The Paleozoic Hudson Bay Basin in Northern Canada: New Insights Into Hydrocarbon Potential of the Last North-America Conventional Frontier Basin*

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Editor's note: Please refer to the rather closely related article on this subject given herein under Selected References.

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Abstract

The Hudson Bay Basin is the largest intracratonic basin in North America, although it is the only one without any proven hydrocarbon reserves. The stratigraphic succession that fills the basin consists mainly of Paleozoic strata, with a maximum preserved thickness of about 2500 m. The Paleozoic succession includes Ordovician to Devonian shallow marine carbonates, reefs, and shales, with locally thick Devonian evaporites. The Paleozoic strata are locally unconformably overlain by a thin Mesozoic/Cenozoic cover of nonmarine and marine strata. From 1964 to 1985, over 46,000 line-km of seismic reflection data were acquired and 4 onshore and 5 offshore exploration wells drilled. The data acquired at that time led to pessimistic conclusions on source rocks and the thermal rank of the basin and resulted in the stoppage of exploration activities. However, hydrocarbon shows or indicators were identified in well-log data and seismic-reflection profiles. The likelihood of active petroleum system has also been recently supported by recognition of pockmarks on the seafloor and possible marine oil slicks identified on satellite images. New studies of geological, geophysical, and biostratigraphic data reveal that the Hudson Bay Basin had an irregular subsidence and uplift history. Syntectonic deposition occurred during the Late Ordovician (?) to Early Devonian and sag-basin deposition during the Middle to Late Devonian. The basin contains four unconformity-bounded sequences, with significant depocenter migration over time. Analyses of petroleum-system data indicate the Hudson Bay Basin has higher petroleum potential than previously considered. Porous platform limestones, reefs, hydrothermal dolomites, and siliciclastics form potential hydrocarbon reservoirs. Upper Ordovician organic-rich shales with Type II-S organic matter are

recognized at several locations in the basin. Newly acquired organic matter reflectance and Rock-Eval Tmax data indicate Ordovician–Silurian strata locally reached the oil window. Basin modelling demonstrates significant potential for oil generation and expulsion from Ordovician source rocks. Five petroleum play types are identified in the Hudson Bay Basin, including an untested fault-sag / hydrothermal-dolomite play. The synthesis of the petroleum system information indicates that the Hudson Bay Basin is, at least locally, prospective for oil accumulations.

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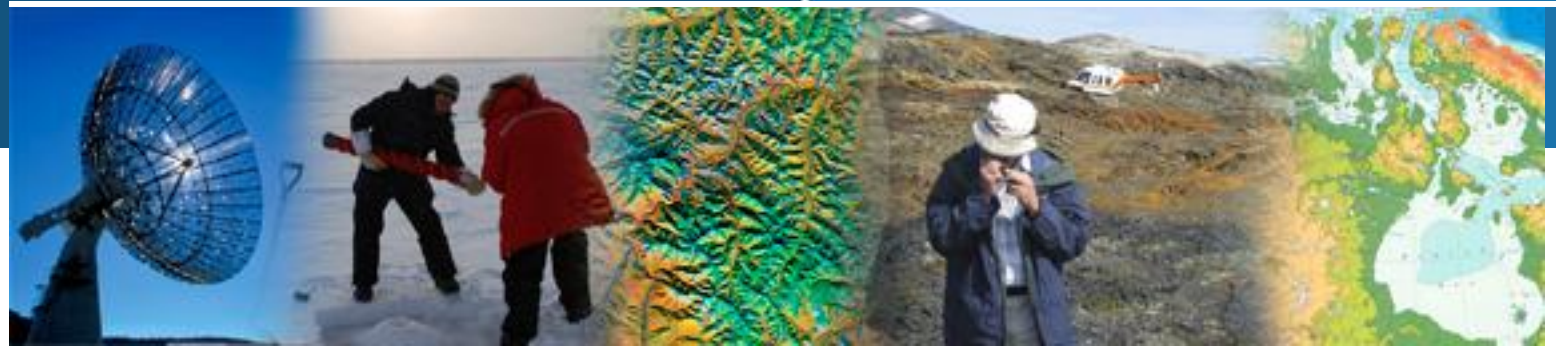

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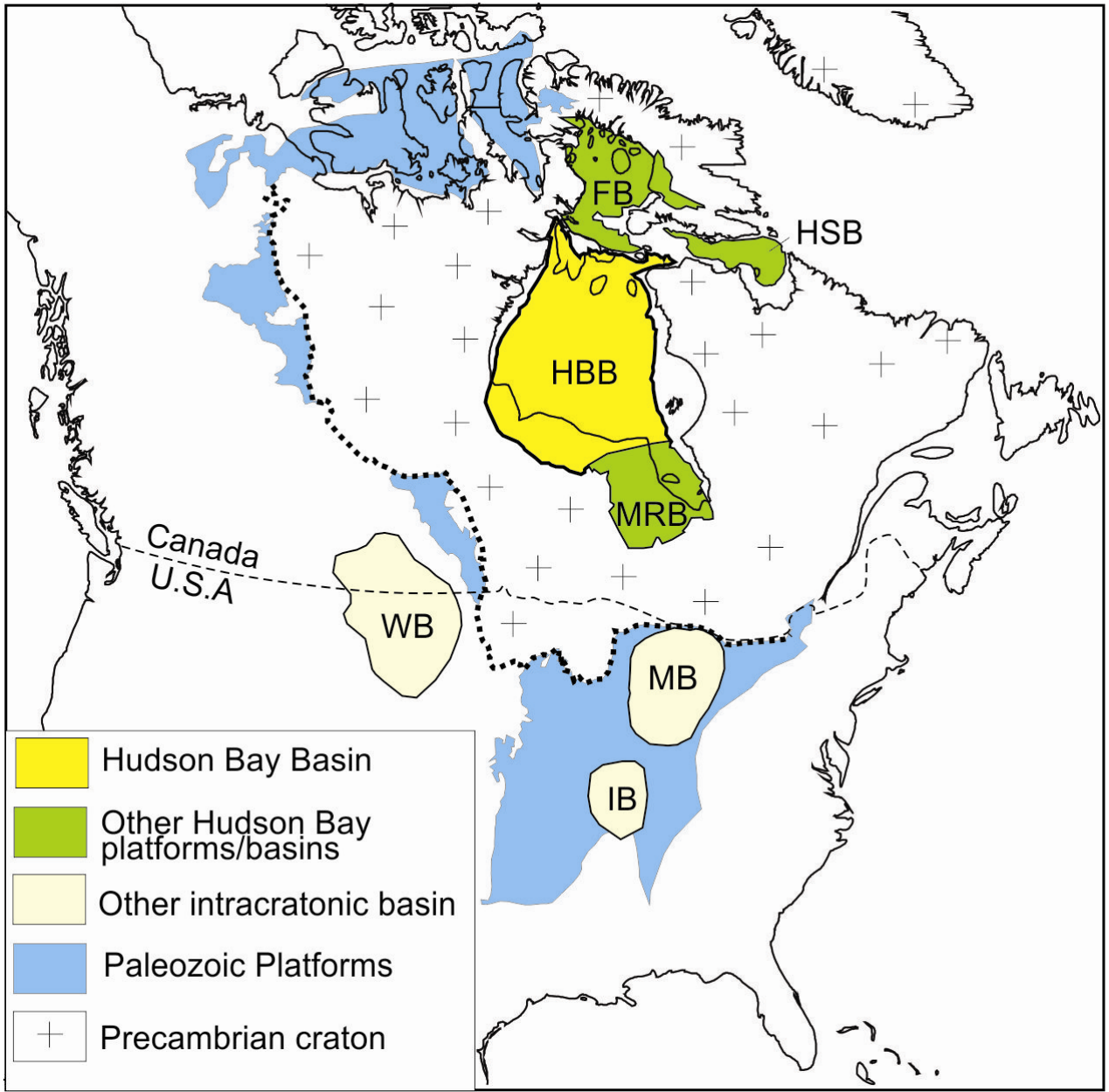
OUTLINE

Hudson Bay Basin

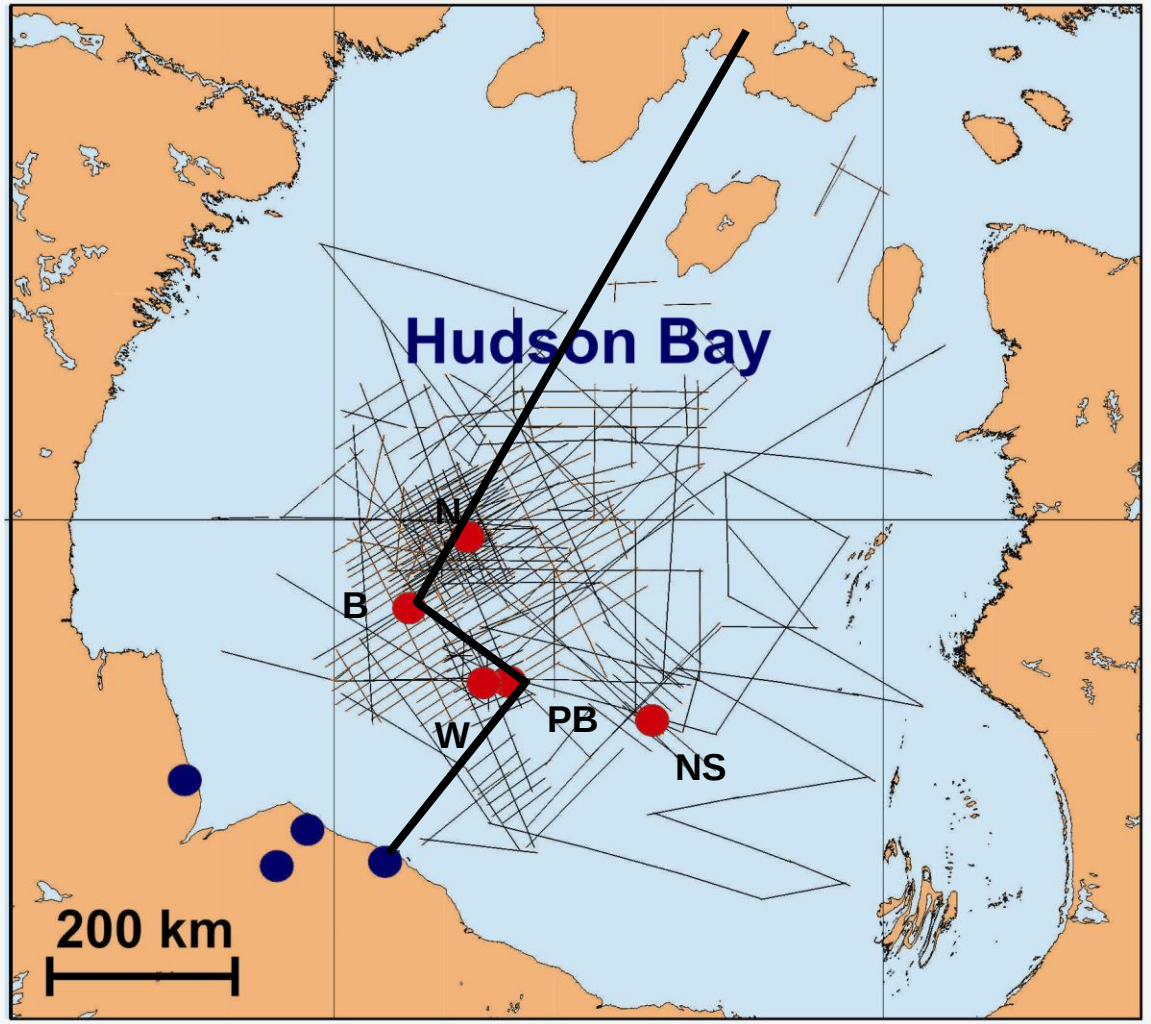
1. Geological setting and historical review
2. Stratigraphy and structural framework
3. Hydrocarbon system data
   - Source rock – nature, distribution, maturity
   - HC generation modeling
   - Play types
4. Evidence for active hydrocarbon systems
5. Conclusions

