

^{AV} Revisiting Judy Creek: Uncovering 100 Million Barrels of In-Place Oil*

By

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Abstract

Judy Creek Beaverhill Lake ‘A’ Pool is a Devonian reef complex. The pool is one of the largest reservoirs in the giant Swan Hills oil field in northwestern Alberta. A previous reservoir study was conducted more than a decade ago. The recent infill drilling for EOR and by-passed pay required revisiting the field for a new integrated study, incorporating 40 new wells. A more accurate in-place oil estimate using a thorough reservoir modeling approach helped uncover more than 100 million barrels of previously unrecognized oil in this carbonate complex.

A workflow based on 3D reservoir modeling was developed for an integrated reservoir characterization study. Based on detailed petrophysical analysis, it was found that the previous models significantly underestimated reservoir pore volume because of a serious bias in changing scales of well-log porosity with a skewed distribution. The new workflow allowed the model not only to honor the depositional characteristics of the reef complex, but also to honor the intrinsic statistical distribution of well-log porosity, significantly improving subsurface pore space estimation and its 3D distribution. Furthermore, an uncertainty evaluation of stock tank oil initially in-place (STOIIP), based on rigorous geologic and petrophysical analyses, was implemented to provide a probability distribution of STOIIP estimates.

The new STOIIP estimate, with additional 100 million barrels, has significant implications on field development planning to target unswept oil in the reservoir.

Revisiting Judy Creek

Uncovering 100 Million Barrels of In-place Oil

Y. Zee Ma, Schlumberger-DCS

Andrew Seto, Pengrowth Corp.

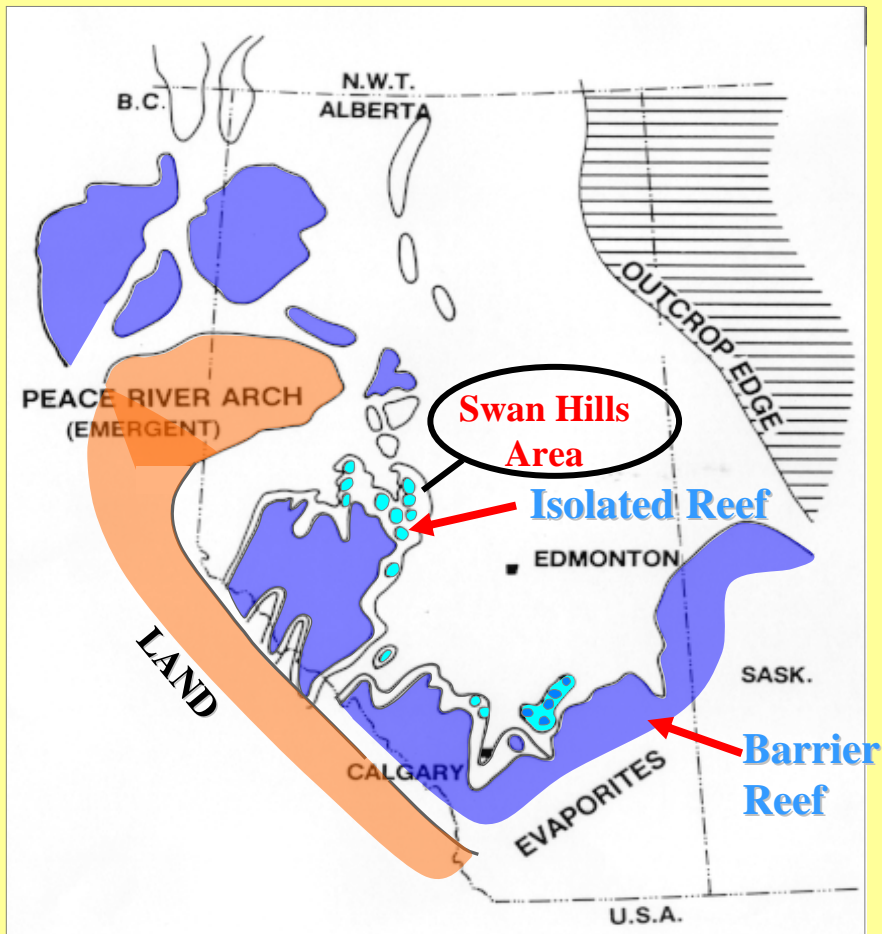
Dan Edwards, Krishelle Enterprises Ltd

Ernest Gomez, Schlumberger-DCS



Outline: Integrated Modeling Workflow

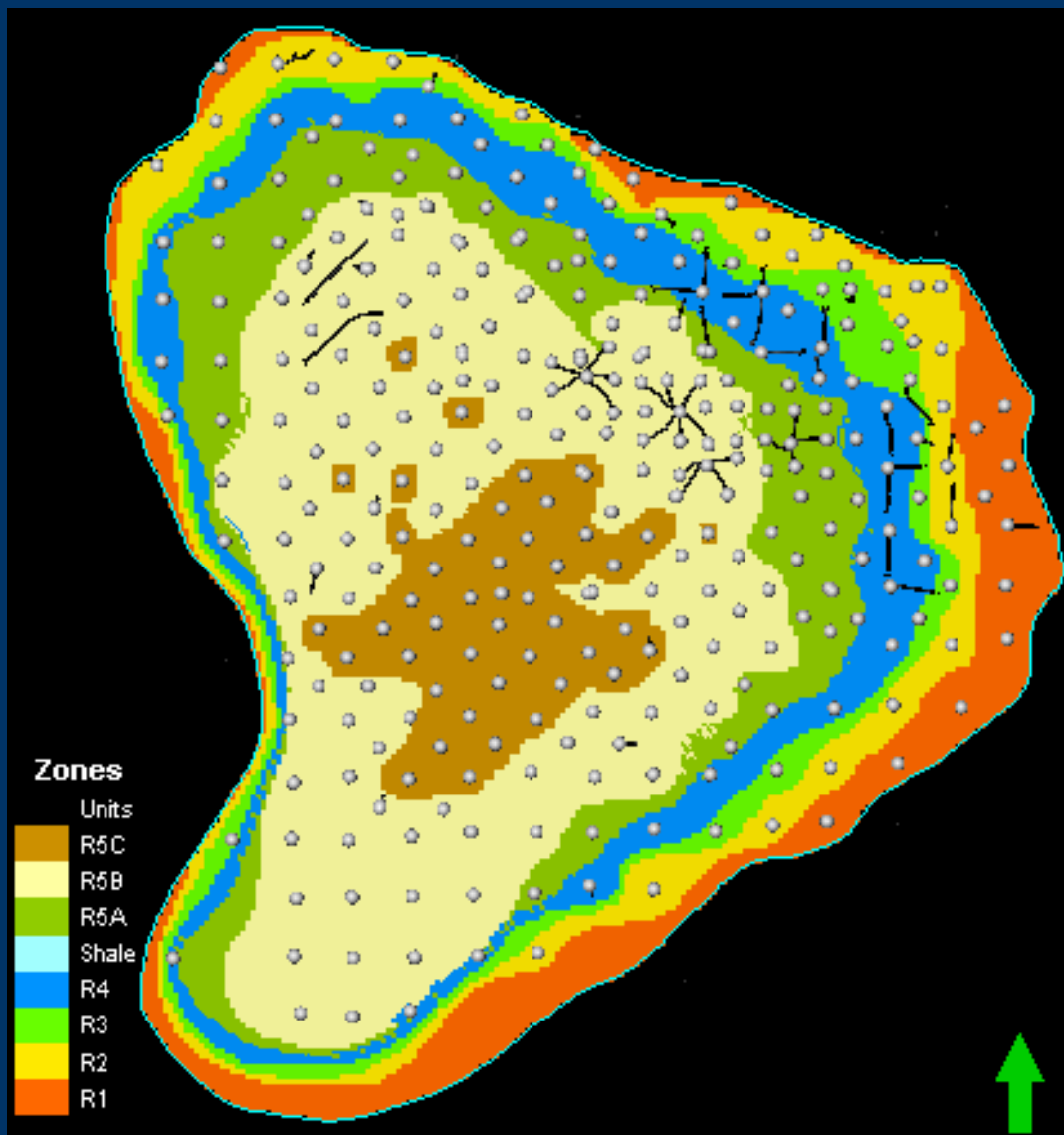
Devonian Swan Hills Formation



- Judy Creek 'A' is part of Swan Hills Oilfield.
- In-place oil estimate & uncertainty evaluation
- Infill drilling and EOR



Back-Stepping Reef Buildup: Oil-bearing



1994, 755 MMbbl STOIP, Previous Op

2005, 776 MMbbl STOIP, Pengrowth

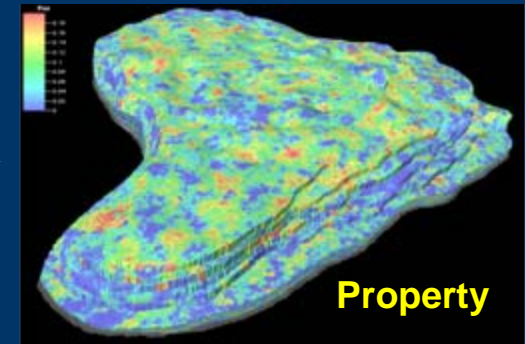
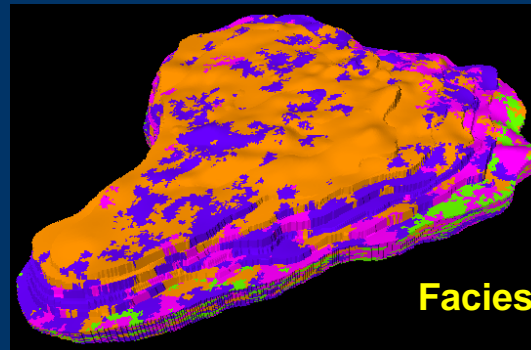
- Modeled porosity using SGS.

2007, 885 MMbbl STOIP, SLB-PGH

- Modeled facies honoring depositional characteristics,
- Modeled porosity honoring facies & intrinsic statistics using SGS.
- Uncertainty evaluation.

