

Oil to Source Rock Correlation and Implications for Petroleum System Analysis, Western Newfoundland*

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Abstract

The presence of natural oil-seeps and old, accessible well sites along the coast of western Newfoundland have refocused the interest on Lower Paleozoic Cow Head and Northern Head groups. Part of the Humber Arm Allochthon, these groups contain viable source rocks for hydrocarbon exploration. Most oil seeps and old wells containing light oil are concentrated around the Parson's Pond area, an inlet located in the thrust belt of the northeastern Canadian Appalachians. The former passive continental margin represented by these slope and rise deposits contains potential source and reservoir rocks. These rocks were imbricated in thrust sheets consisting of repeated Upper Cambrian to Ordovician strata. Total organic content (TOC) concentrations of up to 10.35% and high hydrogen index (HI) values of over 840 [mg HC/g TOC] demarcate the Green Point Formation of the Cow Head Group and the Middle Arm Point Formation of the Northern Head Group as viable sources. However, the nature of the connection between these source rocks and produced hydrocarbons and oil seeps is not well understood. Here, we present a systematic source rock analysis of the Cow Head and Northern Head Group in conjunction with detailed biomarker analysis to identify specific characteristics of the source rock, as well as live oil and oil seep samples. These are utilized to establish oil families, which will be used for oil-to-source correlation and thermal maturity models for the expelled hydrocarbons. The results will give further input for a complete basin model and a better understanding of the petroleum system.

Selected References

Enachescu, M.E., 2011, Petroleum Exploration Opportunities in Area "C", Flemish Pass/North Central Ridge: NL11-Call for Bids NL11-02, p. 95. Website accessed July 31, 2016, http://www.nr.gov.nl.ca/nr/invest/enachescu_NL1102Flemish.pdf.

Enachescu, M.E., M. Martin, J. Stead, J. Hall, A. Carroll, and P. Einarsson, 2008, Hopedale Basin exploration potential, East Coast Atlantic Canada: Website accessed July 31, 2016, Search and Discovery Article #10170 (2008), http://www.searchanddiscovery.com/documents/2008/08263enachescu/ndx_enachescu.pdf.

Radke M., 1988, Application of aromatic compounds as maturity indicators in source rocks and crude oils: *Marine and Petroleum Geology*, v. 5, p. 224–236.

Radke M., D.H. Welte, and H. Willsch, 1986, Maturity parameters based on aromatic hydrocarbons: Influence of the organic matter type: *Organic Geochemistry*, v. 10, p. 51–63.



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Regional Context

North America Appalachian Basins

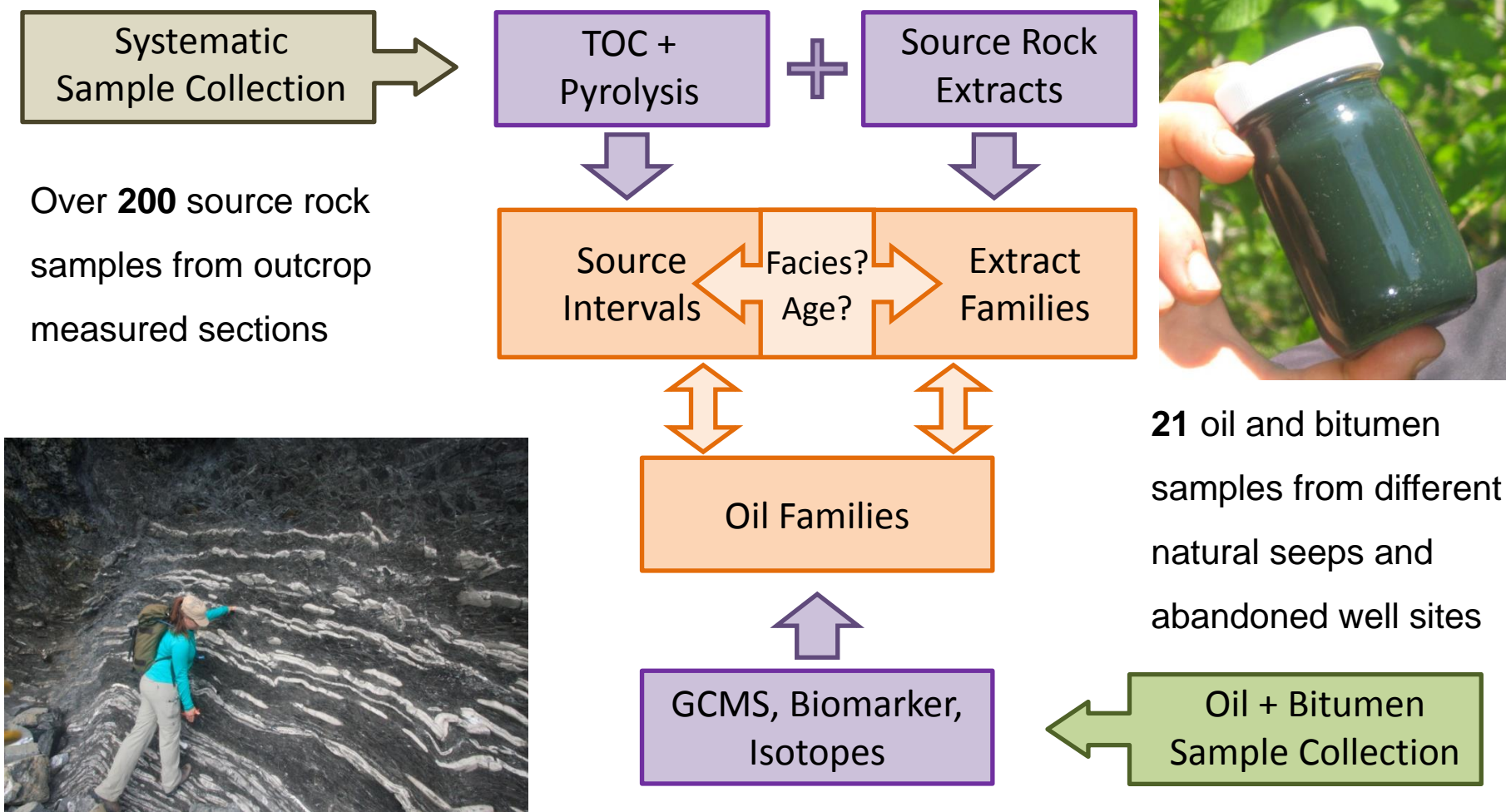


1. Hopedale (Labrador)
2. St. Anthony
3. **Anticosti**
4. Sydney
5. Magdalen
6. St. Lawrence Lowlands
7. Appalachian
8. Michigan
9. Illinois
10. Black Warrior
11. Arkoma
12. Anadarko
13. Dalhart
14. Palo Duro
15. Forth Worth
16. Midland
17. Delaware
18. Val Verde

500 km

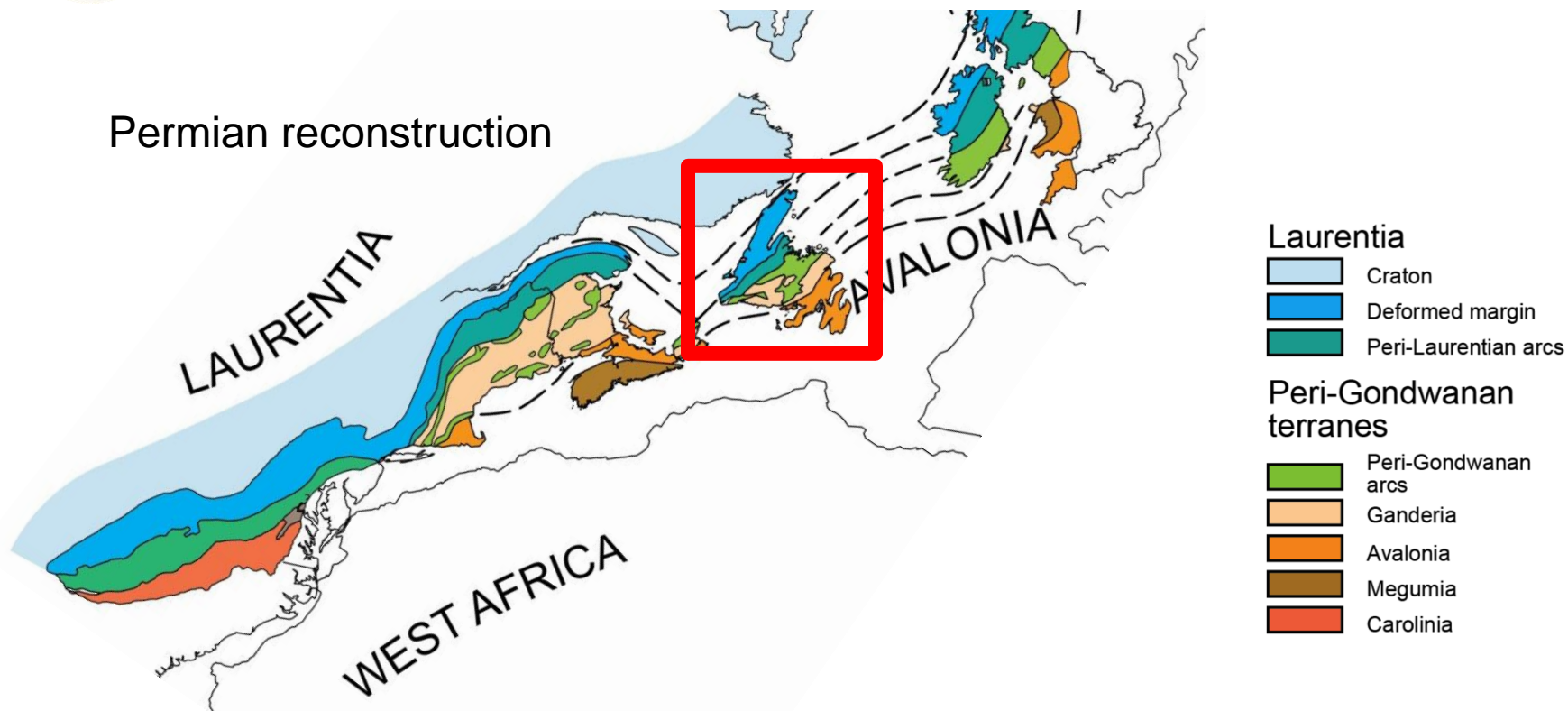
Enachescu, 2011

Workflow and Motivation



Regional Geology

Permian reconstruction



Late Cambrian – Early Ordovician

W

Rift Sediments (Labrador Gp.)

