Lower Paleozoic Shale Gas and Shale Oil Potential in Eastern Canada: Geological Settings and Characteristics of the Upper Ordovician Shales*

Denis Lavoie[1]

Search and Discovery Article #80242 (2012)**
Posted July 31, 2012

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, USA, April 22-25, 2012

[1]Geological Survey of Canada, Natural Resources Canada, Quebec City, QC, Canada (delavoie@nrcan.gc.ca) .

Abstract

The Upper Ordovician Utica Shale (50 to 300 m thick) and Macasty Shale (40 to 100 m thick) are found in southern Quebec and Anticosti Island, respectively. Over the years, these two units have been studied for their hydrocarbon source-rock potential. The Utica and Macasty calcareous shales overlie the Ordovician carbonate foreland platform; the calcareous shales started to accumulate when, because of rapid increase of relative sea level rise, the backstepping carbonate-producing zone was partially shut-down, leaving siliciclastic muds with subordinate carbonate mud to accumulate in an interpreted deep marine, poorly oxygenated setting. Largely unknown basin configuration resulted in variation in thickness and lateral character of the sedimentary accumulations, whereas the variations in the vertical succession resulted from yet-to-demonstrate, higher frequency sea-level fluctuations in a larger scale eustatic sea level fall in Late Ordovician. Both shales were deformed during the Late Ordovician Taconian Orogeny although, if the degree of deformation was relatively minor, it increases significantly with structural thickening in the Appalachian domain. Previous works on the source-rock potential of the Utica and Macasty shales have led to a regional understanding of the distribution of thermal domains. The Utica Shale (TOC up to 3%) in southern Quebec is almost entirely in the gas window, whereas the Macasty Shale (TOC up to 5%) in Anticosti Island straddles the oil and gas windows. Understanding of mineralogical variations and mapping of TOC and HI domains are available for the Utica, although this level of detail is currently not available for the Macasty.

Exploration in the Utica Shale in southern Quebec started in 2007 and has demonstrated potential for yielding significant volume of natural gas after multistage fracturing. Pre-commercial production pilot projects are in the planning stage. Preliminary geological data indicate that the Macasty Shale could represent a shale oil target in Anticosti Island.

Selected References

Castonguay, S., D. Lavoie, J. Dietrich, and J.-Y. Laliberte, 2010, Structure and petroleum playhs of the St. Lawrence Platform and Appalachians in southern Quebec; insights from interpretation of MRNQ seismic reflection data: Bulletin of Canadian Petroleum Geology, v. 58/3, p. 219-234.

Lavoie, D., M. Obermajer, and M.G. Fowler, 2010, Rock-Eval/TOC data from Cambrian-Ordovician of the Sant Lawrence Platform and Humber Zone, and Silurian-Devnonian of the Gaspe Belt successions, Quebec: Geological Survey of Canada, Open File 6050, 34 p.

Lavoie, D., N. Pinet, J. Dietrich, and P. Hannigan, 2009, Petroleum resources assessment, Paleozoic successions of the St. Lawrence platform and Appalachians of eastern Canada: Geological Survey of Canada, Open File 6174, 273 p.

Miall, A.D., and R.C. Blakey, 2008, The Phanerozoic tectonic and sedimentary evolution of North America, *in* A.D. Miall, (ed.), The sedimentary basins of the Unted States and Canada: Elsevier Amsterdam, Netherlands, v. 5, p. 1-29.

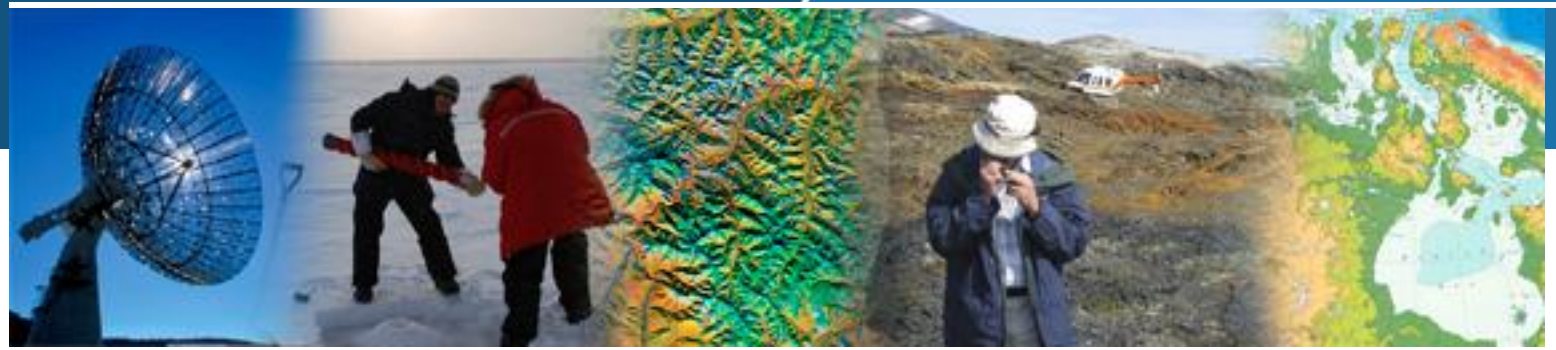
Ross, C.A., and J.R.P. Ross, 1988, Late Paleozoic transgressive-regressive deposition, *in* C.K. Wilgus, B.J. Hastings, H. Posamentier, J.C. van Wagoner, C.A. Ross, and C.G. Kendall, (eds.), Sea Level Changes: An Integrated Approach: Society for Sedimentary Geology (SEPM), Special Publication, v. 42, p. 227-247.

Websites

Corridor Resrouces, Inc., 2011, Corridor reports independent Macasty Shale resource assessment for Anticosti Island. Web accessed 19 July 2012.
http://www.corridor.ca/media/2011-press-releases/20110713.html

EIA, 2011, Shale Gas and the Outlook for U.S. Natural Gas Markets and Global Gas Resources. Web accessed 19 July 2012.
http://photos.state.gov/libraries/usoecd/19452/pdfs/DrNewell-EIA-Administrator-Shale-Gas-Presentation-June212011.pdf

Lower Paleozoic Shale Gas and Shale Oil Potential in Eastern Canada: Geological Setting and Characteristics of the Upper Ordovician Shales



Denis Lavoie
Geological Survey of Canada – Québec office

Ressources naturelles Canada
Natural Resources Canada
Canada

Outline

1. Introduction

2. Regional geological context of the Upper Ordovician shale basin (Utica and Macasty shales)

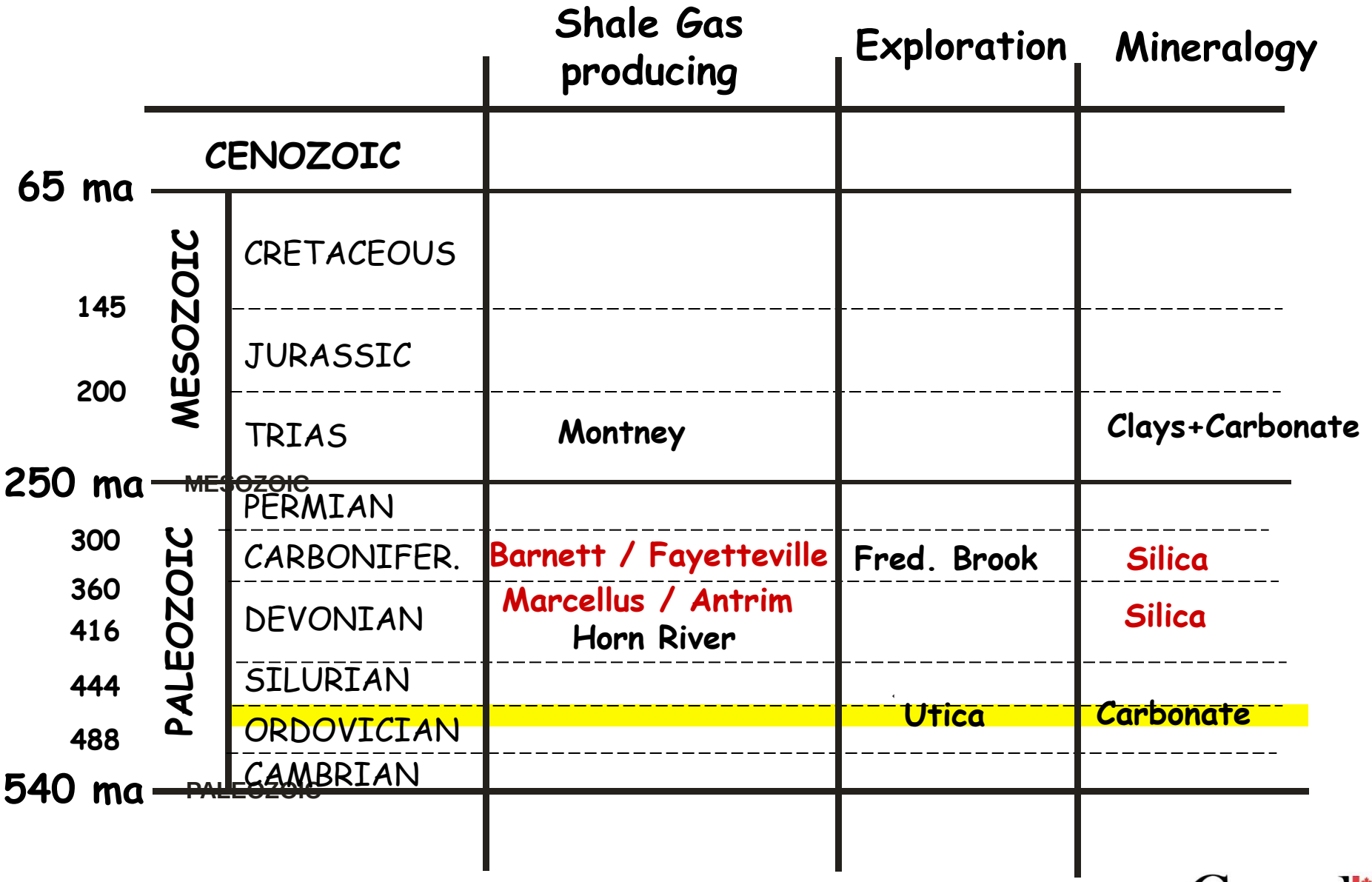
3. Thermal maturation domains and organic geochemistry

4. Initial test results

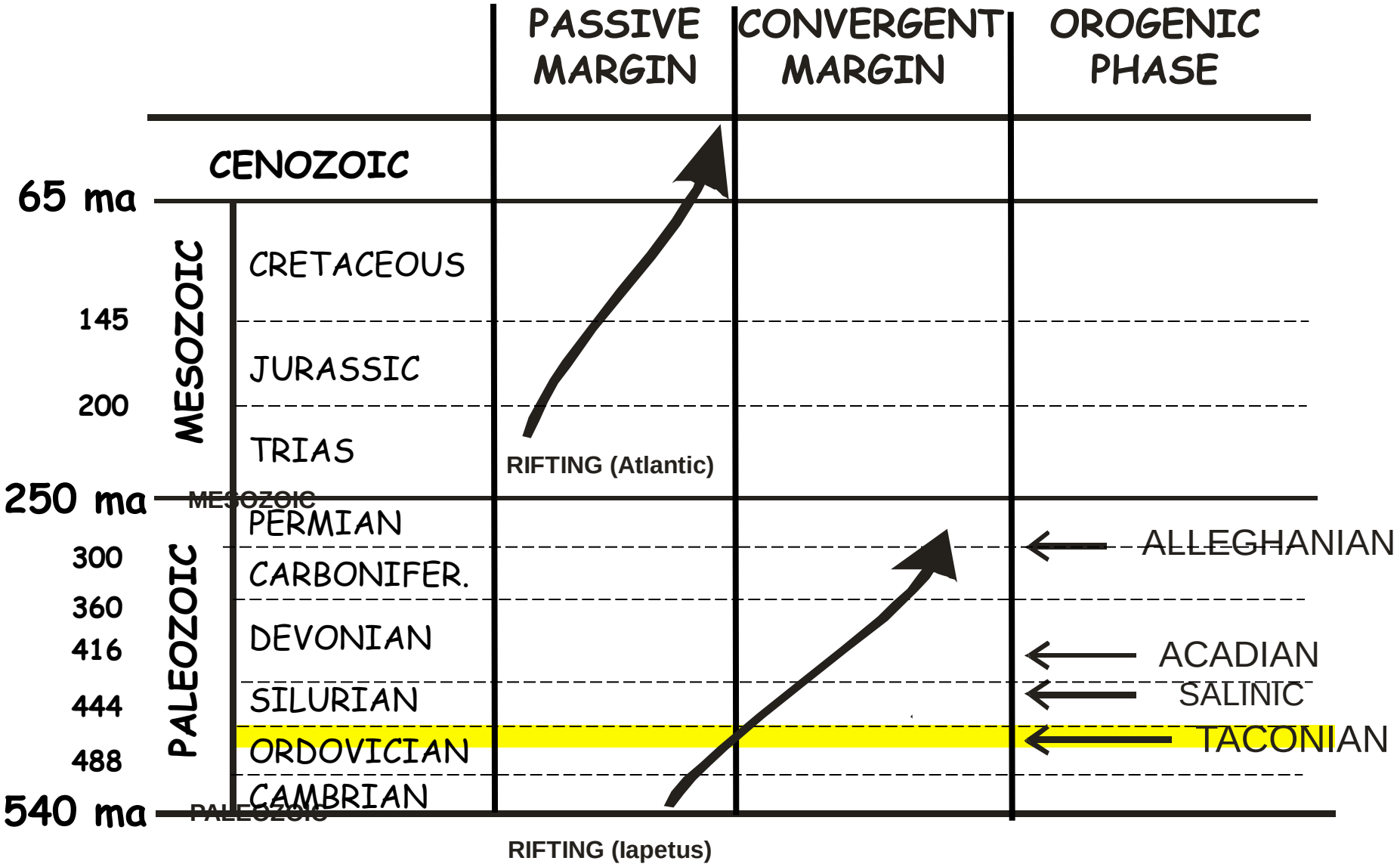
5. Liquid-rich domain from southern Quebec to Anticosti Island

Thanks to Robert Thériault (MRNFQ) for Utica data


North American shale plays
(as of March 2011)
Muskwa-Otter Park, Evie-Klua
Lower Besa River
Muskwa-Otter Park
Montney
Doig Phosphate
Colorado Group
Niobrara*
Bakken
Cody
Heath**
Gammon
Mowry
Hilliard- Baxter-Mancos-Niobrara
Niobrara*
Mancos
Monterey-Temblor
Hermosa
Monterey
Lewis
Pierre-Niobrara
Excello-Mulky
Woodford
Fayetteville
Bend
Avalon
Barnett
Barnett-Woodford
Eagle Ford
Eagle Ford, La Casita
Eagle Ford, Tithonian
Pimienta
Pimienta, Tamaulipas
Maltrata
Haynesville-Bossier
Tuscaloosa
Floyd-Neal
Conasauga
Chattanooga
Macasty
Utica
Frederick Brook
Horton Bluff
Antrim
New Albany
Devonian (Ohio)
Marcellus
Utica
Current shale plays
Stacked plays
Shallowest / youngest
Intermediate depth / age
Deepest / oldest
* Mixed shale & chalk play
** Mixed shale & limestone play
Prospective shale plays
Basins
N
Miles
0 200 400 600 800
eia

