Pore Imaging of Late Miocene Calcareous Marl from the Pannonian Basin (Tótkomlós Member, Endrőd Formation) and Comparison with North America Productive Calcareous Marls*

G. Mallarino[1], A. É. Csoma[2], K. Milota[2], A. Sóron[2], and Á. Szabó[3]

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[1]Department of Geology, Eötvös Loránd University, Budapest, Hungary (gianni.mallarino@ttk.elte.hu)
[2]MOL Group Exploration and Production, Budapest, Hungary
[3]Lithosphere Fluid Research Laboratory, Eötvös Loránd University, Budapest, Hungary

Abstract

The Tótkomlós Member of the Endrőd Formation, in the subsurface of the central Pannonian Basin (Hungary), consists of hemipelagic calcareous marls deposited in the early Late Miocene in structurally-controlled sub-basins. TOC values ranging from 0.5 to 3 wt% make it a potential target for unconventional hydrocarbon exploration. Here we describe the pore systems of this calcareous marl and compare it with similar rocks from the productive Eagle Ford and Niobrara unconventional plays (USA).

Microfacies of the Tótkomlós Member consists of calcareous mudstone with detrital quartz, mica, few bioclasts, and dispersed pyrite. No pore space is visible in thin sections. FIB-SEM imaging reveals that the carbonate matrix is mostly made of coccoliths with calcite overgrowths. At high magnifications (10,000× and above) the pore system is clearly visible. Pore types are interparticle (i.e. mineral pores) and associated with organic-matter (OM). Interparticle pores occur either between coccoliths or authigenic clay platelets and their size ranges from 100 nm to 1 µm. Pores associated with OM are smaller and range from 20 nm to 500 nm. Generally, OM surrounds euhedral crystal terminations indicating that it moved into an open interparticle-pore space after the crystal growth. This suggests that the OM was originally a mobile hydrocarbon phase. Subsequent thermal cracking of this early hydrocarbon phase likely generated the present-day pore space associated with it. Detrital OM is also present but much less abundant and mostly pore free.

Both in the Upper Eagle Ford (UEF) and the Niobrara-B Chalk (NBC) TOC spans from 1 to 5 wt%. Pore types are similar to that described in the Tótkomlós Member. In the UEF mineral-pore size ranges from 100 nm to 4 µm and OM pores from 10 nm to 2 µm. In the NBC mineral-pore size ranges from 50 nm to 2.5 µm and OM pores from 10 nm to 1 µm. Similarly, to the Tótkomlós Member, in both North America calcareous marls the majority of OM pores are associated with residual hydrocarbon that seems to have originally filled the interparticle mineral pores.

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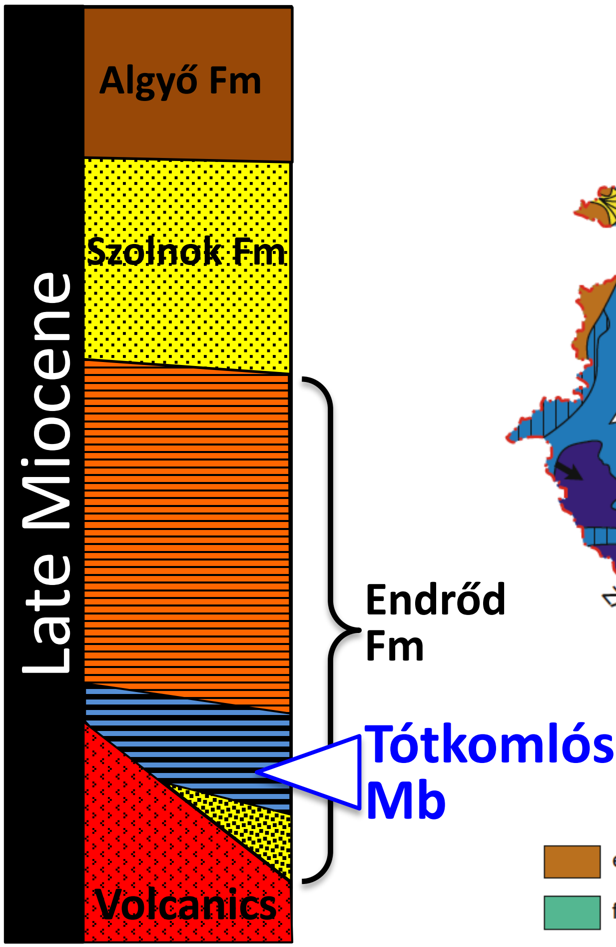
Goals and Main Results

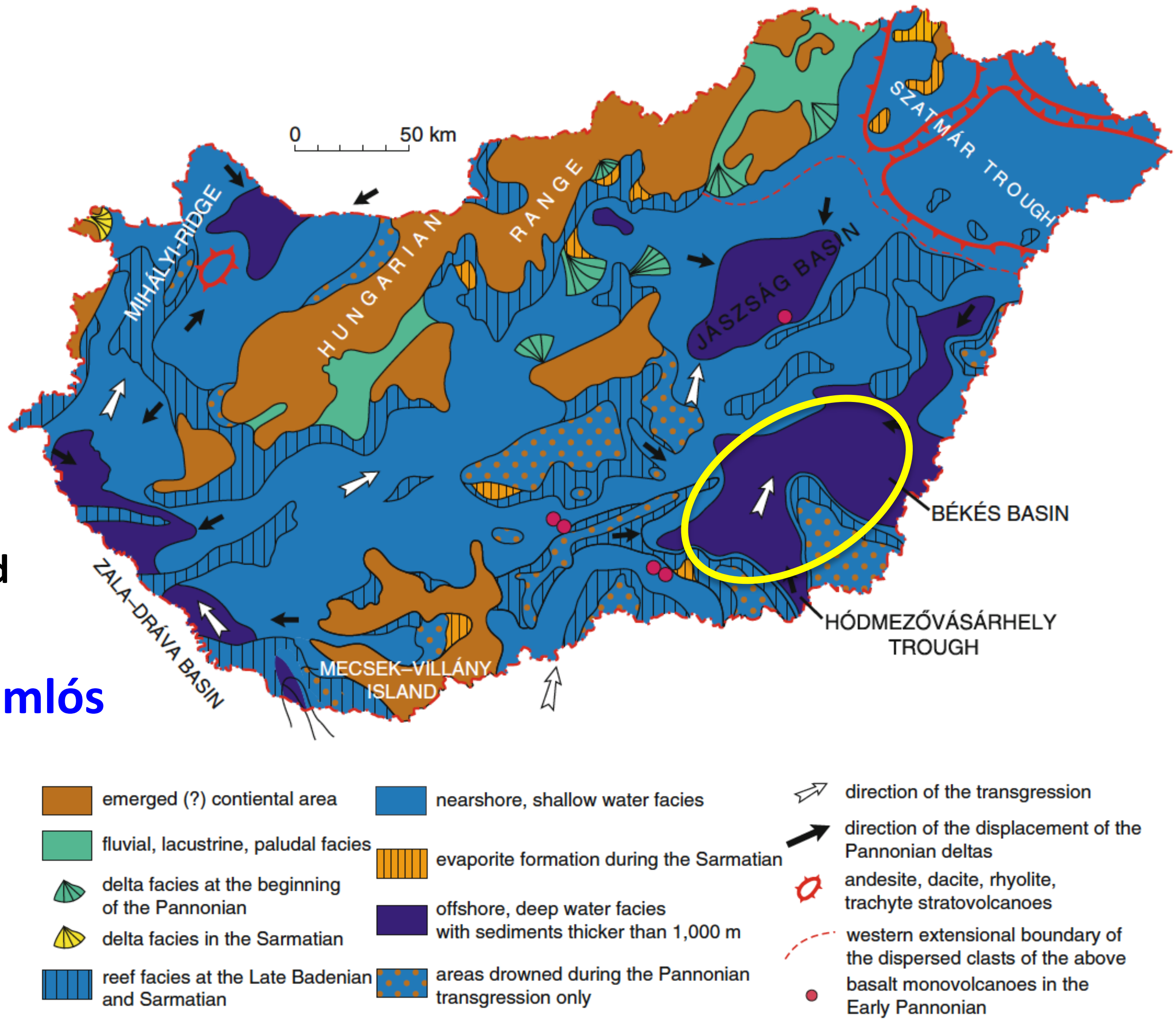
- There is a renewed interest in unconventional exploration in the Pannonian Basin. Characterizing the pore systems of these fine-grained rocks is crucial to understand their potential to host hydrocarbons
- This study documents for the first time the pore types of the Miocene Tótkomlós Member and compare it to similar rock types from the productive Upper Eagle Ford and Niobrara B Chalk plays
- Furthermore this study reconstructs the porosity evolution of the Tótkomlós Member

