

# **The Final North America Conventional Oil Frontier: The Intracratonic Hudson Bay Basin in the Canadian Arctic\***

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## **Abstract**

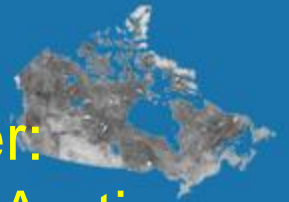
The Hudson Bay Basin covers ~820,000 km<sup>2</sup> and is the largest intracratonic basin in North America. The succession of the Hudson Platform consists mainly of Paleozoic strata, with a maximum preserved thickness of about 2,500 m. The Paleozoic succession includes Ordovician to Devonian shallow marine carbonates, reefs and shales with locally thick Devonian evaporites. Paleozoic strata are unconformably overlain by erosional remnants of Jurassic, Cretaceous and Tertiary non-marine and marine strata. In a first phase of exploration (1973-1985), over 46,000 line-km of seismic reflection data were acquired and five offshore exploration wells drilled. Most of the seismic profiles and all of the exploration wells are located in a relatively small area in the central part of Hudson Bay.

Re-evaluation of the available seismic indicates that syn-tectonic sedimentation occurred in Late Ordovician (?), Silurian and Early Devonian with significant depocentre migration with time. New biostratigraphic data, supported by the seismic evidence, suggest three major unconformities, with the most important one at the Silurian-Devonian boundary. Preliminary interpretation of AFT data suggest that maximum burial occurred likely in Middle to Late Devonian and in agreement with organic matter reflectance data (Rovit of 0.60 to 0.91%), imply that the Ordovician - Silurian interval went through the oil window. Available hydrocarbon system data are synthesized in five prospective petroleum plays, including recently recognized porous hydrothermal dolomites and reefs. Type I/II Upper Ordovician oil shales are recognized at several locations in the basin with TOC values up to 35% and thickness up to 11 metres. Lower Silurian shales may also have local potential (TOC values up to 2%). New high-resolution bathymetric surveys in Hudson Bay led to the recognition of circular sea-floor depressions similar to fluid-escape pockmarks and preliminary interpretations of RADARSAT images suggest possible oil slicks at sea surface. Some direct hydrocarbon indicators are interpreted from the vintage seismic information. Taken together, these new hydrocarbon systems data suggest that large areas of the Hudson Platform are prospective for oil accumulations.

## Selected References

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# The Final North America Conventional Oil Frontier: The Intracratonic Hudson Bay Basin in the Canadian Arctic



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# OUTLINE

## Hudson Bay Basin

1. Geological setting and historical review
2. Stratigraphy and structural framework
3. Hydrocarbon system data
  - Source rock – nature, distribution, maturity
  - HC generation modeling
  - Play types
4. Evidence for active hydrocarbon systems
5. Conclusions



# Hudson Bay Platform

## A major FRONTIER sedimentary basin in Northern Canada

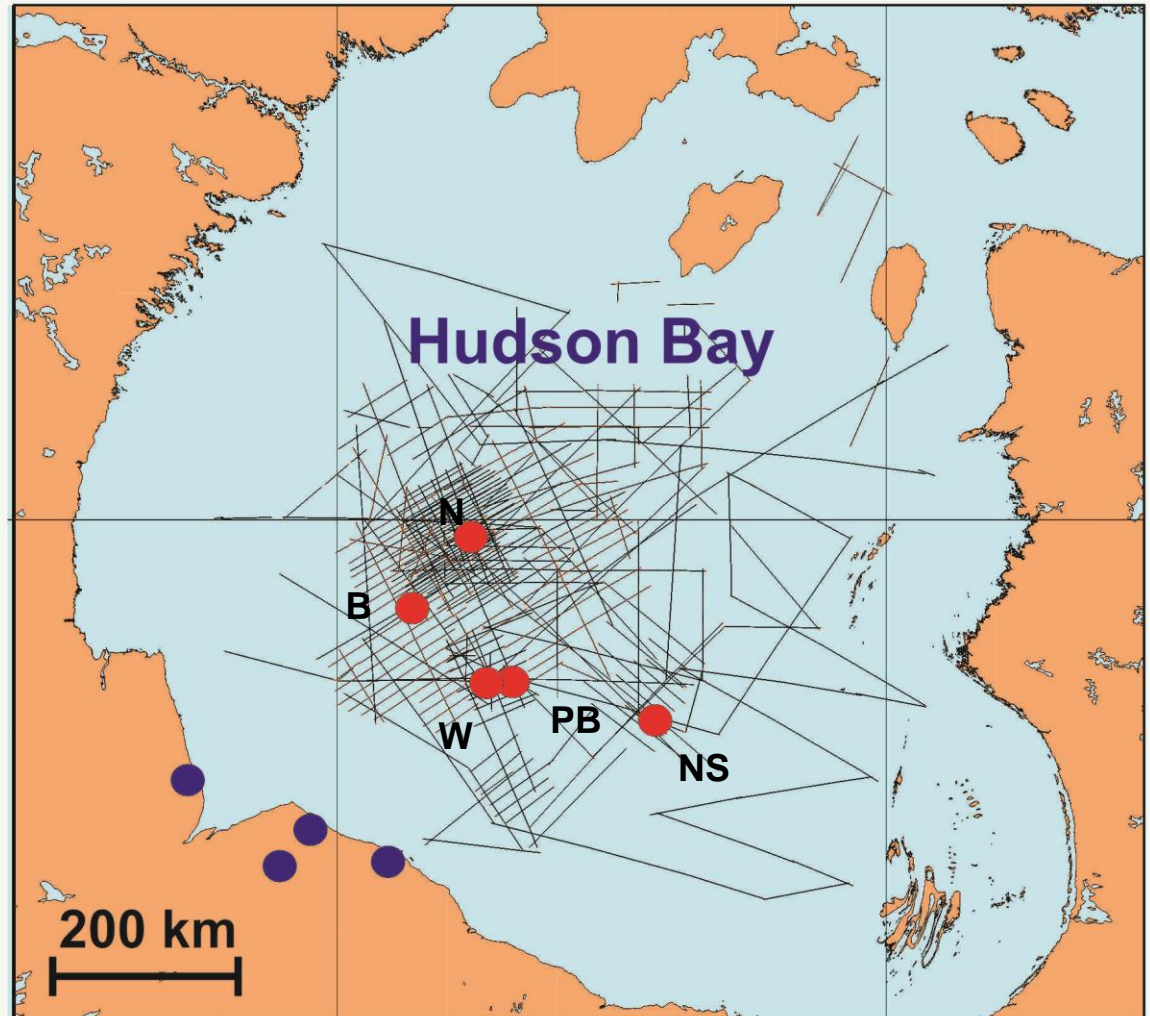


# Petroleum Exploration in Hudson Bay Basin

● 4 Onshore Wells  
(1966 - 1970)

● 5 Offshore Wells  
(1974 - 1985)

／ 46,000 Line-Km  
Marine Seismic  
Reflection Data  
(1970s - 1980s)



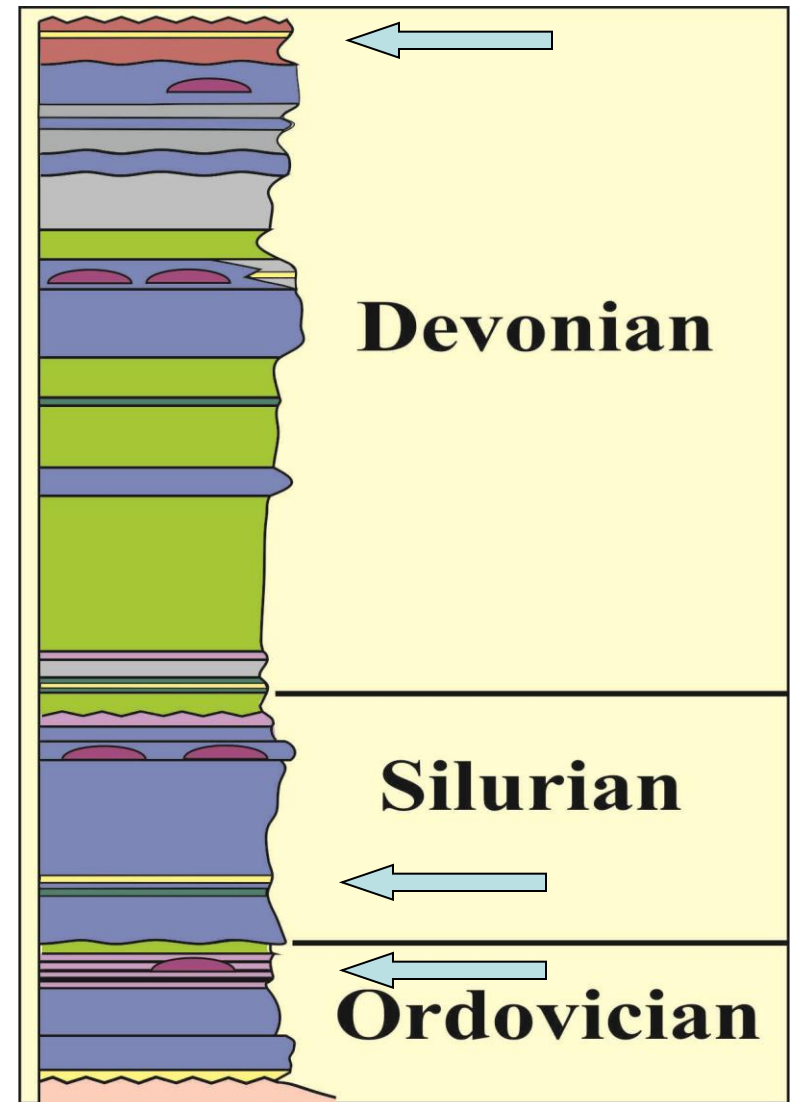
**Devonian to  
Upper Ordovician  
shallow marine platform  
carbonates, shales and  
local bioherms**

