Reducing Uncertainty and Increasing Confidence in Reservoir Seismic Characterisation

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Reservoir Seismic Characterisation

- Objective:
  - This presentation explains the use of seismic data for reservoir characterisation
  - It is also shown how uncertainty can be quantified in the reservoir characterisation process
- Key Learnings:
  - To understand the advantages and limitations of combining seismic and well data for reservoir characterisation
  - To establish ways of increase confidence and minimize risk
  - To find how to revise the chance of success (COS)

Presentation outline

Introduction

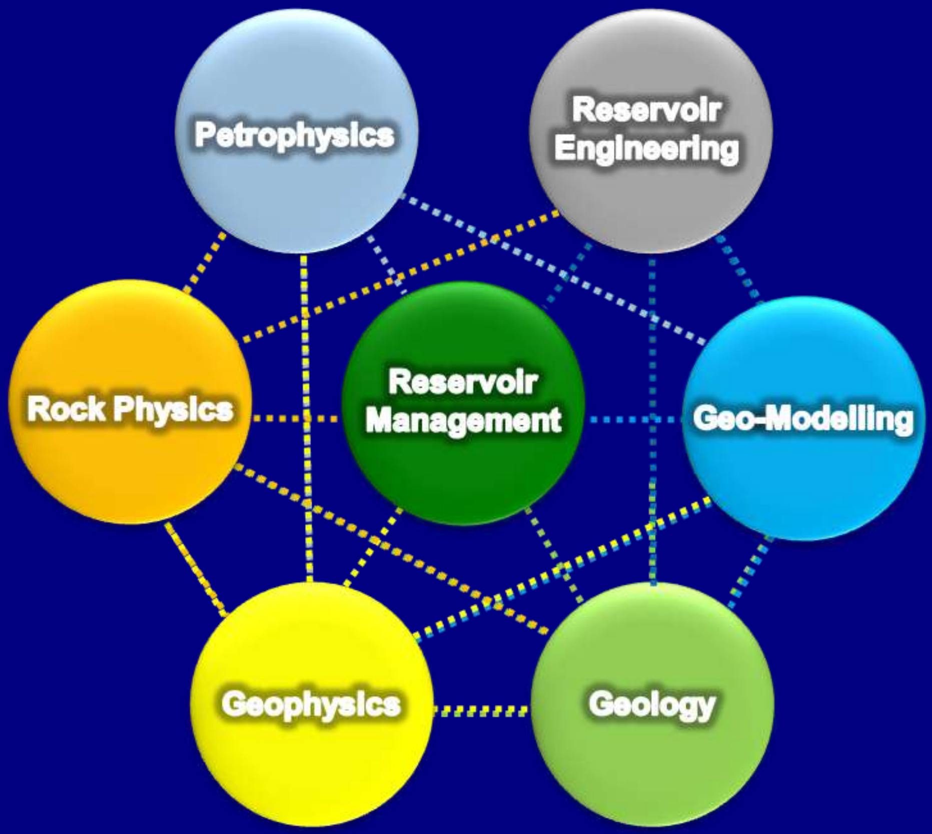
Qualitative versus quantitative analysis

- **What the industry is doing today**
- **What can we do better?**

- **Reliability and Uncertainty**
- **Improving our Chance of success**

What is Reservoir Seismic Characterisation? (RSC)

A multi-discipline effort to combine geological and geophysical well based data with seismic information to achieve accurate 3D reservoir distribution.



Objectives:

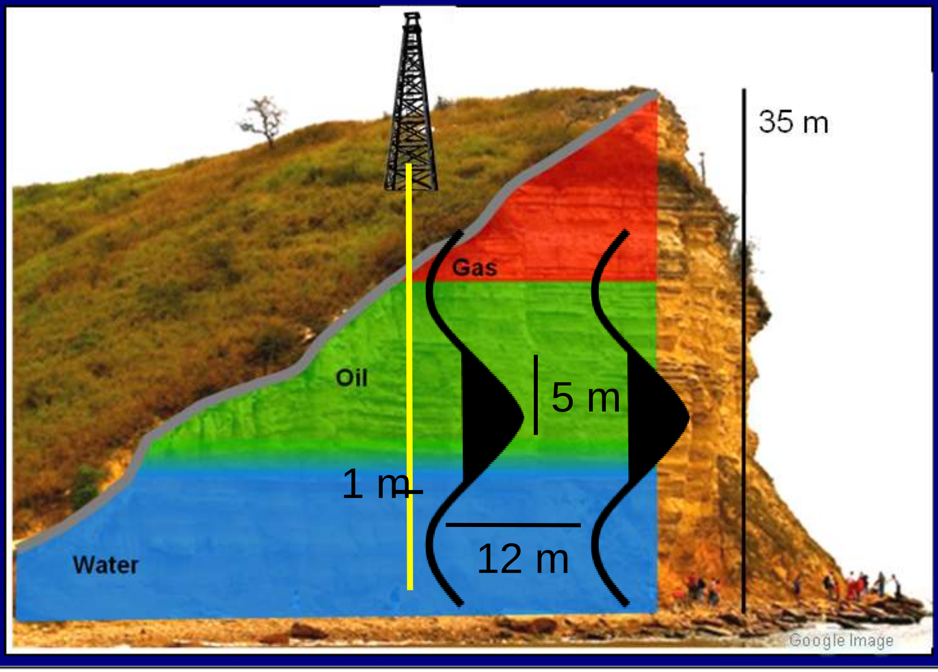
<u>Reservoir delineation</u>: Geometry, faults, and facies distribution.

<u>Reservoir description</u>: Spatial distribution of the reservoir properties.

<u>Reservoir monitoring</u>: Time-lapse evaluation of reservoir production.

Why do we need multiple disciplines?

We need to use all data available!



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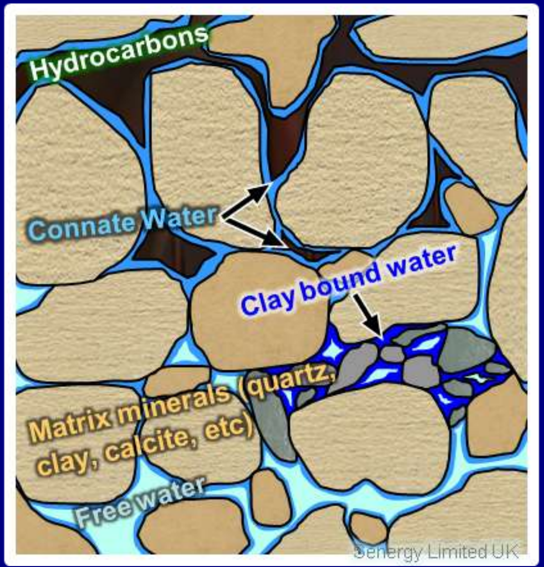
0.05 m



