Geomechanical Properties of the Upper Ordovician Macasty Shale and its Caprock, Anticosti Island: A Regional Evaluation for a Promising Tight Oil Play*

Denis Lavoie[1] and Stephan Séjourné[2]

Search and Discovery Article #80542 (2016)**
Posted August 8, 2016

*Adapted from oral presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016
**Datapages © 2016 Serial rights given by author. For all other rights contact author directly.

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

Abstract

The geological integrity of the cap rock overlying targeted unconventional reservoirs is a theme that generates significant interest. On Anticosti Island (eastern Canada), the Upper Ordovician Macasty Shale is a current exploration target for its light oil and condensate potential with the first horizontal wells planned for summer 2016. The Geological Survey of Canada has recently carried out a regional evaluation of the geomechanical parameters (Young's modulus, Poisson ratio, Sh min) of the Macasty Shale and its Upper Ordovician – Lower Silurian caprock on the island to better understand their spatial variability and their controls. This study is based on the available petrophysical logs from the oil and gas wells drilled between 1960 and 2010 for conventional targets on the island and through a calibration with data from the only reference well on the island for which a sonic log of the S wave is available. A series of calibration tests were conducted to determine the best method to generate a synthetic sonic log of the S wave for each of the wells considered. On the basis of the available regional data and the parameters required for the calibrations, eight wells were selected for the regional geomechanical study. At the scale of the well, the results highlight the presence of clear mechanical contrasts between the Macasty Shale and the overlying and underlying formations. These mechanical contrasts are reflected in the existence of barriers to the propagation of hydraulic fractures outside the Macasty Shale. Furthermore, the analysis of two wells located on both sides of a regional-scale fault, the Jupiter Fault, reveals that the vicinity of the fault does not affect significantly the mechanical properties of the caprock. The closer well was located in the footwall, about 300 m from the fault. At a regional scale the results demonstrate a remarkable homogeneity from a well to another, except in the south-central part of the island where a barrier to the hydraulic fractures is identified stratigraphically

higher in the caprock rather than immediately above the Macasty Shale. This study demonstrates that it is possible to extract regional geomechanical parameters from a very limited set of data in a frontier basin.

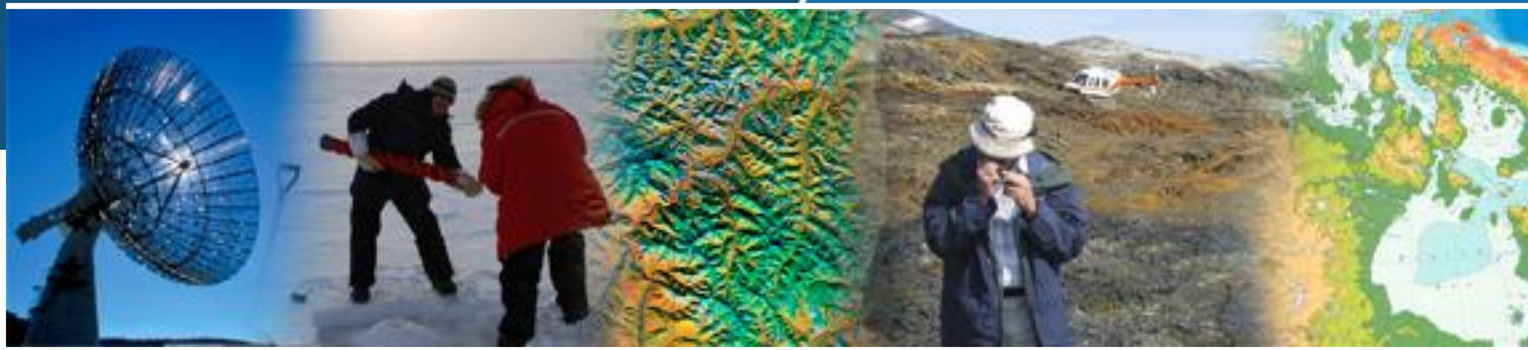
References Cited

Chen, Z., D. Lavoie, C. Jiang, M.J. Duchesne, and M. Malo, 2016, Geological Characteristics and Petroleum Resource Assessment of the Macasty Formation, Anticosti Island, Quebec, Canada: Geological Survey of Canada, Open File 8018, 67 p. doi:10.4095/297865

Eaton, B.A., 1969, Fracture Gradient Prediction and its Applications in Oilfield Operations: Journal of Petroleum Technology, v. 21/10, p. 1353–1360.

Séjourné, S., 2015, Étude géomécanique de la Formation de Macasty et de sa couverture dans un puits pétrolier et gazier (Pétrolia/Corridor Chaloupe No. 1), Île d’Anticosti, Québec. Commission géologique du Canada, Dossier Public 7892, 52 p.

Séjourné, S., 2015, Étude géomécanique régionale de la Formation de Macasty et de sa couverture d’après les puits pétroliers et gaziers de l’Île d’Anticosti, Québec. Commission géologique du Canada, Dossier Public 7907, 114 p.



Geomechanical properties of the Upper Ordovician Macasty Shale and its caprock, Anticosti Island; A regional evaluation for a promising tight oil play.

Denis Lavoie[1] and Stephan Séjourné[2]

1. Geological Survey of Canada – Quebec Division
2. Consulting Geologist, Montréal

Ressources naturelles Canada | Natural Resources Canada

Canada

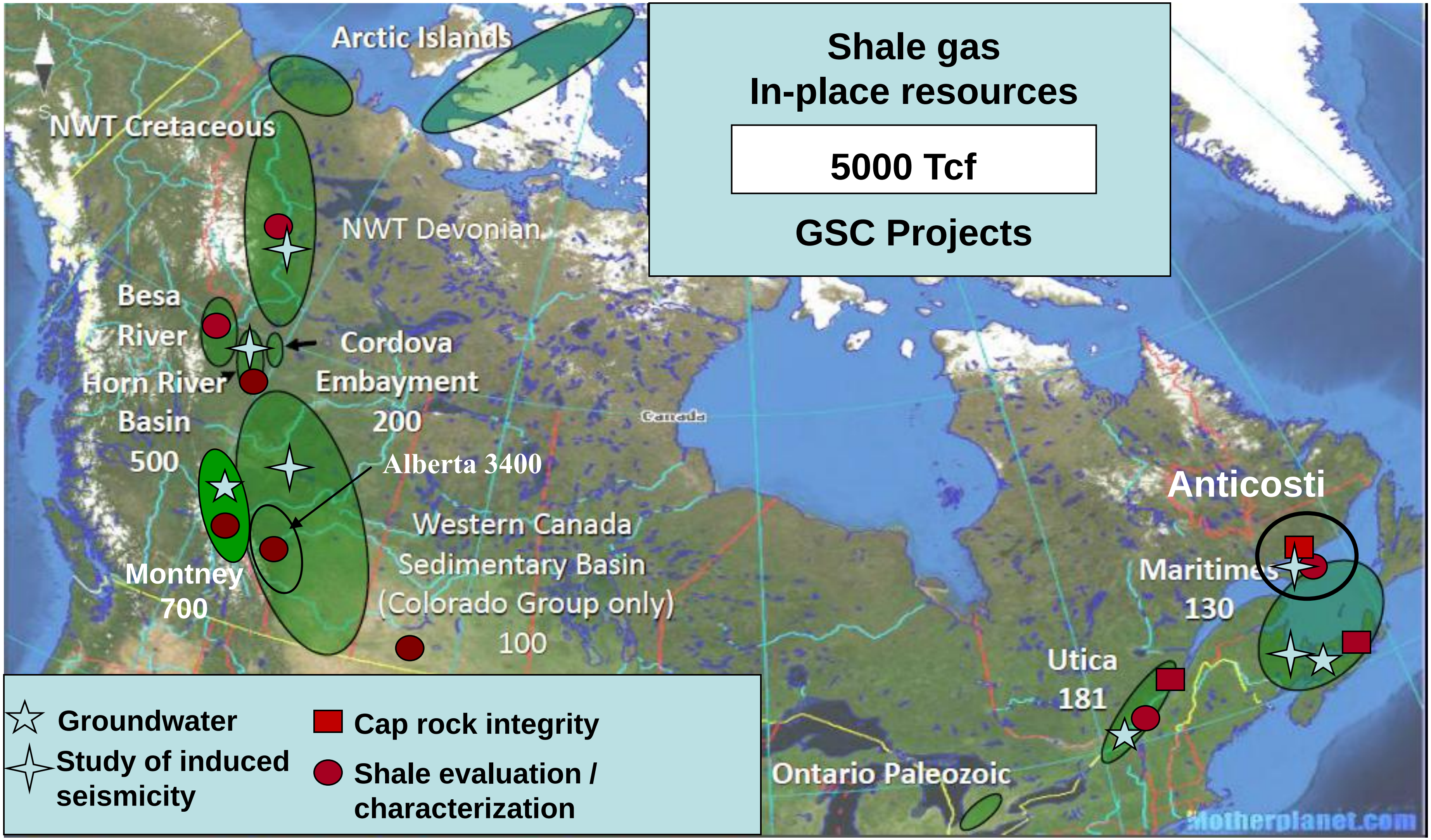
Shale gas / tight oil exploration in eastern Canada

- Shale gas / tight oil targets are identified in eastern Canada
  - Carboniferous Albert Shale / Horton Bluff in NB and NS
  - Upper Ordovician Utica Shale in southern QC
  - Upper Ordovician Macasty Shale on Anticosti Island, QC

