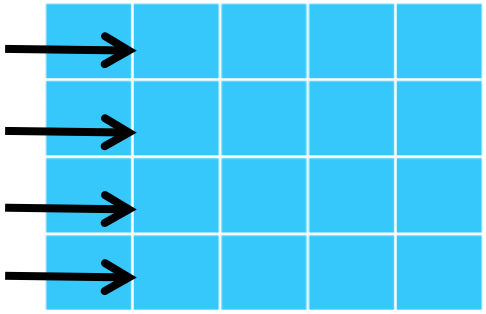
The Problem

The Reality…

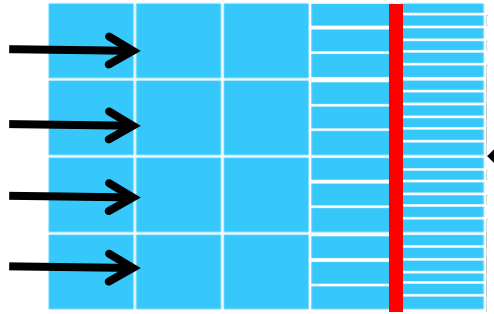


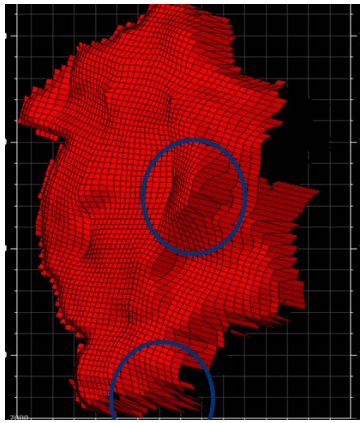


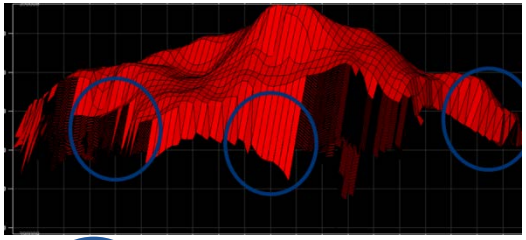




Fluid Flow





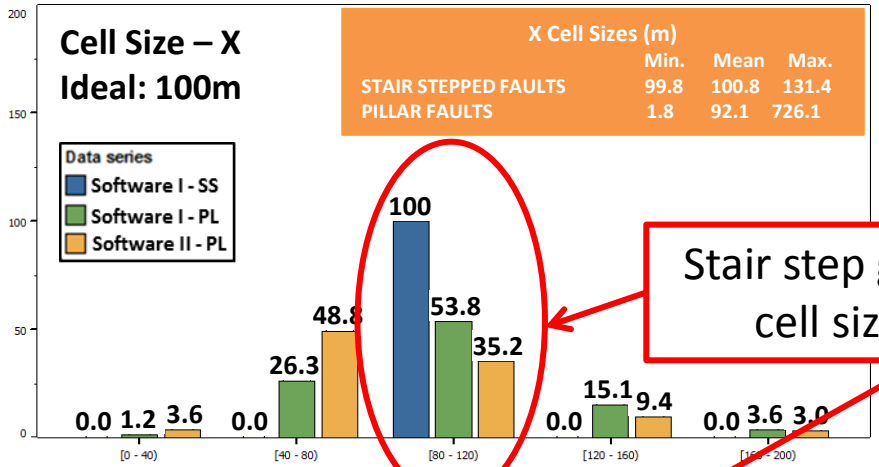


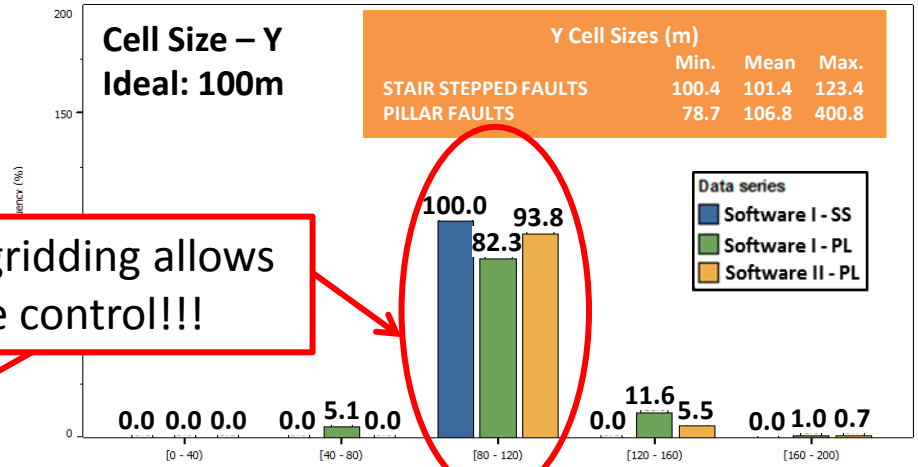
Grid Problems

Structural Uncertainty and Associated Challenge

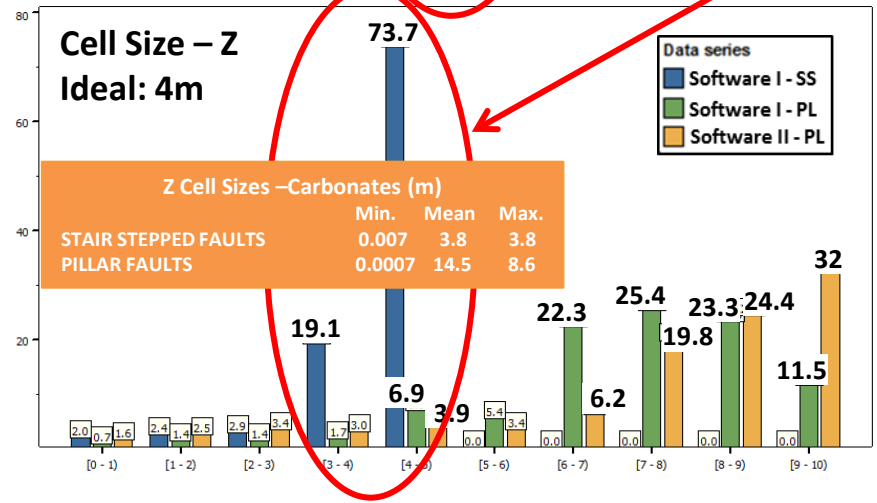
Angry Engineer!!!