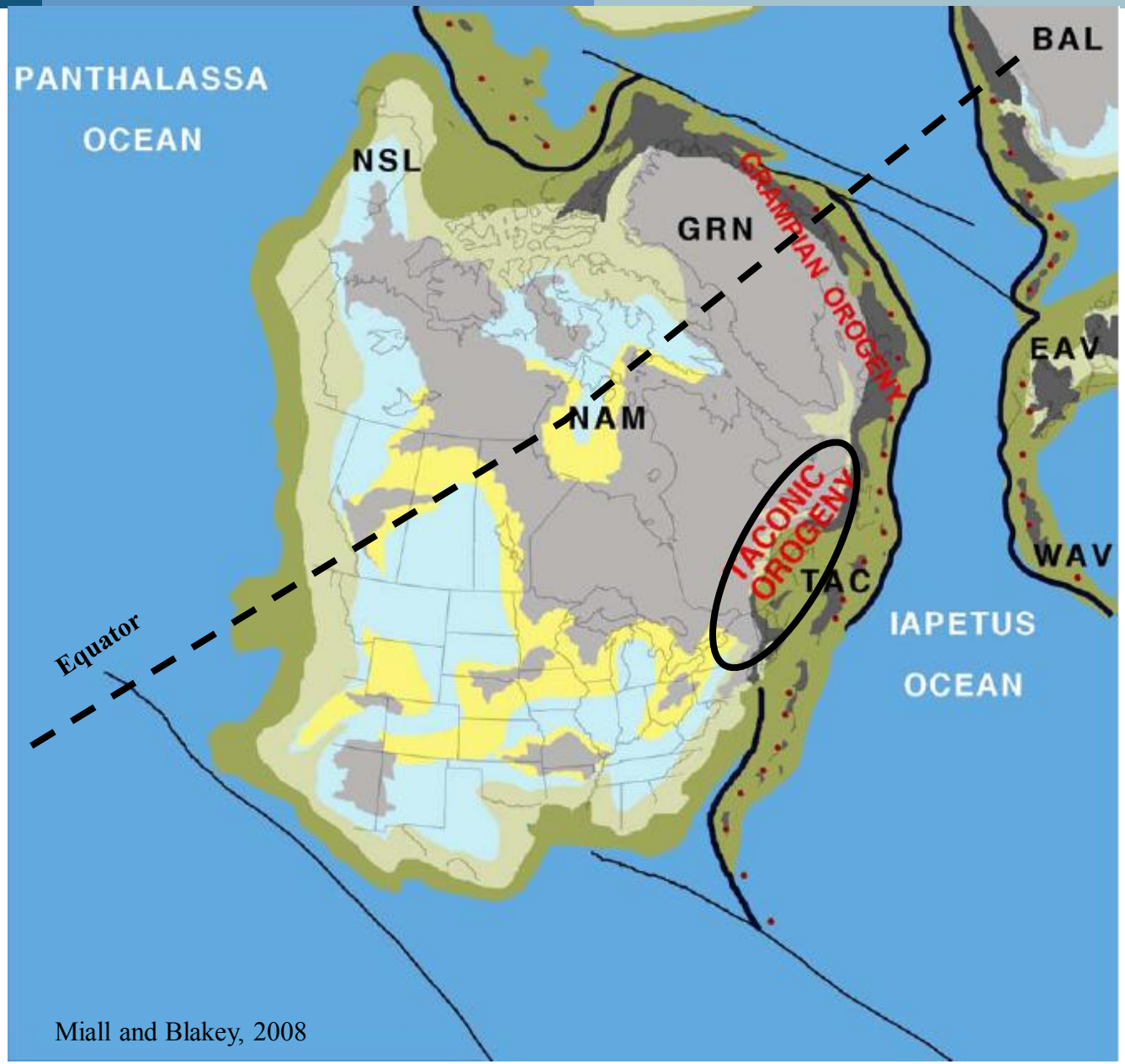

Shale Gas producing
Exploration
Mineralogy
CENOZOIC
65 ma
MESOZOIC
CRETACEOUS
145
JURASSIC
200
TRIAS
Montney
Clays+Carbonate
250 ma
MESOZOIC
PERMIAN
300
PALEOZOIC
CARBONIFER.
Barnett / Fayetteville
Fred. Brook
Silica
360
DEVONIAN
Marcellus / Antrim
Horn River
Silica
416
SILURIAN
444
ORDOVICIAN
Utica
Carbonate
488
CAMBRIAN
540 ma
PALEOZOIC

REGIONAL GEOLOGICAL CONTEXT

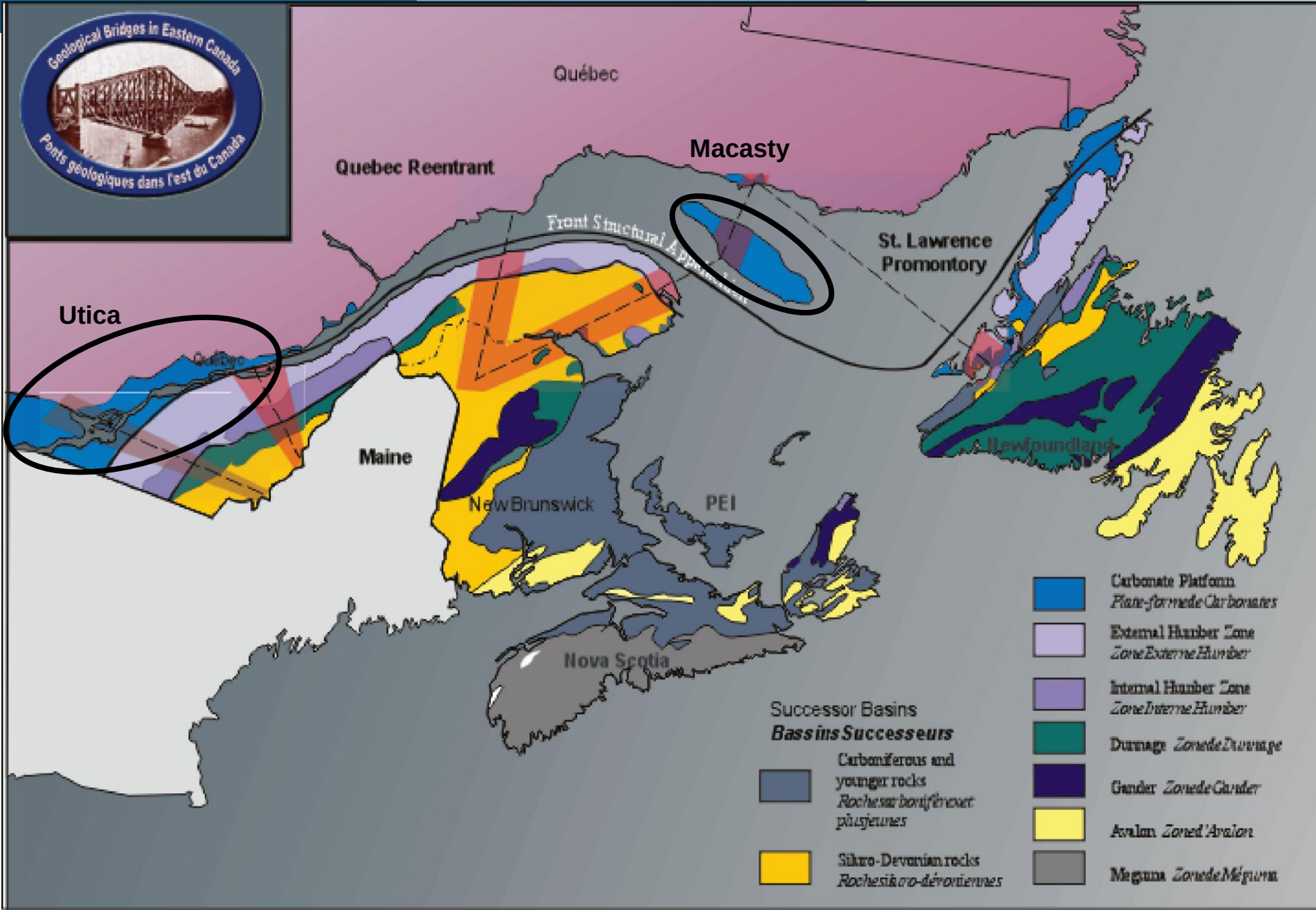

PASSIVE MARGIN
CONVERGENT MARGIN
OROGENIC PHASE
CENOZOIC
65 ma
MESOZOIC
CRETACEOUS
145
JURASSIC
200
TRIAS
RIFTING (Atlantic)
250 ma
MESOZOIC
PERMIAN
ALLEGHANIAN
300
CARBONIFER.
360
DEVONIAN
416
ACADIAN
SALINIC
444
SILURIAN
488
ORDOVICIAN
TACONIAN
CAMBRIAN
540 ma
PALEOZOIC
PALEOZOIC
RIFTING (Iapetus)

Mid to Late Ordovician

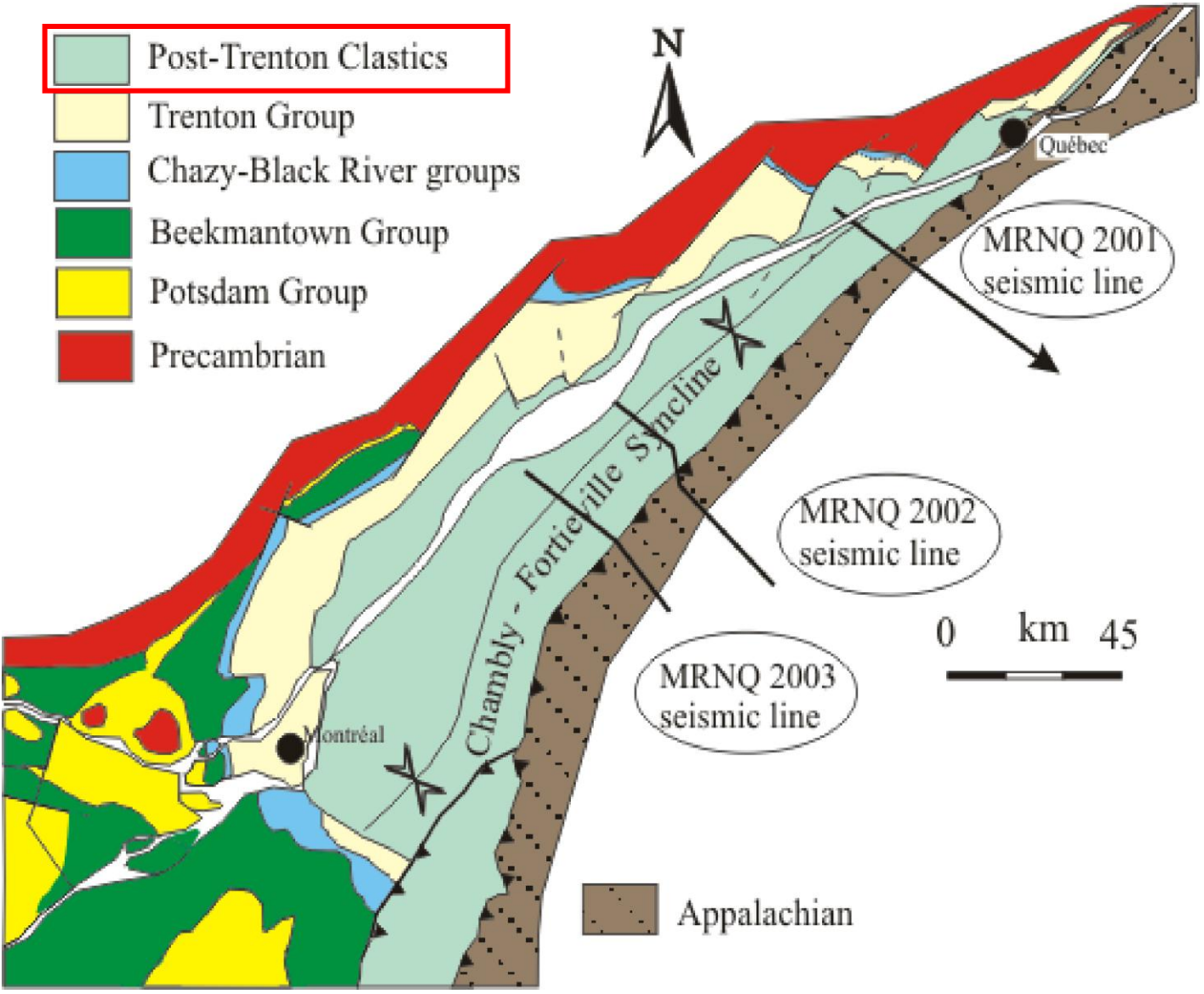
Formation of a tectonic foreland basin

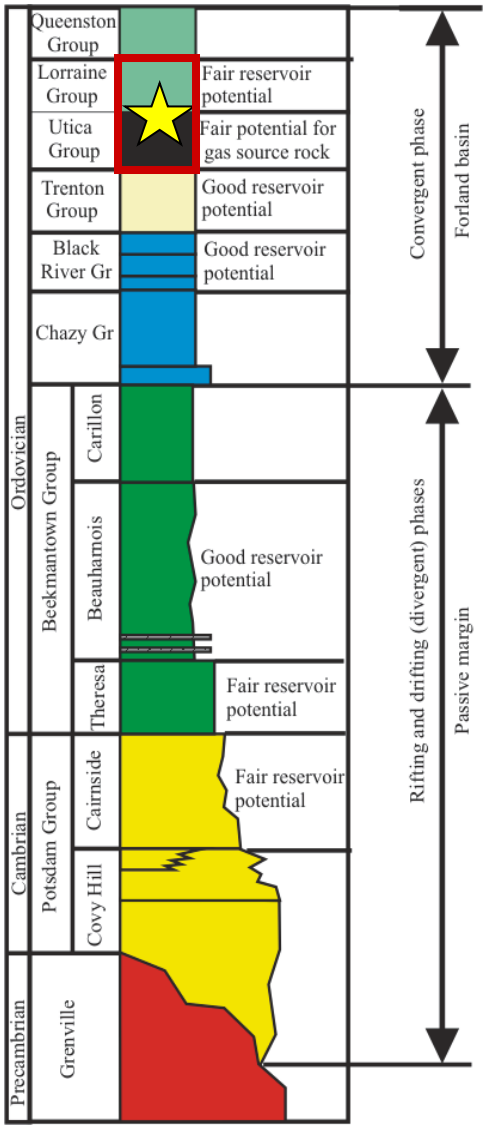


Miall and Blakey, 2008


Geological Bridges in Eastern Canada
Ponts géologiques dans l'est du Canada
Québec
Quebec Reentrant
Macasty
Front Structural Appalachian
St. Lawrence Promontory
Utica
Maine
New Brunswick
PEI
Nova Scotia
Newfoundland
Successor Basins
Bassins Successeurs
Carboniferous and younger rocks
Roches carbonifères et plus jeunes
Siluro-Devonian rocks
Roches siluro-dévoniennes
Carbonate Platform
Plate-forme Carbonates
External Humber Zone
Zone Externe Humber
Internal Humber Zone
Zone Interne Humber
Dunnage Zone de Dunnage
Gander Zone de Gander
Avalon Zone d'Avalon
Meguma Zone de Méguma