Hierarchical Modeling Workflow

- Hierarchical modeling of multiscales of heterogeneities

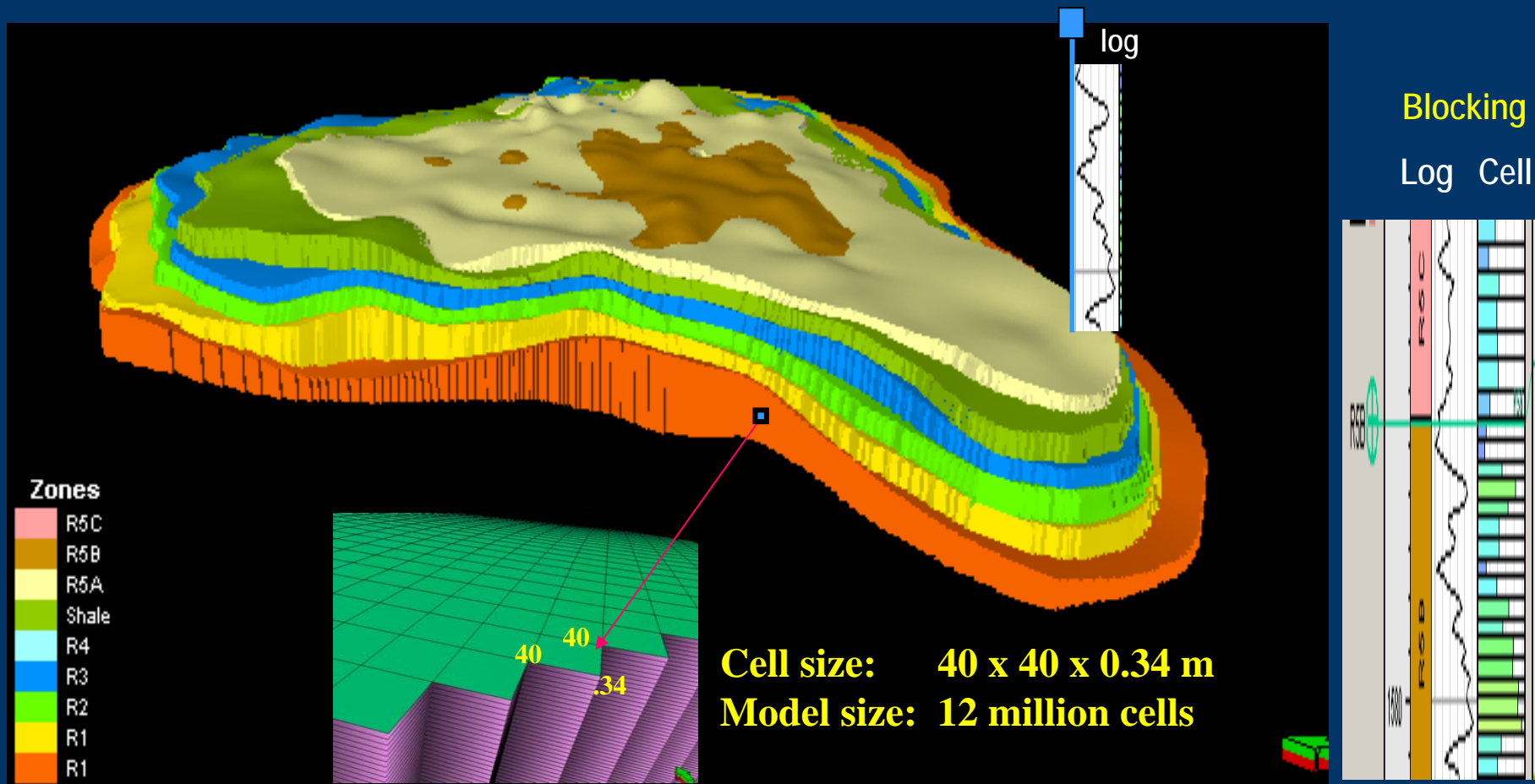


- Sequence stratigraphic interpretations were used to build the stratigraphic model.
- Facies were distributed in the 3D model using SIS honoring the core, log facies data, and the depositional characteristics.
- Petrophysical properties are distributed using geostatistics, honoring the well-log data and facies model.

• 3D Model-based HCPV:

$$\text{OOIP} = \sum_{i=1}^N V_i * \text{NTG}_i * \Phi_i * (1 - S_{w_i})$$

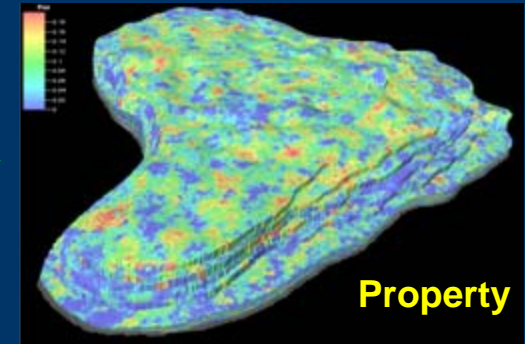
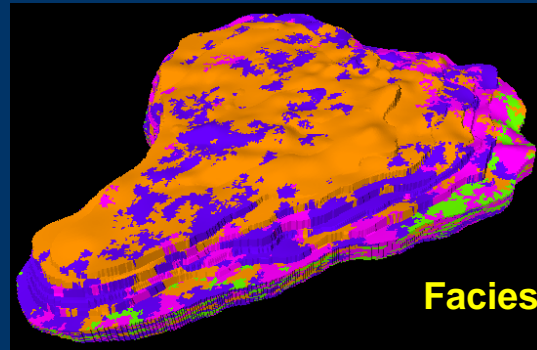
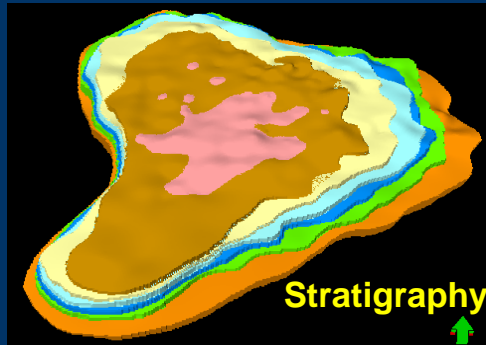
Stratigraphic Model



- Honoring the back-stepping geometry.

Facies Modeling

- Hierarchical modeling of multiple scales of heterogeneities



- Sequence stratigraphic interpretations were used to build the stratigraphic model.

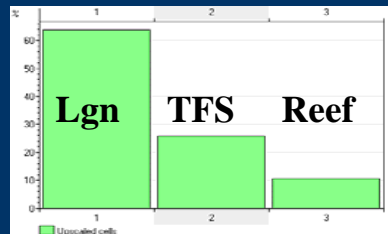
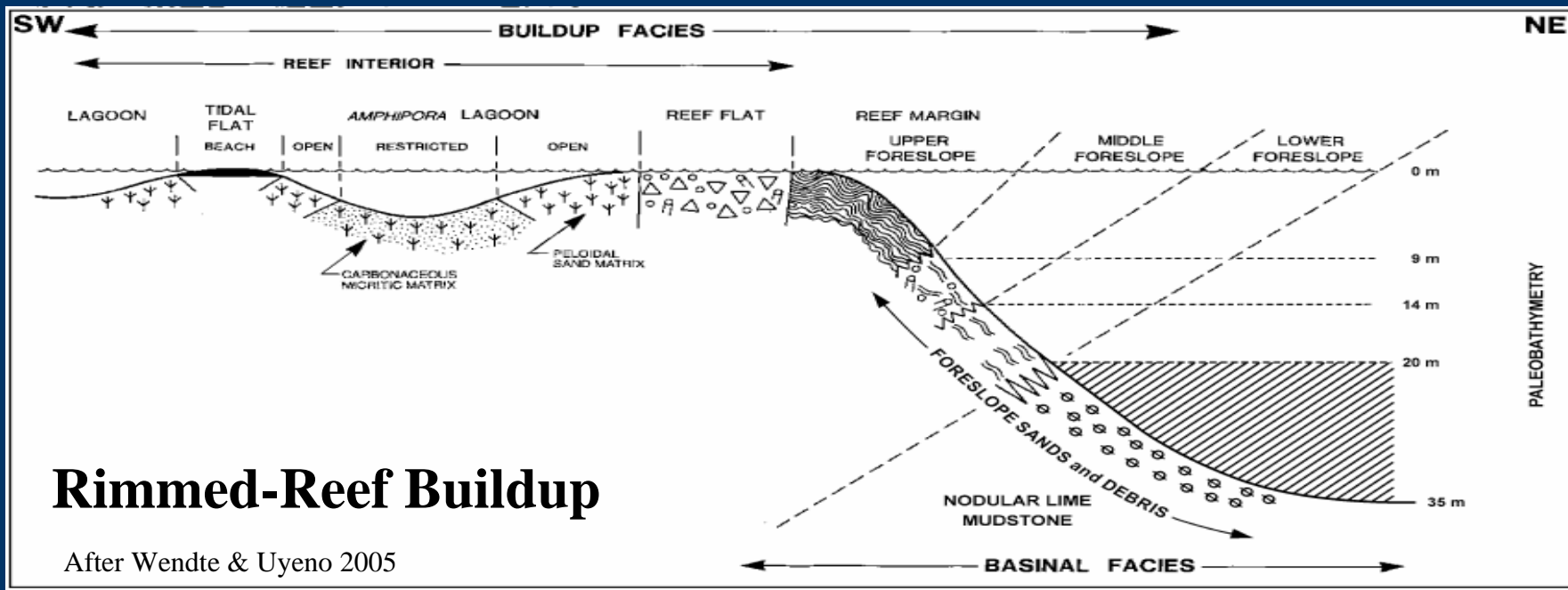
- Facies were distributed in the 3D model using SIS honoring the facies data at wells and the depositional characteristics.

- Petrophysical properties are distributed using geostatistics, honoring the well-log data and lithofacies model.