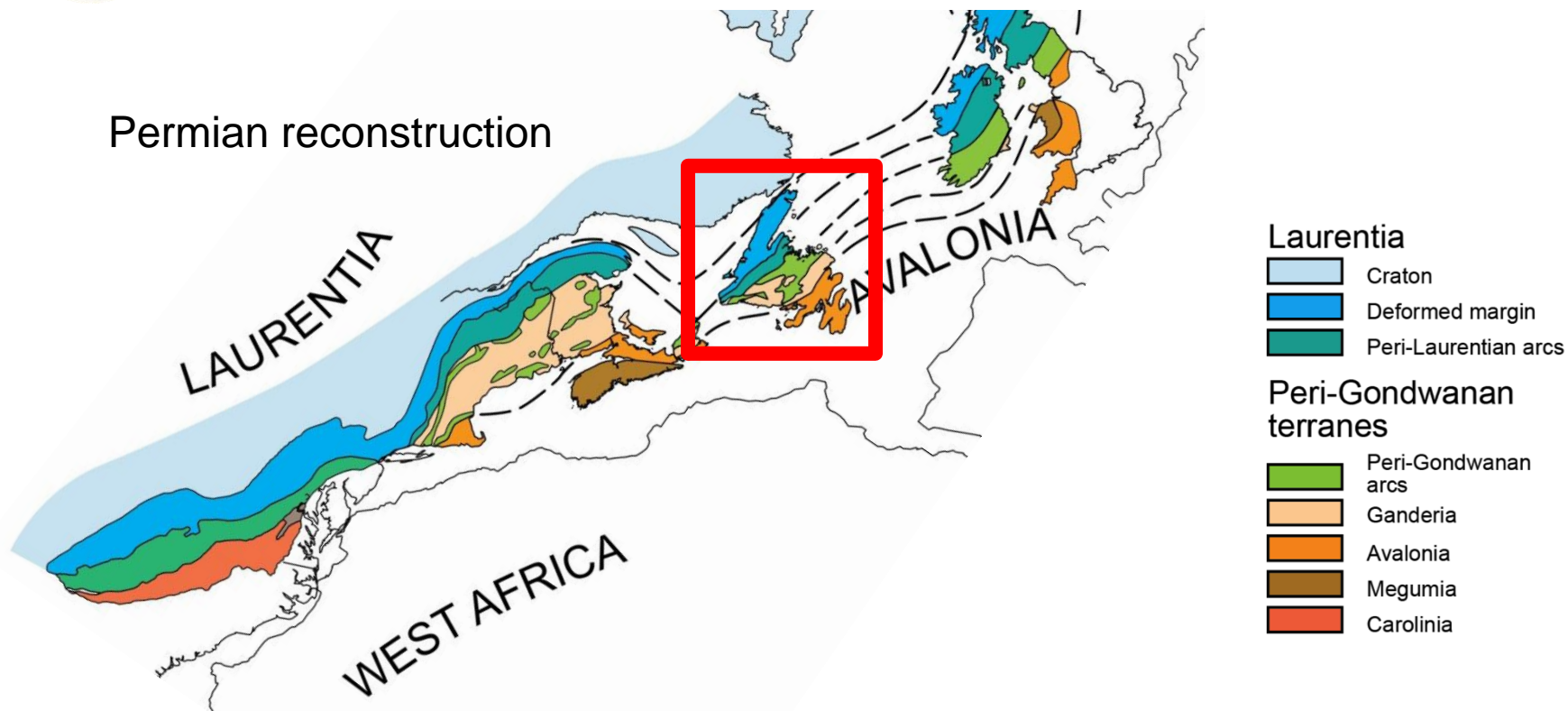
E

Undivided Platform



Regional Geology

Permian reconstruction



Middle Ordovician

W

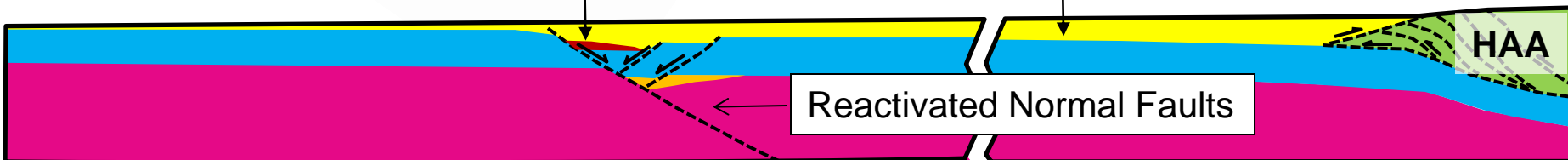
Fault Scarp Deposit

Flysch Sediments

E

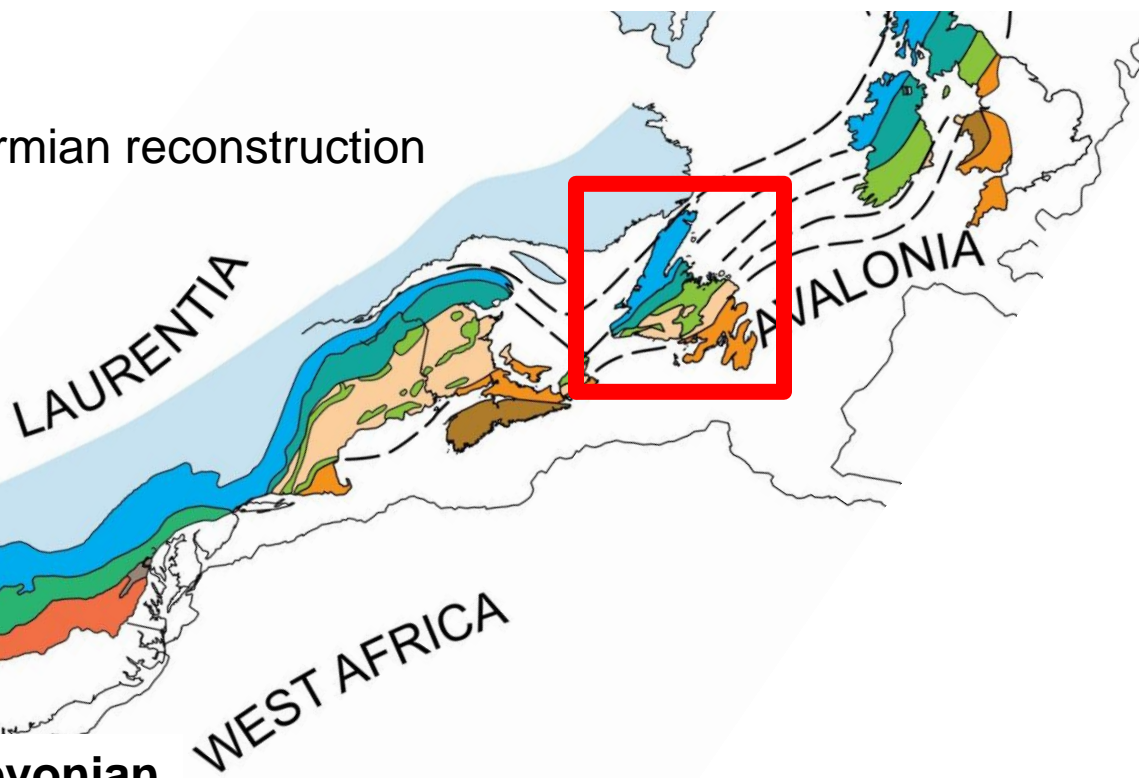
Reactivated Normal Faults

HAA






Regional Geology





Permian reconstruction



Laurentia

-  Craton
-  Deformed margin
-  Peri-Laurentian arcs

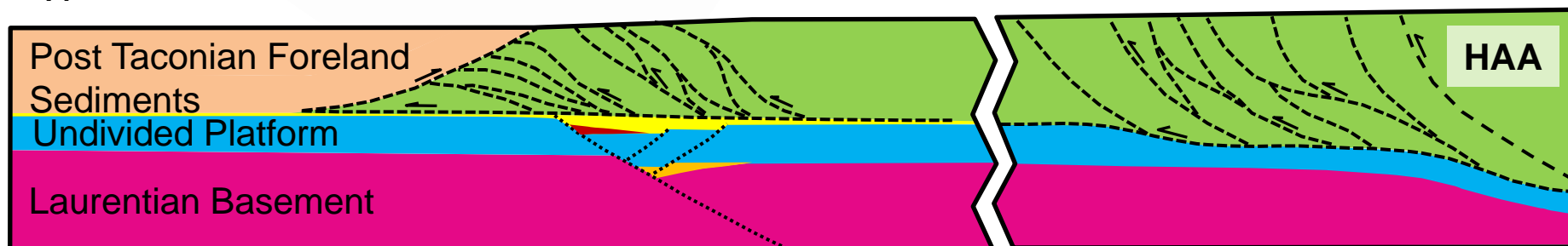
Peri-Gondwanan terranes

-  Peri-Gondwanan arcs
-  Ganderia
-  Avalonia
-  Megumia
-  Carolina

Early Devonian

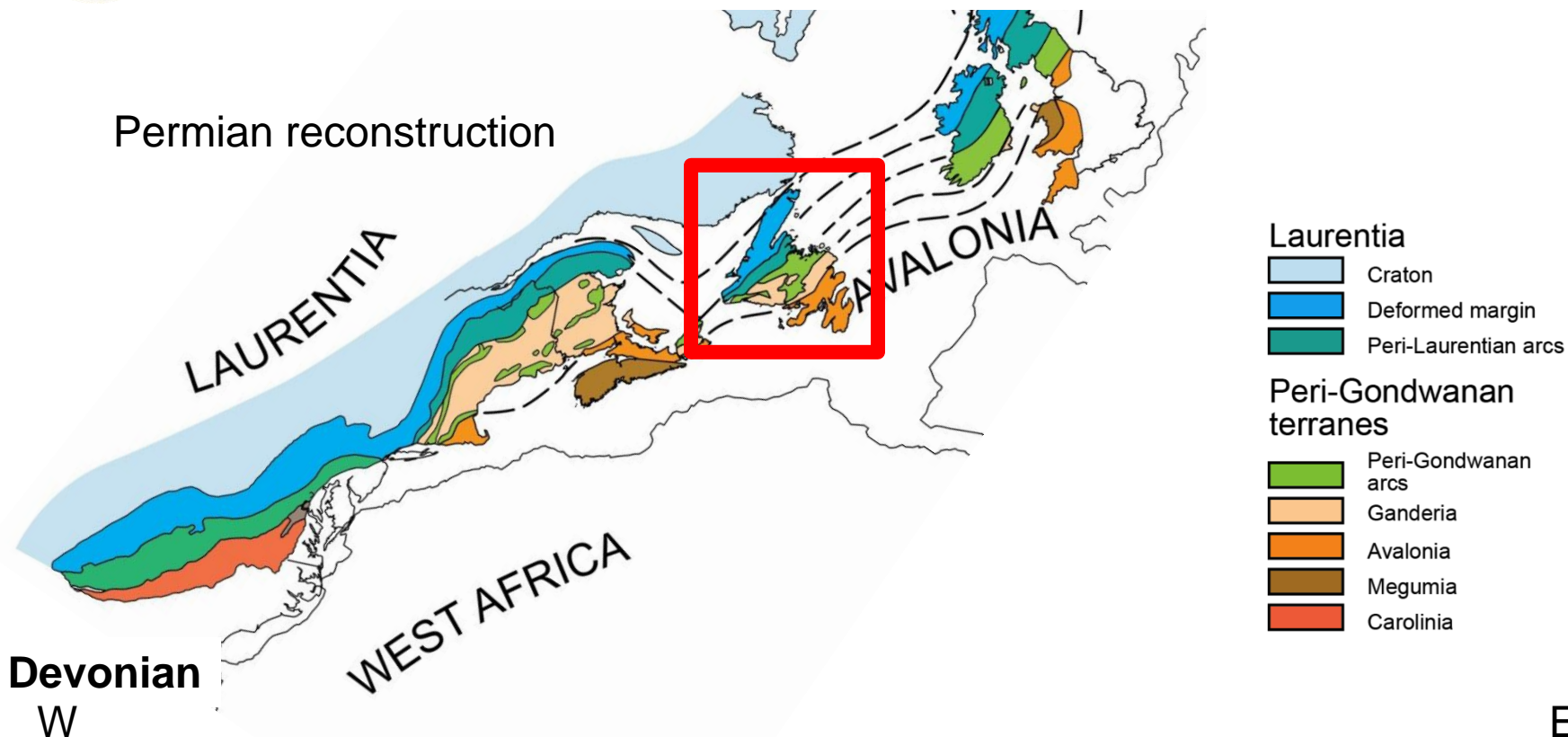
W

E



