

The Duvernay Formation (Devonian): Sedimentology and Reservoir Characterization of a Shale Gas/Liquids Play in Alberta, Canada*

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Abstract

The Frasnian Duvernay Formation of Alberta Canada ([Figure 1](#)) is a proven source rock which has sourced much of the oil and gas to the adjacent Devonian, conventional fields including the prolific Rimbey-Meadowbrook Reef Trend (Stoakes and Creaney, 1984). It is stratigraphically age equivalent to the Muskwa Formation of the Horn River dry shale gas play to the northwest ([Figure 1](#)). What makes the Duvernay particularly attractive as a “shale gas” play is its potential to produce liquids due to its over pressured nature significantly above the bubble point.

Play Extent

Based on a comprehensive database from 302 wells, comprised of 14 cores, 8,800 km 2D seismic, 2,200 square km 3D seismic the prospective trend extending over 400 kms from the Wildriver Basin in North to the West Shale Basin in the Southeast ([Figure 2](#)) with thicknesses ranging from 35 to 60 m. The VRo% equivalent maturity is published and well documented with the wet gas mature and volatile oil mature portions represent approximately 24,000 square kilometers (5.9 million acres) at drill depths of 2,800 to 3,600 meters (9,200 to 11,800 feet).

Depositional System

The Duvernay represents the deep basinal toe sets of the prograding “shaley” Ireton Formation (Stoakes and Creaney, 1984). Increased organic matter preservation has been variably attributed to anoxic bottom waters due to reduced circulation in Leduc reef controlled sub basins and/or increased primary productivity (Stoakes and Creaney, 1984, Jenden and Monnier, 1997 and Chow et al., 1995). Five component lithofacies have been described from core: argillaceous mudstones, bioturbated limestones, siliceous organic rich mudstone and mixed siliceous mudstones and limestones ([Figure 3](#)). The siliceous organic rich mudstones are interpreted as the most basinal deposits that become variably diluted in proximity to “Ireton” clay rich sources and the Leduc carbonates producing the argillaceous mudstones and mixed siliceous mudstones and limestones lithofacies respectively. A strong positive correlation between quartz content and total organic carbon (TOC) in the siliceous mudstones indicates a biogenic rather than detrital source for much of the silica (Ross and Bustin, 2008) and produces a mudrock that

is high in TOC but also highly brittle/ “fracable”. The bioturbated limestones are interpreted as being deposited above the anoxic bottom waters in areas of local relief or in areas of increased circulation that break down the anoxic bottom water system ([Figure 3](#)).

Rock Quality to Reservoir Quality Relationships

Based on petrophysics calibrated to core and cuttings samples the Duvernay is characterized by an average porosity of 6.5%; an average permeability of 394 nD; and an average of 4.5% TOC. A strong positive correlation between increased reservoir quality and TOC ([Figure 4](#)) indicates an organo-porosity system that was confirmed using Ion Mill SEM techniques ([Figure 4](#)). The lithologies and porosity system development in the Duvernay are comparable to those in the Marcellus and the Barnett as described by Loucks et al., (2011). Analogous to the Marcellus (Lash and Engelder, 2011) the best reservoir quality rocks (organic matter rich siliceous mudstones) are preferentially developed during the transgressive systems tract and early regressive systems tract. During the later parts of the regressive systems tract reservoir quality is diminished with the input of detrital clays and limestones ([Figure 4](#)).

State of Play

Presently, this is an emerging shale liquids play in Canada. At this early stage there are only a few horizontal wells with hydrologic fracturing stimulation and production tests; so far, results have been encouraging for Industry. In the wet gas/volatile oil maturity only, the resource in-place endowment is estimated by Talisman at 477 Tcf gas and 19 Billion bbls of liquids of which several large and small companies (e.g., Talisman, Shell, Chevron, ConocoPhillips, Encana, Trilogy, Celtic, and Yoho) are in various stages of establishing the play and attempting to prove its commercial viability.