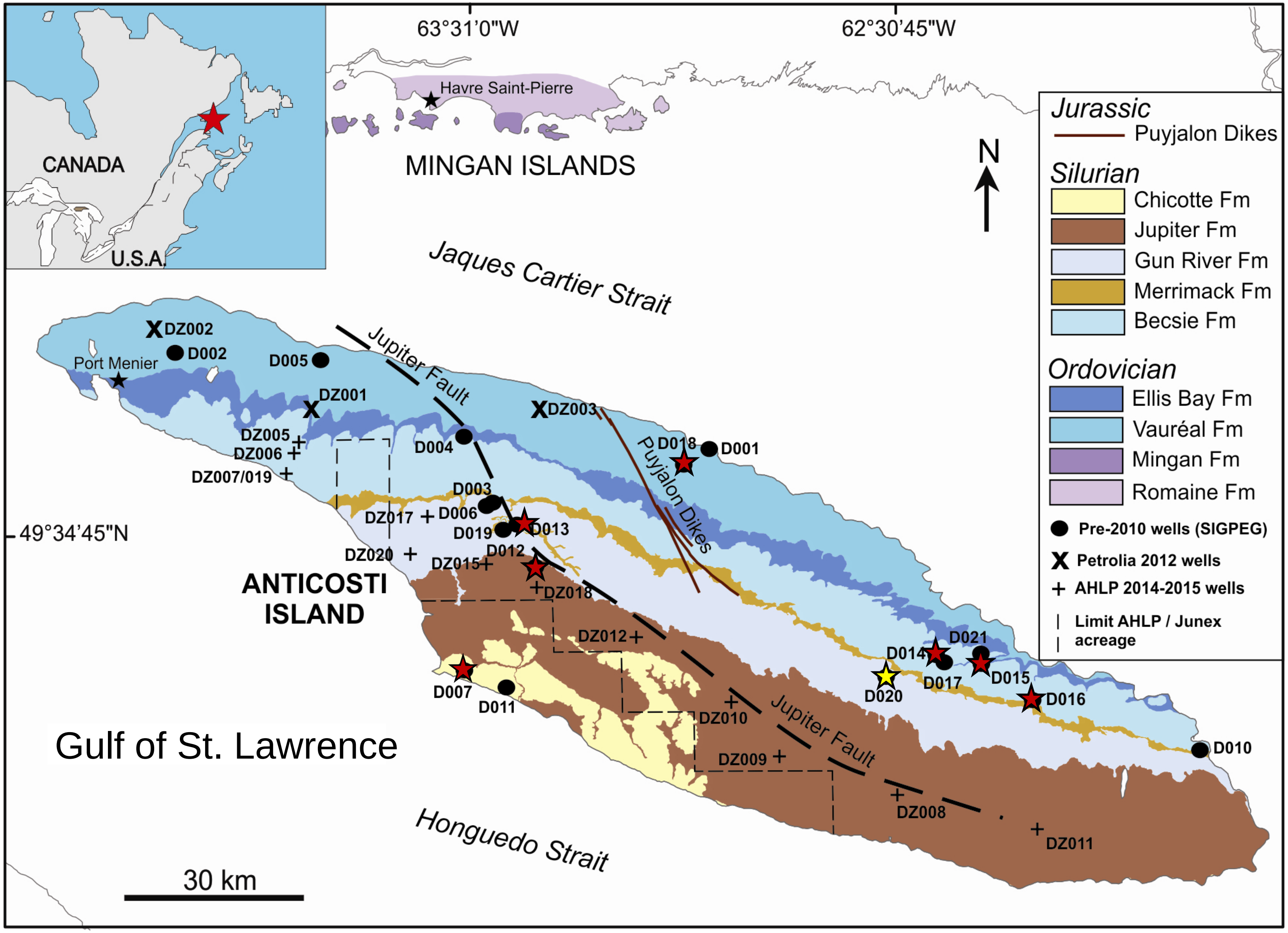
- Exploration / development was stopped in 2010 (QC) and 2015 (NB)

- The main issue – perceived risk of contamination of groundwater from hydraulic fracturing

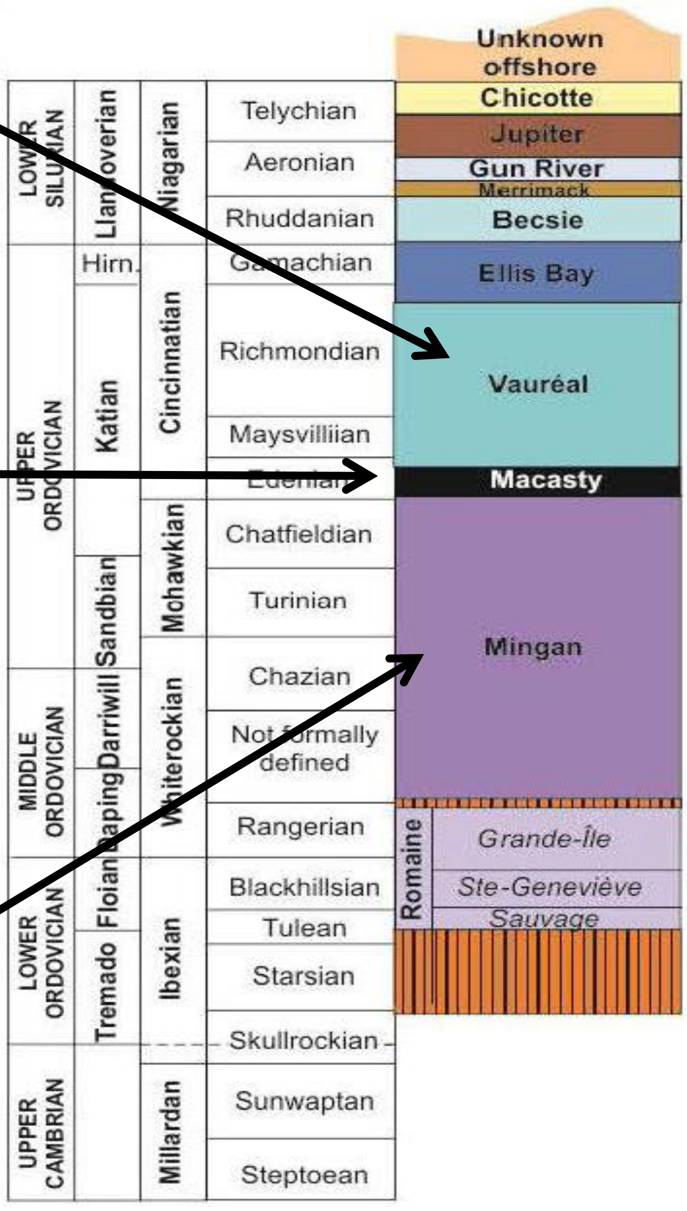
- The Geological Survey of Canada is carrying resource and environmental research on unconventional hydrocarbons since 2011.


Shale gas
In-place resources
5000 Tcf
GSC Projects
Arctic Islands
NWT Cretaceous
NWT Devonian
Besa River
Cordova Embayment 200
Horn River Basin 500
Alberta 3400
Western Canada Sedimentary Basin (Colorado Group only) 100
Montney 700
Anticosti
Maritimes 130
Utica 181
Ontario Paleozoic
Groundwater
Study of induced seismicity
Cap rock integrity
Shale evaluation / characterization

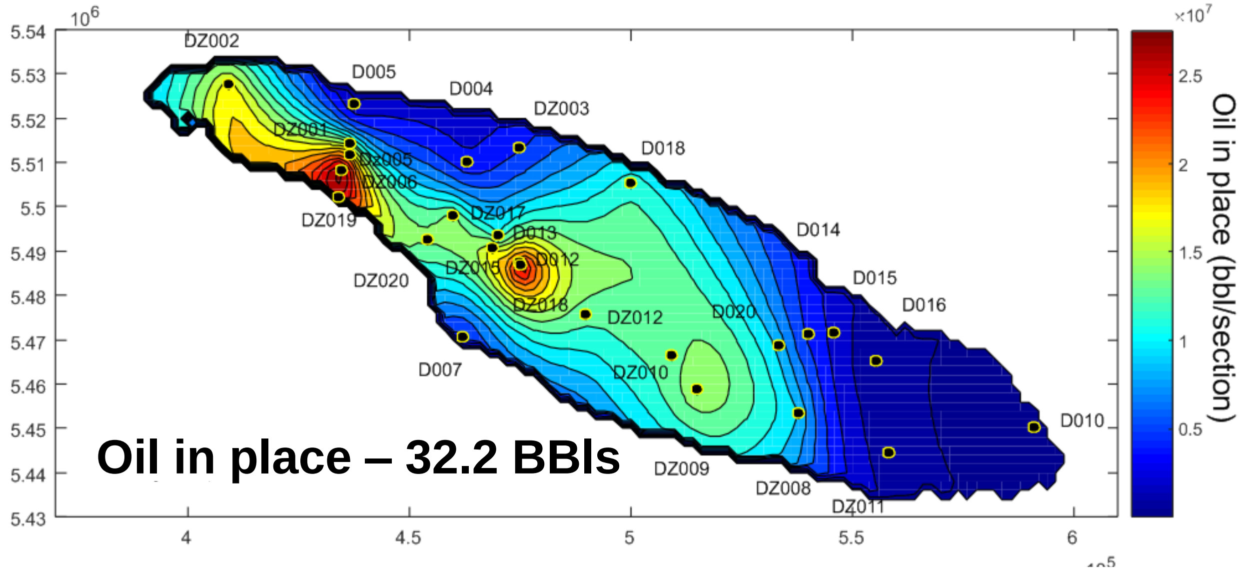
Local geology and studied wells

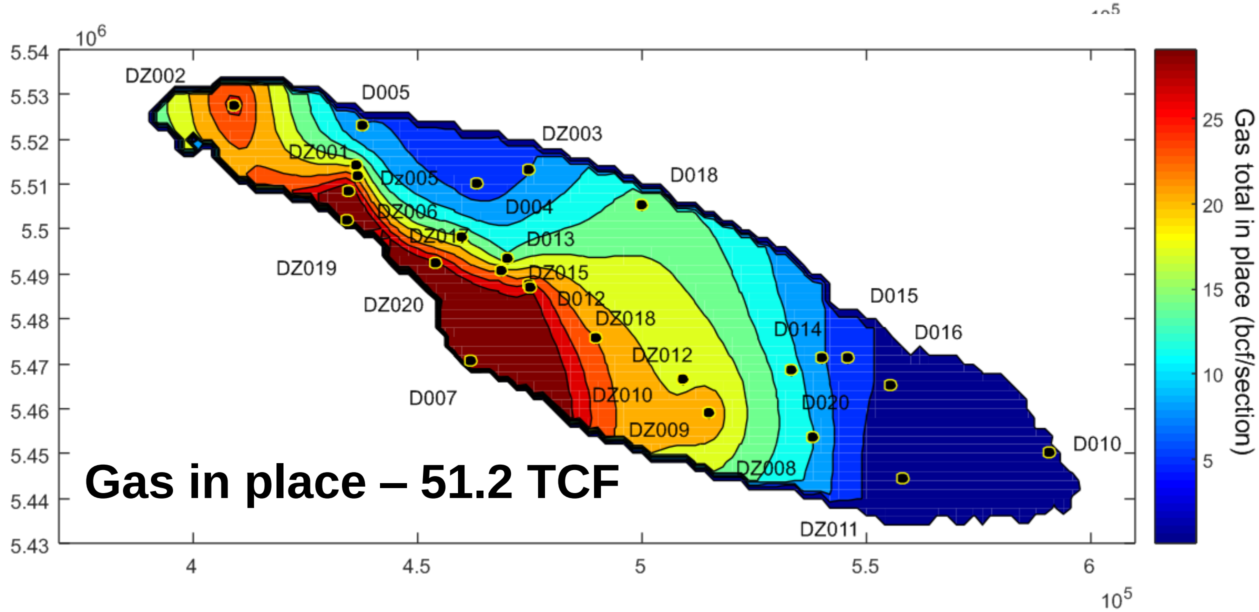


Anticosti Stratigraphy



In place oil and gas resources at P50 (04/2016)

