Utica Shale Petroleum Resource Potential in Quebec, Revised Methodology and Resource Update*

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Abstract

In eastern Canada, the Upper Ordovician Utica Shale has been, since the early days of hydrocarbon exploration in southern Quebec, considered as an excellent hydrocarbon source rock for conventional hydrocarbon systems. The paradigm shift towards its significance for unconventional resource play started in mid-2000 with initial drilling and testing of the Utica Shale with the best IP values of 11 MMcf/d and a stabilized rate after 30 days of 2 MMcf/d. Recent study suggests that Utica Shale is a hybrid resource play with characteristics of mixed reservoirs varying from tight siltstone to organic rich shale. Such a hybrid tight-shale resource play is commonly a closed petroleum system with the crude oil and natural gas originating from organic-rich shale and being stored within the stratigraphic intervals including the tight reservoirs. The matrix porosity may provide the principal storage for expelled petroleum, whereas additional petroleum remains within “organic” pores in the source rock. The matrix and organic pores have very different physical and chemical properties including, water/oil wettability, pore size distribution, and natural gas adsorption capacity. The geological controls of these two porous media types vary significantly and have important implications in resource evaluation. To address the problem of mixed porous media, a dual-porosity model with revised organic porosity estimation is under development and has been applied to the Utica Shale in southern Quebec to evaluate the oil and gas resource potential. This presentation describes the method and recent enhancements and their impact on the resource potential estimation for the Utica Shale in southern Quebec. The new expected in-place resources include 164 TCF of natural gas and 1.8 billion barrels of oil.

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Outline

- Background
  - Unconventional reservoirs
- Methods
  - Dual-porosity system model
  - Workflow
- Resource assessment update
- Summary

Methodology development

- A reservoir volumetric approach with a dual-porosity model for in-place resource estimation
- Well performance-based methods for recoverable resource estimation
  - a productivity-based approach for estimating recoverable resource
  - simulated production curves based on reservoir characteristics if no production data are available
- A cross validation and updating volumetric estimates using available production data or simulation

Reservoir types for “shale” hosted petroleum accumulations

Duvernay
Horn River

Bakken

Utica

Conventional → Tight Reservoirs → Hybrid Reservoirs → Shale or Coalbed Methane Reservoirs

The term “shale” here covers mudstones, siltstones and even very fine grained sandstones, and both of siliceous or carbonate-rich compositions.

Unconventional “shale” reservoirs typically vary from tight sandstone or carbonate to organic rich-mudstone with composition and texture that control reservoir and its mechanical properties.

Two end members are the tight sandstone and organic rich mudstone. Hybrid reservoirs have transition characteristics between the two end members

(Diagram modified from CSUR, 2012)

