

# **Natural Fractures Characterization and Horizontal Drilling of an Oil-Prone Devonian Carbonate - Birth of a New Major Play in Eastern Canada\***

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## **Abstract**

The Galt Oil Project covers an area of 216 sq-km in Eastern Canada. Located in the Gaspesian Silurian-Devonian Basin, Galt is the most advanced oil project in Quebec in terms of geological knowledge and engineering, and in terms of delineation of the structure, wells drilled and resource potential. Based on publicly disseminated information, the project contains the largest Discovered and Undiscovered Oil Resource potential so far established on the Gasp and Eacute Peninsula by independent evaluators. In June 2015, the Best Estimate of the total Oil-Initially-In-Place resources was established at 557 million barrels for the Early Devonian Forillon and Indian Point formations of the Galt property. To make this discovery, the team of Junex has used two main tools: imaging technologies in logging and directional drilling.

Based on a number of in-depth studies performed by Junex and independent experts over the past two years, the Junex Galt #4HZ wellbore trajectory was designed to optimally intersect the maximum number of open, near-vertical, natural fractures in the Forillon. Drilled in Summer 2012, the Junex Galt #4 vertical well served as the vertical pilot hole portion for this horizontal wellbore. Image log tool plays a major role in the natural fractures characterization. Junex Galt #4HZ directionally drilled from the existing vertical wellbore to a total measured depth of 2,400 meters, of which 1,503 meters was drilled within the naturally fractured oil reservoir. Numerous significant oil shows associated with fracture porosity recorded during drilling and results from downhole well logging clearly indicate that the oil reservoir is intensely fractured and that the Galt #4HZ well has therefore achieved the goal of meeting an optimal number of near-vertical natural fractures present in the Forillon reservoir.

We anticipate that additional horizontal drilling and the acquisition of 3D seismic are realized by the end of the year 2016 to better define the reservoir properties and the field reserves. However, we can already state that the use of directional drilling based on well log image analysis played a significant role in the unlocking of this promising Devonian play.

# *Natural fractures characterization and horizontal drilling of an oil-prone Devonian carbonate*

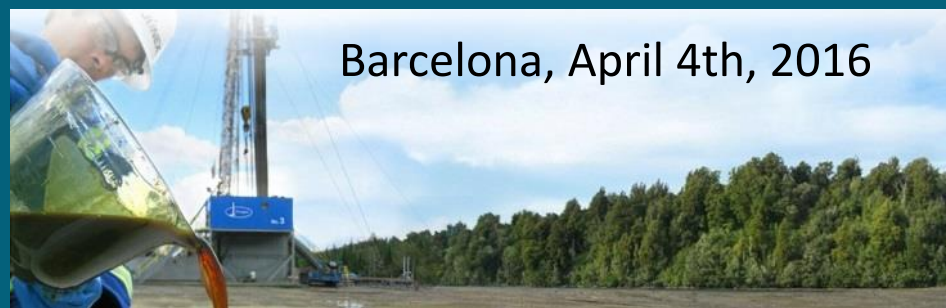
## *- birth of a new major play in eastern Canada*

**AAPG International Conference and Exhibition**  
***Hydrocarbon Traps Session***

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Co-authors : Jérémie Lavoie, Nabila Mechti, Frederick Lavoie, Luc Massé and Peter Dorrins

Barcelona, April 4th, 2016



**AAPG|SEG**  
International Conference  
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# Content of the presentation

Located in the northeastern part of the Appalachian Belt, Galt Oil Project covers an area of 216 km<sup>2</sup>. The explored units belong to the Gaspé Silurian-devonian basin. With a current OIIP estimated to 557 millions barrels, Galt is the most advanced oil project in Quebec in terms of geological knowledge and engineering, and in terms of delineation of the structure, wells drilled and resource potential. This presentation will cover the following geological key points regarding the oil discovery:

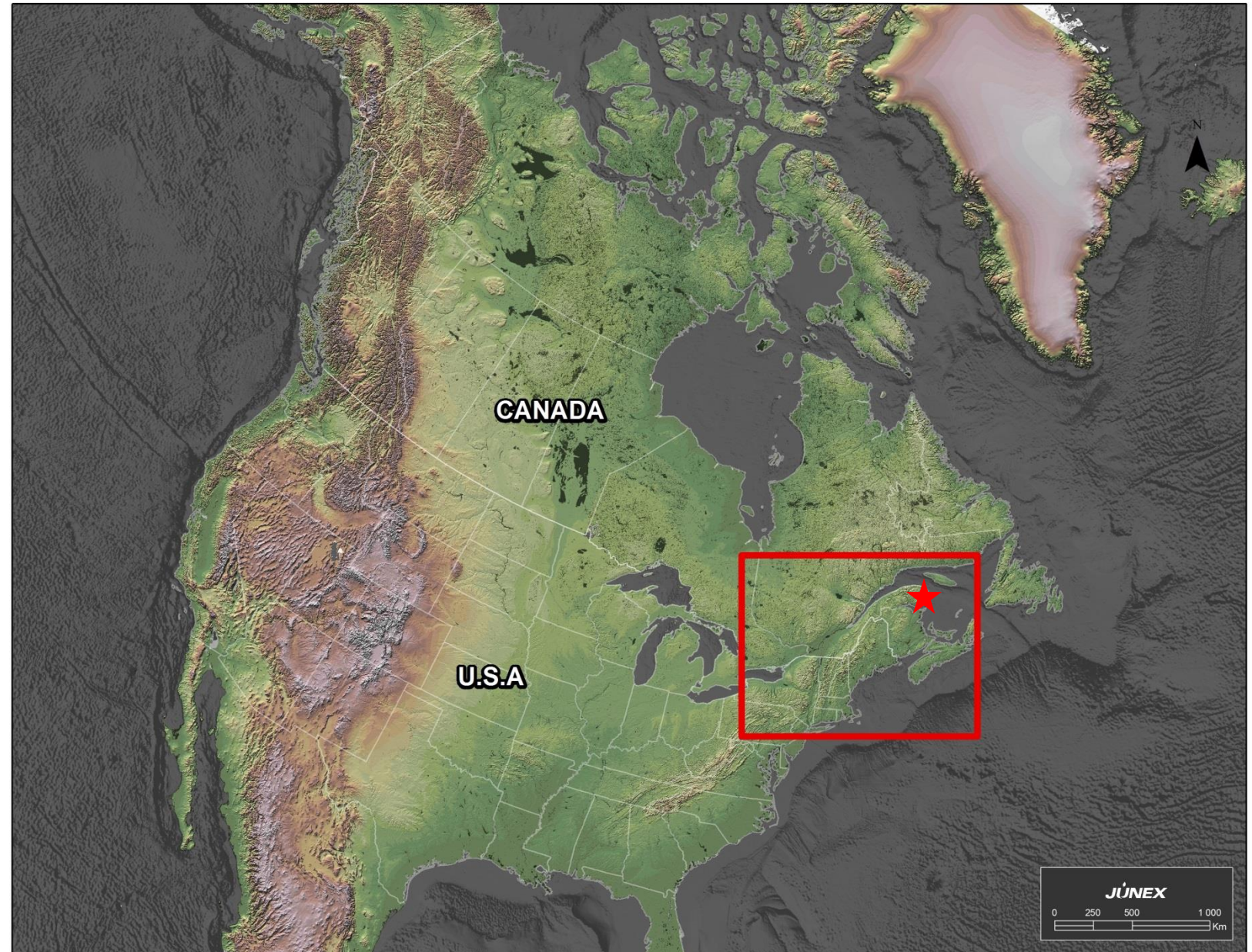
- **Introduction to the geology of the Gaspé Basin;**
- **Characterized the fracture network to find the sweet spot;**
- **Improving the seismic control in a multi-deformed structural zone;**
- **Work in progress related to the stratigraphic definition;**
- **What are the importance of the discovery for the area.**



# Québec, NE America

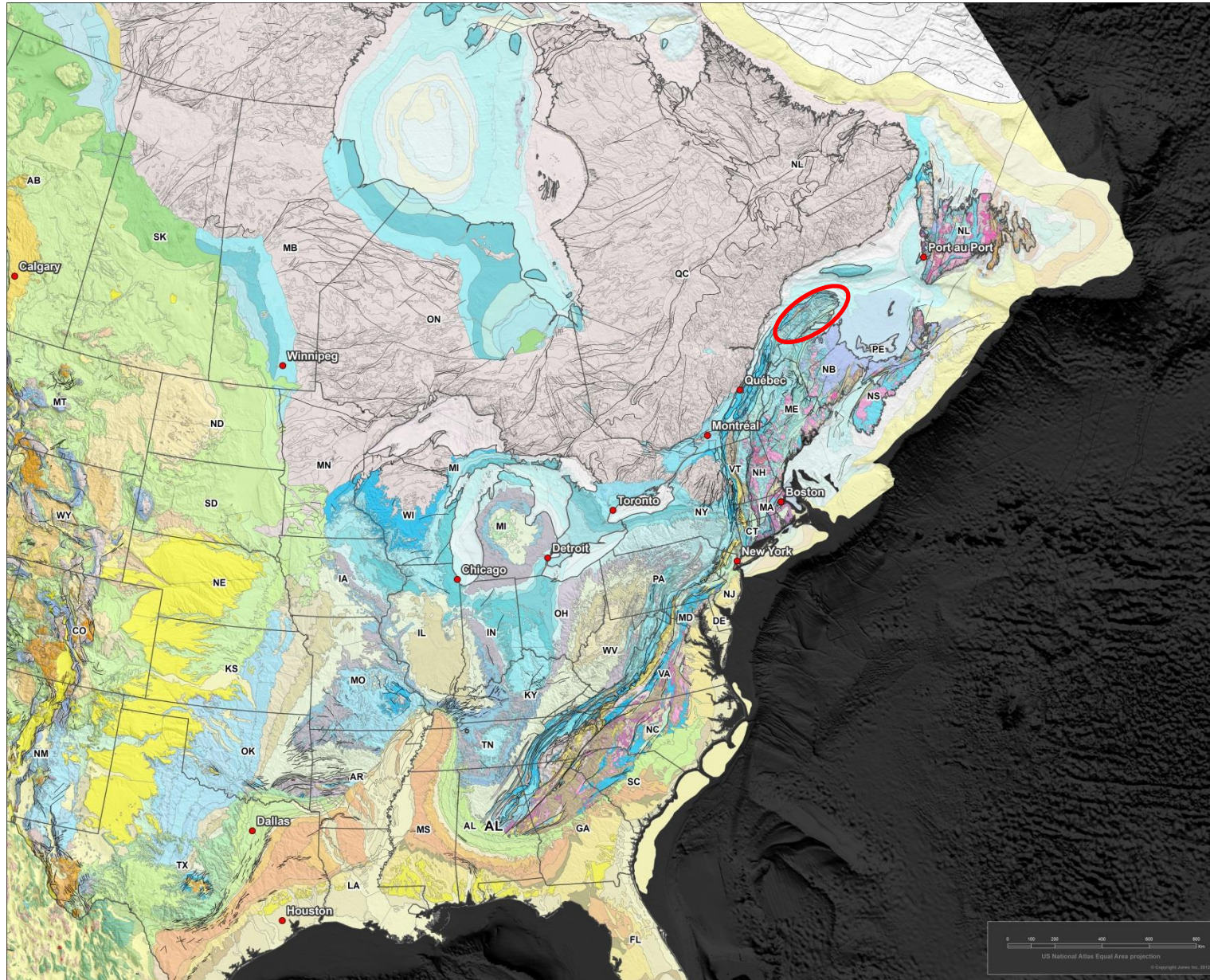
- Sedimentary basins located in the south of the province (200,000km<sup>2</sup>)
- Quebec is an important market for energy consumption:  
300mmboe/year (Hydrocarbons meet 55% of energy needs)
- Daily oil consumption: 350,000 bbl (70% transport)
- Annual gas consumption of 230 Bcf
- Infrastructures : SL Seaway; 2 oil refineries; 3 gas storage facilities; pipeline network.