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**variably thick, restricted  
marine evaporites**  
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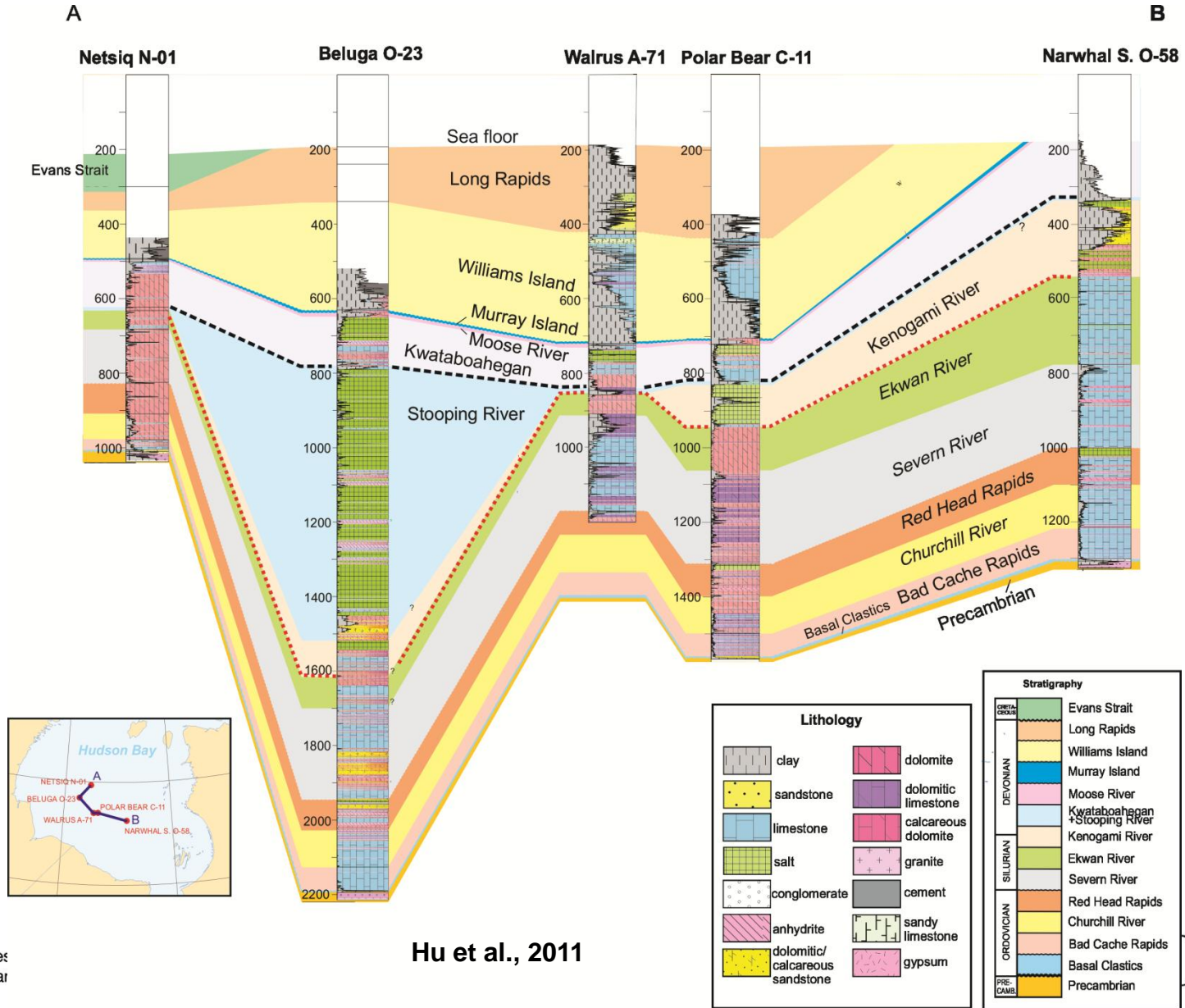
**thin, widespread  
organic-rich shales**  
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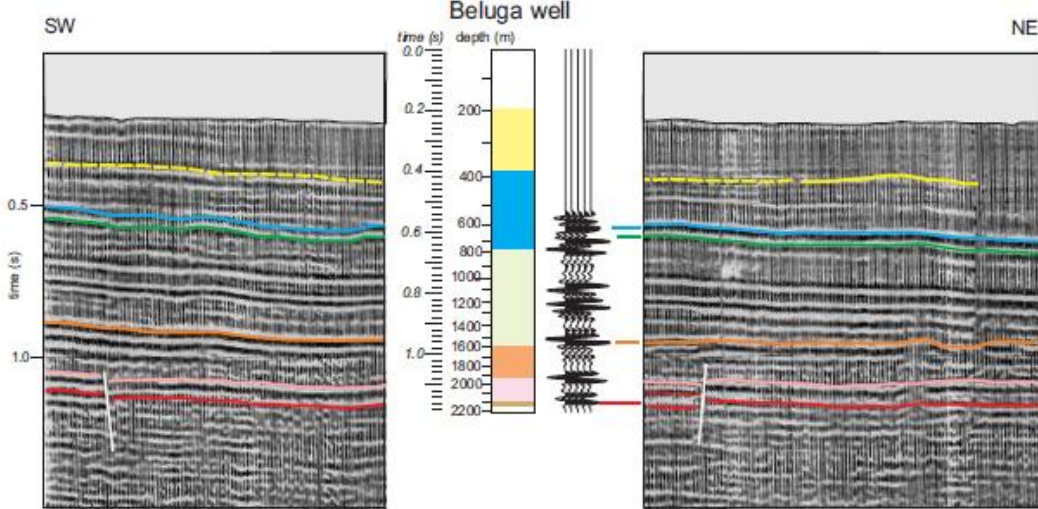
**thin sections of  
coastal plain sandstones**

## Lithostratigraphy

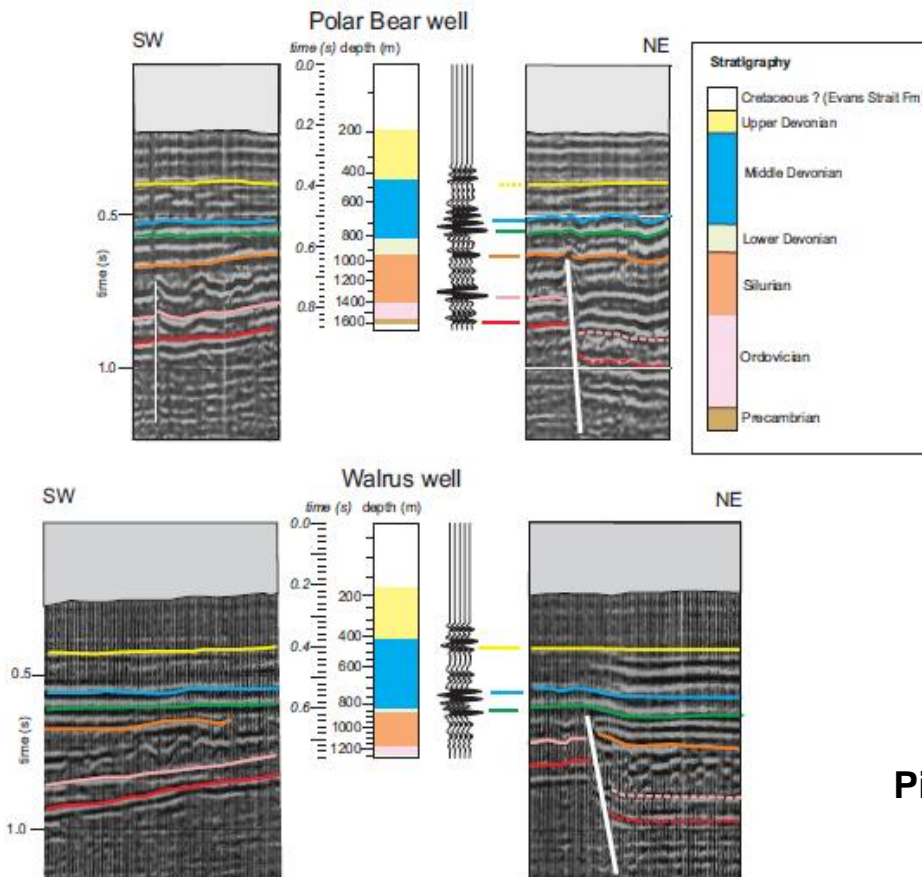


## Hudson Bay - Log correlation and palynology



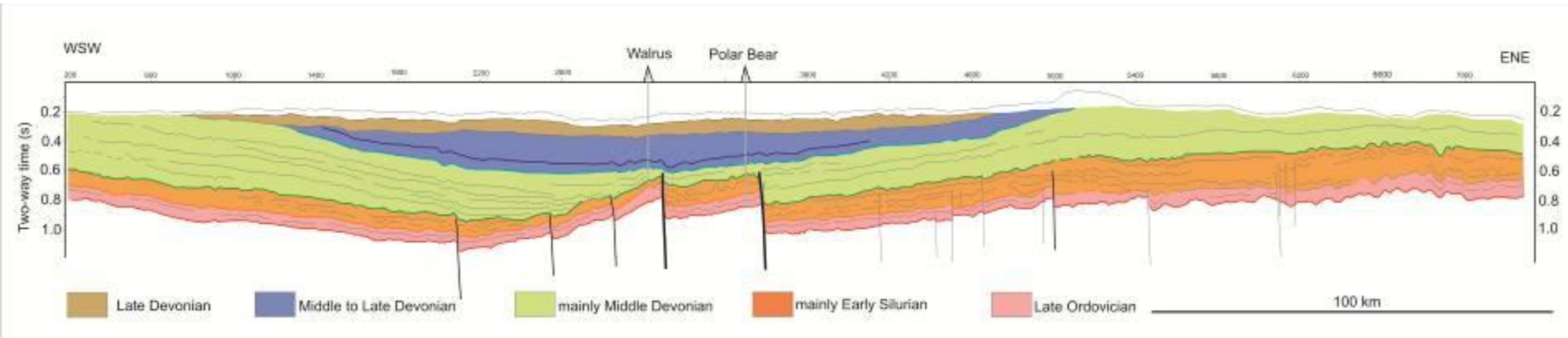


## Wells / logs – seismic ties



Pinet et al (submitted, Earth Science Reviews)

# Basin geometry



## New seismic interpretation

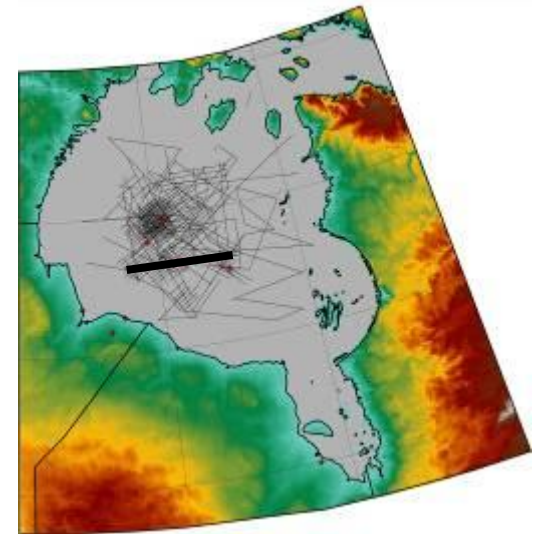
4 major unconformities

Ordovician-Silurian: U1

Upper Silurian-Lower Devonian: U2

Middle Devonian: U3

Upper Devonian: U4



# Petroleum System Elements

## Well and Outcrop Data

**porous reservoirs, including  
hydrothermal dolomites and reefs**

**widespread oil-prone  
Upper Ordovician source rocks**

**oil-window maturation levels  
in Ordovician strata**

## Seismic Data

**five petroleum play types  
(several untested in early drilling)**



# Source rock distribution (outcrop and well data)



Type I/II-S – oil prone



Type II – oil and gas prone

**Yields: 20 - 134 kg/tonne**

**TOC: 5 - 35% Tmax: 421 - 432°C**

**Ro: 0.4 – 0.6%**

— Macauley (1986); Zhang (2009, 2011)

