Origin and Characterization of the Nanopore/Micropore Network in the Leonardian Clear Fork Reservoirs in the Goldsmith Field in Ector Co., Texas*

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Abstract

The Goldsmith Clear Fork field was discovered in 1946 and has produced over 300 million barrels of oil from a thick carbonate section dominated by anhydritic dolomite with lesser limestone. Reservoir quality is low to moderate with a mixed pore network of interparticle and moldic megapores along with intercrystalline nanopores and micropores. The AMOCO #234 Goldsmith core was selected as the type core to define the origin of dolonanopores and dolomicropores and their characteristics. In thin section these pores are seen occurring in patches of the matrix, in peloids and clasts, and in fossils. These occurrences are similar to some examples of micropores networks observed in limestones. As seen on the SEM using Ar-ion milled samples, the nano- and micropores occur between crystals of dolomite that are euhedral and generally range in size from <400 nanometers to 5 micrometers. The crystals are poorly sorted relative to size. In general the pores are triangular in shape because they are positioned between euhedral crystals. The pores range from 20 nm to a few micrometers. Submicrometer diagenetic illite flakes commonly form in the pores further subdividing the pore. The nano-to microsized dolomite formed by replacement of matrix and grains and by precipitation into pore spaces. The resulting pore networks are quite varied. As an example, where the dolomite replaced former calcite microrhombic grains with associated micropores, the nano- and micropores mimic the former calcite micropore network. This is interpreted as a replacement process of microcrystalline rhombic calcite. In some fine peloidal dolopackstones, the peloids are replaced by a dense network of dolomite crystals with some triangular nanopores still present, while in the interpeloidal pores, some nano- to microdolomite crystals precipitated. The interpeloidal pores are small but appear to form a fair connected pore network. The porosities in the studied core are generally less than 15% and permeabilites

are generally less than 10 md with most values less than 1 md. The recognition of nano- and micropores is important because they can be a major contributor to total porosity, while adding little to permeability. They also may affect reservoir saturation in that the megapores may be saturated with hydrocarbon whereas the finer pores are filled with water. Therefore, the quantity of nano- and micropores must be taken into consideration when calculating flow rates and field-wide reserves.

References Cited

Kerans, C., and Ruppel, S. C., 1994, San Andres sequence framework, Guadalupe Mountains: Implications for San Andres type section and subsurface reservoirs, *in* R.A. Garber, and D.R. Keller, editors, Field Guide to the Paleozoic Section of the San Andres Mountains: Permian Basin Section—SEPM (Society for Sedimentary Geology) Publication No. 94-35, p. 105–115.

Loucks, R.G., F.J. Lucia, and L.E. Waite, 2013, Origin and description of the micropore network within the Lower Cretaceous Stuart City Trend tight-gas limestone reservoir in Pawnee Field in South Texas: GCAGS Journal, v. 2, p. 29–41.

Ruppel, S.C., and E. Ariza, 2002, Cycle and sequence stratigraphy of the Clear fork reservoir at South Wasson Field, Gaines County, Texas, *in* F.J. Lucia, editor, Integrated Outcrop and Subsurface Studies of the Interwell Environment of Carbonate Reservoirs: Clear Fork (Leonardian-Age) Reservoirs, West Texas and New Mexico: Final Technical Report for U.S. Department of Energy, Bureau of Economic Geology, The University of Texas at Austin, p. 59-94.

2015 AAPG Annual Meeting

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Reservoir Characterization Research Laboratory

Presenter's notes: New global energy--Very different than carbonates and sandstones. Need to understand basic insights into geology to explore and develop these unconventional resources.

Major Concept

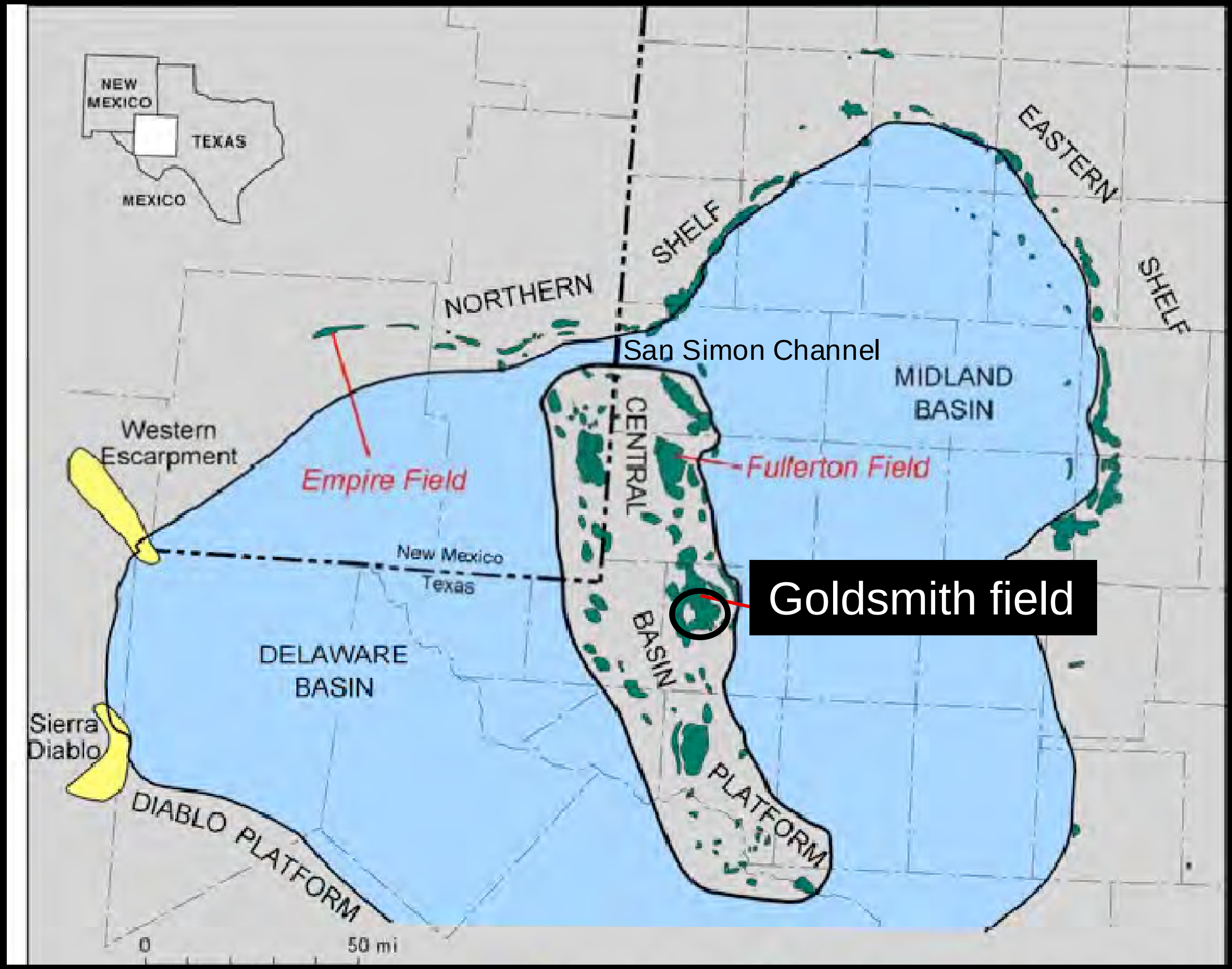
- Recognition of nano- and micropores is important as these pores can be a major contributor to total porosity, while adding little to permeability.
- Affects reservoir saturation calculations in that the megapores may be saturated with hydrocarbon whereas the micropores are filled with water.
- Therefore, the quantity of nano- and micropores must be taken into consideration when calculating flow rates and field-wide reserves.

Presenter's notes: Best way to understand unconventional resources is to look at systems.

Objectives

- Present the general depositional setting and associated lithofacies
- Define Clear Fork nanopores and micropores in both limestones and dolostones
- Provide origins for the three main types of dolomite-related nanopores and micropores
- Review general reservoir quality

Location and Regional Setting



50 mi

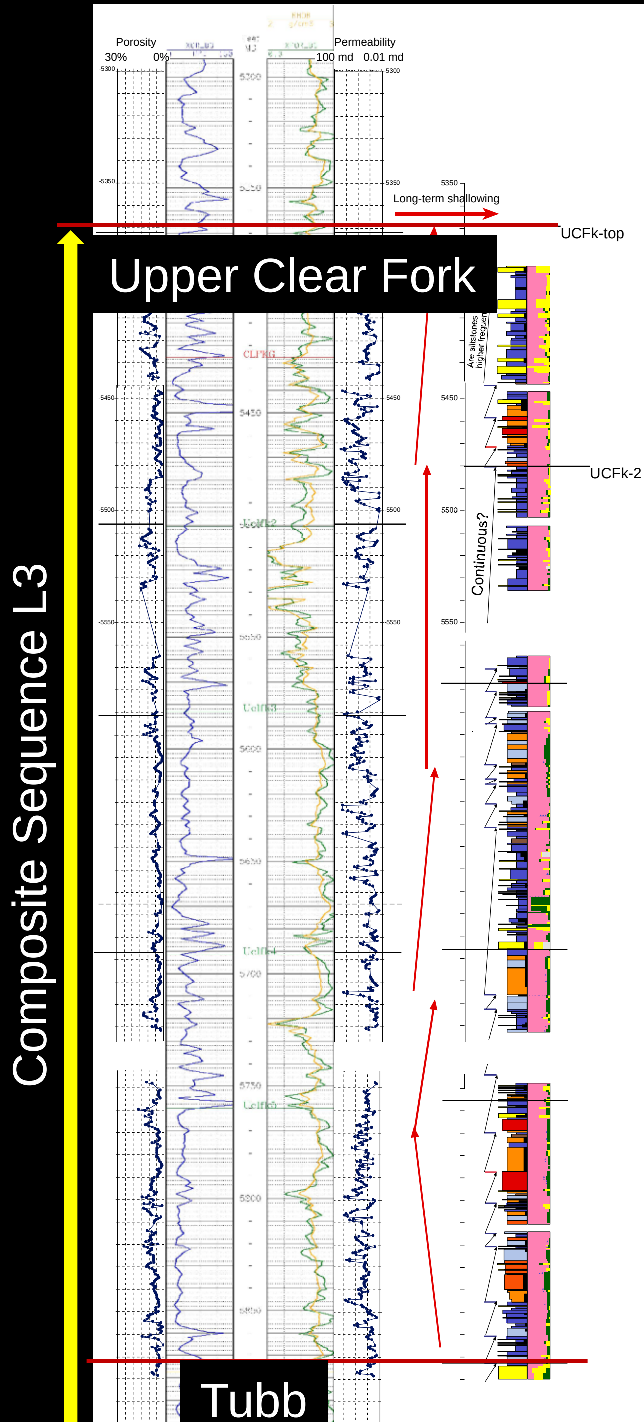
- The Goldsmith field in on the interior of the Central Basin Platform

