Facies Architecture of a Porous Upper Ordovician Reef in the Hudson Bay Basin - A Potential Reservoir Directly on Top of a Type II Source Rock*

Ariane Castagner[1], André Desrochers[1], and Denis Lavoie[2]

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Abstract

The Hudson Bay Basin is the largest intracratonic basin in North America, although the understanding of its hydrocarbon systems has only recently being initiated for this oil-prone basin. The carbonate-dominated succession of the onshore northern segment of the Hudson Bay includes in ascending order, the Upper Ordovician Bad Cache Rapids and Churchill River groups and Red Head Rapids (RHR) Formation and Lower Silurian Severn River, Ekwan River and Attawapiskat formations. The RHR formation is divided into four units and capped by thin-bedded dolomitic limestone with local bioherms up to 500 m in diameter and 10 m of relief. The resistant buildups display massive and porous boundstone and cementstone facies. These massive facies have more in common with the sponge-microbial reefs that dominated worldwide in the Early Ordovician and include the following primary components: early calcified sponge material, microbial elements, and synsedimentary calcite cement.

A close spatial relationship suggests that a poorly preserved decaying sponge framework provided substrates for the attachment and development of microbes, and the microbes played essential roles as reef consolidators. Small centimetre-scale colonial metazoans were present and locally intergrown with the sponge and microbial components. Although altered now to calcite, cement fabrics suggest that metastable aragonite was ubiquitous as sea floor precipitate. Prior to their subaerial exposure at the end-Ordovician, the RHR buildups developed in a shallow-marine evaporative epicratonic sea with physical and chemical parameters distinct from the open ocean. In the more central offshore Hudson Bay Basin, the RHR Formation consists of a mixed succession of anhydrite and minor gypsum beds, limestone, dolomite, and organic-rich shale capped by halite. In spite of its location within 10° of the paleoequator during the Late Ordovician, the study area was under relatively warm and arid conditions leading to the formation of intracratonic platform evaporite deposits.

These reefs likely have excellent potential as reservoir facies judging by their porous nature (up to 15% by visual estimation) and stratigraphic position immediately above high TOC (up to 35%), Type IIs source rock. These reefs are identified in seismic profiles and even if the precise

timing of pore space evolution with respect to hydrocarbon generation and expulsion is still elusive, dead oil and pore-coating bitumen have been reported.

Selected References

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Lavoie, D., N. Pinet, J. Dietrich, and Z. Chen, 2015, The Paleozoic Hudson Bay Basin in northern Canada: New insights into hydrocarbon potential of a frontier intracratonic basin: AAPG Bulletin, v. 99, p. 859-888.

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Zhang, S., 2010, Upper Ordovician Stratigraphy and Oil Shales on Southampton Island - Field Trip Guidebook: Geological Survey of Canada, Open File 6668, 42 p.

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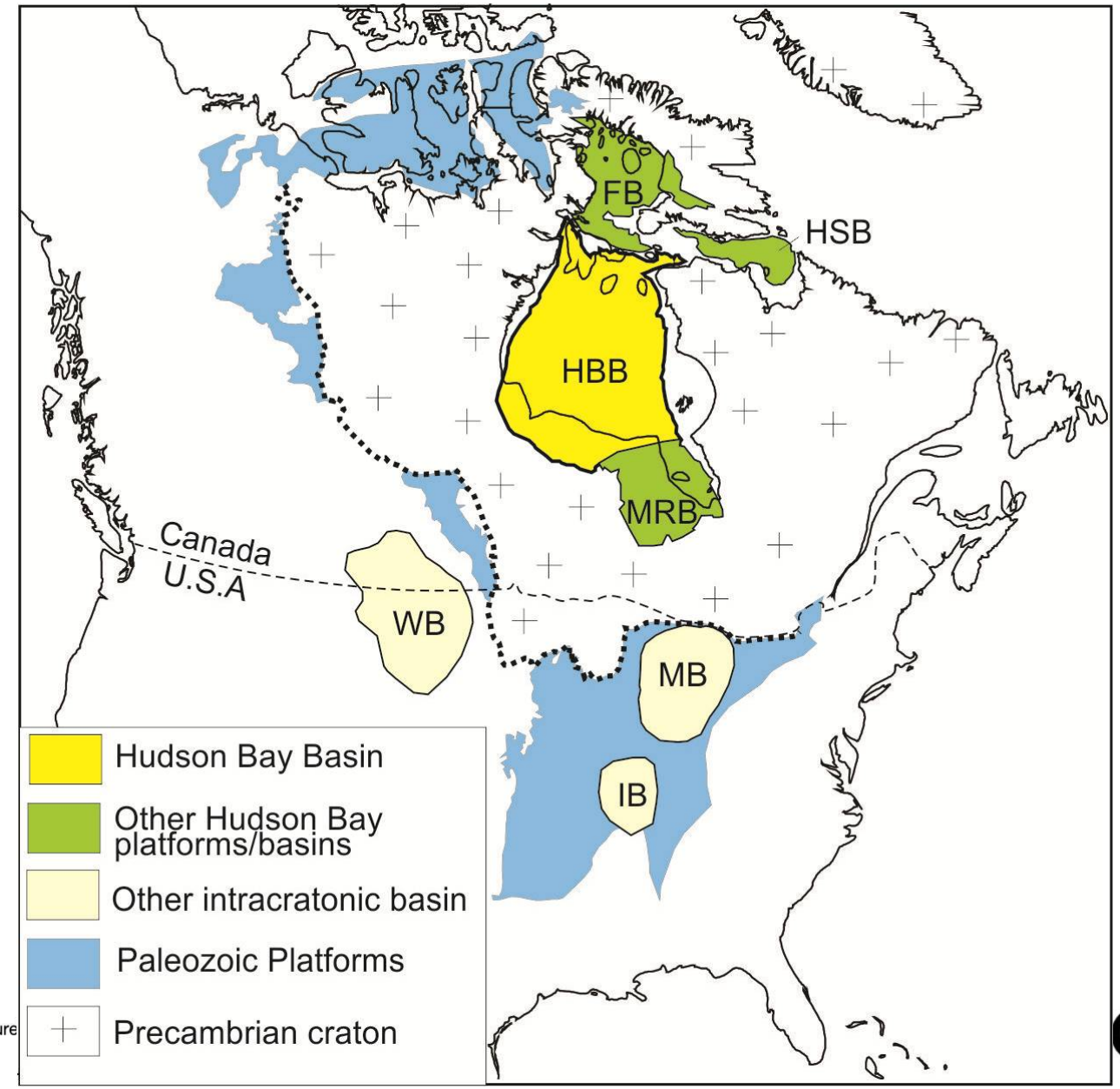
uOttawa

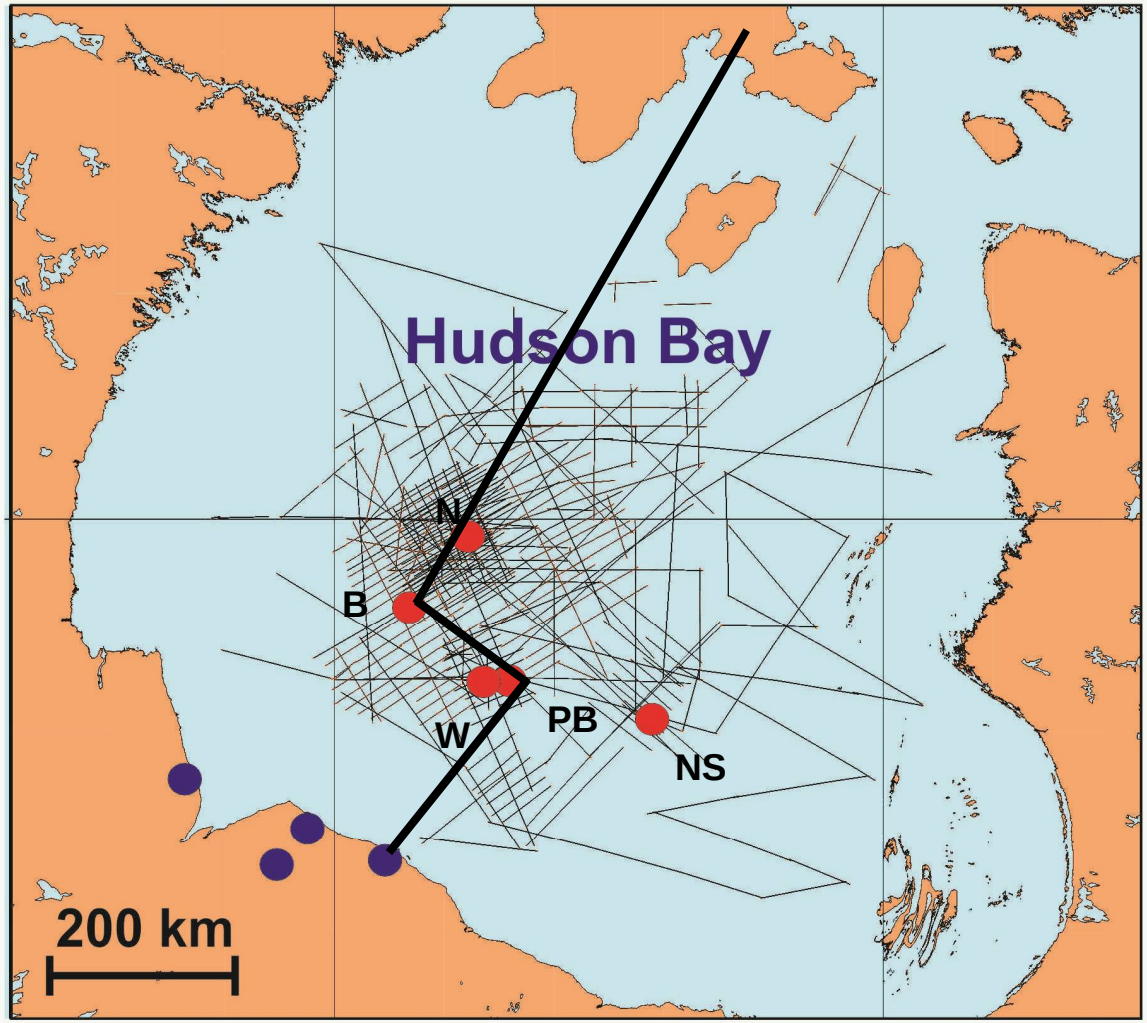
CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