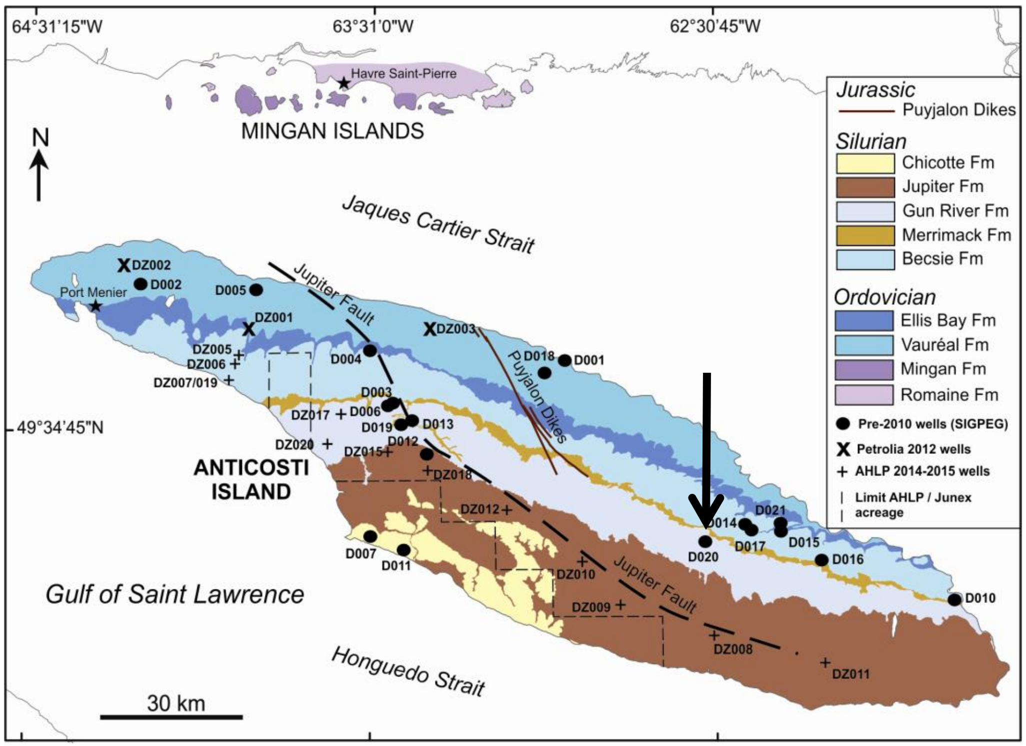


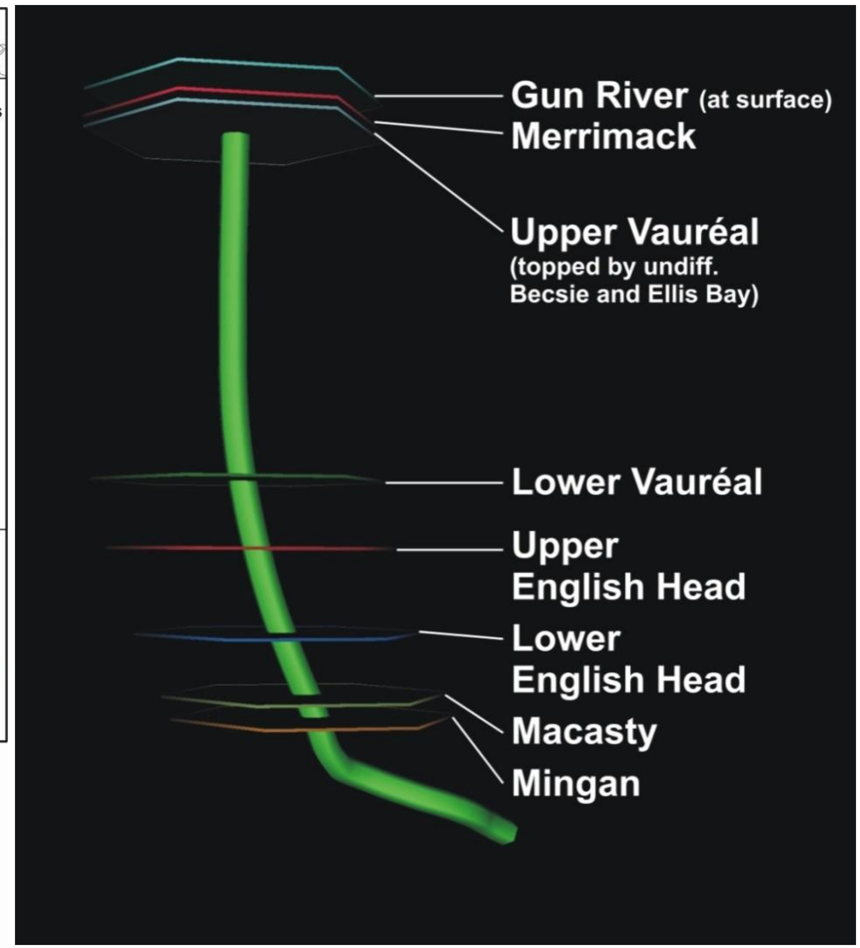


Chen et al. 2016,GSC Open File 8018

Only one well with S wave record

Trajectory and stratigraphy of D020

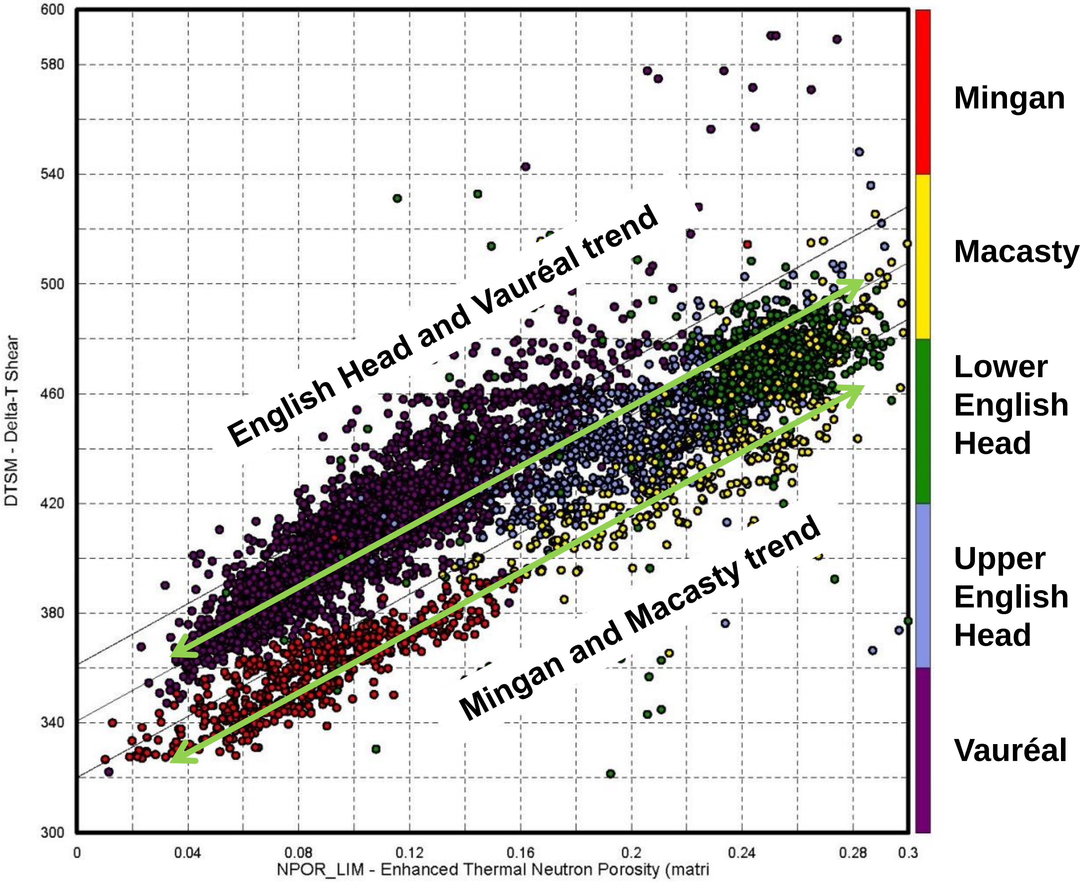




Construction of synthetic S wave

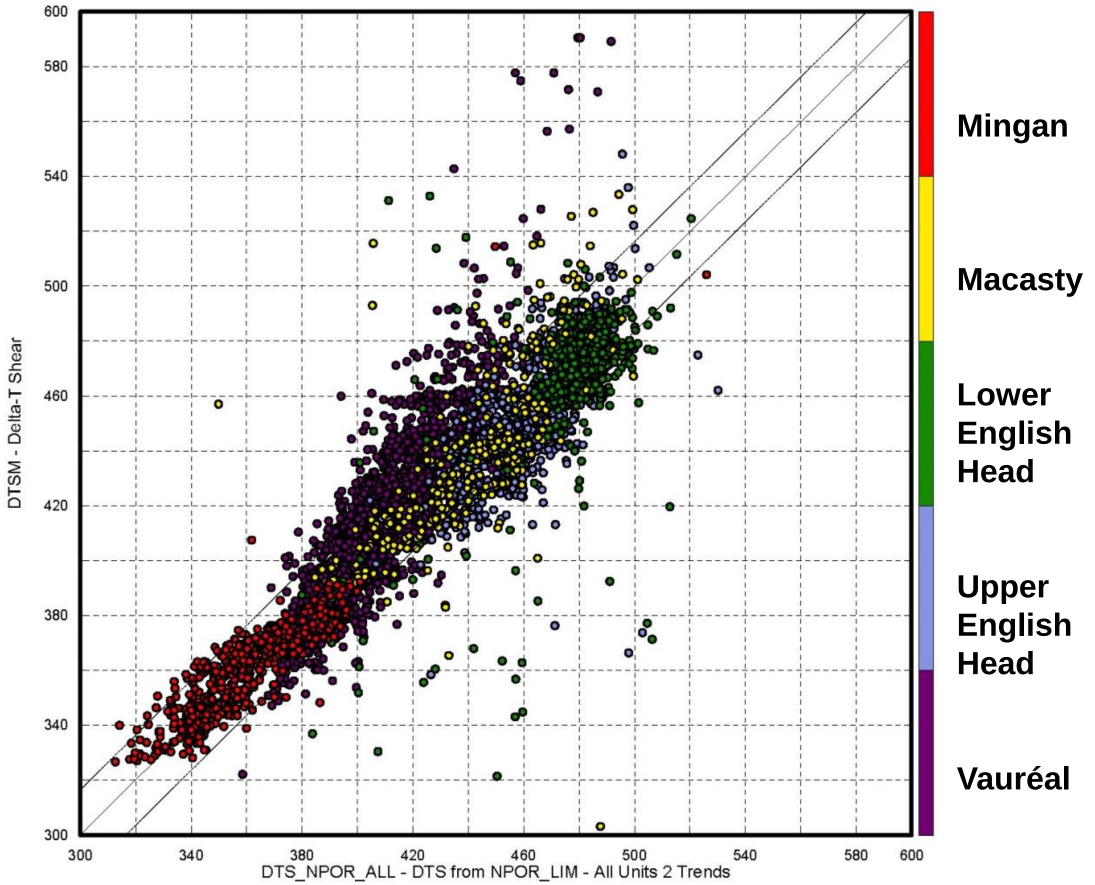
Example of correlation: raw DTS versus NPOR shows two separate trends:

1) Mingan and Macasty Fms (correlation coefficient of 0.949)
2) English Head and Vauréal Fms (correlation coefficient of 0.890)



Construction of synthetic S wave

The combination of the two correlations allows to calculate a synthetic DTS log derived from NPOR for the entire well. Synthetic vs raw DTS has a correlation coefficient of 0.912 using the NPOR log



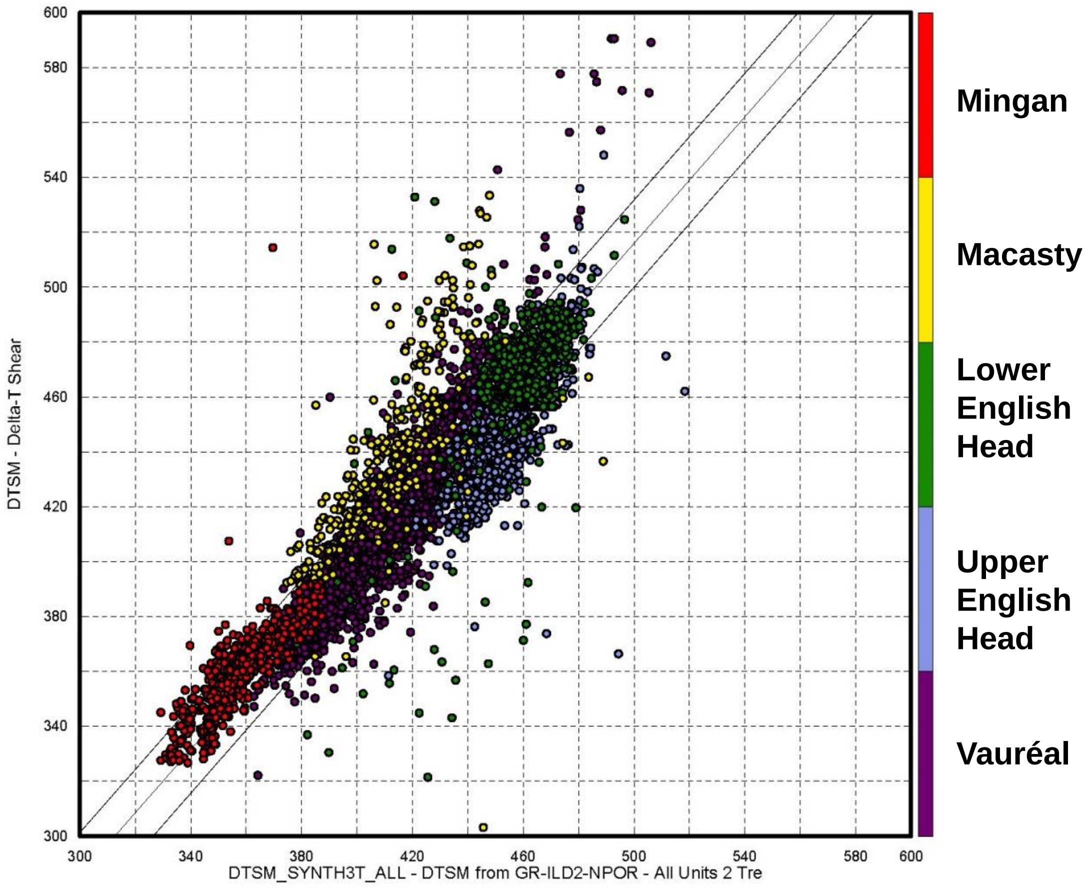
Construction of synthetic S wave

- The same technique is applied to calculate synthetic DTS and synthetic DTP from neutron porosity (NPOR), gamma ray (GR), deep resistivity (ILD) and bulk density (RHOB)
- In some cases some formations must be omitted (e.g. gas effect on resistivity influences DTP in the Macasty and in the Lower English Head)