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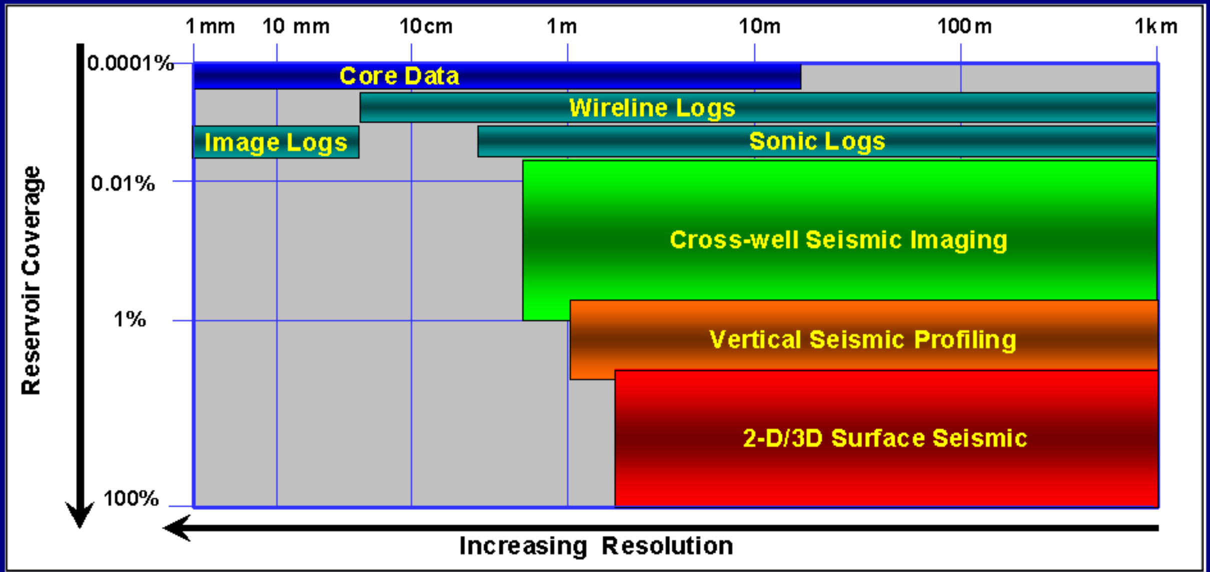
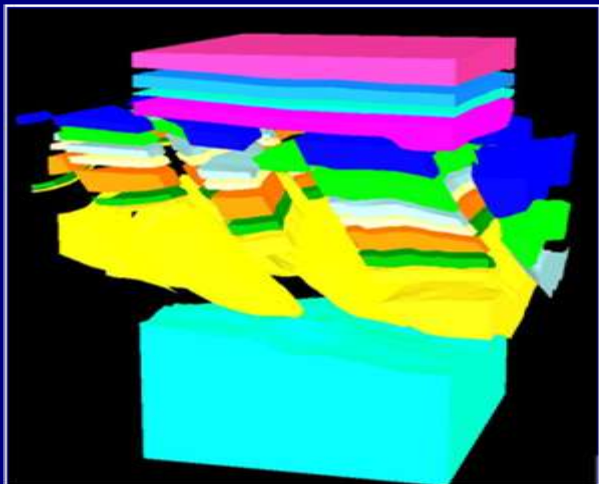
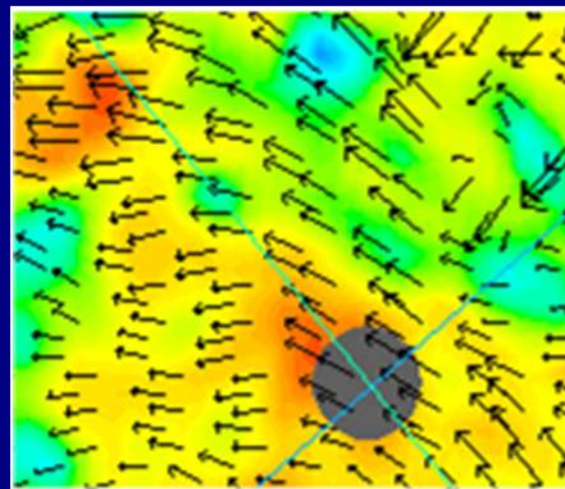


What is the industry doing with seismic these days?