The largest intracratonic basin in North America

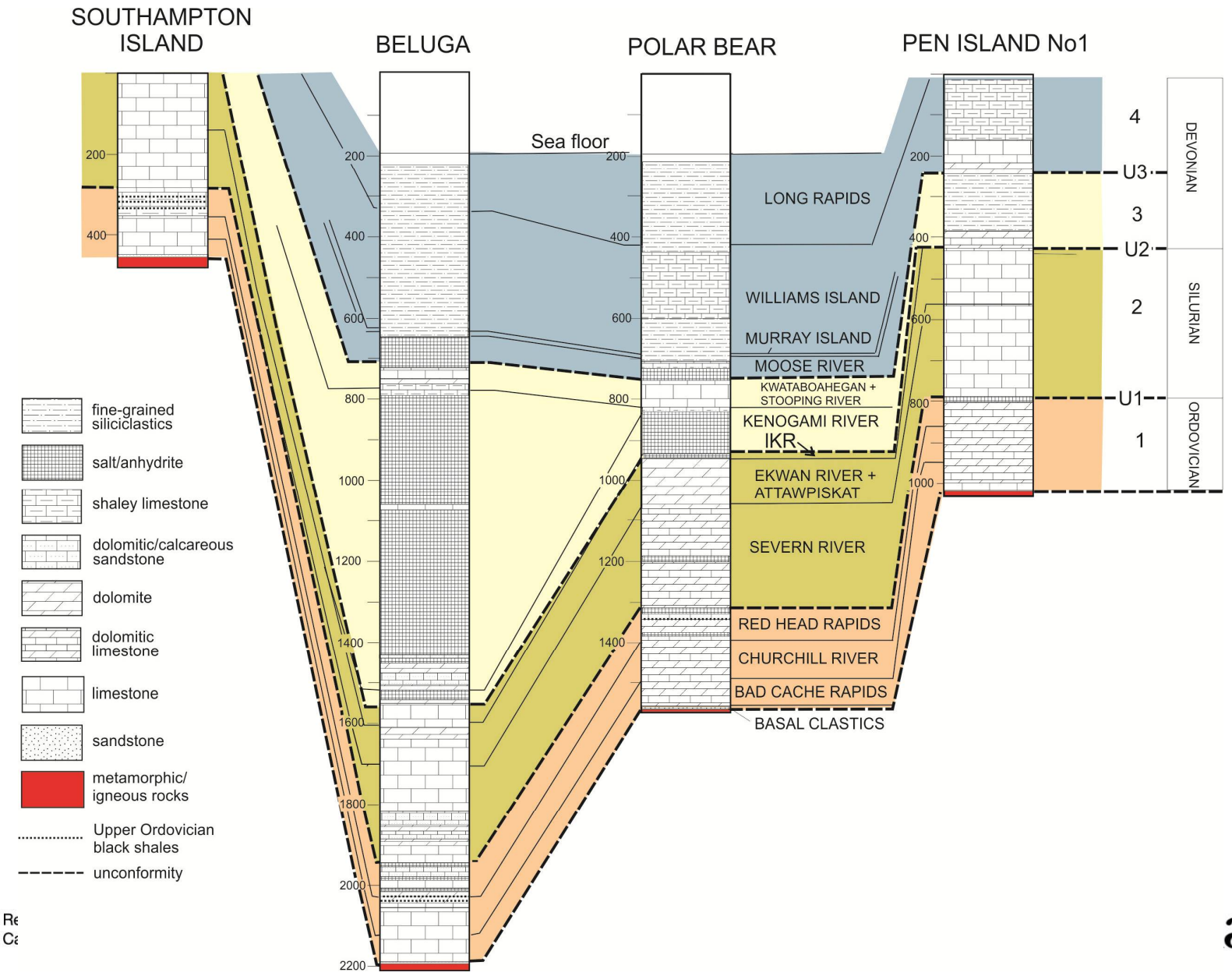


Petroleum Exploration in Hudson Bay Basin

- 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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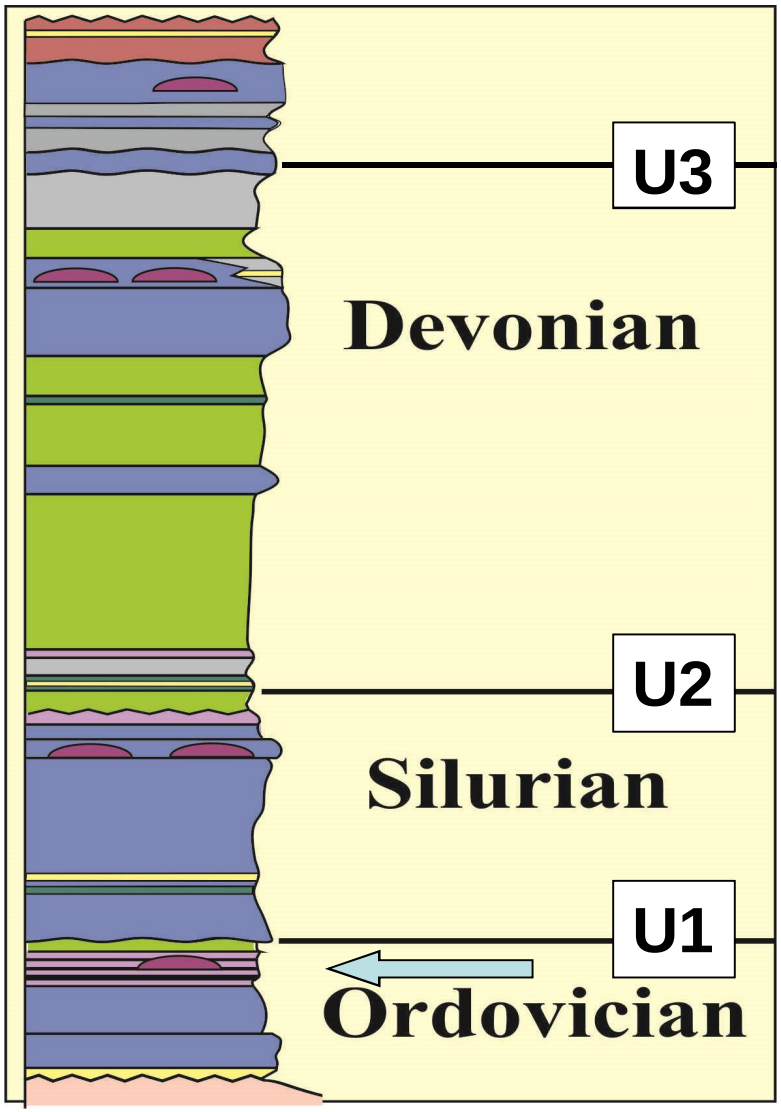
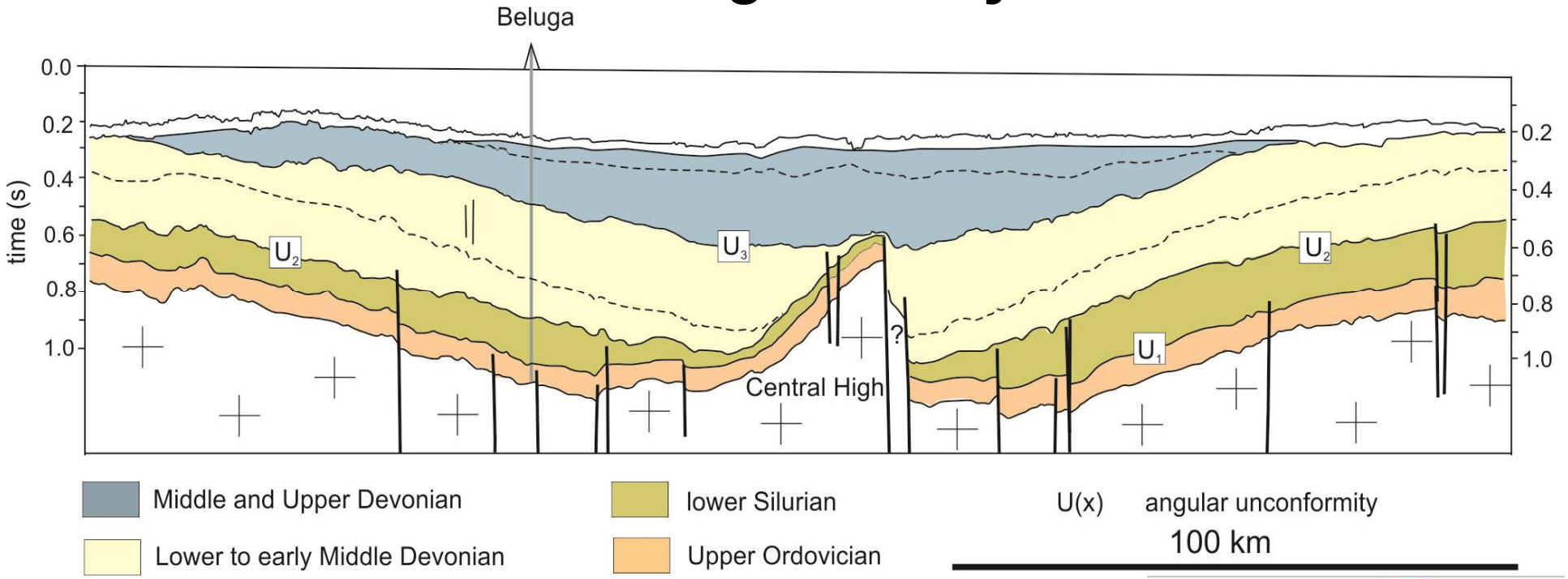
thin sections of coastal plain sandstones

Lithostratigraphy

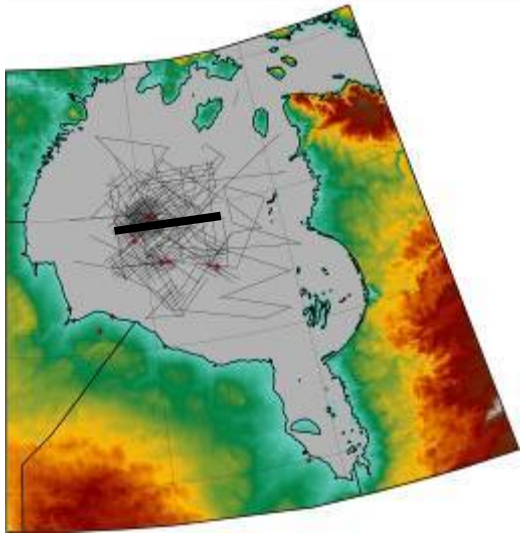


Dietrich et al (2012, SEG)