- Each successful correlation is then integrated into a single equation that allows to calculate a synthetic DTS or a synthetic DTP
- In this case the bulk density curve was rejected because of the low correlation coefficients (0.748 for DTP and 0.684 for DTS). All other correlation coefficients range between 0.849 and 0.966. Thus the synthetic DTS and DTP have been calculated for the well D020 using three reference curves: NPOR, GR and ILD.

- The final synthetic sonic logs are then compared to the raw sonic logs for a last quality check:
    - For DTS, the final synthetic DTS versus the raw DTS has a coefficient of correlation of 0.917
    - For DTP, the final synthetic DTP versus the raw DTP has a coefficient of correlation of 0.937

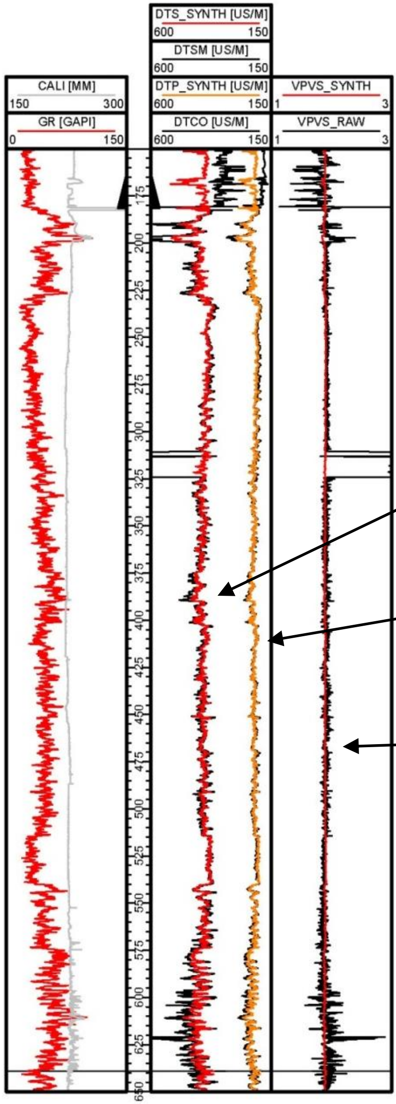
Construction of synthetic S wave

Quality check of the synthetic DTS by comparison with the raw DTS for well D020 (coefficient of correlation of 0.917)



Construction of synthetic S wave

Graphical comparison of the synthetic vs raw DTS, DTP and Vp/Vs values for the Vauréal interval (150-650 mKB MD)



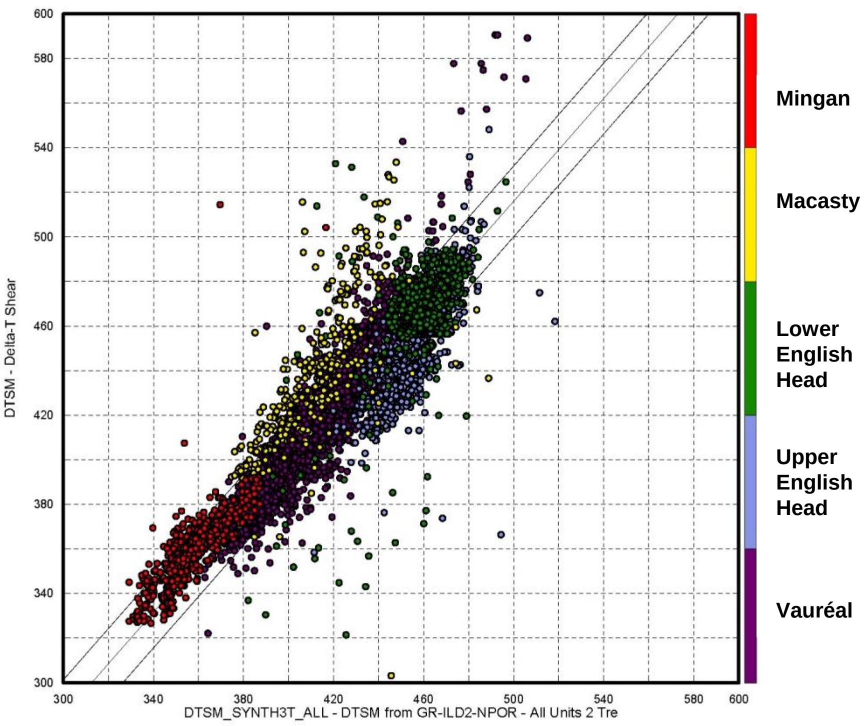
Instrumental error during the recording of the raw S wave corrected in the synthetics