The largest intracratonic basin in North America

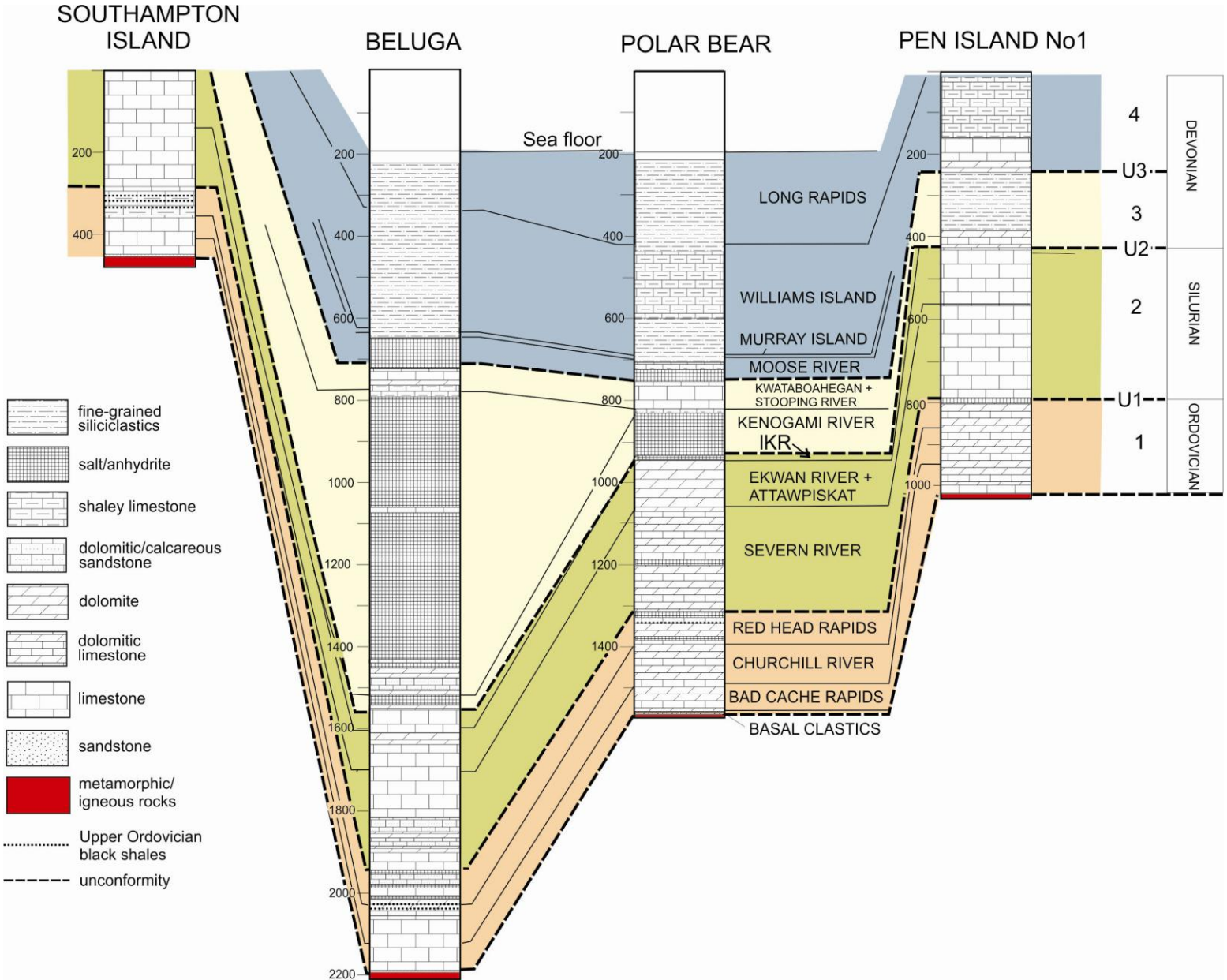


Petroleum Exploration in Hudson Bay Basin

- 4 Onshore Wells (1966 - 1970)
- 5 Offshore Wells (1974 - 1985)
- 46,000 Line-Km Marine Seismic Reflection Data (1970s - 1980s)



Hudson Bay – Stratigraphic correlation



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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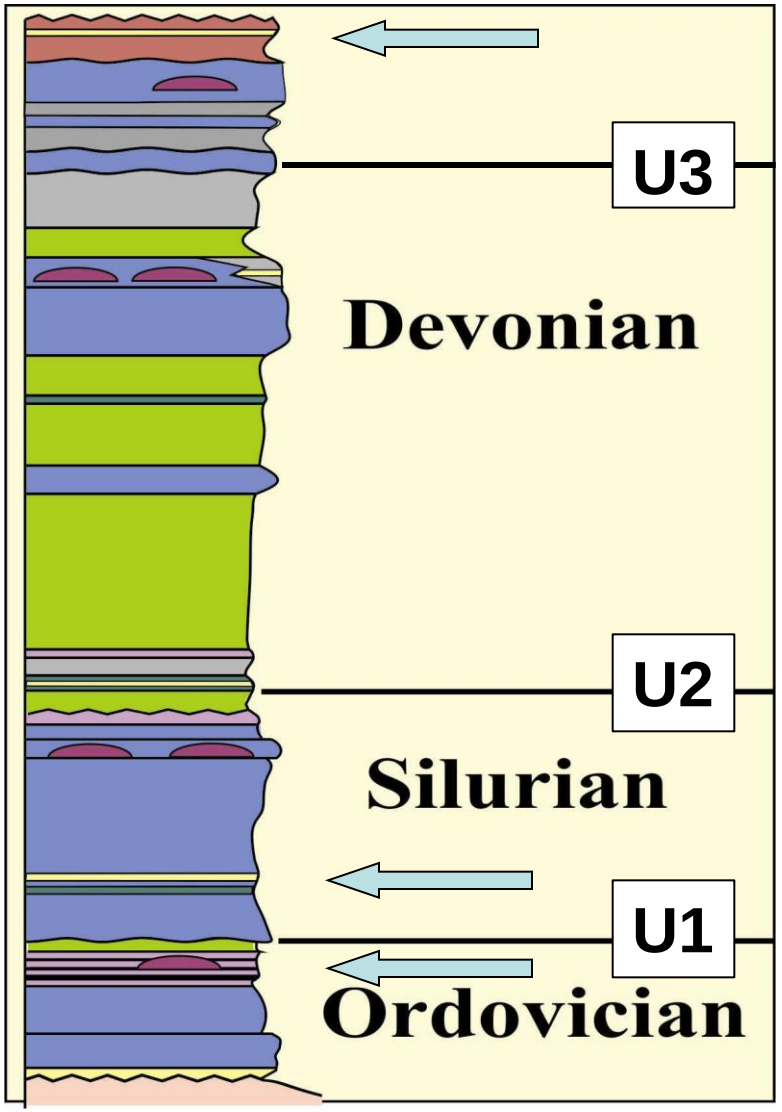
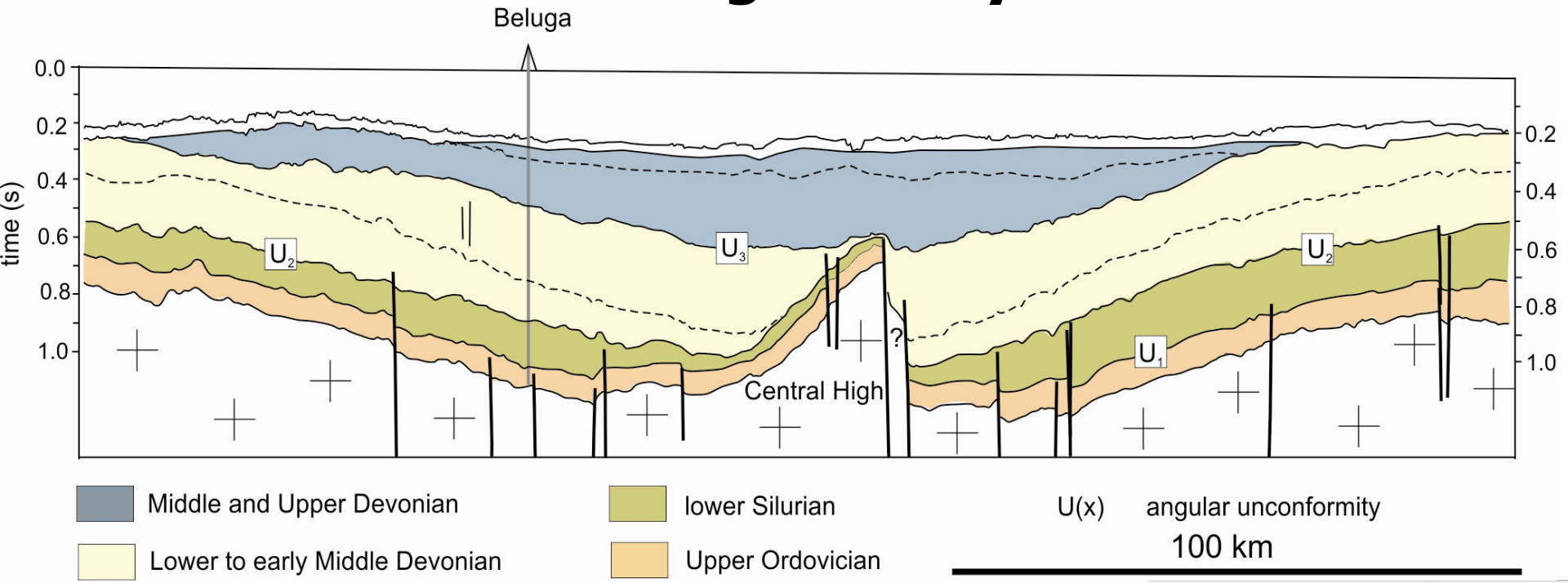
thin sections of
Coastal-plain sandstones

