Upper Ordovician Reefs in the Hudson Bay Basin - Potential for Hydrocarbon Reservoirs*

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Abstract

Upper Ordovician (Katian) buildups are reported from the Hudson Platform on Southampton Island at the northern end of the Hudson Bay. These mounds belong to the Red Head Rapids Formation and consist of a massive core with thinner stratiform counterparts. The core has been loosely described in the past as micritic, algal, or microbial limestones with metazoans of subsidiary importance. The mounds are up to 500 m in width with minimum vertical relief of 15 m. They occur a few metres above Upper Ordovician source rocks. The reefs contain voids, vugs and fractures, some of which are coated or locally filled with bitumen and dead oil.

The Red Head Rapids Formation mound is primarily composed of boundstone and cementstone with various proportions of early calcified sponge tissues, microbial encrusters, synsedimentary cement and small metazoans. The accretionary mechanisms of the mounds were mainly the result of frame building by early calcified sponges and small colonial corals and binding by calcimicrobial elements for the boundstone facies, and of marine cement precipitation near the seafloor for the cementstone facies. Petrography has revealed early diagenetic phases (synsedimentary marine cements and neomorphosed sponge network) as well as bitumen and late cements filling secondary pore space; late stage dolomitization and dedolomitization are observed. Early calcite phases, made up of neomorphosed aragonite, have the least negative δ18O values of all phases and a trend to more negative δ18O and δ13C values is noted for paired early and late cements. Fluid inclusions (FI) have both liquid and vapour phases, with the vapour usually making between 10% and 20% of total volume. Th measurements of FI assemblages generated values of 74°C to 156°C. Limited Tm measurements on these provided a temperature of -12.9°C to -10.9°C, which translate to salinity of 14.9 to 16.8 wt% NaCl equiv. Th values are high given the indications of low temperature history of the succession from other thermal indicators. The correlation of FI and δ18OVPDB (-7.1 to -12.3‰) data indicates that late pore and fracture filling cements were precipitated from a saline fluid having δ18OSMOW values between +4 and +8‰. This suggests that the reef recorded high temperature and saline burial fluids prior to hydrocarbon charge.

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Upper Ordovician reefs in the Hudson Bay Basin: Potential for hydrocarbon reservoirs

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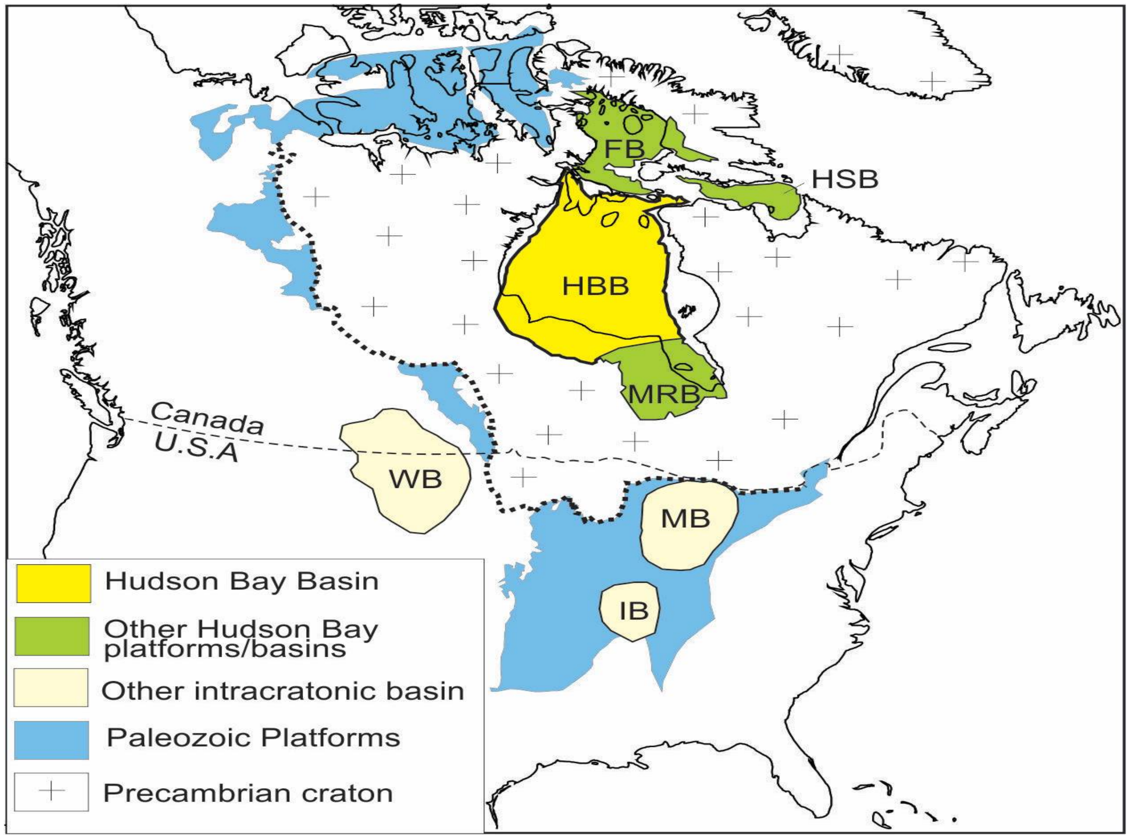
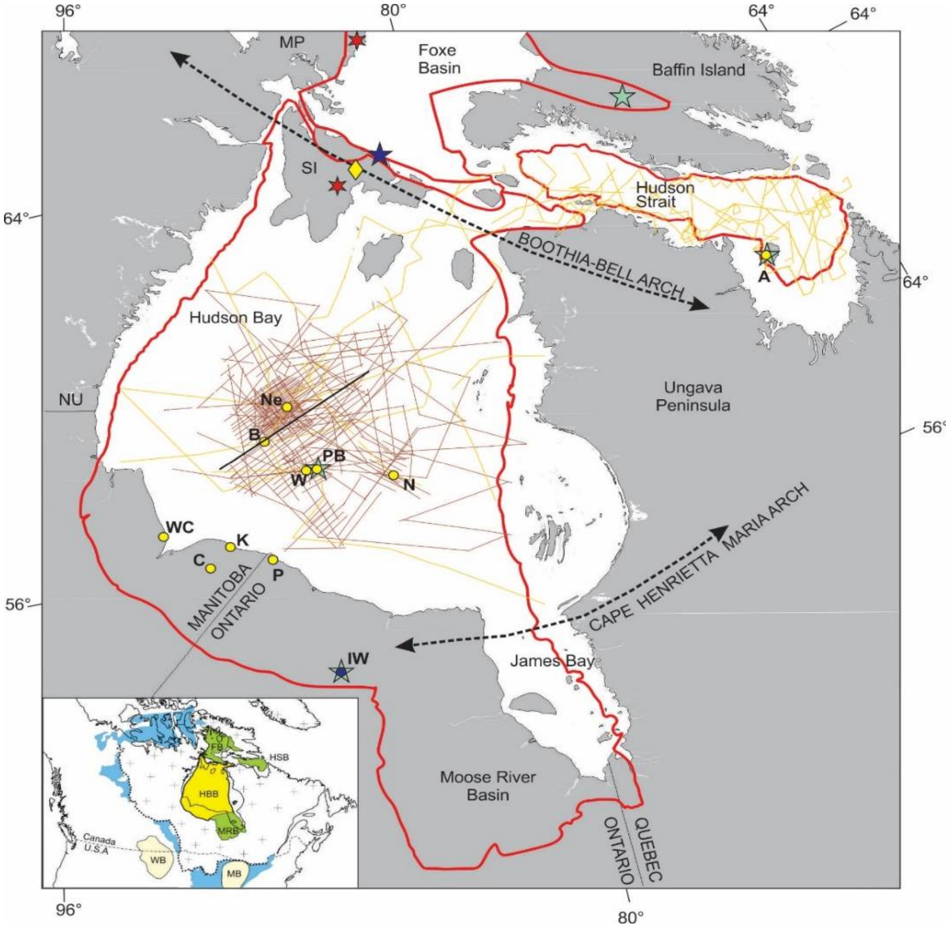
Outline

- The Hudson Bay Basin – geological setting and hydrocarbon exploration history
- Source rocks
- Potential reservoirs
  - Upper Ordovician reef of the Red Head Rapids Formation
  - Diagenetic evolution – petrography-geochemistry-fluid inclusions
- Evidence for hydrocarbon generation and expulsion
- On-going research and conclusions

The largest intracratonic basin in North America



Regional setting and historic background

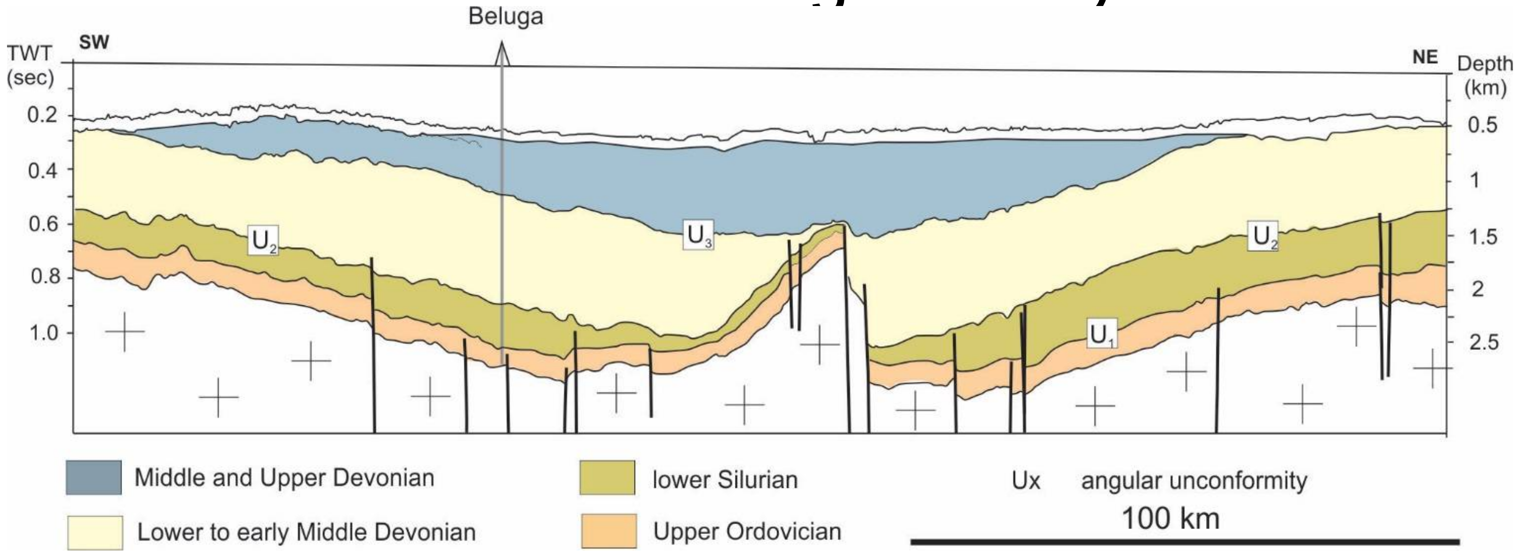


46 000 linear-km of industry seismic (1970's)
40 000 linear-km of GSC seismic (1980-1990)