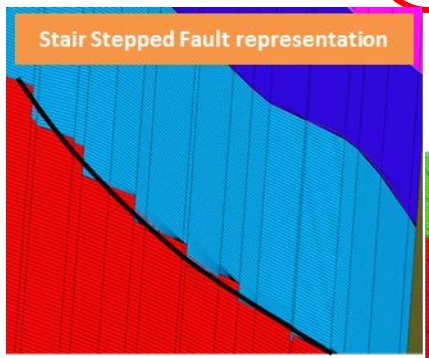
Structural Uncertainty and Associated Challenge

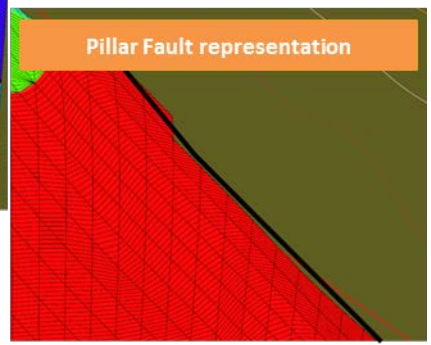




Stair step gridding allows cell size control!!!







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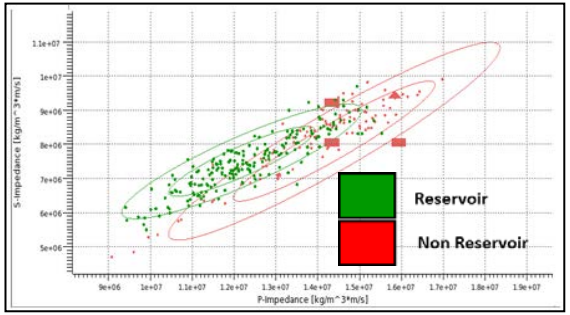
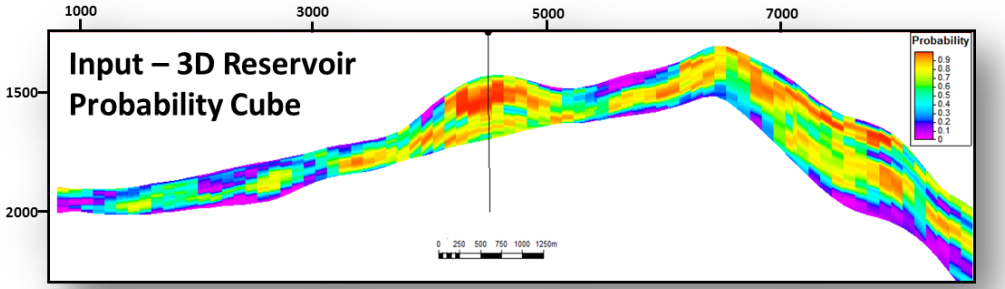
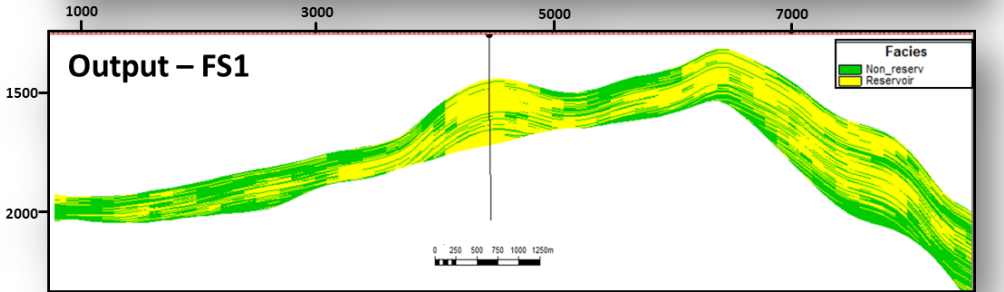
Facies Uncertainty – Facies Scenario 1 (FS1)