Geological Background

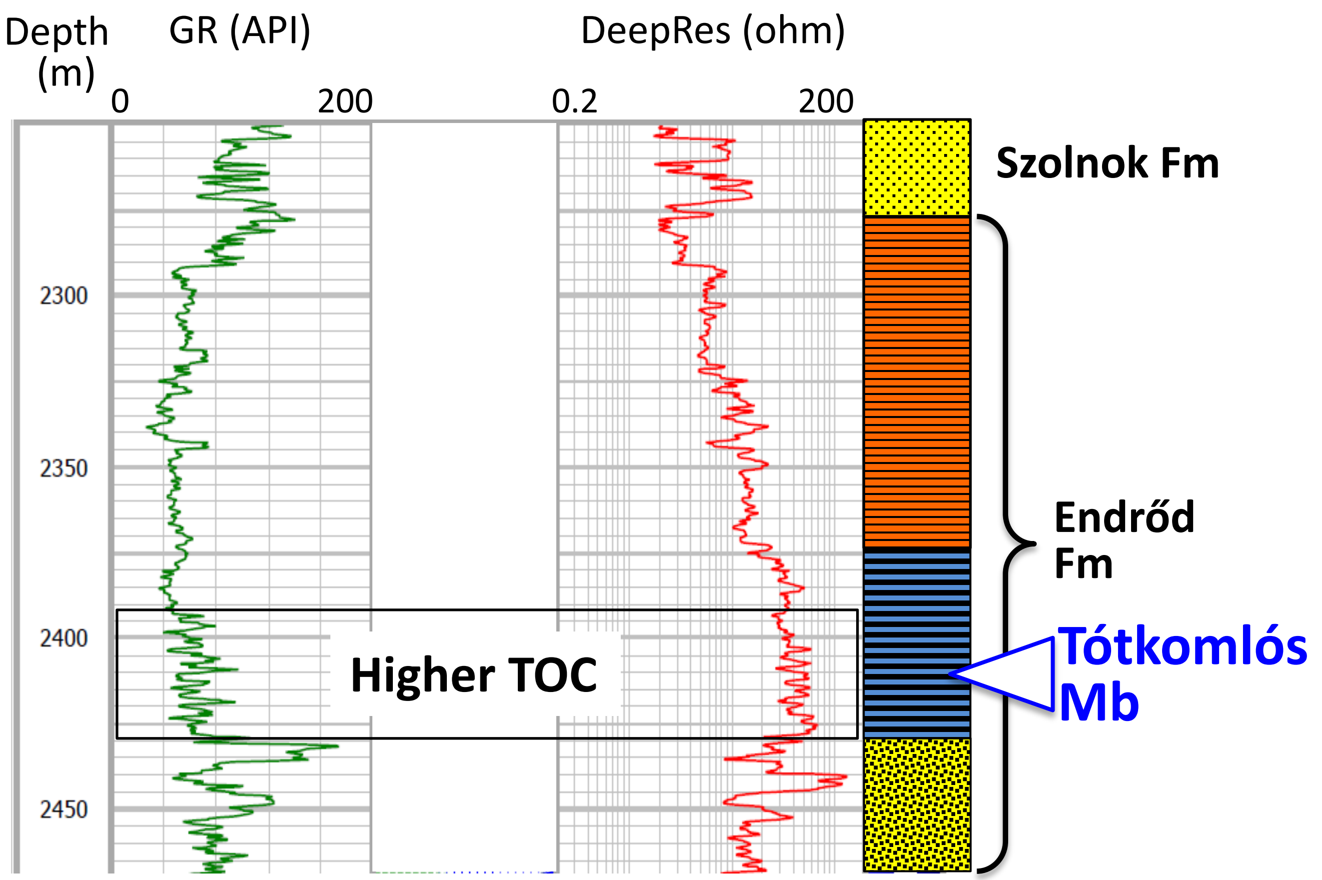
Nagymarosy and Hámor, 2012

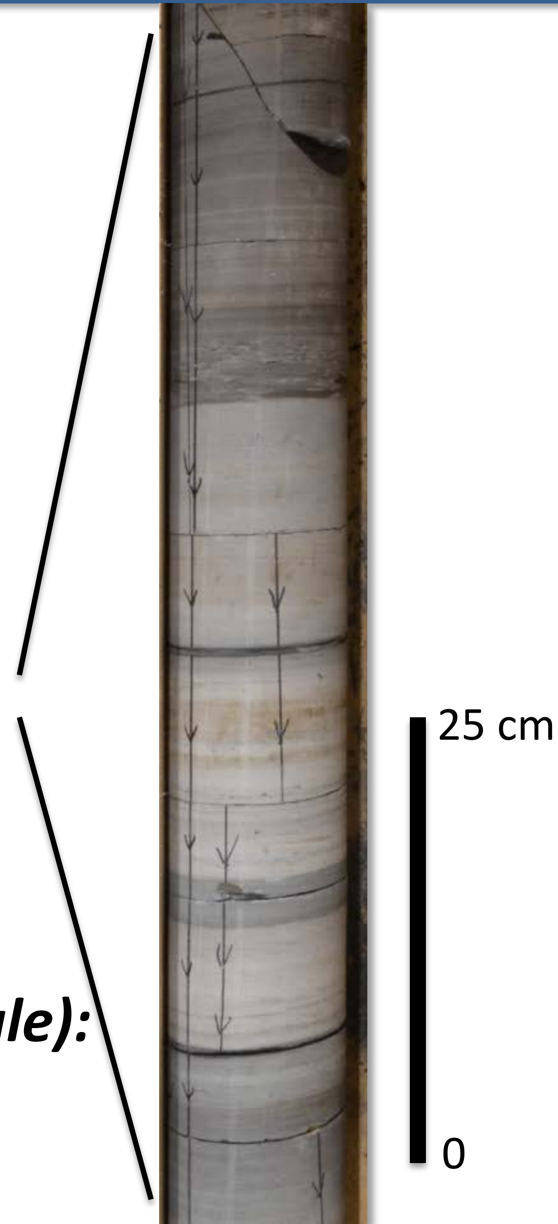
Stratigraphy





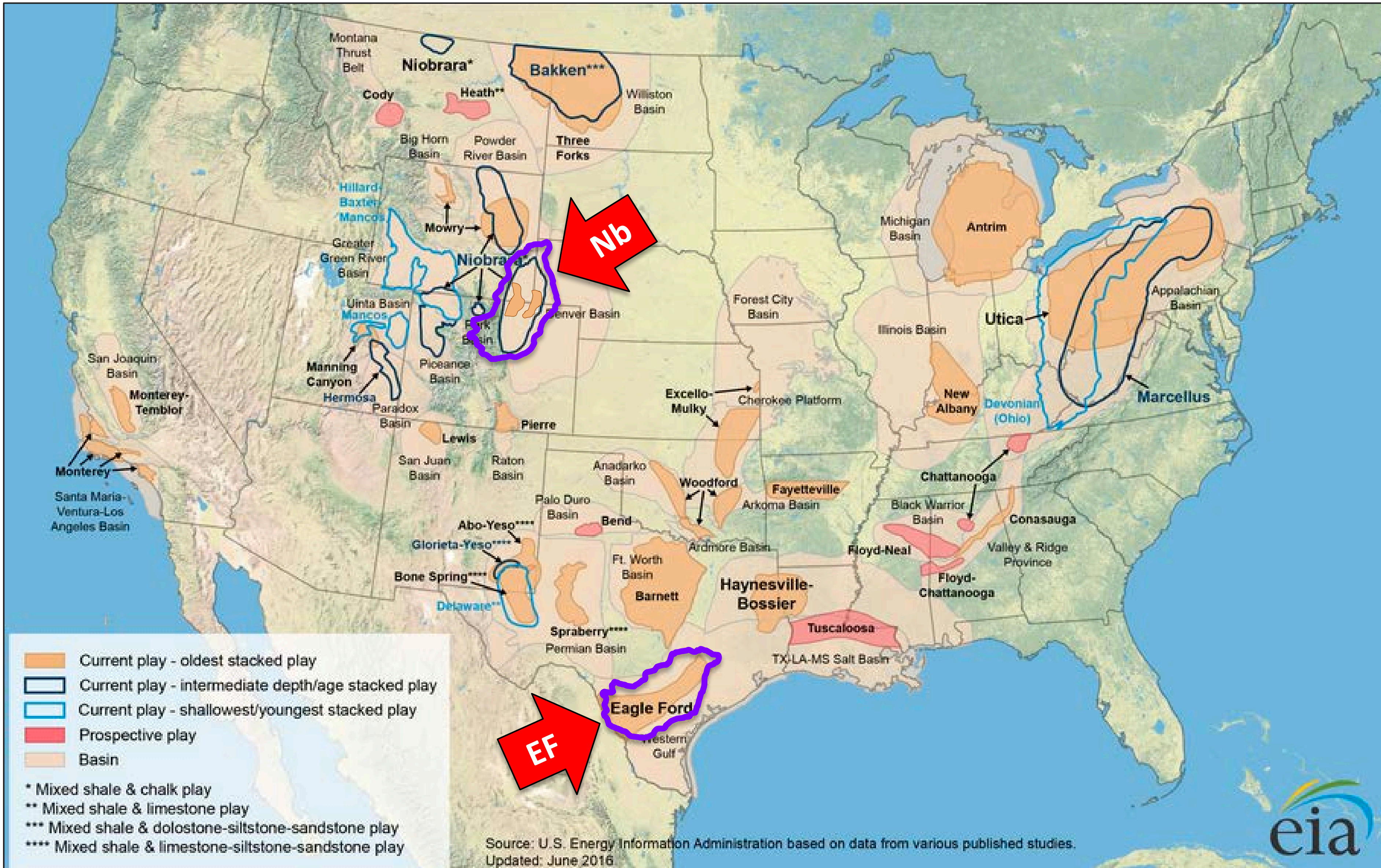
Wireline Logs and Lithology





High vertical heterogeneity (sub-meter scale): limestone/marl alternations

Eagle Ford (EF) and Niobrara Plays (Nb)

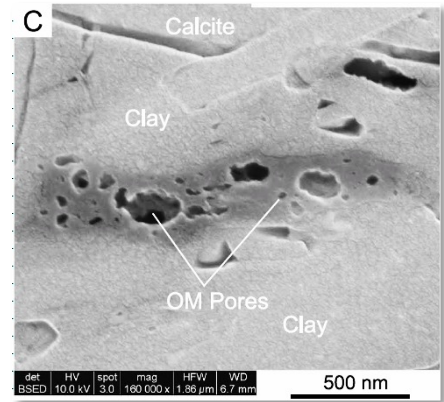


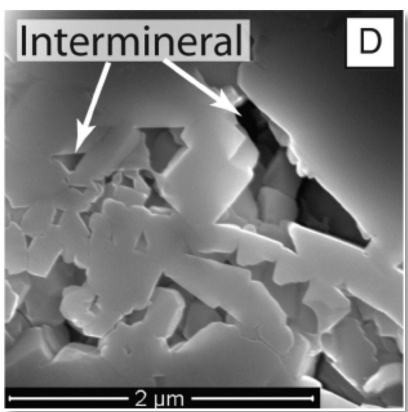
Formation Comparison

	Tótkomlós Member (Late Miocene)	Upper Eagle Ford (Late Cretaceous)	Niobrara B Chalk (Late Cretaceous)
Calcite (wt%)	22 - 90	22 - 90	20 - 95
Quartz (wt%)	3 - 30	5 - 25	3 – 40
Clay (wt%)	4 – 50	0 - 50	0 - 32
TOC (wt%)	0.2 - 4	1 - 4	1 – 4.5
Porosity (%)	1 - 8	4 - 10	4 – 15
Depth (m)	1300 - 3100	1000 - 4000	1000 - 2700
Thickness (m)	20 - 70	10 - 50	70 - 110

