Utica and Other Ordovician Shales: Exploration History in the Quebec Sedimentary Basins, Eastern Canada*

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Search and Discovery Article #10451 (2012)**
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*Adapted from oral presentation given at AAPG Eastern Section meeting, Cleveland, Ohio, 22-26 September 2012. Please see closely related article, "Shale Gas in Quebec's Sedimentary Basins", Search and Discovery article #80139.

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Abstract

Since the announcement in April 2008 about the potential of shale gas in the Staint Lawrence Lowlands in southern Quebec, 25 new wells have been drilled in the area. This announcement has created a small revolution in a region known worldwide for its hydroelectric potential but definitely not for its oil potential. The Ordovician calcareous shales of the Utica Group, rich in organic matter, are the main target of recent exploration efforts. This renewed interest marks a new stage in the history of oil exploration of sedimentary basins in Quebec.

The cradle of oil exploration in Canada, the Province of Quebec, has seen oil rigs searching this territory since the 1860s. Several exploration wells have been drilled without much success, but several gas shows were encountered in the shales. The first tests with the objective to assess the gas potential of the Ordovician shale were done in the early 1970s by Shell Canada and SOQUIP. Obviously, the tests did not met the expected economic goals. The same result was realized for the unsuccessful attempt to achieve a horizontal well in the Lorraine Shales in 1992. It was not until 2004, after using knowledge of successful development results in the Antrim Shale of Michigan and the Barnett Shale of Texas, that Junex initiated an evaluation of modern shale gas potential of the Ordovician of Quebec. In partnership with Forest Oil, the vertical well A250-Junex Becancour No.8, was drilled and tested using the technique of massive hydraulic fracturing during the year 2007. The positive results of these tests, that will be subsequently repeated by other operators in the basin, will launch a series of exploration wells to estimate the gas potential of the Utica Shales of the Saint Lawrence Lowlands.

Current knowledge of the geology of the region has led operators to subdivide the shale gas potential in different play types. To date, most operations were performed in about 1/3 of the shale basin in the deep thermogenic shale gas play (1000-2000 meters), located in the central plain of the Staint Lawrence Lowlands. With OGIP estimates ranging from 120 to 160 BCF per section, the deep play is considered promising.

Based on exploration work conducted in recent years in Quebec, five play types have been described: 1) thermogenic shale gas or liquid-rich shale at shallow to middle depth, 2) overthrusted shale gas, 3) biogenic shale gas, and 4) intra-Appalachian sub-basin shale gas, and last but not least 5) the oil-rich shale of the Macasty Formation (Anticosti Basin).

The exploration history of Ordovician shales in Quebec includes a combination of science, intuition, perseverance and adaptability. But the premises of the story remain similar to those found in other sedimentary basins: the presence of brittle shale which acted as a major source rock. The people living in Quebec are energy intensive and more than half of this energy comes from oil and natural gas. The development of oil and gas potential of Québec will generate significant economic benefits for citizens and will have positive impacts on the competitiveness of its sources of supply.

Selected Reference

Aguilera, R., 1978, Log Analysis of Gas Bearing Fracture Shales in the Saint Lawrence Lowlands of Quebec: SPE Annual Fall Technical Conference and Exhibition, 1-3 October 1978, Houston, Texas, SPE #7445-MS, 16 p. doi:10.2118/7445-MS

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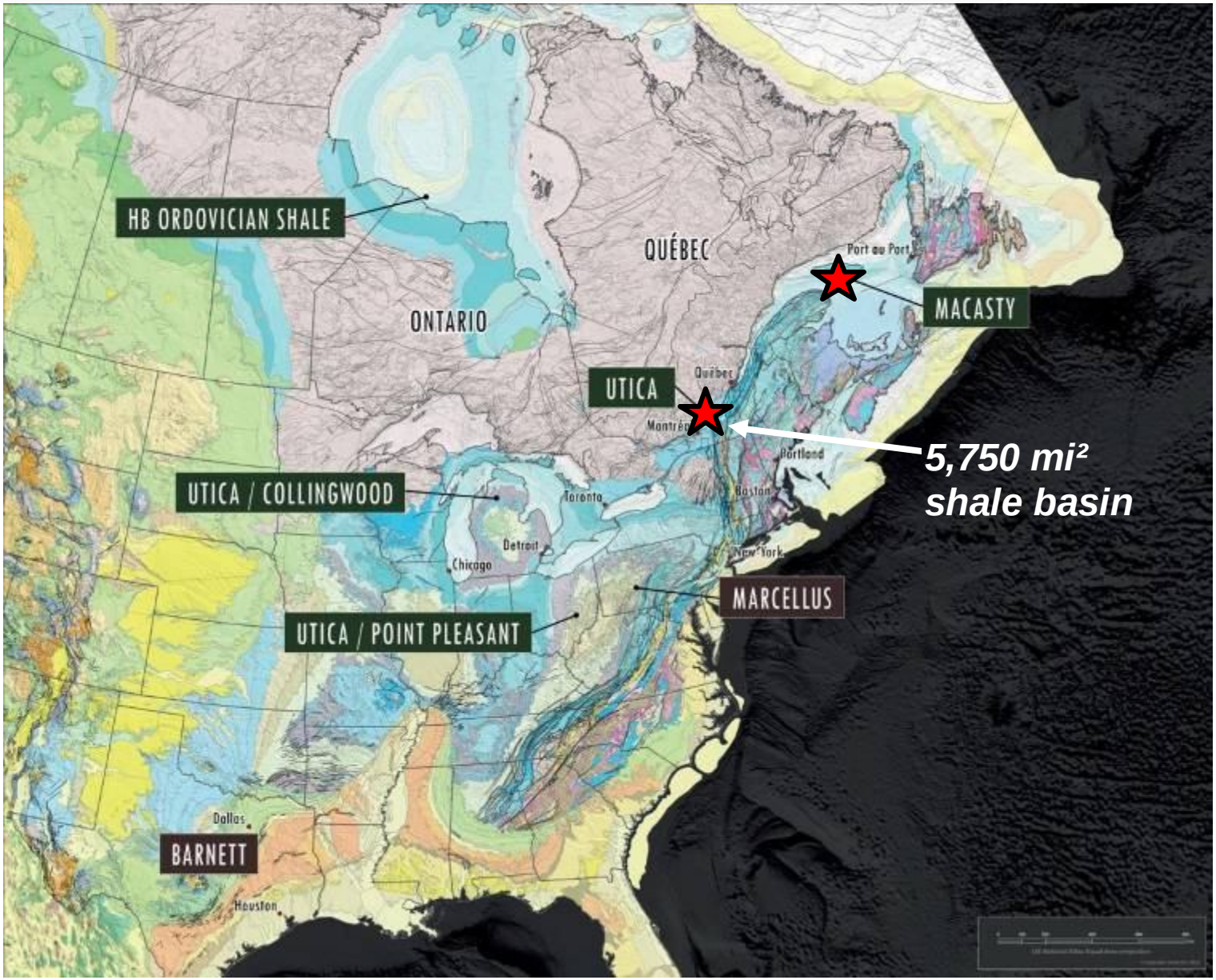
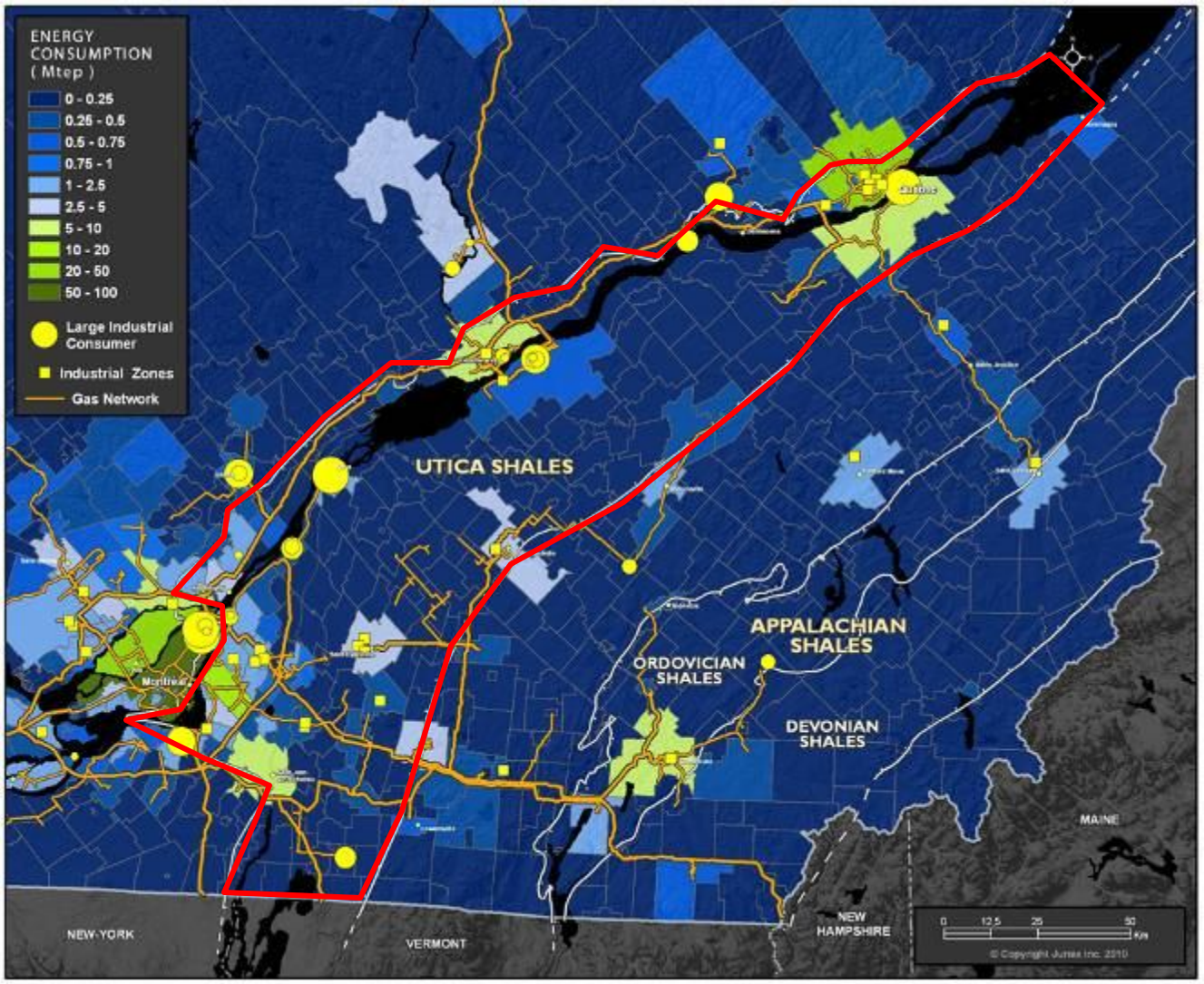
41st Annual Eastern Section AAPG Meeting
Cleveland, Ohio
September 25th, 2012

Quebec's Utica & Macasty Shales in North America



Infrastructure & Energy Consumption



Area with the strongest energy consumption are in green colors

Quebec is one of Canada's largest energy markets : 300 Mboe/year

Daily oil consumption: 410,000 bbl (transport)

Annual gas consumption of 180 Bcf

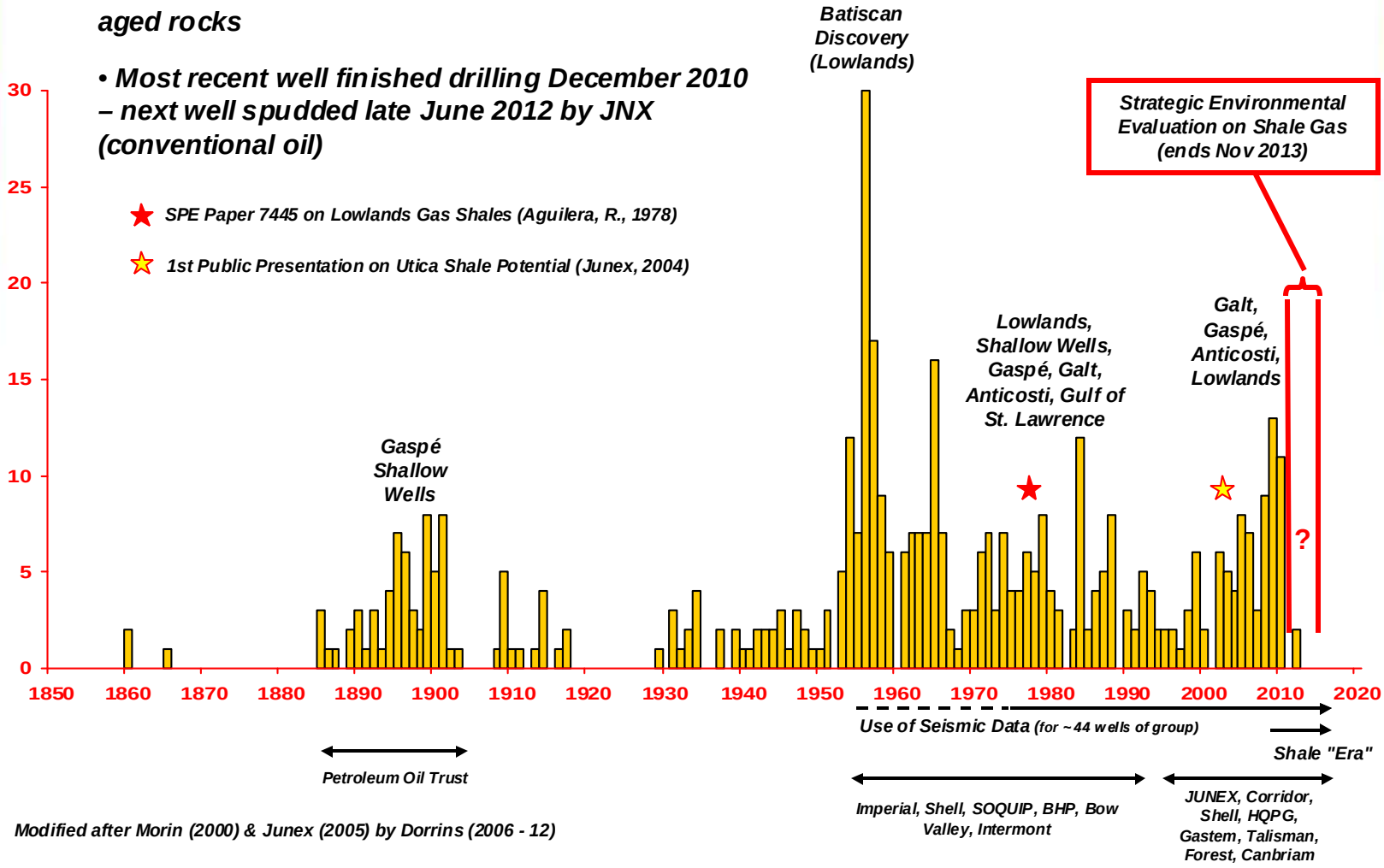
80% of gas consumers are industrial and commercial

Gas network covers several areas in the Utica Shale Fairway

Infrastructures :
2 oil refineries;
3 gas storage facilities;
pipeline network.

O&G Exploration in Quebec - Relatively "Immature"

- *Total Number of Oil & Natural Gas Exploration Wells Drilled in Quebec*
- *~ 450 wells drilled since 1859 into Paleozoic-aged rocks*
- *Most recent well finished drilling December 2010 – next well spudded late June 2012 by JNX (conventional oil)*



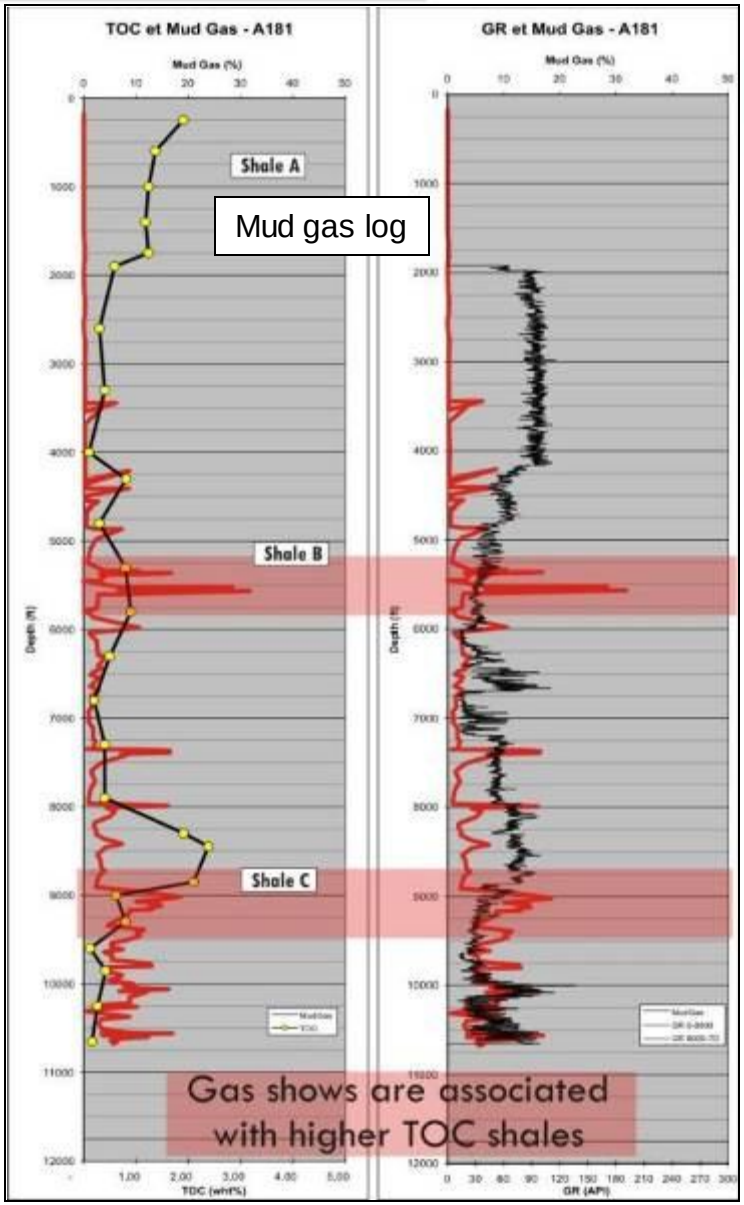
Modified after Morin (2000) & Junex (2005) by Dorrins (2006 - 12)

Utica Shale Gas - Where and when did it start?

Lower Lorraine and Utica Shale Gas

Gas in shales in the St. Lawrence Lowlands known for decades – however low gas prices, little infrastructure, and lack of pertinent technologies to "unlock" the gas precluded its development

Dr. Roberto Aguilera, world-reknowned petroleum engineer & expert in fractured reservoirs, first published about the St. Lawrence gas shales in 1978 ("Log Analysis of Gas Bearing Fracture Shales in the Saint Lawrence Lowlands of Quebec," Paper SPE 7445 (1978))



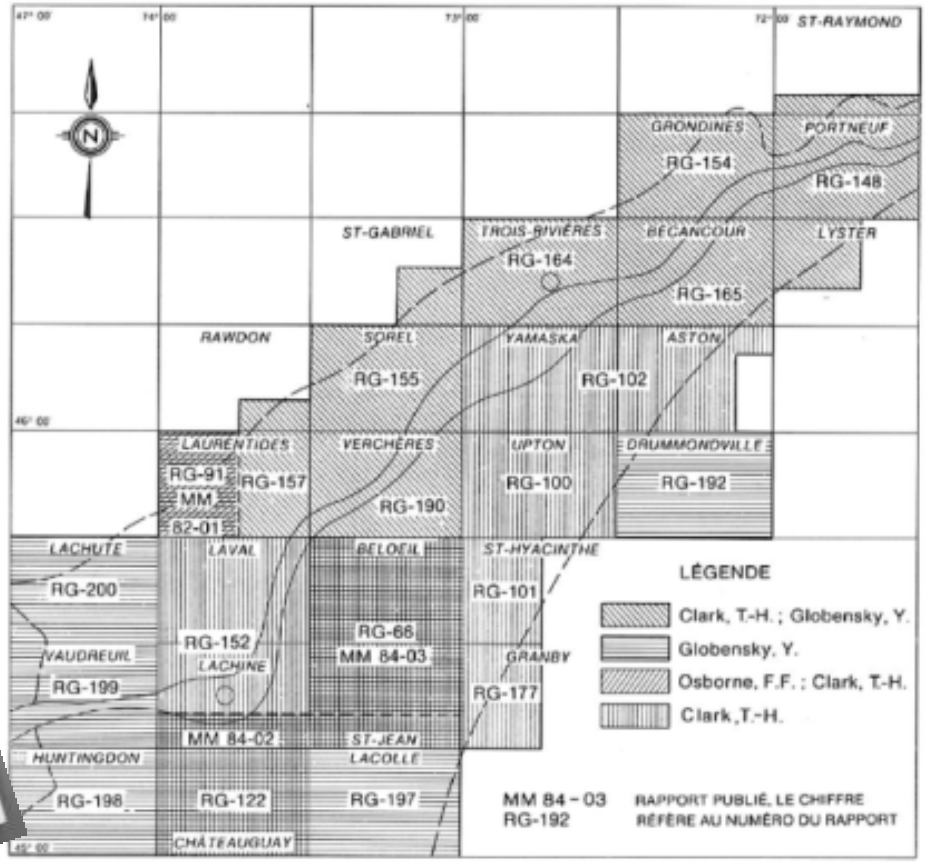
JUNEX (2010)

Mapping the Sedimentary Basin

T.H. Clark and Yvon Globensky

From 1940 to 1990

Several gas show from water wells where mapped.



First Technical Evaluation of the Shale Gas Potential

JUNEX

Roberto Aguilera in 1978

Fractured Shale in the Villeroy Area

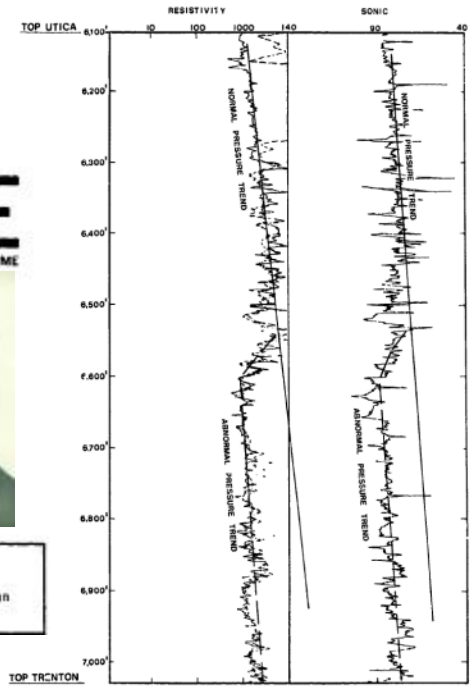
SPE

Society of Petroleum Engineers of AIME

SPE 7445

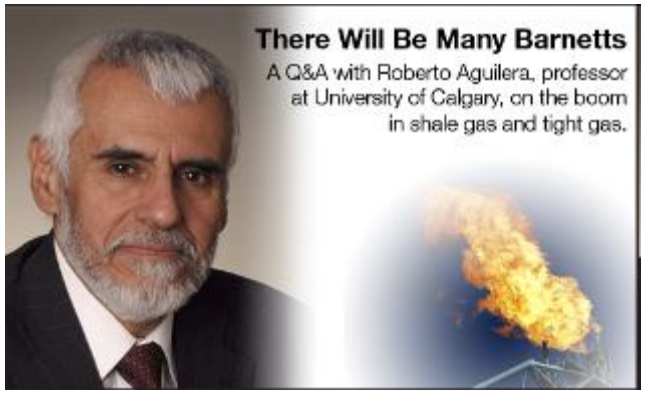
LOG ANALYSIS OF GAS-BEARING FRACTURE SHALES IN THE SAINT LAWRENCE LOWLANDS OF QUEBEC

by Roberto Aguilera, Member SPE-AIME, SOQUIP



Extract from the paper :

Gas-in-place for the 150 sections mapped so far is estimated at 885 BSCF ($25.06 \times 10^9 m^3$). Consequently, the 90 initial "development" wells are expected to recover 25.5% of the original gas-in-place in a 20 year period.