Upper Ordovician foreland clastics

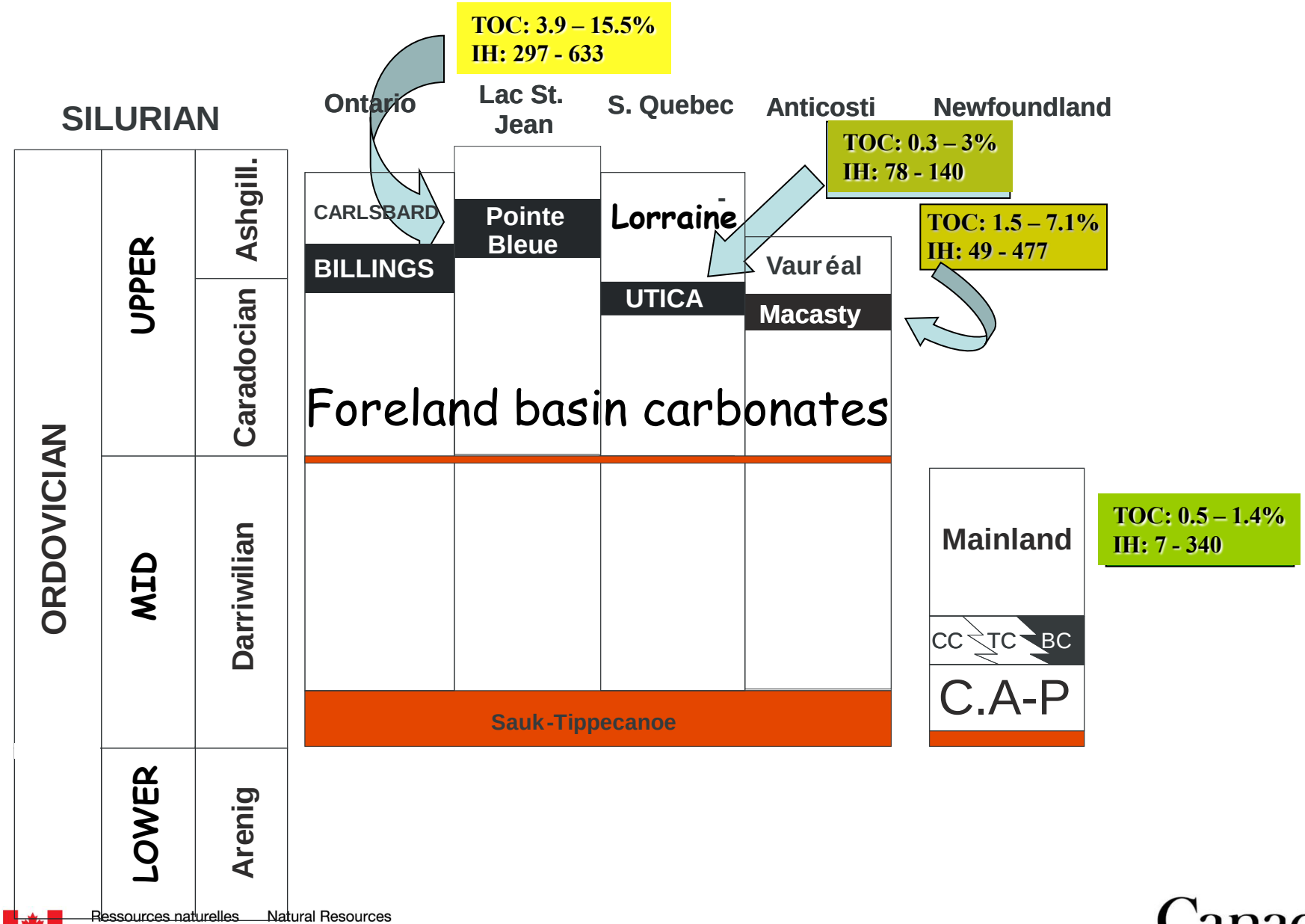




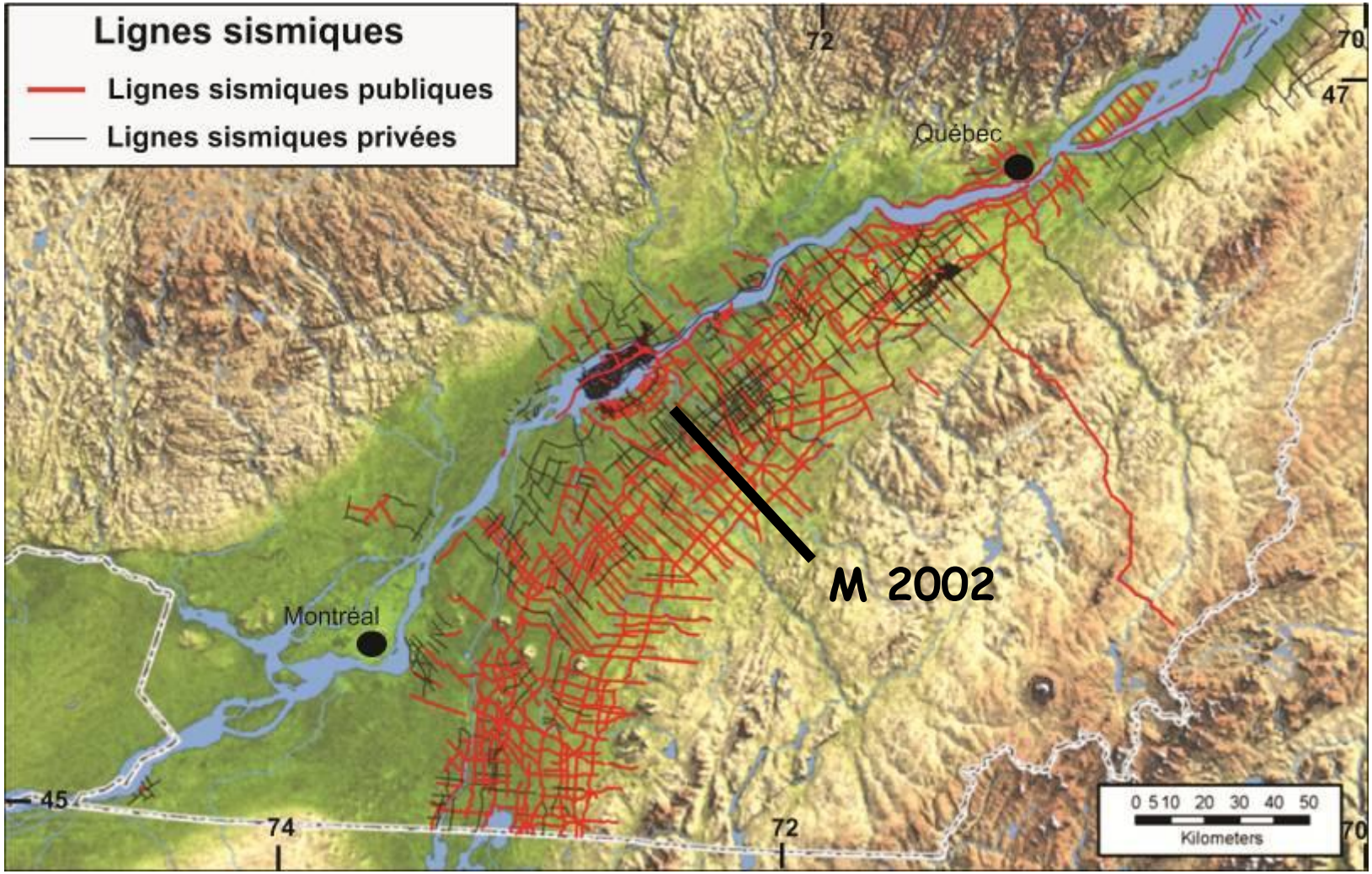
Ressources naturelles Canada
Natural Resources Canada

Canada

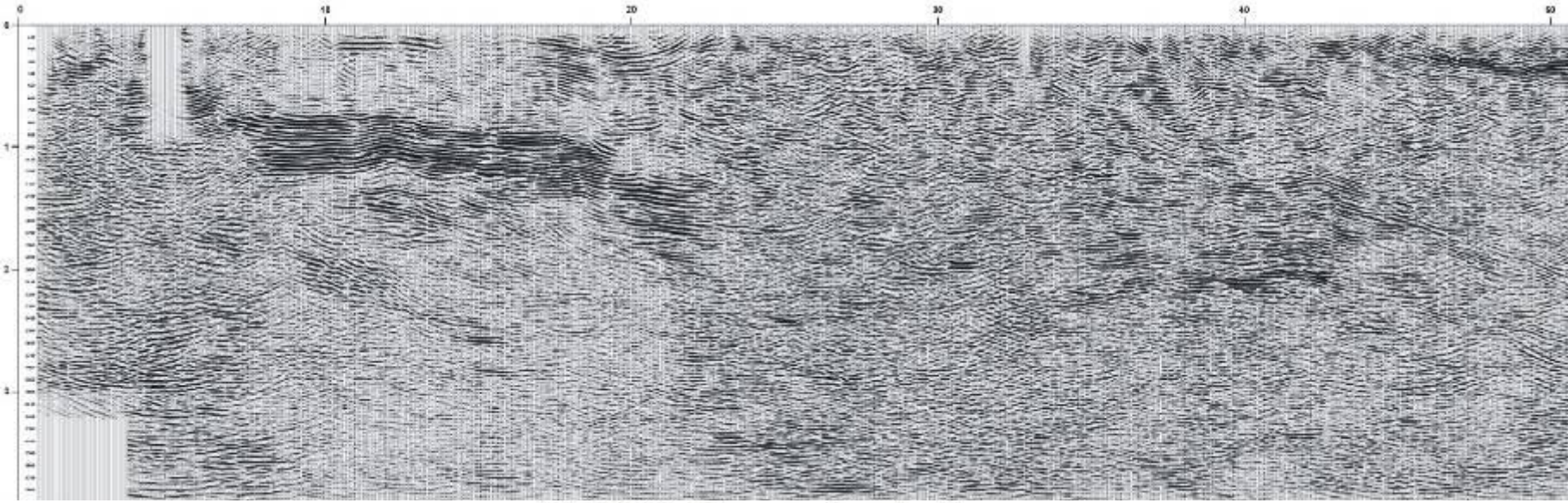
Ordovician black shales in eastern Canada

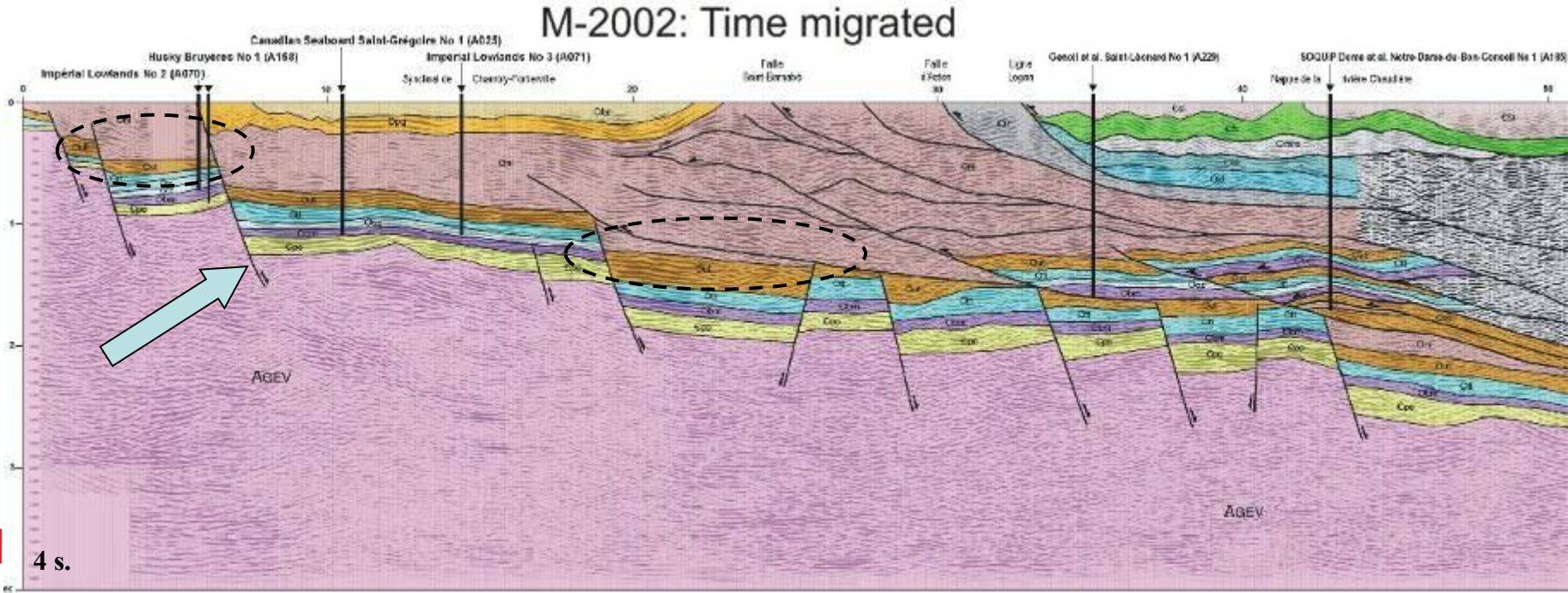


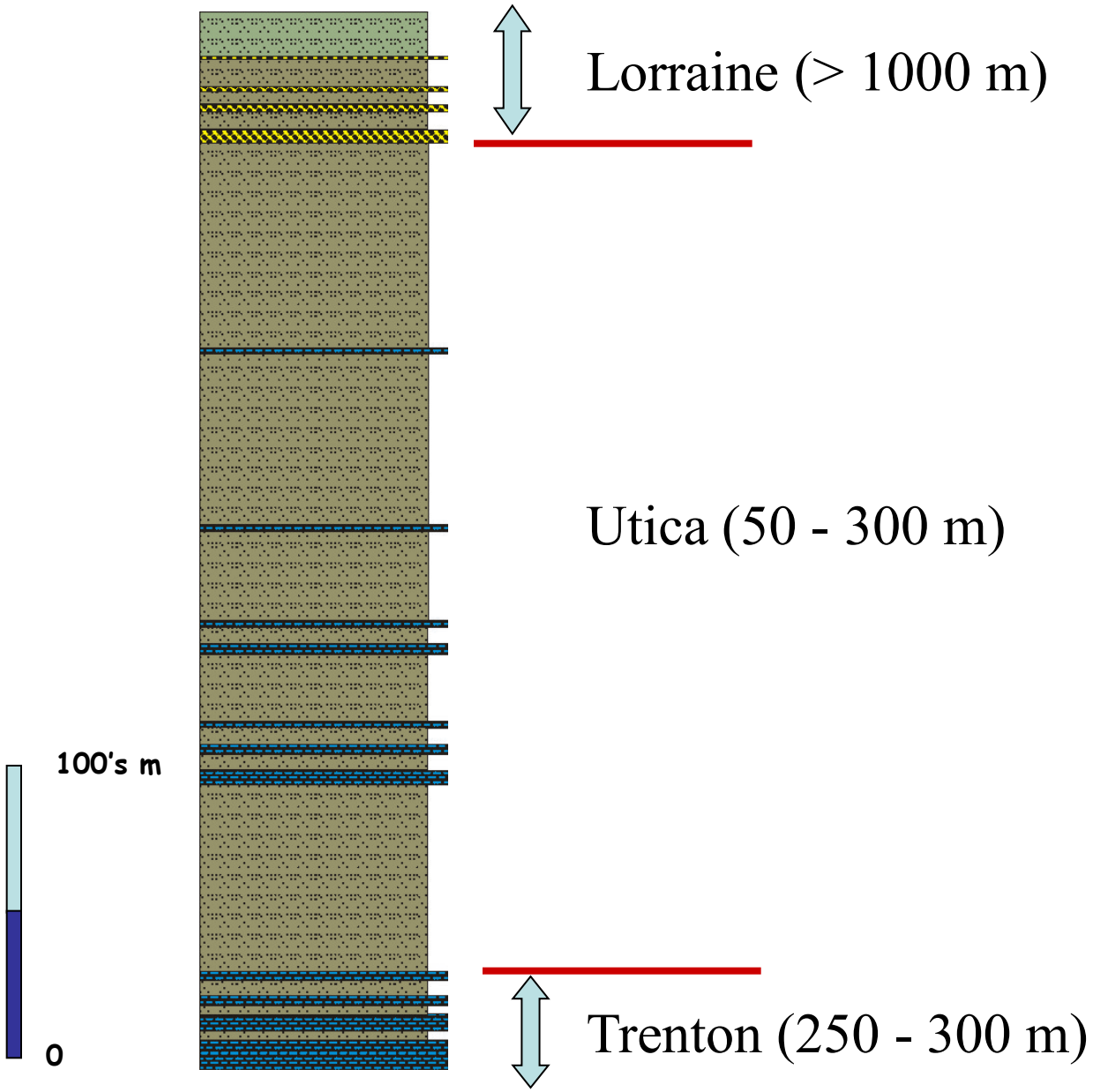
Seismic reflection and subsurface understanding