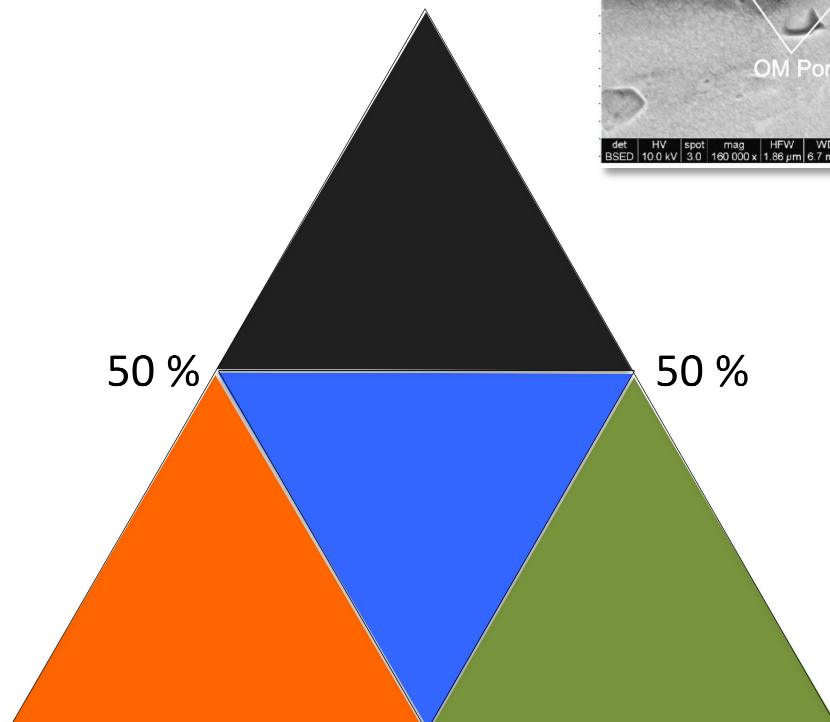
Pore System Classification of Mudstones

Organic-Matter
Pores

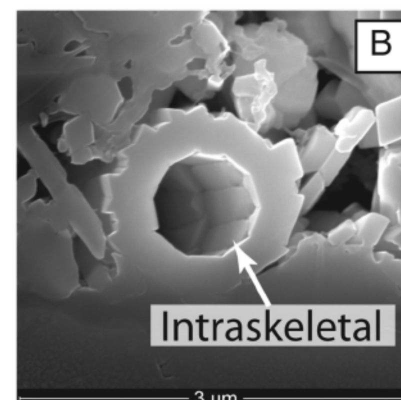




50 %



50 %



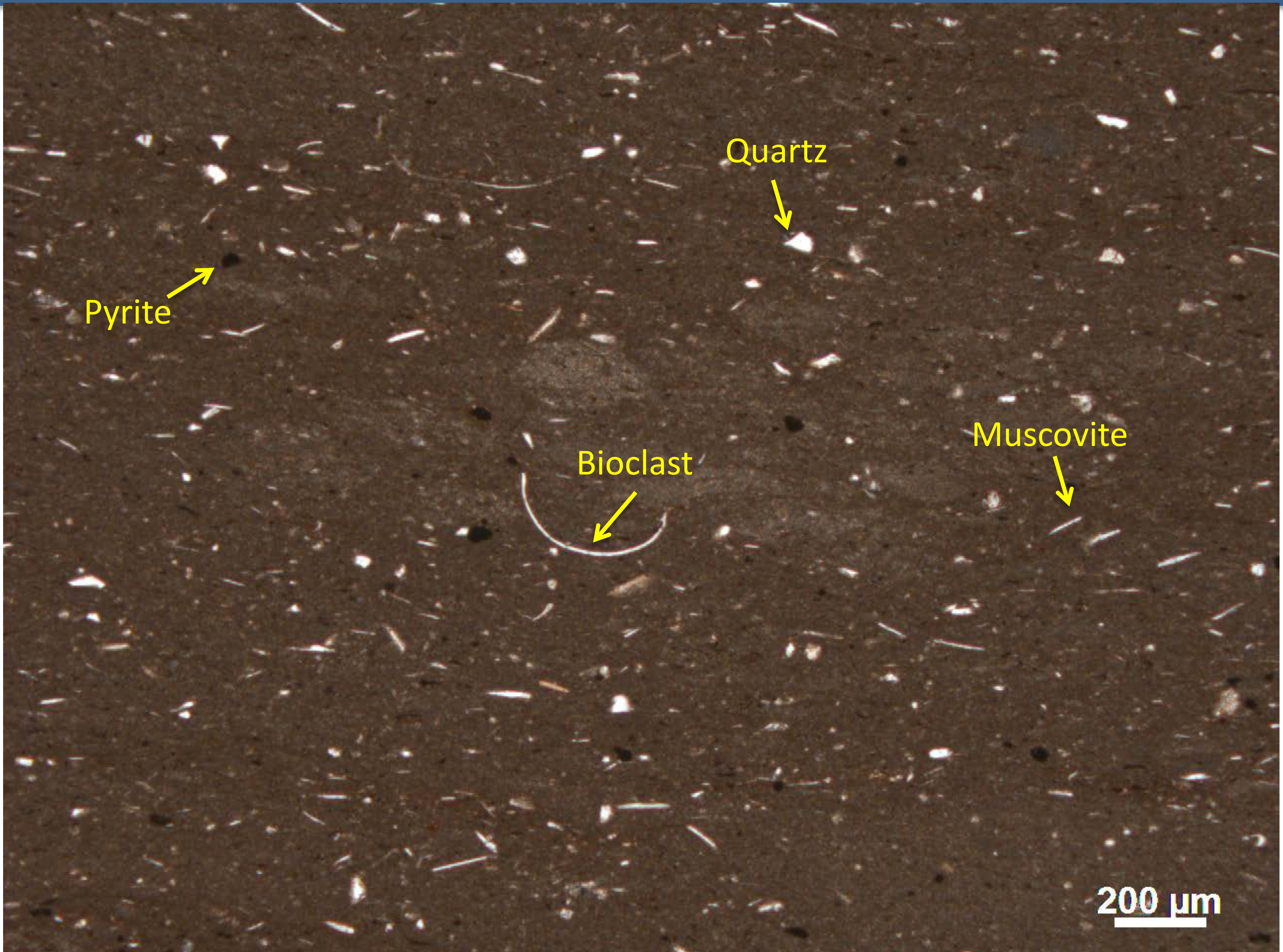
50 %

Interparticle
Pores

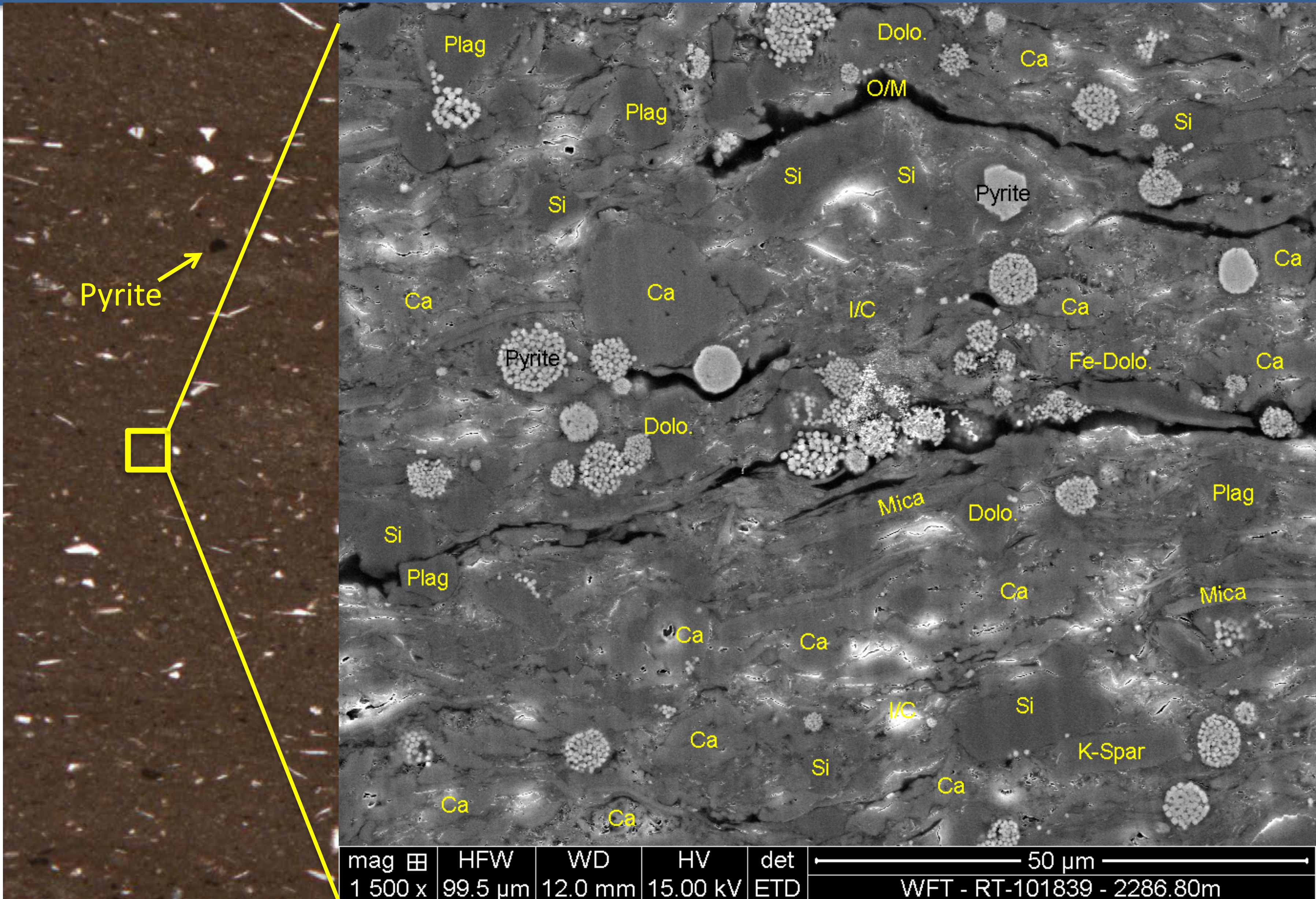
Intraparticle
Pores

