Carbonate sedimentary rocks

Limestones and dolostones

Introduction

- Make up 20 – 25% of all sedimentary rocks
- Precambrian, Paleozoic successions:
  - abundant dolostones
- Mesozoic and Cenozoic carbonates
  - Mainly limestone
- Various textures, structures, and fossils
  - Ancient marine environments
  - Paleoecological conditions
  - Evolution of life forms through time
  - Also economically important
    - Agricultural, industrial purposes
    - Reservoir rocks for >1/3 of the world’s petroleum reserves

Chemistry and mineralogy

- Ca^{2+}, Mg^{2+}, and carbonate (CO_3^{2-}) ions
- CaO, MgO, and CO_2 = 90% of the average carbonate rock
- Silicate minerals and clay minerals
  – Si, Al, K, Na, and Fe
- Trace elements
  – Be, Ba, Sr, Cl
    - Mineralogy, fossil skeletal grains

Chemistry and mineralogy

- Dolomite
  - Few modern environments (supratidal, freshwater lakes)
- Aragonite, calcite
  - Abundant in modern carbonate environments
- Precipitation of calcite
  - Paleozoic and middle to late Cenozoic time
    - Lower Mg:Ca ratio

Composition of fossil organisms

- Molluscs (e.g. pelecypods, gastropods)
- Green algae, stromatoporoids
  – Skeletons of <u>aragonite</u>
- Echinoids, crinoids, benthic forams
  – <u>High-magnesian calcite</u>
- Planktonic forams, coccoliths, and brachiopods
  – <u>Low-magnesian calcite</u>

Limestone textures

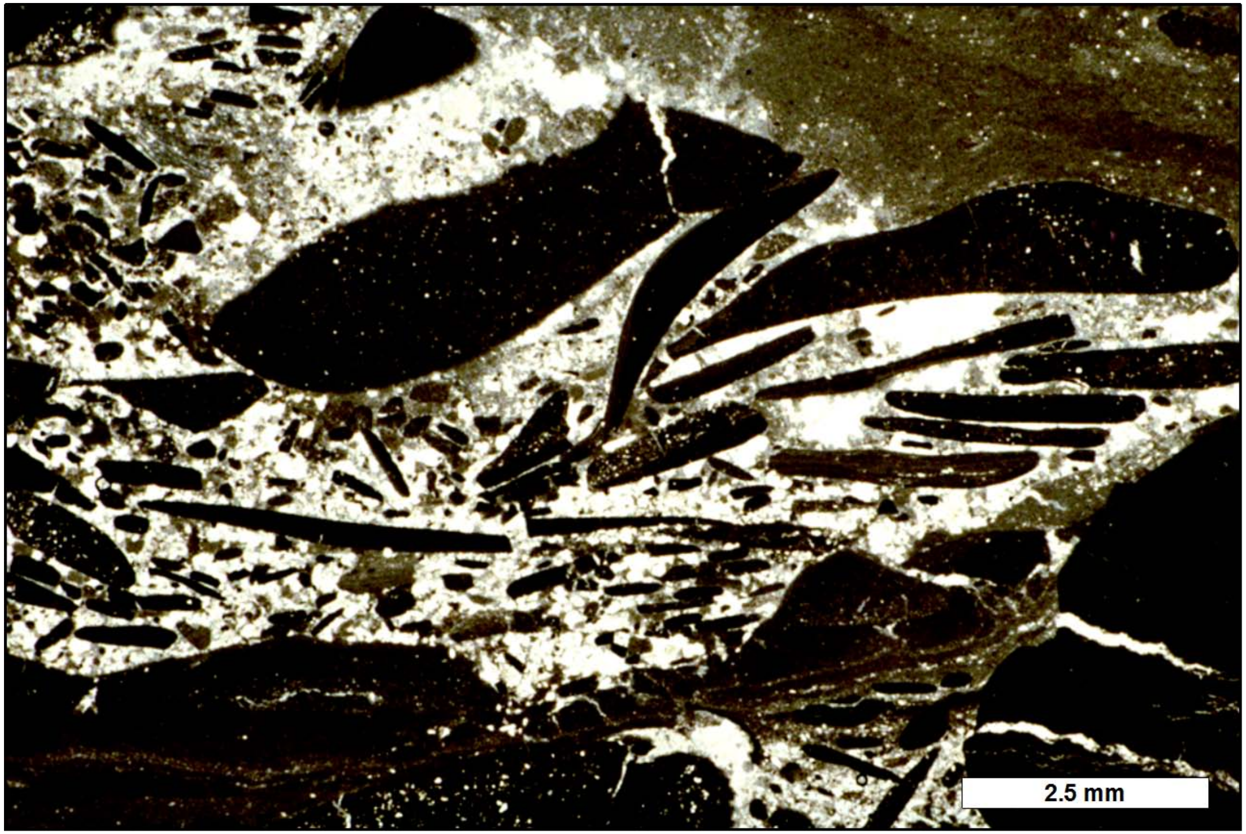
- **Carbonate grains**
  - Ooids, skeletal grains
  - Intraclasts
  - Silt-size or larger aggregates of calcite crystals
- **Microcrystalline calcite**

