



## GLOBAL PETROLEUM SHOW

NORTH AMERICA'S LEADING ENERGY EVENT

JUNE 12 - 14, 2018 CALGARY, CANADA



AnBound Energy Inc.

# MULTIDISCIPLINARY STATIC AND DYNAMIC DATA INTEGRATION TOWARDS BETTER RESERVOIR DYNAMICS UNDERSTANDING: A CASE STUDY OF THE RING BORDER FIELD IN CANADA

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# Outline

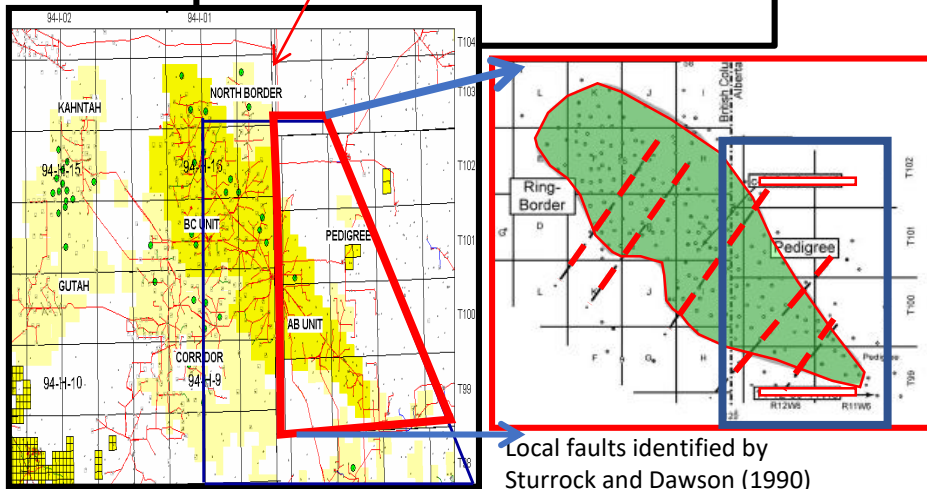
- Introduction of the Ring Border Field
- Geology & Petrophysics
- Geological Modelling
- Reservoir Engineering & Simulation
- Reservoir Characterization workflow
- Conclusions

# Introduction

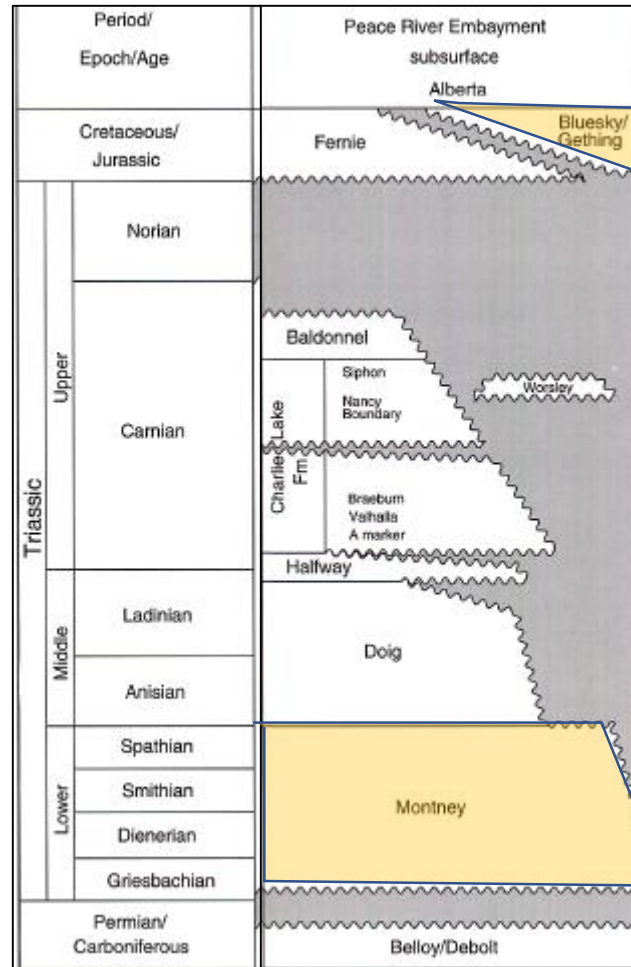
- The Ring Border east field (BC-Alberta) has been producing since the early 1990's.
- There are > 300 wells in the total east field with a cum production of >500 Bcf
- Mostly vertical wells that have been hydraulically-fractured
- Wet gas production with variable condensate production across the field.
- Mobile water production does not appear to be an issue except in the proximity to down dip water contacts (SE of the reservoir)

# Geological & Petrophysical Summary

# Ring Border - Field Location



Local faults identified by Sturrock and Dawson (1990)



Lithostratigraphic units (After Edwards et al)

## • Bluesky Fm:

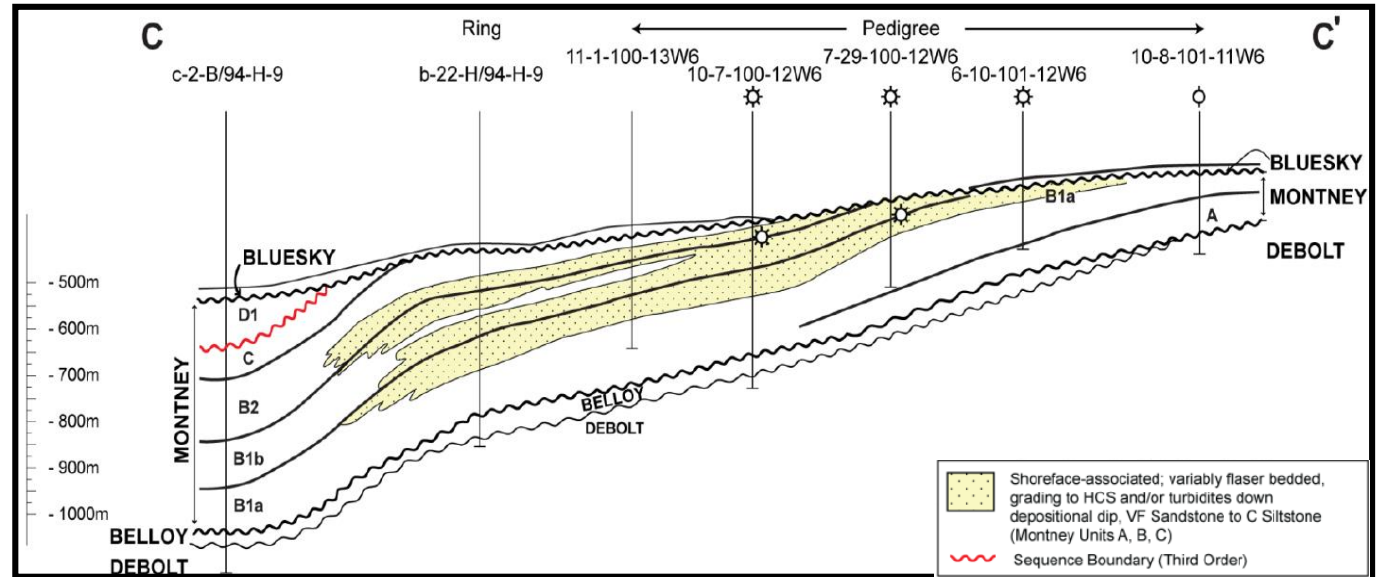
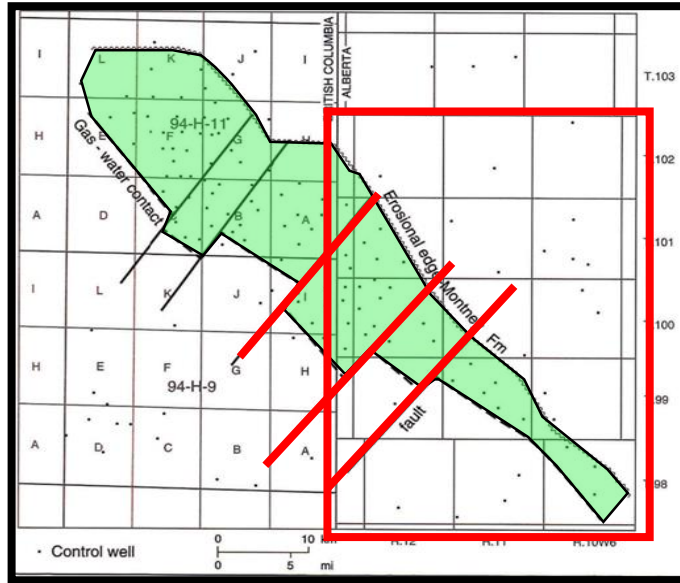
- m-c sandstones/mudstones /congl.
- Transgressive shoreface strata.

## • Montney Fm:

- Lower Triassic-shoreface Fine SS, siltstones, and shales.
- Ring Border produces from very fine-grain and well sorted, sandstones and siltstones.