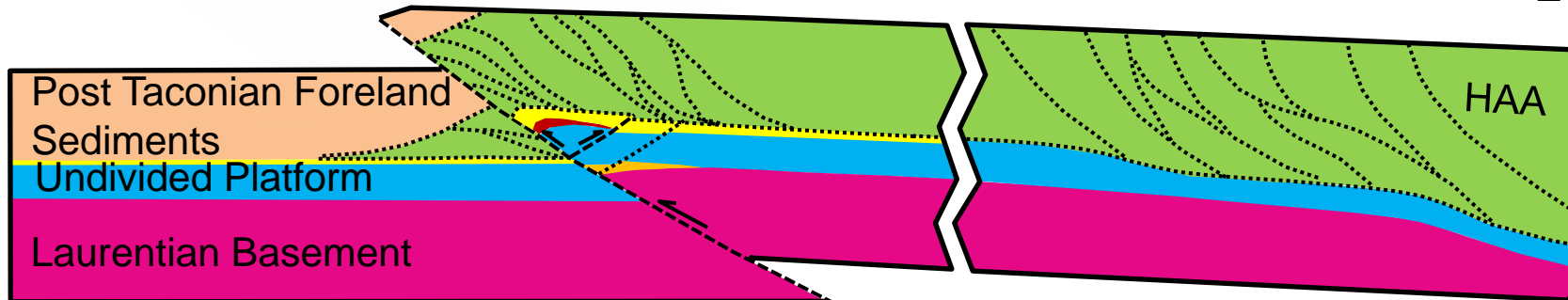
Regional Geology

Permian reconstruction



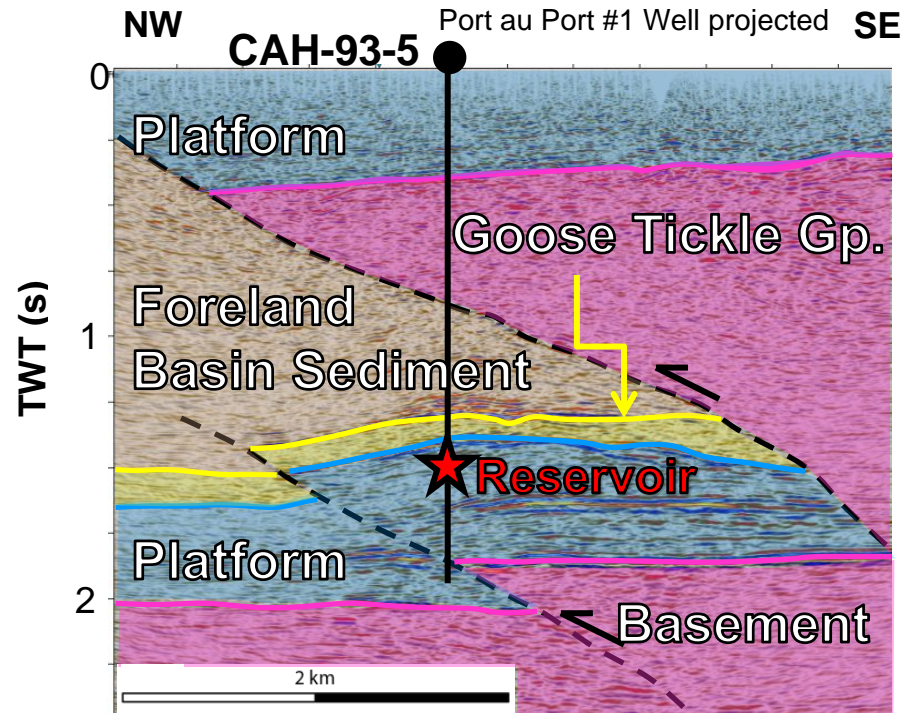
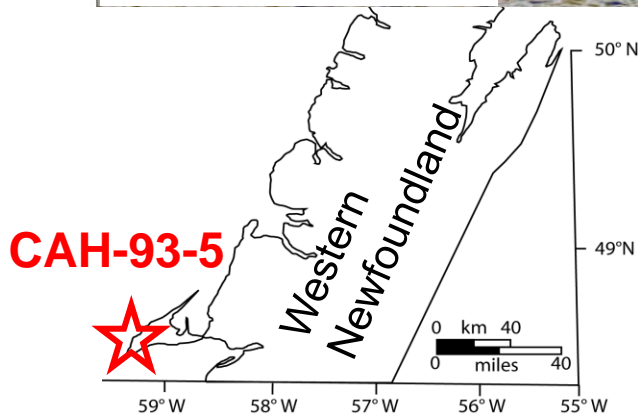
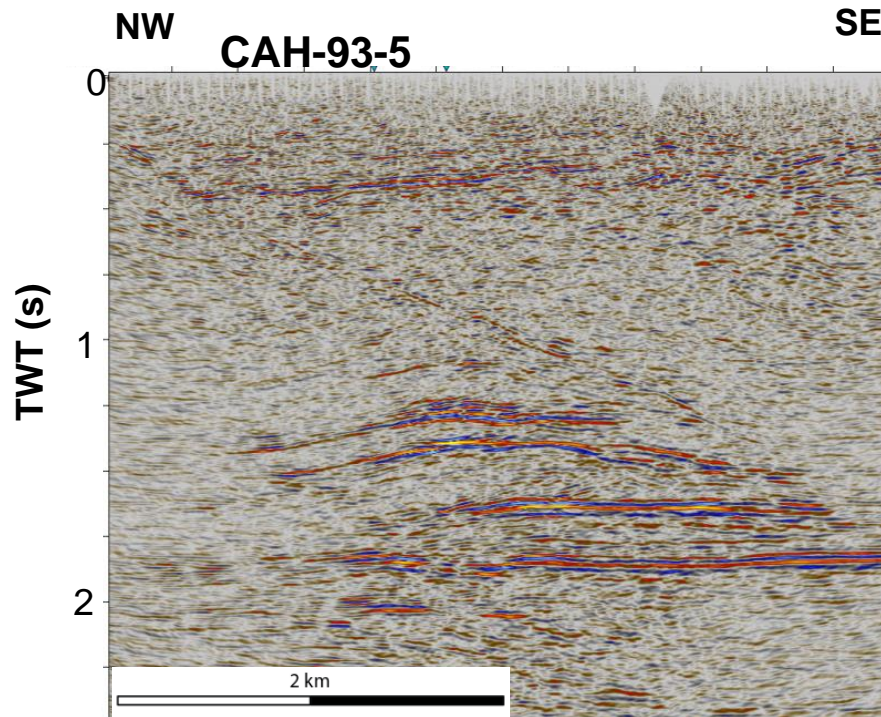
Devonian
W

E



HAA = Humber Arm Allochthon

2D Seismic Profile Port au Port

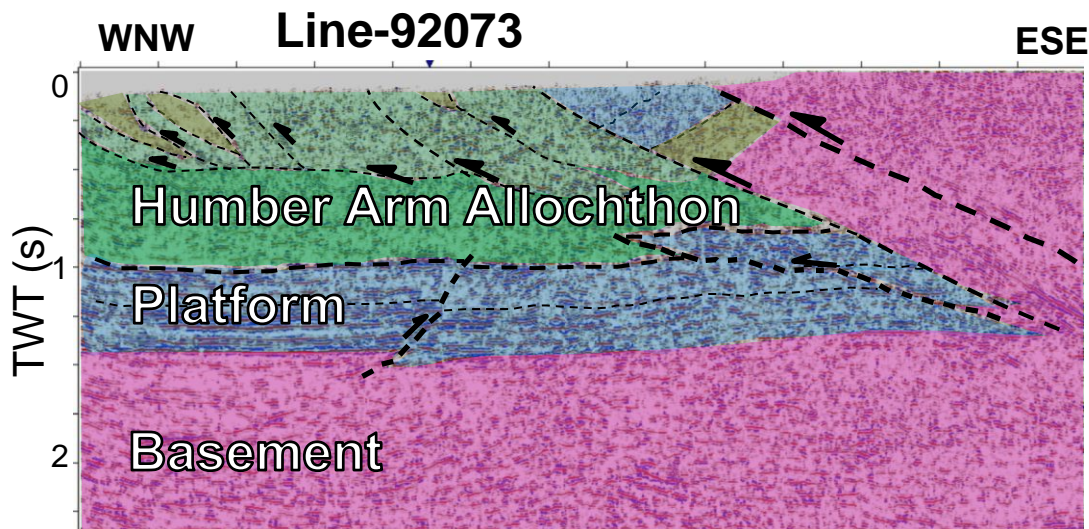
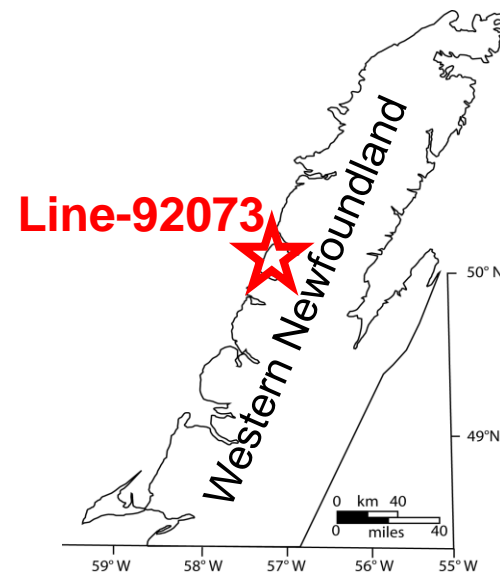
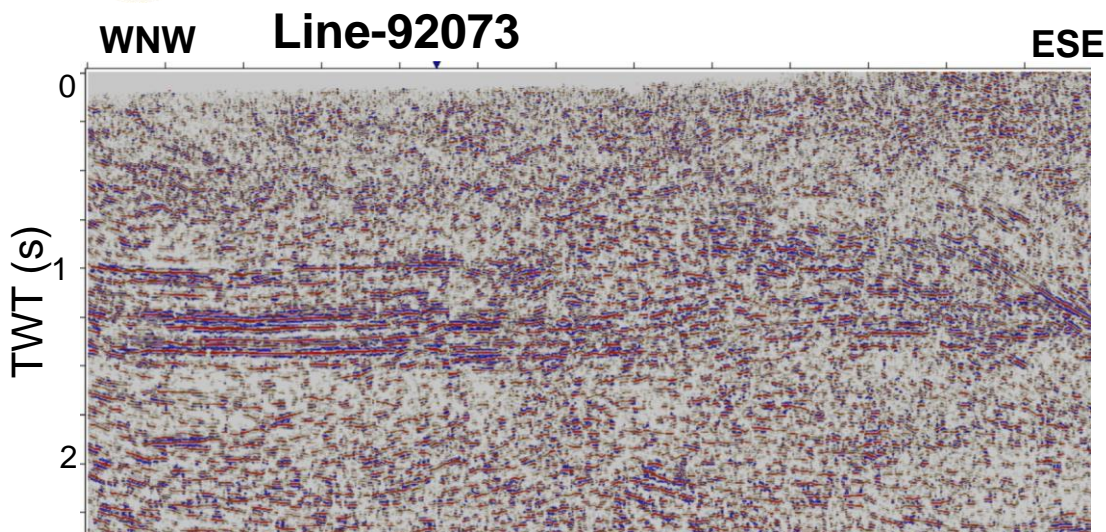


Port au Port #1 Well

- Basement rock structurally above carbonate shelf
- Reservoir in footwall shortcut anticlines
- No source rocks structurally below reservoir → no active reservoir charge