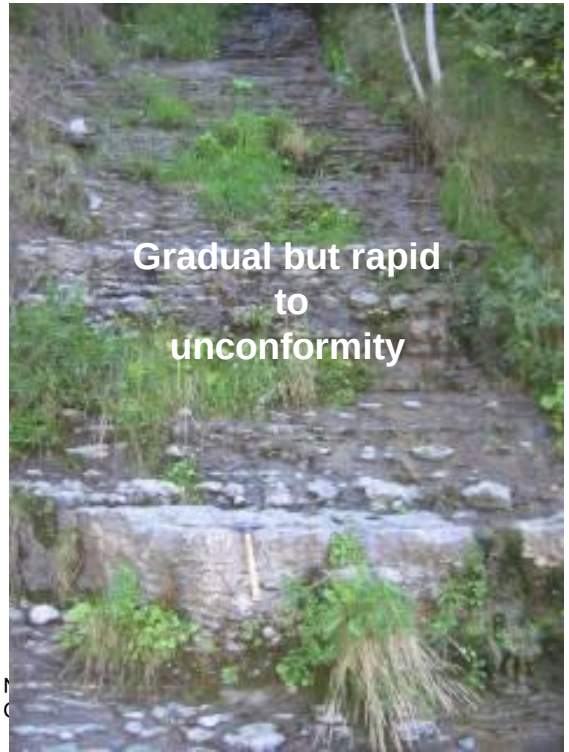
Seismic reflection and subsurface understanding

