Modelling Risk and Uncertainty using Multipoint Statistics

Talk given to Geoscience Wales on Thursday 26th March 2026 at RCA Conwy

Barrie Wells
Conwy Valley Systems Limited

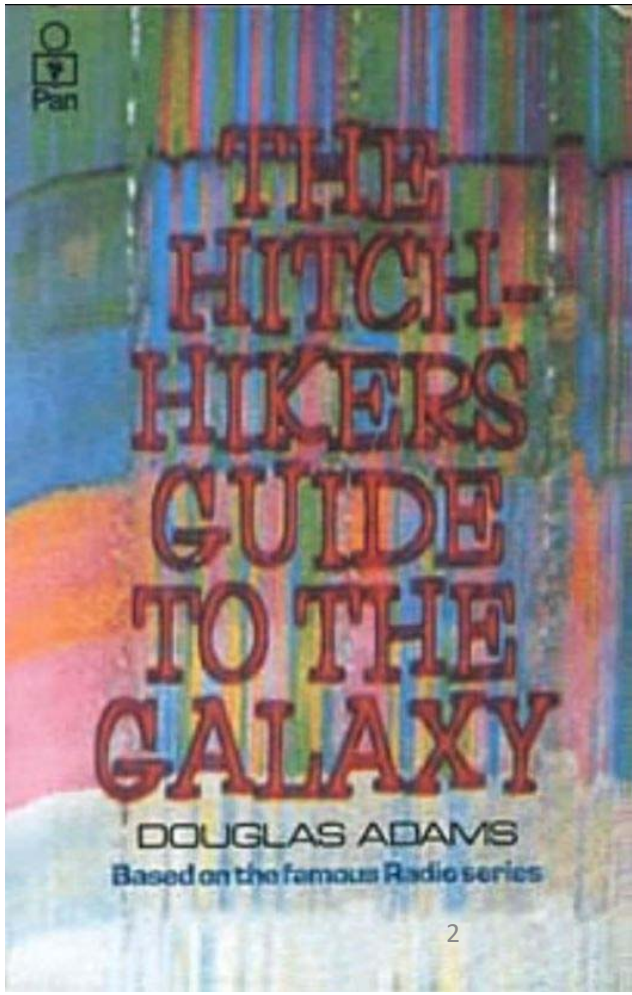
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Things don’t always turn out as we expect:

“First, we thought the PC was a calculator.
Then we found out how to turn numbers into letters with ASCII — and we thought it was a typewriter.
Then we discovered graphics, and we thought it was a television.
With the World Wide Web, we've realized it's a brochure.”

(Douglas Adams, author of the BBC radio series "The Hitchhiker’s Guide to the Galaxy")

Douglas Adams died in 2001. What would he say now?



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Risk and Uncertainty

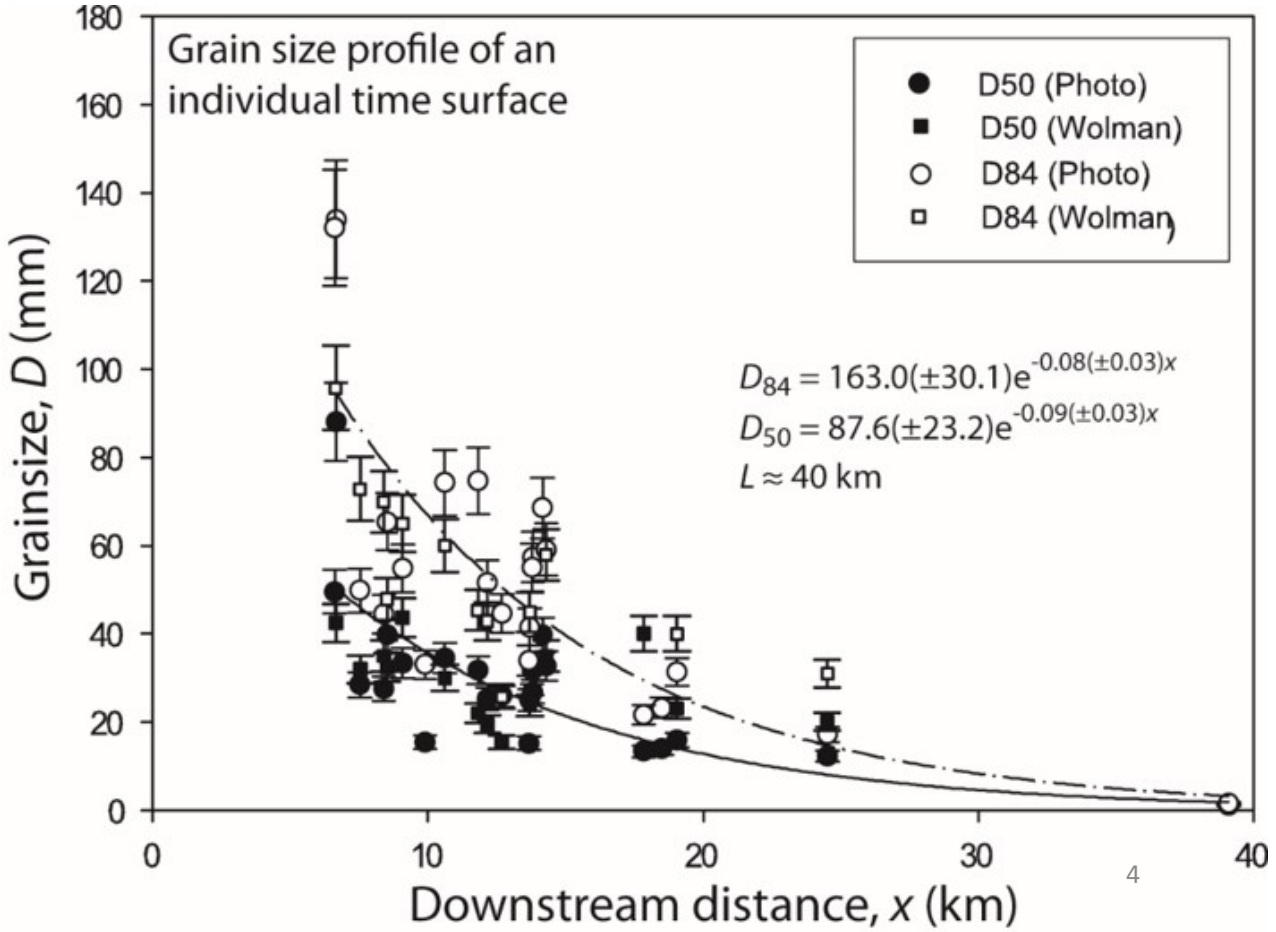
The mathematical modelling of uncertainty, or risk, is based on the premise that any measurement consists of a deterministic component and a stochastic component: i.e. that which we know (or think we know) and that which we don't (the uncertainty, consisting of the "known unknowns and the unknown unknowns").