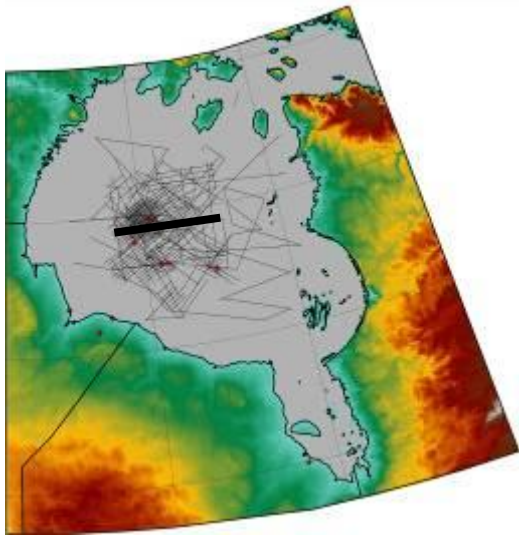
Lithostratigraphy



Dietrich et al (2012, SEG)

Basin geometry





New seismic interpretation
3 major unconformities
Ordovician-Silurian: U1
Upper Silurian-Lower Devonian: U2
Middle Devonian: U3

Petroleum System Elements

Well and Outcrop Data

- **widespread oil-prone Upper Ordovician source rocks**
- **oil-window maturation levels in Ordovician strata**
- **porous reservoirs, including hydrothermal dolomites and reefs**

Seismic Data

- **five petroleum plays, mostly untested in initial drilling**

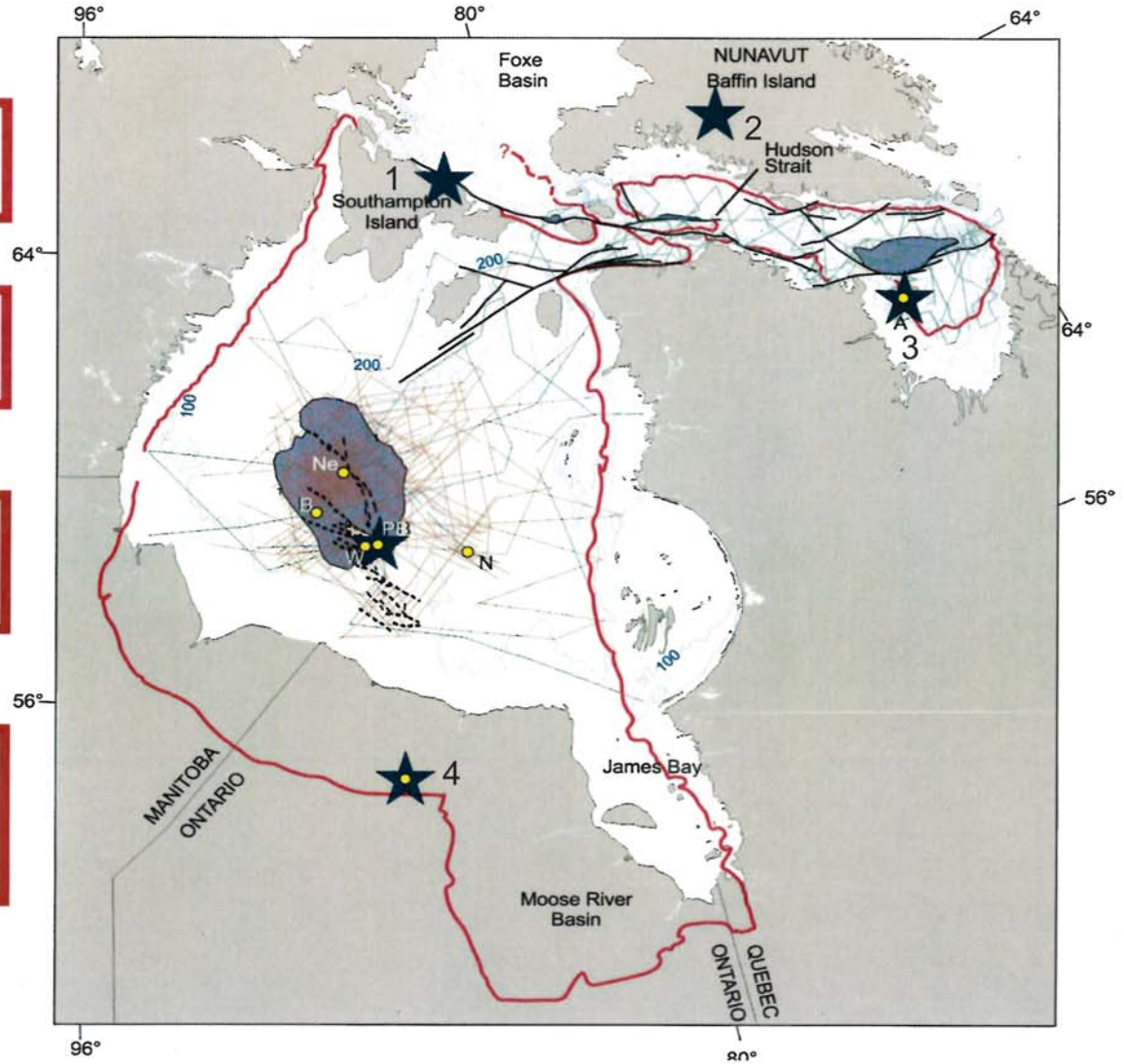
Source rocks

Yields: 20 - 134 kg/tonne
TOC: 5 - 35% - 5 meters 1

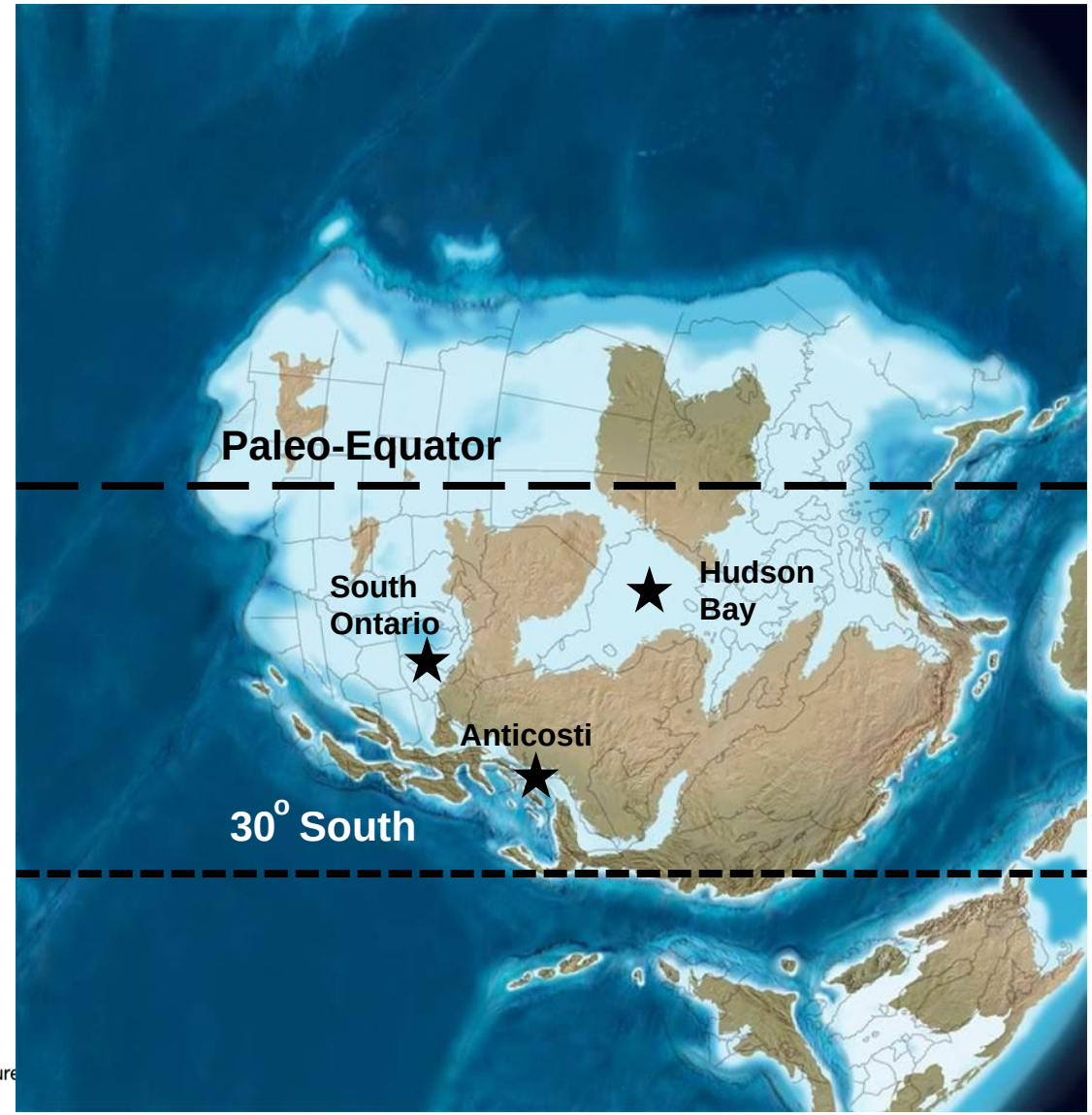
Yields: 16 - 99 kg/tonne
TOC: 3 - 15% - 15 meters 2