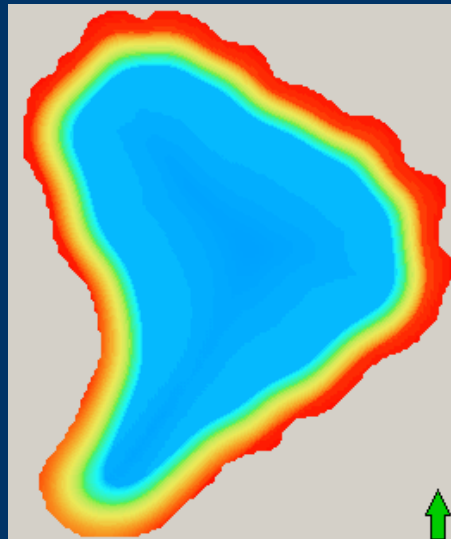
- 3D Model-based HCPV:**

$$\text{OOIP} = \sum_{i=1}^N V_i * \text{NTG}_i * \Phi_i * (1 - S_{w_i})$$

Depositional Facies Analysis



Facies Frequencies
In R4 after grouping

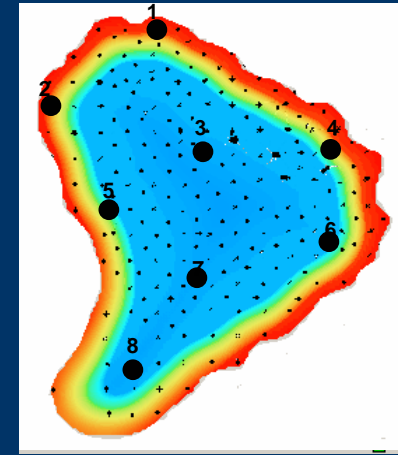
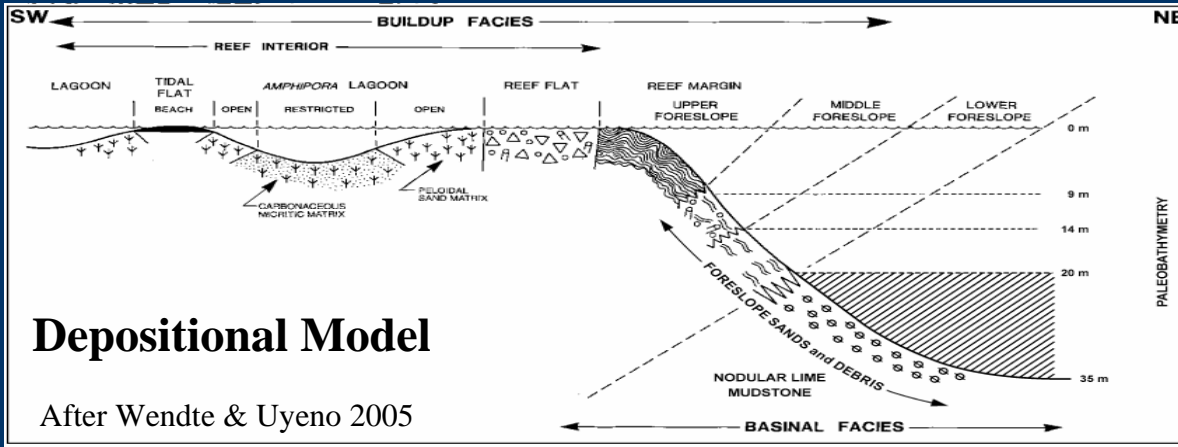


Facies Spatial Propensity

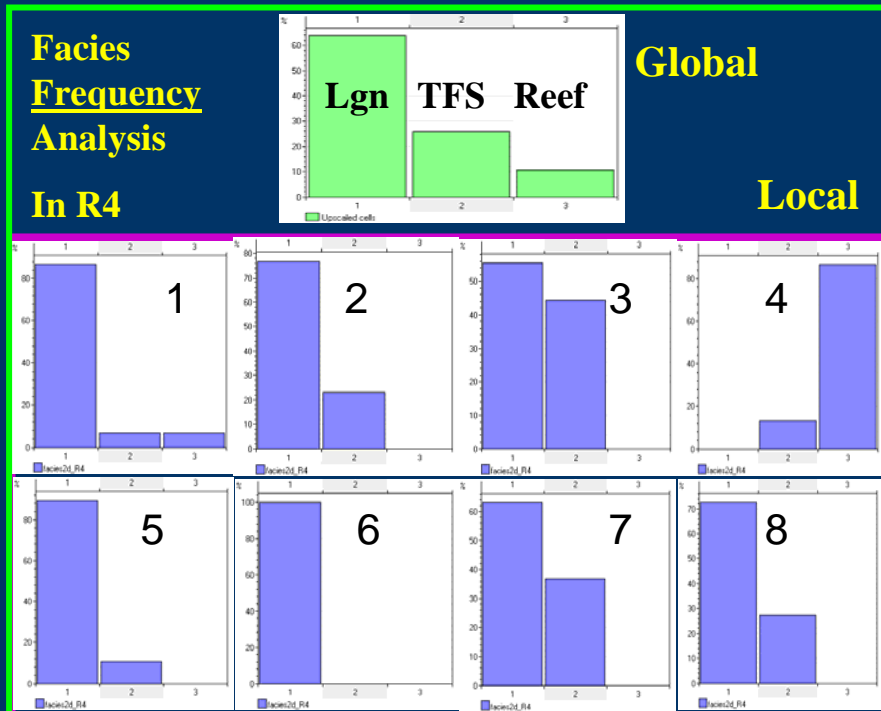
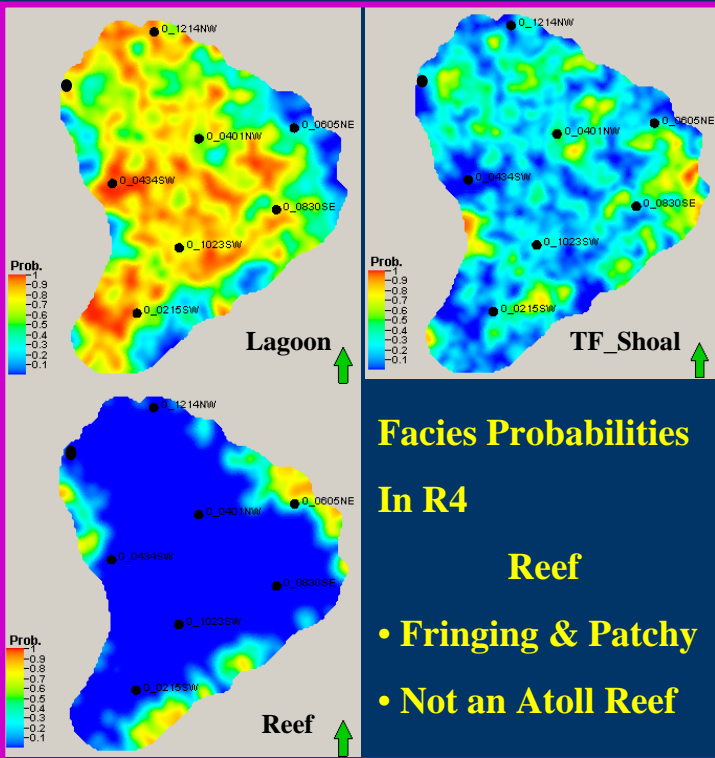
• Is the reef an Atoll?

Depositional Facies: Spatialist meets Frequentist

Judy Creek

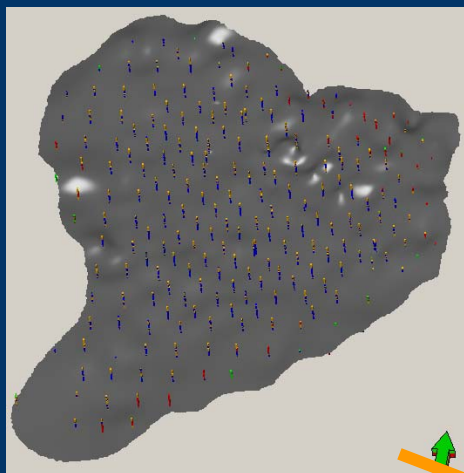


Facies Spatial Propensity: Atoll?

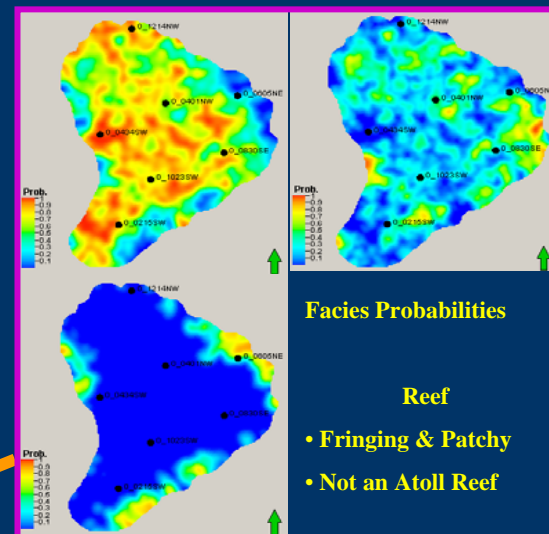


3D Facies Modeling

Judy Creek



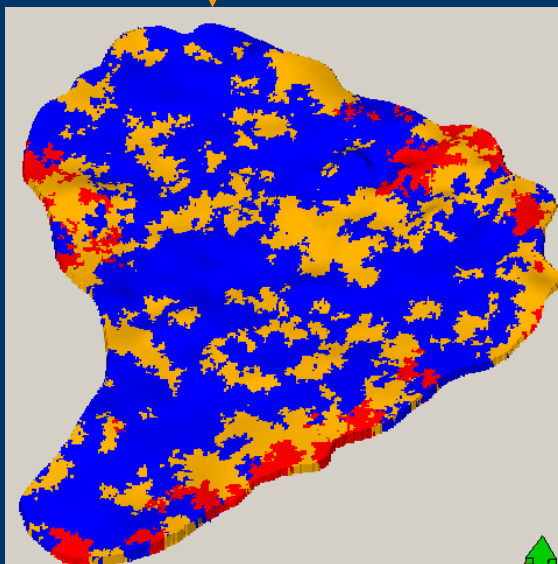
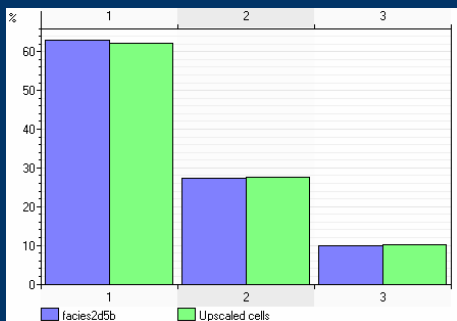
Well-log facies