From Loucks et al., 2012 and Pommer and Milliken, 2015

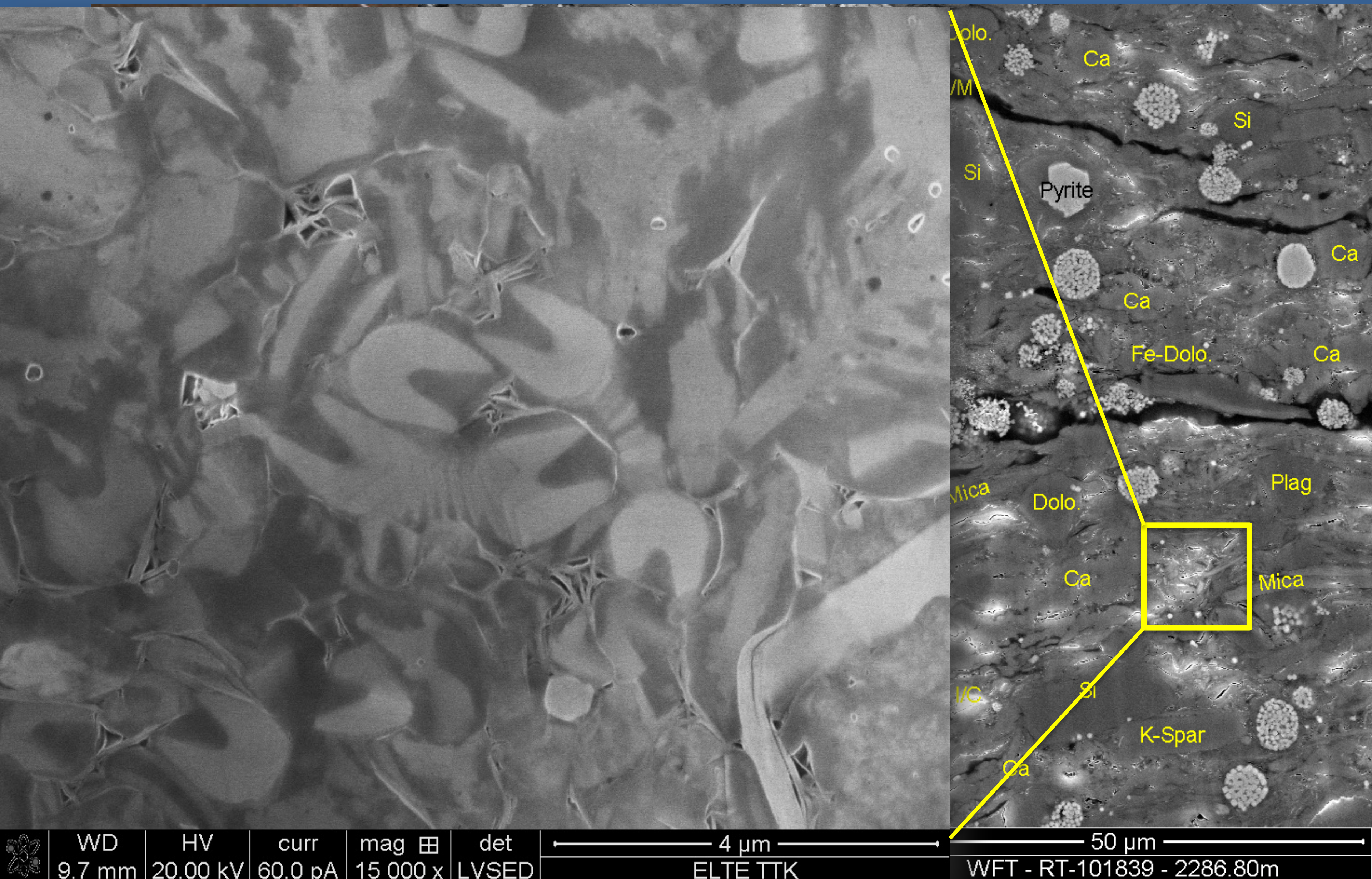
Tótkomlós Marl Micrographs



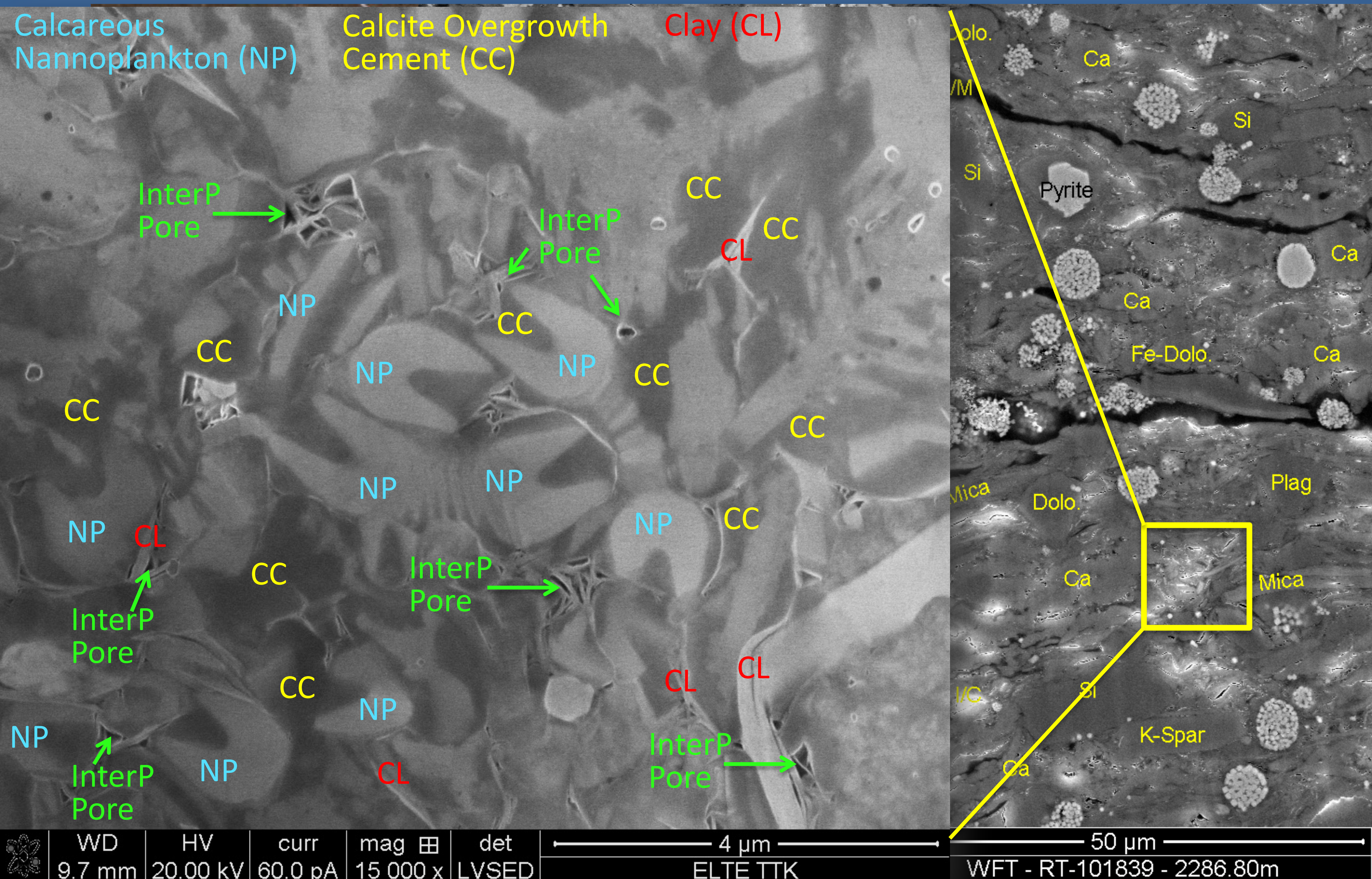
Tótkomlós Marl Micrographs



Tótkomlós Marl Micrographs

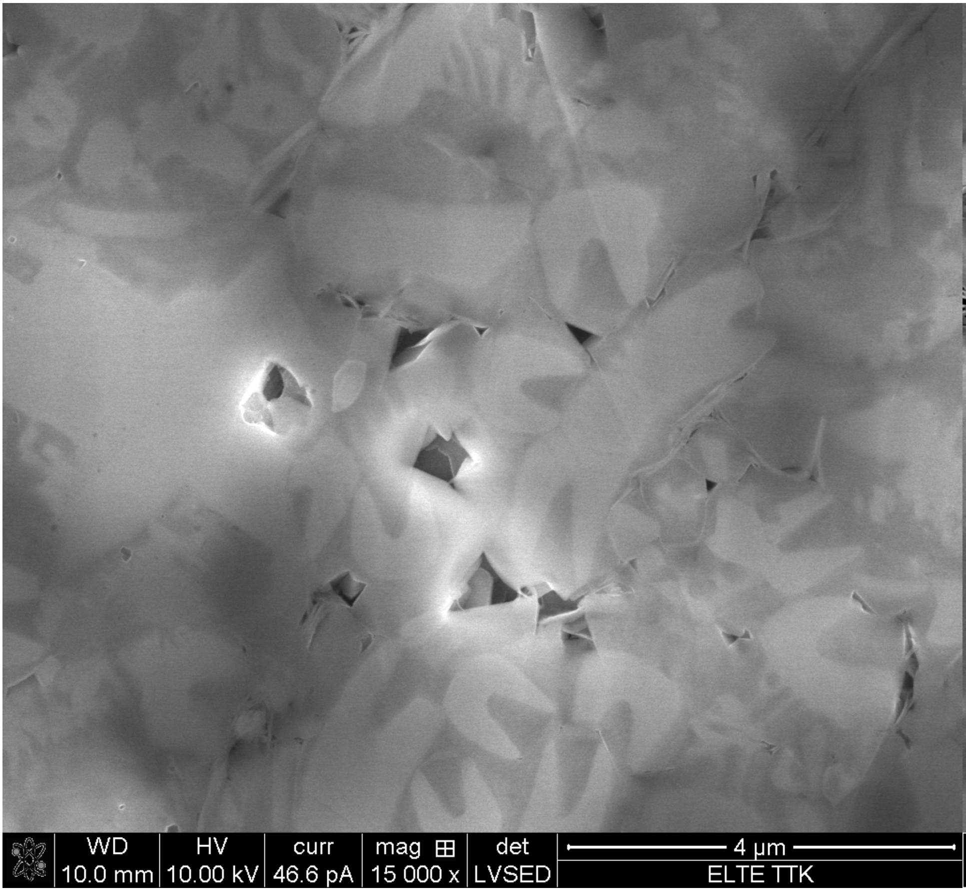


Tótkomlós Marl Micrographs