**Yields: 16 - 99 kg/tonne**

**TOC: 3 - 15% Tmax: 416 - 431°C**

— Macauley (1987); 10-15 metres

**Boas River shale,**

**TOC: 3 – 15% Tmax: 420 - 426°C**

**Ro: 0.6 – 0.8%**

**Armstrong and Lavoie (2010)**

**11 metres**

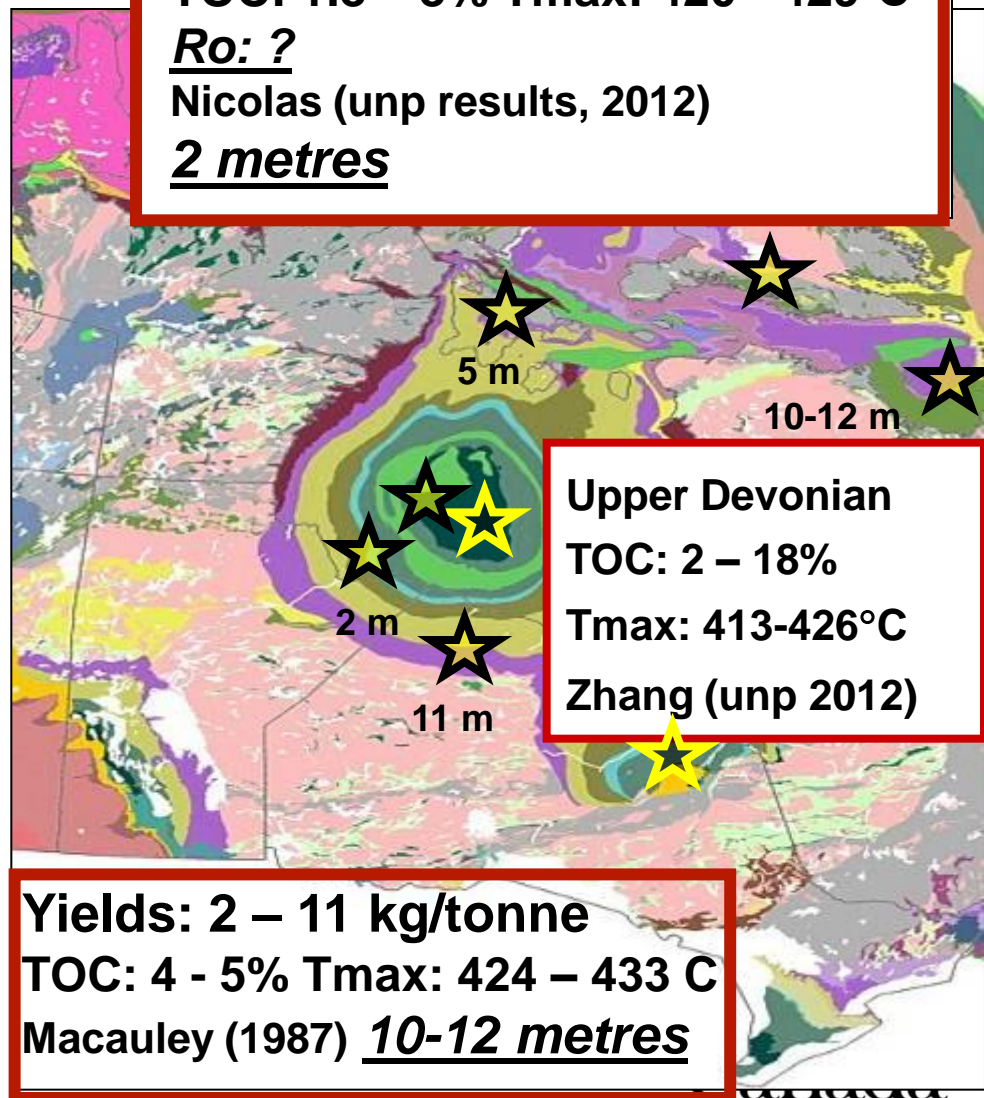
**Boas River shale,**

**TOC: 1.8 – 8% Tmax: 420 - 429°C**

**Ro: ?**

**Nicolas (unp results, 2012)**

**2 metres**



**Upper Devonian**

**TOC: 2 – 18%**

**Tmax: 413-426°C**

**Zhang (unp 2012)**

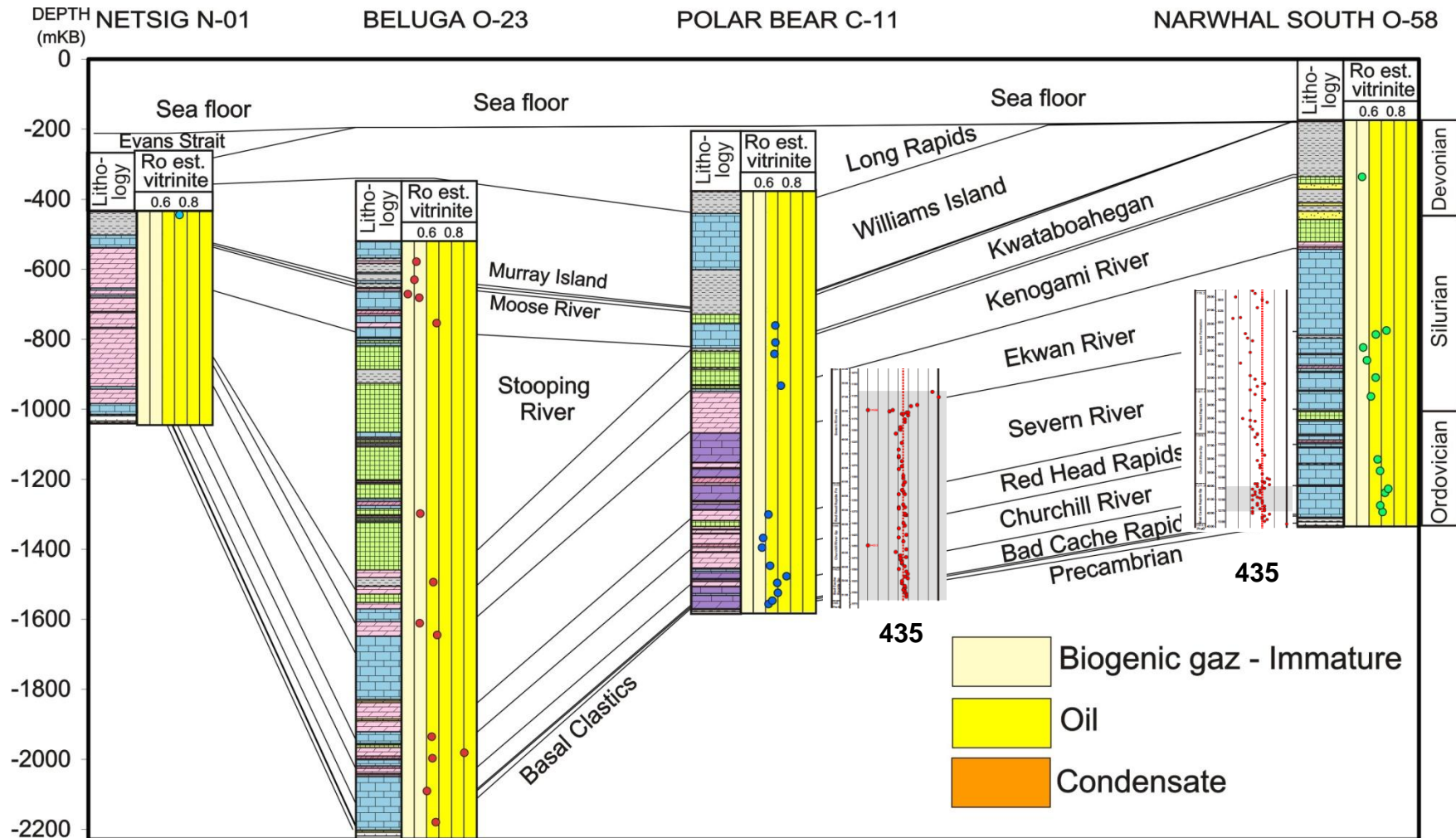
**Yields: 2 – 11 kg/tonne**

**TOC: 4 - 5% Tmax: 424 – 433 C**

**Macauley (1987) 10-12 metres**



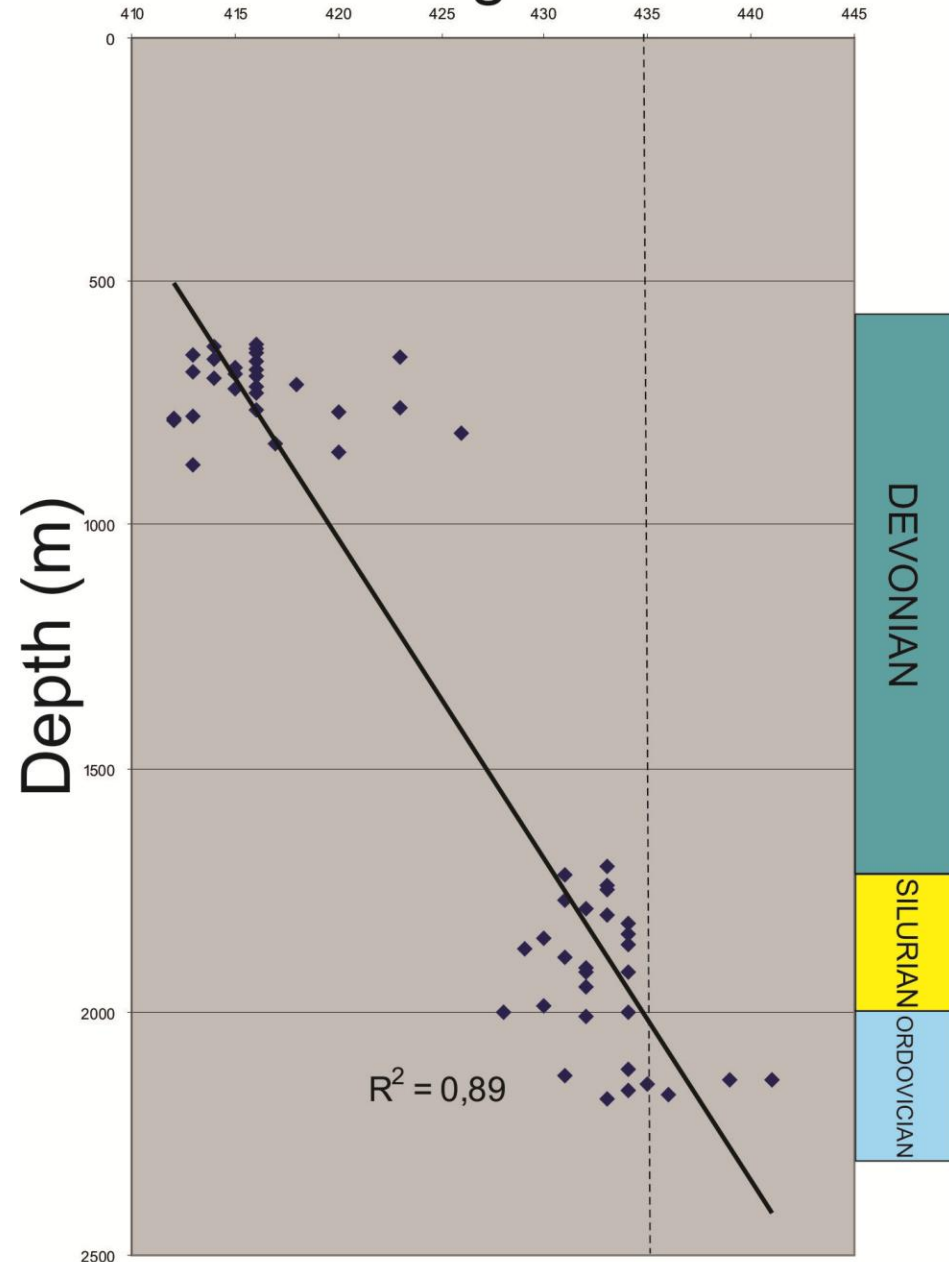
# Organic matter reflectance



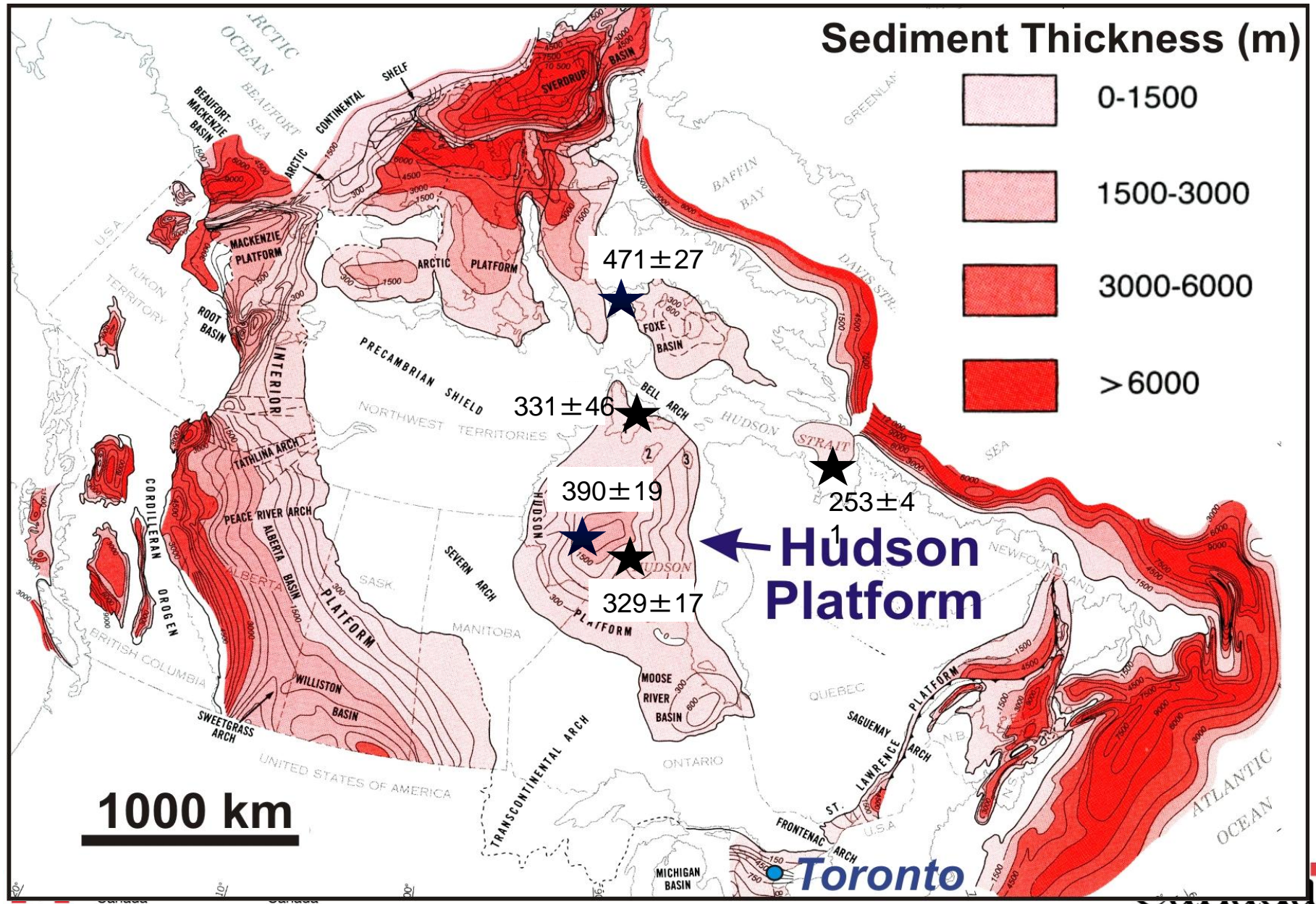