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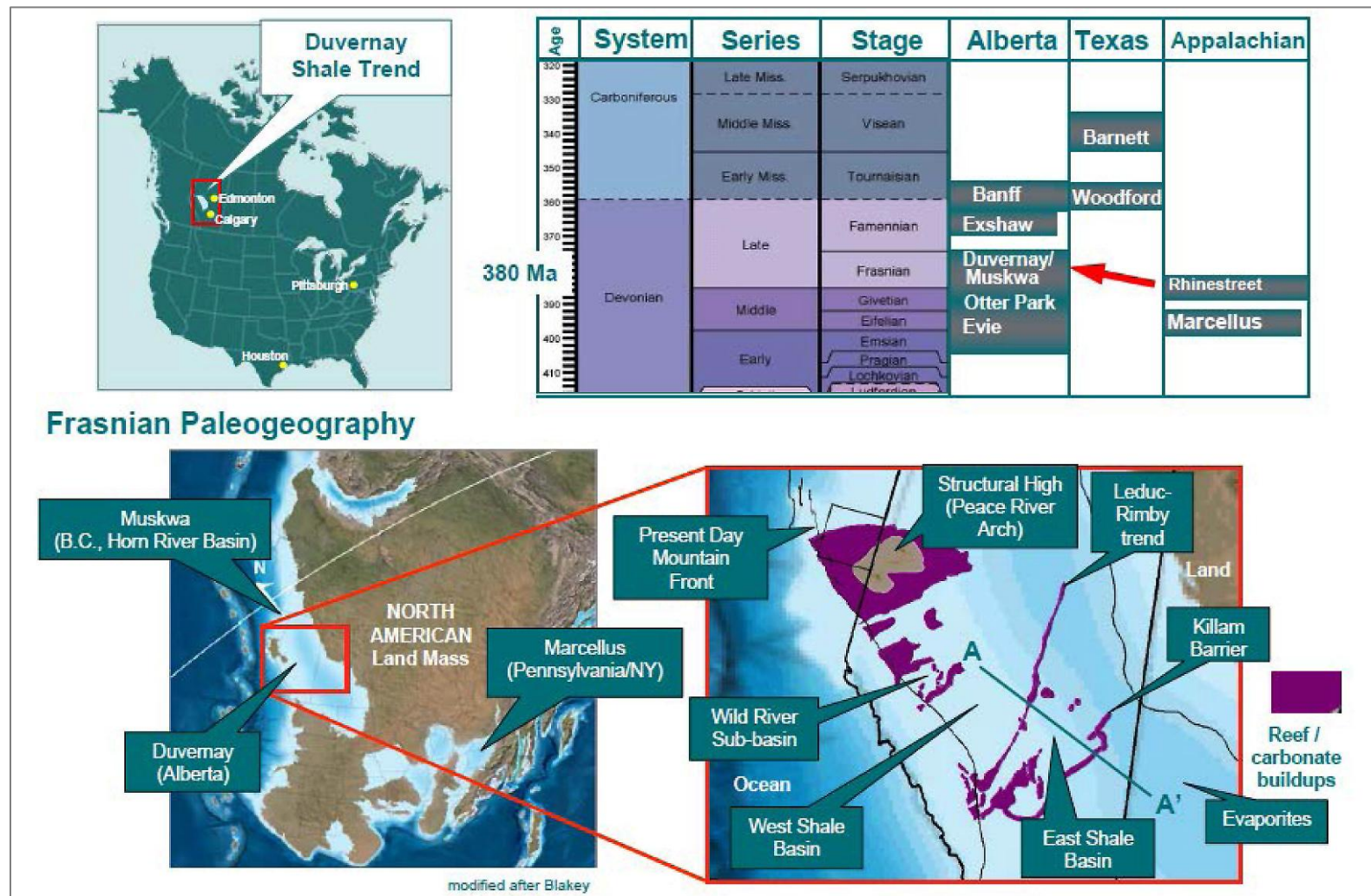


Figure 1. Geographic, Stratigraphic, and Paleogeographic setting of the Duvernay Formation. Palaeogeographic maps adapted from Blakey <http://jan.ucc.nau.edu/~rcb7/globaltext2.html>