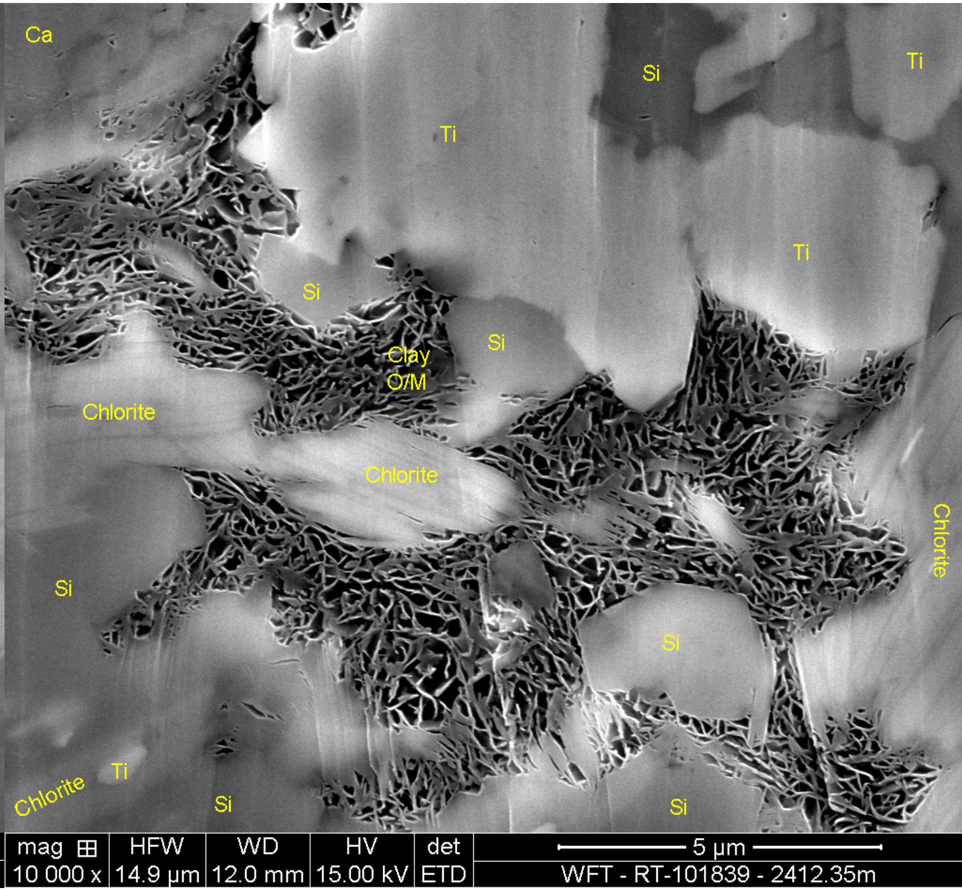


Tótkomlós Marl Pore Types

Interparticle pores between calcite cement (primary)

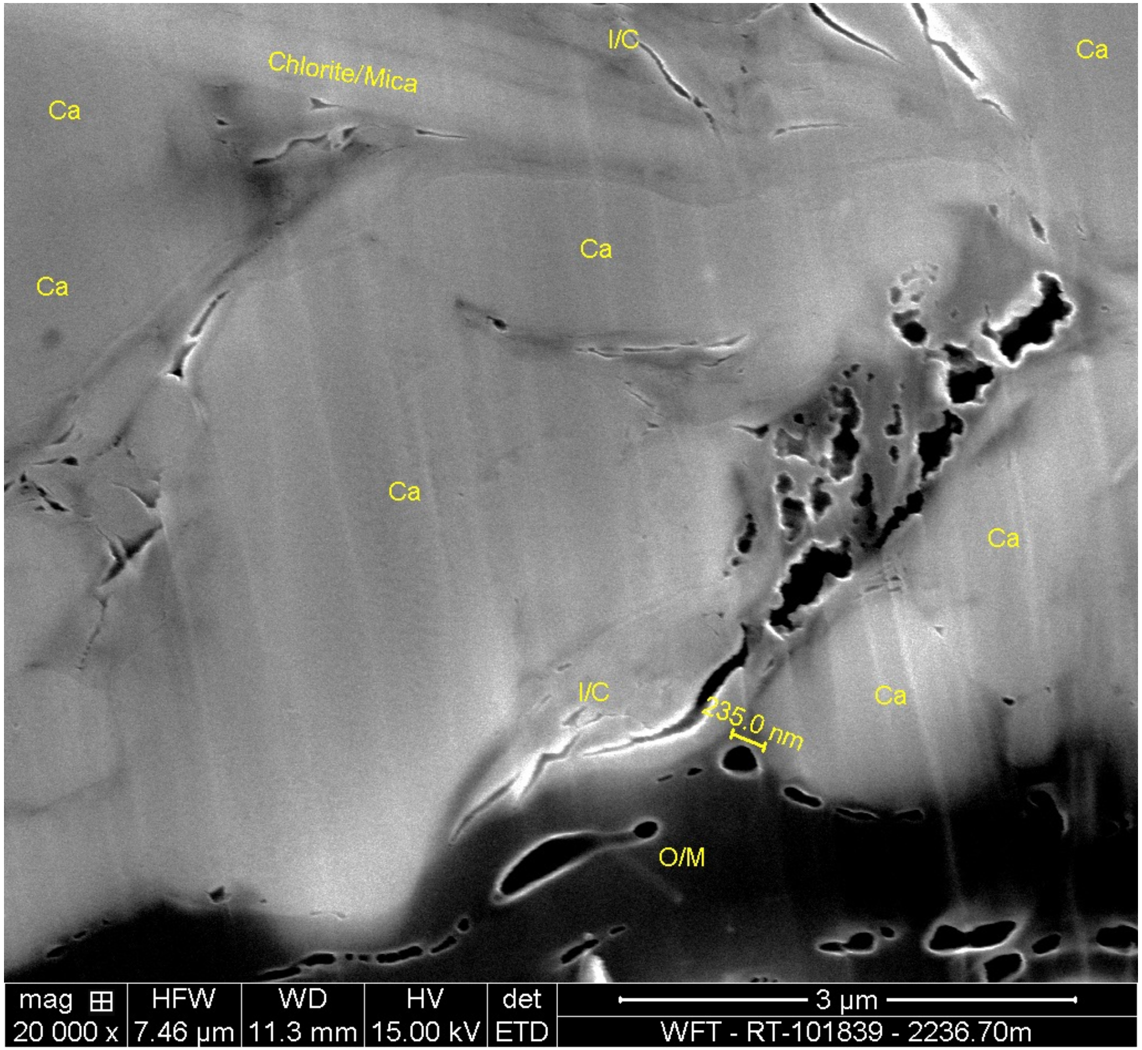


Interparticle pores between authigenic clay (primary)



Tótkomlós Marl Pore Types

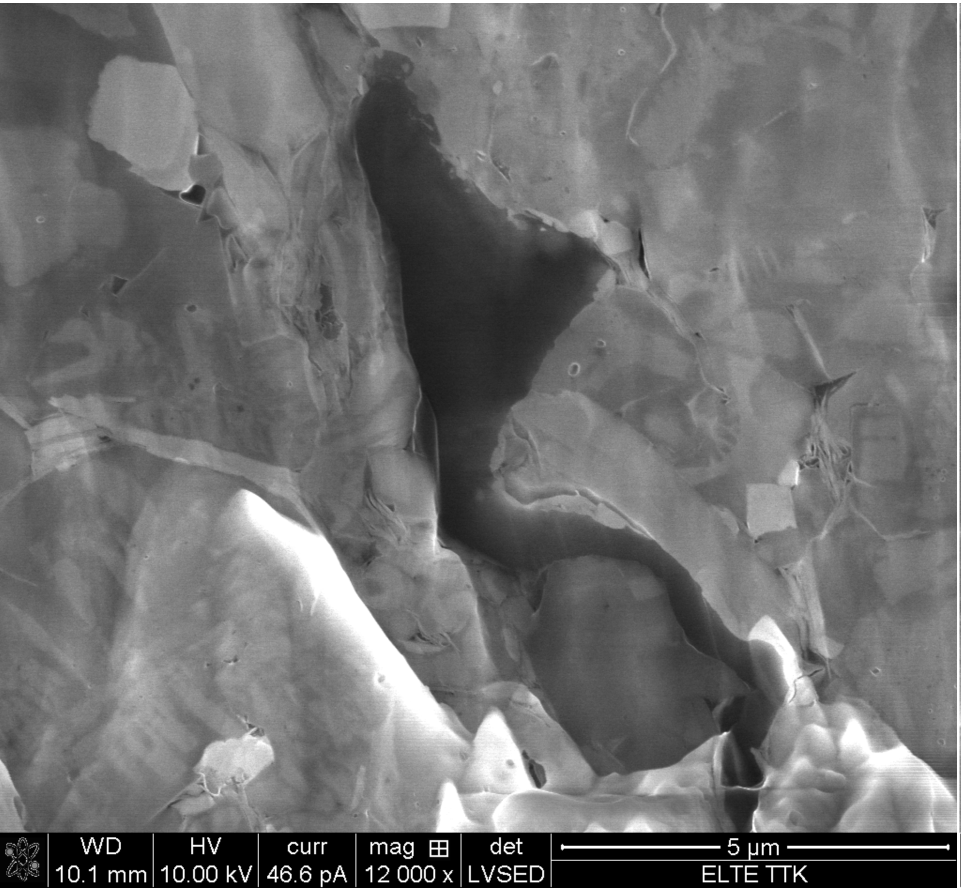
Organic matter pores (secondary)