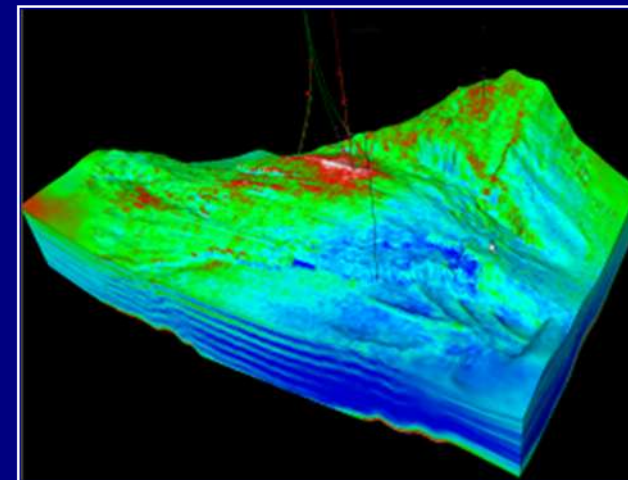
STRUCTURAL FRAMEWORK



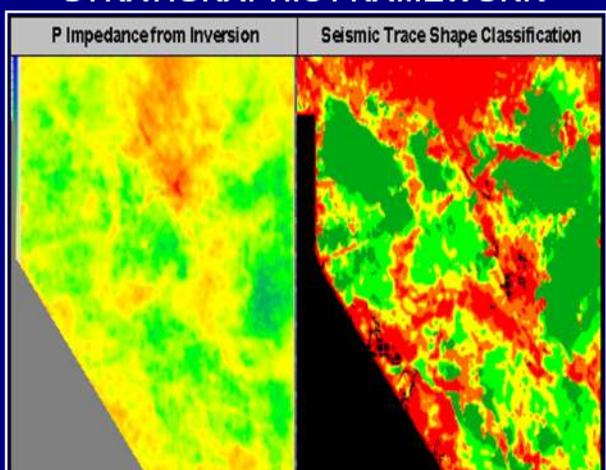
FRACTURE DISTRIBUTION



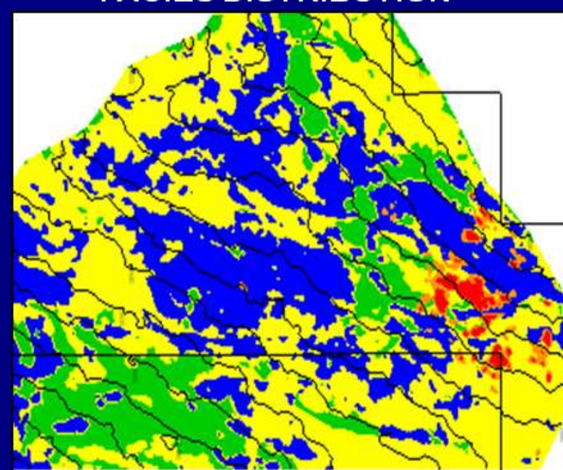
3D PETROPHYSICAL PROPERTIES



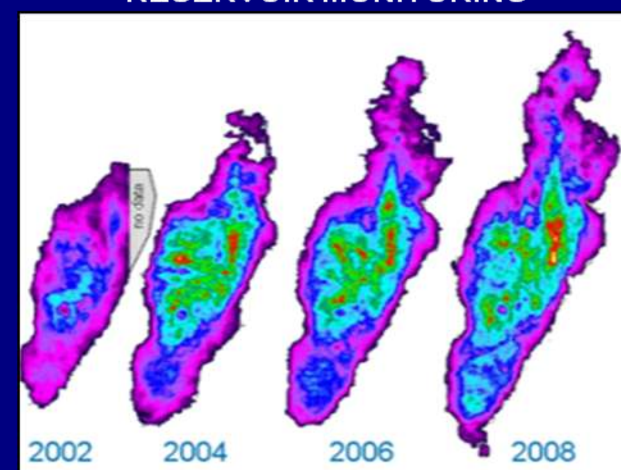
STRATIGRAPHIC FRAMEWORK



FACIES DISTRIBUTION



RESERVOIR MONITORING

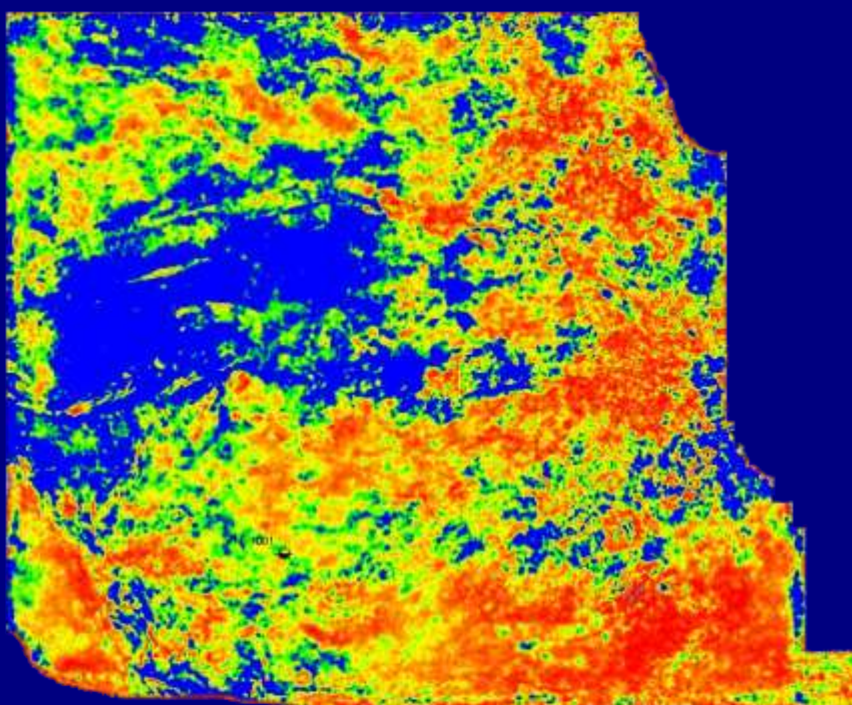


Sandø, et al 2009

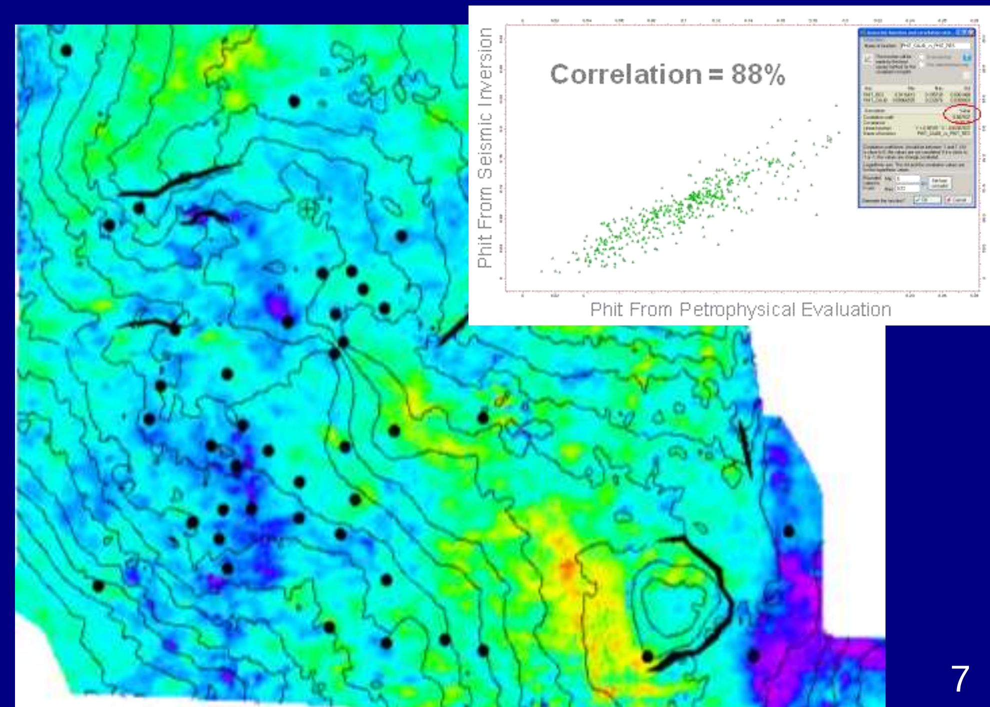
Qualitative versus quantitative analysis

- Qualitative interpretations give trends, “facies” or probabilities as results
- Quantitative interpretation gives estimates of reservoir properties as results
- <u>The same seismic methods like Amplitude versus Offset (AVO) or seismic inversion can be used both qualitatively and quantitatively</u>

Depositional trends (?) from RMS Amplitudes

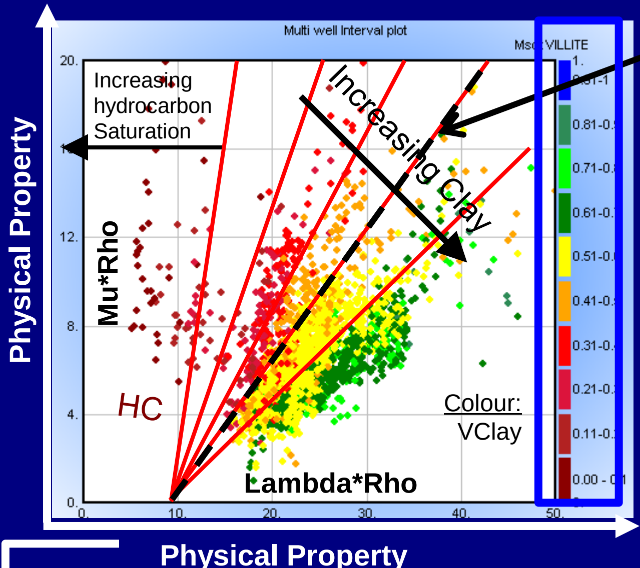


Porosity distribution from seismic inversion



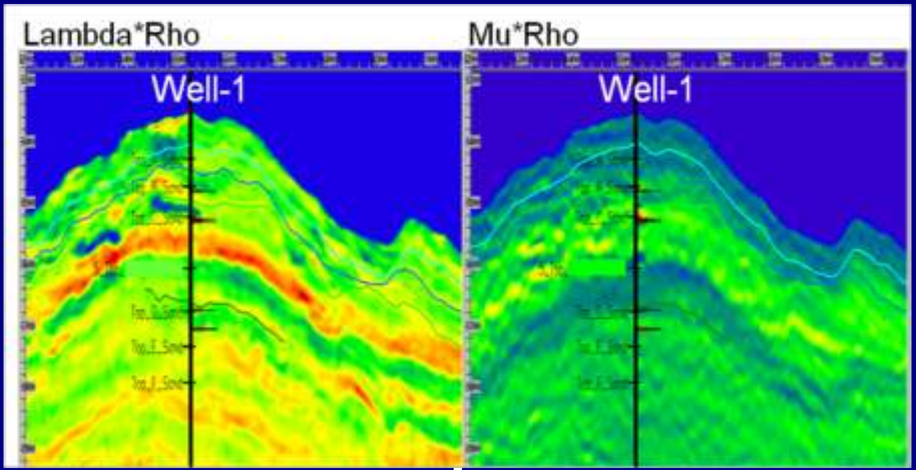
Semi - Quantitative analysis using AVO Simultaneous inversion