2D Seismic Profile Parsons Pond

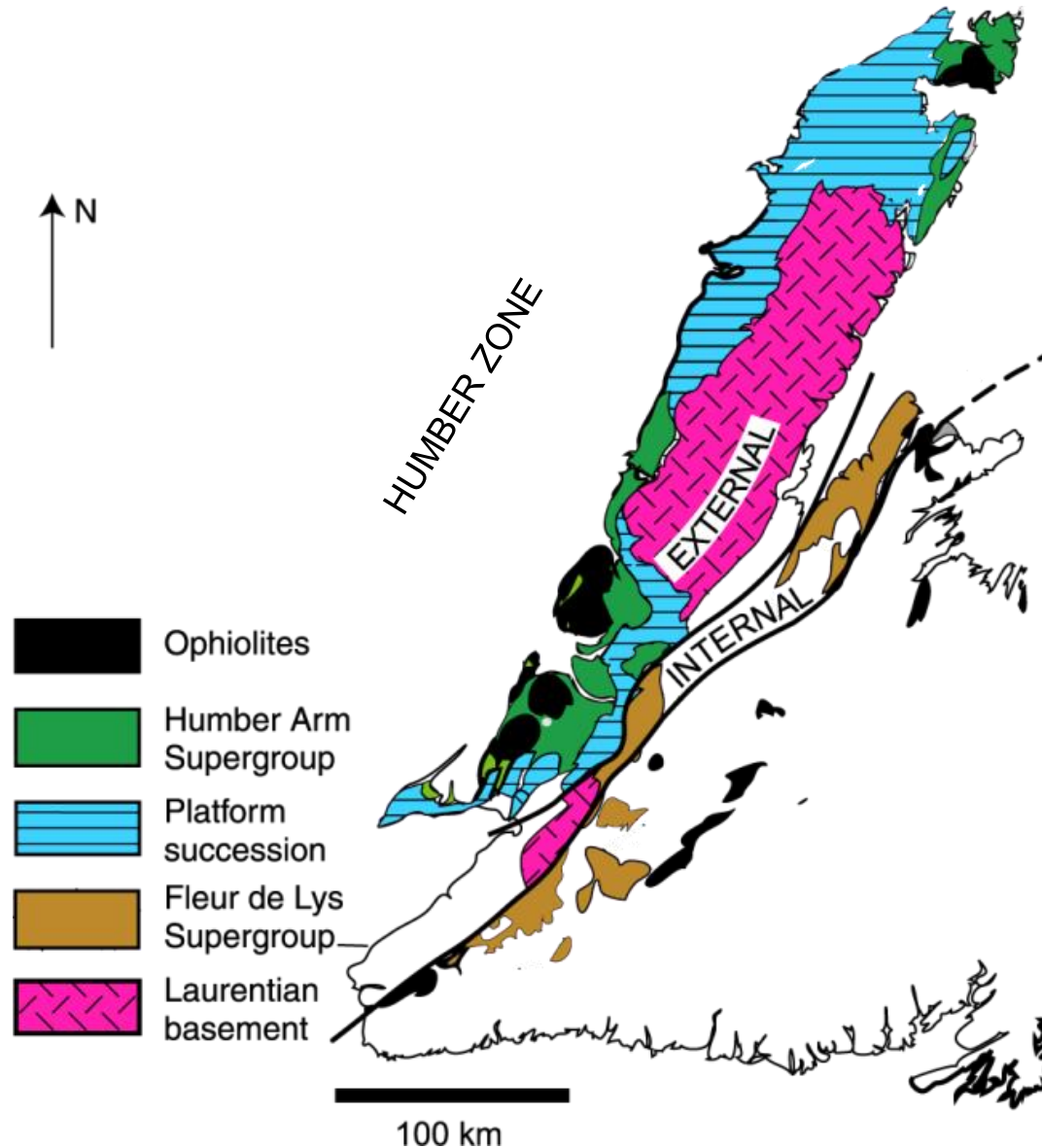


Parsons Pond Area

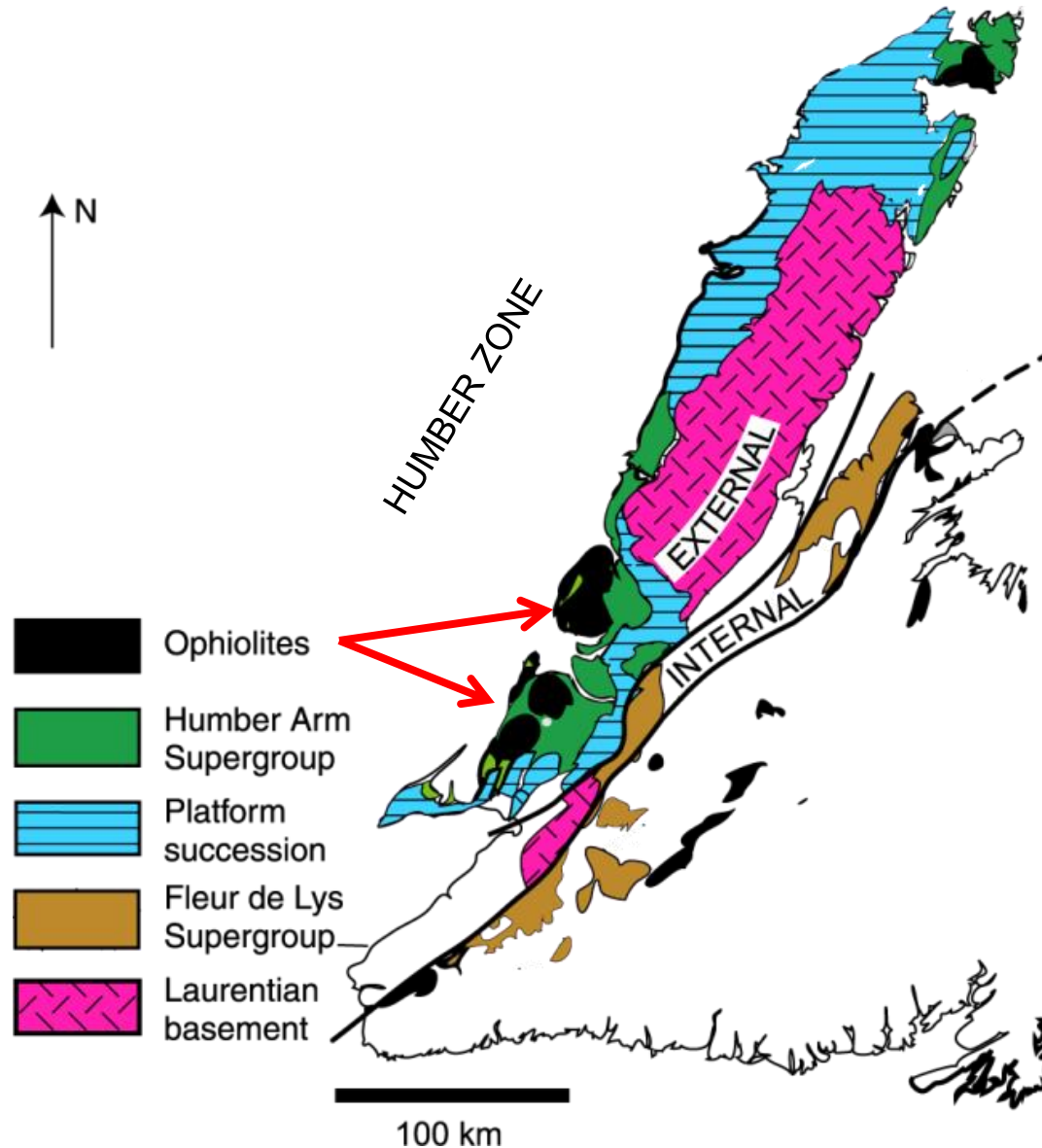
- Similar inversion structures can be found (evidence from seismic and mapping)
- Imbricated Humber Arm Allochthon above platform
- Footwall shortcut anticline has not yet been drilled

S. White in preparation

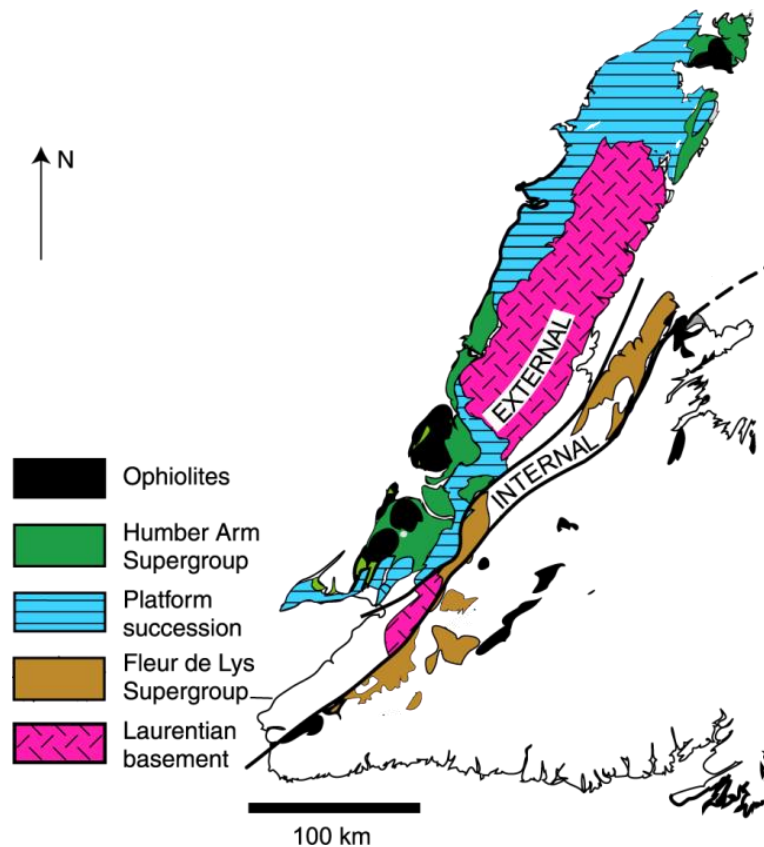
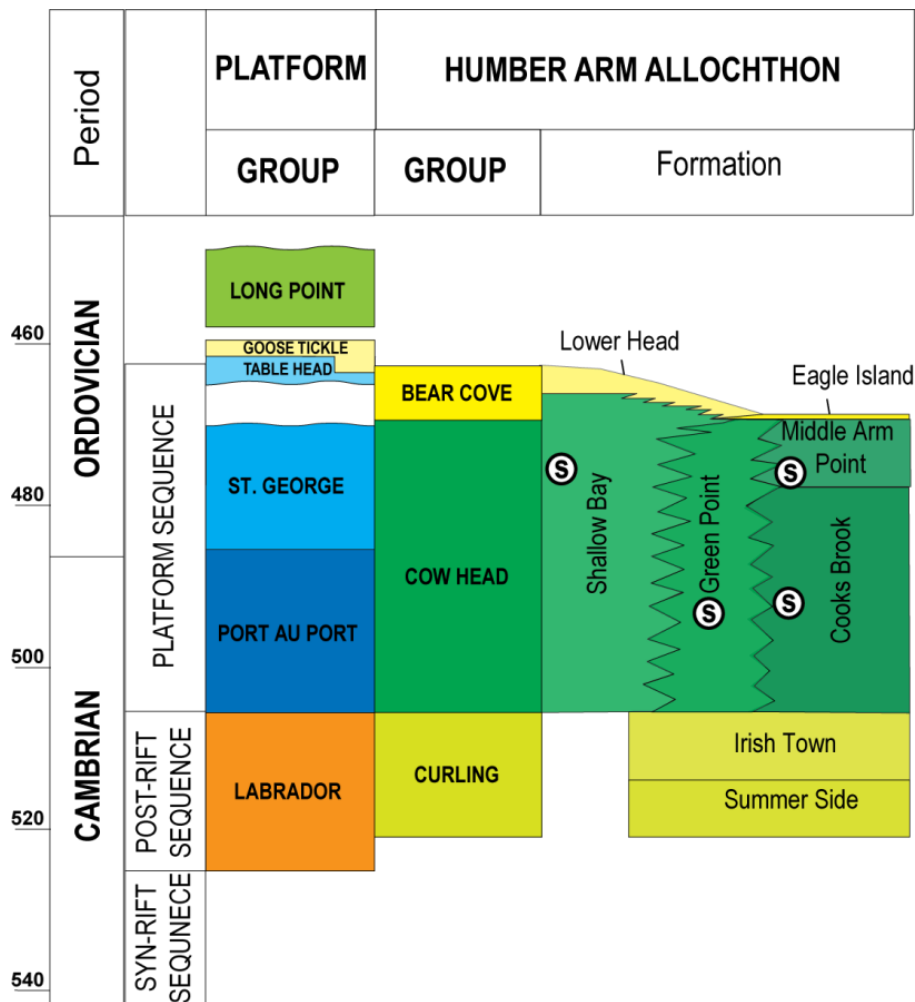
Western Newfoundland Geology