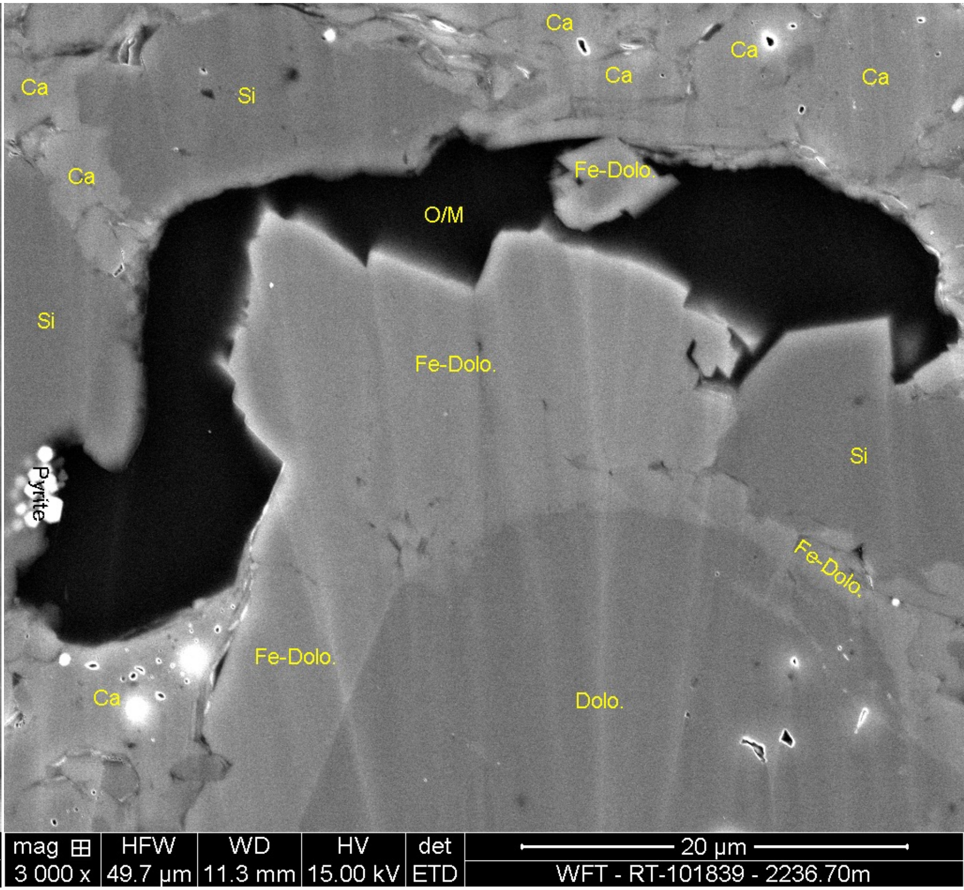


Tótkomlós Marl Organic Matter

Detrital organic matter

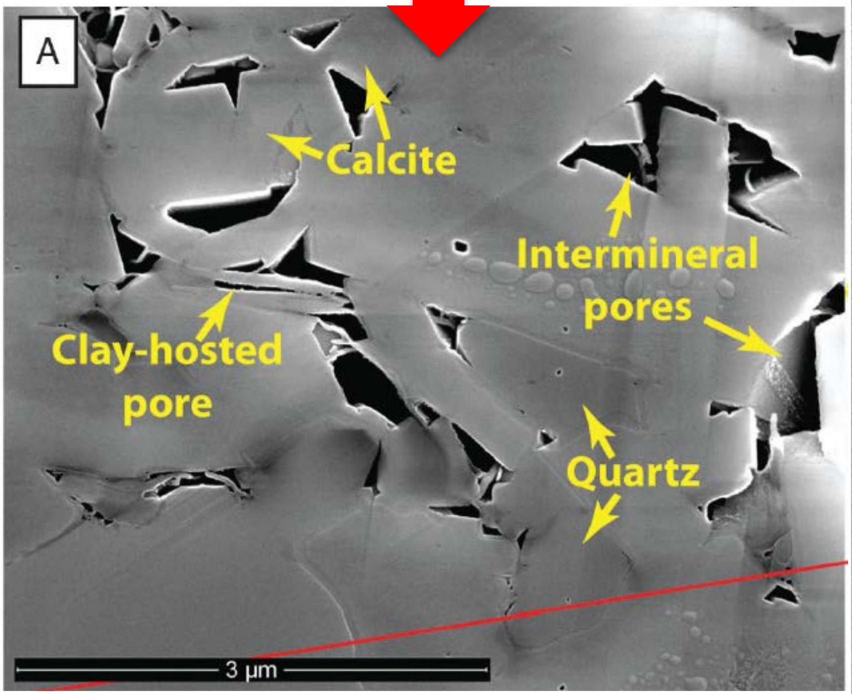
Migrated organic matter (e.g. early hydrocarbons)