Although we don't know (by definition) how large this uncertainty is in any specific instance, mathematical statistics provides tools for modelling it in general.

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Deterministic versus Stochastic:

This distinction, between deterministic and stochastic components of a measurement, is implicitly recognised in standard representations of data:



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Kriging and the start of Geostatistics:

Danie Krige recognised the usefulness of this distinction when he was trying to account for a noticeable bias in predictions of gold grades, using classical modelling methods.
The Kriging predictor looks familiar:

$$\phi_{new} = \sum_{i=1}^{n} \left(\lambda_i \left(\phi_i - \bar{\phi} \right) \right)$$

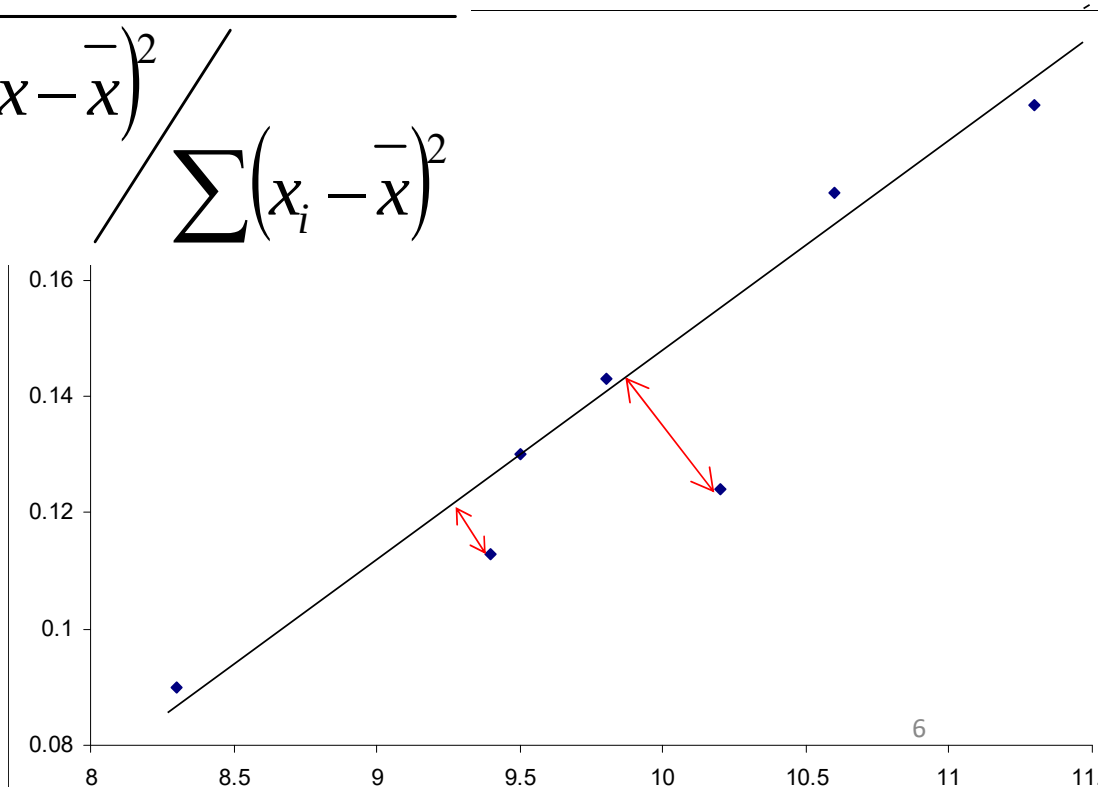
but it was novel because the weights are calculated from variance minimisation.

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Geostatistics and Uncertainty:

Both Kriging and Linear Regression are based on variance minimisation. Uncertainty (or confidence) in linear regression prediction can be calculated from:

$$y = a.x + b \pm t\left(\frac{\alpha}{2}, n-2\right).s(y \mid x).\sqrt{1 + \frac{1}{n} + \left(x - \bar{x}\right)^2 \Big/ \sum\left(x_i - \bar{x}\right)^2}$$



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Calculating Variance using Kriging

The (simple) Kriging estimated value at a new point is found from the Kriging weights as:

$$\phi_{new} = \sum_{i=1}^{n} \left(\lambda_i \left(\phi_i - \bar{\phi} \right) \right)$$

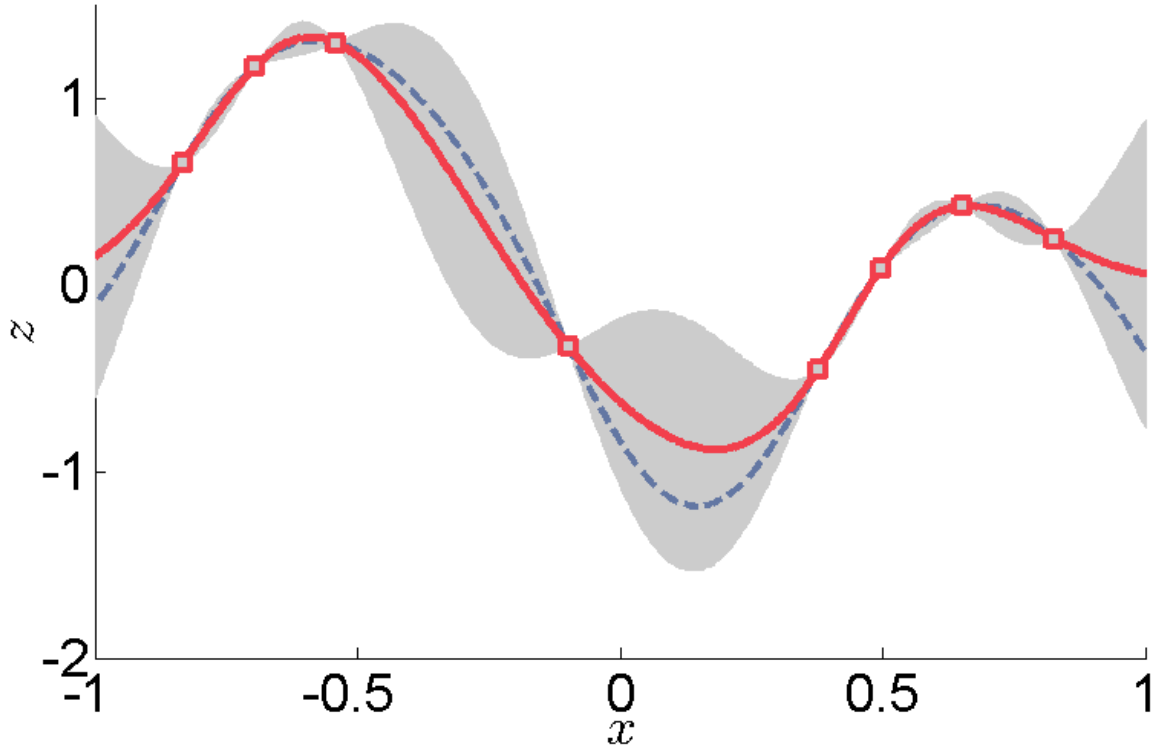
but the weights are found by inverting the variance minimisation:

$$\sigma^2 = W(0) - \sum_{i=1}^{n} \left(\lambda_i W\left(u - u_i \right) \right)$$

which then gives us the equivalent error measure for Kriging.

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How useful is the Kriging Variance in Practice?

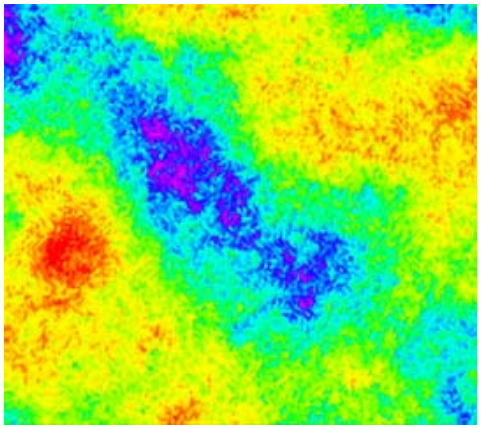


Example of consultant borrowing the client's watch to tell them the time?

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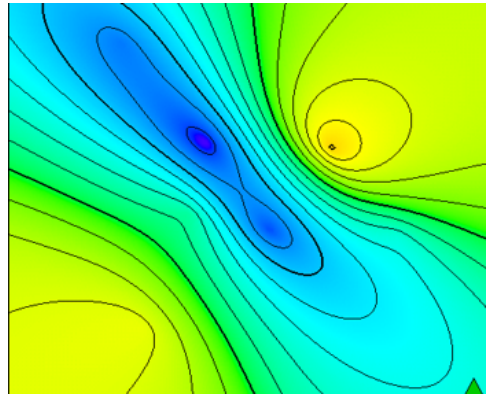
Geostatistics uses the Kriging Variance to put Uncertainty Modelling on a Sound Basis