# Beluga O-23

New RE data for the Devonian allows a more robust vertical correlation of thermal indicators

Oil window threshold at the Silurian-Ordovician contact

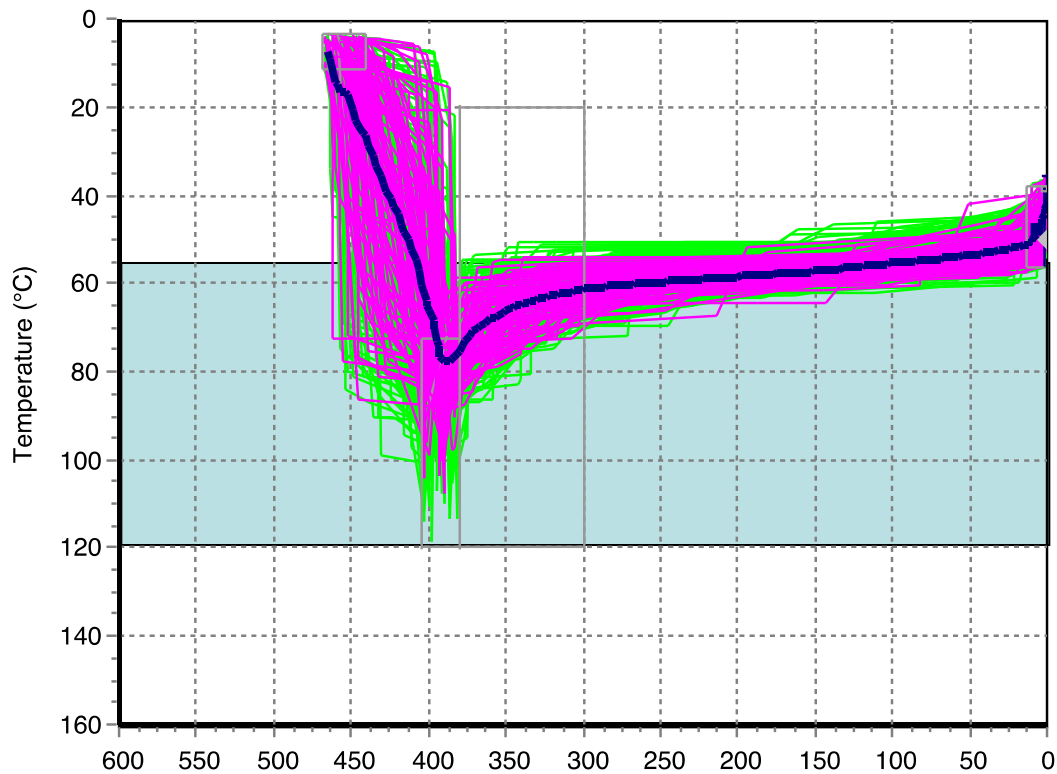


# Apatite fission track ages (Ma)

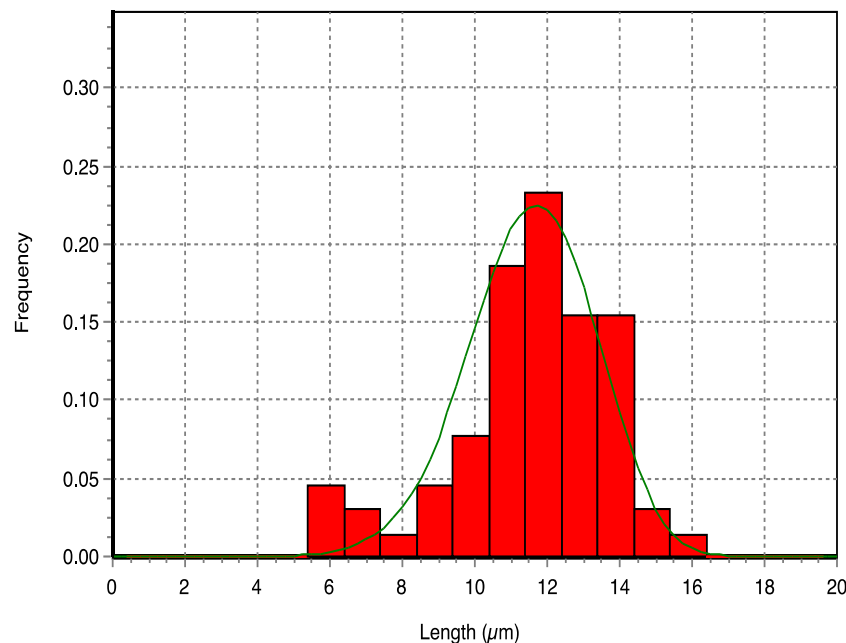


# Thermal history Precambrian basement - Narwhal South O-58 well

Time-Temperature History



AFT: Track Length Distribution



Time (Ma)  
*AFT Age (Ma)*      *Mean Track Length (μm)*

|          |                |                  |
|----------|----------------|------------------|
| Observed | $329 \pm 17.0$ | $11.08 \pm 2.15$ |
| Model    | 328            | $11.54 \pm 1.77$ |
| GOF      | 0.90           | 0.94             |