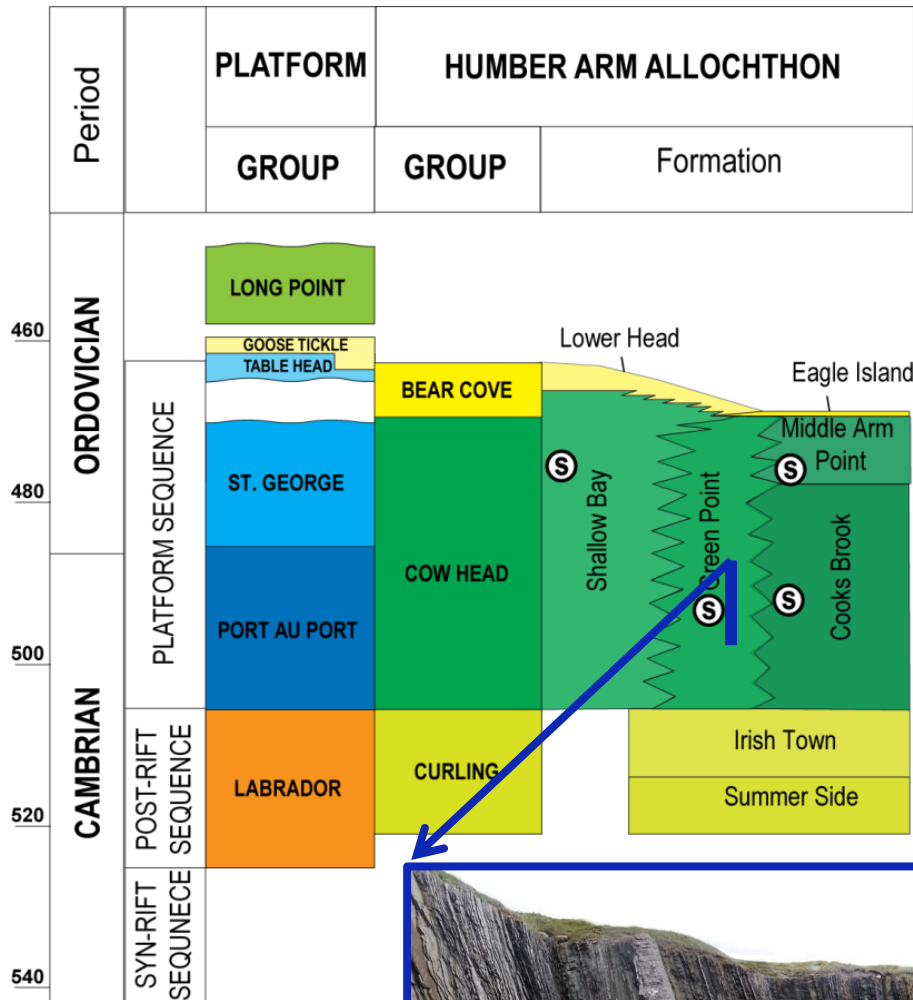
Western Newfoundland Geology








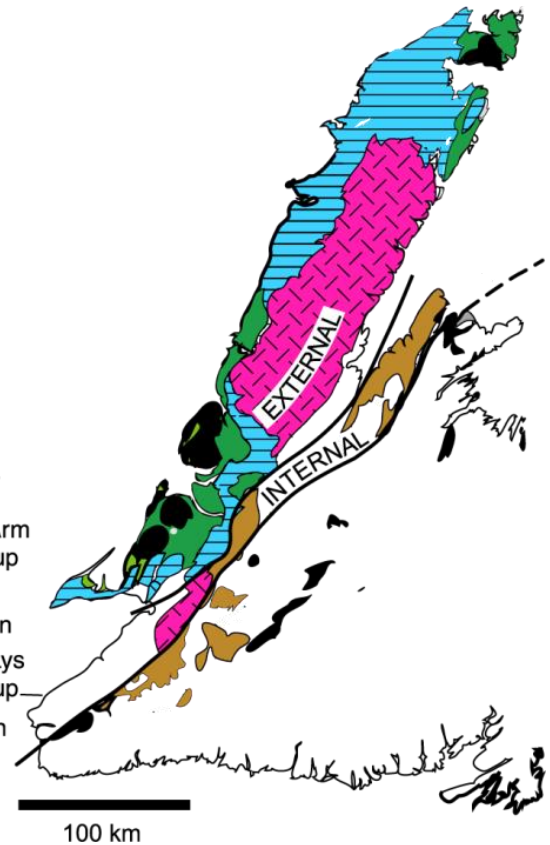
Stratigraphy



Stratigraphy



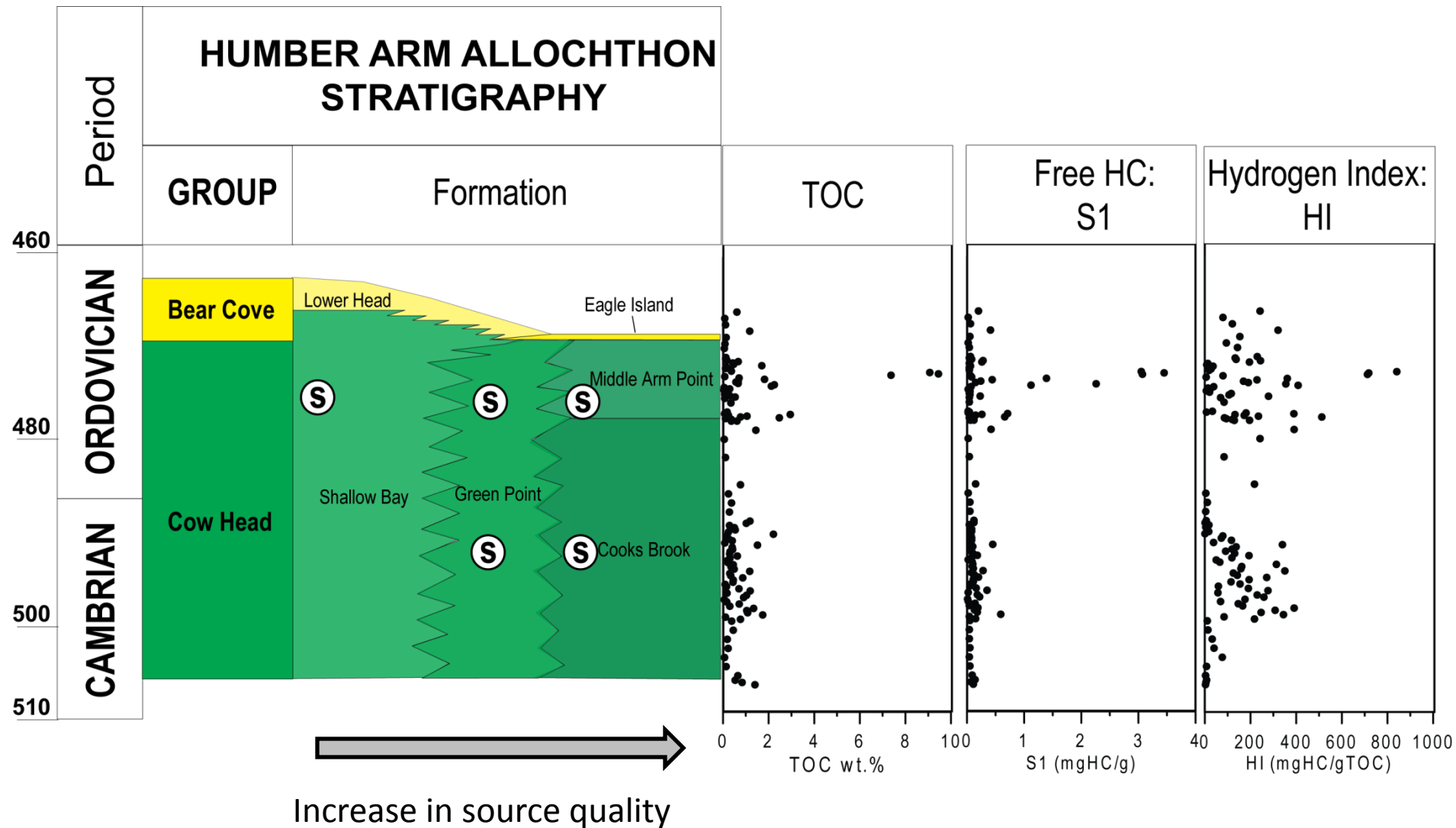
-  Ophiolites
-  Humber Arm Supergroup
-  Platform succession
-  Fleur de Lys Supergroup
-  Laurentian basement



