An explanation of **UNCERTAINTY** for geoscientists and geo-engineers.

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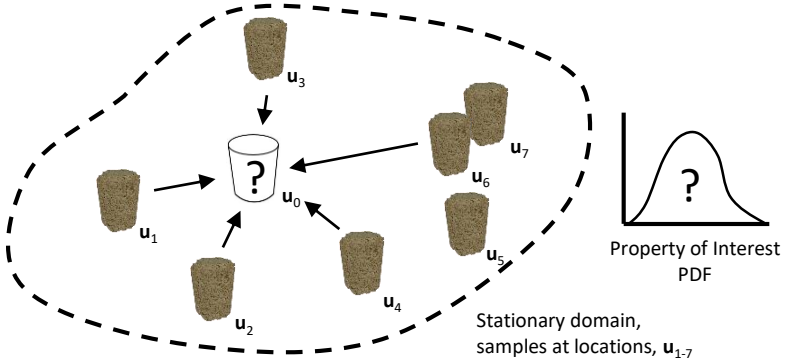
A description of the concepts of uncertainty essential to subsurface data collection, modeling and decision making.

1. What is Subsurface Uncertainty?

Uncertainty is not an intrinsic property of the subsurface. At every location ($\mathbf{u}_\alpha$) within the volume of interest the true properties could be measured if we had access (facies, porosity etc.). **Uncertainty is a function of our ignorance**, our inability to observed and measure the subsurface with the coverage and scale required to support our scientific questions and decision making.

This **sparsity of sample data combined with heterogeneity results in uncertainty**. If the subsurface was homogeneous then with few measurements uncertainty would be reduced and estimates resolved to a sufficient degree of exactitude.

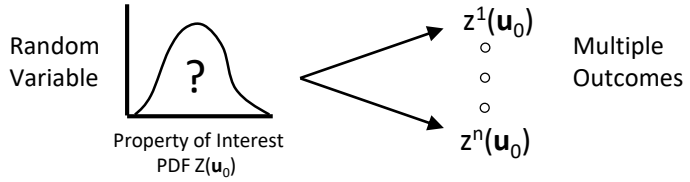


Subsurface uncertainty is a model. We should use the term "**uncertainty model**". As with all models, our uncertainty model is imperfect, but useful. Our uncertainty assessment is a function of a set of subjective decisions and parameter choices. The degree of objectivity is improved by ensuring each of the decisions and parameters are defendable given the available data and judicious use of analogs.

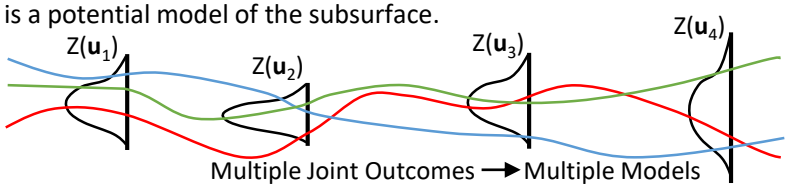
Core image from https://www.fei.com/oil-gas/

2. How Do We Represent Uncertainty?

Random Variables and Functions: A **random variable** is a property at a location ($\mathbf{u}_\alpha$) that can take on multiple possible outcomes. This is represented by a probability density function (PDF).



If we take a set of random variables at all locations of interest and we impart the correct spatial continuity between them then we have a **random function**. Each outcome from the random function is a potential model of the subsurface.



Using Multiple Models: We represent uncertainty with multiple models. It is convenient to assume that each model is equiprobable, but one could assign variable probability based on available local information and analogs. In general, when the input decisions and parameters are changed then these are known as **scenarios** and when the input decisions and parameters are held constant and only the random number seed is changed then these are known as **realizations**.

Working With Multiple Models: It is generally not appropriate to analyze a single or few scenarios and realizations. As Deutsch has recently taught, for decision making, use all the models all the time applied to the transfer function (e.g. volumetric calculation, contaminant transport, ore grade scale up, flow simulation etc.).

3. Comments on Uncertainty.

Calculating Uncertainty in a Modeling Parameter: Use Bayesian methods, spatial bootstrap etc. You must account for the volume of interest, sample data quantity and locations, and spatial continuity.

If You Know It, Put It In. Use expert geologic knowledge and data to model trends. Any variability captured in a trend model is known and is removed from the unknown, uncertain component of the model. Overfit trend will result in unrealistic certainty.

Types of Uncertainty: (1) data measurement, calibration uncertainty, (2) decisions and parameters uncertainty, and (3) spatial uncertainty in estimating away from data. Your job is to hunt for and include all significant sources of uncertainty.

What about Uncertainty in the Uncertainty? Don't go there. Use defendable choices in your uncertainty model, be conservative about what you known, document and move on. Matheron taught us to strip all away all defenseless assumptions. Journel warned us to avoid the **circular quest of uncertainty in uncertainty in...**

Uncertainty Depends on Scale. It is much harder to predict a property of tea spoon vs. a house-sized volume at a location ($\mathbf{u}_\alpha$) in the subsurface. Ensure that scale and heterogeneity are integrated.

You Cannot Hide From It. Ignoring uncertainty assumes certainty and is often a very extreme and dangerous assumption.

Decision Making with Uncertainty. Apply all the models to the transfer function to calculate uncertainty in subsurface outcome to support decision making in the presence of uncertainty.

For more information check out Pyrcz, M.J., and Deutsch, C.V., 2014, Geostatistical Reservoir Modeling, 2nd edition, Oxford University Press.