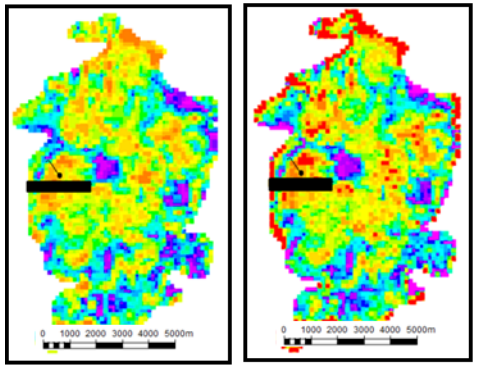
- Electrofacies: Reservoir (FR) or non reservoir (NR);
- 3D Reservoir Probability Cube from Elastic Inversion



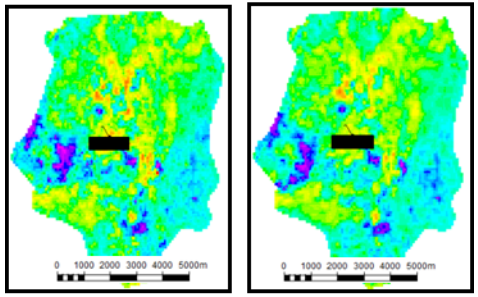




QC Corner



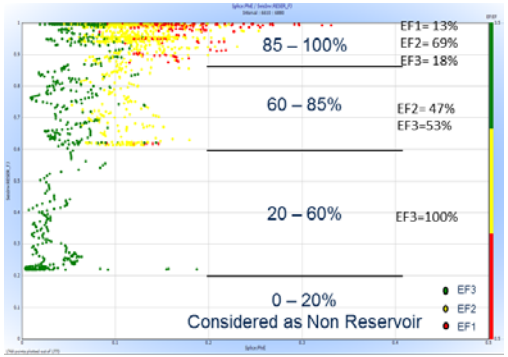
Average Probability Maps for Reservoir I: Input (left) and output (right)



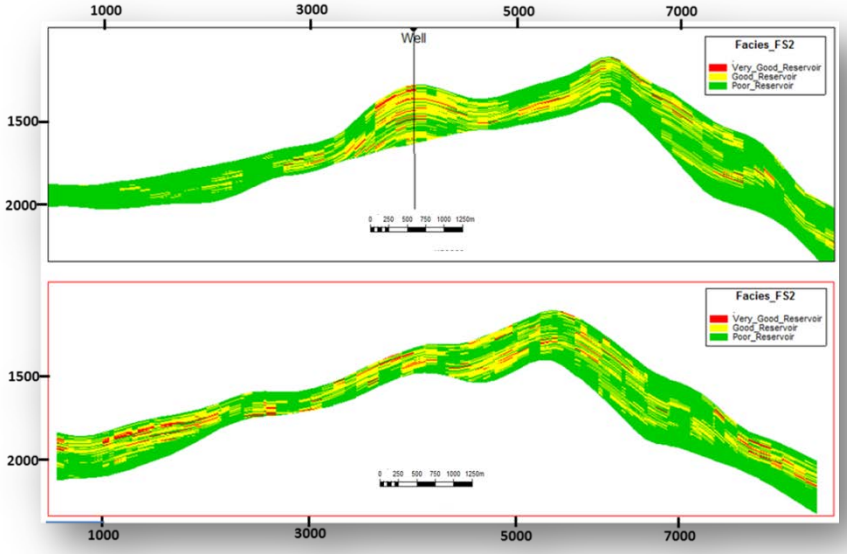
Average Probability Maps for Reservoir II: Input (left) and output (right)

Facies Uncertainty – Facies Scenario 2 (FS2)

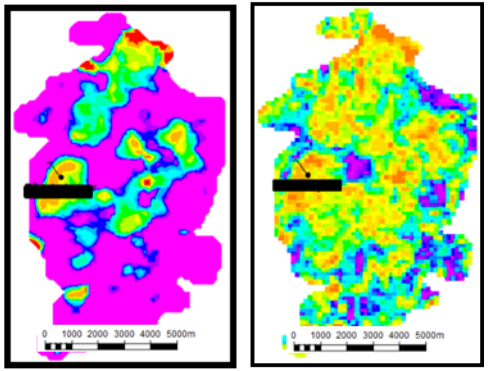
- Based on the concept that reservoir probability cube relates rock quality.
- The relationship is showed on the crossplot of Effective Porosity vs. Reservoir Probability;
- Three different electrofacies;
- The relationship between Electrofacies and Reservoir Probability is used to create a 3D proportion of EF 1, EF 2 and EF 3, that was used as an input in the facies distribution.