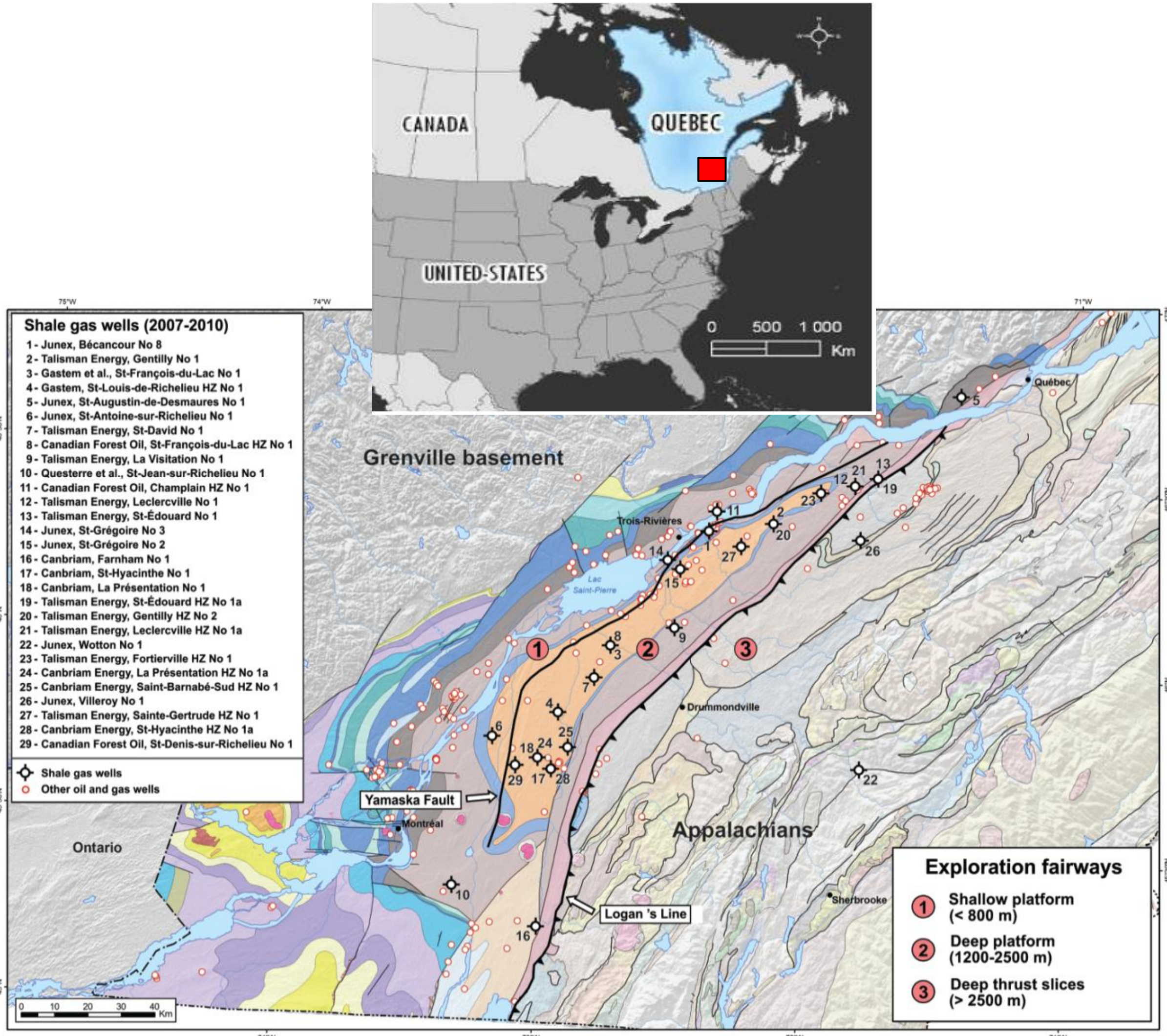
Hybrid tight-shale resource play

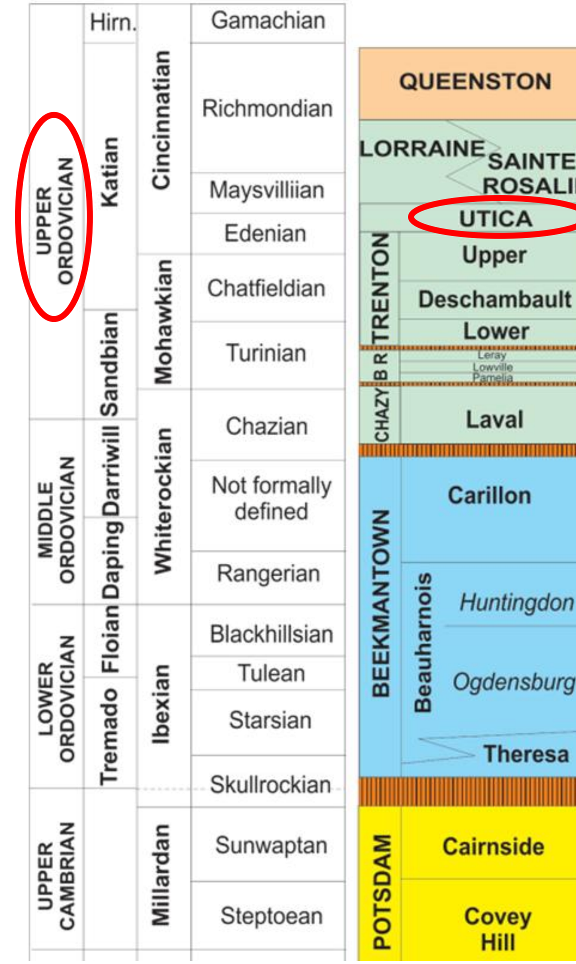
- Commonly a closed petroleum system with the crude oil and natural gas originating from organic-rich shale and being stored within the stratigraphic intervals including the tight reservoirs.
- Matrix porosity may provide the principal storage for expelled petroleum, whereas additional petroleum remains within “organic” pores in the source rock.

Upper Ordovician Utica Shale

- Considered as an excellent hydrocarbon source rock for conventional hydrocarbon systems since the early days of exploration
- Initial drilling and testing for unconventional resource started in 2006
- Recent study suggests that Utica Shale is a hybrid resource play with characteristics of mixed reservoirs varying from tight siltstone to organic rich shale

Geological Setting Utica Shale



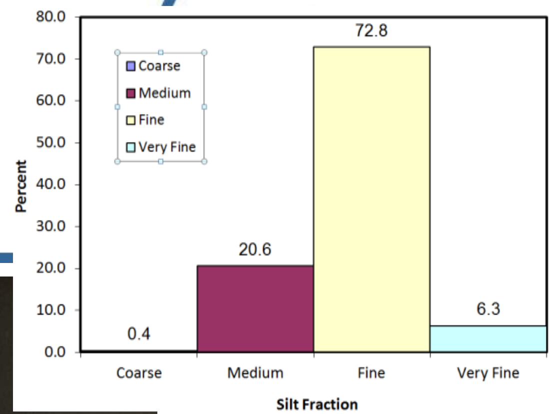


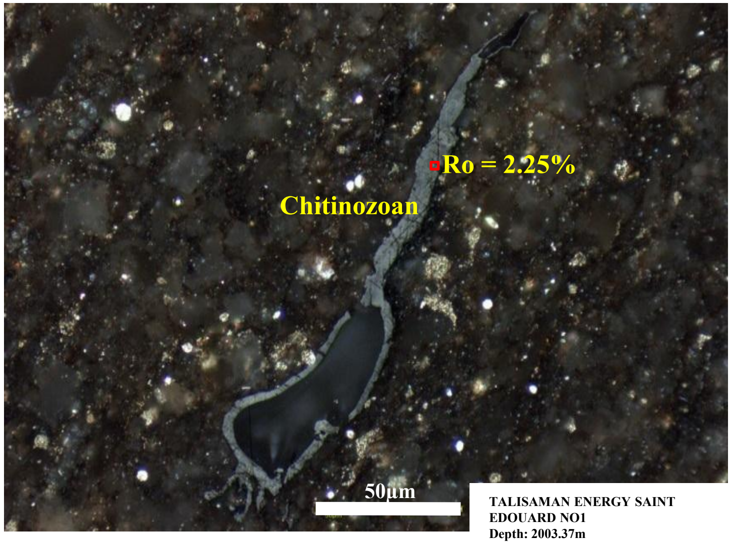
Lavoie et al. (2014 IJCG)

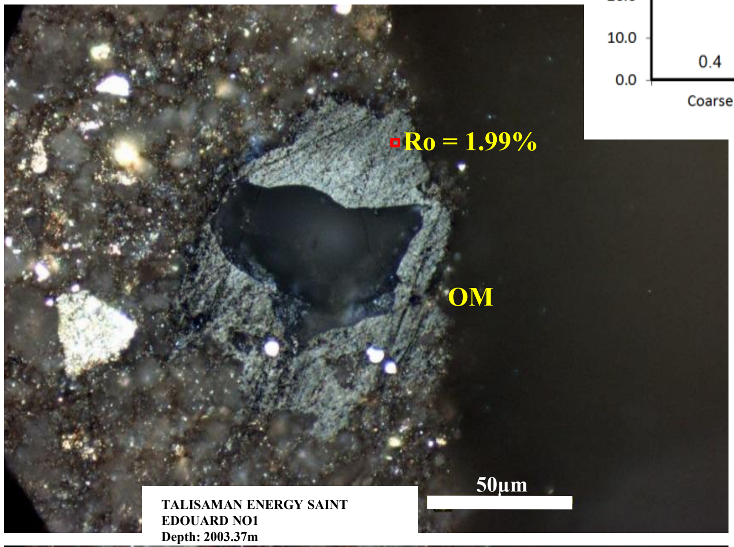
Utica Shale in Quebec

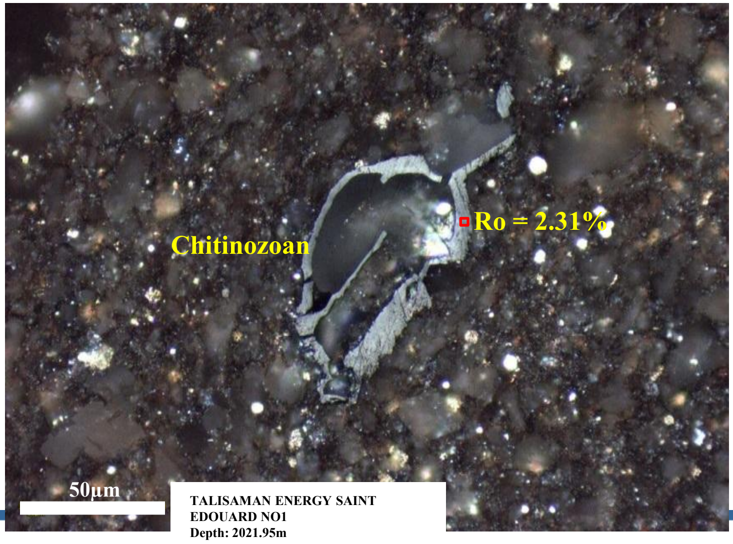
Left: Utica core from the Talisman #1 St. Edouard well. Right: Utica Shale outcrop showing grey to dark grey calcareous shale layers with limestone interbeds.