Sequential Indicator Simulation

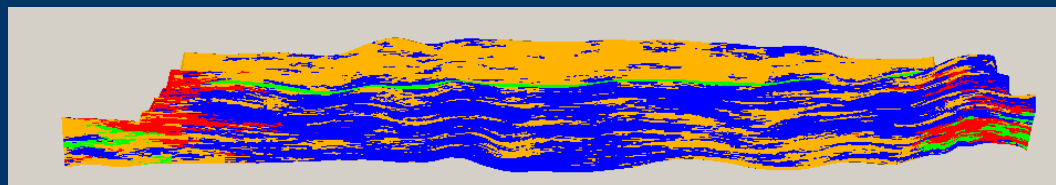
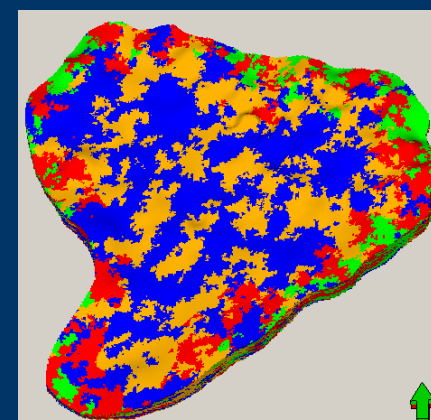
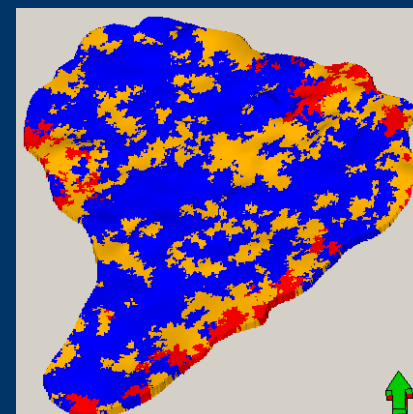
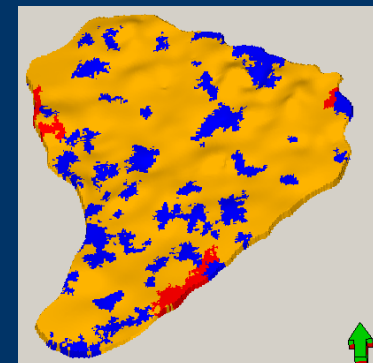
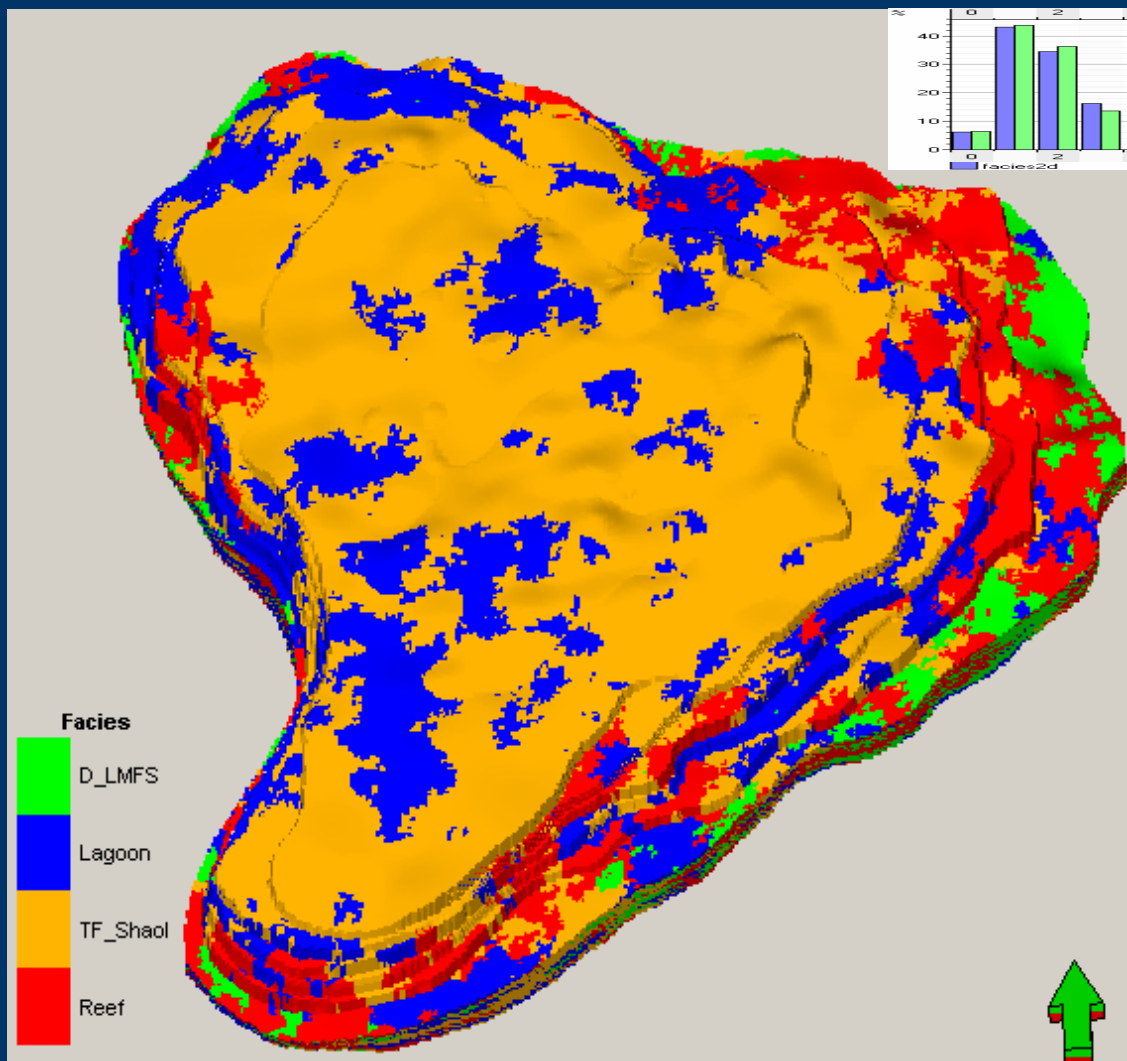
Facies Frequencies Comparison

Green: Sample
Blue: Model



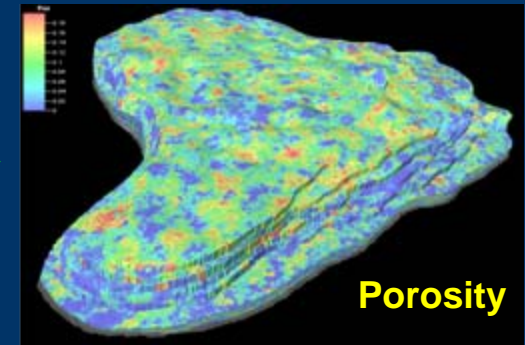
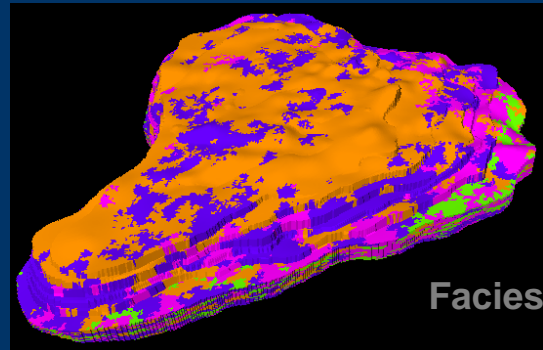
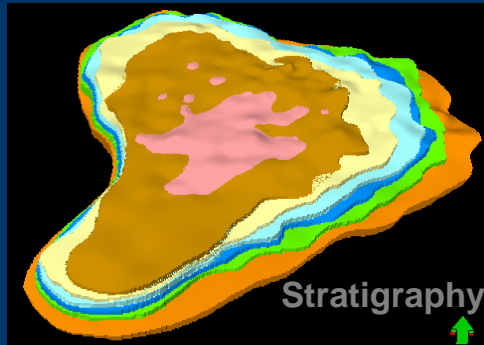
Facies Model
R4 Unit

Facies Model - Highlights



Modeling Workflow - Porosity

- Hierarchical modeling of multiple scales of heterogeneities



- Sequence stratigraphic interpretations were used to build the stratigraphic model.

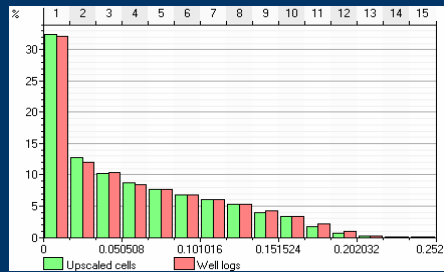
- Facies were distributed in the 3D model based on the lithofacies core & log data, while honoring the depositional characteristics.

- Porosity was distributed in 3D model using geostatistical SGS, honoring the log data and facies model.

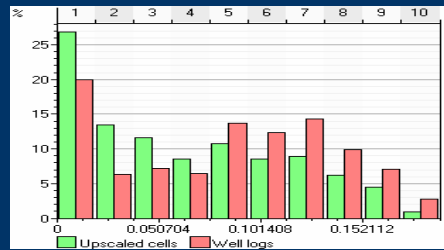
- 3D Model-based HCPV:**

$$\text{OOIP} = \sum_{i=1}^N V_i * \text{NTG}_i * \Phi_i * (1 - S_{w_i})$$

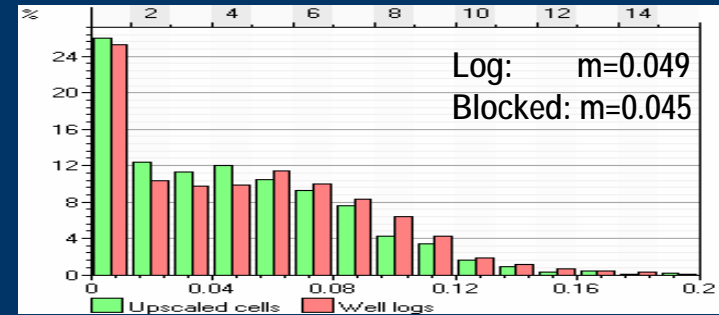
Porosity Dependency on Stratigraphy & Facies