5 offshore wells in Hudson Bay
5 onshore wells

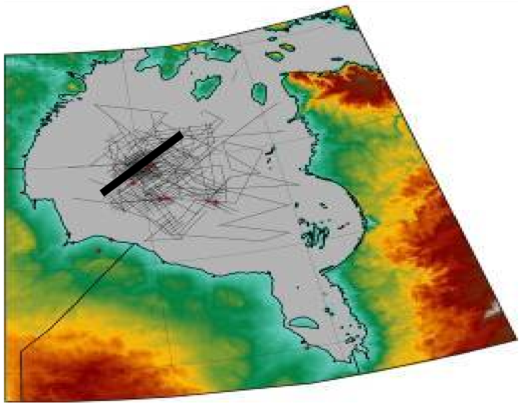
All offshore wells had oil and gas shows, bitumen-impregnated samples, although none was tested. Our petrophysical study (Lavoie et al., 2013, 2015) indicated many by-pass intervals.

Basin geometry



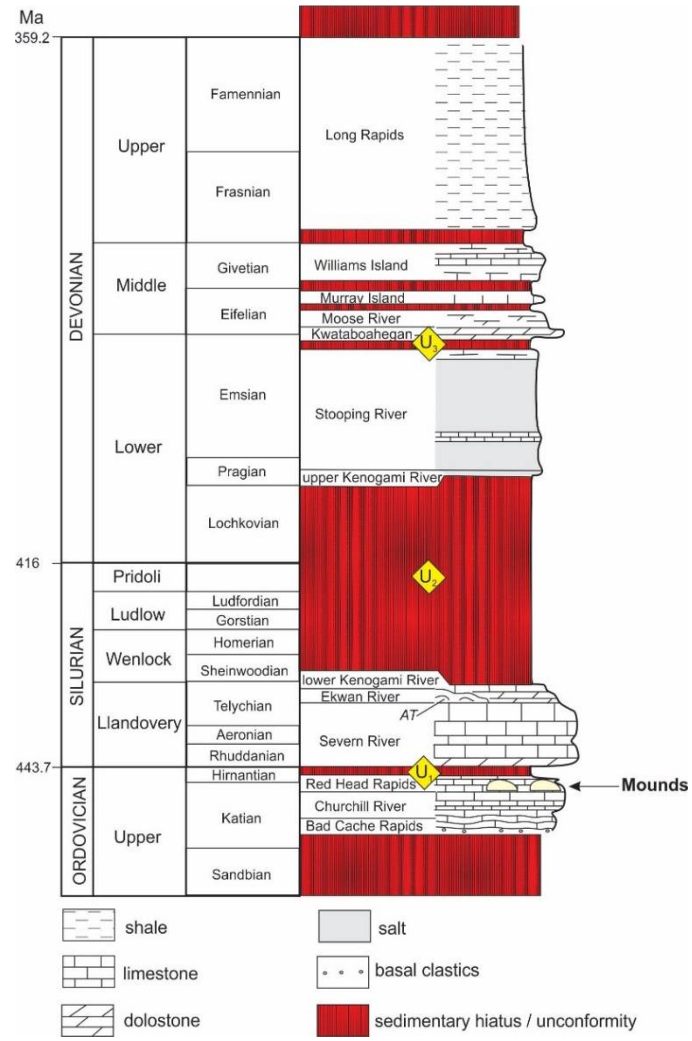
New seismic interpretation
3 major unconformities
- Ordovician-Silurian: U1
- Lower Silurian-Lower Devonian: U2
- Middle Devonian: U3

Ordovician-Silurian active faulting



Stratigraphy

Upper Ordovician to
Upper Devonian
shallow marine platform carbonates,
shales and local bioherms
----
variably thick, restricted marine
evaporites
----
variably thick, widespread
organic-rich shales
----
thin sections of
coastal plain sandstones
at base of the succession