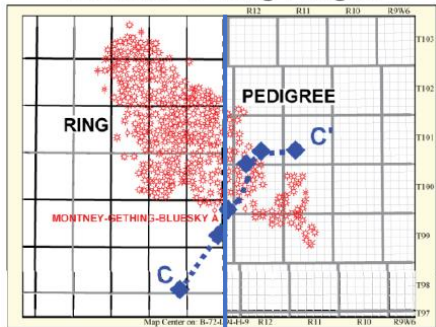
- Townships 99 – 102, Ranges 11-12
- Ring Border Field Alberta side

# Hydrocarbon Trap



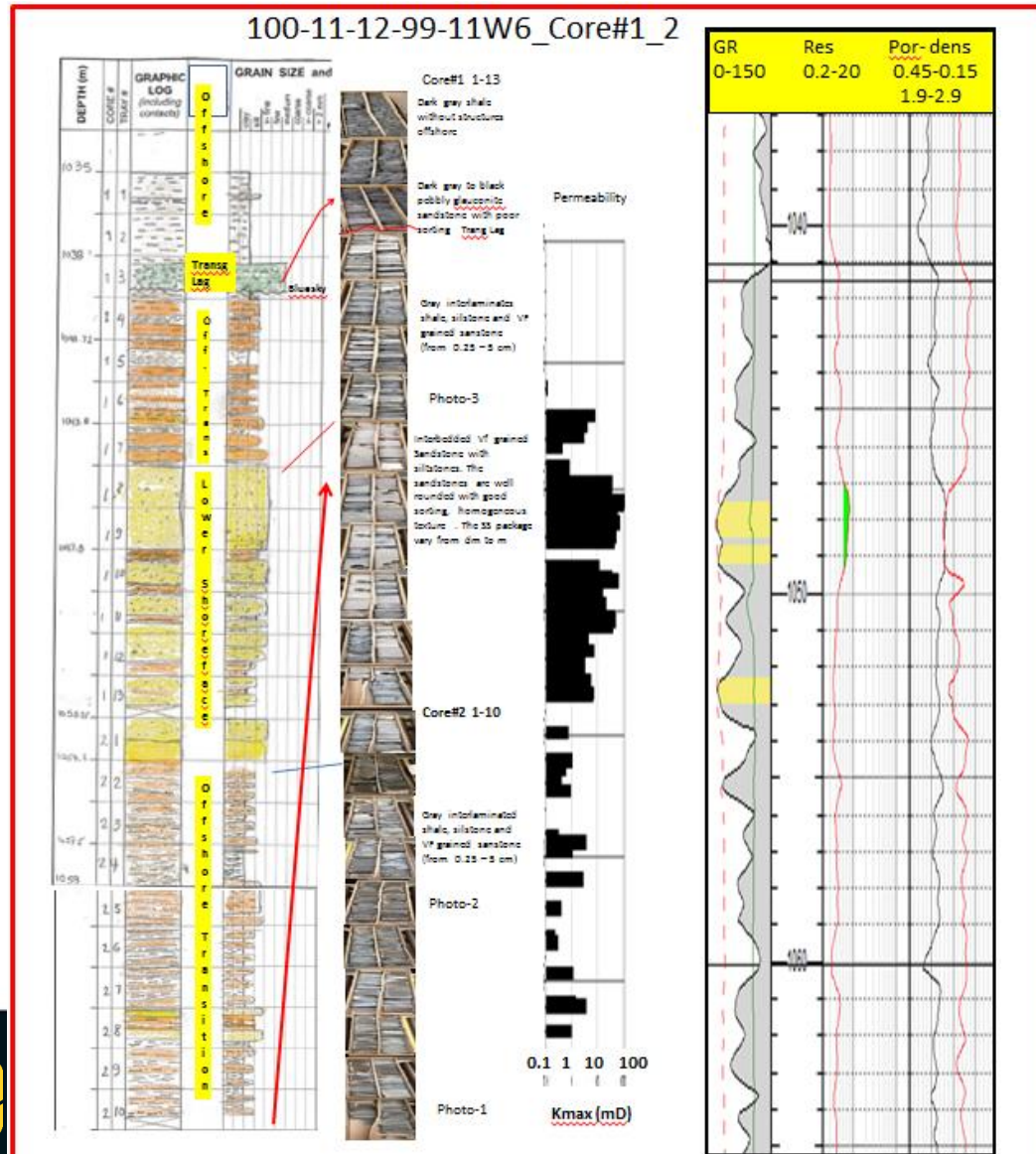
Erosional Edge of the Montney and sub-parallel faults (Edwards et al)

Section C-C' Ring-Pedigree



- The shoreface sandstones from Montney Formation pinch out up dip against the pre-cretaceous unconformity (stratigraphic).
- A regional GWC is present in the lower Montney sands, defining the down dip edge of the hydrocarbon zone.
- The SW-NE faults are subparallel to Hay River Fault system and generate a compartmentalization of the gas field (After Edwards et al).

# Integration of Core Evaluation and Logs



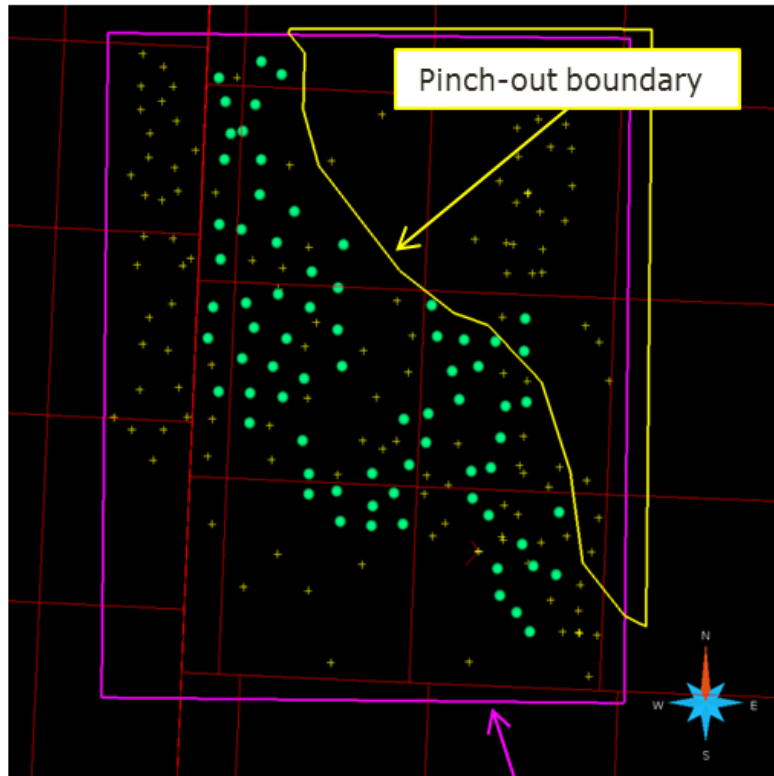
- 26 wells with core from the Montney and Bluesky.
- Core description + logs, and porosity & density ranges used to define main facies:
  - Shaly SS
  - Very Fine SS
  - Shales
- Full Petrophysical interpretation to match logs to core, and many iterations were done to get a good representation of the reservoir.