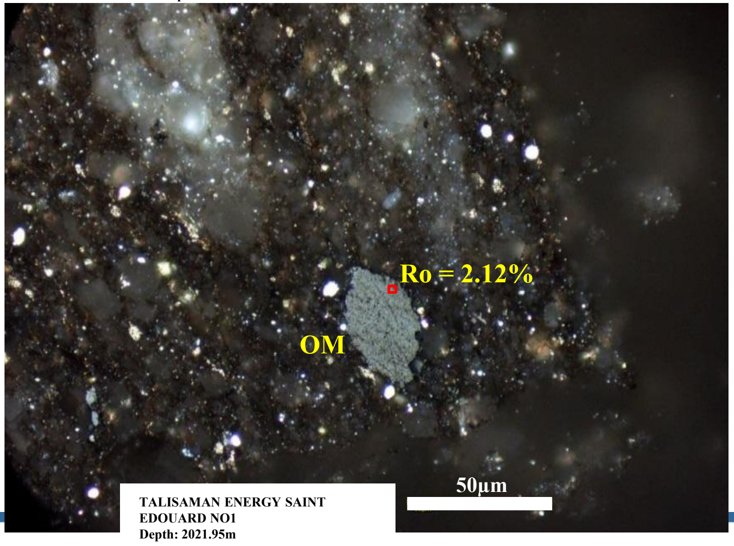
Petrography of the Utica Shale: (organic matter and matrix)





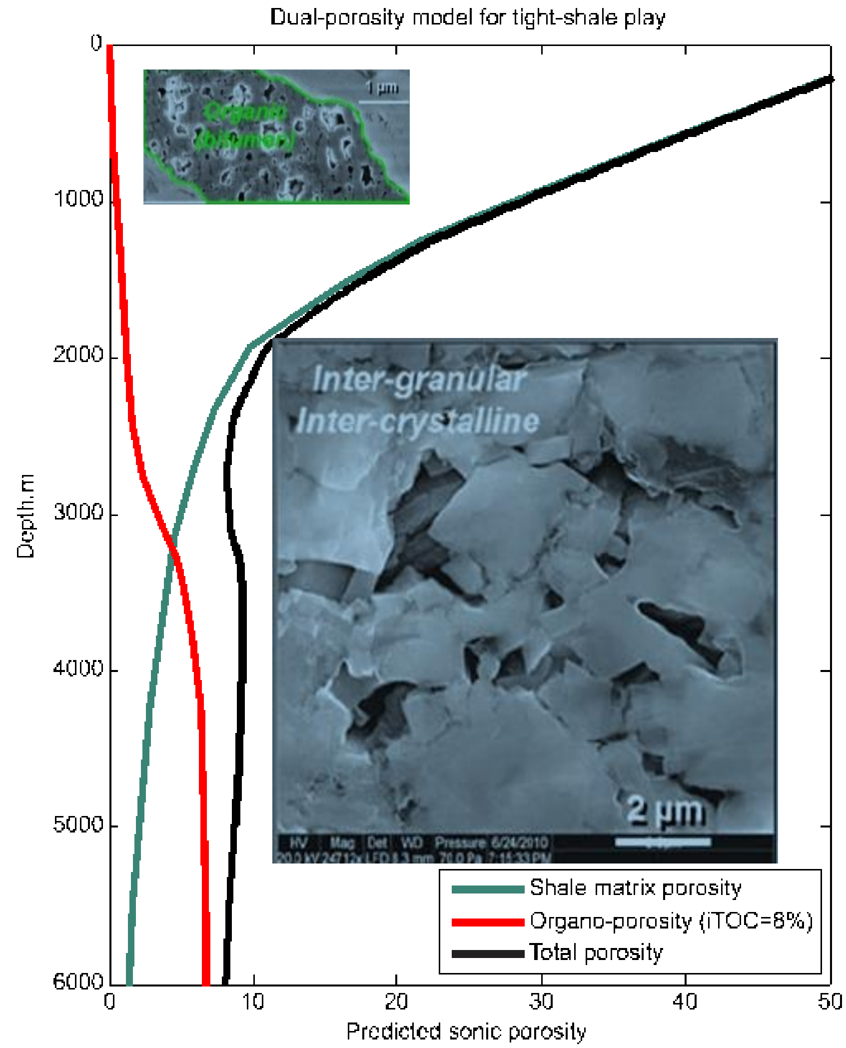




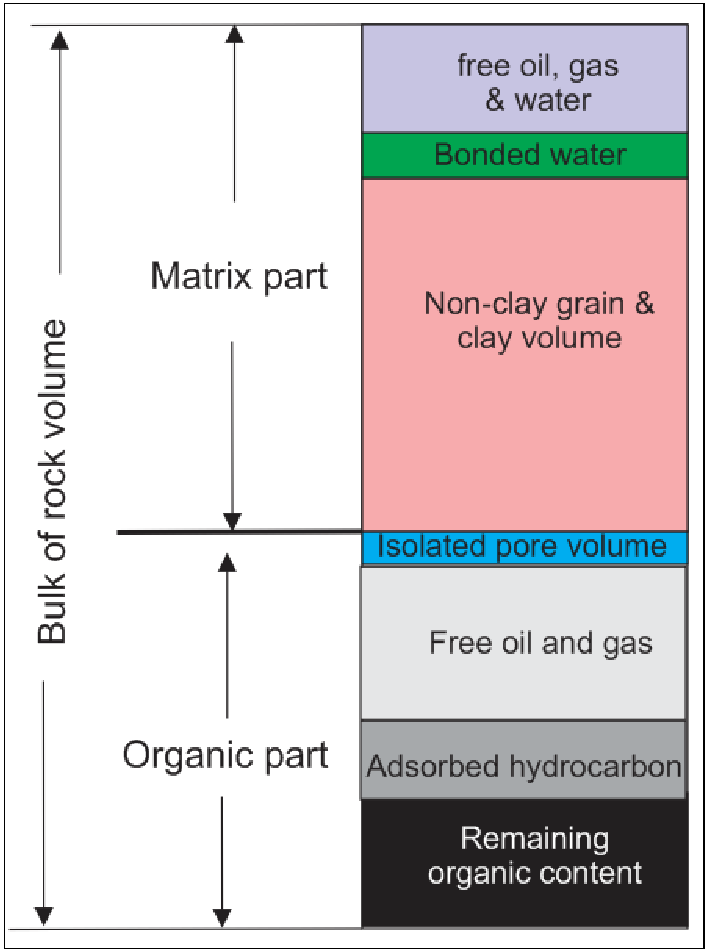


A dual-porosity model for volumetric assessment

- A matrix porosity system
  1. Controlled by compaction and diagenesis
  2. Micro-pore size
  3. Porosity decreases with depth
  4. Water wet
  5. Inorganic inter- & intra-porosity
  6. Migrated oil & gas
  7. Ø negatively correlated with TOC
- A organic porosity system
  1. Controlled by thermal maturity and source rock characteristics
  2. Nano-pore size,
  3. Porosity & pore size increase with thermal maturity, preservation affected by lithology
  4. Oil wet, in situ oil & gas
  5. Ø positively correlated with TOC