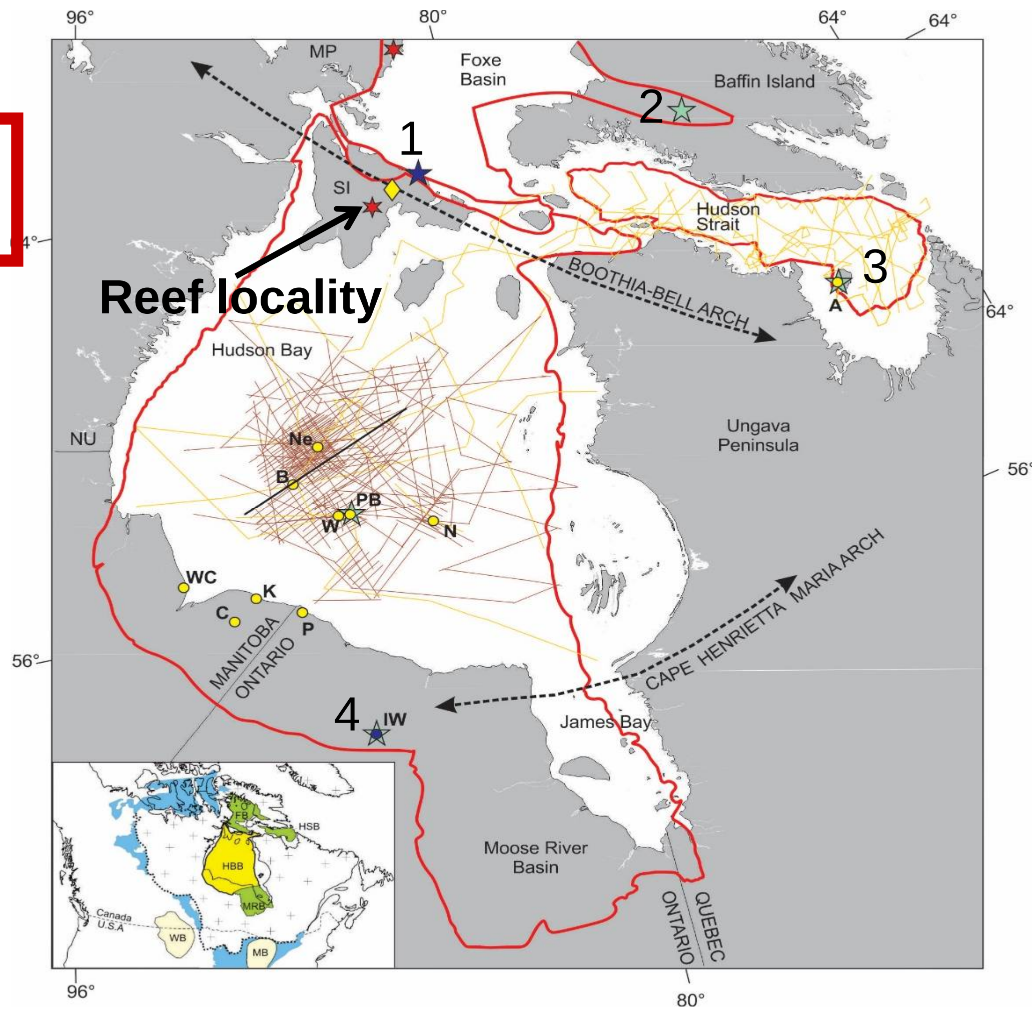
Source rocks

1- Yields: 20-134 kg HC/ton rock
TOC: 5 - 35% - 5 meters

2- Yields: 16-99 kg HC/ton rock
TOC: 3 - 15% - 15 meters

3- Yields: 2-11 kg HC/ton rock
TOC: 4 - 5% - 12 meters

4- Yields: 13-74 kg HC/ton rock
TOC: 3 - 15% - 10 meters

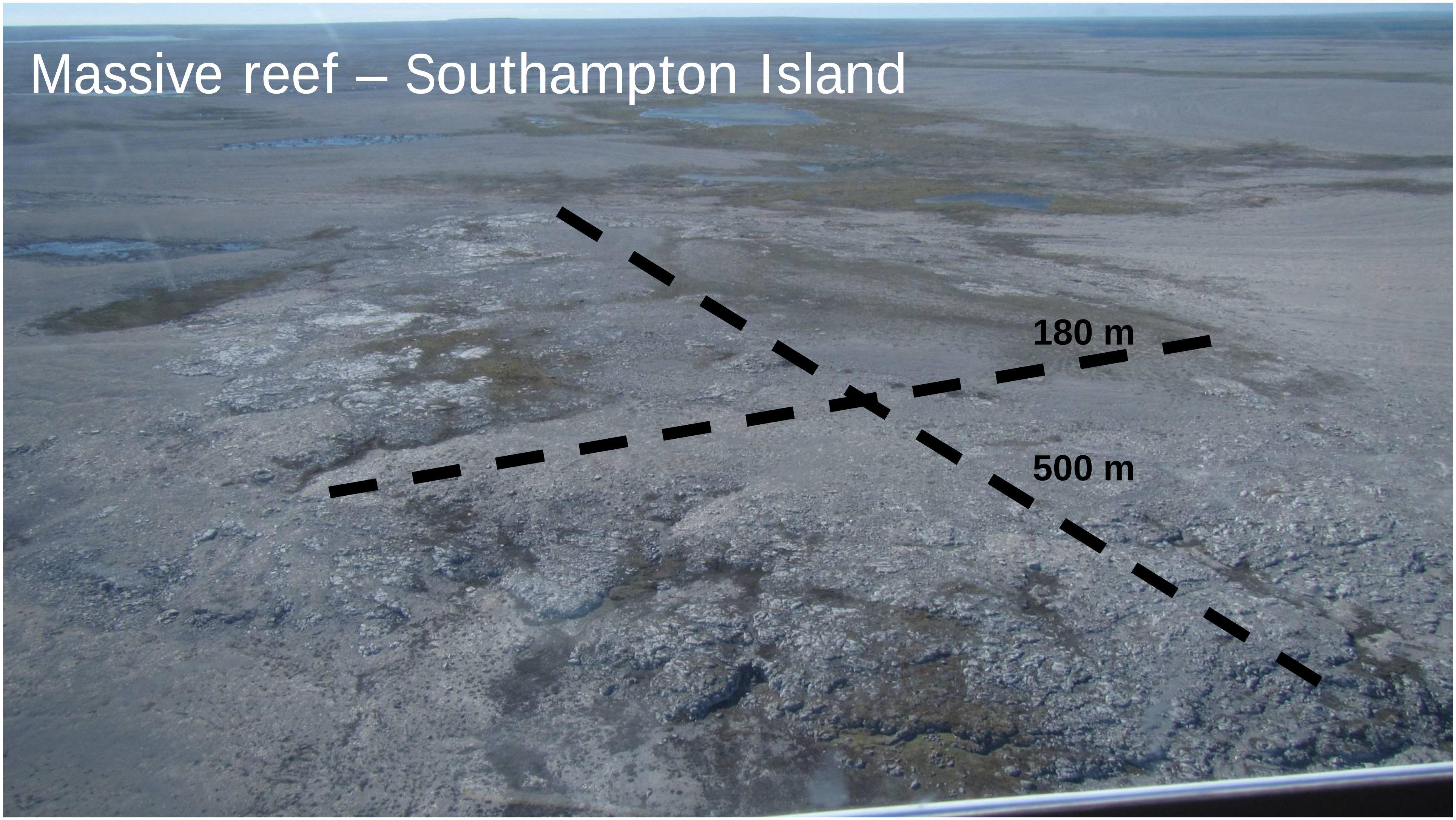


Upper Ordovician reef research highlights

1. The reefs overly TOC-rich, Type I-IIs oil-prone source rock
2. The reefs are locally highly porous with report of dead oil and bitumen in pore space

Research objectives

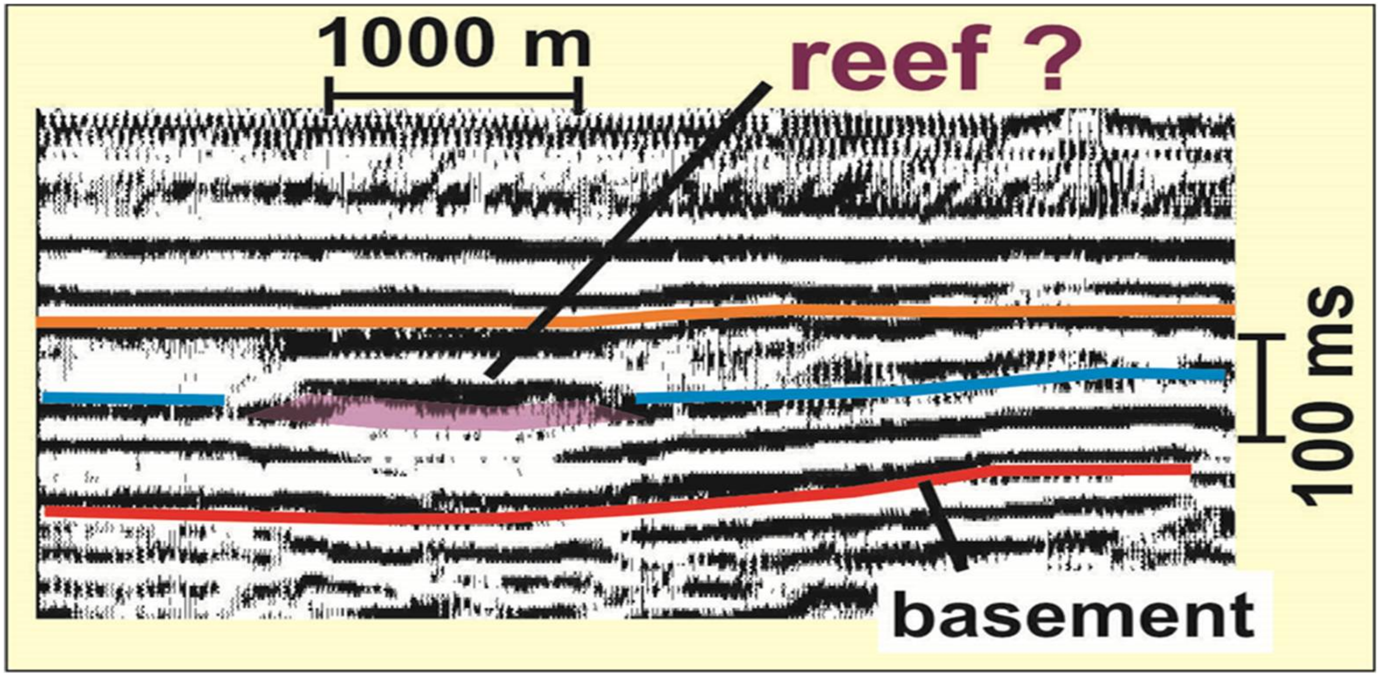
1. Understand the porosity evolution with respect to burial and source rock maturation
2. Evaluate the reservoir potential of the reef facies in the Upper Ordovican Red Head Rapids Formation in the context of hydrocarbon systems in the Hudson Bay Basin


Massive reef – Southampton Island
180 m
500 m

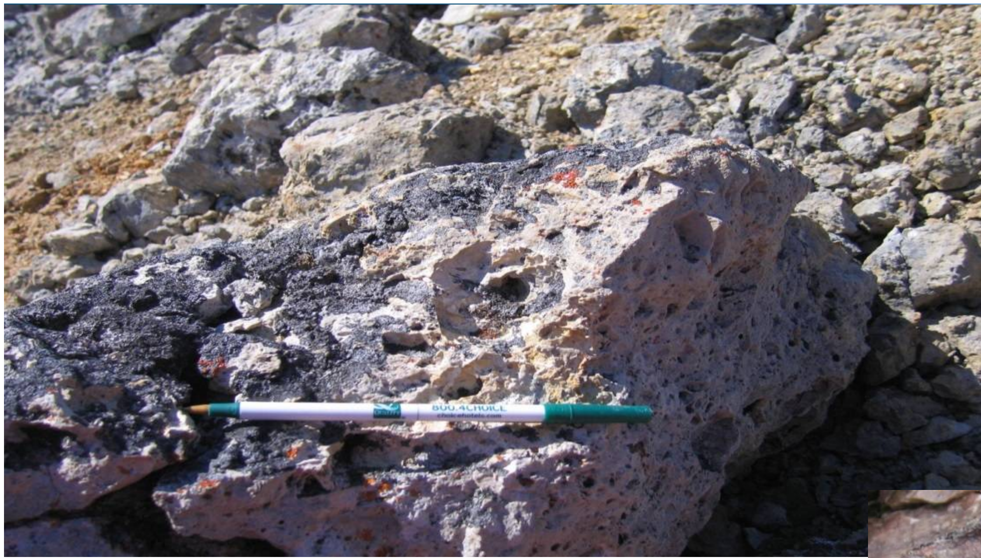
Interpreted sub-surface occurrence

Top Silurian

Top Ordovician




Massive and crudely-bedded



Pore and fracture-filling bitumen

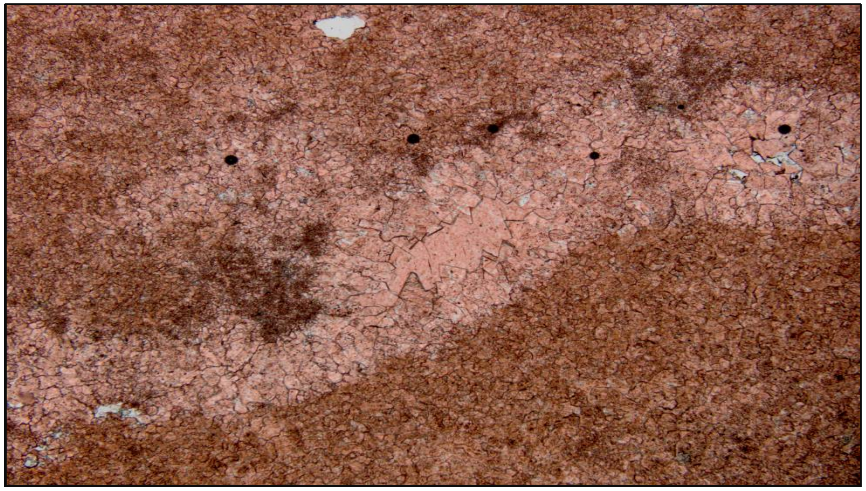
Very porous

Average Po estimates from field outcrop is 25-30%

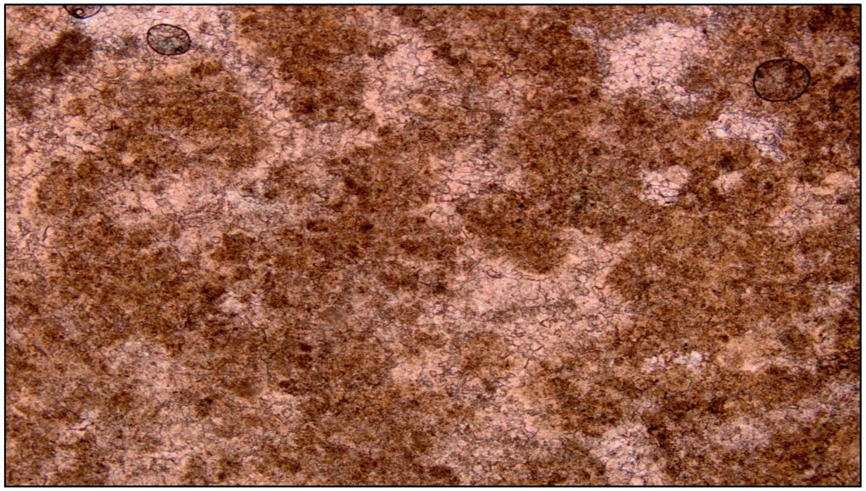
Facies

Two main facies:

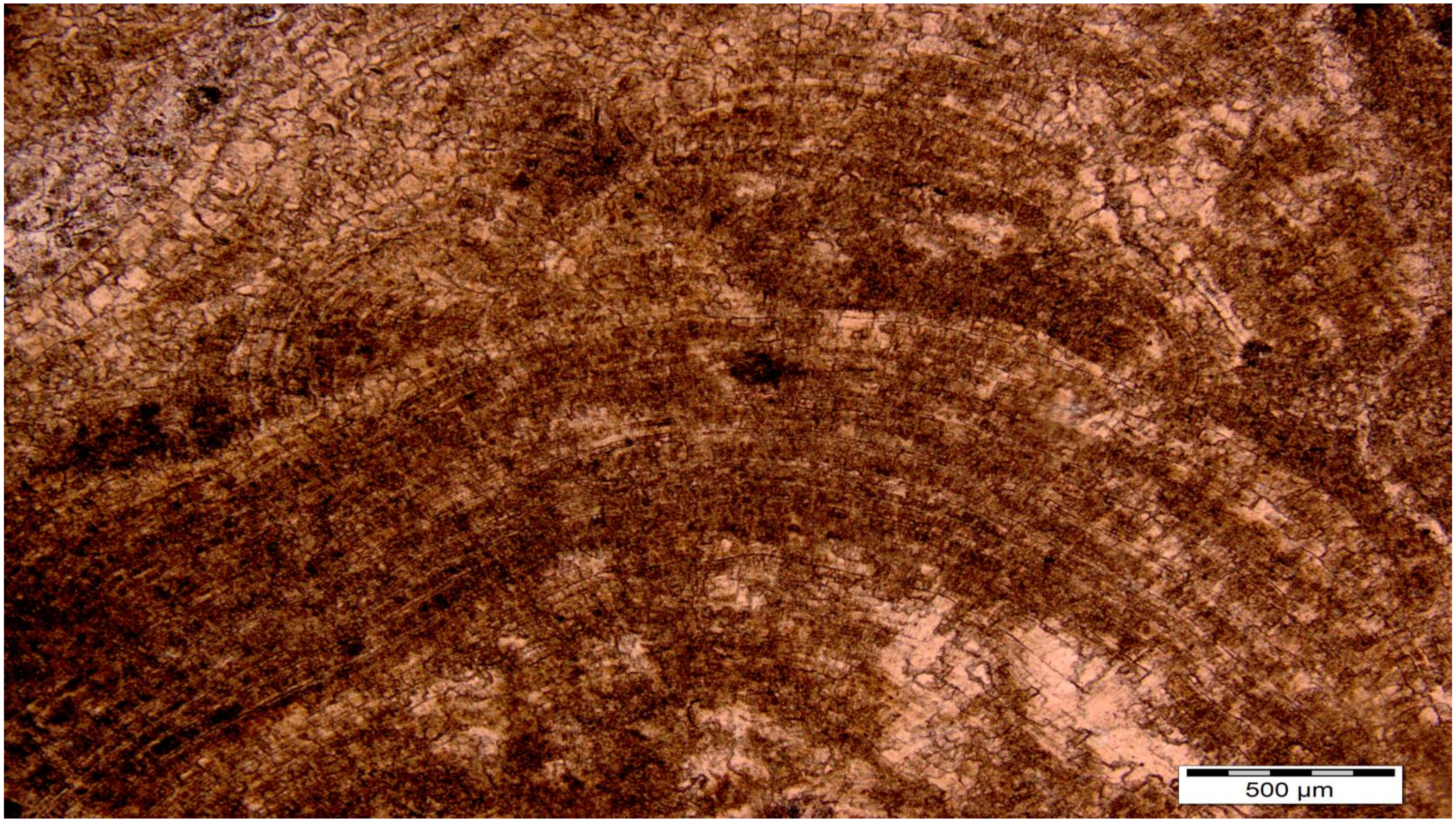
Cementstones



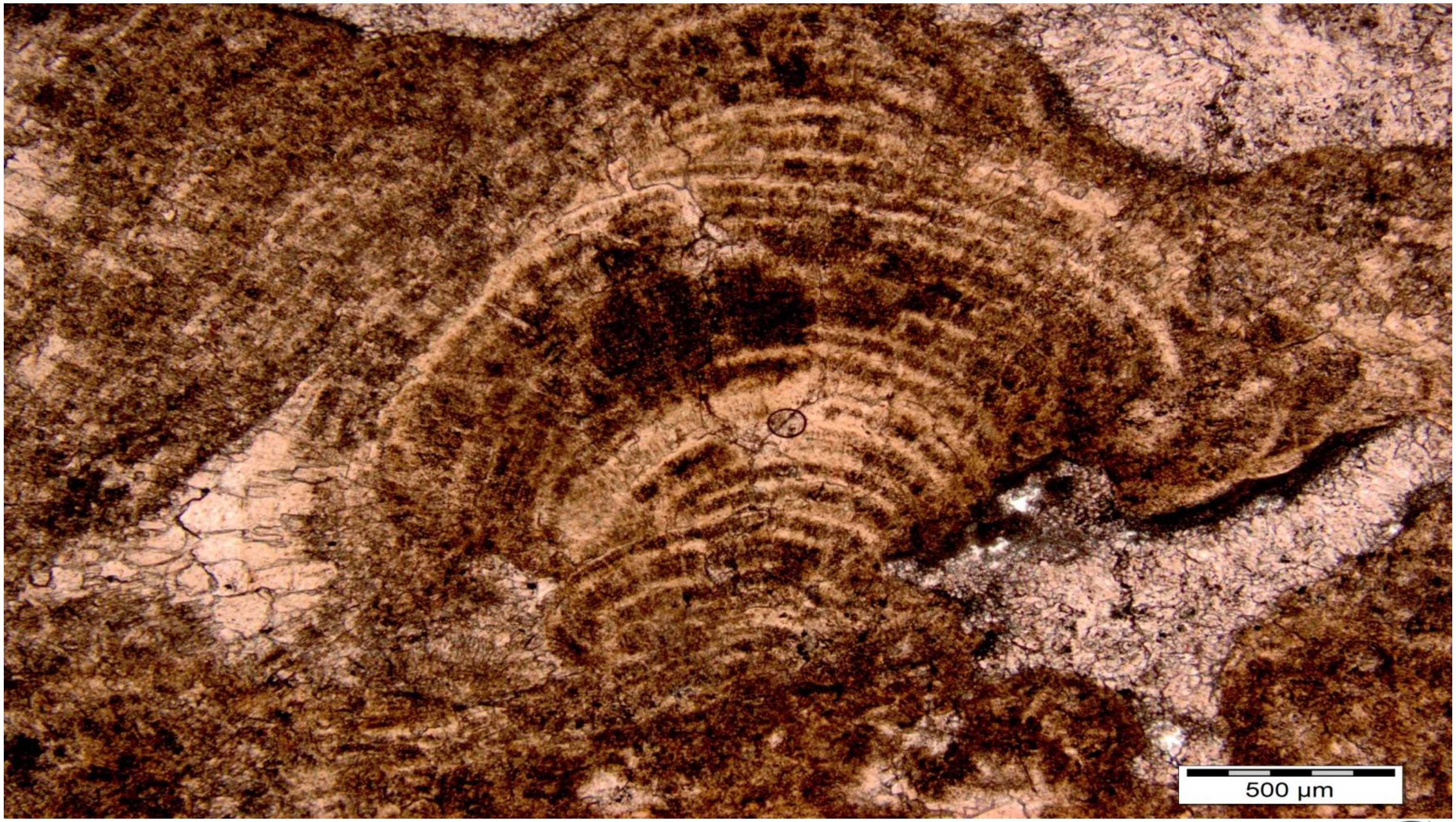
Boundstones



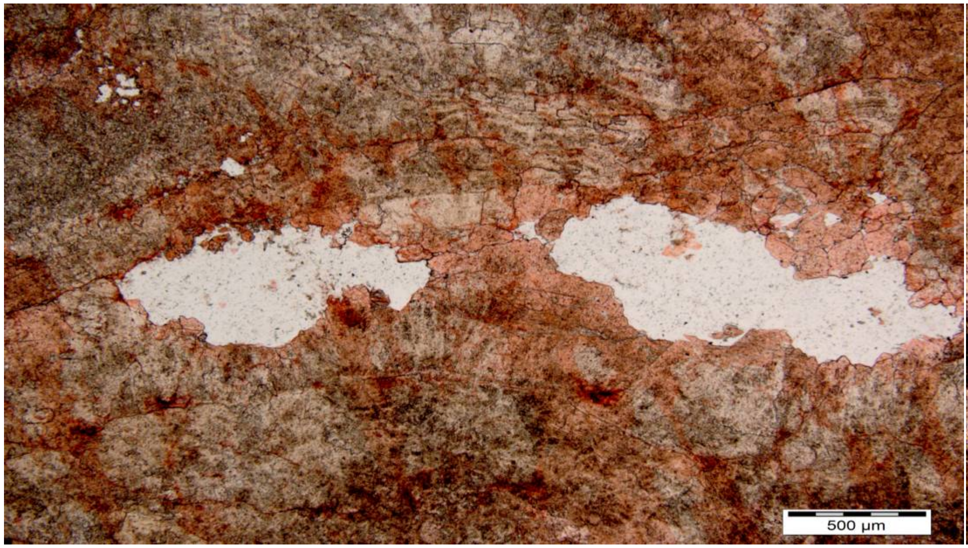
Cement succession – marine isopachous



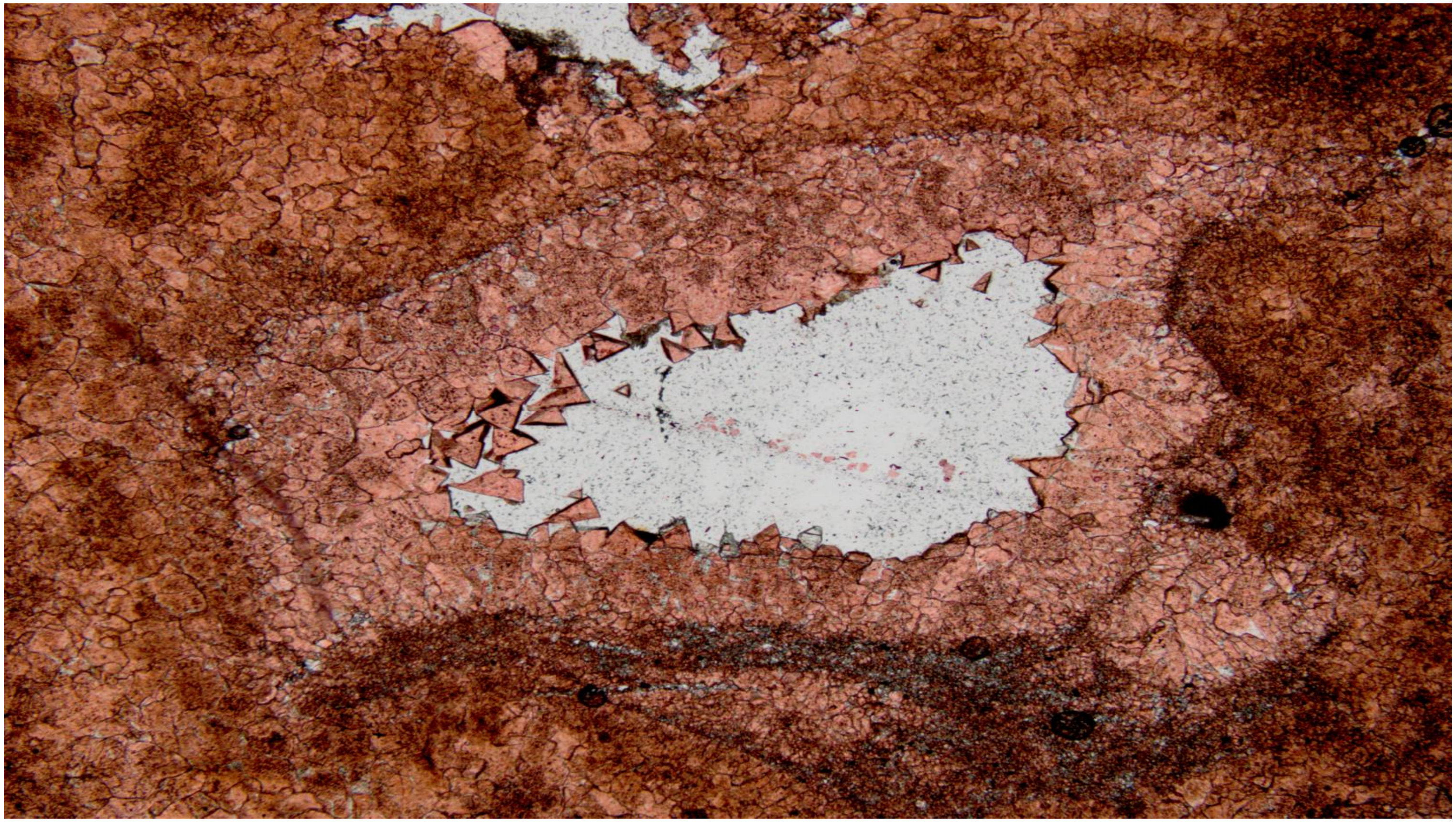
Cement succession – marine botryoids



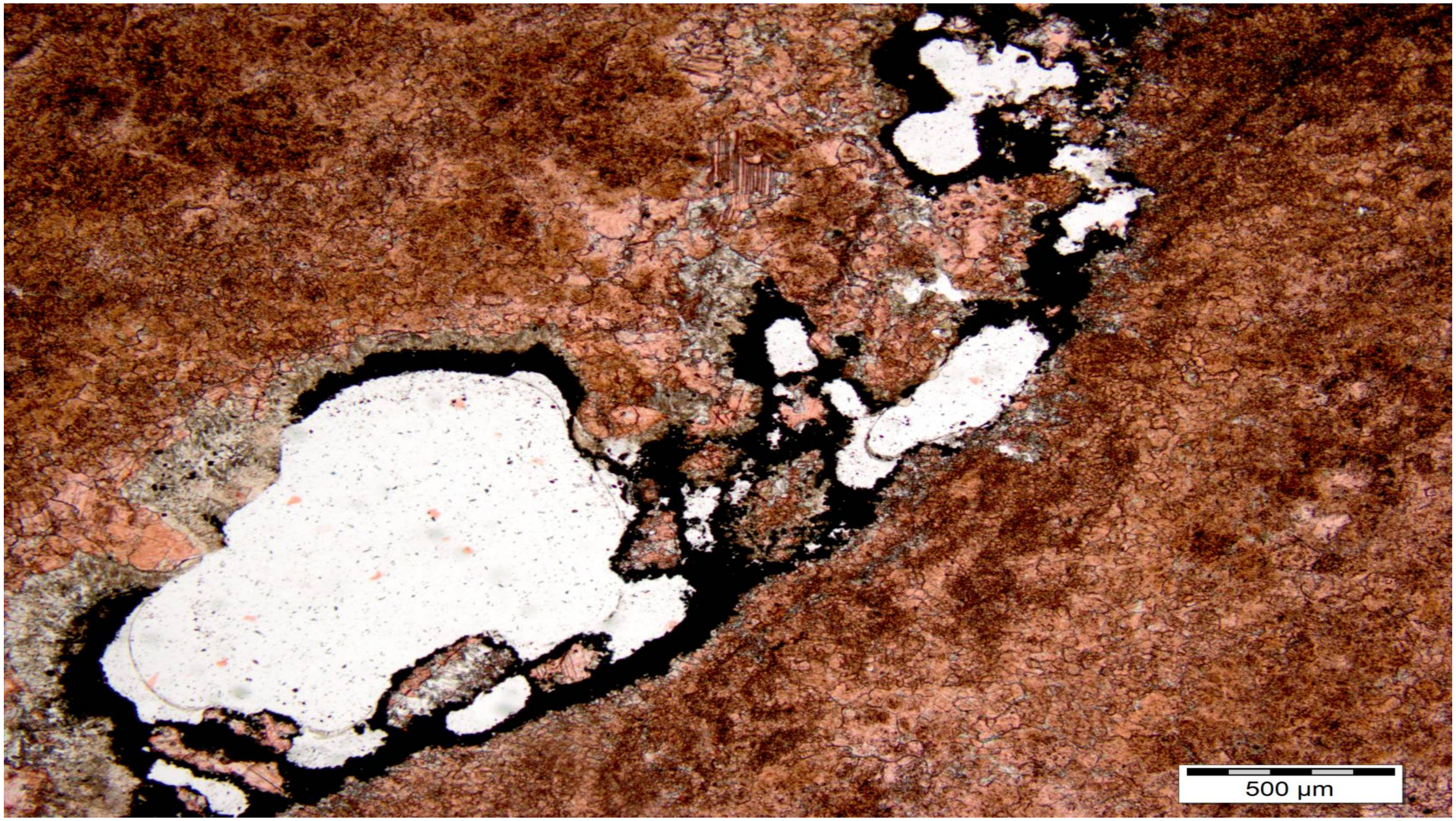
Cement succession – dissolution



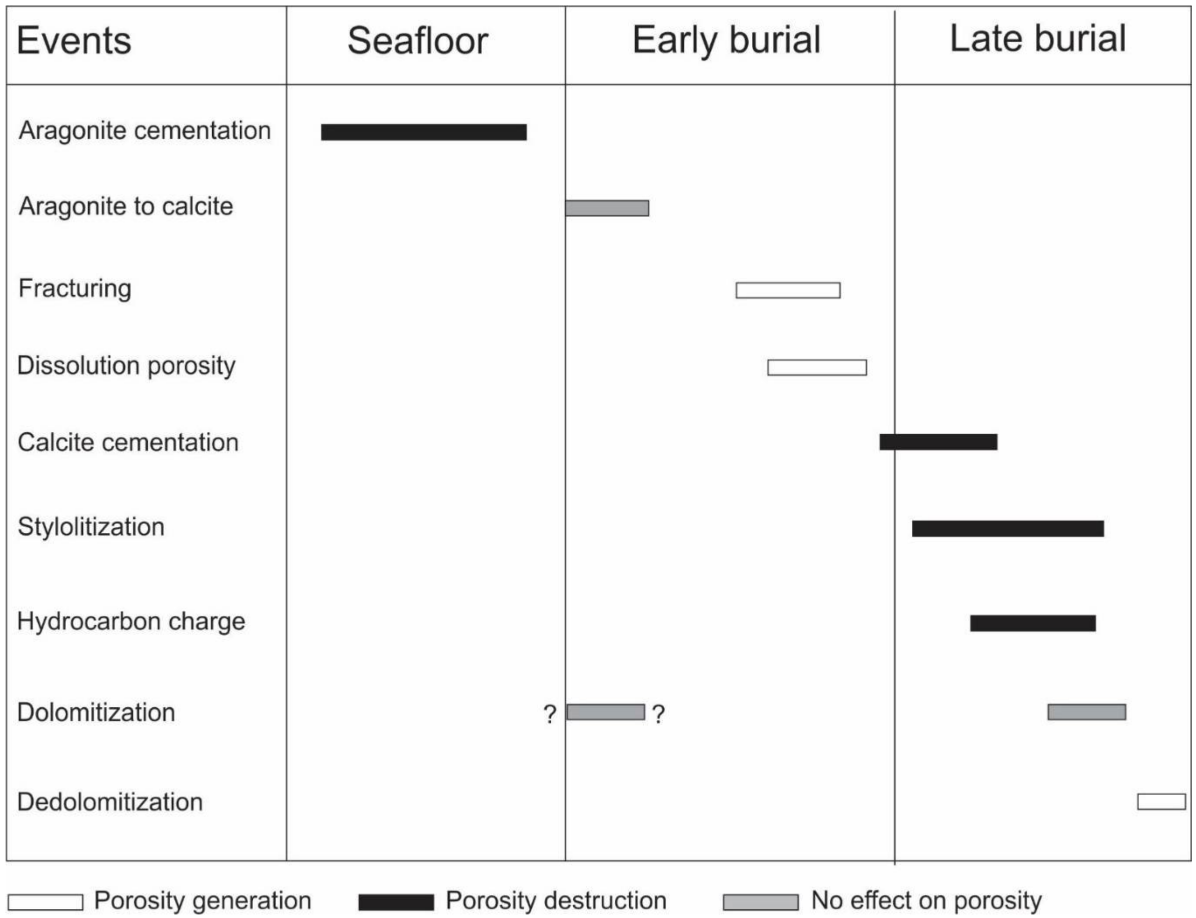
Cement succession - bitumen



Cement succession - bitumen



