Spectrum of Micropore Types and Their Origin in Limestones*

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Note: The presentation was submitted as a poster; in order to follow the request to present it orally, the authors reduced the content somewhat.

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Abstract

Microporous limestones form tight carbonate reservoirs; with the advent of horizontal drilling and fracking these reservoirs are now important exploration targets. Micropores have pore diameters of <10 microns and pore throats ~1 to 3 microns in diameter. In a reservoir, however, arrangement and connection of pores form the basis of reservoir quality. Three main types of micropores in limestones are: (1) micropores associated with transformation of aragonite mud to calcite, (2) micropores associated with transformation of Mg-calcite allochems to calcite, and (3) original pores in coccolith-rich sediments (chalks).

Transformation of aragonite to microcrystalline calcite shows that calcite microspar forms by dissolution of aragonite mud to form microcrystalline calcite with no change in porosity of the mud. Lower Miocene Java Sea limestones have micropore systems of this type.

Transformation of Mg-calcite to microcrystalline calcite and associated micropores has been documented for former Mg-calcite allochems, such as red algae, foraminifera, bryozoans, stromatoporoids, ooids, Lithocodium, and micrite rims. The first stage is documented by Mg-calcite rods in living organisms changing in morphology. The rods appear to precipitate nanoballs along their surface and then separate into individual nanoballs. These Mg-calcite nanoballs dissolve and reprecipitate as microcrystalline calcite. Evidence of this process is found in relic nanoballs observed in ancient microcrystalline calcite. Significantly, no special fluids are needed to transform Mg-calcite to microcrystalline calcite; the Mg-calcite simply needs to become chemically unstable; this can happen in any number of fluids. This transformation probably is completed in the first several thousand feet of burial or, most likely, shallower. The Lower Cretaceous Stuart City and Sligo are examples of formations dominated by Mg-calcite stabilization micropores.

Chalks contain a micropore system, which is a function of original interparticle pores between coccoliths and segmented coccolith platelets. Through time, the coccolith hash compacts (from ~75% to 50% pore space) and cements to form a tighter limestone. The Upper Cretaceous Austin and North Sea Chalks are examples.

Micropores in limestone take three different and distinct forms. They have different origins and distributions at the thin-section level. Understanding these differences is important to the exploitation of microporous limestone reservoirs.

Reference Cited

Macintyre, I.G. and R.P. Reid, 1998, Recrystallization in a living porcelaneous foraminifer (*Archaias angulatis*): Textural changes without mineralogic alteration: Journal of Sedimentary Research v. 68, p. 11-19.

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Spectrum of Micropore Types and Their Origin in Limestone

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Research Goal

- Origin, quantification, and petrophysical properties of micropore-dominated limestone reservoirs

Why Important

- Will help us to understand and explore for low-permeability limestone reservoirs

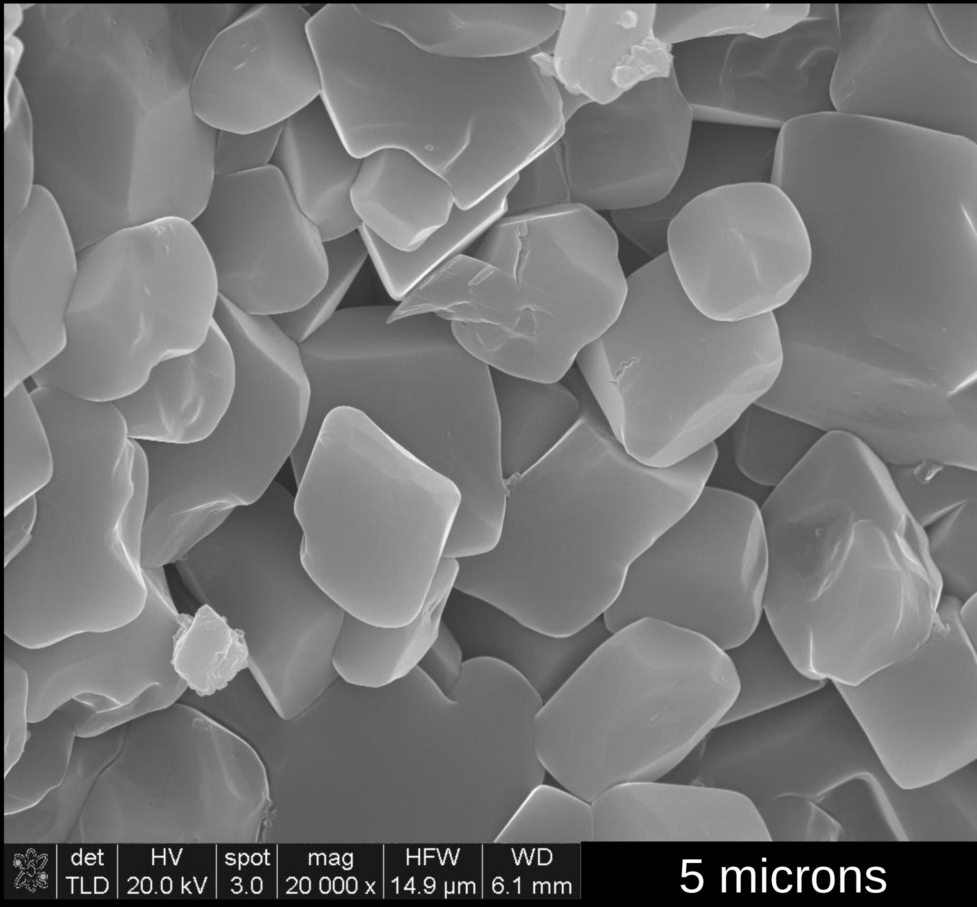
Objectives

- Definition of micropores in limestones
- General origins of limestone micropore reservoirs
- Origin of micropores associated with transformation of Mg-calcite to calcite

Micropore Definition

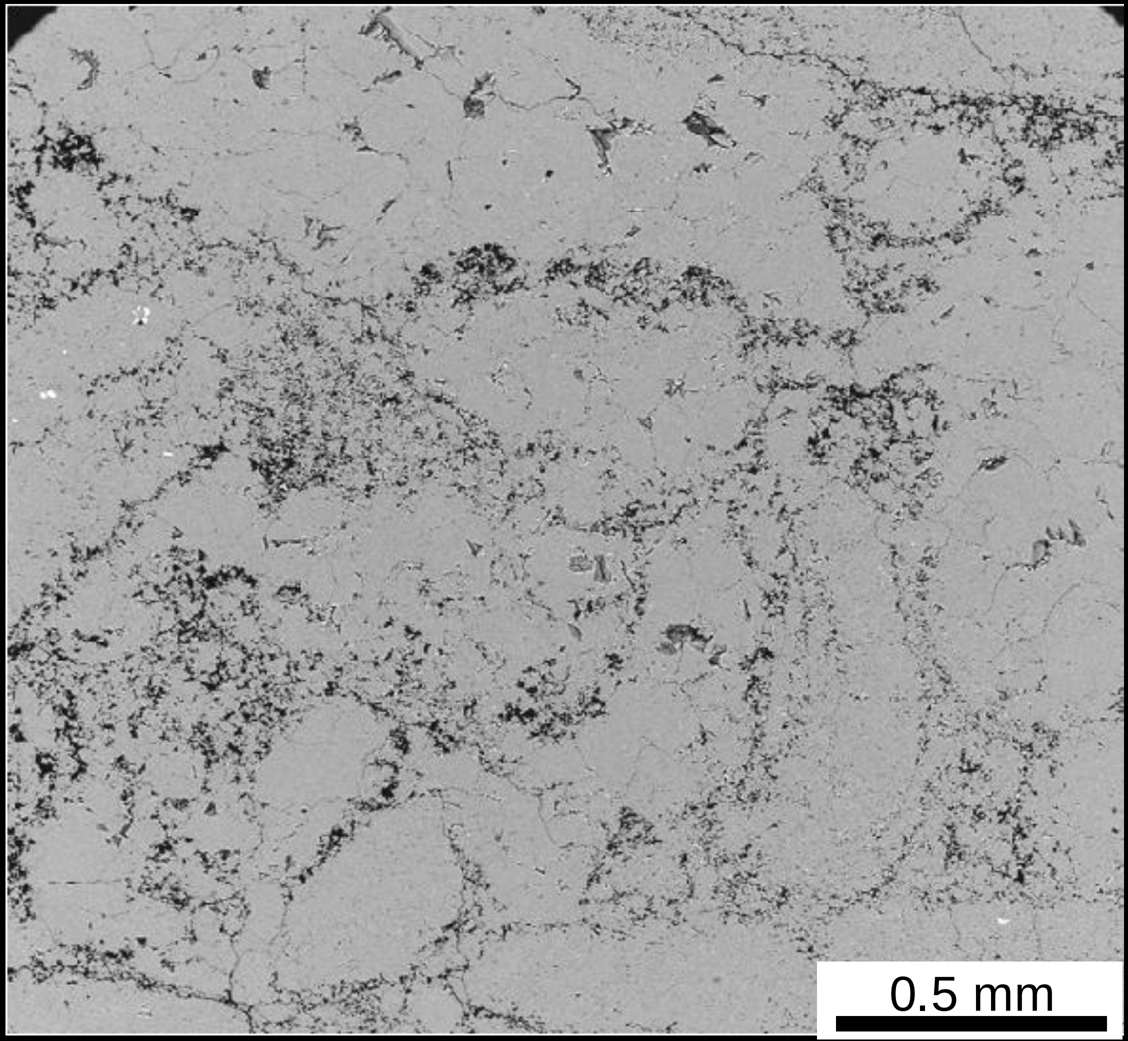
Simple definition: pore diameter <10 microns and/or pore-throat diameter <1 micron