The Pore System Model

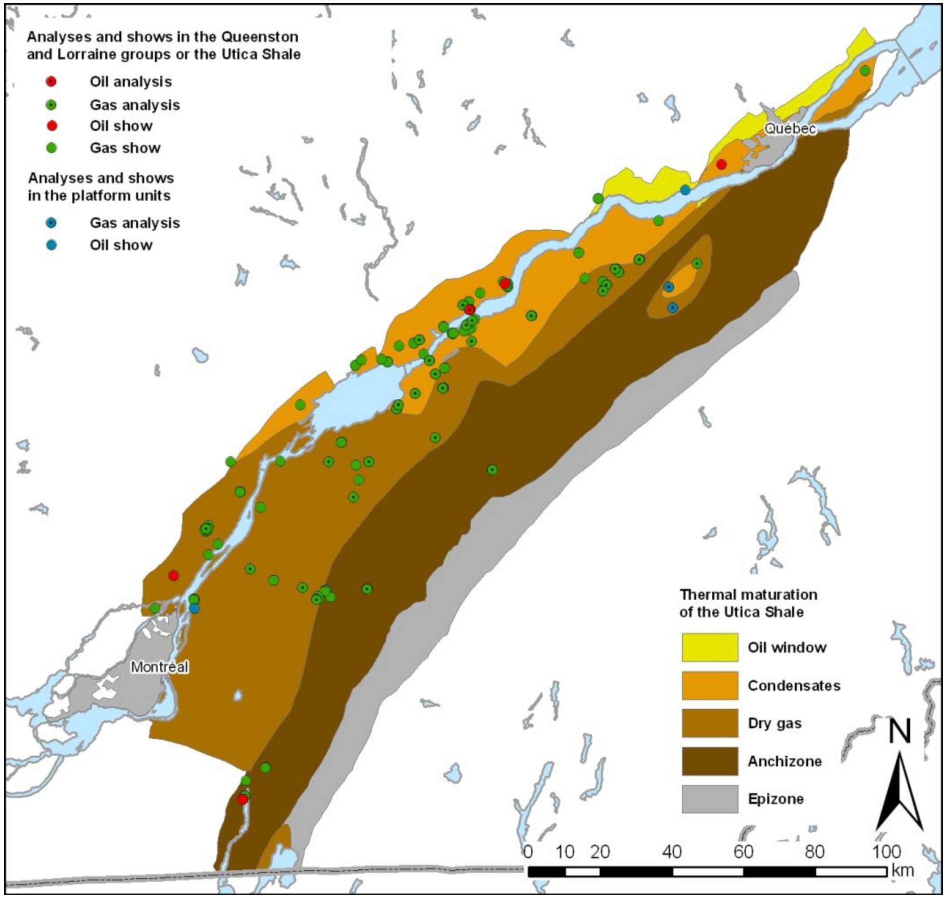


(modified from Ambrose et al. 2012)

- A pore system model for resource estimation in a hybrid shale play where both matrix porosity and organic porosity contribute to the storage of oil and gas accumulation
- Two porosity systems
  - Matrix porosity
  - Organic porosity system
- The percentage of the various components forming the bulk of the rock volume is schematic and does not intend to represent a specific case.

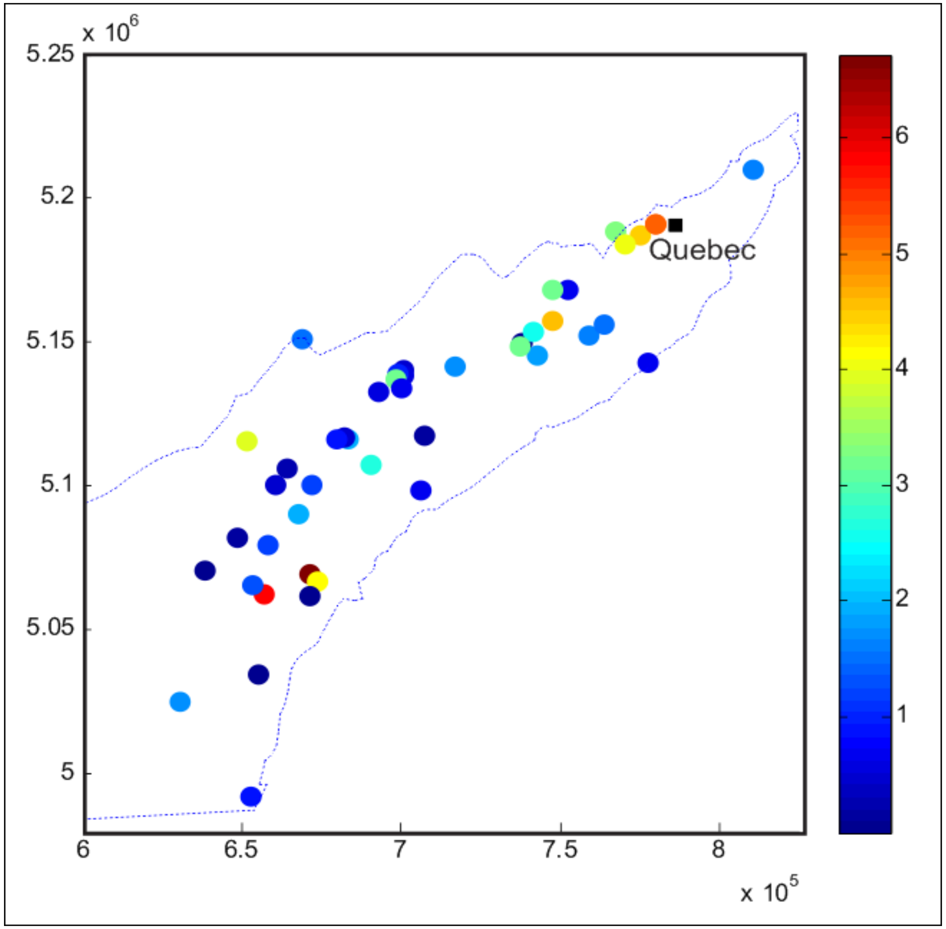
Exploration fairways and data

- Well data
  - 46 exploration wells with digital gamma ray, caliper, sonic and resistivity logs
  - Temperature, pressure
- Rock-Eval pyrolysis & maturity data:
  - analytical results from more than 700 samples in 74 wells and 23 outcrop locations
  - Thermal maturity indicator (vitrinite reflectance equivalent): 138 data points
- Lab analysis of core and hydrocarbon samples from three wells
  - HC composition, porosity, water saturation, grain density, sorption gas,…
- General geological data and information
  - Maps and cross sections for defining the play boundary
  - Depth, thickness