Paragenetic succession

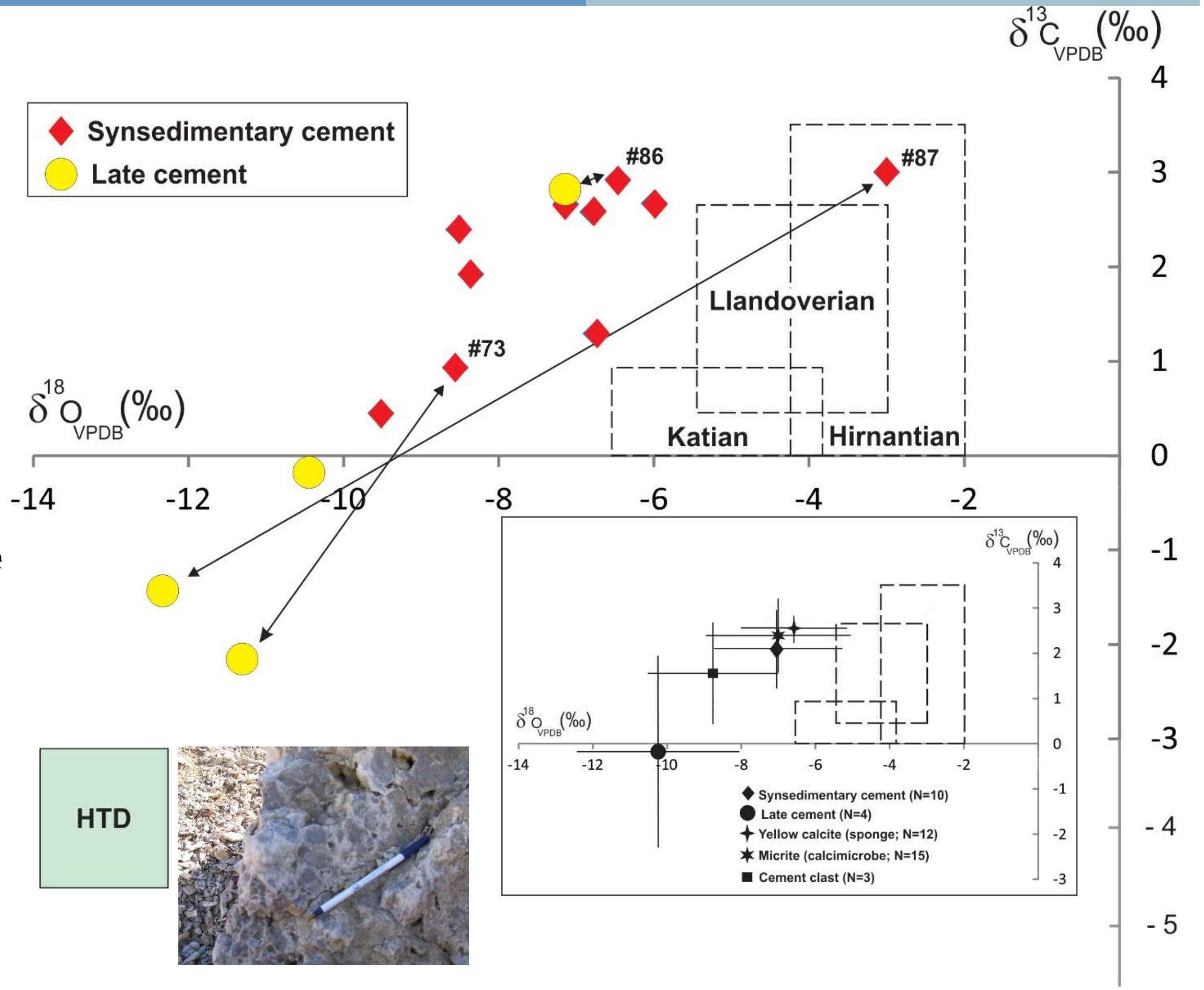


Geochemistry
Stable Isotopes

Synsedimentary cements have less negative $\delta^{18}O$ and $\delta^{13}C$ values compared to burial cements

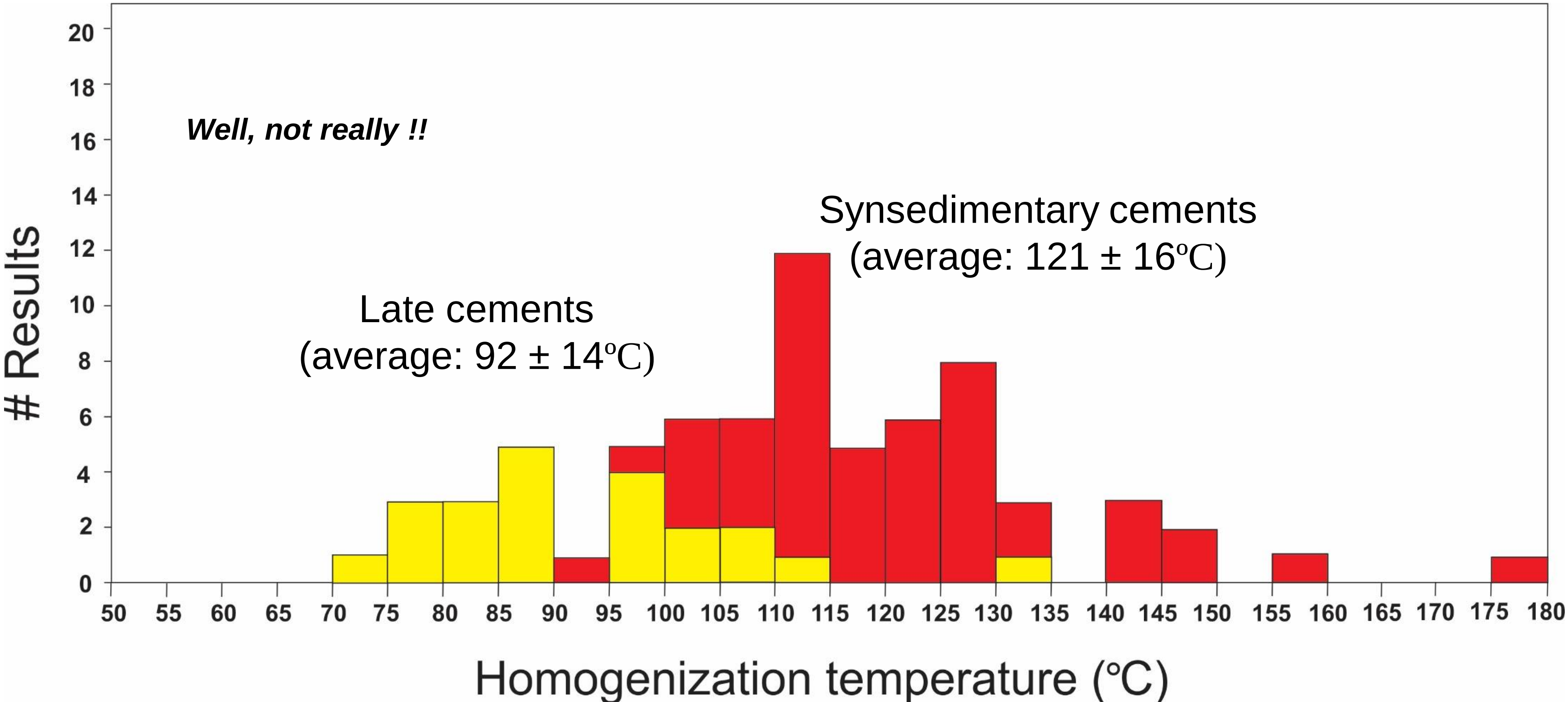
For paired analyses in a single sample, burial cements are more negative for both $\delta^{18}O$ and $\delta^{13}C$ than the associated synsedimentary cement

A simple progressive burial diagenetic evolution?



HTD

