Origin and Analysis of the Nano/Micropore Network in the Upper Cretaceous Ozan/Annona Chalks in the Caddo/Pine Island Field in Northwest Louisiana*

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Abstract

The Campanian Annona Chalk is a shallow (1400 to 1700 foot, however it may have been buried deeper) producing reservoir of light oil (API gravity 42 to 44). The reservoir is a fractured, slightly argillaceous lime chalk, as is the Ozan chalk below. Both units were deposited on the Upper Cretaceous drowned shelf in a moderate-depth, aerobic setting as evidenced by numerous burrows and a high ratio of benthic to planktonic foraminifera. Clay-size material (up to 20%) composed of smectite and microquartz is slightly higher in the Ozan than the Annona. Major allochems are benthic and planktonic foraminifera and fragments of echinoids, ostracods, and bivalves in a finer matrix of coccoliths and coccoliths elements. The coccoliths and associated elements range in size from less than 400 nm to a few microns. The pore network resulting from this fine-grain size and burial cementation produces a reservoir composed of nano- to micropores. Pore throats are in the nanometer range. Porosity averages between 23 to 27%. The origin of this extremely fine pore network is depositional. The original pores between the coccoliths and fragments are interparticle. Minor intraparticle pores are associated with the foraminifera and some voids in the coccoliths.

The coccosphere bodies easily breakdown to coccolith plates and individual elements. With the degradation of the polysaccharides (organic matter that hold the coccolith together) the coccoliths fragments separate. This results in finer material and associated finer pores. Later cementation will reduce these early formed pores. The minor amount of clay affects pore size by dividing the interparticle pores into multiple smaller pores. The clay also appears to promote pressure solution and enhanced cementation. The result of all these processes is to produce a porous reservoir with modest permeability. Natural and induced fractures form the collection network for the oil, but the nano- to micropores are the storage component of the reservoir.

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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.

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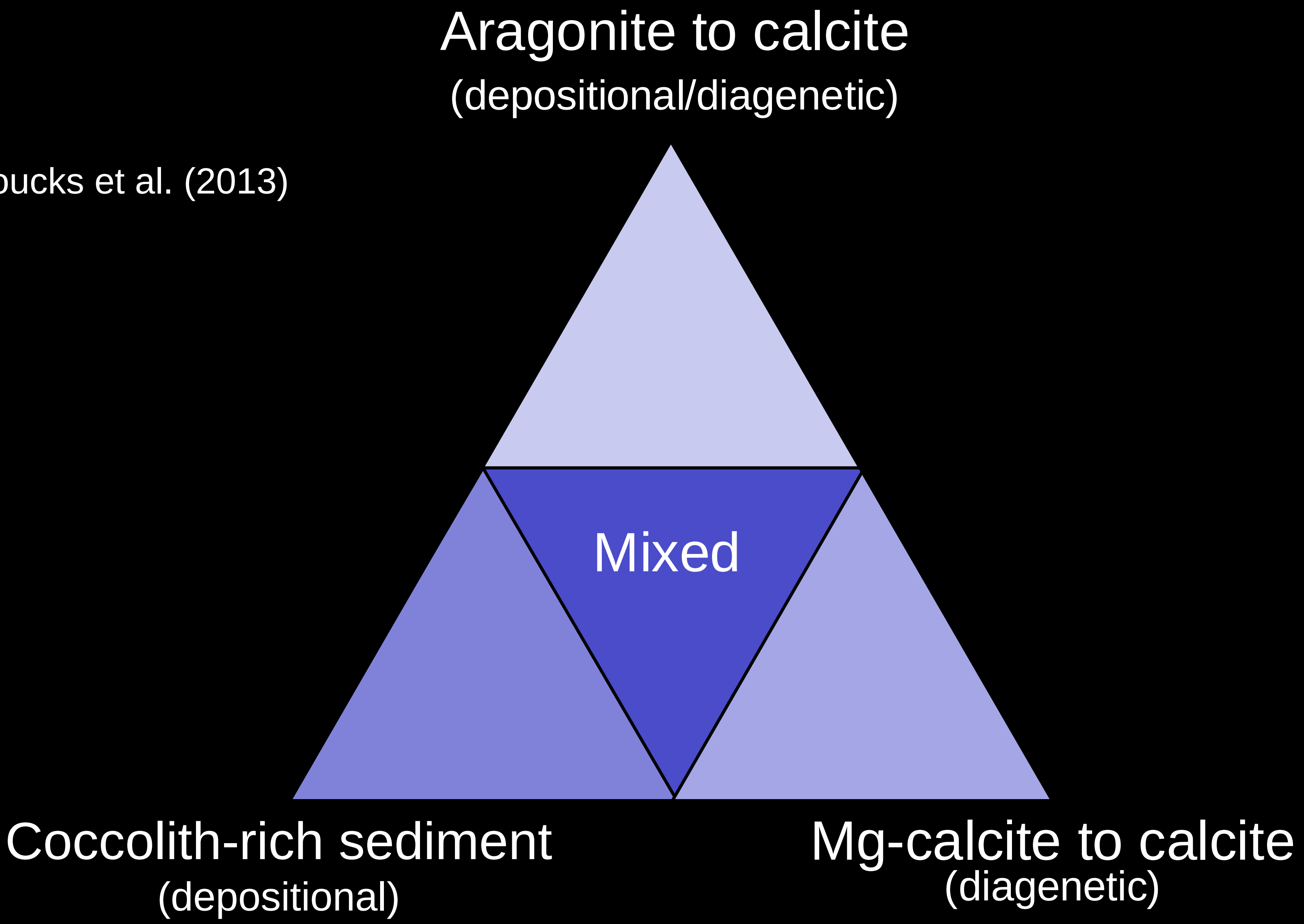
Reservoir Characterization Research Laboratory

General Micropore Types

Loucks et al. (2013)

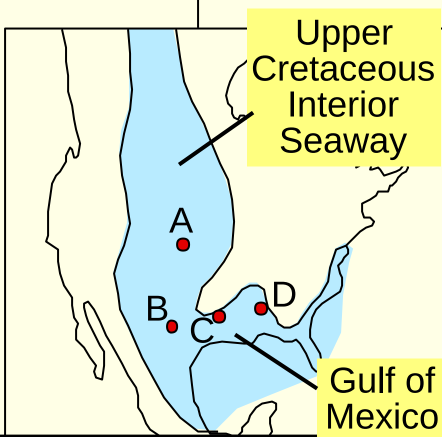


Project Goals

- Present depositional setting of the Annona and Ozan Chalks
- Review lithofacies
- Define pore network and reservoir quality

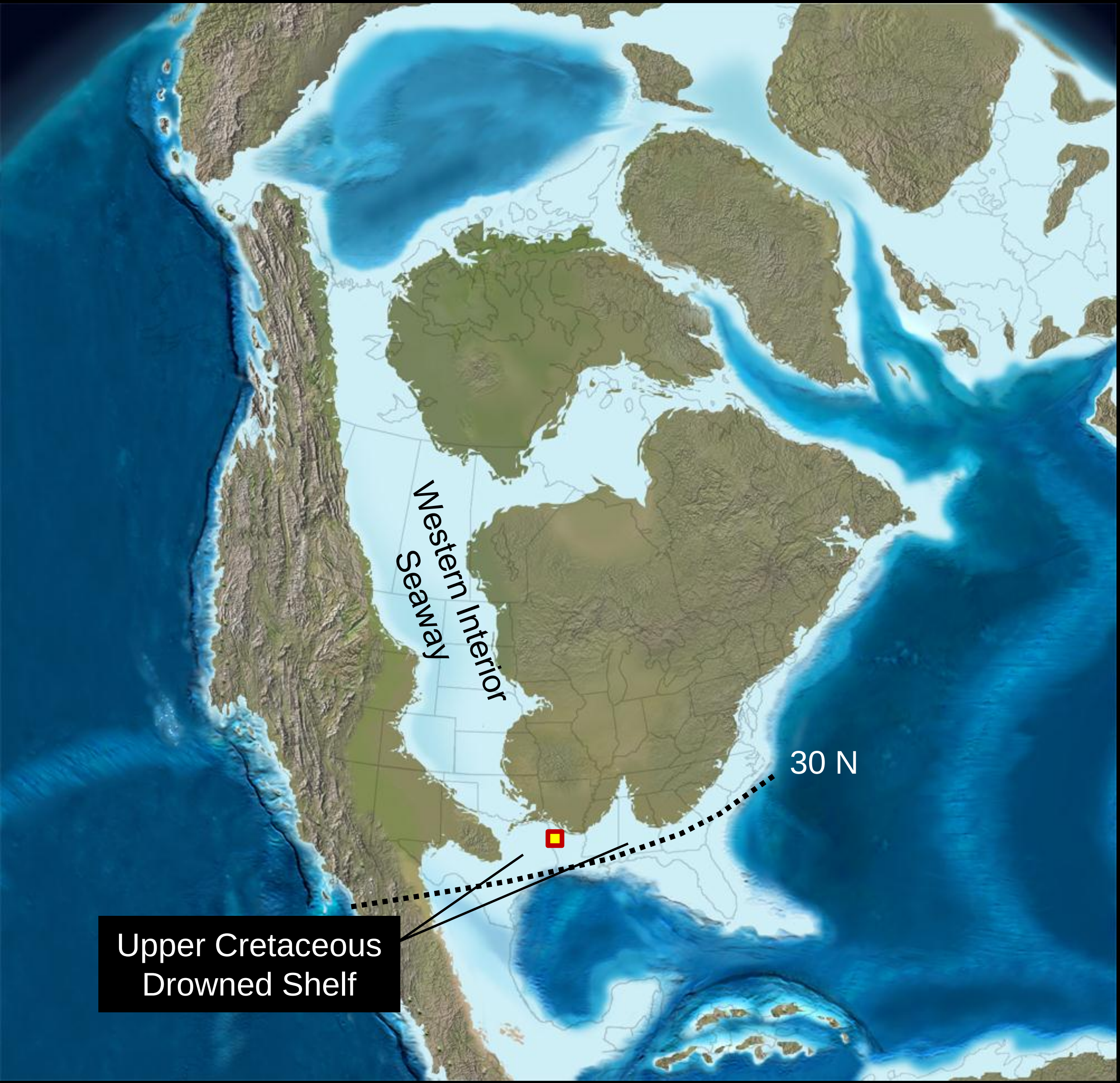
Correlation of Upper Cretaceous Chalks

Stage	Age (M.Y.)	Central Western Interior A	Central Texas B	South-western Arkansas C	Western Alabama D
	66				
Maastrichtian	72.1				
Campanian			Pecan Gap	Saratoga Annona Ozan	Demopolis Arcola
Santonian	83.6	Niobrara	Austin		
Coniacian	86.3				
Turonian	89.8	Fairport	Eagle Ford		
Cenomanian	93.9	Greenhorn	Buda		



Modified from Bottjer (1986)
Ages according to IUGS (July 2012)

