Pore Type Characterization, Petrophysical Properties, and Diagenesis of Jurassic Thrombolite Reservoirs*

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Abstract

The geometry of pore space in reservoirs depends on its genesis. When the reservoir corresponds to sedimentary rocks, the pore system characteristics start with depositional fabric, and evolve through subsequent diagenetic alteration of the rock. In sedimentary carbonate rocks the pore system can be very complex because of the great diversity of possible depositional rock fabrics (carbonates can be clastic, chemical or biogenic in origin), and their great susceptibility to diagenetic alteration due to mineralogy. Carbonate minerals can undergo rapid dissolution, cementation, recrystallization, and replacement at ambient conditions in a variety of diagenetic environments.

Thrombolite reservoirs are biogenic in origin, and their depositional porosity has a weak relationship with grain size, but it is strongly related to the arrangement of the grains (mainly peloids clusters) and early cementation, what creates distinct microtextures and pore geometries. Subsequent diagenesis causes modifications in the pore system. Dolomitization, calcite cementation and dissolution are the main diagenetic events that changed petrophysical properties in the Jurassic Smackover Formation reservoirs in the southwestern Alabama area.

The main pore types in the Smackover Formation thrombolites are vuggy, intercrystalline, and more rarely intergranular. The vuggy pore type is the most common pore type, and it can be depositional (constructed voids), formed by the arrangement of the peloids in clusters, or it can be diagenetic, resulting from dissolution processes. The intercrystalline pore type occurs because of non fabric-selective dolomitization, associated with calcite dissolution processes. The intergranular pore type occurs where peloids are not arranged as typical clusters, and the grains have uniform distribution. The intergranular pore type occurs mainly in the top of the thrombolite bioherms. This microtexture can be considered a response to the sea level rise during deposition, when the microbial activity weakened due to the greater water depth.

All the Smackover Formation thrombolite reservoirs discovered so far are intensely dolomitized, except at Little Cedar Creek Field, where most of the depositional features of the thrombolite are preserved. Samples from Little Cedar Creek, Appleton and Vocation fields were analyzed and compared. Porosity, permeability and capillary pressure analysis was completed on thrombolite samples with no dolomitization

and samples with distinct degrees of dolomitization. The dolomitization, associated with dissolution of calcite, created an intercrystalline pore network in the thrombolite, increasing porosity and pore connectivity (permeability), and usually reducing pore size. These processes also caused the high petrophysical heterogeneity of the thrombolite to decrease laterally and vertically, resulting in a more homogeneous pore system.

References Cited

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Mancini, E.A., W.C. Parcell, W.M. Ahr, V.O. Ramierz, J.C. Llinas, and M. Cameron, 2008, Upper Jurassic updip stratigraphic trap and associated Smackover microbial and nearshore carbonate facies, eastern Gulf coastal plain: AAPG Bulletin, v. 92/4, p. 417-442.

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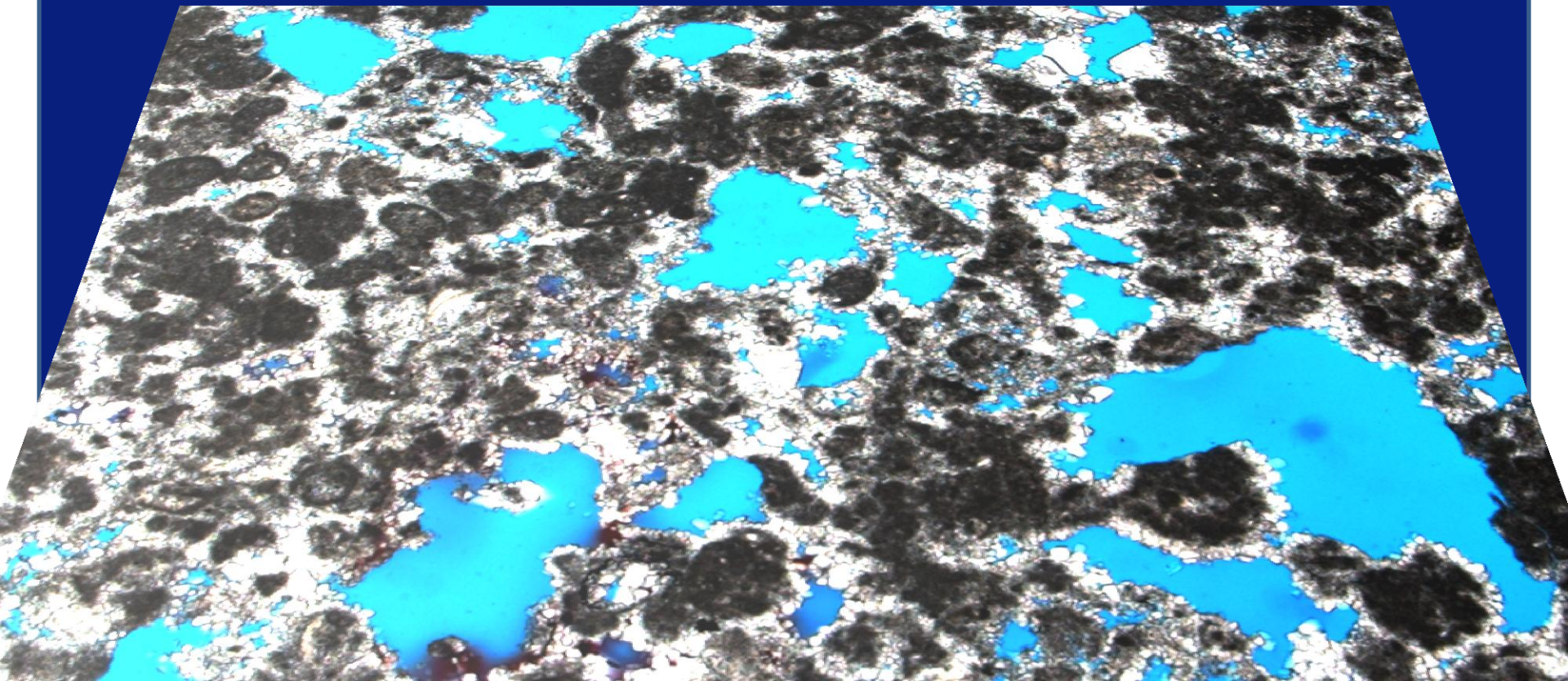
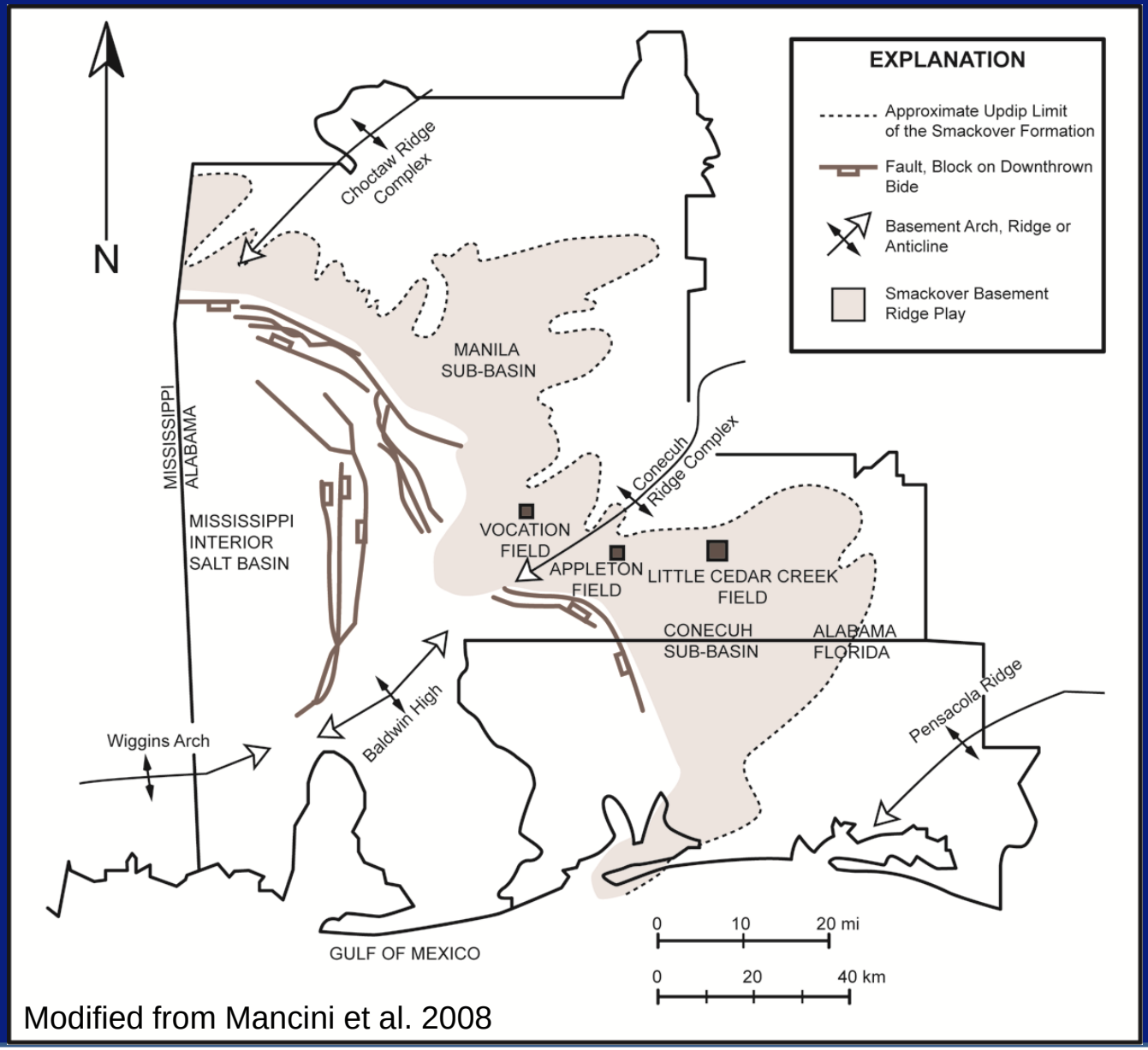
Michael C. Pope