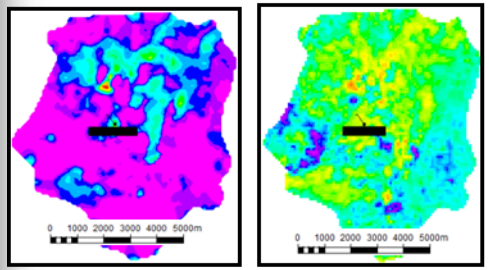
Effective Porosity x Reservoir Probability form Elastic Inversion



QC Corner

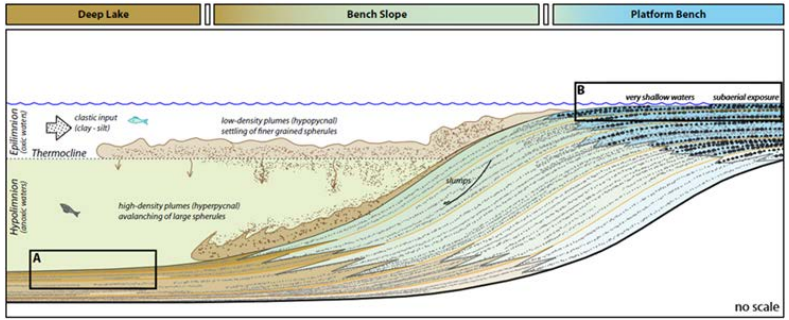


Average Probability Maps for Reservoir I: Input (left) and output (right)

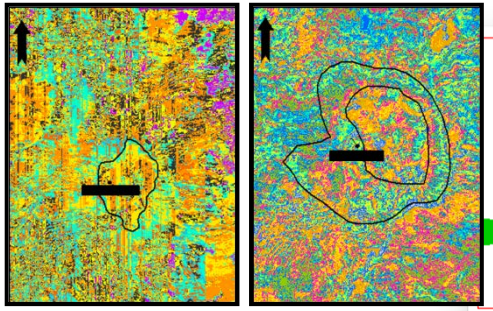


Average Probability Maps for Reservoir II: Input (left) and output (right)

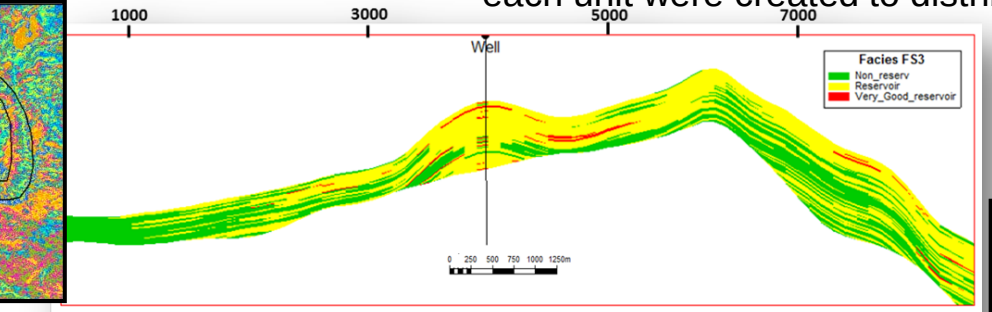
Facies Uncertainty – Facies Scenario 3 (FS3)

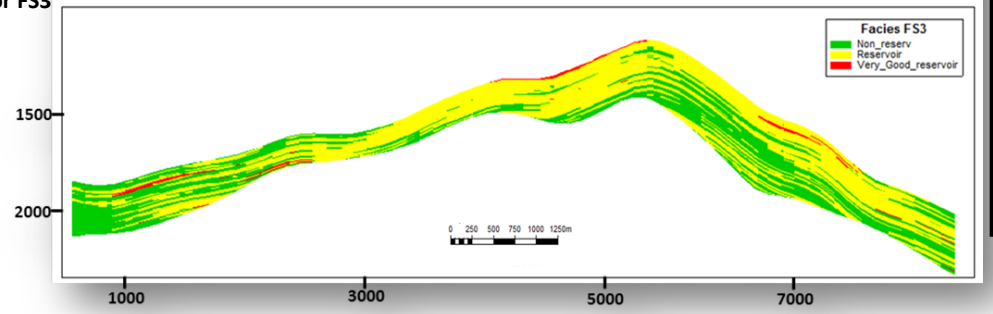


- Using seismic facies maps and the geological concept to create different areas,
- The polygons show the clinoforms limits of each depositional zone,
- Using these polygons different proportion facies maps for each unit were created to distribute each electrofacies.