Basin geometry



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



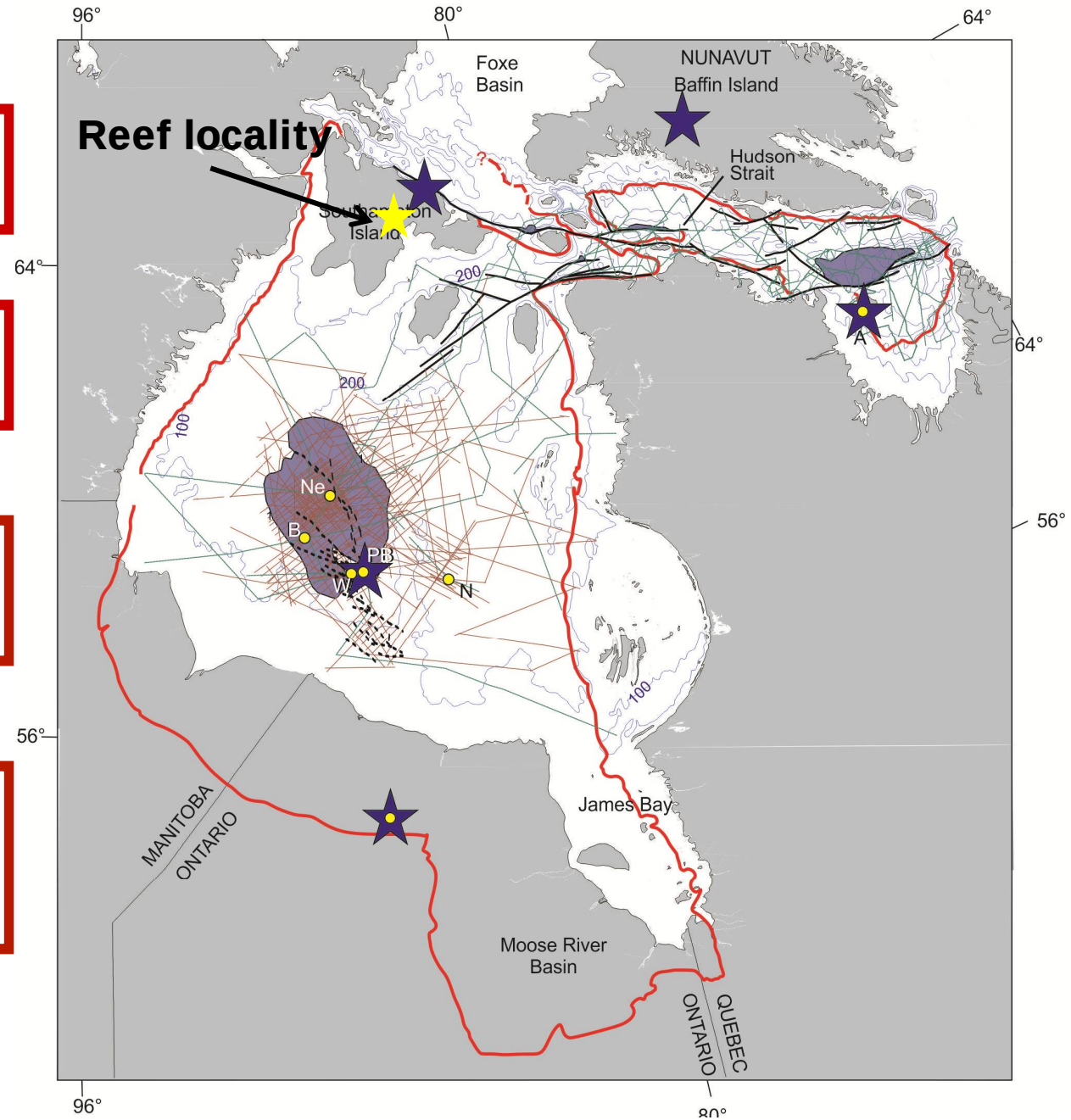
Source rocks

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

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

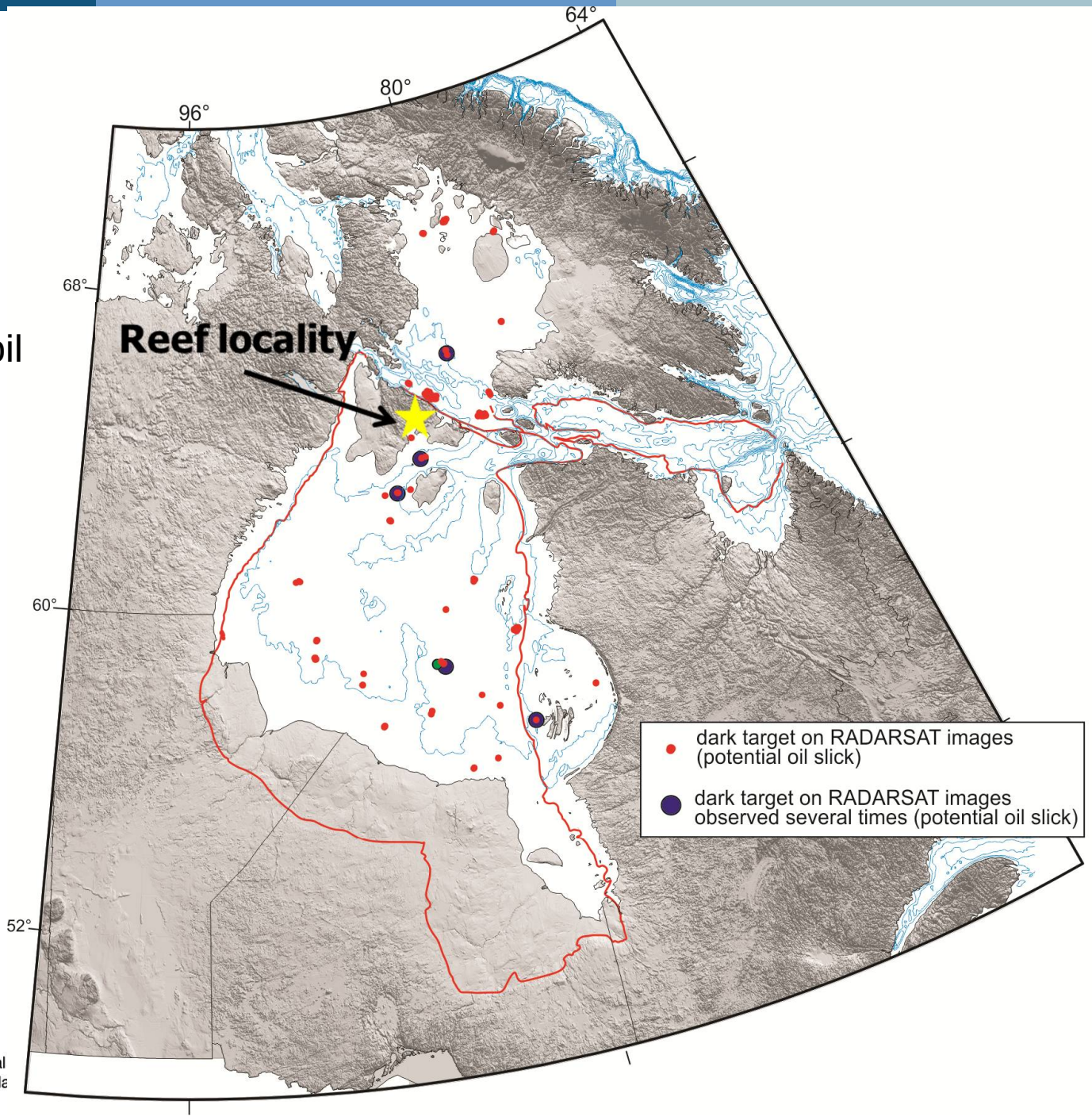
Yields: 2 – 11 kg/tonne
TOC: 4 - 5% - 12 meters