$T_{max}$  weighted mean =  $\sim 77^\circ \text{C}$  at 394 Ma

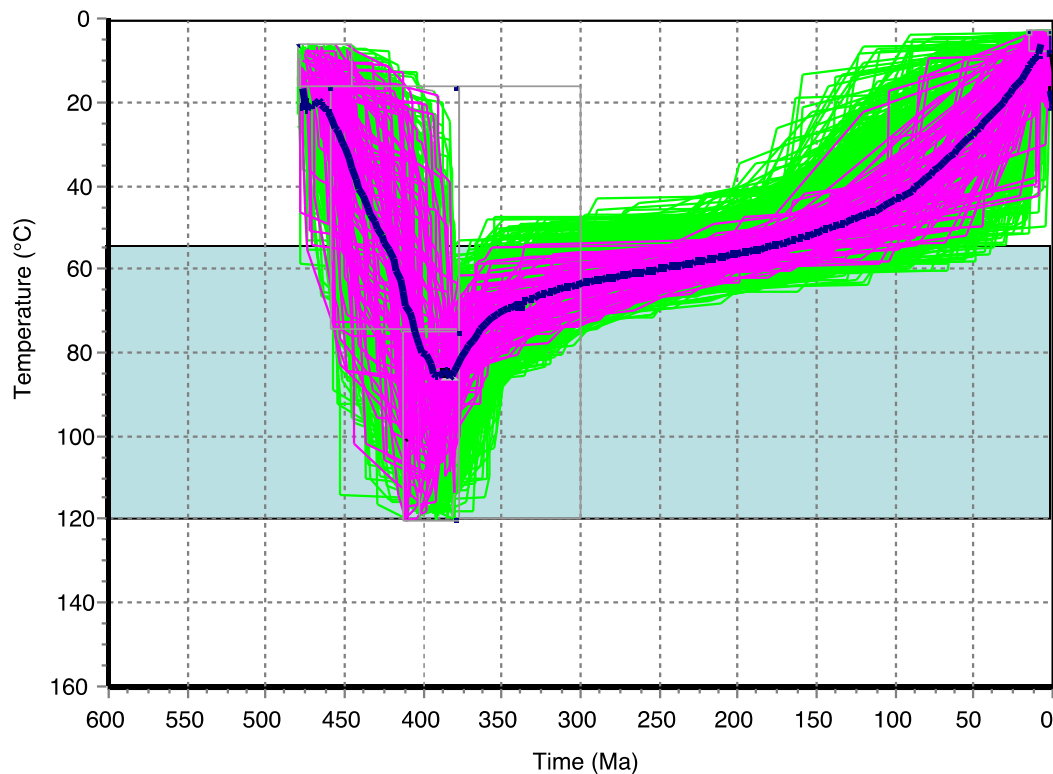
$T_{max}$  best fit =  $\sim 81^\circ \text{C}$  at 392 Ma

**Late Devonian (3km)**

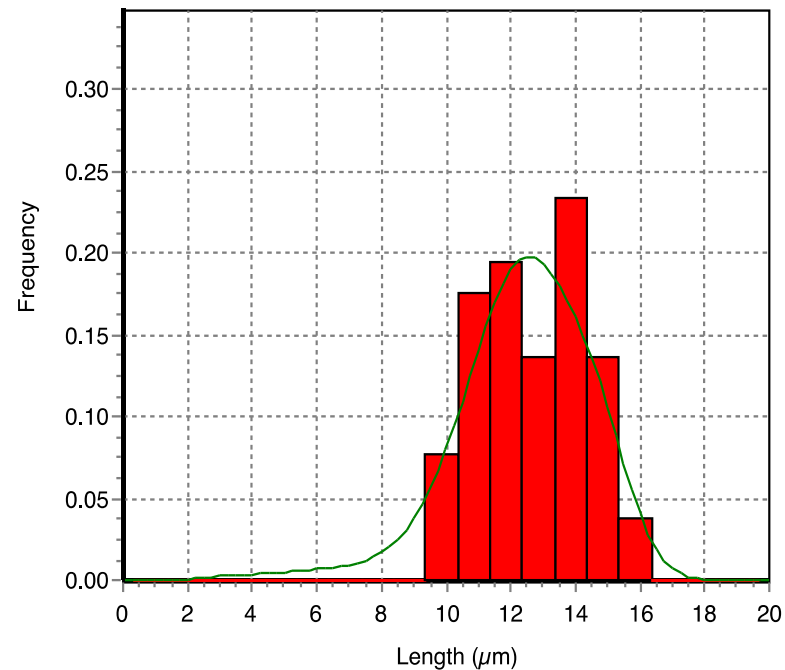


# Thermal history Upper Ordovician Sandstone – Southampton Island

Time-Temperature History



AFT: Track Length Distribution



*AFT Age (Ma)*      *Mean Track Length (μm)*

|          |          |              |
|----------|----------|--------------|
| Observed | 331 ± 46 | 12.36 ± 1.65 |
| Model    | 329      | 12.38 ± 2.18 |
| GOF      | 0.86     | 0.91         |

*T<sub>max</sub> weighted mean = ~85° C at 393 Ma*

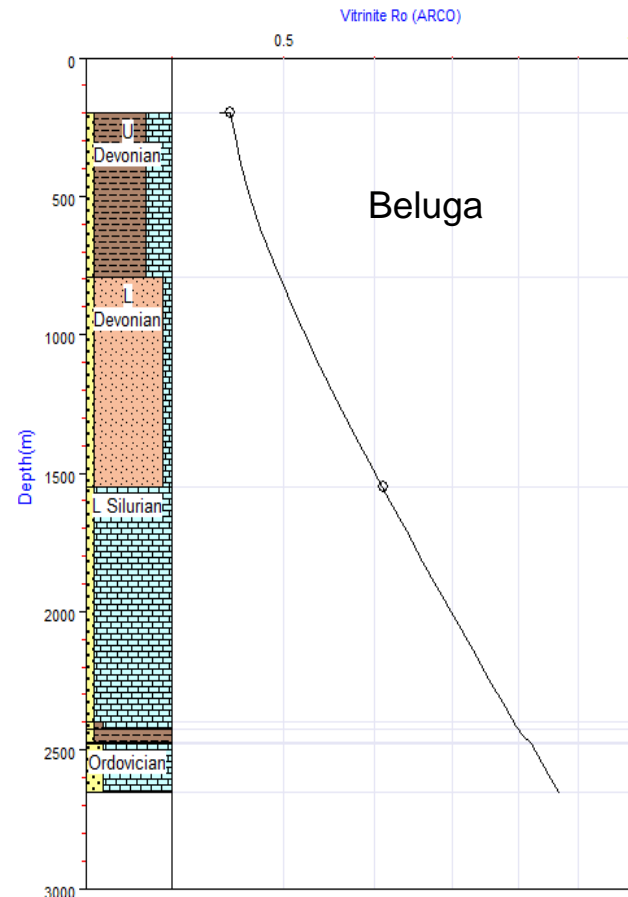
*T<sub>max</sub> best fit = ~98° C at 393 Ma*

**Late Devonian (3.3 km)**

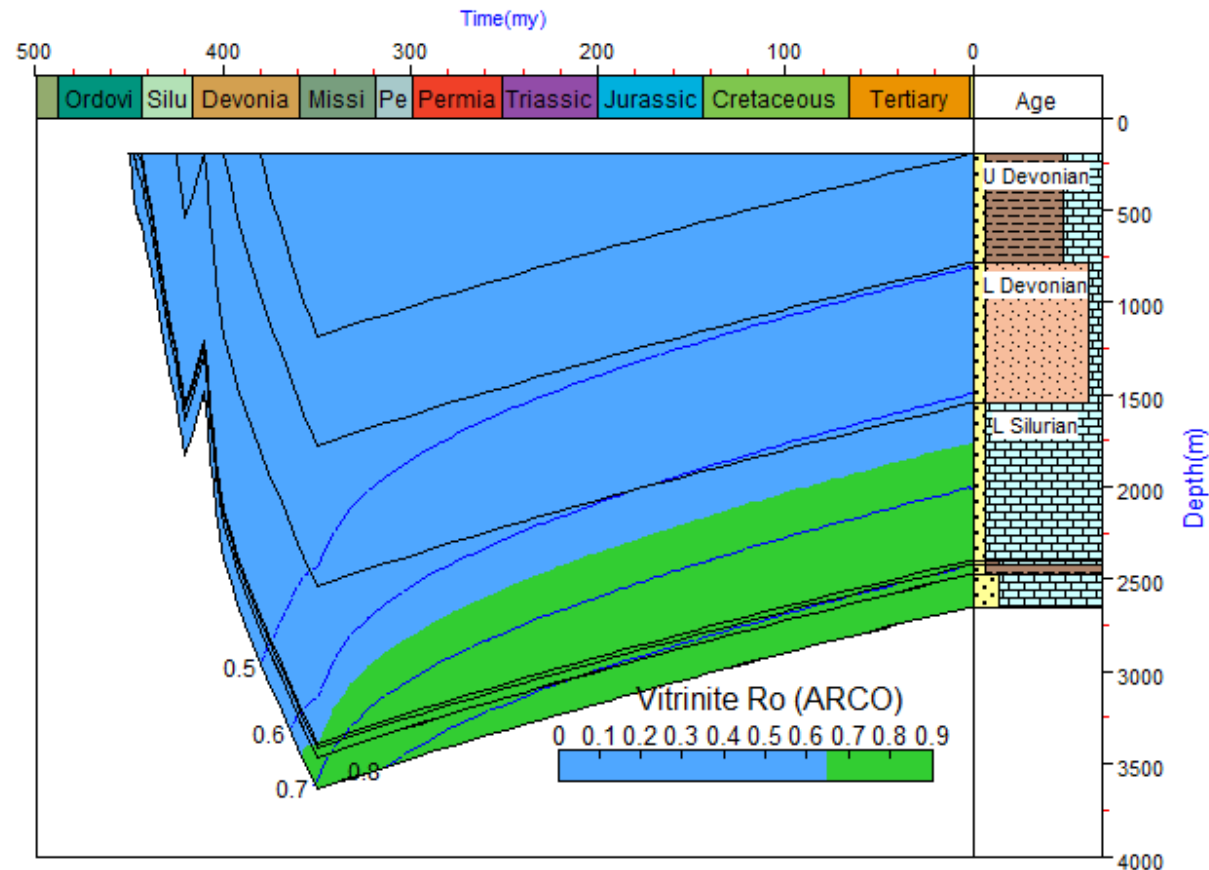


# Hydrocarbon generation modeling

Hydrocarbon generated from Type IIS organic matter – peak generation in Late Devonian