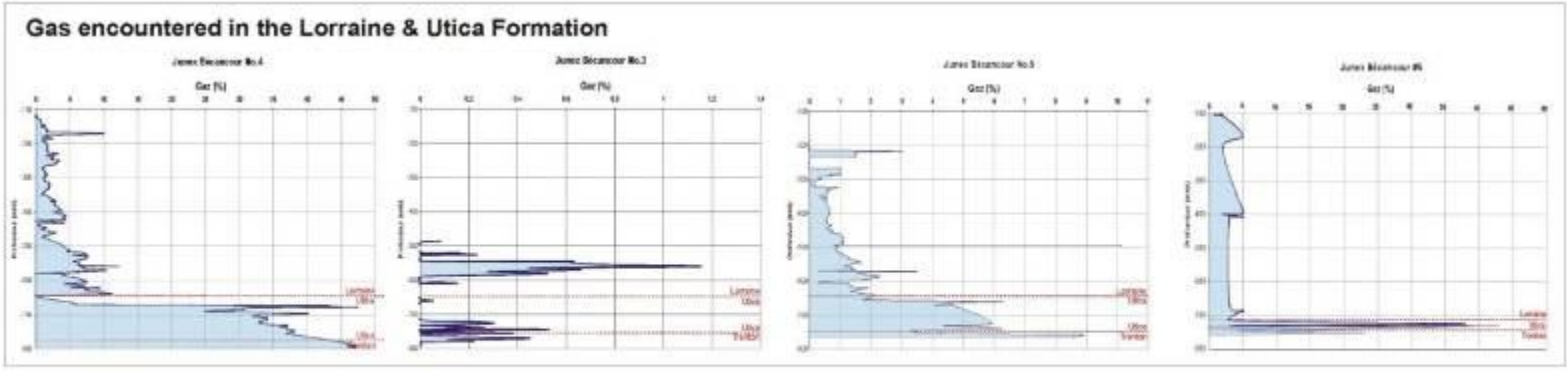


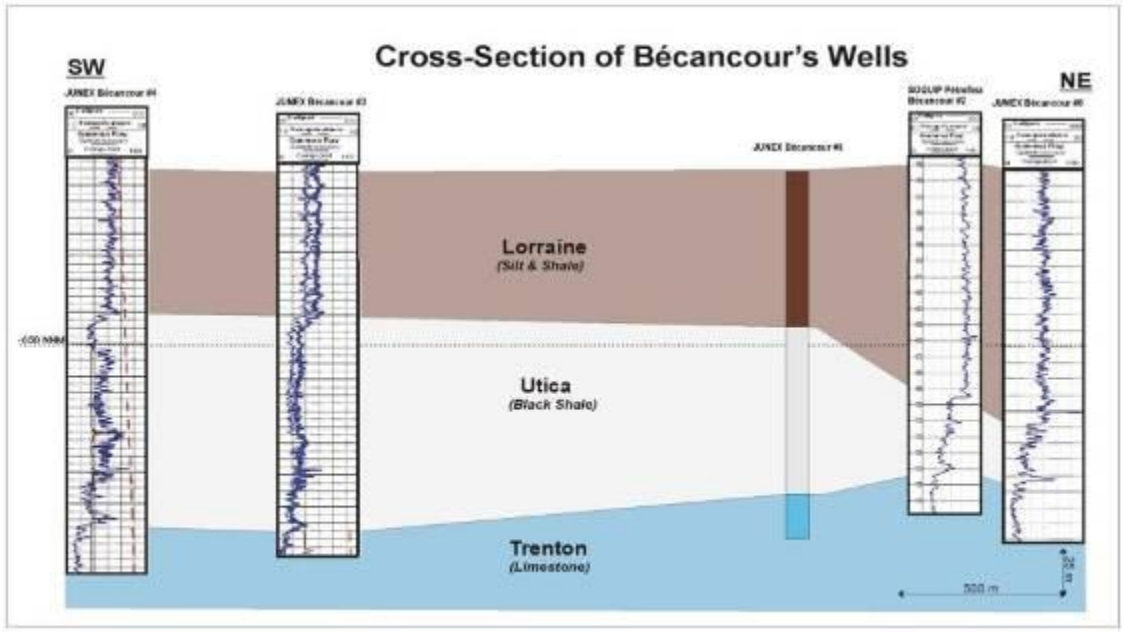
And from a recent interview with Roberto Aguilera (2009)

http://www.energytribune.com/articles.cfm/1806/There-Will-Be-Many-Barnetts-A-QA-with-Roberto-Aguilera

The New Era – Shale is a « play » now

Start with Junex in 2004 to 2006 : Resource Play Identification





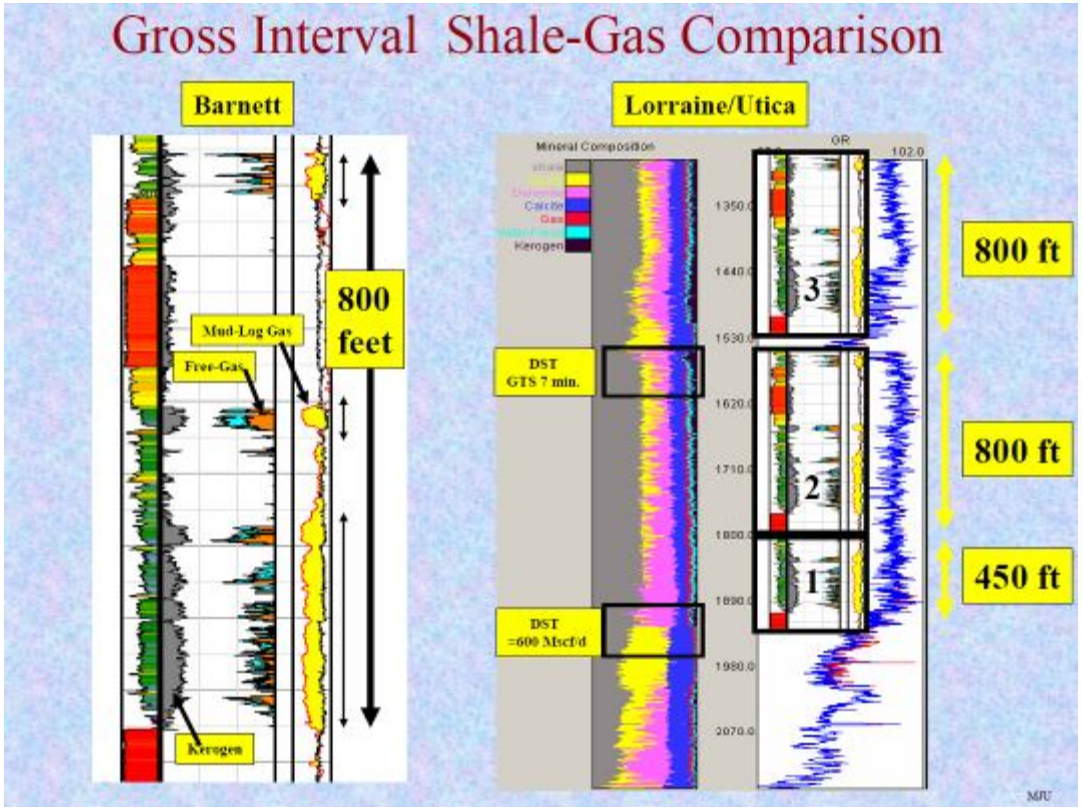
Correlation with the US Shale Gas (2007)

Unconventional & Conventional Opportunities in the Province of Quebec, Canada

Offered by AMQUE, U.L.C.

NAPE February, 2007 Booth #1845

Presented by: Jim Morabito, AMQUE Partner



First Press Release of Positive Results (2008)

2008 Analyst Conference

New York City
April 1, 2008

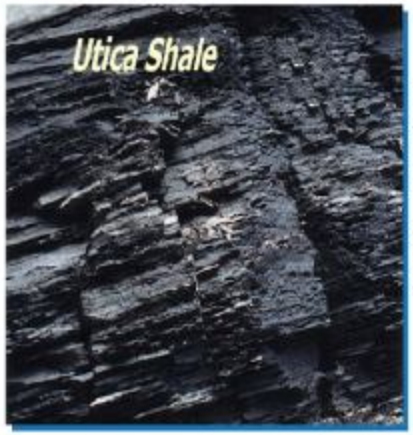
Utica Shale – St. Lawrence Lowlands, Quebec

Large Resource Potential and Acreage
- 4.1 Tcf of net resource potential
- Low cost of entry
- 339,000 gross acres, ten year term

Excellent Rock Properties
- Comparable to Barnett Shale
- At least two prospective Utica horizons

Test Concept
- Test rates up to 1,000 Mcf/d
- Significant gas content demonstrated
- Next Step → Drill Horizontally

Existing Infrastructure and N.E. Market
- Easy access to pipelines
- Premium pricing to NYMEX



	Utica	Barnett
Depth (ft)	2,300 – 6,000	4,500 – 9,000
Thickness (ft)	500	150 – 700
Clay Content (%)	15 – 26	15 – 30
TOC (%)	1.0 – 3.1	3.5 – 5.0
Gas-Filled Porosity (%)	3.2 – 3.7	3.0 – 4.8
Pressure Gradient (psi/ft)	.45 – .60	.46 – .50
Maturity (Ro)	1.3 – 2.0	1.0 - 2.2
Gas Price ($)	NYMEX + 1.05	NYMEX - 0.53

"Rock Properties Comparable To The Barnett Shale But With Premium Gas Price"

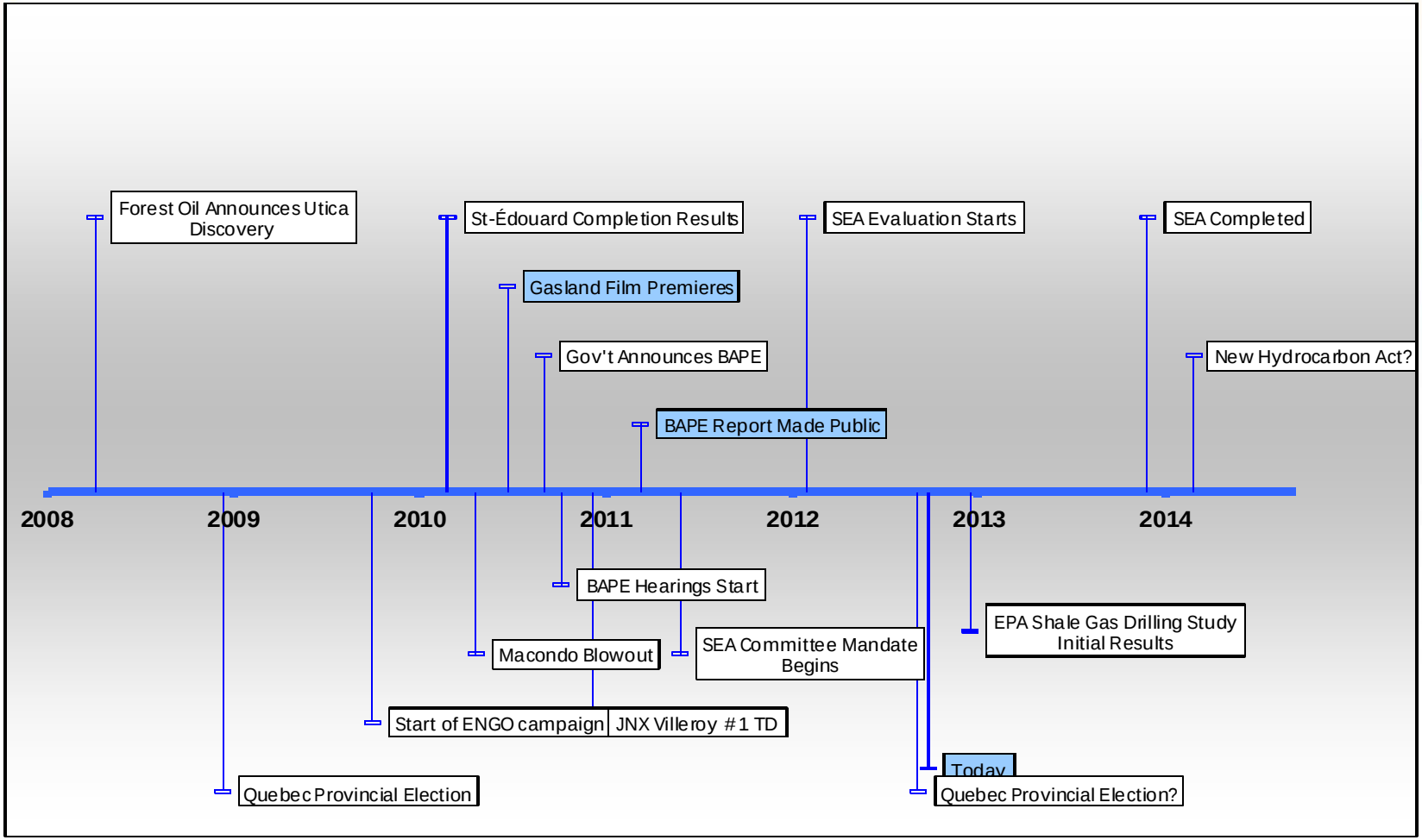
FST's Utica Test Well

Possible Sequence of Events

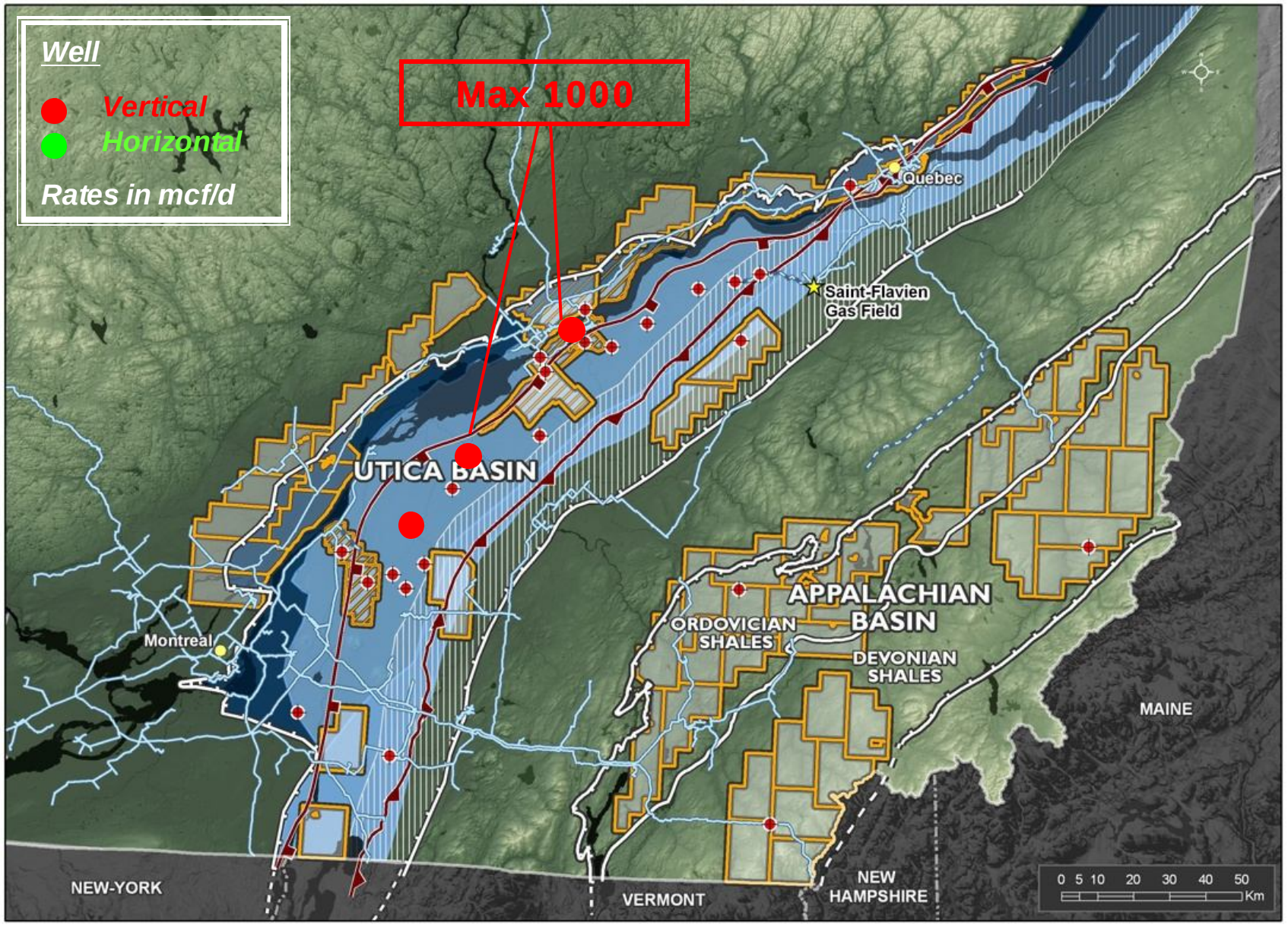
Past Events

Possible Future Events

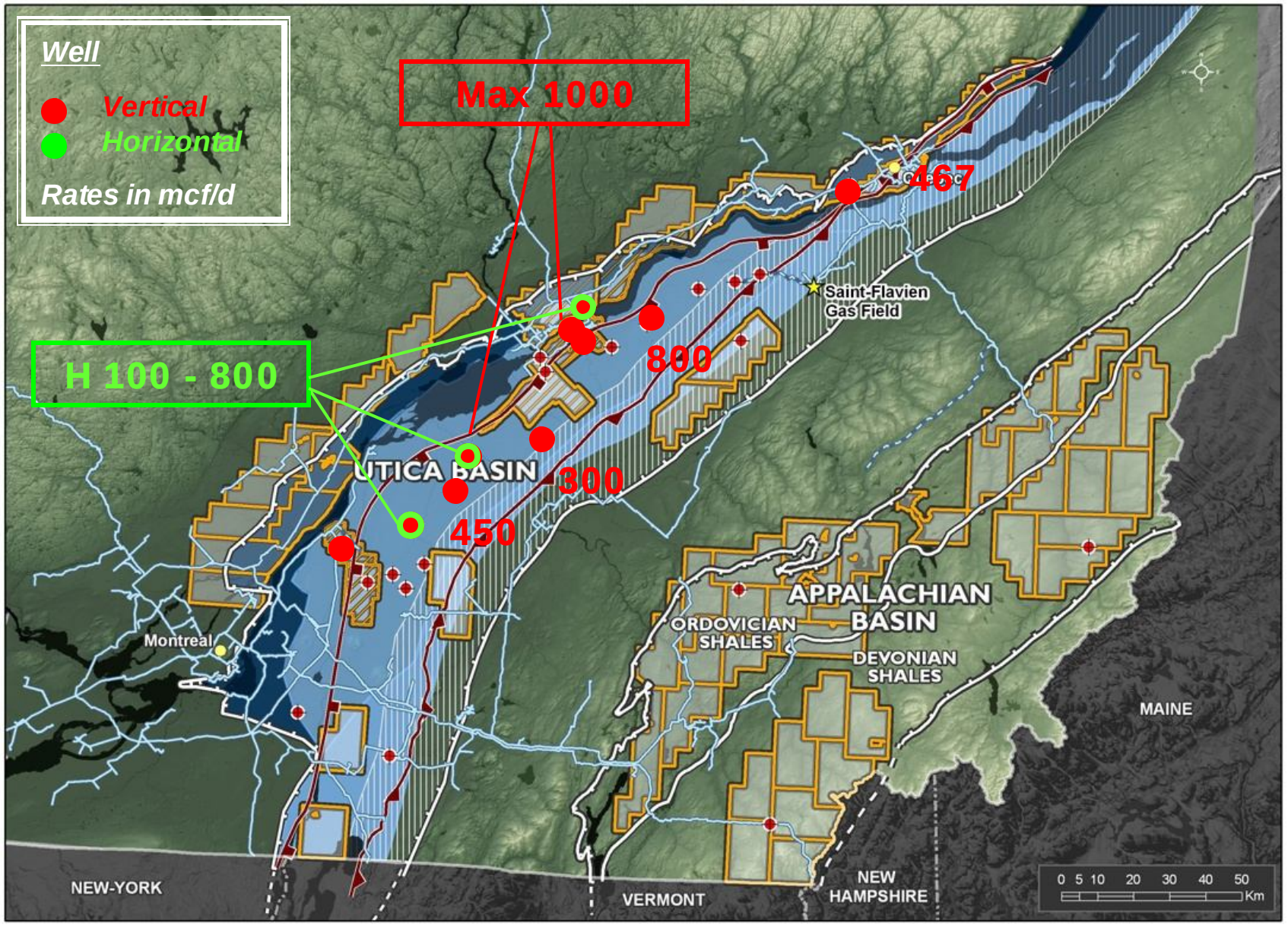
(i.e. predictions may be inaccurate)



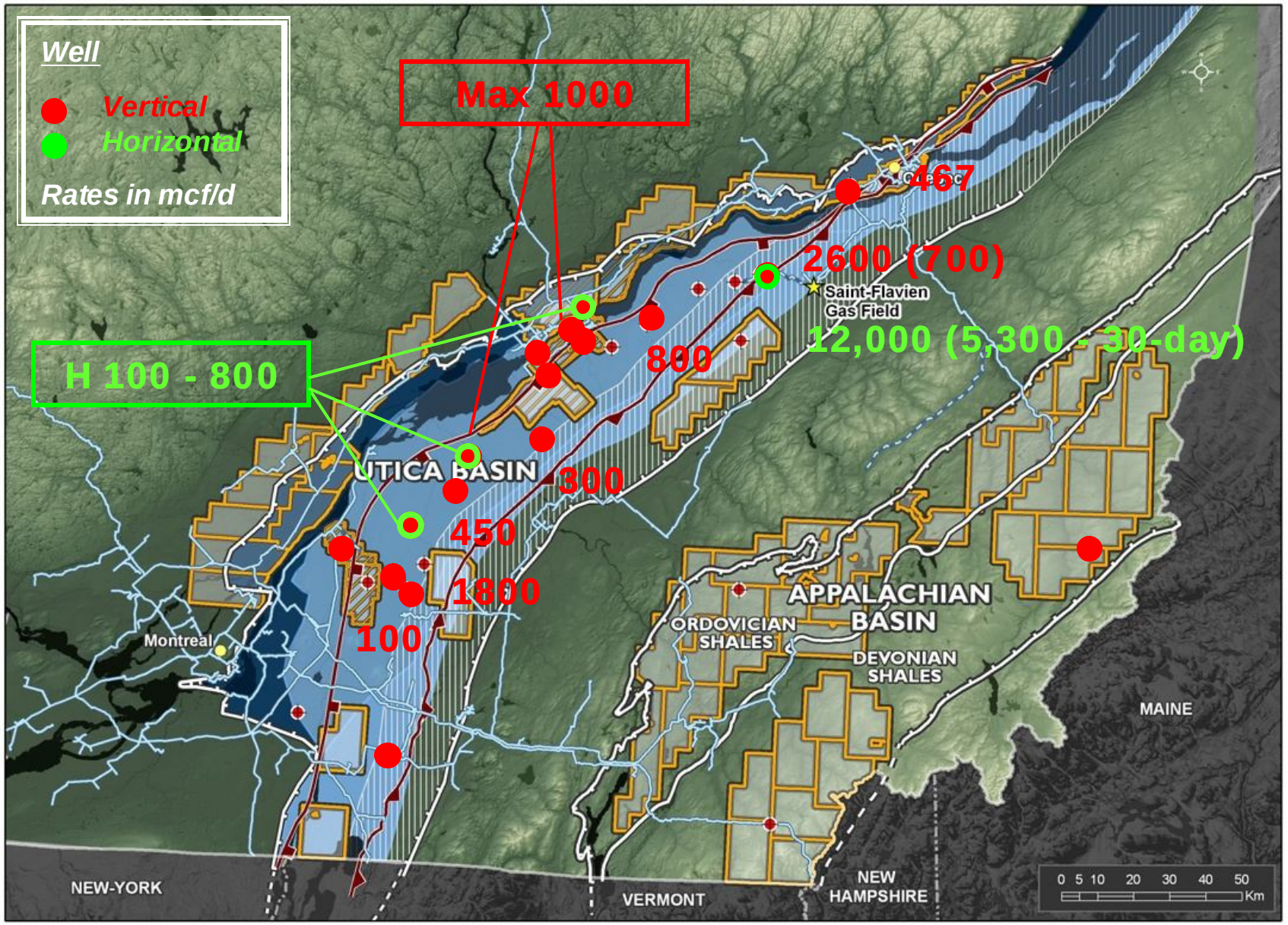
Southern Quebec Shale Wells '07 – '08 (Utica & Other)