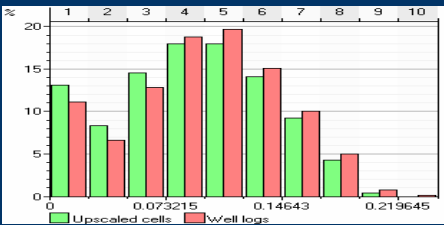
All units



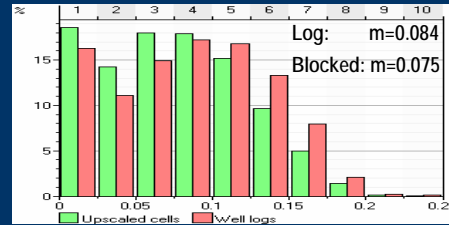
R5C



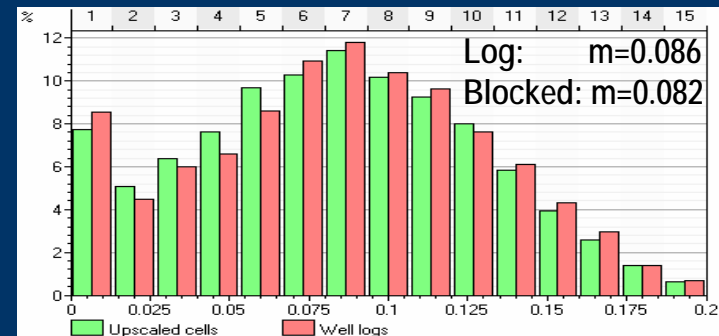
R5A Porosity in Lagoon



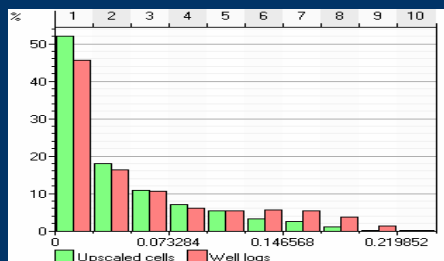
R5B



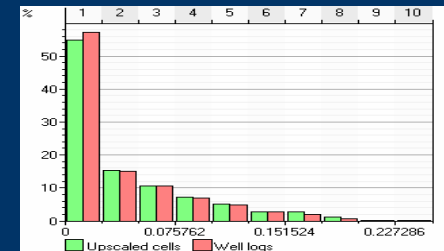
R5A



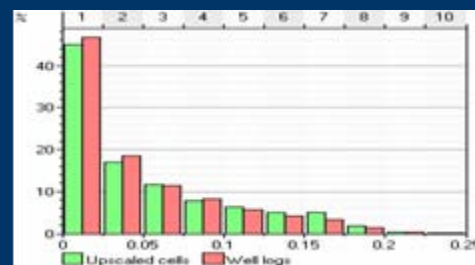
R5A Porosity in TF_Shoal



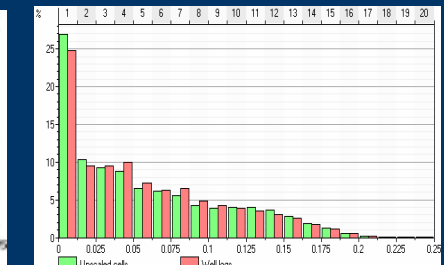
R4



R3

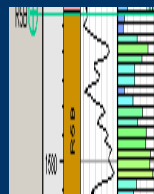


R2

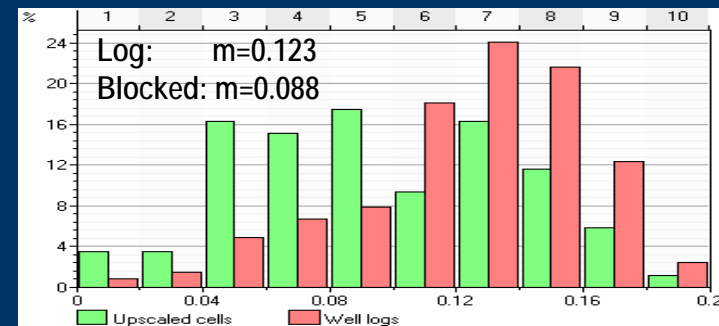


R1

Blocking



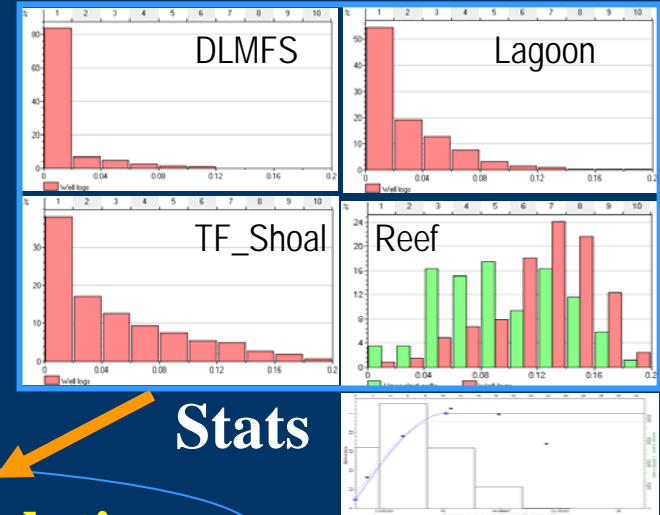
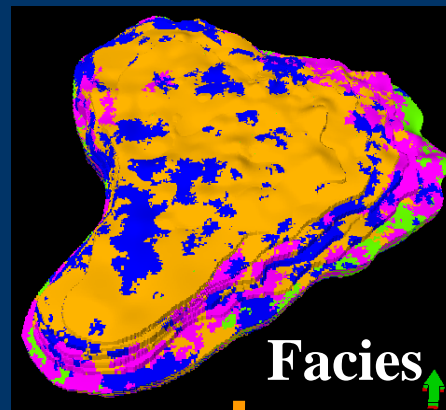
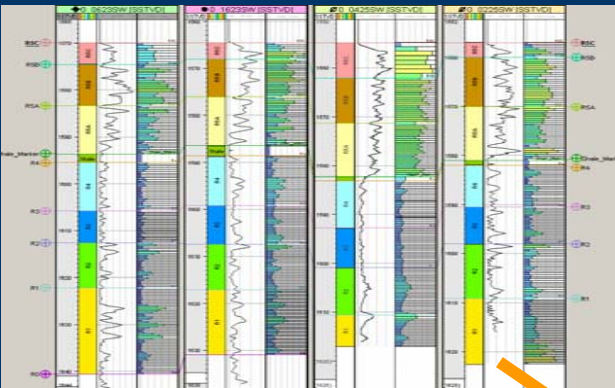
Blocked Well-Log => green,
Actual Well-Log => orange



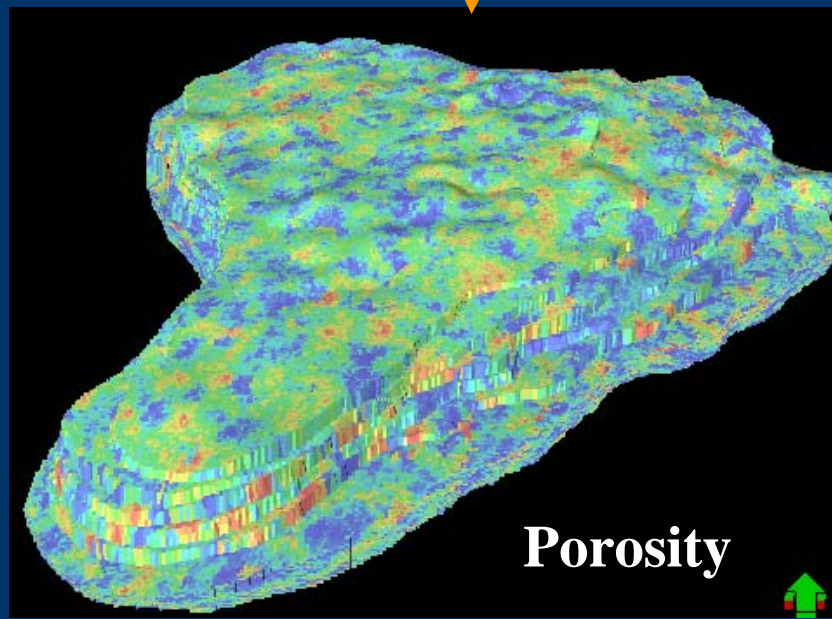
R5A Porosity in Reef

3D Porosity Modeling

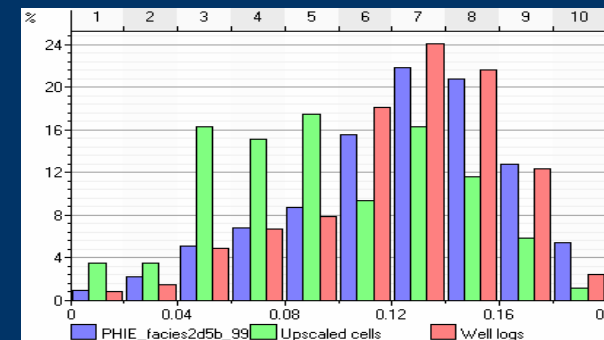
Judy Creek



Sequential Gaussian Simulation



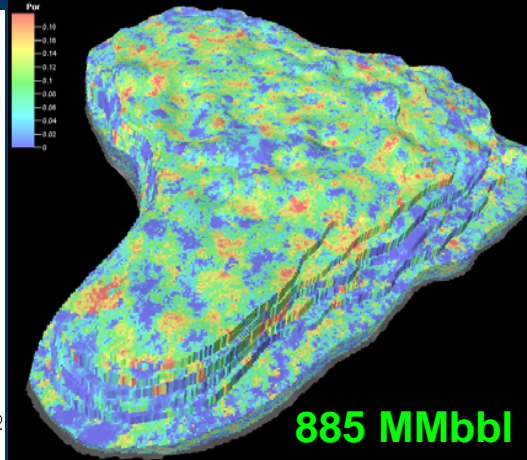
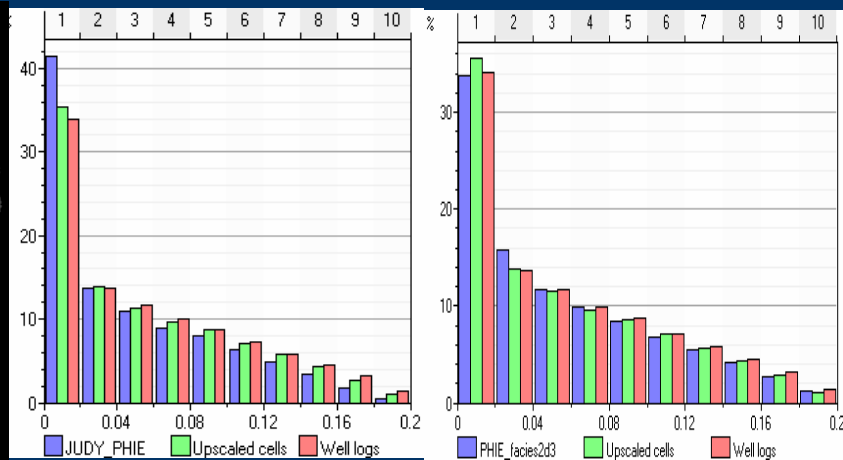
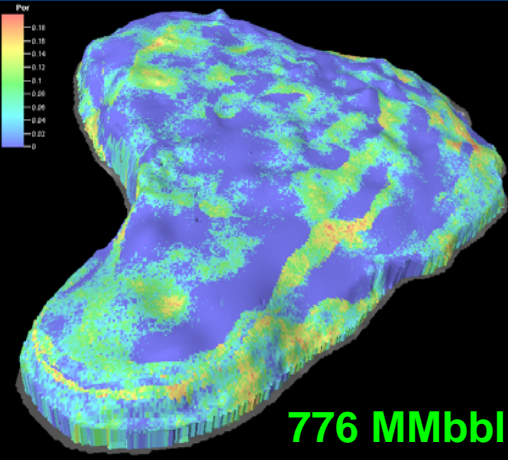
R5A Reef Example