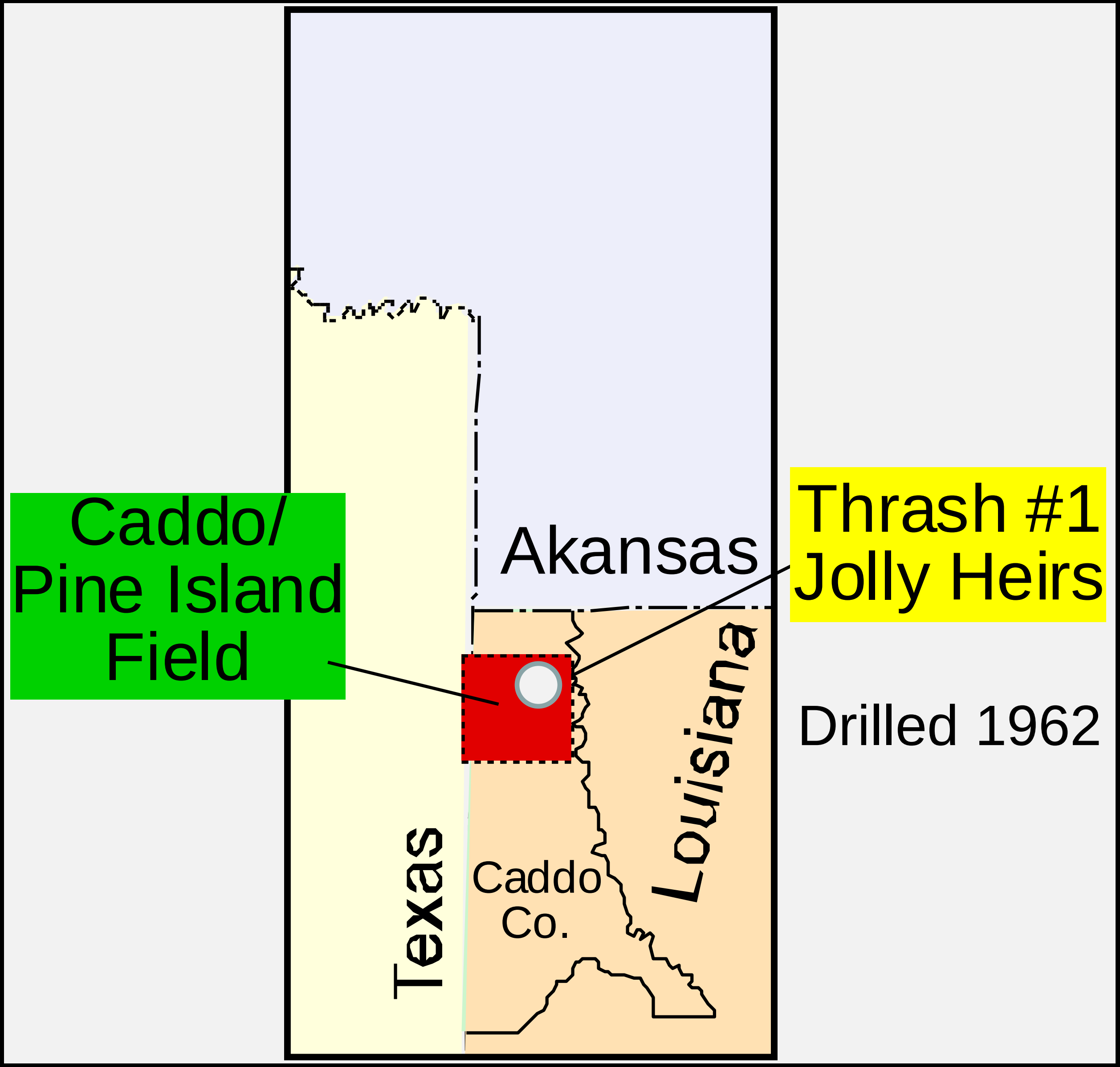
Regional Paleogeographic Setting



Late Cretaceous (75 Ma) Campanian

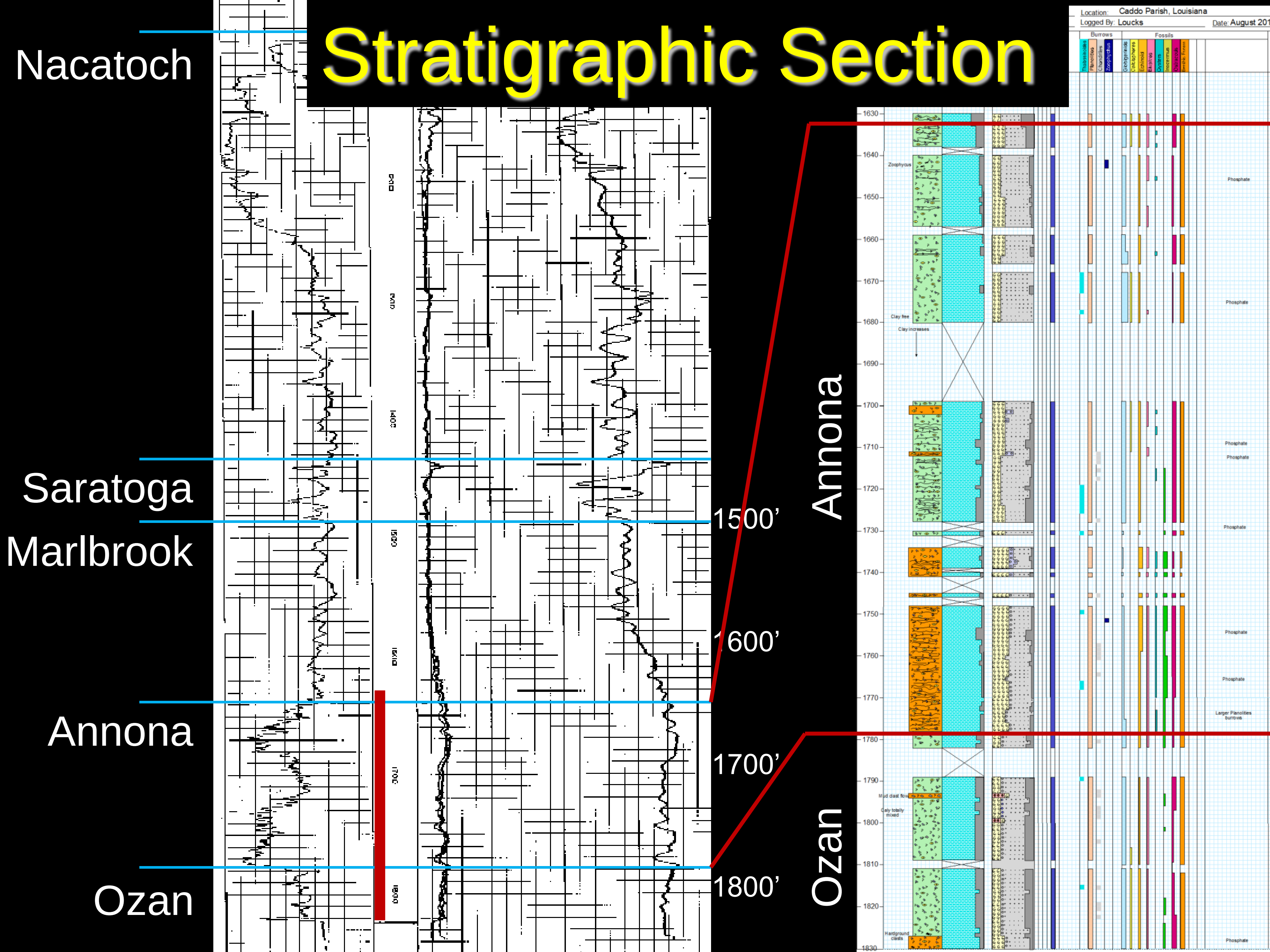
R. Blakey (2013)

Study Area

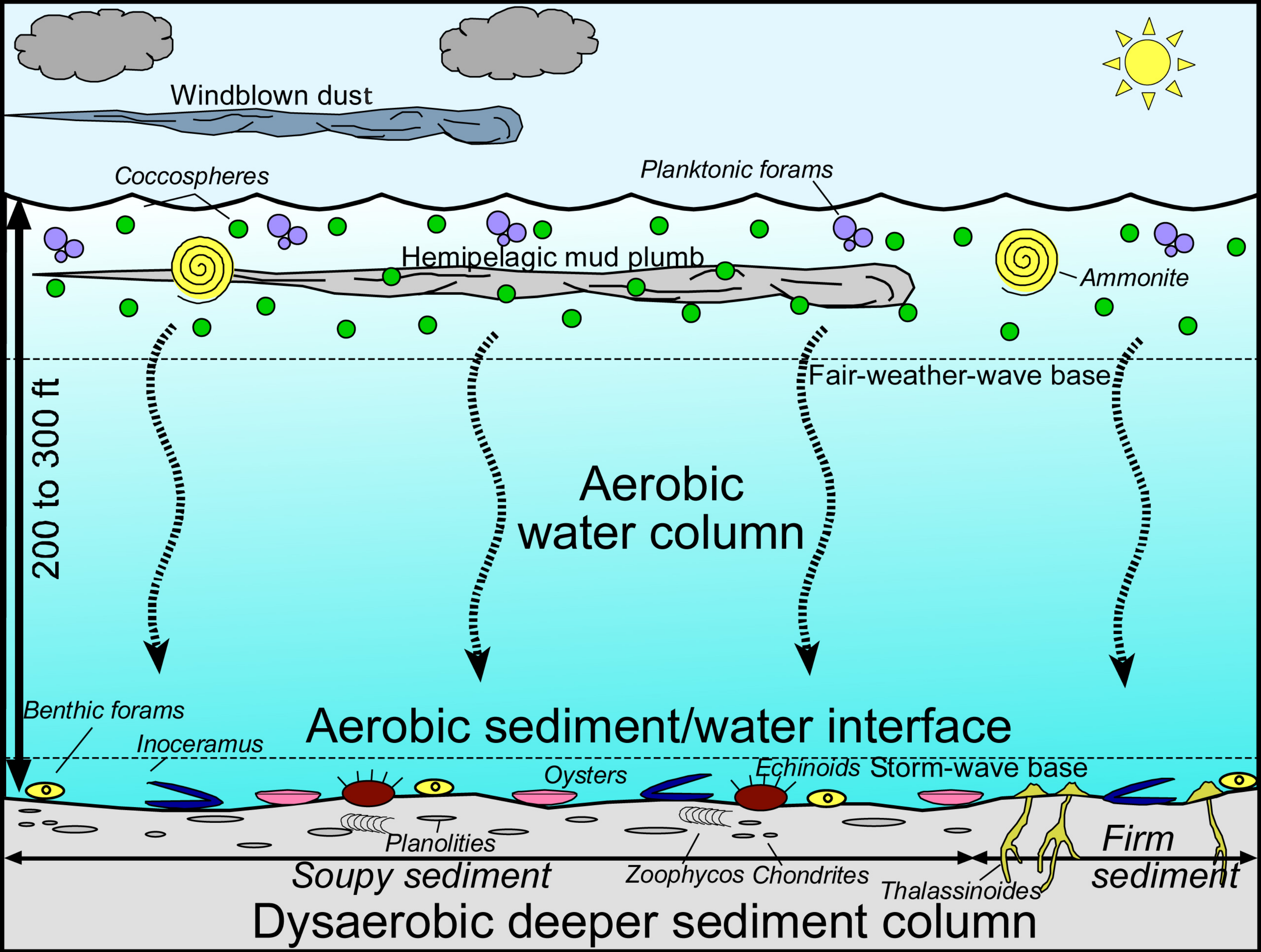


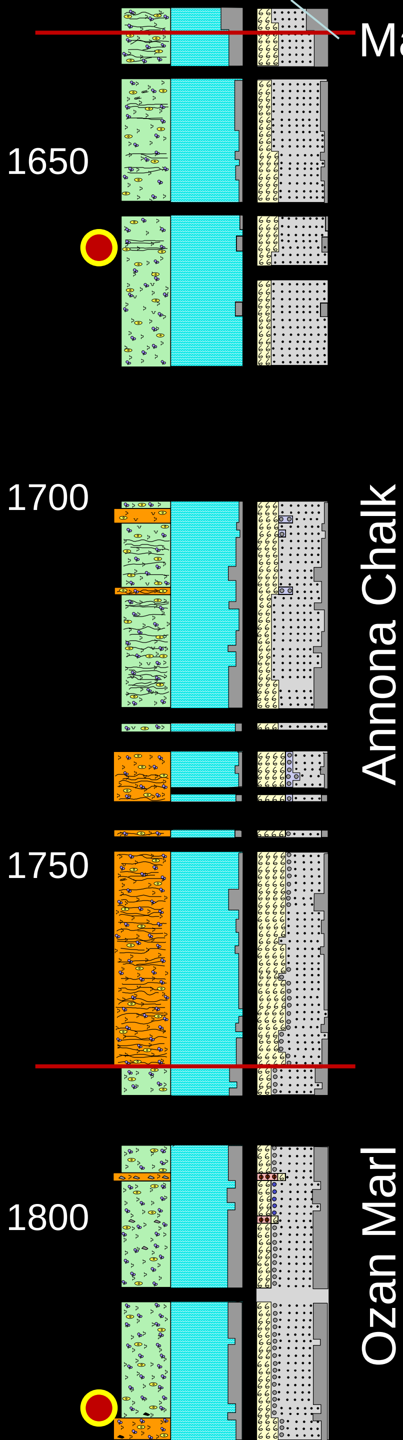
Caddo/
Pine Island
Field
Akansas
Thrash #1
Jolly Heirs
Louisiana
Drilled 1962
Texas
Caddo
Co.