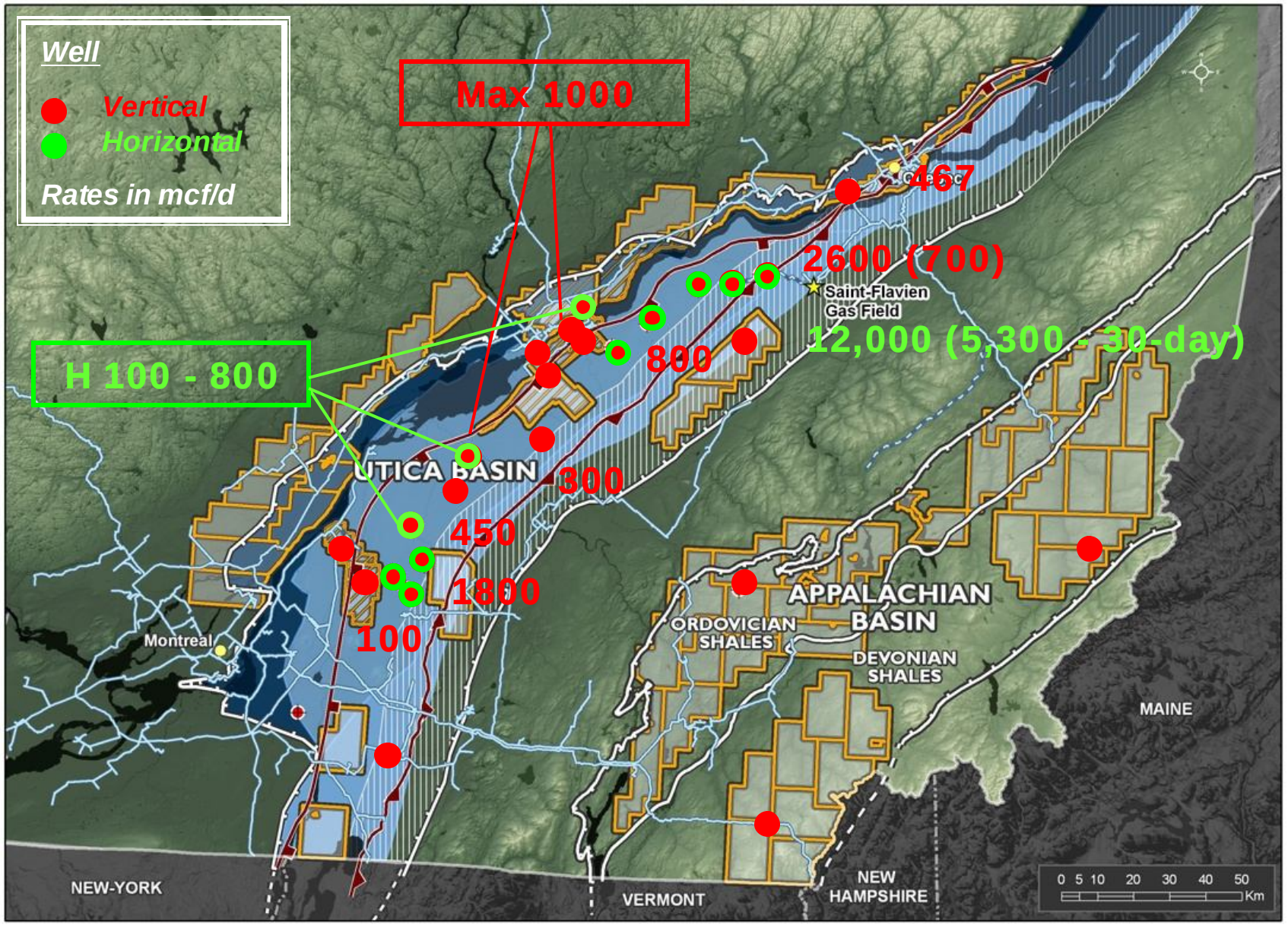
Southern Quebec Shale Wells '07 – '08 (Utica & Other)



Southern Quebec Shale Wells '08 (Utica & Other)

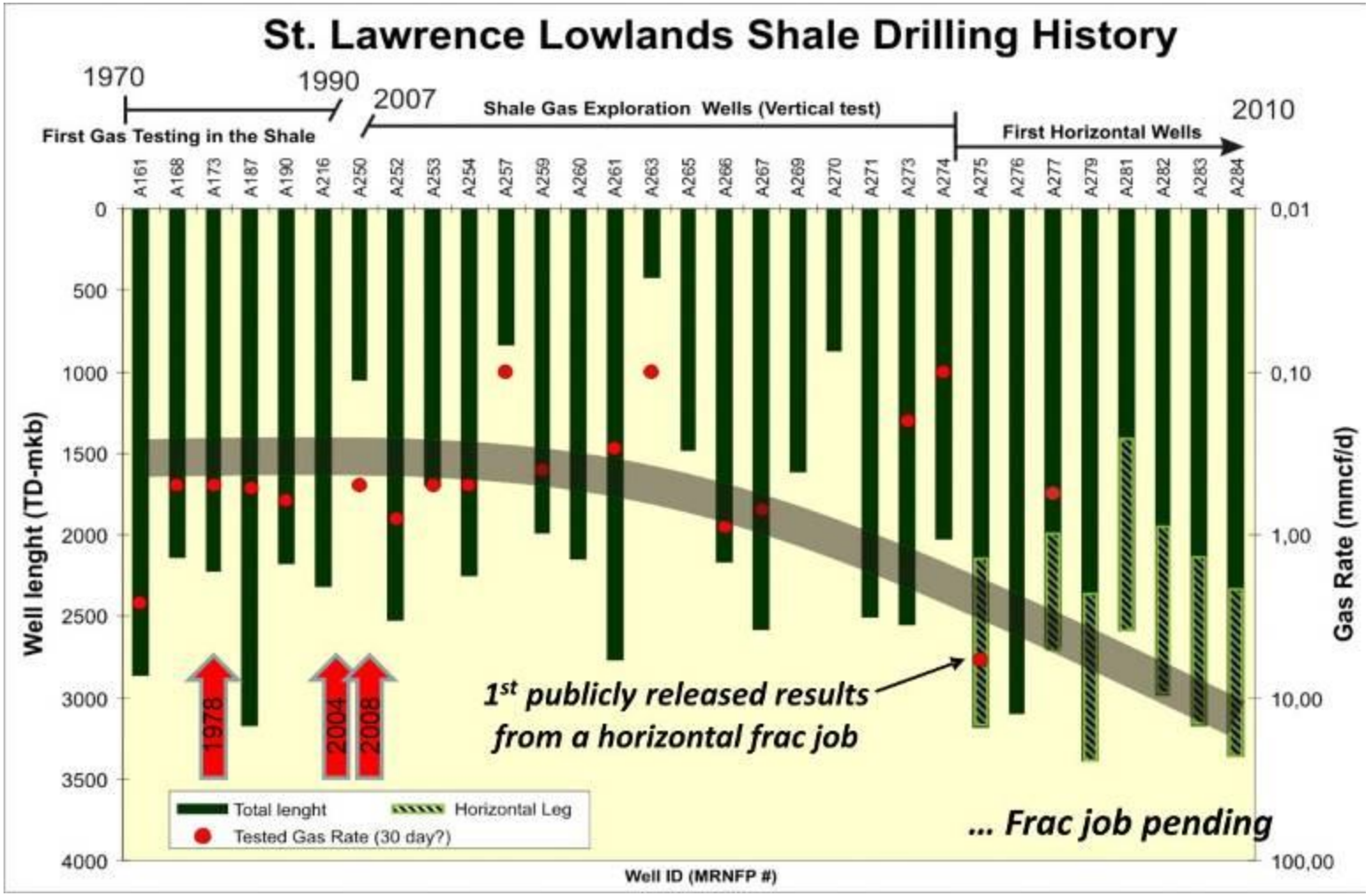


Southern Quebec Shale Wells '10 (Utica & Other)



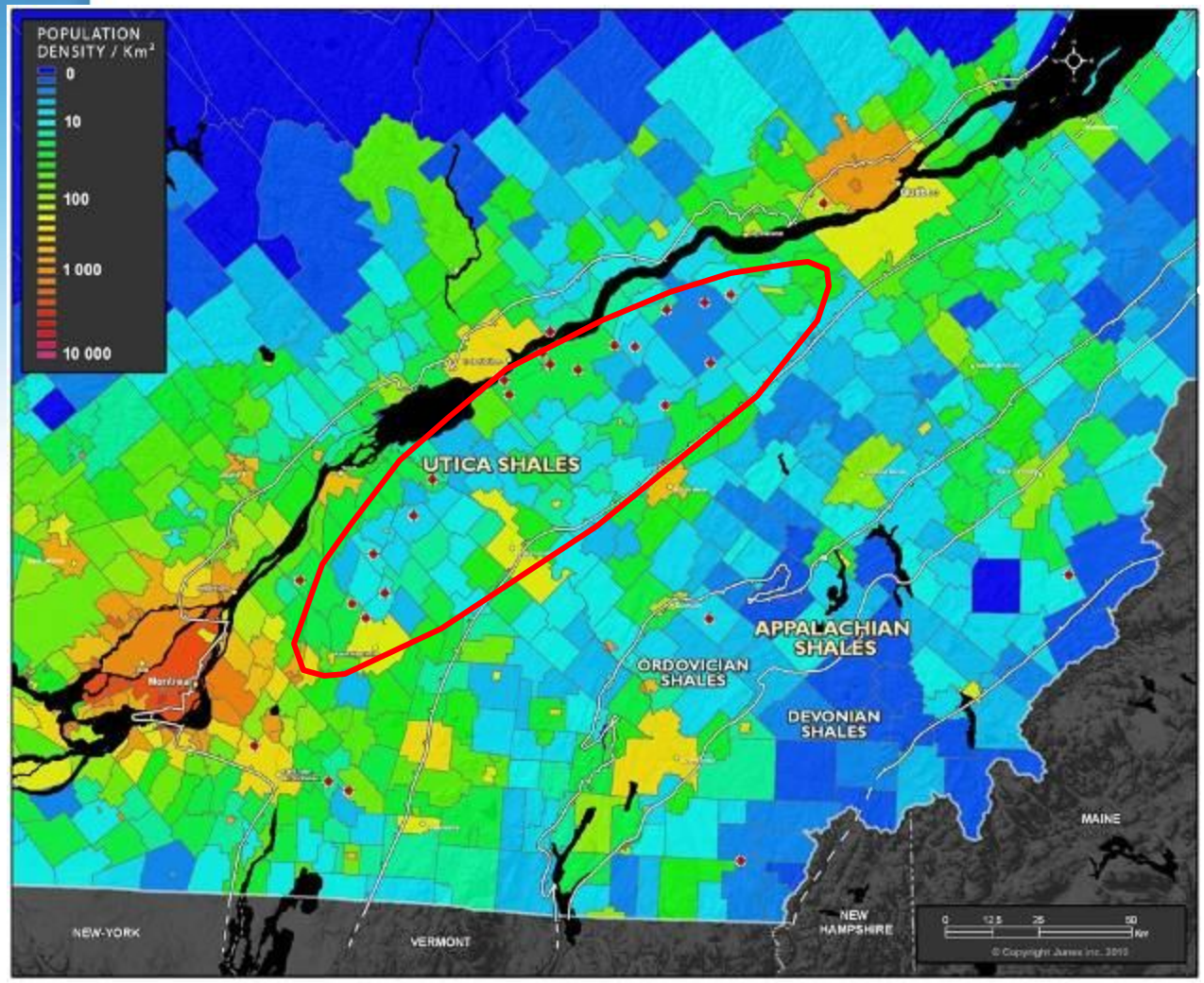
Quebec Shale gas play history

Exploration Drilling activities



Land Management Considerations

Population Density & Shale Gas Exploration

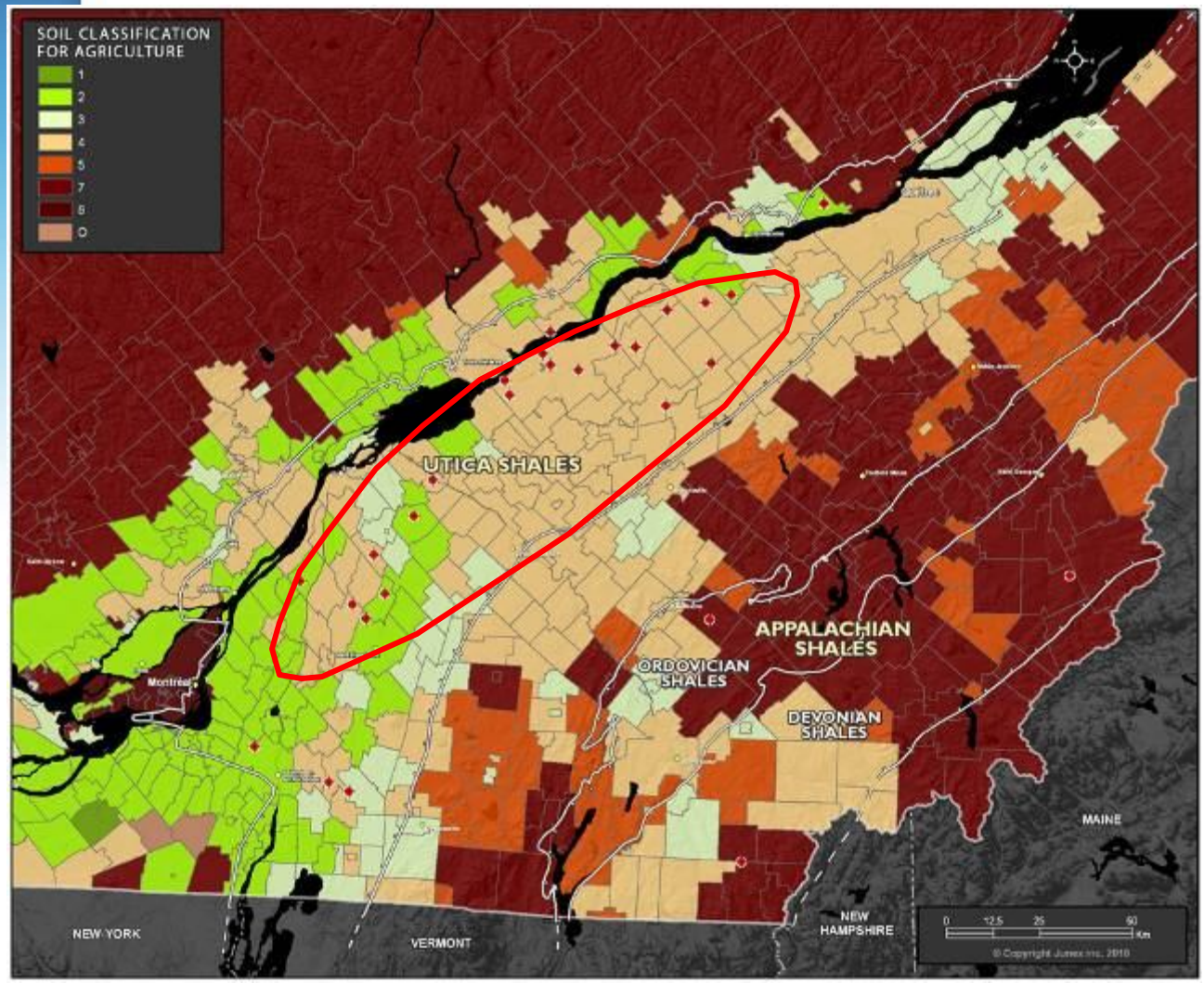


GIS/Mapping tool helps land management of shale gas exploration

Main exploration operations performed to date in area with lower population density (0 to 10 persons/ km²)

Land Management Considerations

Agriculture & Shale Gas Exploration



Green colors (Class 1-2-3) represent the area with the highest soil potential for agriculture

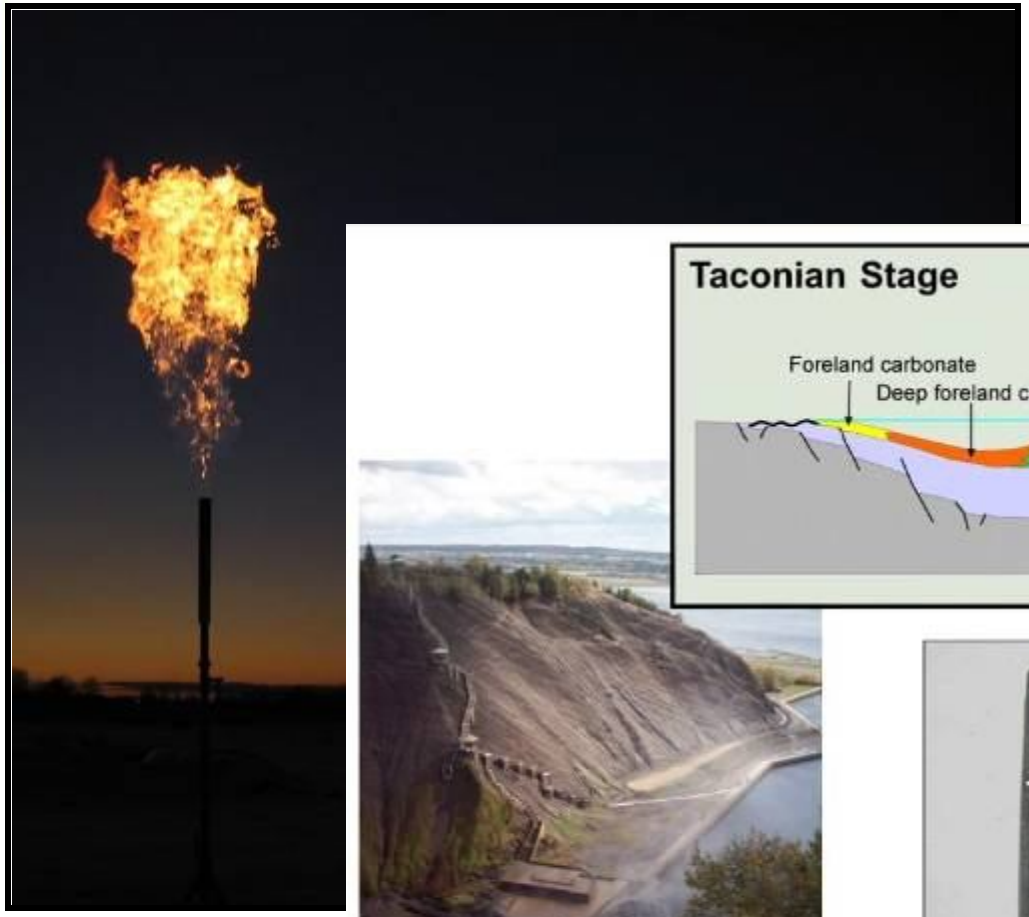
Main Utica exploration operations to date mainly in Class 4 area

Soils in Class 4 have very serious limiting factors that restrict the range of crops or require special conservation measures or have two disadvantages

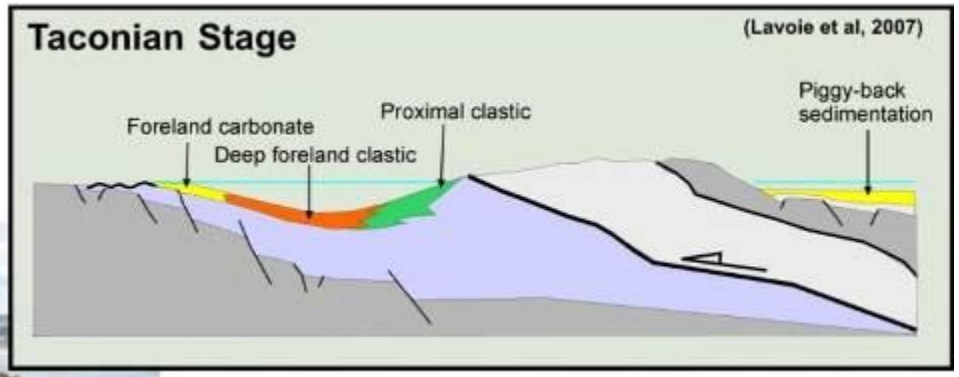
Soils in Class 5 to 8 have less potential

Southern Quebec Appalachian Shales in area of lesser agricultural potential than Lowlands

Saint Lawrence Lowlands Ordovician Shales gas



Sources : JUNEX



Unconformity - Utica-Lorraine contact Evidence of shallow water environment

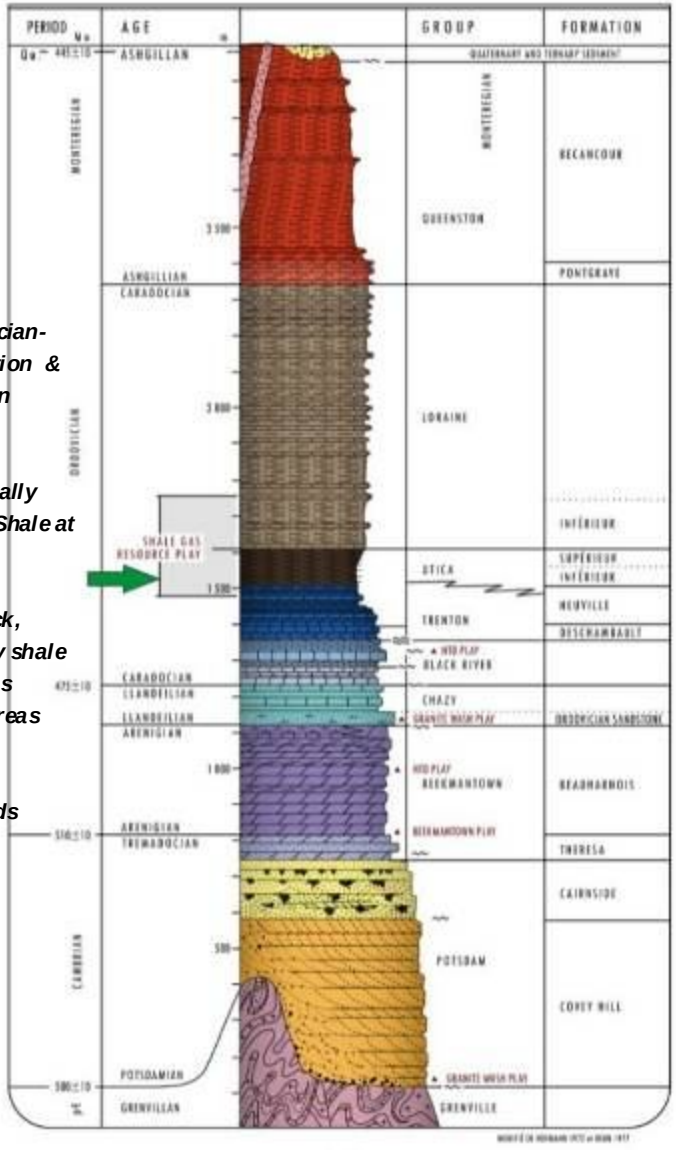
Utica Shale Geology

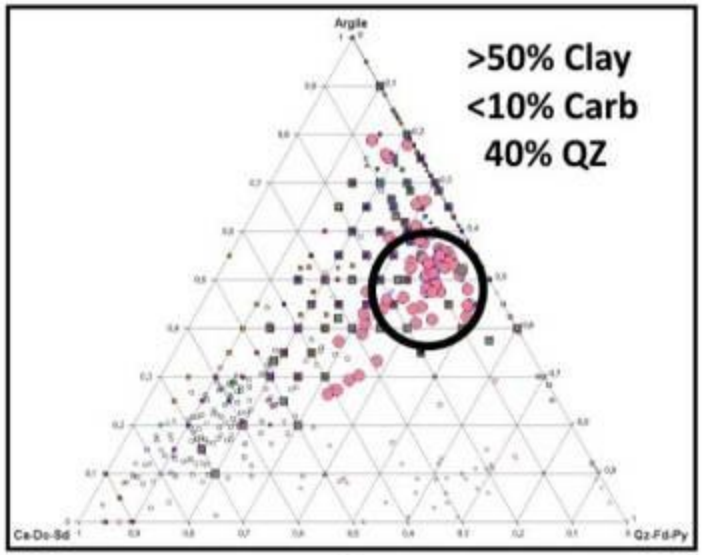
Prospective Shale Intervals – Ordovician-aged Utica Formation & Lorraine Formation Shales