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



Ressources naturelles Canada
Natural Resources Canada

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



Ressources naturelles Canada

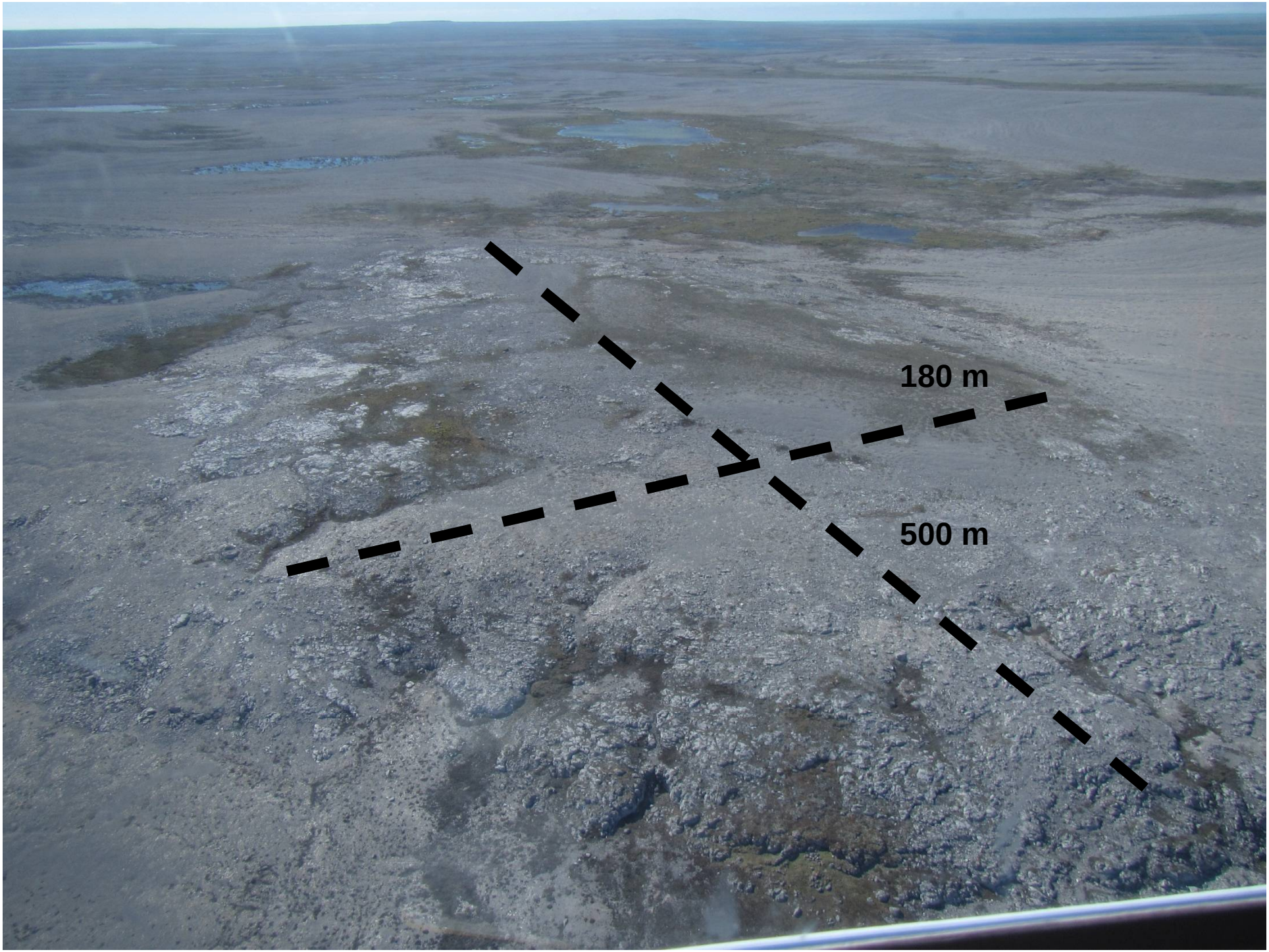
Natural Canada

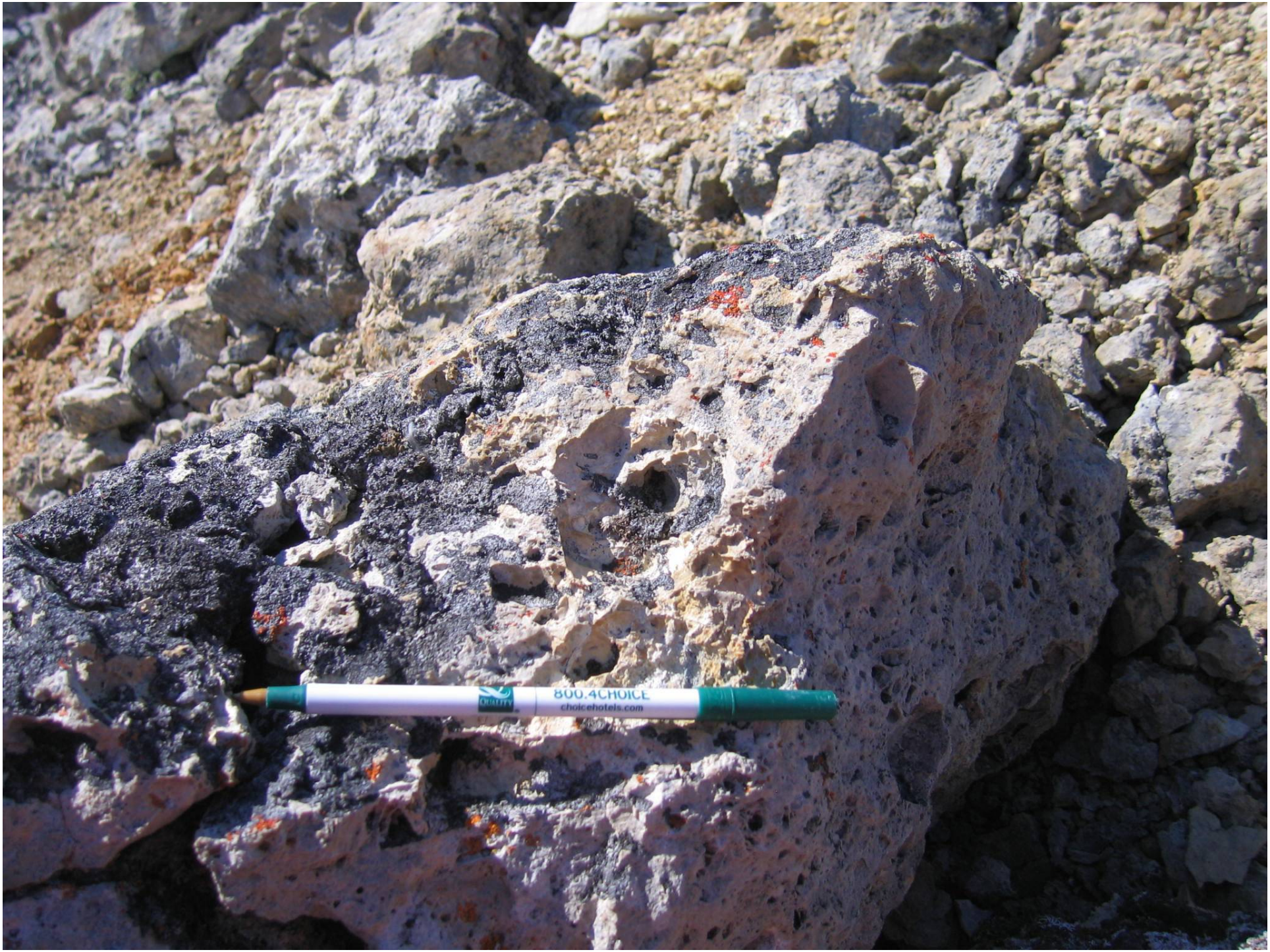
Research highlights

1. 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

2. The reefs are directly on top of TOC-rich Type II-s source rock

3. The reefs are locally highly porous with report of dead oil and bitumen in pore space


180 m
500 m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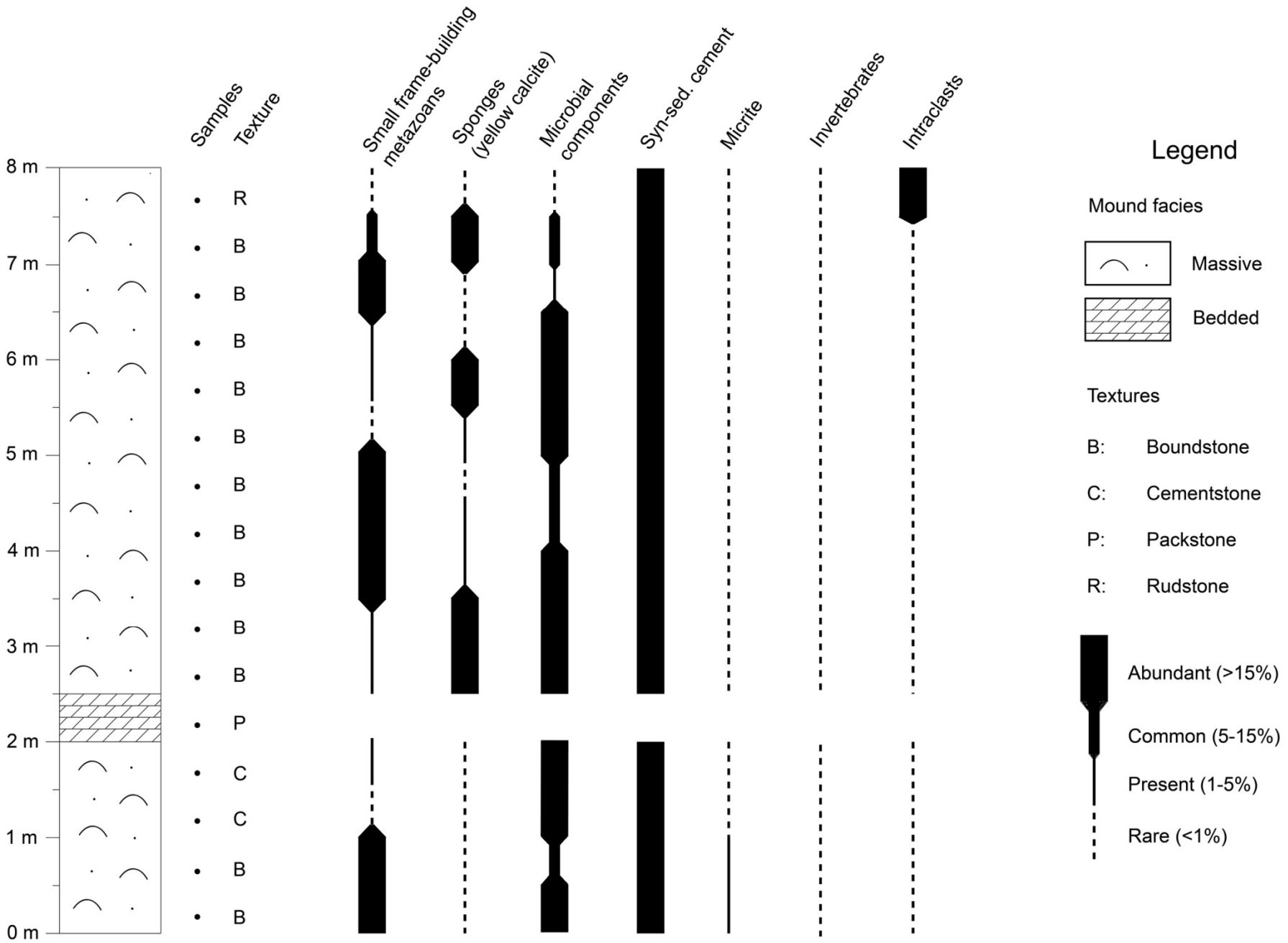
choicehotels.com