DTS: raw (black) vs synthetic (red)

DTP: raw (black) vs synthetic (orange)

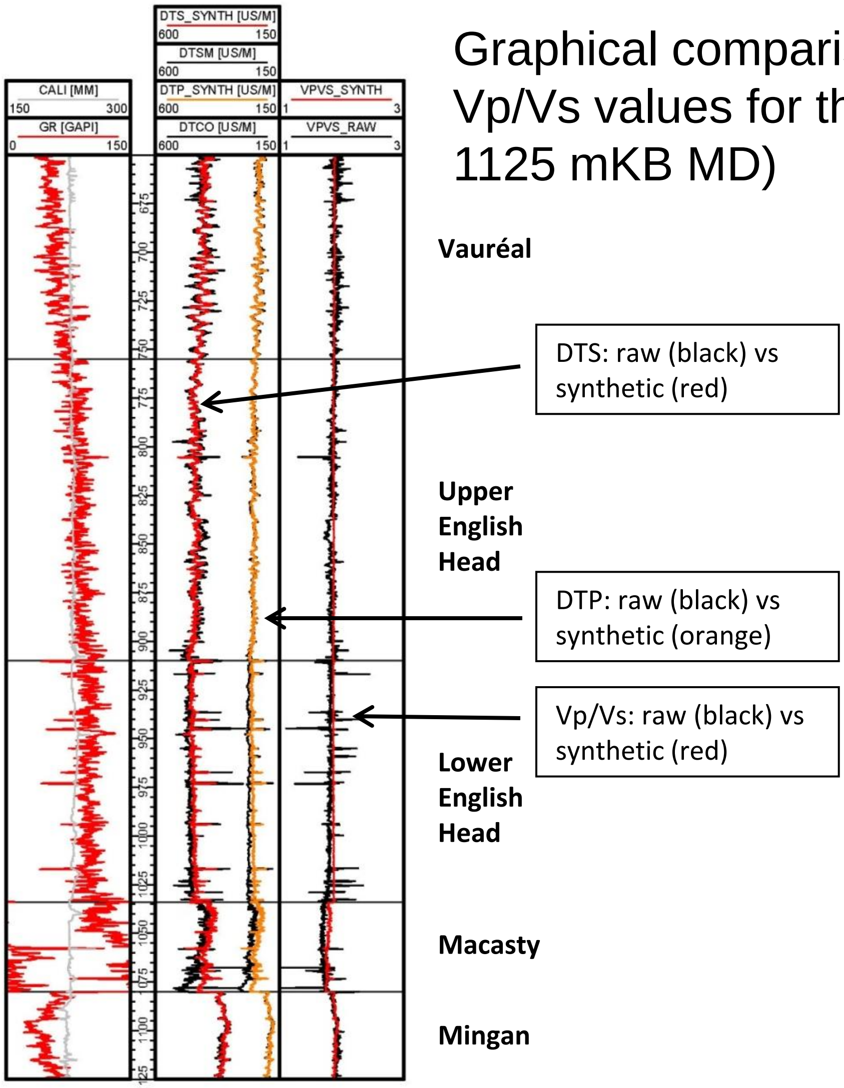
Vp/Vs: raw (black) vs synthetic (red)

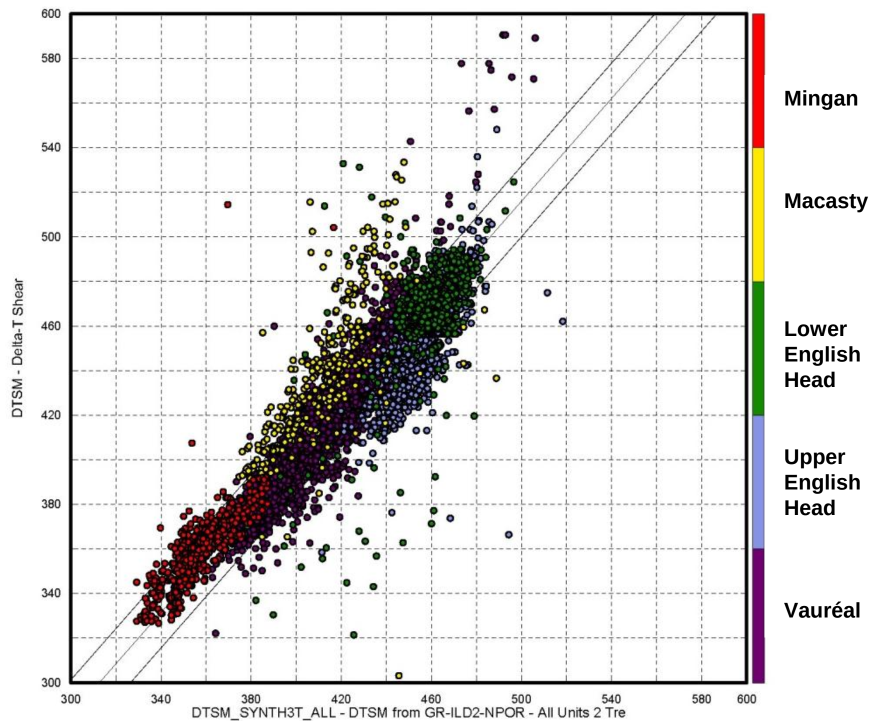
Increased irregularity of the borehole impacting both the raw P and S waves corrected in the synthetics



Construction of synthetic S wave

Graphical comparison of the synthetic vs raw DTS, DTP and Vp/Vs values for the Lower Vauréal to Mingan interval (650-1125 mKB MD)