Key points

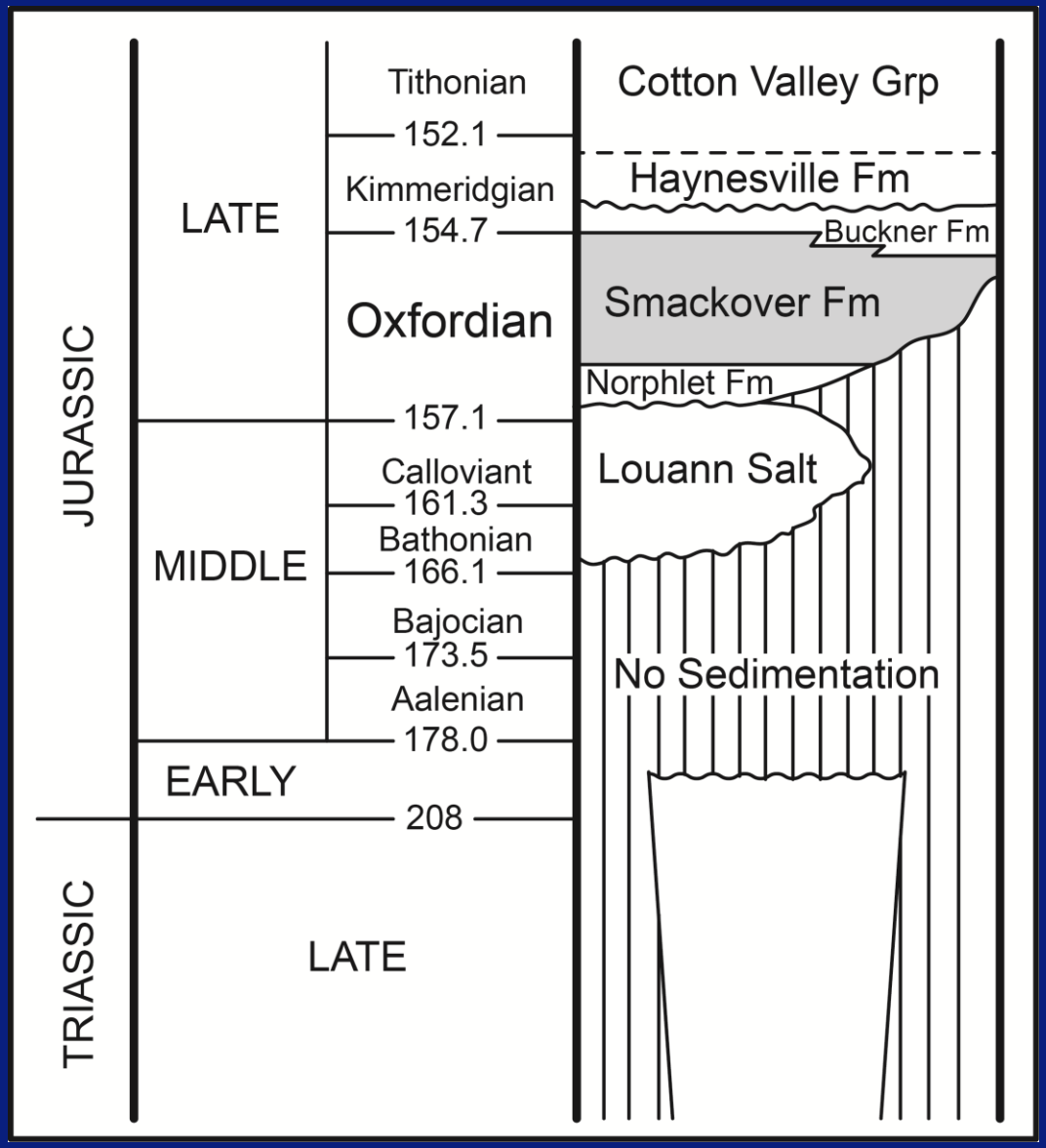
- Upper Jurassic Smackover Formation microbial thrombolite building blocks are mainly peloids, and some ostracods and benthic foraminifera.
- The arrangement / density of the peloids and very early diagenetic marine calcite cement give shape to the initial pore system.
- Late burial diagenetic events caused significant modifications in the pore system.
- Dolomitization process destroys the depositional texture, and improves pore connectivity and reservoir quality.