  (carbonate mud; micrite)
  - Extremely fine size calcite crystals
- **Sparry calcite**
  - Coarser grained calcite crystals

Carbonate clasts

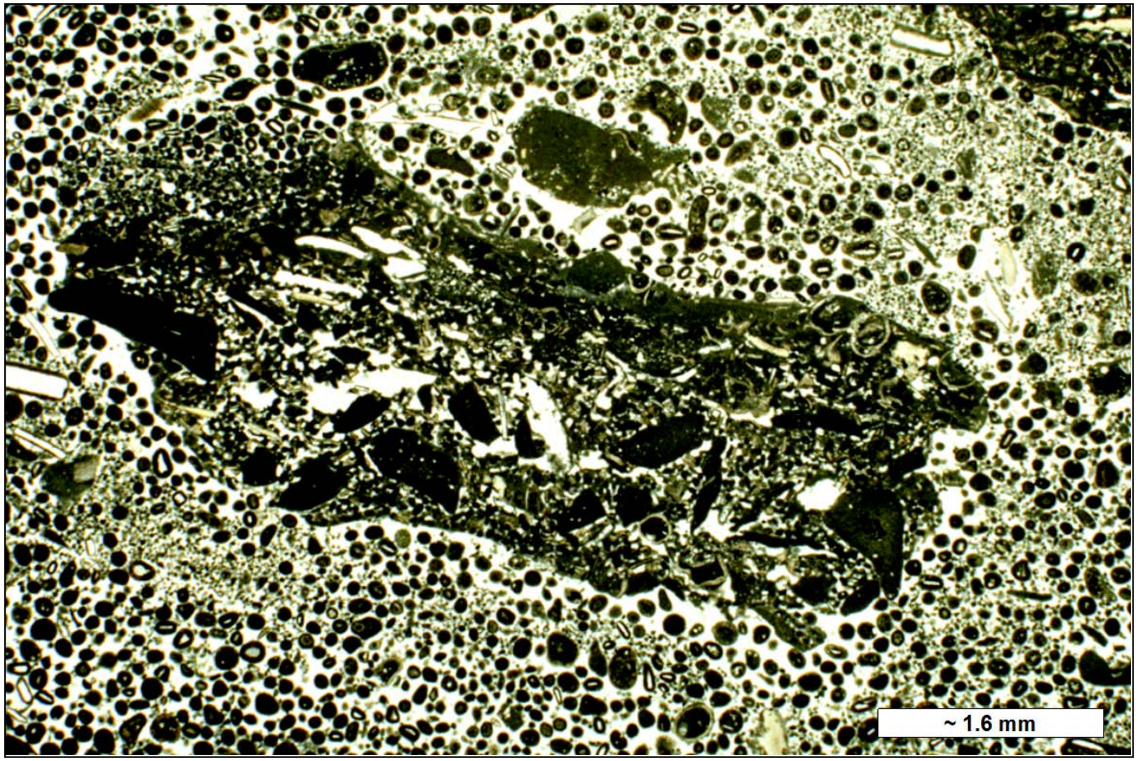
- **Intraclast**
  - A fragment of penecontemporaneous, commonly weakly consolidated, carbonate sediment that has been eroded and redeposited, generally nearby
  - Typically large grains (several mm to several cm or more) with moderate to good rounding, and with multi-grained internal fabrics
  - Usually monomict (that is, they were all derived from a common nearby environment and thus have similar composition and texture).