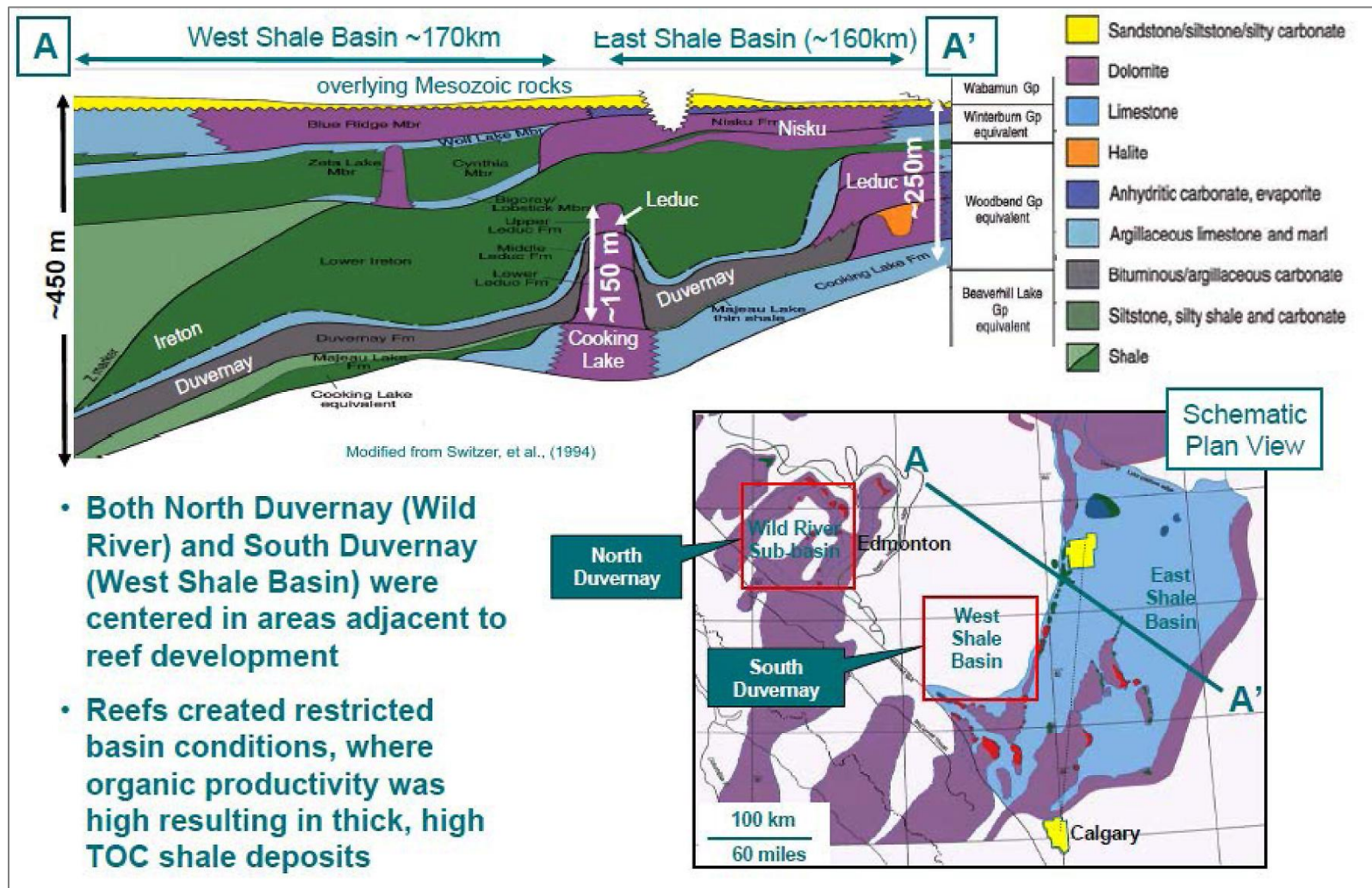


Figure 2. Schematic cross-section and map of paleogeographic map of perspective areas adapted from Switzer et al., (1994).

