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An Integrated Approach to Reservoir Uncertainty Assessment: Case Study of a Gulf of Mexico Reservoir

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Abstract

Integrated uncertainty analysis of a carbonate reservoir in the Gulf of Mexico was performed to quantify the contribution of factors such as lithofacies definition criteria, reservoir structure, total and fracture porosity, net-to-gross cut-offs, and measurement scale disparities on geologic uncertainty. An innovative approach to derive facies definition criteria and net-to-gross cut-offs based on k-mean cluster analysis is presented. A detailed analysis of scale up of petrophysical properties using the variance of mean concept was performed and its implication on geologic model uncertainty was assessed. Finally, innovative approaches to verify and visualize spatial uncertainty models are presented.

A detailed geologic model for the fractured carbonate reservoir was available and the study objective was broken down into an assessment of uncertainty due to: i) structural model, ii) sedimentary model, iii) petrophysical model, and iv) scale-up/upscaling. Systematic investigation of each of these aspects as well as a fully probabilistic integration of uncertainty models was performed.

Uncertainty in original oil in place was computed by sampling from the component distributions. The study results indicate that the OOIP exhibits significant sensitivity to factors such as cut-offs for lithofacies and net-to-gross definition. An important result that points to a paradigm shift in uncertainty modeling is the sizeable contribution of scale-up to the uncertainty models. The results further reveal that the determination of net-to-gross and lithofacies definition thresholds using cluster analysis vastly enhances the accuracy of the prediction of net-pay at a new well location.

The paper presents a complete workflow for integrated reservoir uncertainty assessment. Besides demonstrating the use of data analysis tools such as cluster analysis for deriving more robust criteria for facies and net-to-gross definition, a fundamental contribution of this paper is to demonstrate the role of scale up on uncertainty assessment. While this has been alluded to by several researchers in the past, this paper is the first to demonstrate a modeling workflow that explicitly handles uncertainty due to scale up and promotes the notion of "soft" conditional simulation.

Introduction

The work for investigating the uncertainty in geologic reservoir models used the current reservoir model built using the Petrel software and developed procedures for assessing structural uncertainties from seismic, uncertainty in lithofacies models, variations in petrophysical properties within lithofacies and uncertainty due to scale-up/upscaling. The specific tasks performed included:

- Exploratory data analysis
- Evaluation of uncertainty in structural model
- Assessment of sedimentary (depositional) model uncertainty
- Assessment of uncertainty in petrophysical model
- Multiscale rock properties modeling
- Integration of structural, geologic, petrophysical and scale-up uncertainties

Uncertainty assessment and reservoir modeling was performed for a particular zone E of the reservoir that is comprised of 5 carbonate facies – dolomite, packstone, grainstone, wackestone and mudstone.