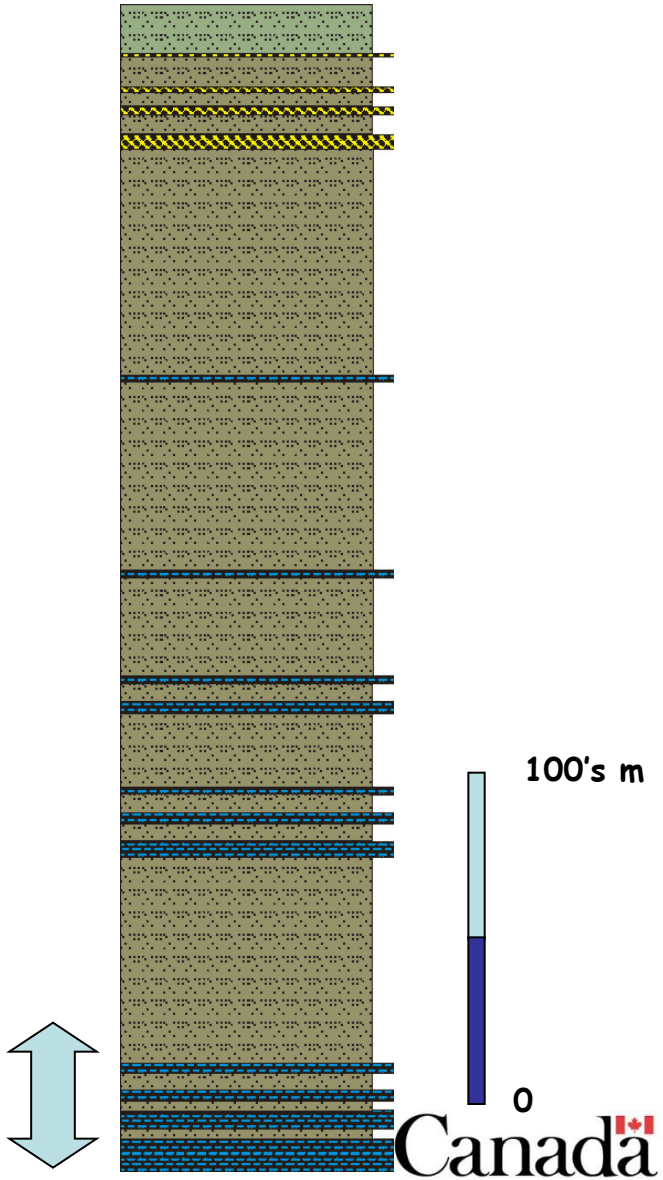




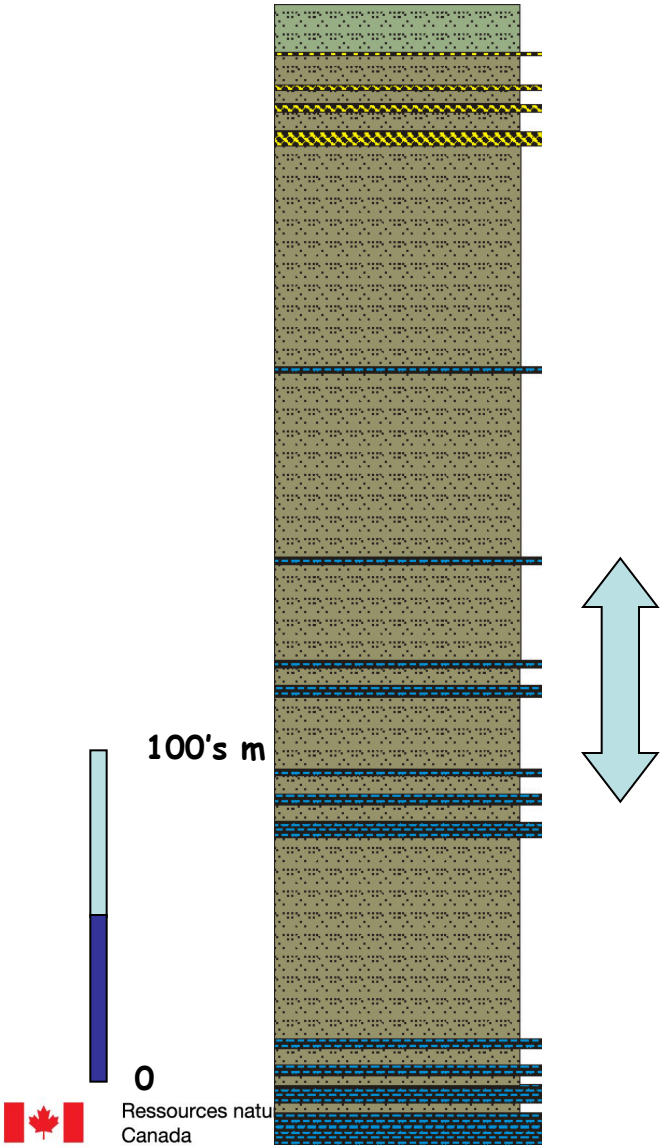

Lorraine (> 1000 m)
Utica (50 - 300 m)
Trenton (250 - 300 m)
100's m
0

The Trenton – Utica transition





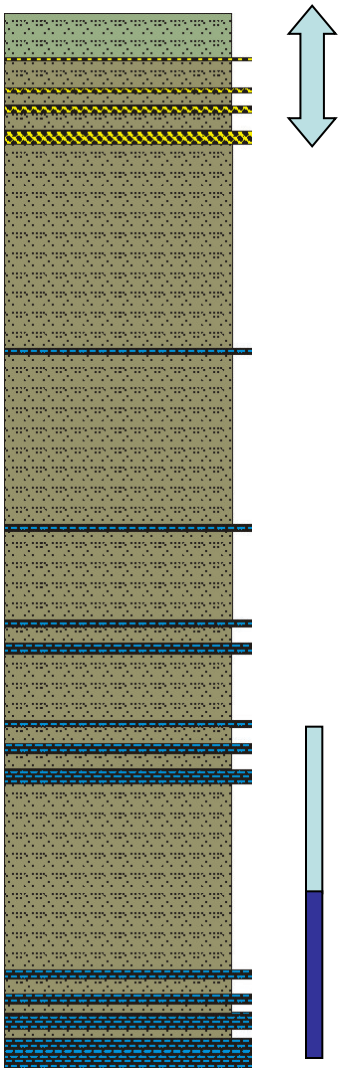
The Utica


100's m
0
Ressources natu
Canada


Burrows
Ostracodes, cephalopods,
Trilobites, Chitinozoans,
Little to NO pyrite

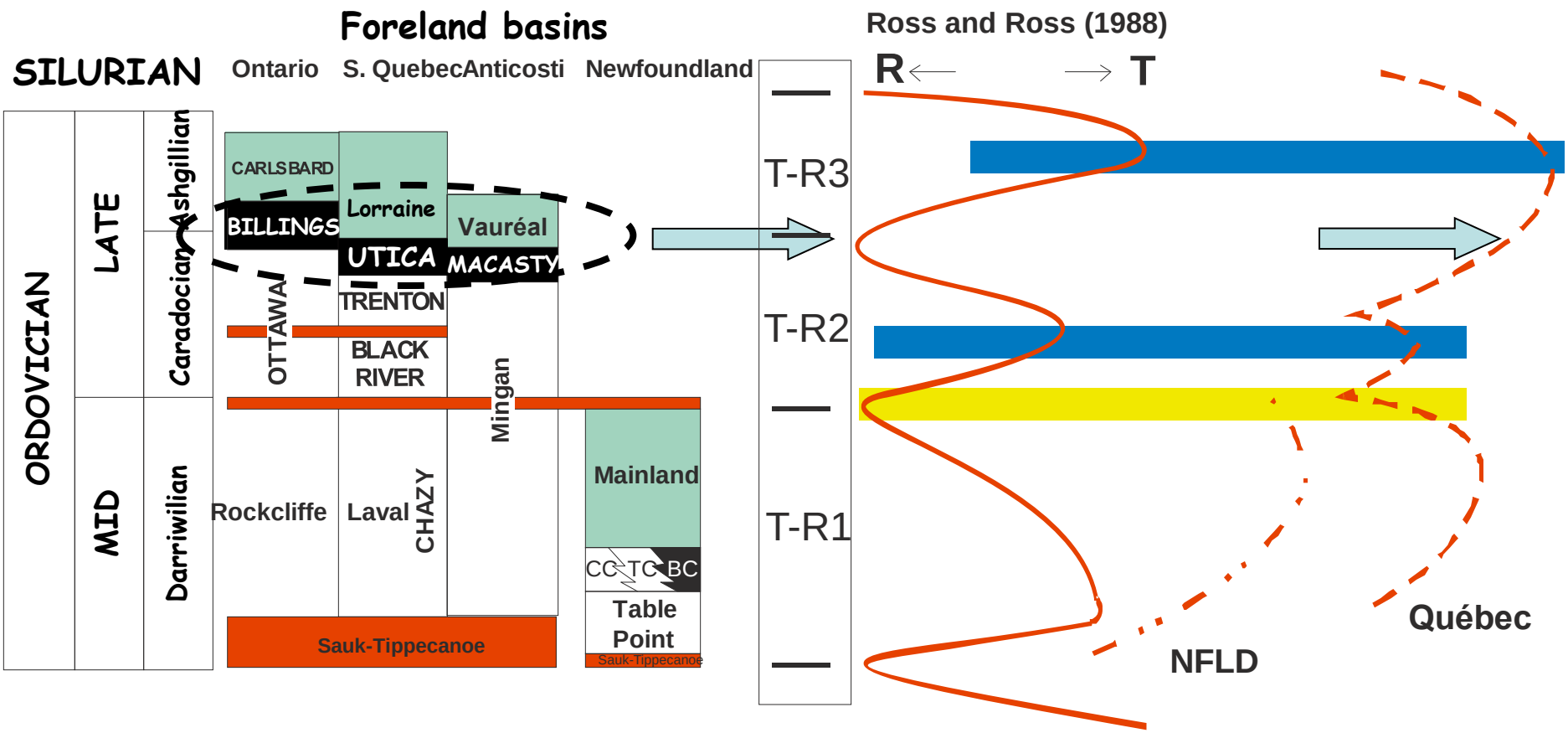

Cyclic micrite beds

The Utica-Lorraine flysch transition

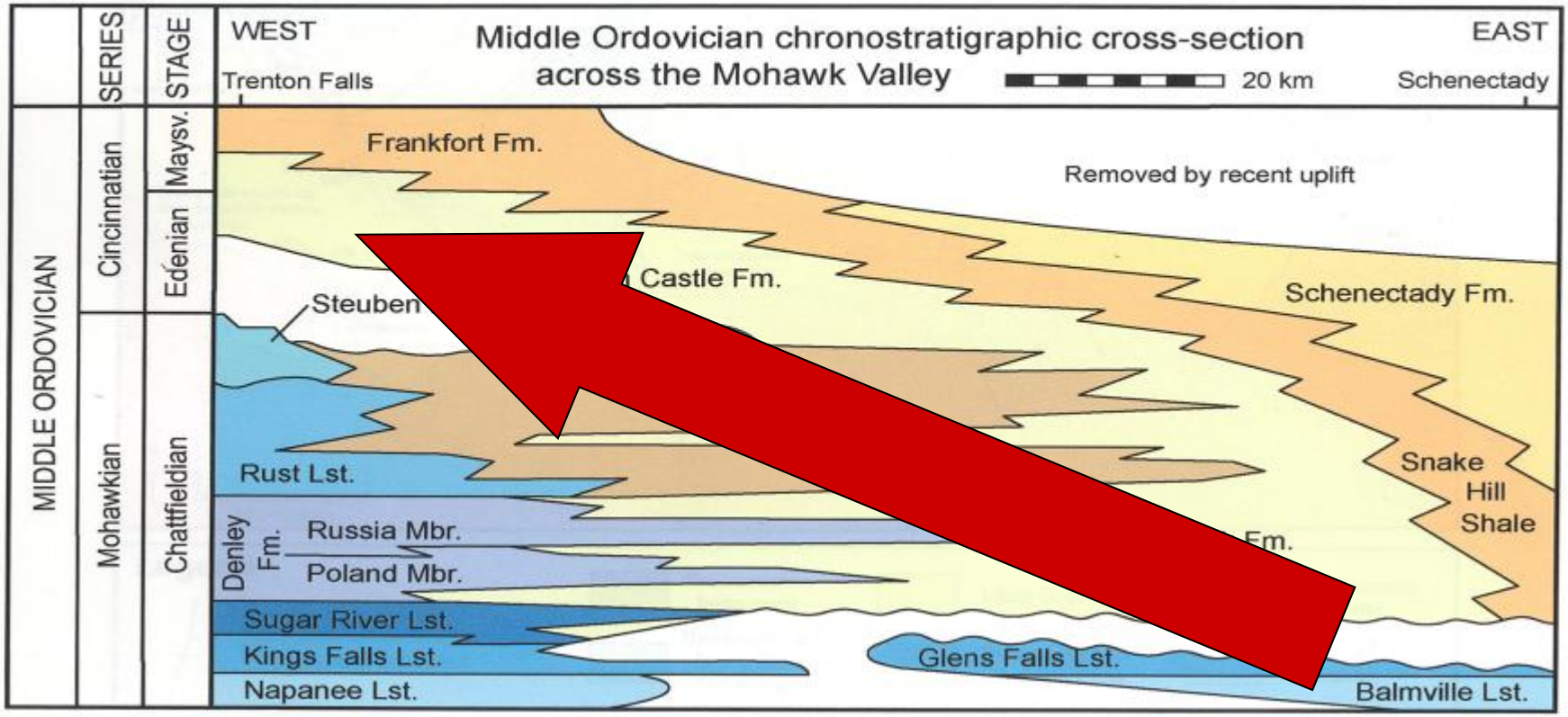


Ressources naturelles Canada