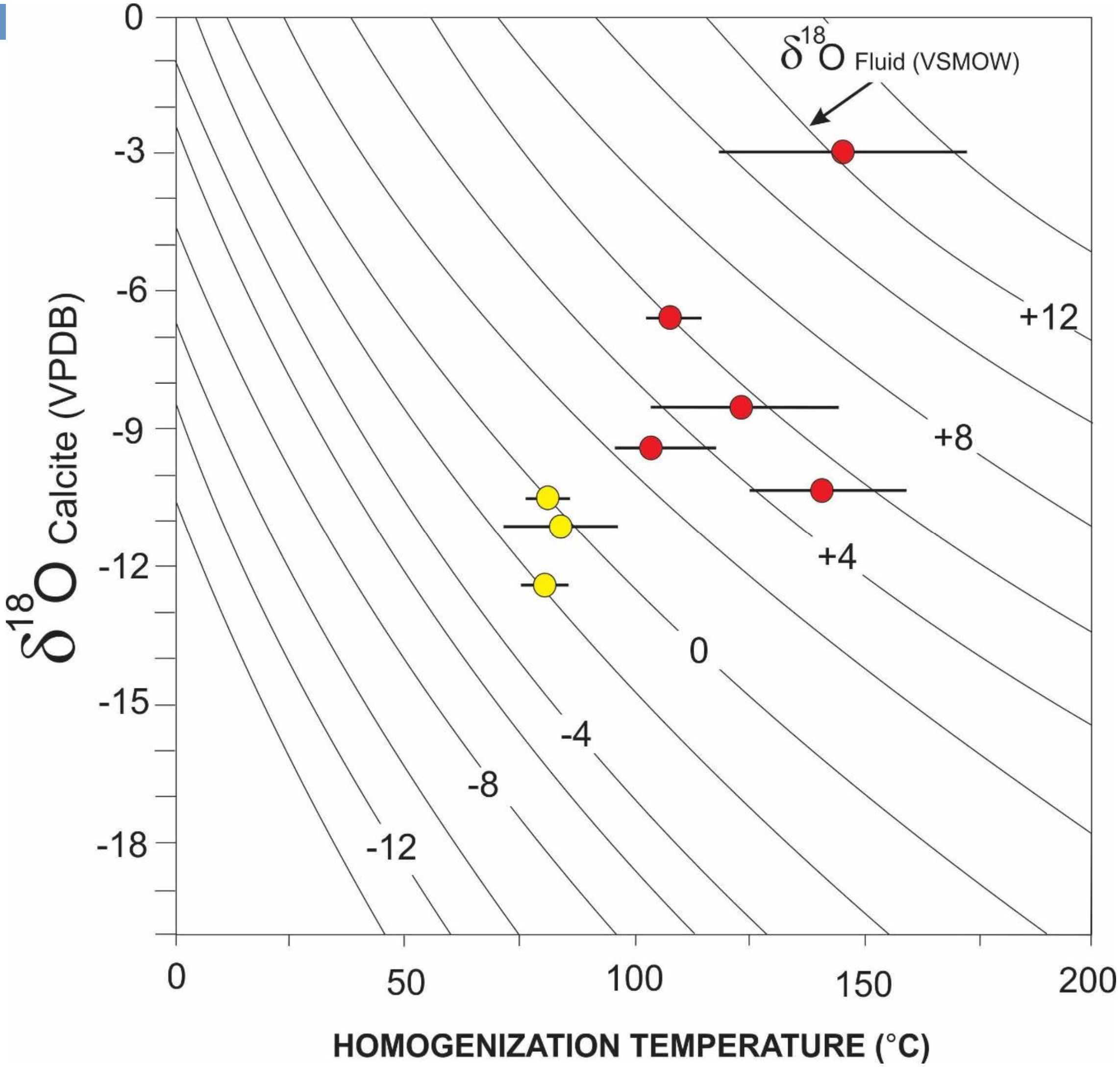
Fluid inclusions – Homogenization temperatures



Fluid $\delta^{18}O_{SMOW}$ composition

- Synsedimentary cements
- Late burial cements

Fluid inclusions in recrystallized synsedimentary cements record the effects of high-temperature brines responsible for secondary porosity to be later filled by calcite and bitumen



Ongoing and upcoming research: refining thermal history

Rock Eval (T_{max}): immature (T_{max} suppression?)