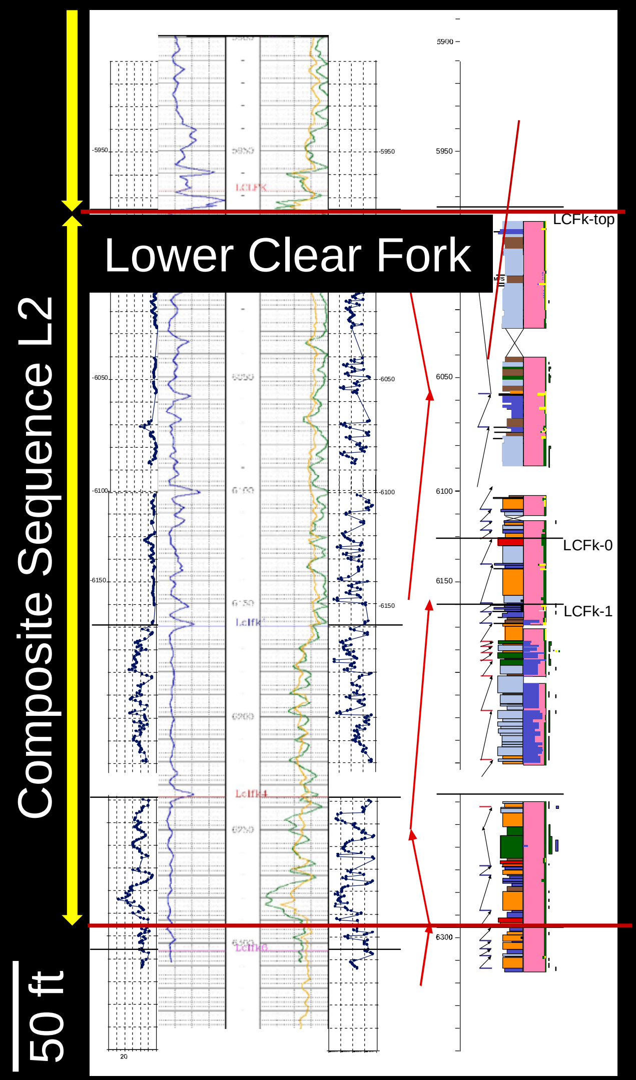
Stratigraphy

Series	Stage	Suburface					
		Central Basin Platform				Northern Shelf	
		New Mexico		Texas			
Lower Permian		San Andres		San Andres		San Andres	
	Leonardian	Glorieta		Glorieta		Glorieta	
		Yeso	Paddock	Upper Clear Fork	Clear Fork Group	Upper Clear Fork	Clear Fork Group
			Blinebry			Middle Clear Fork	
			Tubb	Tubb		Tubb	
			Dinkard	Lower Clear Fork		Lower Clear Fork	
		Abo		Abo	Wichita Group	Abo	Wichita Group
		Wolfcamp		Wolfcamp		Wolfcamp	

Ruppel (2002)

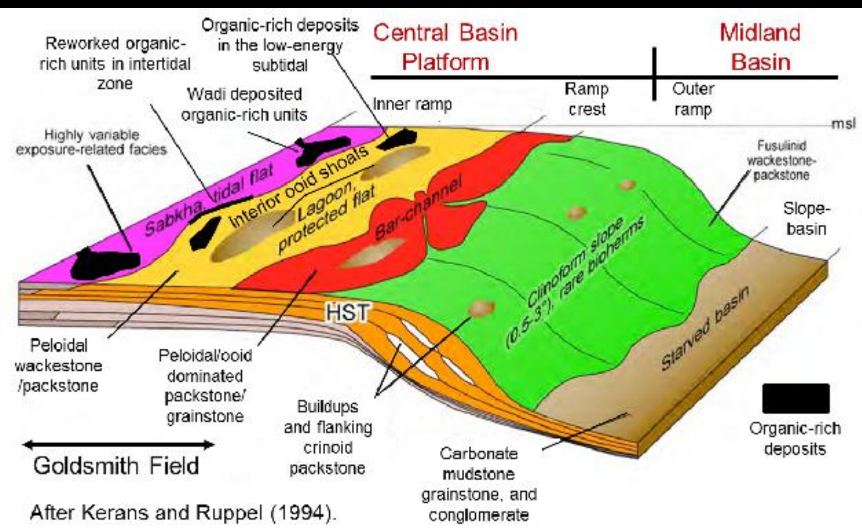
Core Description
Amoco #234 GLDU





- 900 ft of secton
- Transition icehouse to greenhouse
- Numerous higher order cycles; both tidal-flat capped and subtidal capped
- According to Ruppel (2002) Clear Fork is comprised of two composite sequences
- Only the lower fifth of the section contains limestone; rest of section is dolostone

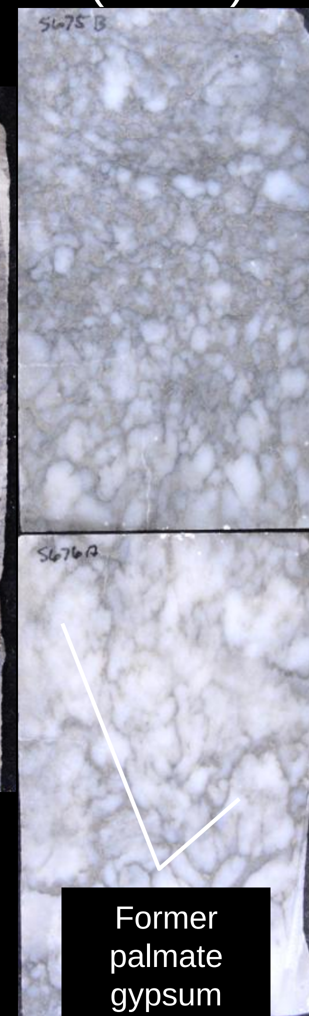
Depositional Environments



Algal stromatolite

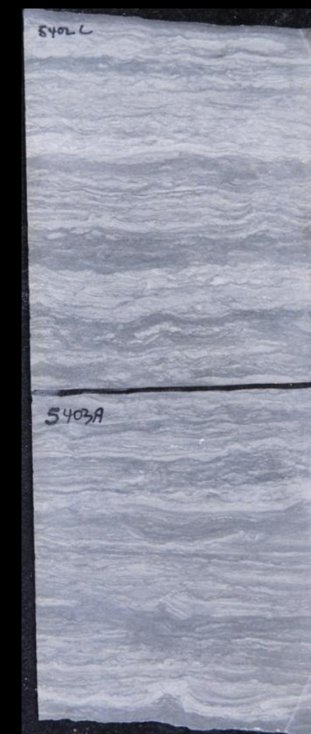
4 in

Palmate anhydrite (salina)