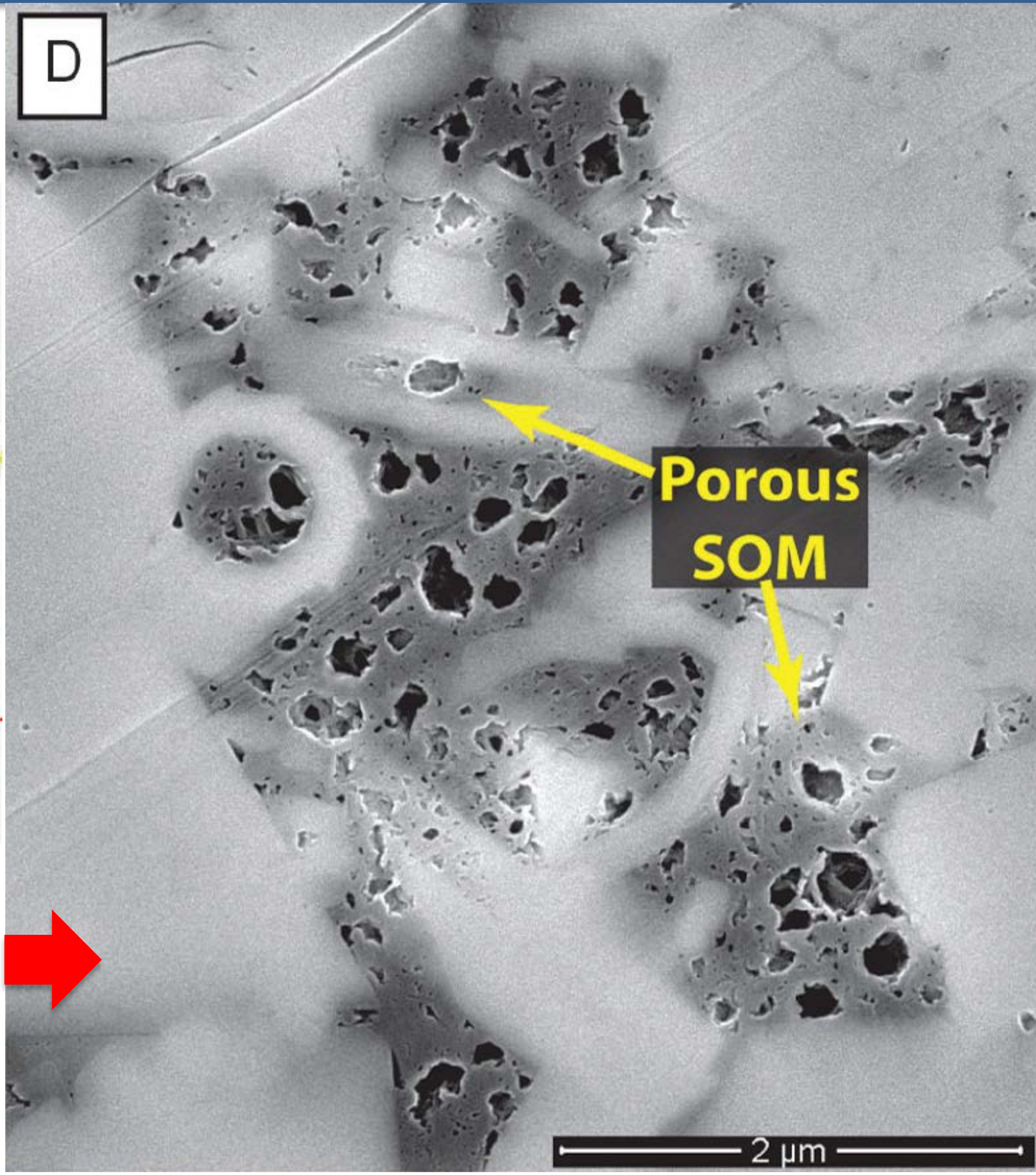


Upper Eagle Ford Pore Types

Interparticle pores

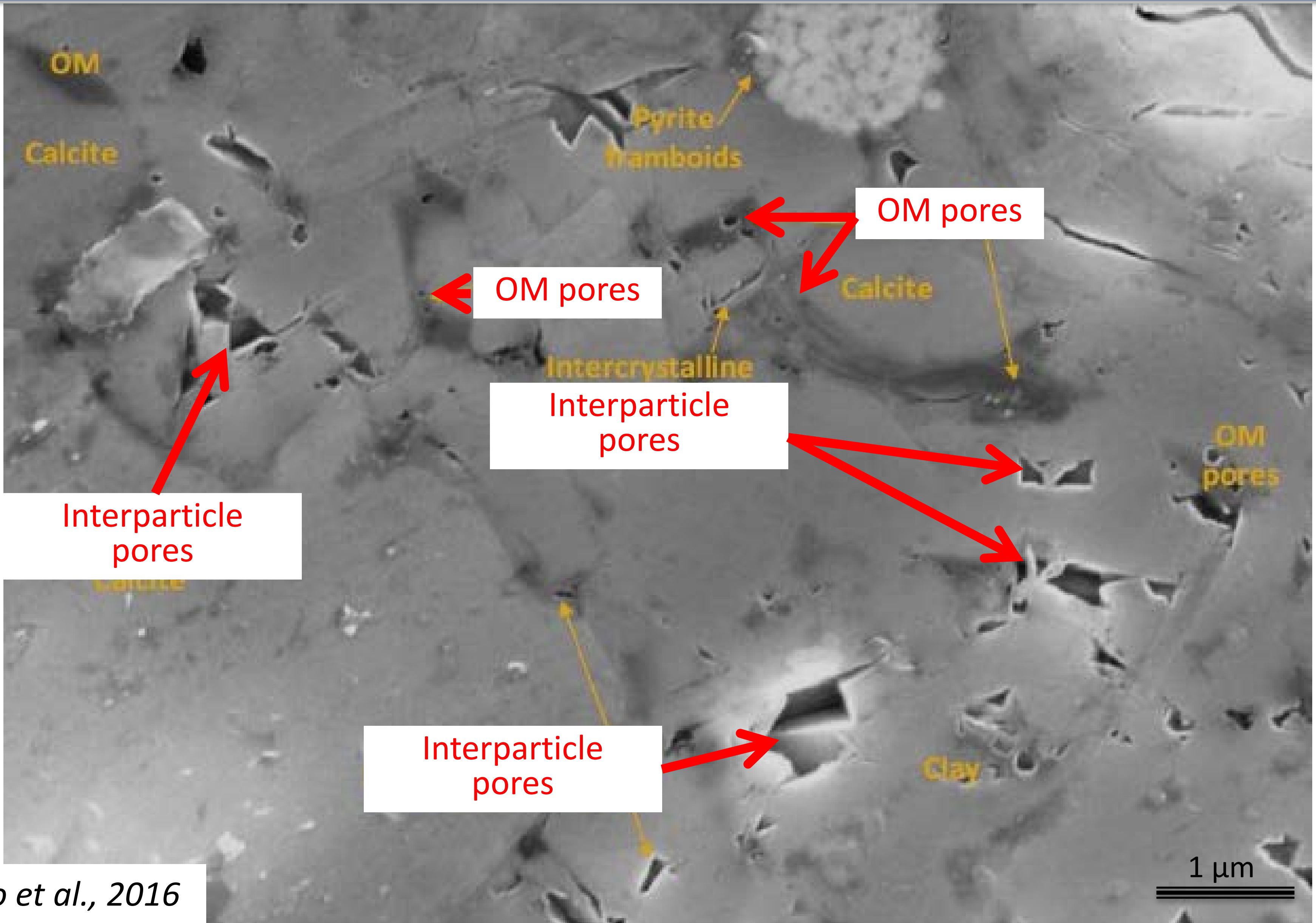


Organic matter pores



Pommer and Milliken, 2015

Niobrara B Chalk Pore Types

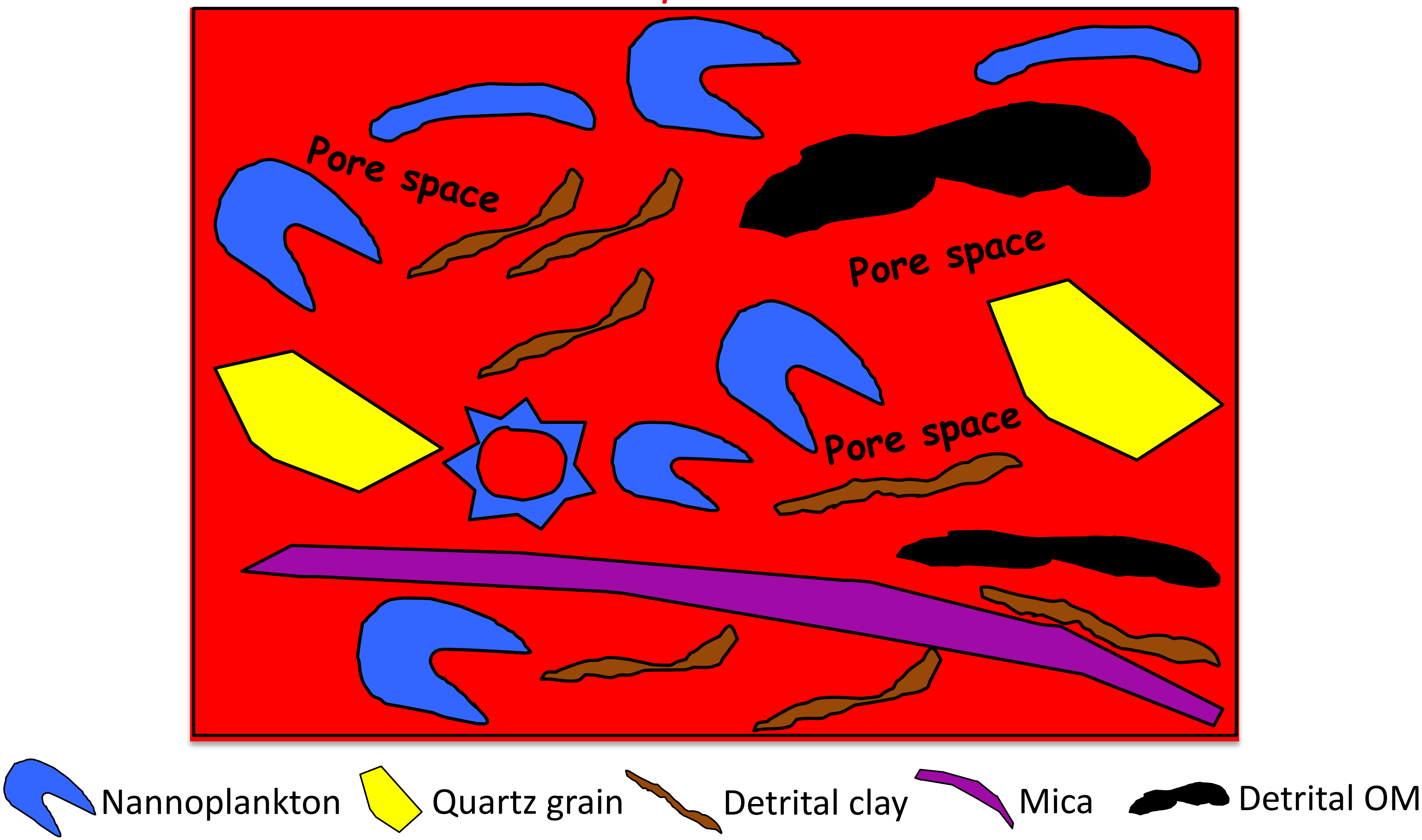


Cho et al., 2016

Tótkomlós Marl Porosity Evolution

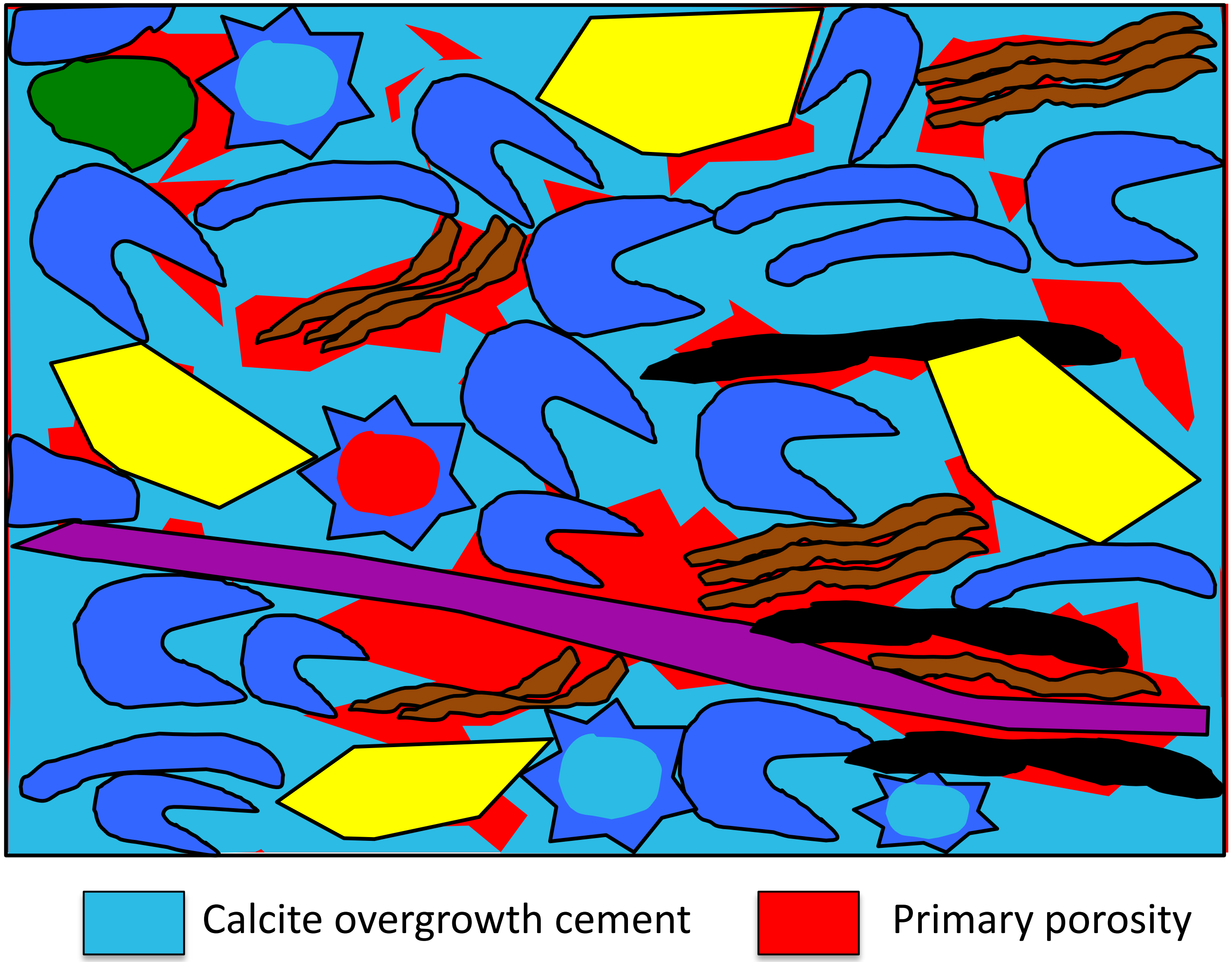
Initial sediment

Φ = up to 80%



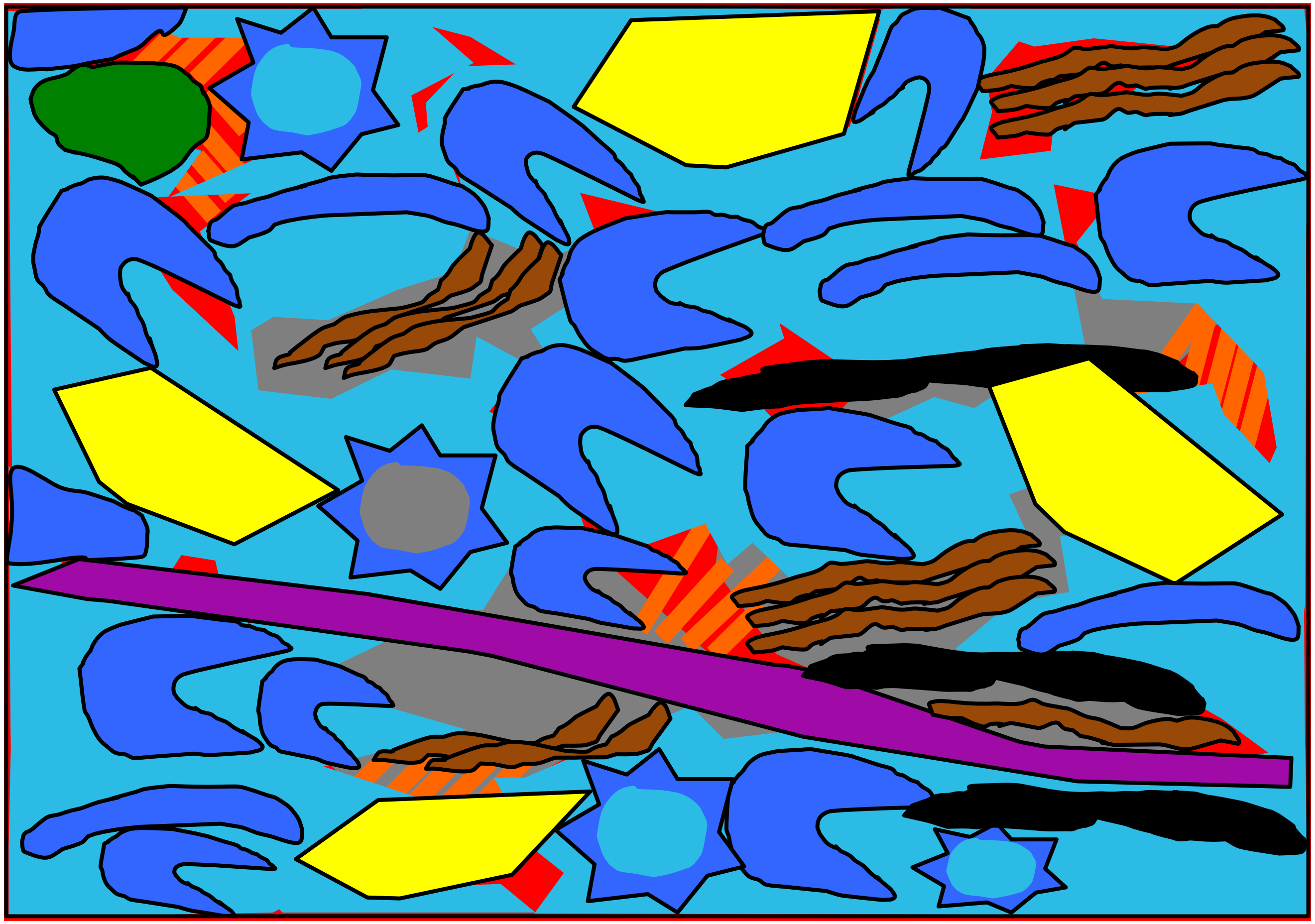
Tótkomlós Marl Porosity Evolution

Compaction and cementation
(intermediate burial; porosity loss)



Tótkomlós Marl Porosity Evolution

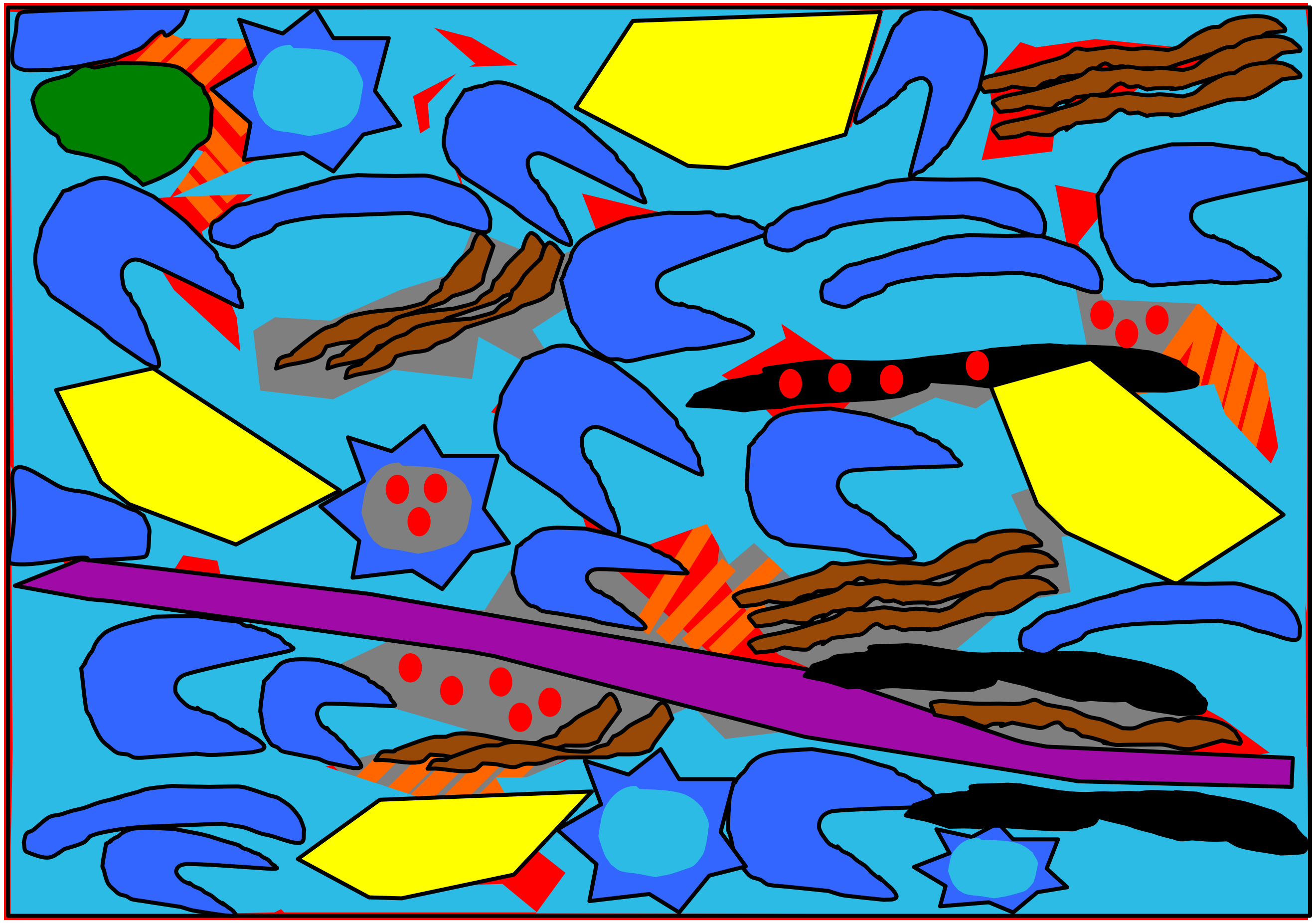
Early hydrocarbon migration
(intermediate/deep burial; porosity loss)



Tótkomlós Marl Porosity Evolution

Organic matter thermal cracking (deep burial)

