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Dynamic Modeling of Multiple Regionally-Extensive Reservoirs Using a Unified Fluid Description

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Abstract

A novel approach to perform basin scale compositional simulations for a group of Gulf of Mexico reservoirs has been conducted. The main objective of such an effort has been to integrate reservoirs with potential dynamic communication through a single sensible initialization model in the simulator. In the past, some of these reservoirs were modeled stand alone, and the current information has forced us to connect multiple reservoirs that are connected laterally. Performance of three Gulf of Mexico (GOM) reservoirs was assessed using basin-wide compositional dynamic simulation approach. Like many reservoir simulation projects, at the initial phase of this project, “isolated” performance prediction of the subject reservoirs was considered, mainly due to unknown lateral connectivity and the differences in the discovery dates. In later years, there was a need to predict the unified system performance based on surveillance data, and to be able to test the possibility of the connectivity of the multiple reservoirs and reservoir segments.

In addition to the surveillance production data, we have also gathered data based on basinwide analysis and geochemistry that focused on reservoir compartmentalization. Such data confirmed well responses and helped us to initialize the reservoir correctly. Along with the analysis of the particular case to be discussed here, the reasons behind the graded oil/gas reservoirs will also be discussed and will be provided to highlight the broader implications of field observations as well as some of the ideas presented in the literature.

Introduction

It has been realized that compositional PVT variations between fluids do not necessitate achieving thermodynamic equilibrium. The overwhelming evidences for dynamic communication have led to the hypothesis that the

thermodynamically unexplained variations in PVT properties amongst the studied GOM reservoirs cannot mean absolute compartmentalization, and in this paper, we show the evidence of such a behavior. Subject reservoirs contained fundamentally different fluids, exhibiting an areal compositional grading in addition to vertical grading, that cannot be explained using depth cross plots. Available tools were not able to ‘representatively’ model the observed grading behavior even within the same target zone, where hydrocarbon fluids can move laterally. As a result, the creation of a single EOS model mimicking the behavior of all reservoir fluids with a single PVT model has become a requirement. In order to accomplish a unified fluid description, a stepwise approach was adopted. One of the fluids was considered as the base fluid, and then various EOS tuning parameters were modified to approximate the behavior of all other fluids of interest. In this approach the only varying factor from reservoir to reservoir was the overall fluid composition, as per the measured compositions.

After the optimization of the tuning parameters for those multiple, but fundamentally distinct fluids, a slight modification to the overall composition of the base PVT deck was still required. Using this single fluid description (EOS), corporate level predictions were performed simultaneously for all three reservoirs and major investment decisions were made. The predictions were in line with the standalone simulations, and most importantly matched actual production data.

Reservoir compartmentalization and compositional grading are extensively studied in the literature and is mainly split between petroleum engineering and geochemistry/basin analysis literature. Schulte¹ published the gravity effect and its implications, in terms of compositional grading, in 1980, for the first time in the petroleum engineering literature. Schulte’s findings numerically confirmed the field observations and later on Riemens et al.², studied a field case (Birba) and published the results in the open literature. This particular case confirmed that the compositional variations could lead to near-critical fluid contacts. Later on, Whitson and his co-workers³⁻⁶, investigated the reasons behind the graded columns mainly focusing on the depth dimension, and connected theory and practice (Hoier and Whitson³). On the geochemical and sub-basin modeling side, Smalley and England^{7,8} focused on the compartmentalization aspects and backed that with geochemical data and Stainforth⁹ focused on