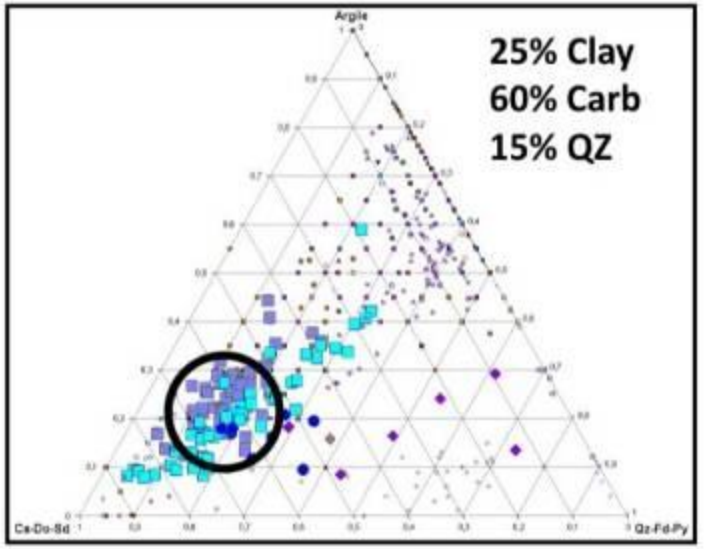
Industry is principally focused on Utica Shale at this time

Utica - mainly black, organic-rich, limey shale with significant gas content in many areas

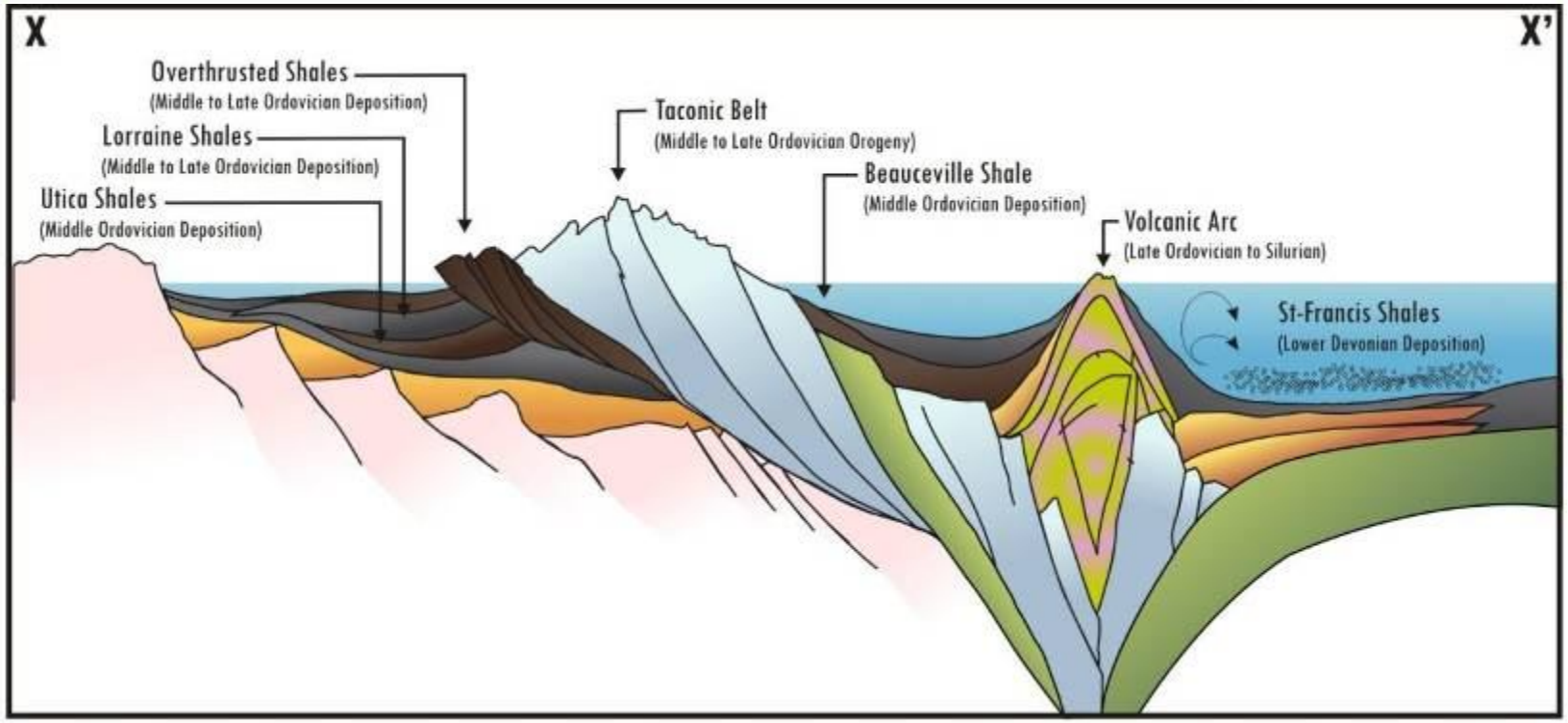
Widespread in St. Lawrence Lowlands







Quebec Basins Schematic Cross-Section



St. Lawrence Lowlands

Play 1 : Medium depth to Deep Shale Gas
Play 2 : Shallow to Medium depth Shale Gas
Play 3 : Structured Shale (Overthrusted)
Play 5 : Biogenic Shale Gas

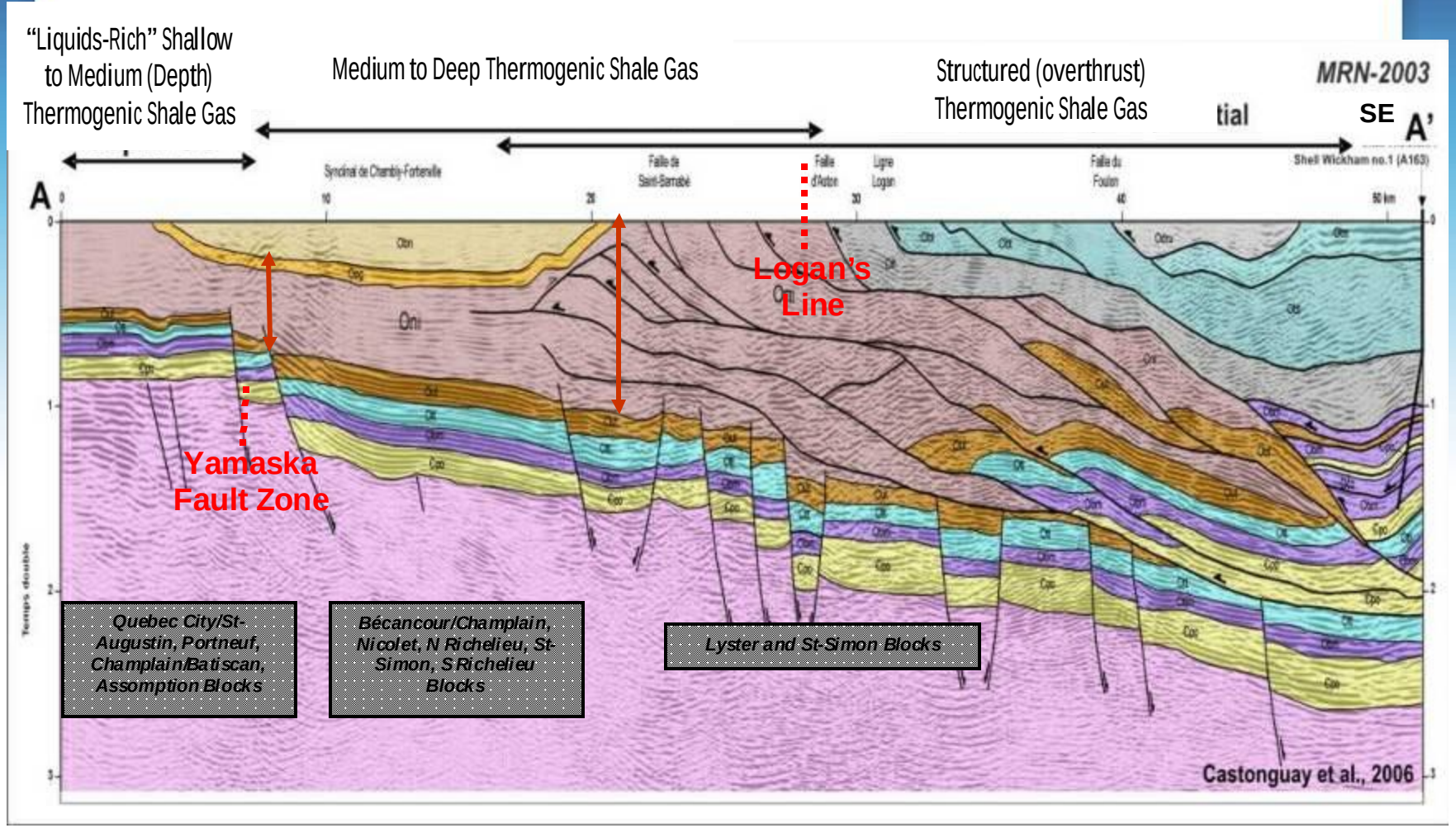
Other Basins*

Play 4: Intra-Appalachian Basin Shale Gas

Anticosti: Macasty Shale (Liquid-rich shale)
Gaspésie: Fortin Mudstone (dry gas shale)

*** Less explored. Not all presented**

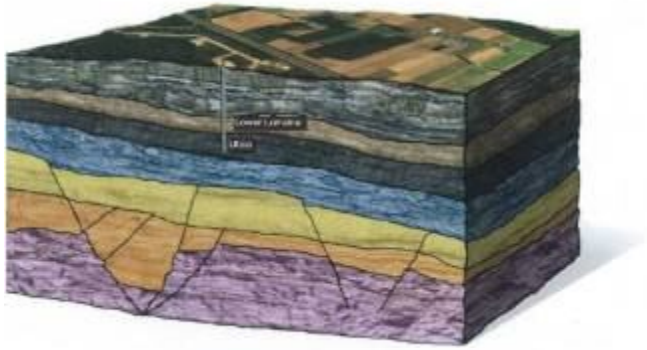
Utica Play Fairways



Utica Play Fairways

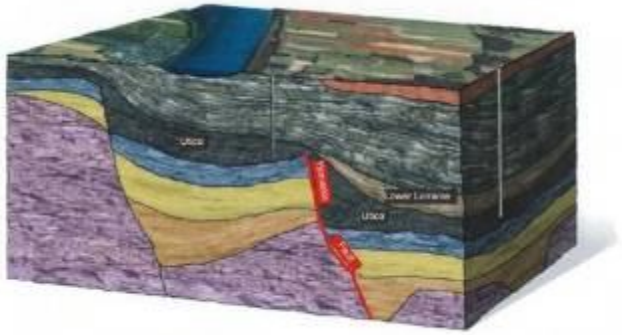
"Liquids-Rich" Shallow to Medium Depth Thermogenic Shale Gas

- *Thickness – 100 to 220 m*
- *TOC – 0.5 to 3%*
- *Maturity – gas condensate to dry gas*
- *Gas Type –thermogenic, liquids-rich*
- *Junex Acreage ~370,000 net acres*



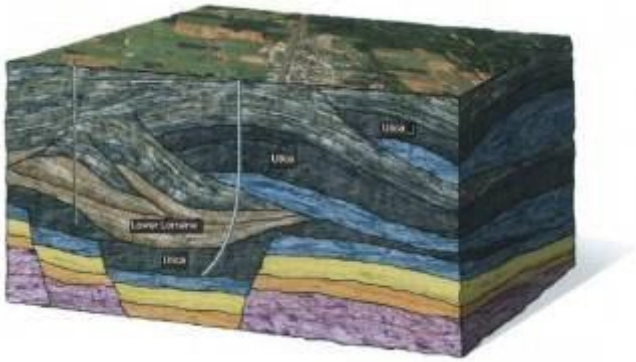
Medium to Deep Thermogenic Shale Gas

- *Thickness – 150 to 400 m*
- *TOC – 0.5 to 2.5%*
- *Maturity – gas condensate to dry gas*
- *Gas Type –thermogenic*
- *Junex Acreage ~250,000 net acres*



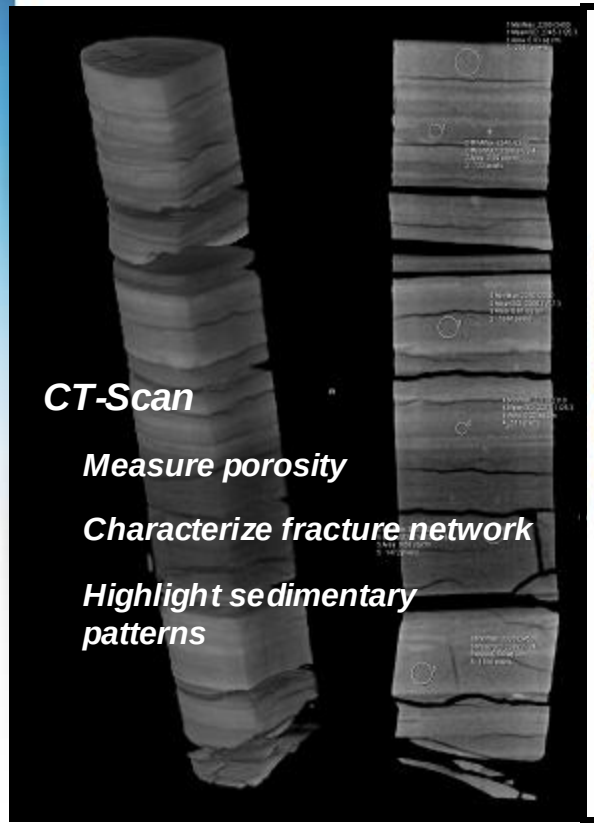
Structured Thermogenic Shale Gas

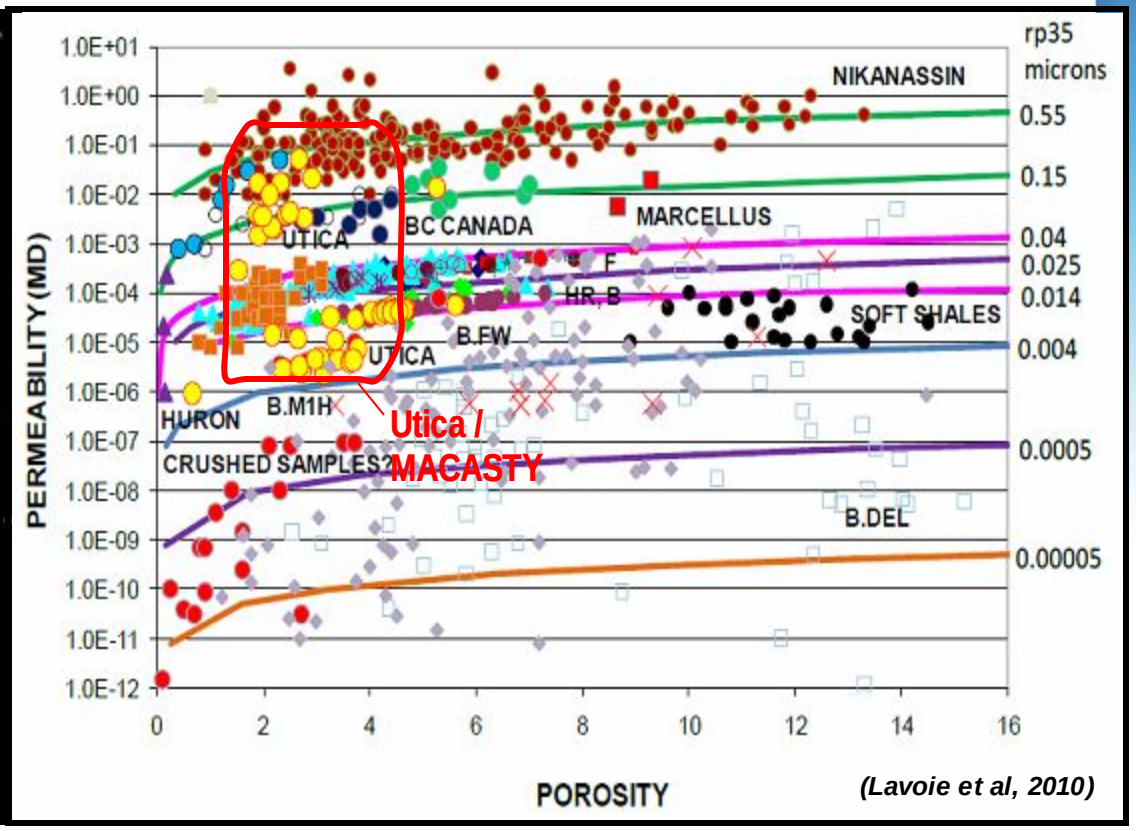
- *Thickness – several slices of 100 to 200 m*
- *TOC – 1 to 5%*
- *Maturity – gas condensate to dry gas*
- *Gas Type – thermogenic*
- *Junex Acreage ~230,000 net acres*



Permeability and Porosity

Estimation of Pore Throat Aperture





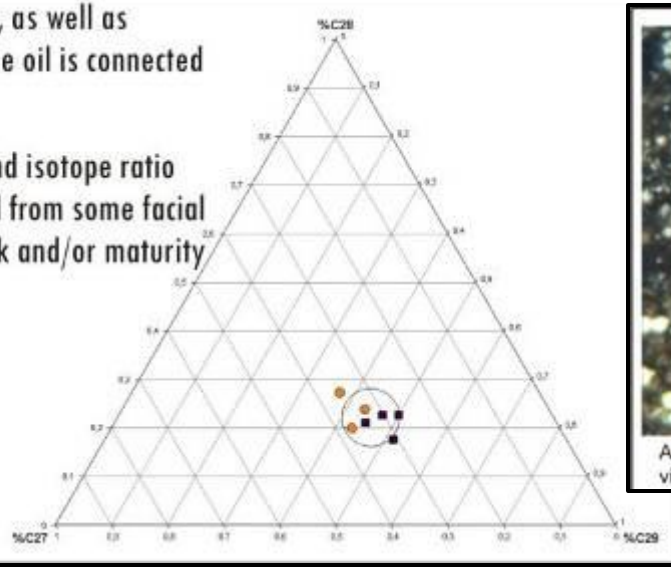
(Lavoie et al, 2010)

Oil molecule size ranges from 0.5 to 3 nm (0.0005 to 0.003 microns)

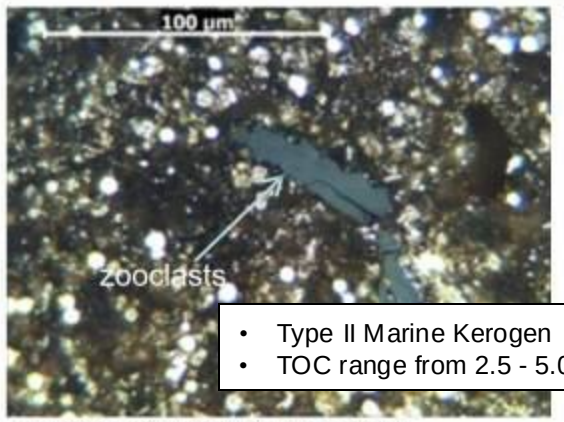
Methane molecule size is 0.4 nm (0.0004 micron)

Utica Shale Source Rock

- Majority of the biomarkers, as well as isotope ratios, suggest that the oil is connected to Ordovician Shale.
- The observed biomarker and isotope ratio differences are likely resulted from some facial changes within the source rock and/or maturity variations

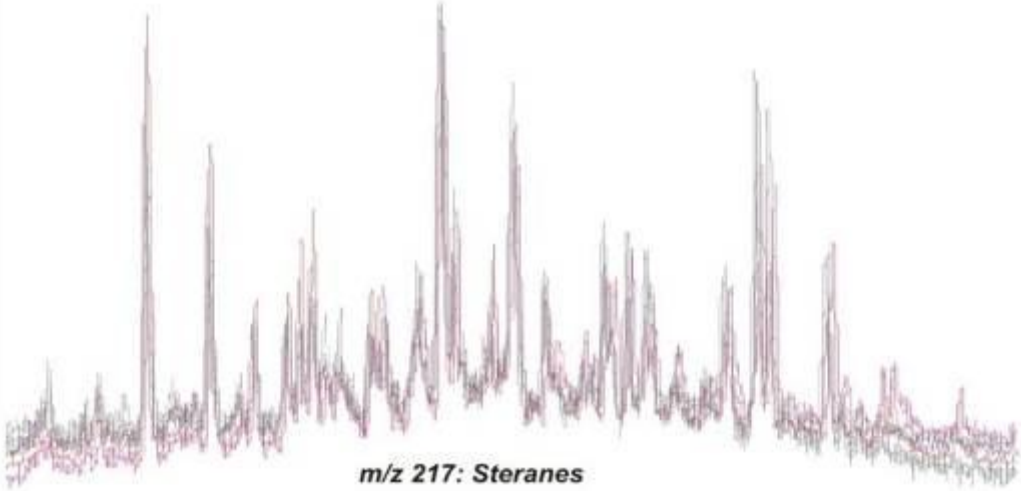


C27-C28-C29
ααα R Steranes



Amorphous organic matter (amorphinite)
vitrinite reflectance equivalent is ~0.90%

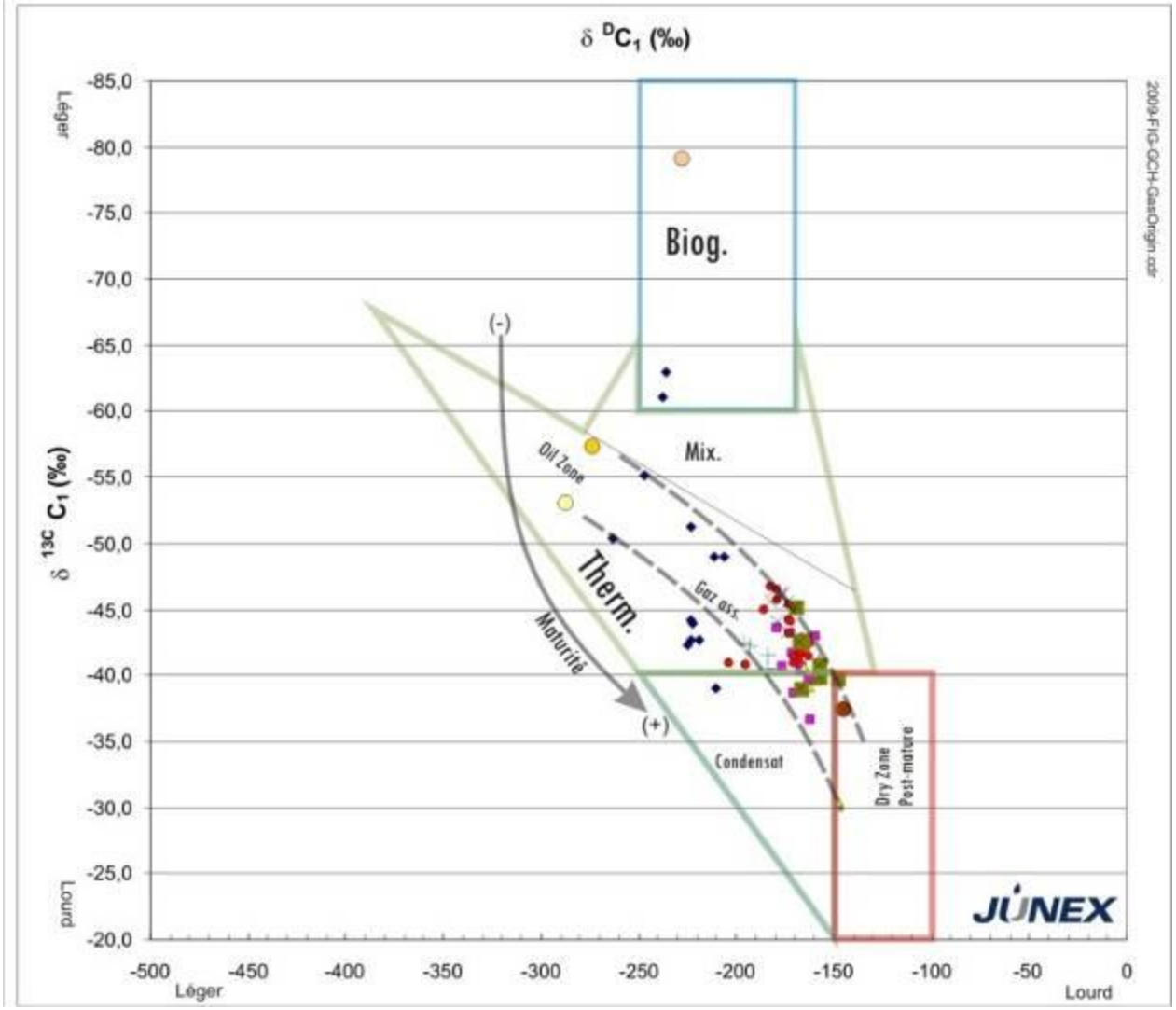
- Type II Marine Kerogen
- TOC range from 2.5 - 5.0 wt.%