Pore, pore throats, and micropore network



FSEM chip

Micropore Definition

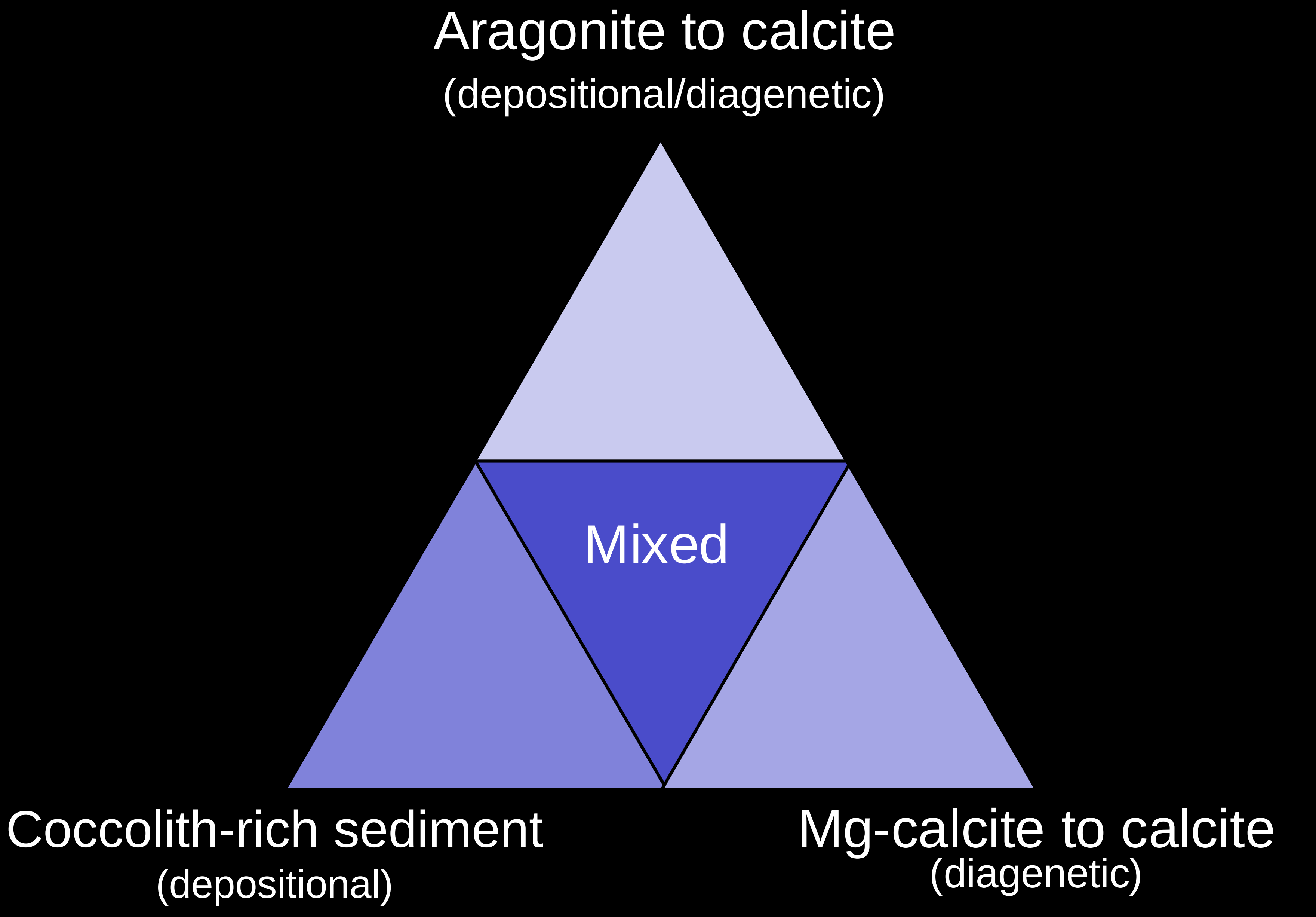


Lower Cretaceous, south Texas

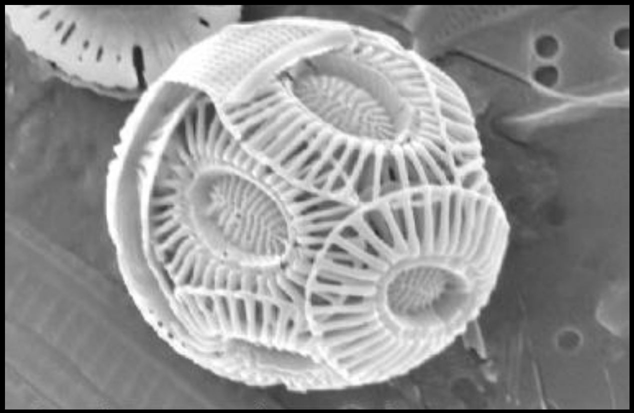
FSEM; polished thin section

Micropore-dominated pore network

General Micropore Types



Chalk (Coccolith) Micropores

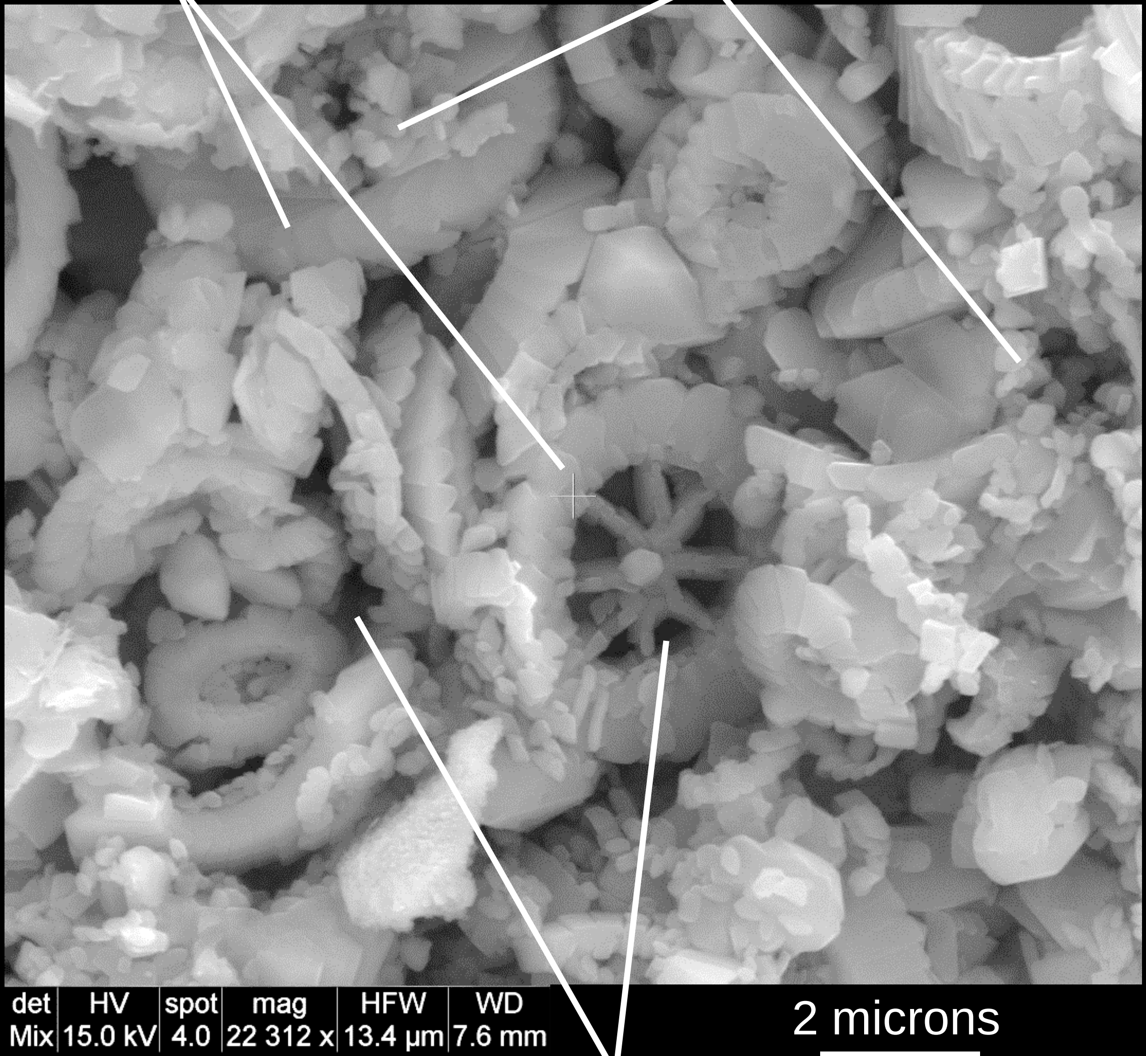


2 microns

Coccosphere (unicellular planktonic algae)

Partly held together by CAPs (coccolith-associated polysaccharides)