Stratigraphic Section

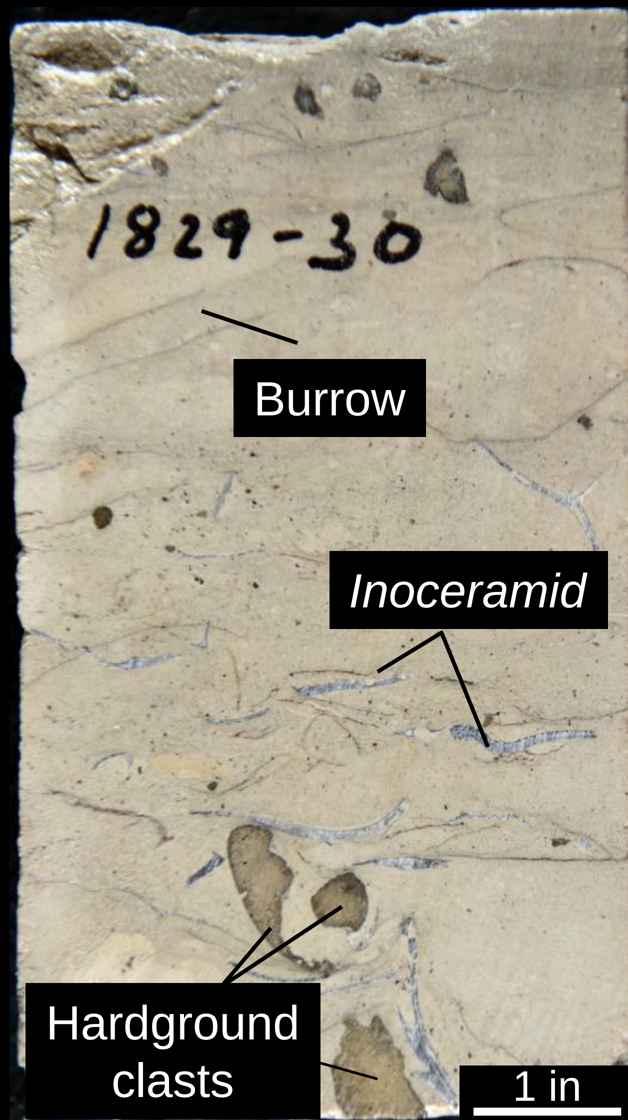


Deposition Model

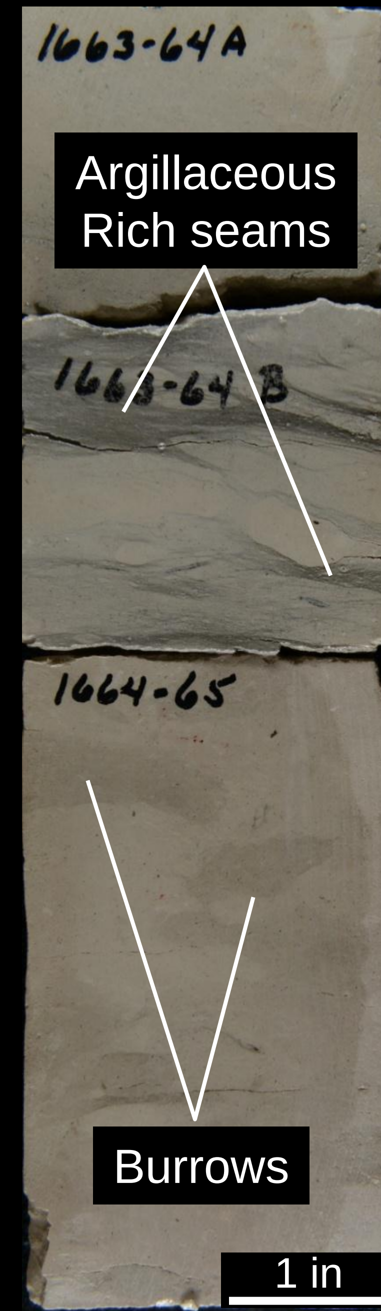




Ozan Marl



Annona Chalk

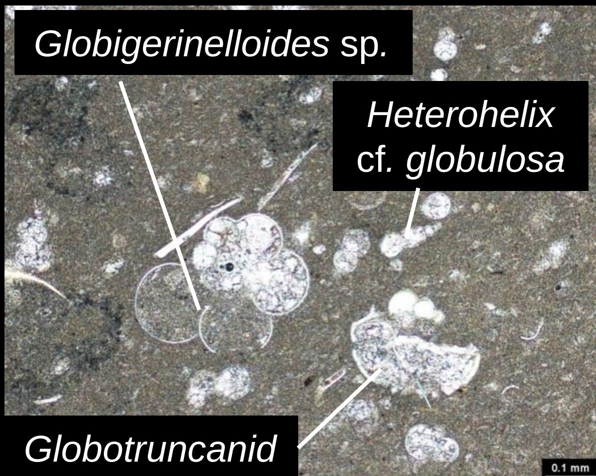


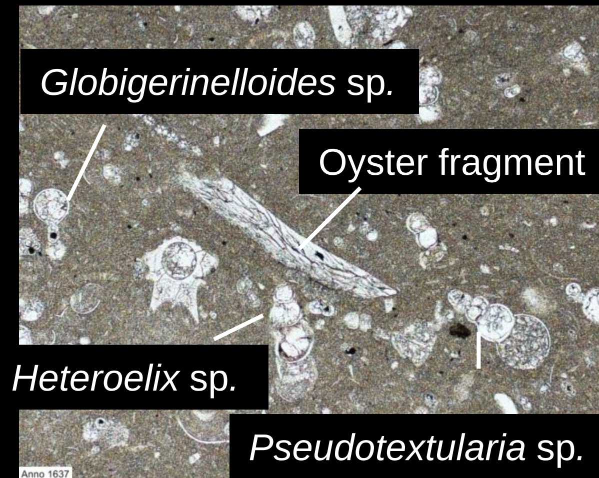
Core slabs

Examples of Biota

Thin sections

Planktonic foraminifera



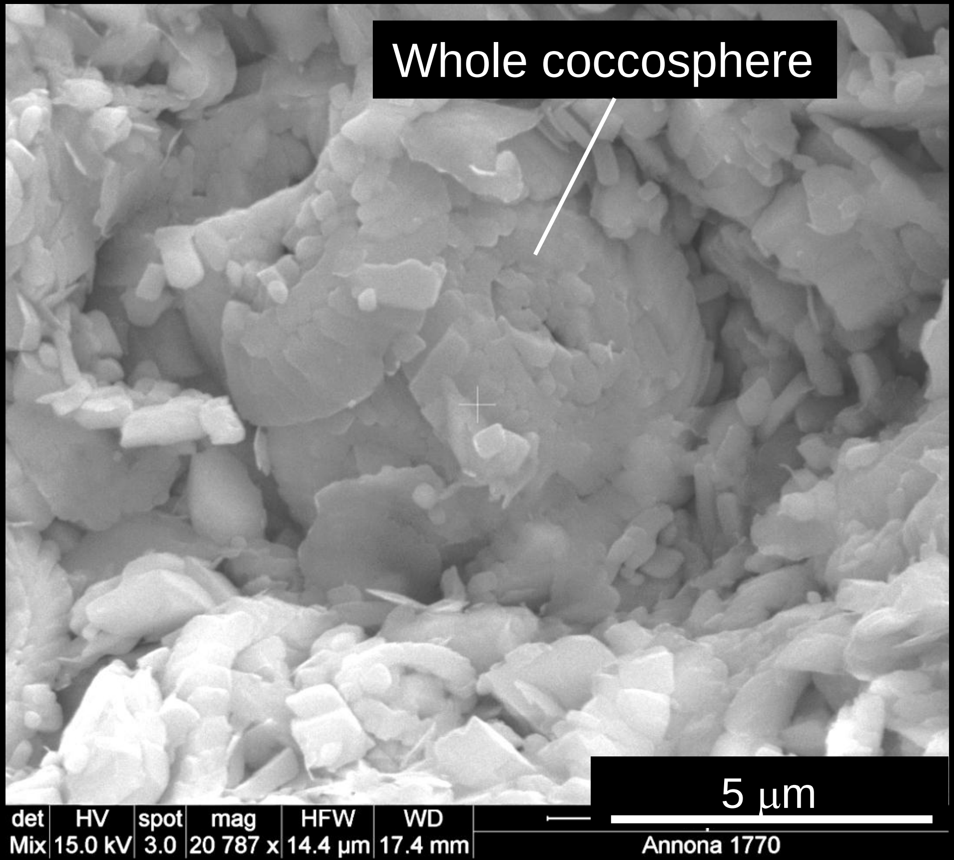


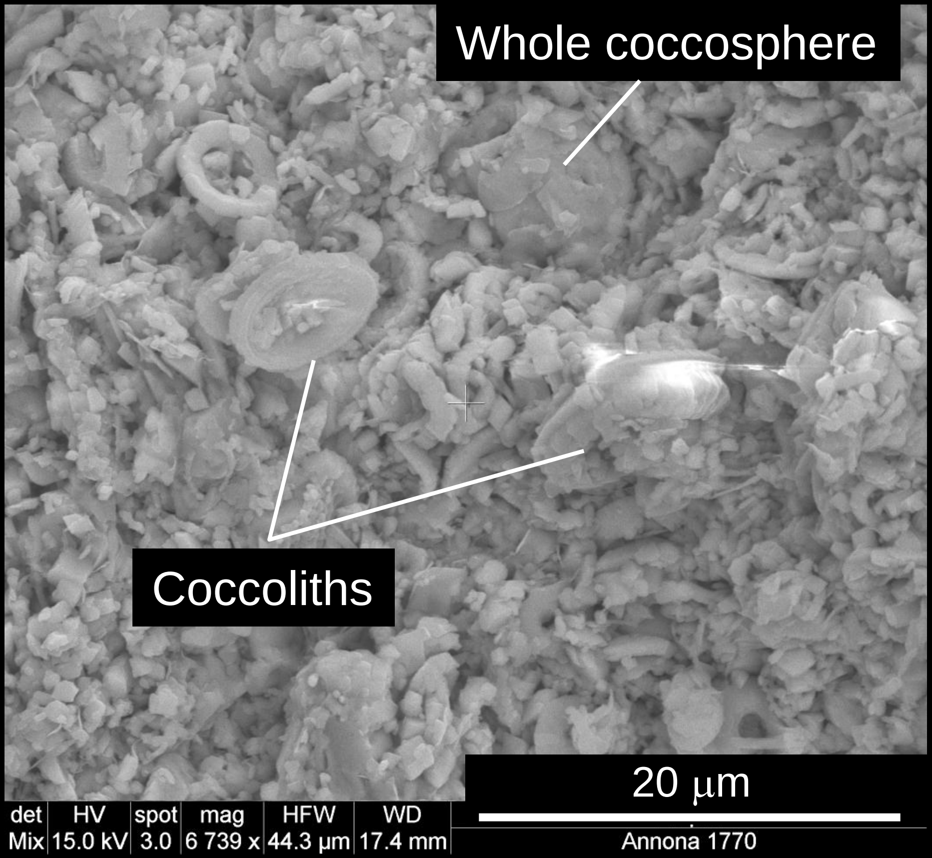
Thin sections

Benthic foraminifera

Wide variety of benthic and planktonic fauna

Coccolith Hash Matrix

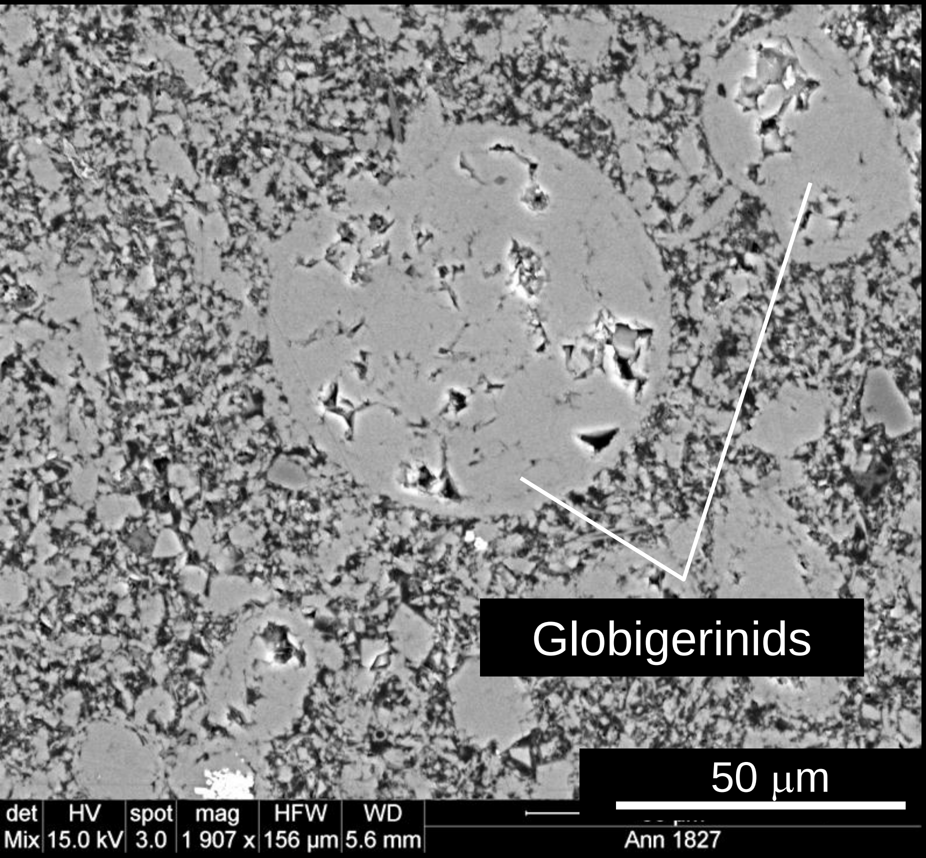




