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Simplified Modeling of Turbidite Channel Reservoirs

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Abstract

Effective properties can represent fine-scale geologic heterogeneities in simple full-field reservoir models without having to explicitly model them. A comprehensive simulation study tests the sensitivity of dynamic connectivity in turbidite channel reservoirs to a large number of stratigraphic and engineering parameters. Simulations performed using geologically realistic sector models at multiple levels of stratigraphic resolution show that dynamic connectivity is governed by large-scale architectural parameters such as meander belt size, net-to-gross, and degree of depositional storey amalgamation; and stratigraphic parameters that describe the shale architecture at multiple scales, e.g. shale drape coverage and frequency of occurrence.

We demonstrate how to rapidly generate effective properties at multiple geologic scales, incorporating the effect of channel architecture and reservoir connectivity into simple dynamic models. Use of simple dynamic models in conjunction with effective properties, principally, geologically based pseudo-relative permeabilities, significantly accelerates the simulation workflow. We show that a statistical distribution of the recovery factor can be produced within hours instead of days by combined use of Monte Carlo simulation and a simple dynamic model with effective properties. Recovery factors estimated via our simplified modeling method agree well with observed recovery factor distributions of turbidite channel reservoirs with significant production history.

Introduction

Simplifying the reservoir modeling process by developing a quantitative method to represent a range of fine-scale geologic heterogeneities within relatively simple full-field reservoir models is one way to reduce reservoir modeling cycle-time. Coarse-scale full-field simulations can include the presence of sub-seismic channel architecture by means of connectivity factors implemented in terms of effective properties and derived from representative full-detail and coarse-scale sector model simulations (**Fig. 1**). High-resolution sector model simulations are performed to capture an accurate representation of the geologic detail. Coarse-scale and high-resolution sector model simulations are used together for quantifying the impact of channel architecture.

The goal here is to apply Monte Carlo techniques directly to reservoir simulation by assuming probability density functions for uncertain variables (**Fig. 2**). Monte Carlo simulation techniques become very time-intensive when used with high-resolution descriptions of the stratigraphic architecture. We introduce a way to create relative permeability pseudo-functions to be used in conjunction with rapid coarse-scale dynamic models, which overcome the time-intensive nature of Monte Carlo methods. In the 3D connectivity workflow, proxy models estimate the effective properties, namely, 3D connectivity factors, which are in turn used for calculating the pseudo-relative permeability functions together with the rock curves. Proxy models are closed-form equations derived by training backprogation neural networks (Haykin, 1999) using connectivity factors obtained through flow-simulations on fine and coarse-scale sector models. Resulting pseudo-functions are implemented in relatively simpler, rapid coarse-scale dynamic models to be employed within Monte Carlo applications. Channelized turbidite reservoirs constitute a suitable and relevant first target for the 3D connectivity workflow as the architectural detail is relatively straightforward and well understood to represent with a parametric, geologically consistent integrated reservoir modeling approach.