

The Paradigm Shift in Upstream Oil and Gas - Learning from the Canadian Experience*

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Abstract

The commercialization of the combined technologies of horizontal drilling and multi-stage hydraulic fracturing have truly revolutionized the oil and gas industry in North America. Our perceptions of the resource base, supply picture, product price, and future energy security have all changed. These changes have had some unexpected impacts on the Canadian industry. Canada's oil and gas industry has been tied to demand from the United States for many years. In the early 2000's producers struggled to maintain production and gas prices began to rise. The rising prices encouraged experimentation in both Canada and the USA into extracting hydrocarbons first from low permeability sands, then coals and eventually from shales.

The high initial production derived from horizontal drilling and multi-stage hydraulic fracturing, combined with high product prices attracted considerable capital to the industry. This changed with the recession of 2008. Alberta, produces more than 80% of Canadian gas and chose precisely this time to increase royalties. The combination of dropping prices and higher royalties were a painful experience. A viable royalty structure gradually evolved, but by then the natural gas industry was in sharp decline.

A saving grace in Canada has been oil production from both conventional and unconventional reservoirs, plus extraction of bitumen from the oil sands. Much of this production has also benefitted from technological advances providing substantial growth. Robust prices were in place until the second half of 2012, when excess production, competition from plays like the Bakken, and limited pipeline capacity has caused a wide negative differential between Canada's product price and prices received in other parts of the world.

Hindsight shows some of the downsides including: unrestricted sales of oil and gas rights; the high cost of oil and gas activity in Canada; failing to create adequate upgrading and refining capacity; relying on a single market for products; the social, environmental and infrastructure pressures incurred by rapid growth. Canada has many plays that are benefitting from technological advancement and provides considerable innovation and technical expertise. The many lessons learnt have application to other parts of the world.



The paradigm shift in upstream oil and gas – learning from the Canadian experience

Dave Russum, Director Geoscience
Resource Evaluation & Advisory, Deloitte

AAPG ICE, Cartagena, Colombia
September 9, 2013



Resource Evaluation & Advisory (REA)

Deloitte acquired AJM Petroleum Consultants, an engineering and geoscience consultancy, to provide consolidated evaluation and advisory services to the upstream oil and gas industry

- Provide independent engineering, geoscience, and economic evaluations to the petroleum and financial industry
 - Extensive evaluation of reserves and resources, particularly in ‘unconventional’ reservoirs
 - Work in Canada and Worldwide
 - Gas deliverability forecasting
 - Resource potential studies
 - Development feasibility studies
 - Acquisition and Divestiture advisory services
- Much of our work is independent advisory services for companies and governments considering unconventional activity in many different parts of the world

Private & Confidential

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Presenter's notes: In case you are wondering why Deloitte is presenting at a geological conference - Deloitte acquired AJM Petroleum Consultants in 2011, we provide consolidated M&A, financial plus technical evaluations and advisory services through Deloitte's offices around the world.

Why has unconventional development been so successful in North America?

- ✓ Decline in conventional production ongoing since the 1970's
- ✓ Decreasing supply in 2000-2007 created steady price increase - encouraging investment in new opportunities
- ✓ Evolution of technology to effectively extract gas from low permeability reservoirs (horizontal drilling, multistage fracturing)
- ✓ Subsequent drop in gas price encouraged application to liquids rich gas and oil
- ✓ Regulations and incentives in many jurisdictions that enable and encourage application of technology
- ✓ Access to expertise, equipment, services, and infrastructure to rapidly grow activity
- ✓ A competitive environment with short term leasing arrangements - forces companies to drill rather than sit on acreage

International focus has been on US analogs but there are many examples and useful lessons from Canada that can be applied to other countries