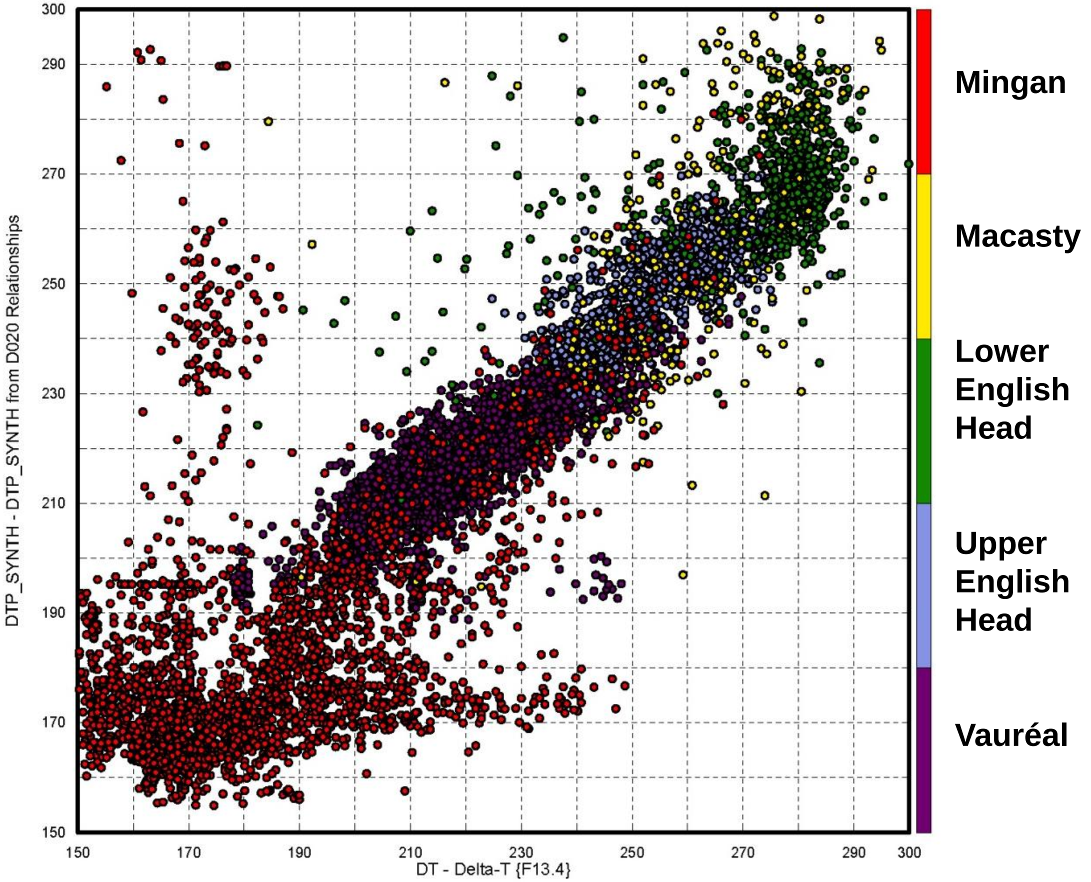


Constructing synthetic waves for other wells

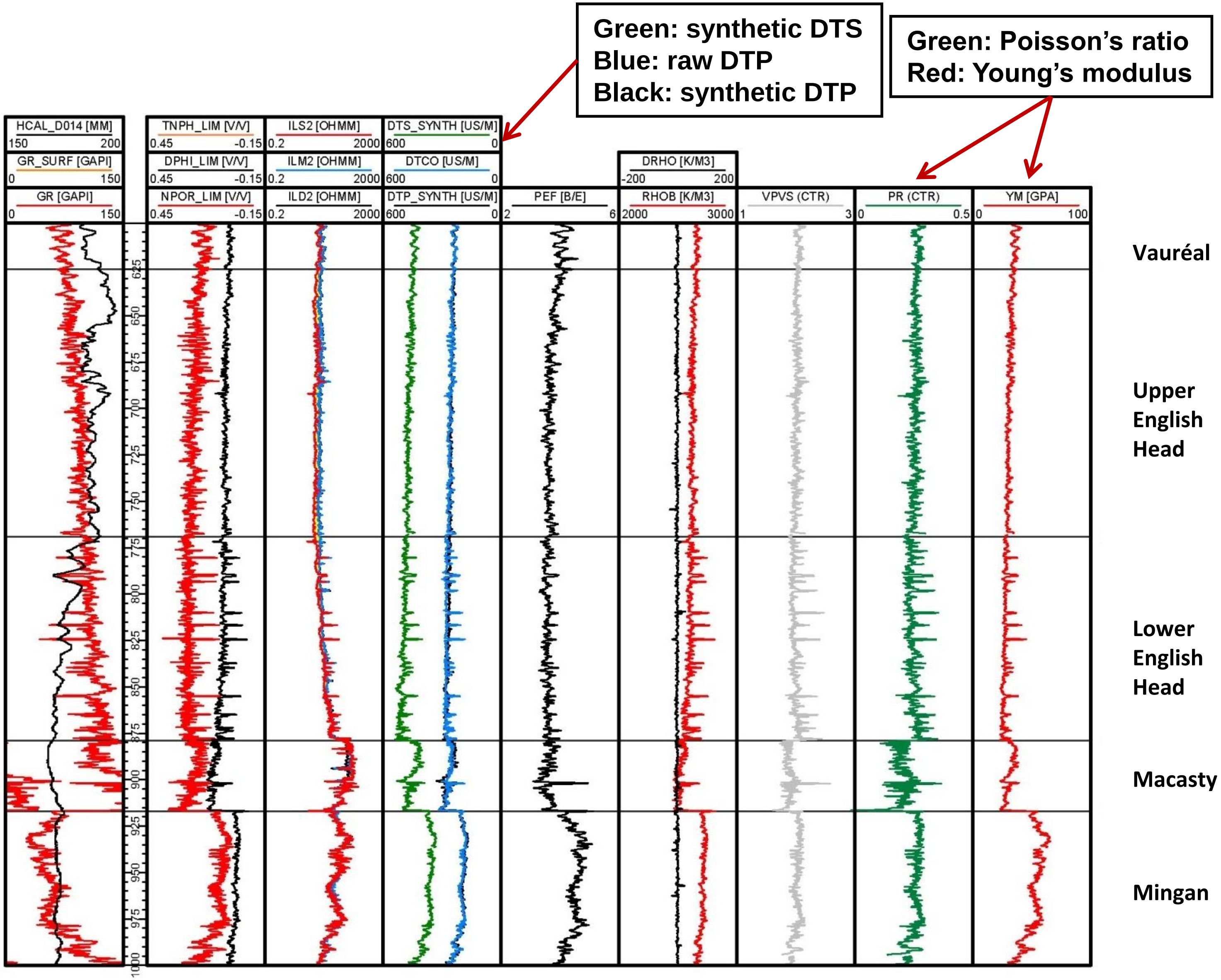
- Nine O&G wells devoid from raw DTS log were considered across the island, to generate synthetic DTS logs based on the correlations established for the well D020
- Eight other wells have been rejected because they did not have logs (3 wells) or because the quality or stratigraphic coverage of the logs was not satisfactory to apply the calibration method (5 wells)
- First, for each well a series of synthetic DTP and DTS have been calculated based on the equations developed for the well D020, and raw versus synthetic DTP has been used to confirm the validity of the method (e.g. answer the following question: do the P waves recorded in the older wells across the island behave in a similar way as in the reference well D020 ? The answer was positive)
- Most wells responded well to gamma ray and deep resistivity. Neutron porosity and bulk density was also valid in some cases but had to be discarded in some others, emphasizing the geological variations and the need for manual quality checks
- Poisson's ratio, Young's modulus and a brittleness index where then calculated using bulk density, raw DTP and synthetic DTS
- <u>Note: Generating a synthetic DTS log with this method beyond the reference well D020 postulates that the Vp/Vs ratio follows a direct and simple relationship for the formations considered. This remains to be confirmed once other raw DTS logs become available from new wells</u>

Constructing synthetic waves for other wells D014 example

Example well D014: Correlation between raw and synthetic DTP to verify the quality of the calibration equations. Good correlation except for the Mingan (the equations where optimized for the Macasty and overlying succession, not the Mingan)



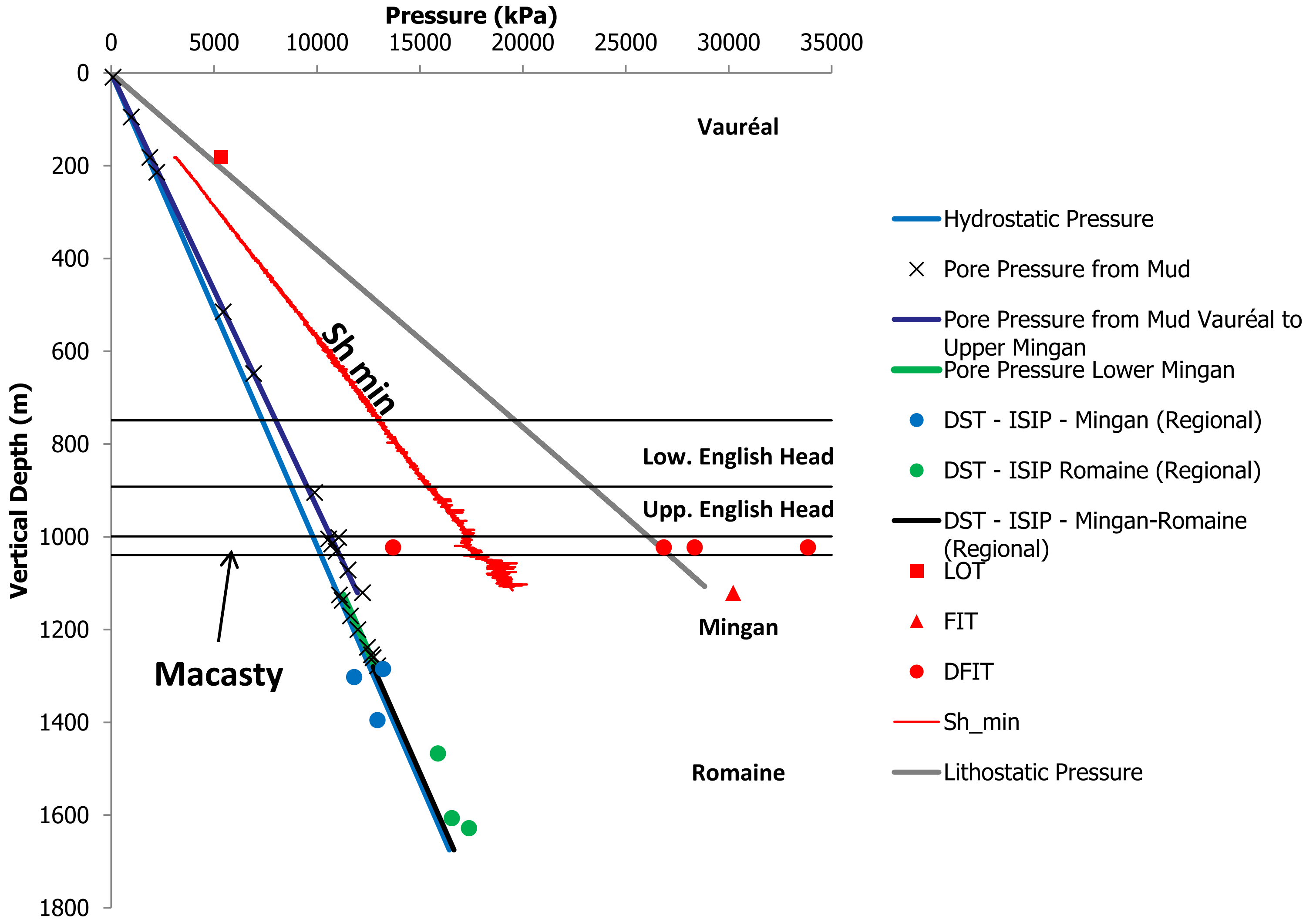
Constructing synthetic waves for other wells D014 example