Yields: 2 – 11 kg/tonne
TOC: 4 - 5% - 12 meters 3

Yields: 13 – 74 kg/tonne
TOC: 3 – 15% - 10 meters
4



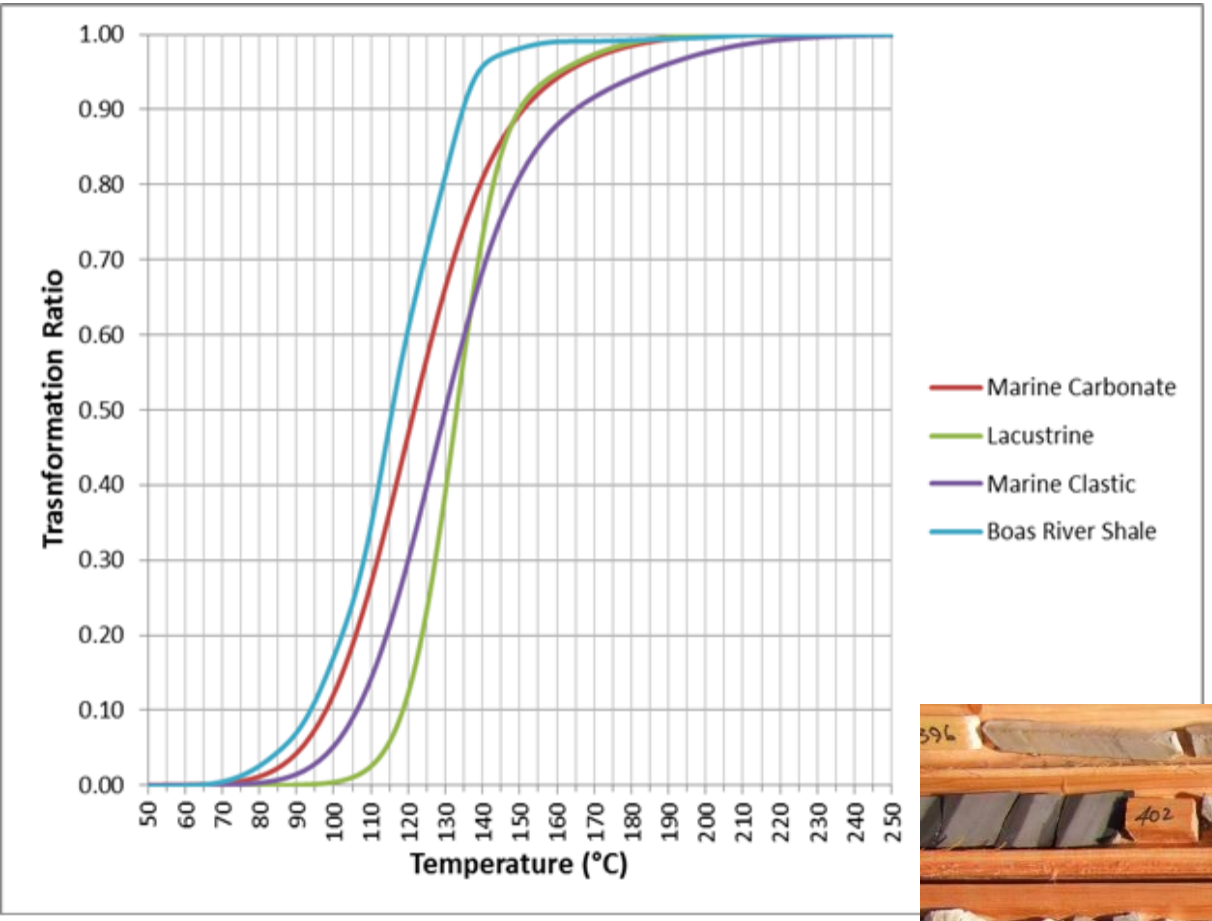
Distribution of Upper Ordovician Hydrocarbon Source Rocks in North America



(Blakey, paleomap)

Source Rock Types

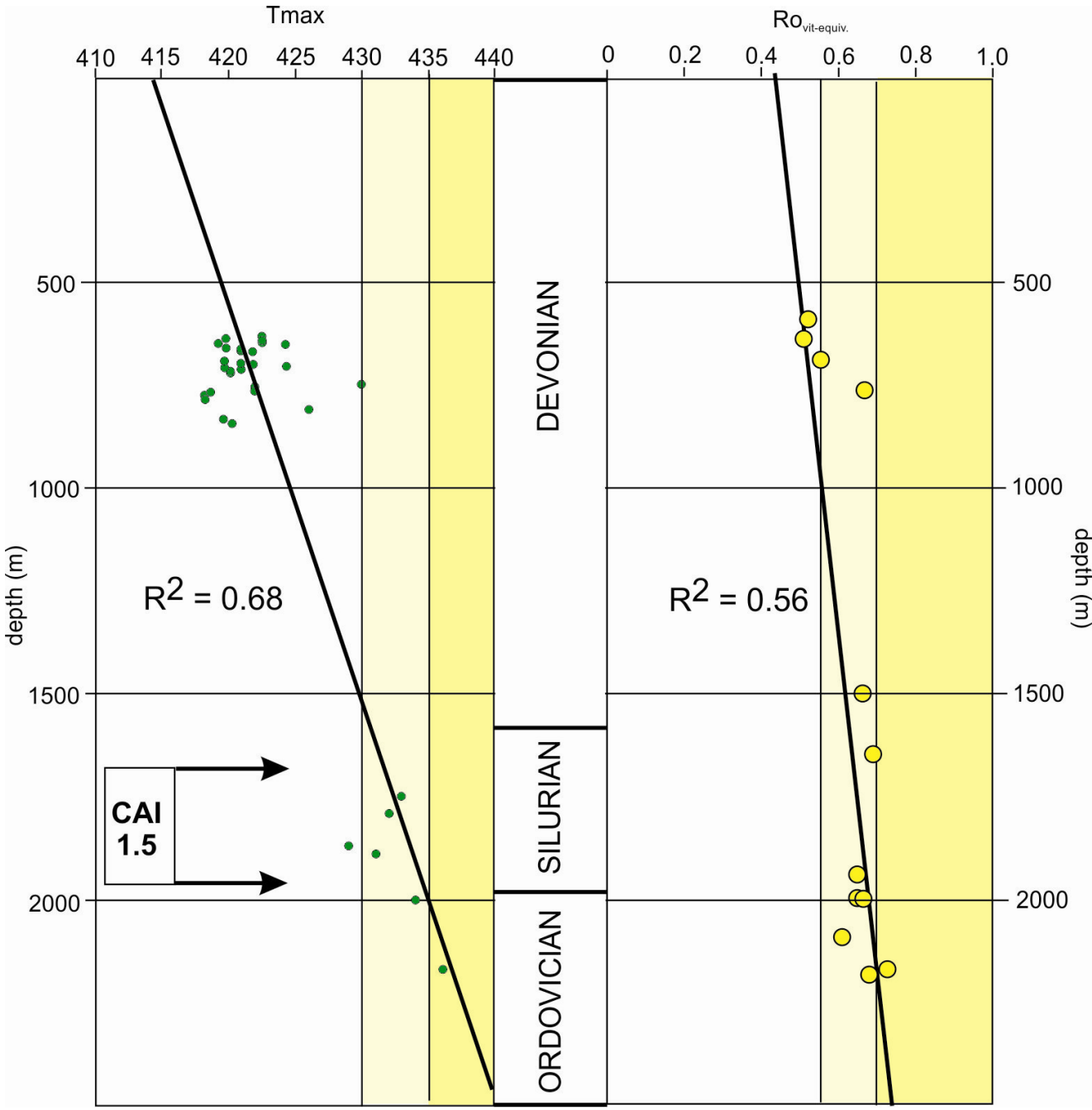
	Laurentia margin	Hudson Bay
Hypersaline - reducing		✓
Pristane/Phytane (Pr/Ph)	>1	<1
Odd carbon predominance between nC15 and nC19	✓	✓✓
High nC27 and nC29		✓
Abundant Gammacerane		✓
Source rock Type	II	IIS



Type II-S Organic matter

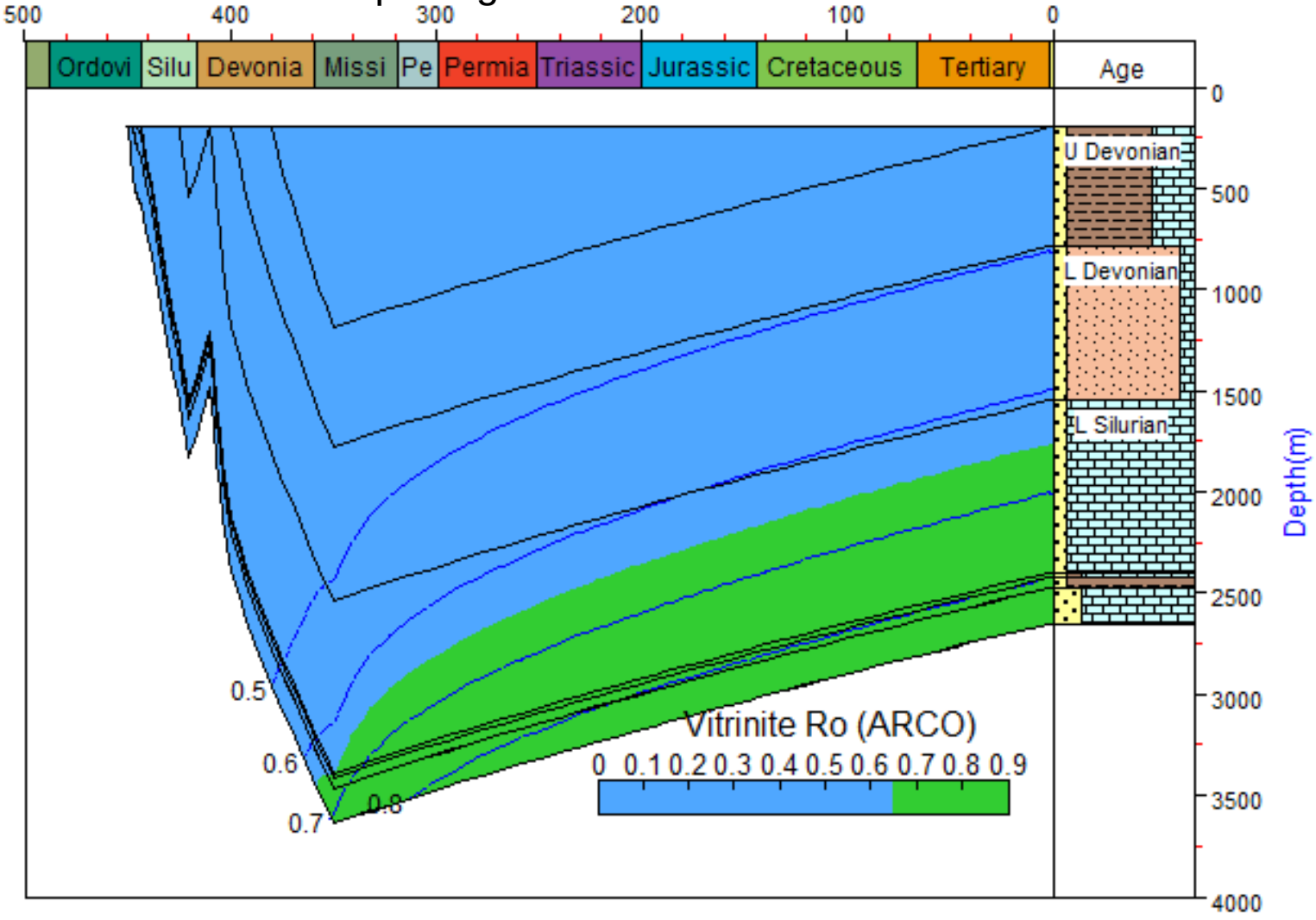
Kinetic study suggests lower activation energy