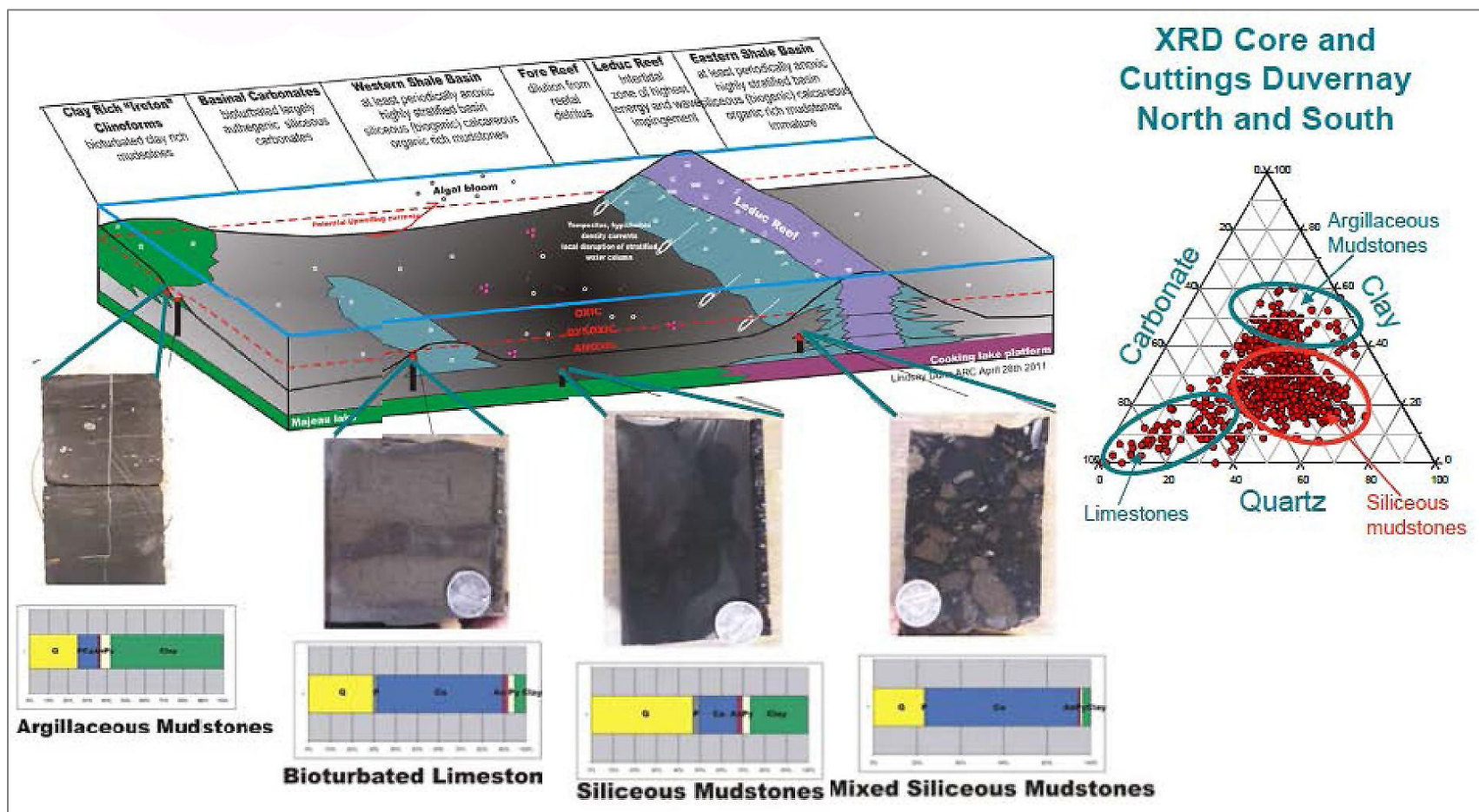


Figure 3. A) Duvernay depositional model for the Wildriver and West Shale Basins with component lithofacies. B) Ternary diagram displaying various lithofacies broken out from cuttings XRD data.