Mechanical compaction and bioturbation may aid in segmentation



FSEM chip

Aragonite Micropores

FSEM chip

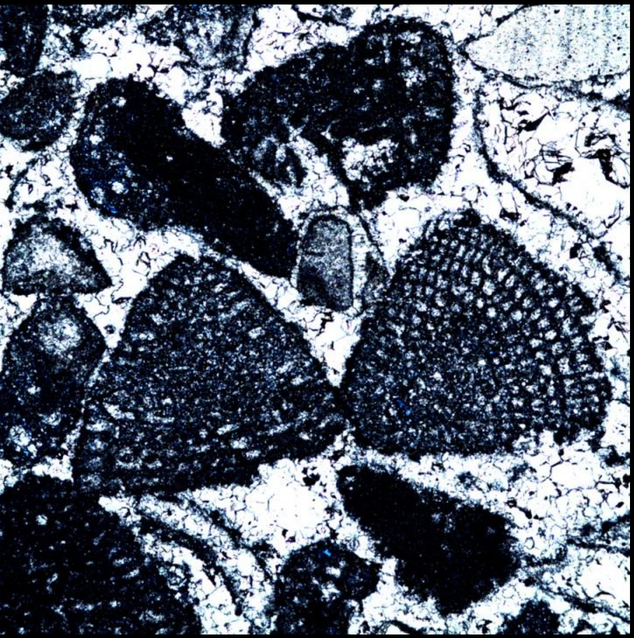
Aragonite needle
mud

FSEM chip

Lower Miocene
microcrystalline calcite
from Java Sea, Indonesia

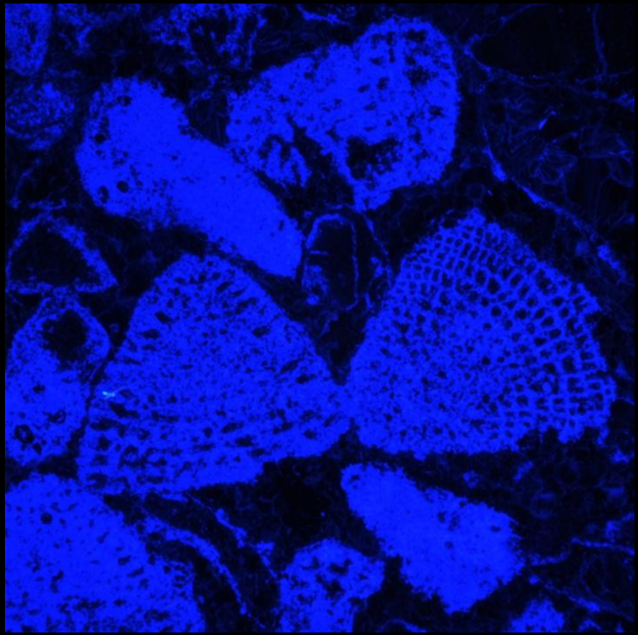
Mg-Calcite Micropores

Plain-light thin section



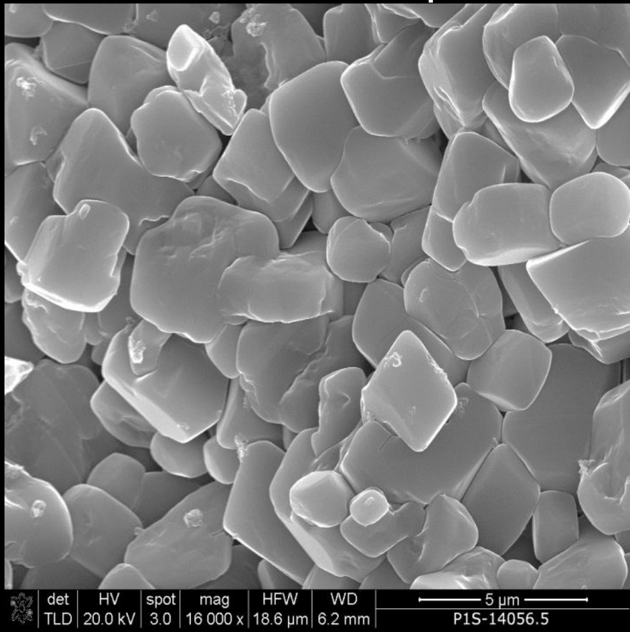
0.2 mm

Fluorescent blue-dyed thin section



0.2 mm

FSEM chip



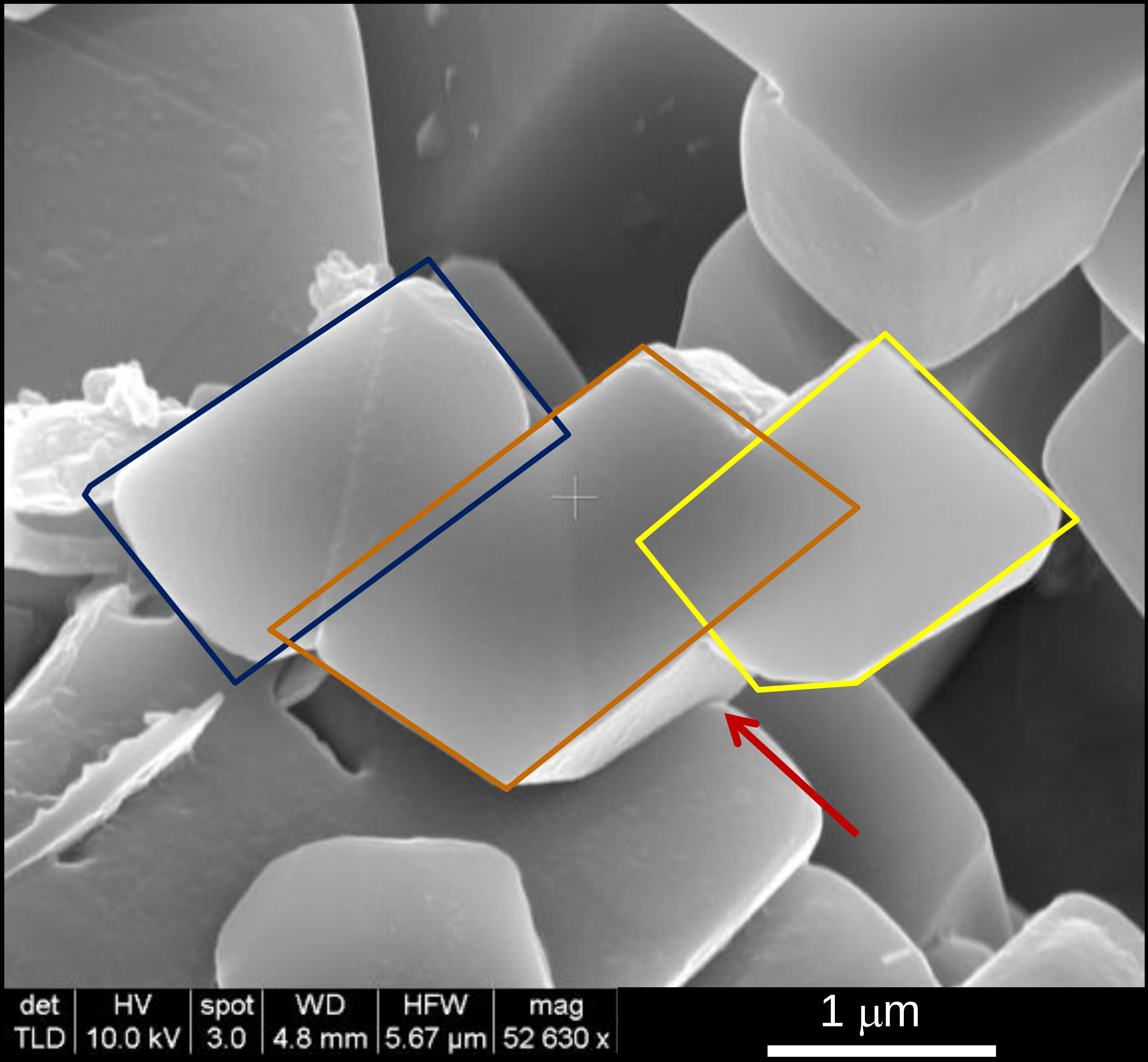
5 µm

<u>EXAMPLES</u>

Foraminifera
Red algae
Lithocodium
Stromatoporoids
Micrite envelopes
Mg-calcite mud

