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Direct Modeling of Reservoirs through Forward Process-based Models: Can we get there?

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Abstract

Long dismissed as impossible, constructing reservoir models by modeling the fundamental processes that formed them should soon become a reality. Recent enabling advances include: new algorithms, increases in computer speed, and new quantitative insights into the processes of flow and erosion. Though now viable, full implementation of process-based modeling for building reservoir models for simulation remains difficult. Modeling physics and honoring known data such as logs and seismic remains extremely challenging.

We will describe some examples of forward models and an example of a full process-based modeling application. We will discuss progress that has been made in conditioning these models to known data (eg. wells and seismic). We will also show some example workflows and technology for extracting value from digital analogs built using process-based modeling techniques. These workflows include the extraction of patterns and statistics for rule-based and geostatistical modeling. We call this type of workflow, process-aided reservoir modeling.

These new modeling methods are needed because current modeling practices cannot duplicate the natural order found in nature, neither can they reproduce the complex interactions of topography, flow, deposition and erosion; representing these interactions accurately is essential to modeling connectivity and reservoir flow behavior. Rule-based parametric and pattern-matching techniques can begin to replicate real geologic geometries, but no technique other than process-based modeling can provide the needed geologically realistic 3D volumes necessary for developing accurate rules or pattern training datasets. 3D seismic can provide some insight, but is

limited in scale and cannot provide direct information on the flows and processes that must have been present to lay down a given deposit. Outcrops and modern data are generally limited to 2D with poor expression of the 3D.

Introduction:

Significant progress has been made in our ability to generate reservoir models based on full numeric modeling of the fundamental processes that formed them. However, significant challenges remain to be solved before these process-based (physics-based) methods can be used as the primary tool for generating fully-realized reservoir models. A recently developed workflow uses intermediate results from process-based models to provide valuable geometric and trend input into models built with more traditional modeling techniques.

Process-based modeling has faced numerous technical challenges, including: (1) a wide span of geologic processes that must be accurately quantified, (2) complex, unknown hydrologic and sedimentologic input parameters with unknown initial conditions, (3) an inability to condition to known data (well data, seismic, target fractions), (4) the potential for non-unique solutions, and 5) limitations in computing power.

Our research has focused on addressing many of these challenges. We've expanded our understanding and ability to quantify inputs through extensive flume experimentation, field outcrop-work, and through analysis of modern satellite and remote sensing data. This analysis has also led to improvements in our forward models, and we have to date developed models representing a span of important depositional settings and processes. Although the ability to condition these models to field data remains a major issue, significant leveraging can be made by using techniques that build on the tremendous scientific progress made in modeling inverse problems in history matching, weather forecasting, and civil engineering. The potential for non-unique solutions remains, but the importance of using multiple realizations to capture a range of uncertainty has grown in recognition, making this an advantage rather than a disadvantage. In addition, by basing a reservoir model on the physical processes that controlled deposition, the resulting multiple realizations should represent more reasonable outcomes than those that might be generated using statistical techniques. Limitations in computing power continue to restrict large-