Source : Whitmore and Pineau, 2015.  
État de l'Énergie au Québec – 2016





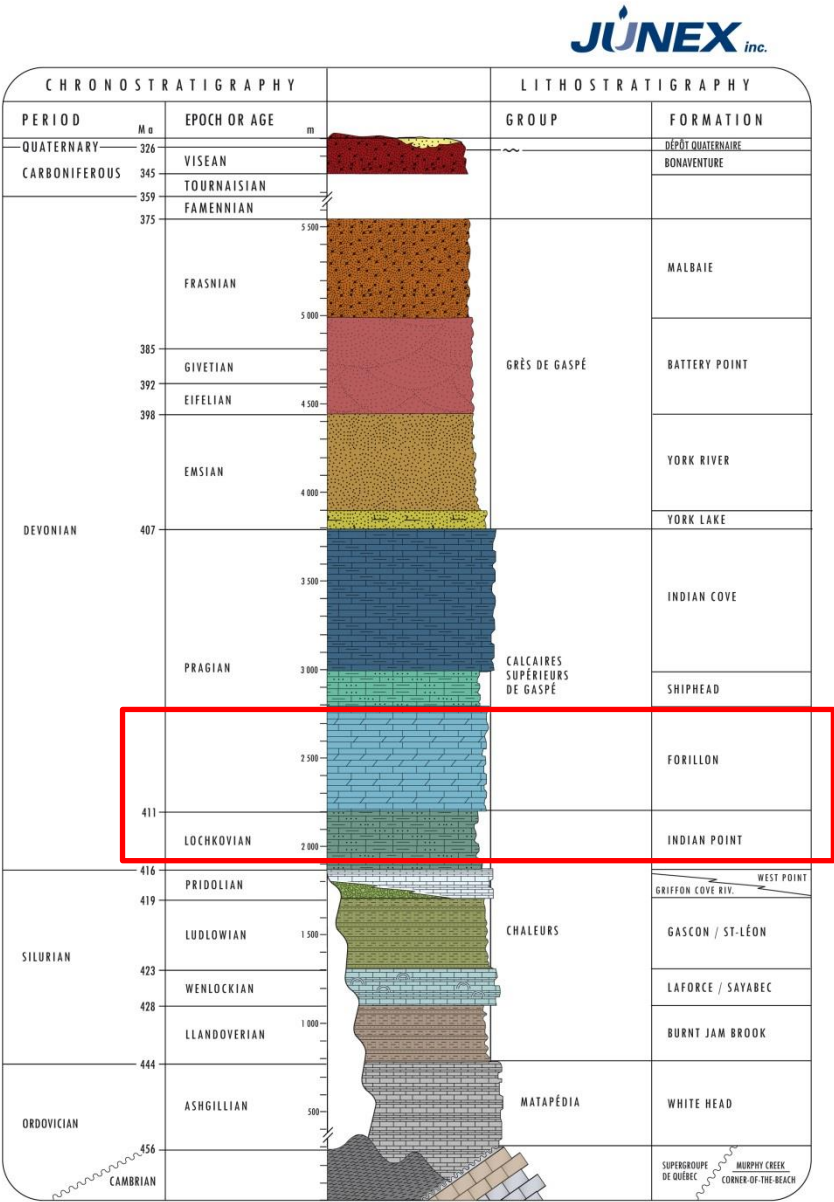
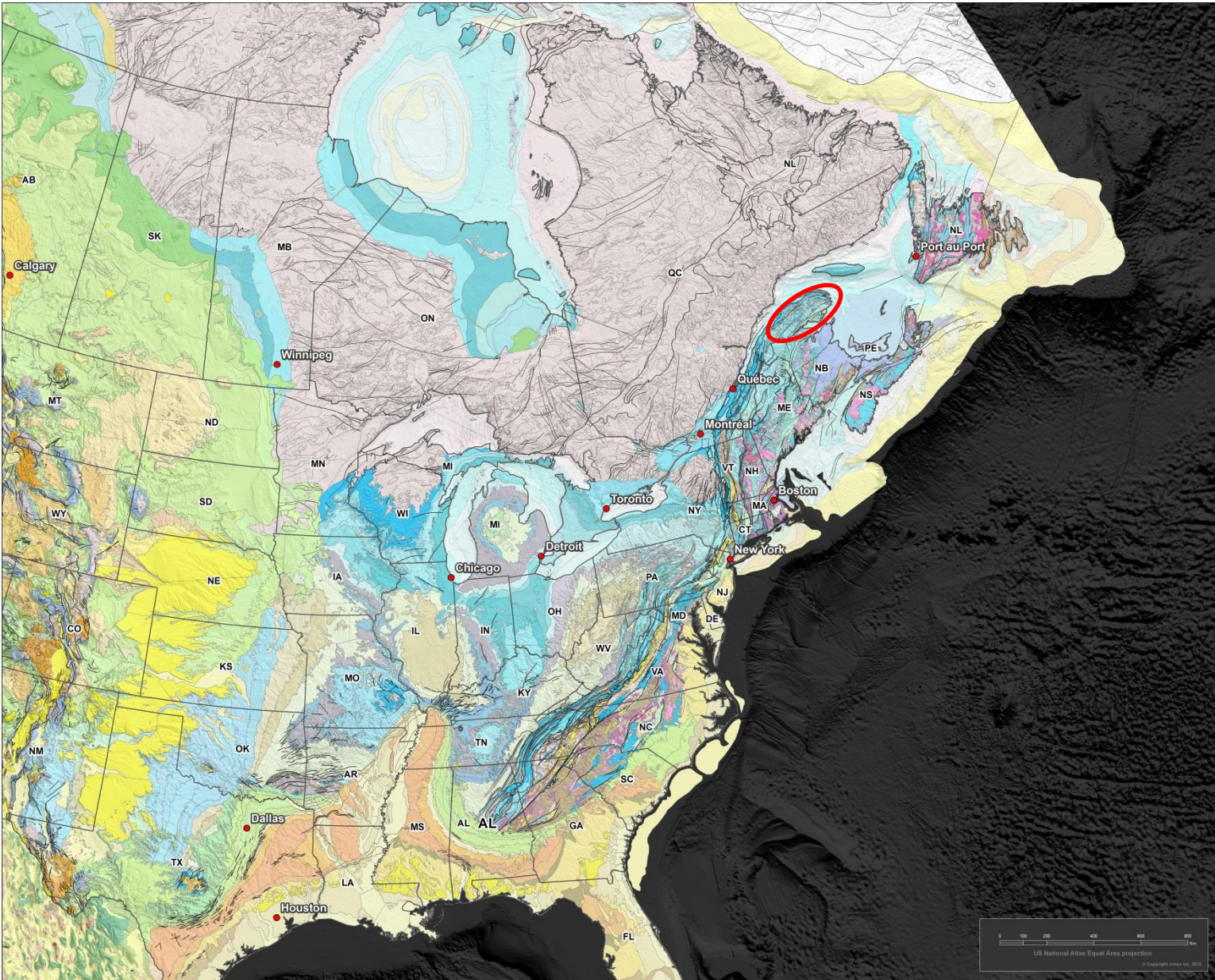
# Gaspé Basin and the Galt Project Location



- Sub-basin located in the NE Appalachian Mountain extends over a length of 300 km and a maximum width of 100 km - covers an area of 30,000 km<sup>2</sup>.
- Explored units aged from Middle Silurian to Lower Devonian



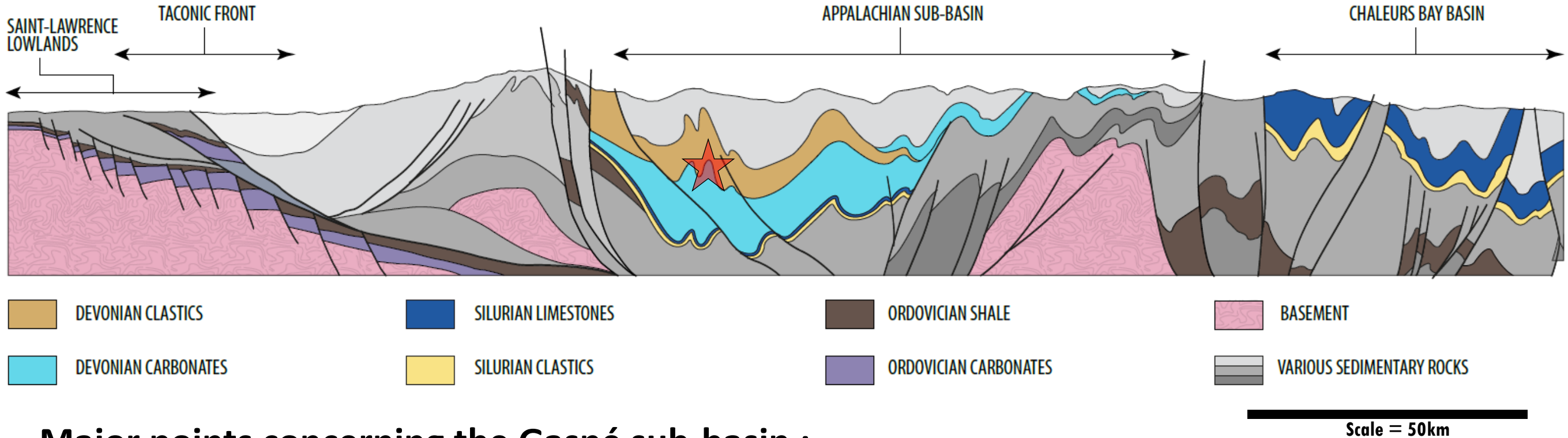
# Gaspé Basin and the Galt Project Location





# Gaspé Basin

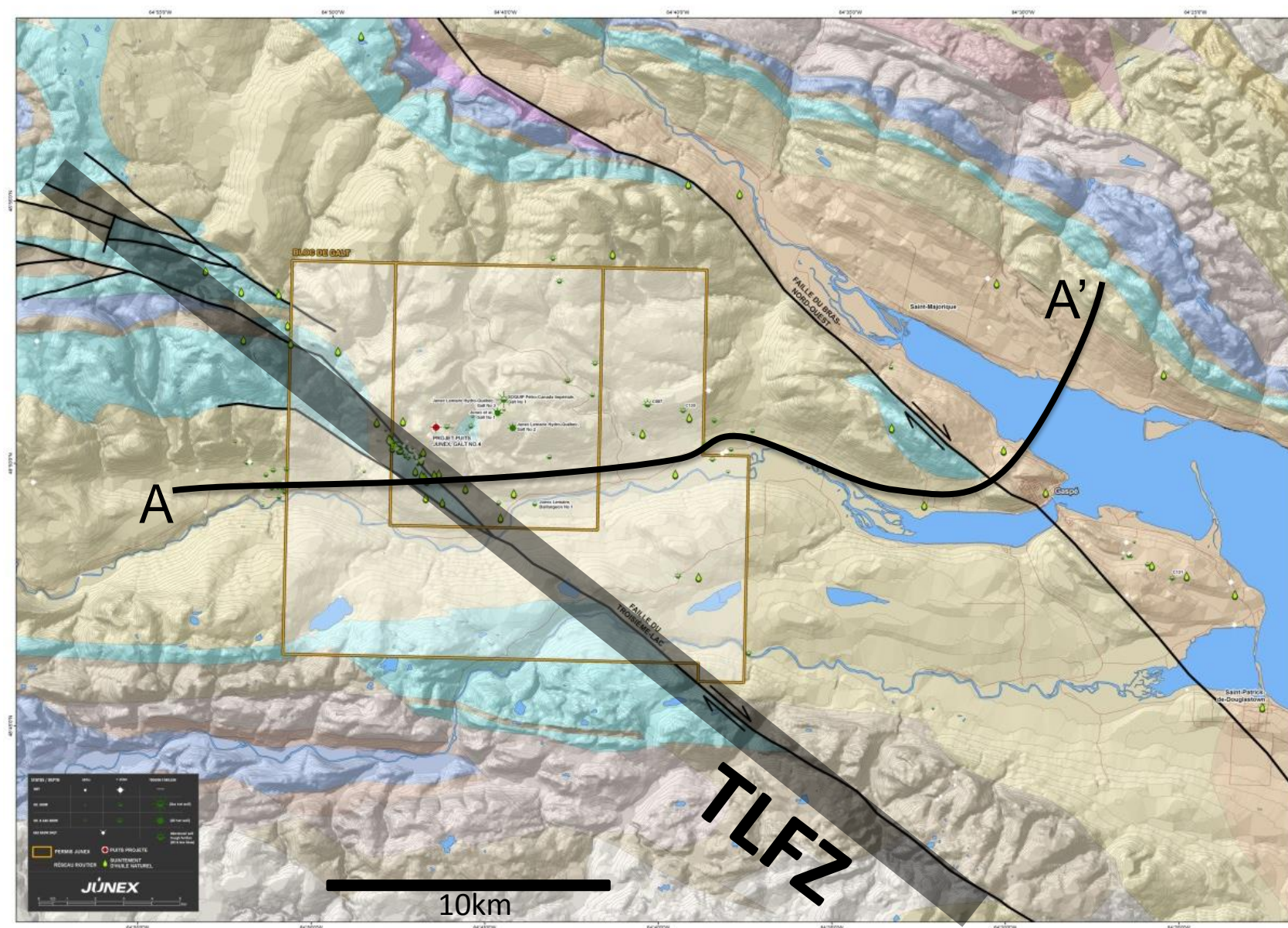
## Summarized Geological Cross-Section of Southern Quebec (NW-SE)



### Major points concerning the Gaspé sub-basin :

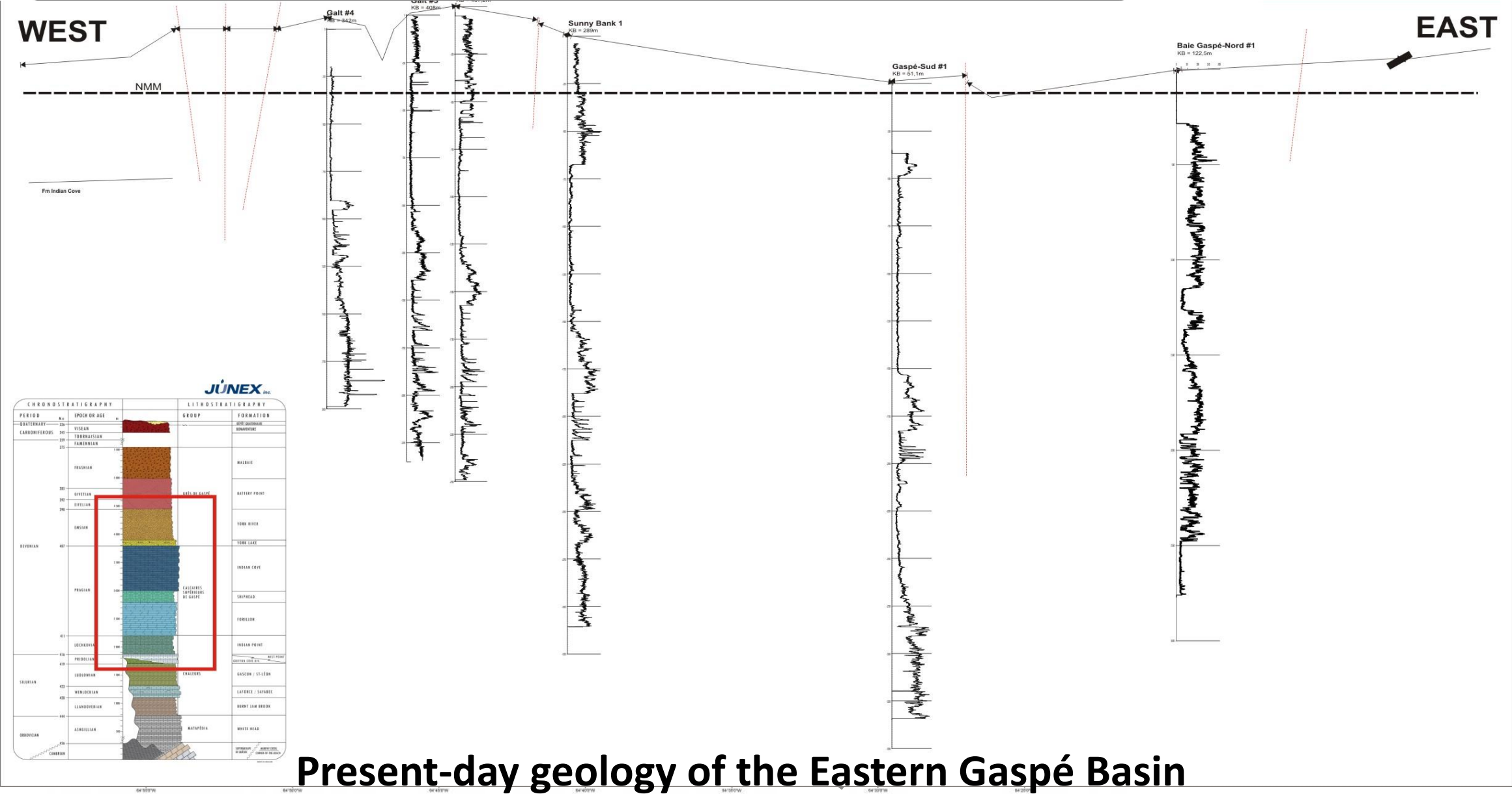
- Oil-prone : Early to Late Oil Window for the Devonian host rocks;
- Most probable source rock : Ordovician marine black shale;
- Regional faulting : Strike-slip deformation corridors created a wide variety of structures.