Samples
Texture
Small frame-building metazoans
Sponges (yellow calcite)
Microbial components
Syn-sed. cement
Micrite
Invertebrates
Intraclasts
8 m
7 m
6 m
5 m
4 m
3 m
2 m
1 m
0 m
R
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B
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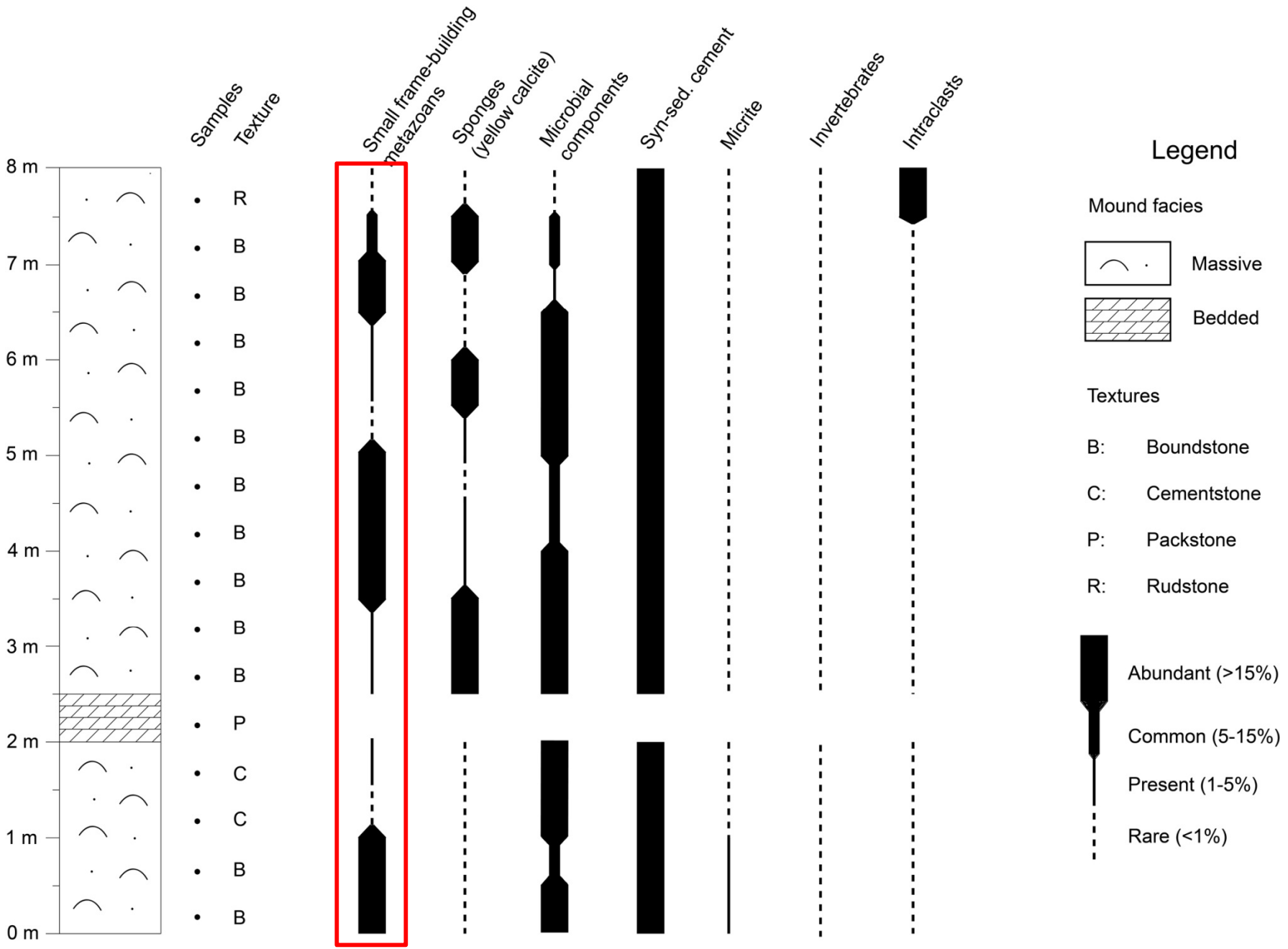
P
C
C
B
B
Legend
Mound facies
Massive
Bedded
Textures
B: Boundstone
C: Cementstone
P: Packstone
R: Rudstone
Abundant (>15%)
Common (5-15%)
Present (1-5%)
Rare (<1%)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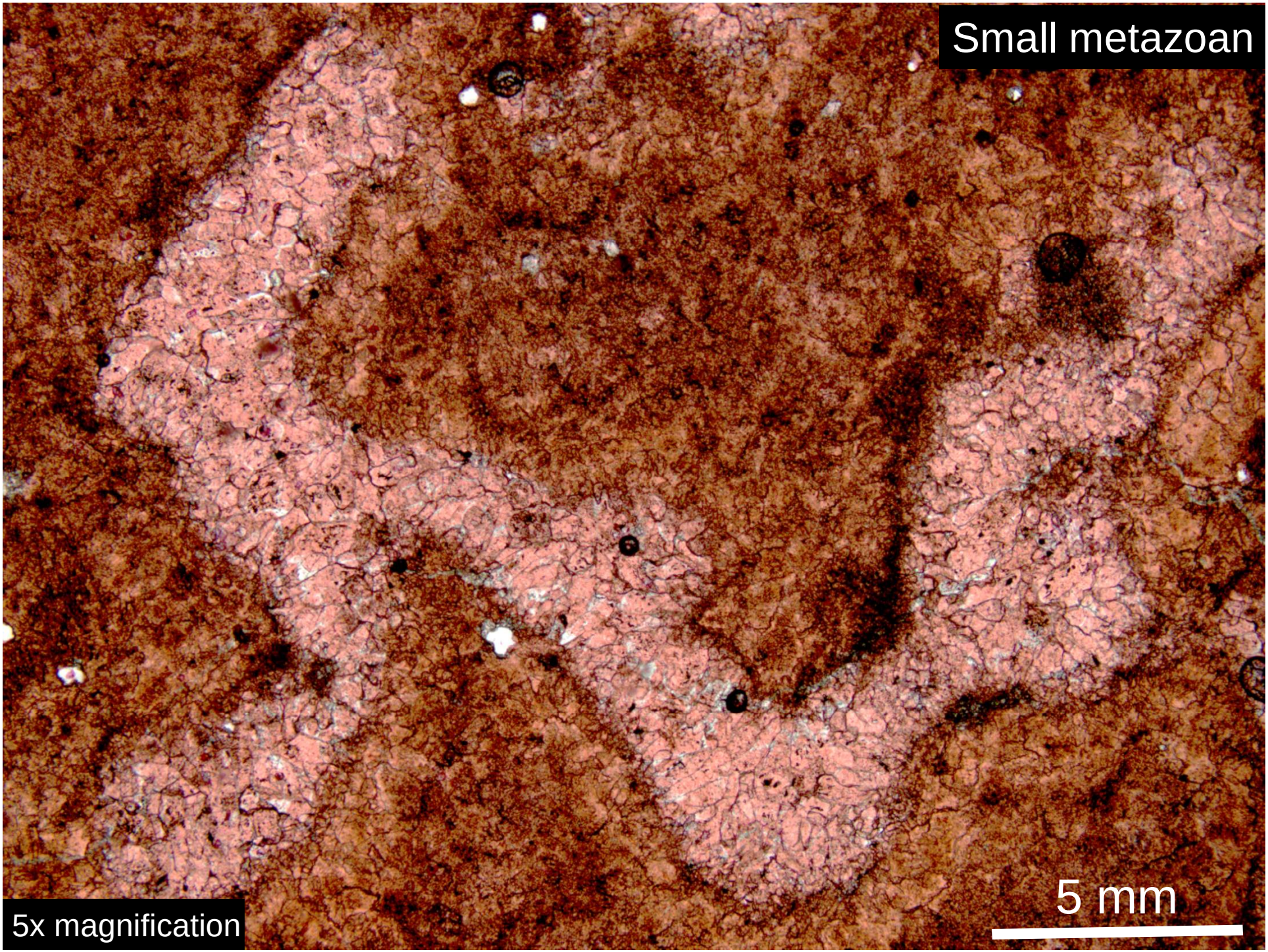
Small metazoan
5 mm
5x magnification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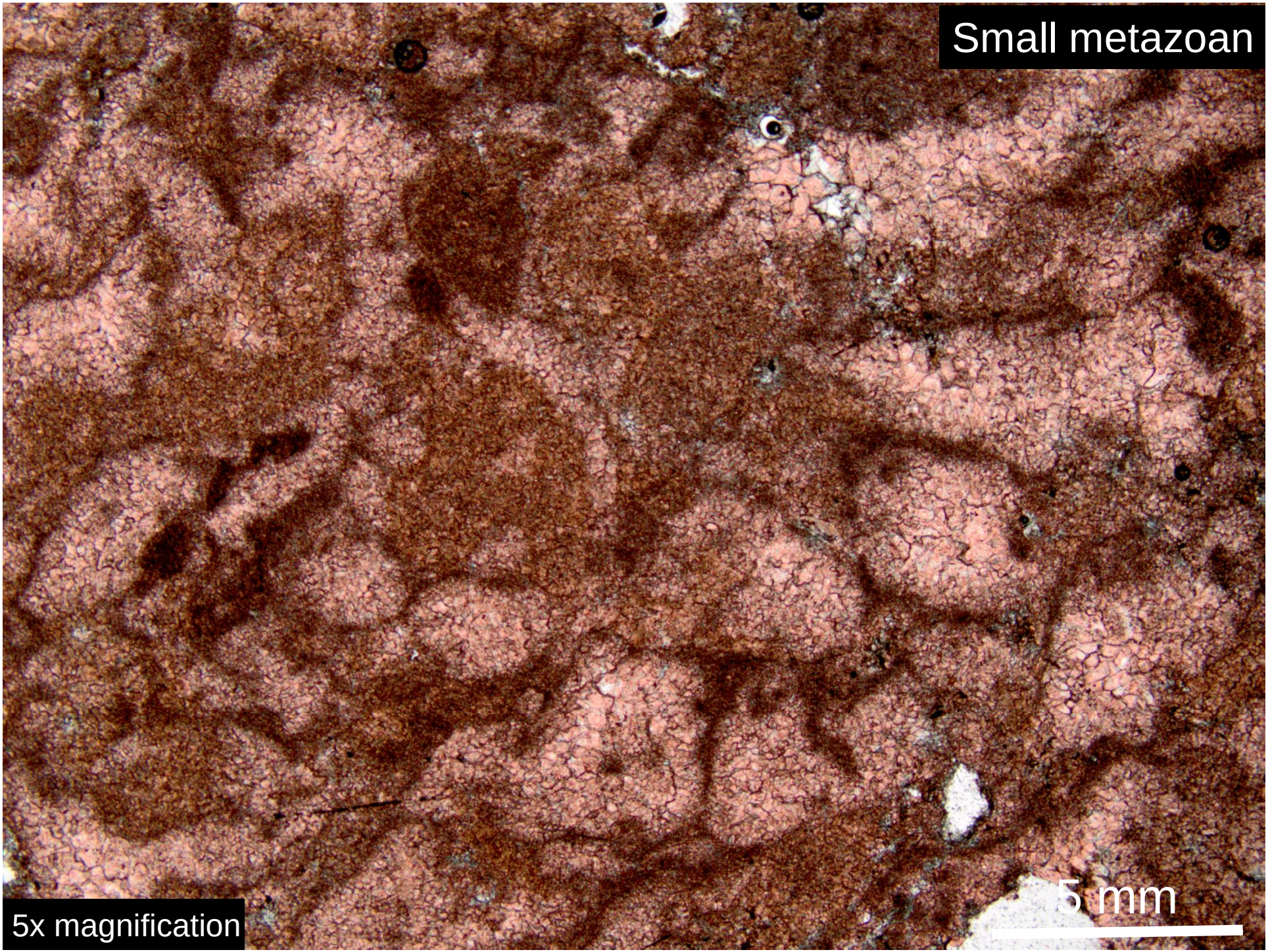
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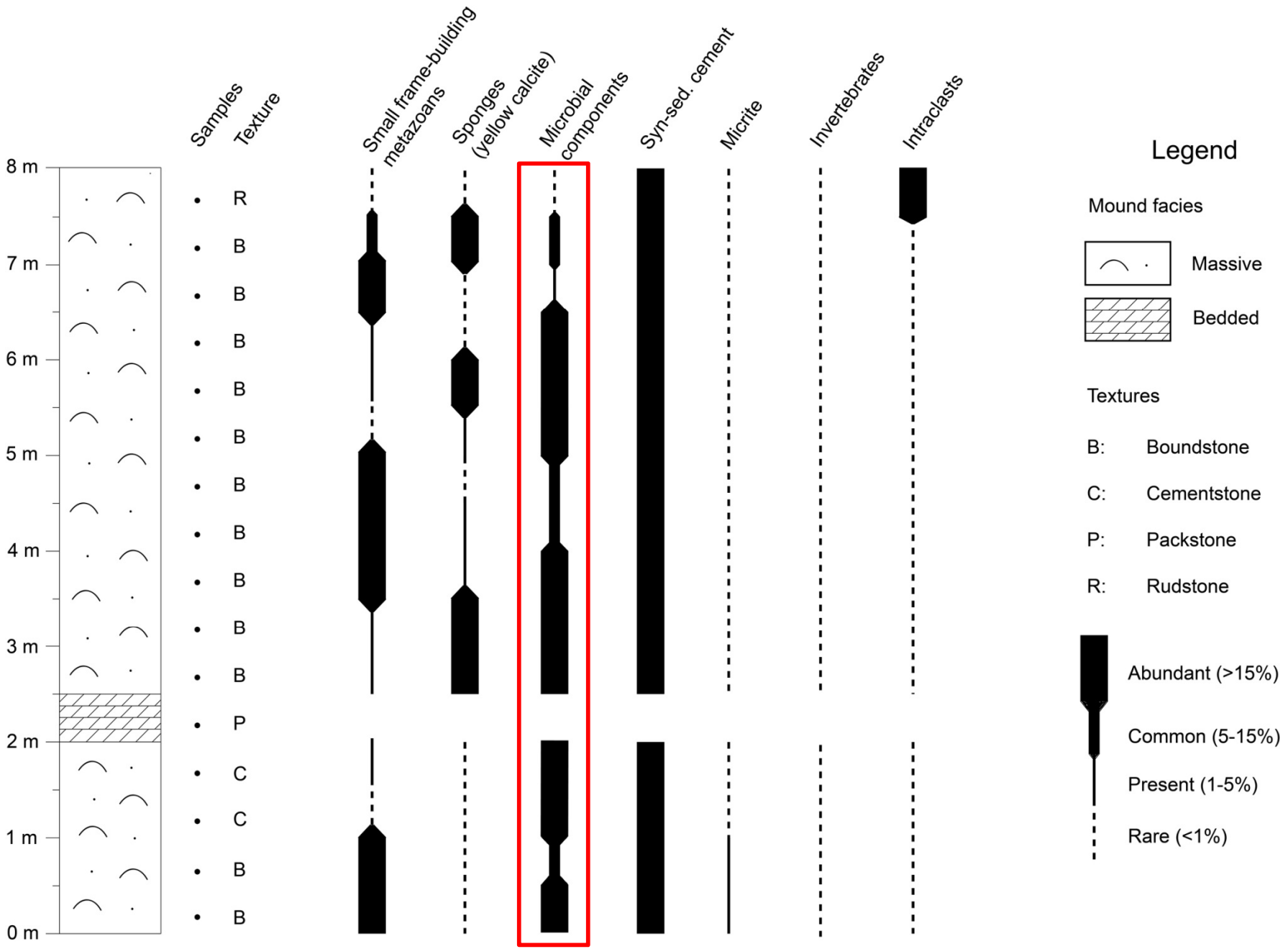
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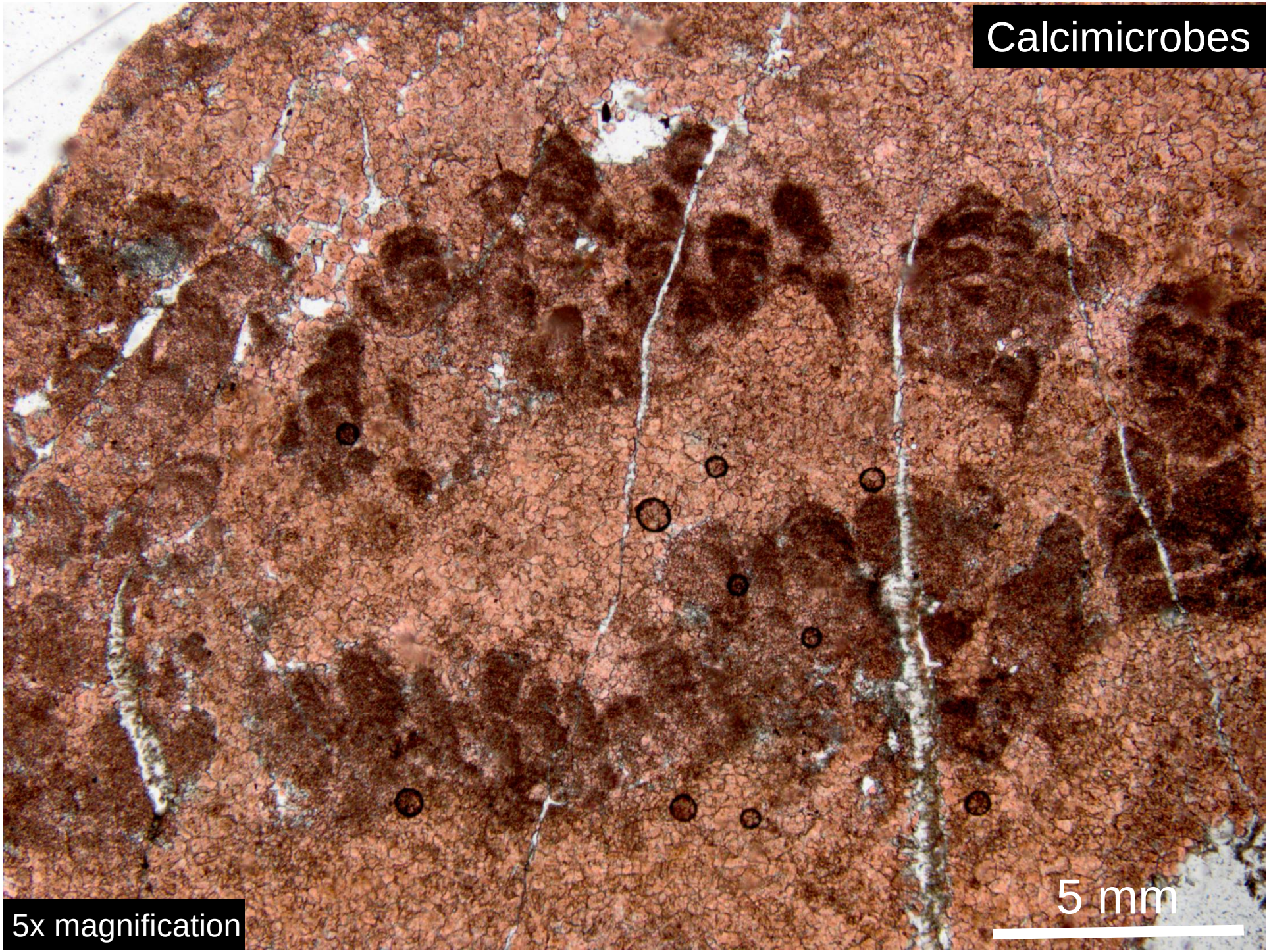
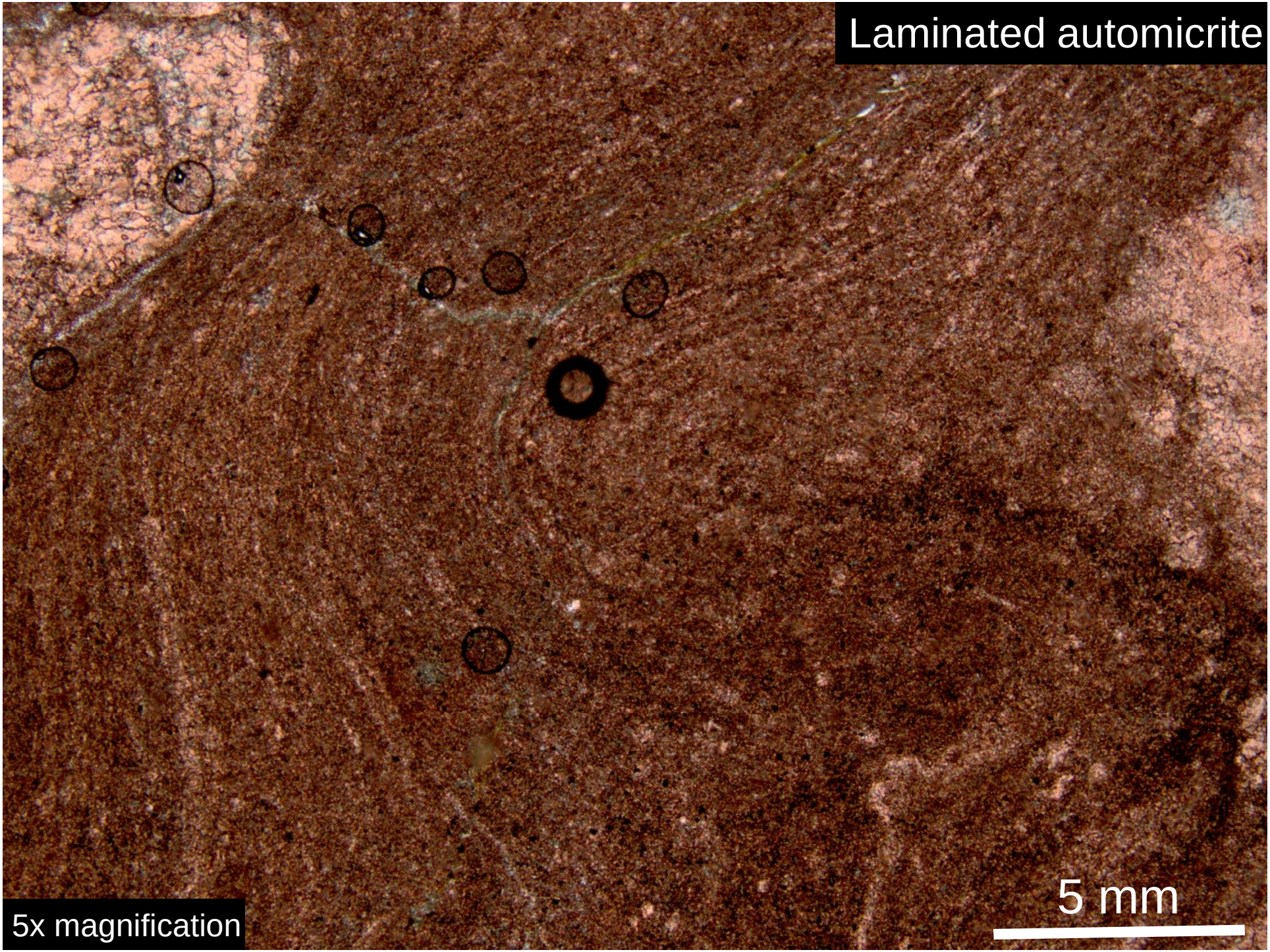
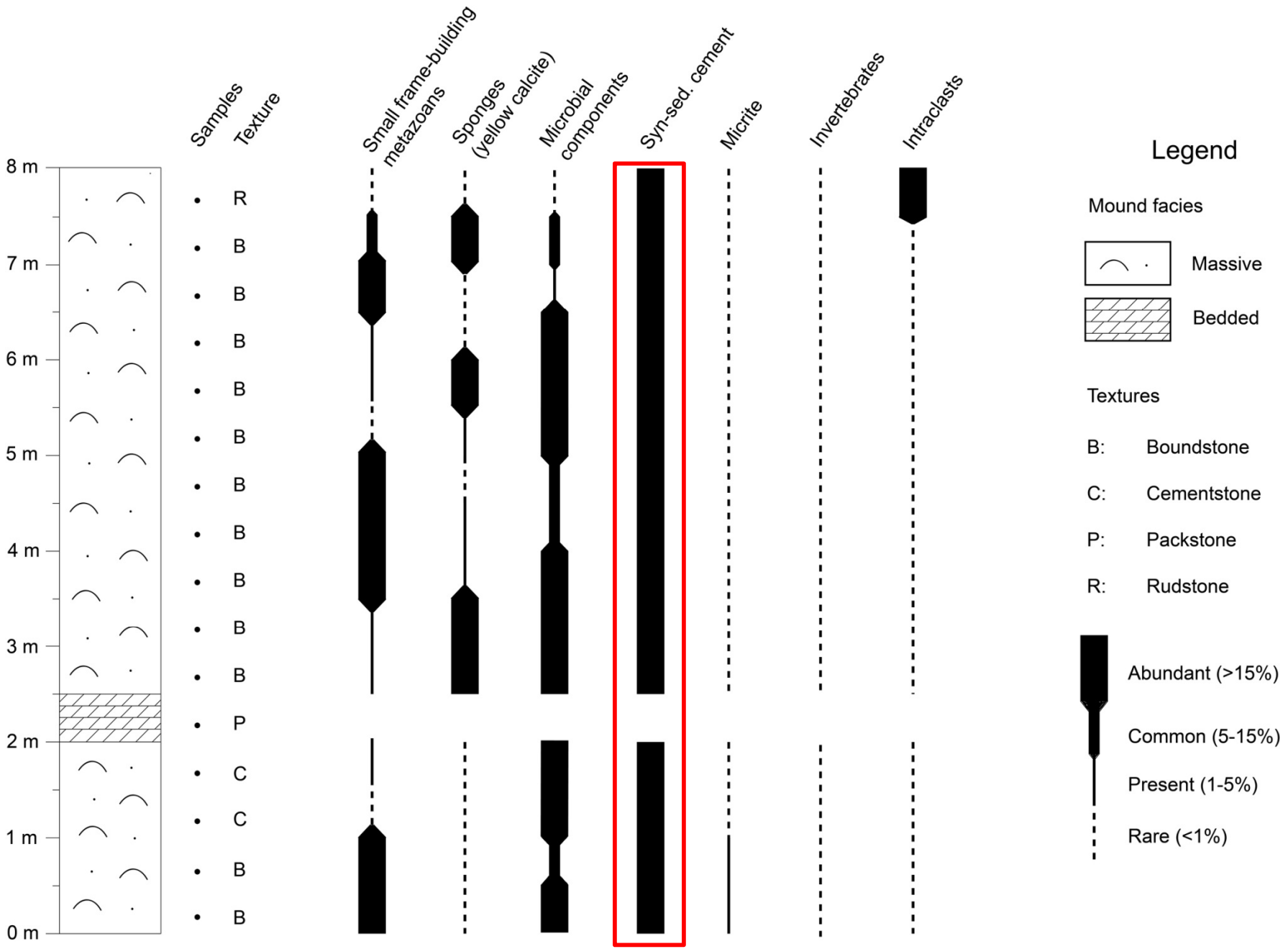