Transformation is a Dissolution/ Reprecipitation Process

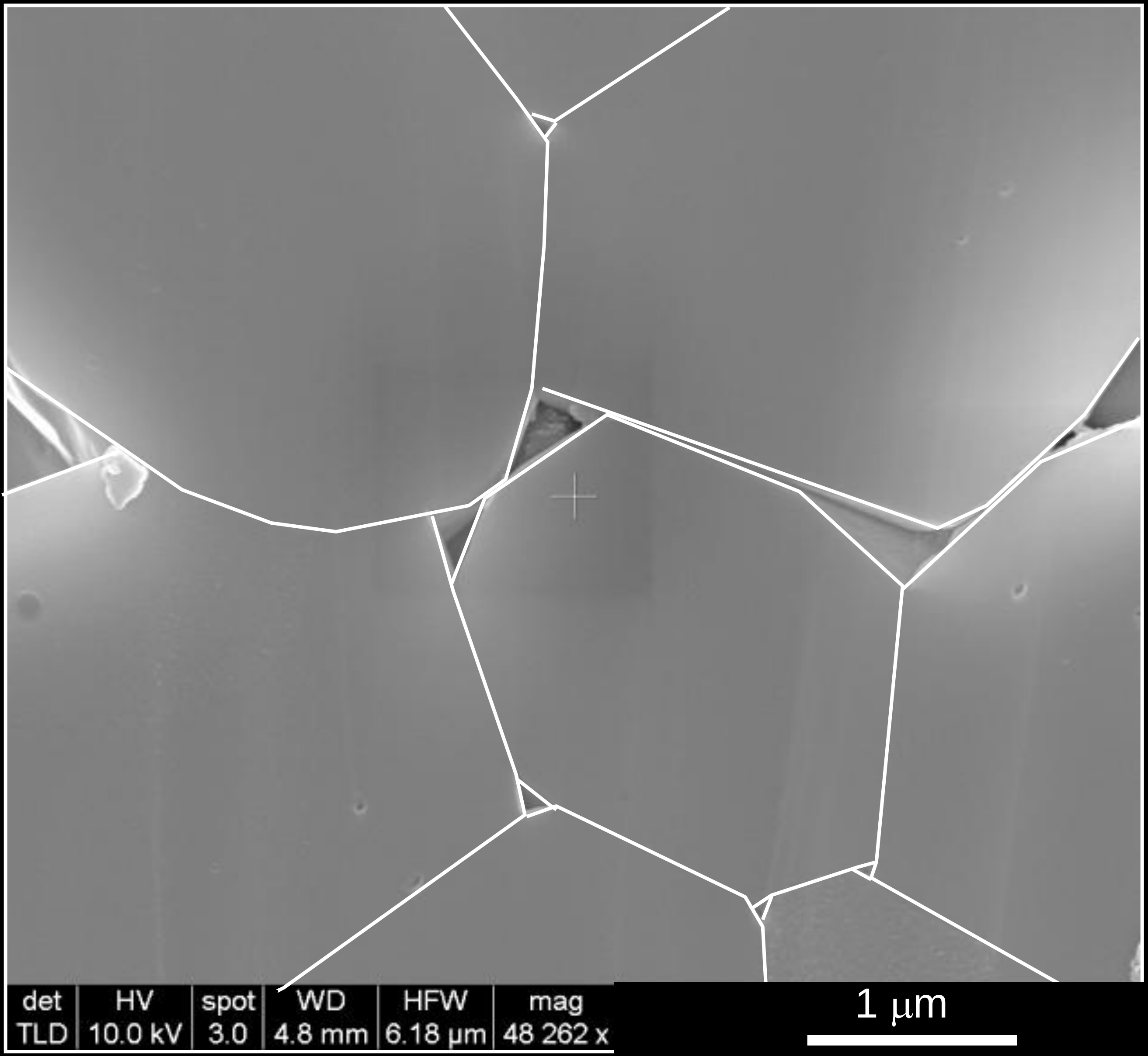
Grows competitively



FSEM ion-milled sample

Competitive Growth

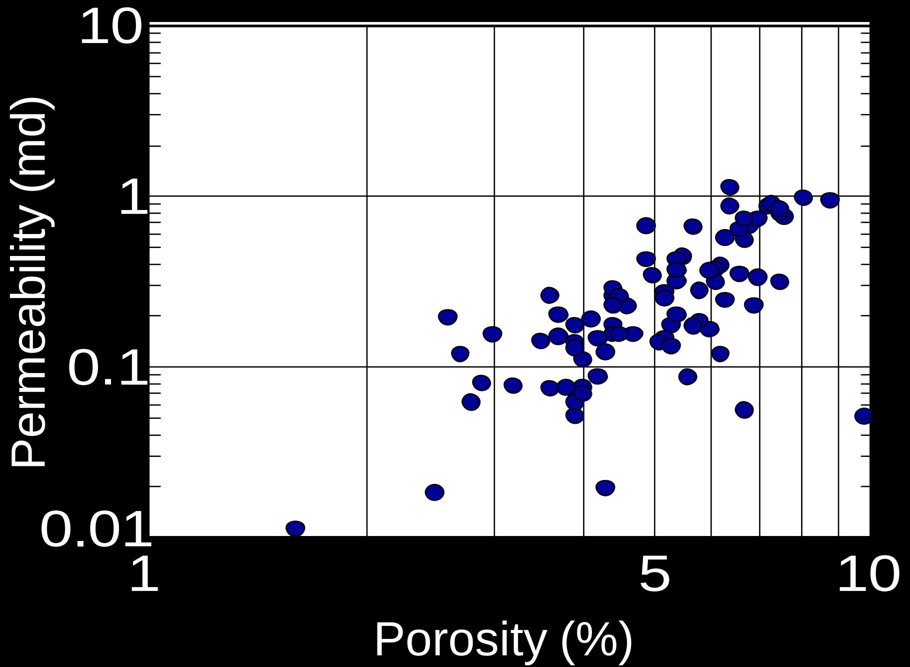
May become difficult to recognize

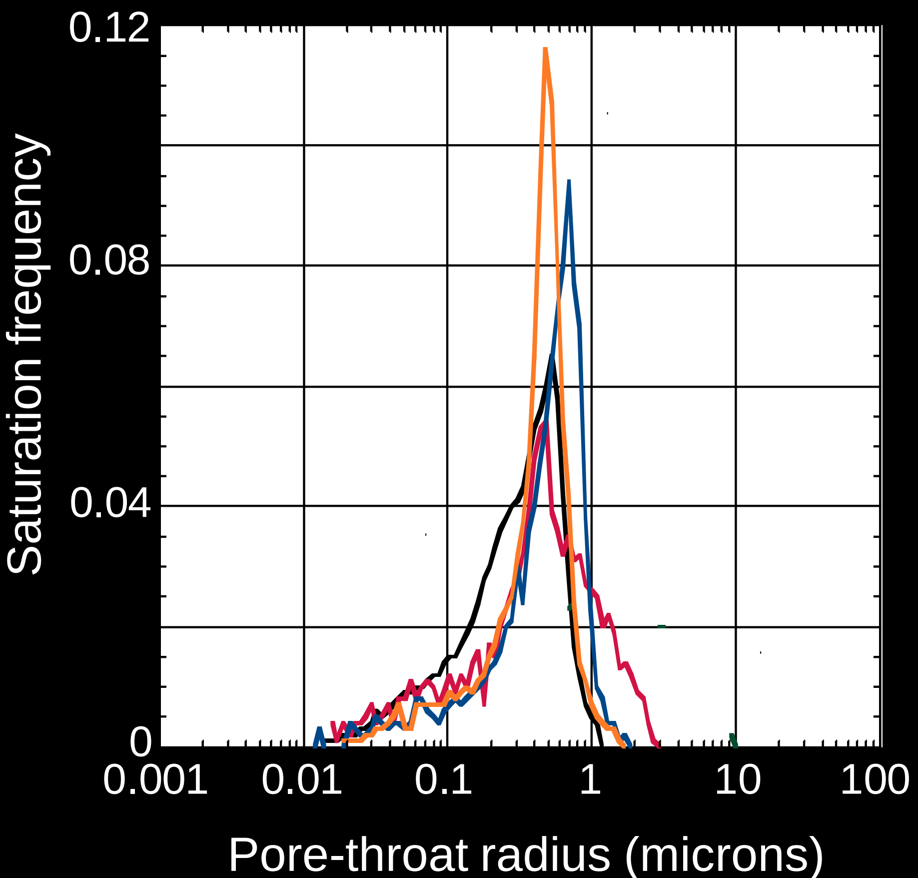


FSEM ion-milled sample

Example of Reservoir Quality

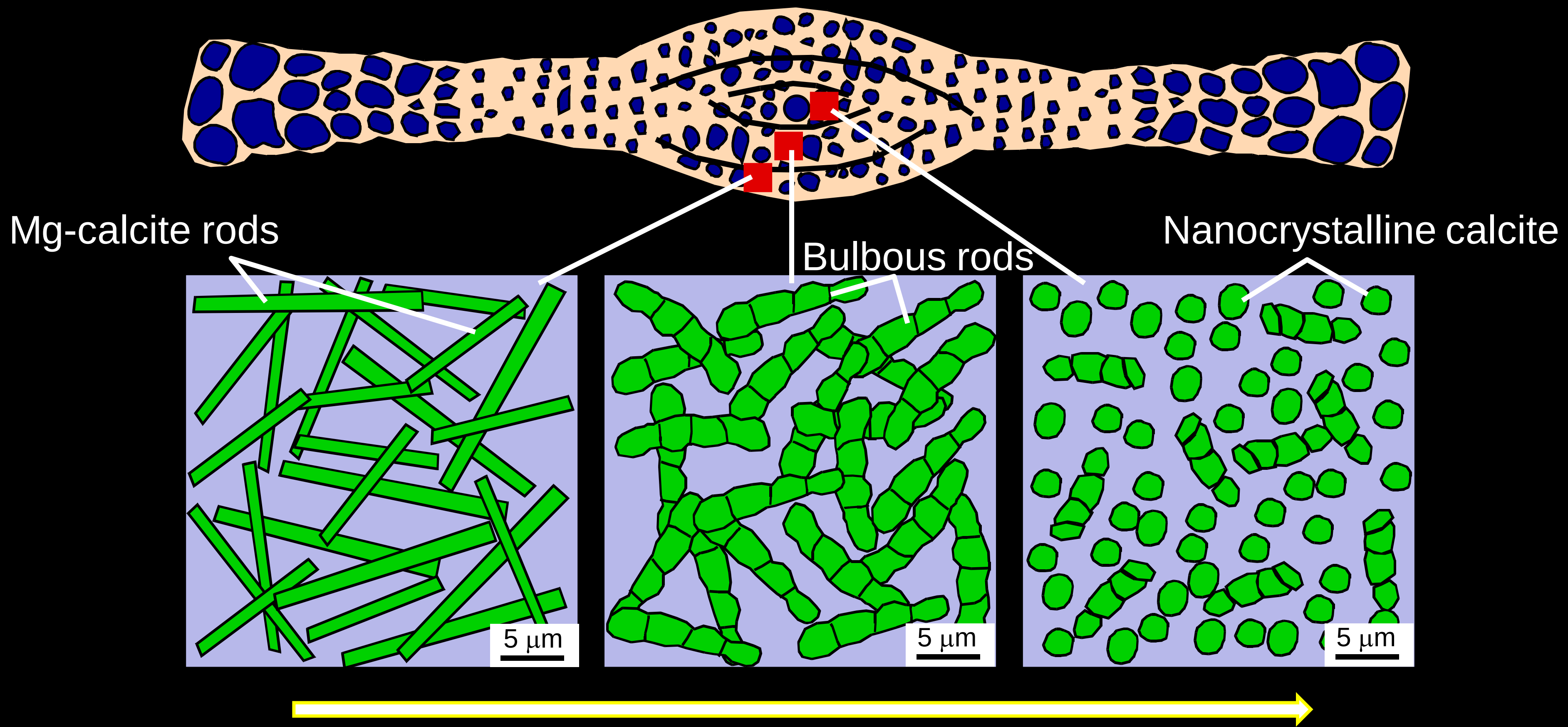
Lower Cretaceous Pawnee Field, Texas





How Does it Happen?

Contemporaneous Diagenesis of Living Foraminifera



Age of foraminifera increases

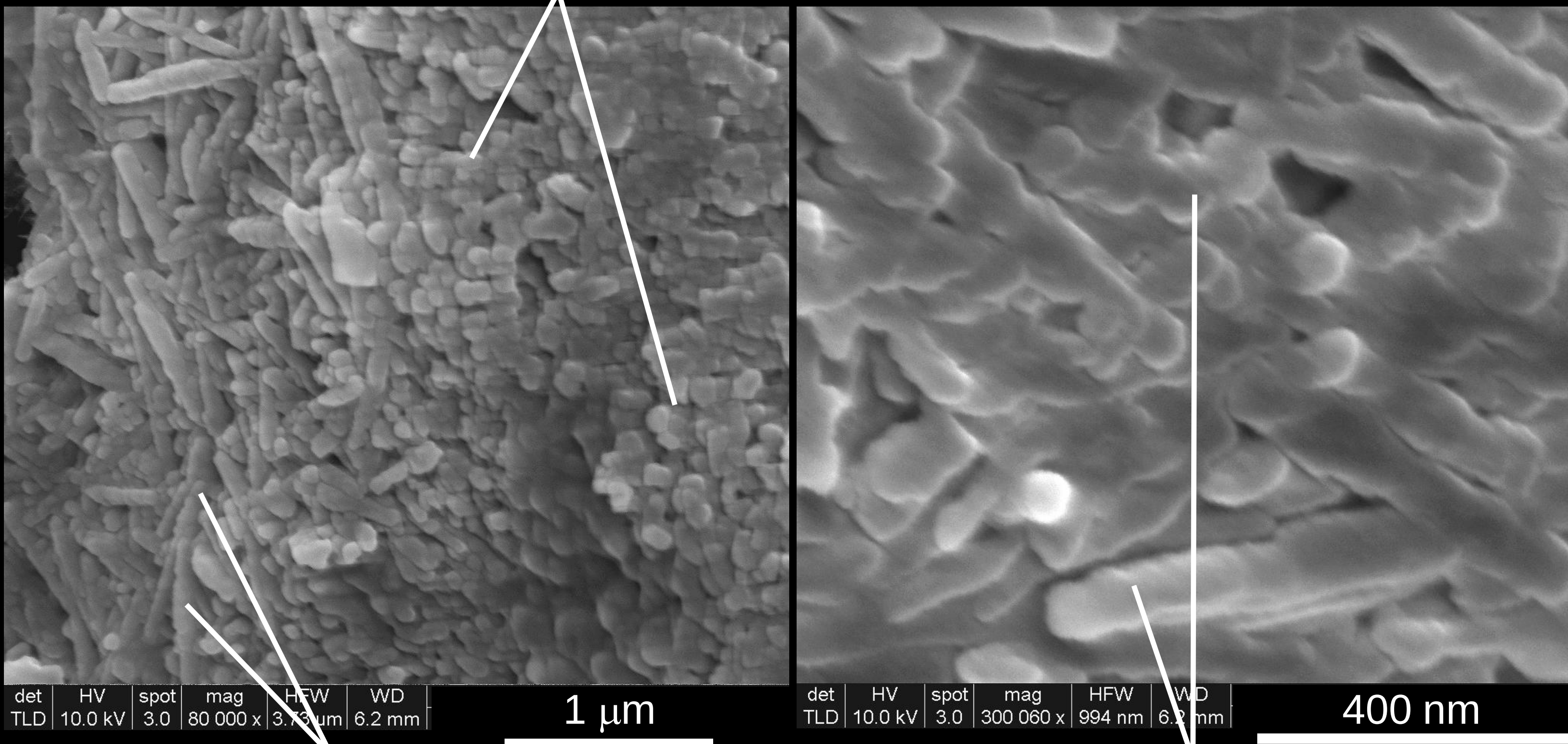
Based on work by Macintyre and Reed (1998)