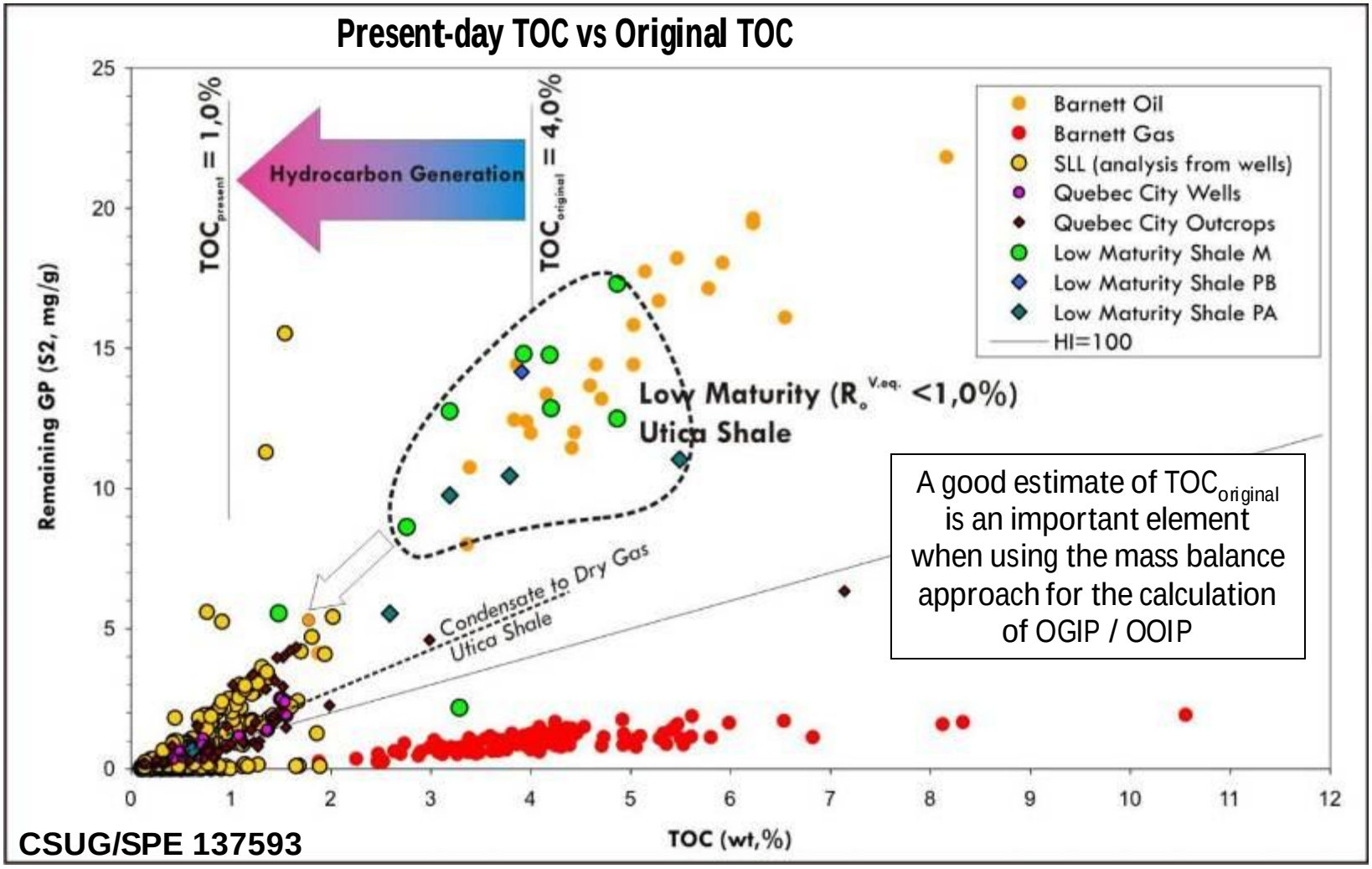
m/z 217: Steranes

Shale Gas Type

Isotopic Characterization

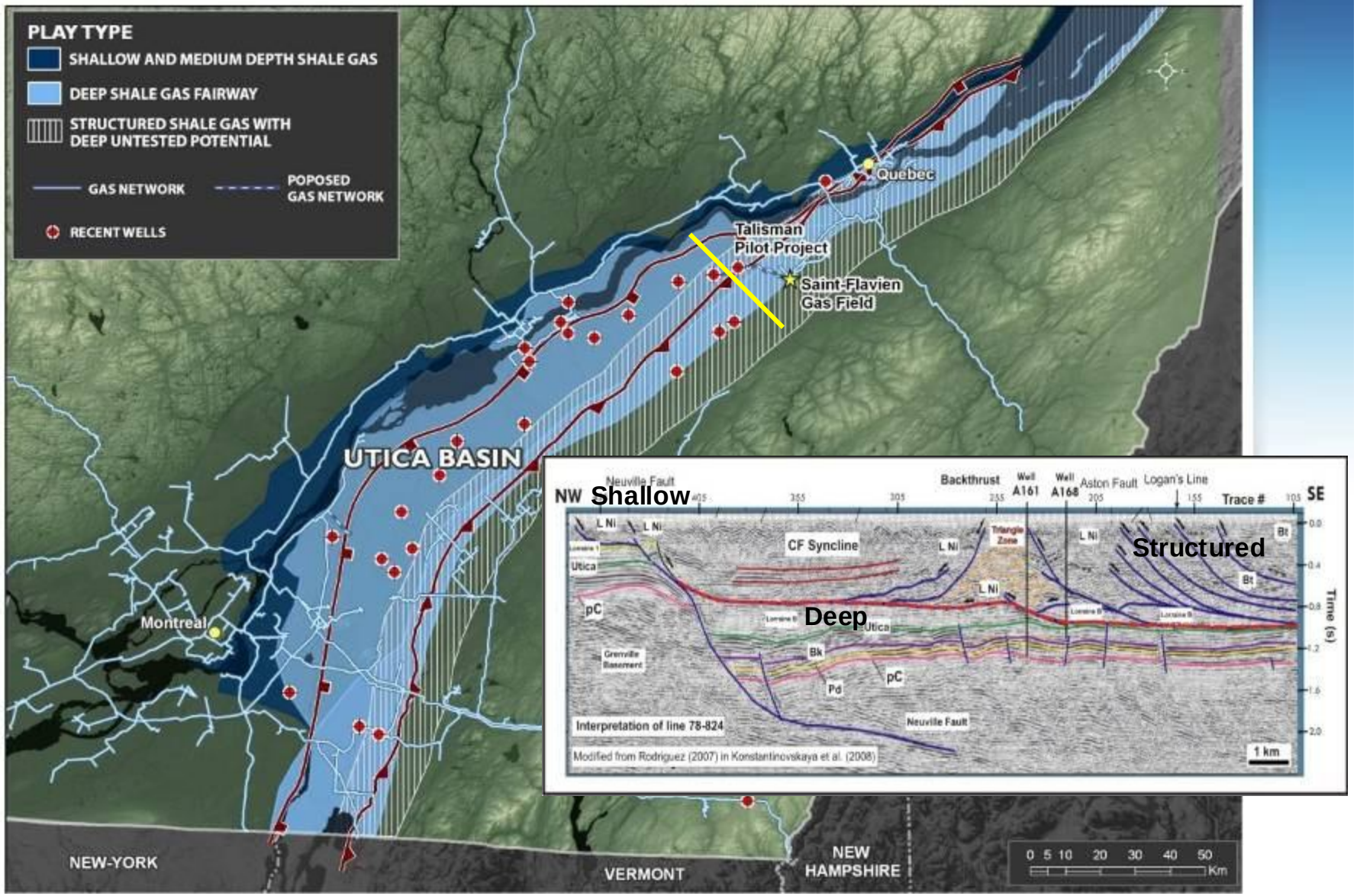


Source rock - Shale Geochemistry

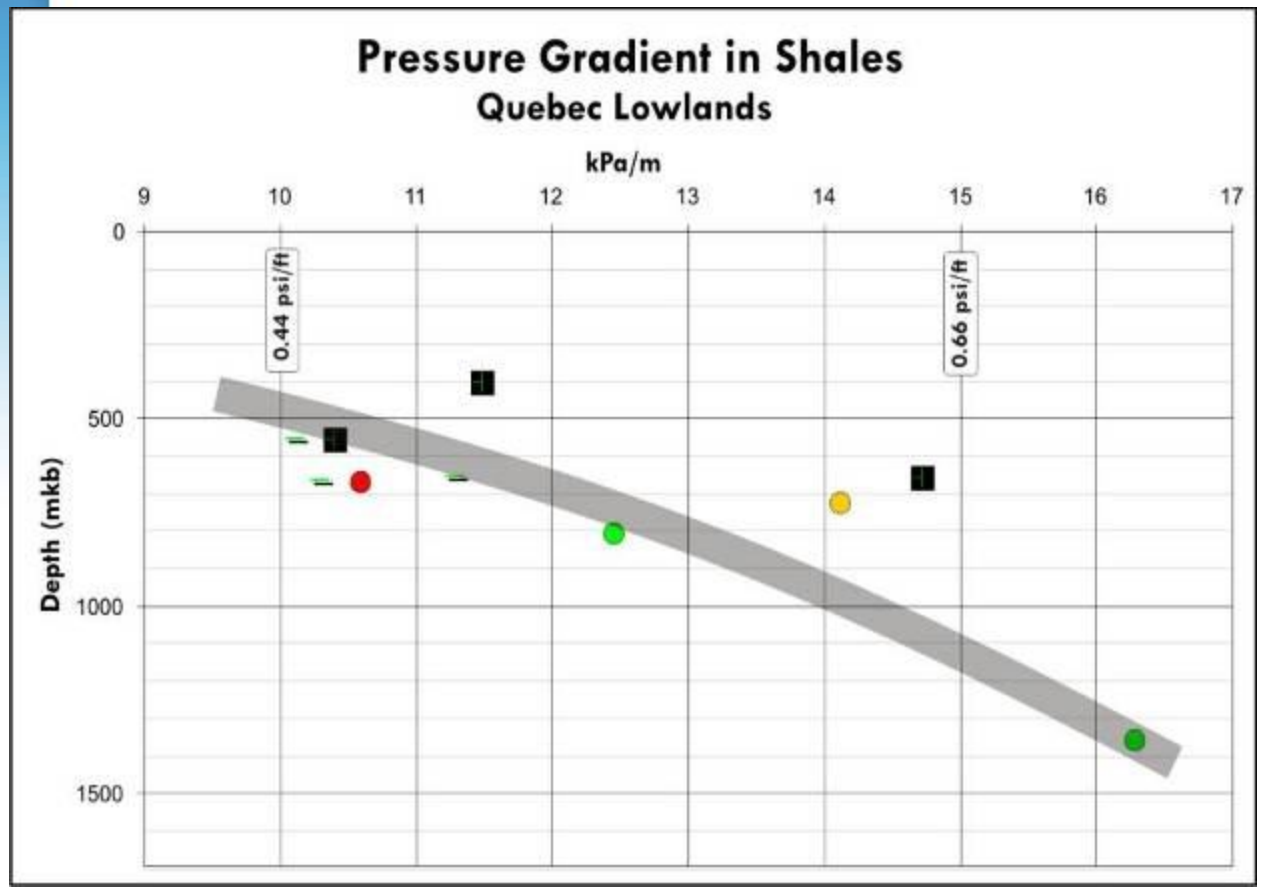


Assuming an original S2 of 12 kg_{HC}/ton_{Rock} with an average thickness of 150 m, the oil generation of the Quebec Utica Shale reach 16 MMbbl/section

Defining the exploration fairways



Pressure Gradient Variation



(modified from Lavoie et al, 2010)

Pressure gradient data for some Shale zones over the Lower Décollement

Increasing pressure gradient with depth

Shale Units are largely overpressured

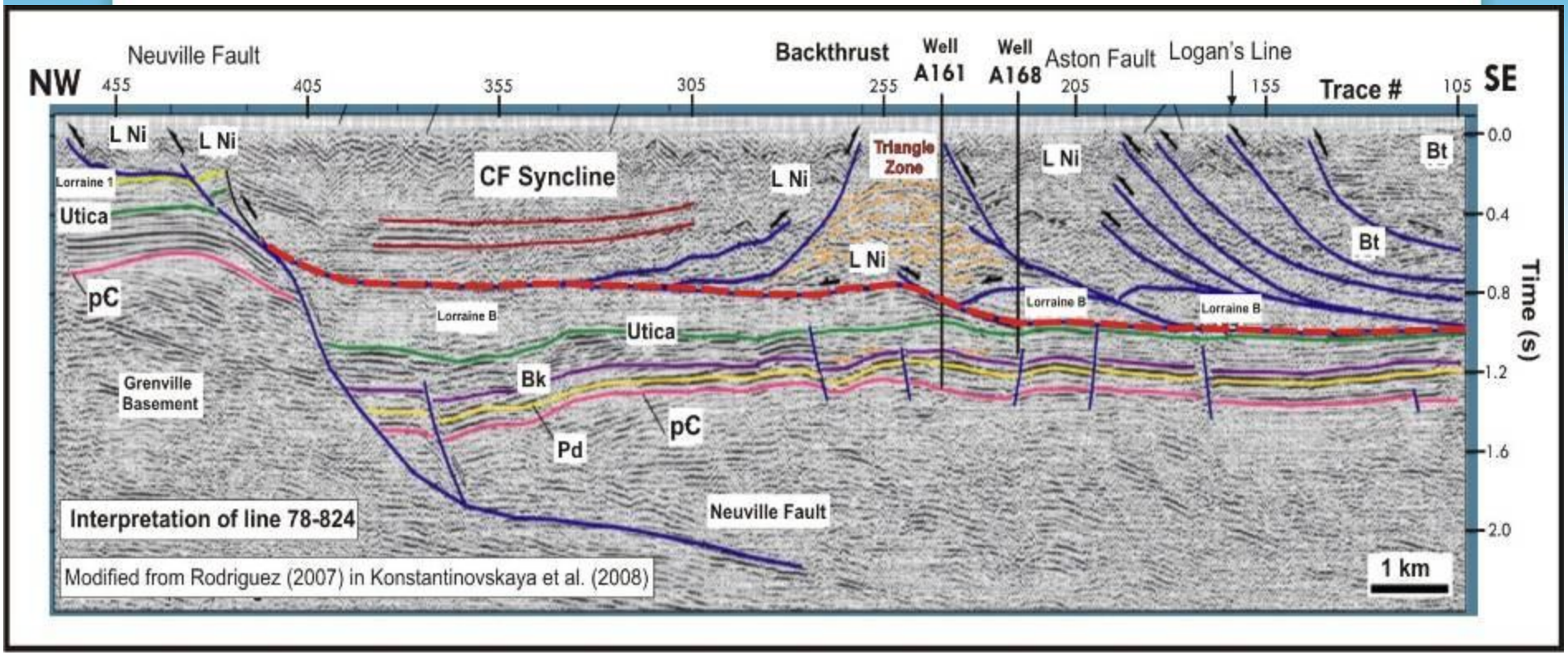
Pression gradient map important to identify favorable areas, as demonstrated in the Haynesville Shale
(Brittenham, 2010)

Utica Play Fairways

JUNEX

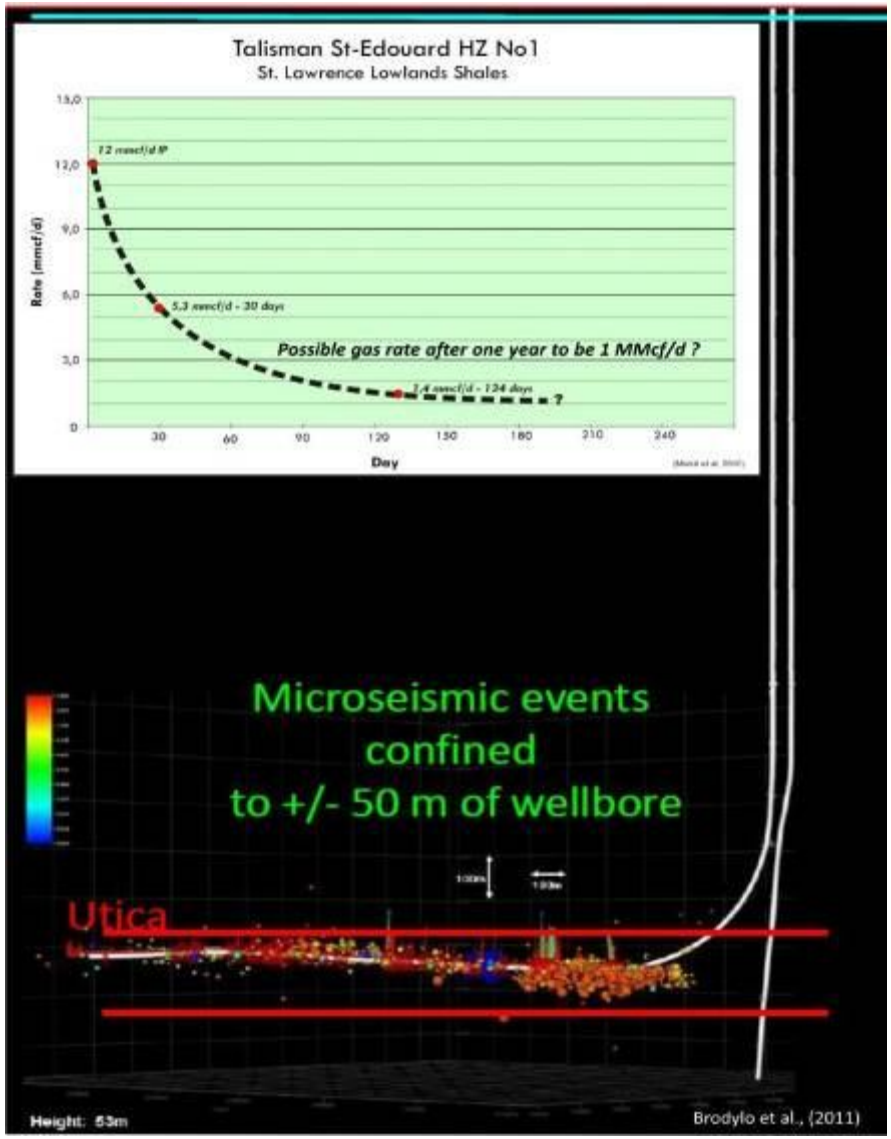
Talisman St-Edouard and Leclercville wells
12 mmcfd IP (5.3 mmcf/d 30-day)