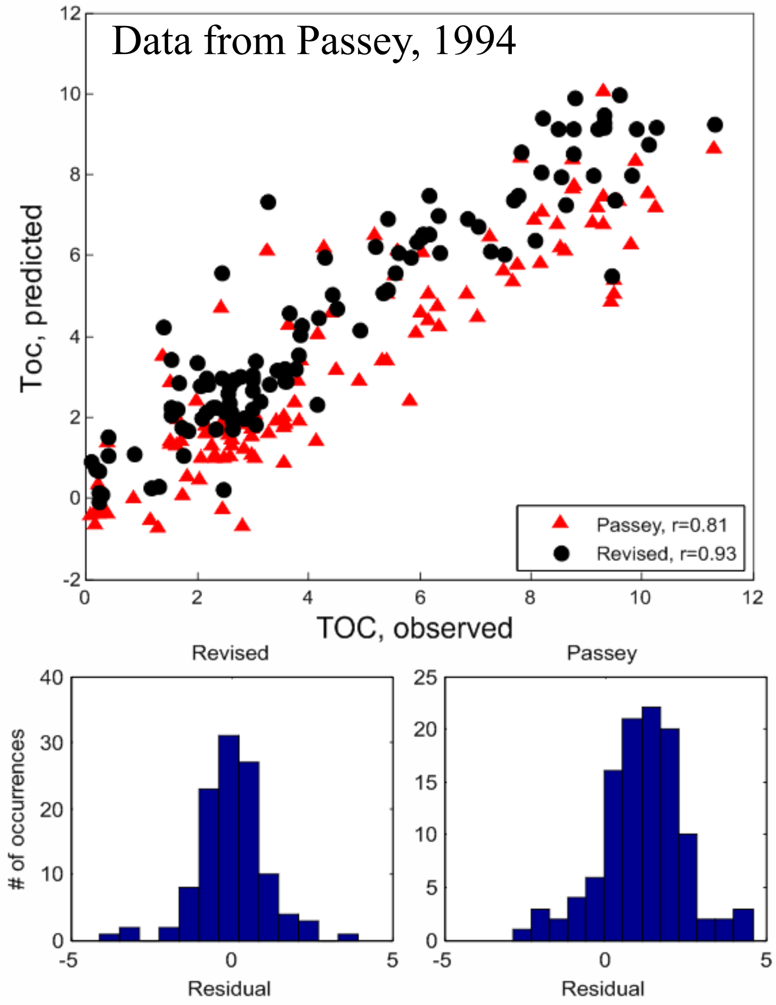
(modified from Séjourné al. 2013)