Geologic Setting



Modified from Mancini et al. 2008

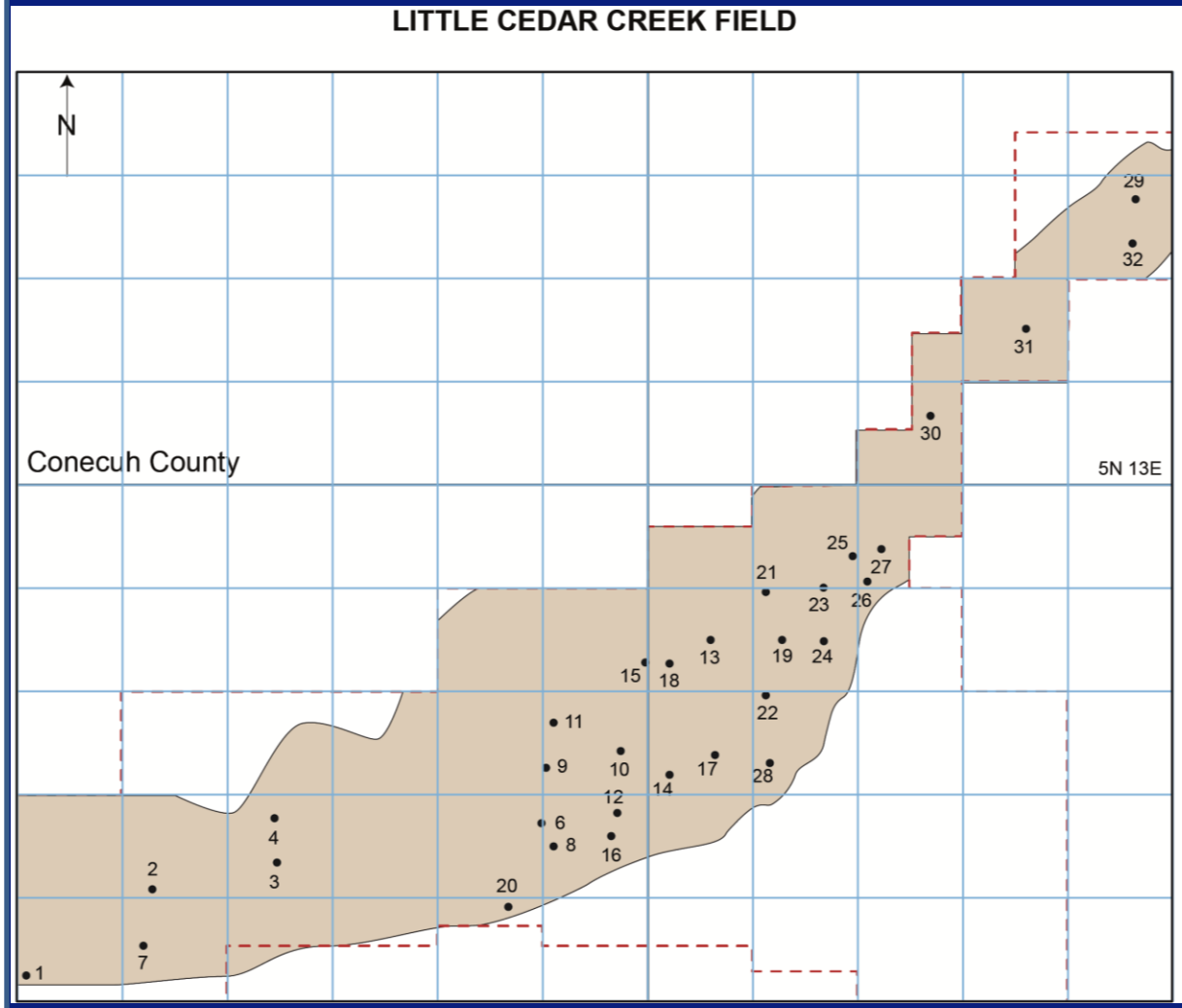
Geologic Setting

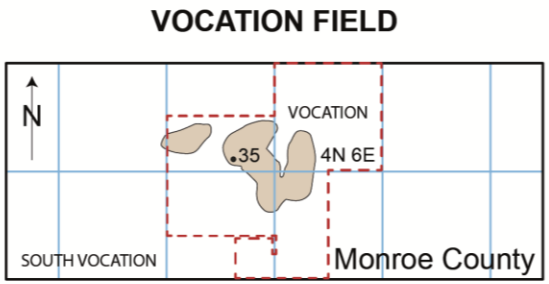


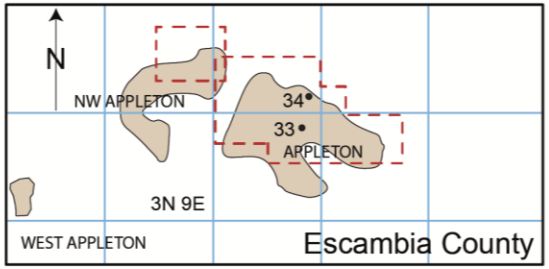
Modified from Heydari and Baria 2006

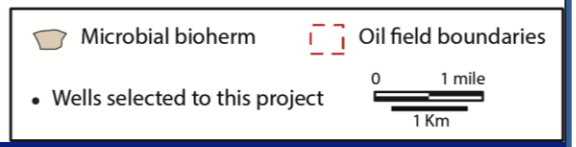
Geologic Setting