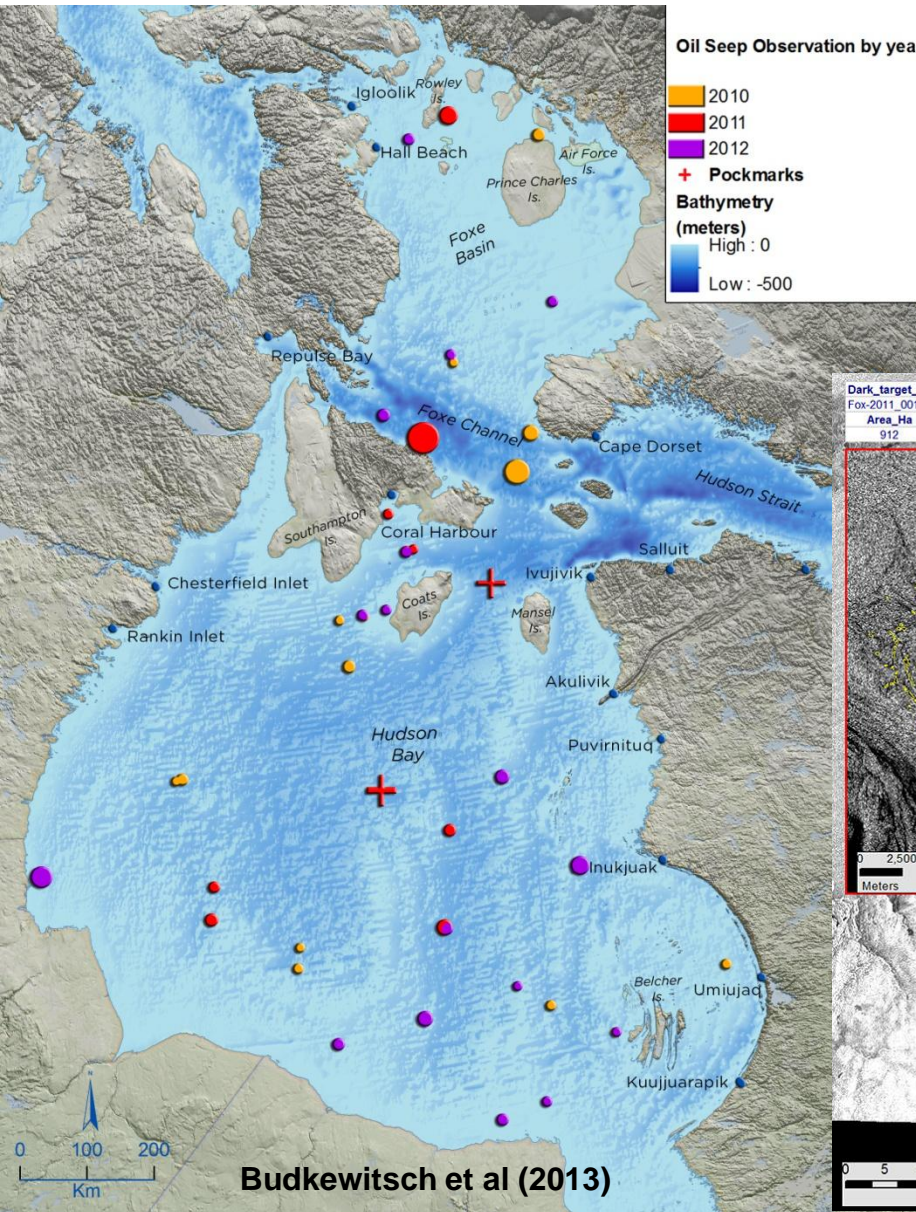


Chen and Dietrich

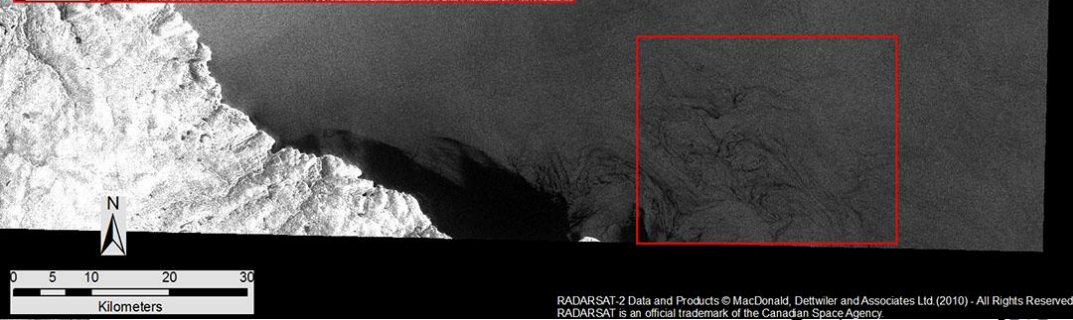
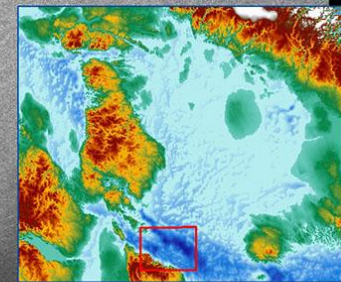
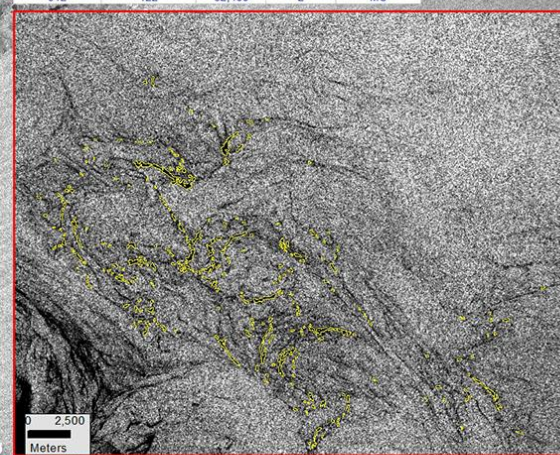


# Oil slicks at the surface of Hudson Bay?

3 years of Radarsat images; identification of 46 anomalies (oil slicks ?)



| Dark_target_ID | Acquisition Date | Beam Mode  | Polarisation | Pass Direction |
|----------------|------------------|------------|--------------|----------------|
| Fox-2011_001   | 2011-11-21       | Wide 2     | VV           | Descending     |
| Area_Ha        | Orientation_d    | Diameter_m | Confidence   | Class          |
| 912            | 122              | 32,400     | 2            | MC             |



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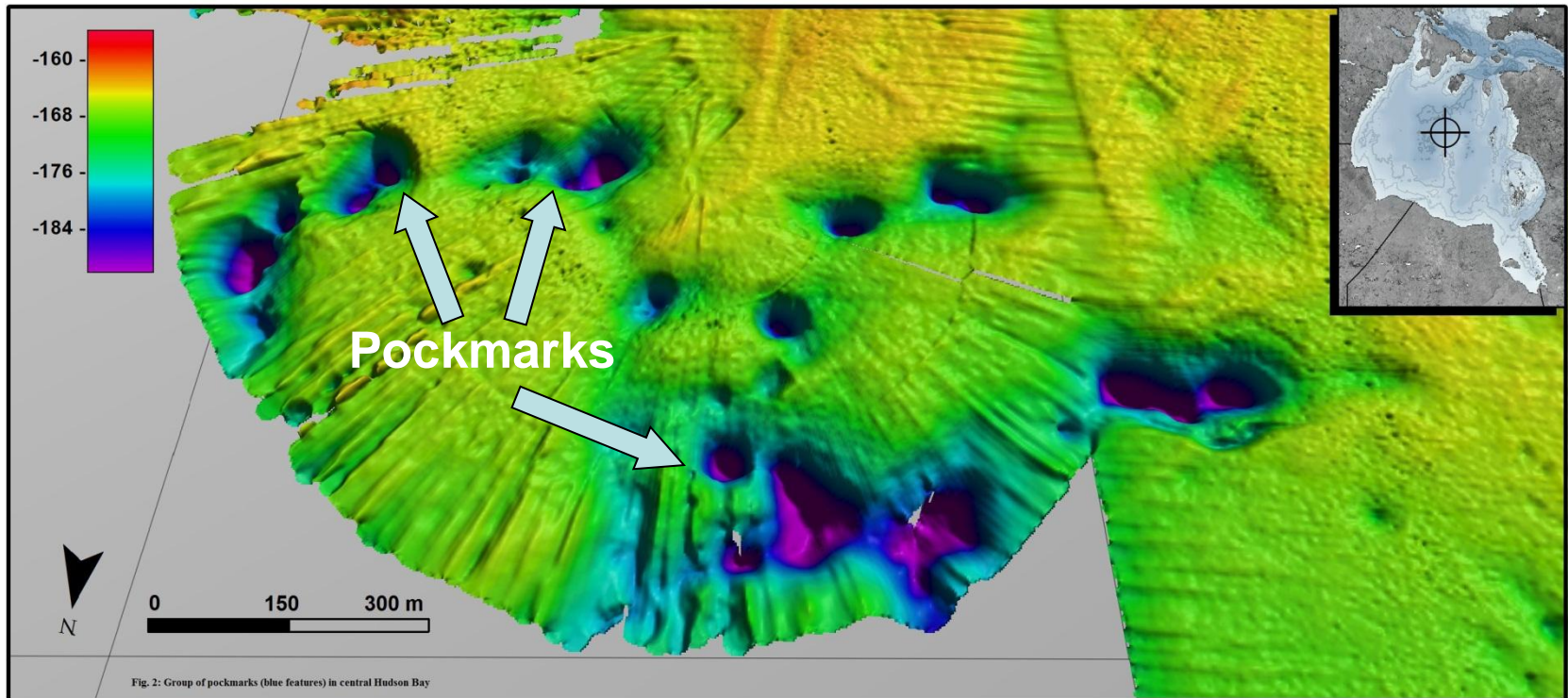


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Natural Resources  
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# Pockmarks in central Hudson Bay



Roger et al. 2011



Ressources naturelles  
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Natural Resources  
Canada