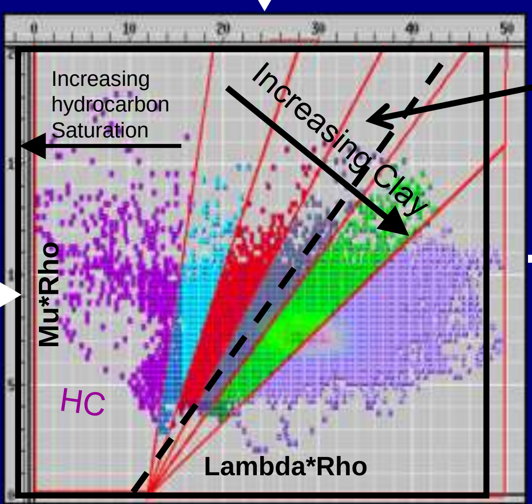
Rock Physics analysis in well data



Rock Physics based interpretation

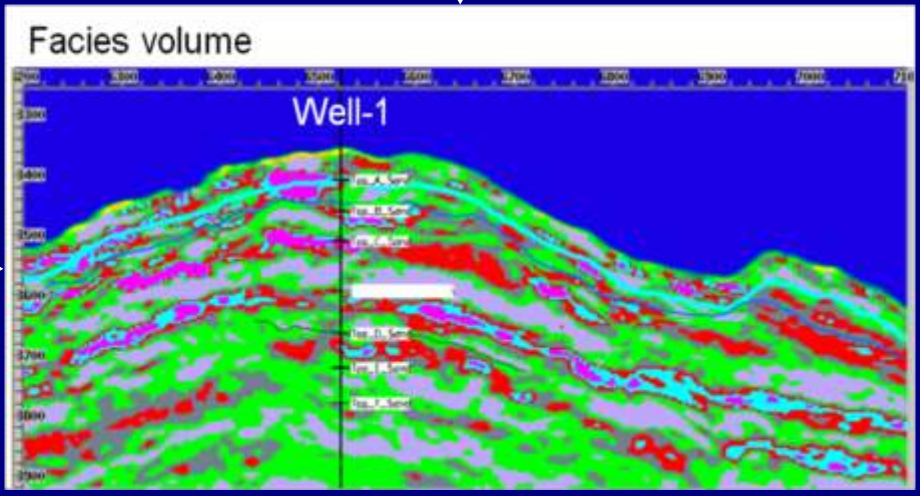
AVO Simultaneous Inversion





Rock Physics analysis in seismic data

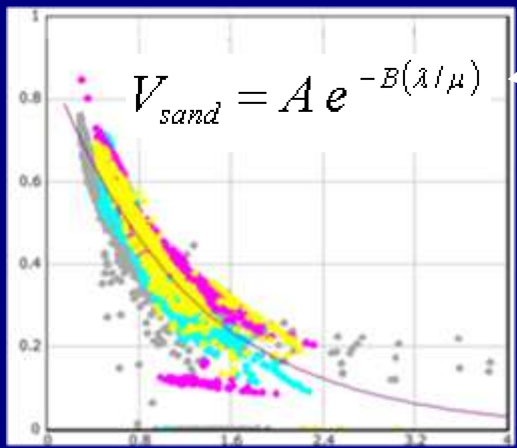
3D facies distribution



Quantitative analysis using AVO Simultaneous inversion

Rock Physics Analysis in wells

Physical Property

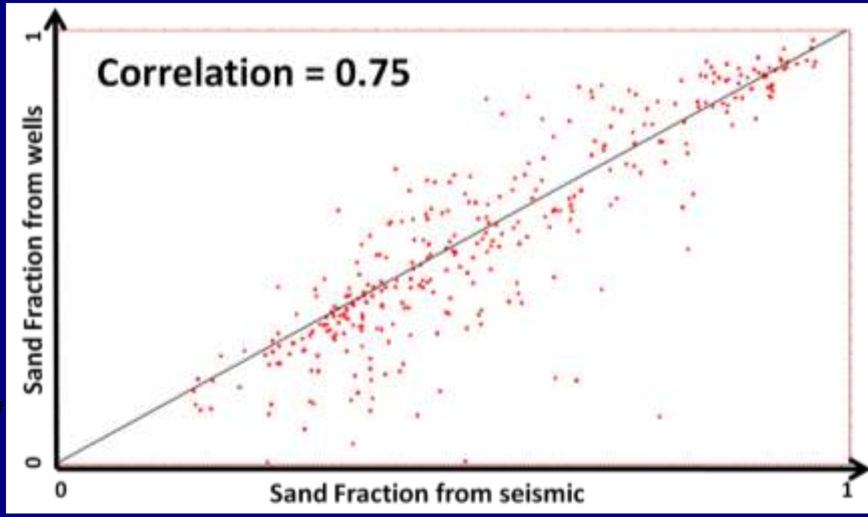


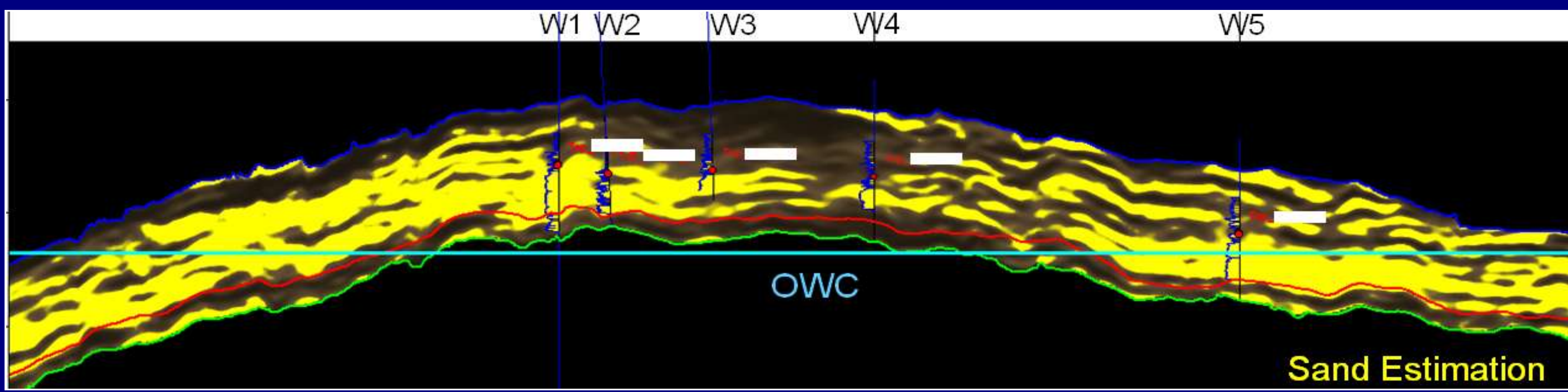
Lambda/mu ratio

Physical Property

Empirical or theoretical equation

Uncertainty analysis

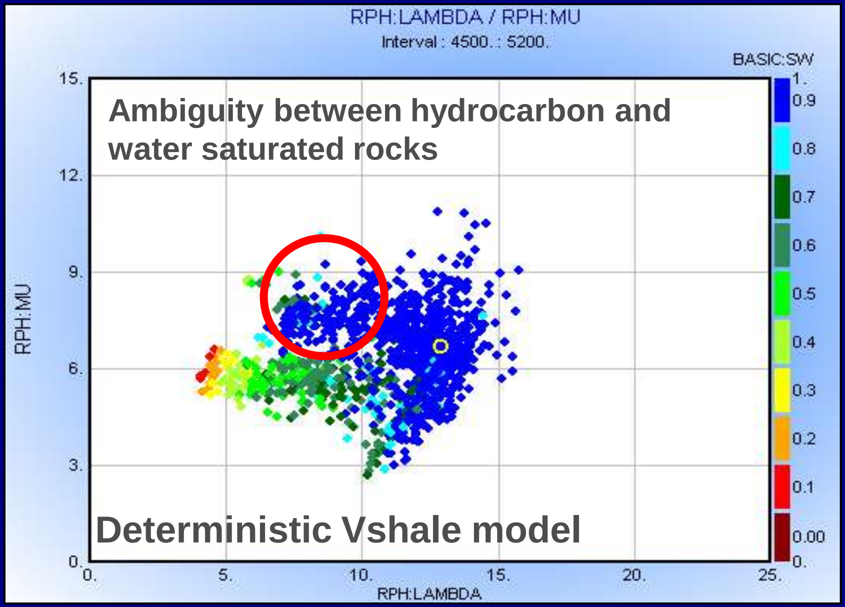


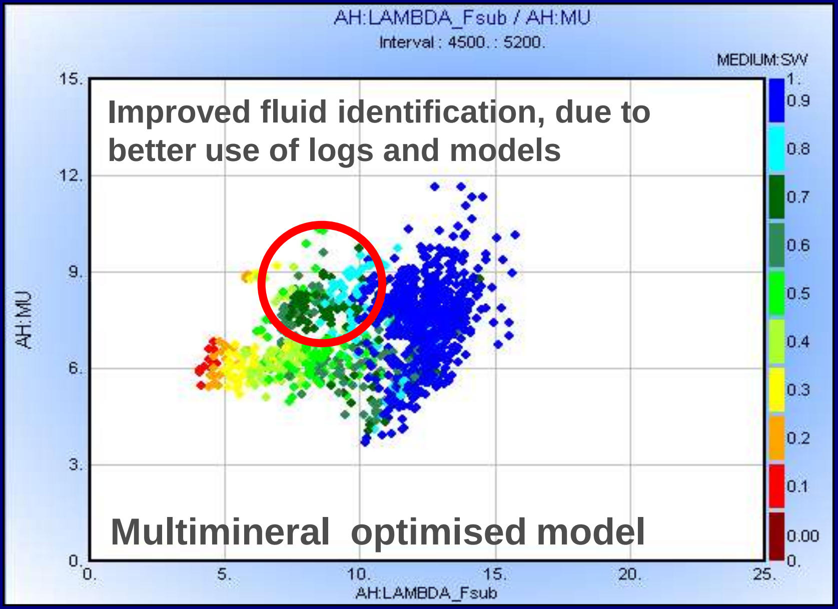