Countour maps of microbial thrombolite reservoirs



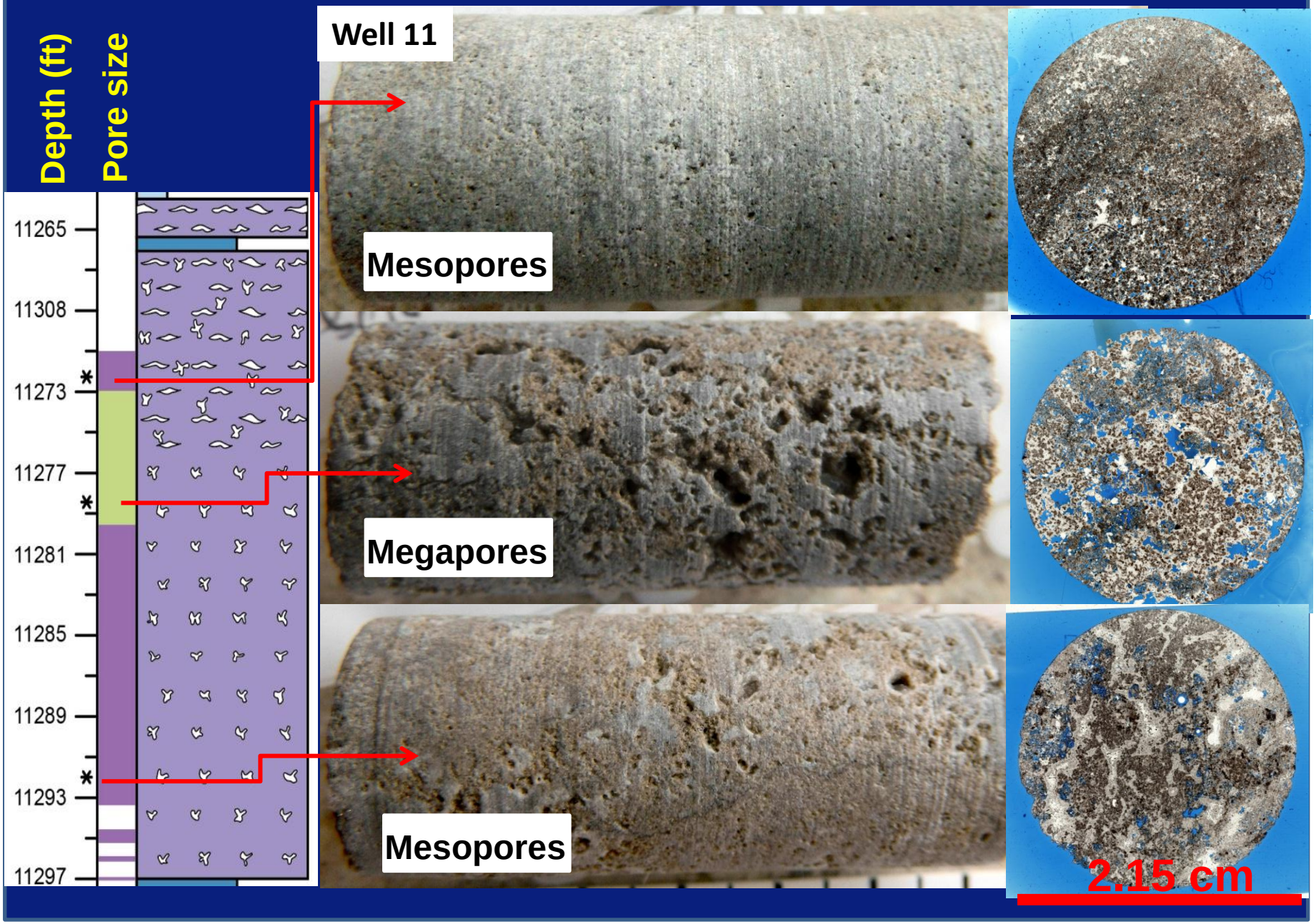




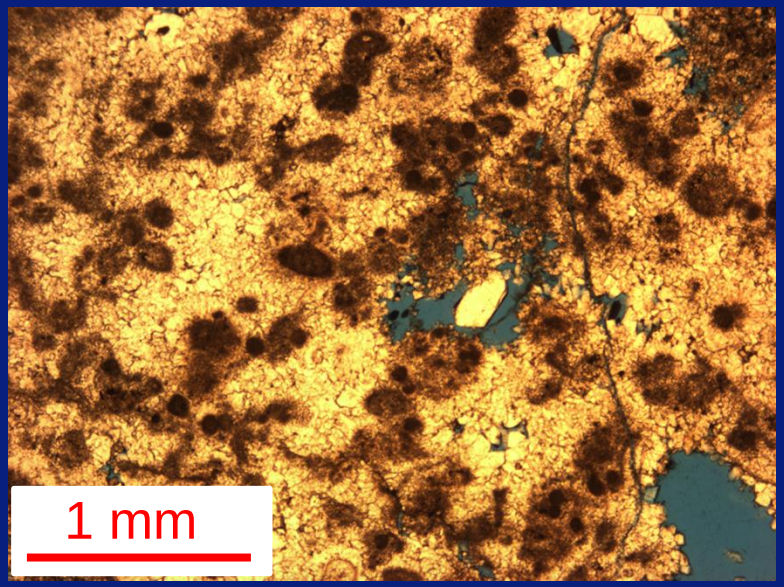


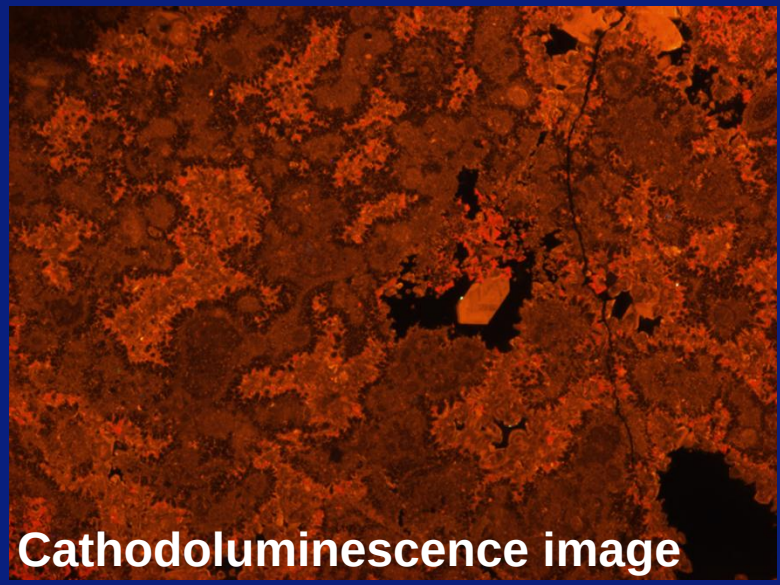
Modified from Tonietto & Pope 2013 and Llinás 2004.

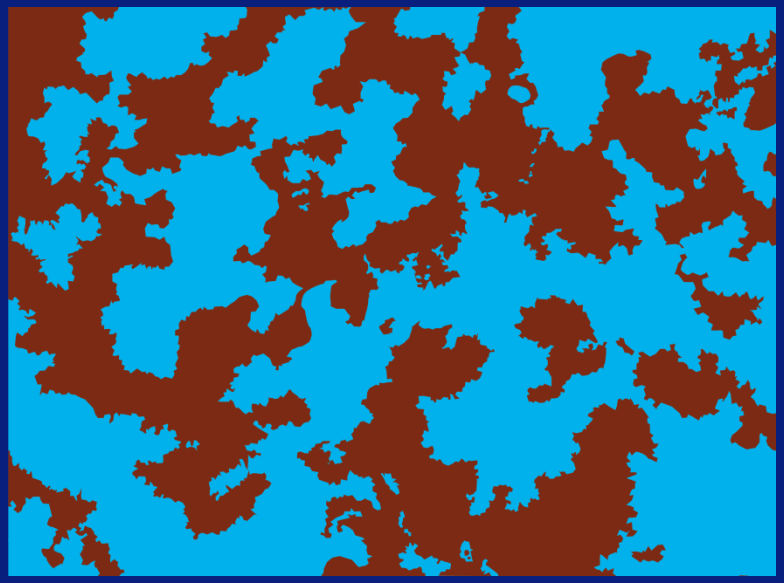
Microbial thrombolite reservoir - Little Cedar Creek Field