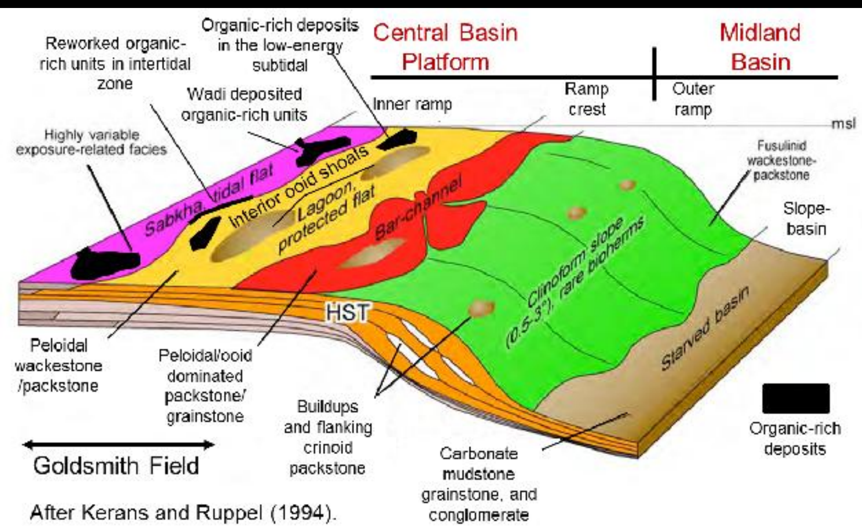
4 in

Algal-laminated terrigenous siltstone

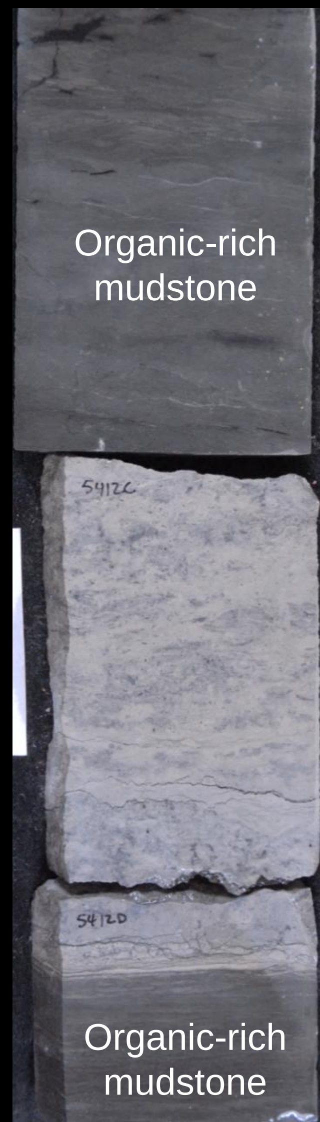


4 in

Depositional Environments



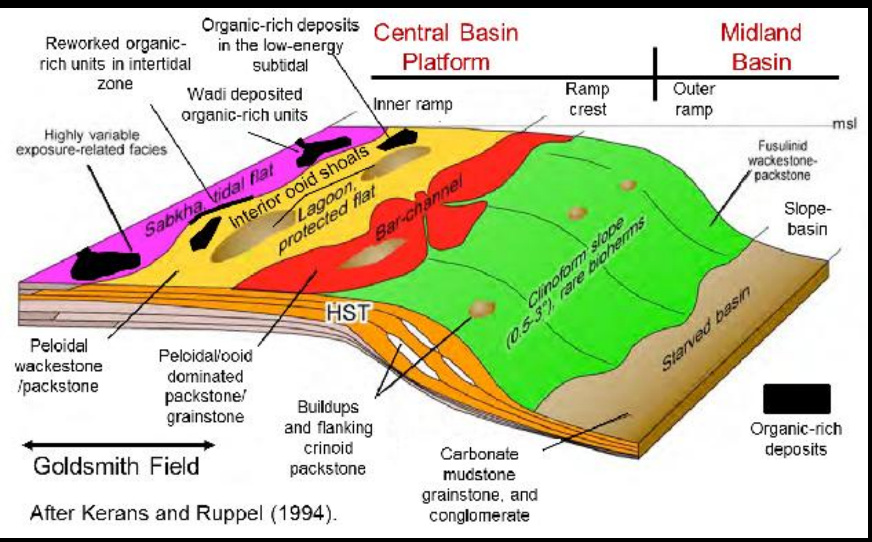
Organic mudstone



Low- to moderate-energy, burrowed peloidal dolopackstone

Moderate energy, skeletal dolopackstone

Depositional Environments



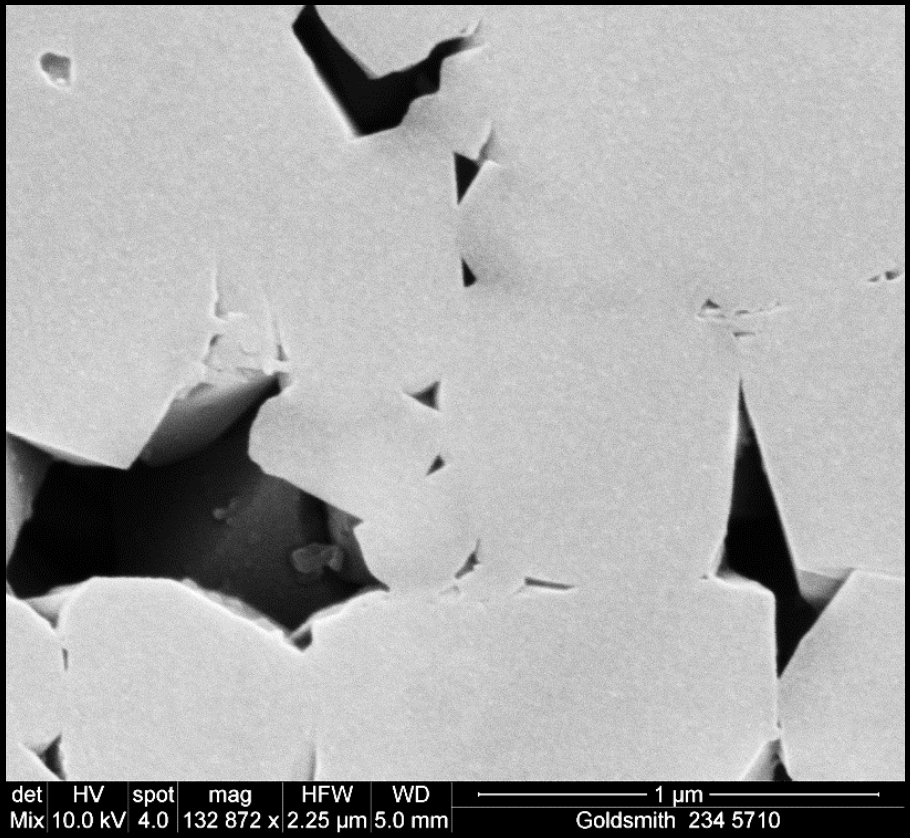
High-energy, cross-bedded peloids ooid dolograinstone