Canada – Exploring for unconventional resources

- pro's and challenges

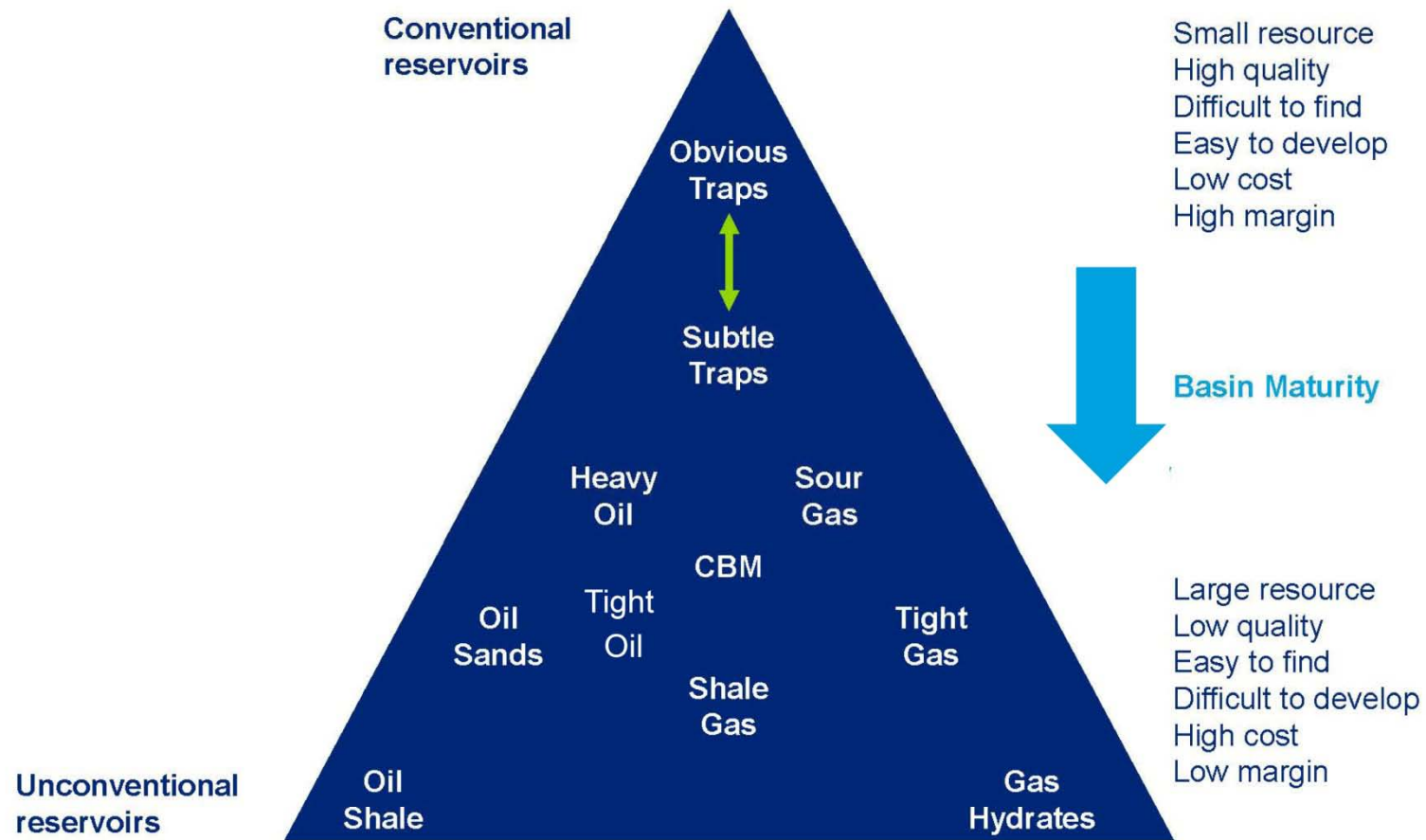
Pro's

- Regulations are well established
- Government controls most mineral rights – available by public auction
- Data from prior wells readily accessible
- Good access to services, infrastructure and skilled personnel
- Low population minimizes friction with other activities
- Wide variety of unconventional oil and gas opportunities
- Basins are large
- Geology well documented

Challenges

- Costs are high
 - Weather conditions – intense cold
 - Some areas inaccessible during certain times of year
 - Distance to market
- No access to global markets
 - United States is currently our only non-domestic market

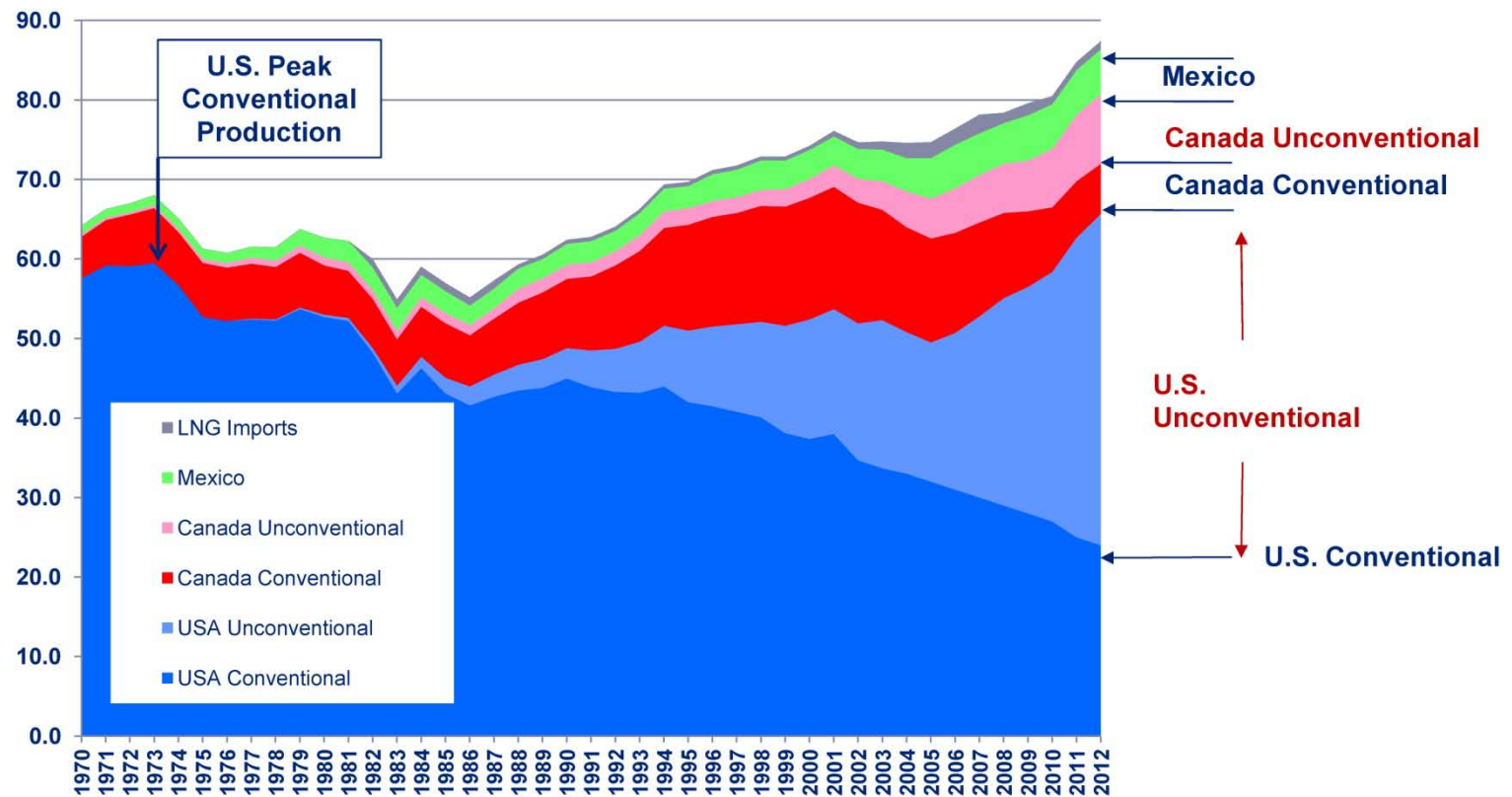
Resource triangle



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Presenter's notes: The resource triangle – with conventional opportunities at the top becoming less conventional and more challenging to extract as move down the triangle.