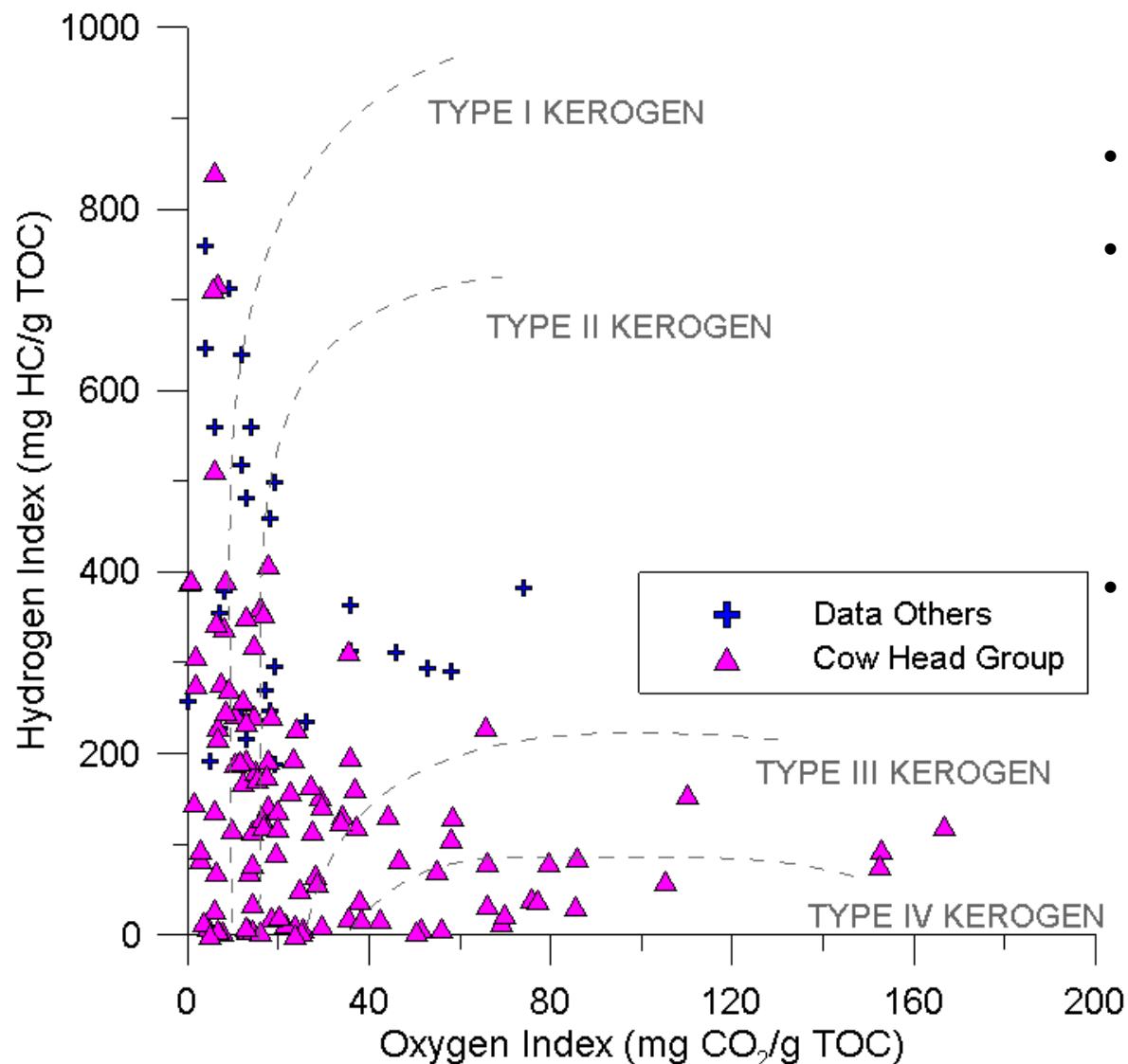
Green Point



Source Characteristics

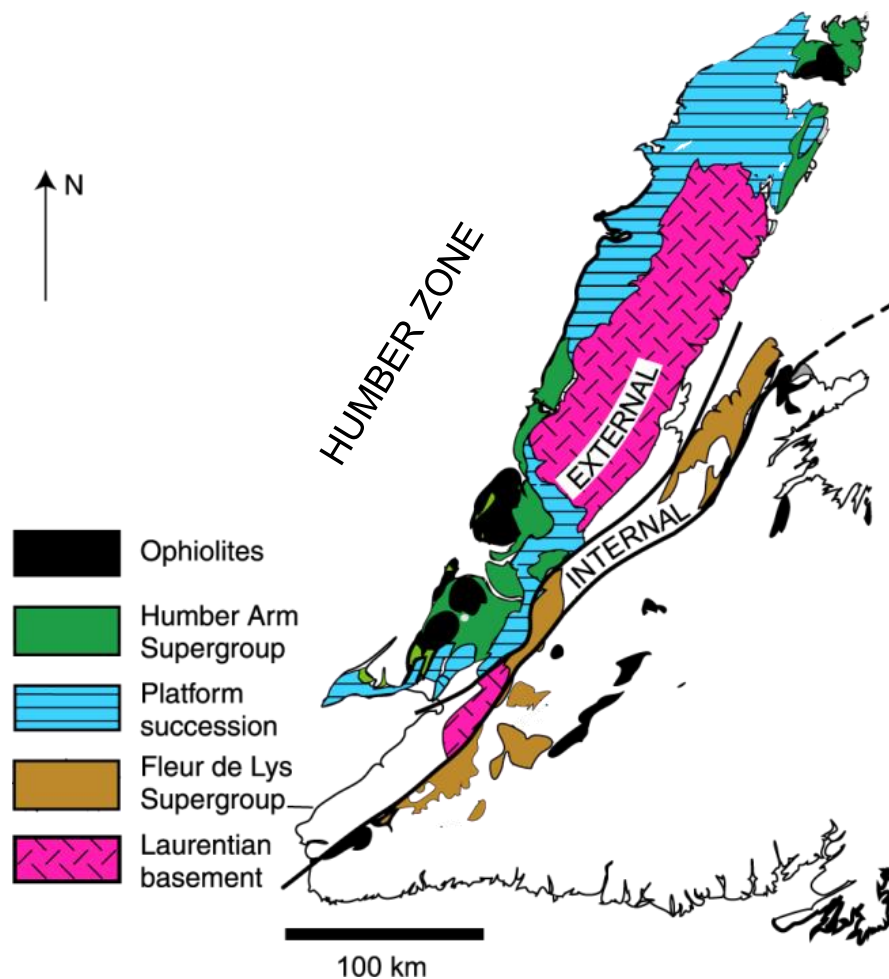


Source Characteristics



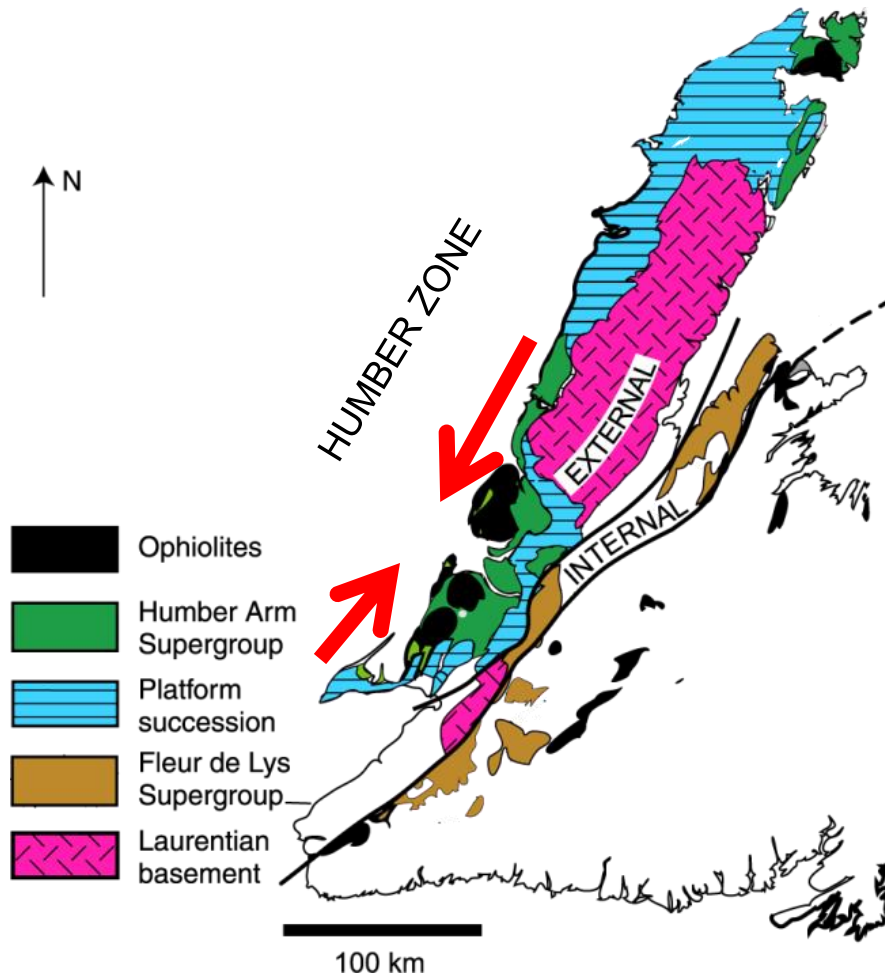
- Type II/III kerogen
- Different level of weathering and oxidation of outcrop samples decreasing HI and TOC
- Over-mature samples related to the ophiolite emplacement fall close to the origin

Source Rock - Summary



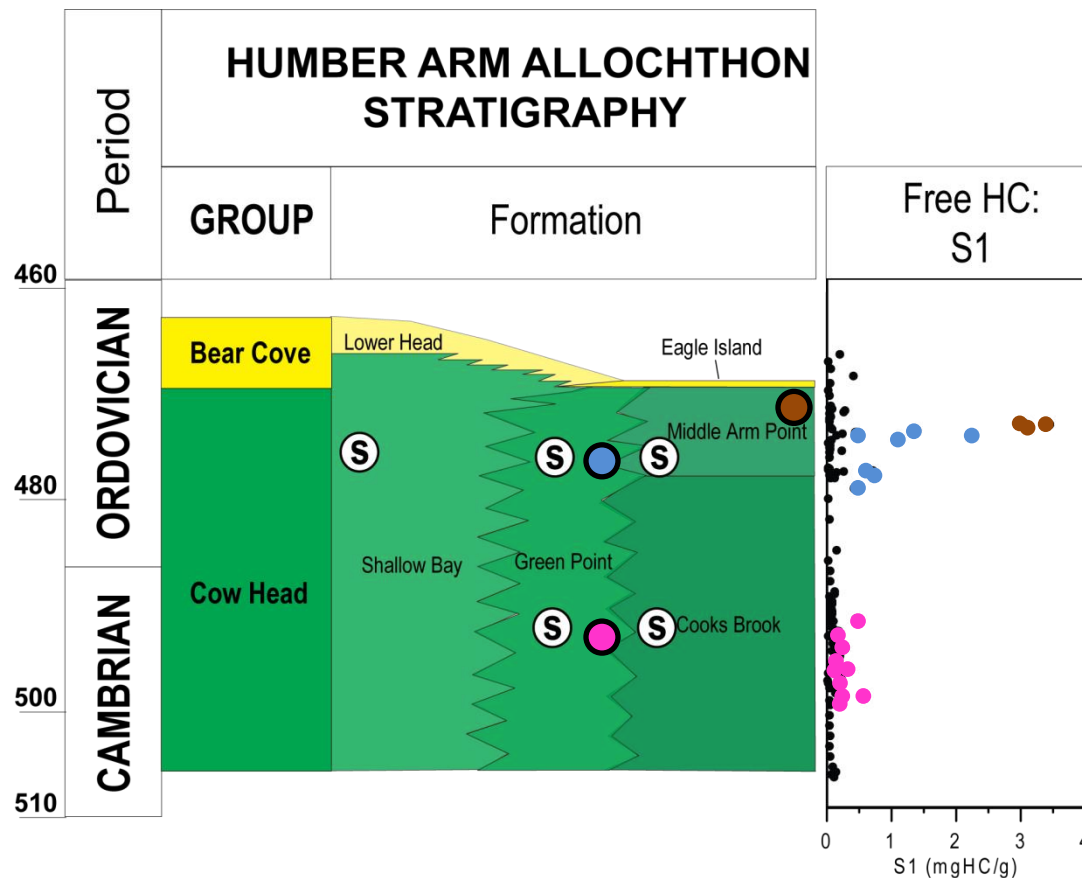
- Good source rocks were deposited during two distinct time periods (Middle Ordovician; Middle to Late Cambrian)
- Source rocks show a fair to good hydrocarbon potential where they have low maturities

Source Rock - Summary

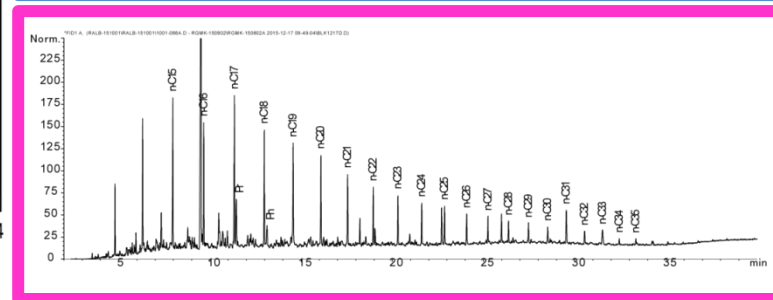
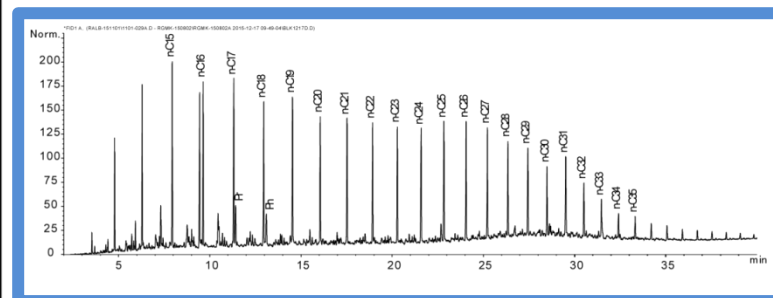
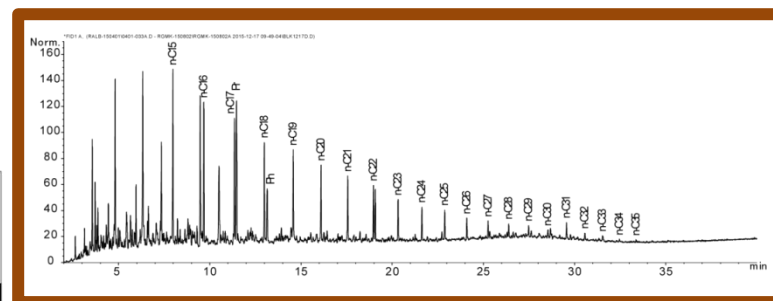