Upper Ordovician source rock

Apatite Fission Tracks: oil window

Upper Ordovician basal sandstone

Fluid inclusions (late cements): oil window

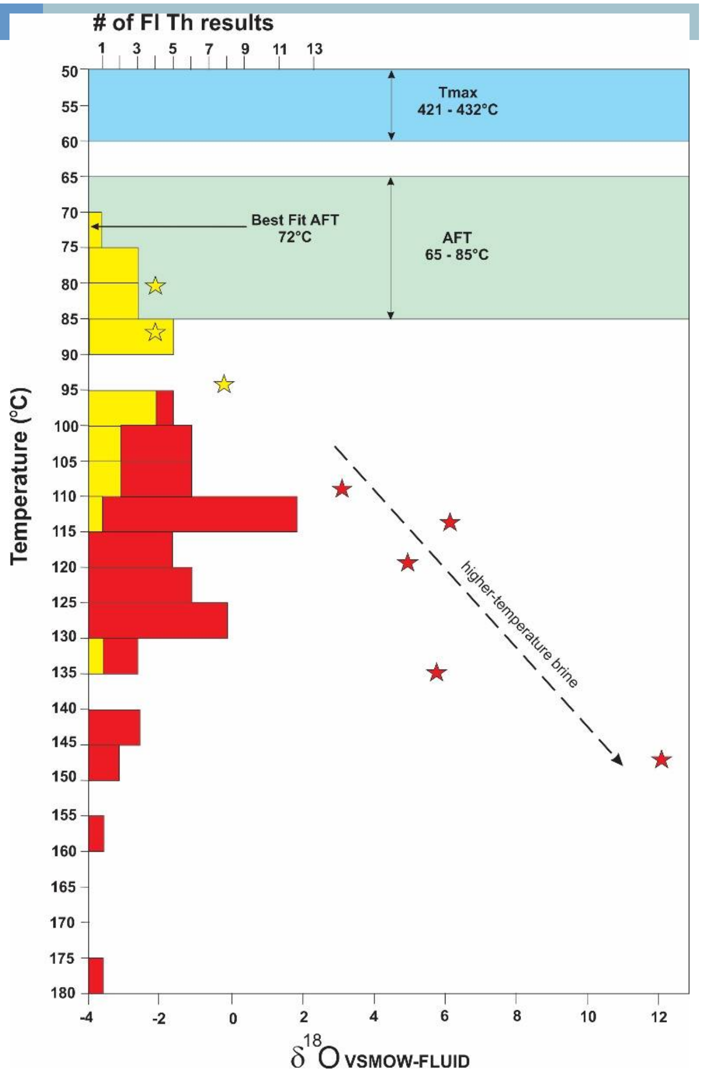
Upper Ordovician reef

Fluid inclusions (pre late cements): early hydrothermal event

Upper Ordovician reef and platform

Clumped isotopes on cements: in progress

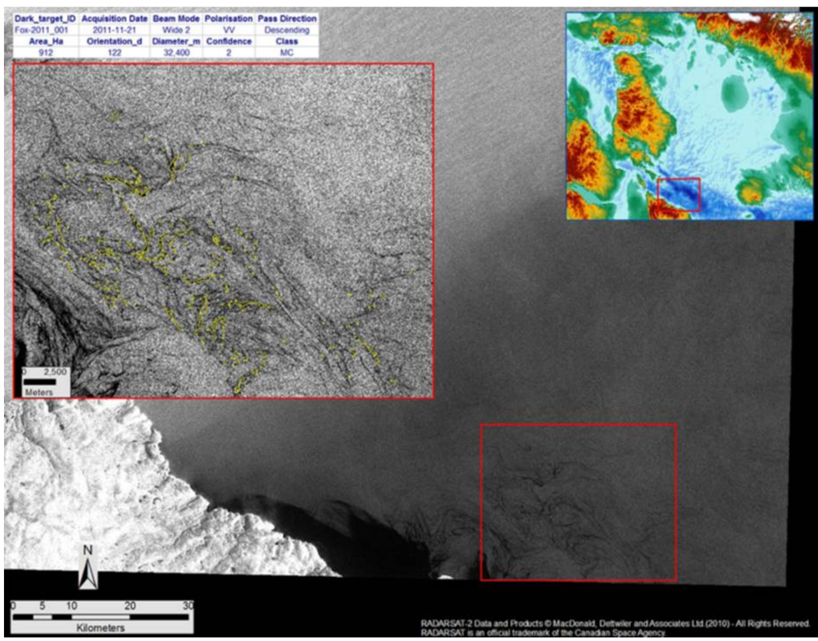
Upper Ordovician reef

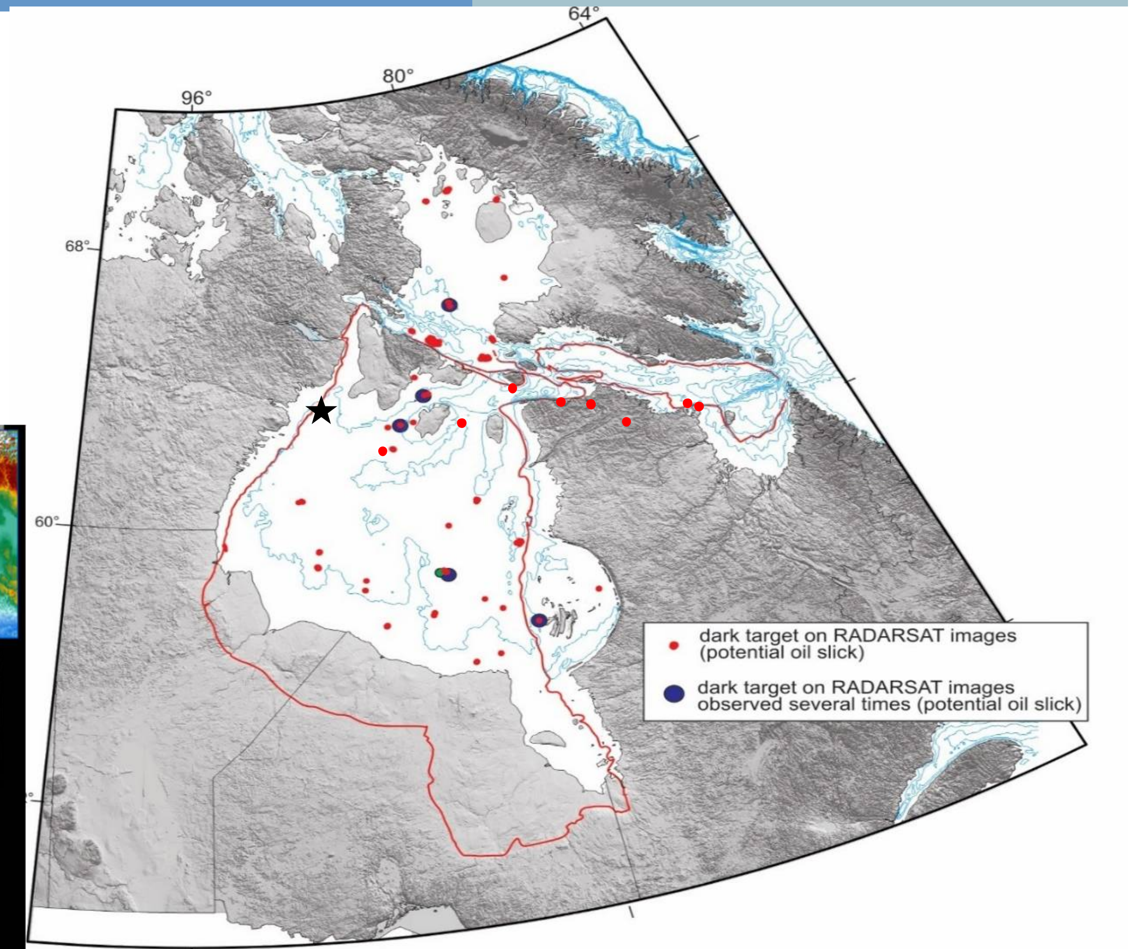


Ongoing research

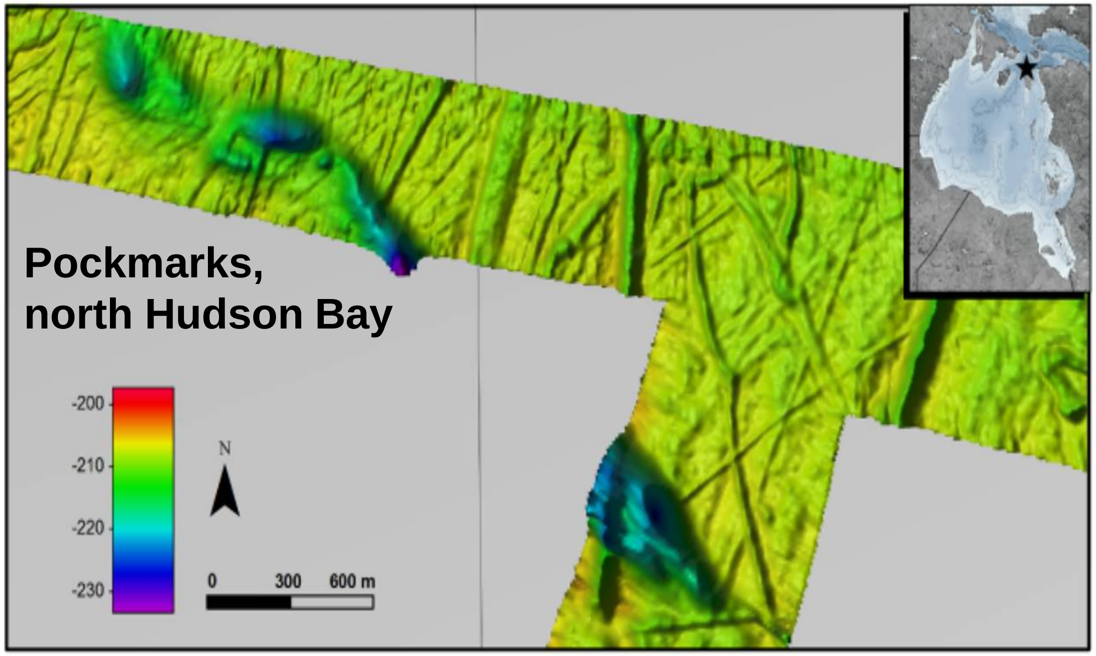
Hydrocarbon generation ?