Model Comparison

Previous

New



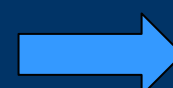
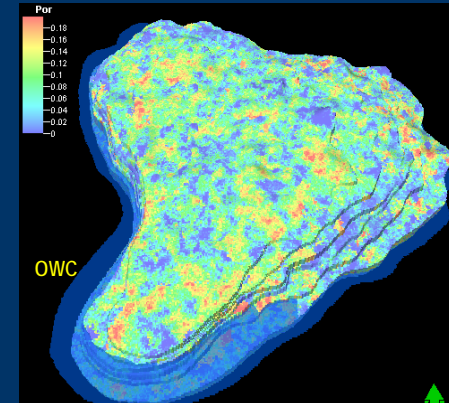
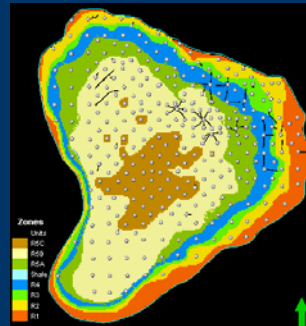
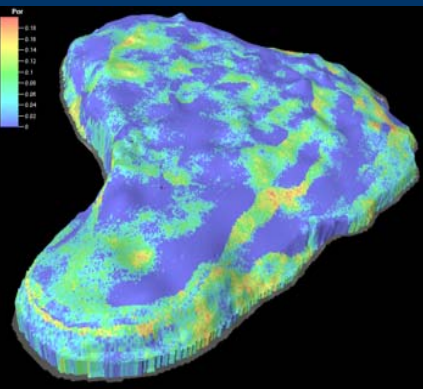
Units	Well logs	Blocked logs	Previous	New
R5C	8.27	6.31	5.37	7.40
R5B	9.56	9.00	9.05	9.46
R5A	8.43	7.51	7.14	8.08
Shale	NR	NR	0	0
R4	5.18	3.87	2.87	4.43
R3	3.61	3.92	2.57	3.77
R2	4.50	4.93	4.16	4.68
R1	5.73	5.65	4.84	5.44
Total	5.69 %	5.53 %	4.71 %	5.52 %

Averages

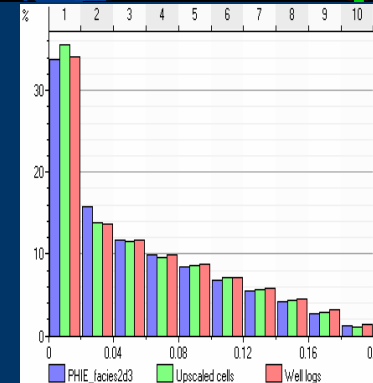
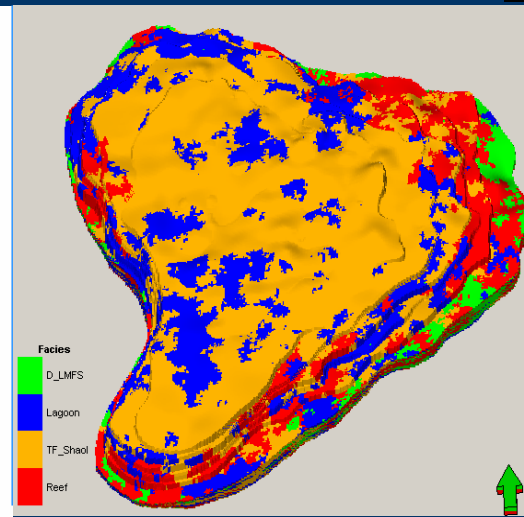
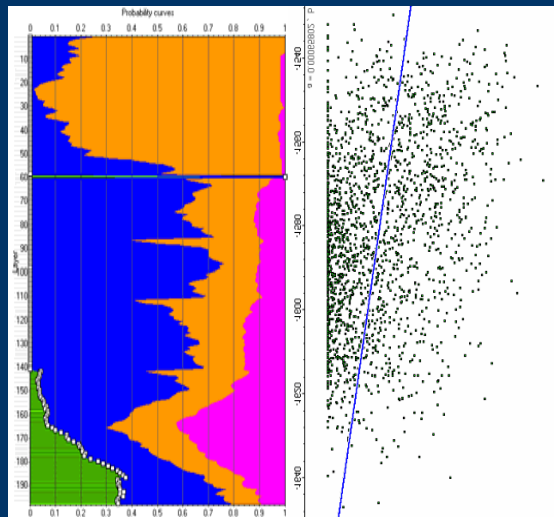
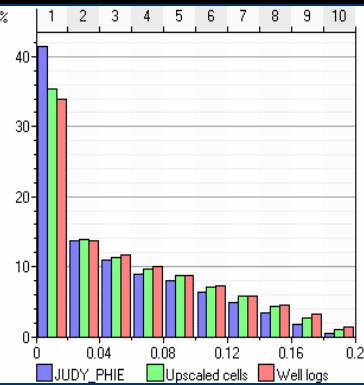
What's the True Meaning of Honoring Data?

Previous

New



'Hard' Data

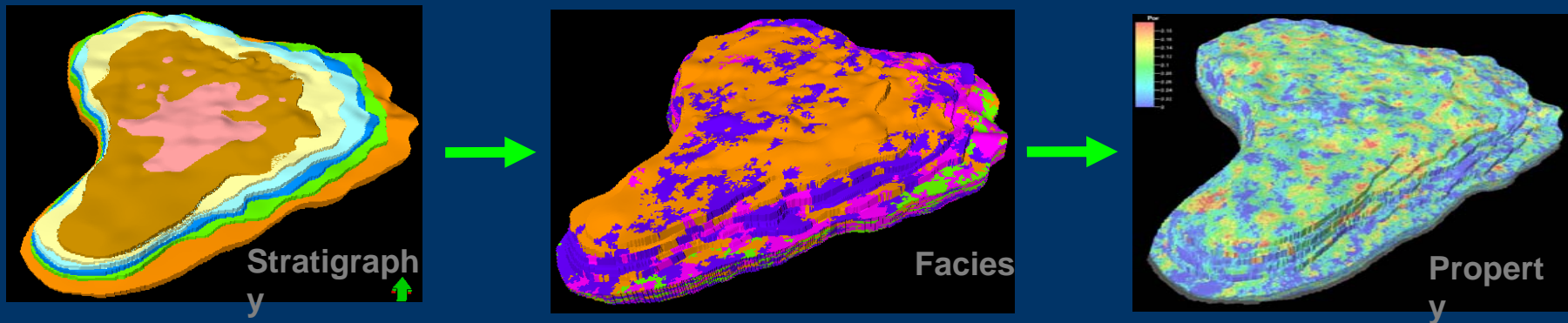


Geologic Propensity "Data" & Depositional Characteristics

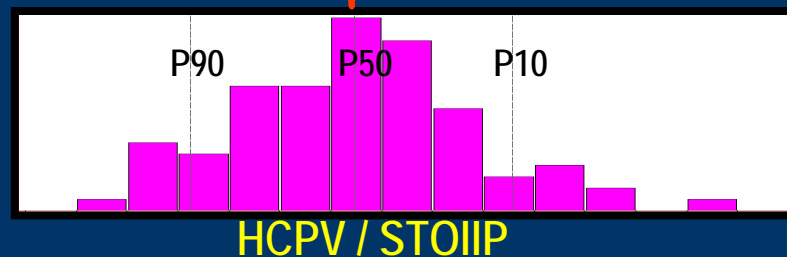
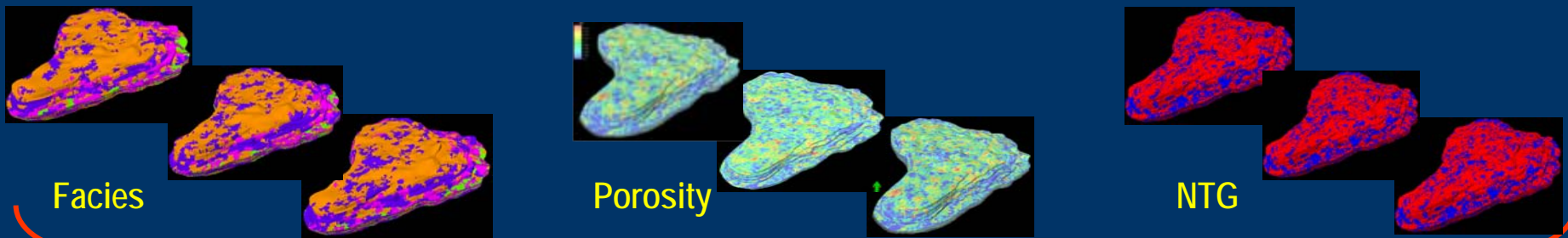
- Is honoring the data sufficient?
- How to make right inference based on limited data?