Canada

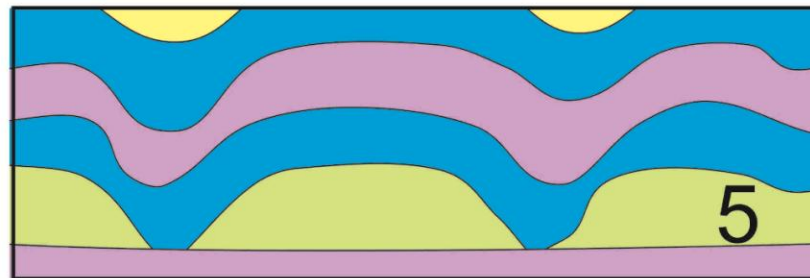
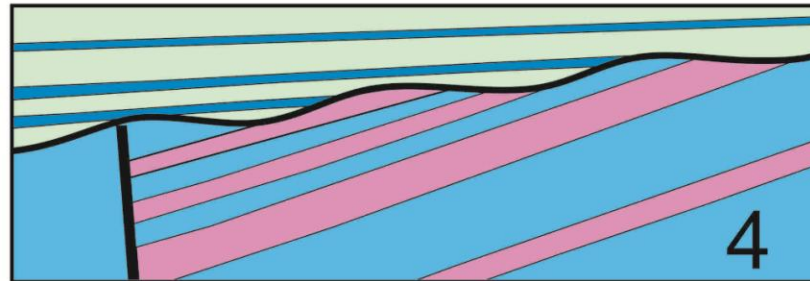
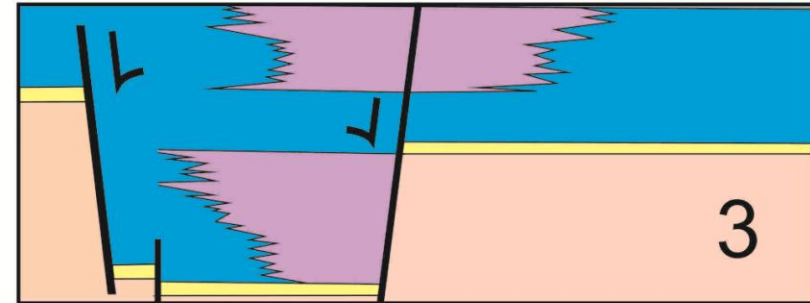
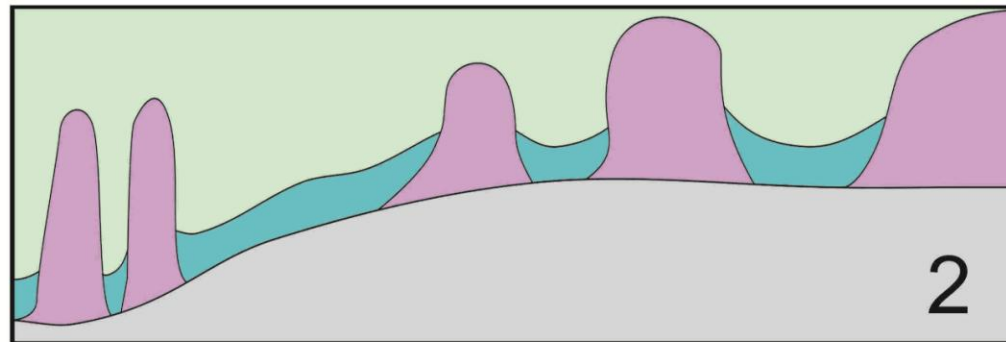
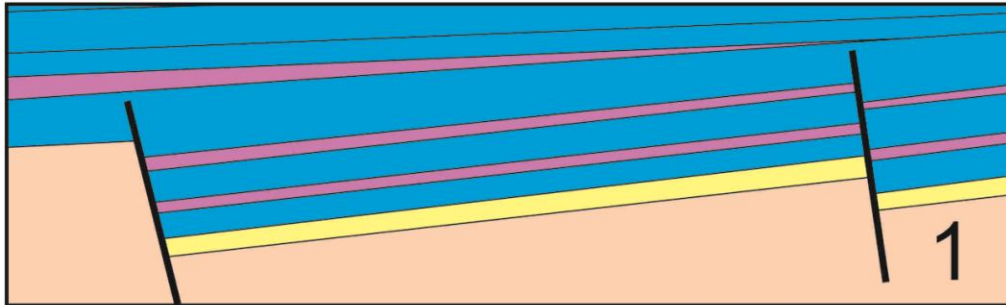
# HYDROCARBON SYSTEM ELEMENTS

5 Play types  
Nature and seismic expression

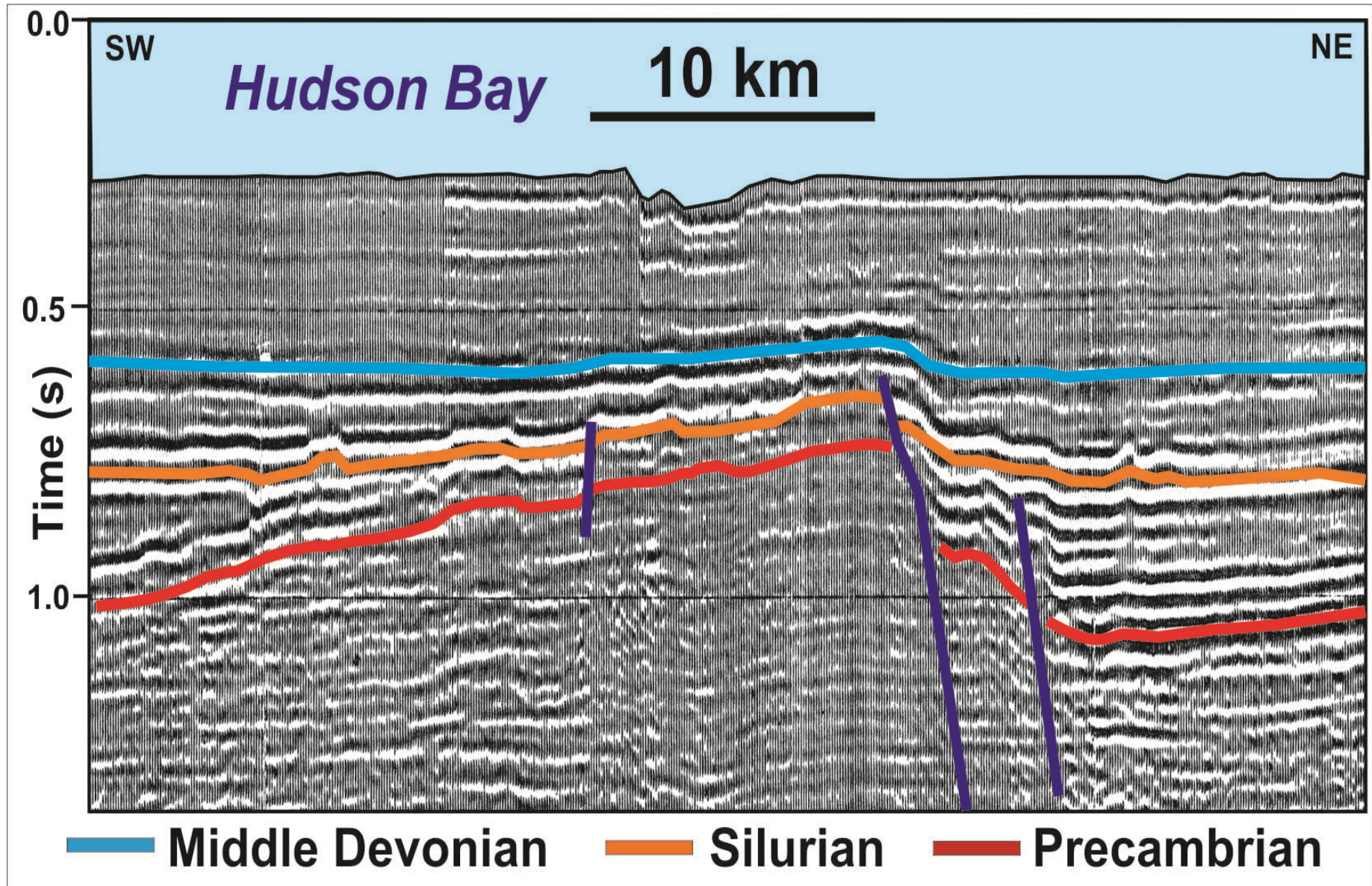


# Five conceptual conventional hydrocarbon plays – based on seismic and field data

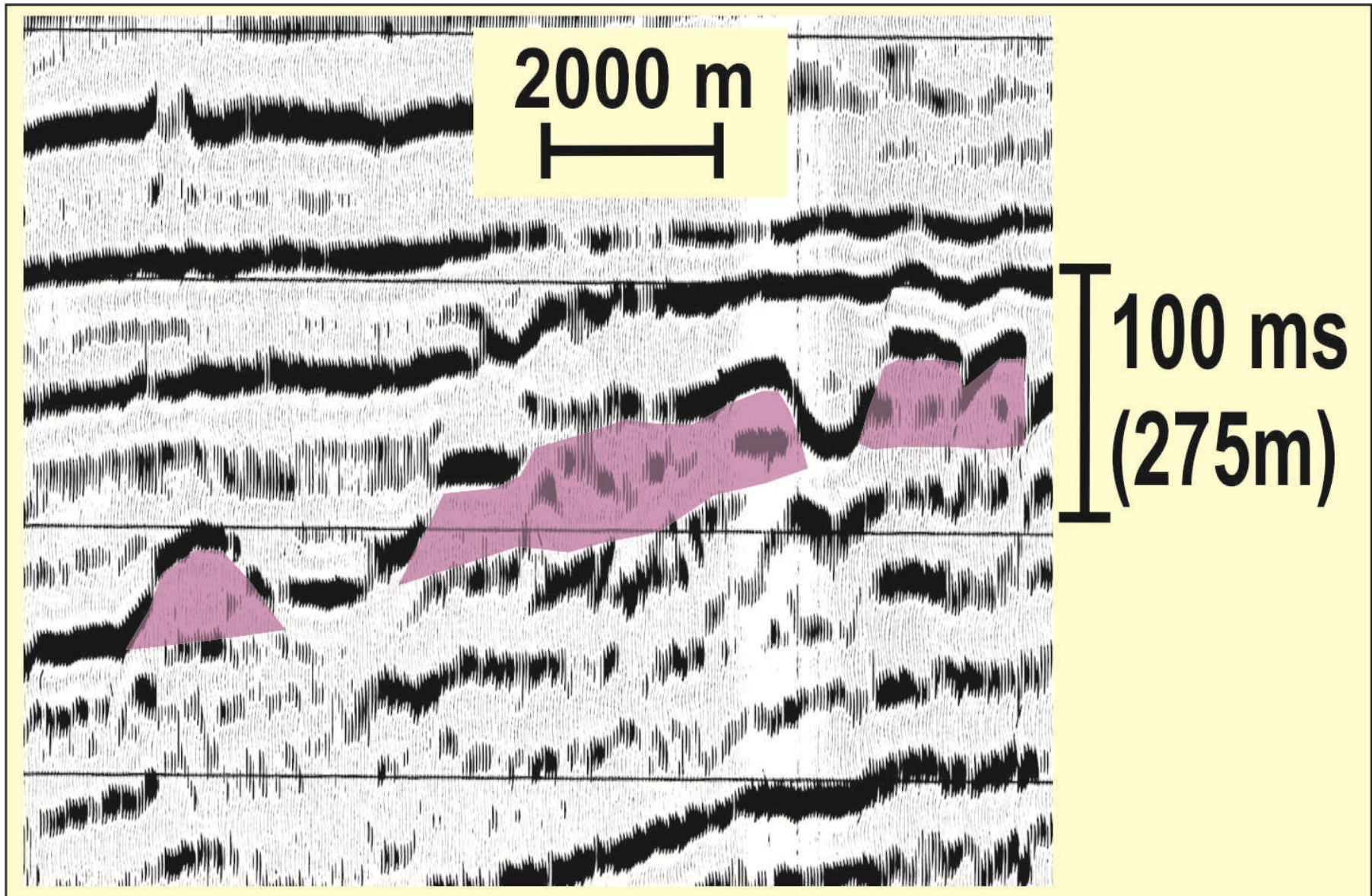
1. Tilted Fault Blocks
2. Pinnacle/Barrier Reefs
3. Fault Sags - Hydrothermal Dolomite
4. Unconformities (Onlap, Truncation)
5. Salt Dissolution Folds