Seismic Facies Maps used as input for FS3





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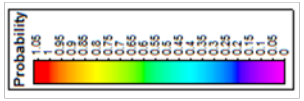

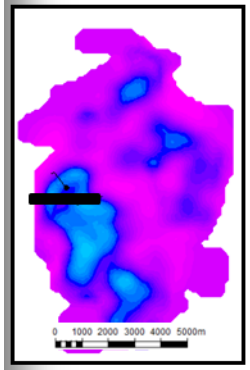

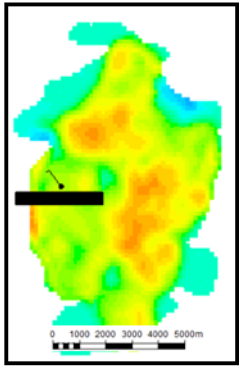

Average Probability Maps for Reservoir II: Output for Facies I (left) and Facies II (right)

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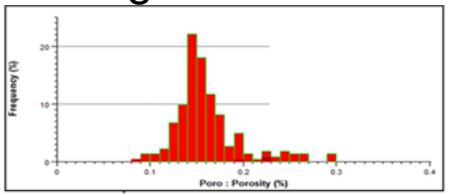
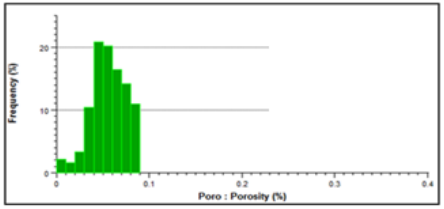
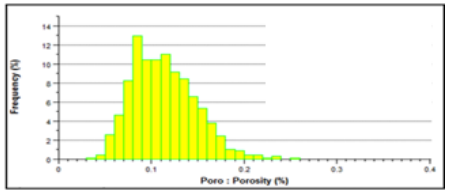
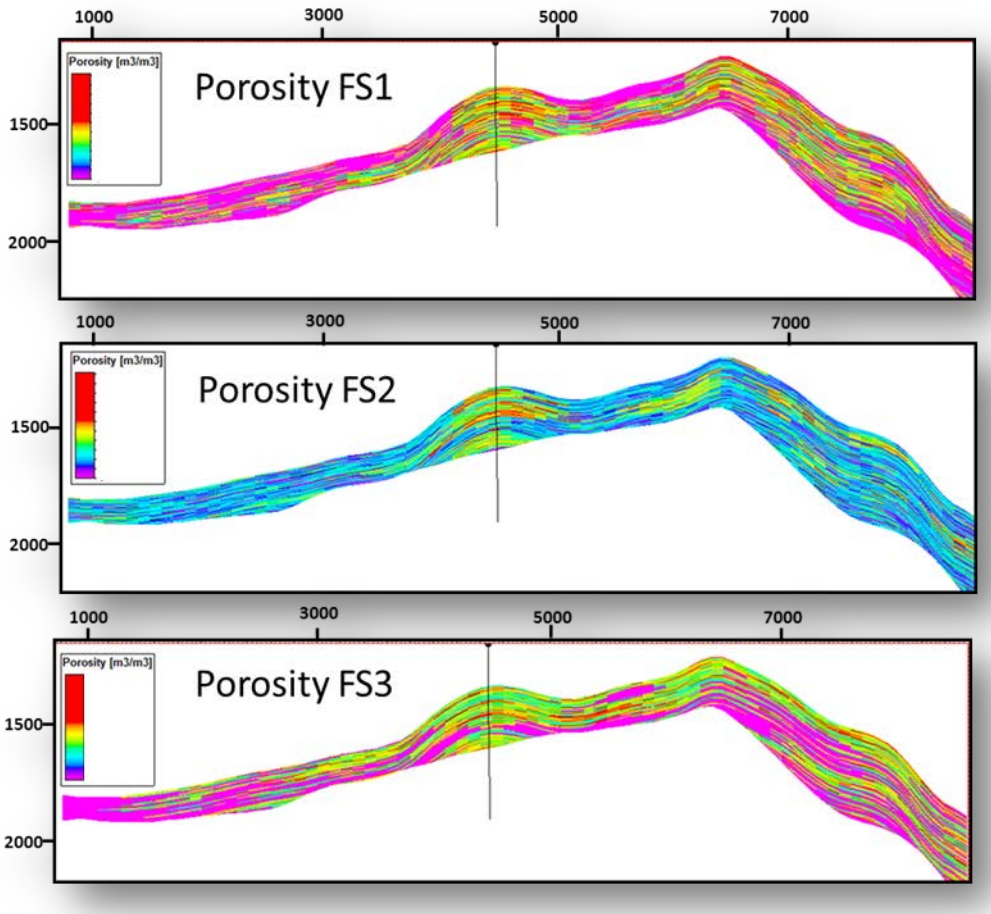
Porosity Model

- The Porosity Model was performed with Sequential Gaussian Simulation (SGS) algorithm using min, max and average from well data.