# Galt Area Geological Overview



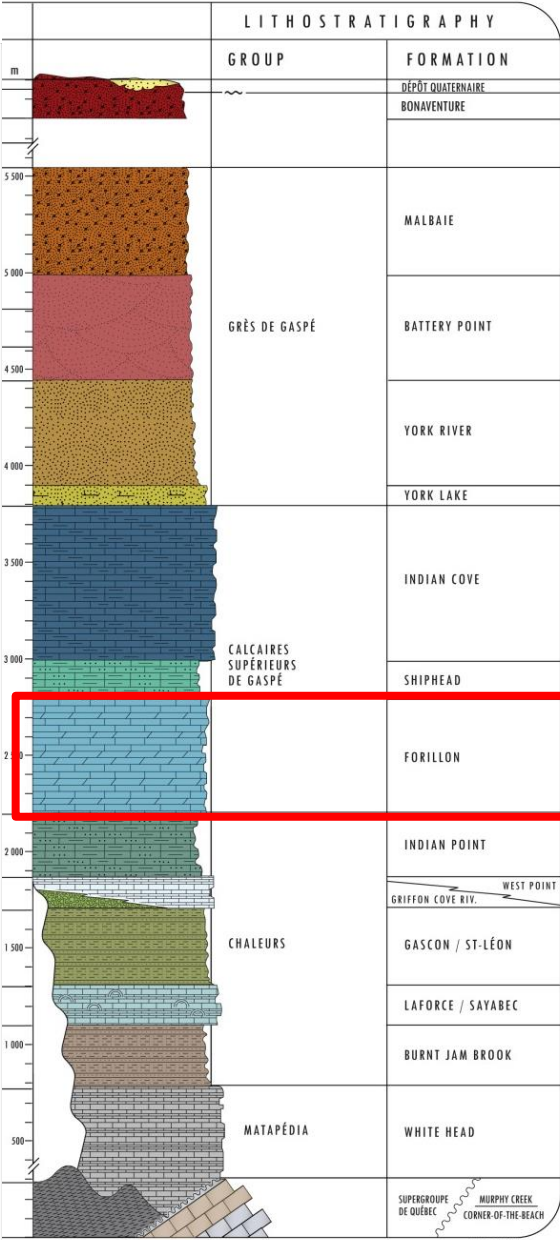
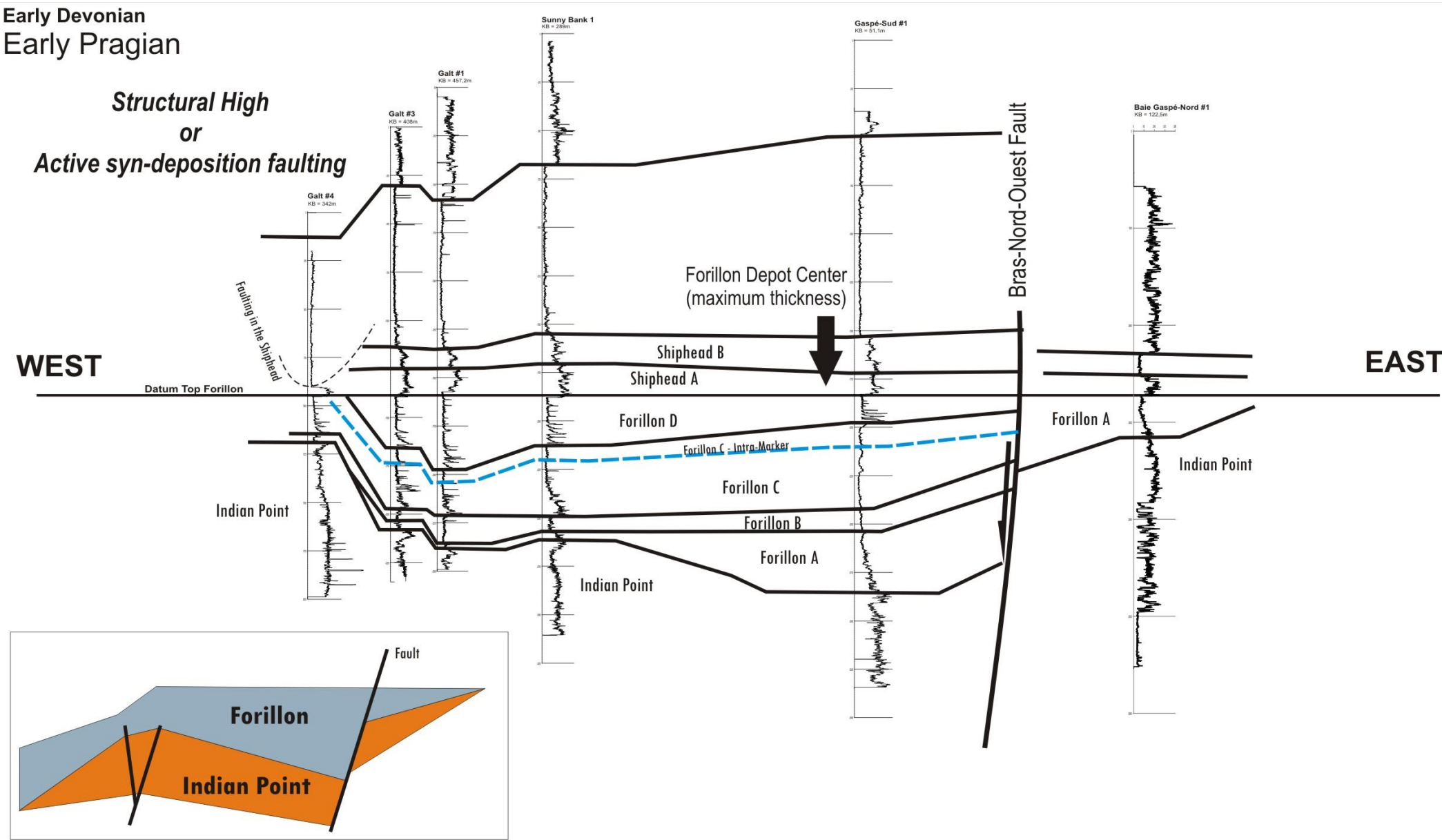


# Galt Area Geological Overview



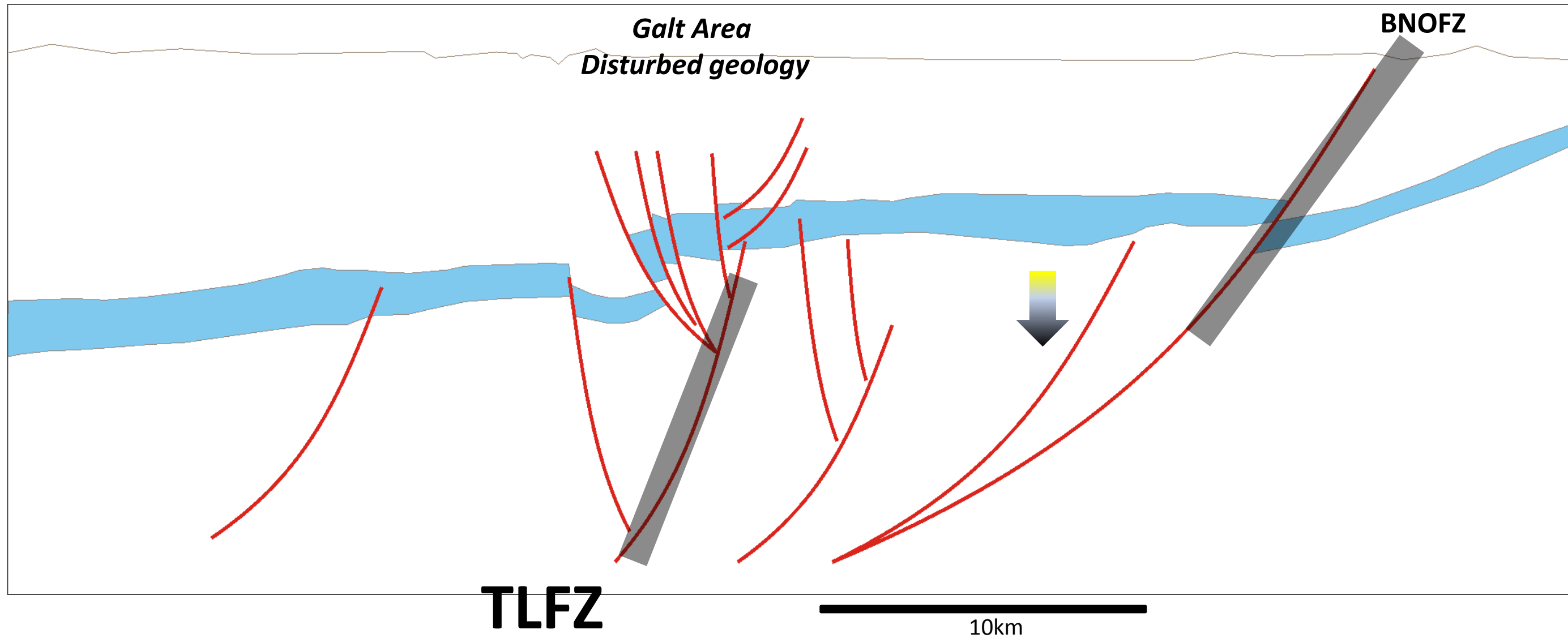
Present-day geology of the Eastern Gaspé Basin

# Galt Area Geological Overview

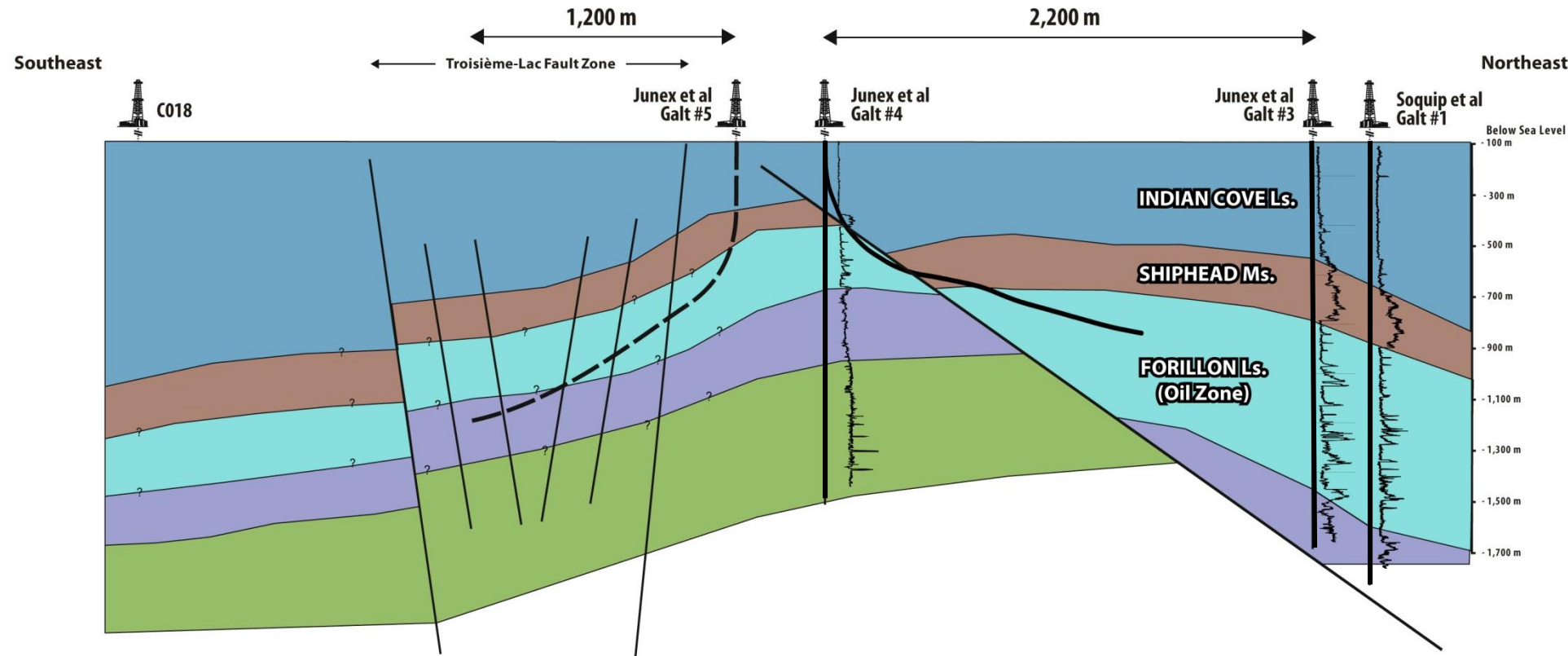




# On Regional Seismic Transect



# Turning point : Horizontal Drilling Program



**Objective** : based on the evaluation of #4VT well, intersecting the maximum number of open fractures in the Forillon Formation carbonates. (Average vertical net pay thickness of 200m)

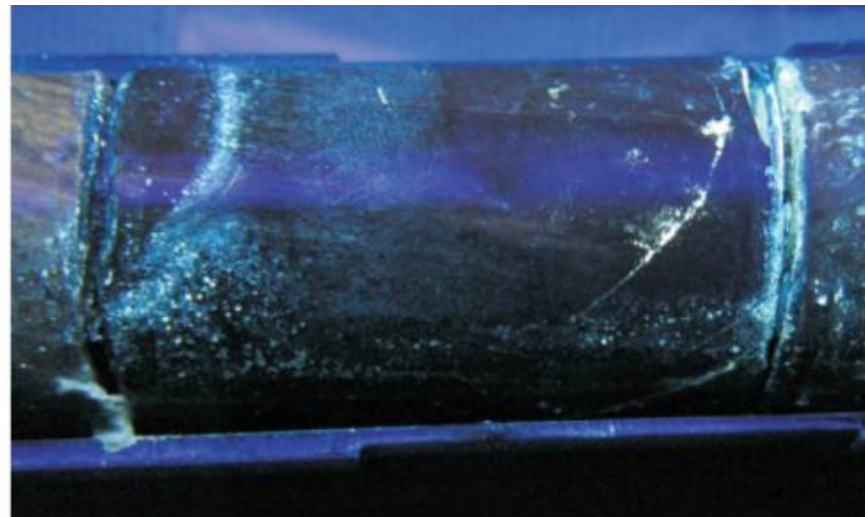
**Results**: 1,503m was drilled within the oil reservoir with numerous significant oil shows associated with fracture porosity. (Further testing demonstrated the good quality of the reservoir with production rate reaching 400 bopd, including some artesian flowing, and the high quality of the light crude)