A focus on gas - North American gas supply (Full year average in Bcf/d)

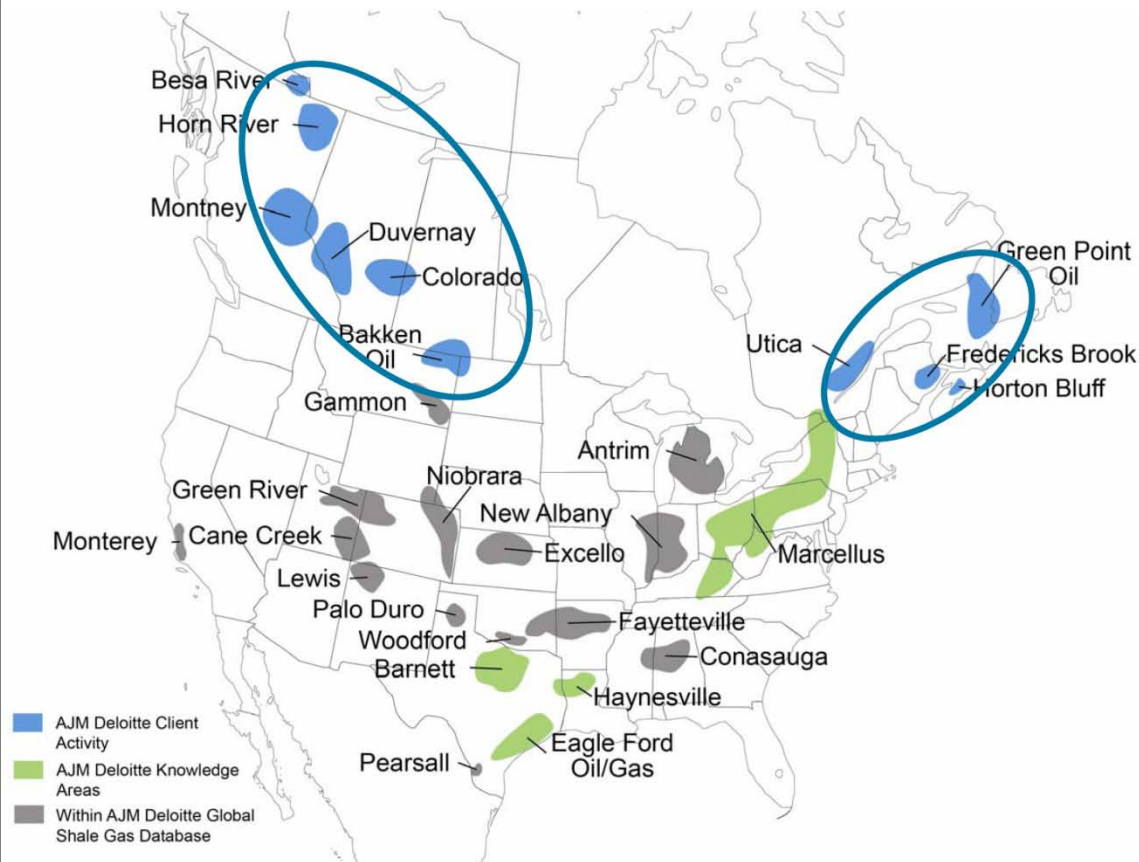


Source: BP 2013, Splits and Forecast Deloitte

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Presenter's notes: The remarkable turnaround in US gas production is from unconventional reservoirs utilizing the dual technologies of horizontal drilling and multi-stage fracturing.

North American shale and other unconventional plays



W. Canada gas plays

- (excluding shallow gas and CBM)
- Mainly in deeper (western) part of basin
- Cretaceous, Jurassic, Triassic, Devonian

W. Canada oil plays

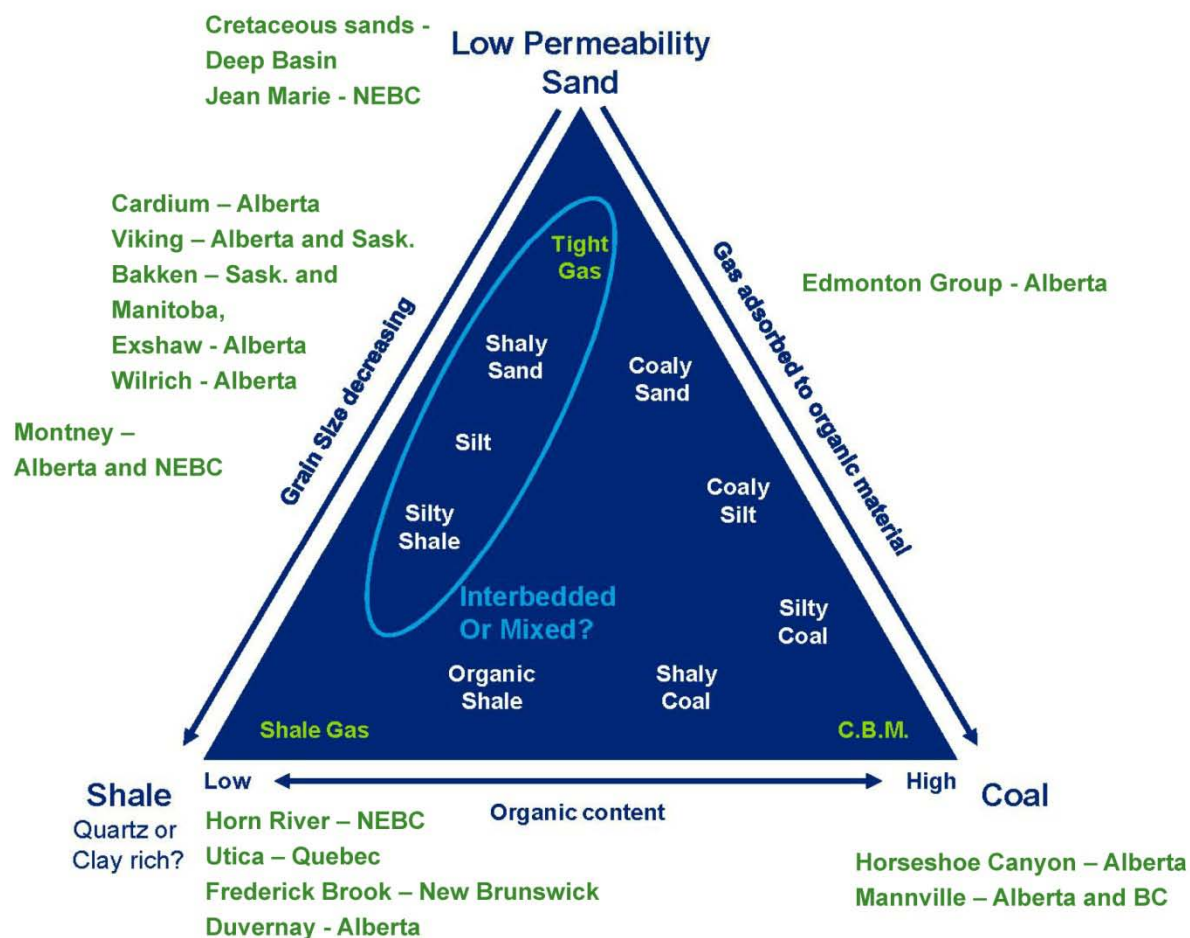
- Excluding oil sands and heavy oil
- Conventional oil in unconventional (low permeability) rocks that benefit from modern technology:

- Cardium
- Viking
- Shaunavon
- Amaranth (Spearfish)
- Pekisko
- Bakken (Exshaw, Three Forks)
- Swan Hills
- Slave Point

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Presenter's notes: While the US shale plays – Marcellus, Haynesville, Barnett, Eagle Ford are very familiar – plays in Canada are less well known. The next speaker will be talking about Eastern Canada so I will focus the rest of this presentation on Western Canada. The Horn River is perhaps the largest shale play of all when extension to the west and north is considered while the Montney is a hybrid with many types of conventional and unconventional reservoirs.

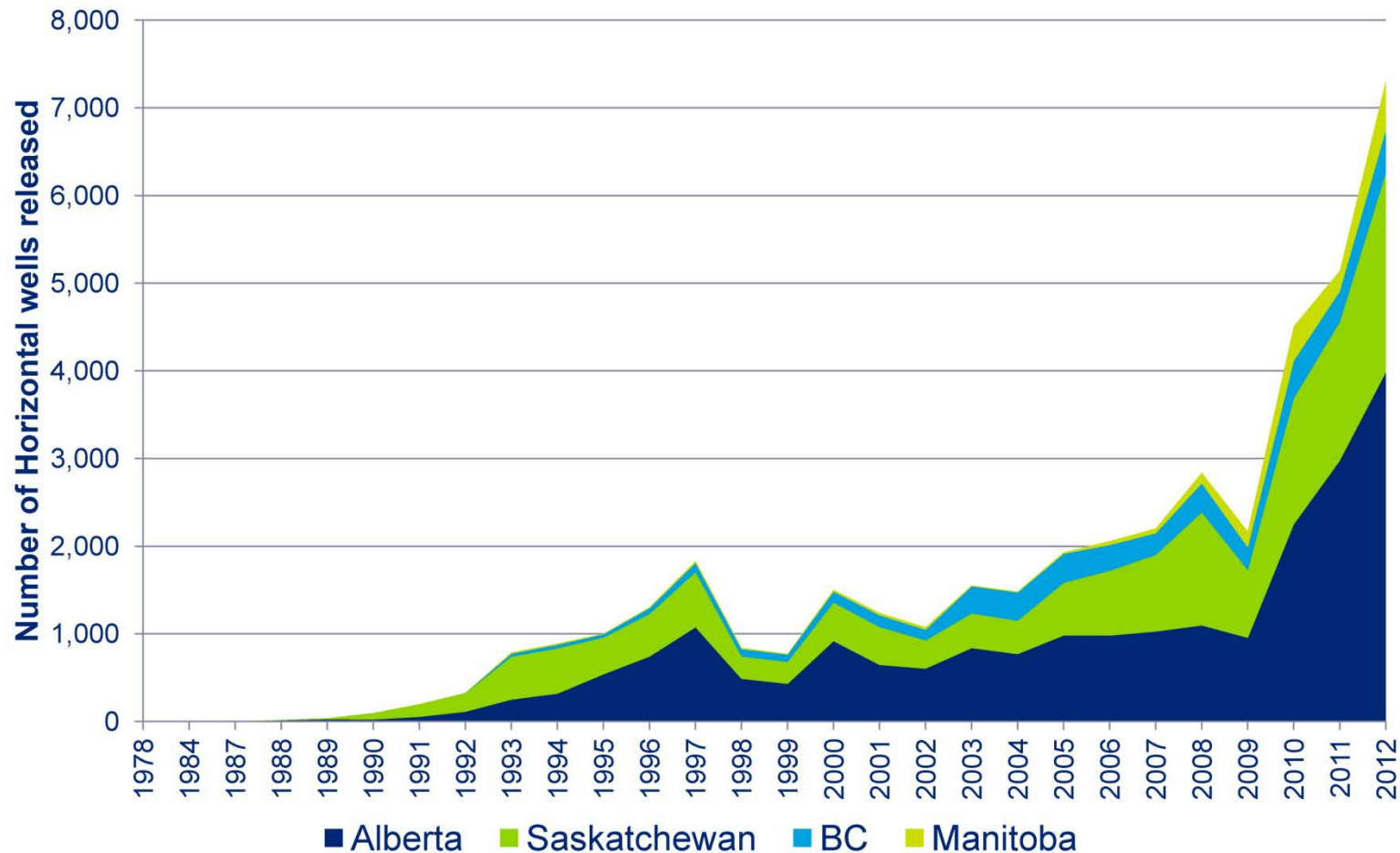
Unconventional “Big Three” – tight sands and carbonates, shales, coal reservoirs – Western Canada



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Presenter’s notes: Unconventional plays can typically be divided into 3 types low k sands and carbonates, shales and coals. Western Canada has many examples that fall into all 3 categories but many of the most interesting opportunities fall on the left side of the triangle with variable coarse and fine grained rock components.

