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Integration of Lithofacies and Natural Fractures in a Nexen Horn River Shales Gas Core

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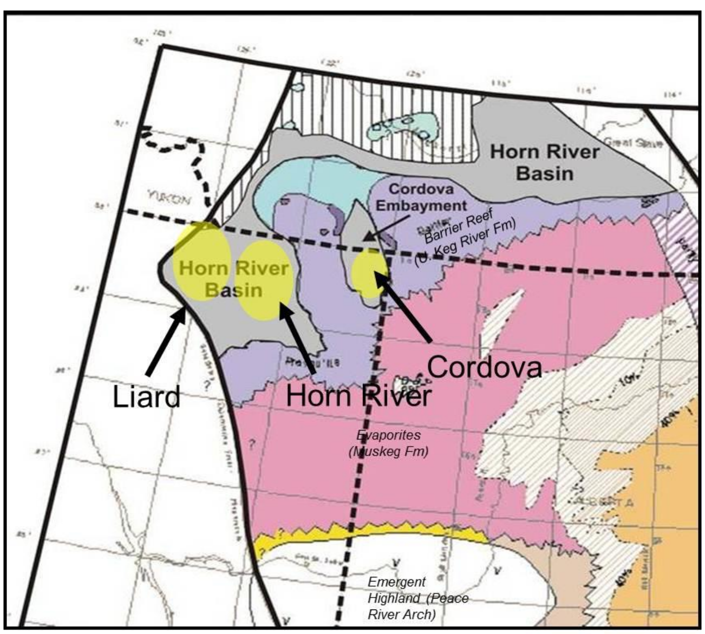
Introduction

Nexen Energy ULC is currently developing the Horn River unconventional shale gas play in northeast British Columbia (Figure 1). The Mid-Late Devonian Horn River Shale Reservoir is one of the thickest shale reservoirs in North America (Figure 2). Isopachs from the Muskwa to Lower Keg River formations across the Horn River Basin range from 155 to 190 meters over Nexen land. It is hypothesized that the natural fracture characteristics of this exceptionally thick over pressured shale package have a significant impact on hydraulic fracture propagation and the subsequent production behavior from the resulting stimulated network. Understanding reservoir and geomechanical rock properties in conjunction with the natural fracture stratigraphy is absolutely critical to effectively design well pads to maximize recovery from this very rich resource. Currently an upper and lower target formation is drilled to optimize stimulated surface area and recovery from this thick shale package.



Paleogeography during Evie Deposition

Figure 1) Location of the HRB in the northwestern portion of the WCSB(Modified from Oldale and Munday, 1994).

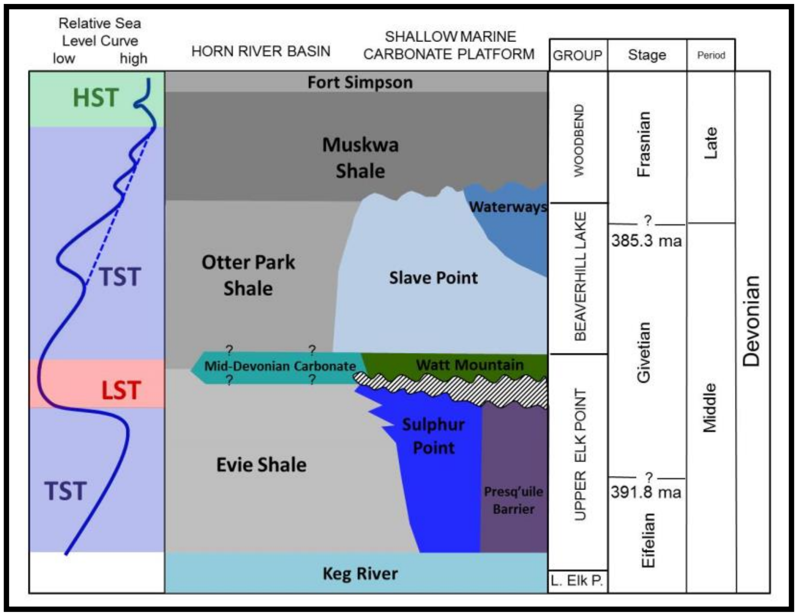


Figure 2) Stratigraphic column and depositional history for the Horn River Basin (Modified from Mossop and Sheltsen, 1994, and Hulsey, 2011)

Theory and/or Method

Shale lithologies and natural fractures are logged in detail to understand the lithological stratigraphy as well as the natural fracture stratigraphy of the cores. Image logs and drilling induced fractures from core are used to help interpret the orientations of natural fractures observed in core.

Rock samples are taken to evaluate and calibrate rock facies and rock mechanics properties to wireline log data. Rock facies lab analysis includes XRF, TRA (Tight Rock Analysis), TOC, rock-eval, pyrolosis, vitrinite reflectance, thin section analysis and SEM/EDX. Geomechanic rock property lab analysis includes fracture toughness, proppant embedment, unconfined compressive strength, multi-stress compression, triaxial compression and brazil tensile strength test.

