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Statistical Pattern Learning, Drawing and Morphing for Integrated Reservoir Modeling

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Abstract

Process-based geologic models follow the physicochemical laws of deposition and diagenesis. These models appear geologically realistic and attractive, but do not necessarily honor data from wells, seismic volumes, and production history. This is because the data are not directly integrated into the model but rather indirectly used to infer a set of its input parameters. Conditioning process-based geologic models to various data is critical for reservoir characterization and has been challenging for decades. The traditional approach to conditioning a process-based geologic model is to tune its input parameters by trial-and-error or through an automated inverse scheme. This can improve model calibration to certain data but can hardly integrate all existing data. This paper presents a statistical pattern recognition approach for integrating well, seismic and production data into process-process geologic models.

We start with a process-based geologic model (of deposition and/or diagenesis) whose input parameters are already tuned to reach a certain degree of data conditioning. To further condition the model, we adopt the regionalized multiple-point statistics (MPS) approach where the process-based geologic model along with its relevant seismic attributes are used as coupled training images for geologic pattern learning and simulation.

The regionalized MPS method is based on Bayes' law and Gaussian kernel approximation of conditional probability instead of a probability combination scheme or a heuristic rule. It calibrates process-based geologic models to well and seismic data while preserving its geologic patterns. Moreover, the regionalized MPS method can also be implemented as a transformation from a uniform random field (or latent space) to a geologically meaningful model, and hence the gradual deformation method can be applied for history matching. Ultimately, the regionalized MPS method becomes a vehicle of geo-consistent integration of well, seismic and production data into process-based geologic modeling.