Invert the seismic for rock properties (AVO based methods)

Pitfalls: Use of Petrophysics in Rock Physics

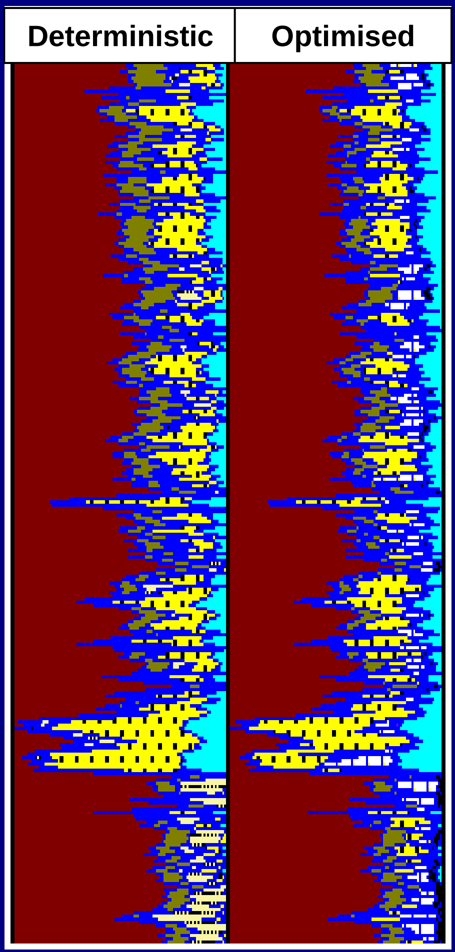
- Geophysicists usually ignore the importance petrophysics and its impact on the reservoir characterisation process





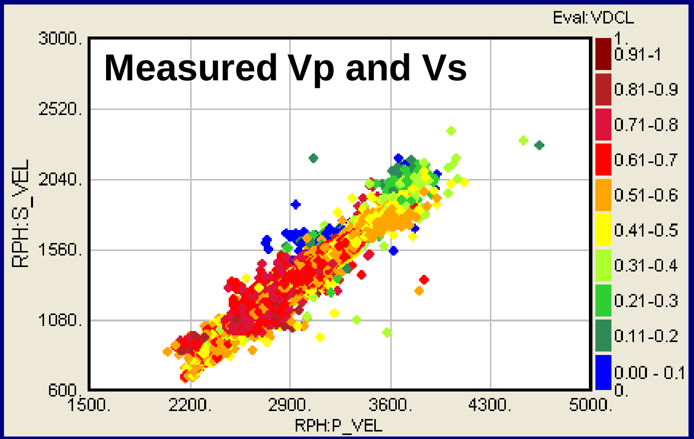
- Ask the next questions
  - Is the petrophysical model reliable?
  - Are we using all the logs?
  - Can we trust the parameterisation?
  - Are the parameters changing from well to well?

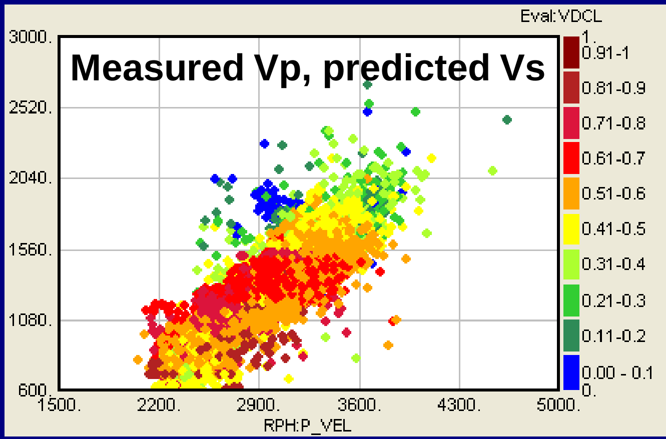
Pitfalls: Petrophysics and seismic modelling, details matter, do not trust your eyes!



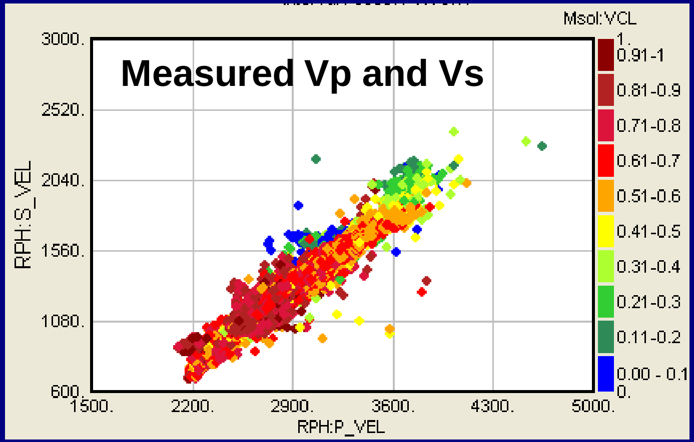
They look the same,
But are they?