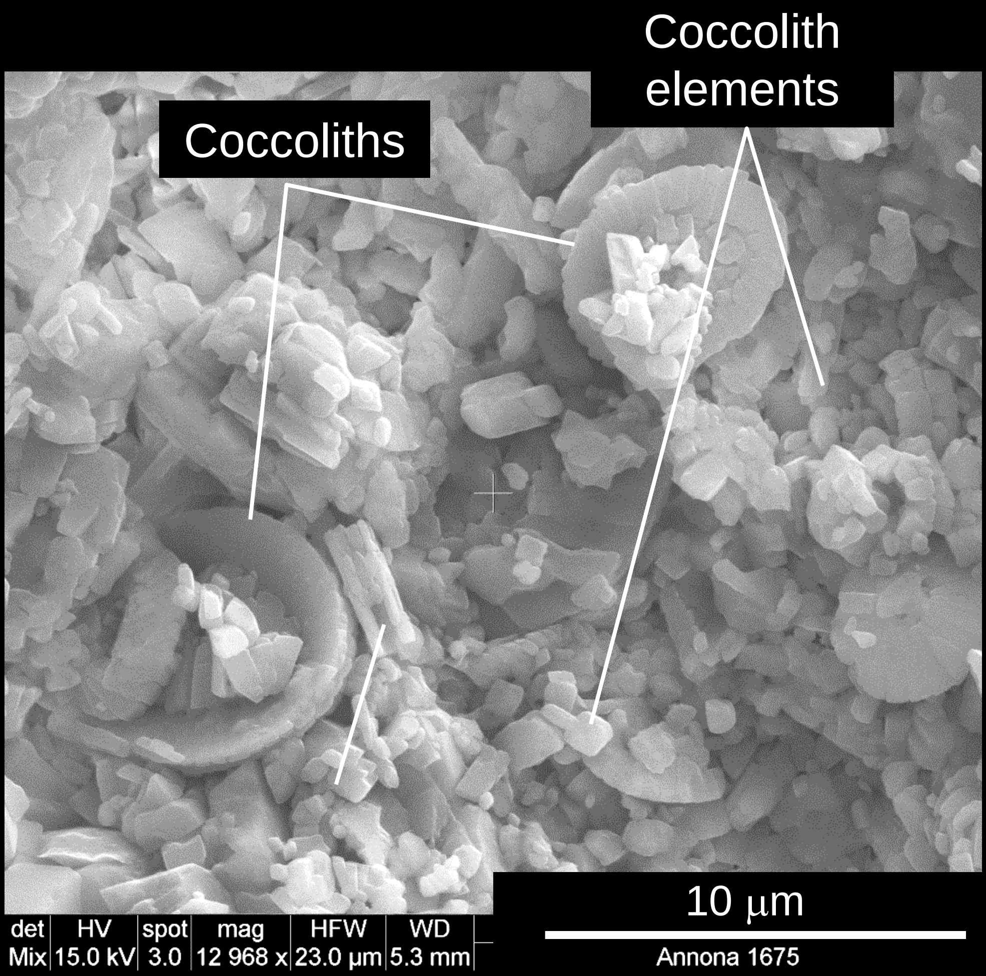
Coccolith-rich limestone with cementation

SEM chips

Texture and Fabric



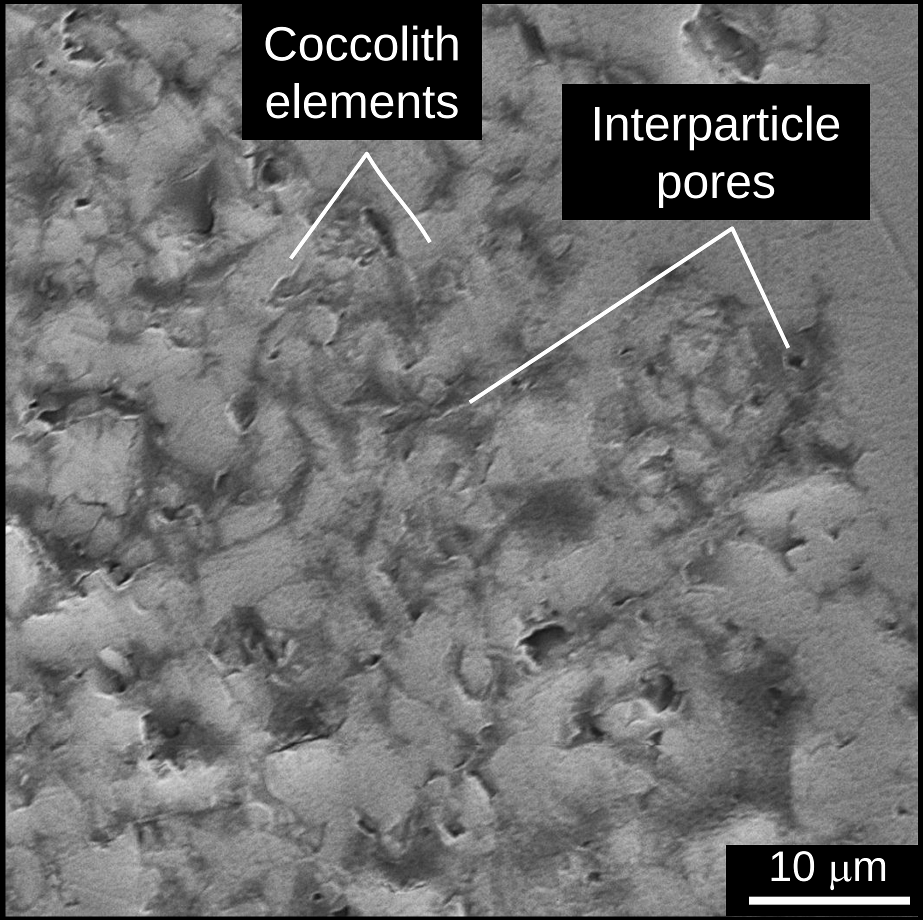
1827 ft: Polished thin-section sample



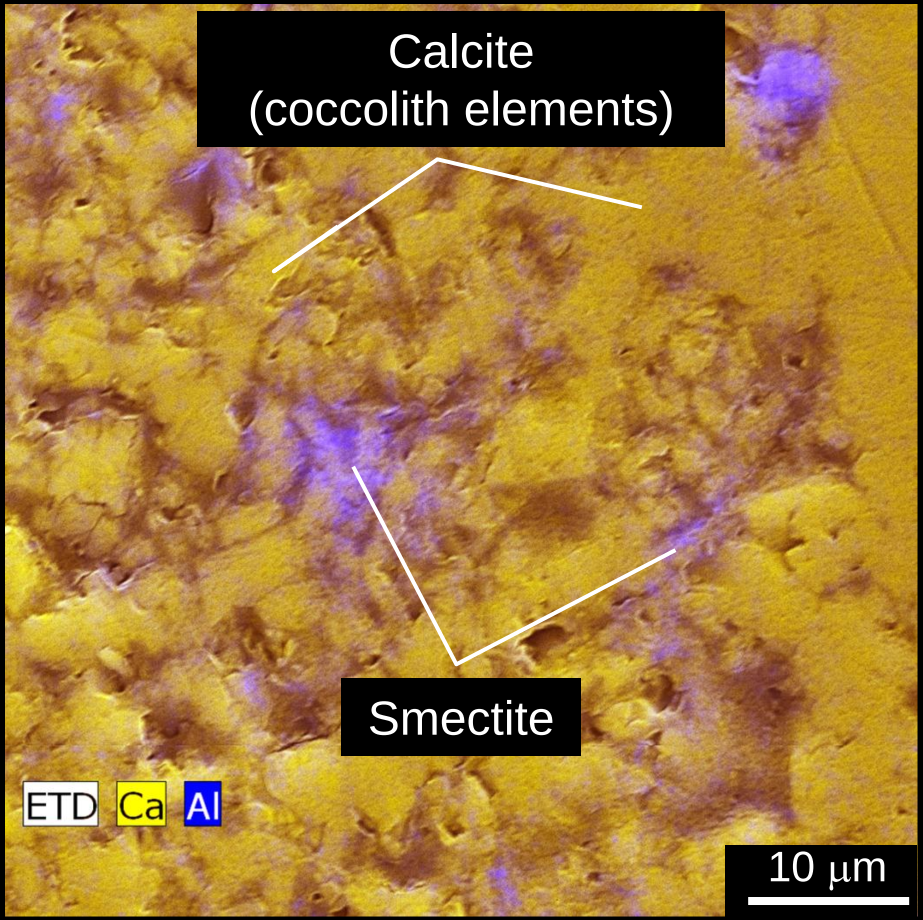
1675 ft: SEM chip sample

Predominant allochems are foraminifera and coccoliths

Mineralogy



Secondary electron photo

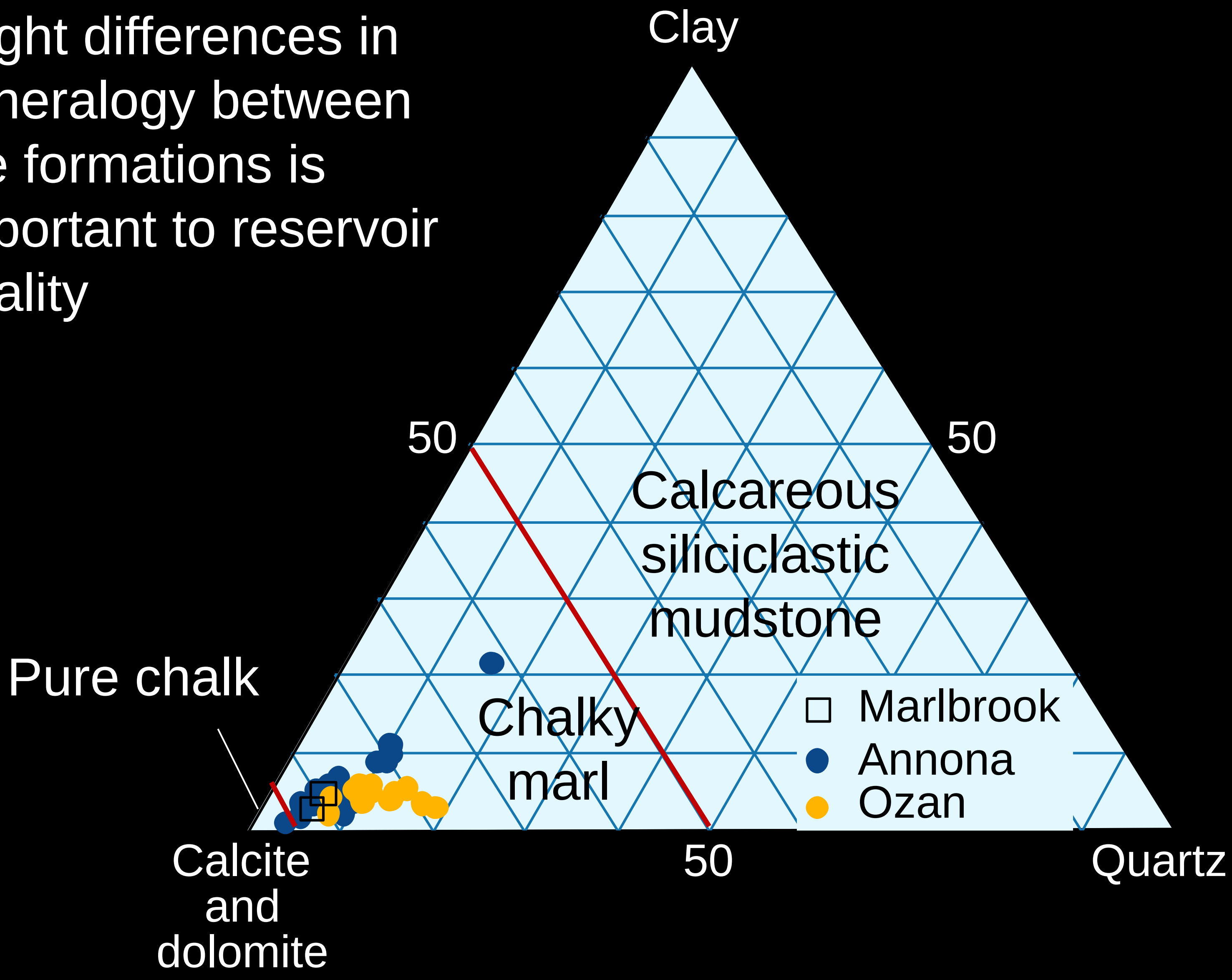


Calcium and aluminum EDX map

1827 ft: SEM polished thin section (Ozan)

Mineralogy

Slight differences in mineralogy between the formations is important to reservoir quality