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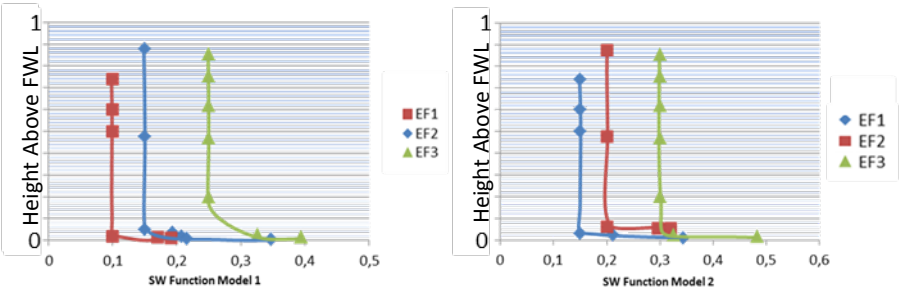
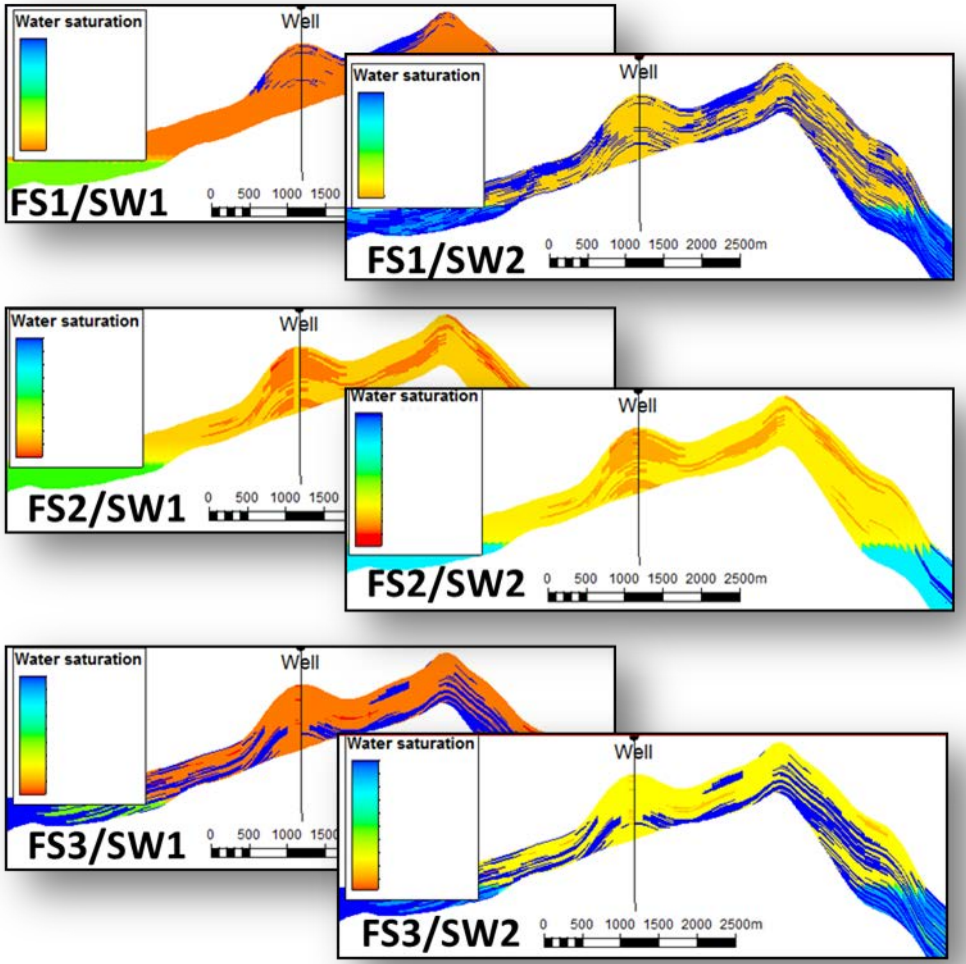
Water Saturation Uncertainty

- **Sw 1:** Archie derived Sw versus Height Above FWL defined for each electrofacies. Swi were defined using the side wall core SCAL data.
- **Sw 2:** Sw versus Height Above FWL defined for each electrofacies. In this model the Swi was defined with NMR, using the T2 cutoff for Free Fluid defined in laboratory.