Oil window at the Silurian-Ordovician contact

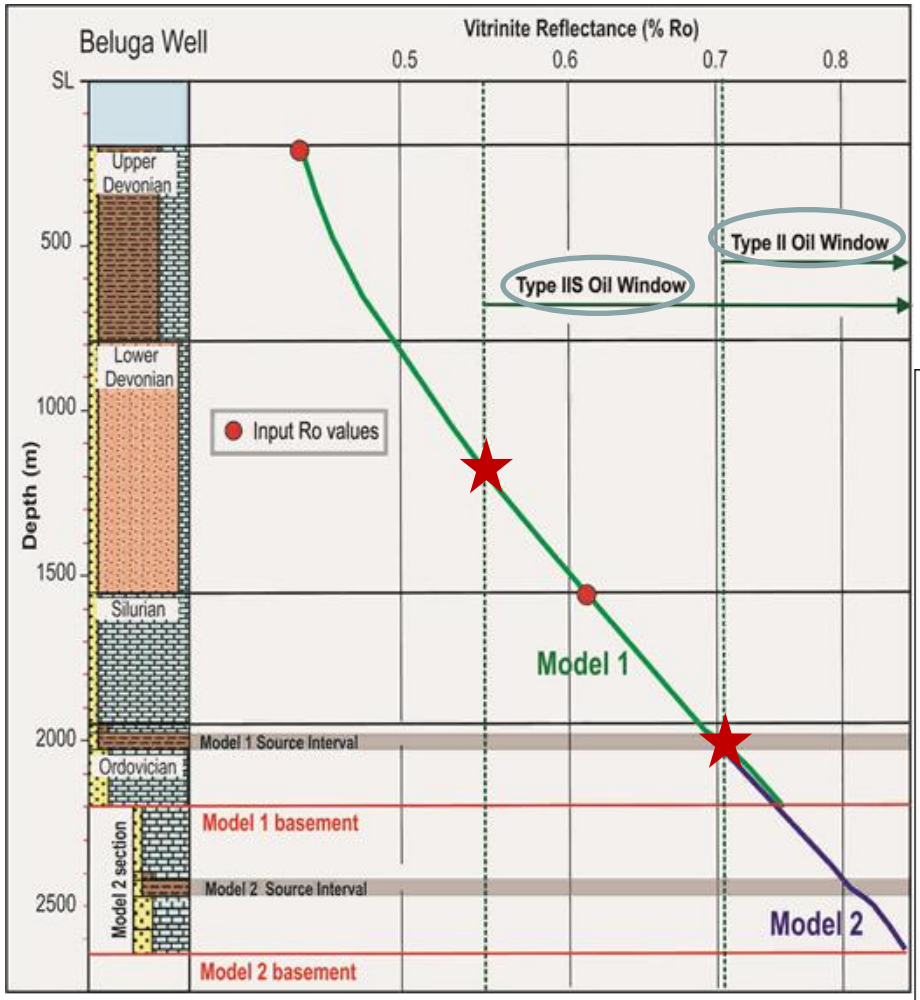


Hydrocarbon generation modeling

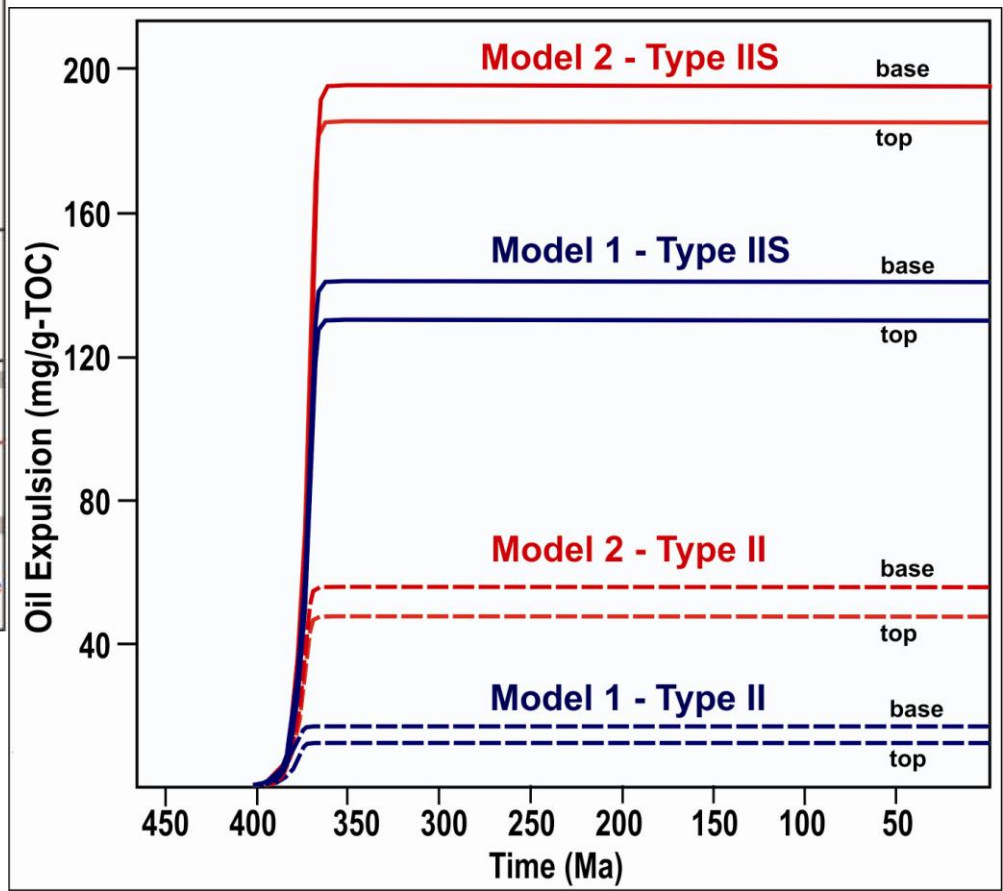
Hydrocarbon generated from Type IIS organic matter – peak generation in Late Devonian



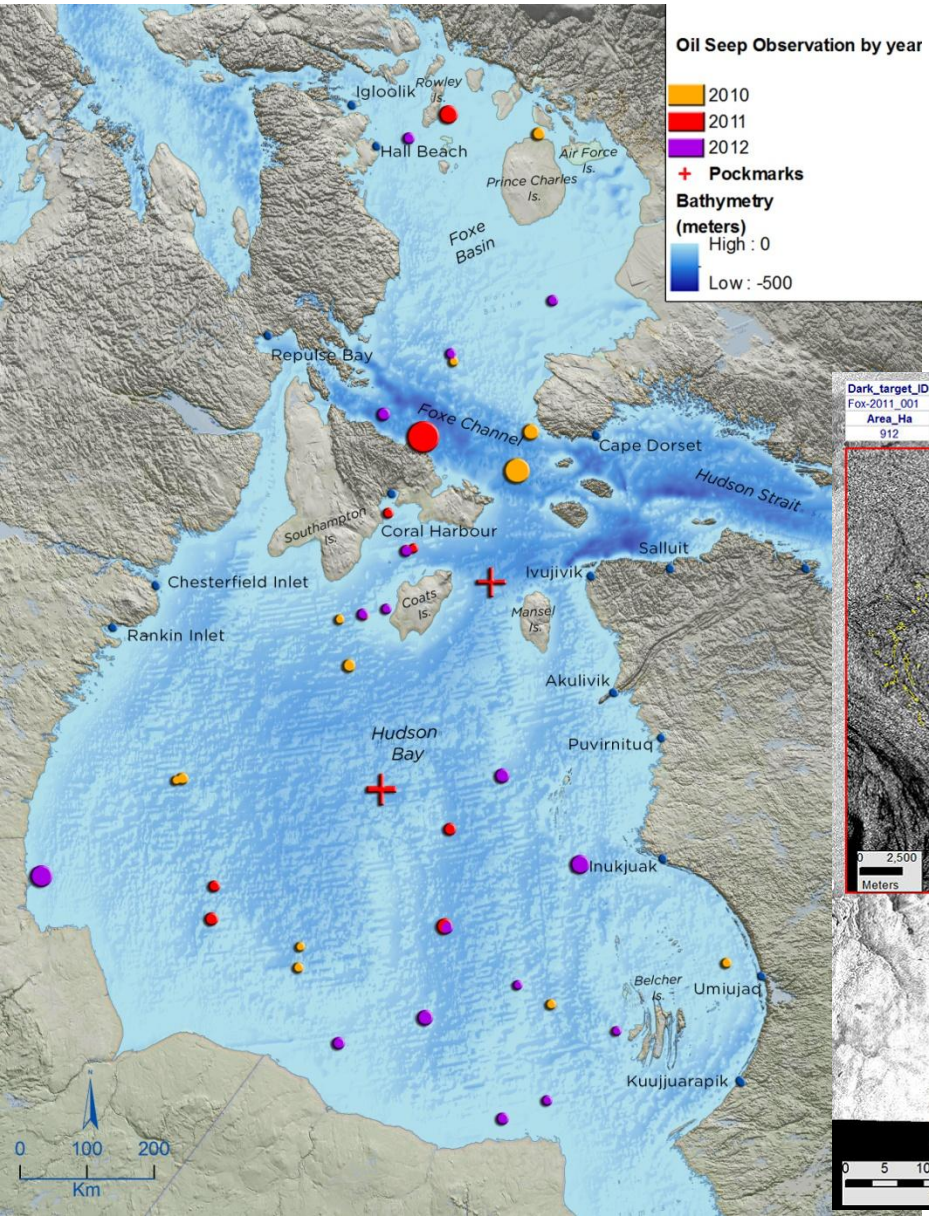
Hydrocarbon Generation and Source Rock Types