Natural Resources Canada

A major tectonic control

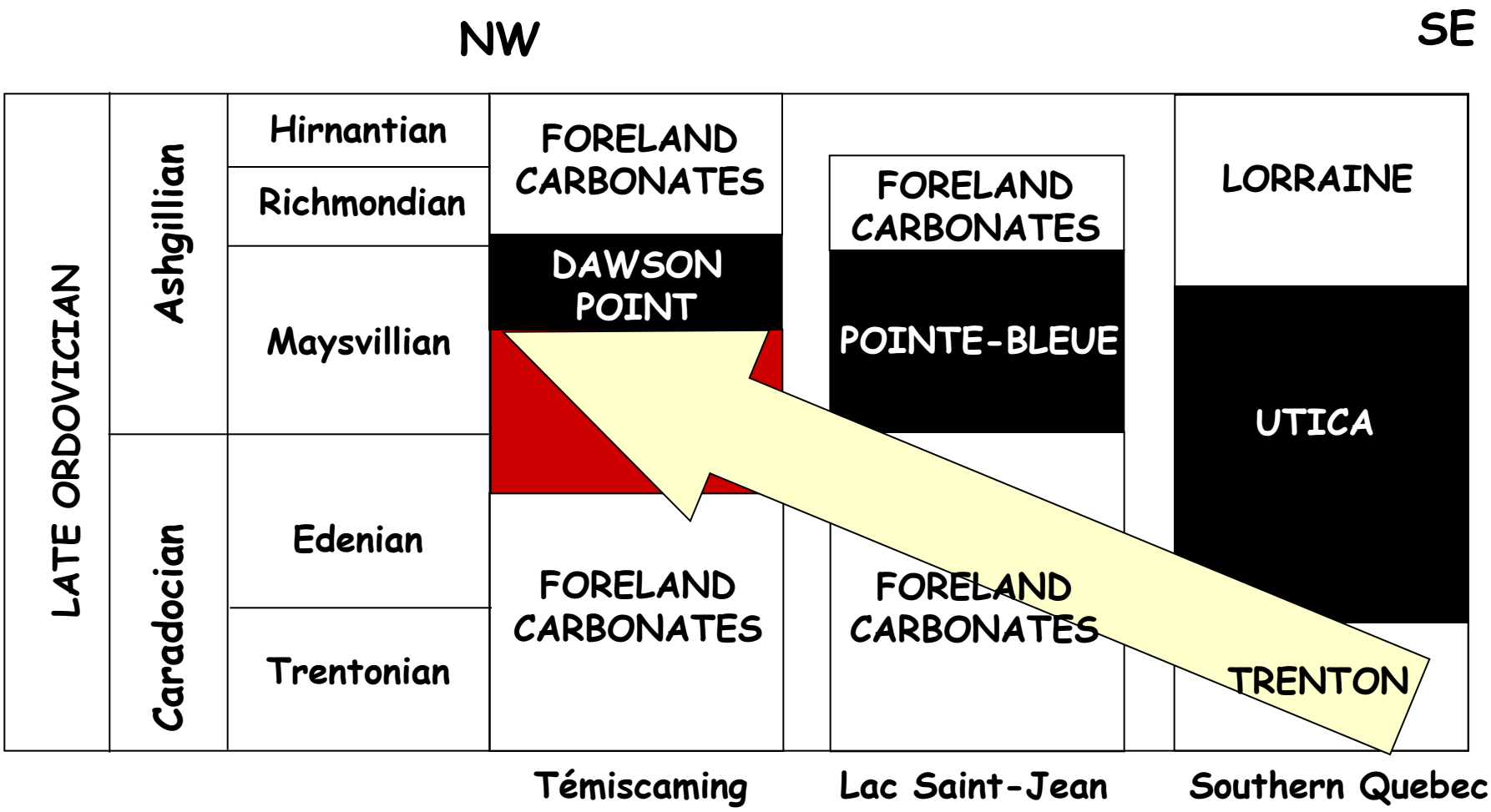


Stratigraphic framework – Trenton / Utica New York

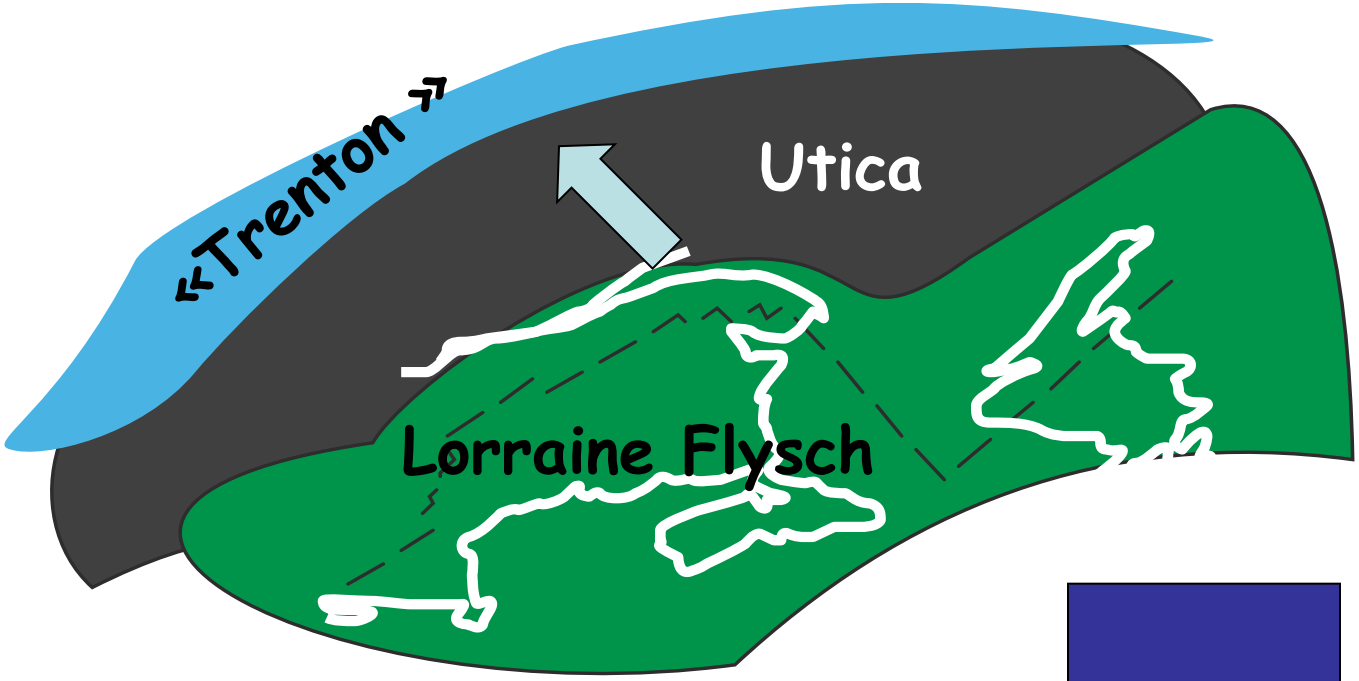


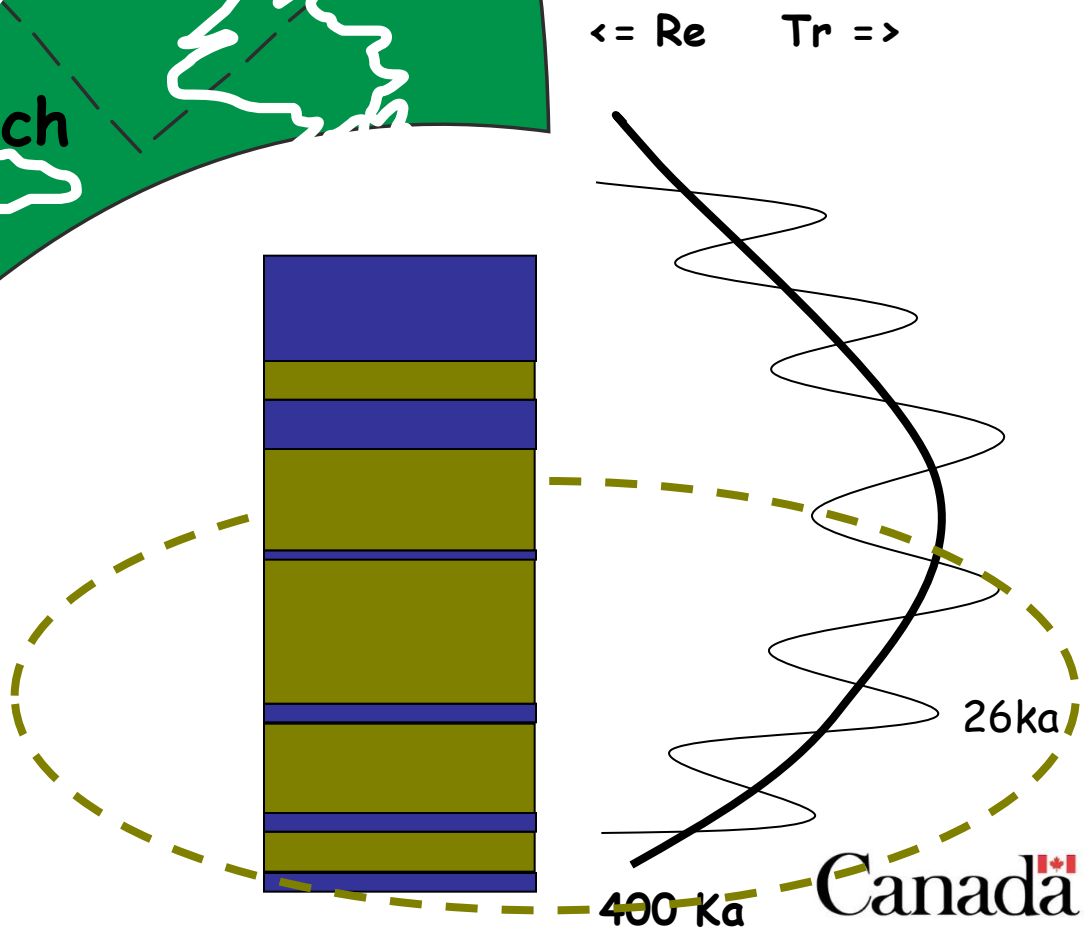
Thanks John Martin

Stratigraphic framework Late Ordovician
Limestones vs clastics

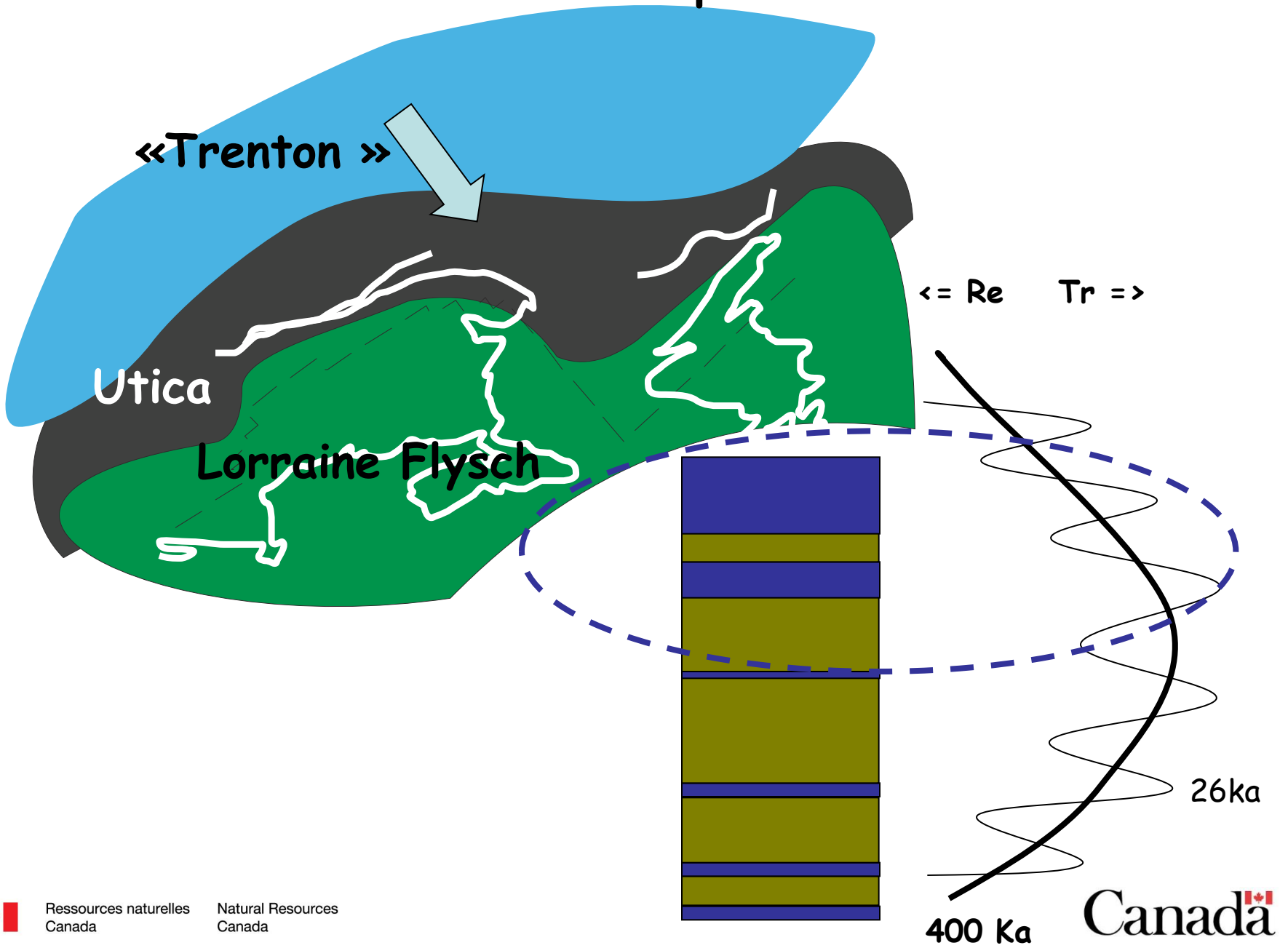


Shallow platform collapse – carbonates trapped to the north





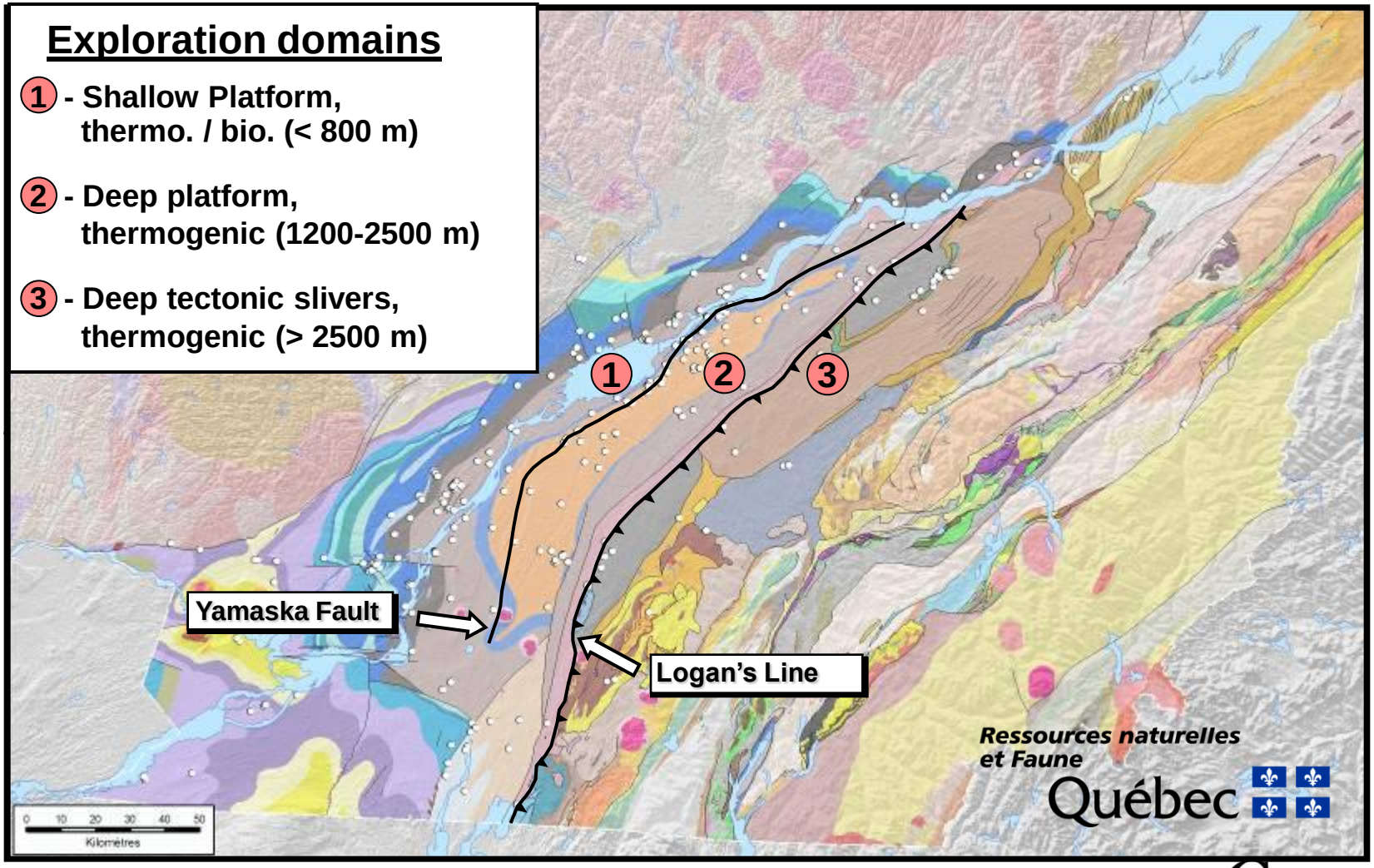
A Late Ordovician carbonate platform on the craton