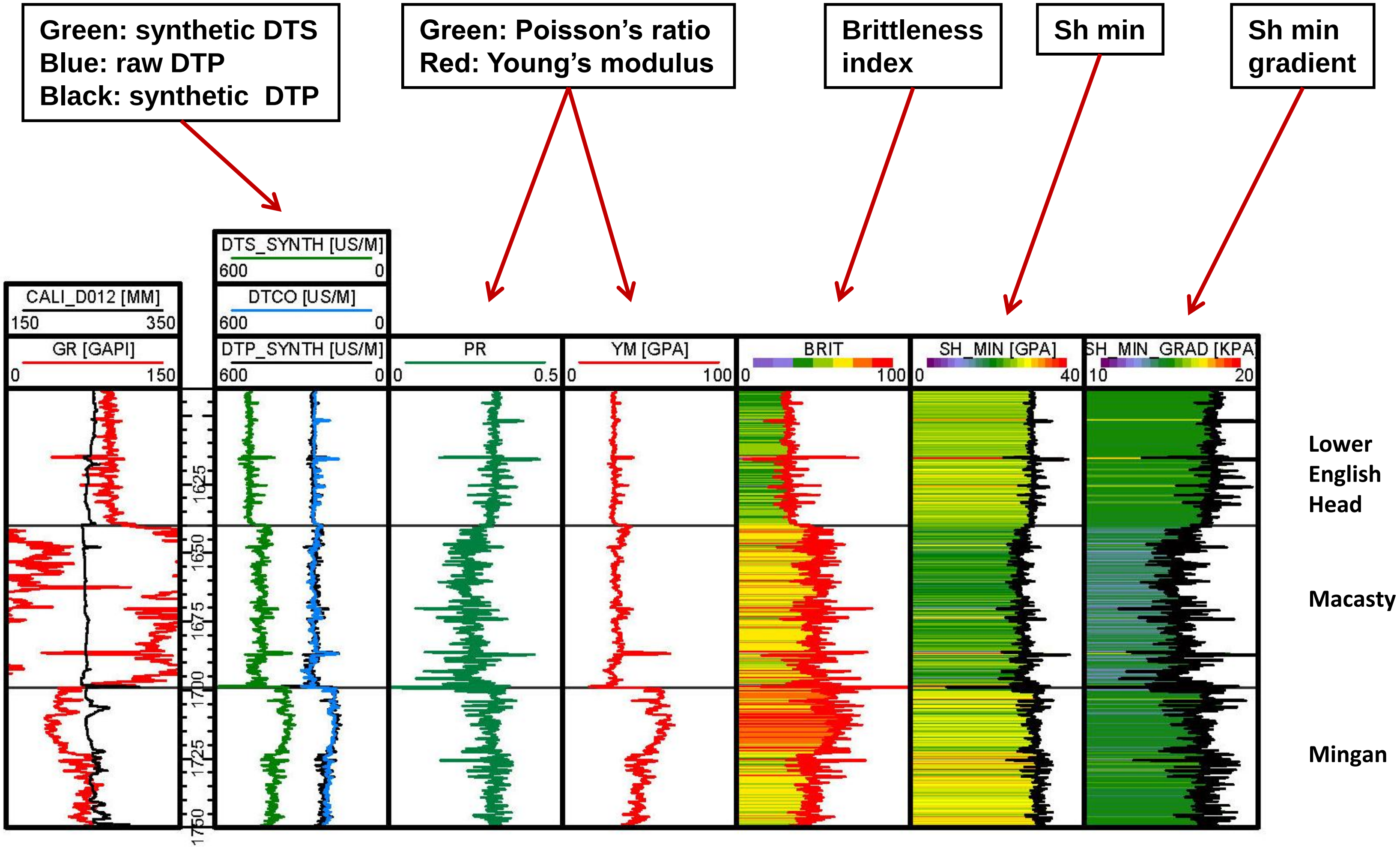
Determination of Sh min

- The least principal horizontal stress (Sh min) is estimated from the Poisson's ratio, the lithostatic stress and the pore pressure following Eaton (1969)
- The pore pressure is derived from available DST, LOT, DFIT and mudweights constraint by gas kicks and fluid losses