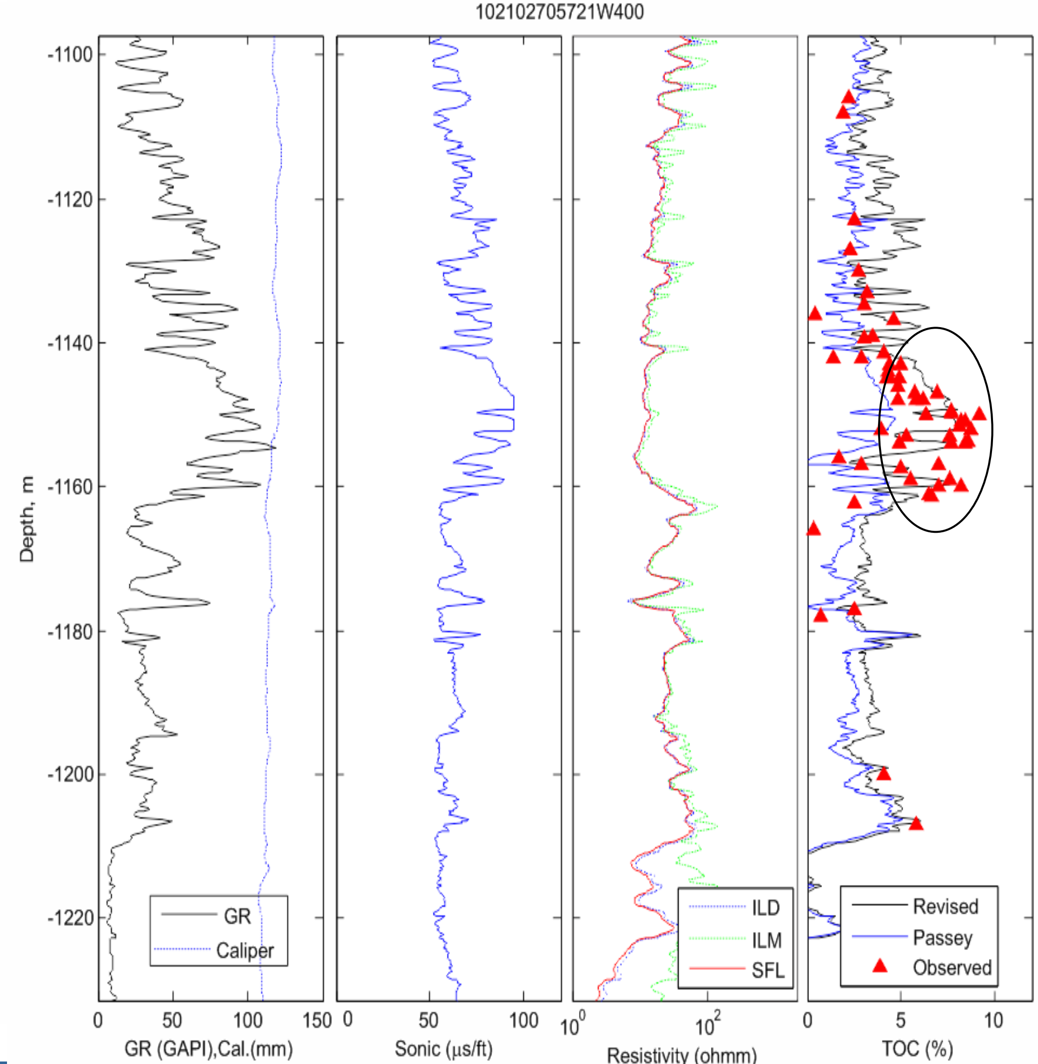
Data well locations



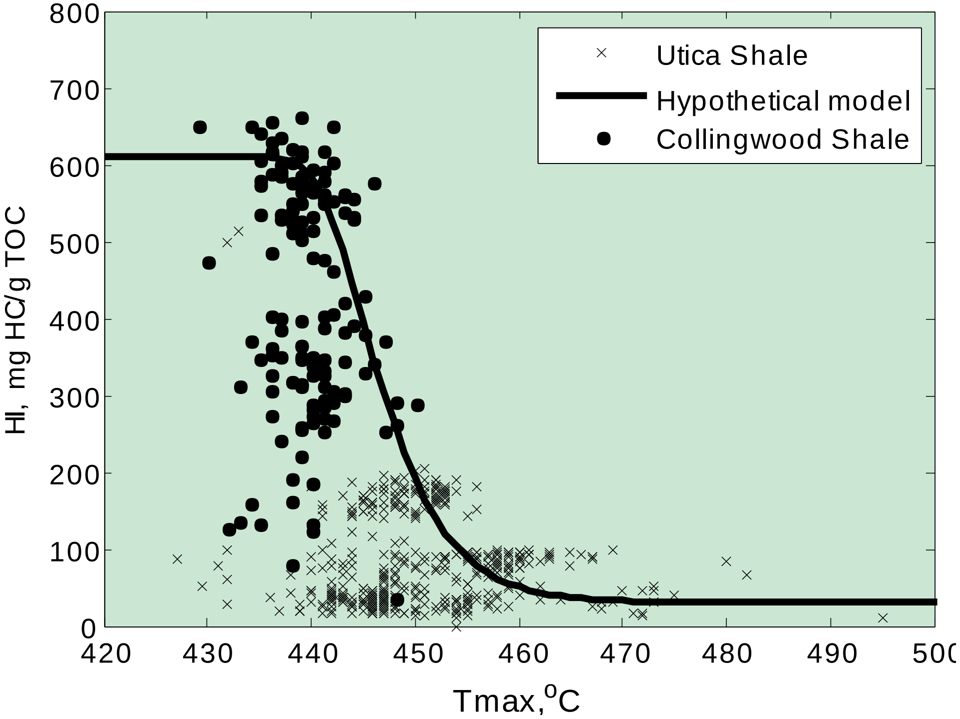
Wells location map showing the locations of data wells with adequate physical log curves for evaluation of hydrocarbon pore volumes. The color of the dots and colorbar on the right indicate the estimated hydrocarbon net thickness in metre. The black square is the location of Quebec City. The coordinate is an UTM projection (zone 18).

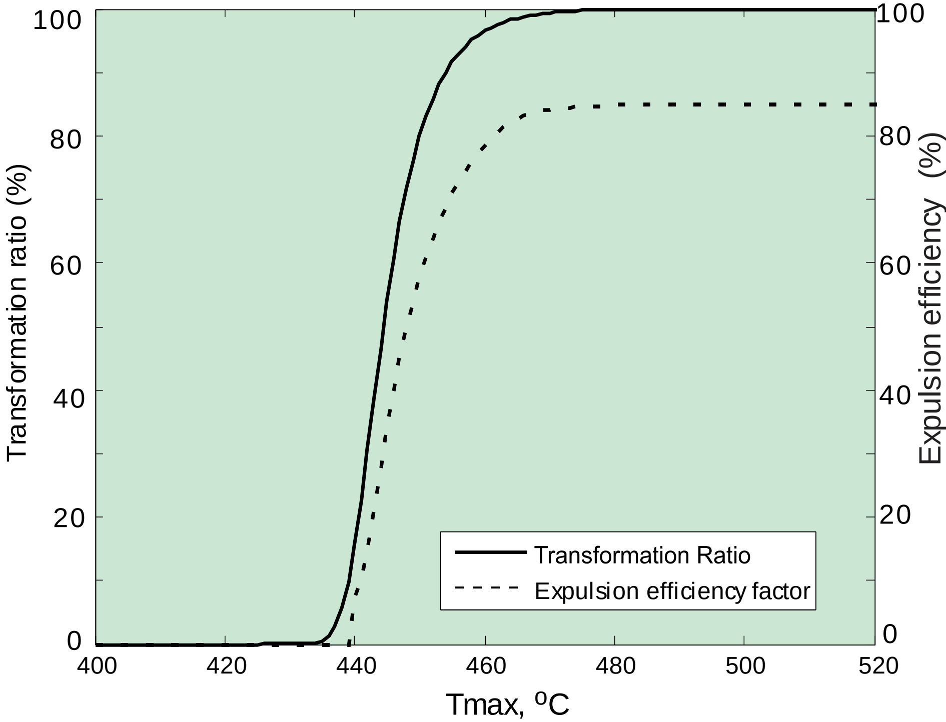
Revised Passey Model





Kinetic and generation models
Utica Shale, Quebec





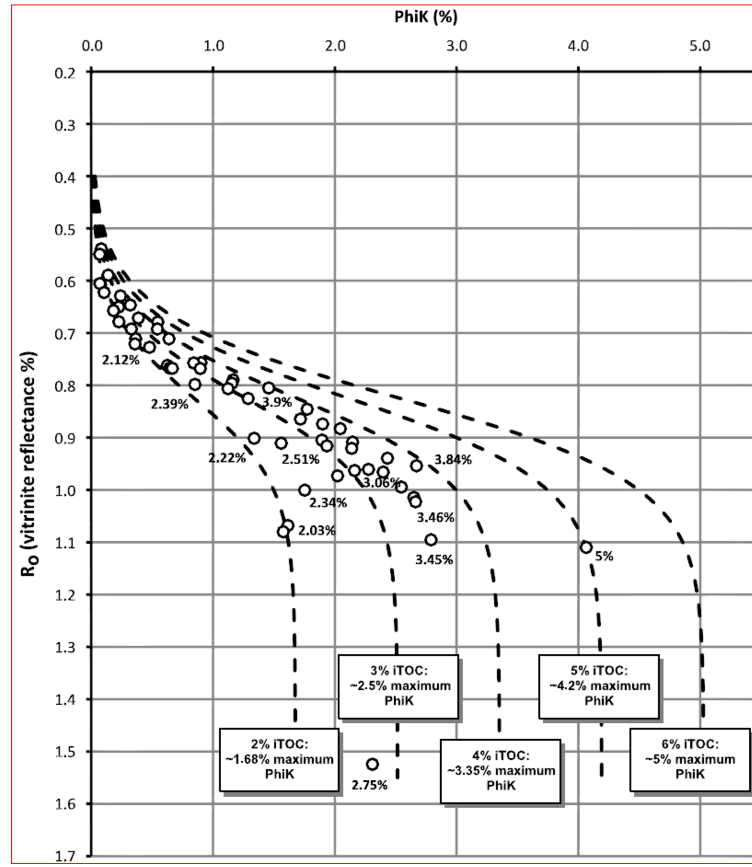
Estimating organic porosity (Modica and Lapierre, 2012)

- $\emptyset_{org}$ is a function of TOC richness, kerogen type and maturity
- $\emptyset_{org}$ increases with thermal maturity