# Geological Modelling Summary



# Structural Model

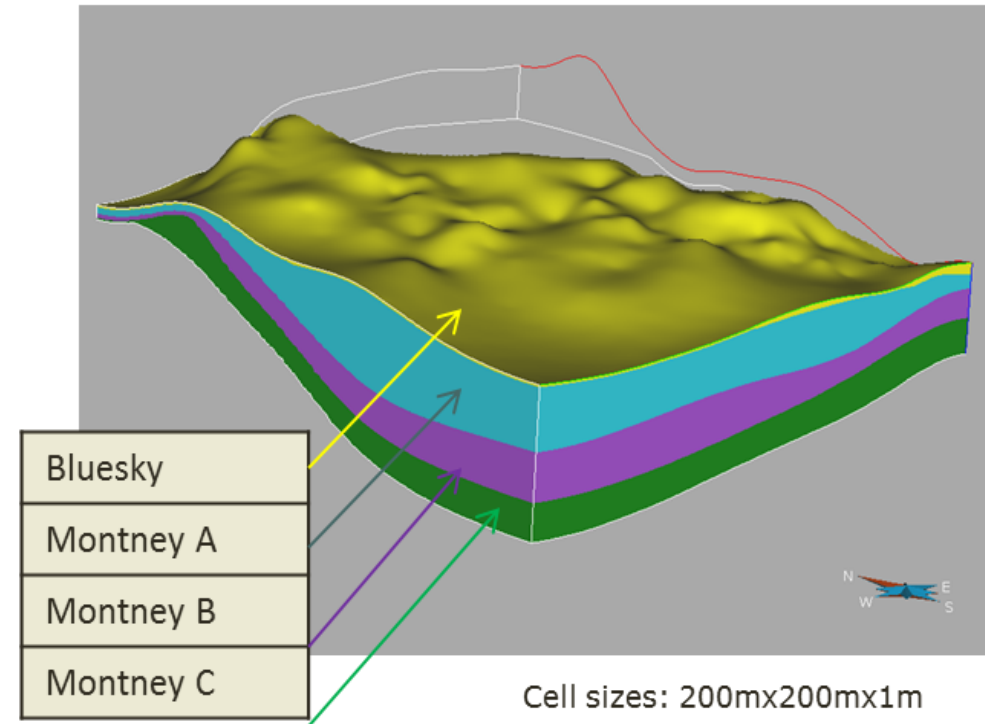
## Model Boundaries



Wells used in model

Model boundary

## Divided into four units



Bluesky

Montney A

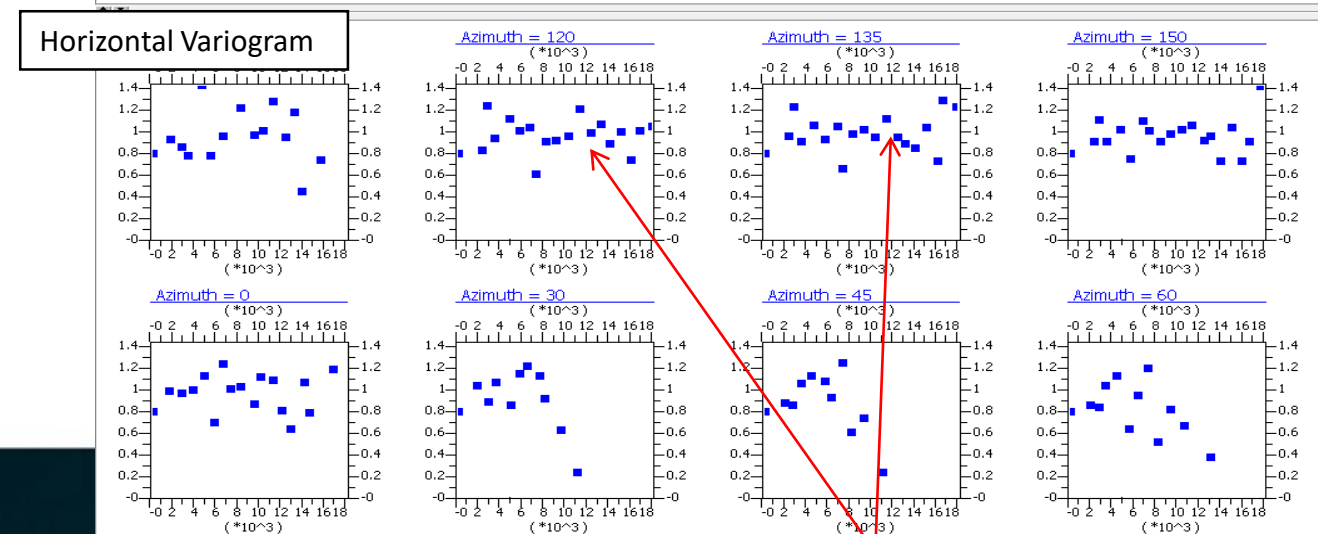
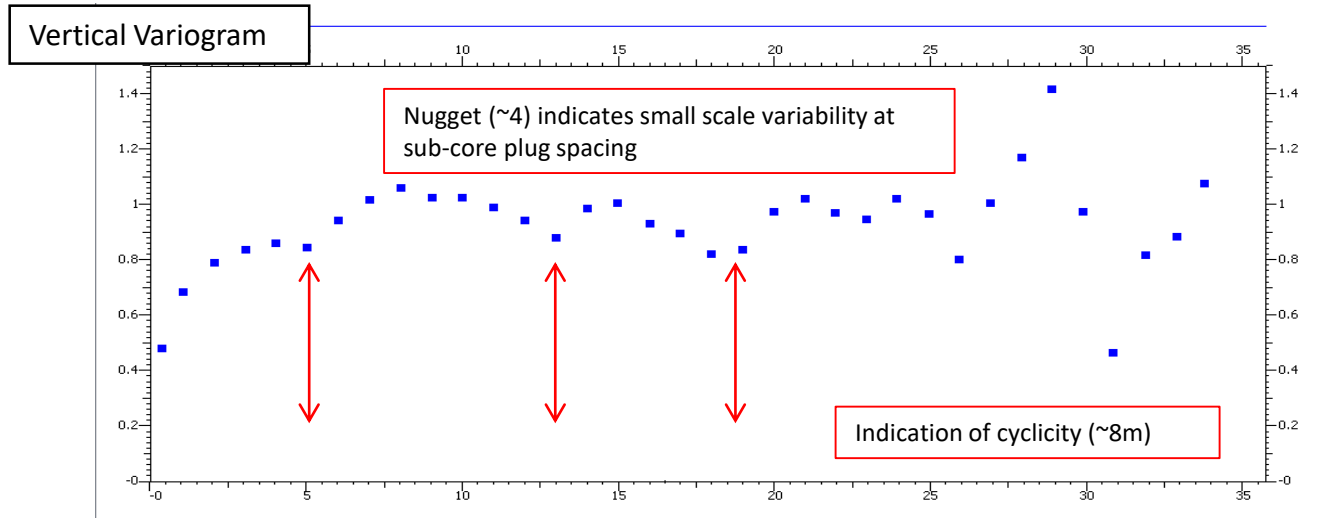
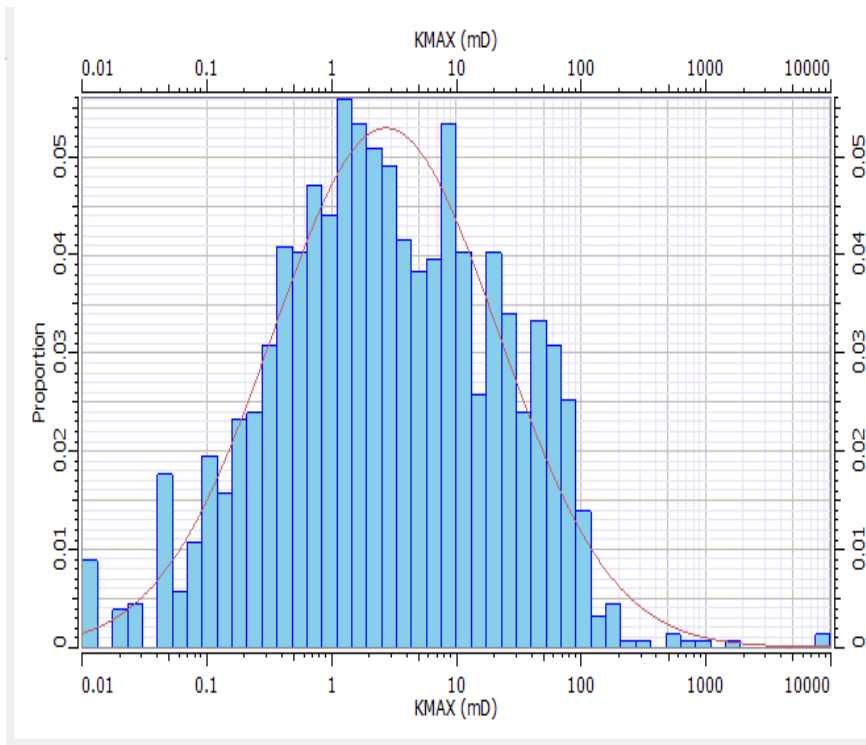
Montney B

Montney C

Cell sizes: 200mx200mx1m

# Variogram Modelling

## Core data – Perm (All Zones)

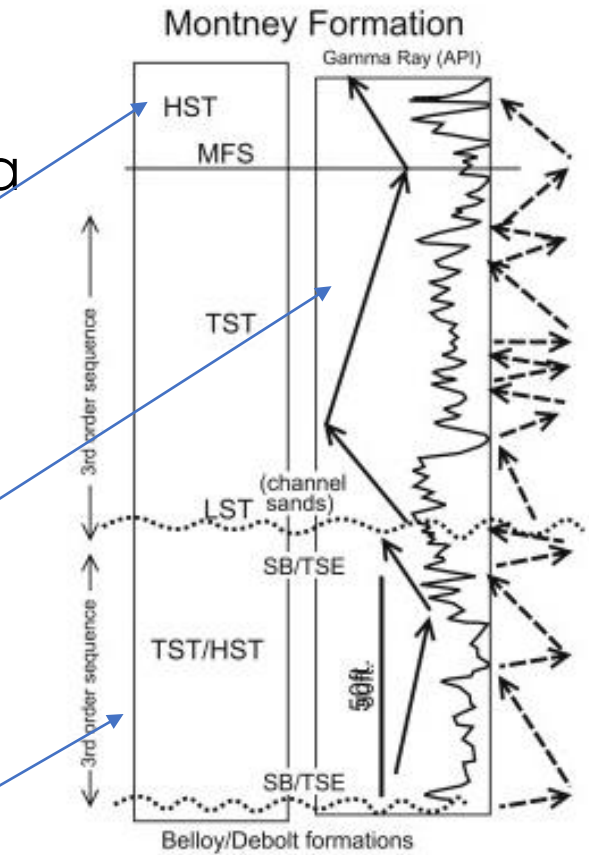
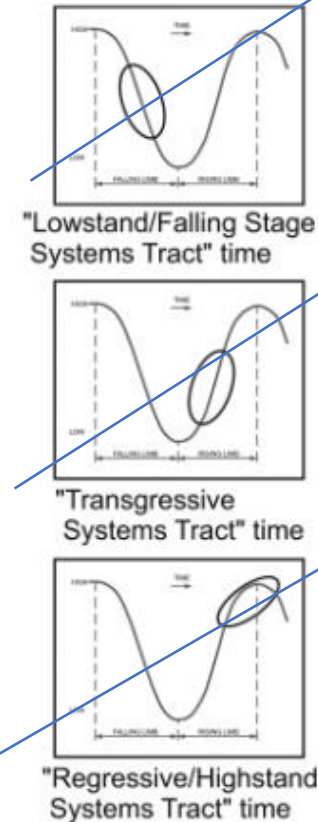
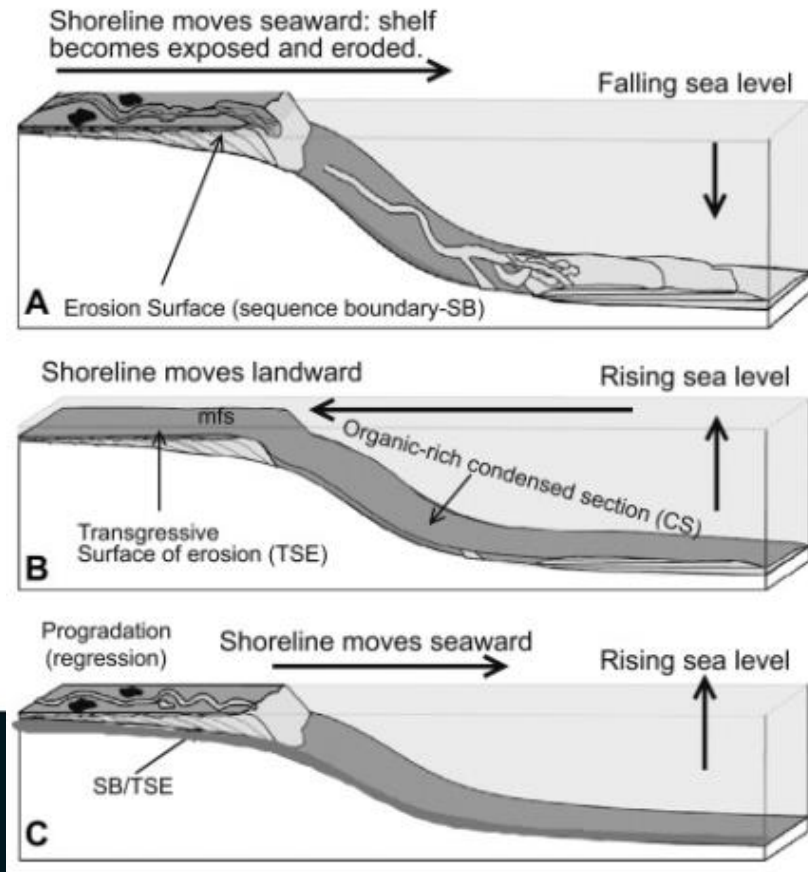


Observed cyclicity mainly in the vertical variograms.