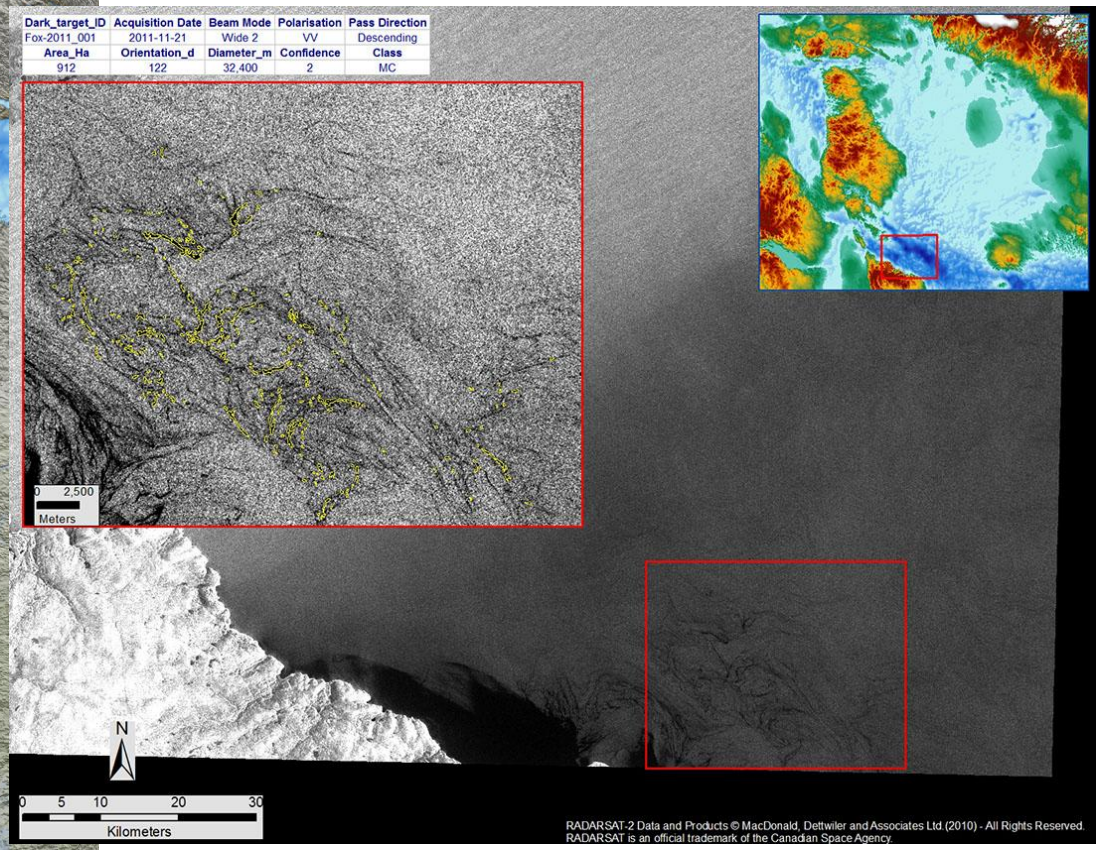
Significance for little buried basins



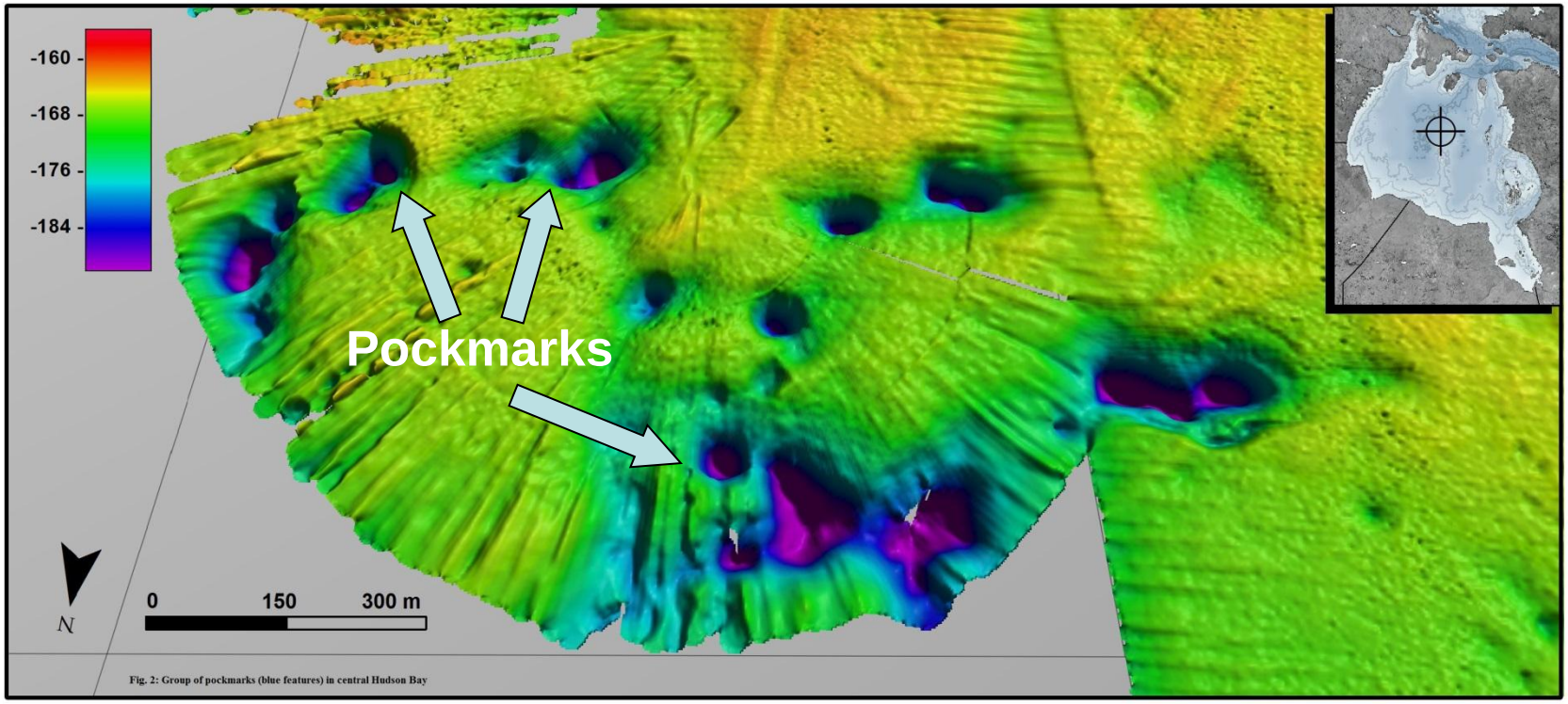
Oil slicks at the surface of Hudson Bay?



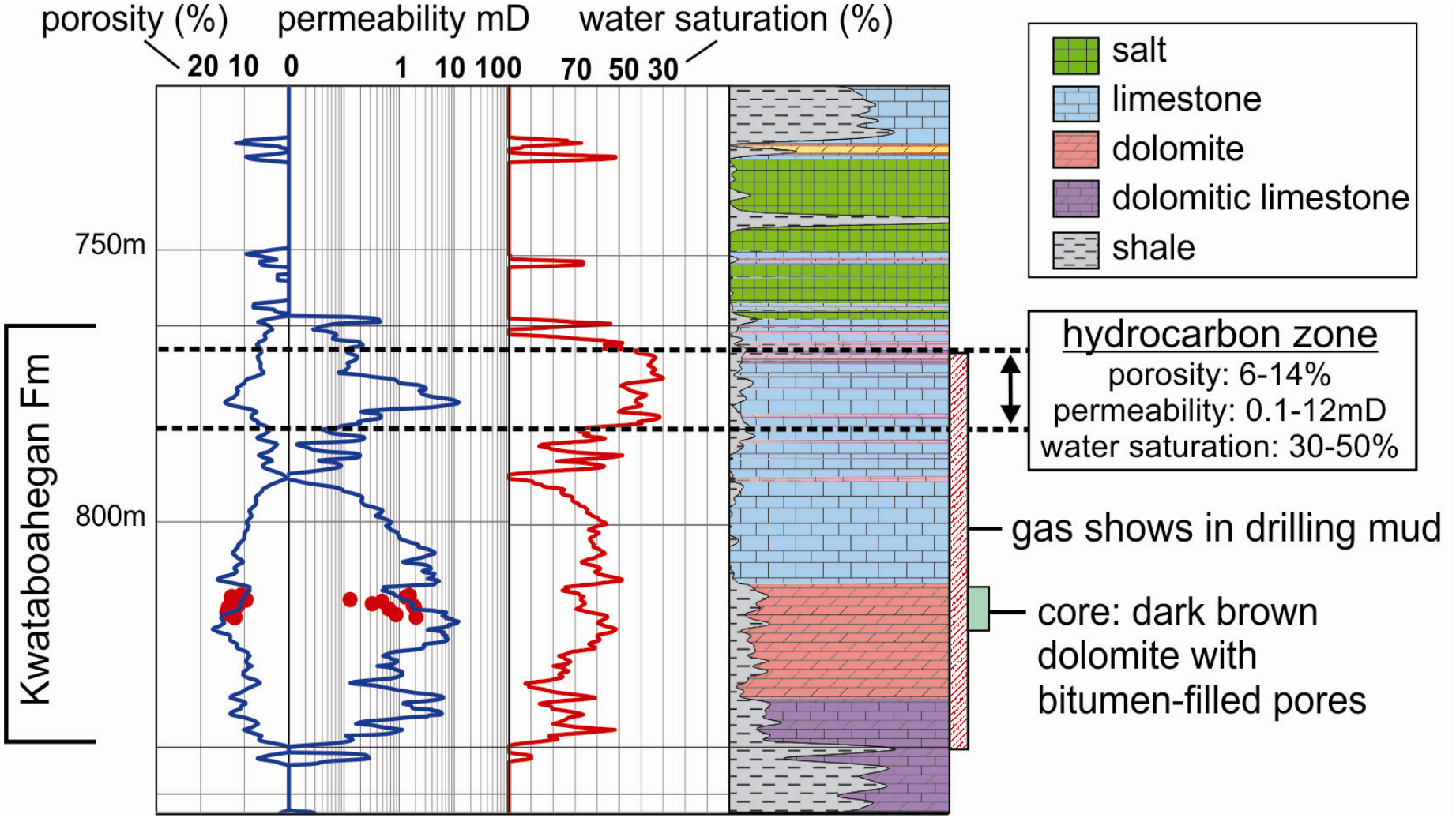
3 years of Radarsat images; identification of 41 anomalies (oil slicks ?)