Calcimicrobes
5 mm
5x magnification


Laminated automicrite
5 mm
5x magnification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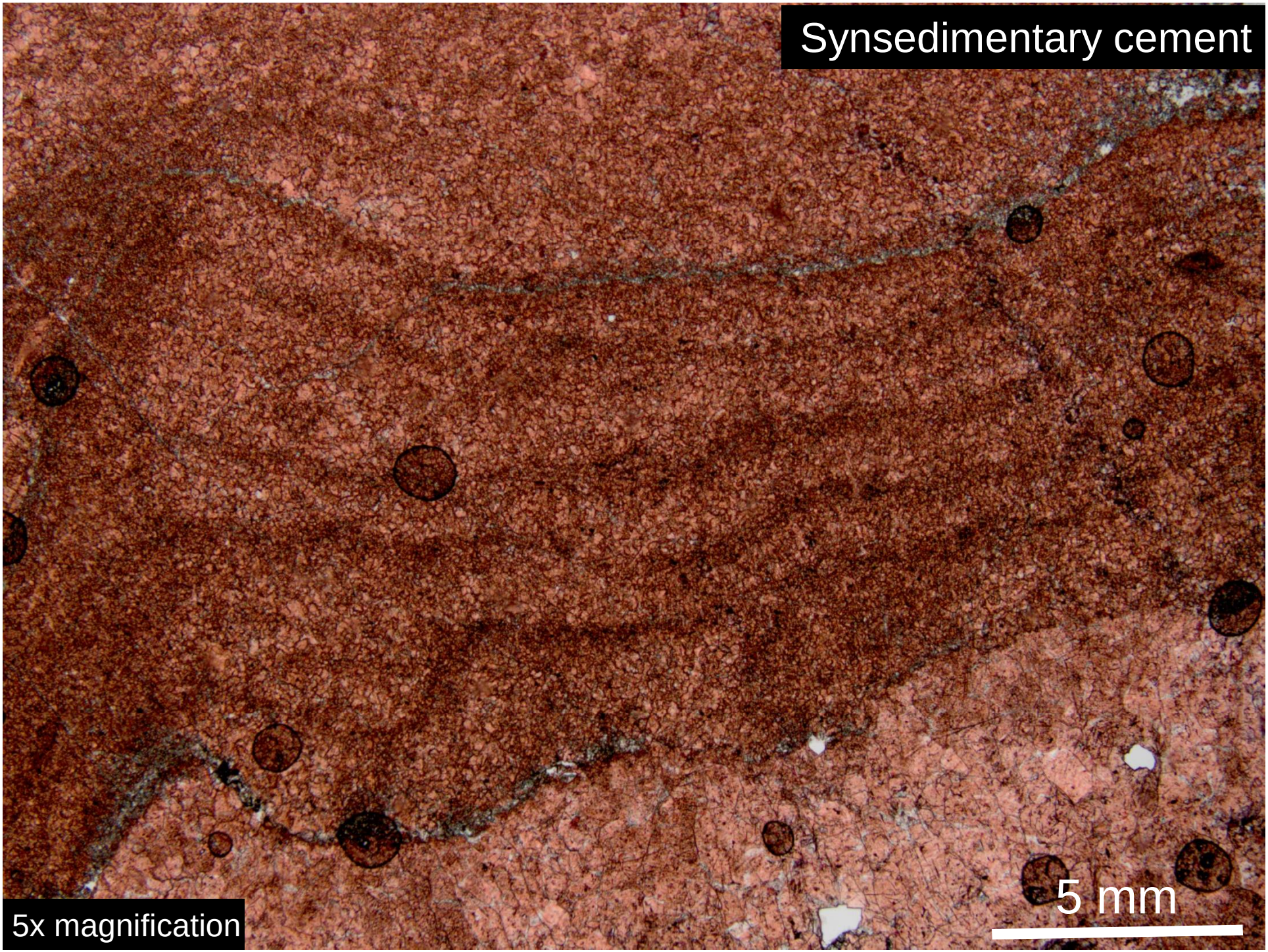
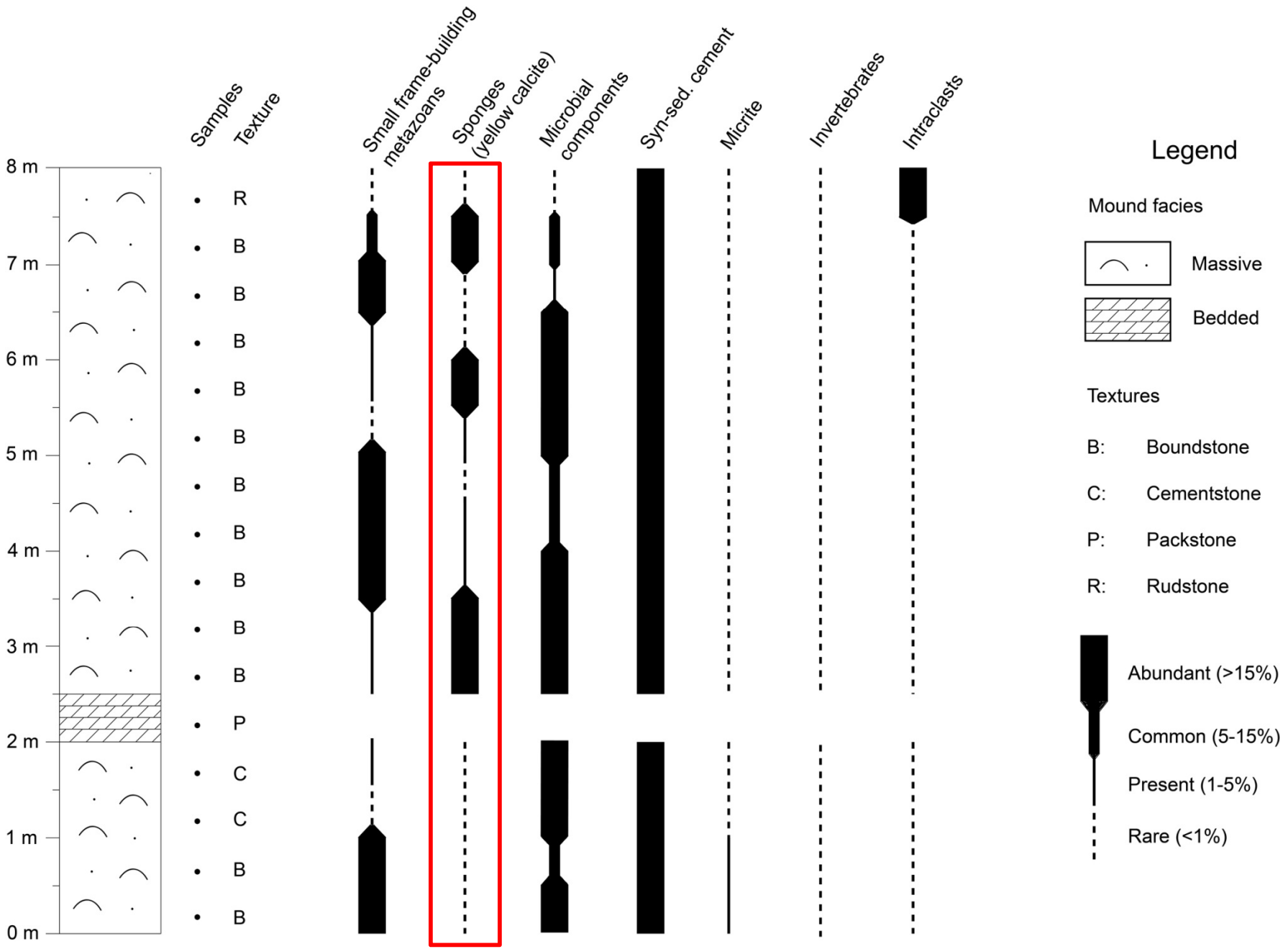