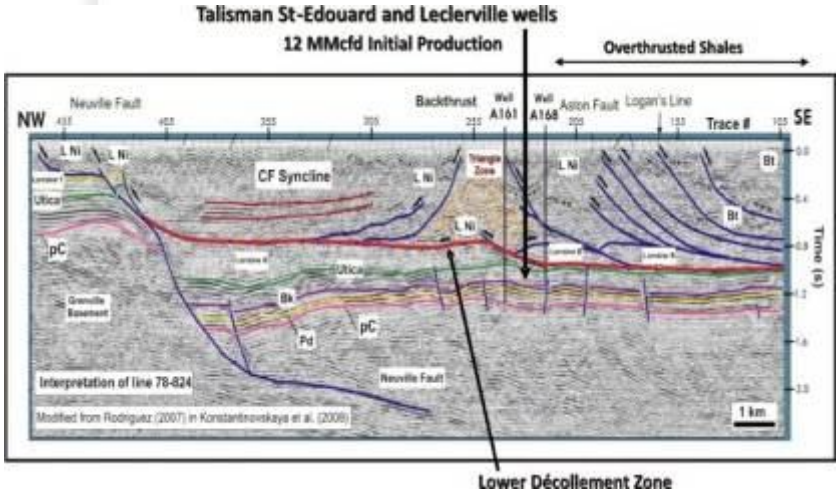
Overthrusted Shales



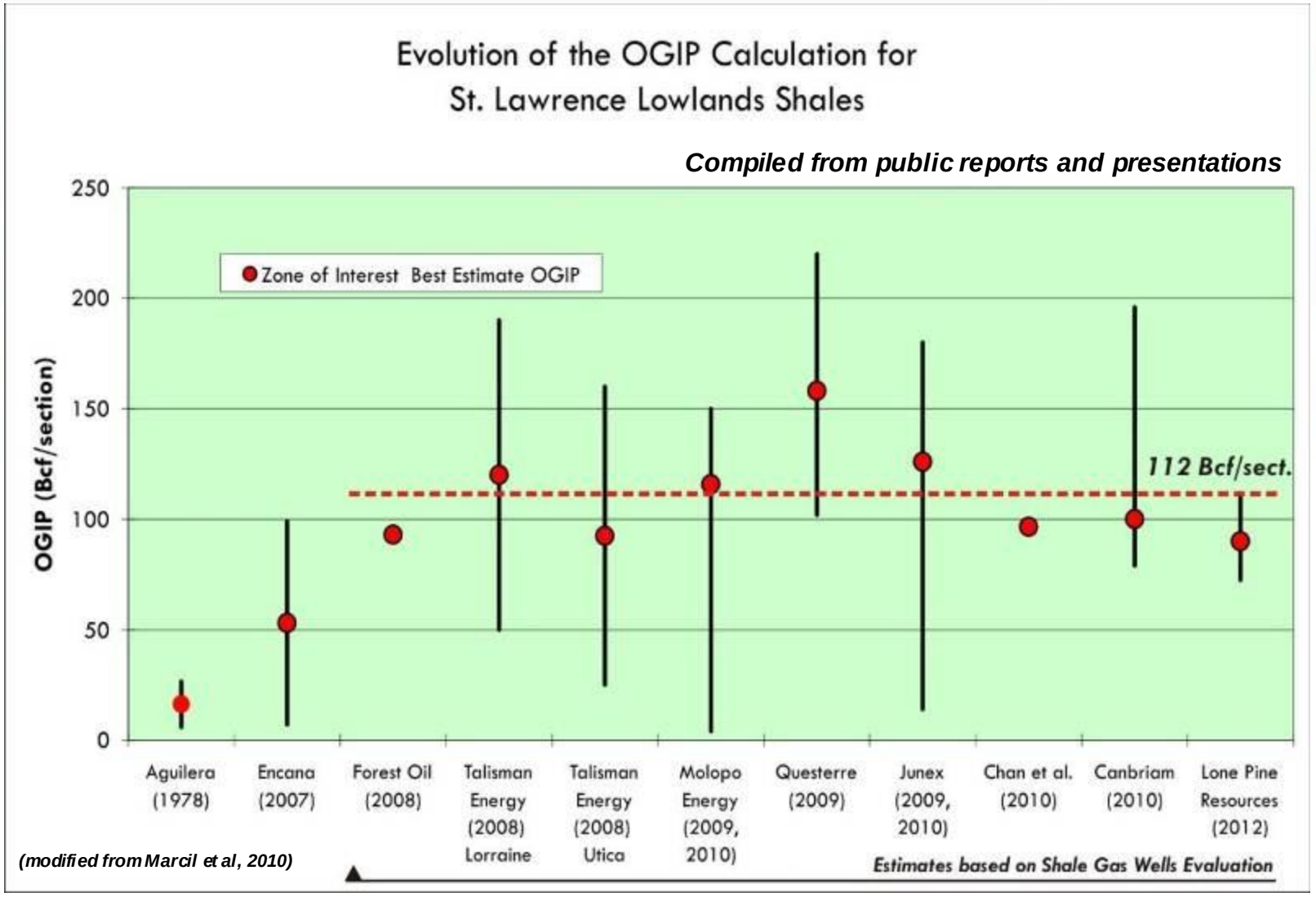
First long-term testing

Stimulated Horizontal Well - Deep Shale

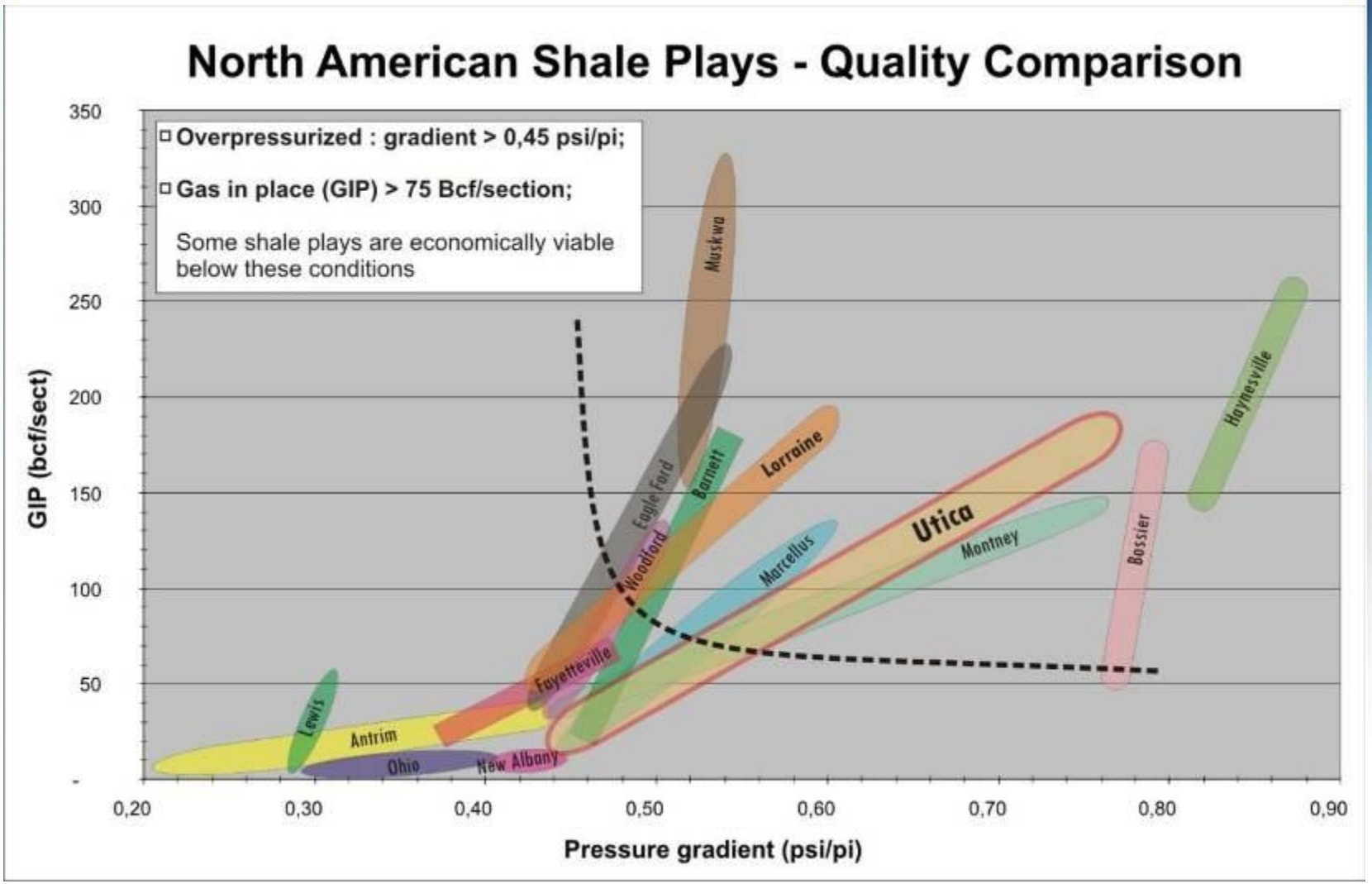




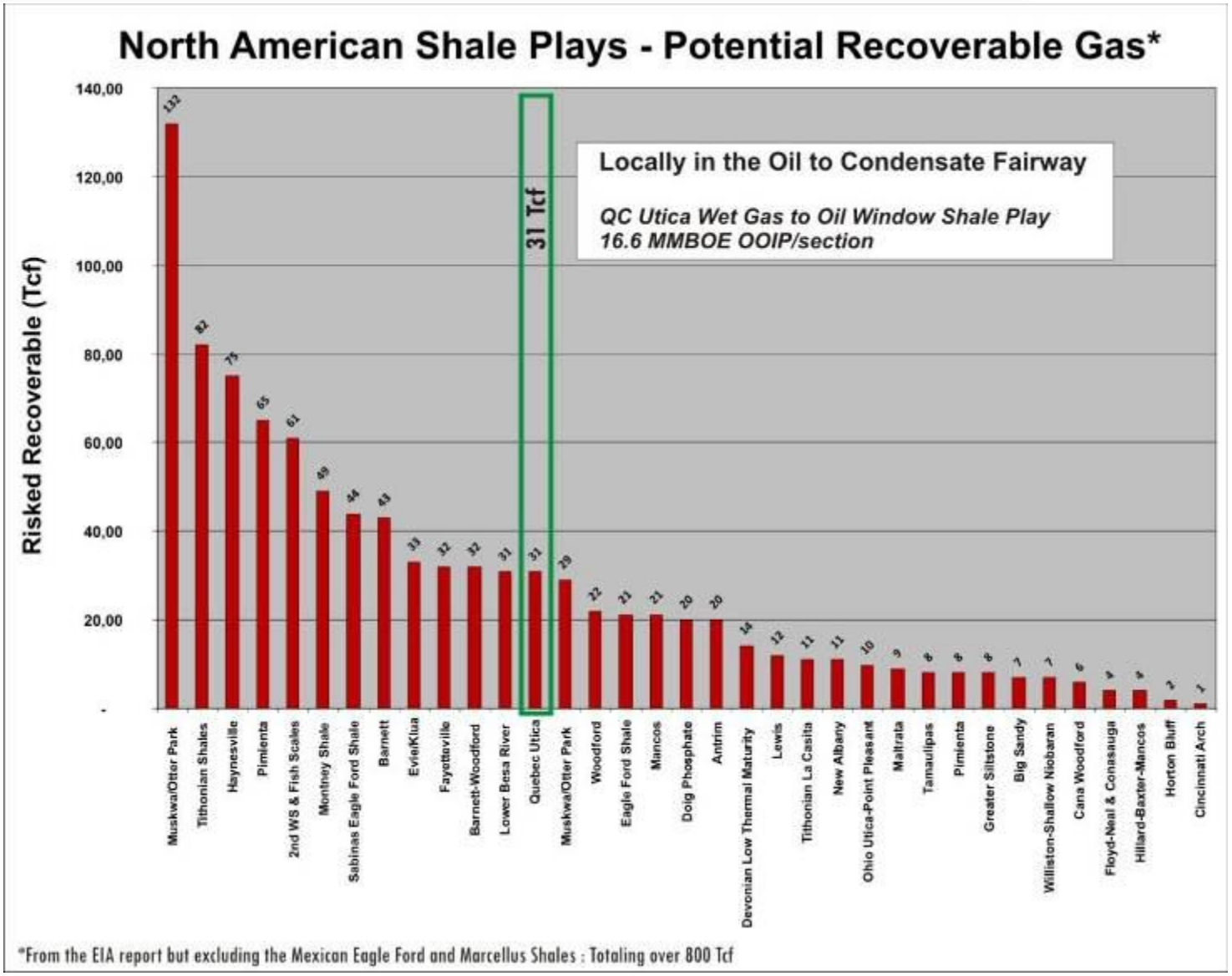
Utica Shale Original Gas-in-Place Estimates



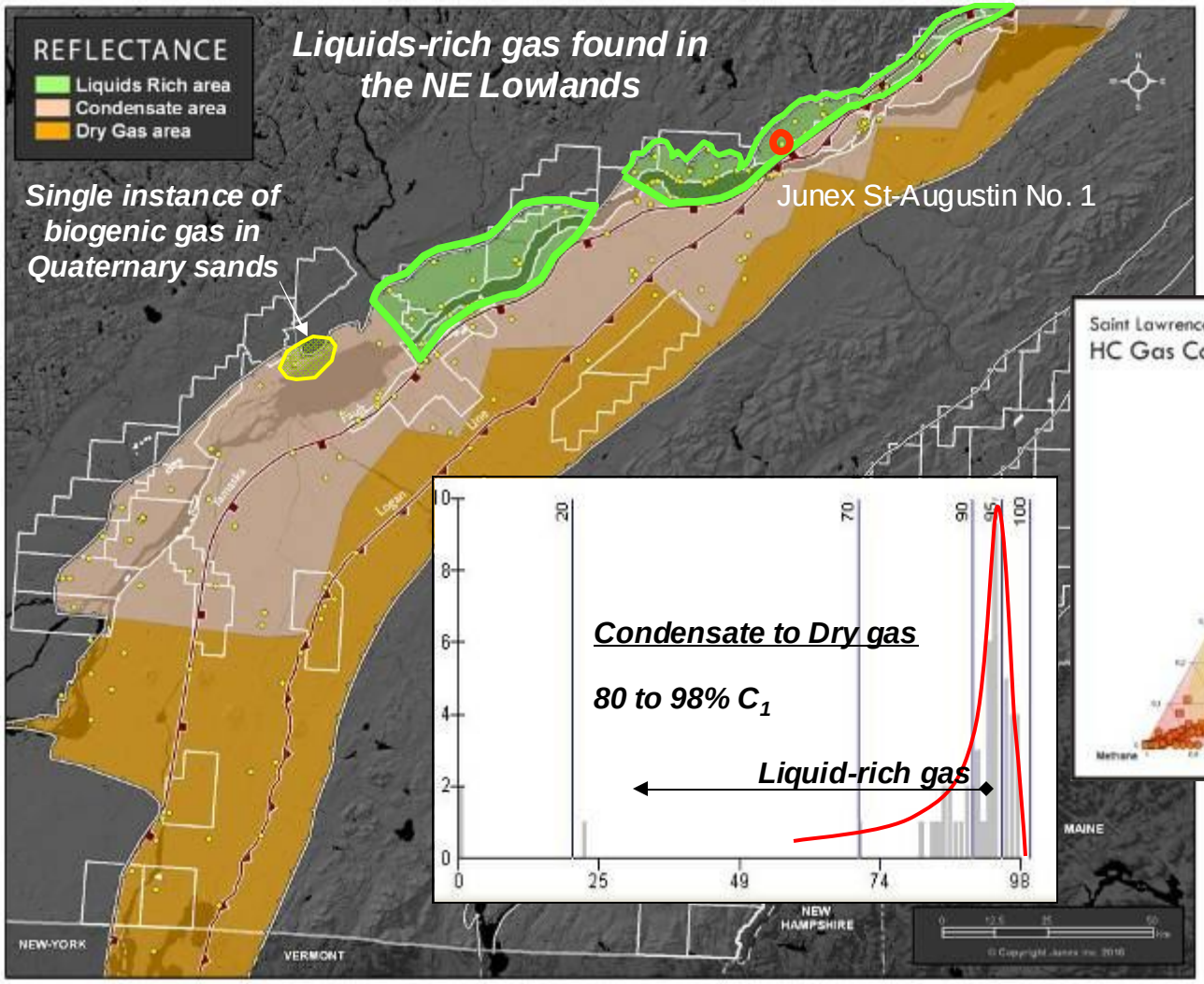
Play Comparaison

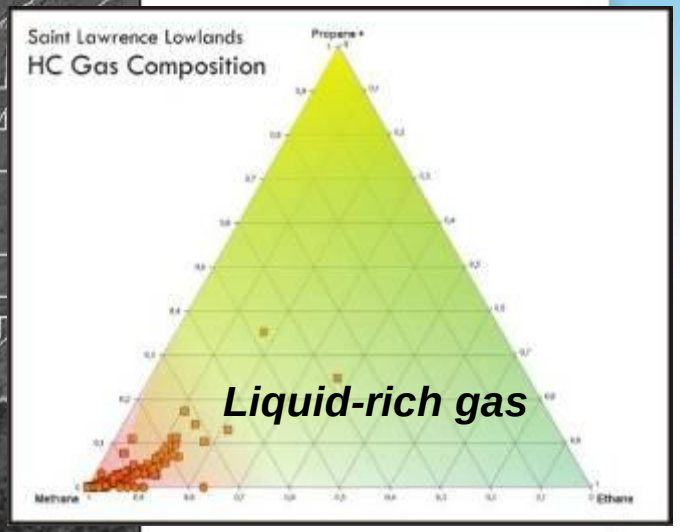


A world-class Gas Resources



Liquid-rich Gas



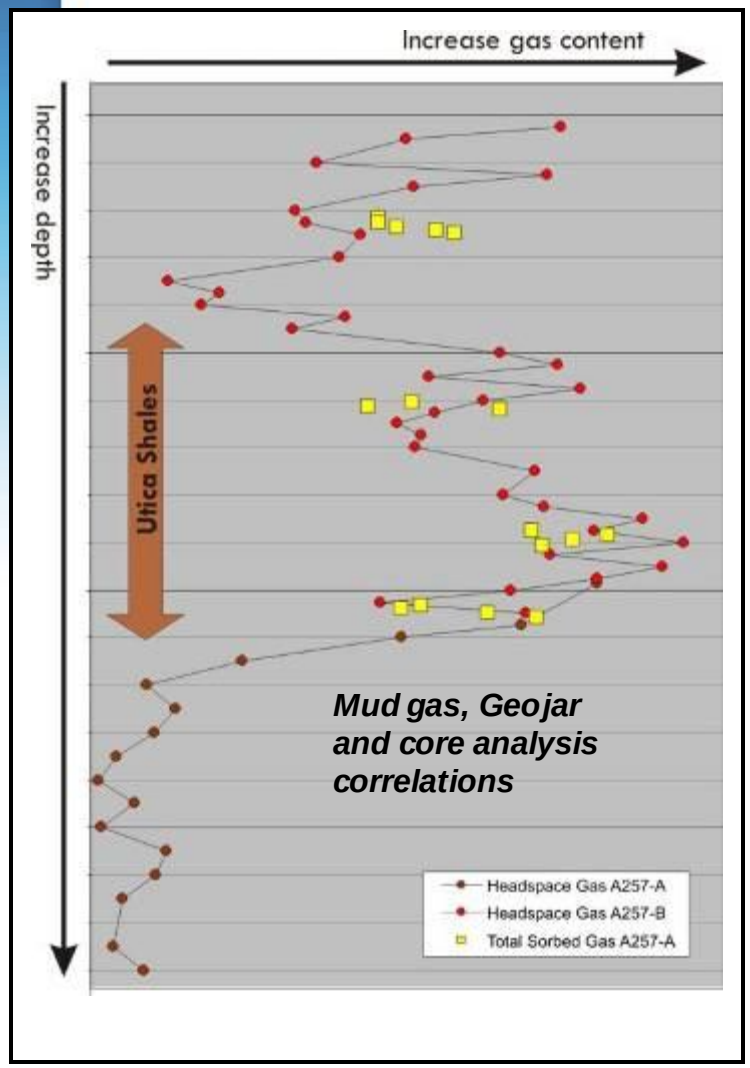


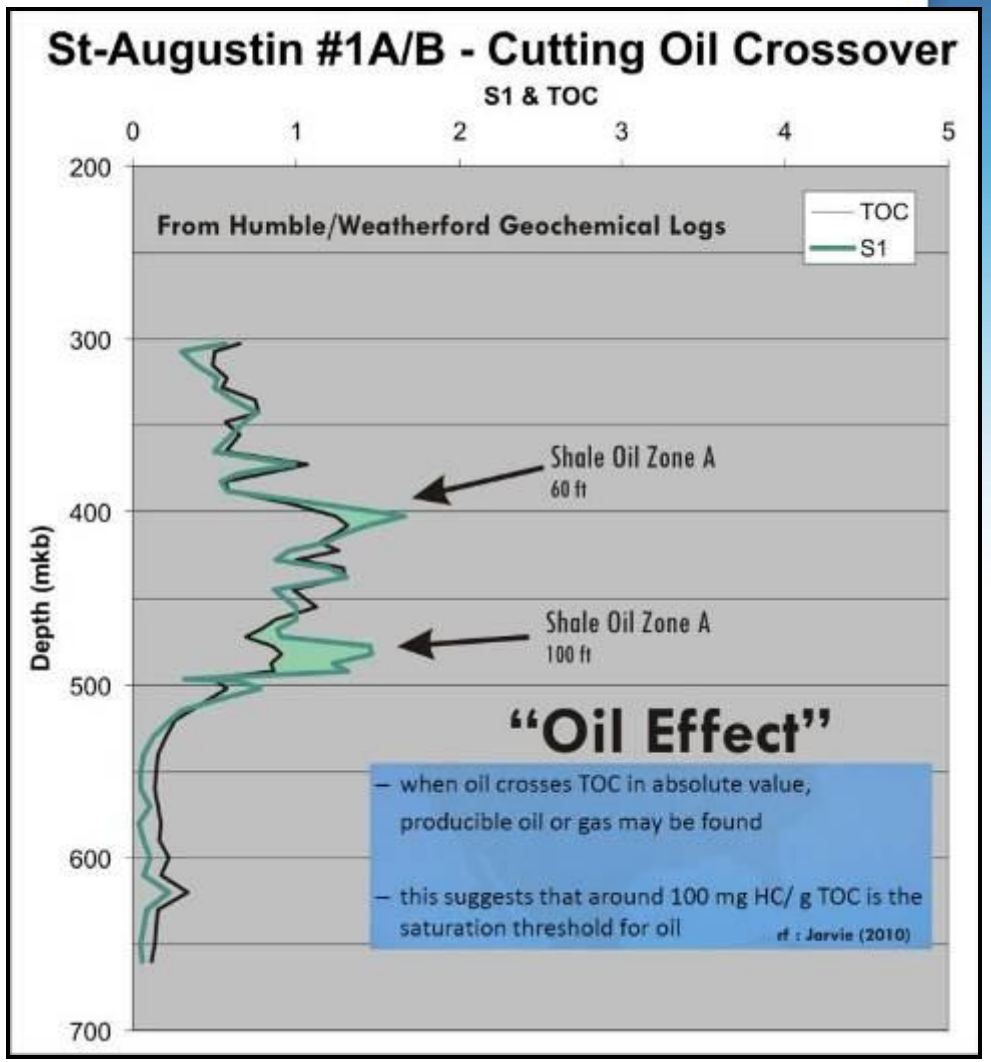
***Coincidence of Liquids-Rich Belt with part of Shallow-Medium Depth Shale Gas Fairway** (mostly JNX land)*

Condensate/Gas Belt overlaps portions of all three fairways

Isotopic analyses indicate gas found in other water wells or seeps are thermogenic, Utica shale sourced

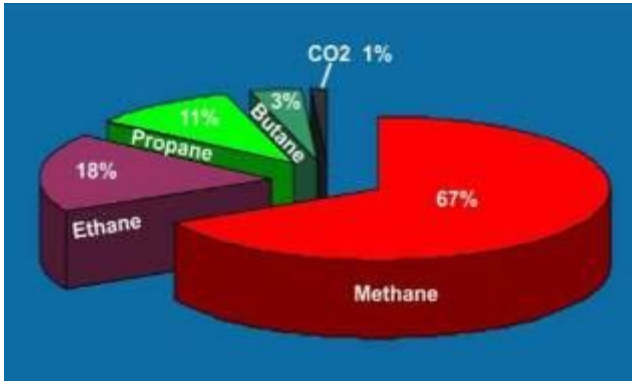
St-Augustin Well Geochemistry





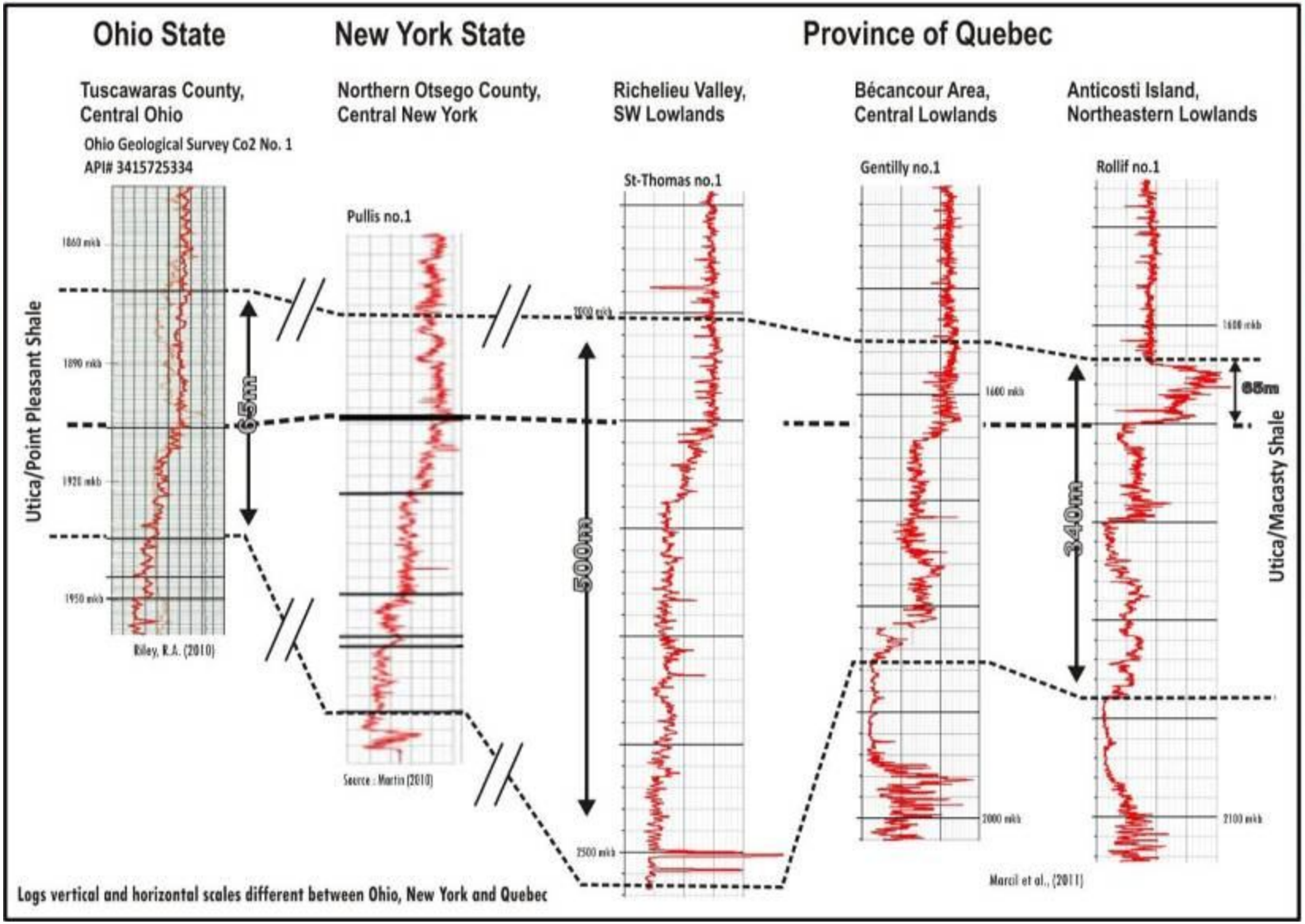
Propane Frac of Liquids-Rich Utica

- *Propane frac selected due to presence of liquids-rich gas in Utica*
- *Little formation damage should be induced (propane already present in gas, no phase trapping)*
- *Rapid frac fluid clean-up with high recoveries*
- *Possible improvements in productive capacity (no frac fluid left behind)*