- Good source rocks were deposited during two distinct time periods (Middle Ordovician; Middle to Late Cambrian)
- Source rocks show a fair to good hydrocarbon potential where they have low maturities
- Decrease of source potential towards the Ophiolites

Source Rock Extracts



Extract GCMS

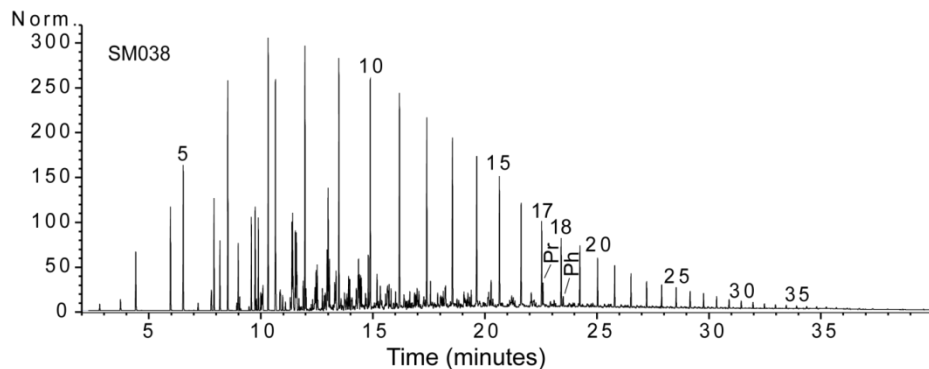


Oil Seep Samples

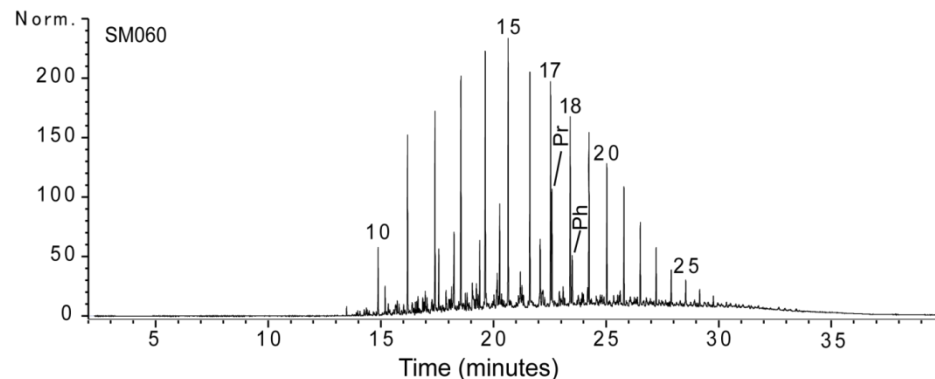
Port au Port #1 (Garden Hill)



Parsons Pond

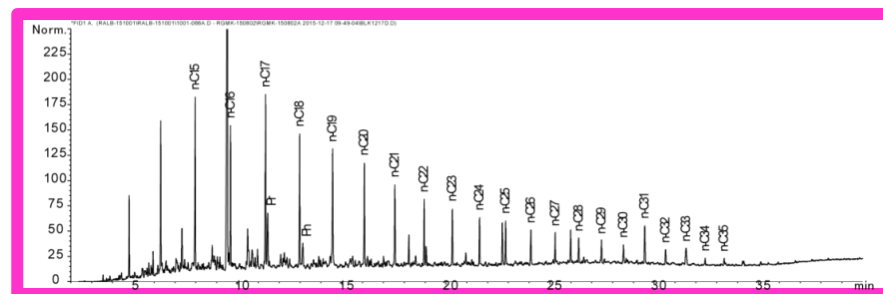
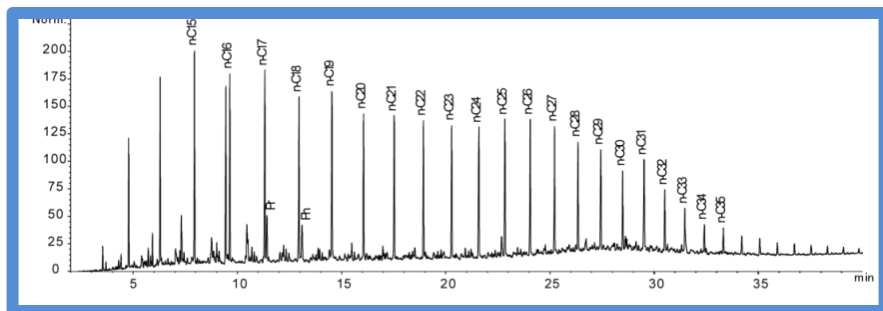
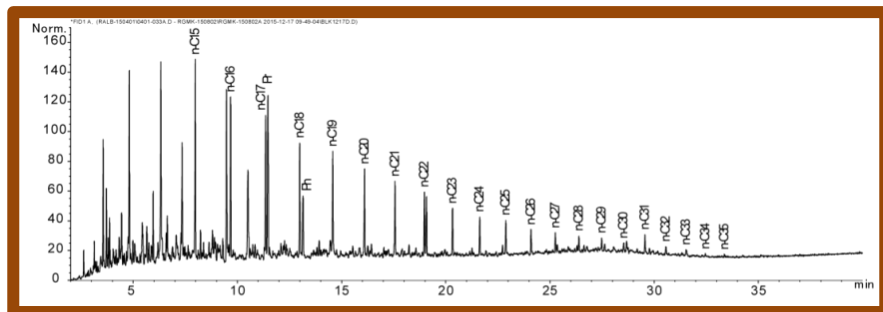


API° = 45.23



API° = 33.92

Extract GCMS

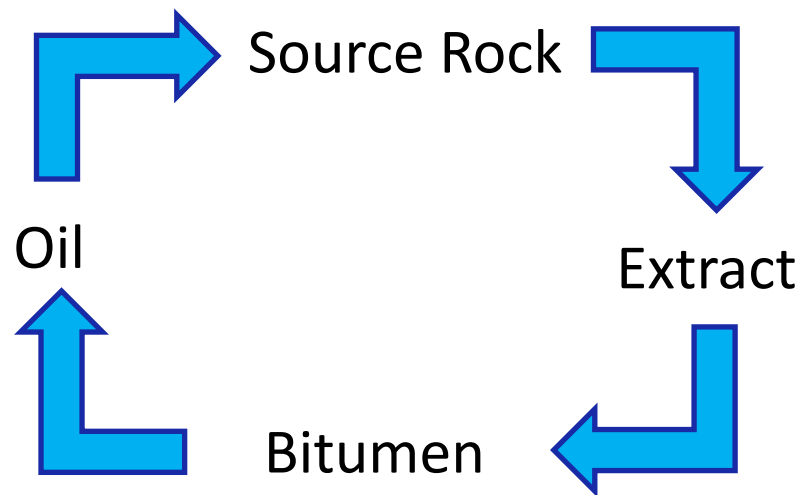
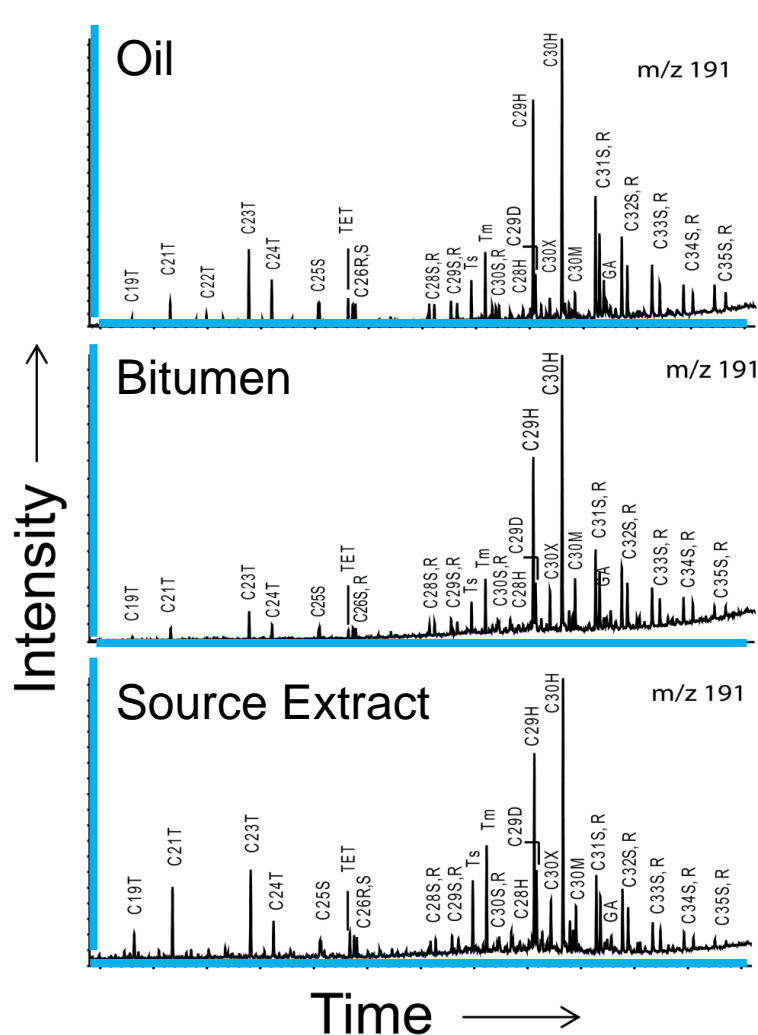


Fingerprinting

- n-alkane + Isotope
- Terpane (m/z 191, 177)
- Sterane (m/z 217, 218)
- Aromatic (m/z 245, 253, 231)