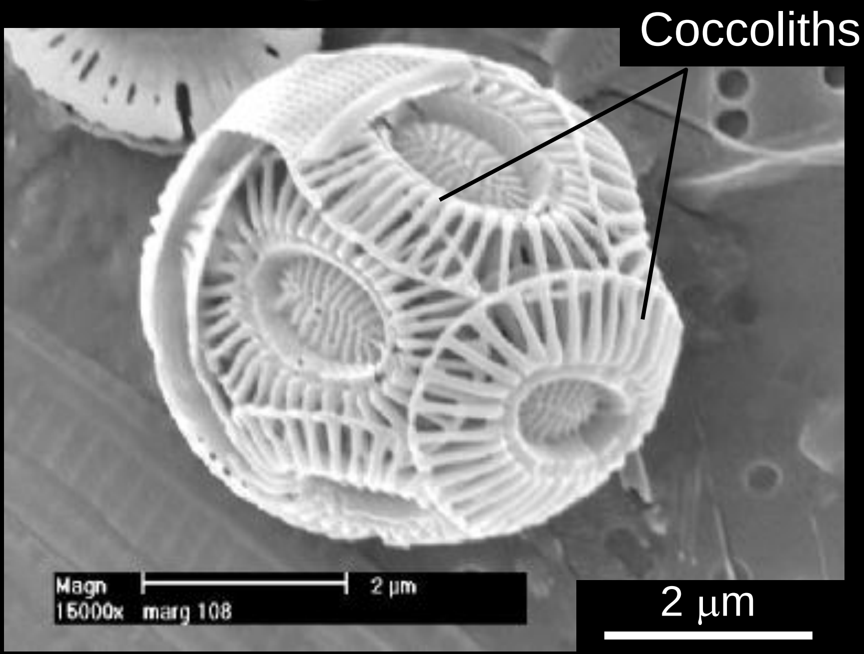


General Diagenesis of Chalks

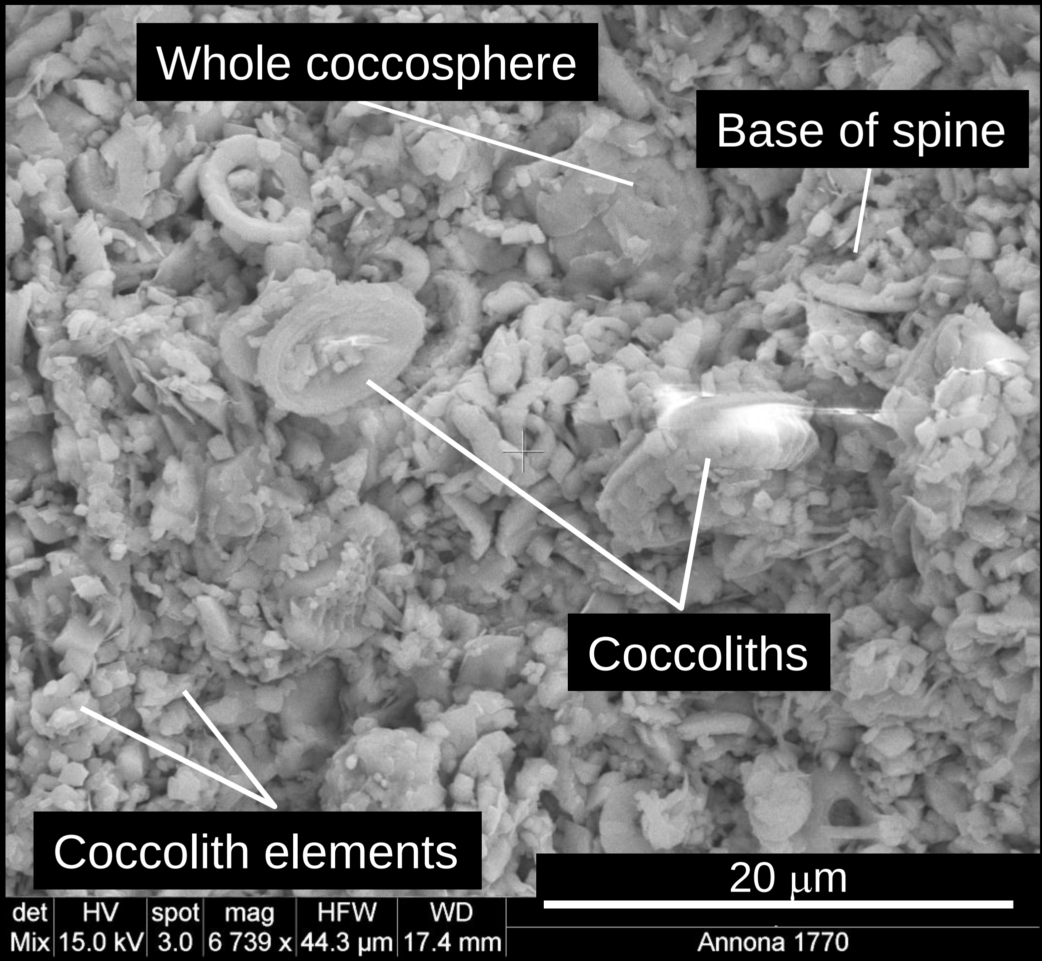
- Compaction (~75% ➡ ~50%*)
- Segmentation
- Cementation
- Effects of clay

*Based on diagrams from Scholle (1977)

Segmentation of Coccospheres

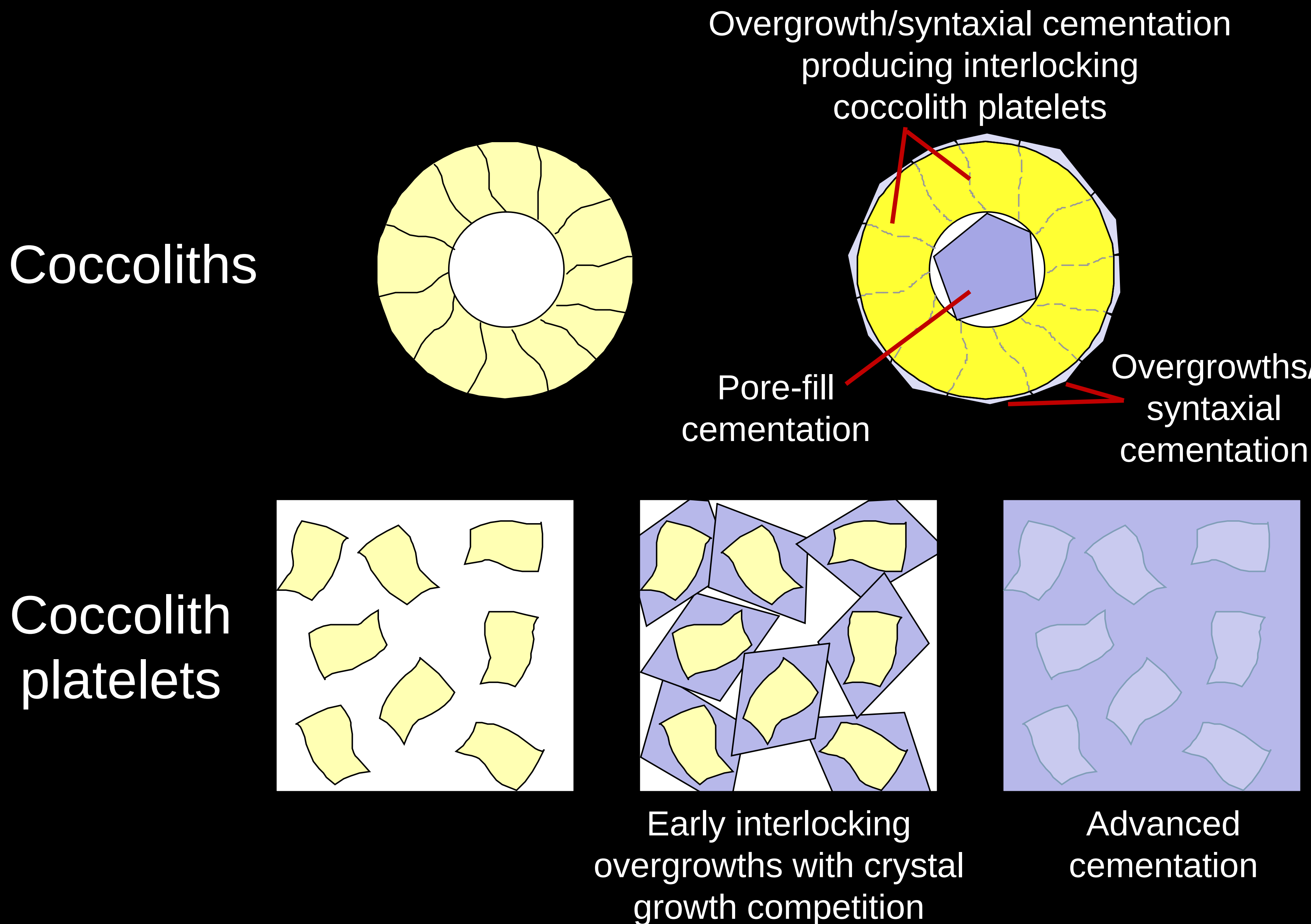


- Coccosphere (unicellular planktonic algae)
- Partly held together by CAPs (coccolith-associated polysaccharides)
- Mechanical compaction and bioturbation may aid in segmentation

