WHAT IS GEOSTATISTICAL RESERVOIR CHARACTERIZATION OR GEOSTATISTICAL/STOCHASTIC INVERSION?

In recent years, the interest in petroleum geostatistics has increased, resulting in a wealth of publications discussing geostatistics in general and geostatistical reservoir characterization and modeling in particular.

In this series of articles, the focus will be on seismically constrained geostatistical reservoir characterization and modeling.

Our first article will start with a brief discussion of what reservoir characterization and geostatistics are in the first place. Then we will see how geostatistics and reservoir characterization work together and the role of the seismic in this process.

What is Reservoir Characterization?
Reservoir characterization is about describing the rocks and fluids of the reservoir to understand its mechanics, physics, volumes, spatial distributions and flow that ultimately can be expressed in models. The full process can be described as ‘Reservoir Characterization and Modeling’. The resulting reservoir models are used to predict and optimize the production of the reservoir.

What is Geostatistics?
Describing and modeling a reservoir, which is after all underground at a depth of hundreds or thousands of meters, has always been a great challenge. Well logs provide a wealth of detailed information at fine resolution, but these are most often available at no more than a few locations. To model the whole reservoir, the obvious next step would be some form of interpolation, using known values at sampled locations to estimate unknown values at unsampled locations. This is where geostatistics can play an important role.

In general terms geostatistics is ‘sophisticated interpolation’ in that it recognizes that data values located closer together are more similar than those located farther apart and therefore gives different weights to different values. More specifically in geostatistics the spatial relationships between measured data values are captured and modeled, and then used to provide unbiased estimates of data values at unsampled locations.

Estimation
Estimation methods produce one single answer, a ‘best guess’ solution given the available data. We call such methods deterministic. The most commonly known method in this group is kriging.

Simulation
Simulation methods produce multiple plausible answers given the available data. We refer to each answer as a ‘realization’. Each realization is possible: there is no objective way to say that one is ‘right’ and the others are ‘wrong’. The main benefit of simulation approaches is that they yield answers with realistic spatial variations and allow us to quantify the uncertainty. The most commonly known method in this group is Sequential Gaussian Simulation.
What is Geostatistical [Seismic] Reservoir Characterization?

Geostatistical [Seismic] Reservoir Characterization is more than just sophisticated interpolation. It is about taking all available prior information and measurements into account. Using Bayesian inference, we can incorporate a variety of data and expert knowledge to obtain more realistic predictions.

Bayesian inference is a very powerful technique that can integrate all kinds of prior information with measurements to express a ‘global’ posterior probability. Evidently, one very important and valuable piece of information is the seismic data, which has extensive lateral coverage compared to the sparse information provided at well locations.

Figure 1. Multidisciplinary Integration for Reservoir Modeling through Bayesian inference. Seismic (highlighted in red) is a key piece of information. Electromagnetic and Gravity data cannot yet be used in CGG’s GRC applications, but could in principle also be integrated through Bayesian inference.

A weakness of common industry practices is generally that not all the available information is used. Geomodelers and geophysicists are both interested in modeling the reservoir. While geomodelers use information such as geological knowledge, geostatistical relationships and probability density functions, the results are realistic but may not be correct away from the wells. If seismic is used in the process, it is often in the form of attributes used as a guide. Geophysicists on the other hand mainly use seismic data and rock physics relationships deterministically to model the reservoir.

The generated reservoir model explains the seismic, but because some of the geological information is not incorporated, the spatial variations in the model may not be geologically realistic. The two disciplines tend to work in different domains (time vs. depth) and use very different parameters. They therefore build very different models. The problem is how to effectively combine the information from both sides into a single consistent model.

Geostatistical seismic reservoir modeling helps us tackle this problem by integrating the two approaches. In geostatistical reservoir characterization, we combine different sorts of information to generate equally plausible models. From the generated realizations, we can also estimate uncertainties.

Figure 2. Combination of the two domains: More accurate results away from well control, greater detail and more realistic uncertainty quantification.
Why is it still called inversion?

Simply because seismic data is taken into account. Although we are not inverting the seismic data mathematically in terms of matrix inversion, conceptually we can call it inversion because seismic is an indirect measurement of the properties we are interested in. Extracting information about those properties from indirect measurements is an inversion process. However, seismic data is just one input among others and does not necessarily carry more weight.

What is the difference between Geostatistical and Stochastic processes?

A stochastic process is a process that involves random numbers, drawn by a random number generator. This type of process can therefore have many different outcomes (known as realizations) due to its randomness.

A geostatistical process is a process based on a statistical modeling of the spatial continuity of phenomena.

Geostatistical simulation and inversion are stochastic processes: they involve randomness and can produce multiple realizations. However, not all stochastic inversion methods are geostatistical. So stochastic inversion has a more general meaning than geostatistical inversion, even though the two terms are often used interchangeably.

Added value to deterministic inversion

Figure 3. The pressure predicted by the model built using geostatistical seismic reservoir characterization (red) is a close match with the actual information coming from production data (purple). The pressure predicted by the model built using deterministic inversion (green) has much less accuracy in comparison.
Figure 4. This figure compares production data at a well (dark green) with production predicted by two different models. Model 1 (red) is purely based on geological modeling and is mainly driven by well log data. Model 2 (light green) is the result of seismic-driven geostatistical modelling. Model 2 shows higher accuracy in reservoir history matching than Model 1.

Join the discussion!

Join our LinkedIn GeoStatistical Inversion Discussion Group by clicking [here](#). By joining the conversation you’ll connect with peers who want to share and gather new ideas, best practices and insights for getting the best geostatistical inversion results.

Don’t miss our next article on the 4th May 2017!

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