Uncertainty Evaluation

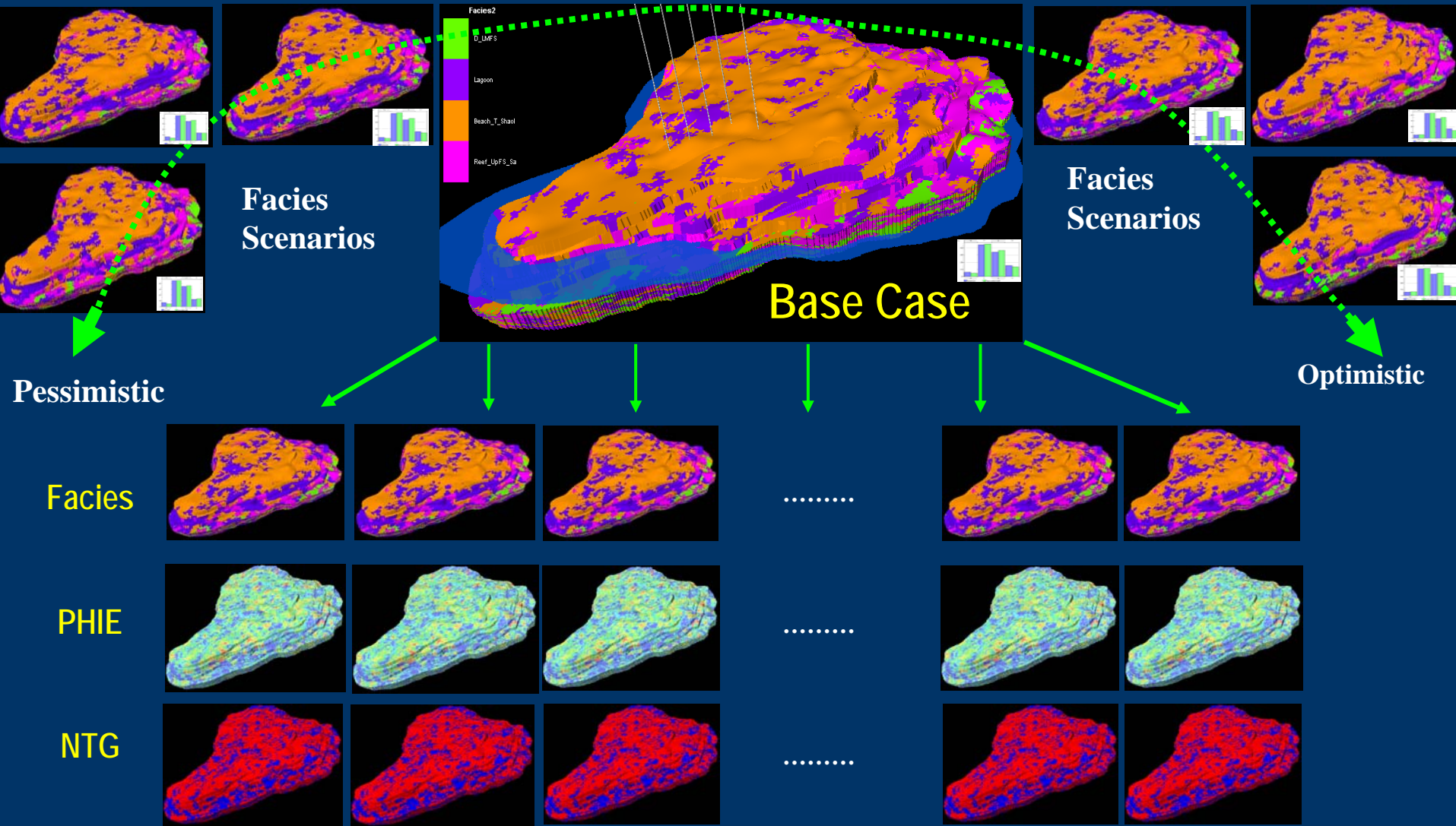
• Modeling Workflow



• Uncertainty Evaluation Workflow

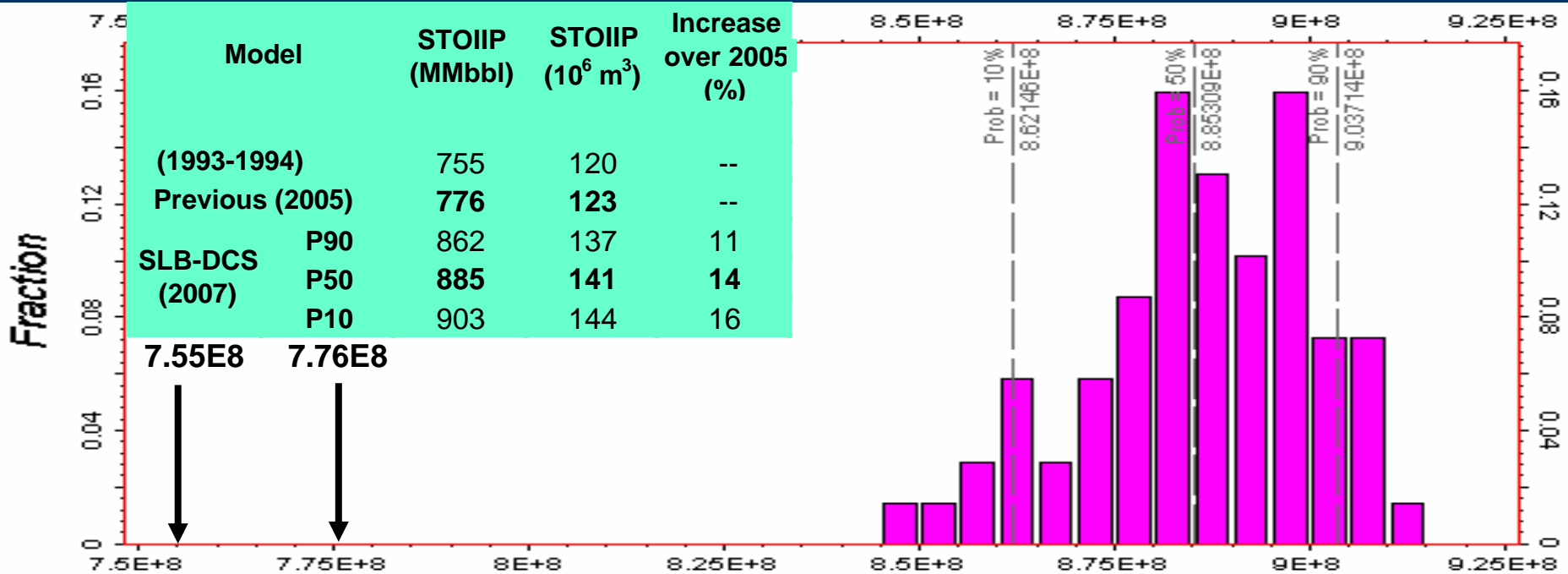


Input-Model Uncertainty Hierarchy

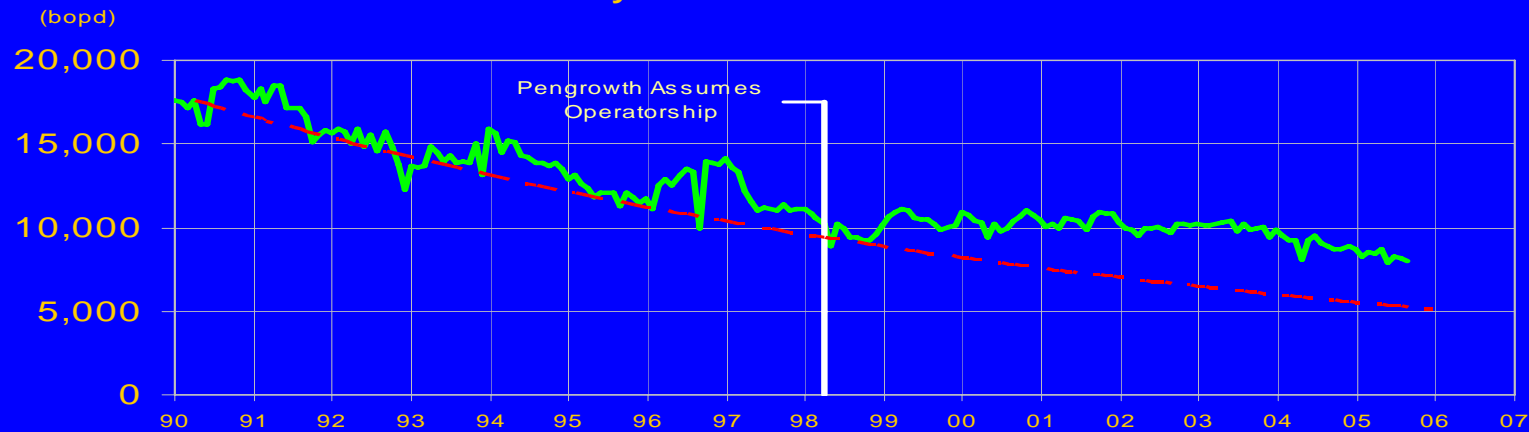


- 10 realizations for each scenario (7 x 10 = 70 models)
- Each realization followed the hierarchical modeling workflow