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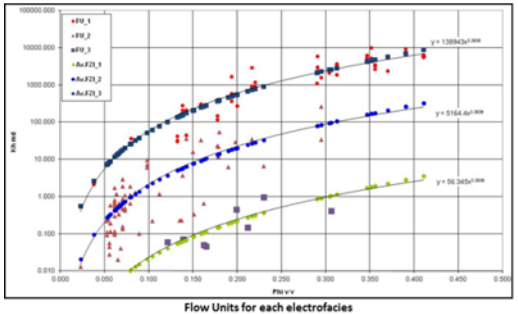
Permeability Uncertainty

- Flow_Unit: using a poro-perm function for each electrofacies.
- KSDR: using SGS to populate KSDR permeability log of the well constrained by porosity.

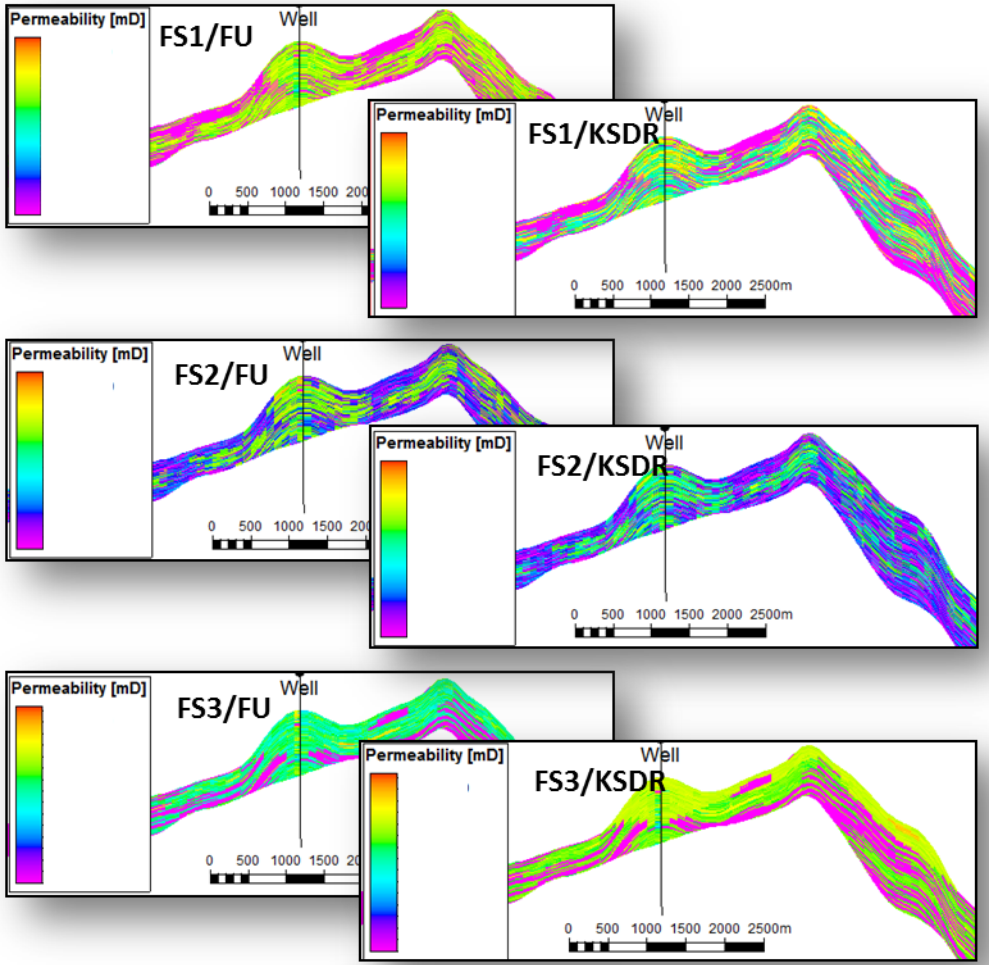


Flow Units for each electrofacies

*Values normalized to 4000 units

Zone	EFAC	Min	Mean	Max
A	EF1	230	230	4000
	EF2	0.33	22	544
	EF3	0	0.85	7.55
B	EF1	5	570	141
	EF2	0.08	17.6	215
	EF3	0	1.12	15