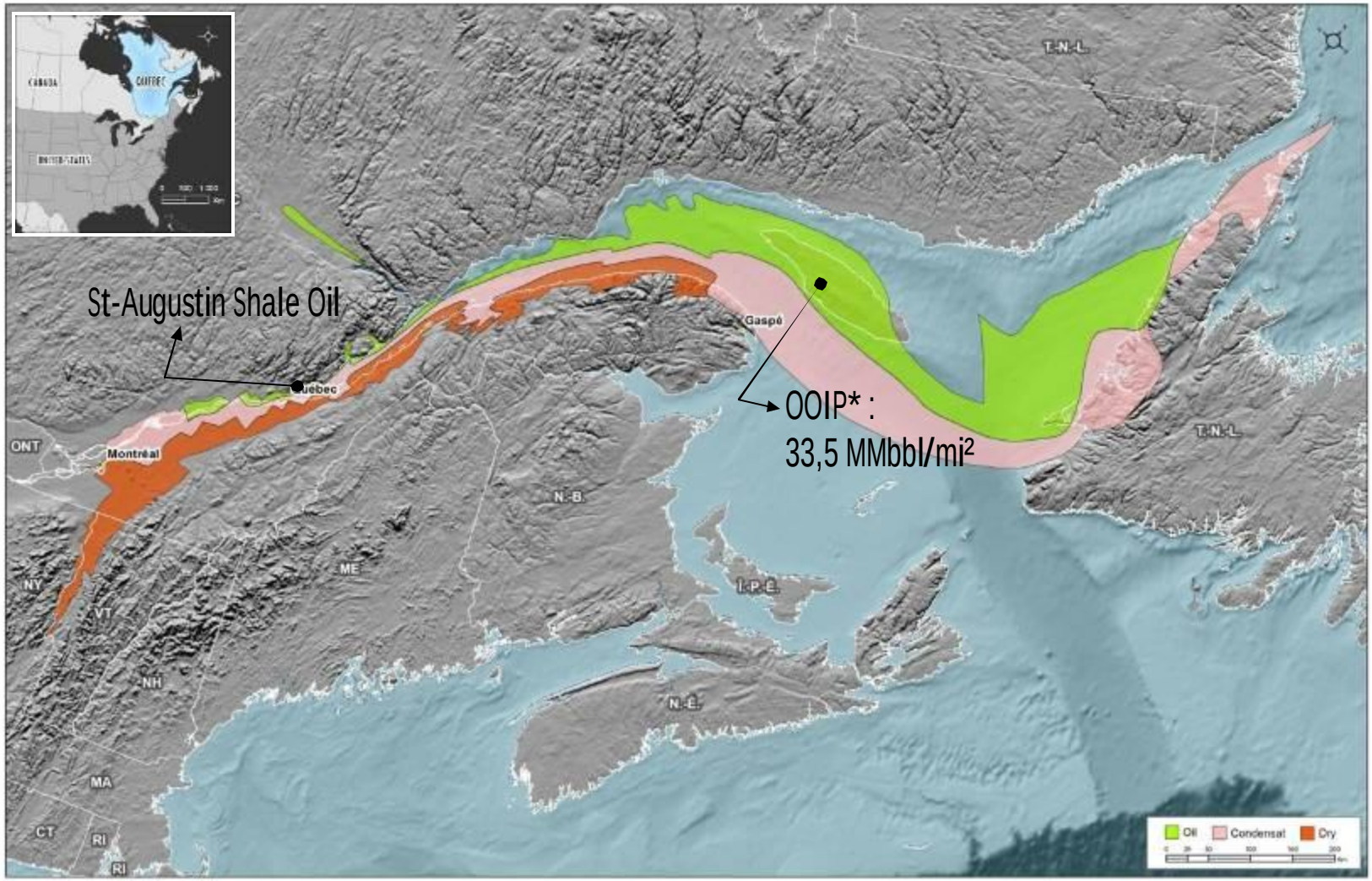


- *Zero frac water to dispose of*
- *If frac results fall below expectations, then other frac methods, such as Slick Water fracs, can still be done in the same wellbore*
- *First propane frac of a Gas Shale in Eastern Canada*

NE America – Ordovician Shale Correlation

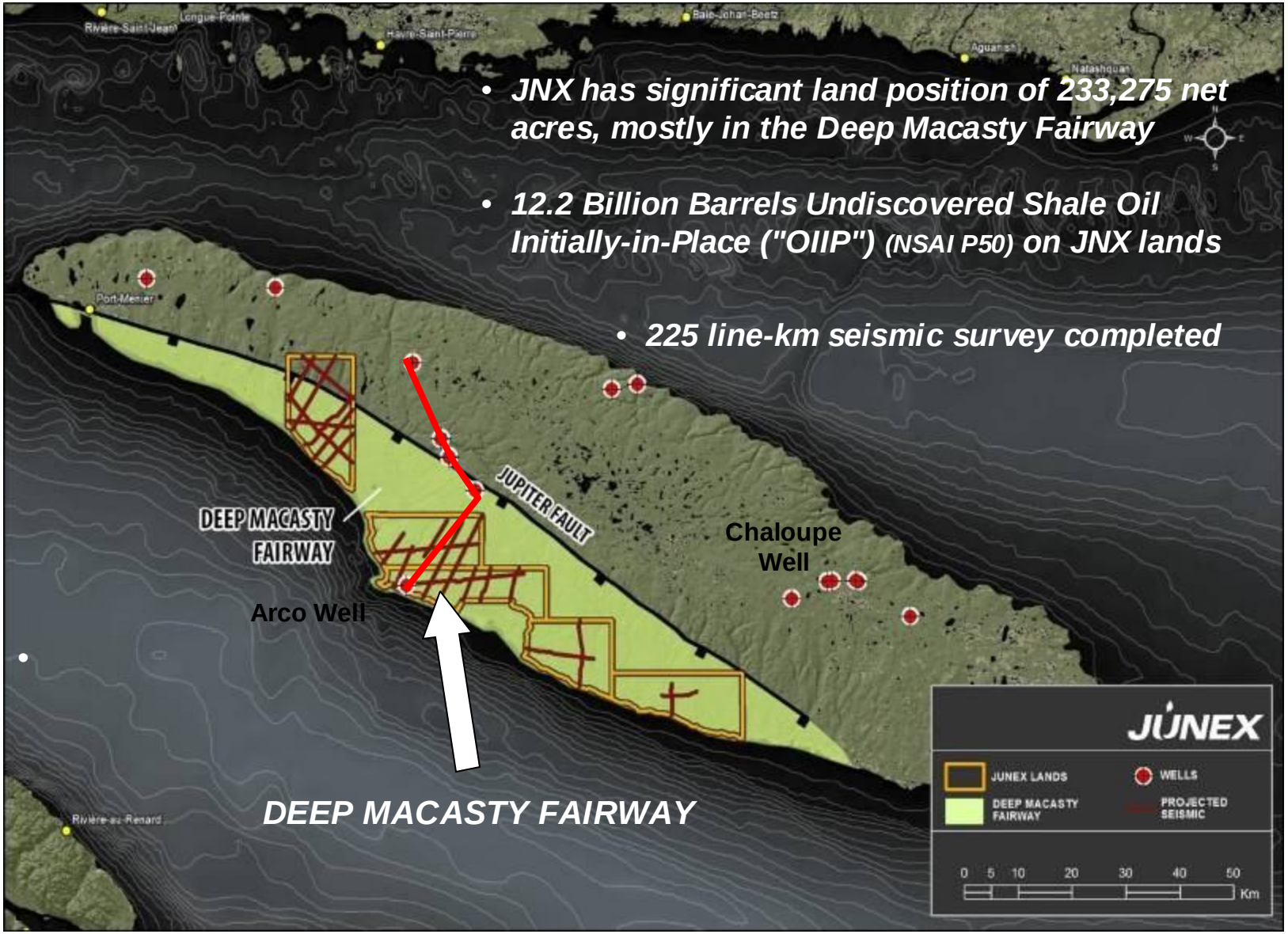


Ordovician Shale Thermal Maturity Zonation

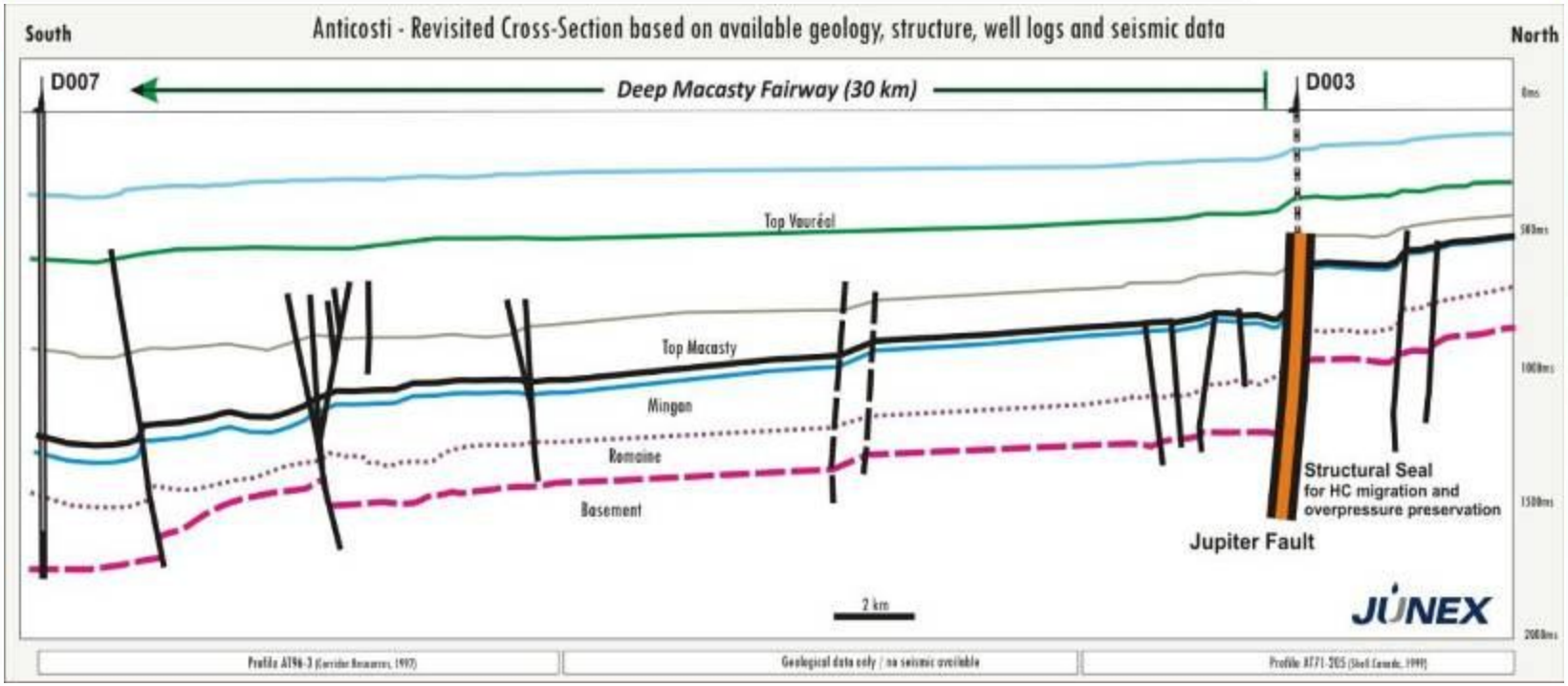


* From September 2011 – Netherland Sewell and Associates Inc. Ressource Estimates Independant Report for South Anticosti Island

Anticosti Island – Macasty Shale Oil Potential

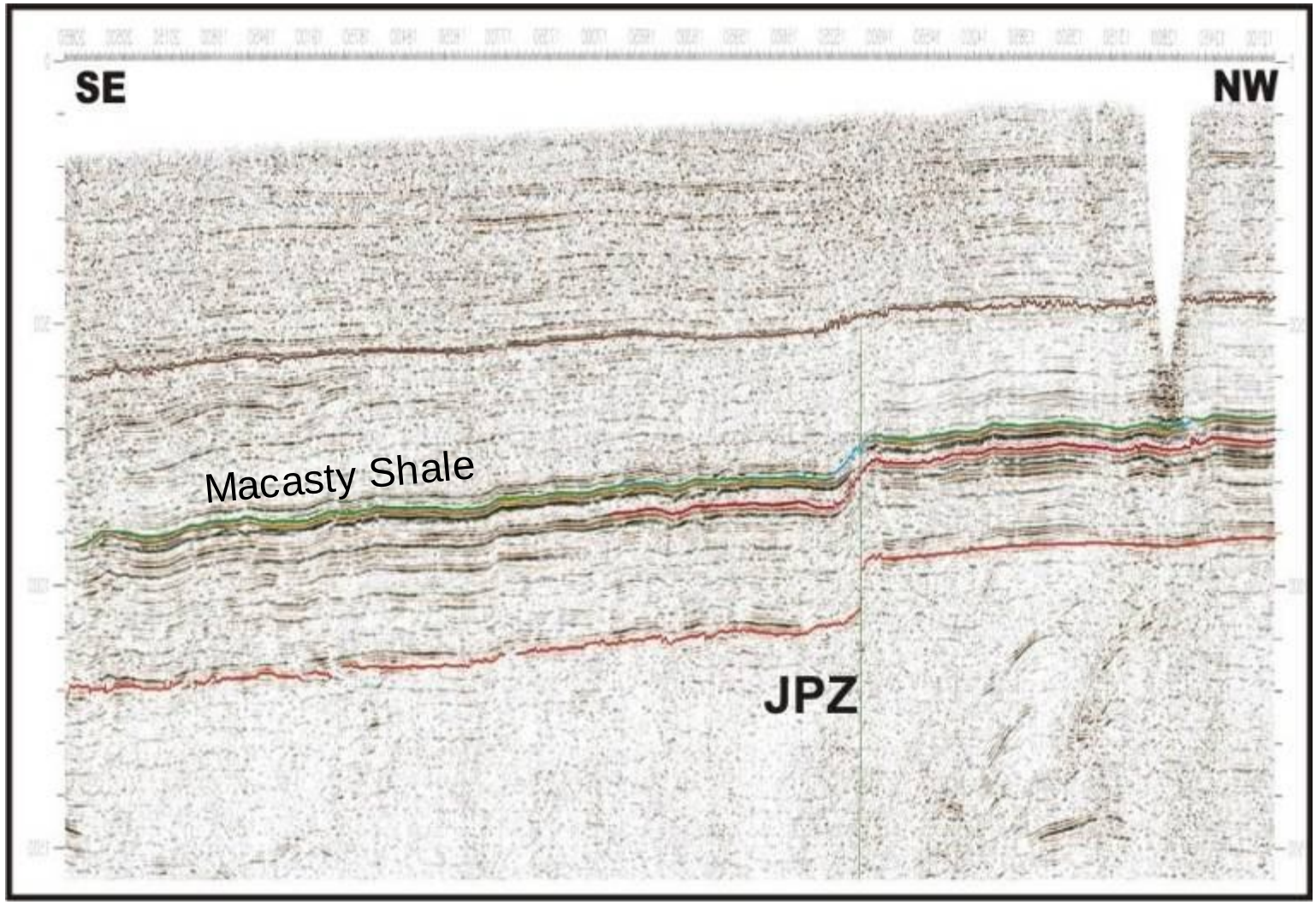


Macasty Fairway Cross-Section

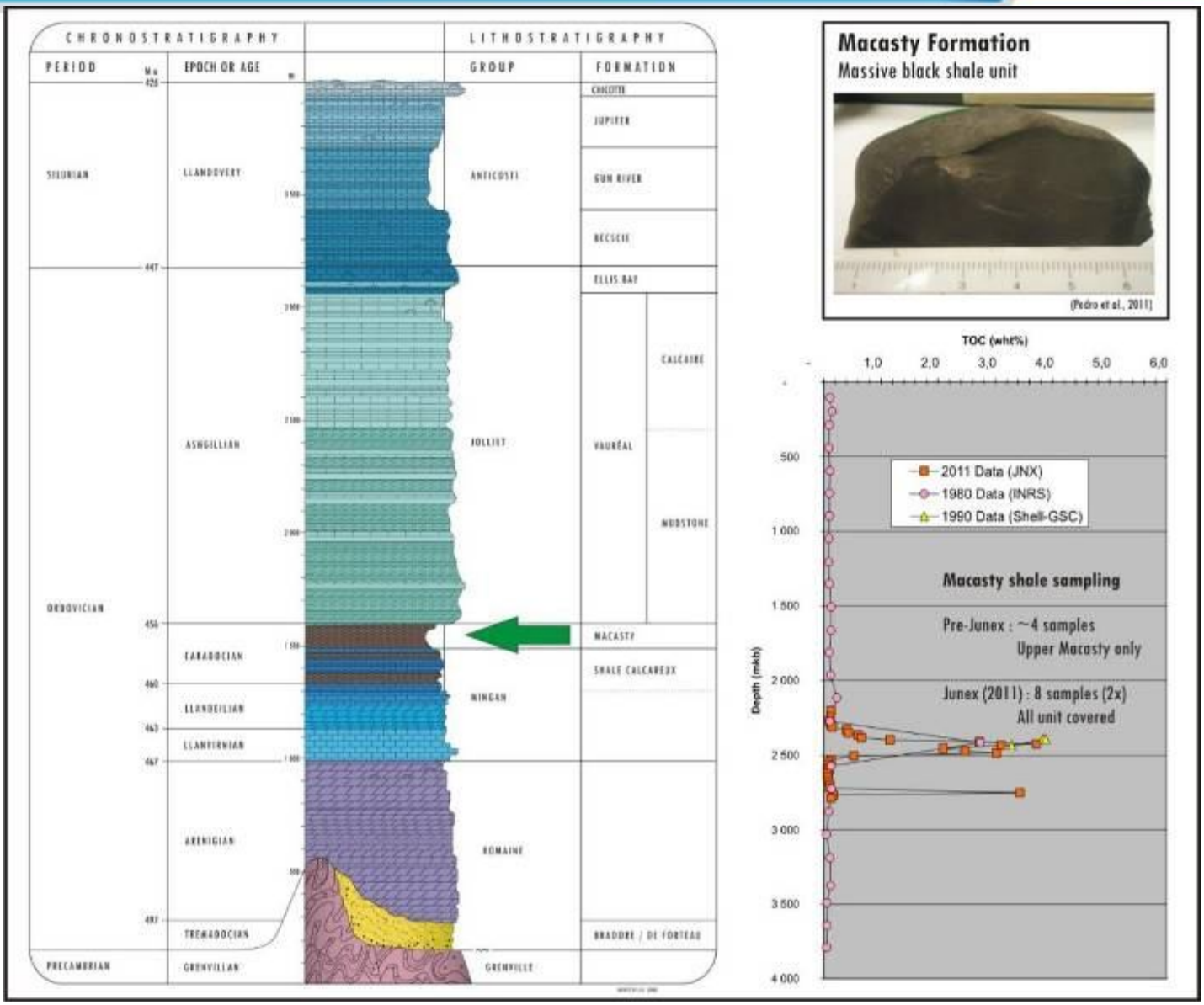


- ***Macasty Shale is the stratigraphic equivalent of the Utica Shale Lowlands***
- ***Thicker in Deep Macasty Fairway than on other side of Jupiter Fault zone*** *(ave. 80m vs 40m at Chaloupe well)*
- ***"Brittle" mineralogy - ave. 50% Quartz + Feldspar, 35% Carbonate, and 15% Clays***
- ***Good to Excellent Organic Richness with an average TOC content of 2.6 wt %*** *(range of 1.2 to 3.7 wt %)*
- ***Good Porosity – average porosity of 6.3%*** *(range of 4.0 to 8.6%)*
- ***Deep Fairway – dominantly in Oil window of thermal maturity***
- ***Higher reservoir pressure = greater reservoir energy in Deep Macasty Fairway***