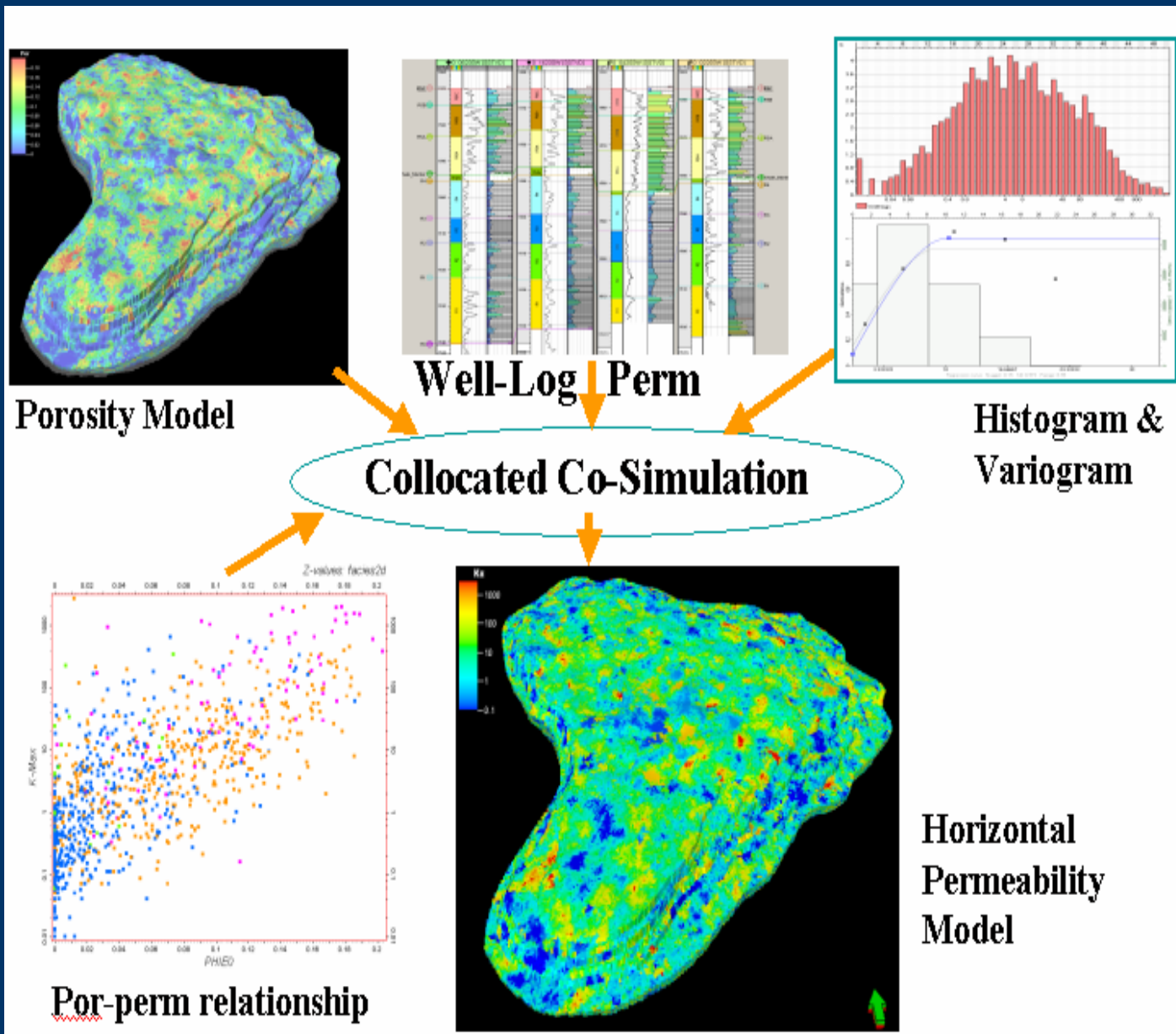
STOIIP Uncertainty and Comparison



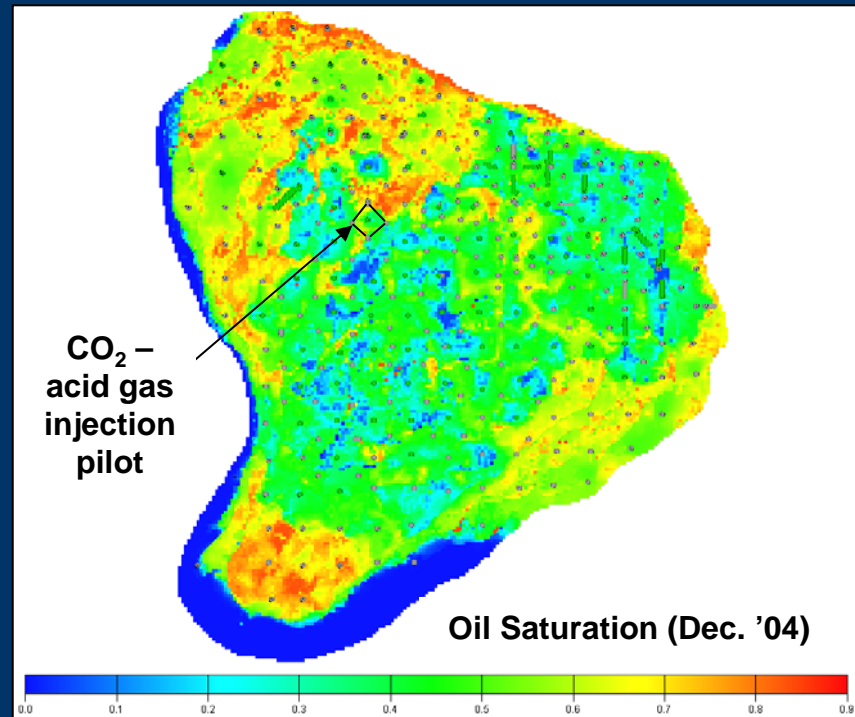
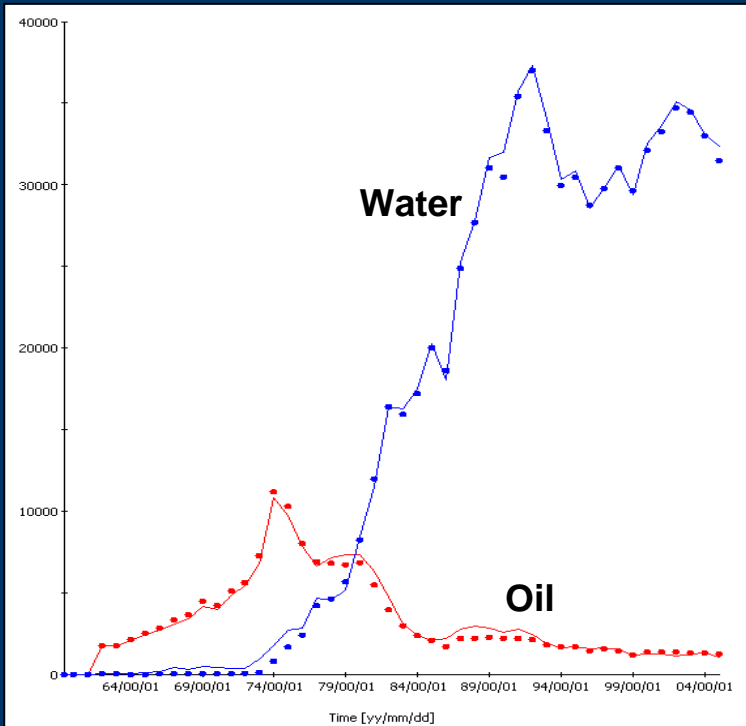
Judy Creek Oil Production



Horizontal Permeability Modeling Workflow



Reservoir Simulation and EOR



Streamline Model

- Pool-wide water flood and hydrocarbon miscible flood history match and forecast to identify new infill, secondary, tertiary and quaternary flood candidates

Compositional Model

- Individual HCMF / CO₂ pattern flood models, based on pool-wide history-matched model, to optimize operational strategies and quantify incremental enhanced oil recoveries.

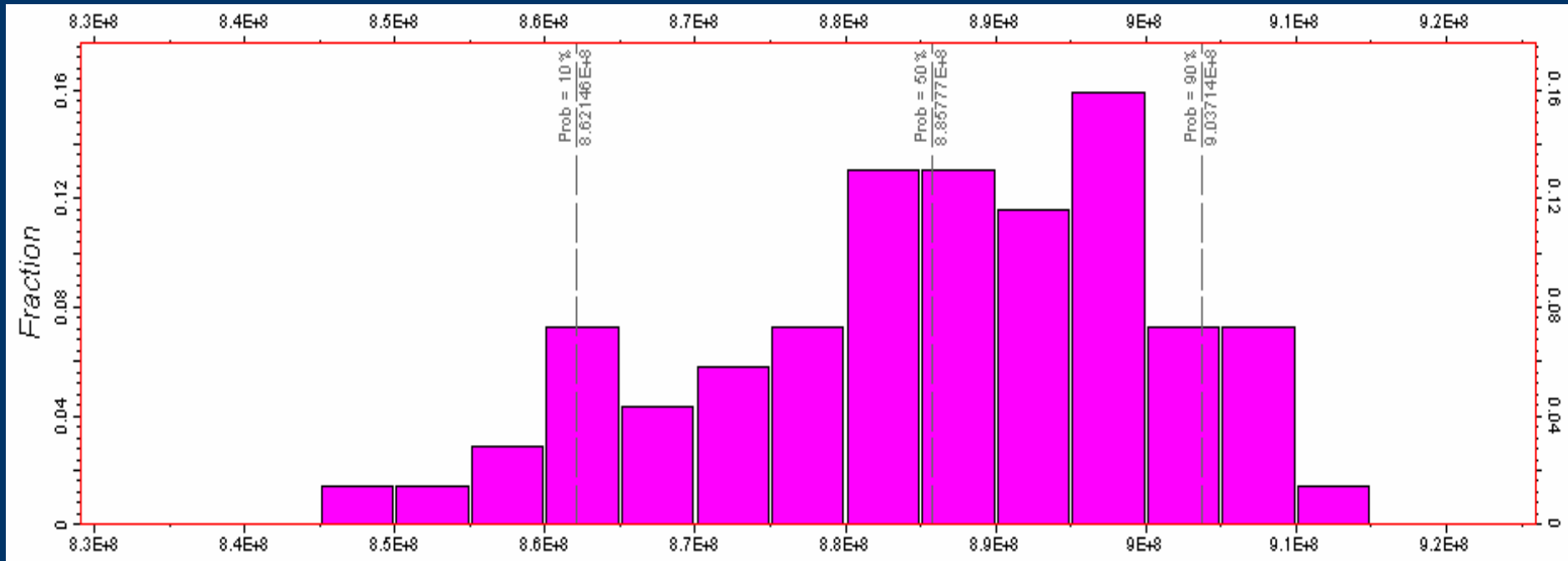
Conclusions

- The multi-scales of heterogeneities were modeled by integrating geology and petrophysics, while honoring the carbonate reef depositional characteristics & intrinsic statistics of the **well logs'** petrophysical properties (Sci. & stat. inferences).
- This led to an increase of >100 MMbbl additional STOIP.
- With larger original oil-in-place, waterflood recovery factor is smaller than originally anticipated.
- More infill drilling to target unswept or stranded oil is planned.
- Support possibility of higher residual oil saturation (50% vs. 30%) after waterflood, as reported by Esso in 1990. More water flood residual oil is available for ongoing incremental recovery through tertiary and quaternary floods.

STOIIP Uncertainty

• 3D Model-based HCPV:

$$\text{STOIIP} = \sum_{i=1}^N V_i * \Phi_i * \text{NTG}_i * (1 - S_{w_i}) / B$$



- Optimistic models (Facies, Porosity, NTG) gave high STOIIP, P10 = 903 MMbbl
- Pessimistic models gave lower STOIIP, P90 = 862 MMbbl
- P50 model had a STOIIP of 885 MMbbl