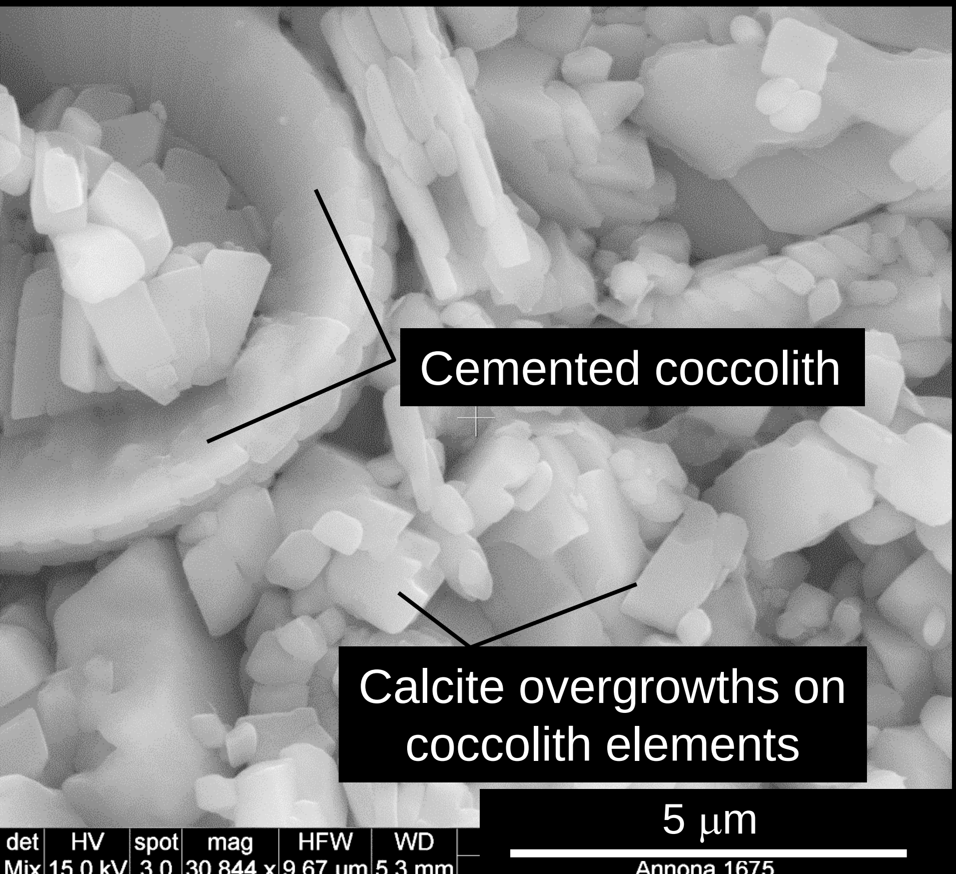


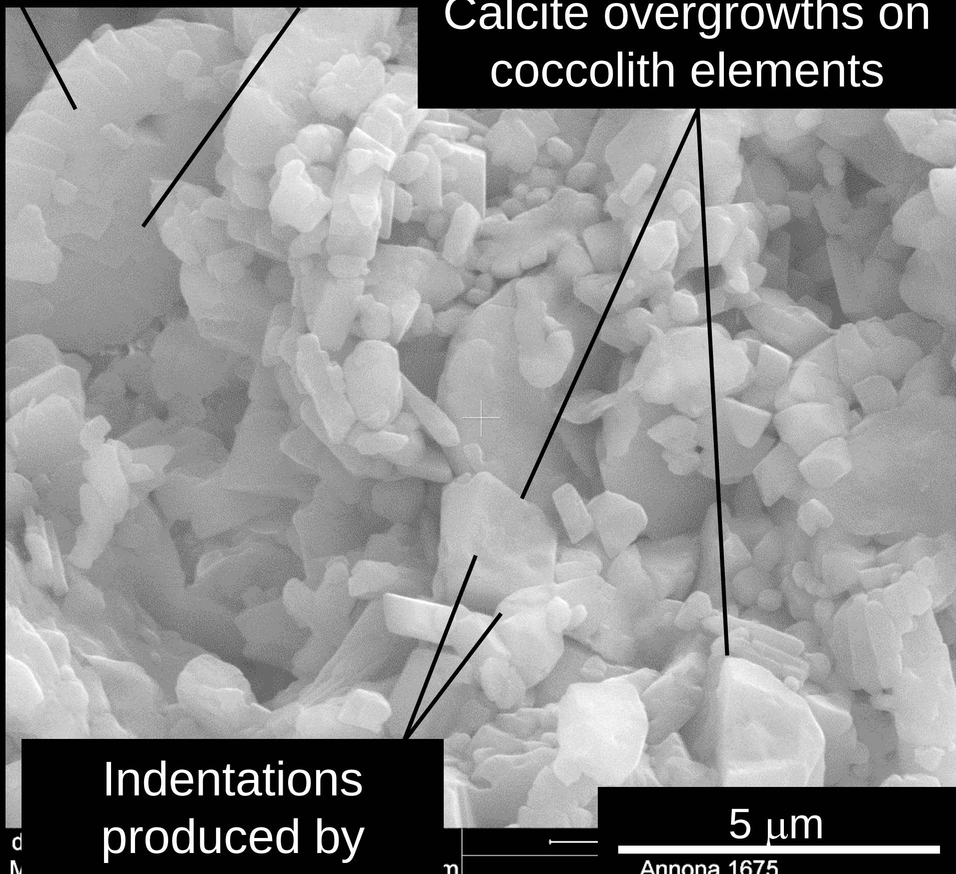
SEM chip

Cementation



Cementation

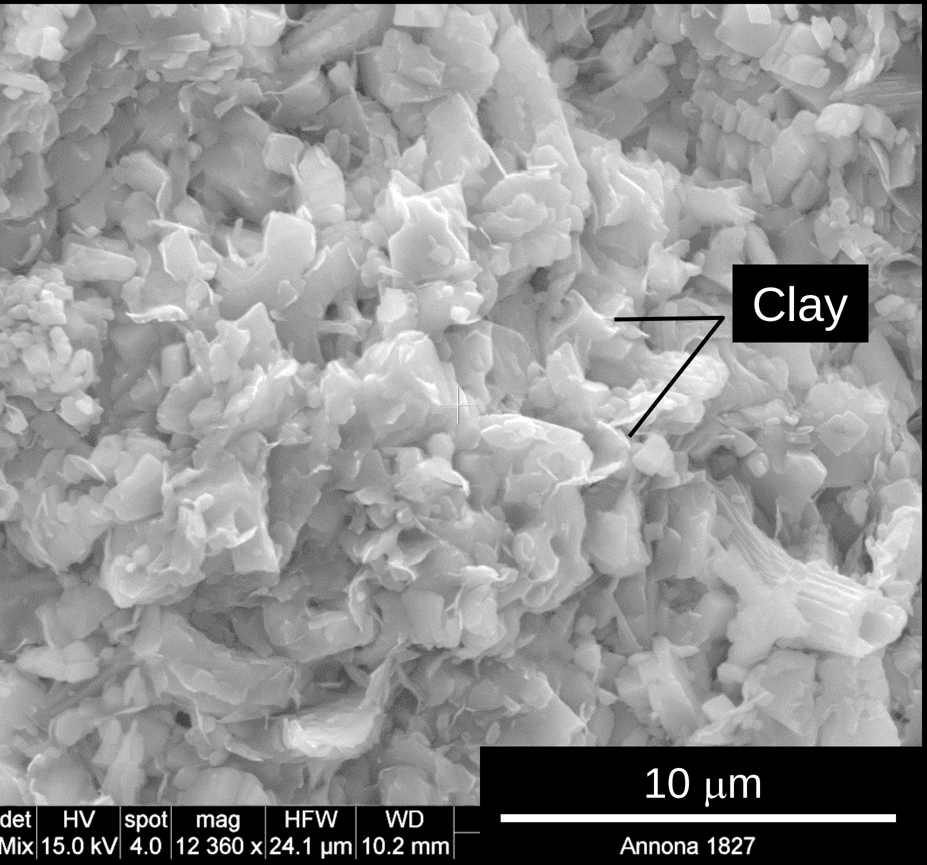


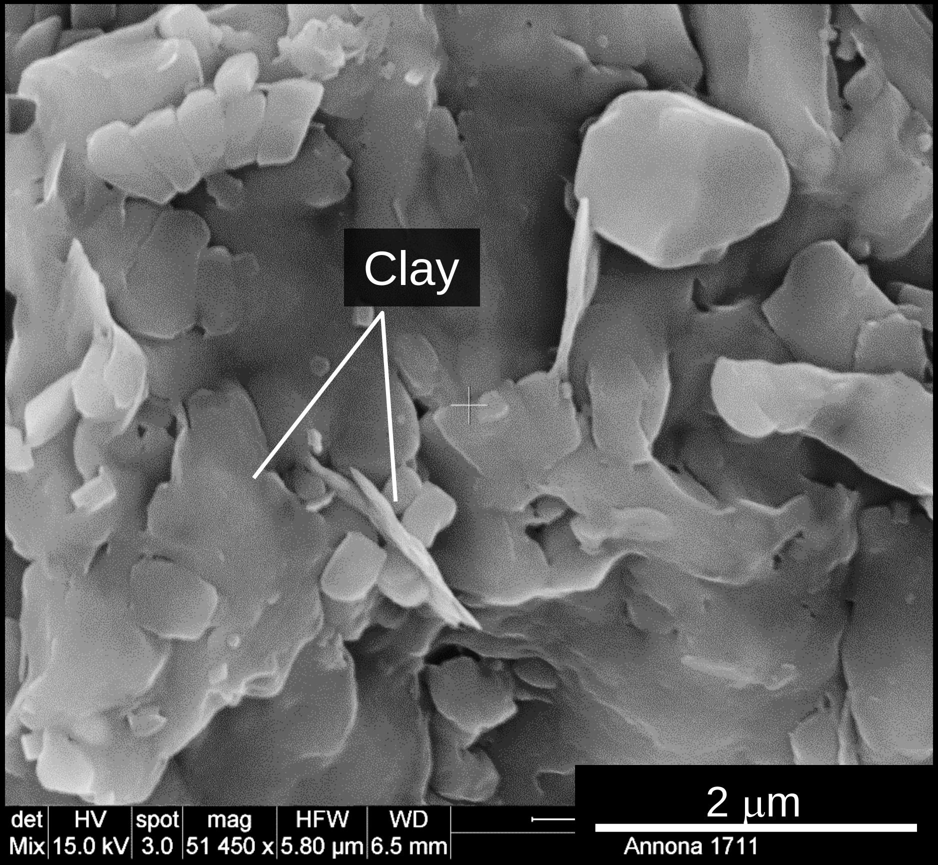


Cements nucleate on the coccolith elements

SEM chips

Effects of Clay

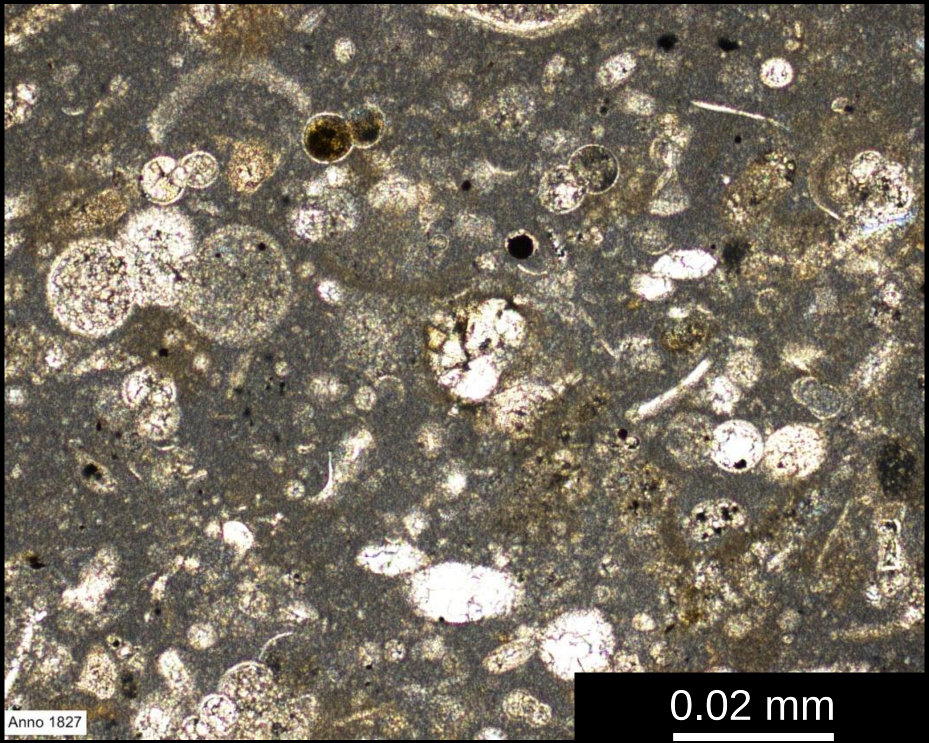


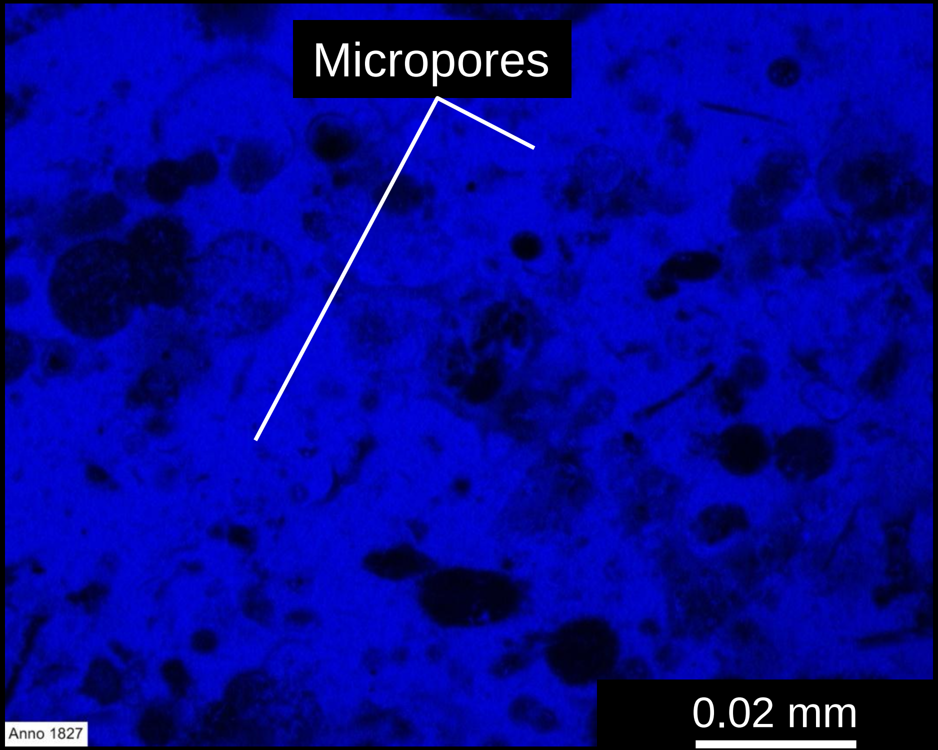


Clay appears to promote cementation

SEM chips

Thin-Section View: Micropores





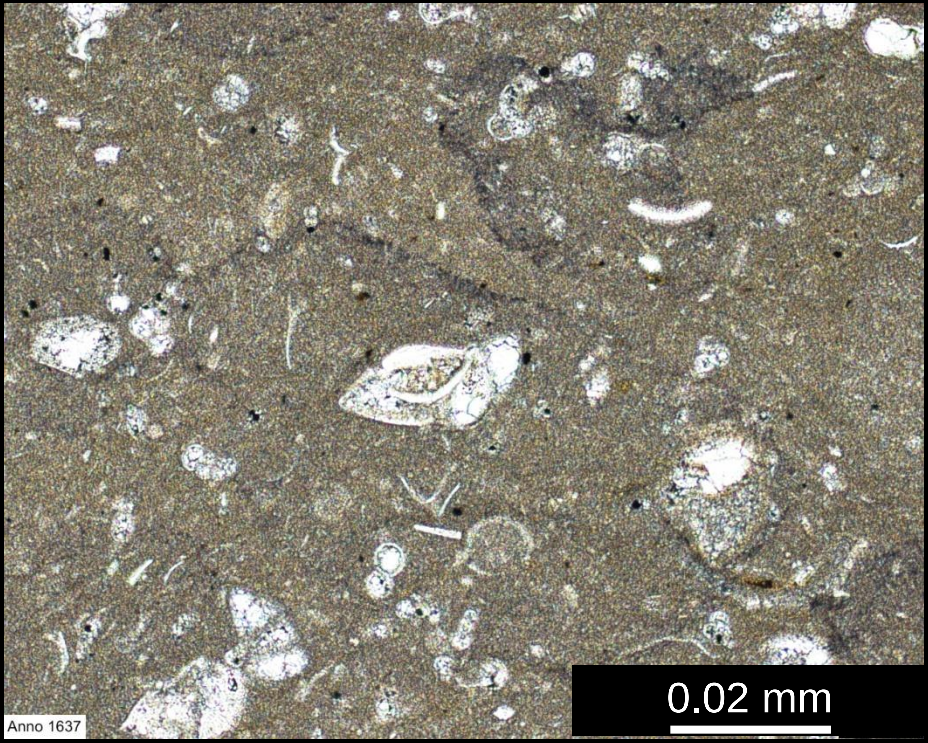
Plain light

UV light

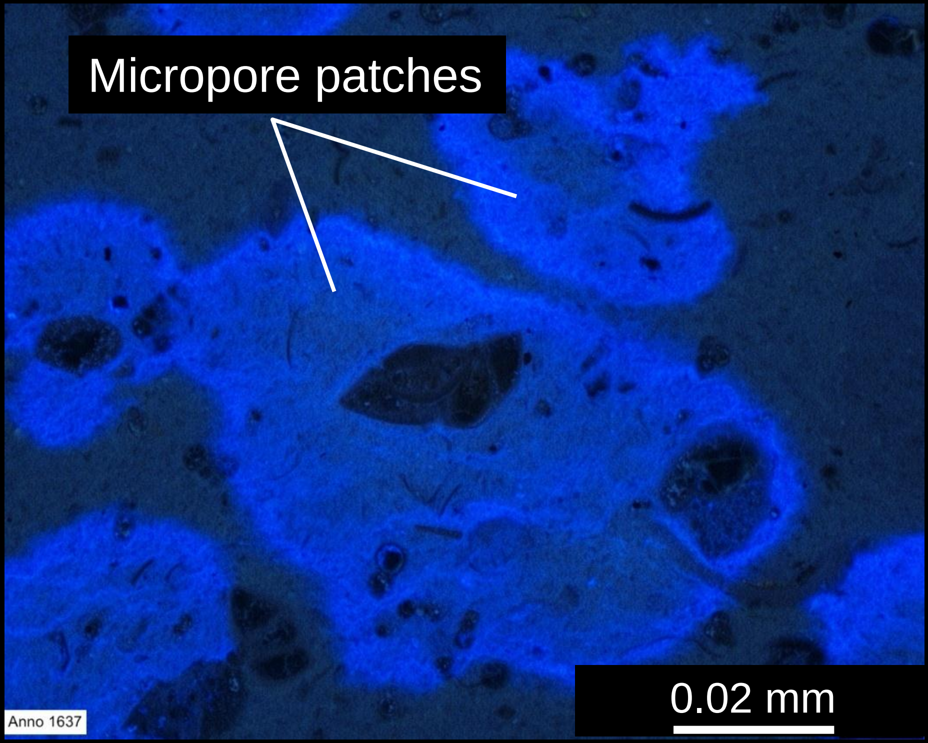