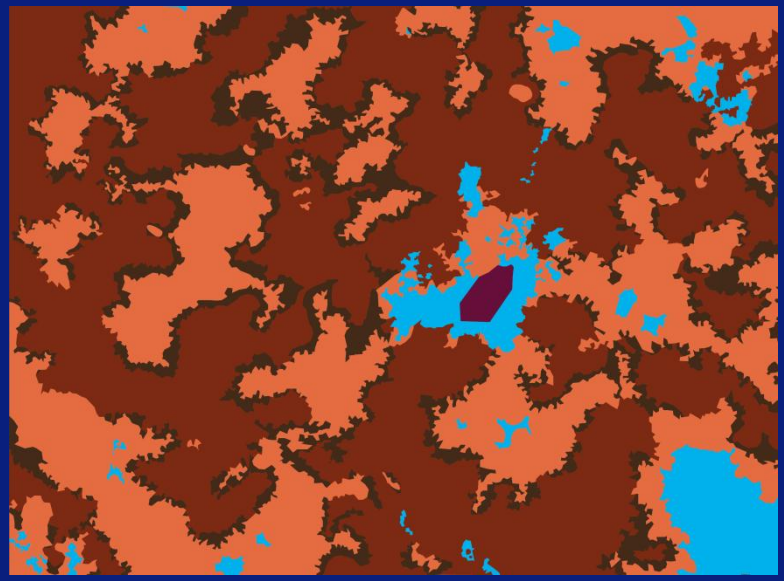


Microbial thrombolite reservoir - Little Cedar Creek Field

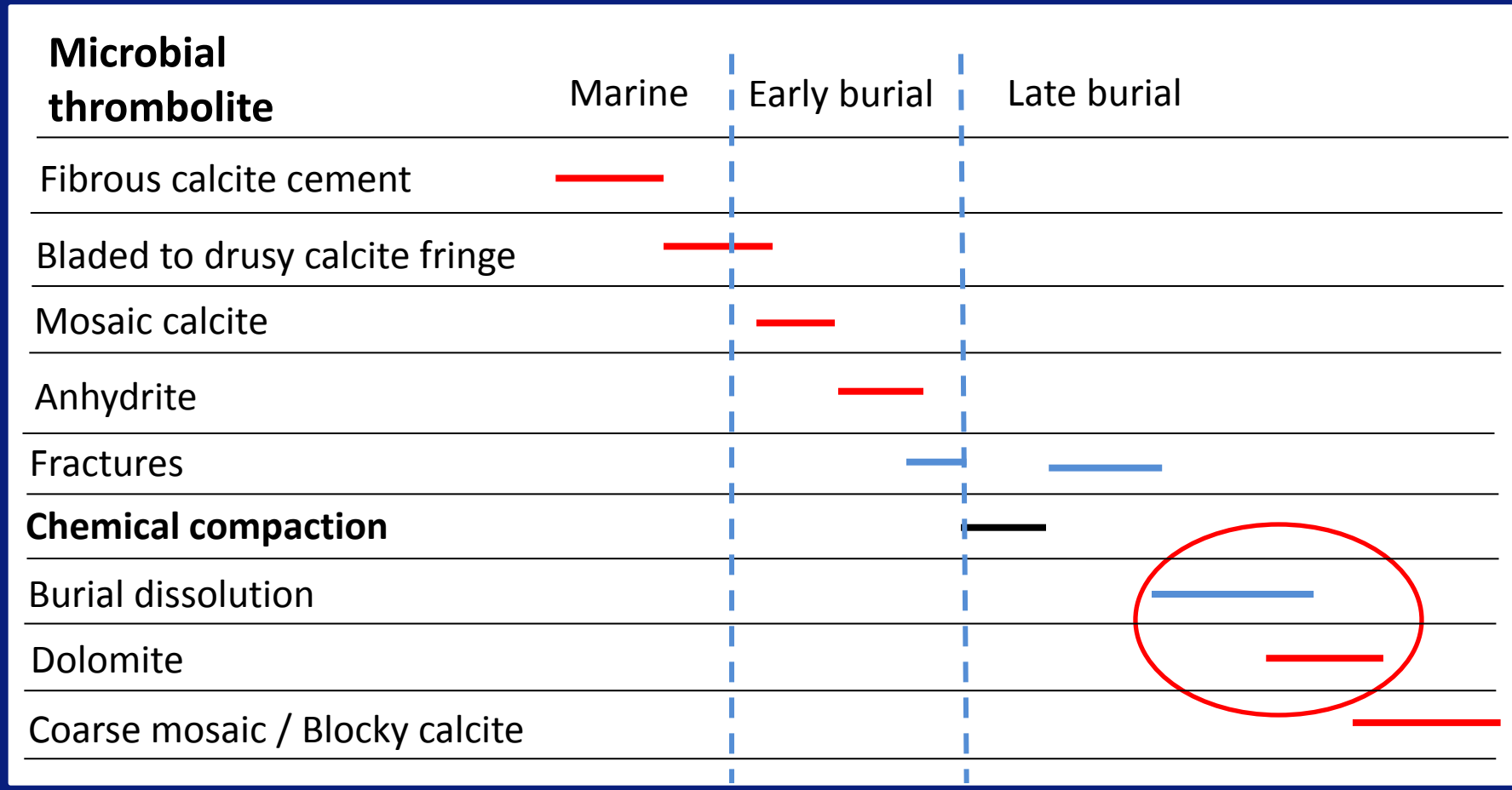


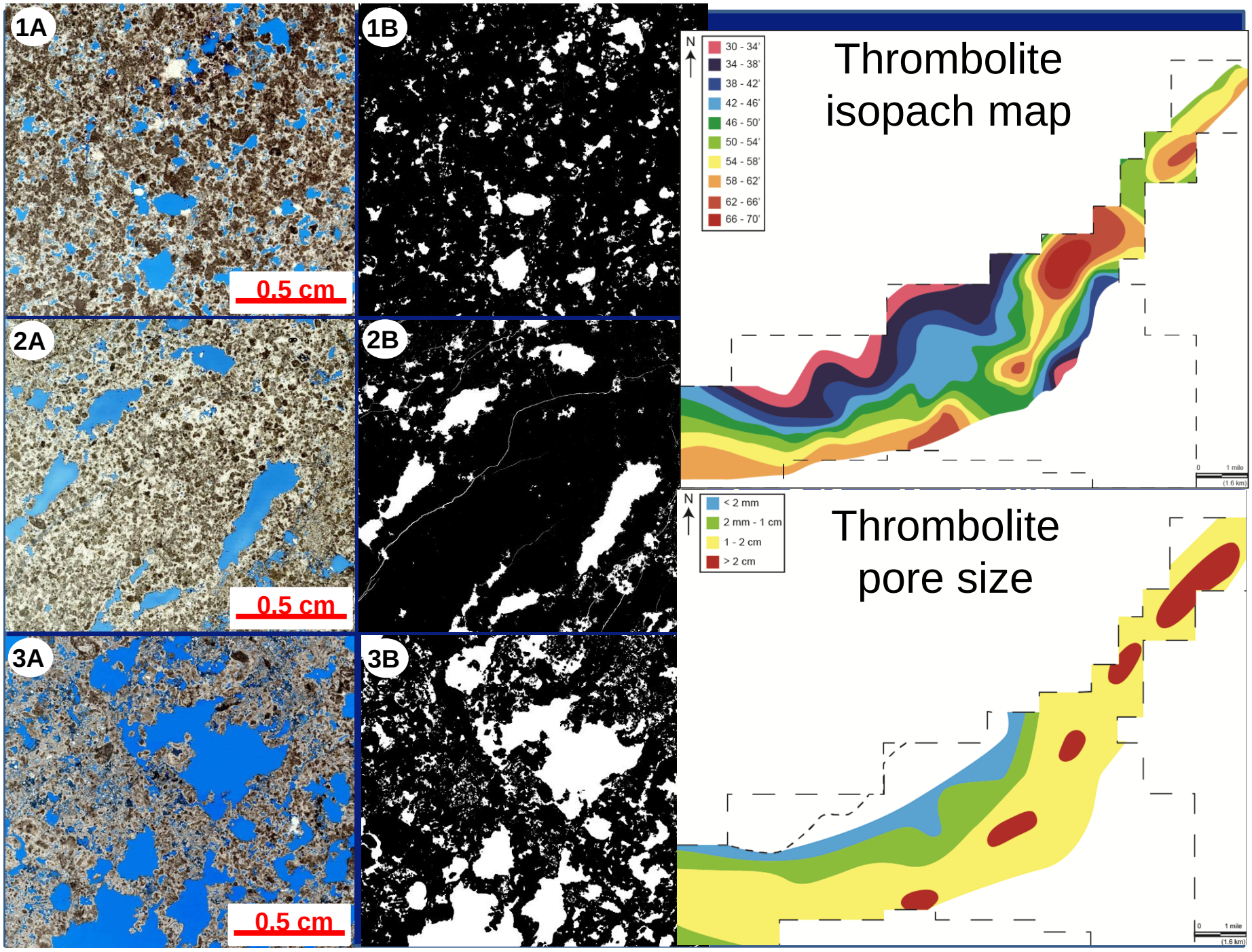






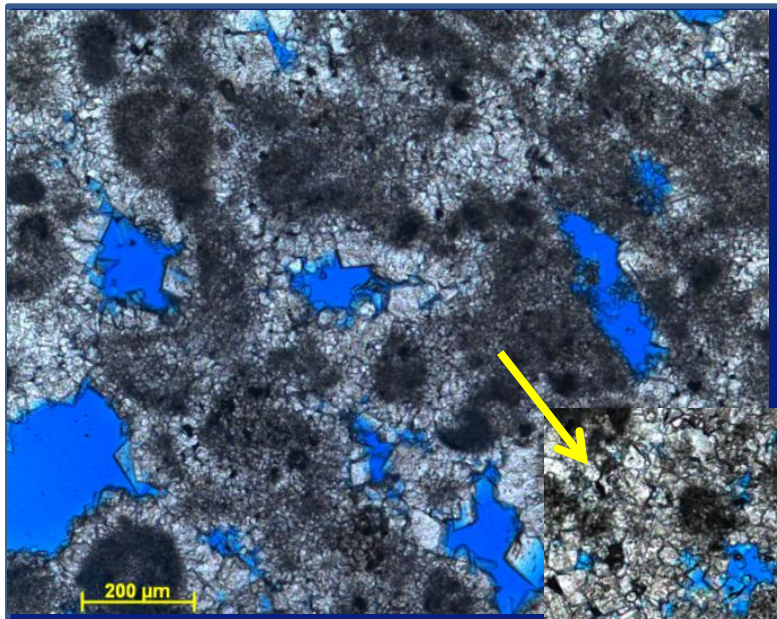
Paragenetic Sequence
Microbial thrombolite reservoir
Little Cedar Creek Field