Representative (what we **might** see): Stochastic Simulation

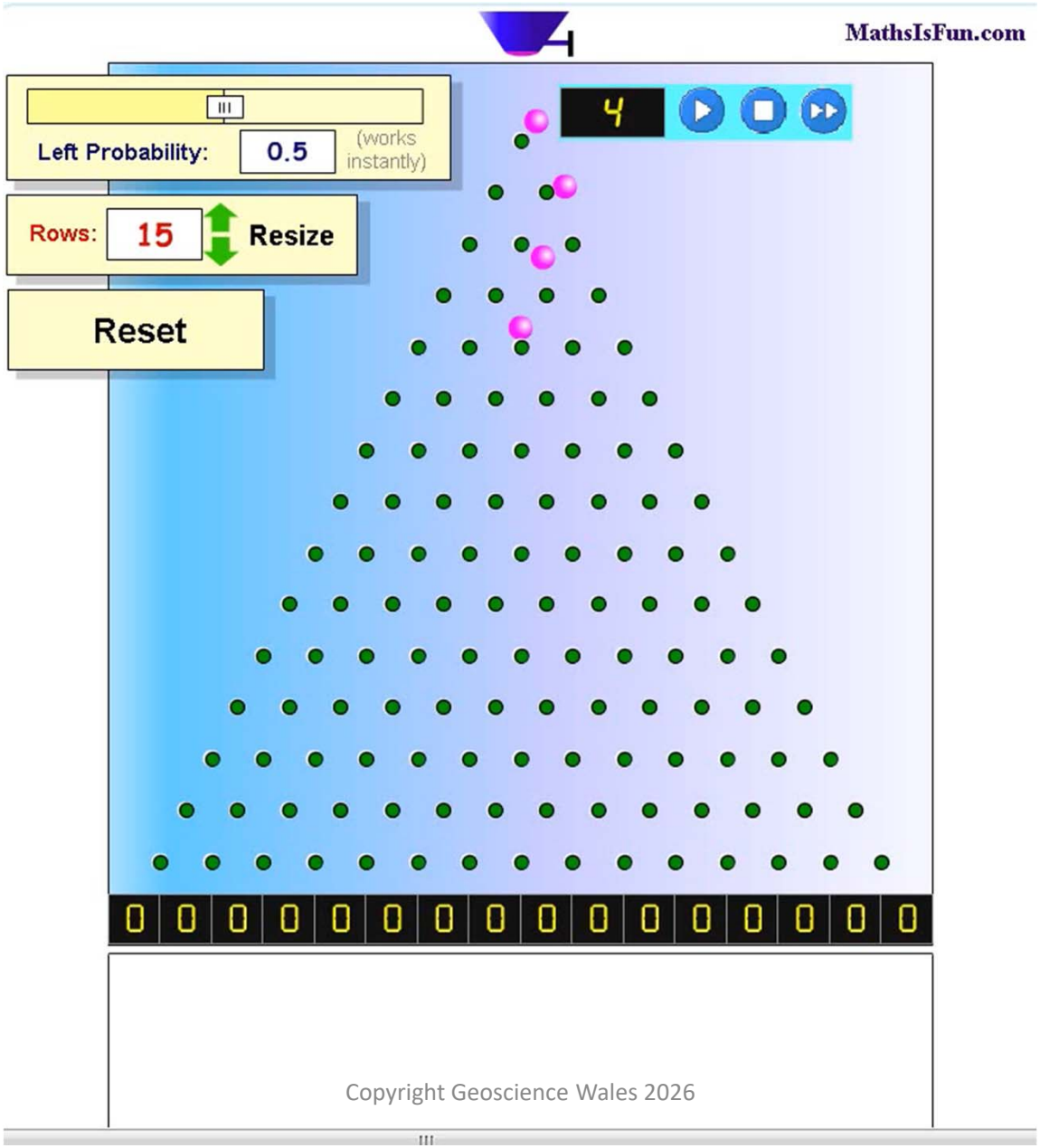


versus

Most Likely (what we'll **probably** see): Kriging



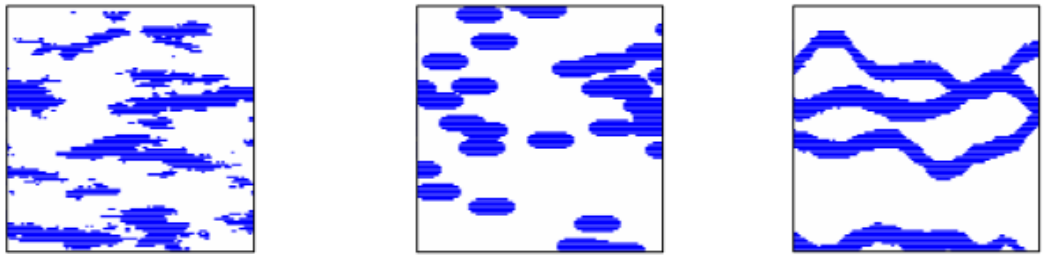
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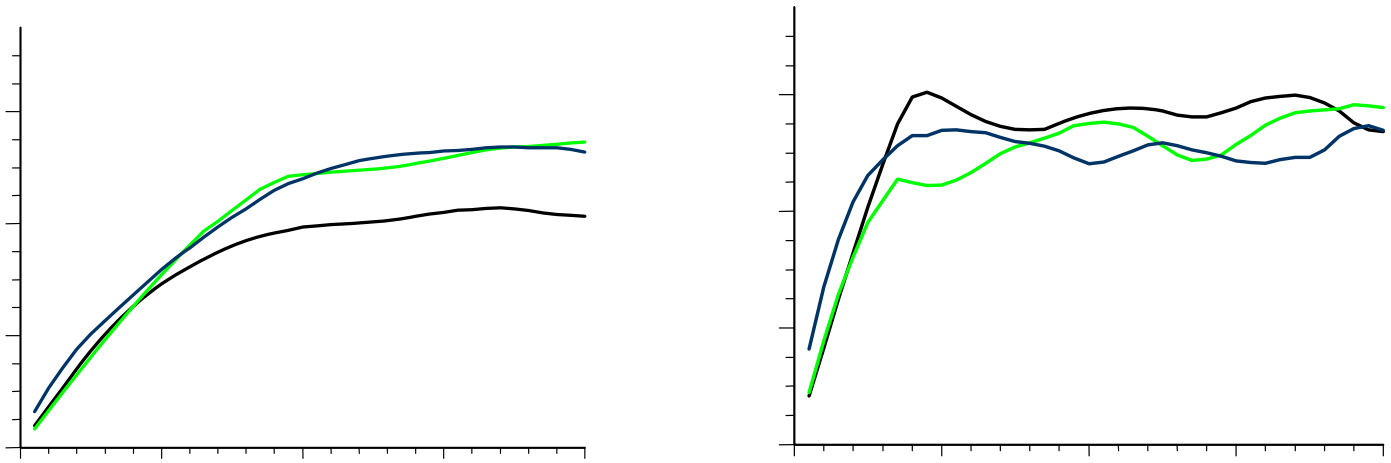
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Limitations of traditional geostatistics:

Important differences in connectivity:



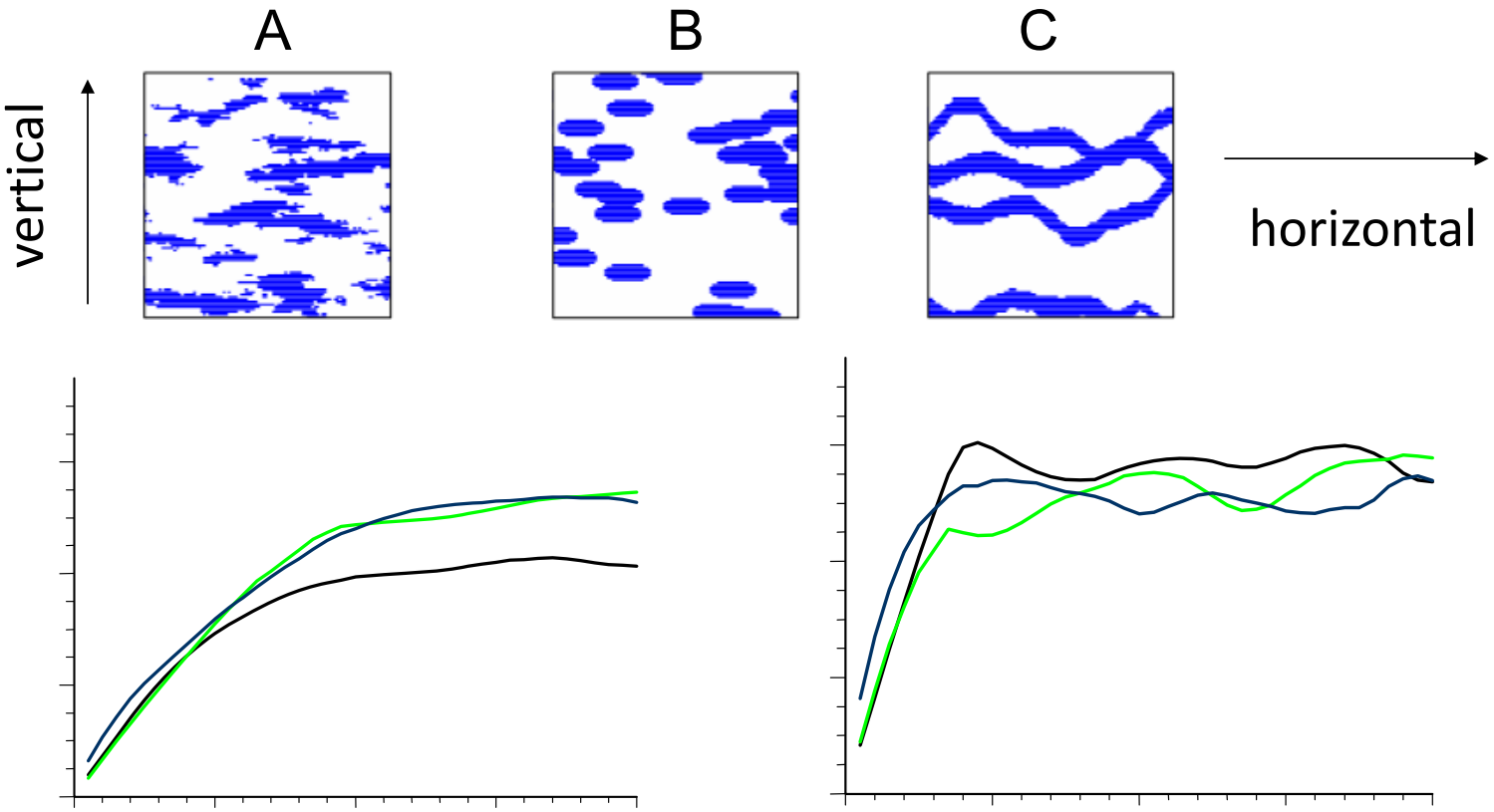
are not always fully reflected in the semivariogram:



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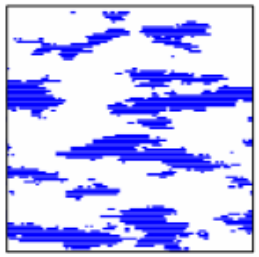
Semivariogram modelling:

Which of the 3 semivariograms (green, blue, black) represents which of the three geological models (A, B, C)?