$$\emptyset_{org} = TOC(i) C_{conv} f_k T_R \frac{\rho_b}{\rho_k}$$

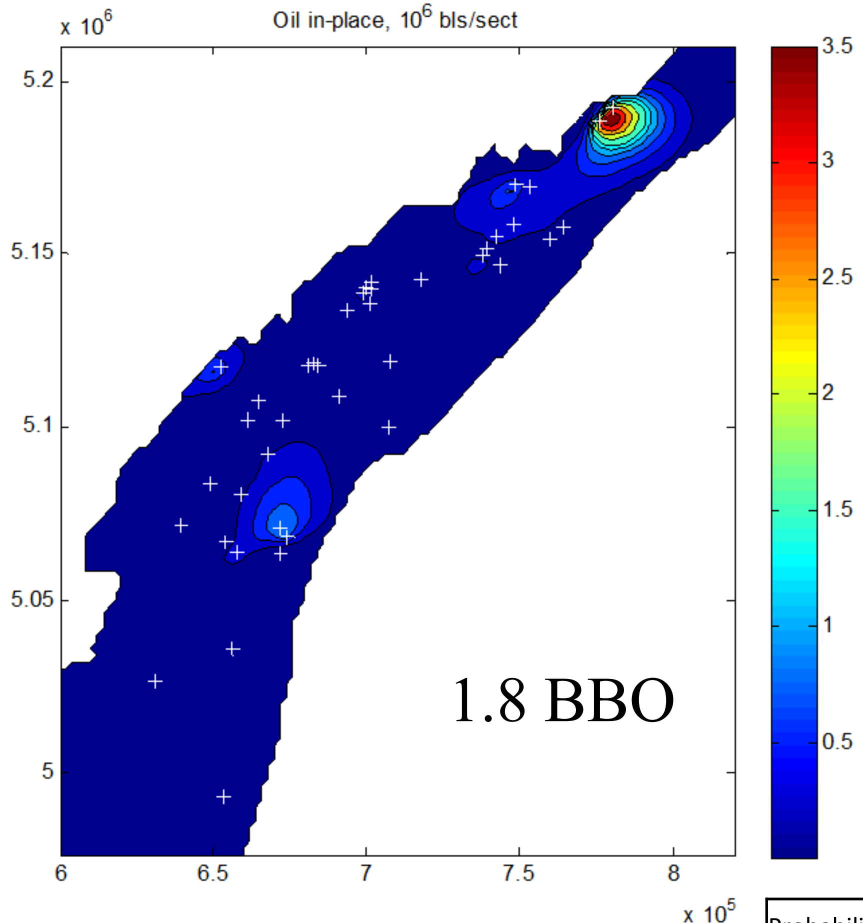
TOC(i): initial total organic content in %w, C_{conv}: fraction of labile organic carbon in kerogen, f_k is a dimensionless scale factor used to estimate a kerogen mass from a labile carbon mass; T_R: transformation ratio of organic matter to hydrocarbon; ρ_b and ρ_k are rock bulk density and density of kerogen respectively.

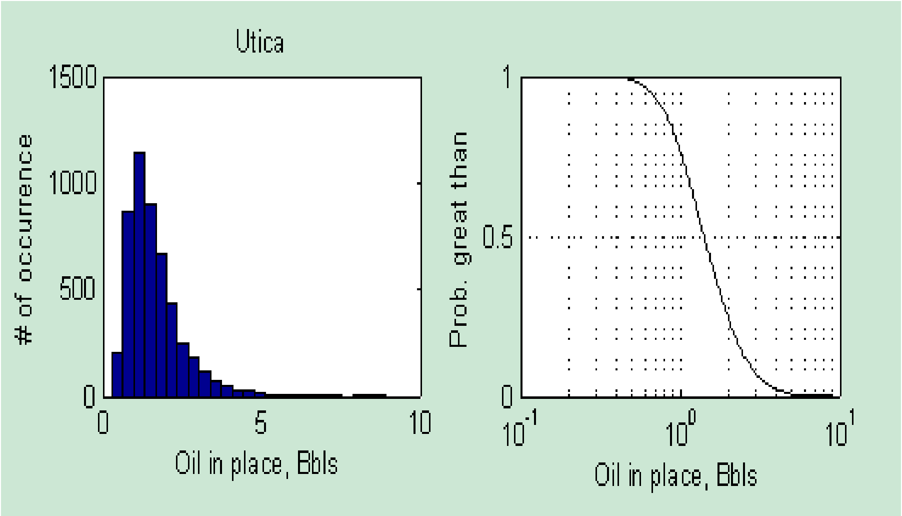
(for a given a kinetic model)



(Modica and Lapierre, 2012)

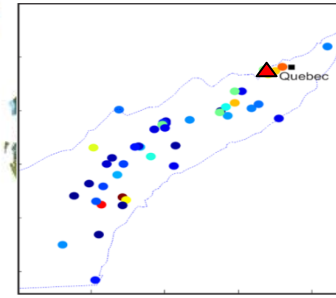
Estimated oil in-place resource distributions





Probability Distribution	95%	90%	75%	50%	25%	10%	5%	Mean
Oil in-place (Billion Barrels)	0.69	0.83	1.11	1.55	2.22	3.06	3.72	1.80

Utica Shale,
St-Augustin # 1 well



Well logs

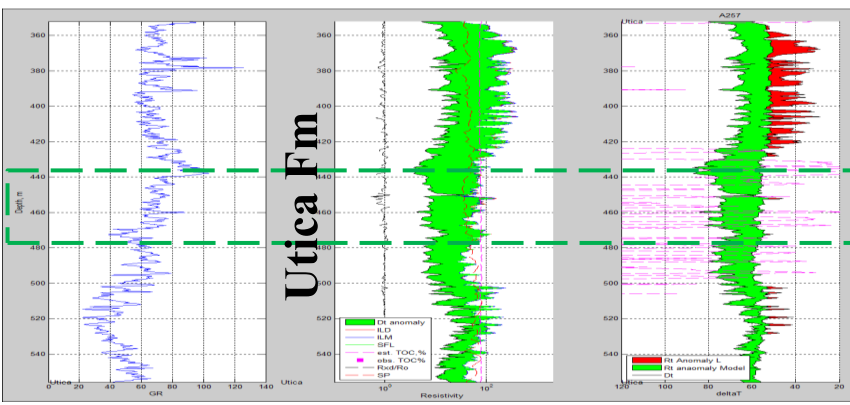
Gas log

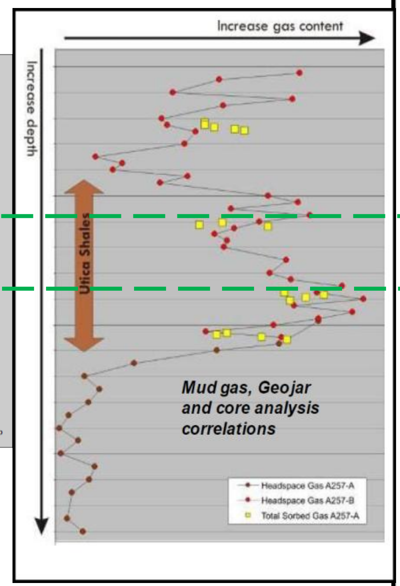
Geochemical plot

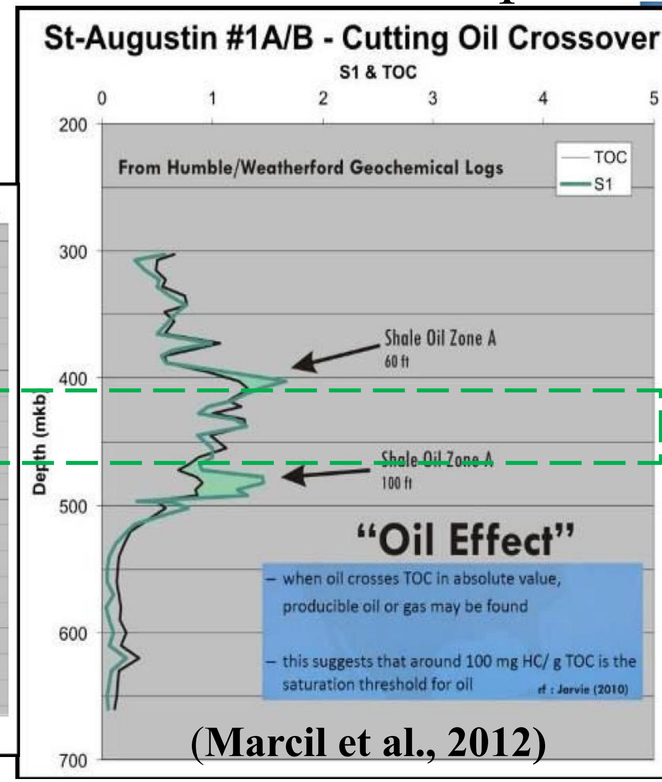
GR

Resistivity

Sonic







(Marcil et al., 2012)

