The Mowry Shale of the Powder River Basin: A Multiscale Re-Evaluation of a Super Basin Source Rock and Emerging Unconventional Play

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The Mowry Shale is a prolific source rock in numerous Laramide basins, having yielded large volumes of oil and gas. In the Powder River Basin, cumulative Mowry-sourced production in all Cretaceous conventional reservoirs is estimated at ~1.2 BBO and 2.2 TCF, with over half a billion barrels of oil expulsed into the underlying Muddy Sandstone alone (Anna and Cook, 2008). With an estimated undiscovered potential of 198 MMBO and 198 BCF (Anna and Cook, 2008), operators are now testing the Mowry Shale as an unconventional reservoir. Our work on the multiscale heterogeneity helps in defining regional sweet spots and optimum horizontal targets.

During the Albian to Cenomanian, the Mowry Seaway was separated from the warmer southern waters of the Tethys Ocean. Cold, boreal waters yielded a hemipelagic mixture of radiolaria, marine kerogen, fish debris, and clay. Volcanism to the west provided sporadic inputs of silica-rich ash. High-energy events, including sediment-gravity flows and storm waves, frequently punctuated this suspension fallout, delivering and reworking terrigenous silt and sand.

Mowry Shale end members range from biosiliceous mudstone to muddy siltstone and sandstone, with intervening facies containing varying amounts of silt laminae. Vertical facies successions with upward increasing coarse-grained detrital content and concomitant increasing bioturbation characterize Mowry parasequences; amalgamated bentonites typically overlie the bounding flooding surfaces. Parasequences, in turn, stack to form three regressive packages in the Mowry, interpreted as highstand systems tracts.

The Mowry has an average 2-3 wt% TOC of a mixed Type II/III source. Mean porosity is ~7% and permeability averages 200-300 nD in core samples. Silty and sandy facies generally exhibit elevated extrabasinal silica, lower hydrocarbon saturations, lower TOC, slightly higher porosity, and increased permeability relative to more biosiliceous facies. Thermal maturity has a major influence on reservoir quality. Elevated maturity is associated with decreased illite/smectite content, significantly lower water saturations, and higher permeabilities. A strong positive correlation between permeability and maturation in the early oil window, up to approximately 1.0% Ro, suggests that factors such as organic content, clay content, and silica diagenesis influence pore development. Early results from low-pressure gas adsorption experiments confirm an increase in meso- and macroporosity (2-50 nm and >50 nm pore widths, respectively) associated with higher maturity samples.

Improved well performance is based on location, target selection, and completion techniques. Horizontals typically land in the upper portion of the middle Mowry highstand systems tract, which combines favorable TOC content, oil saturation, and mechanical properties. Best production comes from the newest wells, with higher oil gravity and GORs. The evolution to drilling longer laterals with higher fluid concentration per perforated foot, greater proppant load, more fracture stages, and decreased stage lengths is now generating economics comparable to some of the best U.S. shale plays.