4 in

Open-marine, peloidal fusilinid dolopackstone

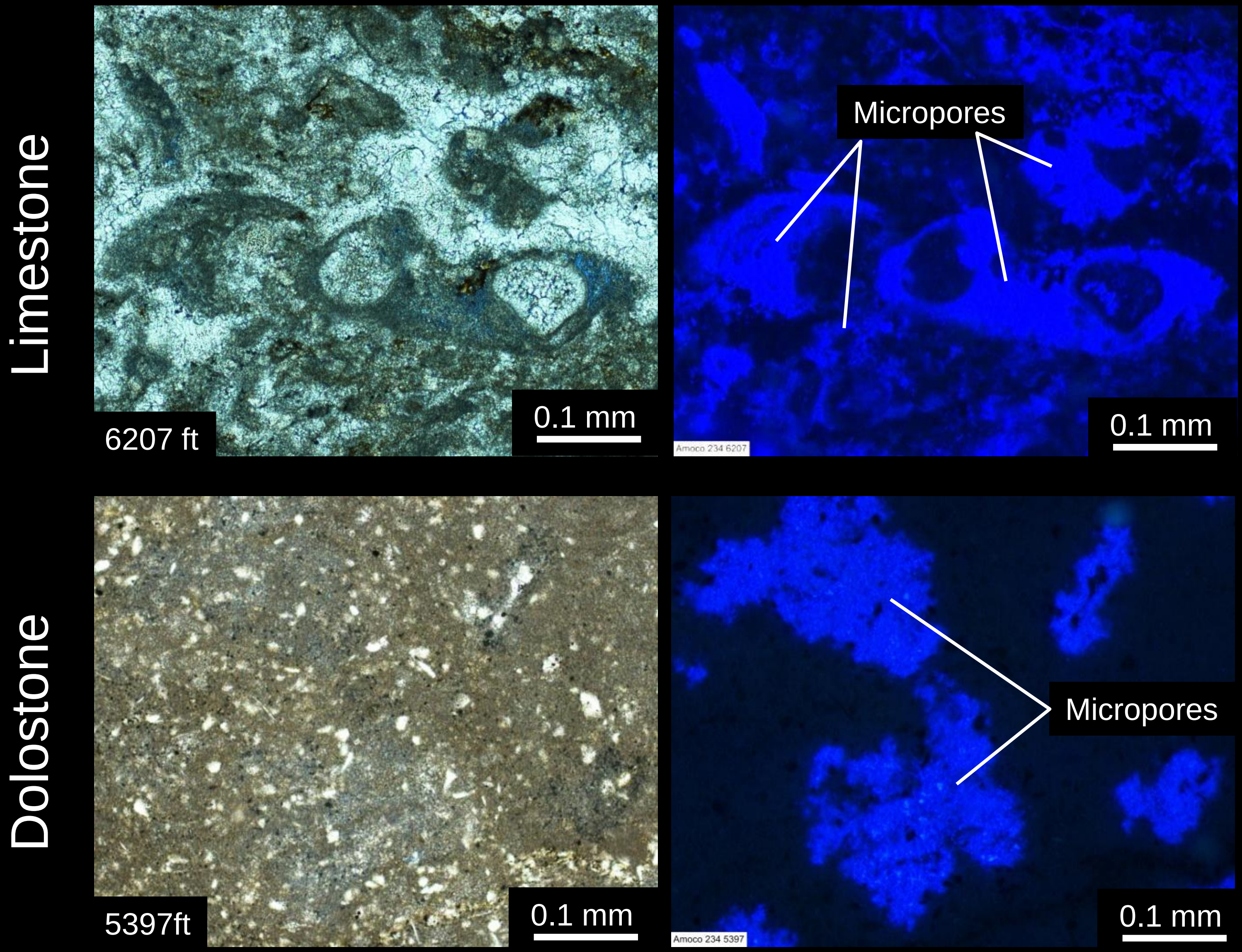
4 in

Pore Networks Composed of Nanopores and Micropores



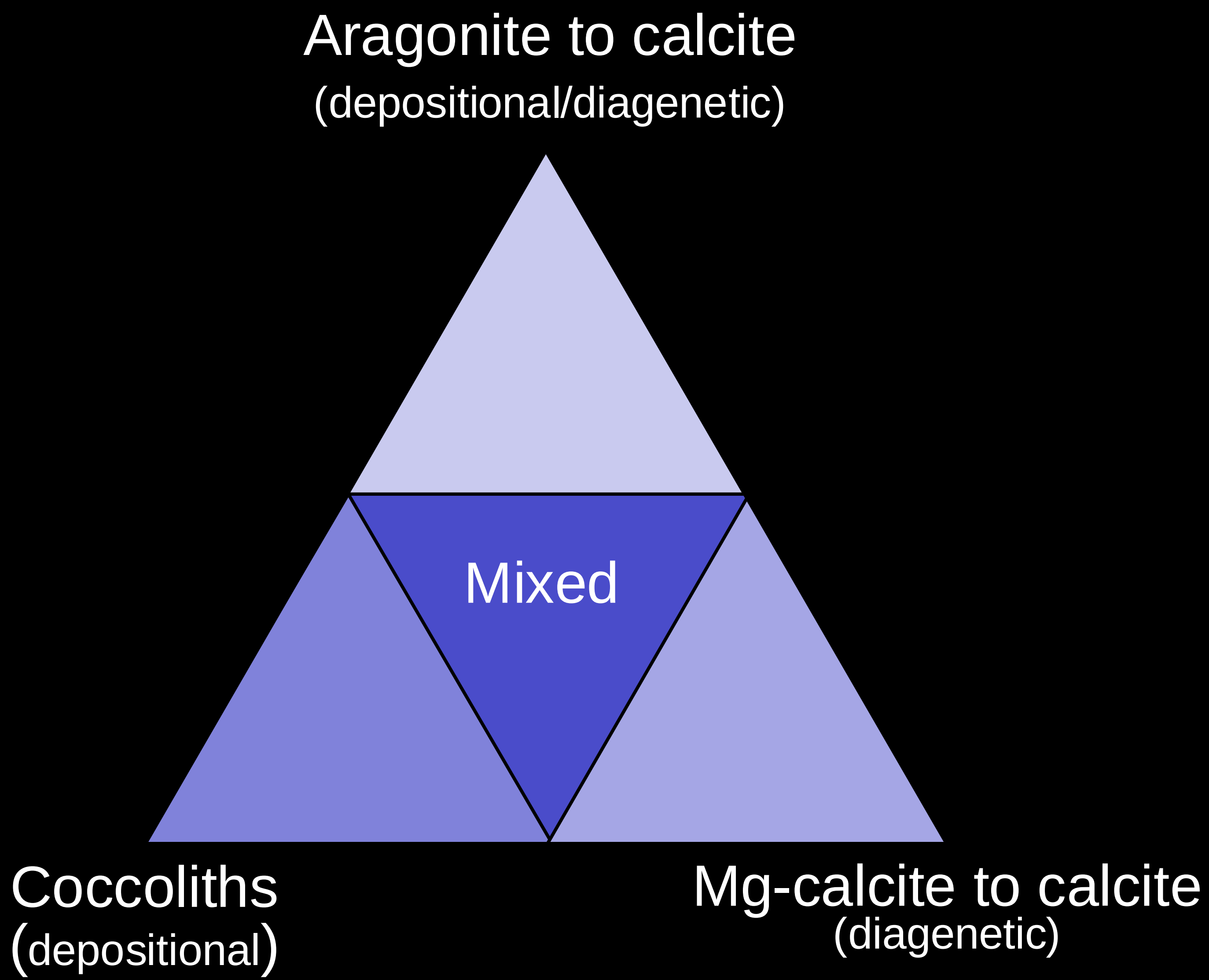
Micropores

Thin sections

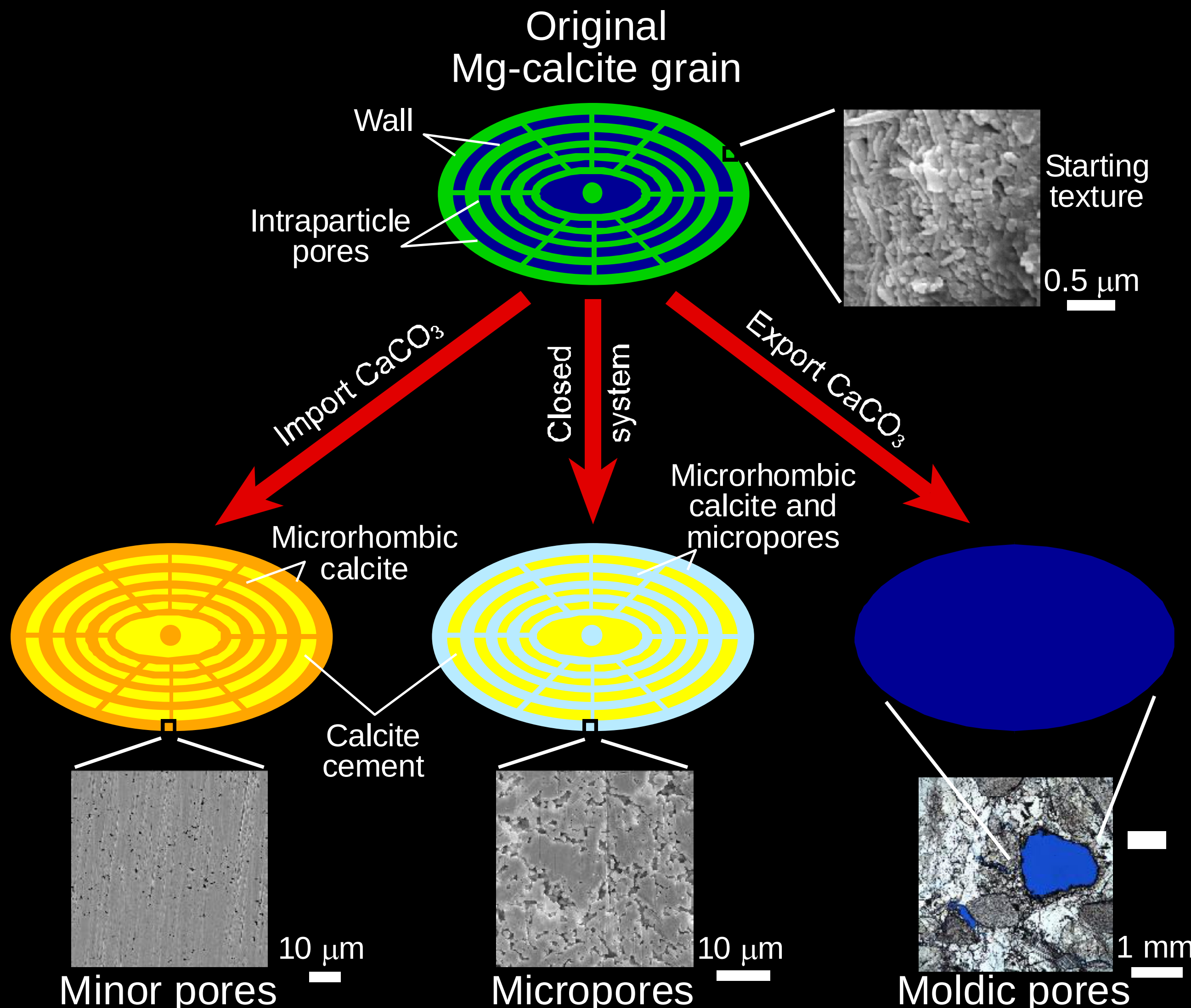


- Micropores occur in both limestones and dolostones

Origin ofGeneral Micropore Types in Limestone



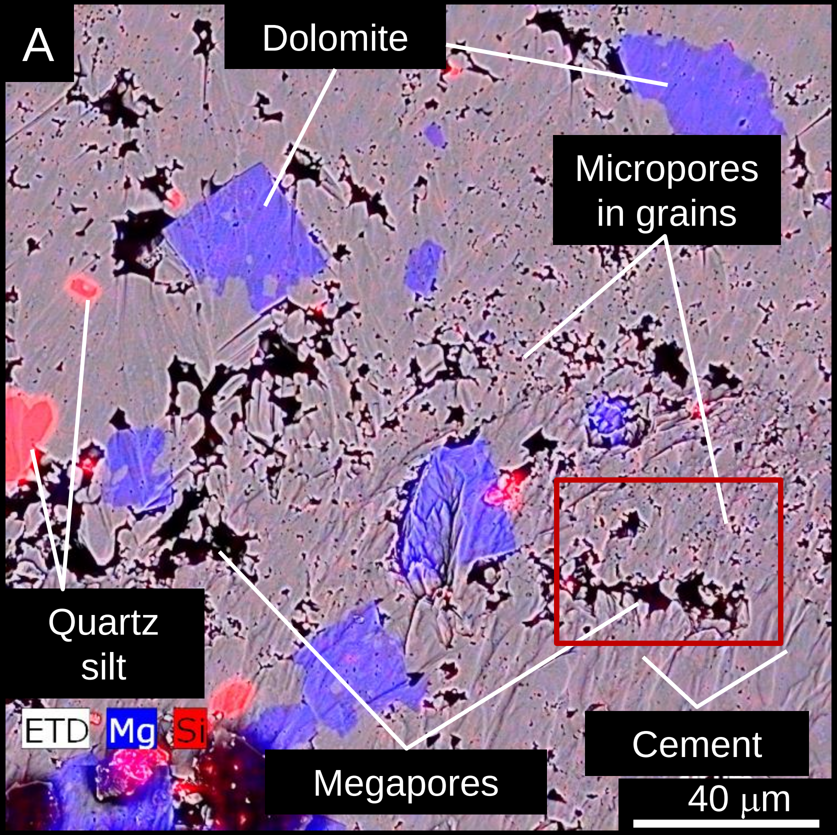
Mg-Allochem Transformation



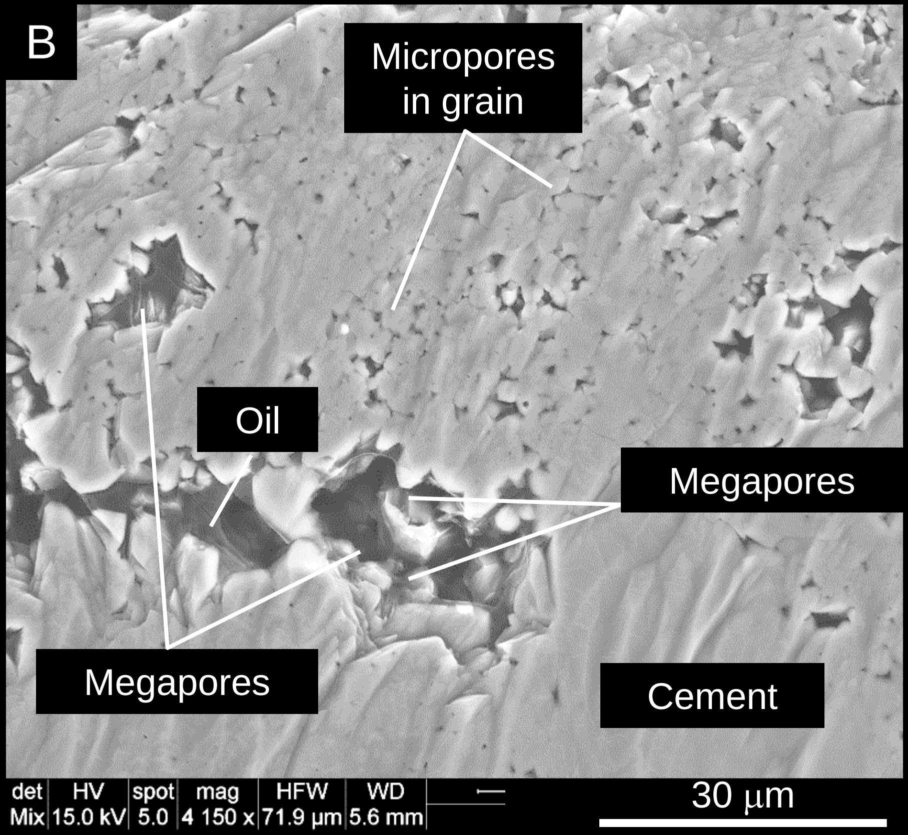
Loucks et al., 2013
GCAGS Journal

- Mg-calcite allochems stabilization produces micropores

Micropores in Limestone



SEM EDAX composition map



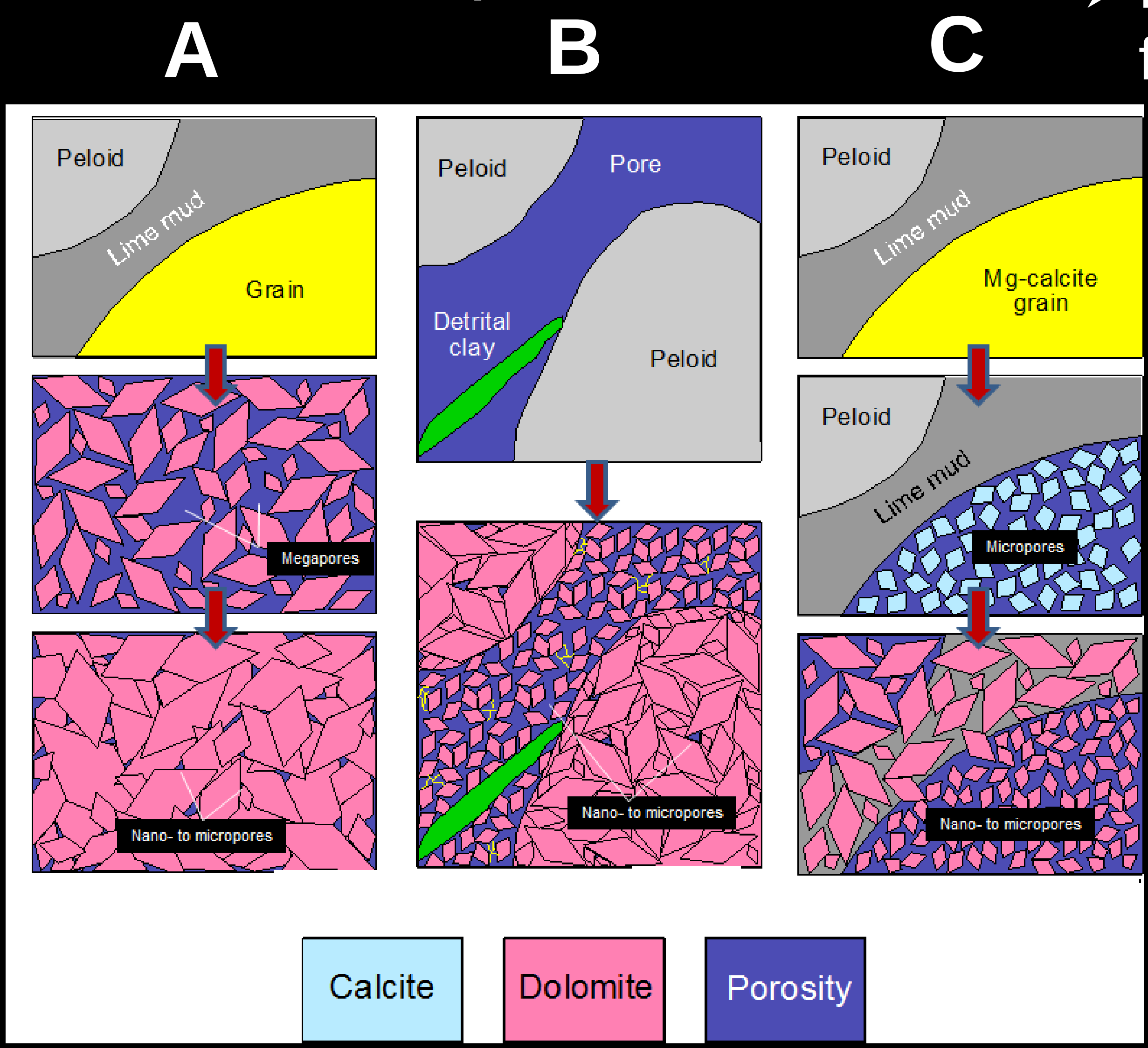
SEM Ar-ion milled sample

6257 ft