KSDR Permeability Statistics for Flow Units for each electrofacies



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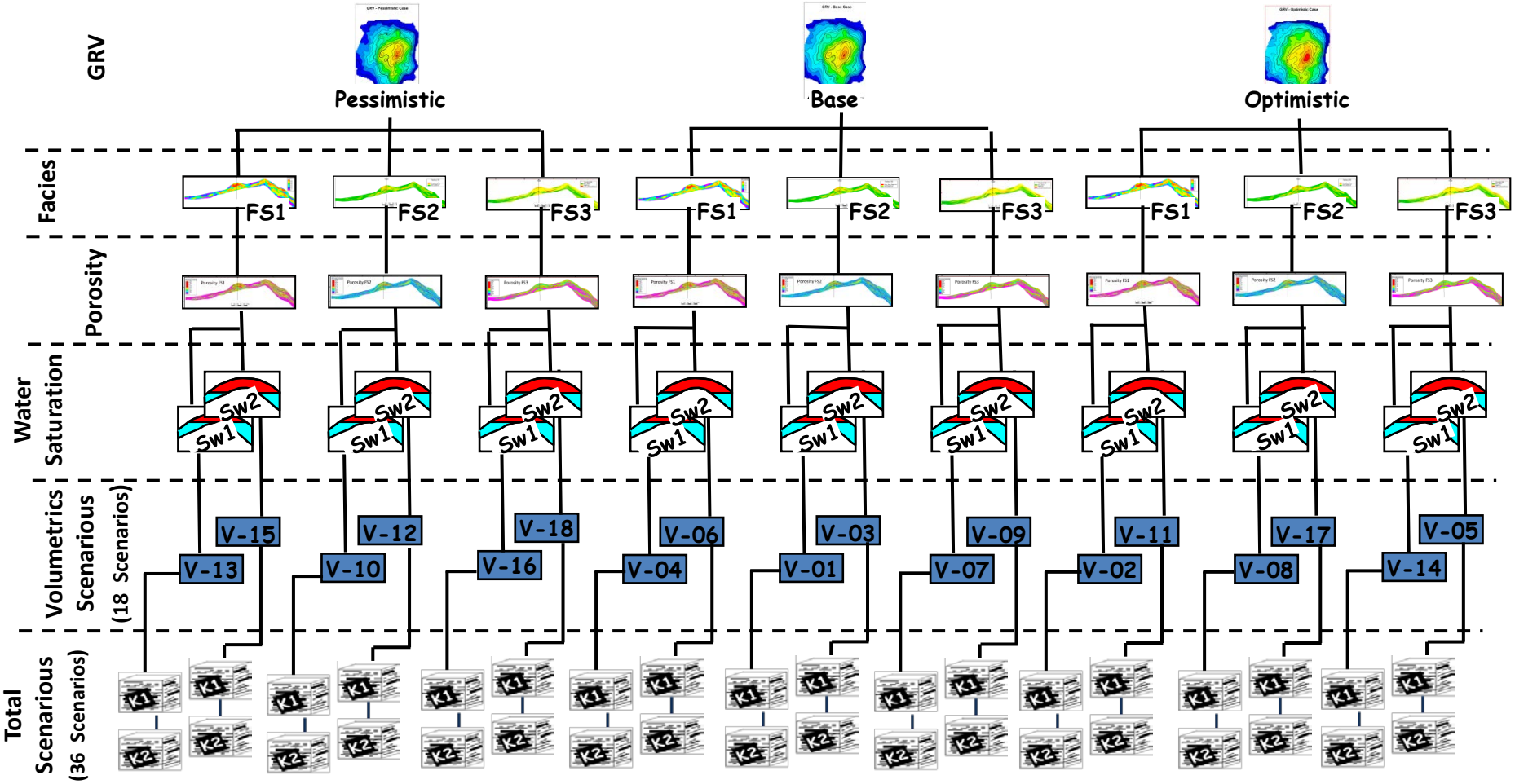
Results


GRV
Pessimistic
Base
Optimistic
Facies
FS1
FS2
FS3
Porosity
Water Saturation
Sw2
Sw1
Volumetrics Scenarious (18 Scenarios)
V-15
V-13
V-12
V-10
V-18
V-16
V-06
V-04
V-03
V-01
V-09
V-07
V-11
V-02
V-17
V-08
V-05
V-14
Total Scenarious (36 Scenarios)
K1
K2

Agenda

- Modeling Challenges
- Uncertainty Management
- Structural Uncertainty and Associated Challenge
- Facies Uncertainty
- Porosity Model
- Water Saturation Uncertainty
- Permeability Uncertainty
- Results
- Final Considerations

Final Considerations

- As result of the uncertainty related to the structural model, the GRV in the optimistic case is around 100% larger than the pessimistic case.
- The facies model results allow ranking the most pessimistic (FS2) and the most optimistic (FS3) scenarios.
- Related to the S_w model, the S_w1 scenario shows the most optimistic results than the S_w2.
- As result of the analyses of permeability models, the K1 scenario shows lower values of permeability compared to the K2 scenario.
- It was possible to quantify that the variation of the hydrocarbon-in-place between the most pessimistic and the most optimistic scenario is around 320%.
- Structural model uncertainty has the greatest impact in the volumetric results at this early stage of a discovery.