A Predictive Approach for Tight Oil and Gas Exploration

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ABSTRACT

This paper presents an integrated approach to study tight oil/gas sweet spots with petroleum systems modeling. The final deliverable of this study is a geological model with real predictivity for potential drilling candidates. Tight oil/gas plays are usually considered as large lateral continuous oil accumulations with low water saturation, no gas cap or downdip water contact, without the requirement of a structural trap in deep basin. Tight gas typically occurs in low porosity (<10%) and low permeability (in microdarcy range) reservoirs immediately adjacent to source rocks.

This study integrates seismic inversion results with petroleum systems modeling (PSM) to capture the major controls of the tight oil/gas trapping mechanisms discussed above. A 3D geological model is populated by a lithology cube obtained from prestack stochastic seismic inversion data. The lithology model reflects all available well data and geological understanding of the area, a pro-delta/delta front system, which is characterized by sandstone/siltstone/shale laminations vertically and sandstone/siltstone/shale interfingering laterally. The compaction properties are taken from a standard data base. Measured capillary pressure and porosity data are used for model calibrations.

The Petroleum Systems approach takes into account hydrocarbon generation, migration, and accumulation history of the deltaic system, considering buoyancy forces, formation pressures, capillary pressures, and permeabilities of each lithology through geologic history. The target tight oil reservoirs were charged by the interfingering delta front and/or underlying pro-deltaic shales. Connectivities between porous sand/sandy bodies are one of the most critical factors controlling hydrocarbon migration and accumulation. They are the migration paths for the charge of conventional accumulations in structural highs, however, isolated sand/sandy bodies could also be sweet spots of unconventional plays in deeper parts of a basin, if properly charged. It is not easy to understand and describe the effects of sand/sandy body connectivity in such complex lithofacies distribution system. PSM appears to be the only method to handle this challenge with help of numerical simulation. Furthermore, a model with more realistic lithofacies distributions enables better pressure and hydrocarbon distribution predictions. The predicted liquid hydrocarbon saturation by the PSM study successfully matched the typical tight oil play concept, which is located in deeper areas in the basin, is not structurally dependent, and lies adjacent to source rocks, etc.

Based on the PSM study, the tight oil/gas trapping mechanism is better understood. The sweet spot area of tight oil is mainly controlled by the following factors: 1) Isolated sand/sandy bodies in the deep basin; 2) close association with source rocks (short migration distance); 3) well developed porous bodies connecting the kitchen areas to structural highs. These types of lithologic bodies could also be excellent conduits for conventional accumulations, which is, however, beyond the scope of this study. The systems need to be carefully assessed based on the type of target, considering factors which can be positive for conventional targets or can be negative for unconventional targets. Improving high-resolution lithofacies and properly modeling the petroleum systems by applying advanced geophysical workflows are essential requirements to construct petroleum system models which provide better understanding and predictions in these plays.