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Multi-Scale Data Integration in Characterizing and Modeling A Deep-Water Turbidite Reservoir

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Abstract

Information from cores and wireline logs, processed according to different methodologies, were integrated to provide a consistent facies classification, petrophysical characterization and 3D geological model of a deep-water turbidite reservoir in the Gulf of Mexico.

A number of sedimentological facies (sed-facies), either heterolithics or single-lithology, were first identified on cores and used for generating a conceptual depositional model of the reservoir. At the same time, the conventional wireline log recordings from both cored and uncored wells were processed using a multivariate statistical technique (cluster analysis) to provide a Net-to-Gross (or V_{shale})-based log-facies classification. The relationship between sed-facies and log-facies is not straightforward, as some of the latter include different amounts of different sed-facies, either heterolithics or not.

The petrophysical characterization of the log-facies was carried out using a Process-Oriented Modeling approach. Realistic fine-scale, 3D digital models of the different sed-facies were generated. These models were populated at the lamina scale using the statistics of porosity measurements from a selected subset of the core plugs and the statistics of permeability measurements from a mini-permeameter, both parameters having been overburden-corrected in advance. Next, the fine-scale 3D models of the sed-facies were stacked according to their observed amount in each log-facies, and several porosity and permeability grids for each log-facies were stochastically generated. Eventually, the 3D log-facies models were analytically and numerically upscaled to respectively provide effective porosity and permeability statistics for use in the property modeling phase of the 3D geological model of the reservoir.

This workflow has the great advantage of allowing the use of data of types acquired at different scales (mini-permeameter, core plugs and wireline logs) in a consistent manner with respect to their volumes of investigation, and also allows for honoring the conceptual sedimentological model of the reservoir.

Introduction

Hydrocarbon production from ‘easily characterized and produced’ reservoirs has slowly declined worldwide in the last decades: as a consequence, exploration and production targets progressively shifted towards more challenging environments and/or more ‘difficult’ reservoirs. Turbidite deposits in deep and ultra-deep water offshore are a typical example. Besides their overall architectural complexity (amalgamated channels, channel-levee systems, channel-lobe systems), some of these deposits include heterolithic facies consisting of thin, cm- or mm-sized, alternating horizons of sandstone, siltstone and shales.

Infact, the overall architectural aspects of deep-water turbidite deposits can be reasonably modeled if the appropriate geophysical-geological information and sedimentological conceptual models are provided as input to any commercially available 3D geo-modeling tool with object-based geostatistical modeling (Bratvold et al., 1994). On the other hand, the petrophysical characterization of heterolithic reservoir is still a very demanding and challenging task, as the very thin alternations of sandstones, siltstones and shales cannot be resolved by conventional wireline logs, which makes the parameters derived from conventional quantitative log interpretation of little use. Relying on the sparse, often biased, data from core plugs can also be misleading (Scaglioni et al., 2006). Nordhal et al. (2005), Phillips & Wen (2007), Ringrose et al. (2005), Ruvo et al. (2005), Scaglioni et al. (2006) have shown that improving the characterization of heterolithic reservoir requires a well-focused data collection and the adoption of non-conventional approaches, such as the Process-Oriented Modeling at the core/near-wellbore scale (Wen at al., 1998). But, most importantly, all of the above authors point out that the greatest attention is to be paid to the meaning of data in terms of their support volume.