Unconventional Resource Play Potential of the Pennsylvanian Leo/Minnelusa Formations of the Powder River and Denver Basins: A Perspective via Integrated Petroleum Systems Analysis

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ABSTRACT

A successful unconventional resource play is often linked to commercial conventional plays; typically an unconventional source/reservoir contains petroleum of variable saturation in a mixed lithology of fine-grained siliciclastics, variable amount of carbonate, and mature organic matter deposited in a marine environment such as the Wolfcamp play in the Permian Basin and the Eagle Ford play in Texas. Based on regional understanding of stratigraphy and structural geology and a review of historical petroleum production data, our basin-scale screening efforts identified the Pennsylvanian Leo/Minnelusa Formations and equivalents of the Powder River and Denver Basins with potential for an unconventional resource play. While our evaluation is multi-disciplinary and integrated; in this presentation we focus on petroleum systems analysis including the evaluation of source potential and maturity, bulk and molecular properties of reservoir fluid and source rock (SR) extracts, 3D burial history model, reservoir pressure/temperature and PVT considerations for the purpose of evaluating reservoir fluid deliverability.

We utilized a large database of historical data, including conventional oil and gas production, formation tops of more than 64,000 wells, core analyses, wireline logs, geochemistry analyses, pressure and temperature data, about 800-mile of 2D seismic interpreted with 20 synthetic ties, and relevant published literature. We analyzed basin-scale variation in SR organofacies and maturity, bulk and molecular properties of SR extracts and reservoir fluids and we built a 3D burial history model which includes multiple stratigraphic horizons, uplift/erosion and spatially-variant temperature gradients. We then calibrated the model to observed basin-scale trends in hydrogen index (HI) data and the published maturity map (Ro equivalent) for the data-rich shallower Mowry interval of Cretaceous age.

Our integrated evaluation identified high-quality and mature source rock and our calibrated 3D burial history model predicts a large area with desirable maturity for the Leo/Minnelusa Formations in the Powder River and Denver Basins. However, individual source beds in the Leo/Minneulsa Formations are thin and OM-related porosity is volumetrically insignificant. While we interpret the bulk of petroleum fluids in the Leo/Minnelusa Formations likely of the same origin, the observed variability in fluid properties (bulk and molecular) appears to be at "dis-equilibrium" with predicted maturity. We interpret such dis-equilibrium as the result of effective lateral migration from the basin center to basin margin and we perceive limited basin-wide retention of petroleum of in-situ maturity within the Leo/Minneulsa Formations (which is confirmed by petrophysics interpretations of 20 wells in the Powder River and Denver Basins). The reservoir pressure generally is at or below hydrostatic condition, consistent with observed porosity vs. permeability data and the aforementioned interpretation of effective lateral petroleum migration. We believe the stratigraphic architecture and the Laramide-related uplift and erosion may have contributed to basin-scale

dissipation of pressure and/or petroleum distribution; and that such factors collectively may have rendered the Leo/Minnelusa Formations in the Powder River and Denver Basins ineffective for a viable basin-scale unconventional resource play.