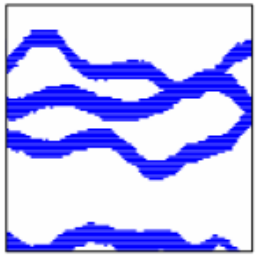


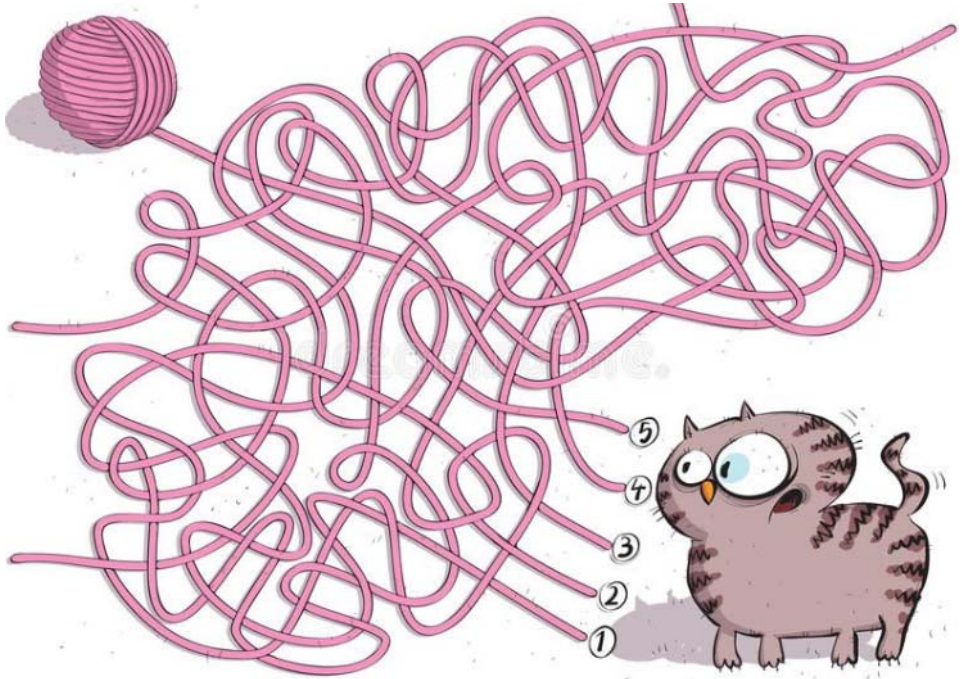
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Can we match the schematics with their semi-variograms?

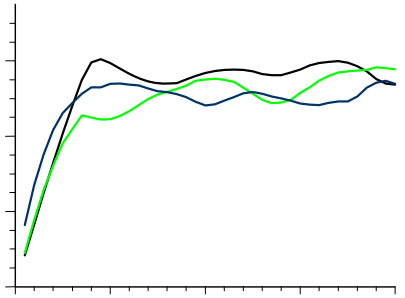






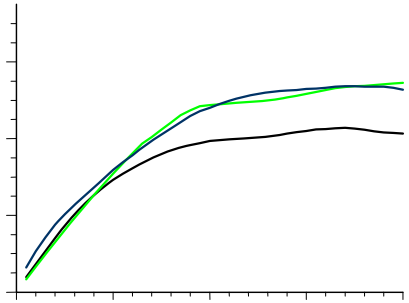


Black



Blue

Green



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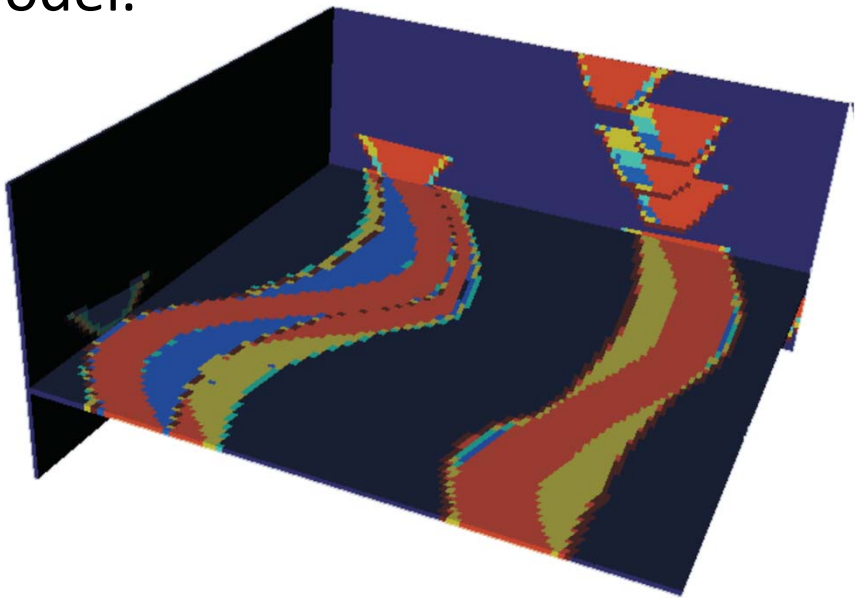
Making MPS Work for Modelling Uncertainty

When we create a facies model in MPS, we impose our own ideas and interpretations on the model. It embodies our best deterministic knowledge but has no information about how likely it is that this is correct.

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Typical training image: e.g. channels

An MPS training image can be made to match the available data and hence be geologically representative of our best estimate – the deterministic or expected model.



We cannot make multiple training images that are representative of the uncertainty. MPS has lost the rigorous basis for modelling uncertainty and risk.