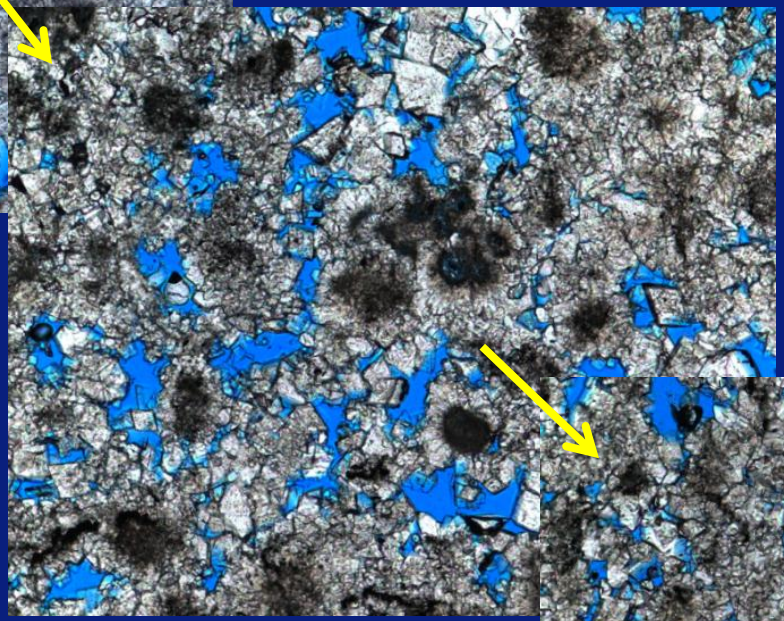

1A
0.5 cm
1B
2A
0.5 cm
2B
3A
0.5 cm
3B
N
30 - 34'
34 - 38'
38 - 42'
42 - 46'
46 - 50'
50 - 54'
54 - 58'
58 - 62'
62 - 66'
66 - 70'
Thrombolite isopach map
0
1 mile
(1.6 km)
N
< 2 mm
2 mm - 1 cm
1 - 2 cm
> 2 cm
Thrombolite pore size
0
1 mile
(1.6 km)