- Micropores in this limestone are interpreted to be associated with the stabilization of Mg-calcite allochems

Origins of Micropores in Dolomite

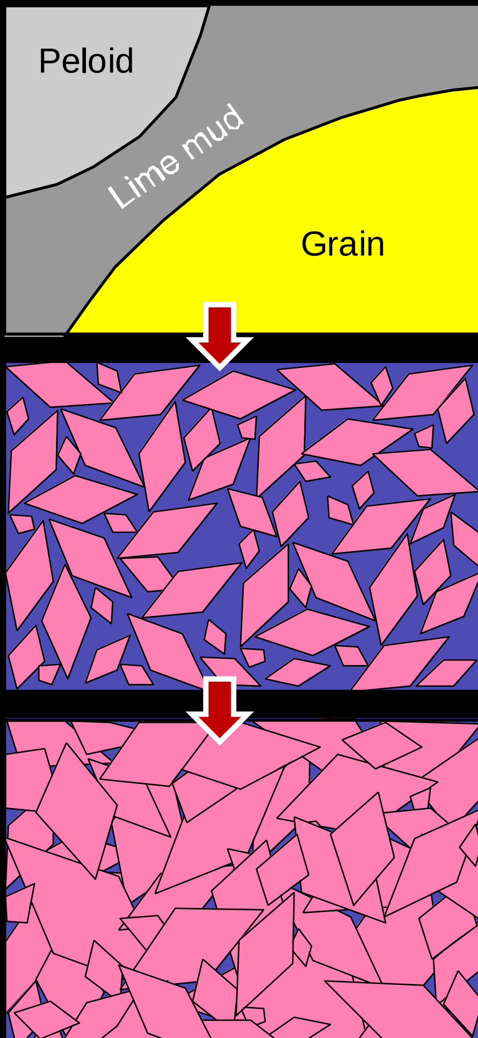
Three processes

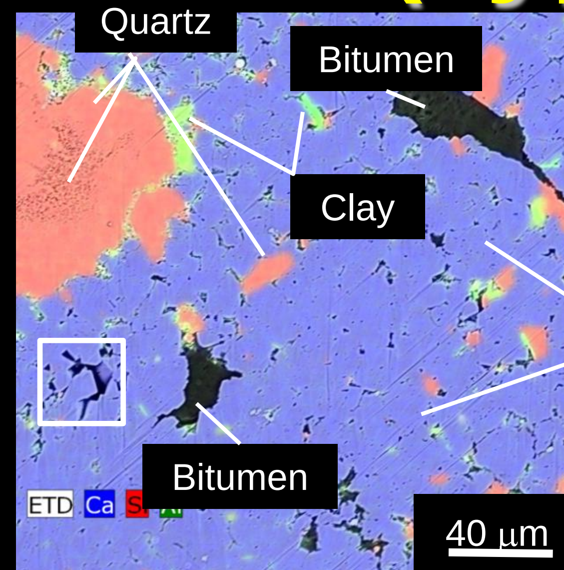


- Dolonano/micropores form by :
  - (A) Over-dolomitization
  - (B) Contrasting precipitation/ replacement processes
  - (C) Transformation of Mg-calcite to microrhombic calcite and later dolomitization

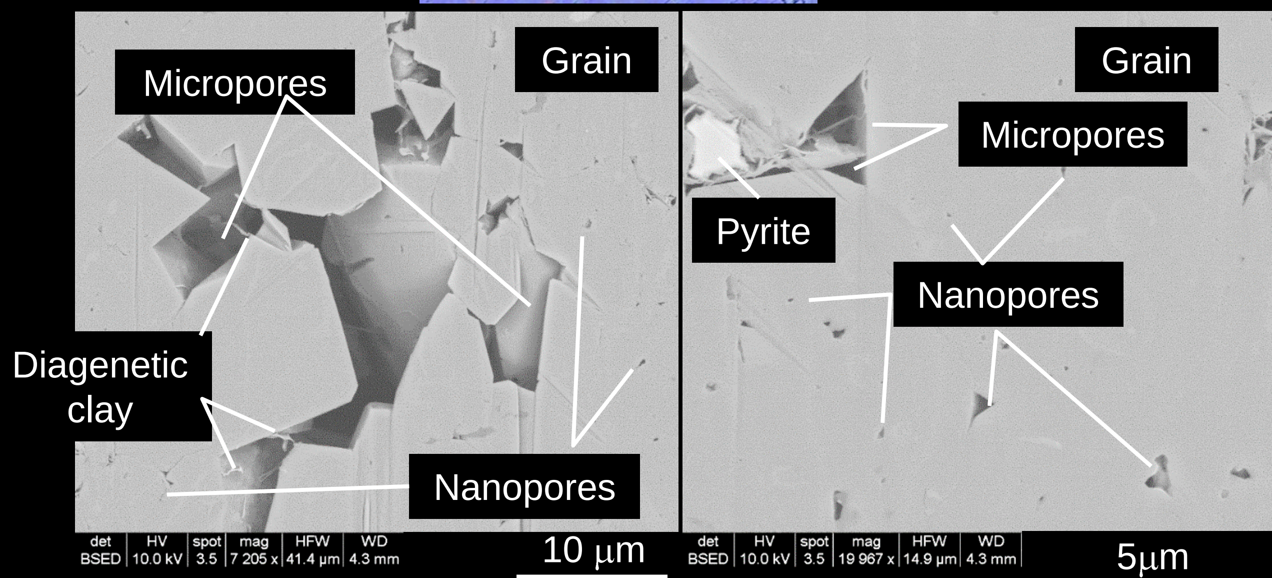
Micropores in Dolomite (Type A)

Overdolomitization





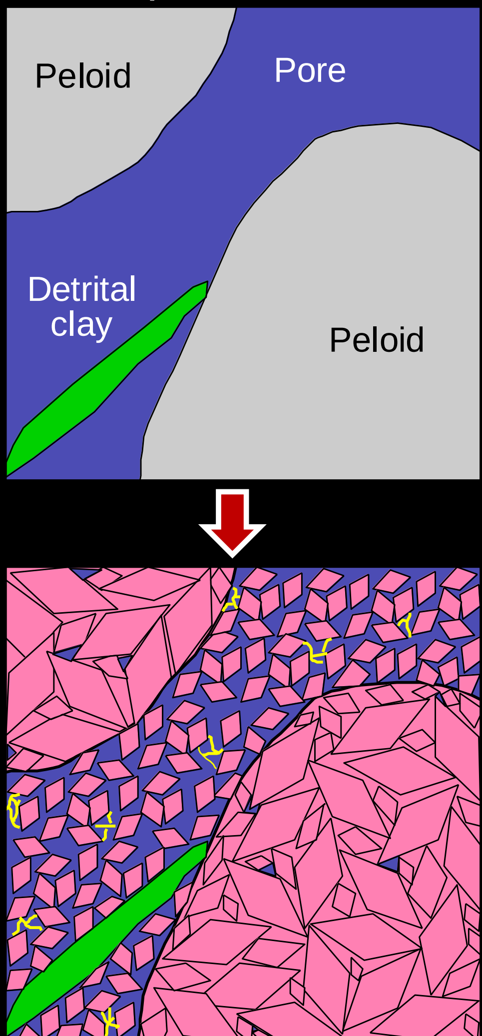
5768 ft
Ar-ion milled

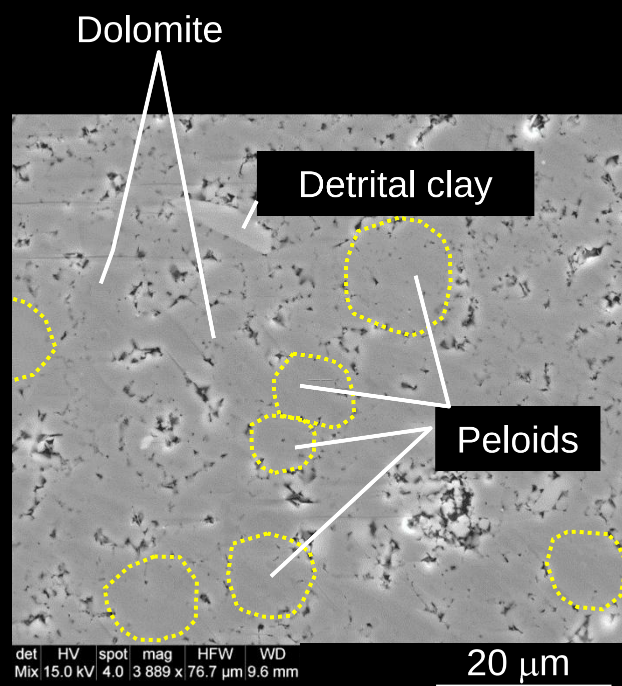


- Dolomite crystals grow to a point where they have filled nearly all the intercrystalline pore space

Micropores in Dolomite (Type B)