Number of horizontal wells rig released by province



>40,000 horizontal wells drilled in Western Canada to 2011

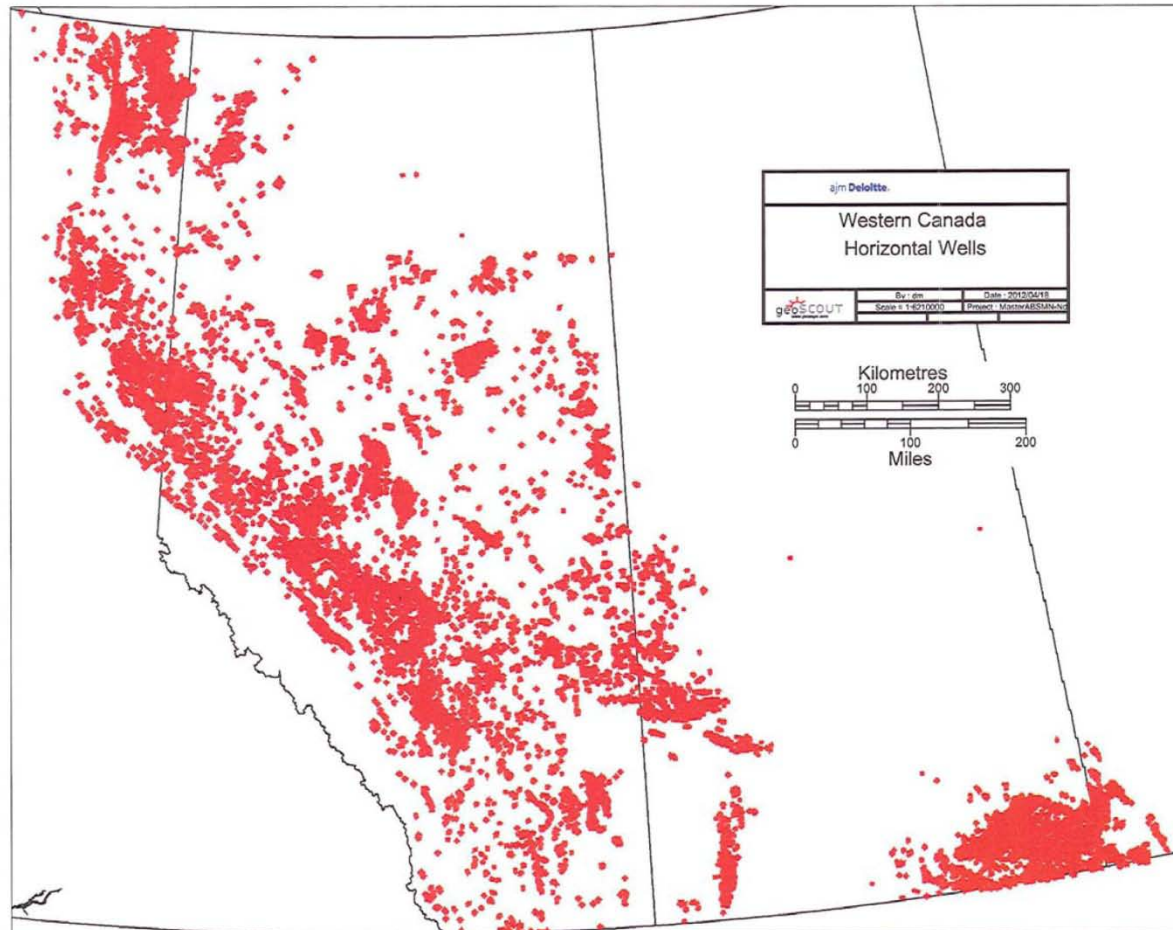
A further 7,000 in 2012

Data source: Deloitte, 2012

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Presenter's notes: Horizontal drilling has increased exponentially across western Canada in the past few years. Over 40,000 wells have been drilled to date with about half using multistage fracturing.

Western Canada horizontal drilling 1987 - 2011



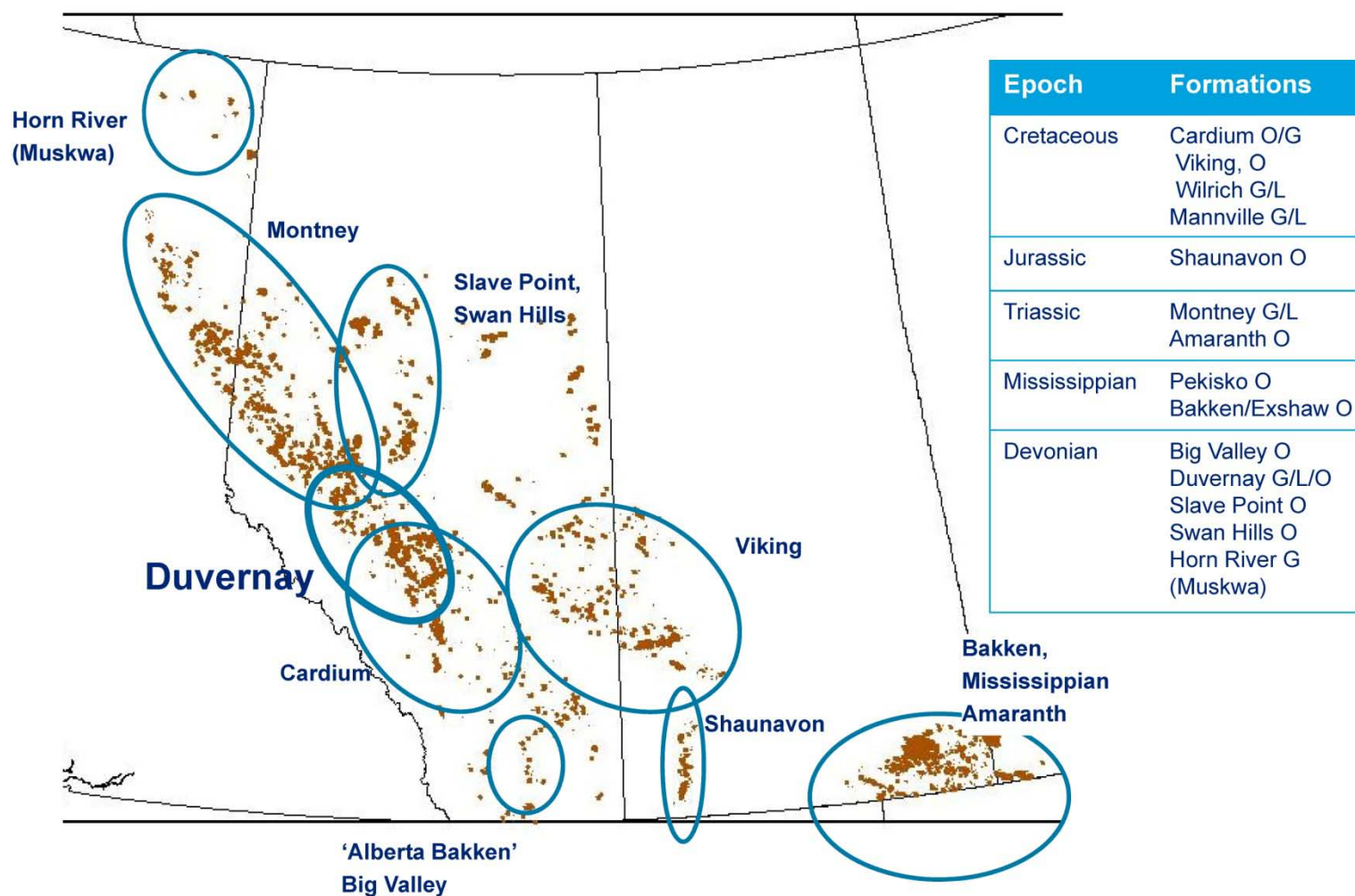
Horizontal drilling has occurred in virtually every area and play in Western Canada

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Presenter's notes: Horizontal drilling has been used in virtually every play in western Canada.