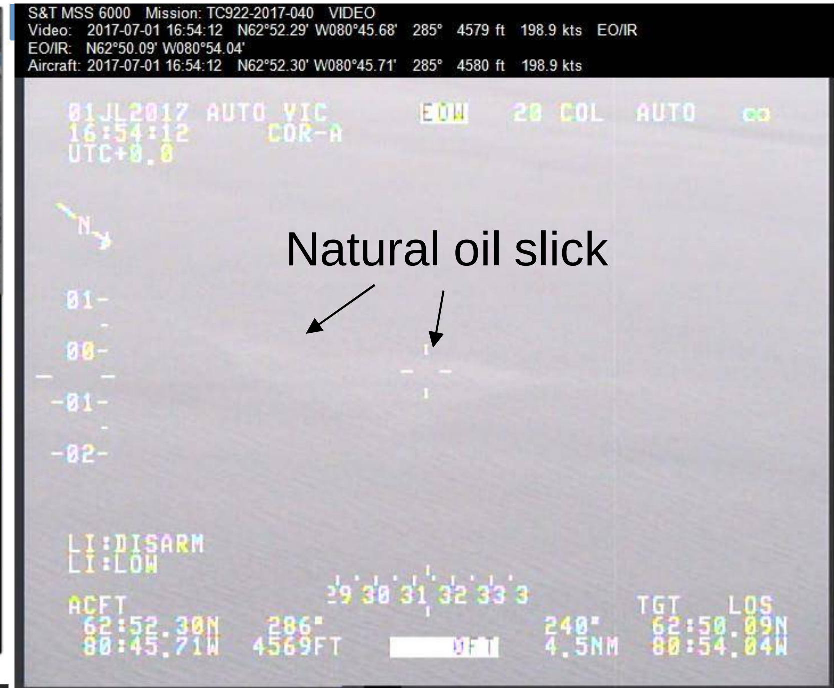
Abundant, potential oil slicks in the area as determined through RADARSAT images analyses

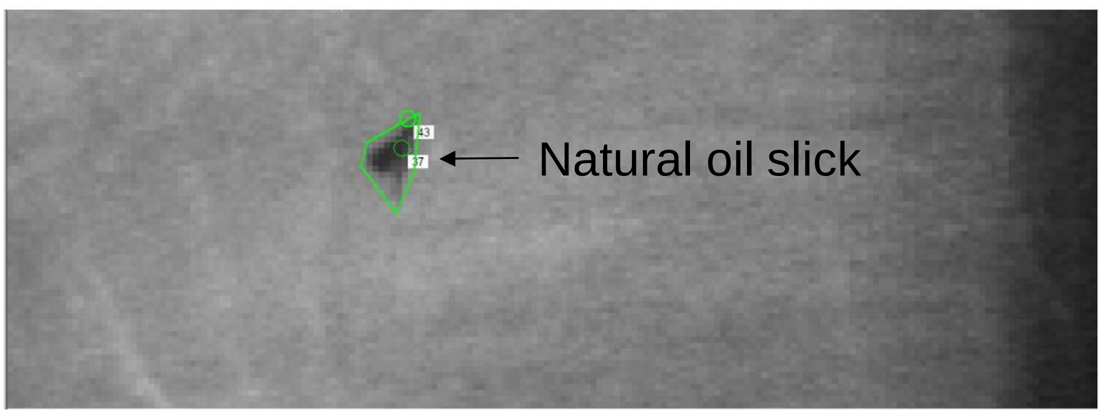




Canada







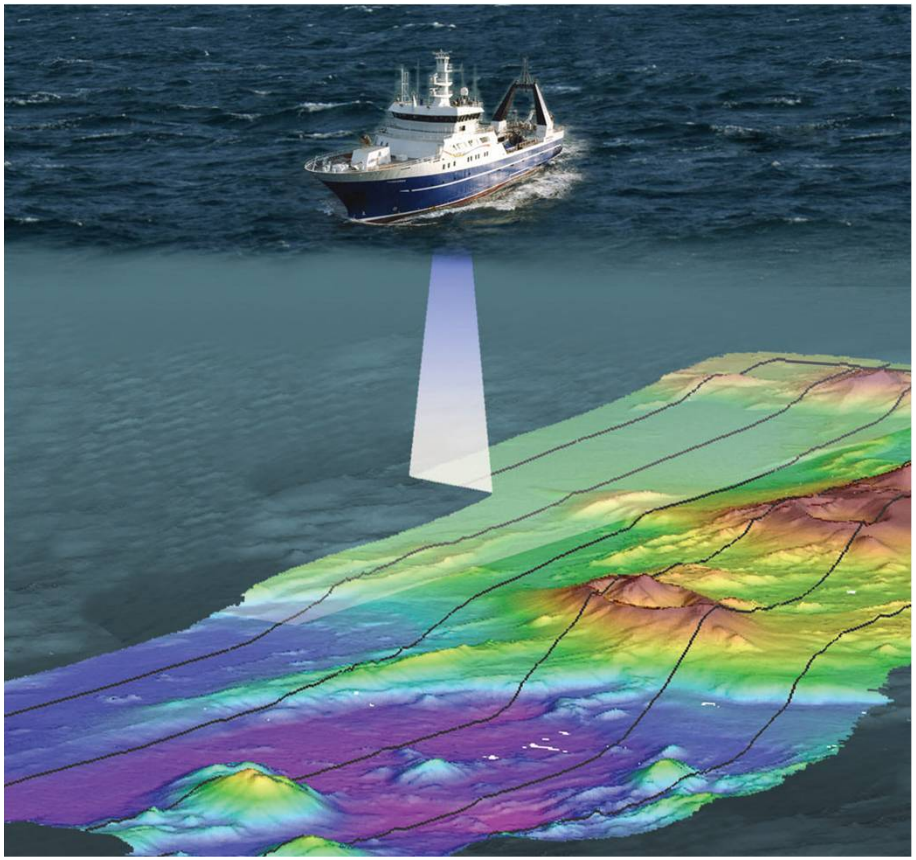
Hydrocarbon generation?

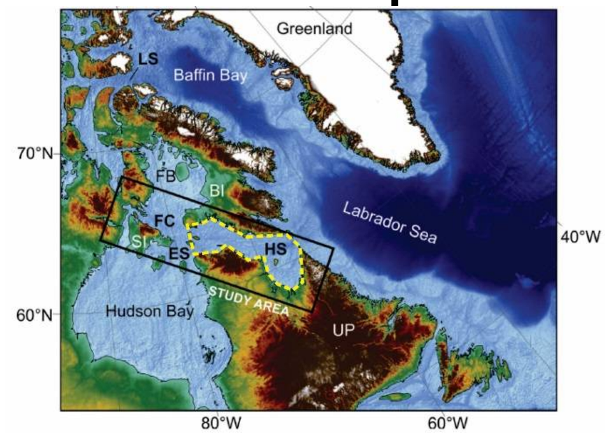
A limited airborne SLAR survey – Natural oil slick coincident with seafloor pockmarks

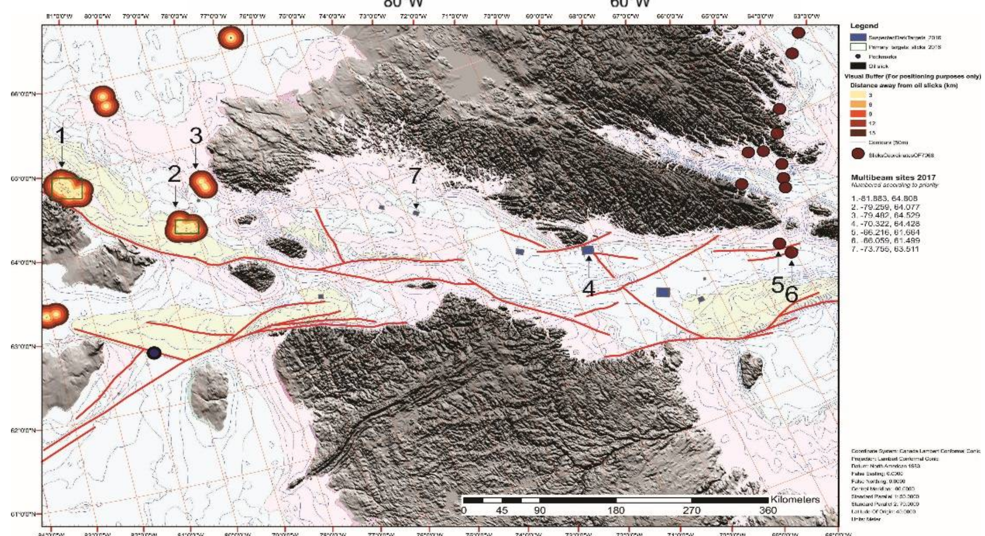
Canada

Upcoming research (2018) – the hunt for pockmarks

Seabed mapping and sampling in strategic areas







Conclusions

1. The Upper Ordovician reef displays boundstone and cementstone facies with abundant marine (aragonite – now calcite) and later burial (calcite) cements.

2. Bitumen occurs in fracture and dissolution pore spaces. 25-30% pore space.

3. Fluid inclusions are mostly saline (>12%) with 2 T_h groups: 1) early marine cements with average of 121°C and 2) late burial cements with average of 92°C.

4. High-temperature and $\delta^{18}O_{VSMOW}$ heavy brines affected marine cements.

5. Local circulation of fault/fracture controlled hydrothermal fluids – generation of significant early pore space. HTD breccias recognized elsewhere in the Upper Ordovician succession.


THANK YOU !