Continuous micropores in matrix

Blue fluorescent dyed thins section

Thin-Section View: Micropores



Plain light

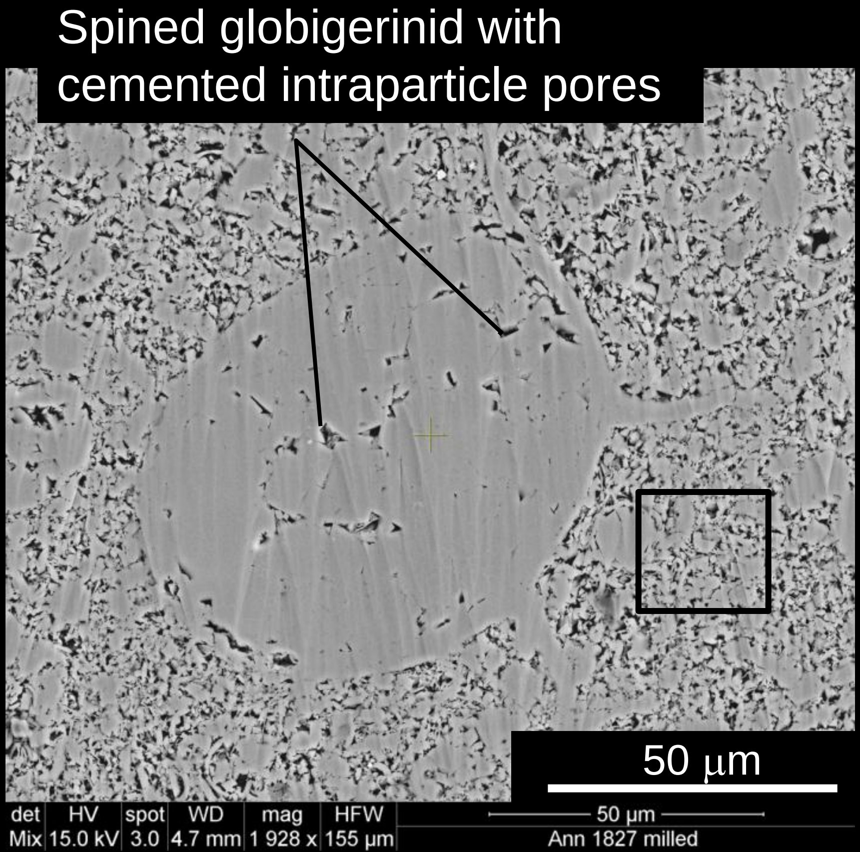


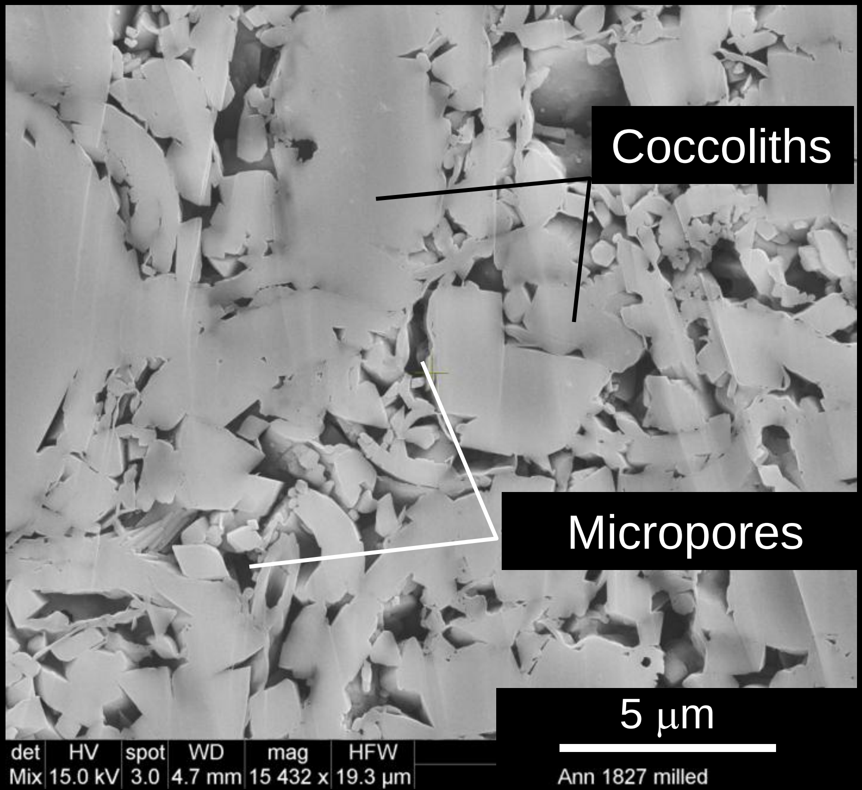
UV light

Large, patchy areas of micropores; patches may be associated with peloids

Blue fluorescent dyed thins section

Pore Network (FSEM Ar-Milled)

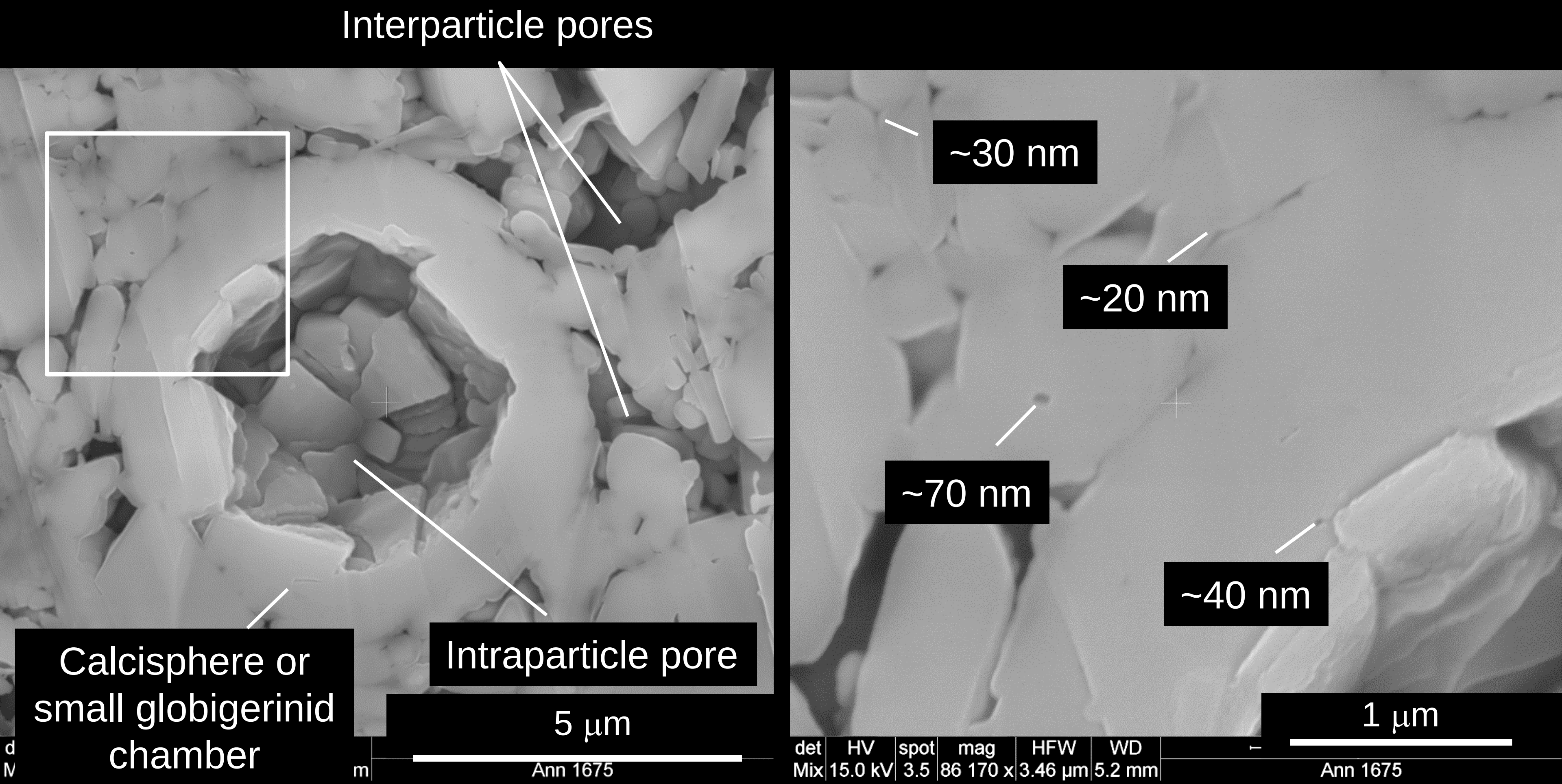




Ozan nanometer- to micron-scale pores

SEM Ar-ion milled stub

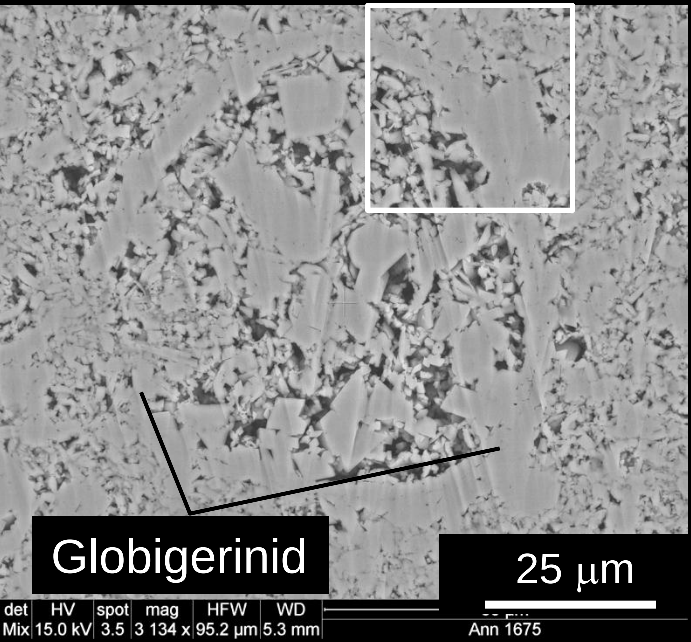
Pore Network (FSEM Ar-Milled)