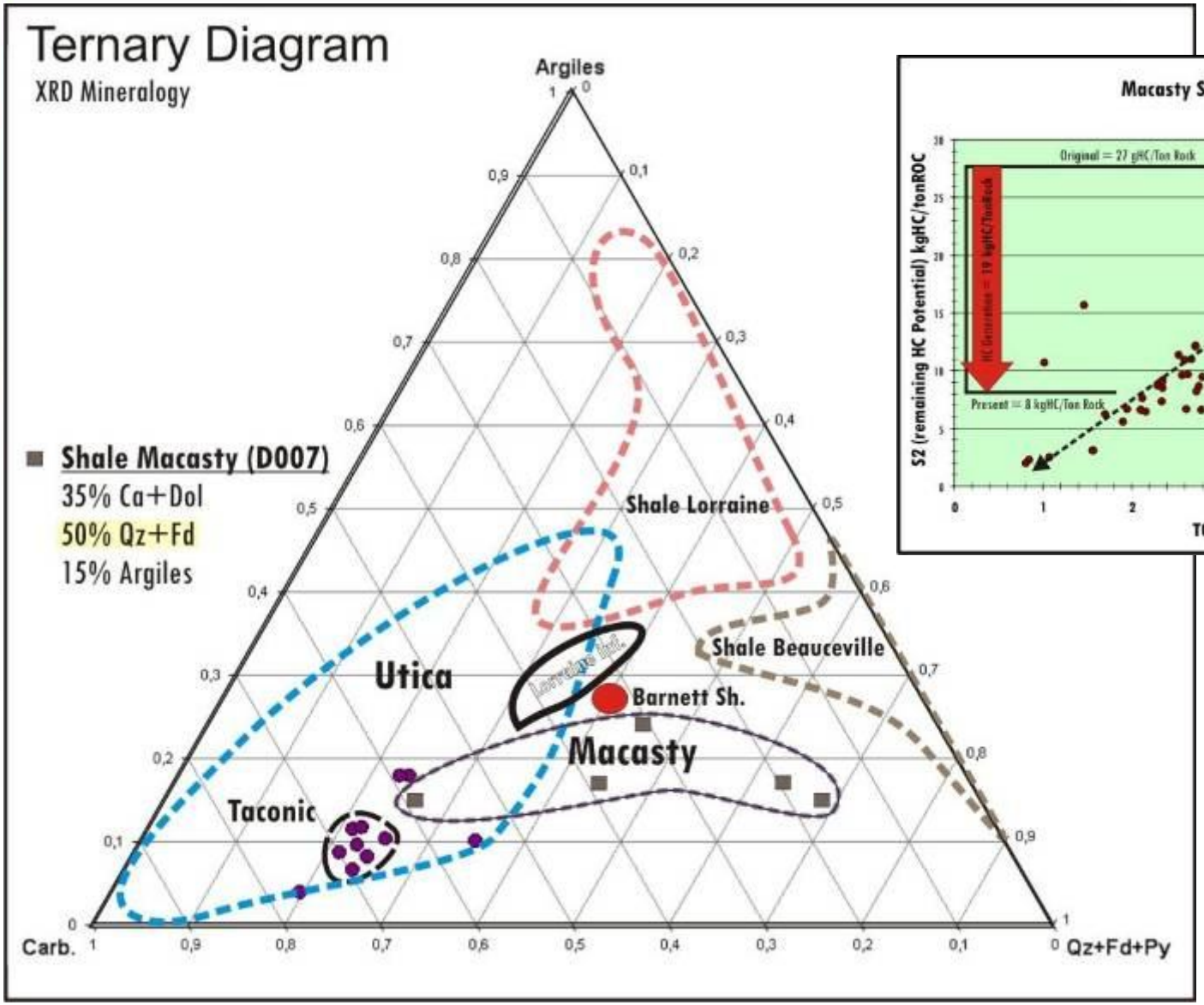
Macasty Shale – Seismic Profile



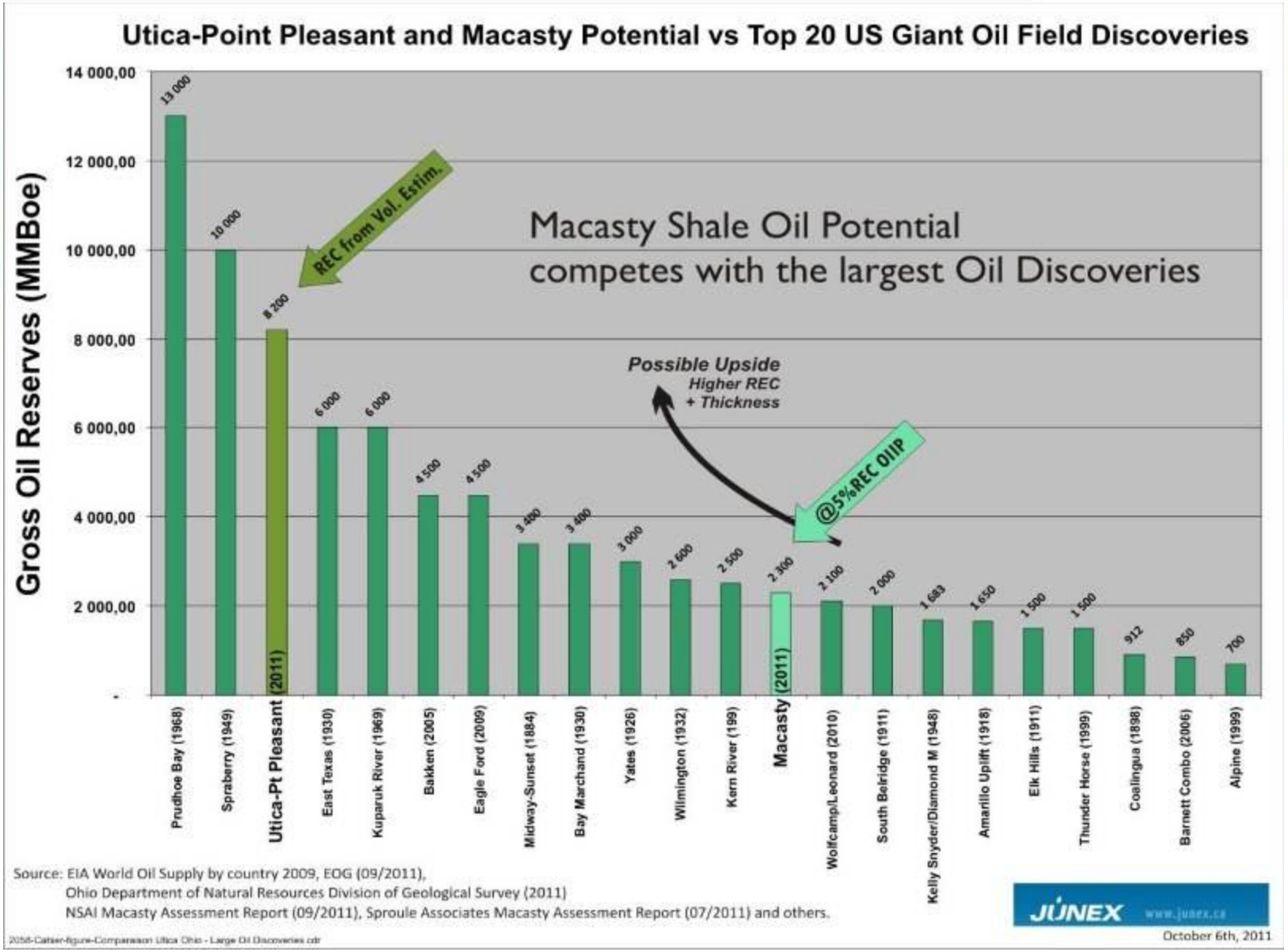
Macasty Shale - Geology



Macasty Shale – Mineralogy & Geochemistry

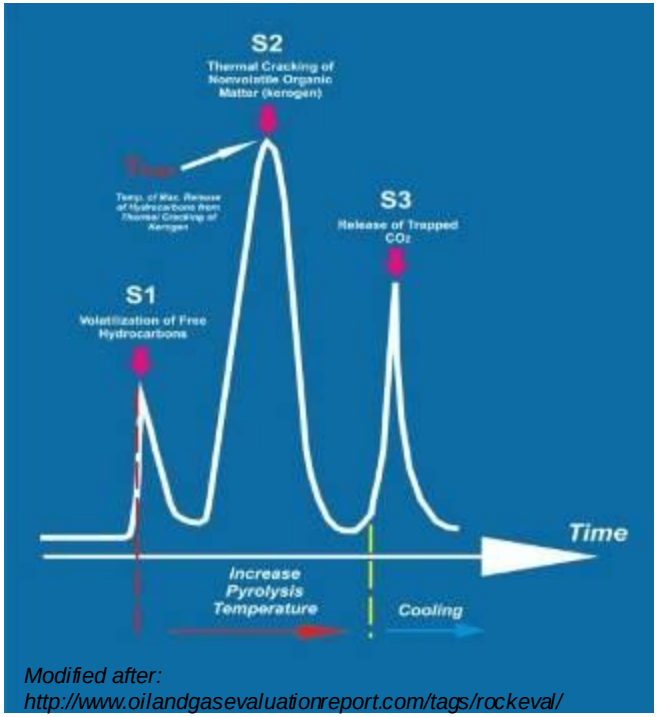


Anticosti Island – Macasty Shale Oil Potential



Anticosti Island – Macasty Shale Oil Potential

Geochemical Parameters from Rock-Eval

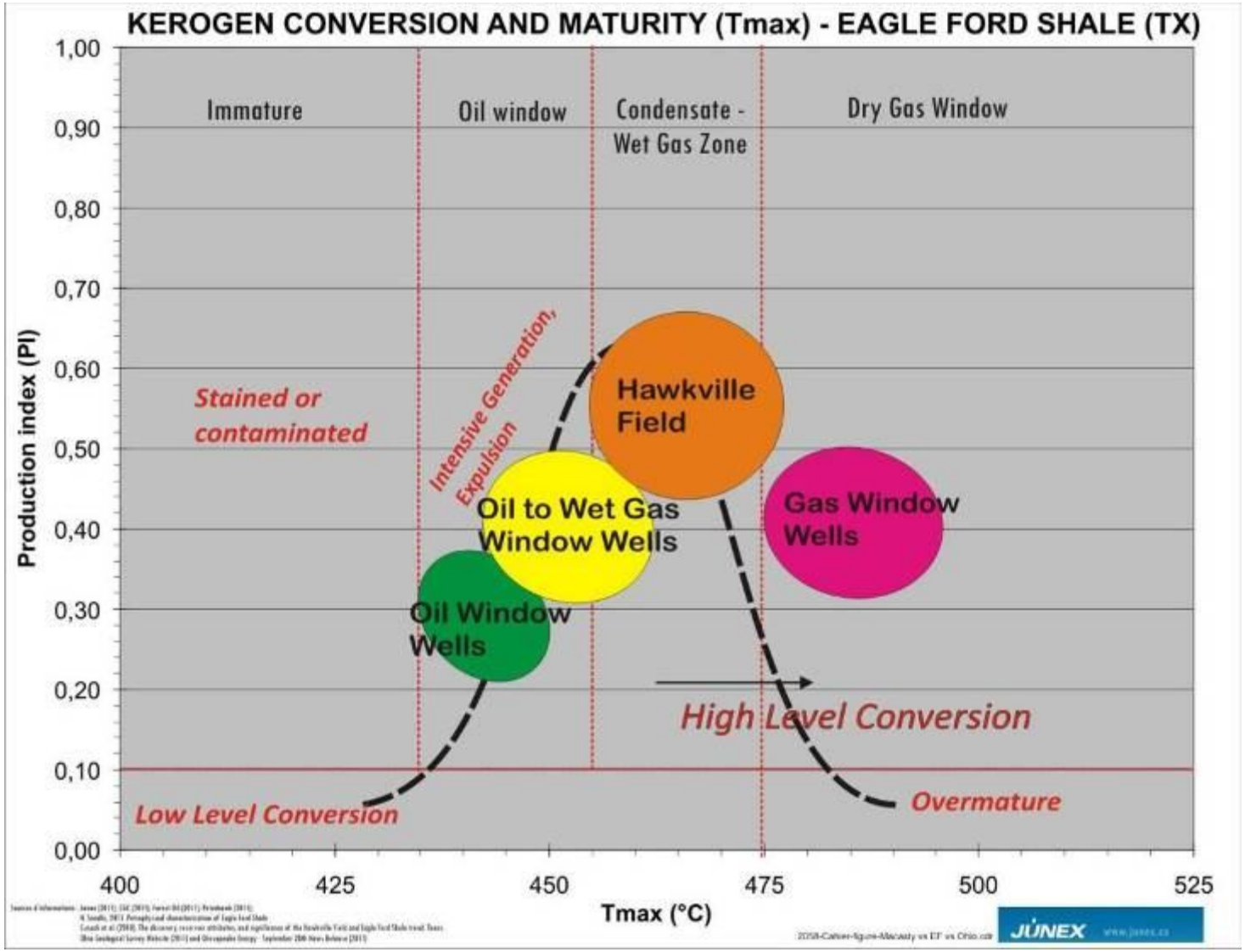


Modified after:
http://www.oilandgasevaluationreport.com/tags/rockeval/

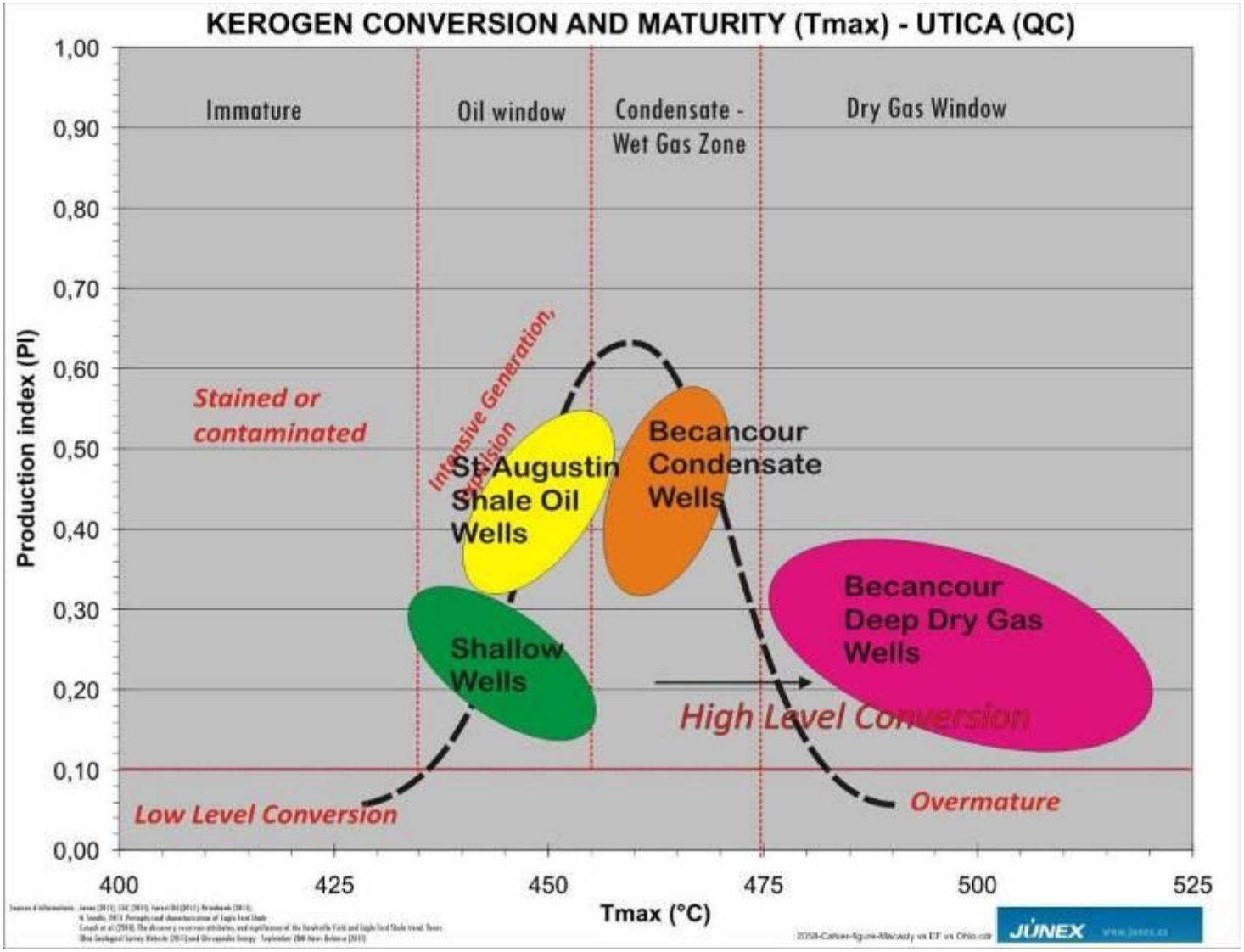
- ***Remaining Hydrocarbons***
  - ***S1 – amount of free oil and gas already generated in the rock***
  - ***S2 – amount of hydrocarbon generated from thermal cracking of non-volatile organic matter (kerogen)***
- ***Tmax – temperature of maximum release of hydrocarbons***

- ***Production Index – S1 / (S1 + S2)***
  - ***Ratio of Already Generated hydrocarbons to Potential Hydrocarbons***
  - ***Low ratio – immature or extremely post-mature***
  - ***High ratio – mature stage or contamination***

Comparison of Macasty to Utica & Eagle Ford



Comparison of Macasty to Utica & Eagle Ford



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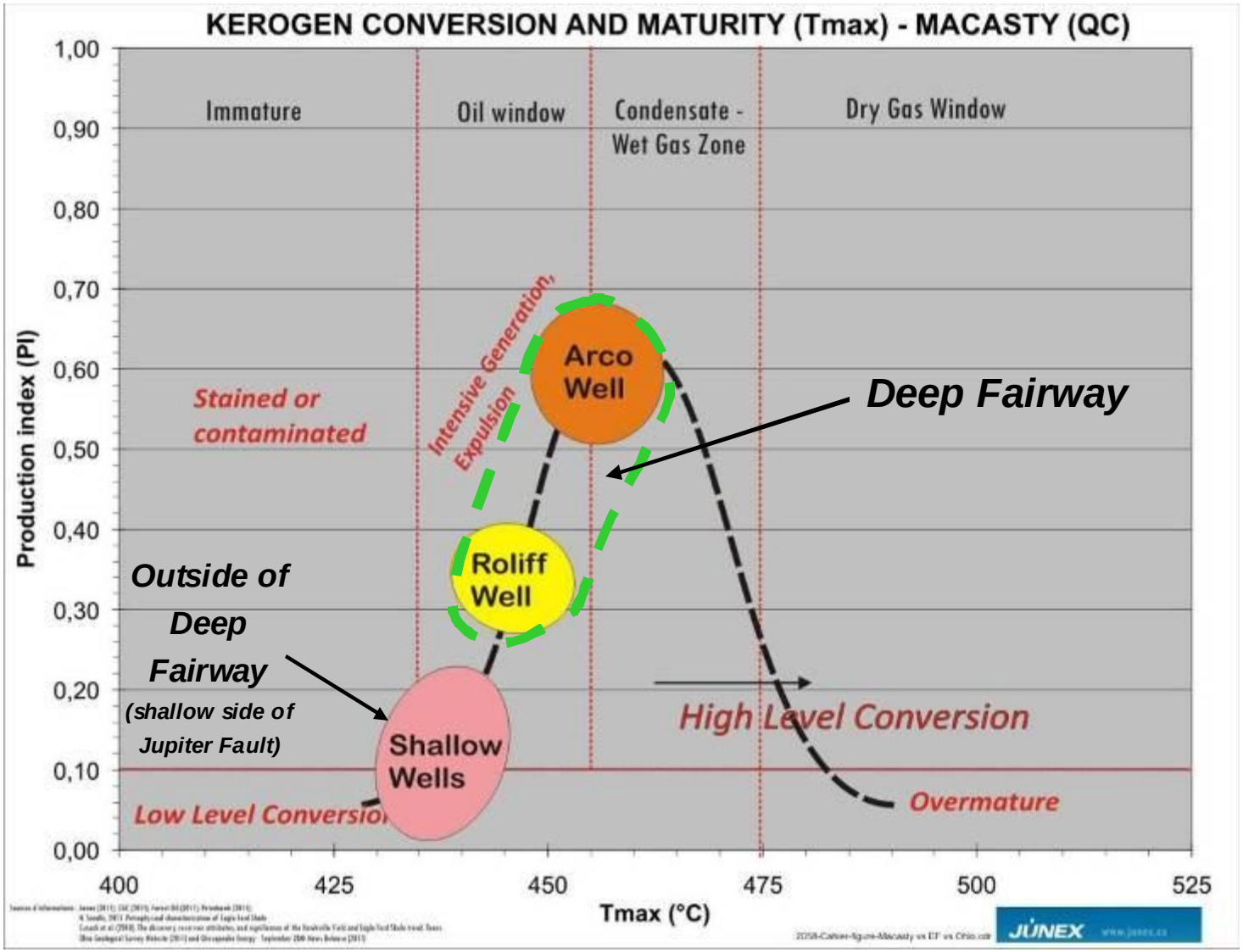
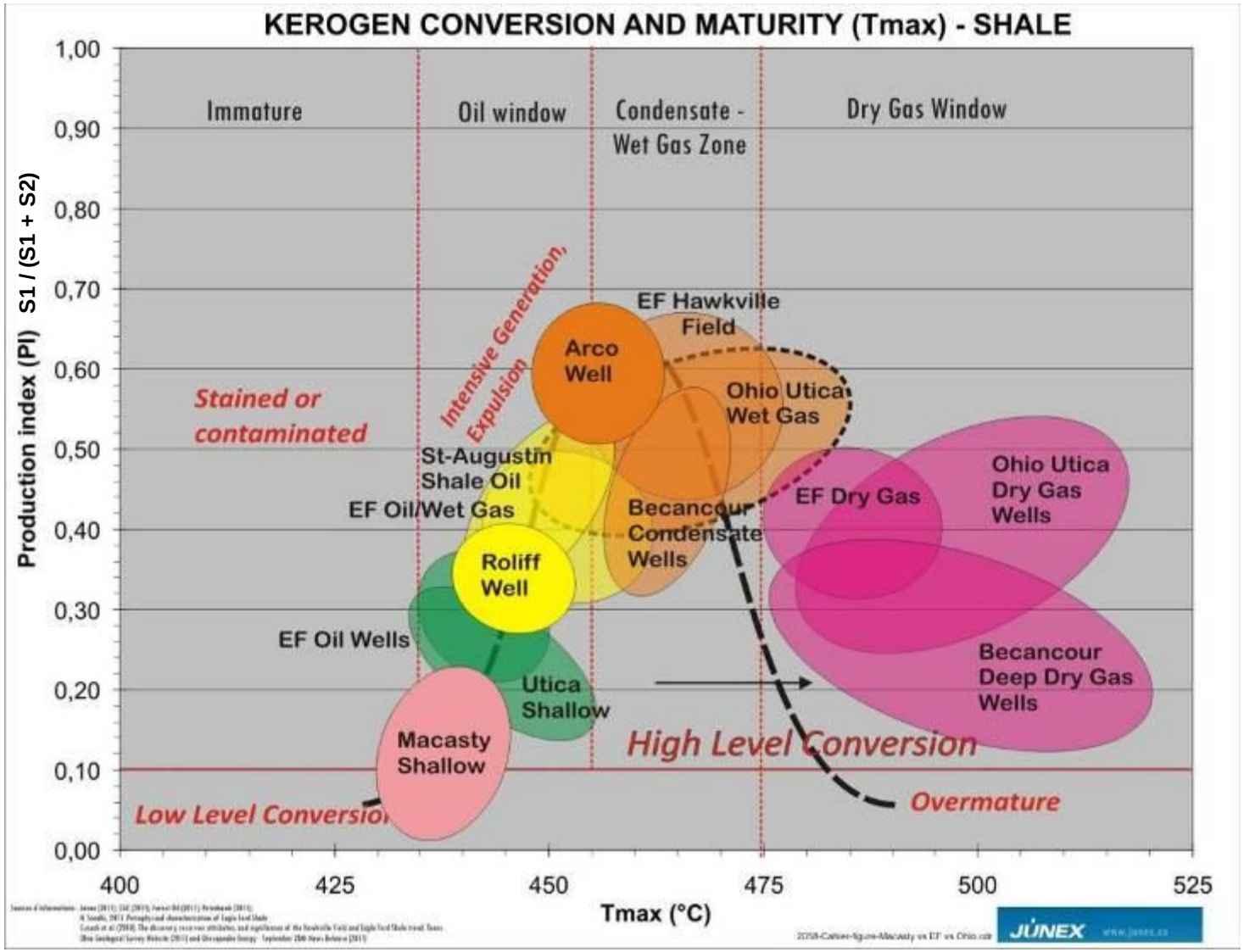
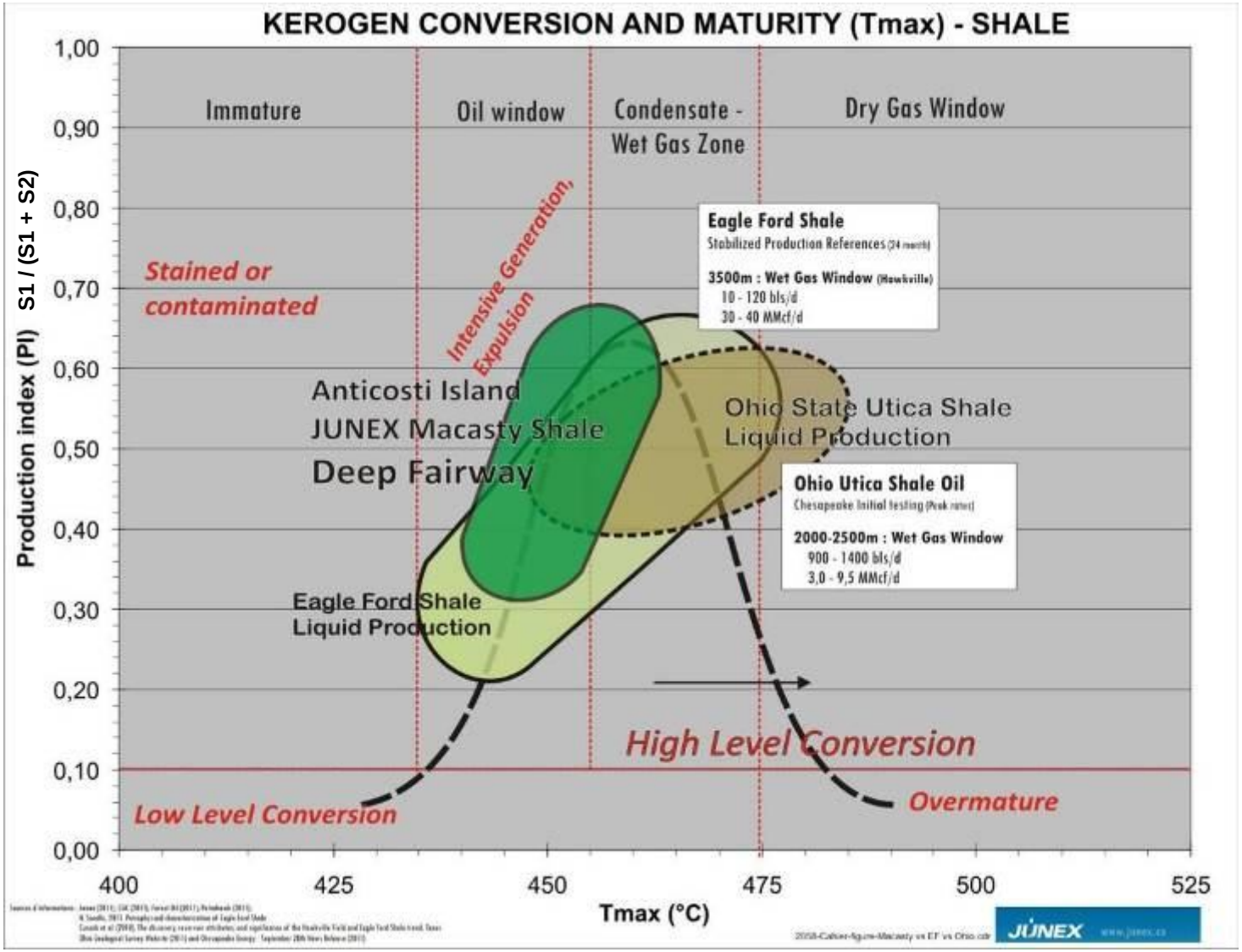


Comparison of Macasty to Utica & Eagle Ford



Comparison of Macasty to Utica & Eagle Ford

Comparison of Macasty Deep Fairway to Ohio Utica & Eagle Ford



Conclusions

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- *The Shales in Province of Québec are promising plays*
  - *Widespread source rocks – Utica, Lorraine & Macasty Shales*
  - *Utica Estimated (average) OGIP for the most advanced area: +100 Bcf/section*
  - *Macasty Shale OIIP potential about 40 billion barrel of oil*
- *Utica Shale solely:*
  - *Hi-quality resources - High BTU (heating value) Liquids-rich Gas and Oil*
  - *Demonstration of gas production rates (Utica)*
  - *Existing infrastructures & local market*
  - *Utica Shales: Proven fracturability in verticals & horizontals*
- *Impacts on the Resources Exploration all over the province*
  - *Re-looked at the Anticosti, Appalachian and Gaspesie Basins Potential*
  - *Paradigm Shift in the way Quebecers see the energy potential of their land*
  - *New Hydrocarbon and Mining Act*
- *SEA Report current works*
  - *Science reports recently release (http://ees-gazdeschiste.gouv.qc.ca/en/)*
- *Newly Elected Government*
  - *With a strong desire to increase the Energy Independency of the province*
  - *in a very high level Environmental protection.*

Acknowledgments

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Nabila Mechti, exploration geologist
Bertrand Marcotte, field geologist
Daniel Cantin-Plante, mapping specialist
Luc Massé, reservoir engineer

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