Pockmarks in central Hudson Bay

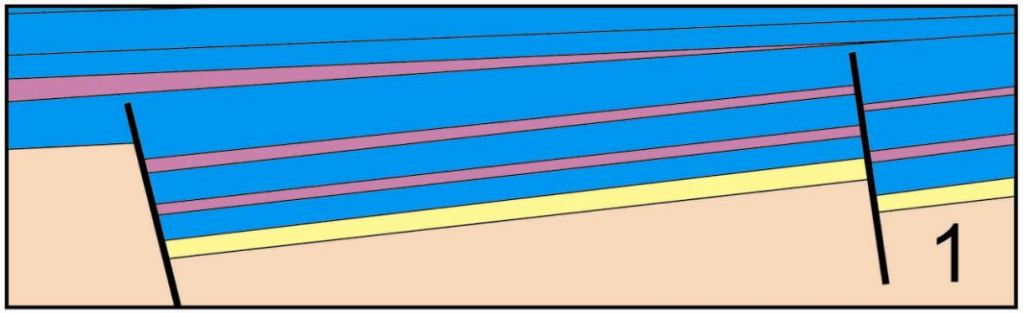


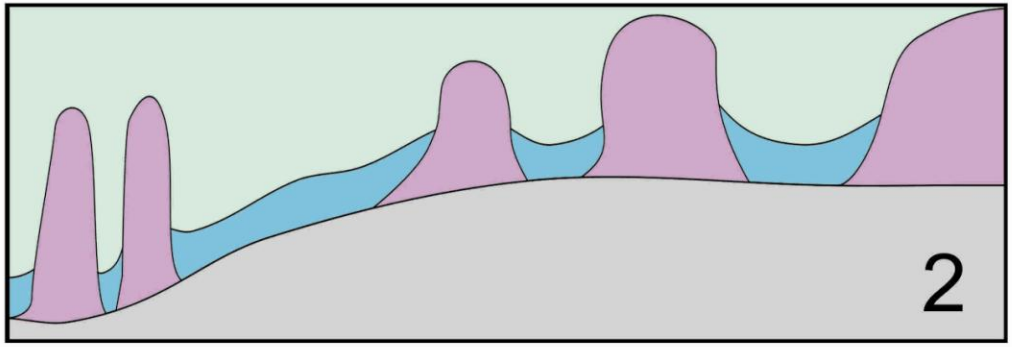
Significant number of untested pay zones

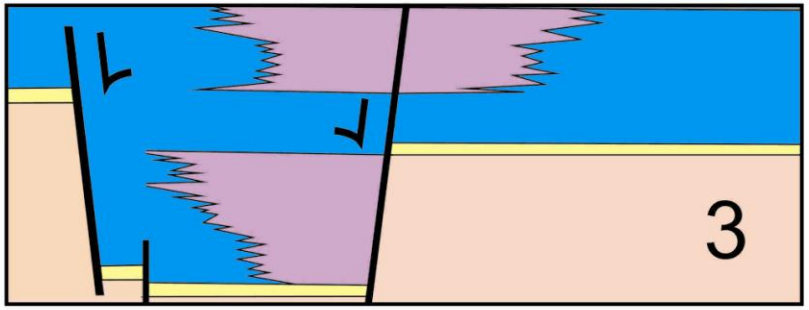


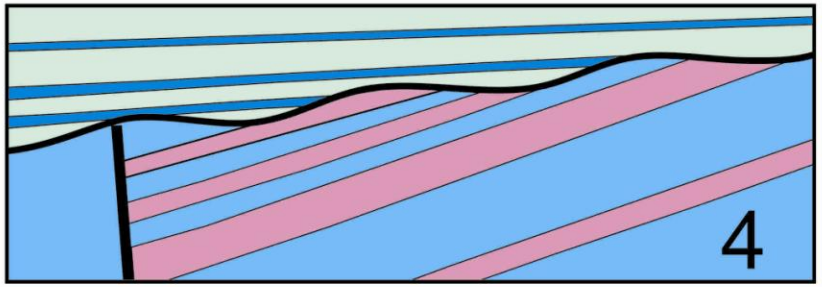
Five conceptual conventional hydrocarbon plays – based on seismic and field data

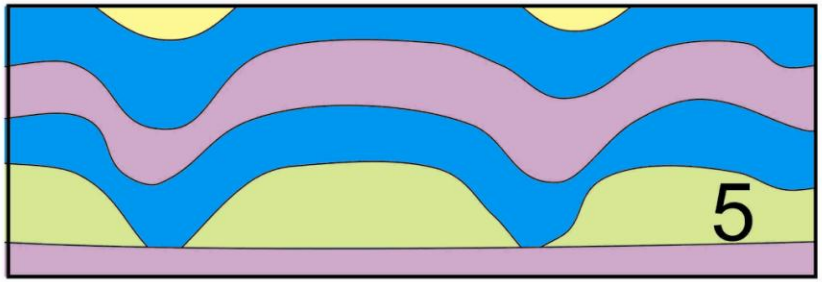
1. Tilted Fault Blocks
2. Pinnacle/Barrier Reefs
3. Fault Sags - Hydrothermal Dolomite
4. Unconformities (Onlap, Truncation)
5. Salt Dissolution Folds



