Characterization of Duvernay Formation Mudrocks Using Detailed Sedimentological Analysis

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Abstract

The Duvernay Formation of the Western Canadian Sedimentary Basin is well studied as a prolific source rock, but in recent years has seen growing interest in its potential as an unconventional reservoir, with early production exploiting thick packages of organic-rich, calcareous, biosiliceous mudstones in reef-distal areas of the basin. Knowledge of the character and distribution of quality reservoir facies is in its infancy. Internal sedimentological heterogeneities are tied to reservoir quality and reflect changes in depositional processes and conditions through which these organic-rich mudstones accumulated. Identification and characterization of internal heterogeneities allow for the creation of depositional and sequence stratigraphic models, upon which exploration and production strategies may be based.

Detailed core analysis, combined with petrographic evaluation using extra-thin thin sections and SEM, reveals heterogeneities within apparently homogenous dark grey-brown mudstones. Facies were characterized based on mineralogy, sedimentary structure and fabric on a macro- and micro-scale, microfossil content, cement type and abundance, as well the abundance and character of natural fractures. Correlation of identified facies to wireline logs allows for the extrapolation of interpretation beyond core control. A basin-scale wireline correlation describes the distribution of reservoir and nonreservoir strata and allows for upscaling of core analyses to form a depositional and sequence stratigraphic model. Parallel geochemical and petrophysical studies allow for integration of datasets for more robust interpretations.

Organic-rich basinal deposits are characterized by dark grey-brown, finely laminated to massive appearing mudstones. These mudstones are commonly enriched in authigenic quartz and pyrite and are only slightly calcareous. Slightly shallower water deposition is characterized by parallel laminated argillaceous calcareous silty mudstones and wavy laminated bioturbated argillaceous calcareous silty mudstones with lower TOC values. Fully bioturbated calcareous argillaceous mudstones (in the East Shale Basin), reef-derived limestone breccias (in reef-proximal locations), and bioturbated nodular calcareous argillaceous mudstones represent relatively shallow water deposition within the Duvernay Formation. During transgression, basinal, restricted deposits become more prevalent and are deposited on top of shallower water carbonate rich facies. Normal highstand regression introduces semi-locally derived carbonate, and distally derived quartz and clay detrital material. Falling stage and lowstand system tracts are characterized by increases in shallower water carbonate facies. Carbonate-rich intervals are associated with decreases in TOC. Geochemical redox proxies indicate that deposition of TOC-rich intervals was associated with more reducing conditions.

Macro- and microscopic variability of Duvernay Formation deposits, characterized by detailed sedimentological analysis, provides the foundation for a depositional and sequence stratigraphic model. An understanding of depositional controls allows for more efficient exploitation of reservoir strata and a sequence stratigraphic framework provides a pathway for extrapolation of localized data sets.