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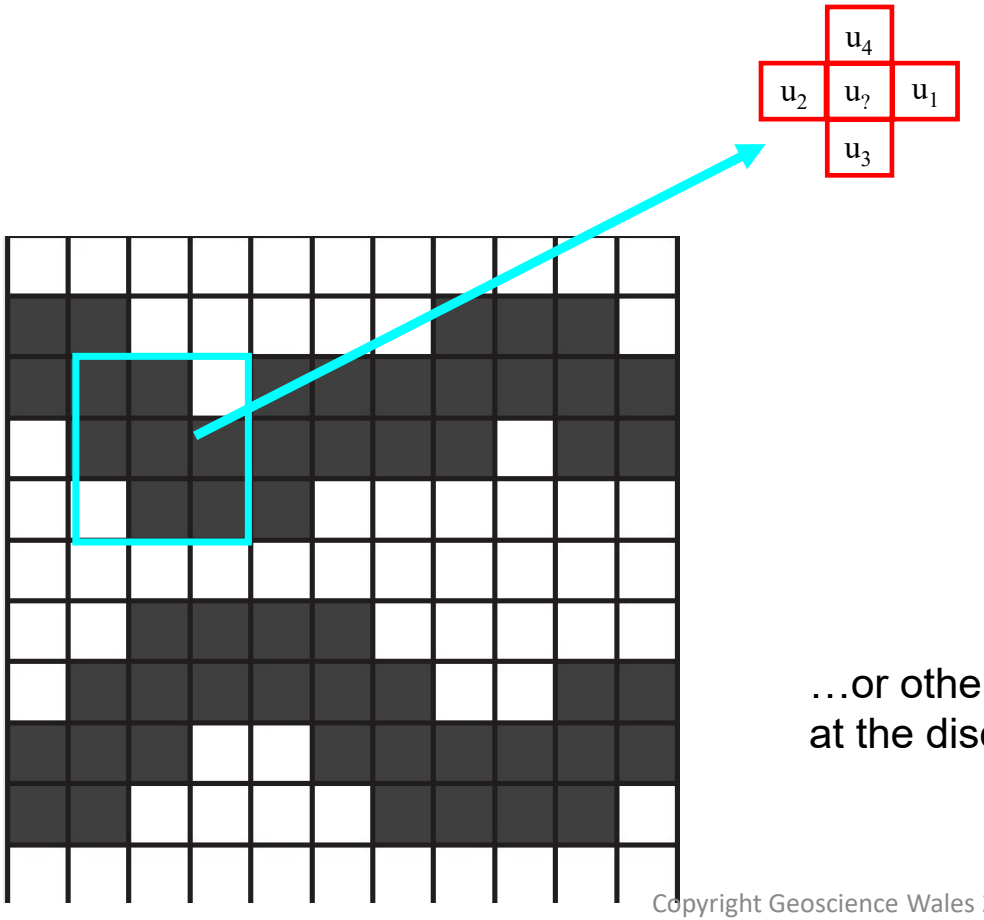
Making MPS Work for Modelling Uncertainty

When we create a facies model in MPS, we impose our own ideas and interpretations on the model. It embodies our best deterministic knowledge but has no information about how likely it is that this is correct.

This intrinsic shortcoming is compounded by the method's implementations in software, which further remove the availability of a method for determining the likelihood.

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Setting up MPS in Petrel: Pattern extraction:





$$p(\mathbf{u}; \text{black_pore} \mid d_n) = \frac{i}{n}$$



$$p(\mathbf{u}; \text{white_matr ix} \mid d_n) = \frac{j}{n}$$



Probability: e.g.

0.75 sand, 0.25 shale

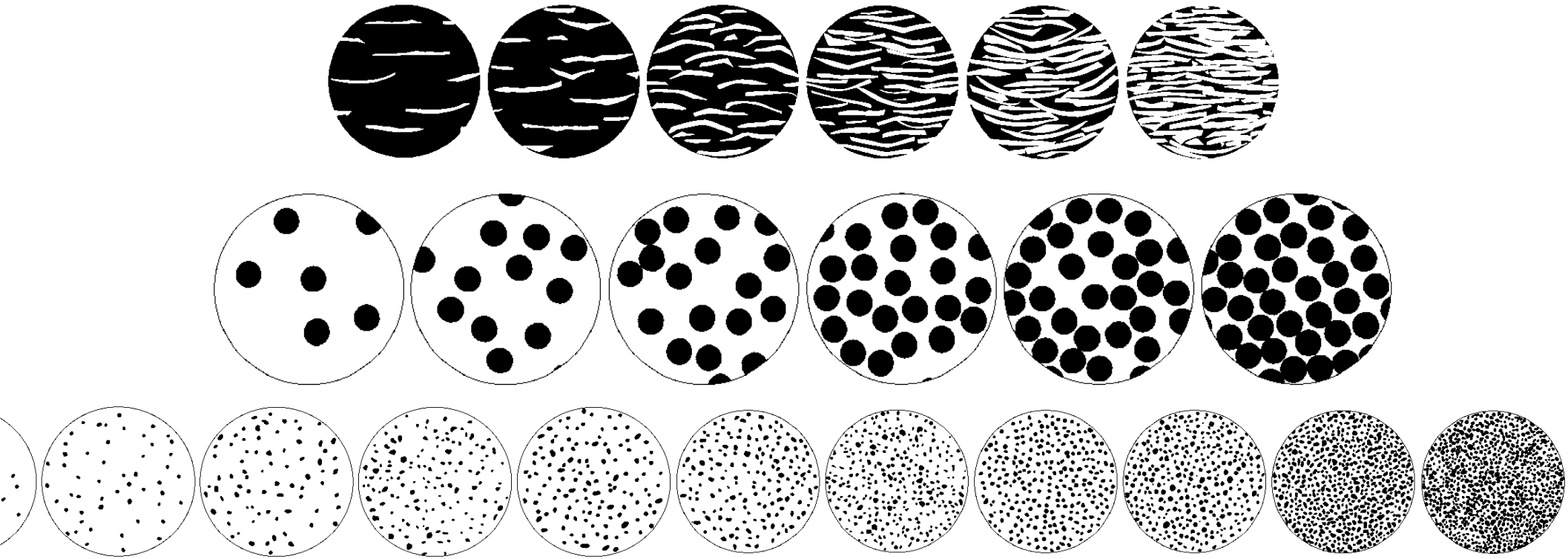
…or other shapes, other sizes, it's all at the discretion of the modeller.

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Setting up MPS in Petrel: Honouring Data

Which is correct, the pattern or the data?

How good are we at estimating relative percentages when drawing?