Less periodicity in the horizontal direction but more noise

# Cyclicality in the Montney

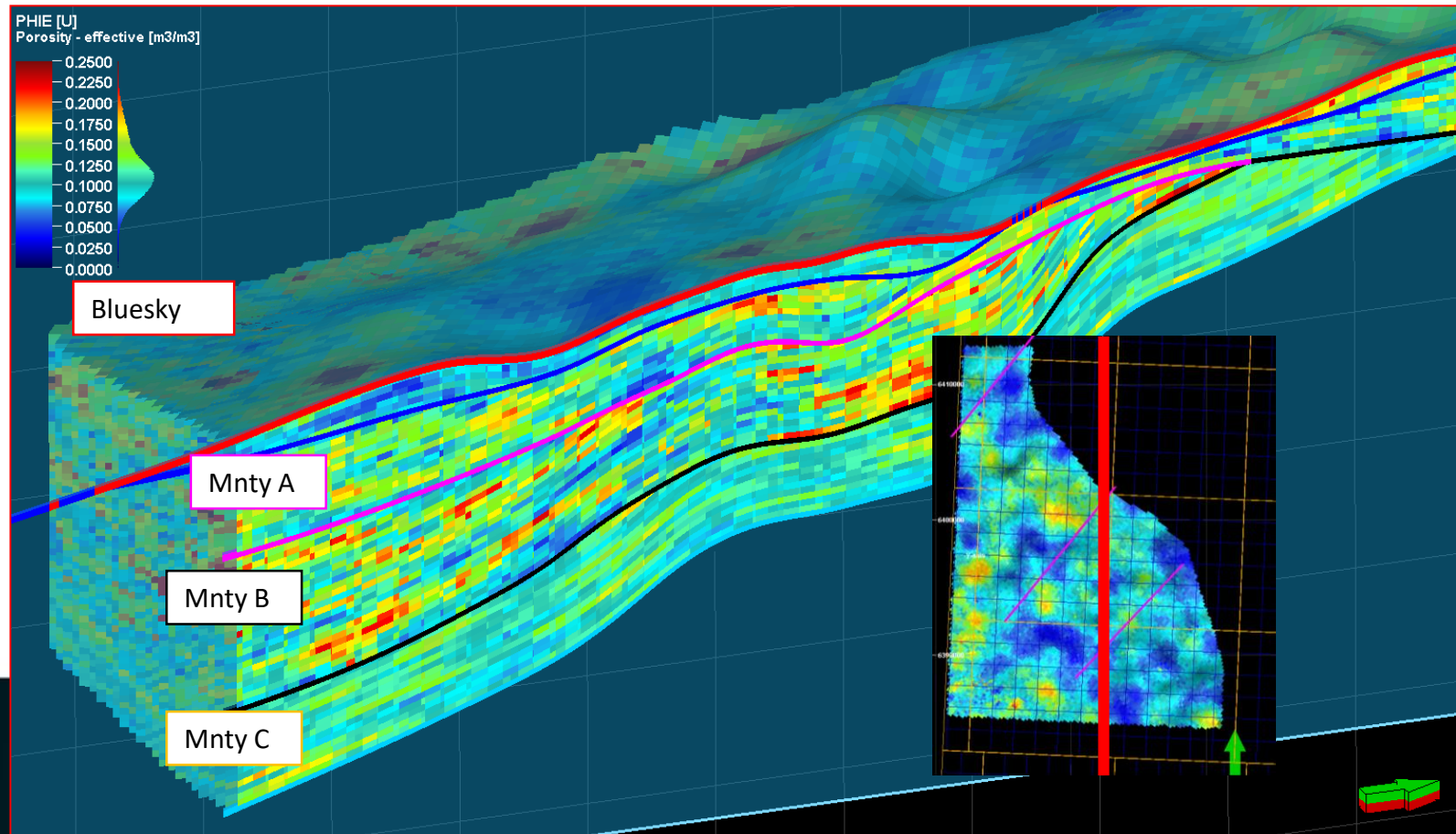
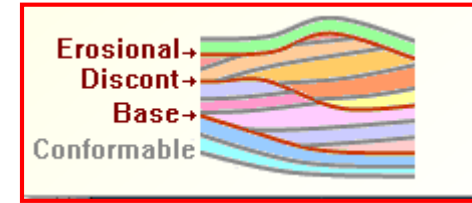
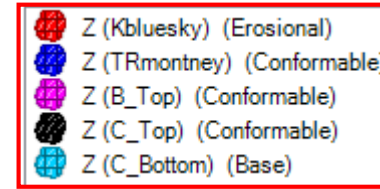
- Slatt et. al (2012) applies Traditional sequence stratigraphic principles to gas shales
- Gamma ray interpretation provides information on sea level changes and progradational shoreline changes



Low order cyclicality      High order cyclicality

# Geological Model

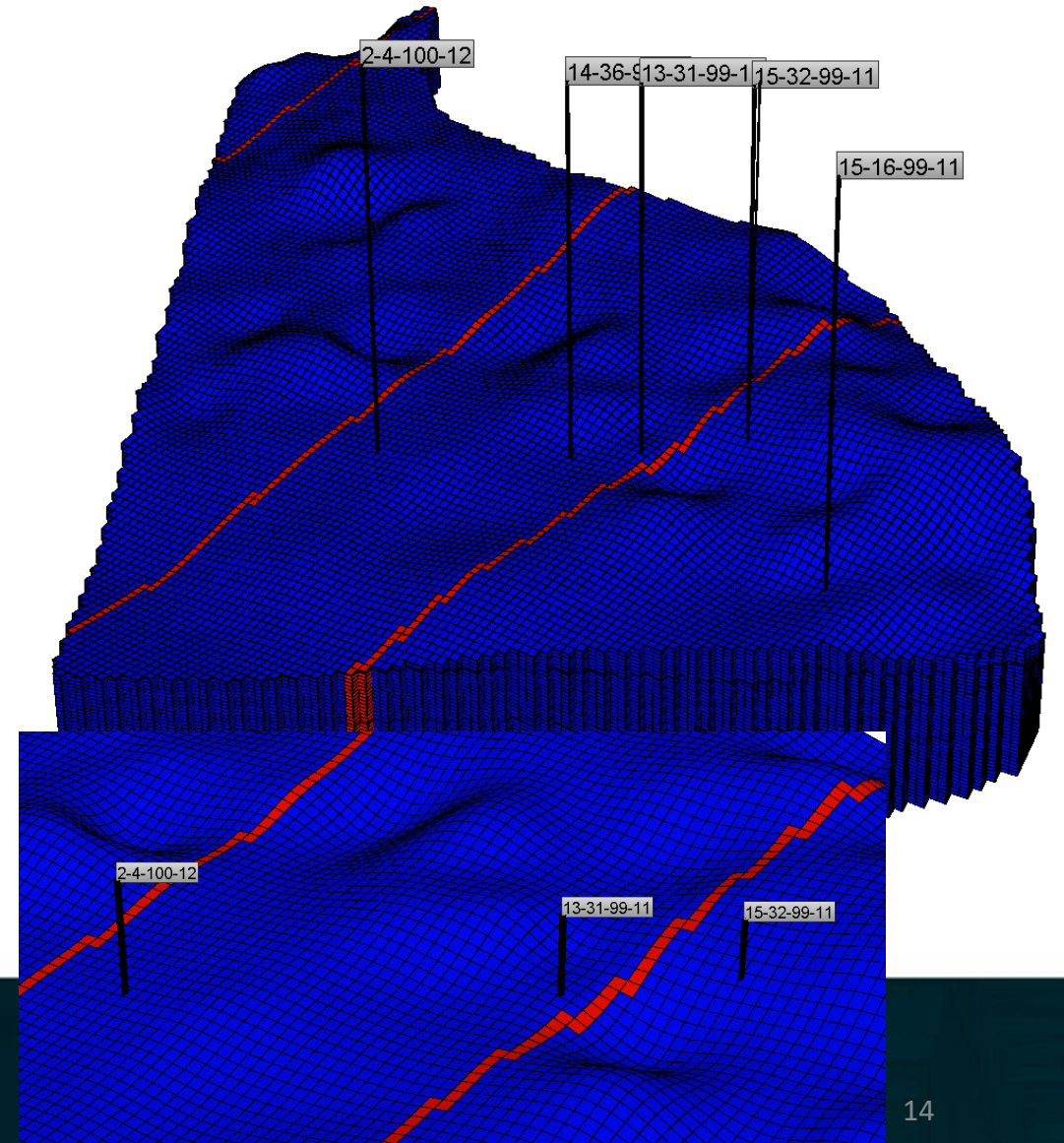
- Porosity cross section
- Multiple realizations run and ranked