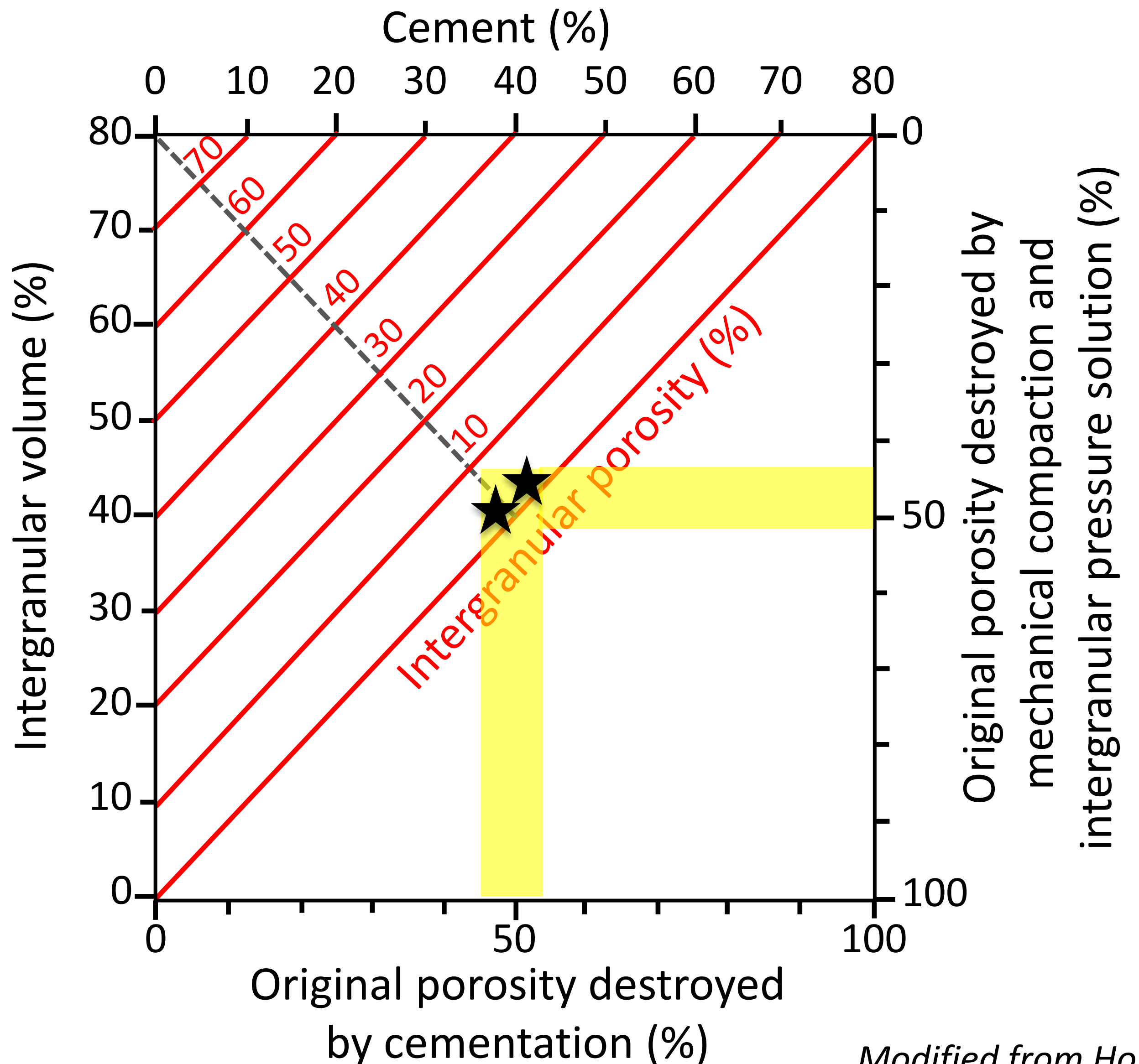
porosity gain, present-day Φ = up to 8%



OM secondary porosity

Primary porosity

Quantification of Porosity Loss



Modified from Houseknecht (1987)

Conclusions

- In the Tótkomlós Member pore types are both primary (i.e. interparticle) and secondary (i.e. associated with organic matter)
- Migration of early hydrocarbon initially occluded pore spaces but its subsequent thermal cracking created new secondary porosity
- Quantitative data show that cementation was as important as compaction in reducing the initial porosity
- Pore types and porosity evolution of the Tótkomlós Member shows strong similarities with the productive Upper Eagle Ford and Niobrara B Chalk formations from North America

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