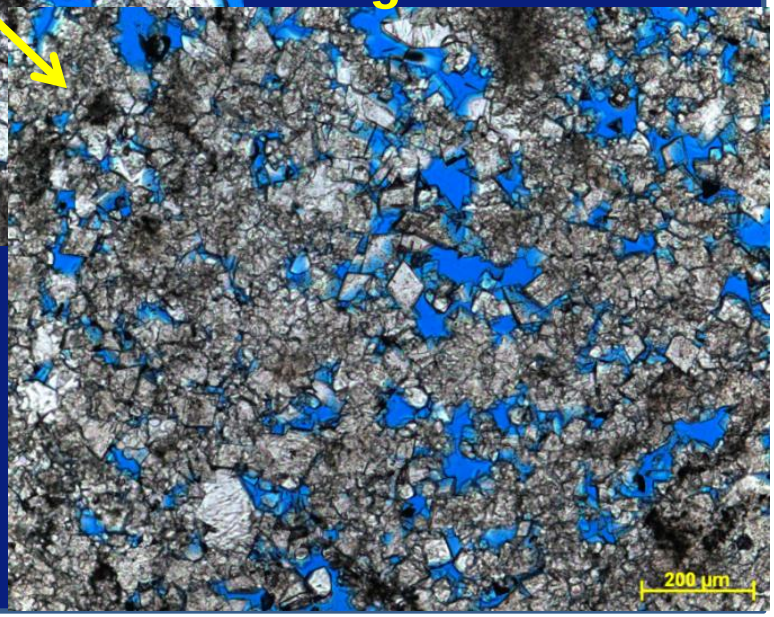
Dolomitization

modifies pore geometry and connectivity



Depositional texture

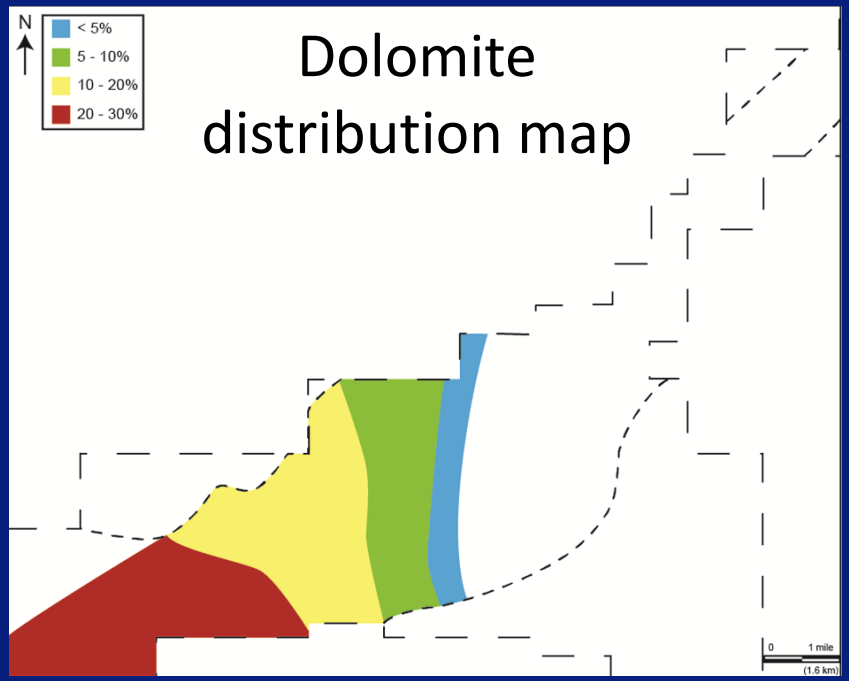


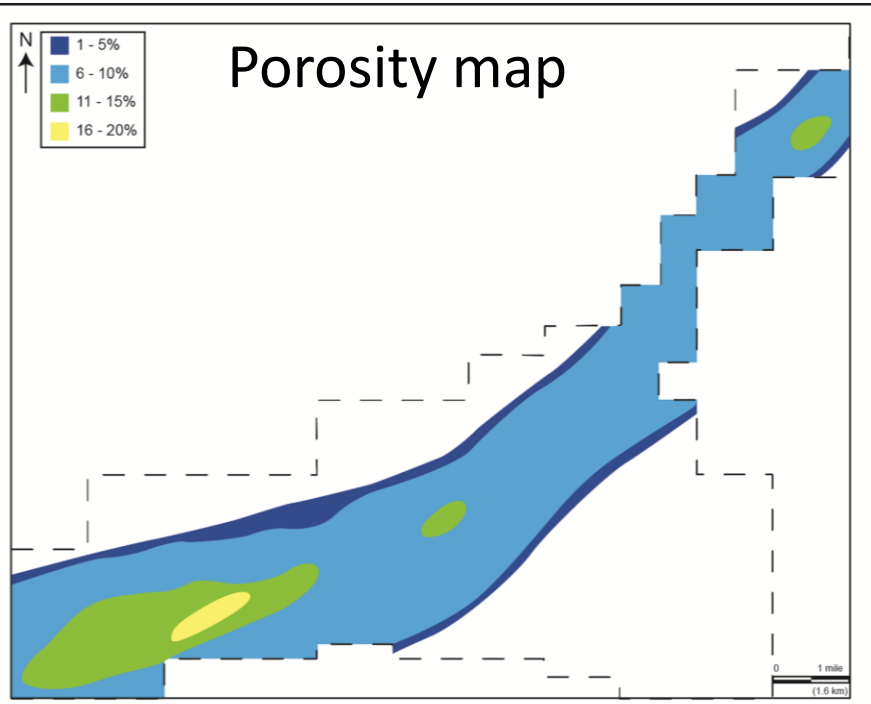


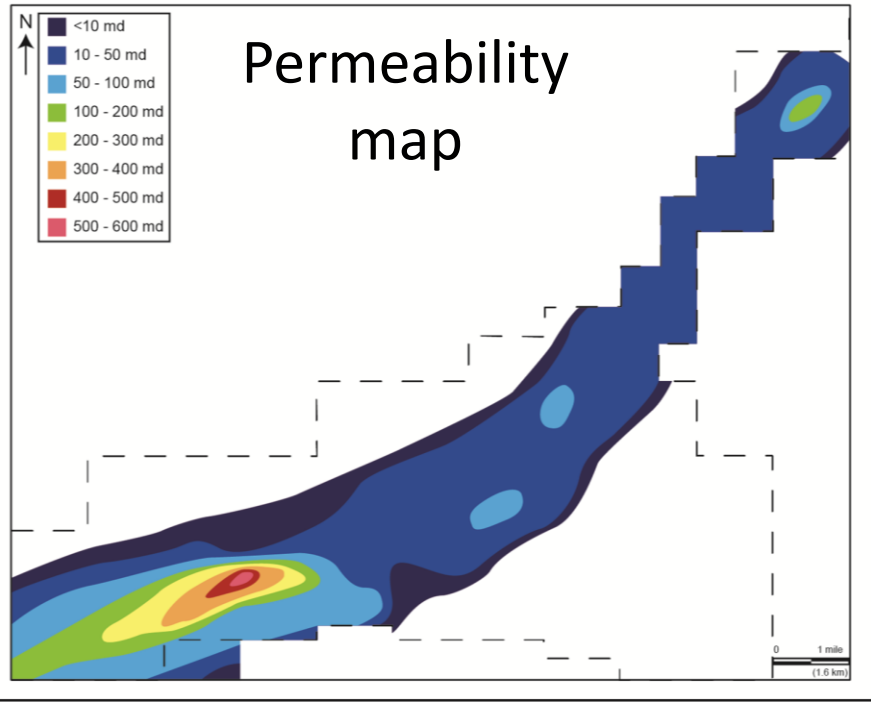
Diagenetic texture

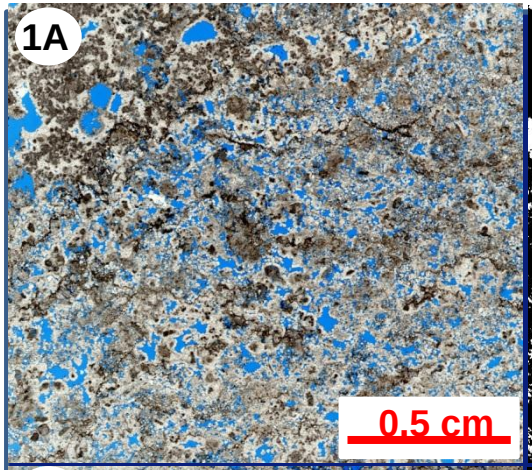
Little Cedar Creek Field

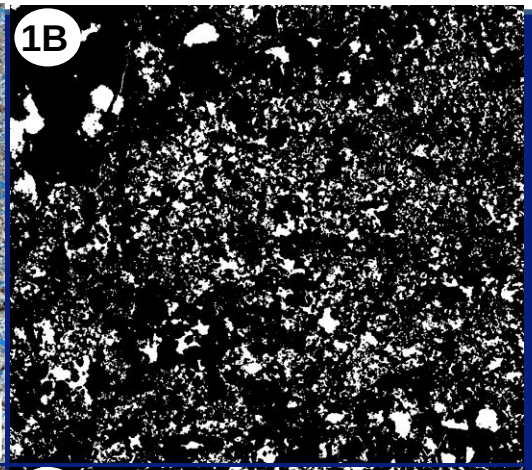
Microbial thrombolite reservoir - Little Cedar Creek Field