# Reservoir Engineering & Simulation Summary

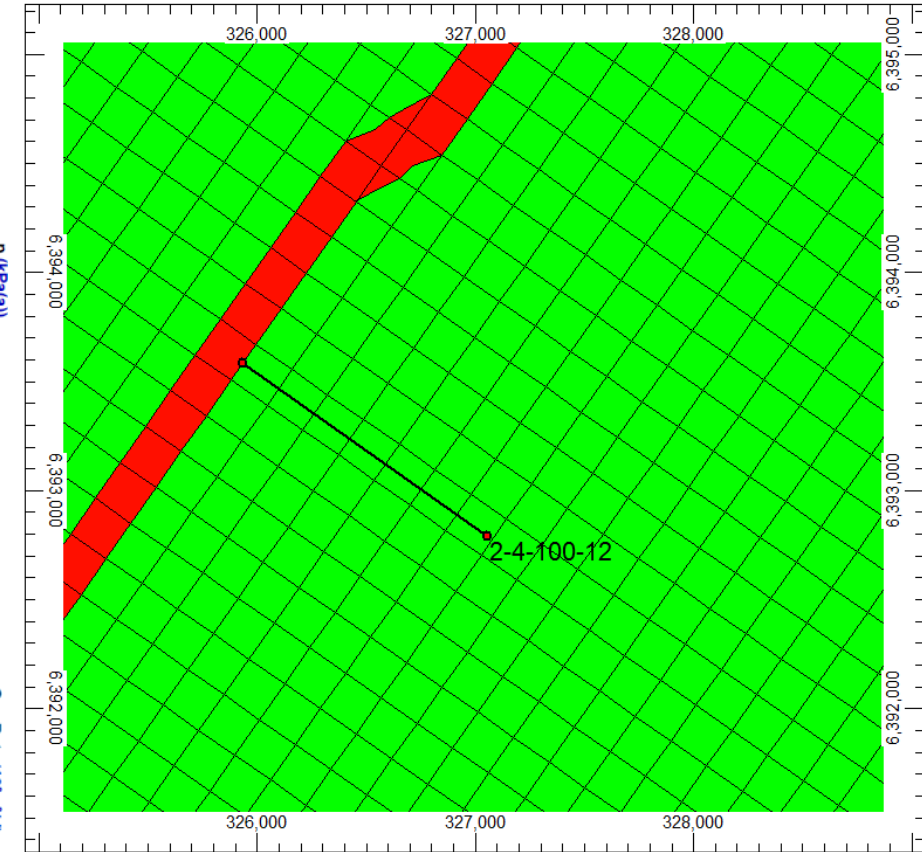
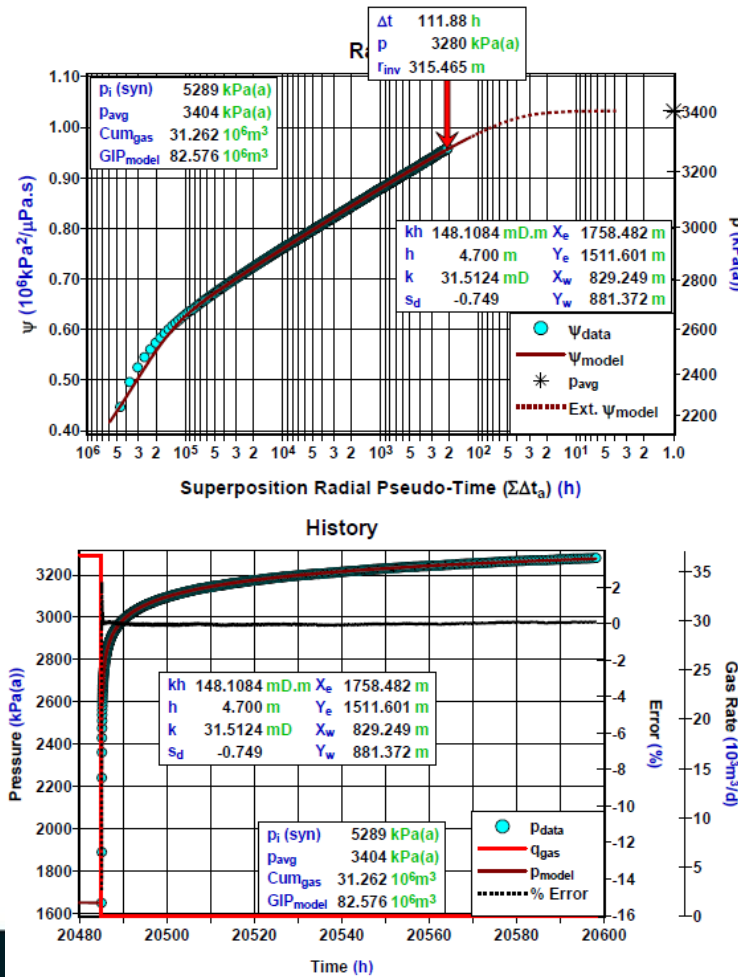
# Using Flow Simulation to Assess Fault Sealing Behaviour

- Identification of wells with well test data close to faults:
  - 2-4-100-12
  - 13-31-99-11
  - 15-32-99-11
- Well distance to the fault was too long, compared with the tests radius of investigation, so they were not detected by the tests. Simulation HM of well tests also corroborated that.



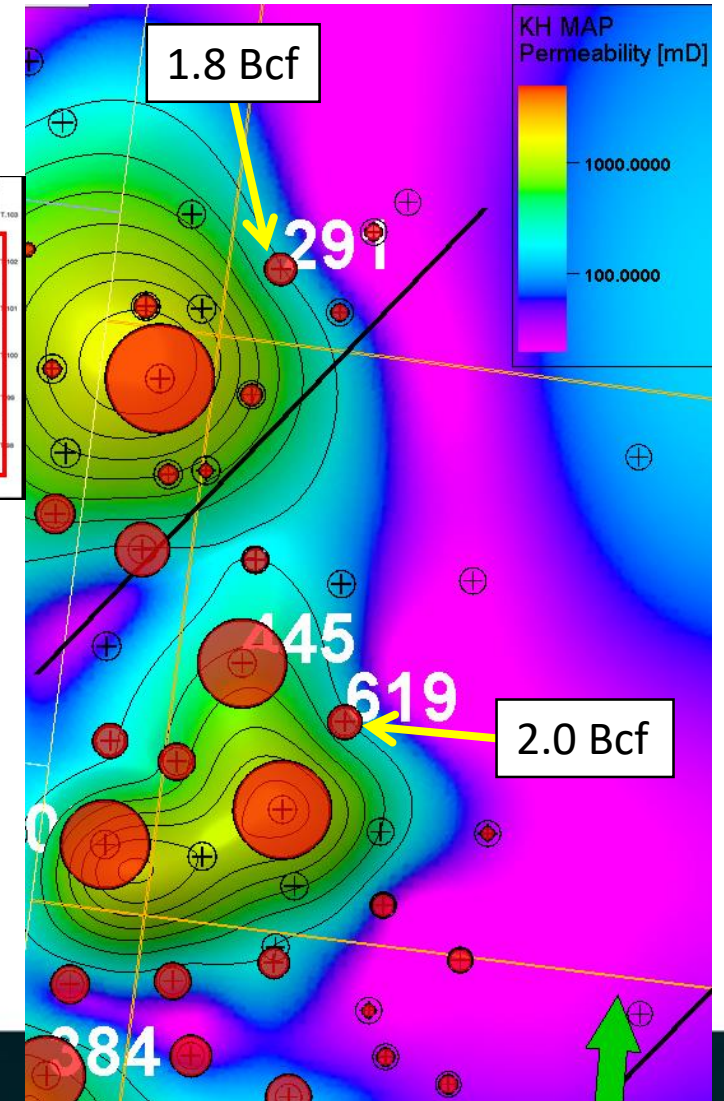
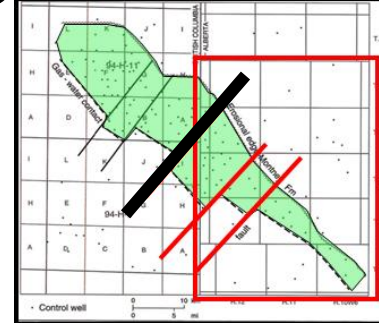
# Using Flow Simulation to Assess Fault Sealing Behaviour

- 02-04 is about 1300m away from closest fault
- Well test estimates radius of investigation of ~315m
- We don't expect to see boundary effects in this well test analysis.



# Fault Seal Interpretation Using Dynamic Data Integration

- Mapping Kh, Cum. Prod., and Pressure
- North Fault Interpretation:
  - Static pressures taken in 1998
  - Both wells have similar production but North well has significantly lower pressures
  - High productivity coincides with high Kh
  - North Fault displays sealing behavior.