## Galt #4 Horizontal Well Oil Discovery – Milestone for Junex and for Quebec

- 1<sup>st</sup> horizontal **oil exploration** well ever drilled by industry in Quebec
- Production test – oil production rates are highest ever seen in Quebec & translate into a commercial level of oil production



# Fracture characterization



**Galt #1**  
Fracture semi-ouverte



**Galt #3**  
Fracture ouverte

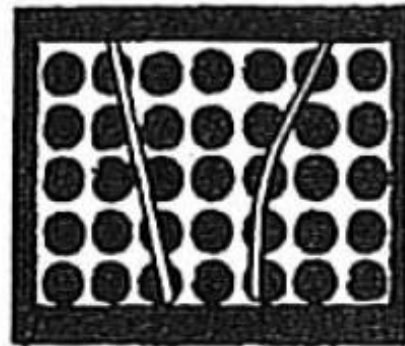
**Galt #3**  
Fracture fermée

**Galt #4**  
Faille / Brèche



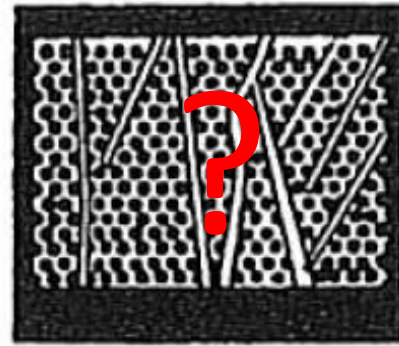
# Fracture characterization

## Porosity distribution



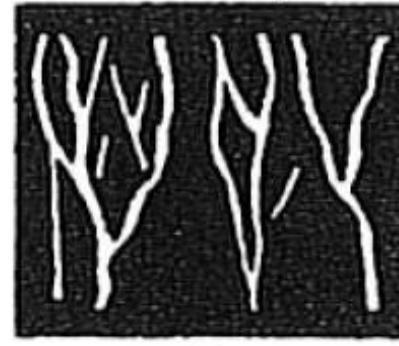
A.

High storage capacity in matrix, low storage capacity in fractures.



B.

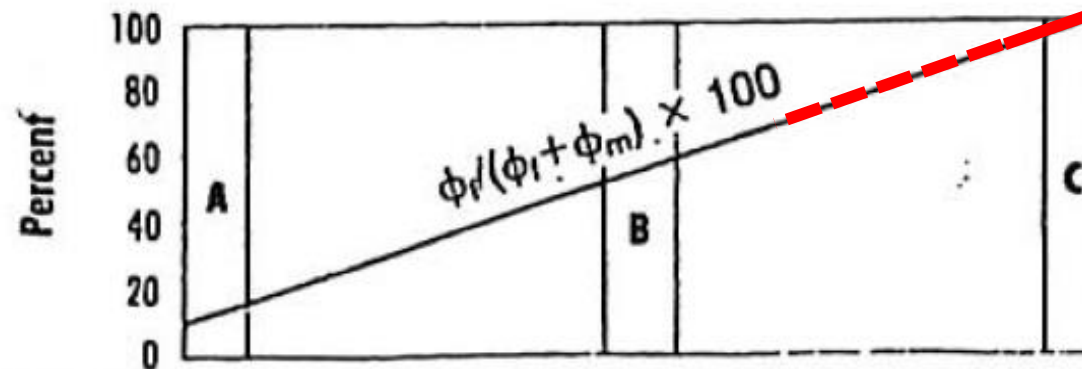
About equal storage capacity in matrix and fractures.



C.

All storage capacity in fractures.

Percent reservoir porosity in fractures



Aguilera (1995)

Galt #1  
Fracture semi-ouverte



Galt #3  
Fracture ouverte



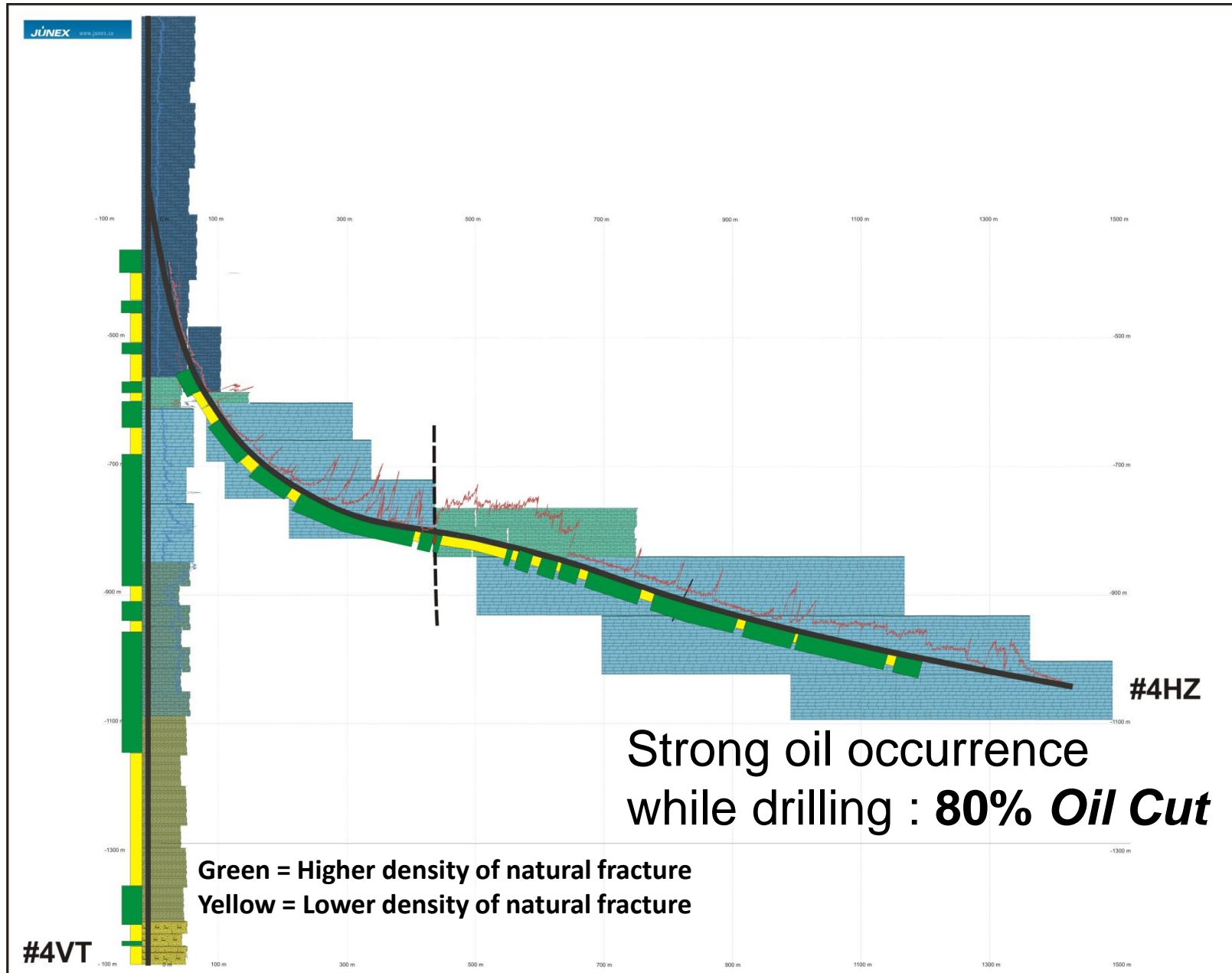
Galt #3  
Fracture fermée



Galt #4  
Faille / Brèche

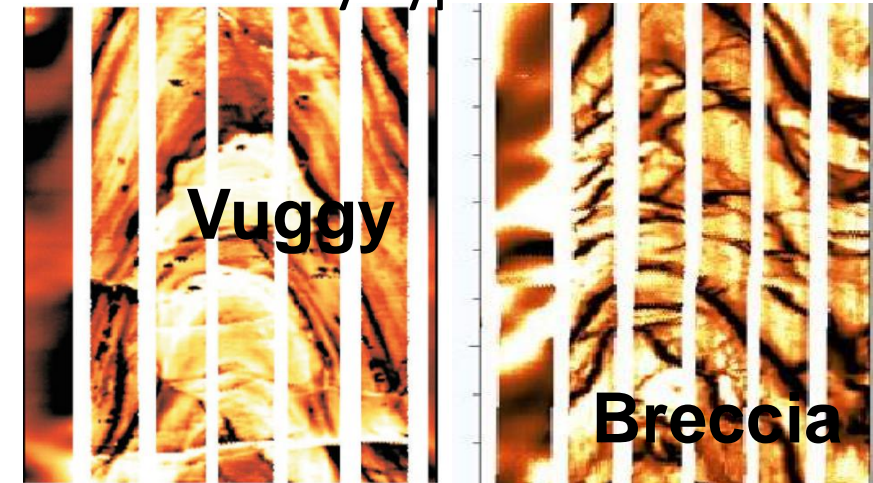


# Fracture characterization

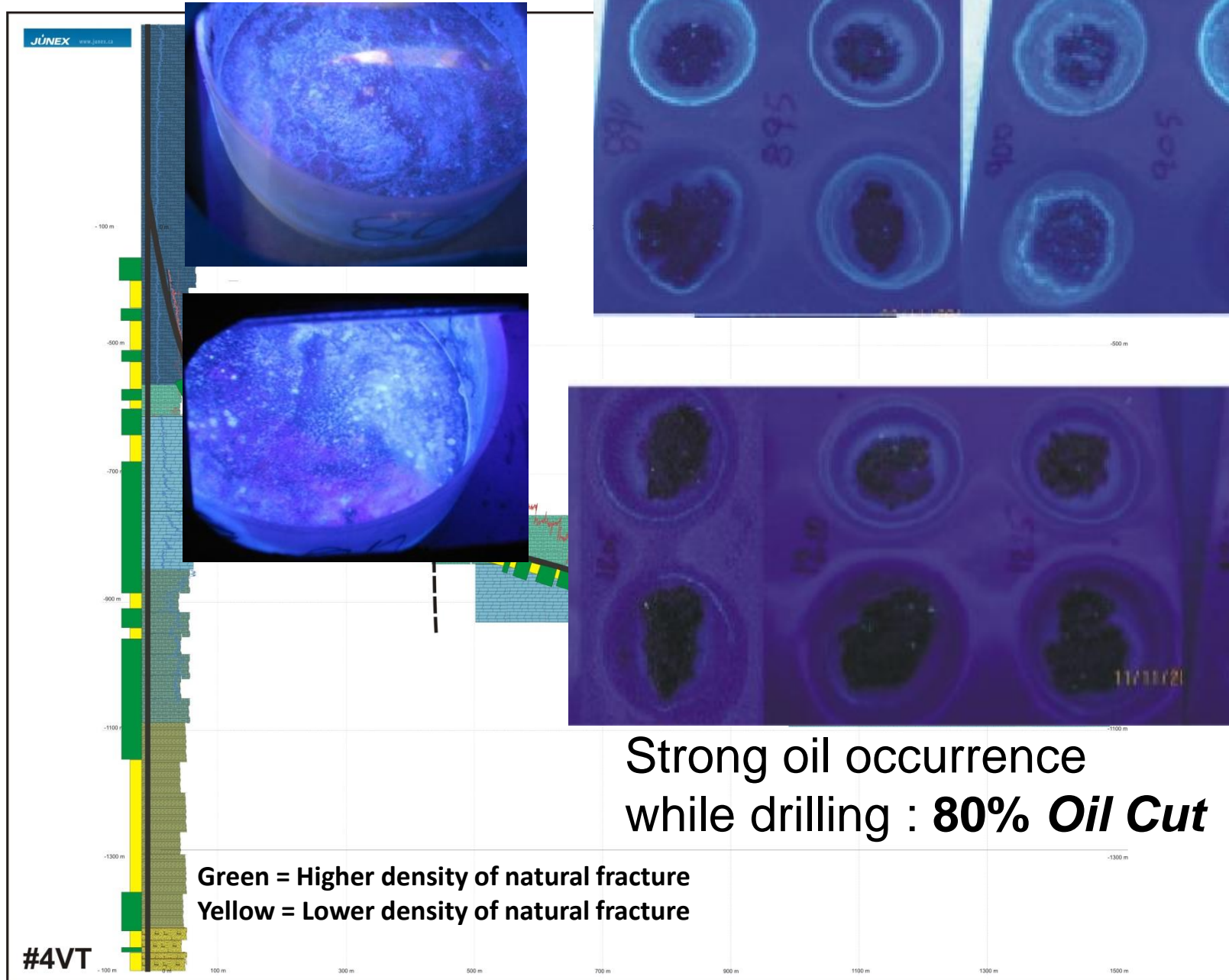


Use of imaging tool help us :

- Measuring bedding;
- Fault orientation ;
- Fracture orientation;
- Fracture density;
- Relative permeability;
- Correlation between oil shows and fractured zones;
- Porosity type identification.