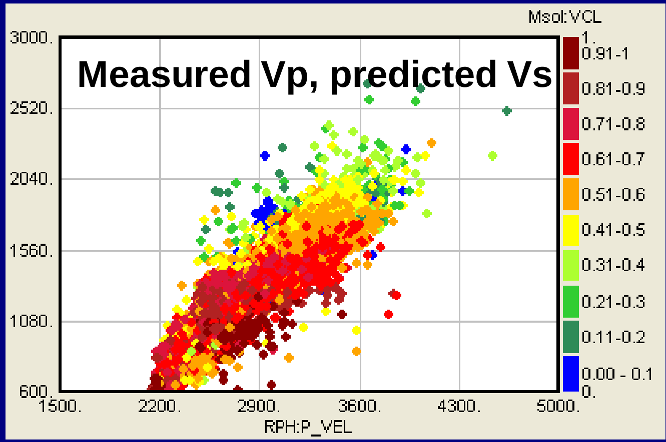
Deterministic model





Mineral Solver





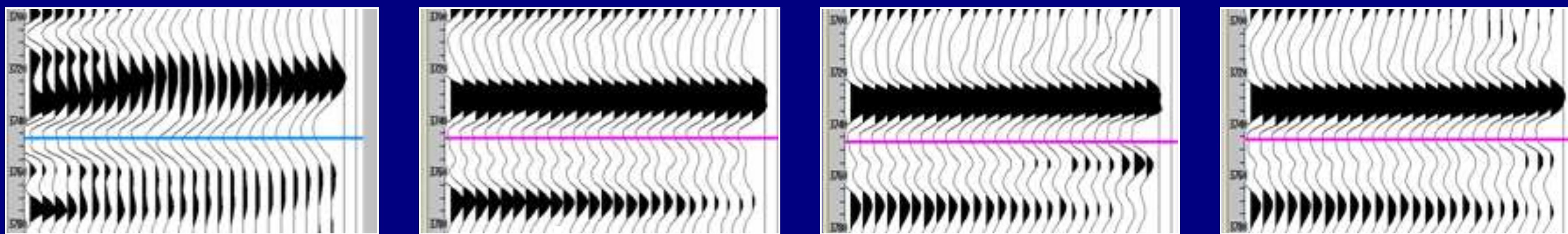
Equation: $V_s = 3.5 - 7 * \phi_T - 2 * V_{cl}$

Pitfalls: Petrophysics and seismic modelling

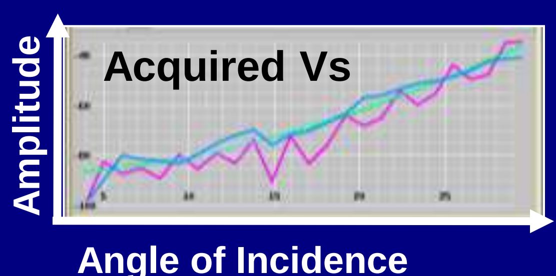
Details matter, do not trust your eyes!

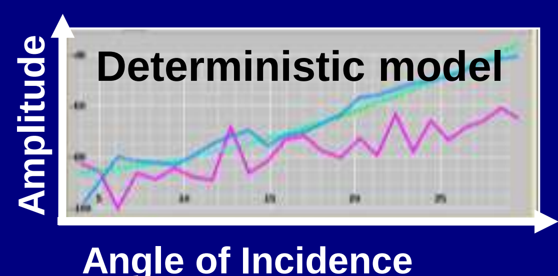
AVO Synthetics

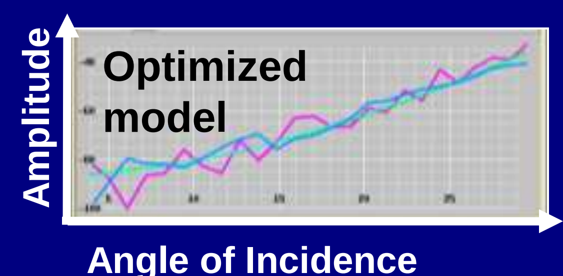
Observed Seismic | **Acquired Vs** | **Deterministic** | **Optimized**



Extracted AVO Responses

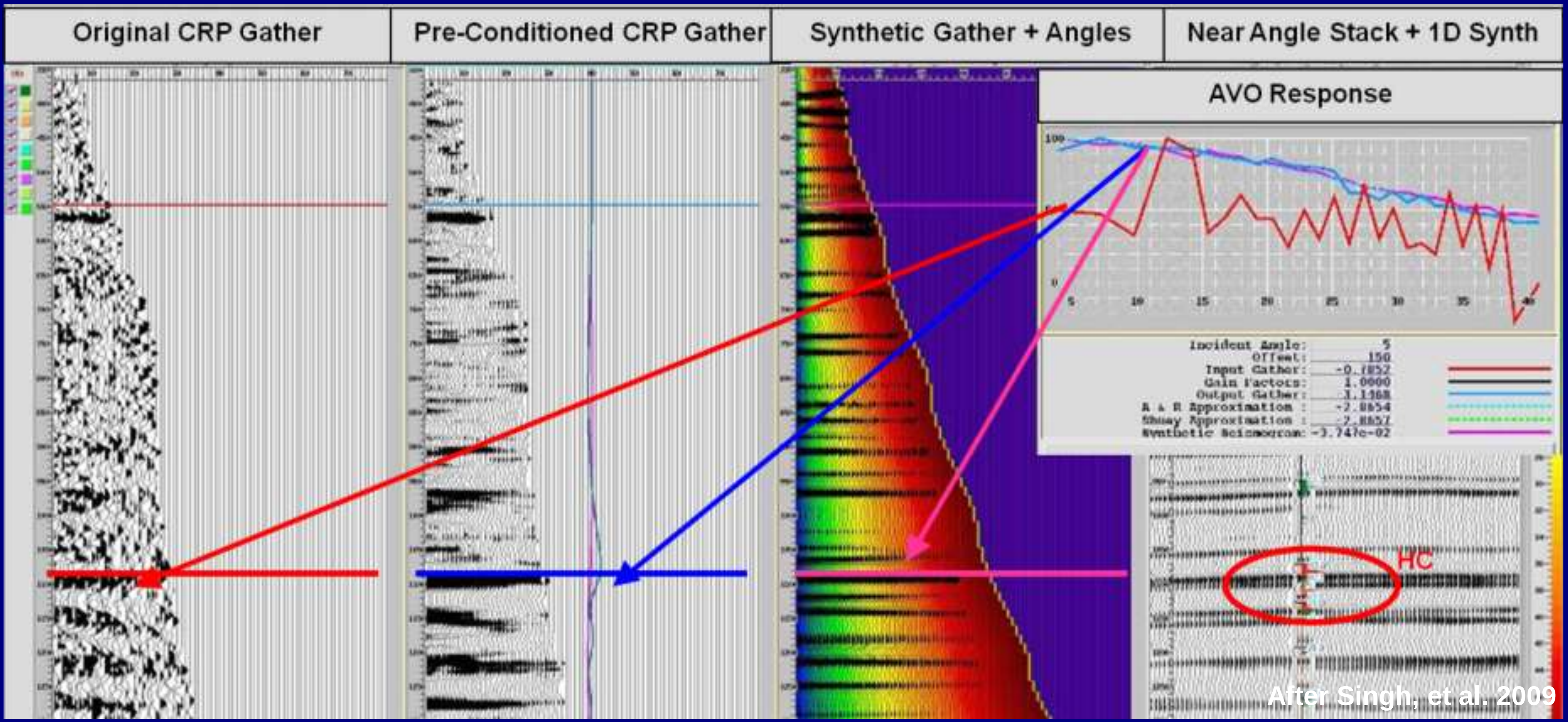






- Small scale details are important for the correct modelling of the seismic
- Our ability to characterise depends upon being able to model correctly!