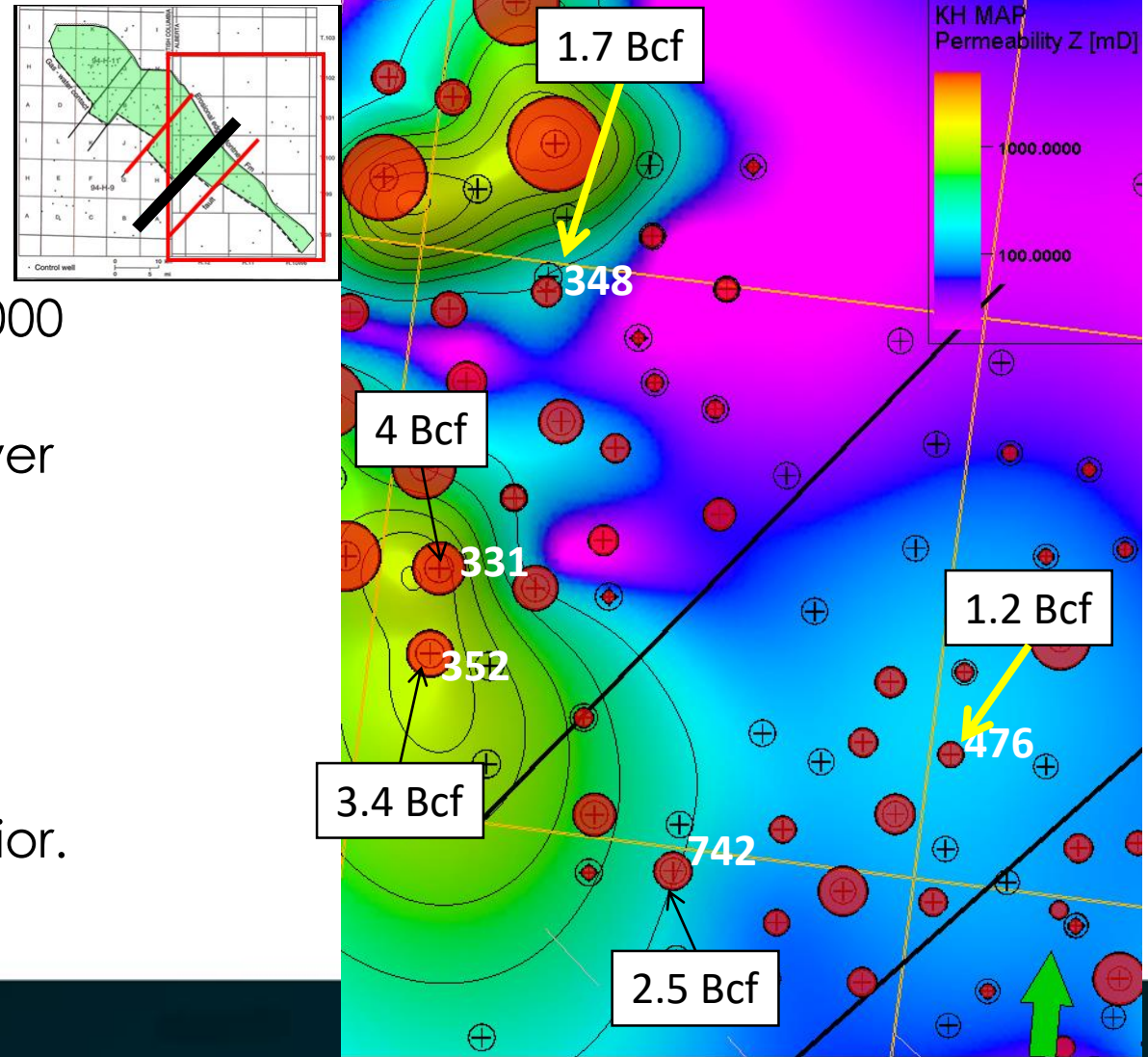


Cumulative production Bubbles



# Fault Seal interpretation using dynamic data integration

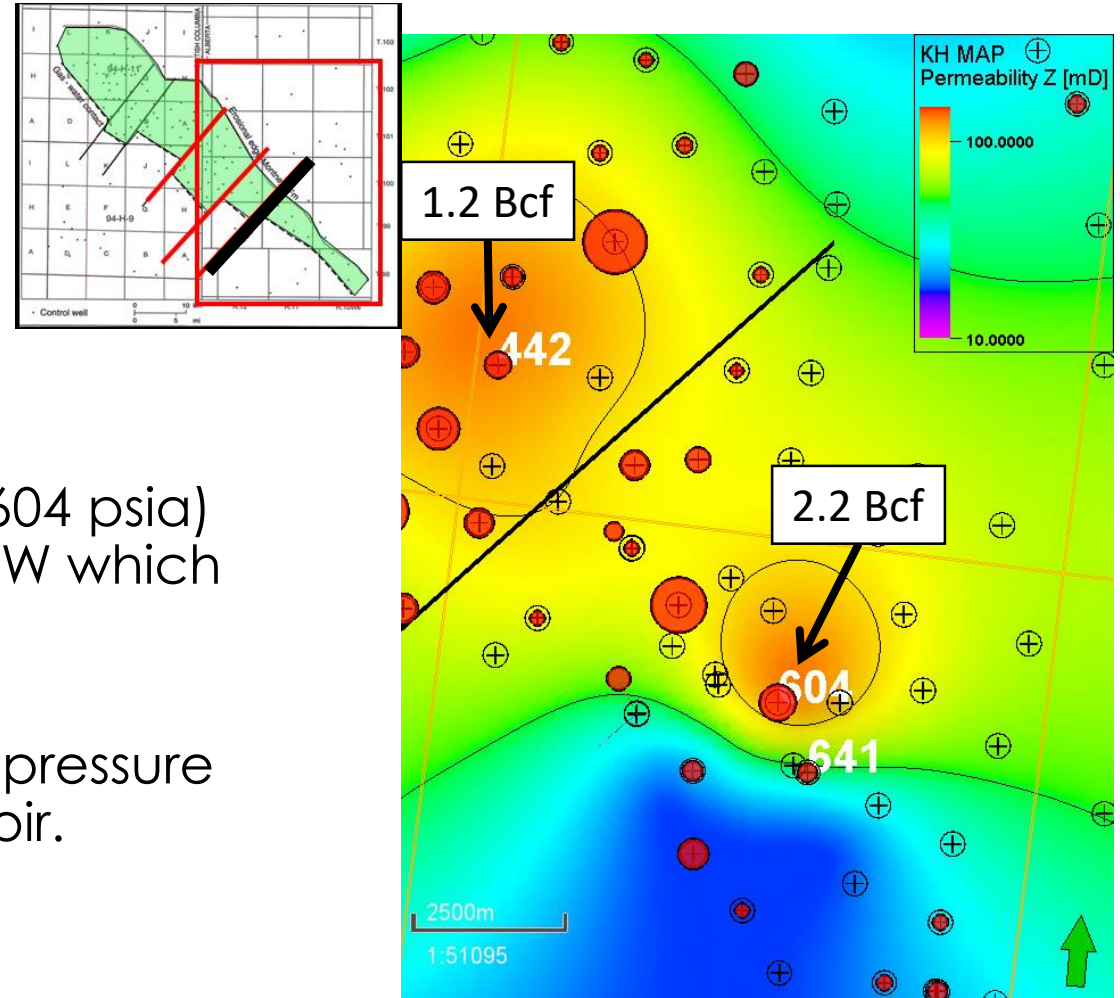
- Central Fault Interpretation
  - Static pressures measured in year 2000
  - Wells in NW of fault have overall lower pressures
  - Lower production in the south also correlates with lower Kh values.
  - Central fault displays sealing behavior.



Cumulative production Bubbles

# Fault Seal Interpretation Using Dynamic Data Integration

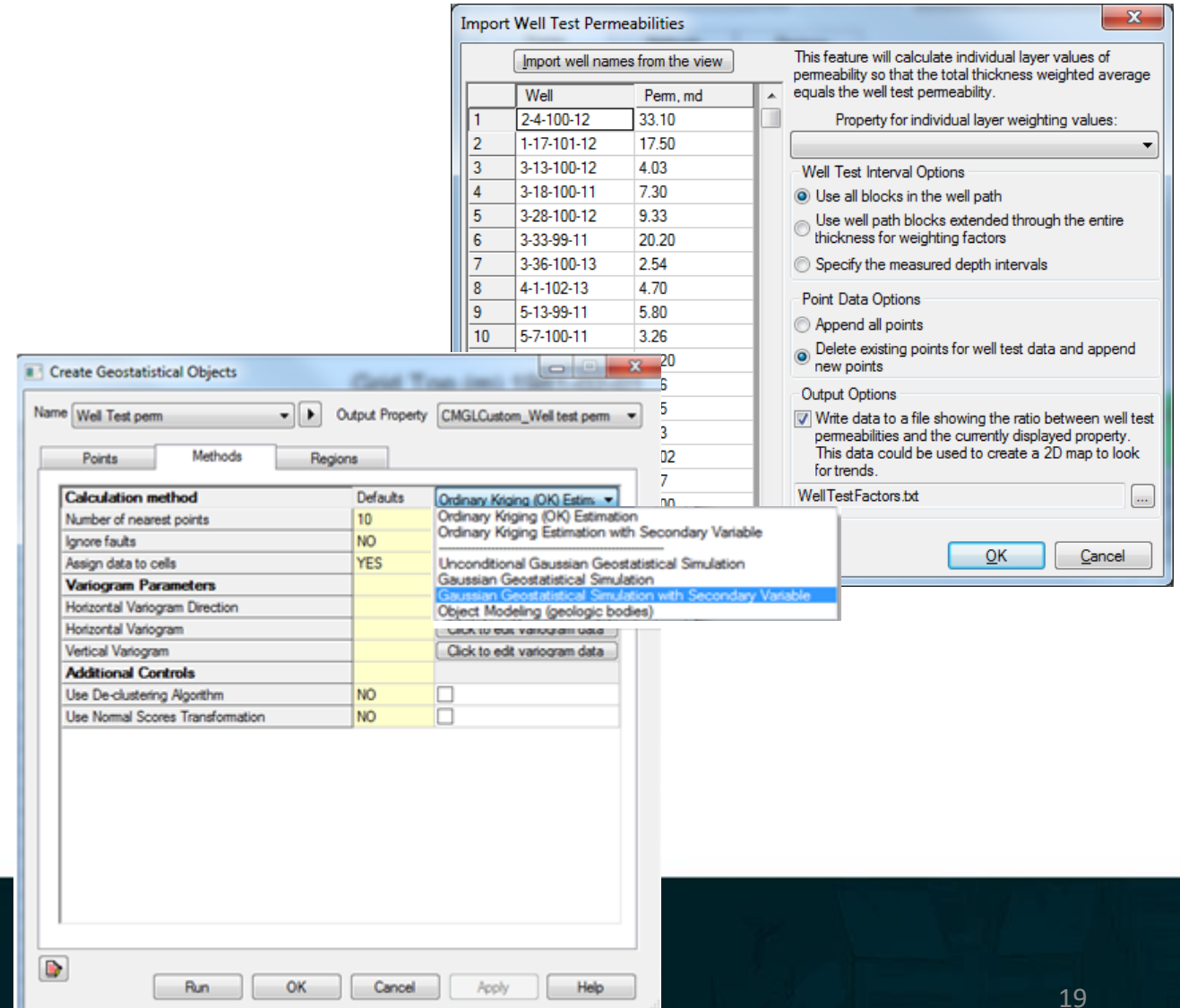
- South Fault Interpretation:
  - Static pressures measured in 1999
  - Well in the SE has higher pressure (604 psia) and produced more than well in NW which has lower pressure (442 psia).
  - There is an aquifer providing some pressure support to the SE side of the reservoir.