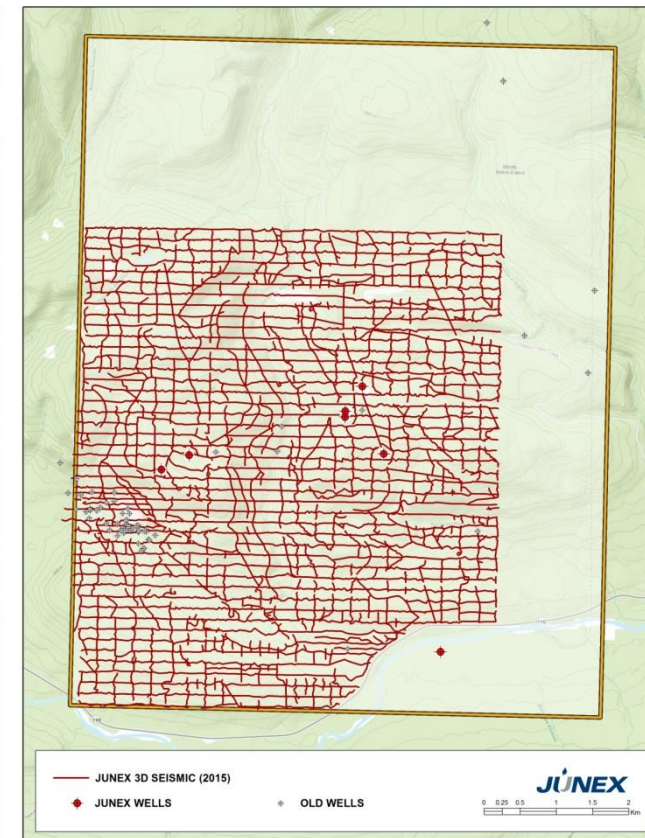
# Fracture characterization





# Seismic control

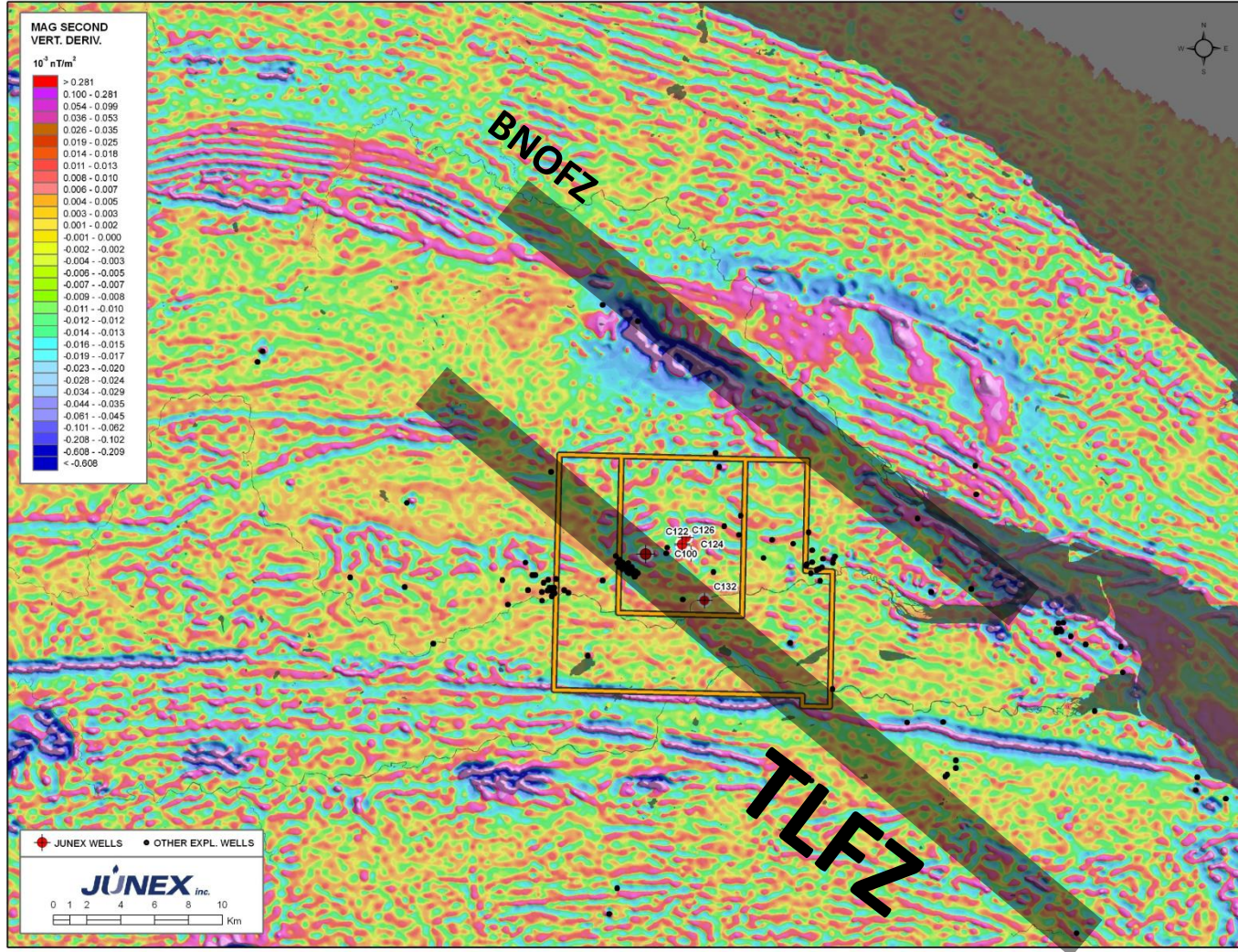
- 500 km of 2D seismic covering the area acquired between 1968 and 2008.
- 37 km<sup>2</sup> 3D survey acquired in 2015





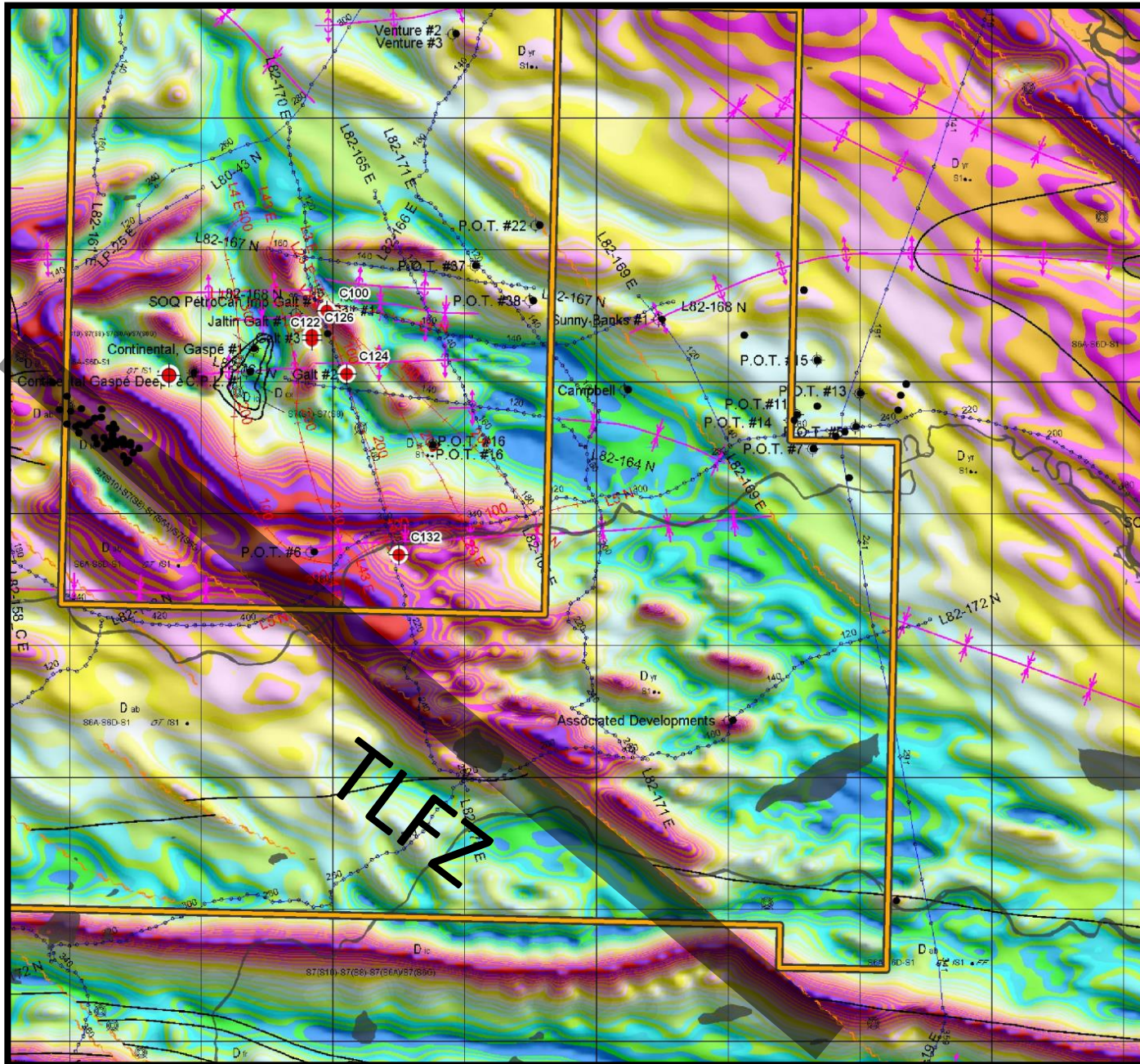
# Multiple deformation in strike-slip zone

- Galt field is located in the deformation corridor of the Third-Lake Fault Zone (dextral strike-slip).





# Multiple deformation in strike-slip zone



- Galt field is located in the deformation corridor of the Third-Lake Fault Zone (dextral strike-slip).
- In the deformation zone at Galt a wide variety of structures is observed :
  - Folds (anticline and syncline);
  - Vertical faults;
  - Oblique faults;
  - High displacement faulting;
  - Low displacement faulting
  - Reverse faults;
  - Normal faults;
  - Strike-slip movement.



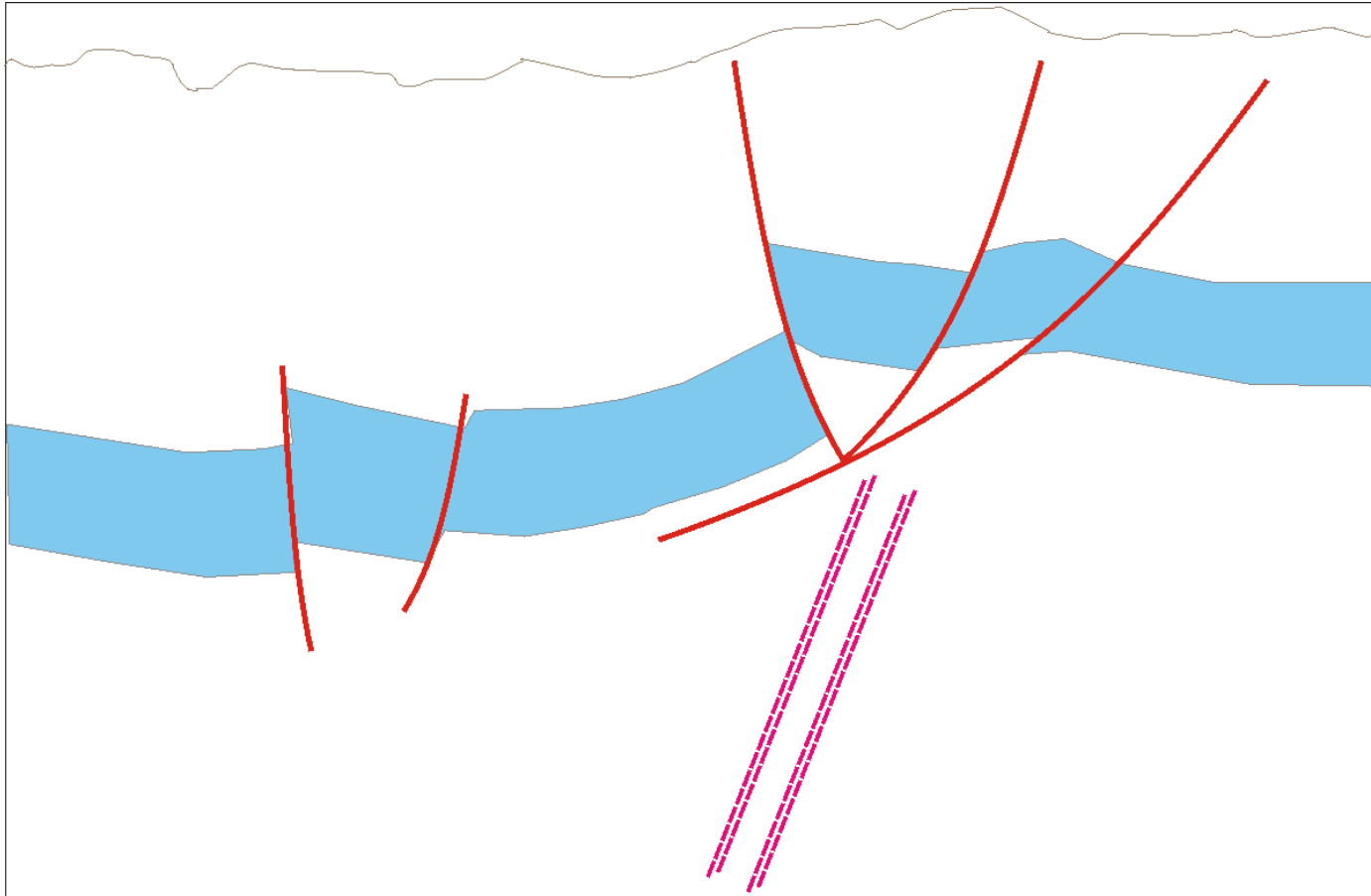
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N. CHRISTIE-BLICK AND K. T. BIDDLE (1985) DEFORMATION AND BASIN FORMATION ALONG STRIKE-SLIP FAULTS. SEPM