Synsedimentary cement
5 mm
5x magnification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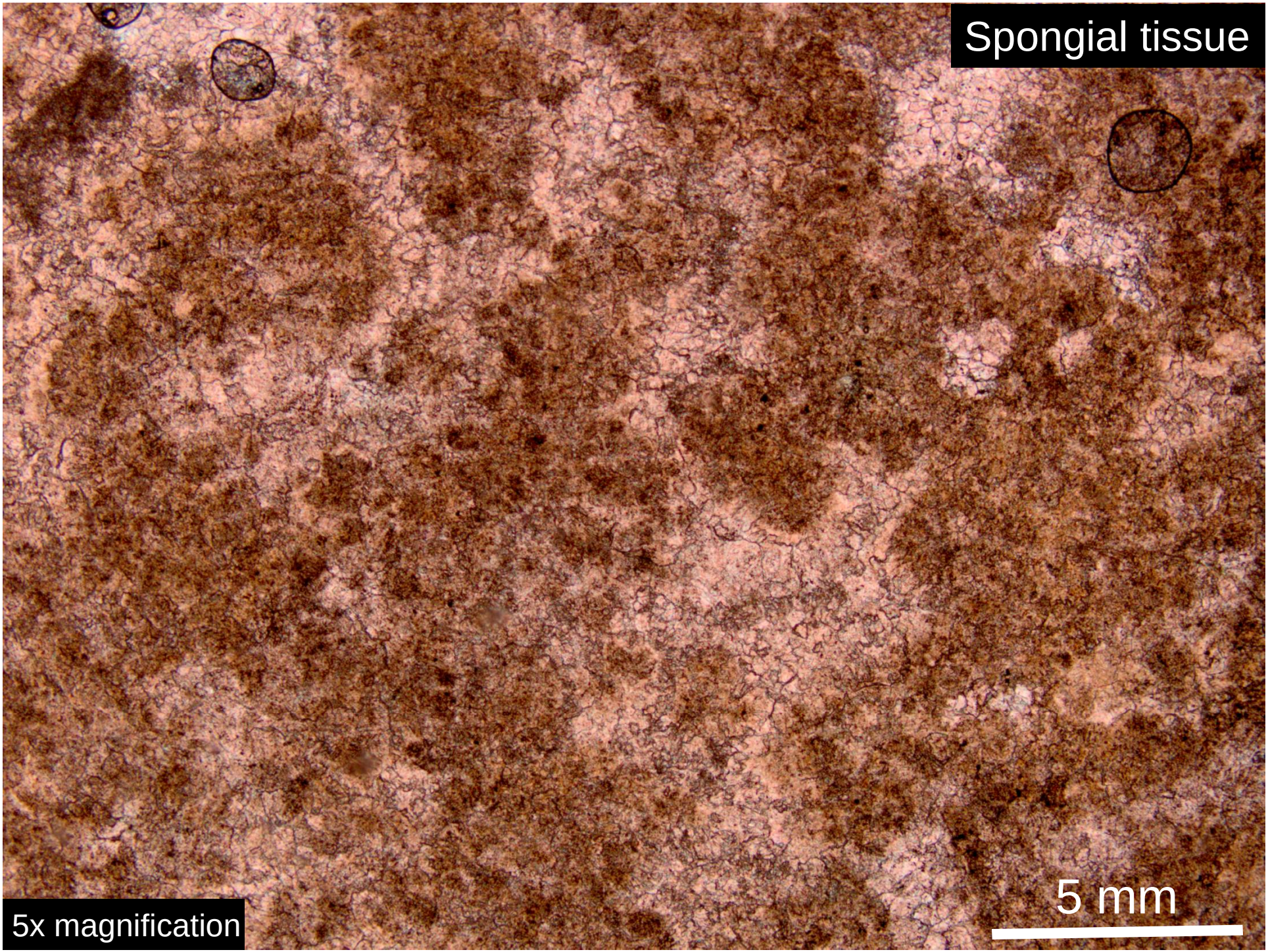
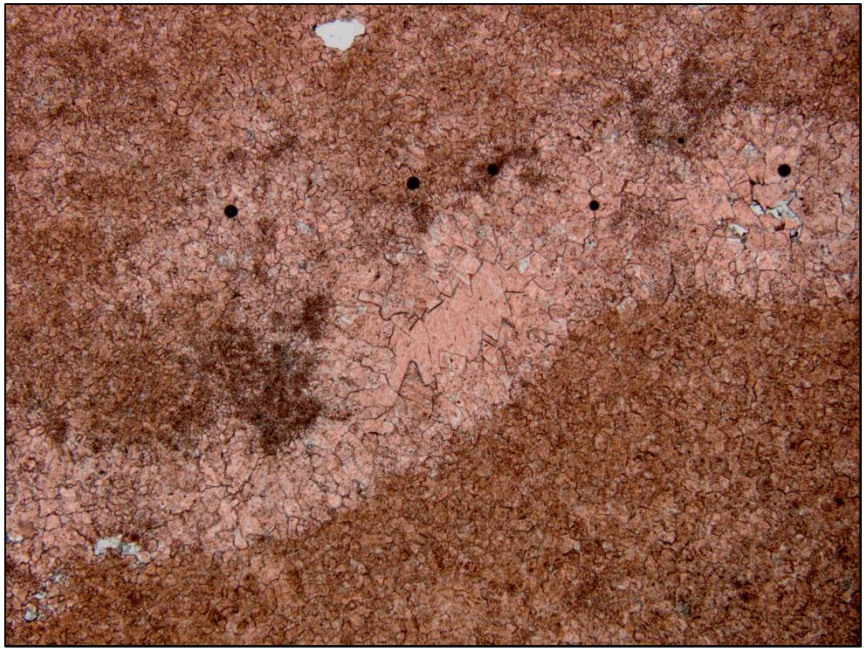

Spongial tissue
5 mm
5x magnification

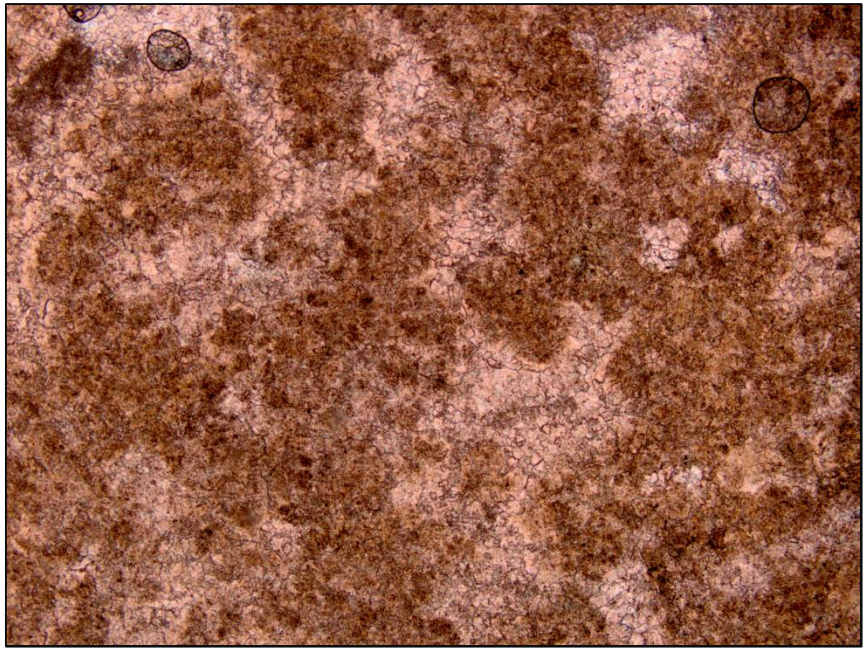
Facies

Two main facies:

Cementstones

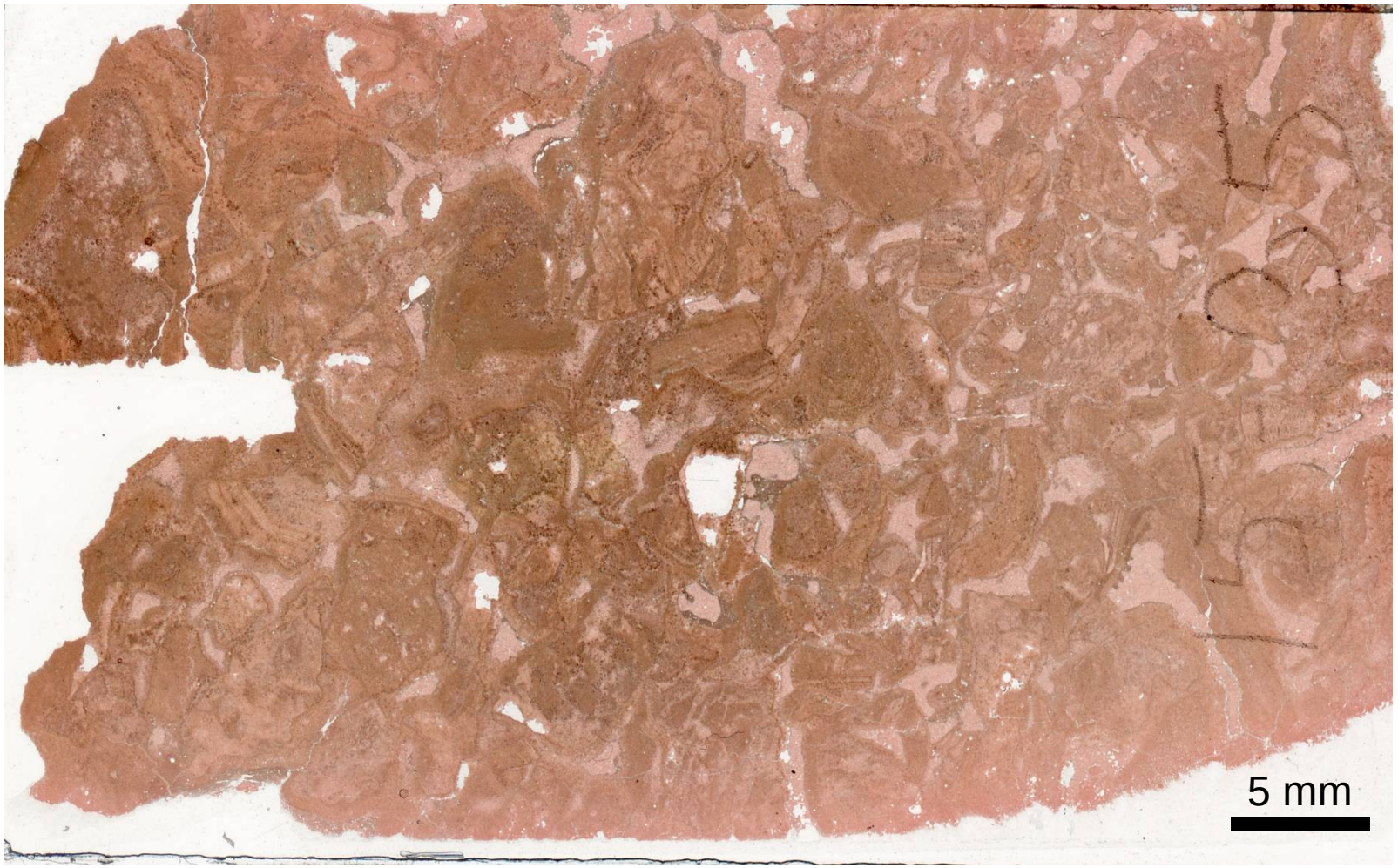


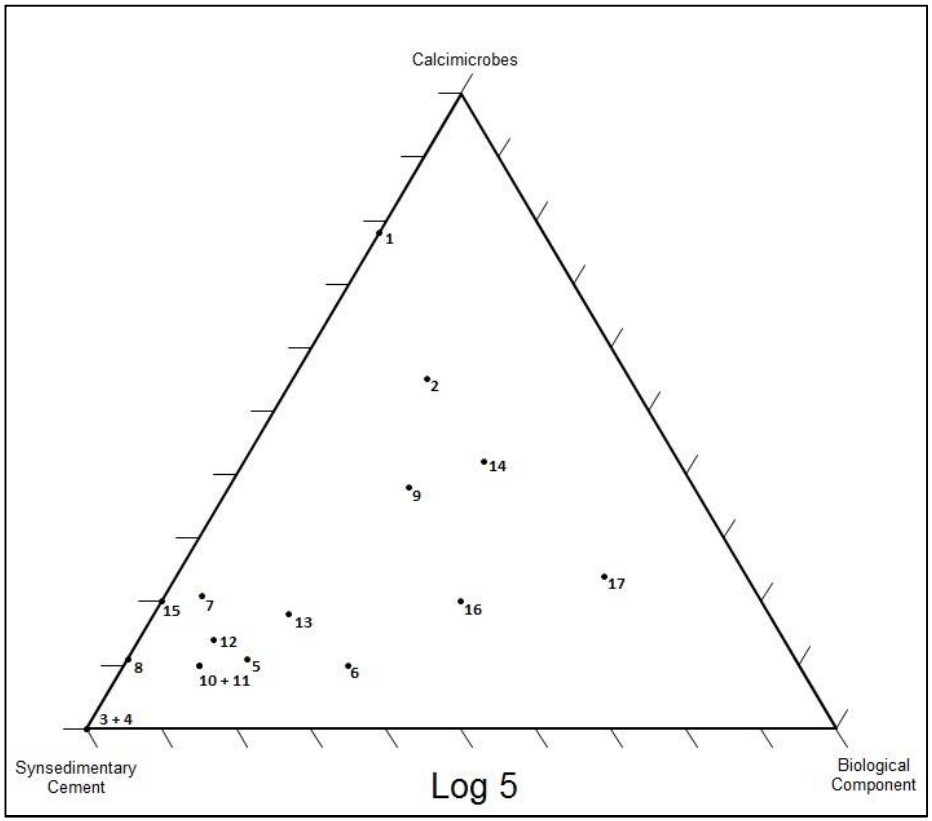
Boundstones

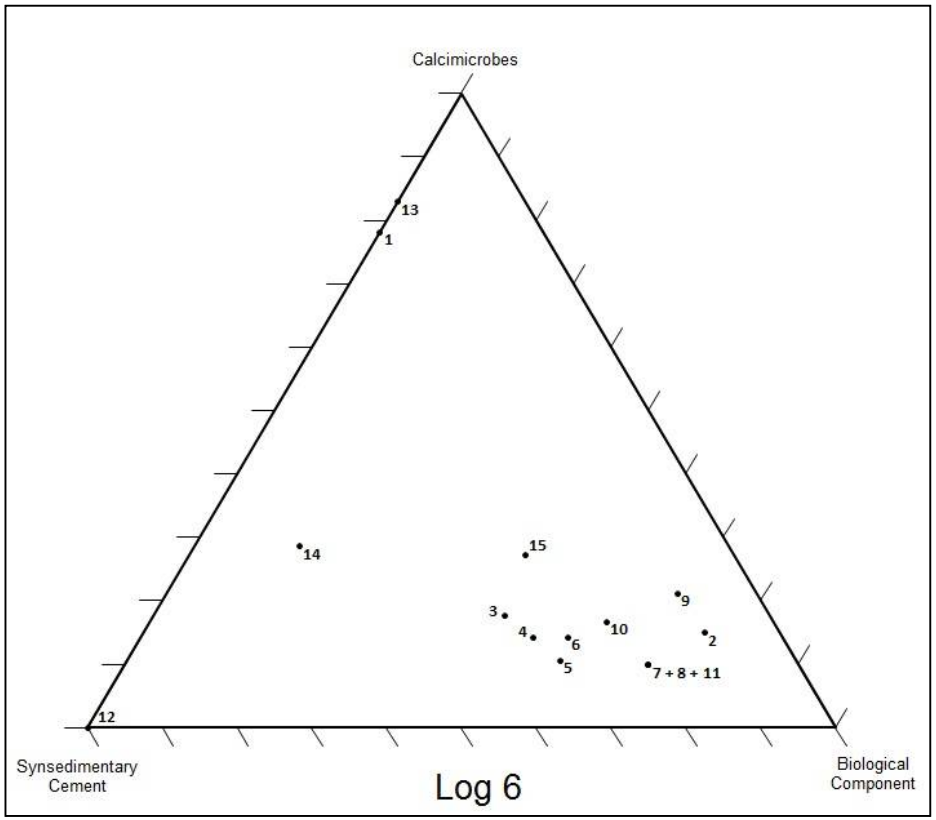


Facies

Synsedimentary cement rudstone

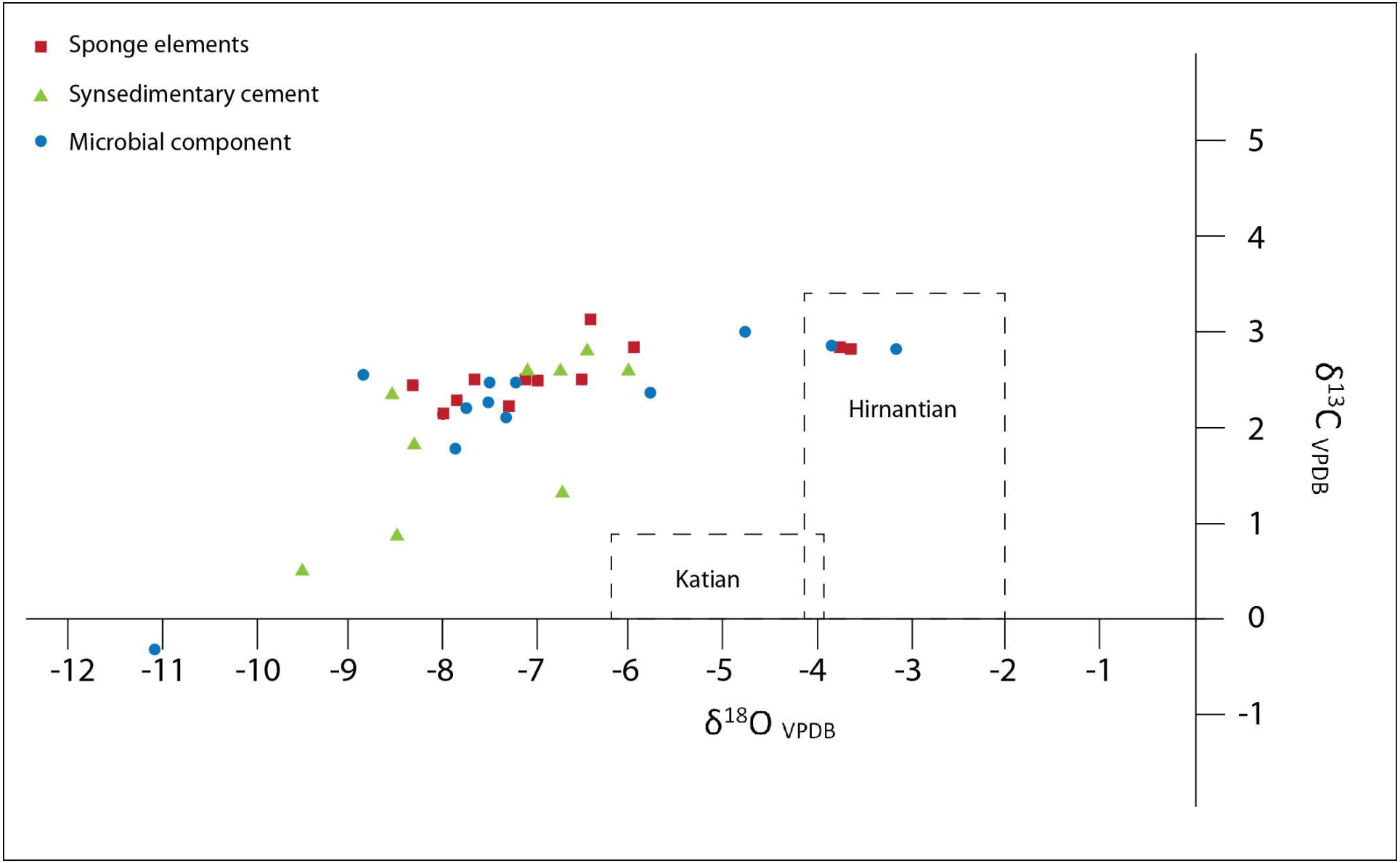



Calcimicrobes
1
2
14
9
17
15
7
16
13
12
8
5
10 + 11
6
3 + 4
Synsedimentary Cement
Biological Component
Log 5


Calcimicrobes
13
1
14
15
9
3
10
4
6
2
5
7 + 8 + 11
12
Synsedimentary Cement
Biological Component
Log 6

Red Head Rapids Formation

- Unusual characteristics:
  - Lack of many typical Ordovician reef fauna
  - Lack of depositional mud
  - Abundance of sponges and calcimicrobes as the main reef builders
  - Abundance of synsedimentary cement
- This sequence may have been deposited in a shallow water environment and isolated from the open ocean
- Increased water salinity was likely lethal to most marine biota


Sponge elements
Synsedimentary cement
Microbial component
Hirnantian
Katian
-12
-11
-10
-9
-8
-7
-6
-5
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-3
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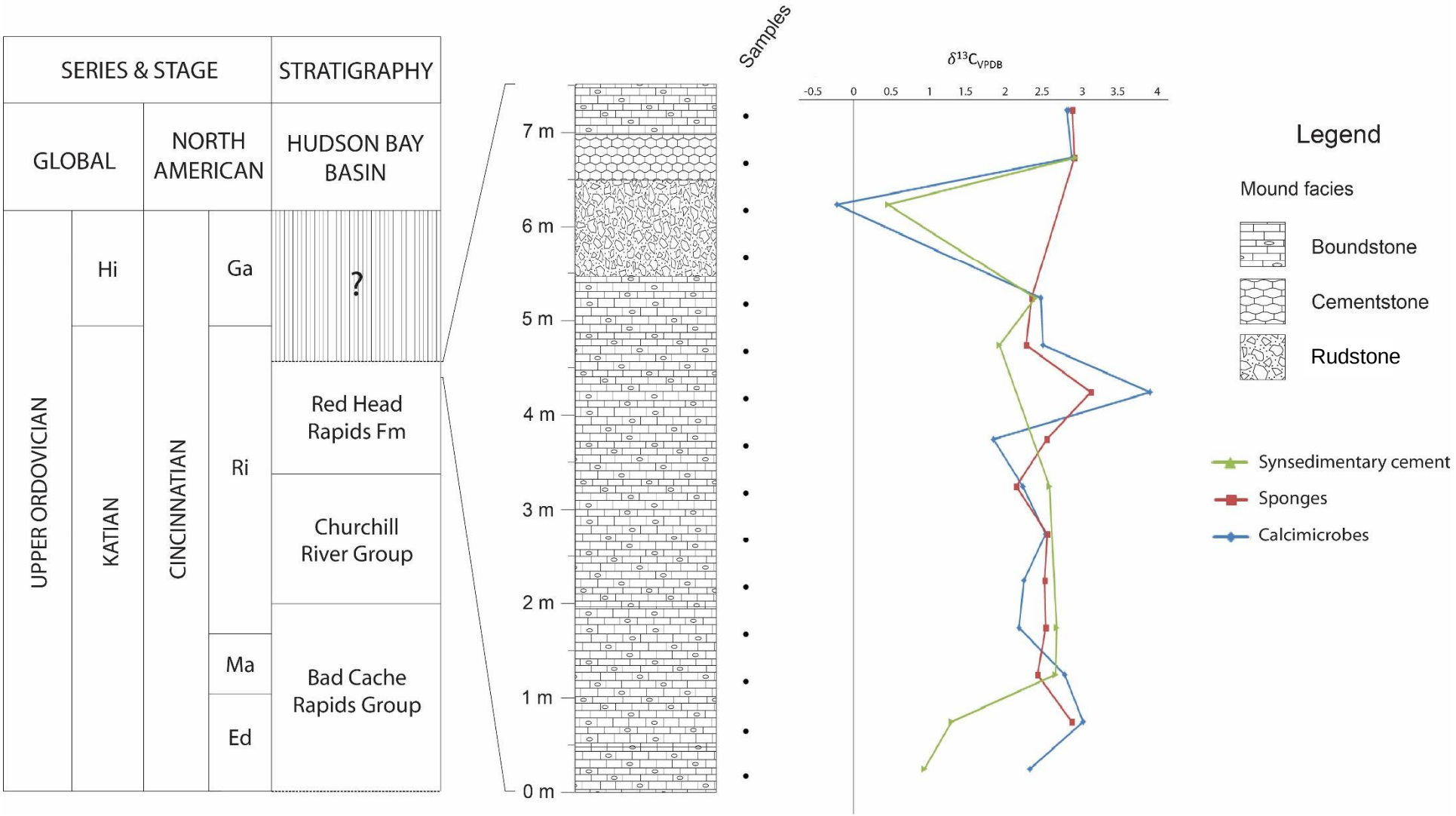
δ13C VPDB


SERIES & STAGE
STRATIGRAPHY
GLOBAL
NORTH AMERICAN
HUDSON BAY BASIN
UPPER ORDOVICIAN
Hi
KATIAN
CINCINNATIAN
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Ri
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?
Red Head Rapids Fm
Churchill River Group
Bad Cache Rapids Group
Samples
7 m
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δ13CVPDB
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3
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4
Legend
Mound facies
Boundstone
Cementstone
Rudstone
Synsedimentary cement
Sponges
Calcimicrobes

Conclusions

1. The Upper Ordovician reef in the RHR Formation mainly displays boundstone and cementstone microfacies with abundant calcified sponge material, calcimicrobes and synsedimentary cement.

2. The accretionary mechanisms of the RHR Formation were the result of frame building and binding by early calcified sopnges and microbial elements (boundstones) and marine cement precipitation near the seafloor (cementstones).

3. This buildup developed on the margin of a shallow-marine epicratonic basin with physical and chemical seawater parameters were distinct from the open ocean. As a result, a diverse community of reef-building metazoans was unable to grow.


Thank you!