Cumulative production Bubbles

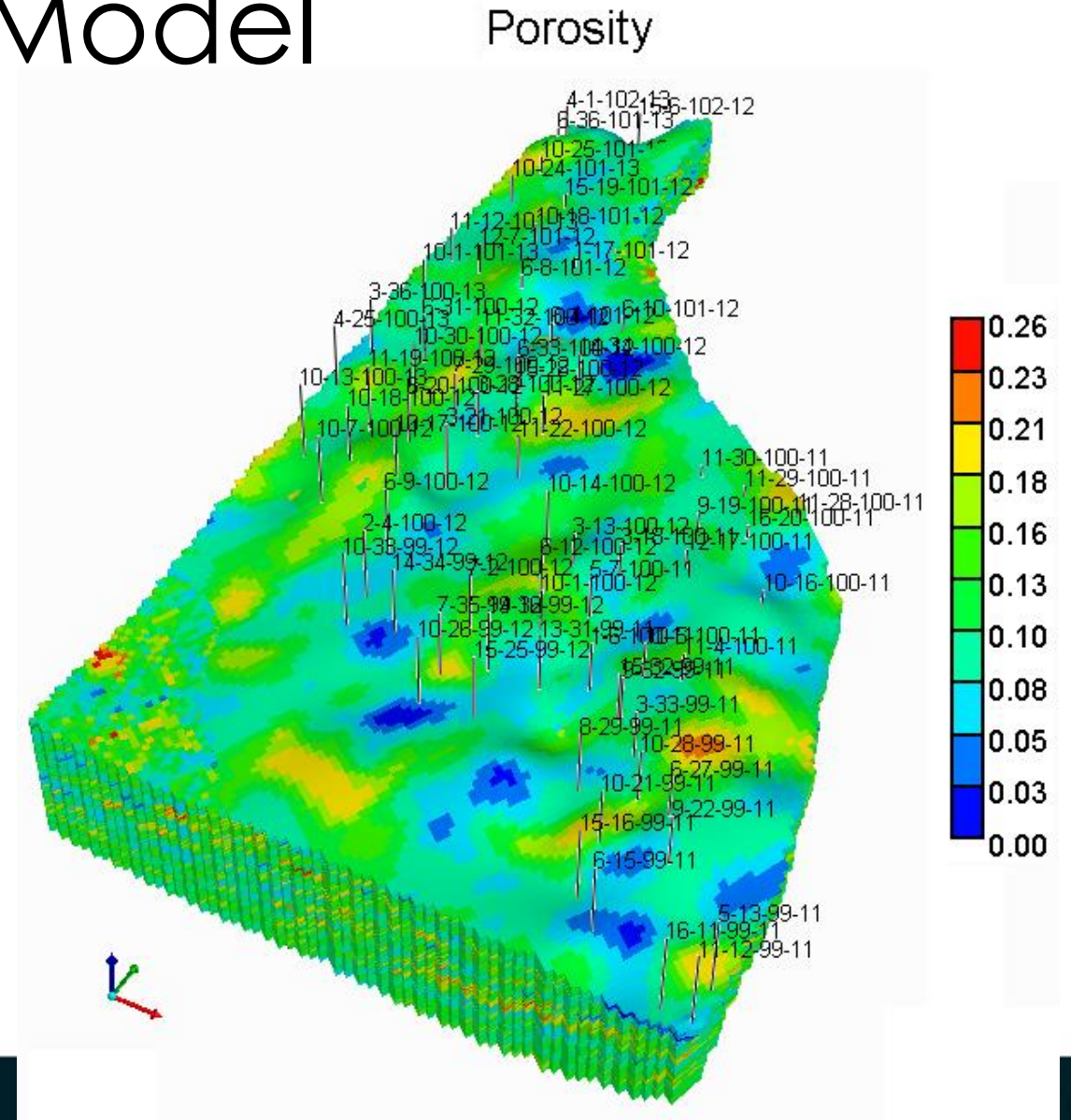
# Well Test Permeability Integration

- Integration of well test data to simulation model:
  - Used SGS with secondary variable to merge well test perms with permeability from logs.
- The resulting permeability was Qced and it matched the well test Kh at the wells



# Full Field Simulation Model

- Model details:
  - 2.2 million grid blocks
  - 200x200x1 m grid block size
  - Total of 72 wells in the model
    - 70 gas producers
      - 40 still producing to date
        - 27 pumping
        - 13 flowing
    - 2 Pressure Observation wells
      - 1-6-100-11
      - 10-28-99-11



# Sensitivity Analysis – Pre-History Match

- Performed using CMOST. Experiments are generated to cover the full combination of parameters by using a response surface methodology
- A proxy model is generated and verified based on simulation results.

CMOST -- E:\UofC\RingBorder\Simulation\CMOSTRING BORDER.cmp

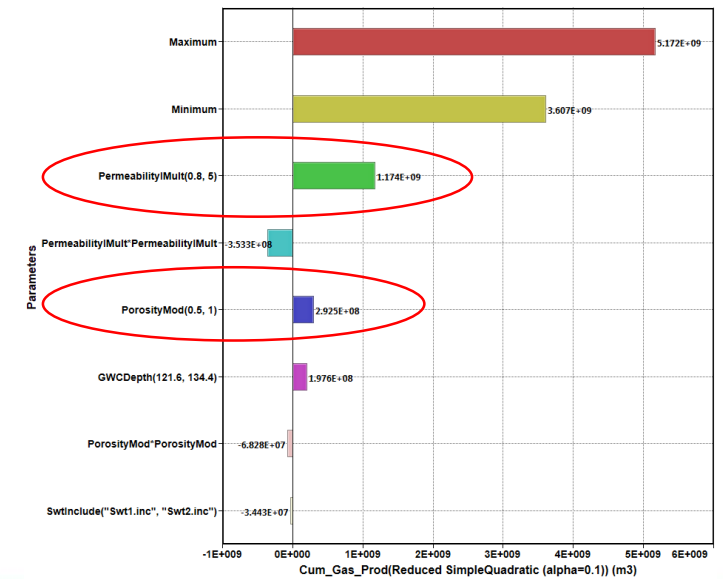
Study Manager SENSITIVITY ANALYSIS \* X

Parameterization

- Parameters
- Hard Constraints
- Pre-Simulation Commands
- Objective Functions
  - Characteristic Date Times
  - Basic Simulation Results
  - History Match Quality
  - Net Present Values
  - Advanced Objective Functions
  - Global Objective Function Candidates
  - Soft Constraints
- Control Centre
  - Engine Settings
  - Simulation Settings
  - Experiments Table
  - Proxy Dashboard
  - Simulation Jobs
- Results & Analyses
  - Parameters
  - Run Progress
  - Histograms
  - Cross Plots

Drag and drop a column header here to group by that column

ID	Generator	Status	Result Status	Proxy Role	Keep SR2	Has SR2	Highlight	GWCDepth	KvKhRatio	Permeabil
1	0	Reuse	Reused	NormalTerminatic	Ignore	Yes	<input checked="" type="checkbox"/>	128	0.9	0.99
2	191	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	129.28	0.7	4.16
3	192	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	122.88	0.52	3.32
4	193	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	126.72	0.7	1.22
5	194	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	121.6	0.88	1.64
6	195	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	133.12	0.76	1.64
7	196	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	131.84	0.94	2.9
8	197	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	129.28	0.94	5
9	198	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	131.84	0.4	4.58
10	199	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	122.88	0.52	5
11	200	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	124.16	0.58	2.48
12	201	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	126.72	0.88	3.32
13	202	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	121.6	0.46	2.06
14	203	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	122.88	0.94	1.22
15	204	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	134.4	0.76	3.32
16	205	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	124.16	1	2.06
17	206	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	121.6	0.82	1.22
18	207	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	125.44	0.4	4.58
19	208	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	125.44	1	3.74
20	209	Response Surface	Complete	NormalTerminatic	Training	No	<input type="checkbox"/>	133.12	1	3.74

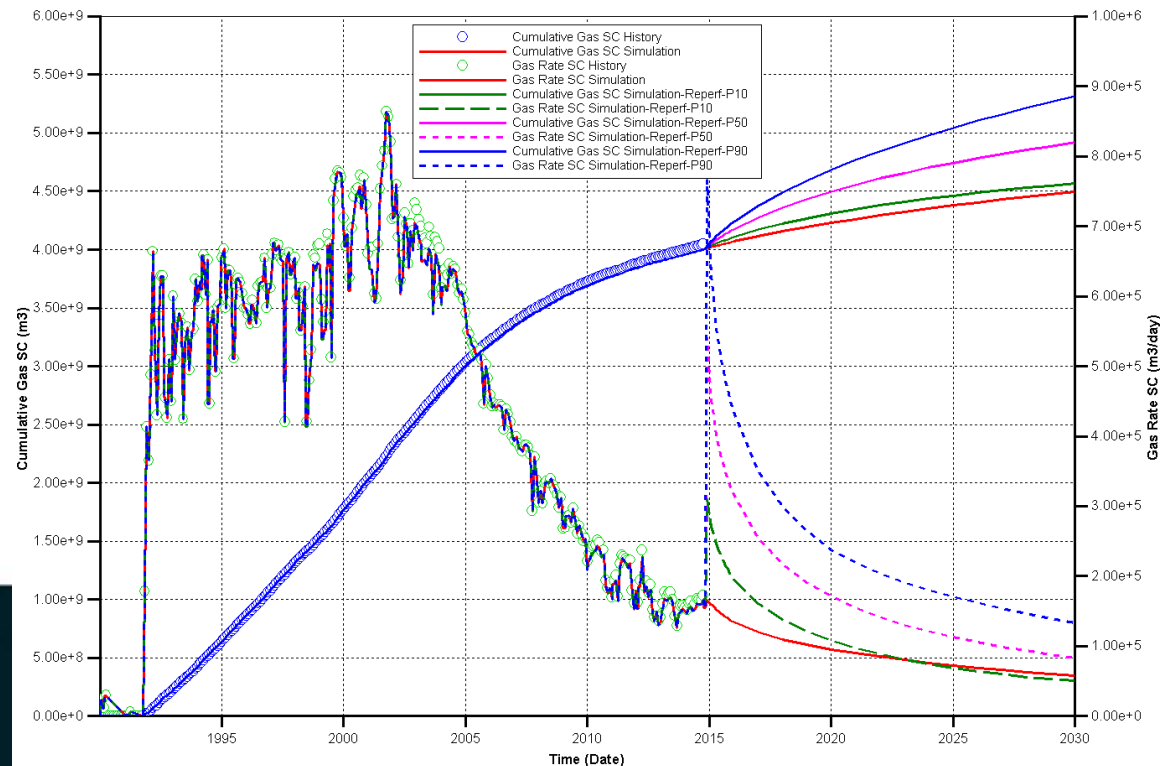
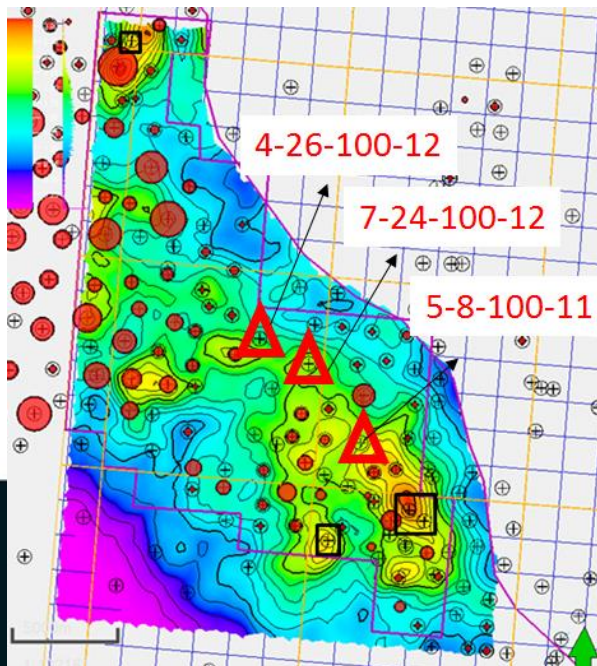