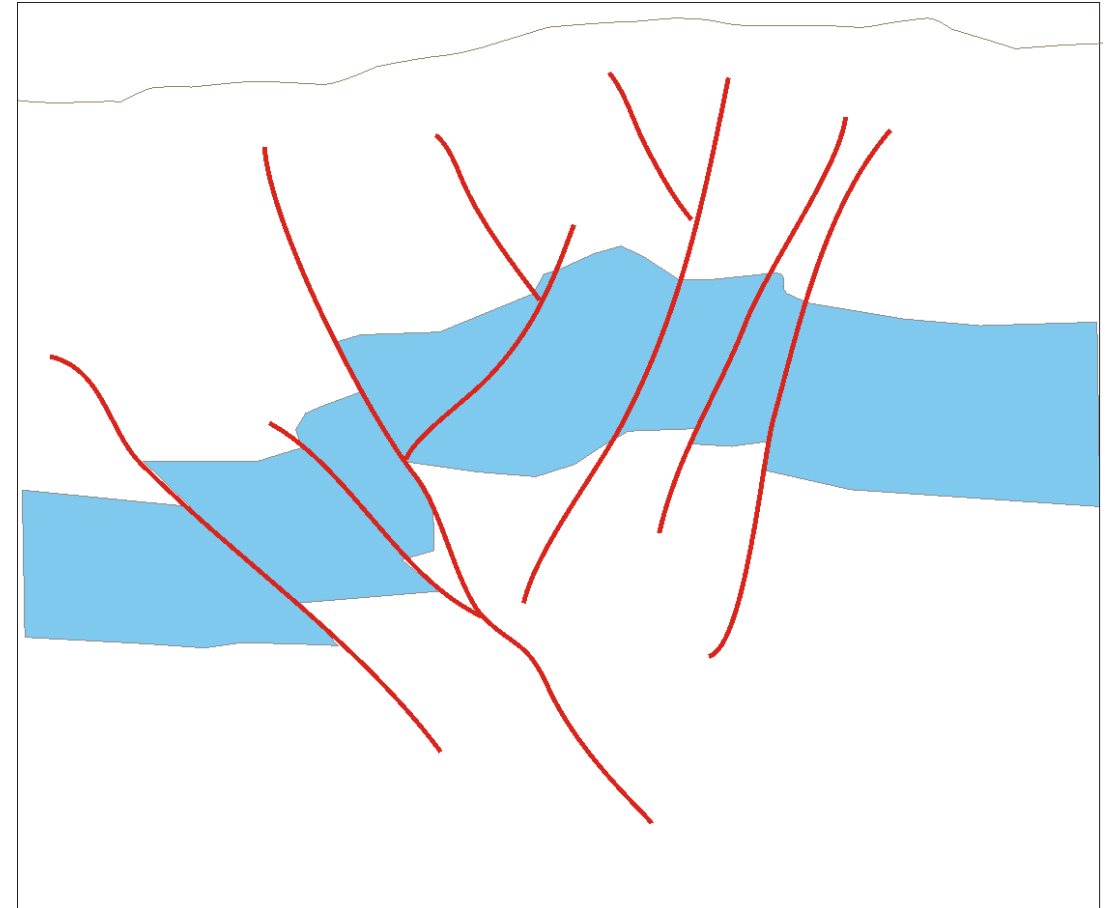


# 2D seismic vs 3D seismic

2D

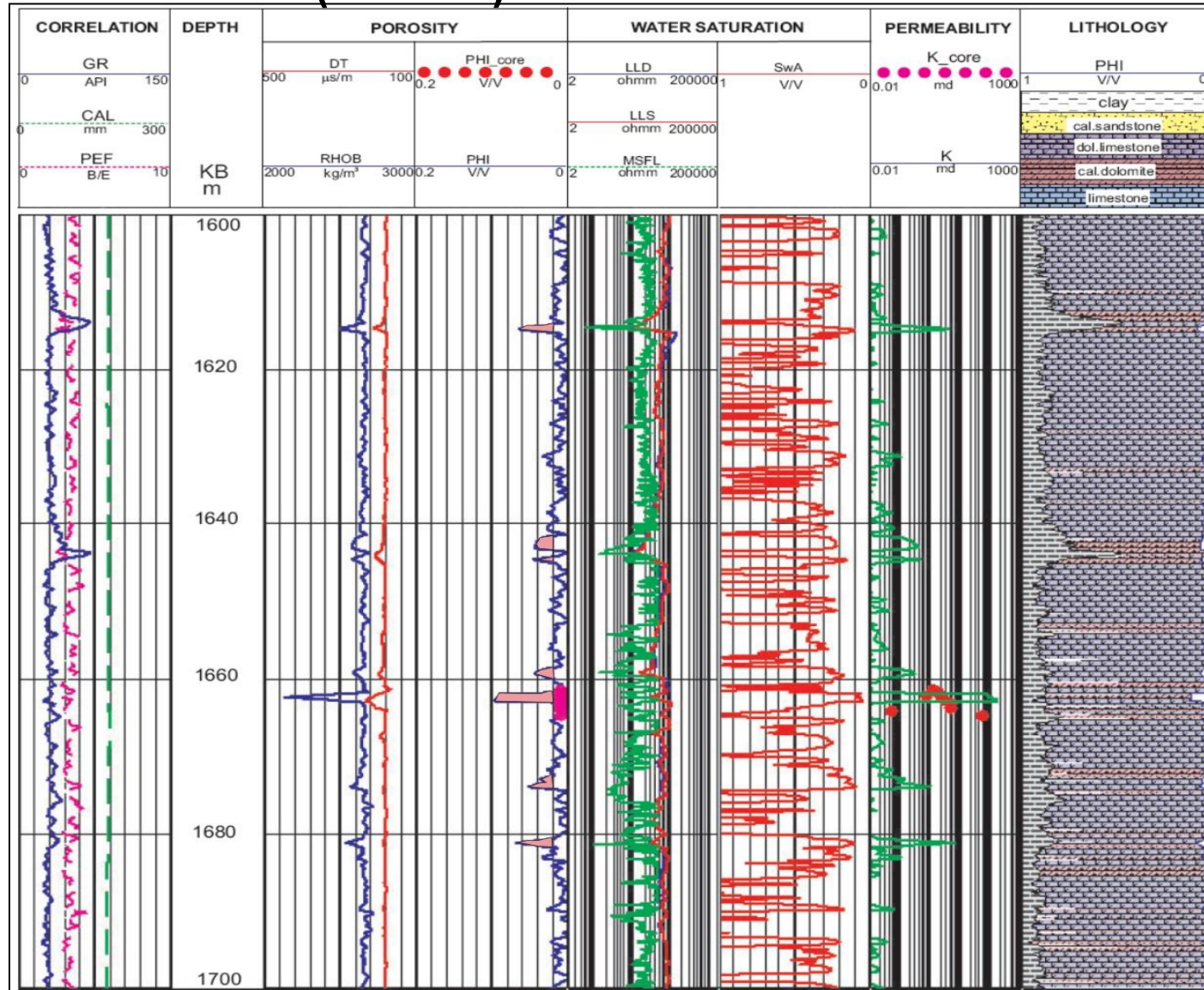


3D



# Stratigraphic control on fracturing

## Well C100 (Galt #1)



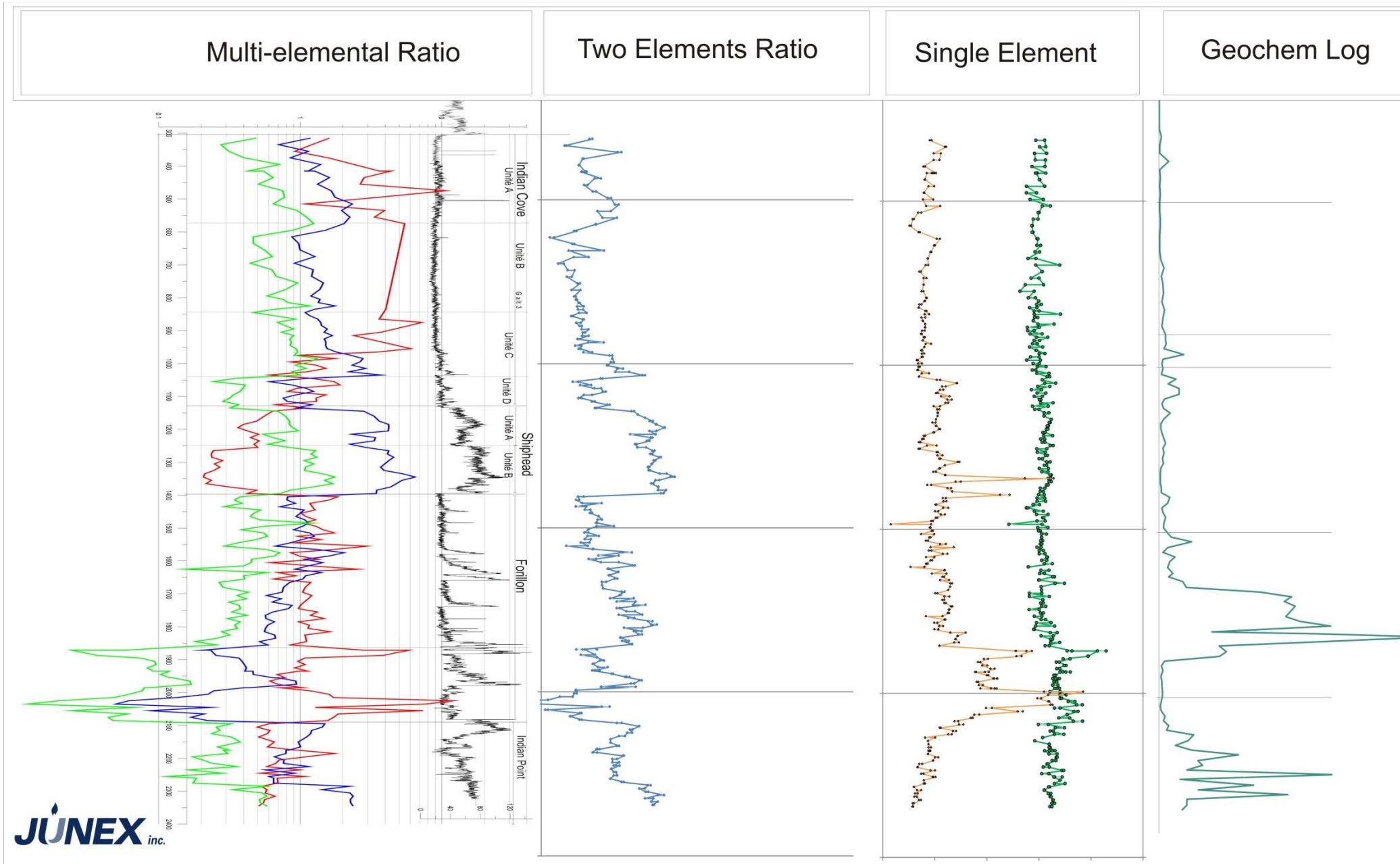
Highest perm related to dolomitic horizon ?



Well C139 (Galt #4)  
SWC in the Forillon Fm



# Stratigraphic works with XRF



## • XRF log :

- Multi-elemental ratios use to identify sub-unit and locate precisely the BHA while drilling ;
- Two element ratios help the facies correlation between wells;
- Single element concentration give better understanding of geological event encountered in the sequence (fault, unconformity, intrusives).

## – Geochem Log :

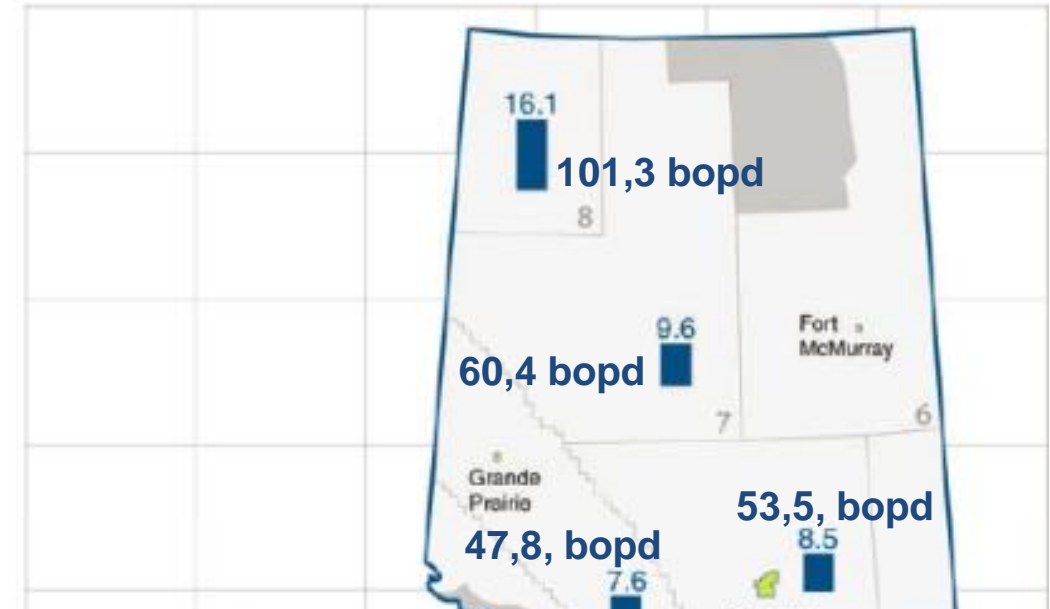
- Correlation with reservoir zones.

# Significance of the Galt Conventional Oil Discovery

*Galt #4HZ - From the test performed in 2015 (no stimulation of any type) :*

*Commercial production rates recorded during testing (up to 396 BOPD) with a 30 day average of 161 bopd.*

*Compare the numbers  
available for Galt discovery  
from the numbers published  
in Canadian mature basins.*



**In Alberta, a new well producing conventional oil  
at a daily rate exceeding 100 bopd  
will be considered as excellent**



Source : Petroleum Services Association of Canada



# The next challenges

- Structural model :
  - Fine-tuning of the subtle geometry
  - Improve the understanding about the timing of different structures
- Oil geochemistry :
  - Reasons for the variation in the oil properties
  - Identification of the source-rock(s)
- Reservoir extension



# Conclusions

## *Galt Conventional Light Oil Discovery is Significant*

- *Junex's technical team used a variety of tools to reduce the exploration risk in frontier basin :*
  - *Formation micro-imaging tool to characterize the reservoir ;*
  - *Detailed and 3D seismic to increase the understanding of the complex structure geometry;*
  - *XRF tool to enhance the control and the definition of the reservoir stratigraphy.*
- *Production test – oil production rates are highest ever seen in Quebec & translate into a commercial level of oil production;*
- *Entirely realized by Junex, from A to Z, Galt discovery demonstrate the success of the exploration strategy developed by Junex's management and technical teams;*
- *First horizontal oil exploration well ever drilled by industry in Quebec;*
- *Galt No. 4 Horizontal Well Oil Discovery – Milestone for Junex and for Quebec;*
- *Sizeable – compares very favorably with largest conventional light oil pools in carbonate reservoirs in western Canada (557 million bbls OIIP (NSAI P50));*
- *Delineation program underway (Horizontal exploration wells & testing, 37 km<sup>2</sup> 3D seismic interpretation) in view of production lease request late 2016.*



# ***Merci, gràcies, gracias, thank you!***



## ***Acknowledgments***

- Junex's technical staff and management;
- Operation crews on the field;
- Project partner;
- Financial partners and investors;
- Researchers at Geological Survey and National Research Institute.