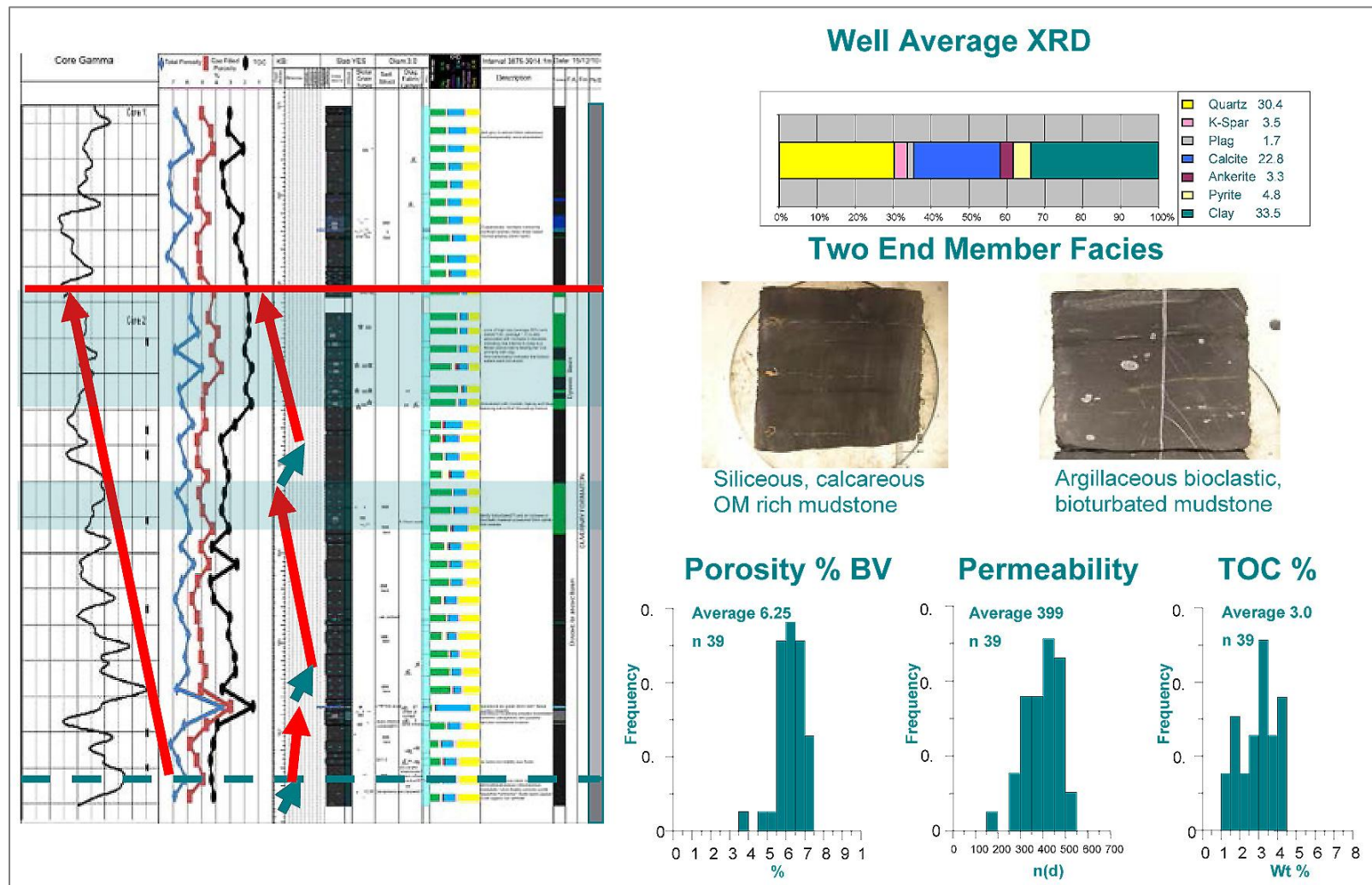
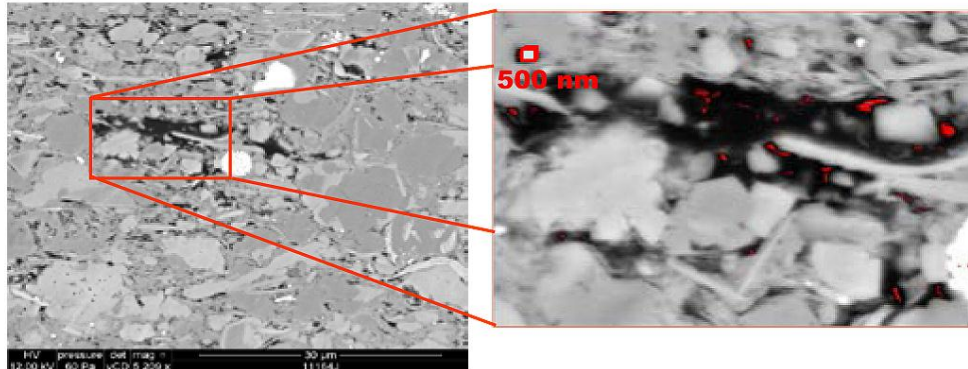
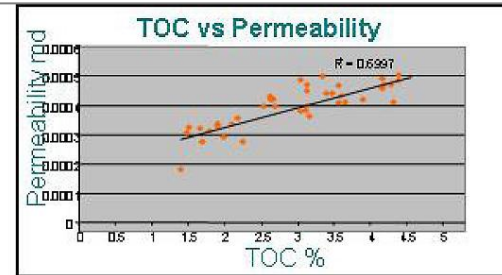