2012 Horizontal Drilling in Western Canada



In 2012 focus on conventional oil in tight reservoirs

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Presenter's notes: 2012 horizontal drilling >7,000 wells focus on oil plays and gas plays with high liquids content. Some of the most significant are highlighted. I want to focus on the emerging Duvernay play.

Duvernay Formation

An emerging giant?



Duvernay Shale Basin Alberta

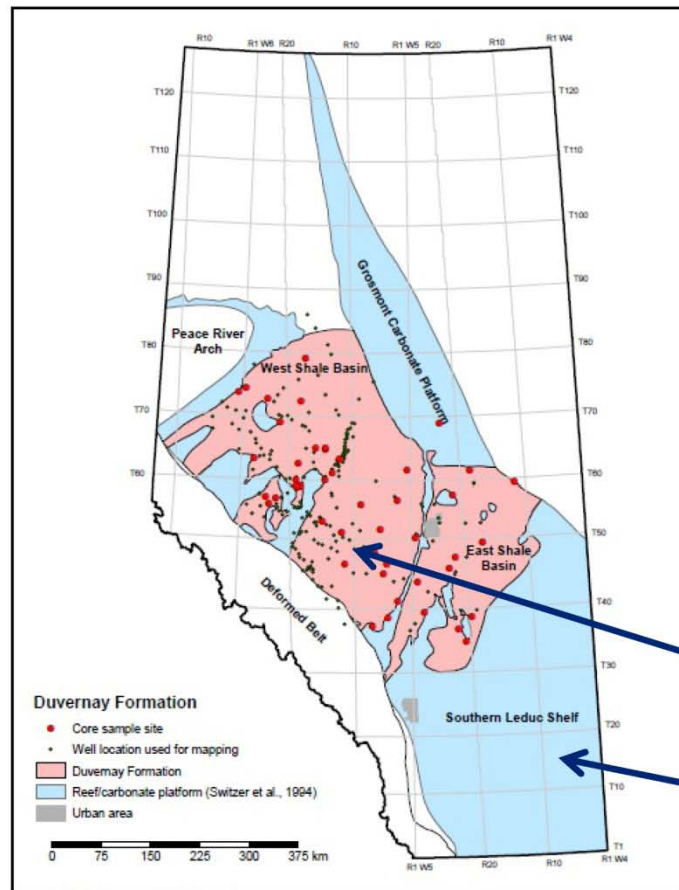


Figure 2.1.1. Index map of the Duvernay Formation.

Duvernay shale - off-reef equivalent and source rock for Devonian reef production

- Gas production with variable liquids
- ~ \$3.5 Billion spent to date
- ~434Tcf and 71 Billion bbl in place
- Depth provides an economic challenge

**Duvernay Formation
- Basinal shale**

**Reef & carbonate
platform sediments**

Image and volume source: ERCB/AGS Open File Report 2012-06 (October 2012)

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Presenter's notes:

- Off reef and hydrocarbon source for productive Leduc reefs – has seen growing activity over the past 3 years
- Over 100 wells have been drilled or licensed to date, most information is still confidential but there are some encouraging reports

Duvernay Shale Basin Alberta

Duvernay shale is the off-reef age equivalent and source rock for Devonian

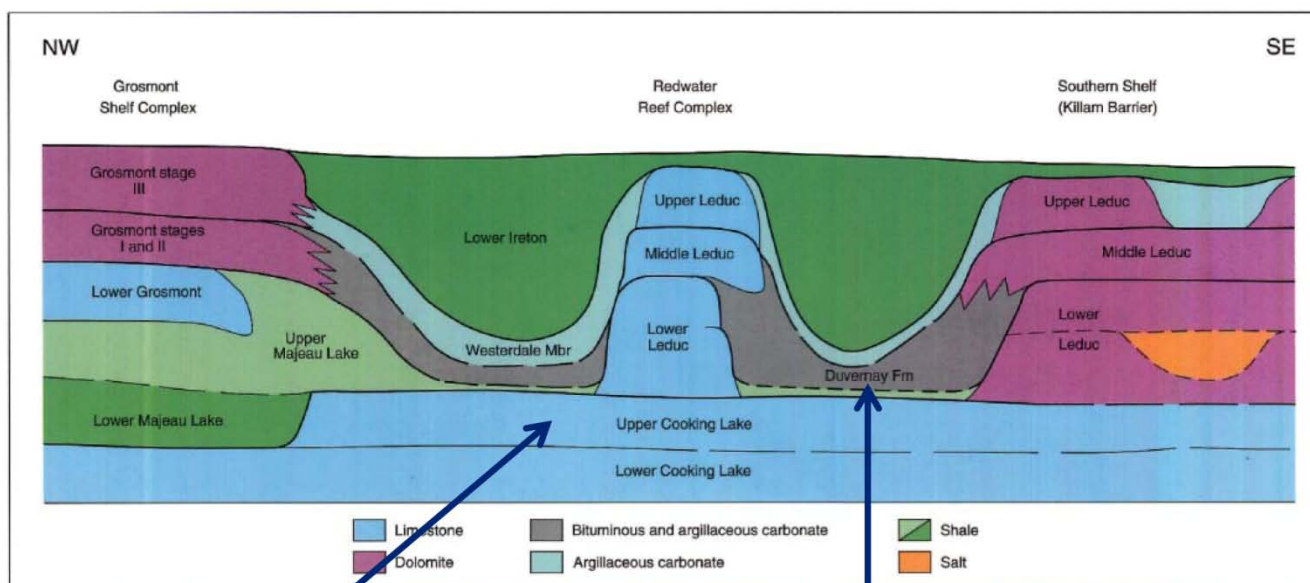


Figure 12.10 Schematic cross section showing stages of reef, shelf and basin-fill development within Woodbend intervals. See Figure 12.7 caption for explanation of the Majeau Lake-Cooking Lake relationship.