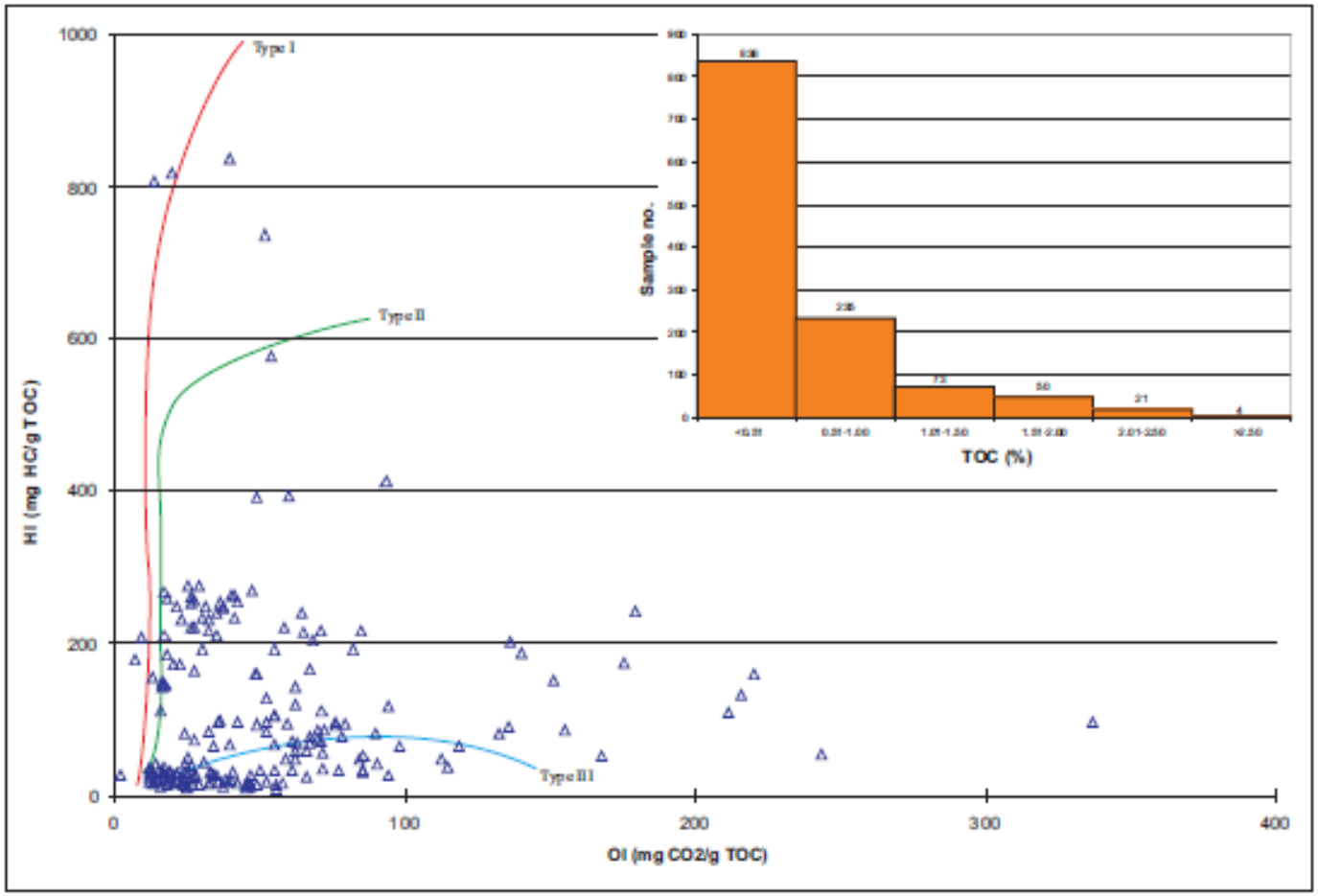
Thermal maturation and organic geochemisty

Available public domain data

THE CURRENT STATUS OF PUBLIC DOMAIN DATA

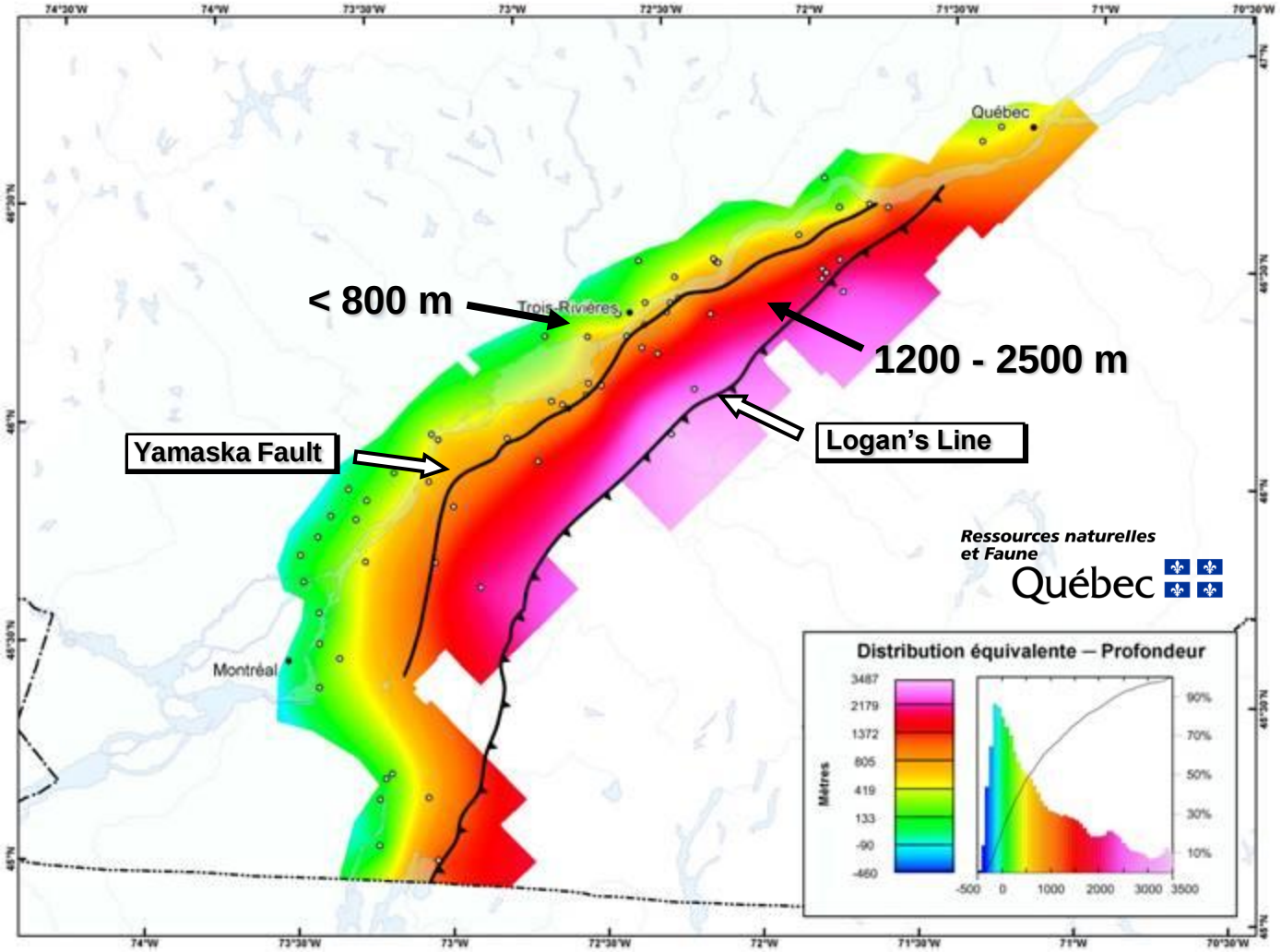


Utica – Lorraine well data

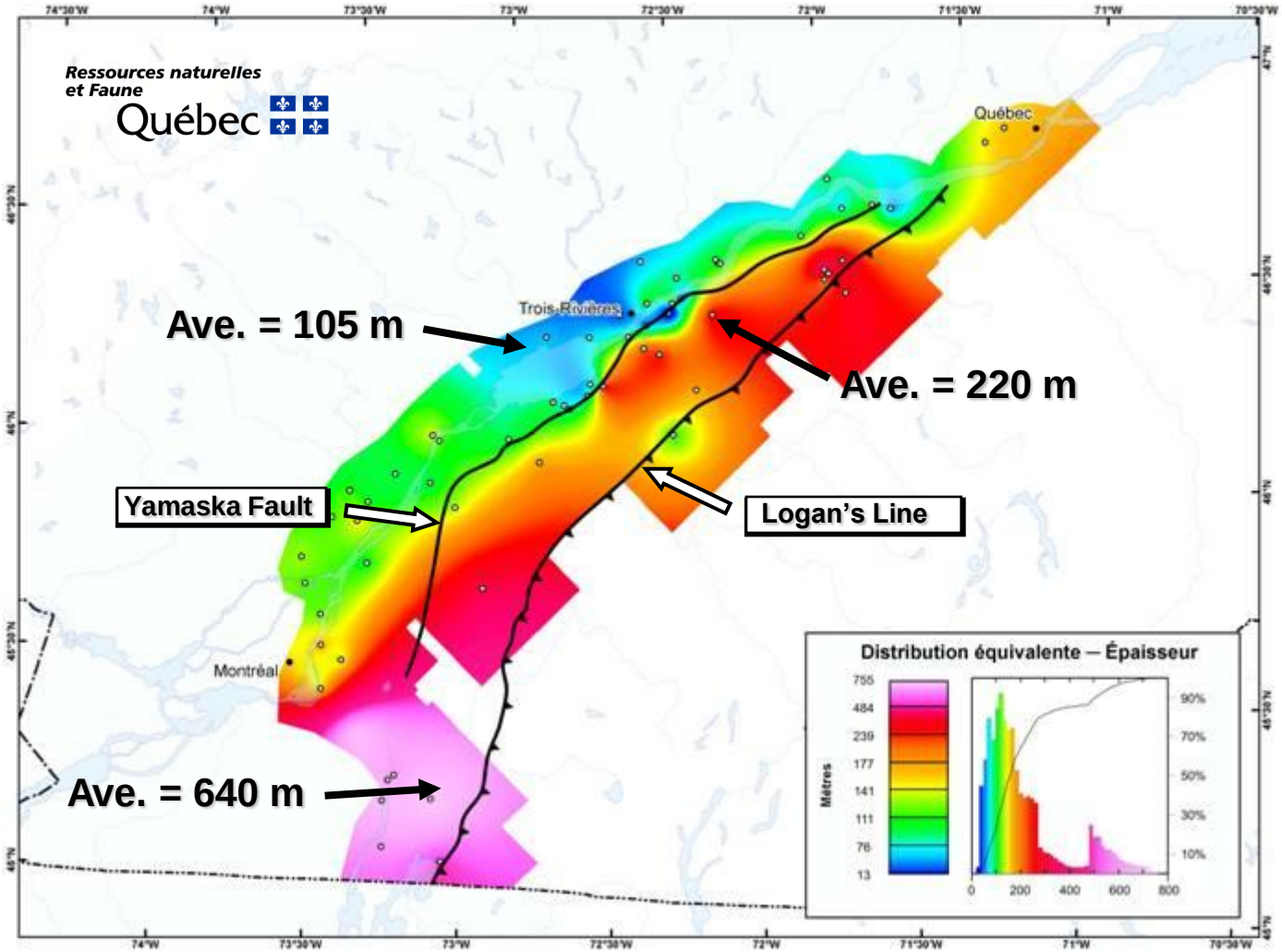


Lavoie et al (2010; GSC Open File 6050)

Depth to the top of the Utica Shale

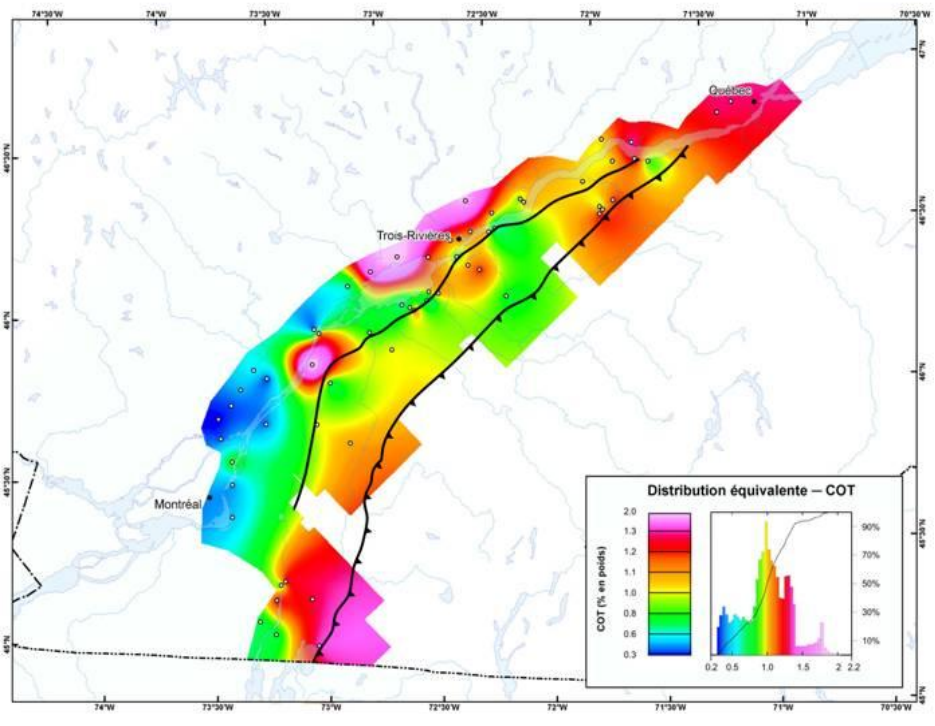


Thickness of the Utica Shale

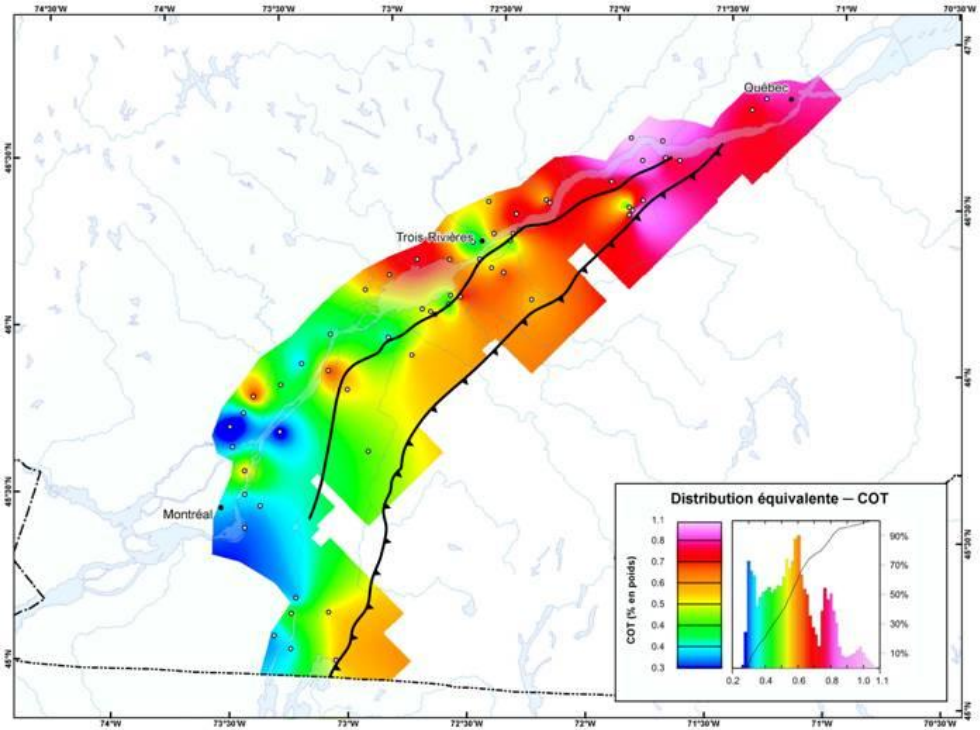


TOTAL ORGANIC CARBON (TOC)