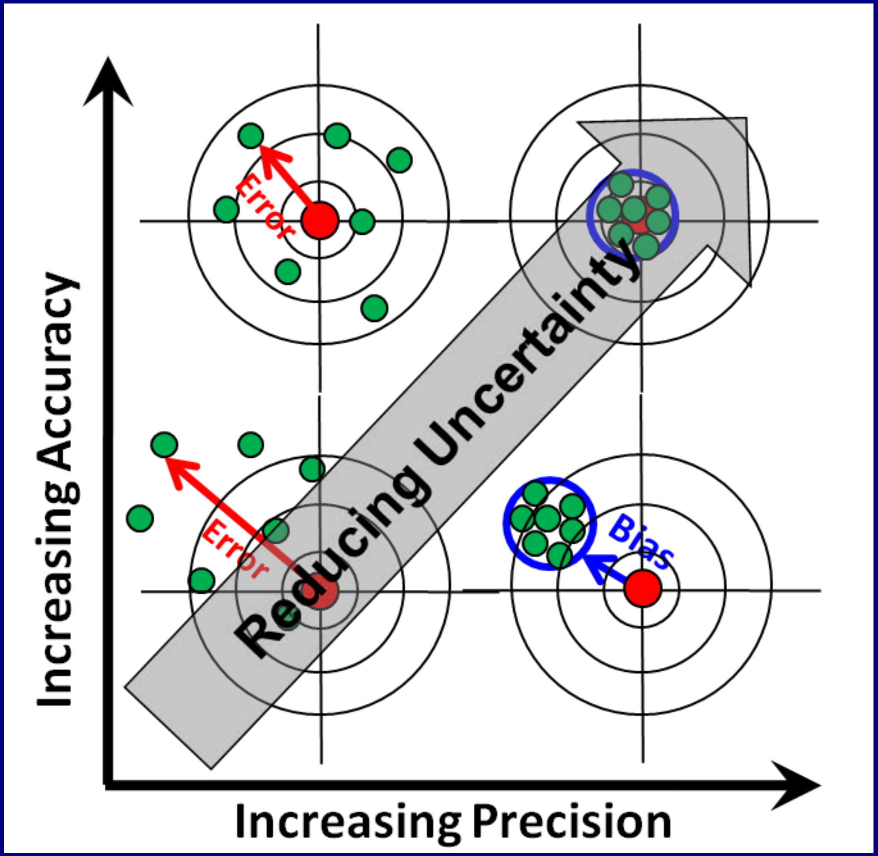
Pitfalls: Seismic data conditioning (preparation for AVO)



- Most AVO/Inversion projects fail because the seismic data is not properly conditioned.. Verify that:
    - The well logs used for the synthetic are correct
    - The observed AVO response matches the model
    - Conditioning parameters are applicable to the full volume
- There are different ways of conditioning seismic, make sure the parameters used are properly documented

What about uncertainty???
First, let's clarify

- ***Precision:*** The closeness of agreement between independent measurements of a quantity under the same conditions
- ***Accuracy:*** The closeness of agreement between a measured value and the "true" value, to know this parameter a <u>calibration</u> process must be performed
- ***Uncertainty:*** The doubt about the result of any measurement, to reduce uncertainty, both precision and accuracy should increase
- ***Tolerance:*** Permissible limit(s) of variation, acceptable magnitudes of errors.



More "precisely"

Quartz watch

Precision: ± 5 seconds per month
Accuracy: Depends on our calibration to a more accurate clock.
Uncertainty: ± 5 seconds with 80 - 90% confidence?

Calibration

Atomic clock

Precision: ± **1** second in 30 million years
Accuracy: 99 % of confidence calibrated to astronomic observations (earth's rotation around the sun)
Uncertainty: ± 3e^{-88} seconds with 99 % confidence

Tolerance: Depends on why I need to measure time:

± 10 minutes

± 0.1 minute!

My requirement of accuracy depends on my use of the time measurement

Uncertainty is often misused...

- Precision is given to us by the method, we can only influence accuracy (it is all about calibration and confidence)
- One can only calibrate using a higher resolution measurement, never the other way around
- Uncertainty cannot be quantified exactly, as the true value is unknown, so we use probability theories.
- We should be talking more about reducing RISK (undesirable outcome) rather than about uncertainty

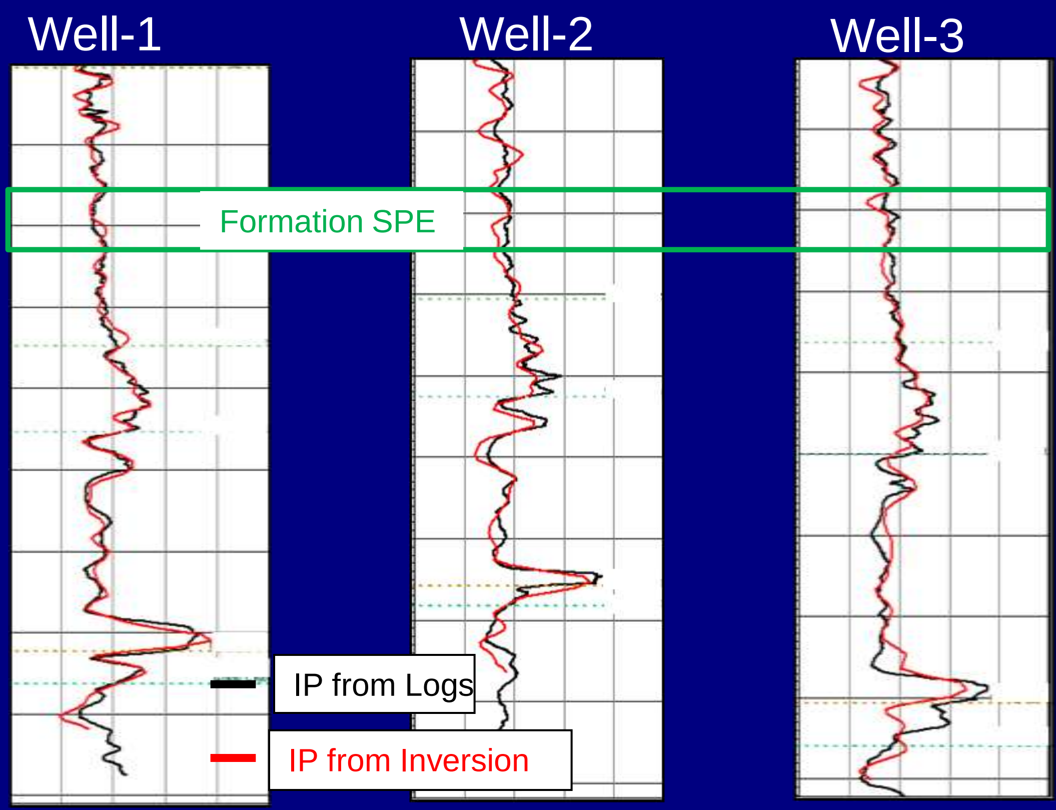
Risk: We don't know what is going to happen, but we do know what the probability is

Uncertainty: We don't know what is going to happen and we do not know what the probabilities are.

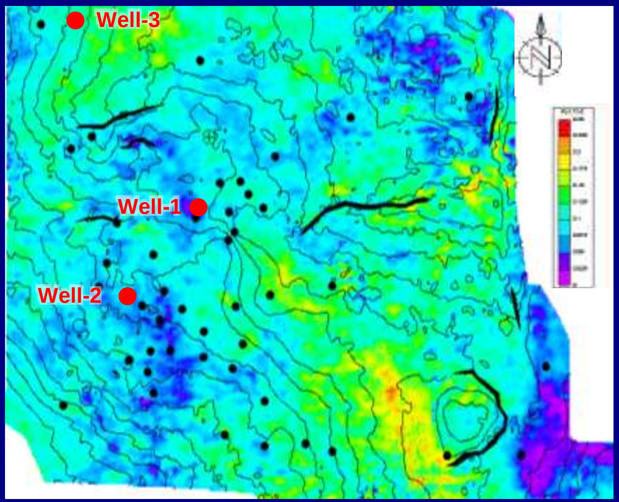
How can we reduce risk?