Oil to Source Correlation

Ordovician Oil





Oil to Source Correlation Summary



Cambrian Source

- Lower in steranes
- High BNH/H ratio
- High Tricyclic/H ratio

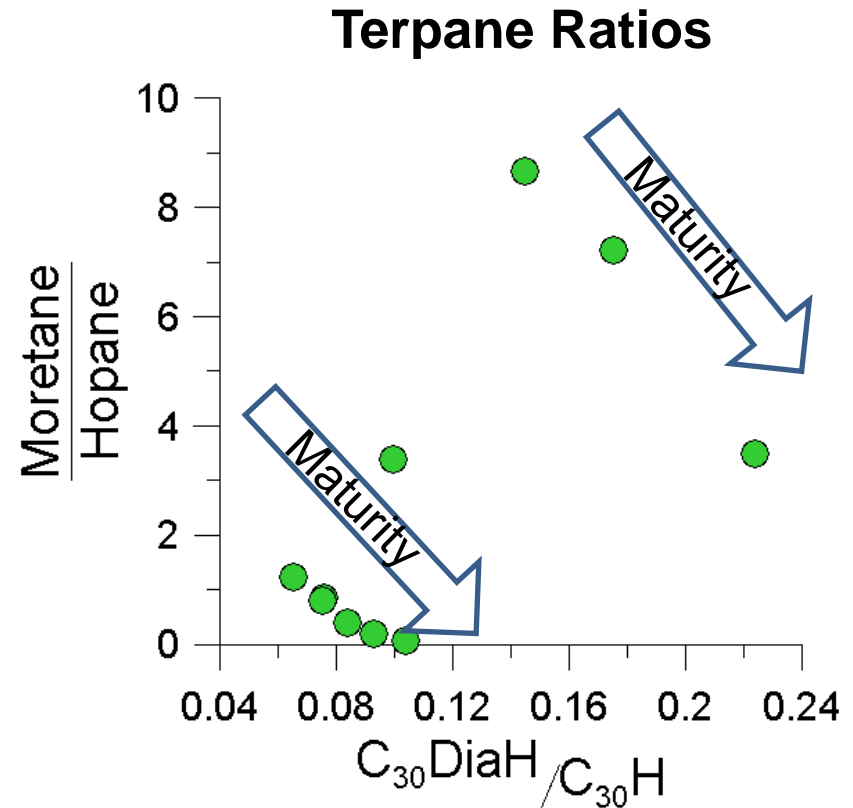
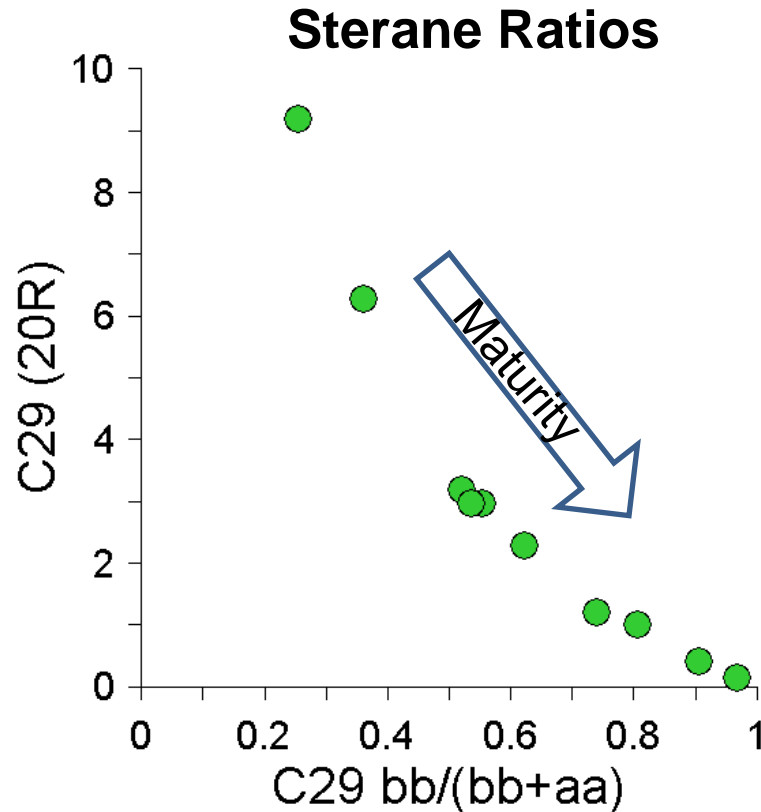
➤ **Primitive, bacterial-derived organic matter**

Ordovician Source

- Higher in sterane concentration
- Low BNH/H ratio
- Low Tricyclic/H ratio

➤ **More evolved, algal-derived organic matter**

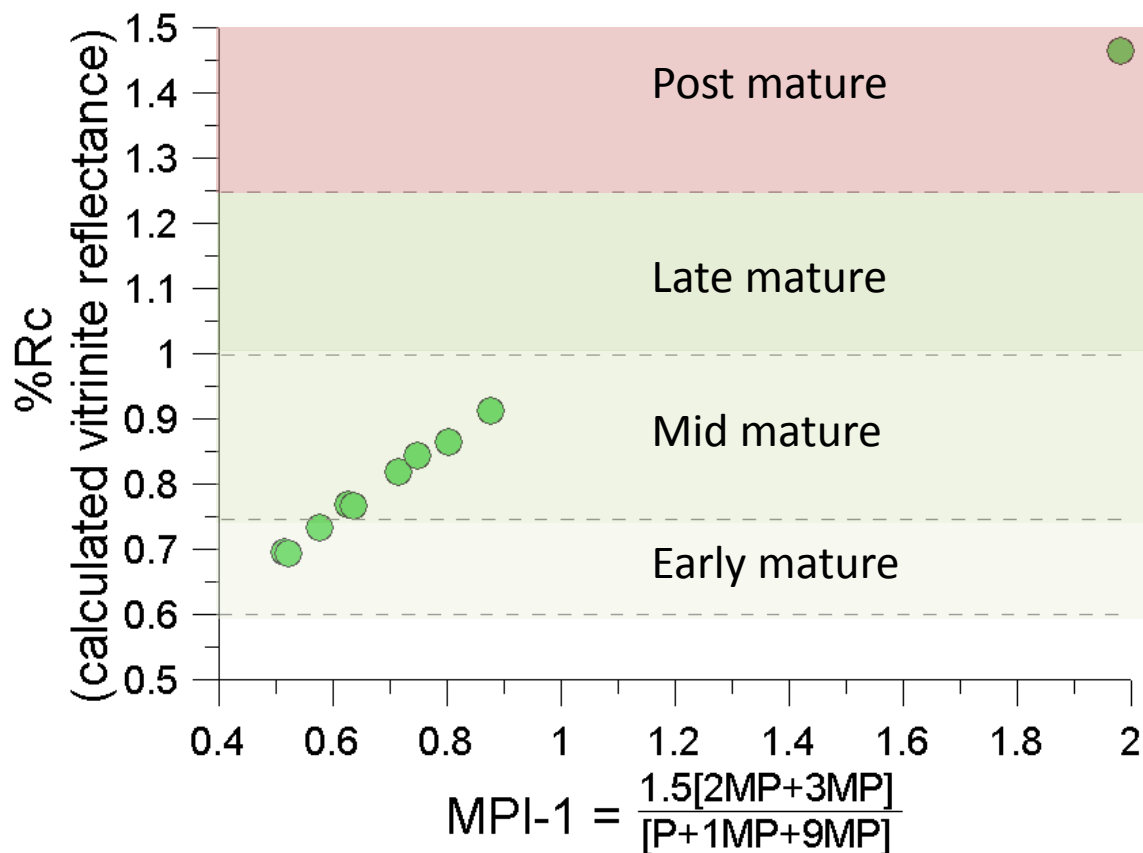
Oil Maturity



- Sterane- and terpane isomer ratios yield similar maturity trends
- Moretane/Hopane is maturity and source-dependent suggesting two different sources



Maturity from Aromatics

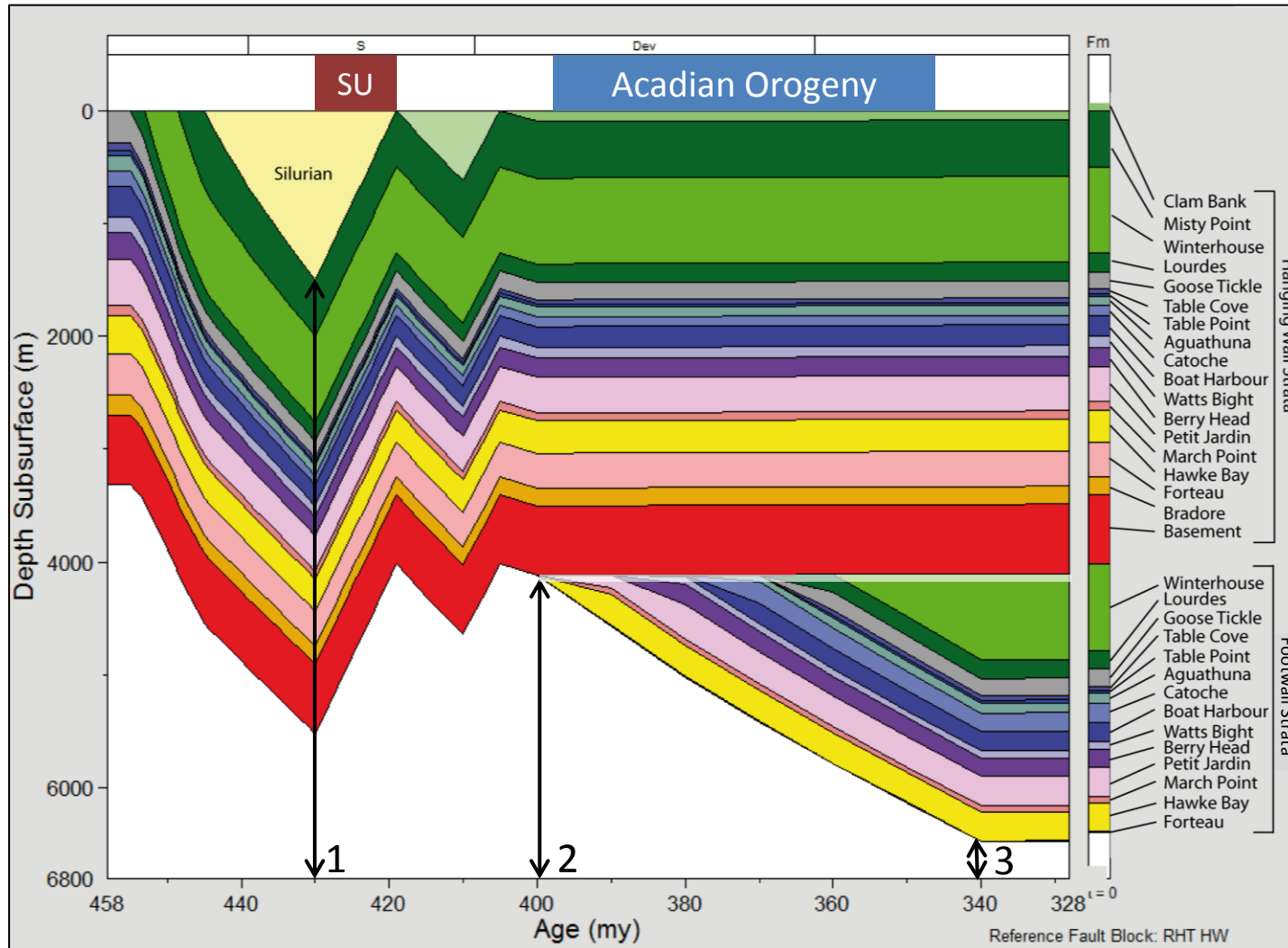


Location	%Rc
Port au Port	1.46
Parsons Pond	0.91
Parsons Pond	0.87
Parsons Pond	0.84
Parsons Pond	0.82
Parsons Pond	0.77
Parsons Pond	0.77
Parsons Pond	0.73
St.Pauls Inlet	0.70
Port au Port	0.69

$$\%Rc = 0.60 \cdot MPI + 0.40$$

(After Radke et al., 1988)

Burial History for Port au Port #1 Well



1. Silurian uplift and erosion
2. Onset of reverse fault
3. End of reverse fault movement



Conclusion

1. Two distinct source intervals can be identified

Cambrian Source Rock

- Type II/III

Increasing source quality from proximal to distal

Ordovician Source Rock

- Type I/II

Increasing source quality from proximal to distal

2. The organic matter of both those intervals show distinctive biomarker distribution

Cambrian Source Extract

- Primitive, bacterial-derived organic matter

Ordovician Source Extract

- More evolved, algal-derived organic matter

3. The same characterizing biomarker in extracts bitumen and oil samples can be identified

Cambrian Oil

- High quality oil ; API° ~ 45°

Ordovician Oil

- High quality oil ; API° ~ 35°



Acknowledgement

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- Petroleum Exploration Enhancement Program
- GeoMark Research, Inc.
- Platte River Associates, Inc.
- Shawna White, Ryan Lacombe and Morgan Snyder
- Larry Hicks, "Earl" Fisherman



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