Figure 4. Detailed core description of Talisman's 12-12-57-22W5 Core. Note reduced reservoir quality at tops of regressive cycles (red arrows) due to detrital clay influx.

A) Positive correlation between permeability and TOC indicates that the majority of the porosity is intra-organic which has been confirmed by ion milled SEM imaging



B) Ion Mill SEM Image confirming presence of “organo” porosity. Organic Pores are small but oil molecules are smaller. 1 million oil molecules will fit in this pore (average 5nm oil molecule)

1 mm = 1,000 µm
=1,000,000 nm

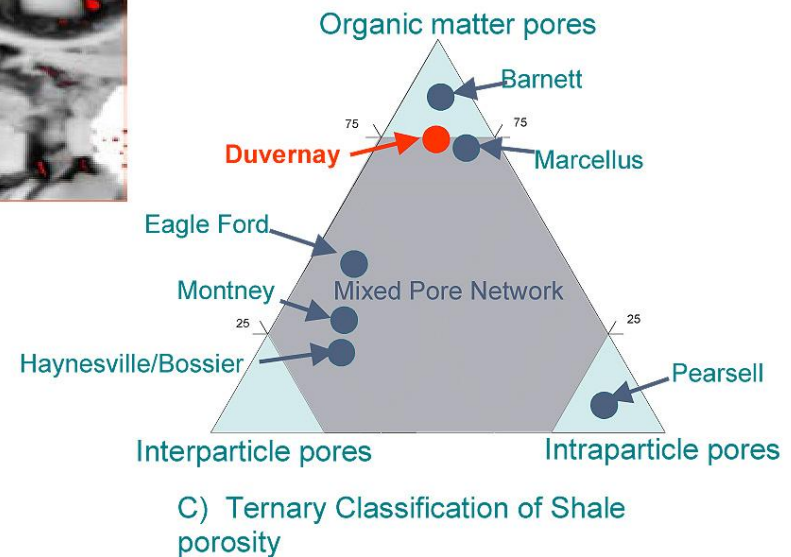


Figure 5. A) Cross plot of TOC versus permeability from the 12-12-57-22W5 core. B) Backscatter Scanning electron images of an ion milled Duvernay samples displaying organo-porosity. C) Ternary plot of shale porosity system adapted from Loucks et al., 2011.