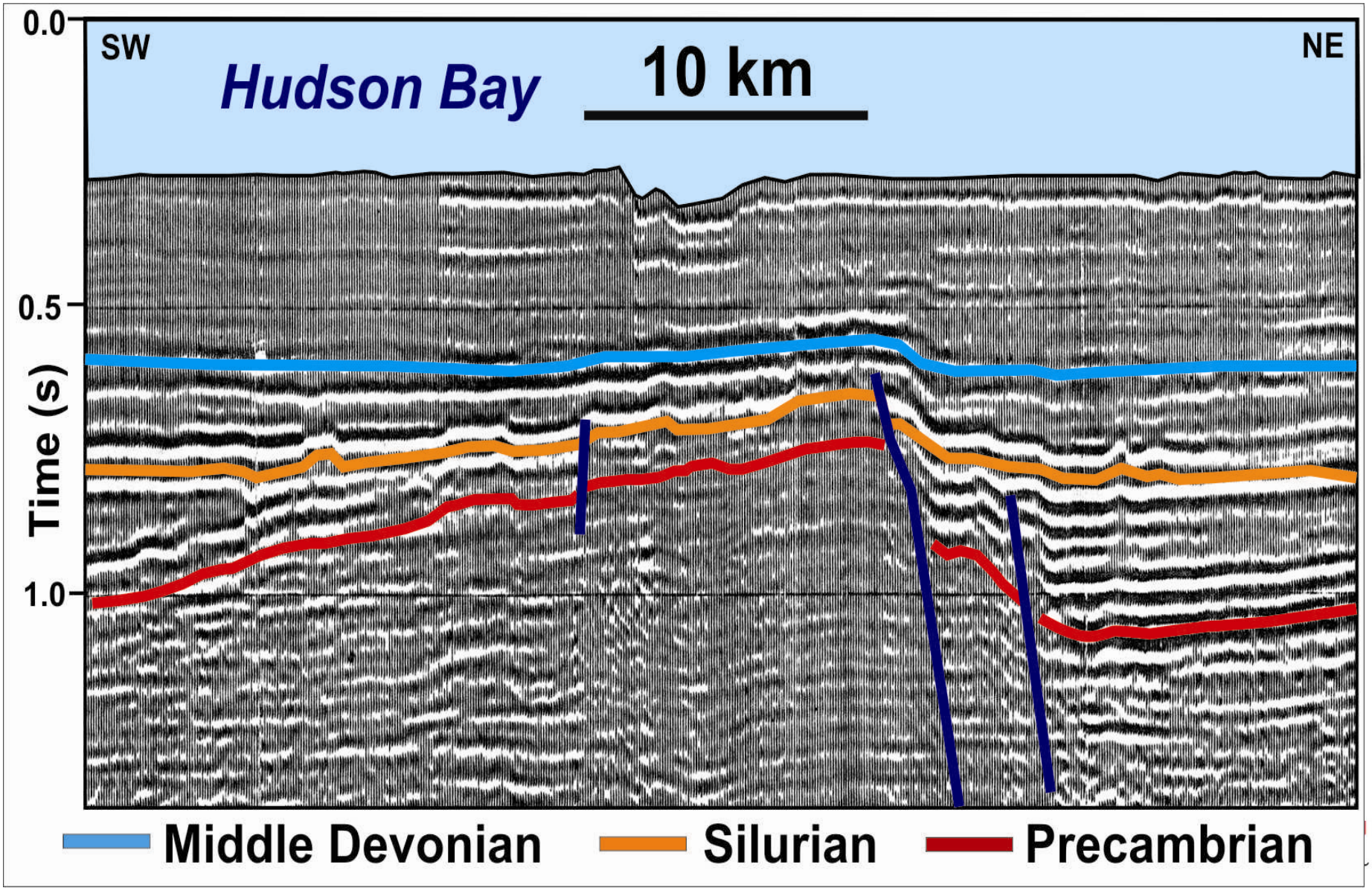




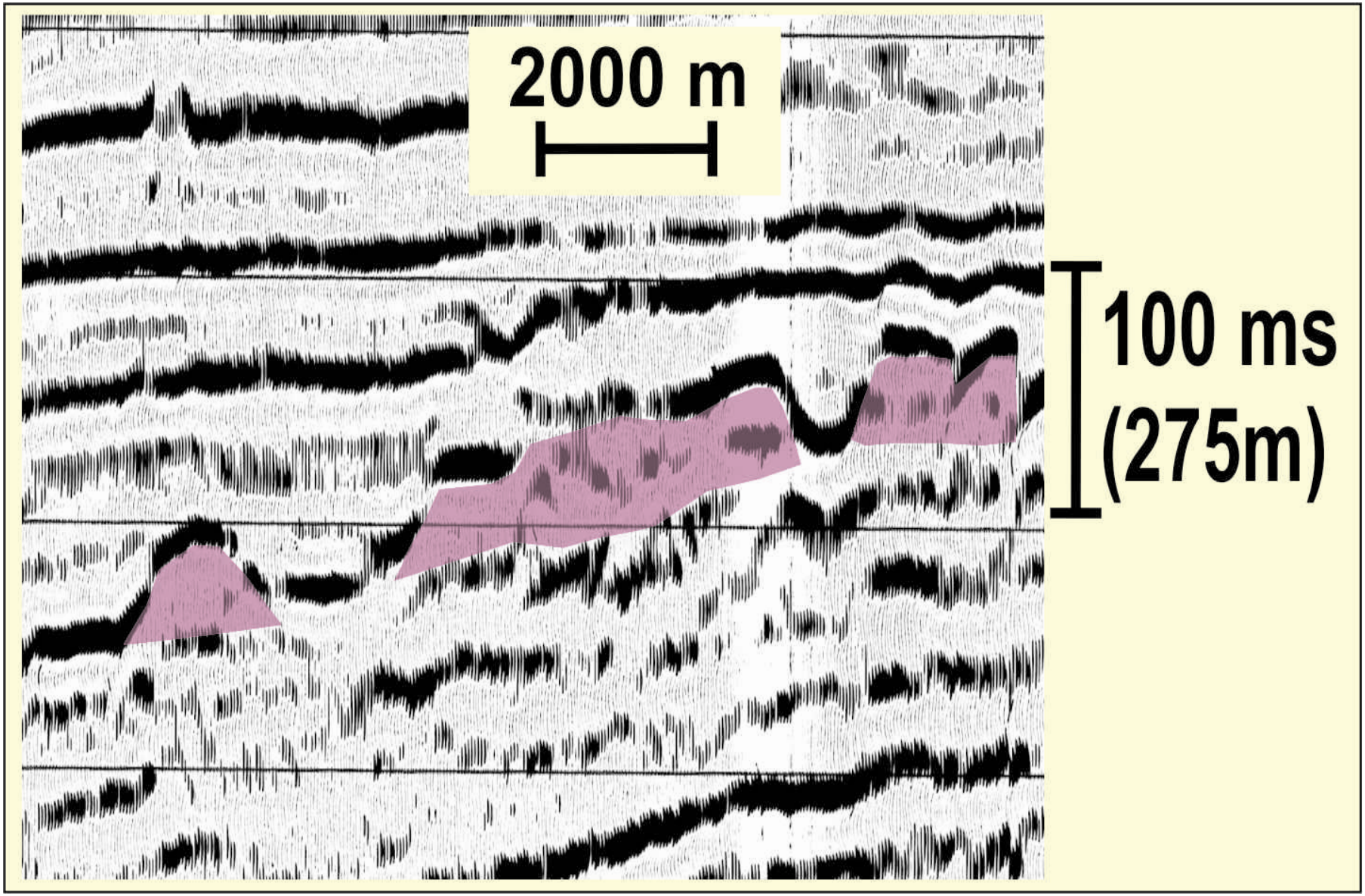




Tilted Fault Block Play



Silurian reefs (Attawapiskat Fm.)

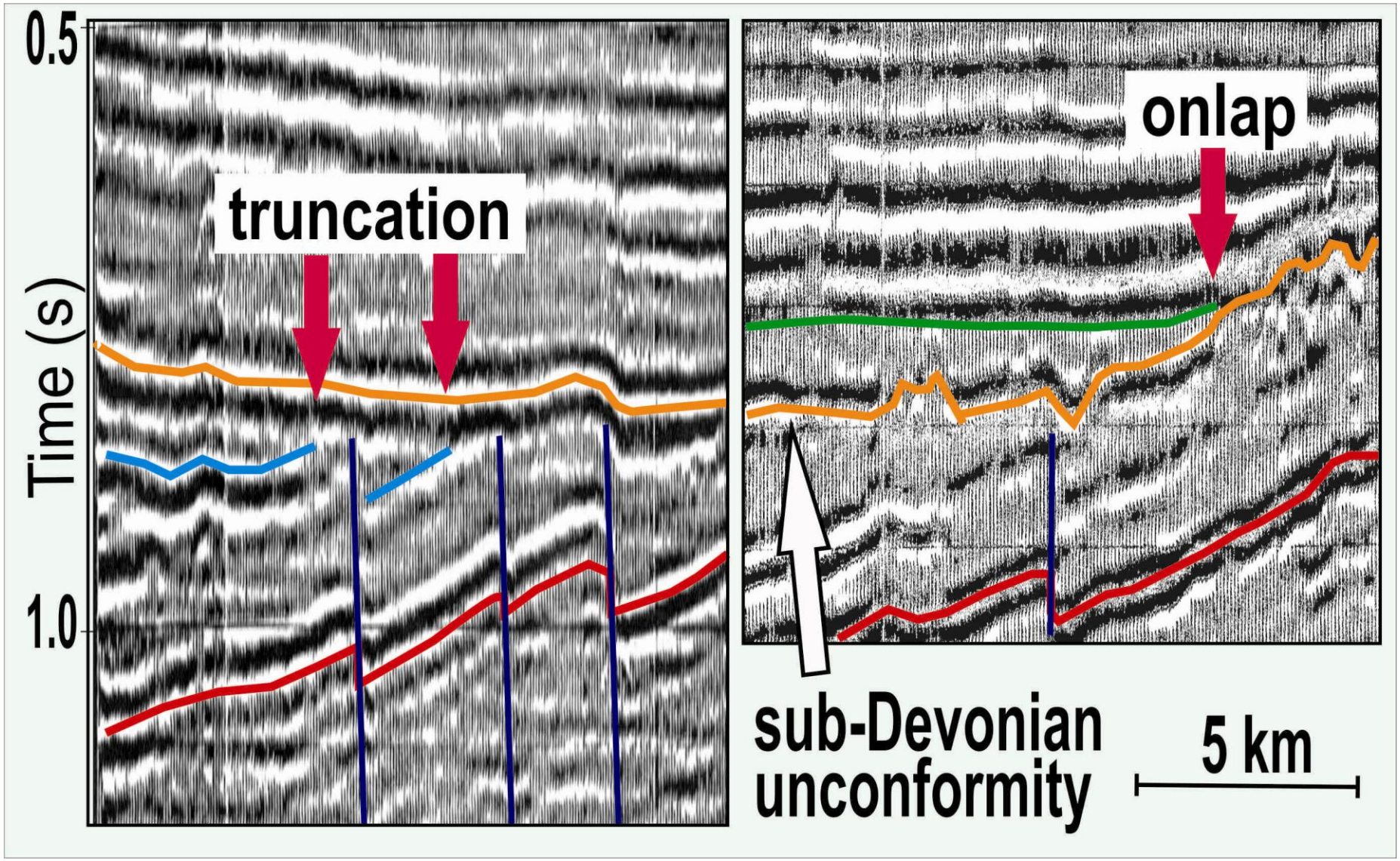


Dietrich et al (2012, SEG)


Upper Ordovician reefs

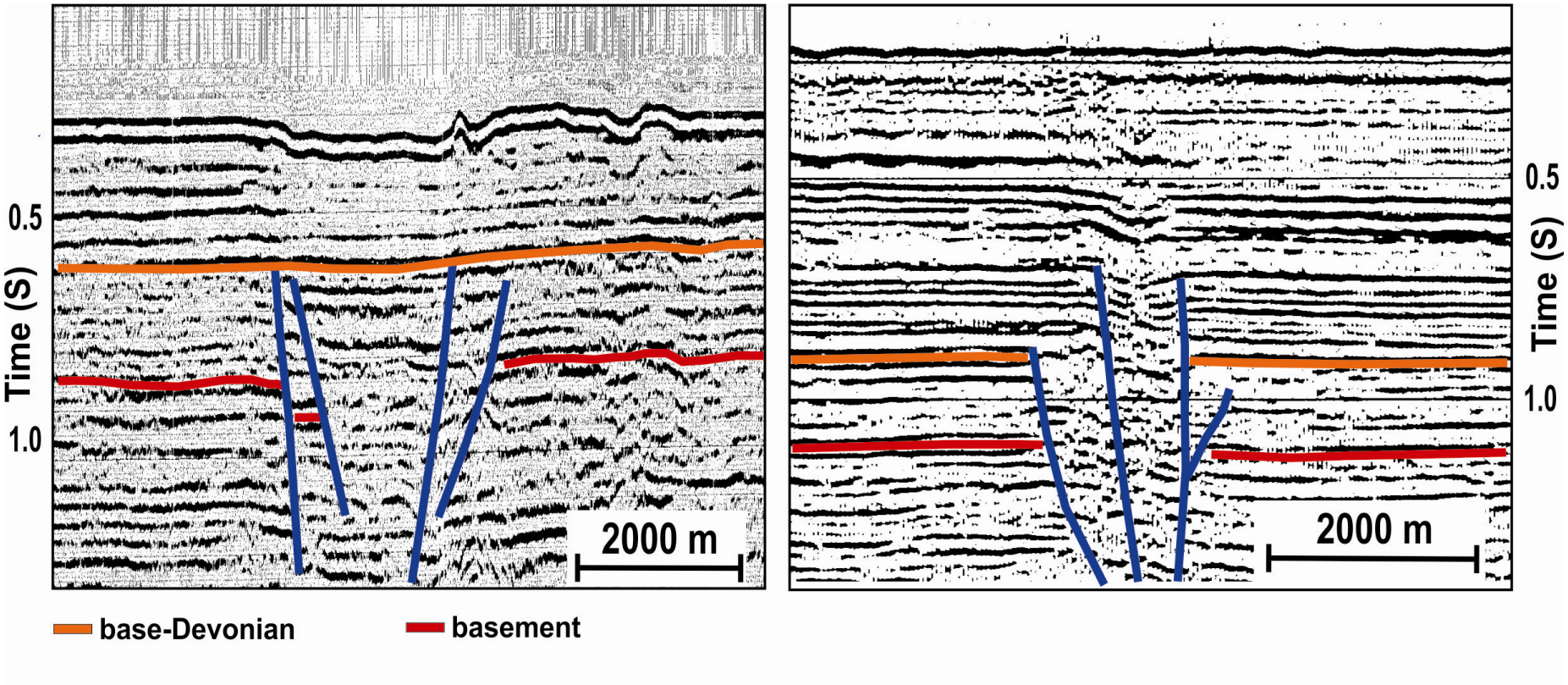

Lower Silurian reefs

Unconformity Play



Dietrich et al (2012, SEG)

Seismic sag




HTD Akpatok


HTD Southampton

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. **Thermal maturation indicators suggest 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.**

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