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Making MPS Work for Modelling Uncertainty

If we had a way to create multiple, equally likely realisations at the reservoir scale, that accounted for the intrinsic uncertainty in the basin-scale controls on sedimentation and acknowledged the physically-imposed interrelationships amongst parameters, we could recreate the theoretical underpinning of risk analysis in reserves estimation.

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What is Needed

What is needed is a theoretical understanding of the interactions amongst the critical parameters controlling or influencing facies creation, that would allow us to create more general rules for modelling uncertainty, given a modeller's best estimate (the deterministic component).

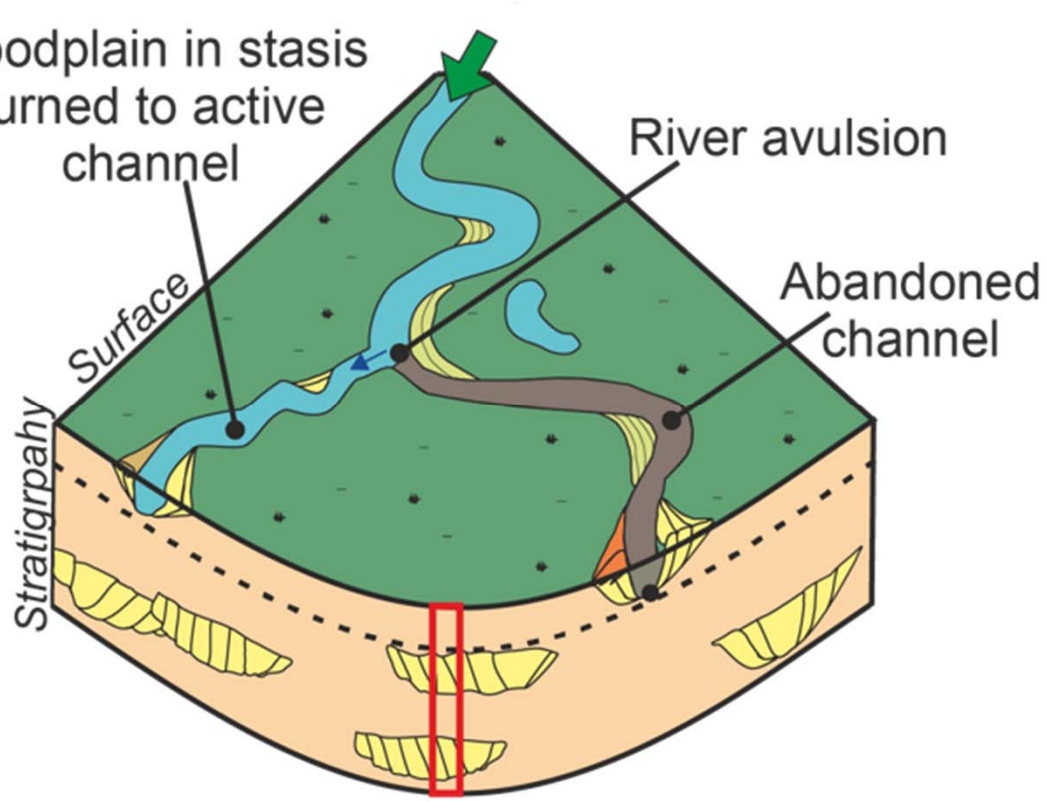
This would be the equivalent, for a facies model, of Gaussian Simulation producing equally likely deviations from a most likely porosity model, which can then contribute to a Monte Carlo analysis of reserves, thus providing a way to both quantify and understand risk and uncertainty.

How to achieve this?

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Making MPS Work for Modelling Uncertainty

We need a way to create multiple, equally likely realisations at the reservoir scale, that account for the intrinsic uncertainty in the basin-scale controls on sedimentation and acknowledged the physically-imposed interrelationships amongst parameters. This would allow us to recreate the theoretical underpinning of risk analysis in reserves estimation.



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Geological controls on geometry and architecture

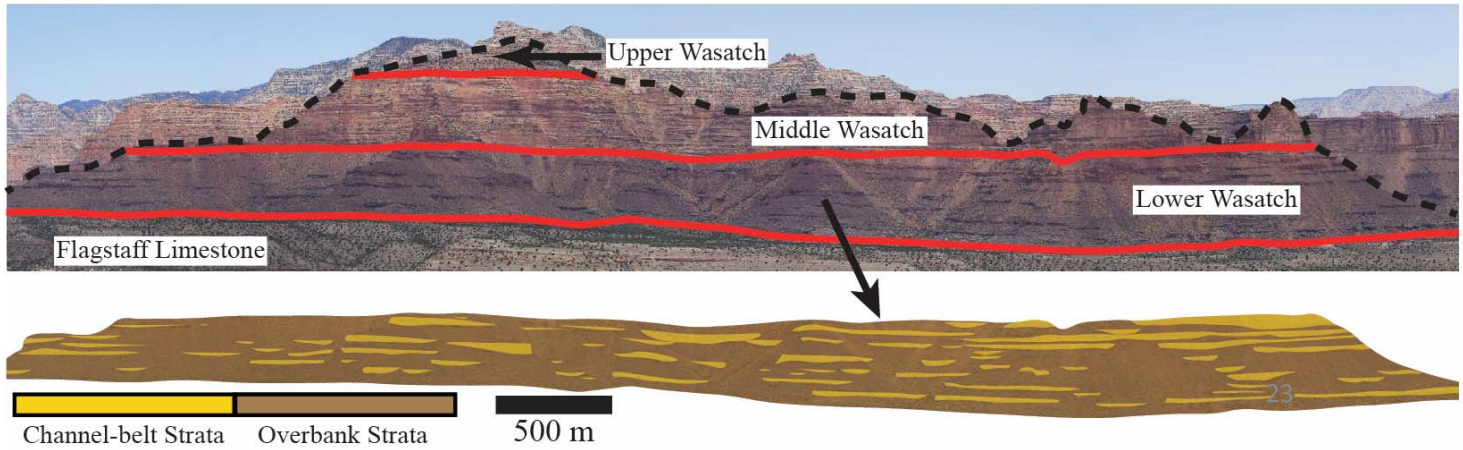
Flume tank experiments (and, to an extent, forward modelling in software) are able to generate multiple equally likely model realisations but would need to be run afresh for each reservoir, basin or other scene. What is needed is to relate the geometry and architecture to geological parameters that are transferrable.