# ***ICE Barcelona***

**AAPG|SEG**  
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3-6 April • Barcelona, Spain



# Junex's Galt Light Oil Discovery

**Birth of a new major play  
in eastern Canada**

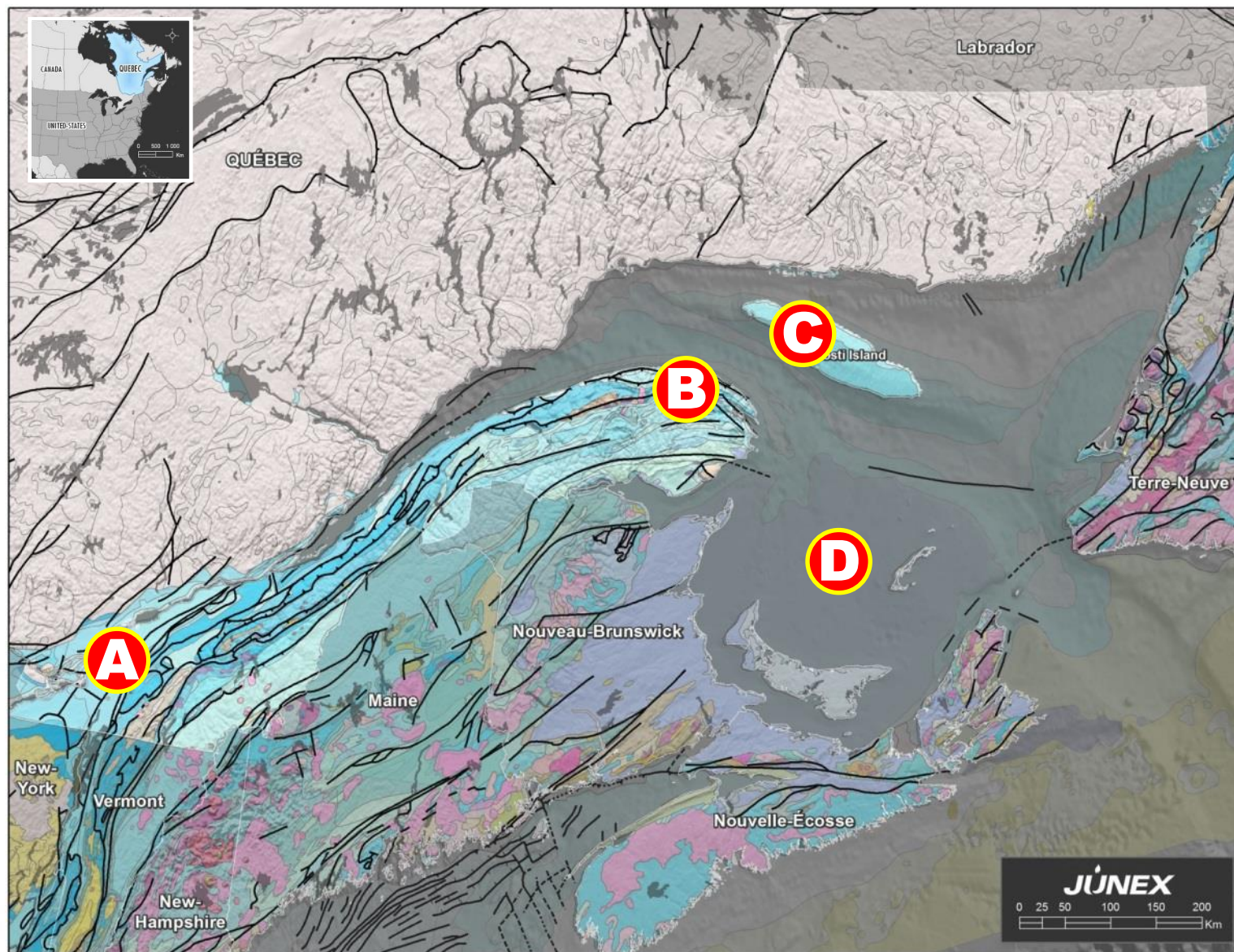


## **Additional information**

- Quebec Oil and Gas Potential;
- Reservoir Facies;
- Field Discovery History;
- Resource Assessment.



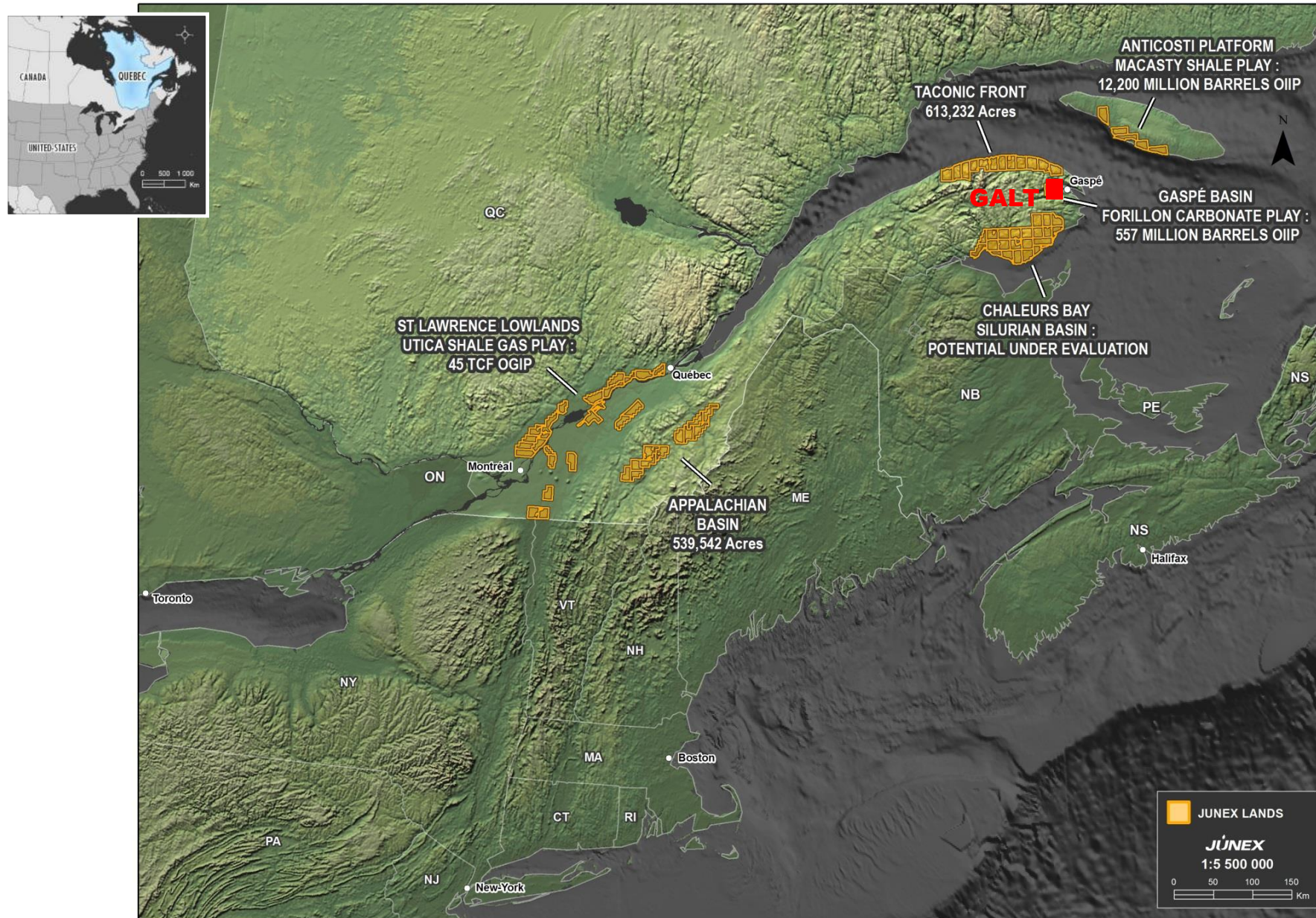
# Quebec Oil and Gas Potential (1)



- A. According to a study published in 2012 by Université Laval, the potential recoverable natural gas contained in the Utica shale vary from 22 to 47 TCF (ie 170 years of current consumption Quebec);
- B. In eastern Gaspé, the findings of three reports from independent experts are used to estimate that over 50 million barrels of oil would be recoverable on a total potential of 650 million barrels of oil initially in place;
- C. According to two studies by independent experts, the total amount of oil initially in place stored in the shale Macasty under the Anticosti Island exceed 40 billion barrels;
- D. In 2009, Geological Survey of Canada an open-file reported an hydrocarbon potential of 39 Tcf or 1,5 billion barrels for the Gulf of St. Lawrence area (Maritimes Basin).



# Quebec Oil and Gas Potential (2)

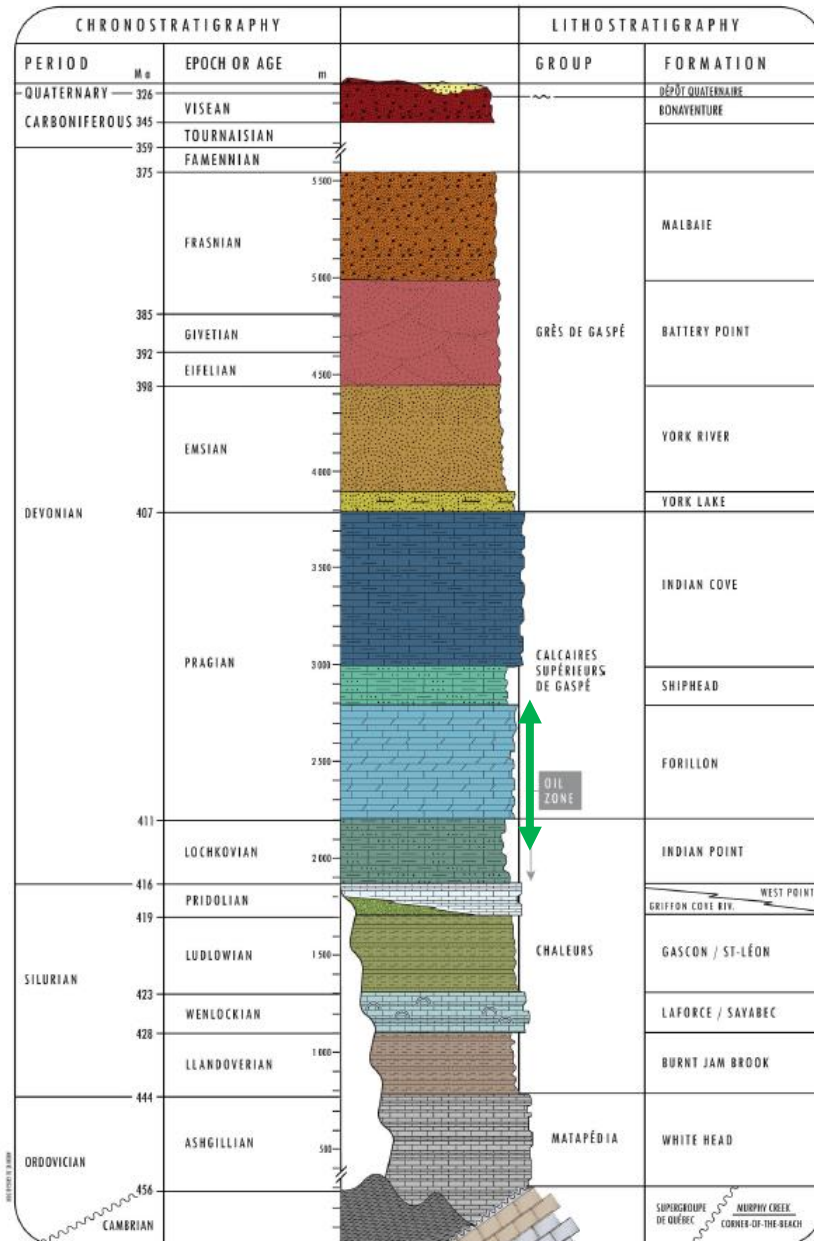


## Major onshore plays and recent exploration success

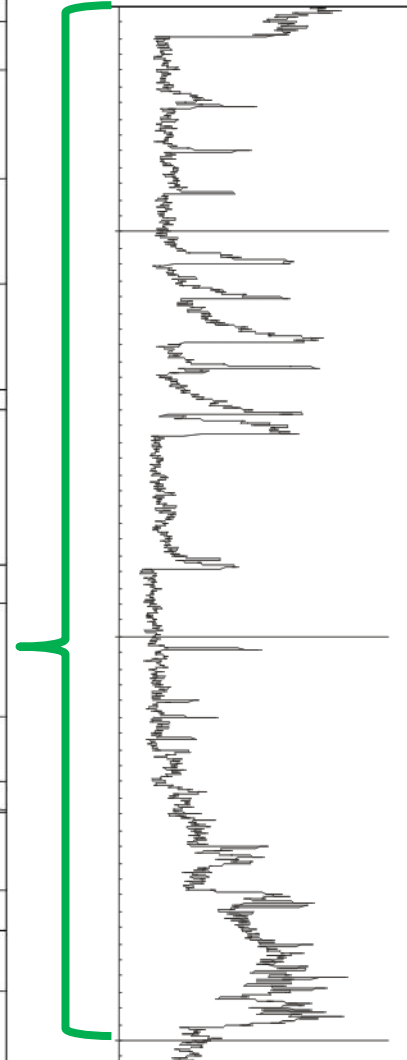
- Utica Shale Gas;
- Ordovician TBR and Beekmantown Carbonates;
- Appalachian Basin Shales;
- Chaleurs Bay Silurian Carbonates and Clastics;
- Taconic Front overthrust belt;
- Gaspé Basin Devonian Carbonates and Clastics;
- Macasty Liquid-Rich Shales



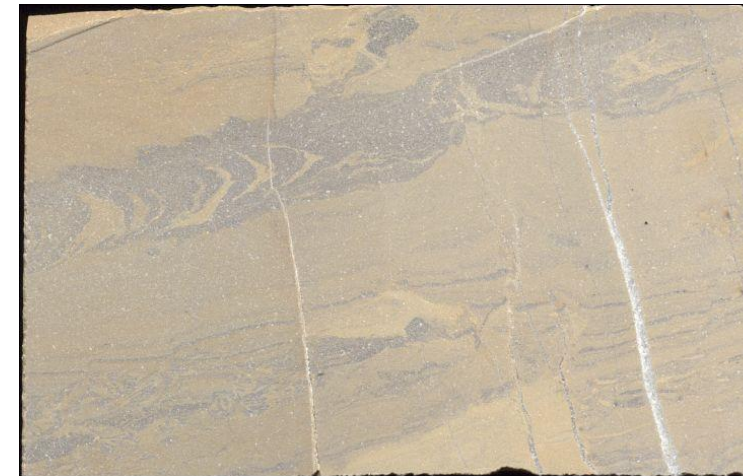
# Gaspé Basin - Forillon Reservoir Facies