## Equation in Terms of Actual Parameters

$$\text{Cum\_Gas\_Prod} = 6.97765\text{E}+08 + 1.54379\text{E}+07 * \text{GWCDepth} + 5.11879\text{E}+08 * \text{PermeabilityIMult} + 1.40443\text{E}+09 * \text{PorosityMod} - 3.44299\text{E}+07 * \text{SwtInclude} - 4.00544\text{E}+07 * \text{PermeabilityIMult} * \text{PermeabilityIMult} - 5.46261\text{E}+08 * \text{PorosityMod} * \text{PorosityMod}$$

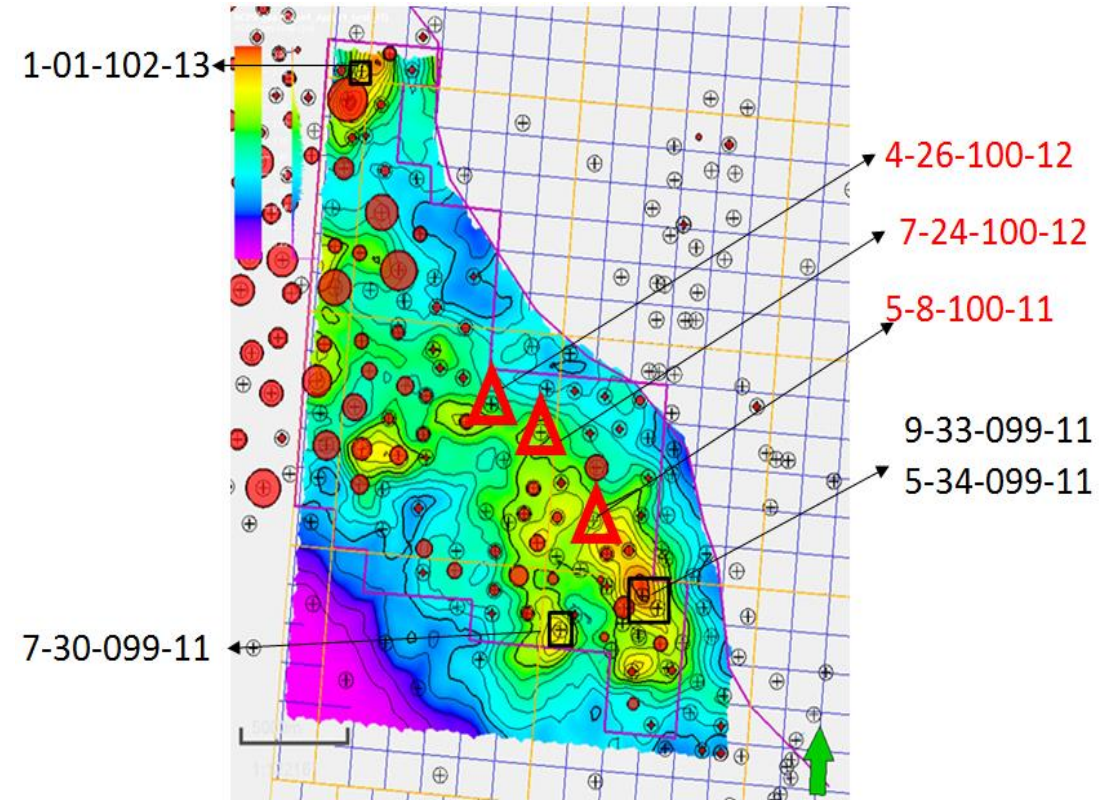
# History Match and Forecasts

- History Match of rates and pressures achieved
- Base case forecast kept 41 wells producing at a set min BHP constraint.
- P10, P50 and P90 forecasts were calculated assuming uncertainty in reactivation success, and reservoir quality variability away from the wells.
- 3 Well candidates were selected for reactivation based on individual well history, log data and HCPV.



# Field Development Plan

- Possible well reactivations.
  - Drilling new wells is not economic
- The selected wells could then be re-fractured and re-completed in order to produce any gas that has been encapsulated by low permeability zones.
- To do this, a fracturing scheme should be designed in order to achieve optimum fracture length and conductivity.

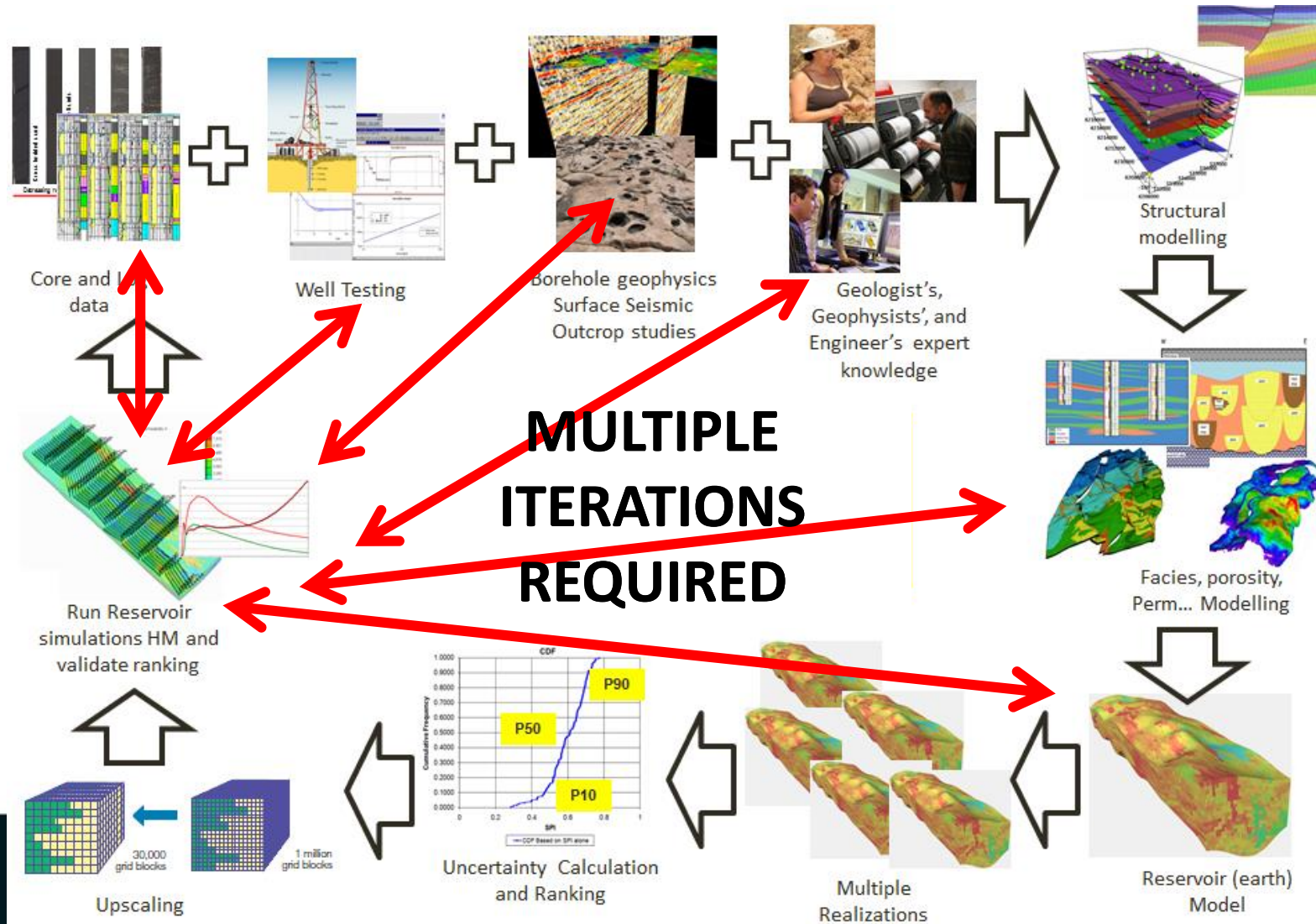


<b>Base Case NPV</b>	<b>\$1,544 Million</b>		
<b>NPV With Re-Activation of 3 wells</b>	<b>P10 (1.6% upside)</b>	<b>P50 (6% Upside)</b>	<b>P90 (10% upside)</b>
	<b>\$1,569 Million</b>	<b>\$1,636 Million</b>	<b>\$1,706 Million</b>

# Reservoir Characterization Workflow



# Reservoir Characterization workflow



# Conclusions

- Data and subsurface interdisciplinary integration allows for better reservoir characterization and understanding of reservoir fluid dynamics.
- Uncertainty analysis is a must as there is no perfect model or unique answers in reservoir characterization.
- Team dynamics are an essential soft skill component that can make a huge difference when working efficiently in a subsurface team.
  - Working with each other not against each other is the key!
- Multiple Iterations are required in order to understand the reservoir better.
- Companies must empower simulation engineers to get the process going.

# Acknowledgements

- Co-Authors:
  - Luz Rodriguez – Senior Geologist at Canacol Energy Ltd.
  - Samuel Quiroga – Geophysicist and Modeller at Cenovus Energy
  - Yemna Kaiser – Reservoir Engineer at the Petroleum Institute, Abu Dhabi
- University of Calgary interdisciplinary specialization in Reservoir Characterization .
  - Supervisors:
    - Dr. Jerry Jensen
    - Dr. Chris Clarkson
- All the software vendors for providing their products to the U of C.



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**THANK YOU!**

**QUESTION?**