Microstructure in Modern Forams

FSEM chip

Microcrystallites

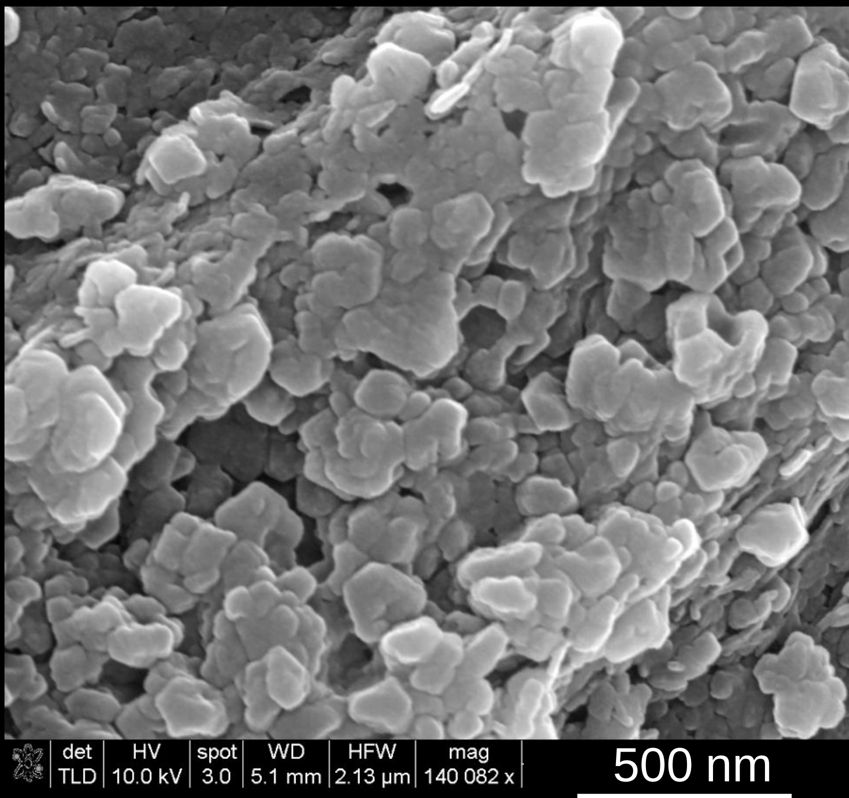
FSEM chip



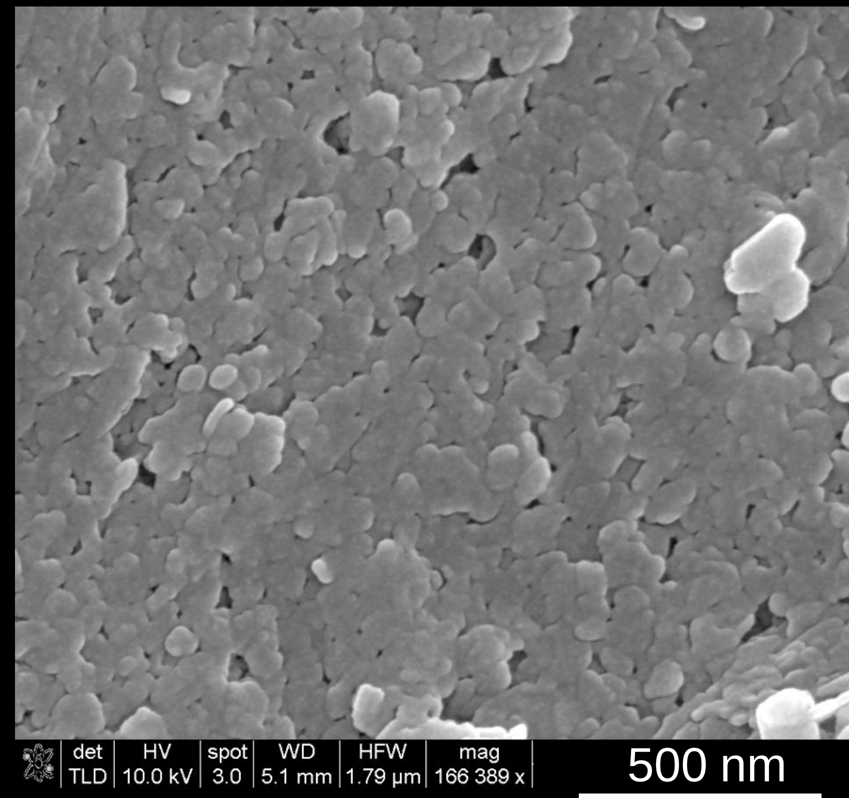
Rods transforming to microcrystallites

Rods transforming to microcrystallites

Microstructure in Modern Red Algae



FSEM chip

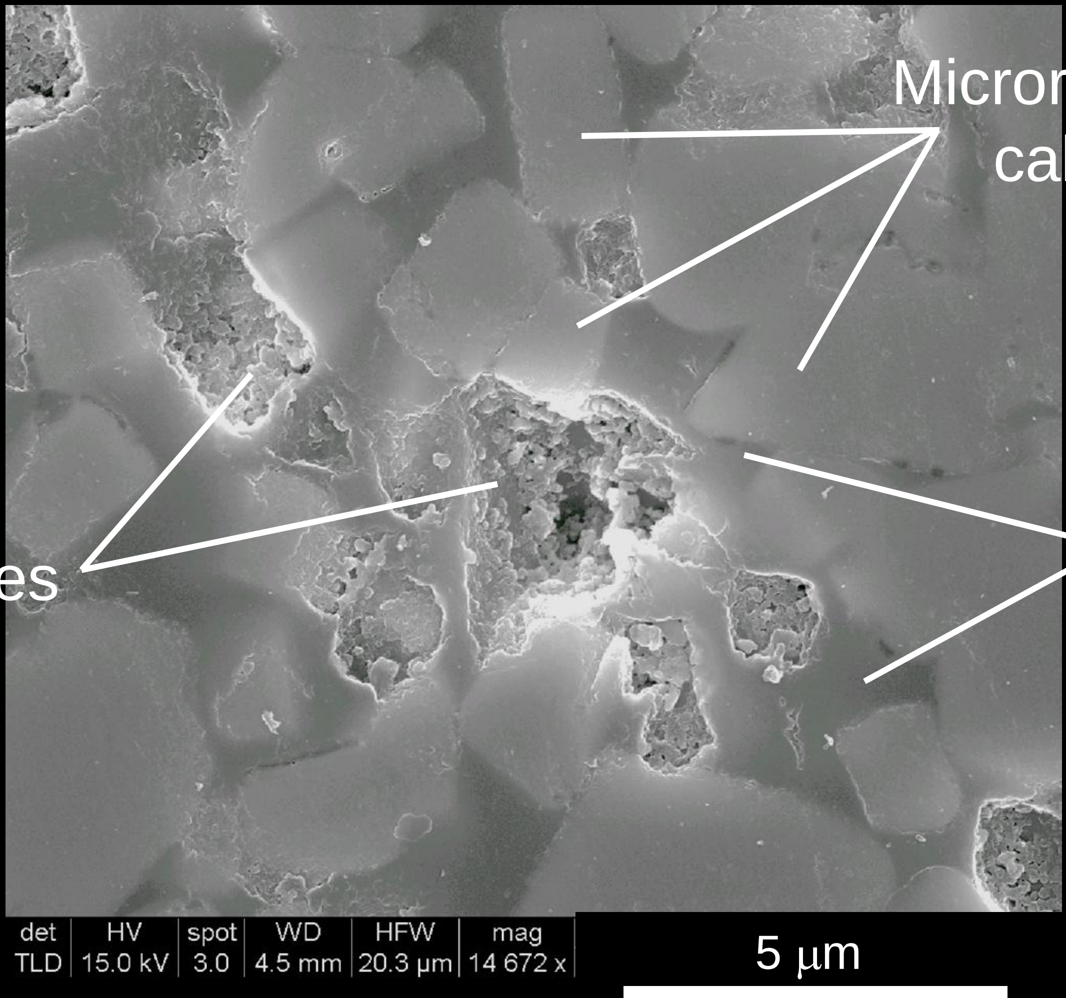


FSEM chip

Modern red algae
(*Goniolithon*)