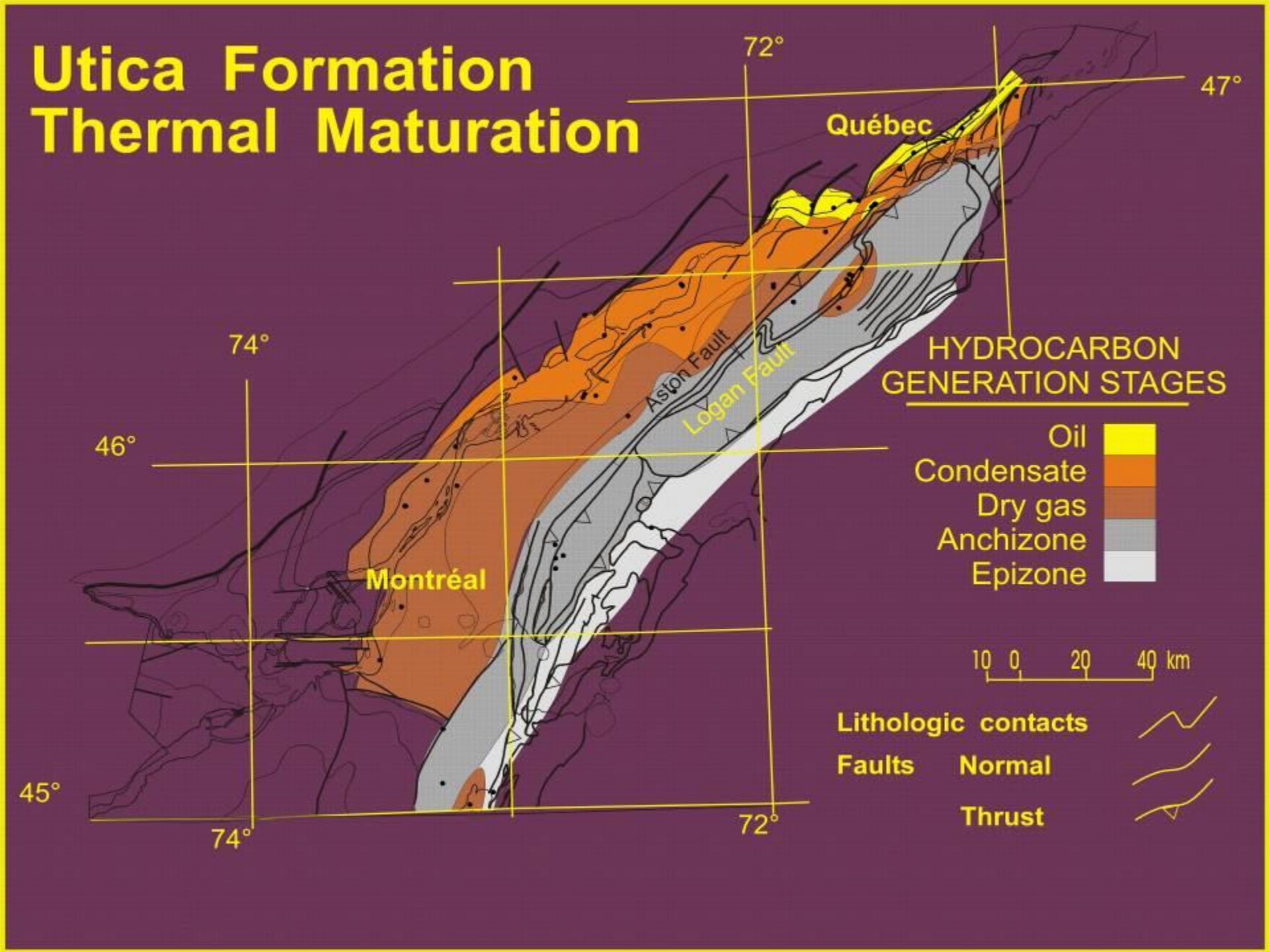
Upper Utica



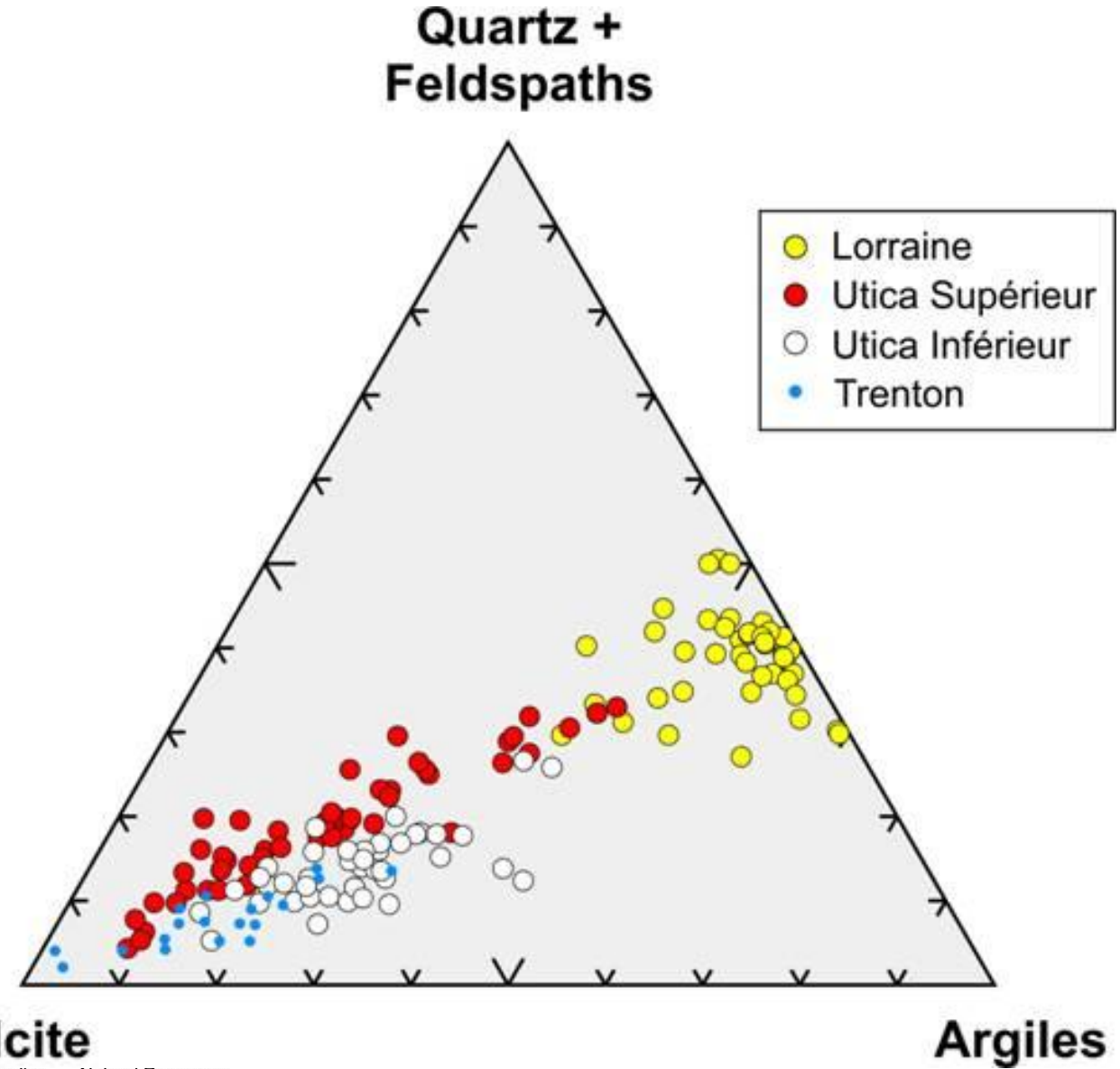
Lower Utica



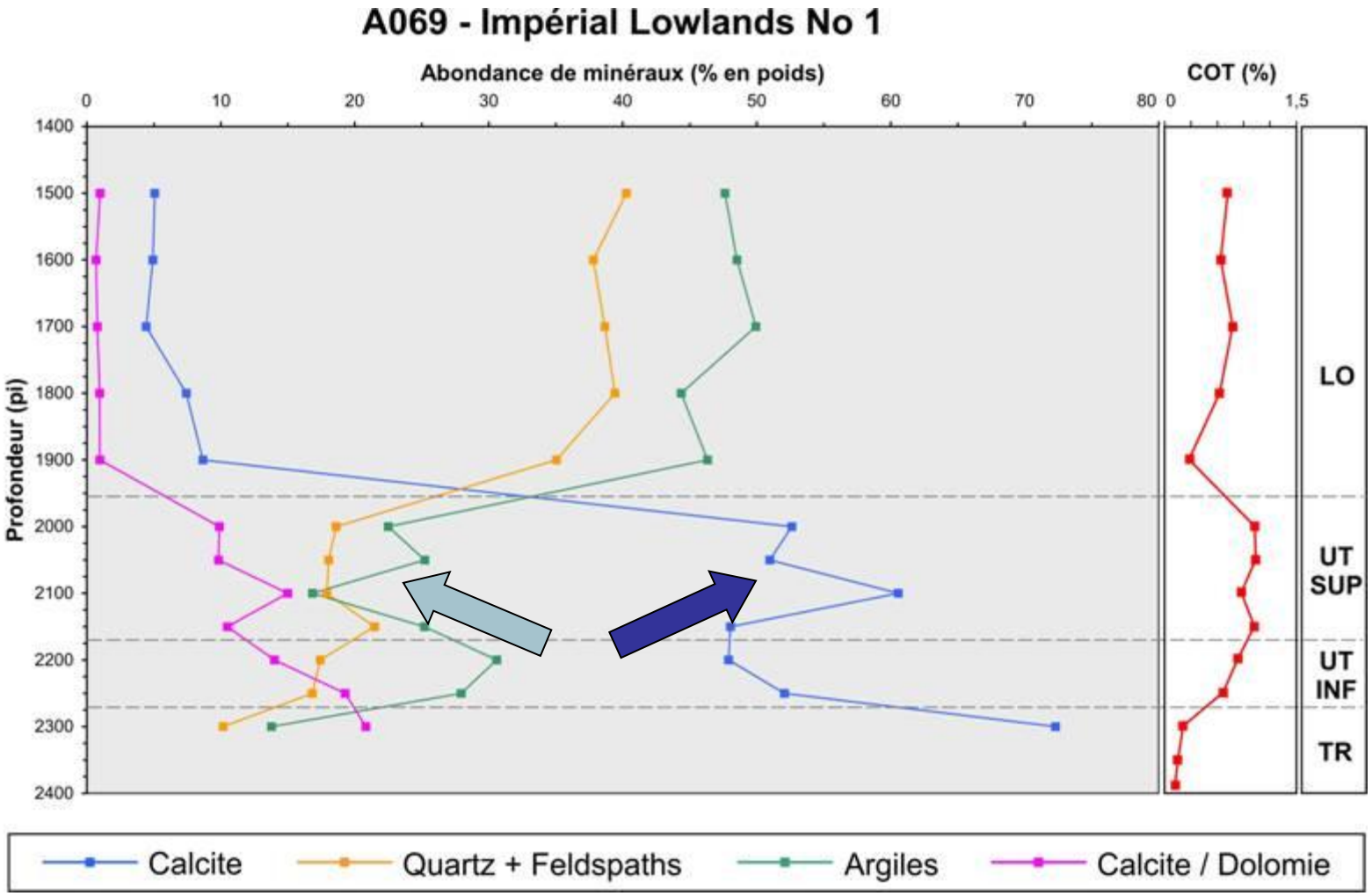
Utica Formation
Thermal Maturation



Mineralogy – X-Ray Diffraction

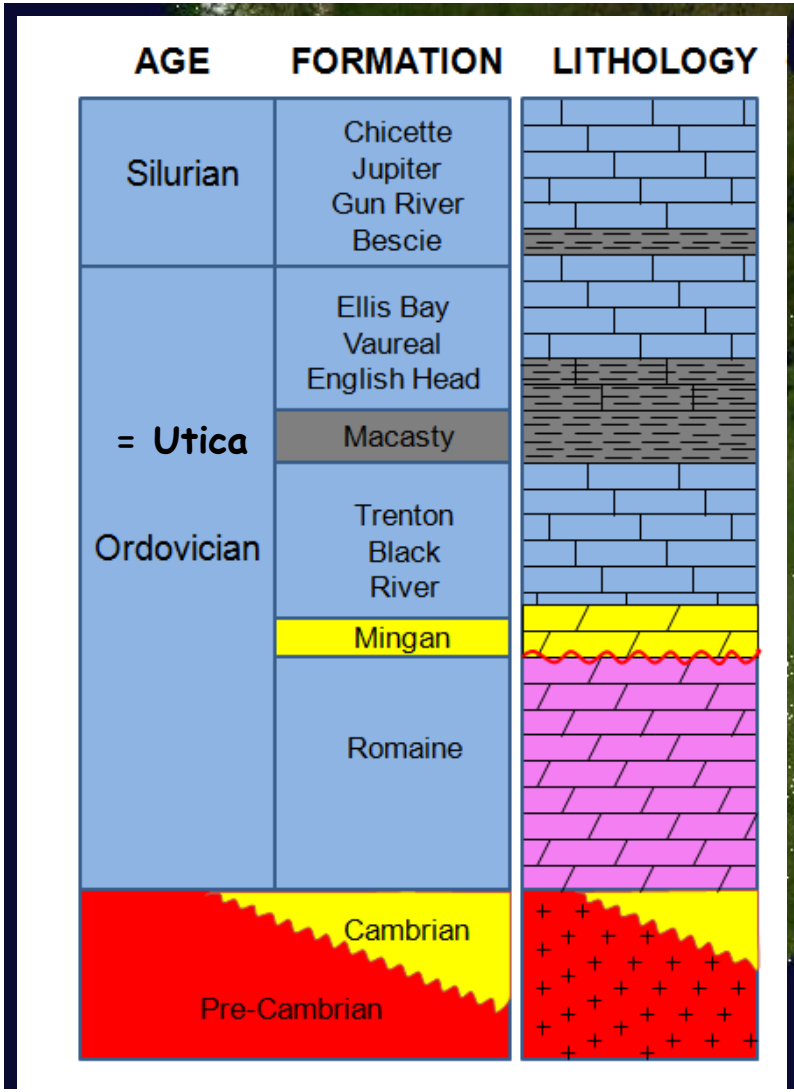


Mineralogy – X-Ray Diffraction

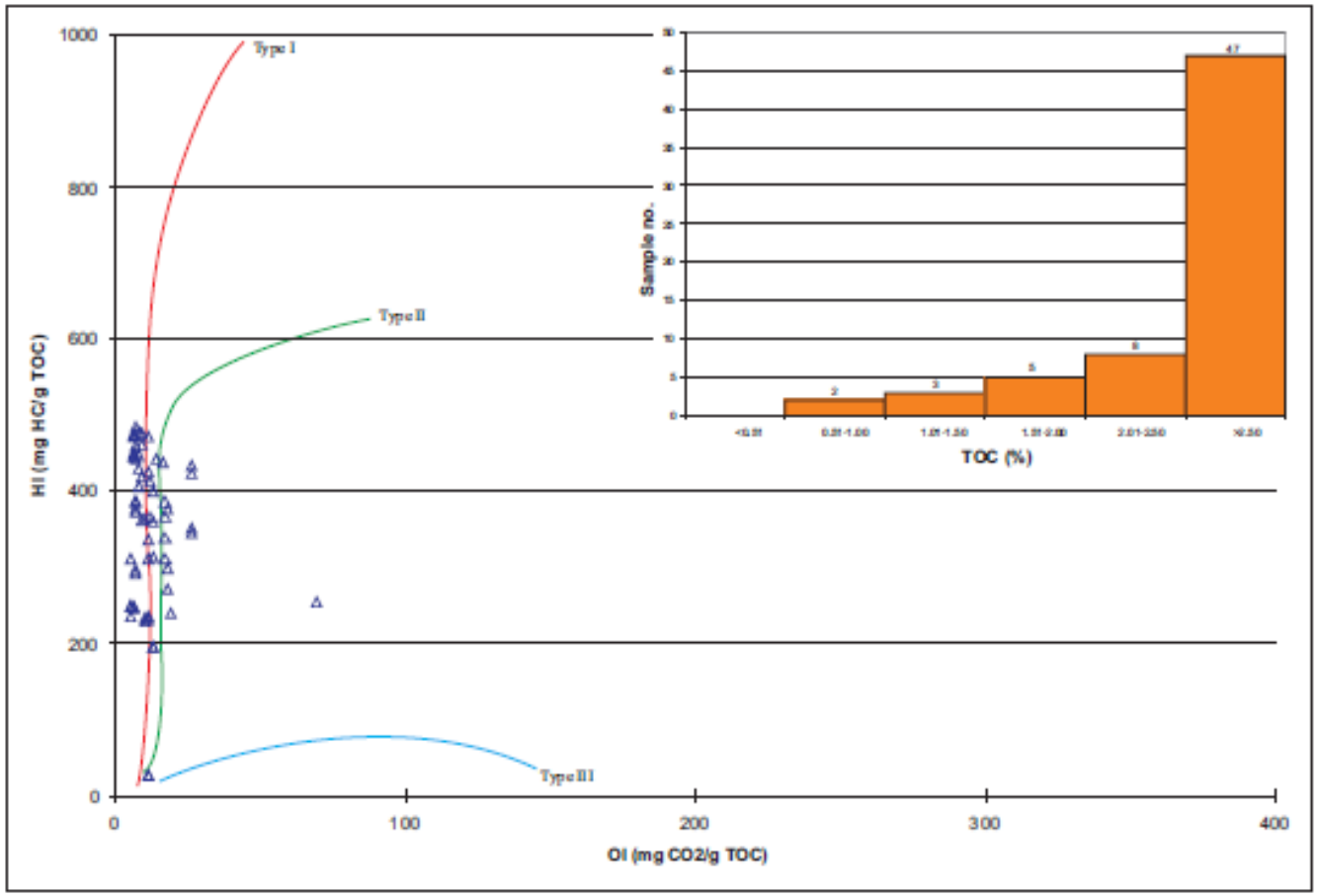


P50 estimate: 120 – 140 TCF OGIP

A new potential target
Shale oil in Upper Ordovician shales on Anticosti Island

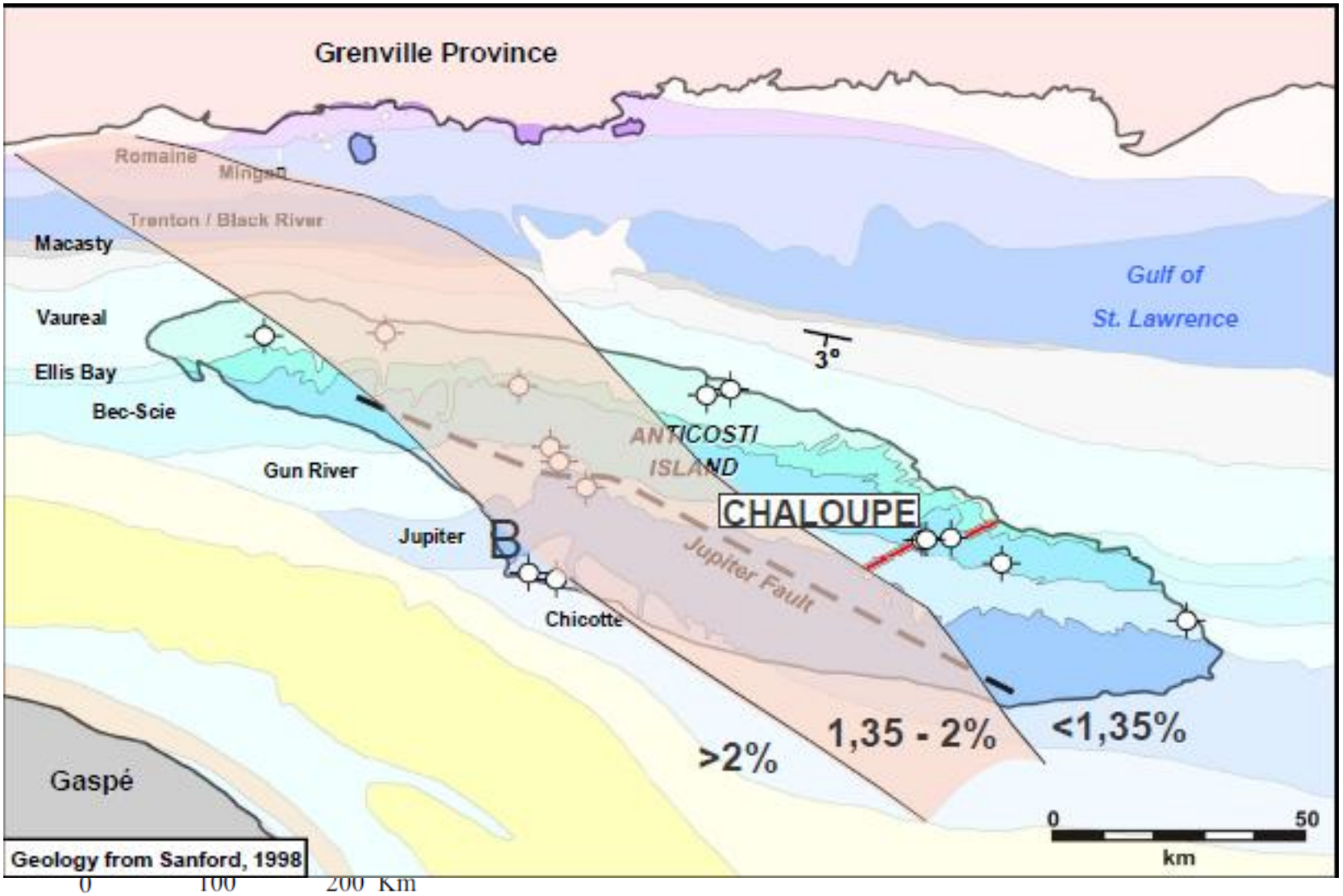


Macasty (Anticosti)



Lavoie et al (2010; GSC Open File 6050)

Geological and thermal settings



Lavoie et al (2009, *GSC Open File 6174*)

Macasty technical data

Low clay, high quartz and carbonate

TOC 2.4-5.7% average 4.3%

Type II kerogen within the oil window

Porosity 2.4-5.1% average 3.6%

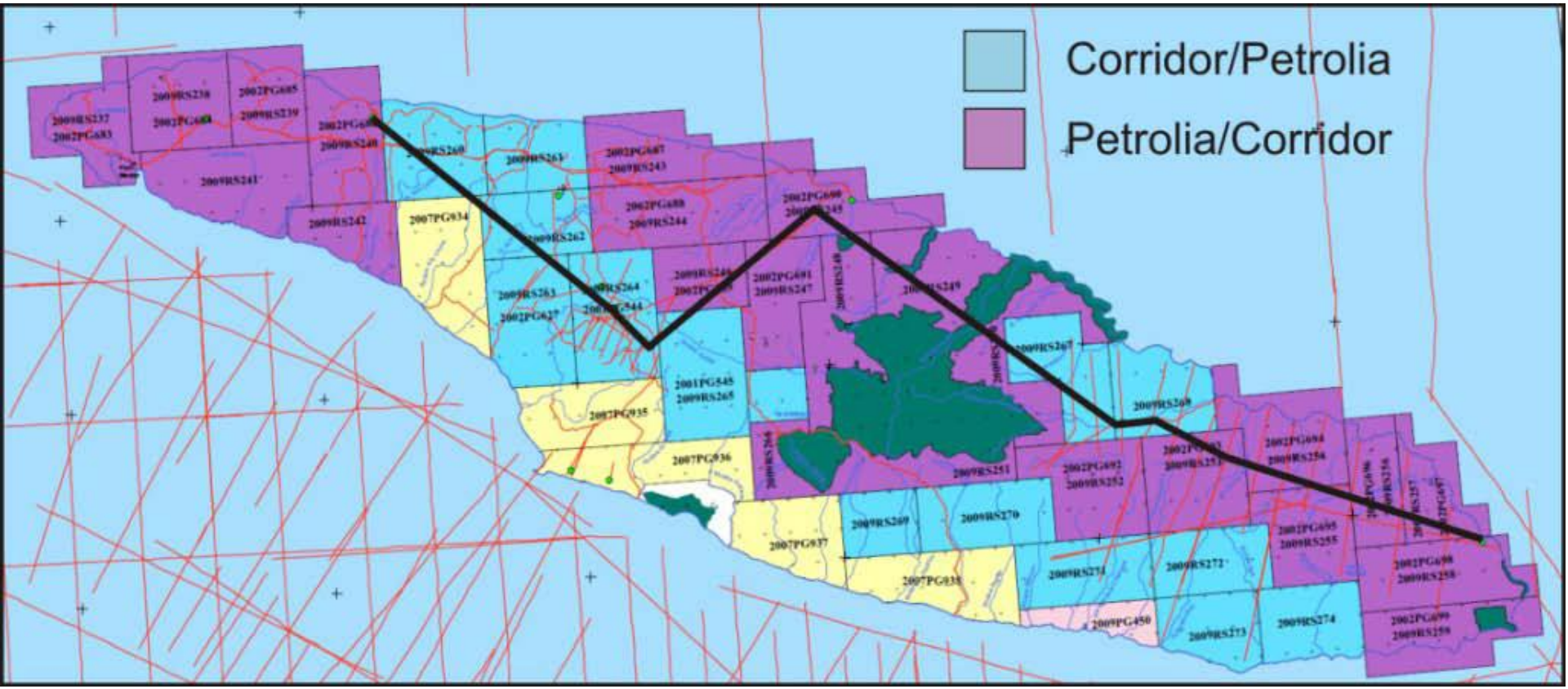
Permeability: 200 to 740 nD average 480 nD

High oil saturation 27%; 35° API gravity

From Corridor Resources, 2011

A new potential target
Shale oil in Upper Ordovician shales on Anticosti Island

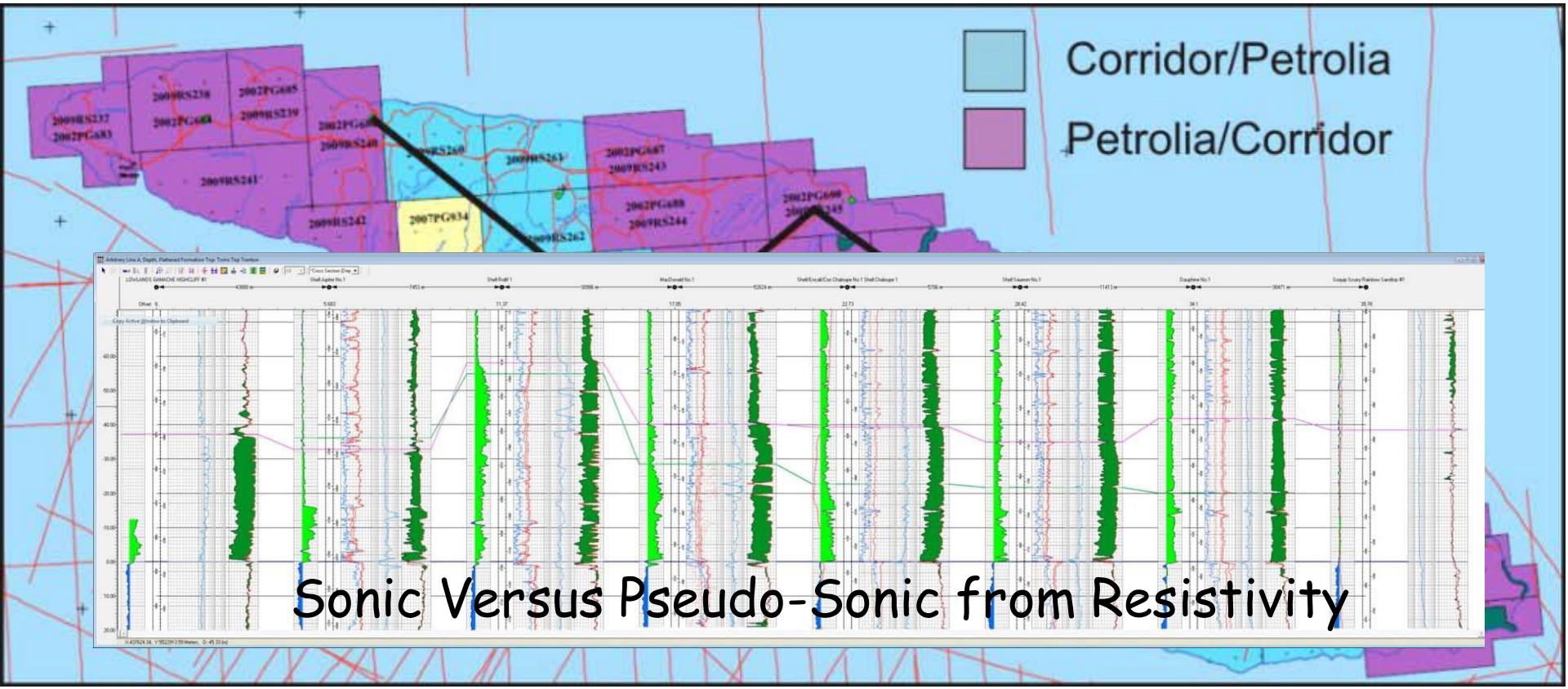
P50 estimate of OIIP: 45 BBO



From Corridor Resources, 2011

A new potential target
Shale oil in Upper Ordovician shales on Anticosti Island

P50 estimate of OIIP: 45 BBO



From Corridor Resources, 2011

Conclusions

1. The Upper Ordovician black shales in Quebec consist of the Utica and Macasty calcareous shales.

2. The Utica Shale has been successfully fracked in southern Quebec with the best IP of 12 MMcf/d.

3. OGIP estimates range between 120 to 140 Tcf (P50);

4. The Macasty has not been tested yet; preliminary technical data indicate that the calcareous shale is oil saturated and in the oil window.

5. Preliminary OOIP estimate is 45 BBO (P50).

Thank you !

Utica Shale along the Jacques Cartier River
30 km southwest of Quebec City