Combined replacement and precipitation processes

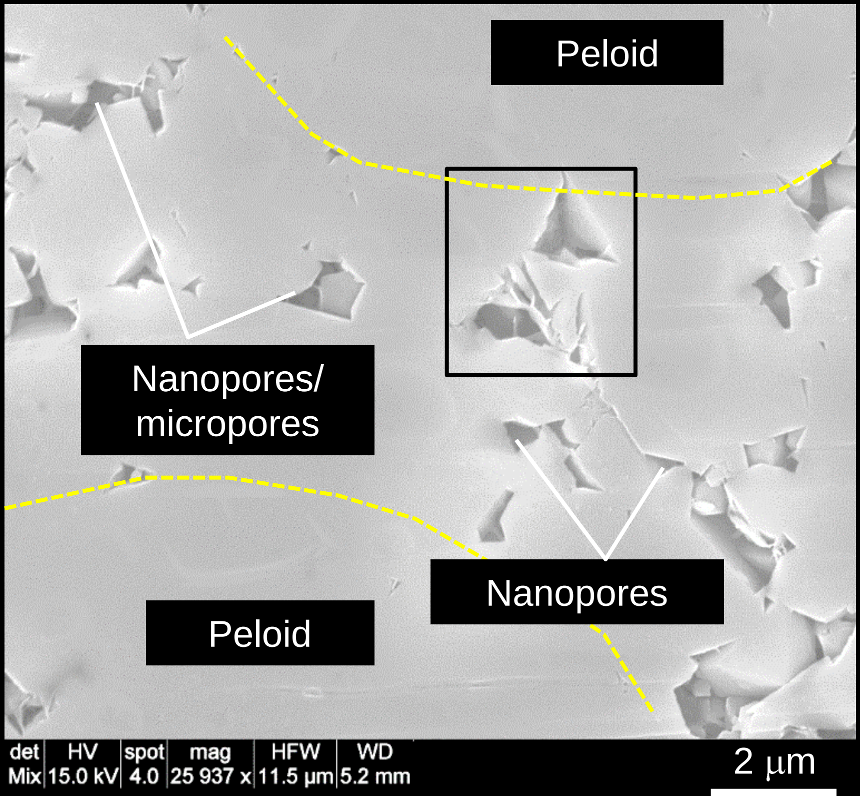


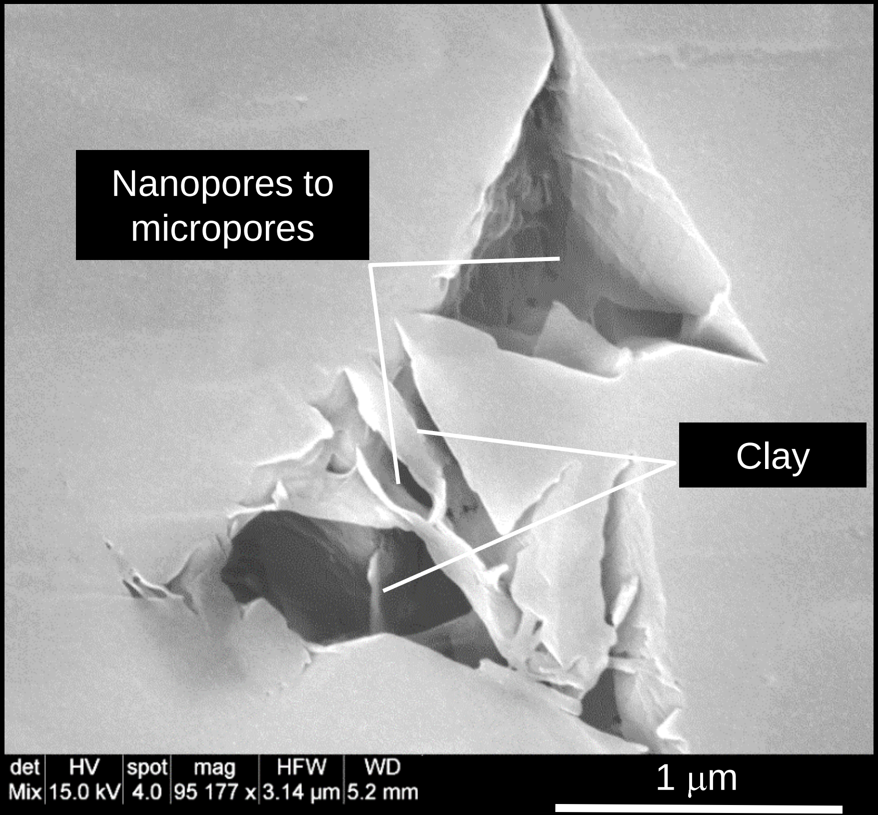


5581 ft
Ar-ion milled

- Replacement versus precipitation processes
- Grains are highly dolomitized with minor few nanopores left
- Dolomite cement precipitated in pores leaves abundant nanopores to micropores

Micropores in Dolomite (Type B)

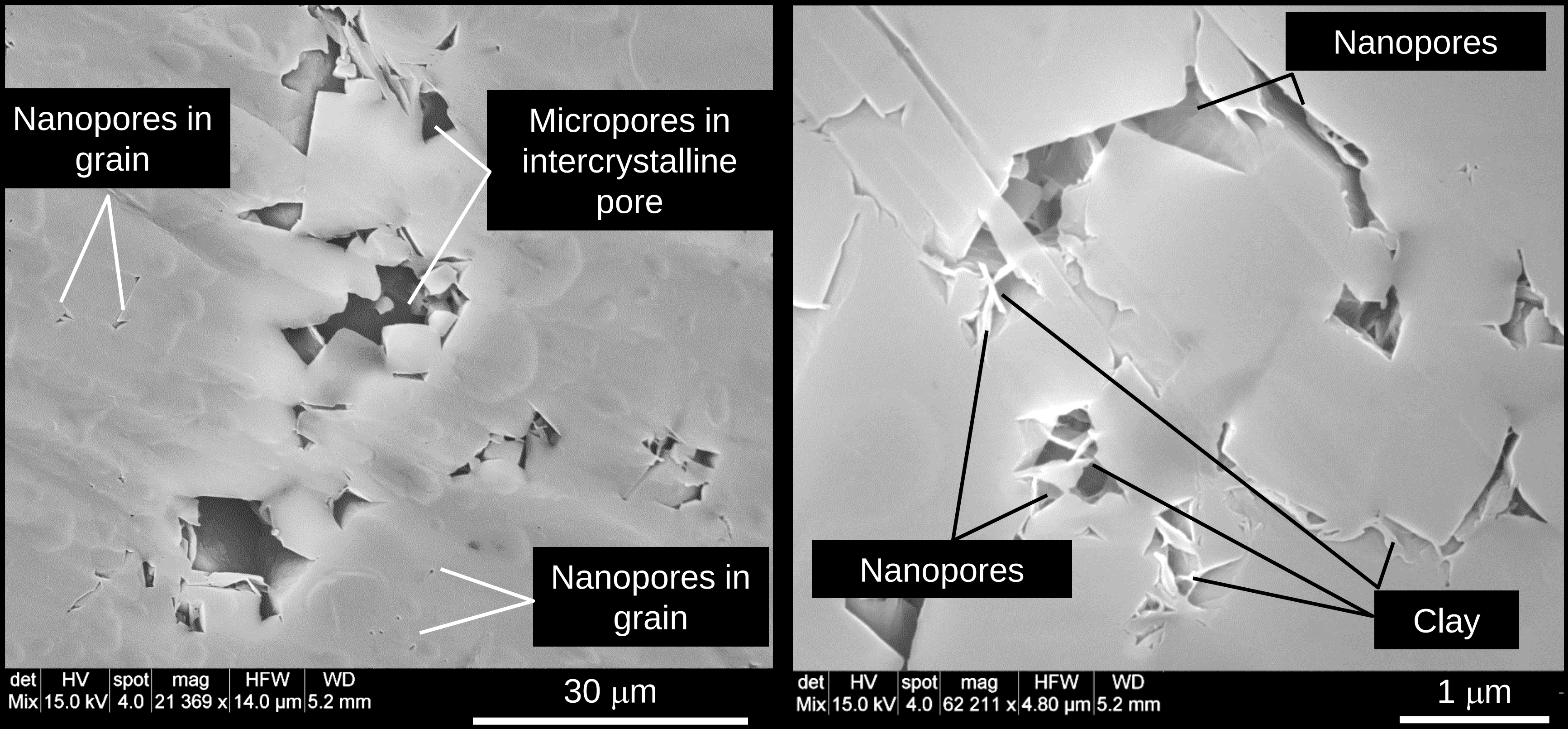




- Nanopores to micropores in former interparticle pore space
- Authigenic clays further reduce pore size

5581 ft
Ar-ion milled

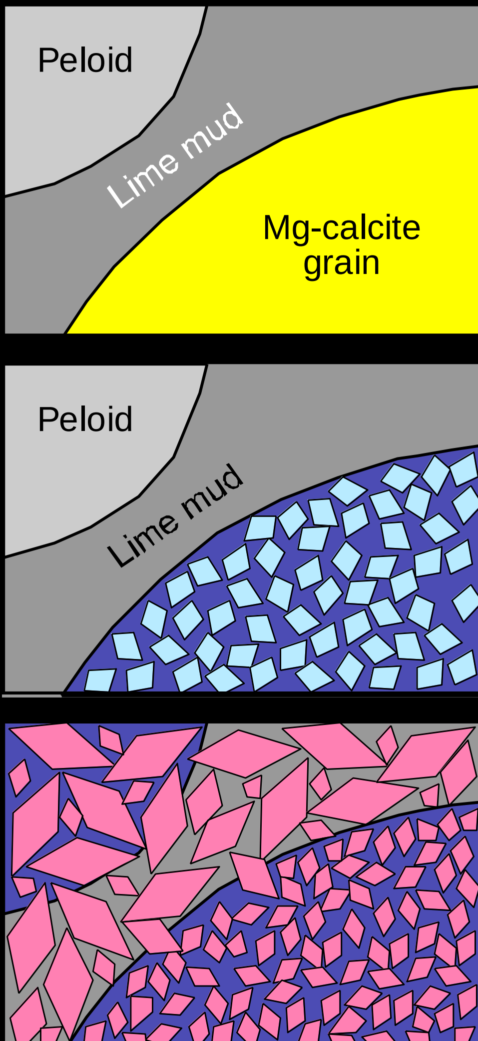
Micropores in Dolomite (Type B)