Origin of Microrhombic Calcite

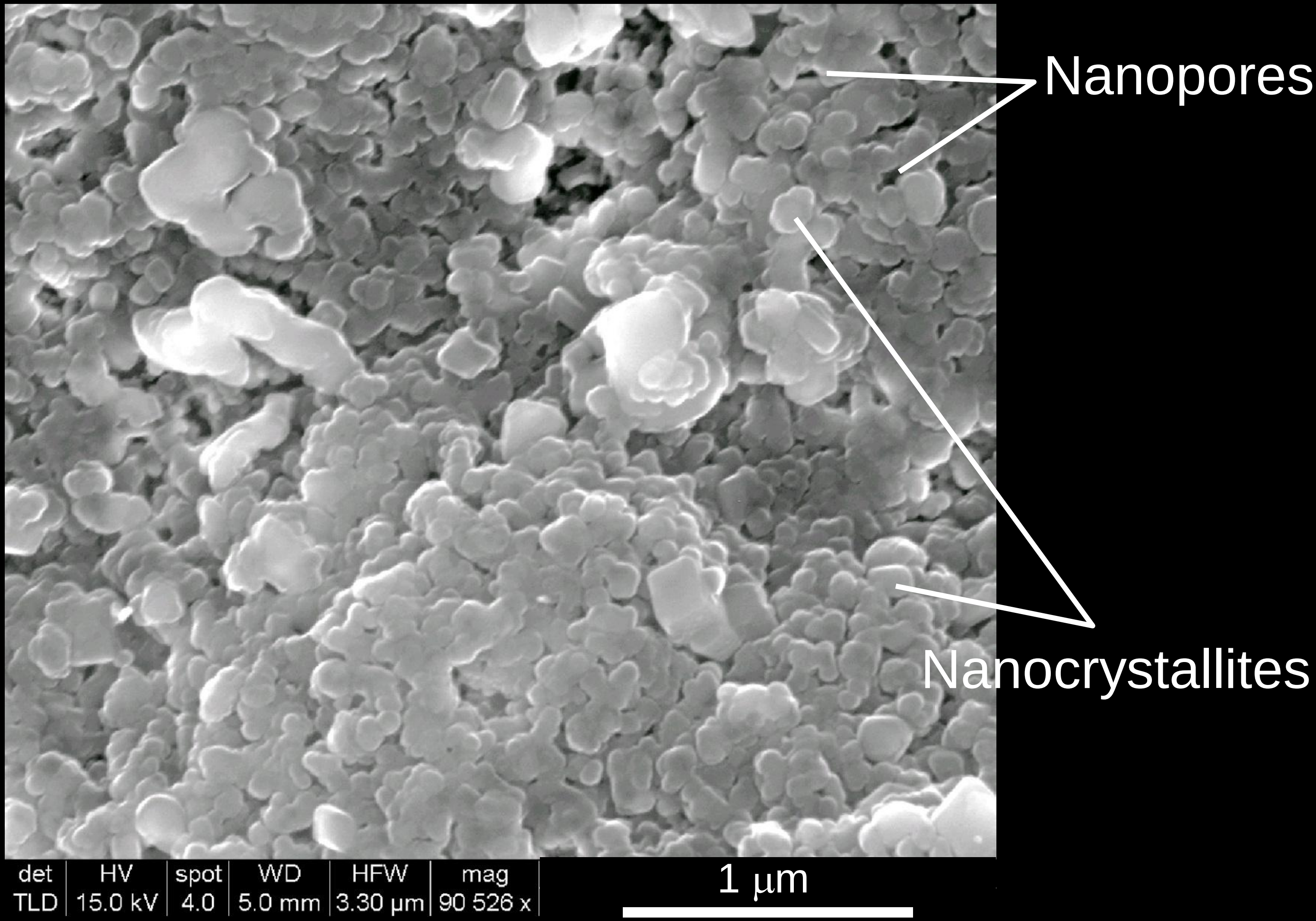
Lower Cretaceous Sample



FSEM polished thin section

Origin of Microrhombic Calcite

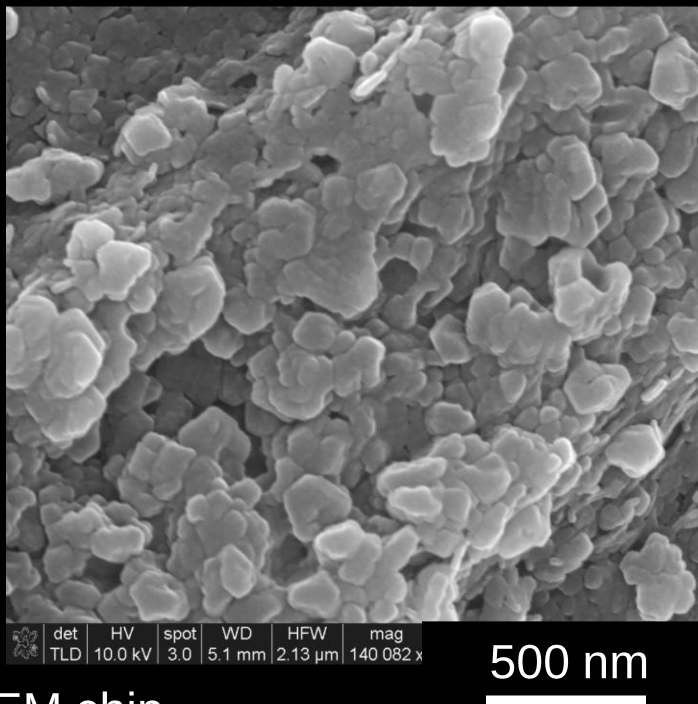
Lower Cretaceous Sample



FSEM polished thin section

Possible Origin of Microrhombic Calcite

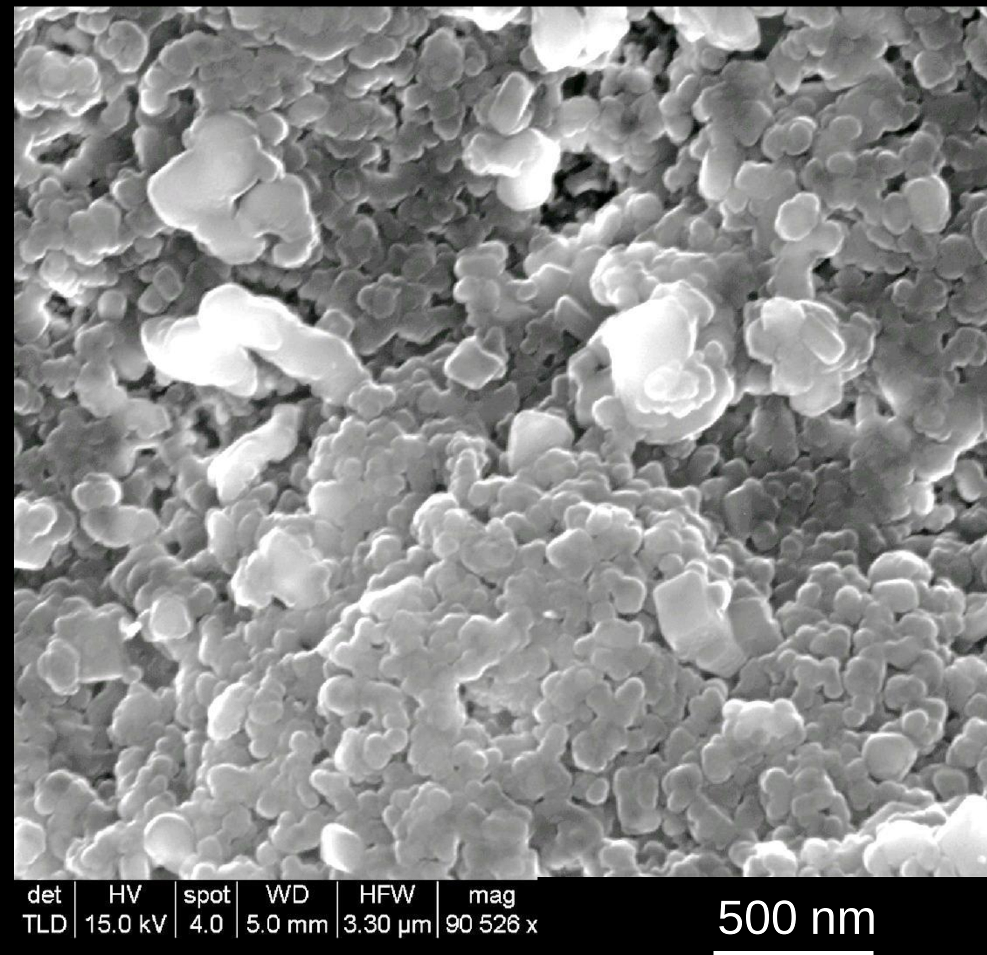
Modern



FSEM chip

Modern red algae
Goniolithon

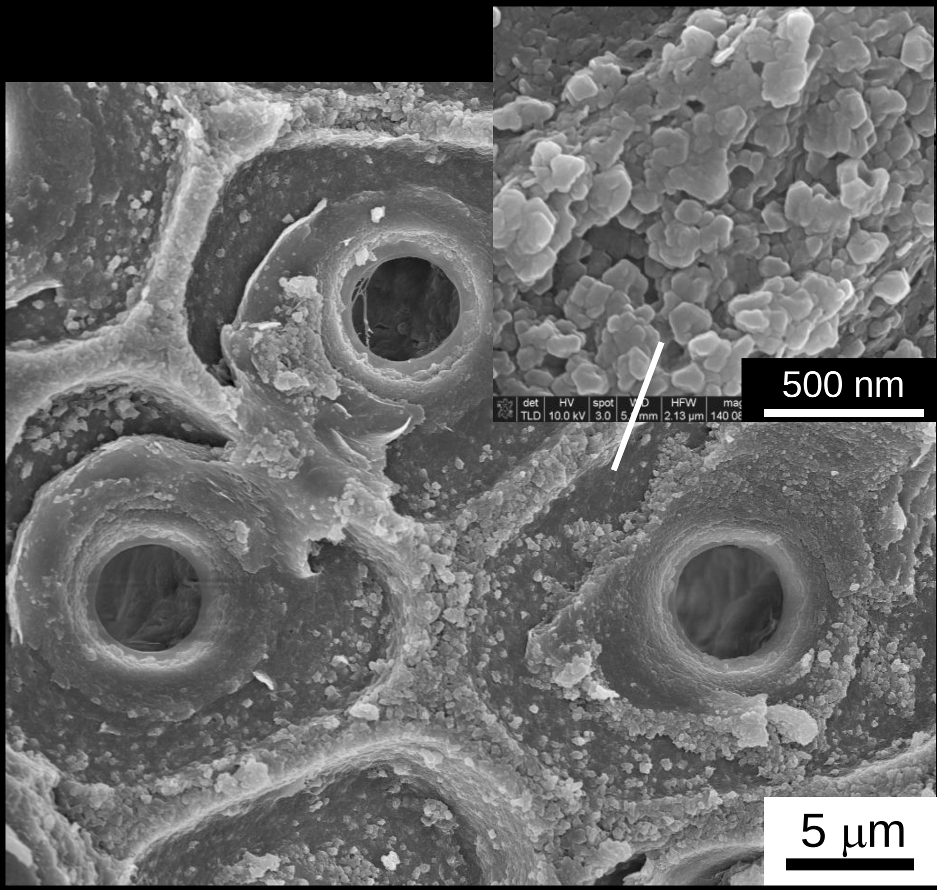
Ancient

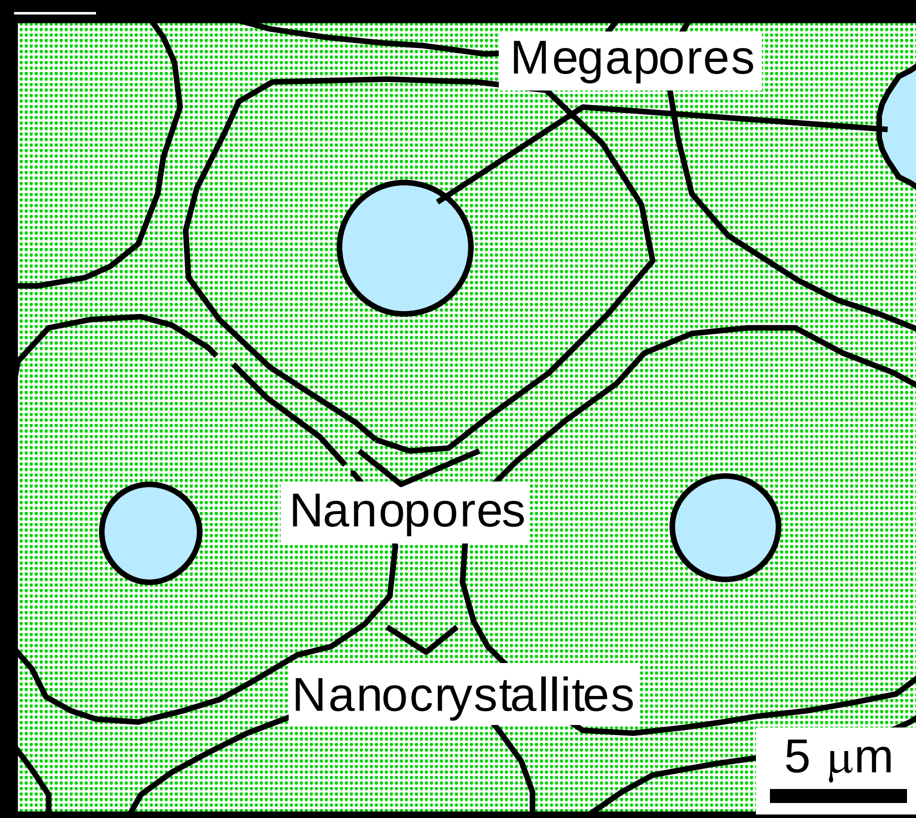


FSEM thin section

Lower Cretaceous

Stages of Mg-Calcite Transformation