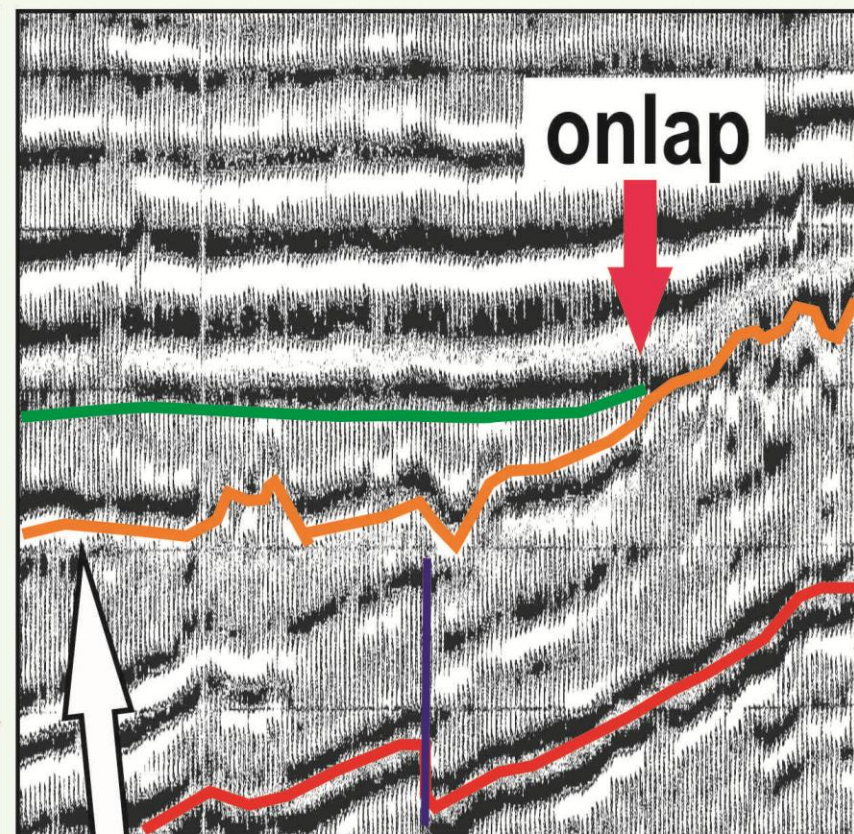
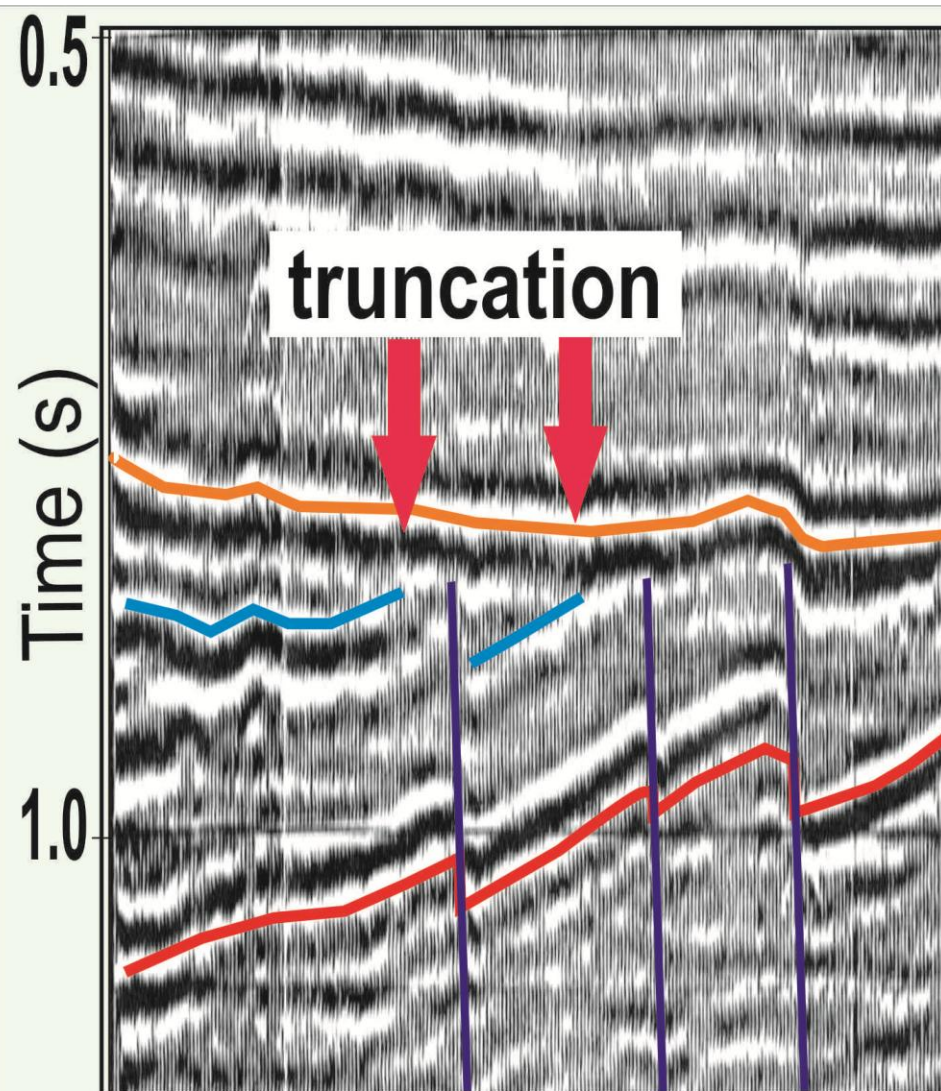
# Tilted Fault Block Play



# Silurian reefs (Attawapiskat Fm.)



# Unconformity Play

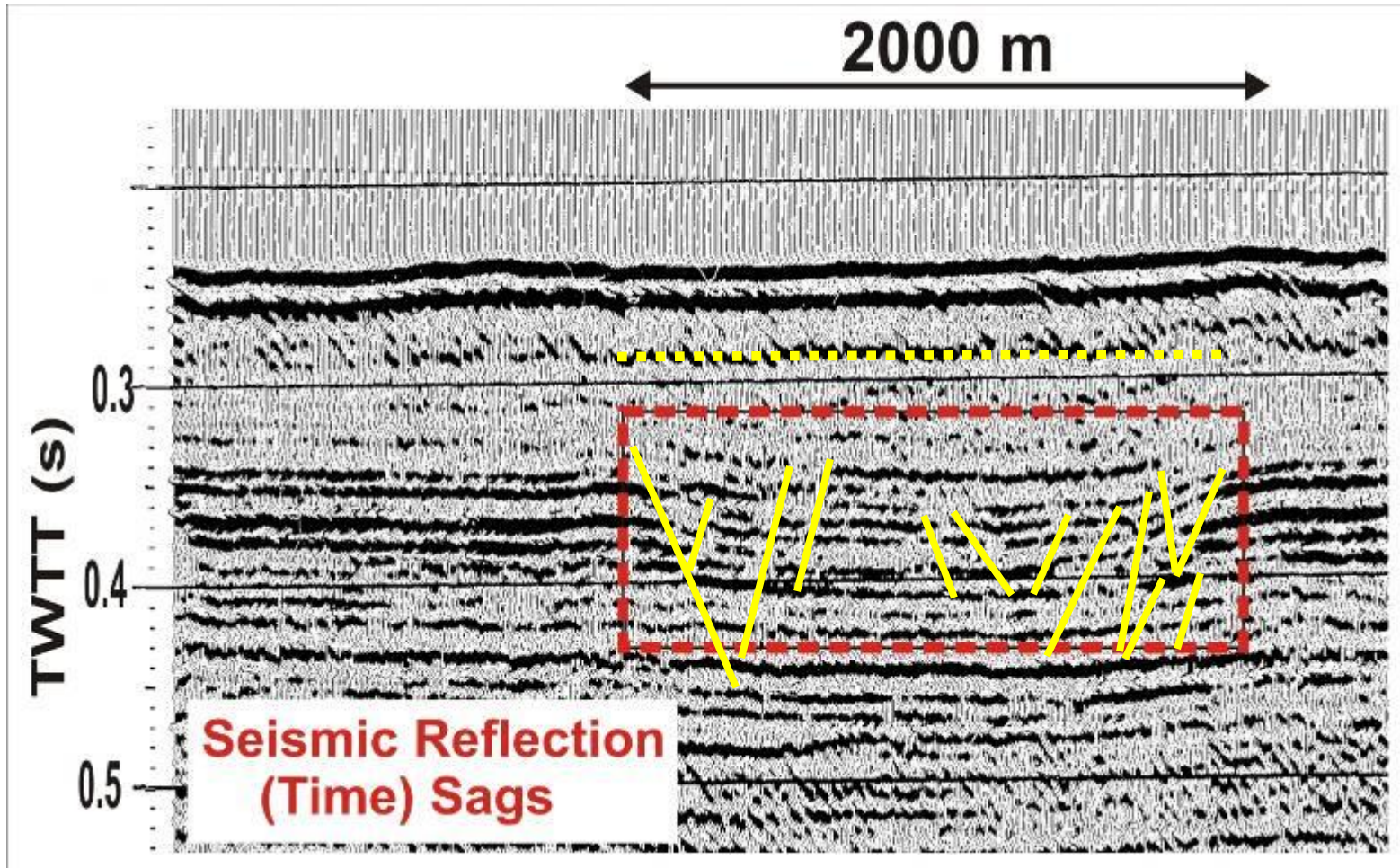


sub-Devonian  
unconformity

5 km



# Seismic sag



# Conclusions

1. Upper Ordovician source rocks are identified around and in the central part of Hudson Bay. Based on petrography, gas chromatography they are dominated by Type II-sulphur rich marine material
2. Organic petrology and AFT data indicates that the Ordovician source rocks went through the oil window. Hydrocarbons were generated in Late Devonian time at maximum burial (3.5 km)
3. 5 hydrocarbon plays are proposed based on seismic and field data; a significant number of « direct hydrocarbon indicators » have been identified on the vintage seismic data.
4. Seafloor map in central and northern Hudson Bay allows identification of seafloor fluid escape structures (pockmarks)
5. RADARSAT images suggest the possible presence of oil slicks at the surface of Hudson Bay waters

**End-Summer / Early fall (Geoscan virtual library)**

**GSC Open File 7363 – Final report  
GSC Open File 7364 – ArcGIS database**



## The usual polar bear final shot Cliff NE side of Akpatok Island