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Geological controls on geometry and architecture

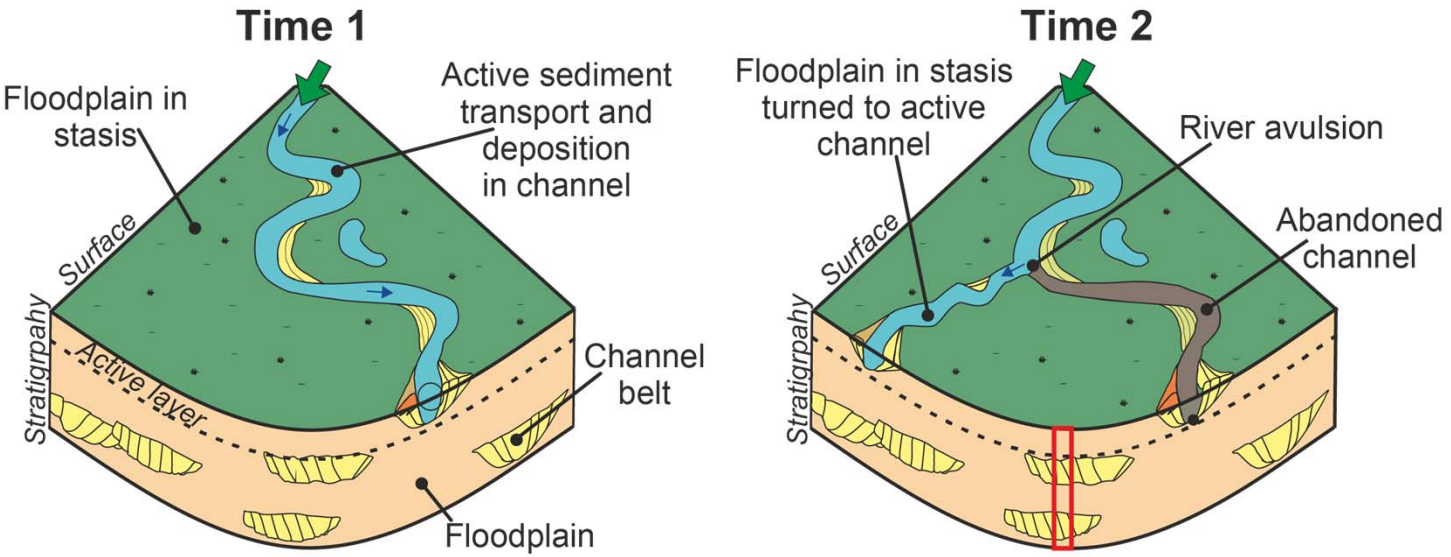
Work at Liverpool and Tulane universities achieves this, allowing a relationship to be generated between flume tank experiment outcomes and a suite of mathematical parameters that can be used to derive equally likely realisations (training images).

"*Coupled channel-floodplain dynamics and resulting stratigraphic architecture viewed through a mass-balance lens*", Straub, Dutt, Duller
Journal of Sedimentary Research (July 2023)
DOI: 10.2110/jsr.2022.012



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Geological controls on geometry and architecture

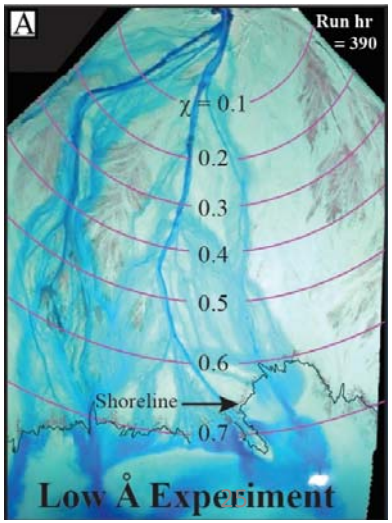


Frequency of river avulsion, new channel direction, etc. are parameters which are preserved in the sedimentary record. If we relate these geological parameters to the geometric and architectural properties of a model, we would have captured the available quantitative knowledge of uncertainty.

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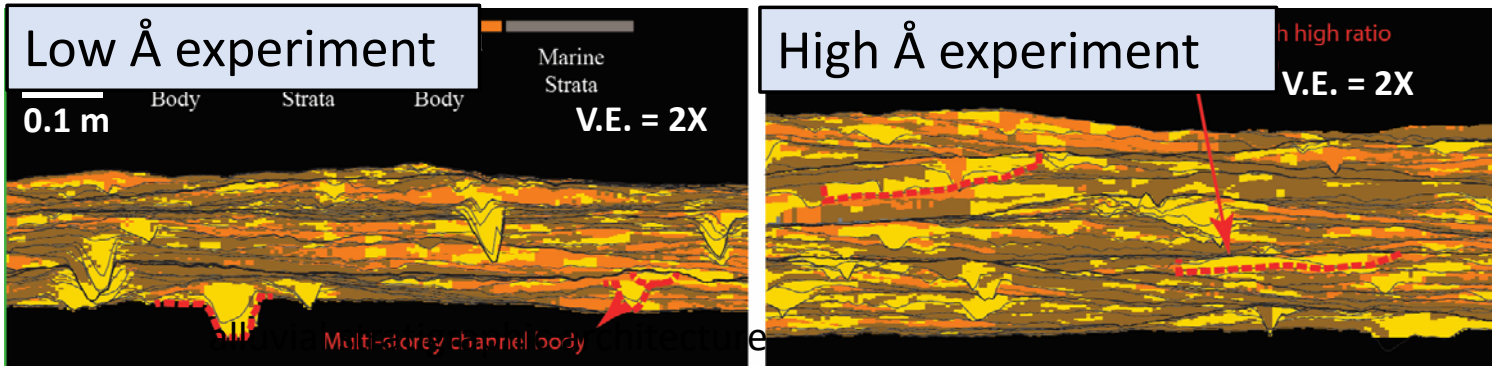
Making MPS Work for Modelling Uncertainty

Just as in Sequential Gaussian Simulation, we can thereby create multiple, equally likely realisations, reintroducing the rigorous approach to uncertainty that had been present prior to MPS.



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Parameterisation: alluvial stratigraphic architecture



Narrow and thick channel storey complexes caused by greater in-channel aggradation between avulsion events.

Wide and thin multilateral storey complexes related to greater channel mobility.

Architecture differences relate to differences in autogenic values. Hence, sand body geometry for input to MPS may be randomly selected from known distributions, reintroducing rigour to the modelling of uncertainty.

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Summary

What Makes a Geoscience Model Useful?

Predictive power.

Is MultiPoint Statistics a useful tool for building Geoscience Models?

Yes, for values; No (currently) for models of uncertainty.

Can MPS be made to be a useful tool for building Geoscience Models of uncertainty?

Yes, by parameterising the setting up of training images, using parameters relating geometry and architecture to geological outcomes (especially facies distributions).

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