- Increase the confidence on the input data (e.g. seismic data conditioning)
- Increase the confidence of the interpretation models (petrophysics)
- By interpreting the results independently with other methods and compare
- By blind testing the results
- Adding more data, revisiting the models

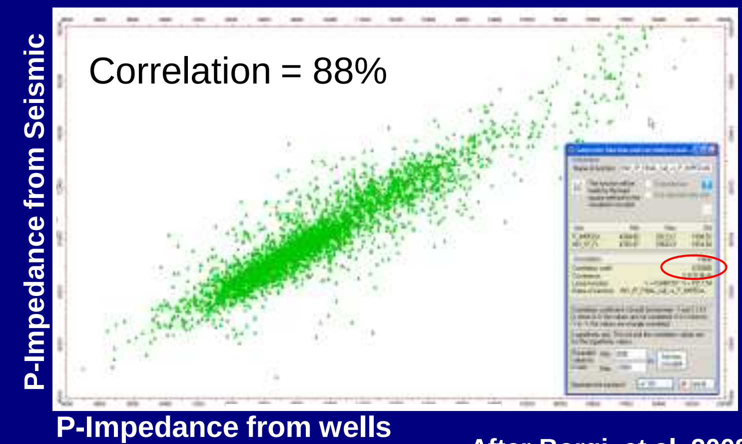
Uncertainty Analysis:
The use of Blind tests to increase confidence



Porosity Map from Seismic



Correlation to well data



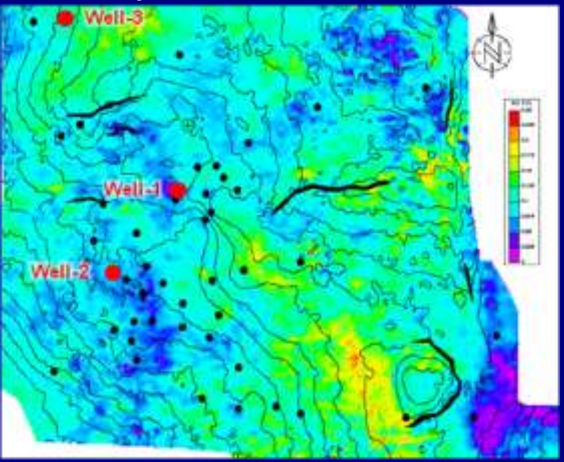
After Borgi, et al. 2008

If we want to quote uncertainty:

The average P impedance at formation SPE at depth Z is 5000 m/s. g/cc ± 100 m/s. g/cc (2%) with an accuracy of 88%

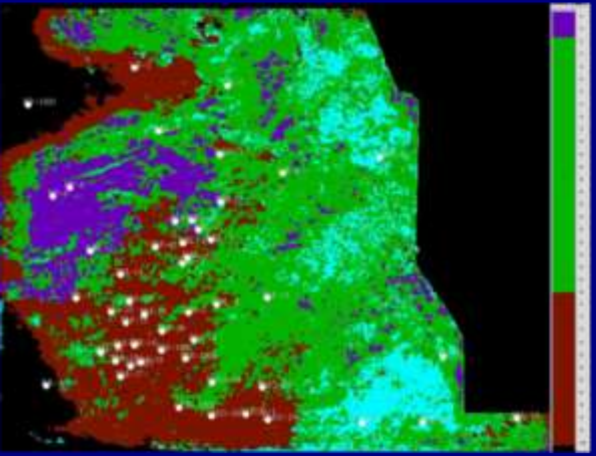
Uncertainty Analysis:
Increasing confidence by measuring twice, diagnostic reliability

Porosity from Inversion



Precision : ±2 units
Accuracy: 88%

Reservoir thickness (neural network)



Precision : ±2 units
Accuracy: 80%

Let’s assume we can find reservoir through either thickness or porosity, so our **detection** chances are:

- Both maps successful: (0.88) (0.8) = **70.4%**

$$P(A \cap B) = P(A)P(B)$$

- One map successful: (0.88)(0.2)+(0.12)(0.8) = **20.7%**

$$P(A \cup B) = P(A \cap not\ B) + P(B \cap not\ A)$$

- Both maps being wrong : (0.12)(0.2) = **2.4%**

$$P(not\ A \cap not\ B) = P(not\ A)P(not\ B)$$

- And the combined uncertainty if using both maps simultaneously is **23.4 % (76.6% certainty)**

$$C = \sqrt{c_1^2 + c_2^2} = \sqrt{(20)^2 + (12)^2}$$

Uncertainty Analysis:
Computing conditional probabilities, Bayes Theorem

- Bayes' theorem links the degree of belief in a proposition before and after accounting for evidence.
- In our case the proposition is called Geological Chance of Success (COS), which tells us the probability that reservoir exists
- Therefore our true uncertainty is the link between the COS and our diagnostic reliability
- The geological chance of success states the probability that reservoir exists, regardless of our ability to detect it

Uncertainty Analysis:
Computing conditional probabilities, Bayes Theorem

- Let's assume we can only find a reservoir using both maps :
  - Our combined uncertainty is: 23.4 % (76.6 % certainty)
  - Let's assume for instance that we have **20** wells in the area **12** of them have reservoir and **8** have no reservoir
  - Our 76.6 % certainty implies that:

RSC Prediction	Positive Outcome (reservoir found)	Negative Outcome (reservoir not found)	Wells
RSC shows reservoir	(12) (0.766) = **9.12**	(12) (0.234) = **2.88**	**12**
RSC shows no - reservoir	(8) (0.234) = 1.9	(8) (0.766) = **6.1**	**8**

RSC Sensitivity	9.12 / (0.19 + 9.12) = 82%
RSC Specificity	6.1 / (2.88 + 6.1) = 68 %

Sensitivity: also called the *true positive rate* measures the proportion of actual positives which are correctly identified as such

Specificity measures the proportion of negatives which are correctly identified

Uncertainty Analysis:

Revising our geological chance of success (COS)

- Let’s assume a COS of **40%** and say we are going to drill 10 new wells, using our **82% sensitivity** and **68% specificity**, our chances are:

Wells: **10**

Hydrocarbons: **4** ← **COS = 40%** → No Hydrocarbons: **6**

RSC shows HC:
(4) (0.82) = **3.3**

RSC shows no HC:
4 – 3.3 **= 0.7**

RSC shows HC:
6 - 4.08 = **1.92**

RSC shows no HC:
(6) (0.67) = **4.08**

Chances of finding reservoir with a positive RSC test:
3.3/(3.3+1.92) = **63 %**

Chances of finding reservoir with a negative RSC test:
0.7/(0.7+4.08) =**14.59 %**

- This means that is possible to revise the chance of success using RSC. In our example, with a dataset **76%** reliable, we can increase the chances of finding reservoir from **40%** to **63%**!!! ($$$$$)

Final message, how to reduce risk and increase confidence with RSC?

Validate

- Many seismic characterisation projects fail because of poor data conditioning or poor use of well logs and petrophysics
- Integrate all data, make sure the inputs are correct

Calibrate

- The correct use of petrophysics is crucial in reservoir characterisation using seismic, small details can make a big difference
- Are we using the correct data to calibrate? Is the model representative of the data available?

Corroborate and calculate risk (revised COS)

- Decrease risk through blind testing and combining independent methods
- Calculate appropriate measurements of uncertainty and reliability
- Put the calculations in the context of chance of success and understand the economic implications (££££)

Thank You!