Reef & Carbonate Platform

Duvernay Formation Shale Basin Sediments

Image source: ERCB/AGS Geological Atlas of Western Canada Sedimentary Basin, Chapter 12

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Presenter's notes:

- Seen in X-sec organic shales are concentrated in the lower part of the basinal section.

Sweet spots

Focus on thickest areas and high-graded to liquids-rich gas to oil maturity areas

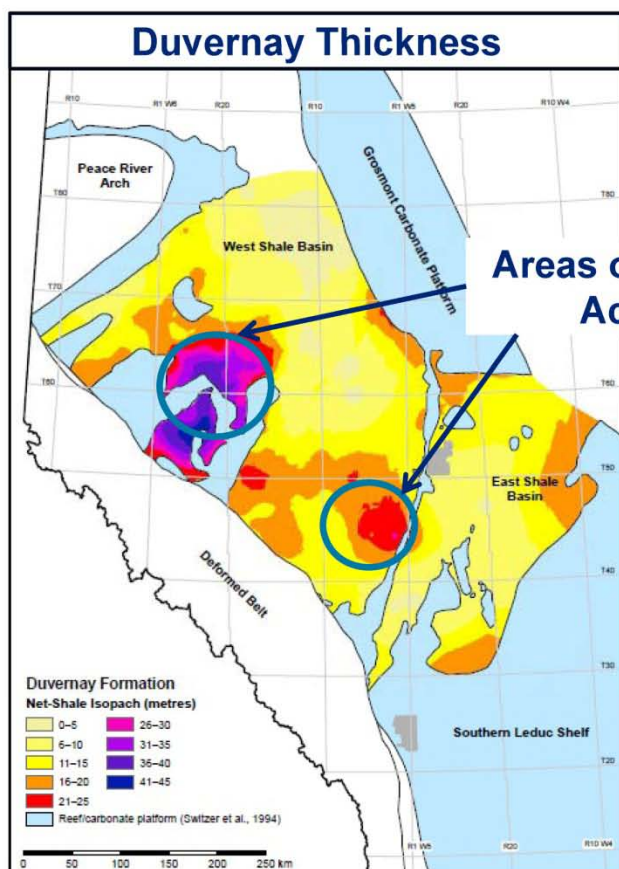


Figure 2.1.5. Net-shale isopach of the Duvernay Formation.

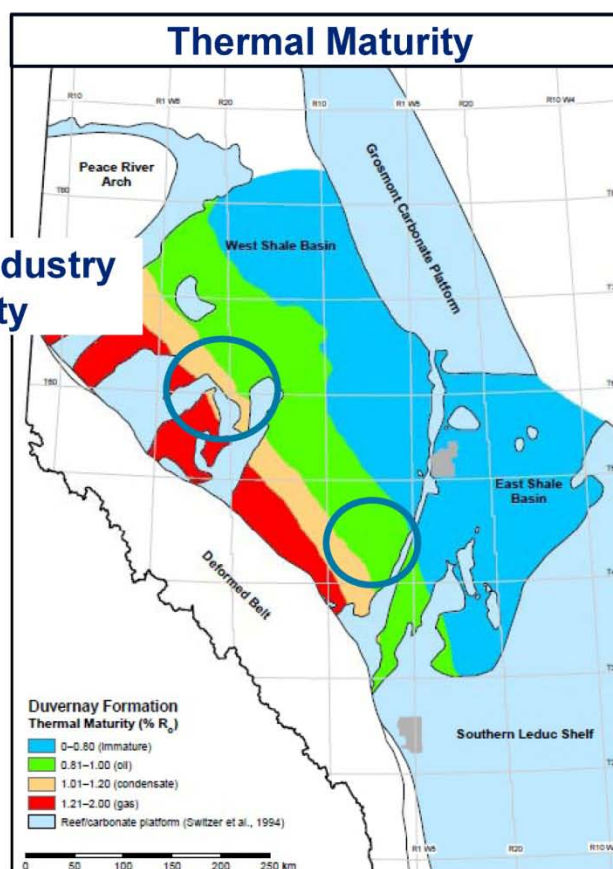


Figure 2.1.7. Thermal maturity map of the Duvernay Formation.

Image source: ERCB/AGS Open File Report 2012-06 (October 2012)

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Presenter's notes:

- Initial screening focused on 2 criteria - thickness of organic shale and maturity.

Duvernay Formation

The importance of sweet spots

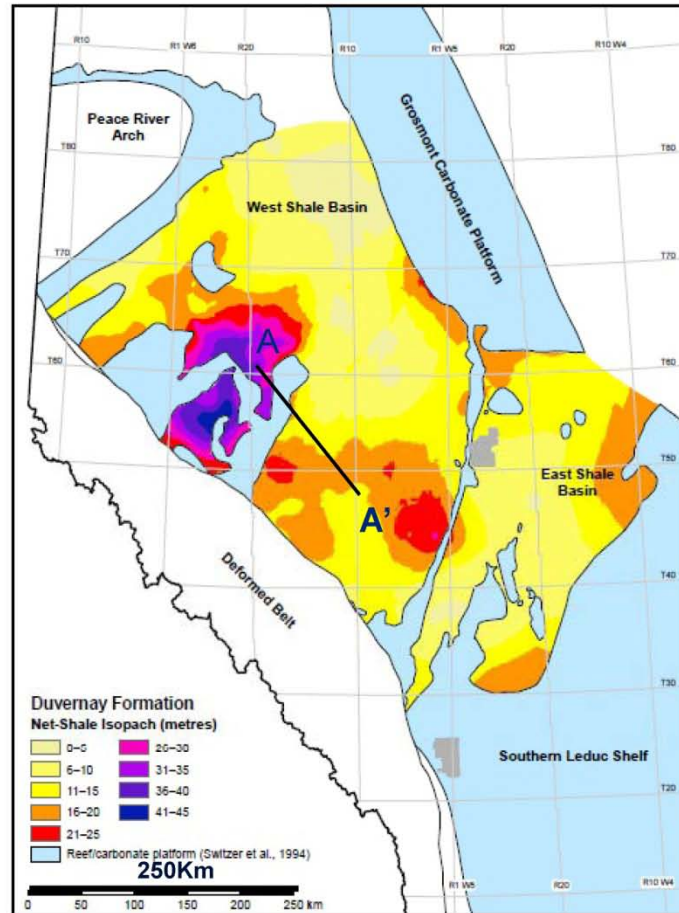


Figure 2.1.5. Net-shale isopach of the Duvernay Formation.

