A Regional Assessment of the Duvernay Formation; a World-Class Liquids-Rich Shale Play

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Summary

The Duvernay Formation sourced the beginnings of Alberta's mid-20th century oil boom with conventional Leduc discoveries near Leduc, Alberta. In the early 21st century, the Duvernay Fm once again spurs exploration and development activity; yet in an unconventional way by targeting the source rock itself in the Kaybob and Willesden Green areas of Alberta.

Exploitation of the world-class, liquids-rich potential of the Duvernay shale requires an integrated approach utilizing classic and avant guard technologies in shale reservoir research. Sweet spot identification began with an understanding of the key input parameters for shale pay identification followed by regional stratigraphic mapping covering over 56,000 square kilometres of the Duvernay shale fairway. The organic-rich Duvernay Formation was deposited within an interior seaway in upper Devonian time; covering a large portion of the western Canadian sedimentary basin. Net shale isopachs within the play area, for the most part, range between 25 and 60 metres; however, over 90 meters thickness has been identified. Regionally, the Duvernay is silica rich, low in clay, with a variable carbonate content, minor pyrite and dolomite; comparing favorably to other unconventional shale reservoirs that have been successfully fracture stimulated.

This unconventional reservoir is bounded by the ductile Ireton Formation shale at its top and, for the most part, the ductile Majeau Lk Formation shale at its base. Understanding the internal stratigraphy of the Duvernay shale and how its character changes across the mapped fairway requires understanding the cyclicity present in the Deep Resistivity Log. The shale can be divided into four primary cycles where each cycle is characterized by a lower resistive base and increasing resistivity up through the cycle. Micritic carbonate and correllateable low-resitivity zones always enter at the base of each cycle. Across the fairway a distinct low resistivity interval exists at the base of the upper most Deep Resistivity cycle (Cycle 4). The low resistive nature of this pay facies can be linked to laminar pyritic mineralogy as shown in the ECA Hz Wahigan 7-17-63-23 cored interval; not increased clay or water saturation as one might expect (Figure 1). This low resitivity facies can be correlated over 300km south to the cored ECA Hz Willesden Creek 2-17-43-4 (Figure 1). In the West Shale Basin the internal stratigraphy of the Duvernay pay package changes as the upper two resistivity cycles thin and the lower two thicken. These cycles are separated by a middle carbonate member we have termed El Diablo. The El Diablo bisects the Duvernay pay interval over a large portion of the play area; exceeding, in some cases, 15 metres in thickness thus potentially decreasing the accessible pay through a single horizontal wellbore. As such, Encana has identified the presence of the El Diablo as a primary risk factor and as such has targeted areas of the play where this member is less than 5 metres in thickness.

Liquid yields in the Duvernay shale do not follow depth based maturity models. Instead they respond to basement scale changes in heat flow and associated fracture patterns. Understanding the distribution of liquid yields across the Duvernay shale requires a comprehensive understanding of the Devonian

Leduc reef complexes. Across the Western Shale Basin and Kaybob the reefs grew along regional lineaments and orthogonal basement structures. They play a primary role in governing autochthonous material distribution, mineralogy, associated sedimentary structures, and stratigraphy. The role of basement scale tectonics in reef development is profound and well discussed in literature; however, these structures also provide the context by which regional pressure cells, associated maturity morphologies, and fracture patterns in the Duvernay shale have been measured, mapped, and predicted. Initial Duvernay pressure gradients of 18 to 21 kPa/m were estimated in Kaybob utilizing absolute open flow tests from isolated Leduc pinnacle reefs within the Wild River Basin. Subsequent Diagnostic Formation Injection Tests (DFIT's) have confirmed that the Duvernay shale is over-pressured across its regional extent with the highest pressure gradients being in the dry gas portions of the Wild River Basin and decrease as a combination of lower reservoir quality and lower maturities in up dip portions of the play. Integrated geochemical data from all publicly available and proprietary data has been modelled and utilized to build maturity maps that have predicted the distribution of liquid yields across the fairway. There is a strong correlation between maturity, pressure, reservoir quality, and shale thickness to the syndepositional tectonic settings across the fairway. An integrated model is presented to explain how these parameters coincide to create one of the most exciting liquid rich shale fairways in North America.

The Duvernay shale sweet spots are defined as: net shale greater than 30m; internal carbonate thickness less than 5m; estimated liquid yields between 50 and 500 Bbls/MMcf; pressure gradients greater than 15.8 kPa/m; and where the pay package has good ductile seals in the overlying Ireton and underlying Majeau Lake formations. By utilizing all of the classic tools of research and basin analysis combined with modern technologies including tight rock analysis, geochemistry, FIB-SEM imaging, advanced fluid analysis, pressured coring, modern log analysis, and a little imagination and creativity; this presentation will show how Encana was able to identify and capture more than half of the high graded fairway in the Duvernay shale.