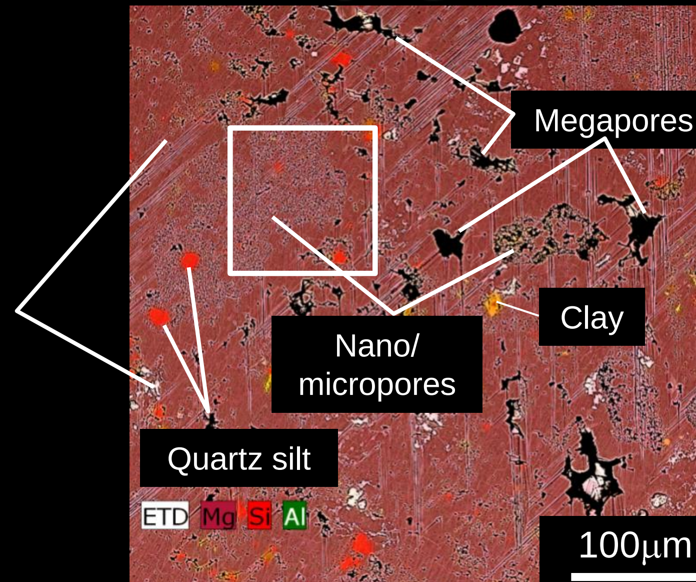
- Nanopores to micropores in former interparticle pore space
- Nanopores in dolomitized grains

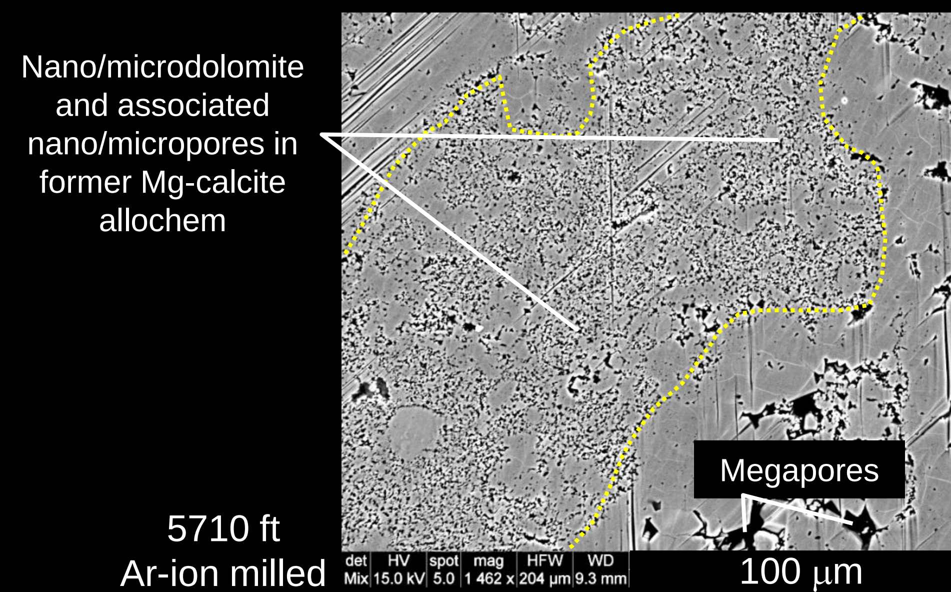
5581 ft
Ar-ion milled

Micropores in Dolomite (Type C)



Replacement of former Mg-calcite microrhombic crystals



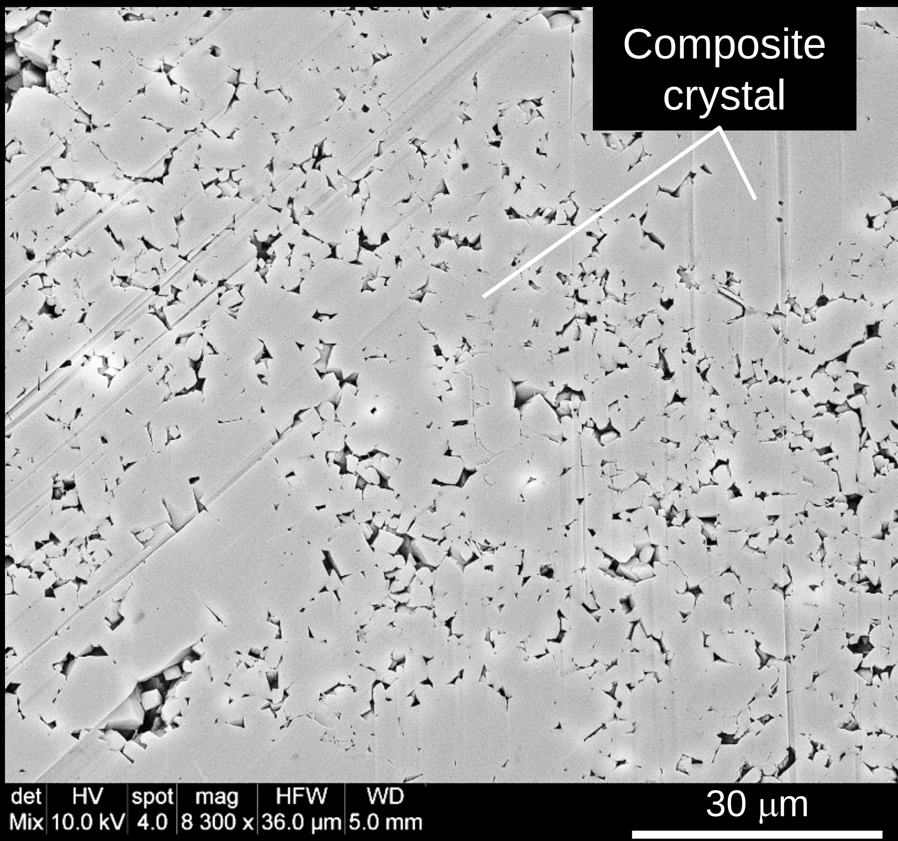


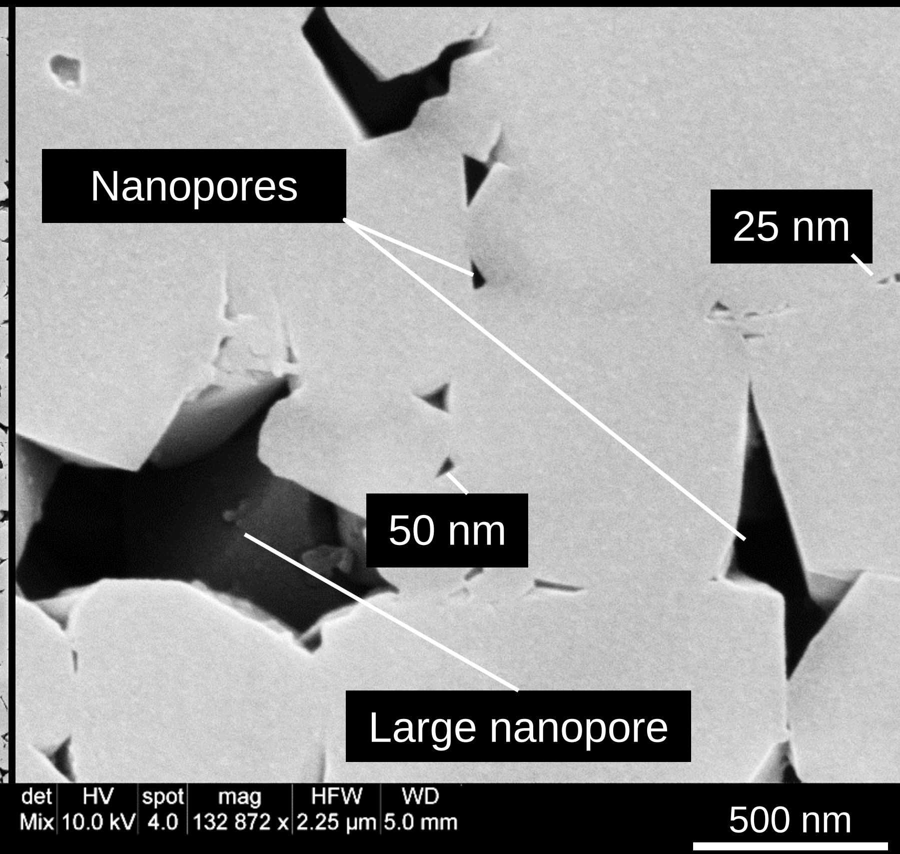
5710 ft
Ar-ion milled

- ➢ Dolomite crystals mimics original microrhombic calcite crystals.

Micropores in Dolomite (Type C)