Stratigraphic column of Eastern Gaspesian Peninsula, Québec, Canada



Coarse grainstone facies



Fine dolostone facies



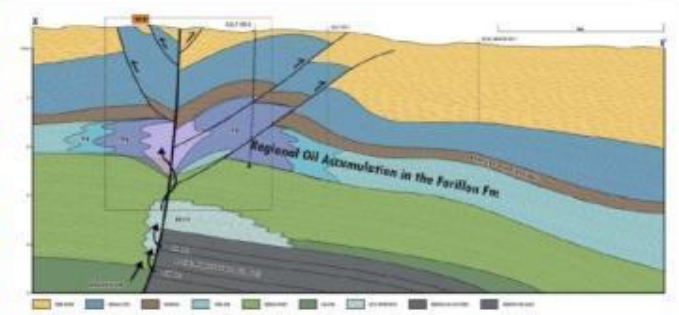
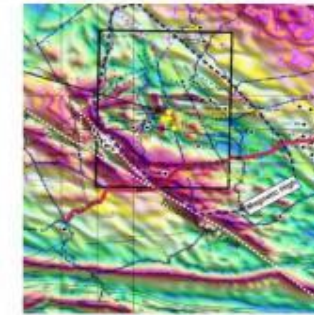
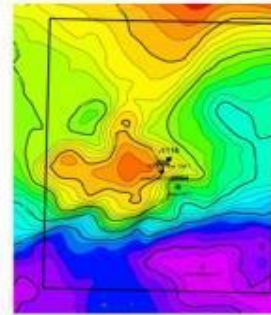
Coarse dolostone facies



# Galt Light Oil Discovery – Recent History (1)

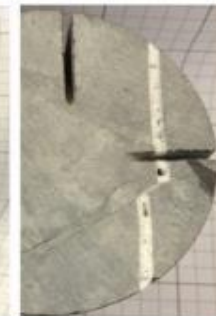
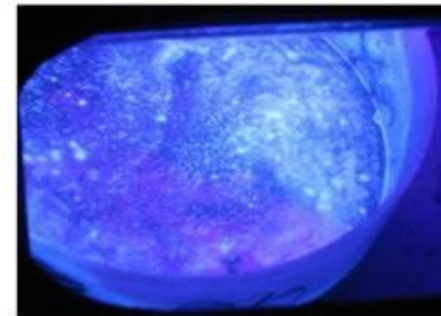
2008

**Detailed seismic survey on the Galt structure.  
Review of the structural and exploration model.**



2009

**The technical analysis focuses on the study of relationships between natural fractures and the accumulation of oil.**



## TIMELINE OF THE GALT PROJECT

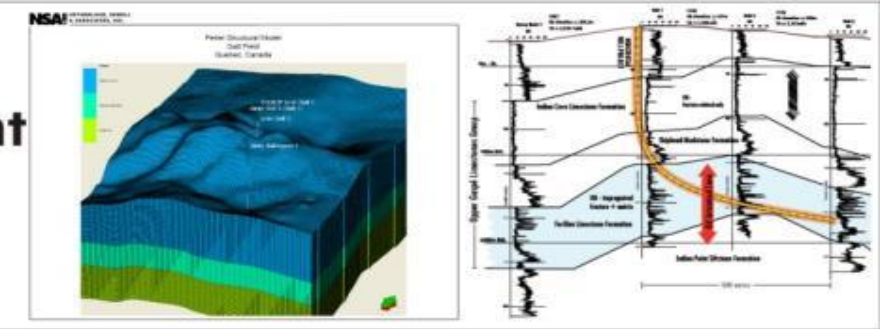




# Galt Light Oil Discovery – Recent History (2)

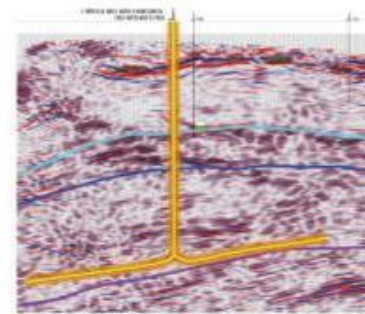
2010

Based on well data, geochemistry and geophysical coverage an important resource in-place was estimated by independant expert.



2011

After technical revision, it was decided to go with a horizontal drilling project in order to optimized the production capacity of fractures.



## TIMELINE OF THE GALT PROJECT





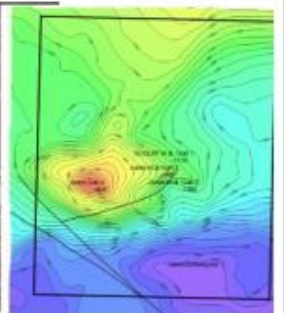
# Galt Light Oil Discovery – Recent History (3)

2012

September 2012

Junex et al. Galt #4 Vertical Test Well.

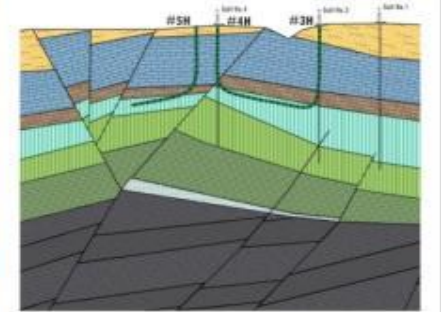
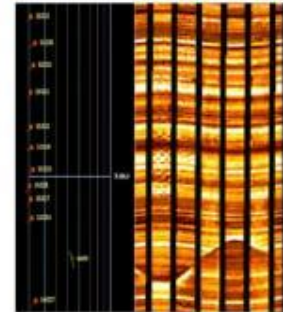
The main objective is to acquire the missing data before implementation of the horizontal well.



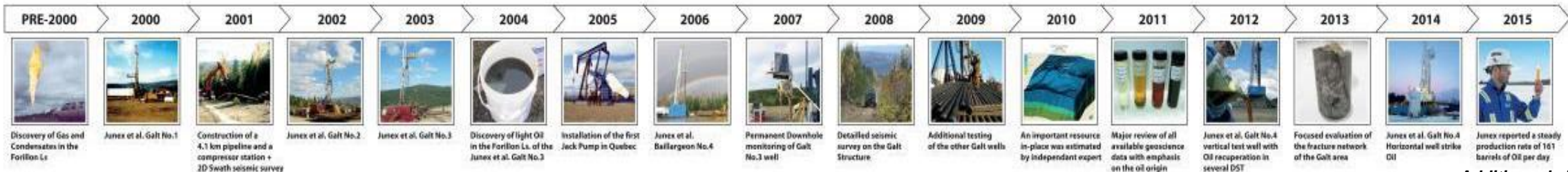
2013

Oil shows and recovery of oil in several DST confirmed the location of the #4 horizontal leg.

A thorough review of the image log and structural data was conducted to finalize the design of the HZ well.



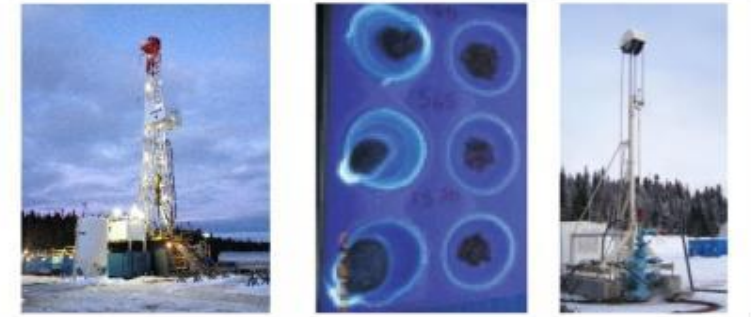
## TIMELINE OF THE GALT PROJECT





# Galt Light Oil Discovery – Recent History (4)

**2014** Junex et al Galt #4 HZ spudded in October 2014.  
On November 27, 2014, Junex announced that it has struck several oil-saturated zones in the Galt #4 horizontal well.

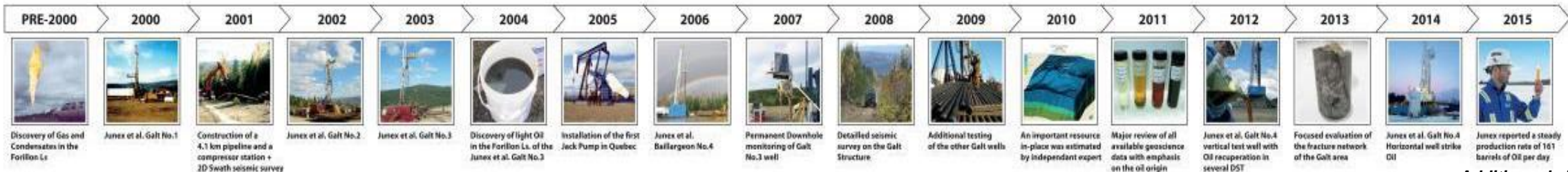


**2015** Junex reported a steady production rate of 161 barrels of oil per day during the final six days of its 14-day production test in its Galt No. 4 HZ well and produced a total volume of 2,017 barrels of light sweet crude oil.



**Following rapid pressure build-up, Junex starts a longer production test at its Galt #4 horizontal well.**

## TIMELINE OF THE GALT PROJECT



# Galt Light Oil Discovery – Update and next steps

Galt #5 Horizontal well started drilling on July 24th and was drilled to a total measured depth of 2,582 metres. This well was drilled in closer proximity to the Troisième Lac Fault zone than previous wells drilled by Junex at Galt.

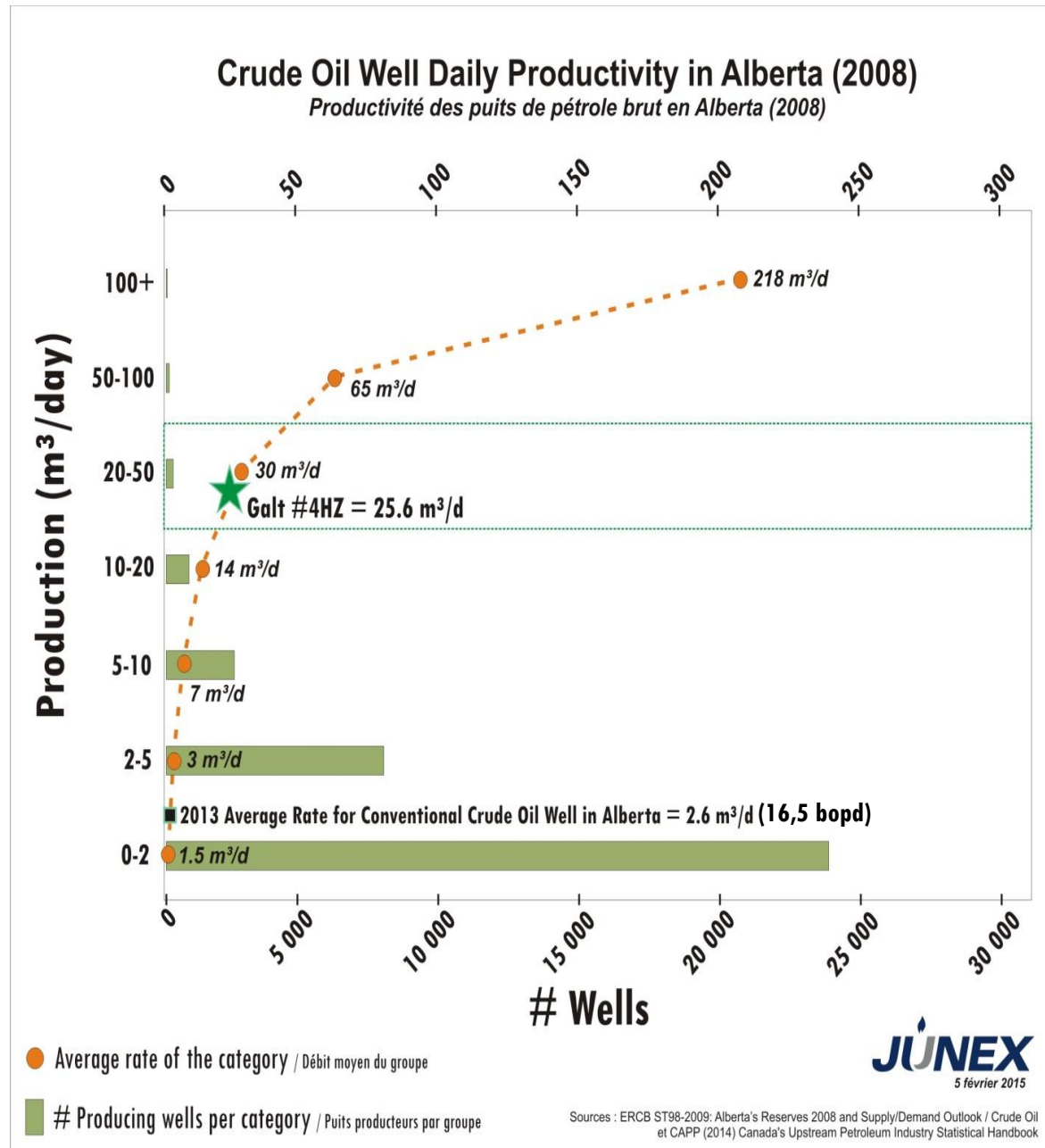
After having drilled the vertical portion of the well and immediately prior to installing the intermediate casing therein, a drillstem test ("DST") was performed in the upper portion of the Forillon Limestone reservoir from which a column of 475 meters (8 barrels) of light crude oil was recovered in the drill string during a total flow period of 1.1 hours. The intermediate casing was then installed followed by the drilling of a horizontal leg into the lower portion of the Forillon Limestone and the upper portion of the Indian Point Formation, both of which have recognized oil potential at Galt.

In March 2015, Junex received a Completion Permit to proceed with the evaluation of its Galt No. 5 Horizontal well. Junex intends to start field operations in the Galt No. 5 well this spring to further evaluate the horizontal leg where abundant natural fractures and oil shows were recorded in the lower portion of the Forillon Limestone and the upper portion of the Indian Point Formation.

3D Seismic Program : 37 km<sup>2</sup> 3D seismic survey was acquired in Fall 2015 to locate future horizontal wells on the Galt Oil property, including the Galt #6HZ and #7HZ wells that form part of the current phase of activity at Galt. This new seismic data will also aid in better defining the nature of the reservoir in the vicinity of the Galt #4HZ and #HZ wells and should provide valuable input about future operations in these wells should they be required.



# Significance of the Galt Conventional Oil Discovery



Galt #4HZ results place the well in the top first **1% conventional oil producing wells** in Alberta

# Galt : Gaspésie

## 557 million barrels of oil initially in place (OOIP resources)

- 476.2 million barrels of Undiscovered OIIP
- 80.8 million barrels of Discovered Contingent OOIP
  - Proved + Probable Reserves (2P) of 23,000 barrels.
- 6 wells drilled since 2001 (All Junex operated);
- Almost 20,000 barrels of light oil extracted from the Forillon Formation;
- Geological concept analogous to producing formations in Western Canada and in the USA;
- Objective for 2016 : Reaching economic production
  - ***Horizontal drilling of an additionnal well;***
  - ***Extended production test on potential reservoir zones.***

40°API Crude Oil



**Results of the first production tests:**  
**Junex Galt 4 HZ, drilled horizontally for a distance of 1503 meters**  
**produced 4735 barrels of oil in 1 month**  
**(7,200 barrels of oil in 45 days)**