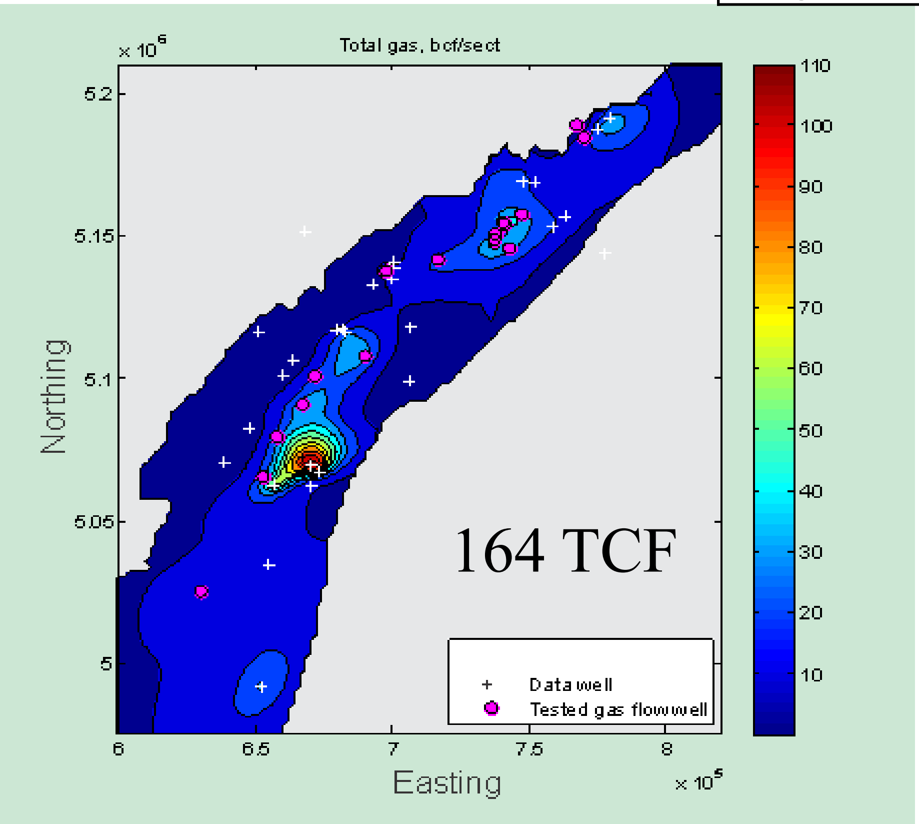
Green fills represent the separation of estimated resistivity by sonic and sonic by resistivity. The red fill represents Passey's ΔlogRt

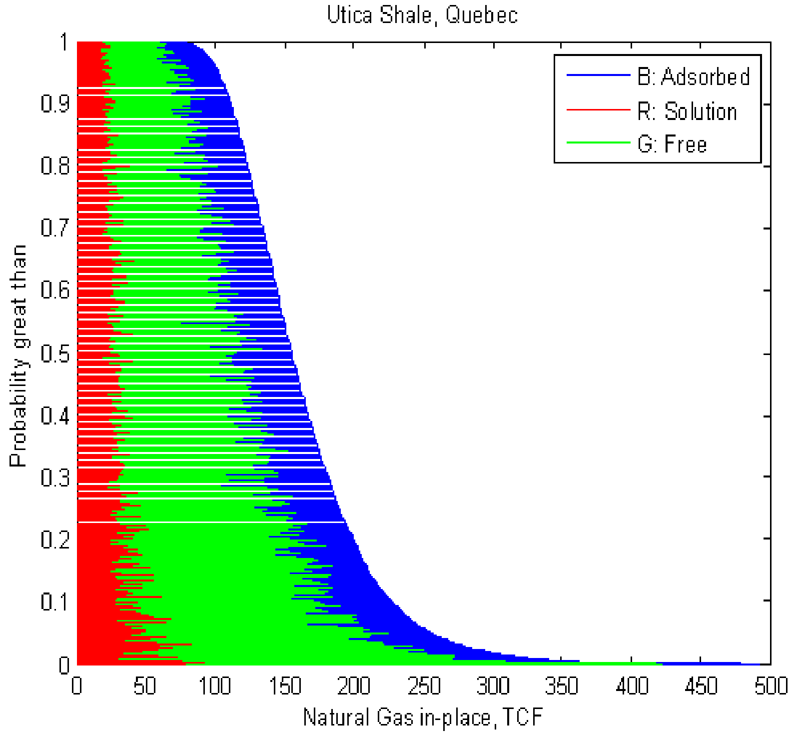
Interval 436.5-473.5m has been hydraulically fractured (propane) and tested: 47 barrels oil/day and 467 mcf gas/day for 109 hrs

Statistical distribution of gas resources

Gas resource in place (TCF)

Probability	0.95	0.9	0.75	0.5	0.25	0.1	0.05	Mean
Adsorbed gas	24.7	27.5	32.5	39.0	47.0	55.6	61.2	40.5
Free gas	47.4	53.7	65.6	83.7	109.5	140.5	163.3	91.9
Solution gas	20.0	21.4	24.2	28.7	35.6	44.4	51.1	31.3
total gas	101.5	110.5	129.4	155.6	188.1	228.1	258.3	164.0





Summary

- Utica shale is a hybrid resource play with characteristics of mixed reservoirs varying from tight siltstone to organic rich shale. Matrix porosity may provide the principal storage for expelled petroleum, whereas additional petroleum remains within “organic” pores in the source rock
- A volumetric method based on dual-porosity is applied to address challenges of the complexity of mixed pore systems in shale reservoir
- A revised model considering mass balance is developed to provide more robust organic porosity estimates
- The new expected in-place resources include 164 TCF of natural gas and 1.8 billion barrels of oil.
- More details (to come) in

Chen, Z., Lavoie, D., Malo, M., Jiang, C., Sanei, H. and O. Haeri-Ardakani. A dual-porosity model for evaluating petroleum resource potential in unconventional tight-shale plays with application to Utica Shale, Quebec (Canada). AAPG Bulletin; submitted

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- Talisman Energy Incorporated for access to core test results


Thank you