Duvernay Formation	~120,000km ²
>20metres thick	~ 12,000km ²
Maturity >1(%Ro)	~ 21,000km ²
Maturity >1(%Ro) and >20metres thick	~5,000km ²

Other sweet spot criteria might include:

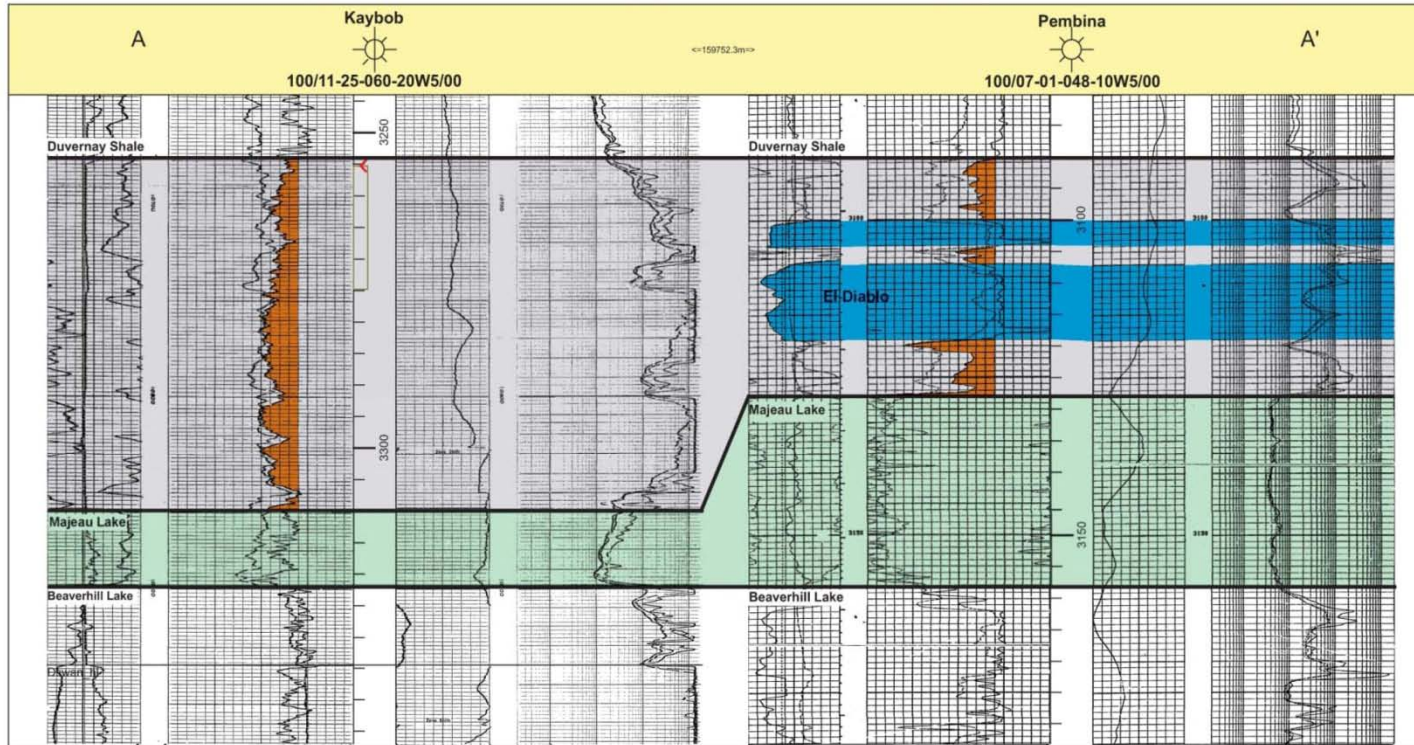
- Porosity (3-12%)
- Permeability (.00001 to .01 mD)
- TOC (1-20%)
- Mineralogy (quartz, calcite rich, low clay)
- Reservoir pressure (Normal to highly overpressured)
- Stress regime
- Ability to create complex fractures
- Ability to constrain fractures

Surface access

Infrastructure

Access to long-term market

Duvernay – the devil is in the details



Encana uses the term **‘El Diablo’** to describe tight carbonates within the Duvernay – reduces thickness of prospective shale and increases horizontal drilling and fracturing requirements

‘El diablo está en los detalles’

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Presenter’s notes: As a caution some area have a tight carbonate within the shale – both reduced the thickness of shale and resource but also makes it very difficult to effectively drill and produce the resource.

Learning from Canadian unconventional projects

- Most successful plays are in areas of proven oil and gas activity
- Target formation has typically been penetrated many times and is known to contain hydrocarbons
- While many of the plays may cover very large areas, the best potential may have limited extent
- Successful opportunities are not necessarily shales
- Understanding the variability of the rocks at the macro and micro scale becomes vital
- All unconventional plays are continuous learning processes
- Large financial investment and persistence are typically required for success
- Risks during the learning and early development makes collaboration, joint ventures, and other shared experience important to accelerate development

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Presenter's notes: Many plays may never be economically - Some of the lessons we've learnt from pursuing unconventional plays in Canada.

The geoscience contribution to unconventional success

- Ensure all available geoscience data has been accessed and included in the interpretation
- Address data shortcomings early
- Focus on sweet spots in play
- Consider collaboration and data sharing with other companies to accelerate learning
- Be aware of geological and environmental risks and uncertainties and take steps to minimize their possible impact
- If risks are too high or potential rewards too low consider an exit strategy
- Geoscience input is vital throughout the identification, exploration, development and production phases of unconventional plays
- In all unconventional plays **‘El diablo está en los detalles’**