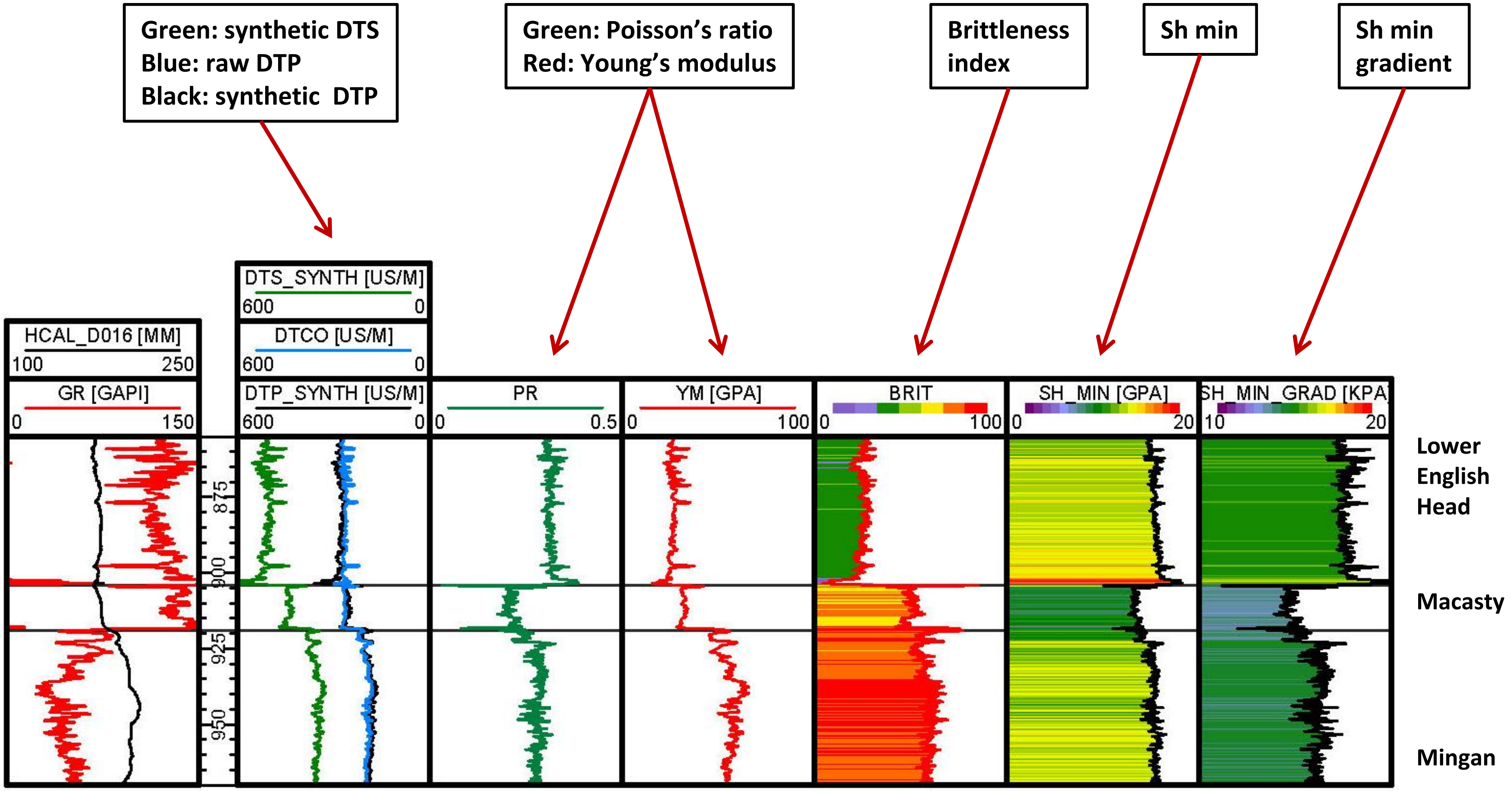
Determination of Sh min



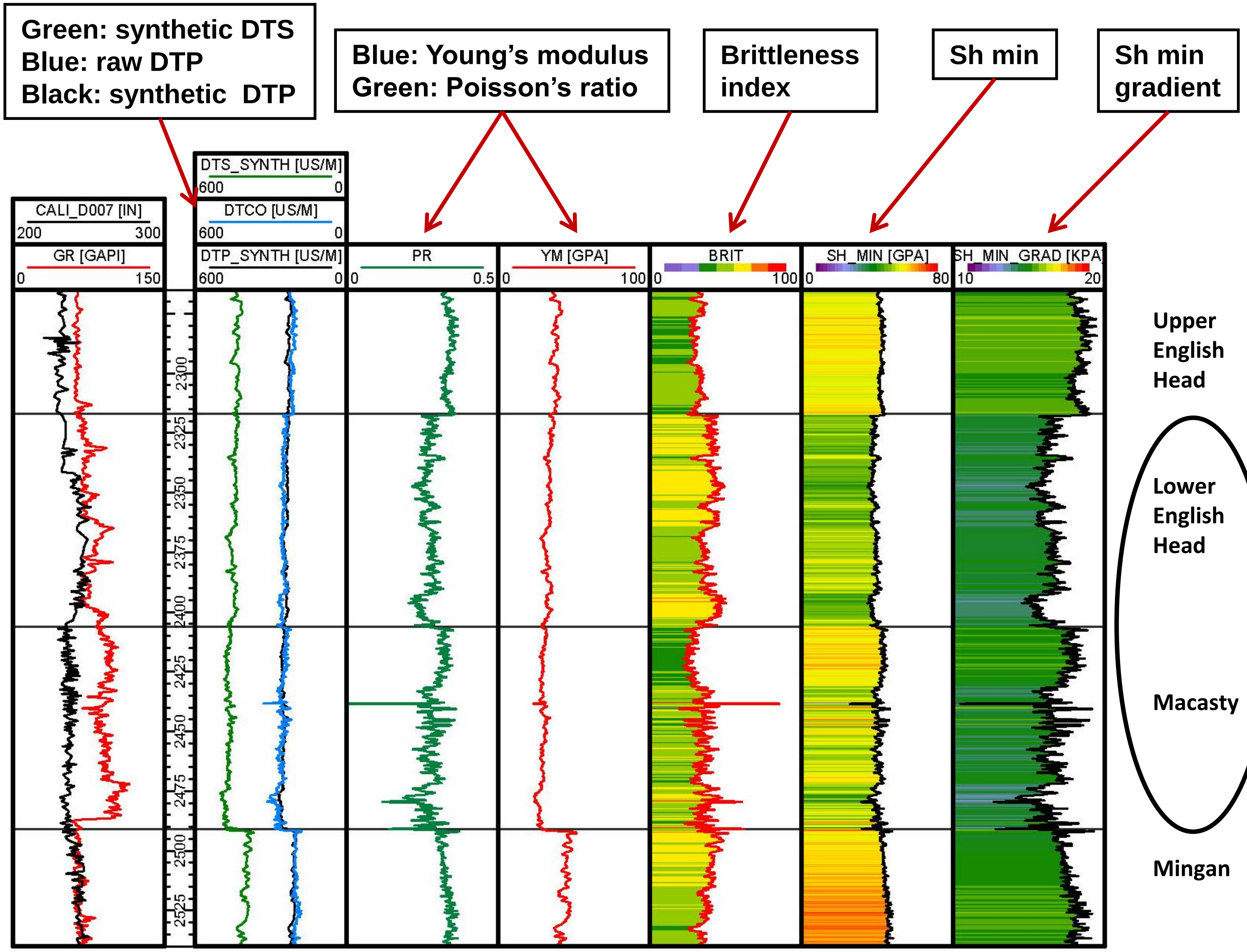
Mechanical contrasts – D012



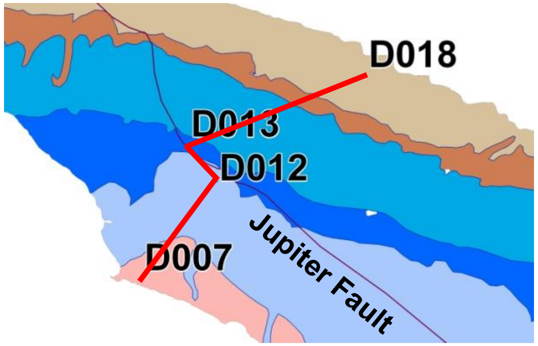
Mechanical contrasts – D016



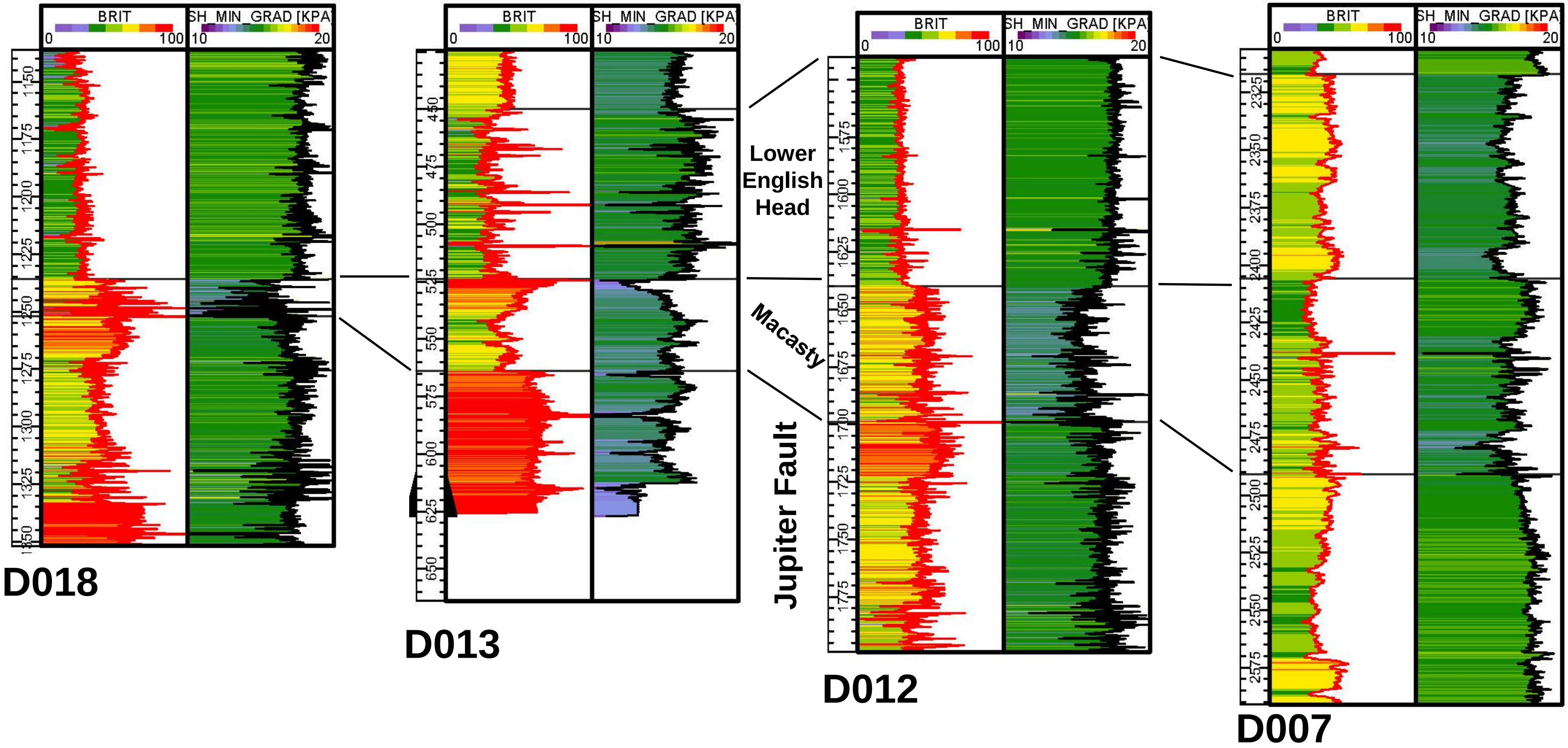
Mechanical contrasts – D007



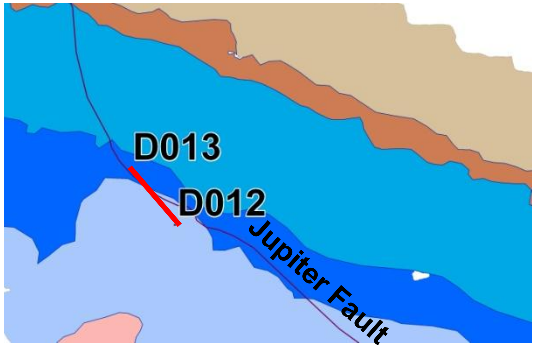
North-South section



- North-South X-Section – wells D018, D012, D013 and D007
  - Thickening of the Macasty to the south
  - No noticeable change in Sh min gradient except for D007
  - D007 is atypical, possibly due to a step in the thermal maturity to the south

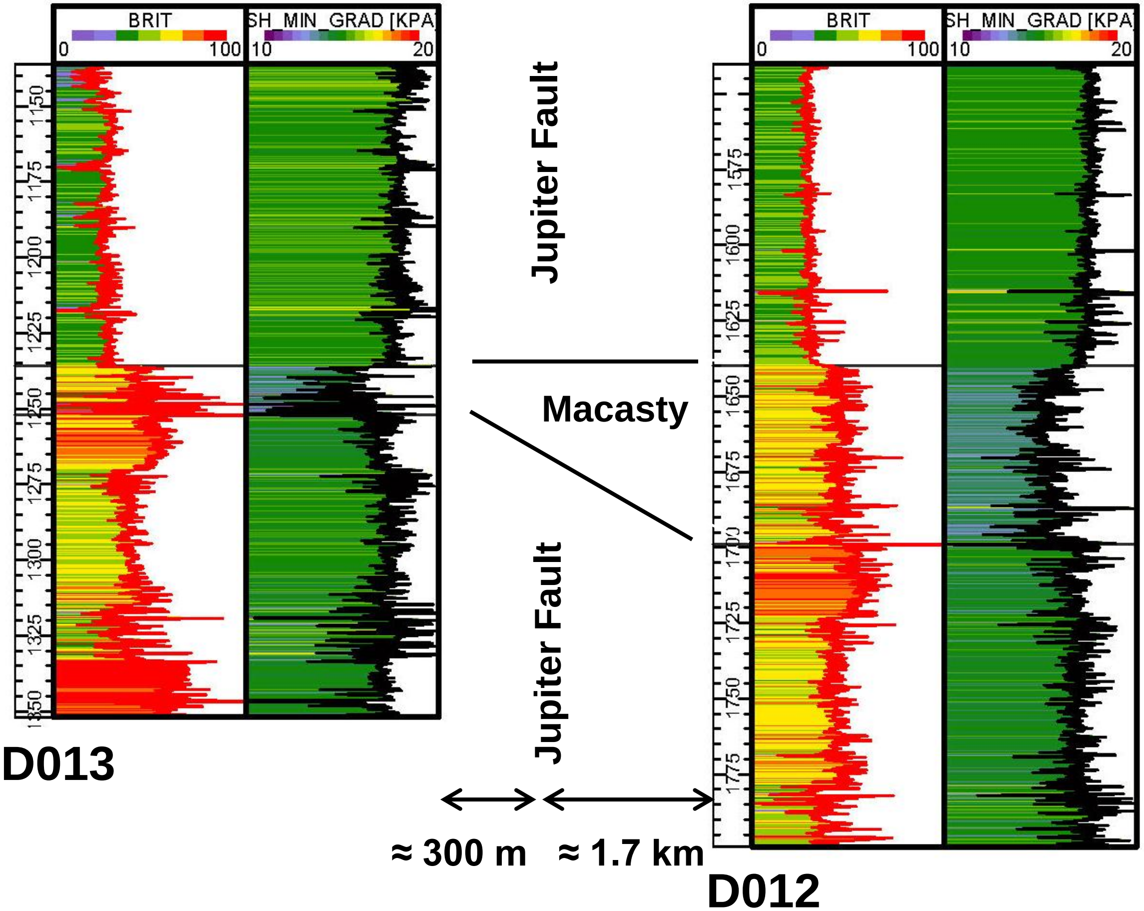


Jupiter Fault



- ➢ Central area and Jupiter Fault – wells D013 and D012
  - Thickening of the Macasty in the footwall of the fault
  - No noticeable change in Sh min gradient

➢ The well D013 is located about 300 m from the interpreted trace of the Jupiter Fault at surface. In spite of the uncertainties in the exact path of the fault, it appears that the mechanical properties estimated for the well D013 are not significantly different from those estimated for the well D012 located about 1.7 km away from the fault



Conclusions

- The Upper Ordovician Macasty Shale on Anticosti Island (Québec) has a significant in-place resource of oil and gas
- 21 public domain conventional exploration wells were available for a geomechanical study, only one well (D020) had a S wave record
- Synthetic S waves were constructed from D020 well and the method was applied to 8 other wells that had the suitable suite of logs
- At the well scale, significant mechanical contrasts are present between the Macasty Formation and the overlying and underlying successions documenting the presence of efficient geomechanical barriers to fracture propagation
- At the regional scale, the geomechanical properties are very homogeneous except for the thermally more mature west-central area where the efficient frac barriers are higher up in the cover succession
- The study of 2 wells immediately adjacent to both sides of the regional Jupiter Fault suggests that the fault did not affect the geomechanical properties of the succession
- These results have to be confirmed by geomechanical analyses of confidential wells drilled in 2014-2015 by operators on the island in which S wave record was acquired.
- **References; Séjourné (2015) GSC OF 7892 and 7907**

Thank you