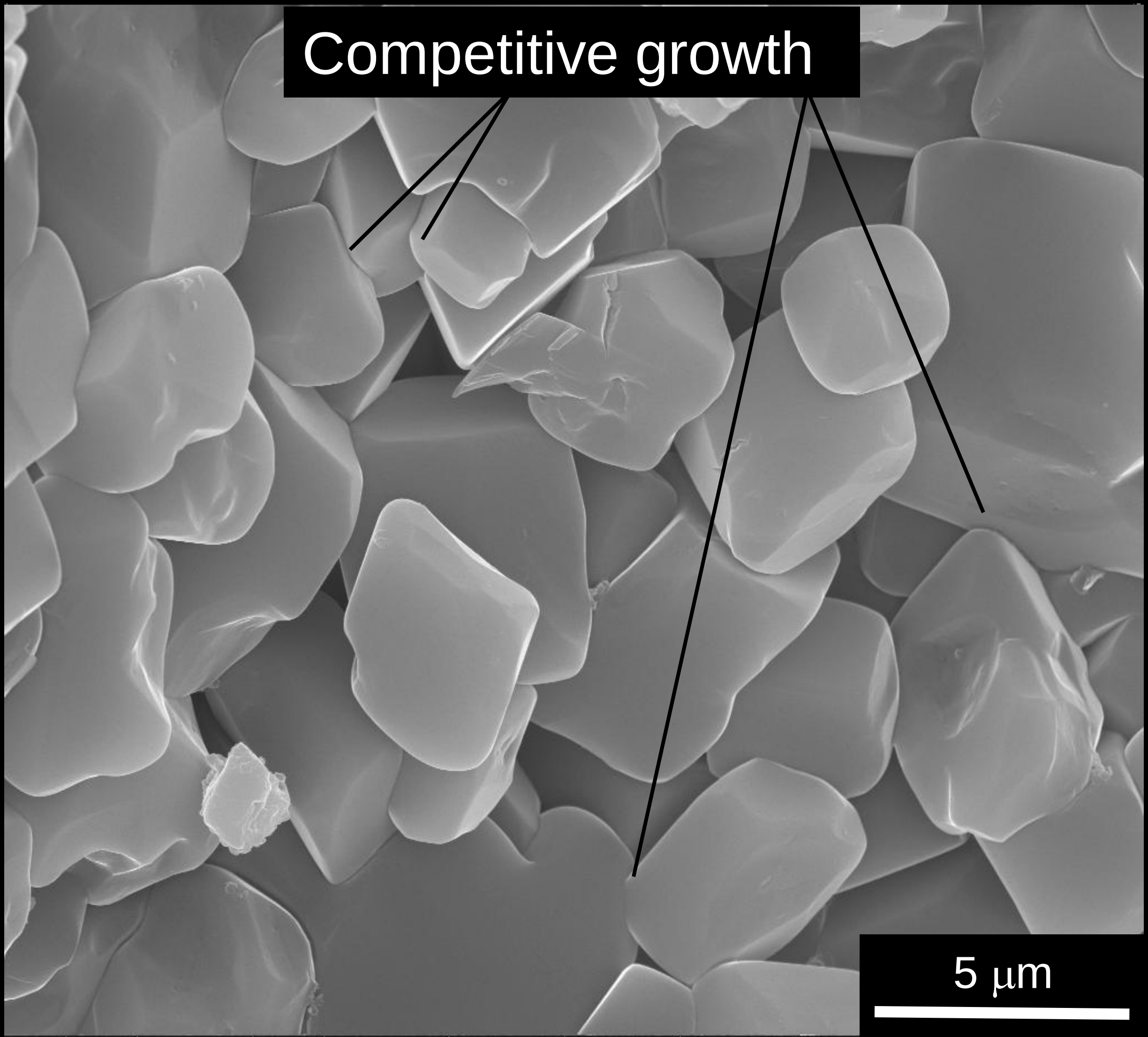


FSEM chip

Starting material

Goniolithon

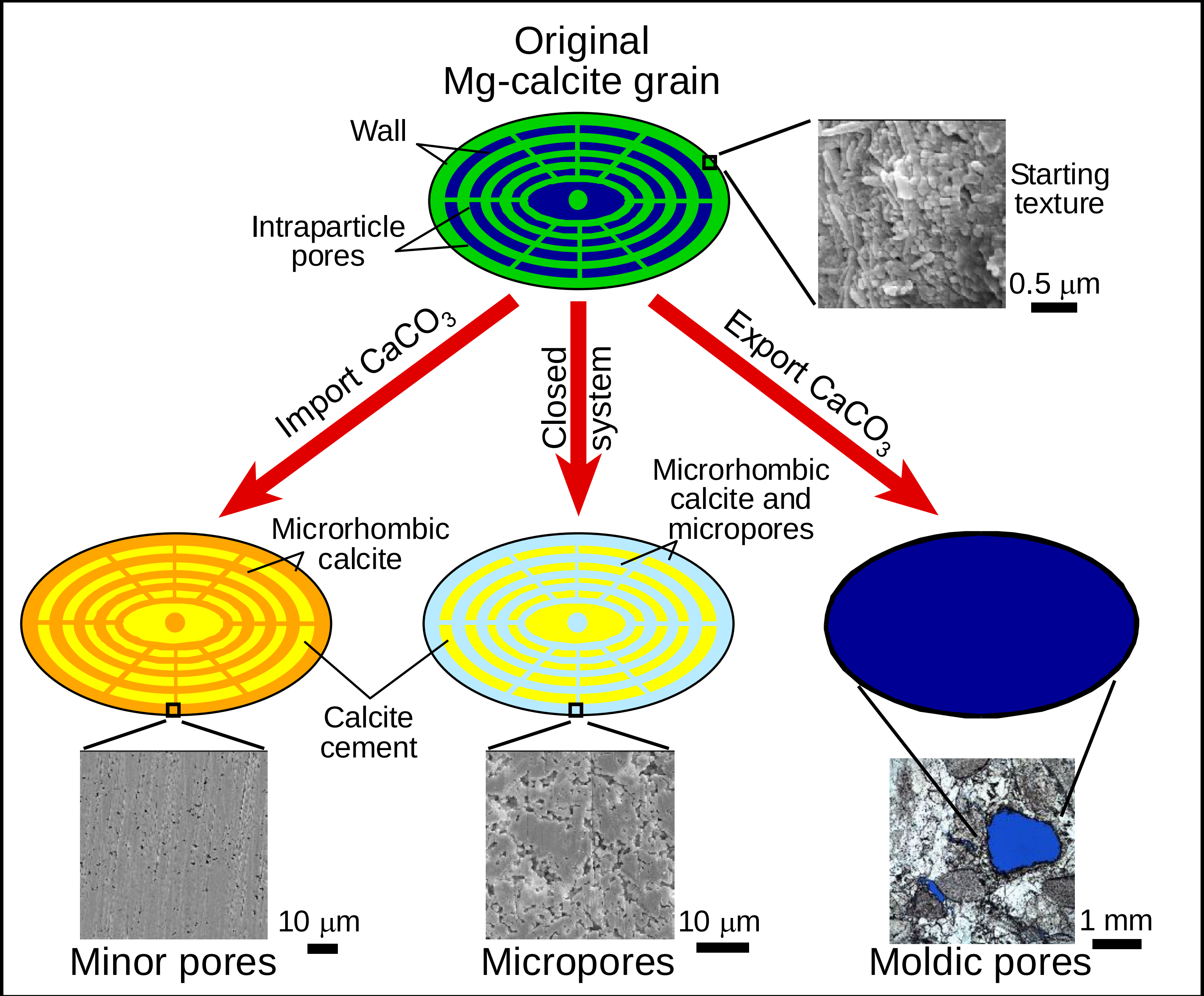
Stages of Mg-Calcite Transformation



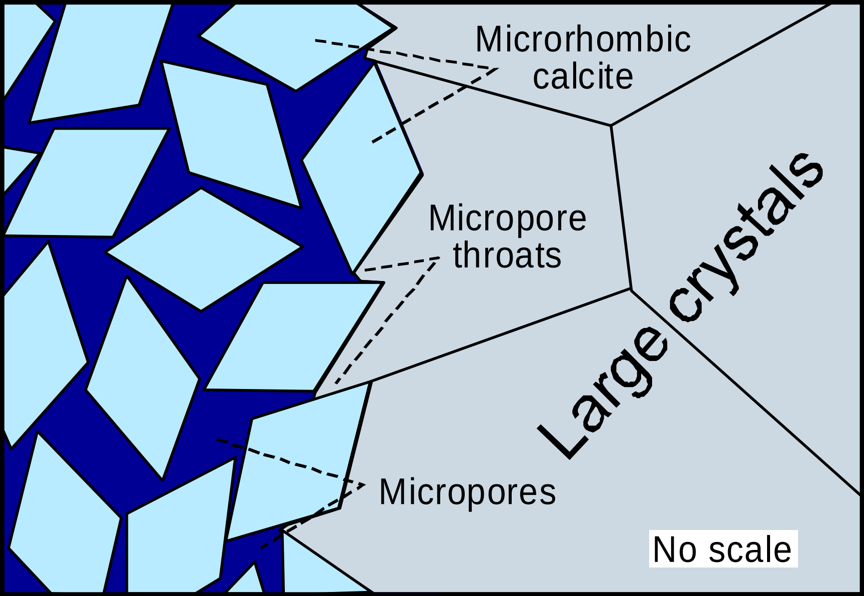
Suggestions about Transformation

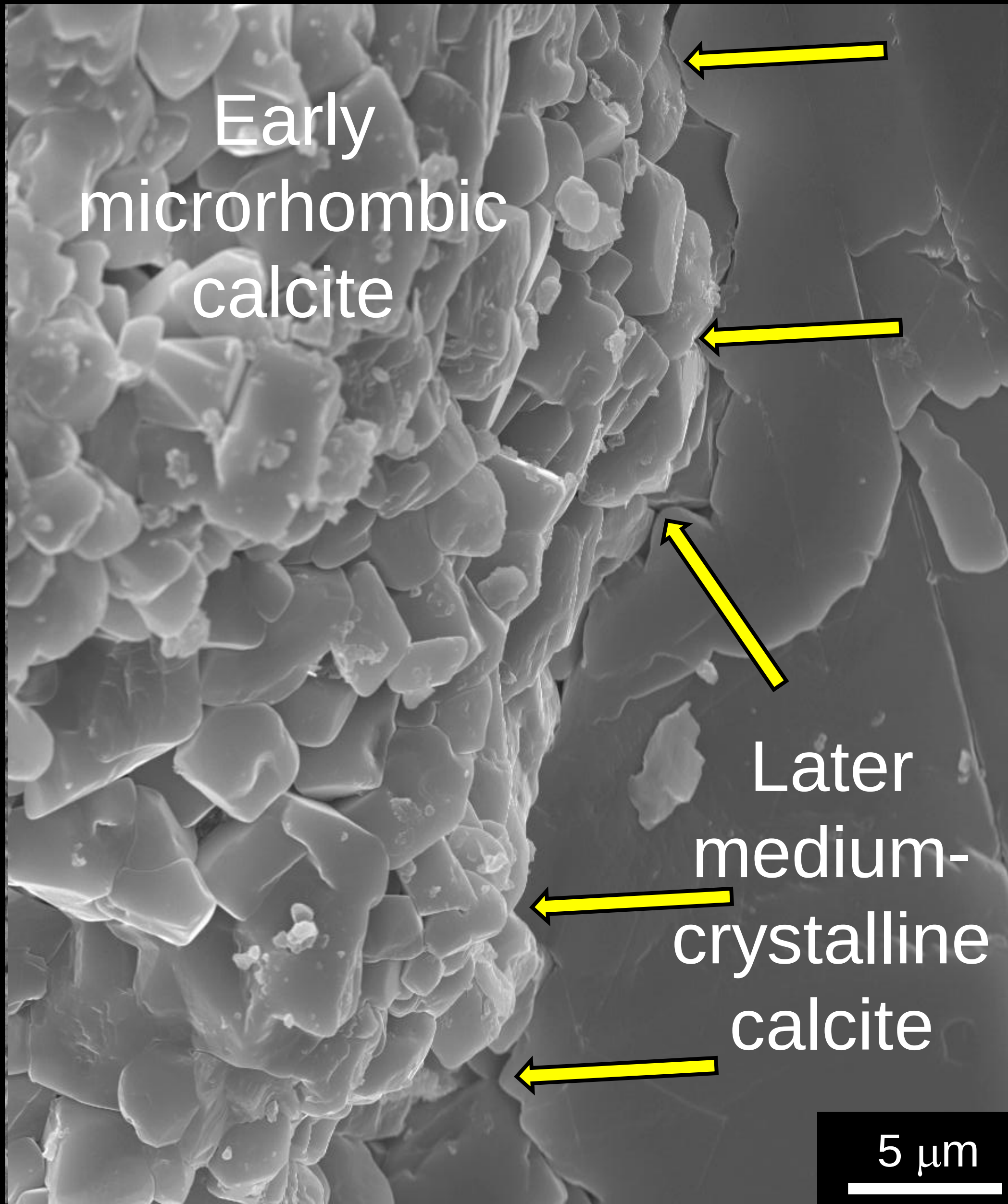
- Simple dissolution/reprecipitation process
- No special diagenetic fluids required
- Microrhombic calcite crystals absorbed chemical memory of host fluids

Mg-Calcite Stabilization



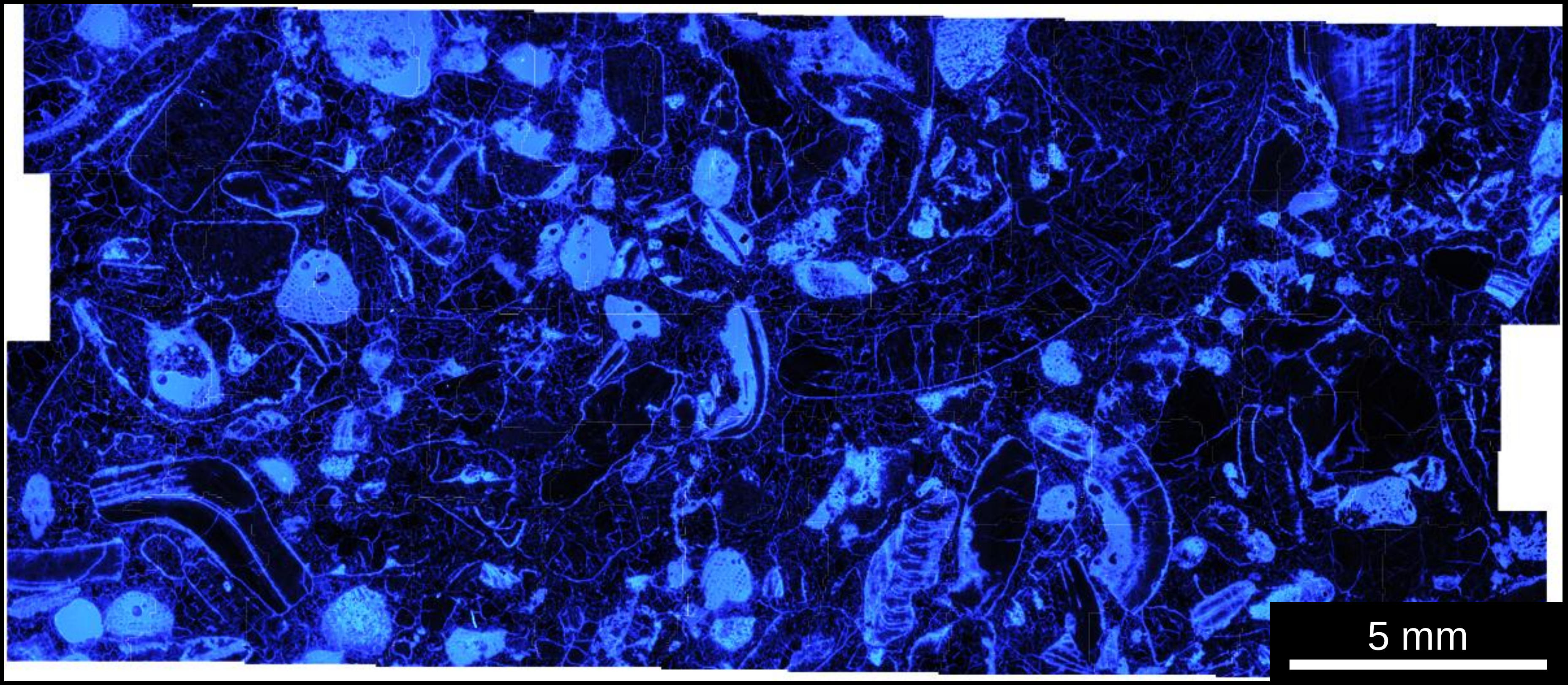
Burial Preservation





Lower Cretaceous Stuart City Limestone Micropore Network

Photomosaic of 50 blue-fluorescent photomicrographs



Light-blue is micropore network composed of pores in grains and micrite envelopes

Parting Thoughts

- Three general types of micropore reservoirs
- Different types of micropore reservoirs can have very different depositional settings and, therefore, different reservoir architecture
- Generally modest-quality reservoirs where micropores are sole pore type
- Micropores may be last pores occluded with burial

Thank You!