Examples

The core for this display comes from the Nexen a-A100-B/094-O-09 well. This well was drilled to a TD of 2743 m MD in February 2011; 146.7 m of core was cut from the base of the Fort Simpson to the Evie B. This rock is mature source rock in the dry gas window with an Ro range from 2-3 (Potter, 2012) and TOC values as high as 0.068 w/w.

The lithofacies in this Horn River core are interpreted to have been deposited in a fully marine setting below maximum storm wave base under anaerobic to dysaerobic conditions. The Evie, Otter Park and Muskwa Formations are unconformably deposited overlying the dolomites and limestones of the Lower Keg River formation and are overlain by the organic-lean argillaceous shales of the Fort Simpson Formation.

The Evie formation is dominated by dark grey to black massive to laminated organic-rich siliceous/calcareous mudstone. The fine-scale laminations are commonly defined by carbonaceous fossil material, mainly styliolinids and occasionally by pyrite. Stylolites and calcite concretions are also observed. The average total organic content, porosity and permeability within the Evie formation are 0.049w/w, 0.045v/v and 205nD, respectively.

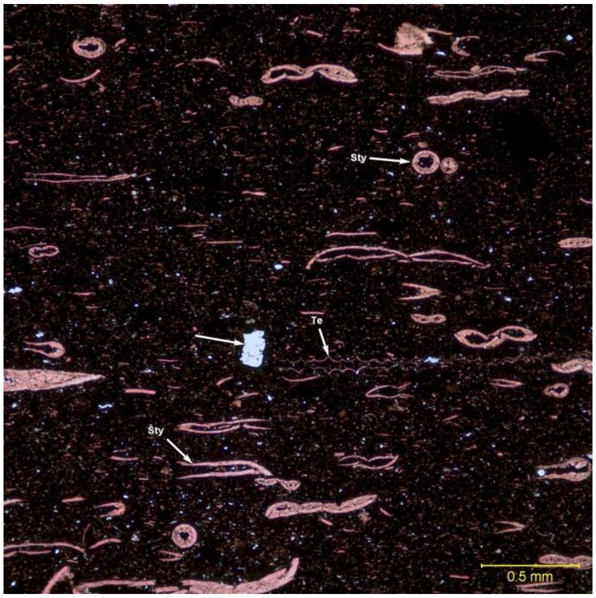


Figure 3) Plane polarized light thinsection photo of *Tentaculities* (Te) and *styliolinid* (Sty) fossils semi-aligned with bedding in an organic-rich siliceous/calcareous mudstone.

The Otter Park Formation is defined by medium to dark grey cryptically laminated to laminated organic-rich non-calcareous to calcareous siliceous mudstone. Minor components include carbonaceous fossil debris, pyrite, clay-rich lenses (or wisps), dolomitic siltstones and organic-lean argillaceous claystone facies. The average total organic content, porosity and permeability within the Otter Park Formation are 0.034w/w, 0.038v/v and 174nD, respectively.

The Muskwa Formation is dominated by alternating medium grey massive silty mudstone and dark grey to black laminated organic-rich siliceous mudstone. Minor components include stylolites, dolomitic siltstone, laminated siliceous siltstone, organic (>50%) and pyrite laminations, framboids and lenses. The main biogenic component is radiolarian, which are predominately preserved by calcite and rarely feroan dolomite. The average total organic content, porosity and permeability within the Muskwa Formation are 0.032w/w, 0.043v/v and 193nD, respectively.

Mineralogically, the Horn River core is dominated by silica (30-80%), which is mostly micro-crystalline quartz with varying amounts of carbonate(matrix, diagenetic and biogenic) and terrigeneous material(argillaceous clay, silt-sized detrital qtz, fsp and mica flakes). The clay component is dominated by illite, with less common mixed layer illite/smectite. The biota assemblage includes identified radiolarian and styliolinids with rare to minor fragmented echinoderms, crinoids, hypothithids, gastropods, bivalves, unidentified shells, calcispheres and conodonts (Bann, 2013). The bioturbation is generally sparse, small–scale and low diversity indicating that the conditions were anaerobic to quasi-anaerobic with rare intervals of dysaerobic dissolved oxygen concentrations. Identified ichofossils include, *Palyaeodictyon, Phycosiphon, Chondrites, Gordia, Cosmorhaphe, Planolites, Zoophycos* and fecal pellets (Bann, 2013).

All of the natural and drilling induced fractures were logged in the A-A100-B core. Individual characteristics for each fracture were recorded which include the fracture orientation, dip, height, termination, fill, aperture and spacing between parallel fractures. This information helped to determine the different fracture types and illustrate the frequency and stratigraphic placement of each fracture type. Thin sections were taken to observe cross cutting relationships and help determine relative timing. Fluid inclusion analysis is currently in progress and could help narrow down the timing of the fracture formation for fracture types sampled.

Conclusions

Detailed lithofacies interpretation from core has been integrated with petrology, ichnology, reservoir properties from core analysis, petrophysical log curves and petrophysical analysis to create a set of electronic facies and a detailed depositional model of the Horn River Basin.

The mineralogy of the shales has resulted in brittle rock which can be effectively stimulated through fracking. Optimizing the completion strategy for each pad involves integrating the geomechanical rock properties with an understanding of natural fractures and faults present. Observations from core are a first step to supplying inputs to discrete fracture network and hydraulic fracture modeling efforts.

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