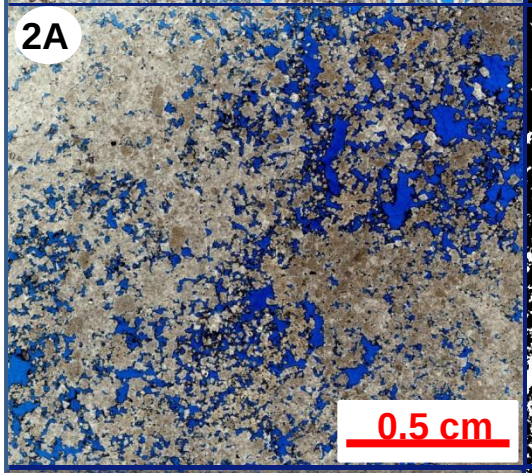


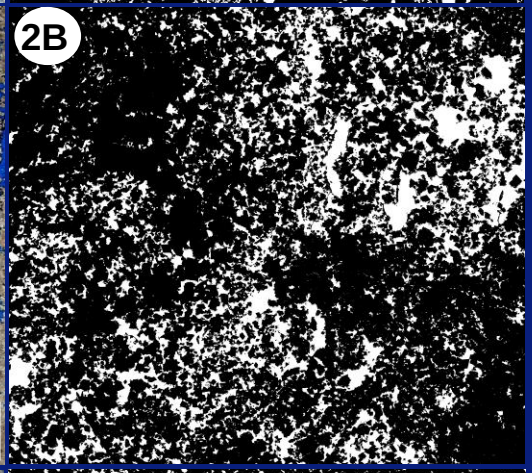


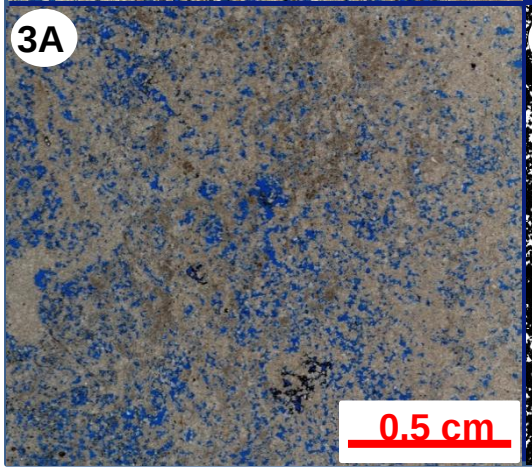


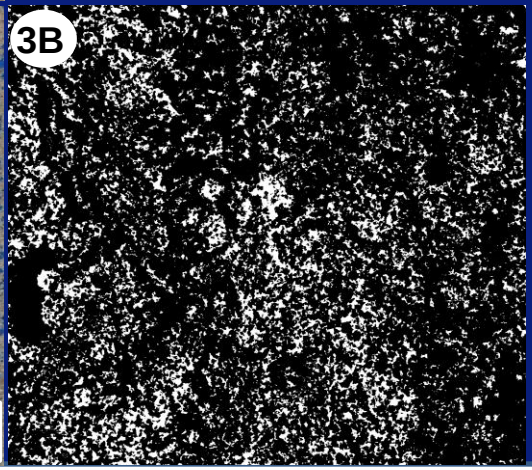












Pores in white

Little Cedar Creek Field
Partially dolomitized thrombolite

Average Φ = 9 % K = 107 md

Φ = 16 % K = 95.9 md

Appleton Field
Dolomitized thrombolite

Average Φ = 17 % K = 356 md

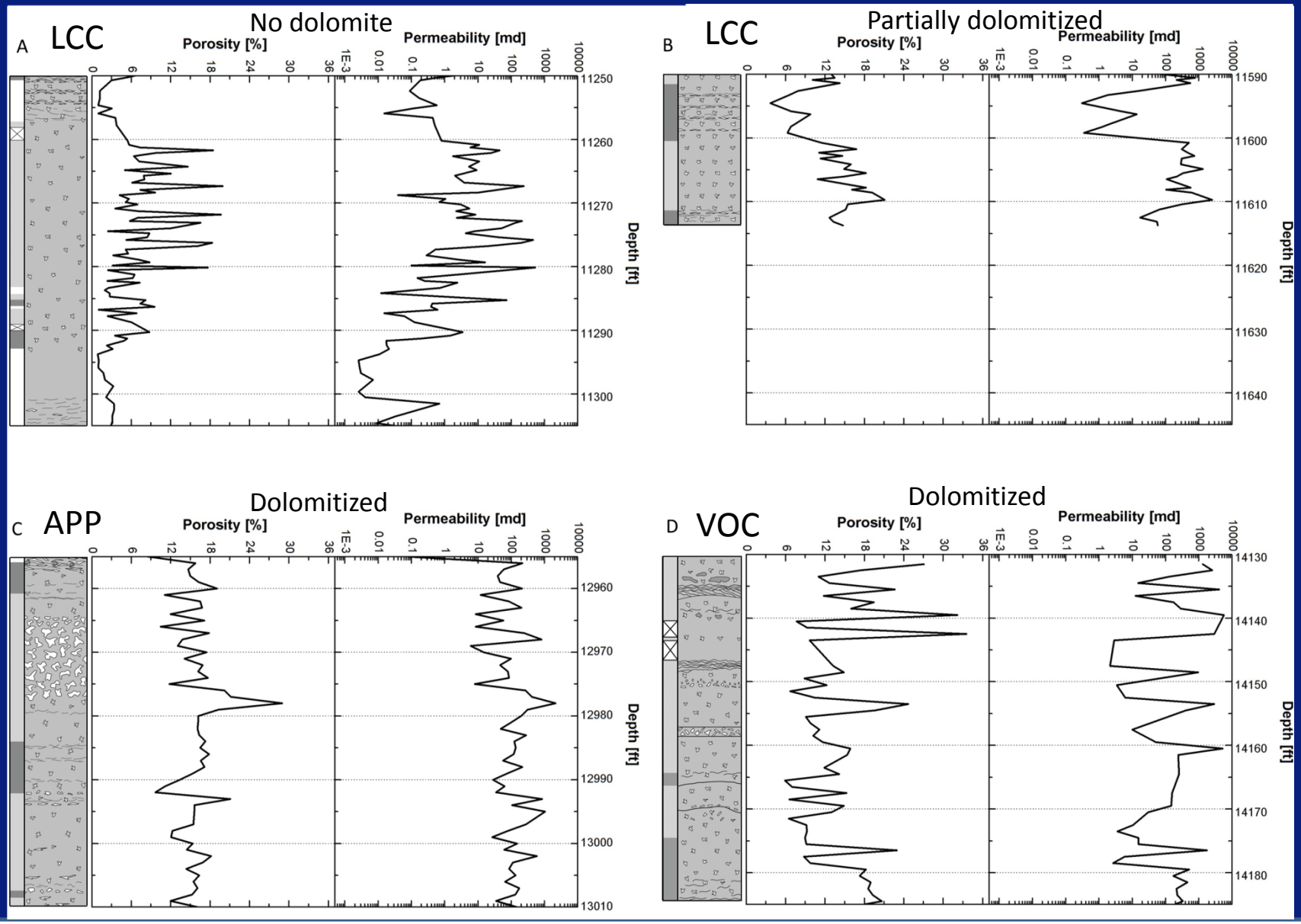
Φ = 18 % K = 786 md

Vocation Field
Dolomitized thrombolite

Average Φ = 13 % K = 175 md

Φ = 12 % K = 37.7 md

Microbial thrombolite - petrophysical data from core plugs



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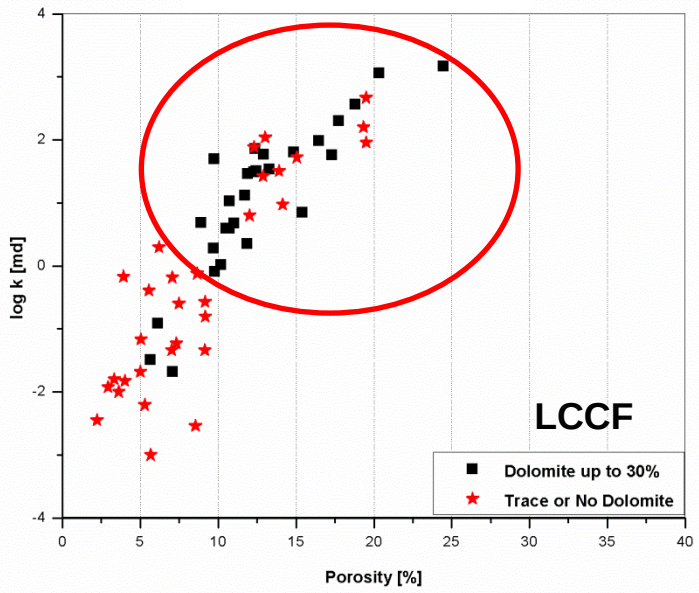

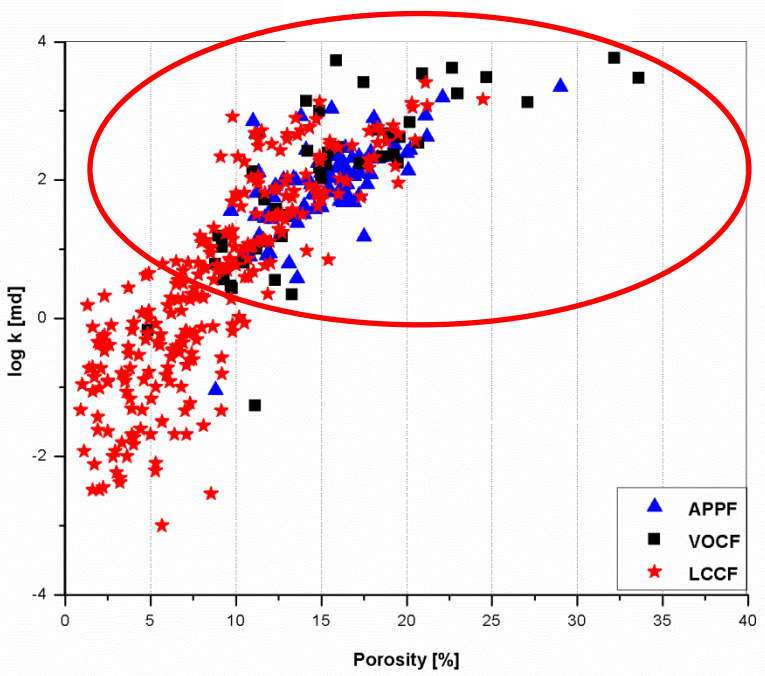

Conclusions

- Depositional facies controls reservoir rocks in Smackover Formation carbonates;
- The arrangement of the peloids and very early calcite cementation influence on the depositional petrophysical characteristics of the microbial thrombolite;
- Diagenesis caused significant modification in the pore system;
- Dolomitization associated with calcite dissolution improves pore connectivity and causes the petrophysical characteristics to be more homogeneous throughout the reservoir.

Acknowledgments


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