5710 ft
Ar-ion milled

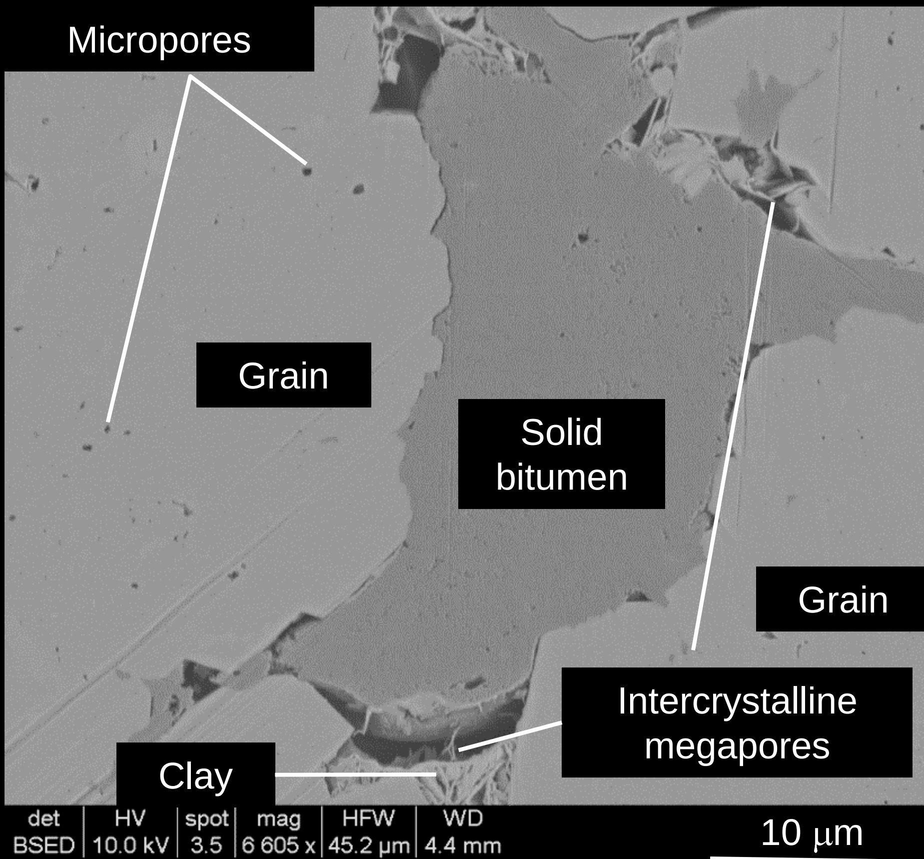


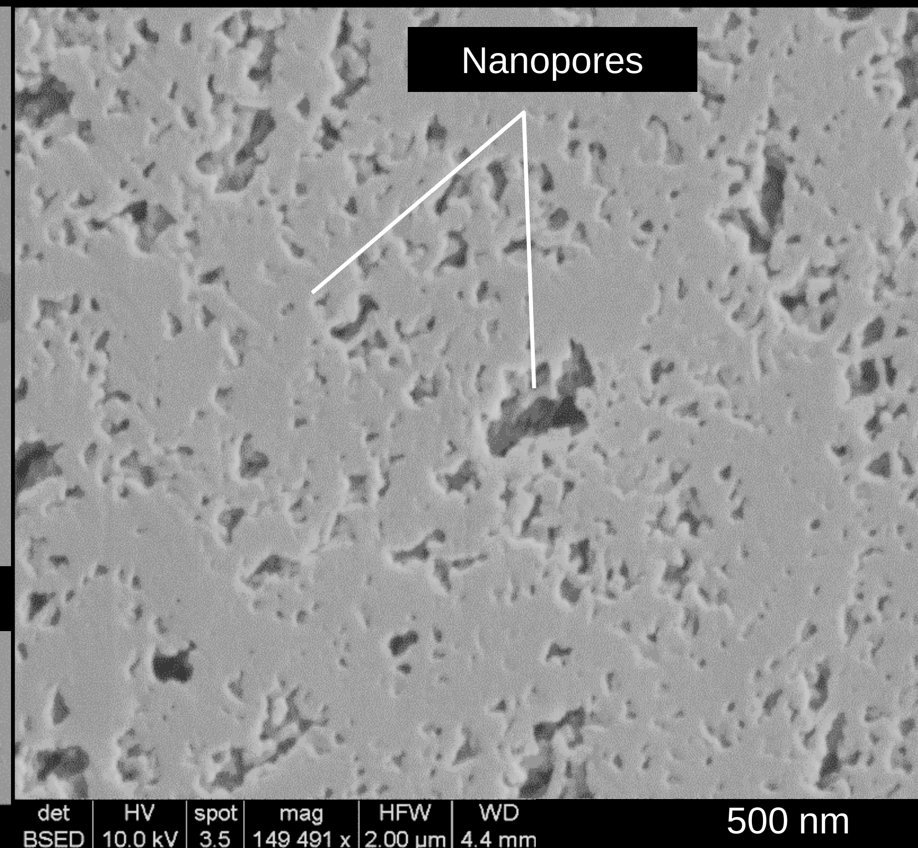


- Replacement of former Mg-calcite microrhombic crystals

Solid Bitumen OM Pores

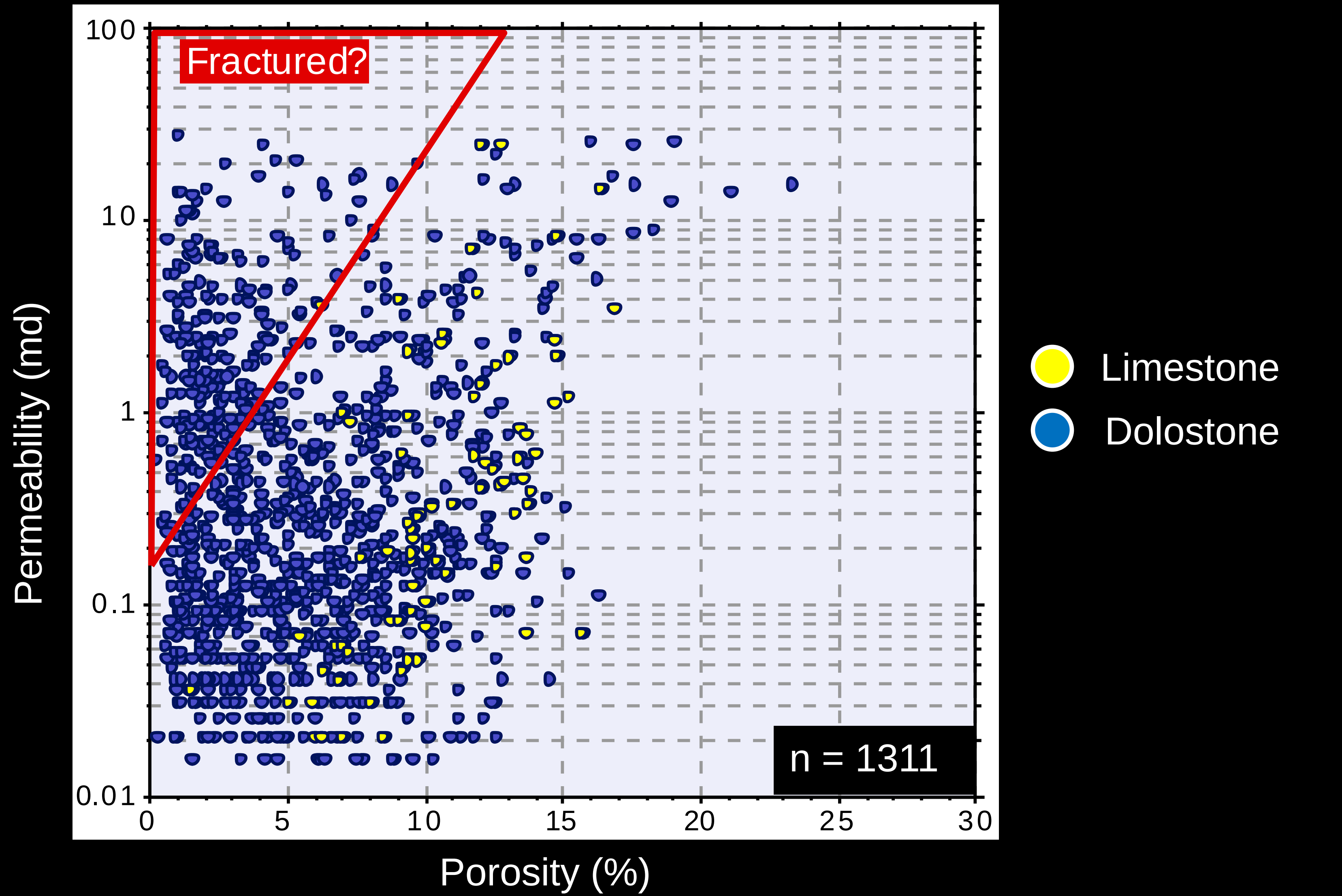
5768 ft
Ar-ion milled





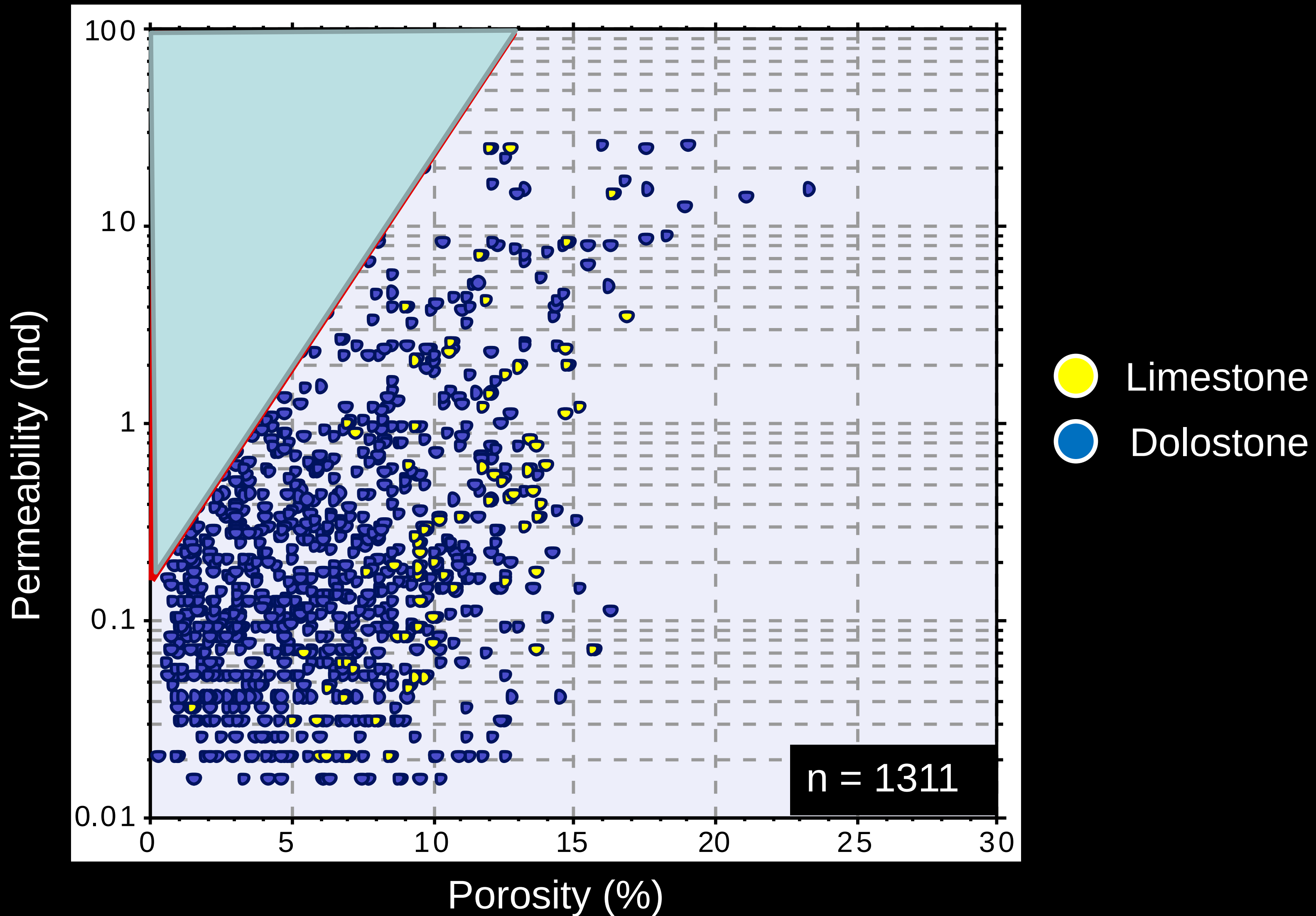
- OM nanopores in migrated solid bitumen

Reservoir Quality by Matrix Type



- Limestones tend to have higher porosities, but both limestones and dolostones have similar permeabilites

Reservoir Quality by Matrix Type



- Limestones tend to have higher porosities, but both limestones and dolostones have similar permeabilites

Conclusions

- Clear Fork reservoirs are a combination of nanopore, micropores, and megapores.
- Dolomite-related nano/micropores form by: (1) "overdolomitization," (2) contrasting precipitation/replacement processes, and (3) transformation of Mg-calcite to microrhombic calcite and later dolomitization.
- Quantity of nano- and micropores must be taken into consideration when calculating flow rates and field-wide reserves.