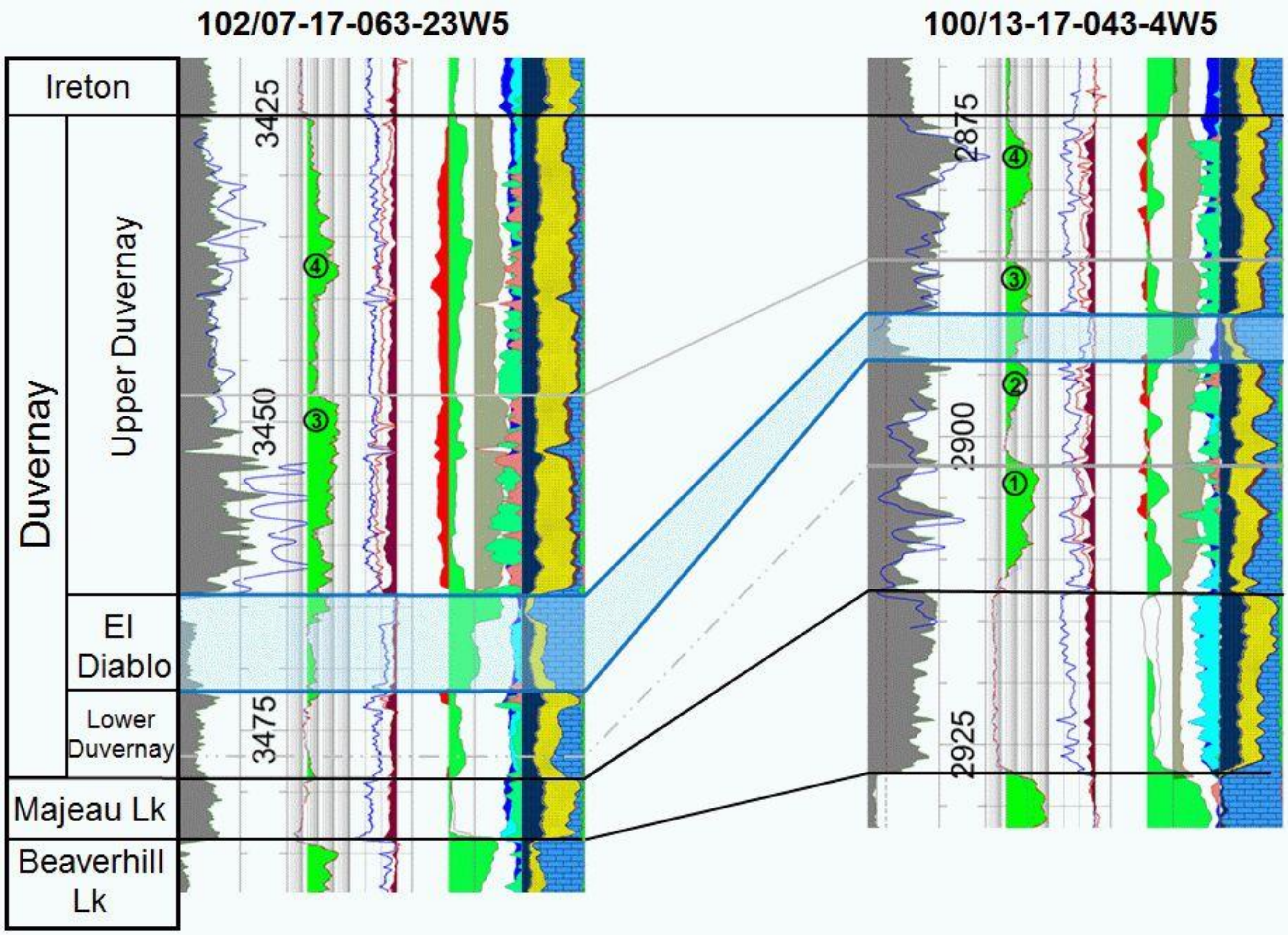

Figure 1. Petrophysical log illustrating stratigraphic nomenclature used for the Duvernay section and bounding units. Log curves, left to right are: log GR and core GR; resistivity with resistivity cycle numbers; density, neutron and effective porosity; Poisson Ratio(red) and Youngs Modulus(green) ; TOC(brown-increasing right) log-derived fluid saturations(fluid colors increasing left) ; multi-mineral analysis clay, silica, pyrite, TOC, limestone, and fluids.