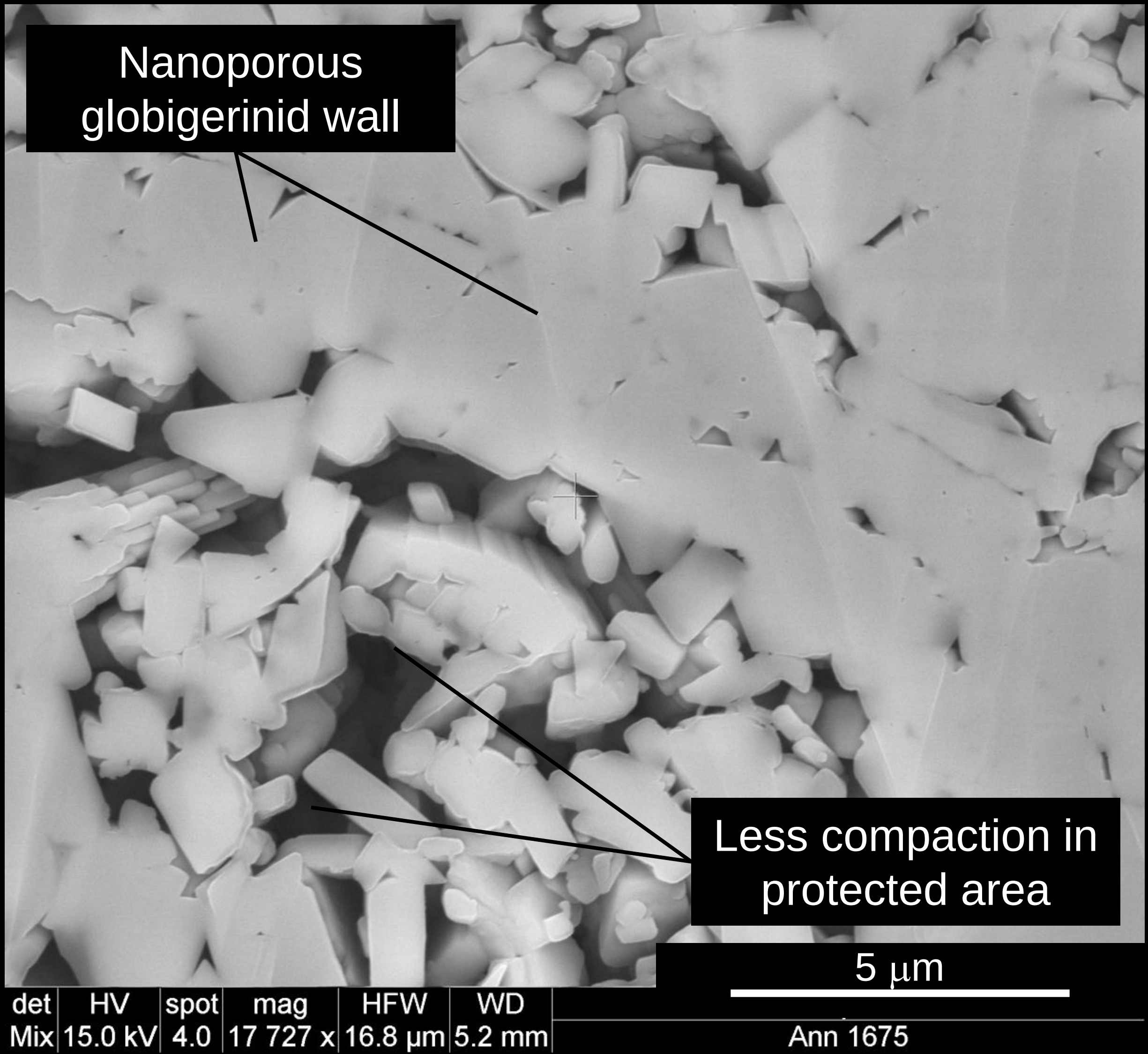
Annona nanometer- to micron-scale pores

SEM Ar-ion milled stub

Pore Network (FSEM Ar-Milled)

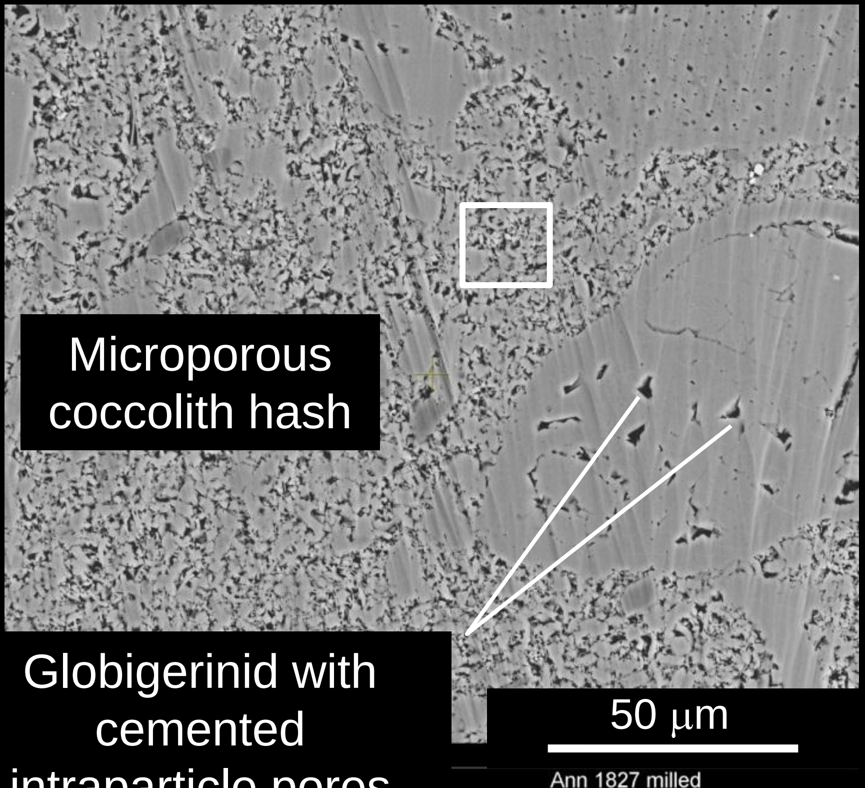


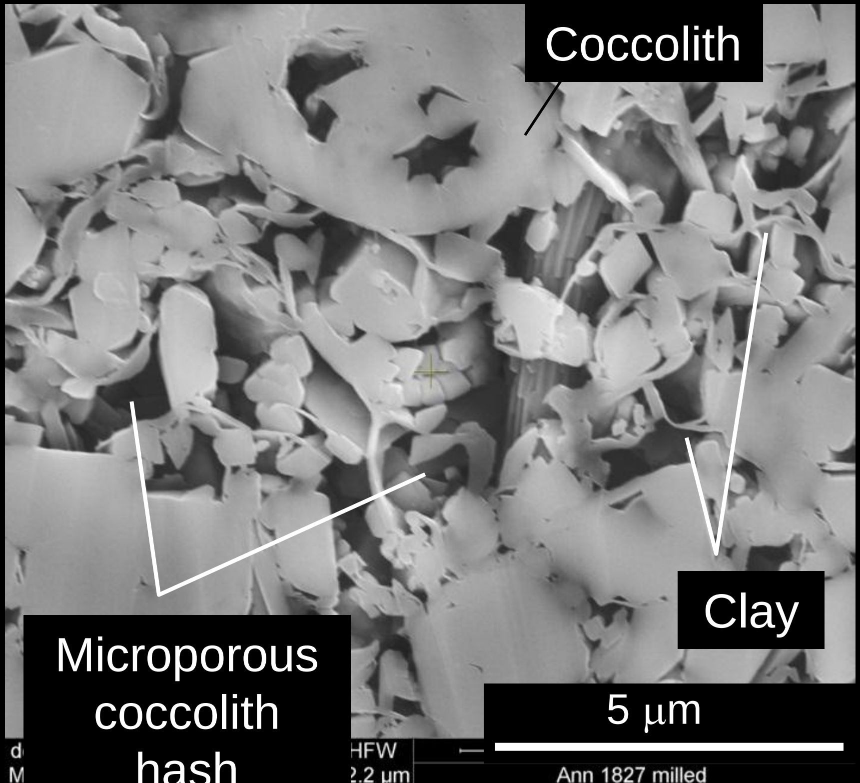
SEM Ar-ion milled stub



Less compaction of coccolith elements inside globigerinid

Pore Network (FSEM Ar-Milled)





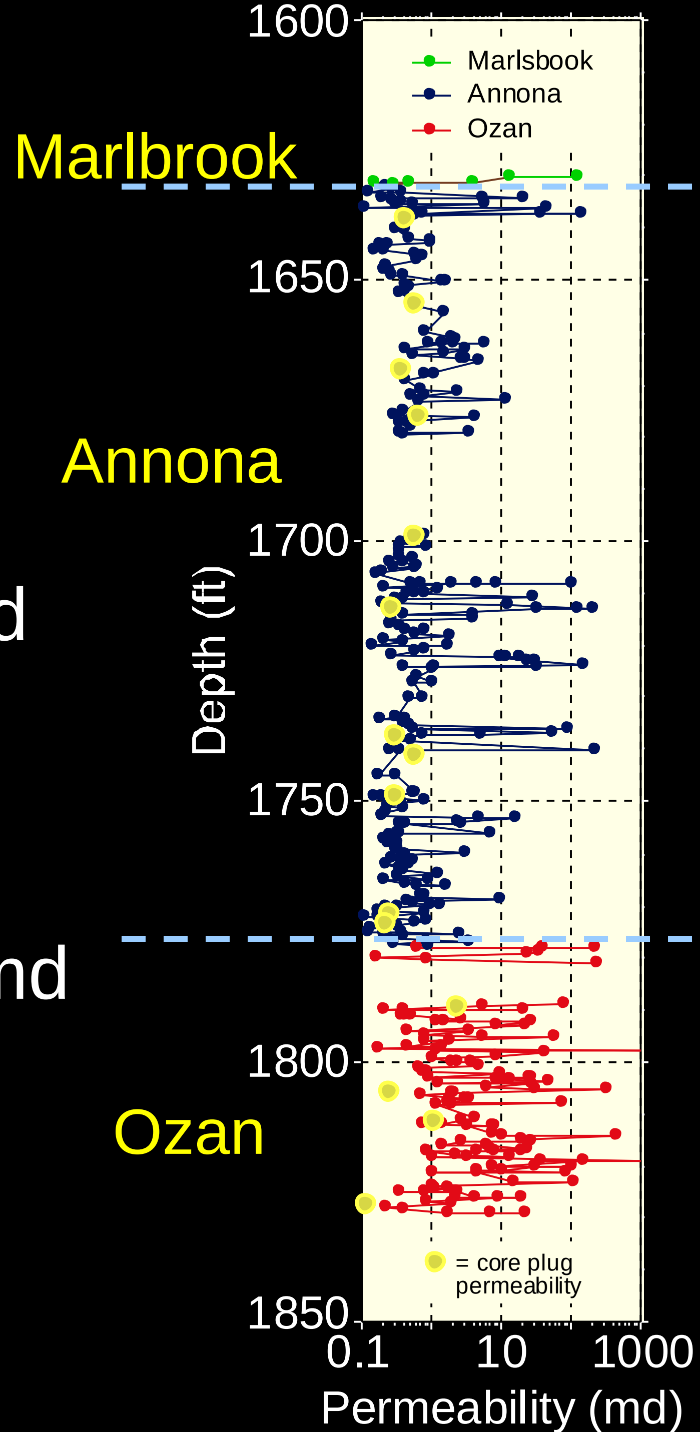
- ➢ Ozan nanometer- to micrometer-scale pores with clay
- ➢ Clay reduces pore connectivity

SEM Ar-ion milled stub

Minipermeability Analysis

Annona
Mean porosity = 23.8%
Mean permeability = 7.10 md

Ozan
Mean porosity = 17.4%
Mean permeability = 23.80 md



Conclusion

- Deposited as chalk on an oxygenated, drowned shelf
- Predominately calcite with 2 to 8 percent clay and microquartz
- Pore network mainly primary interparticle micropores and intercrystalline nanopores within coccolith hash reduced by compaction and cementation
- Will nanopores affect S_w relative to micropores?