Intraclasts



Mid. Triassic Gipsdalen Fm., Jameson Land, East Greenland
Irregular, elongate intraclasts of micritic carbonate
Storm-influenced, stromatolitic, tidal flat areas.

Intraclasts

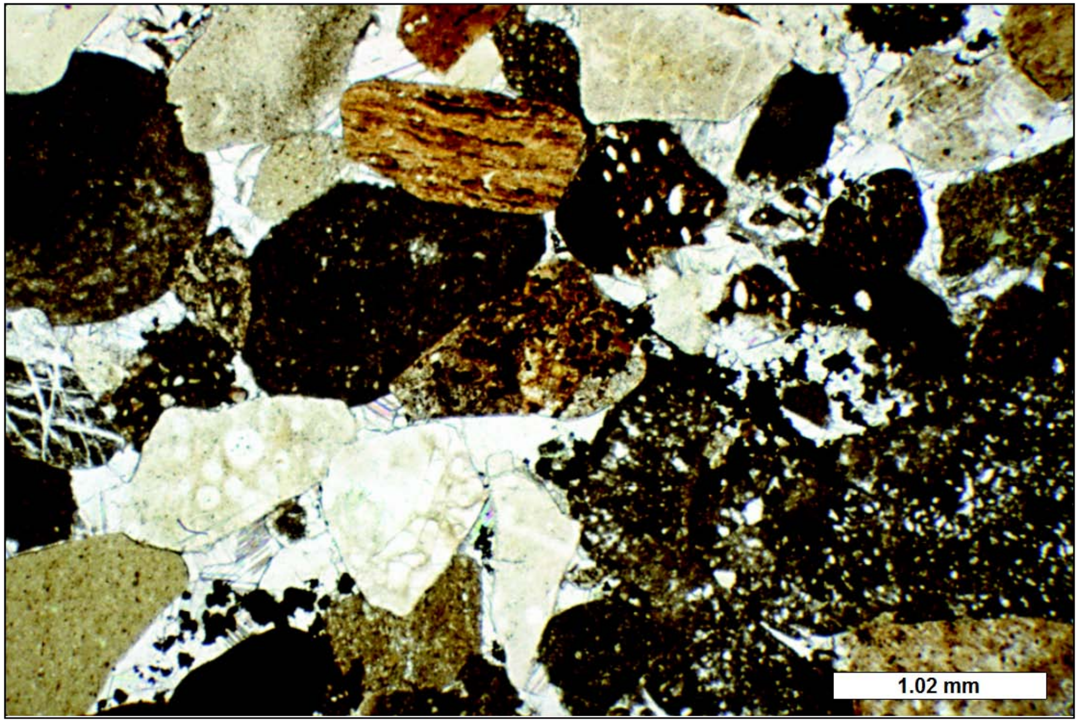


Mid. Ordovician Black River Gp., Kingston area, Ontario, Canada
A large compound intraclast among dominantly fine-grained ooids and peloids.
- Reworked sediment fragment that includes other intraclasts (from an earlier generation of reworking).
- Storm-influenced coastal and shallow shelf settings.

Carbonate clasts

- **Extraclast**
  - A detrital grain of lithified carbonate sediment (lithoclast) derived from outside the depositional area
  - Large, sub-rounded to well rounded grains (unlike angular grains in collapse breccias)
  - Tend to occur as polymict assemblages (i.e., grains with a variety of textures and compositions

Extraclasts

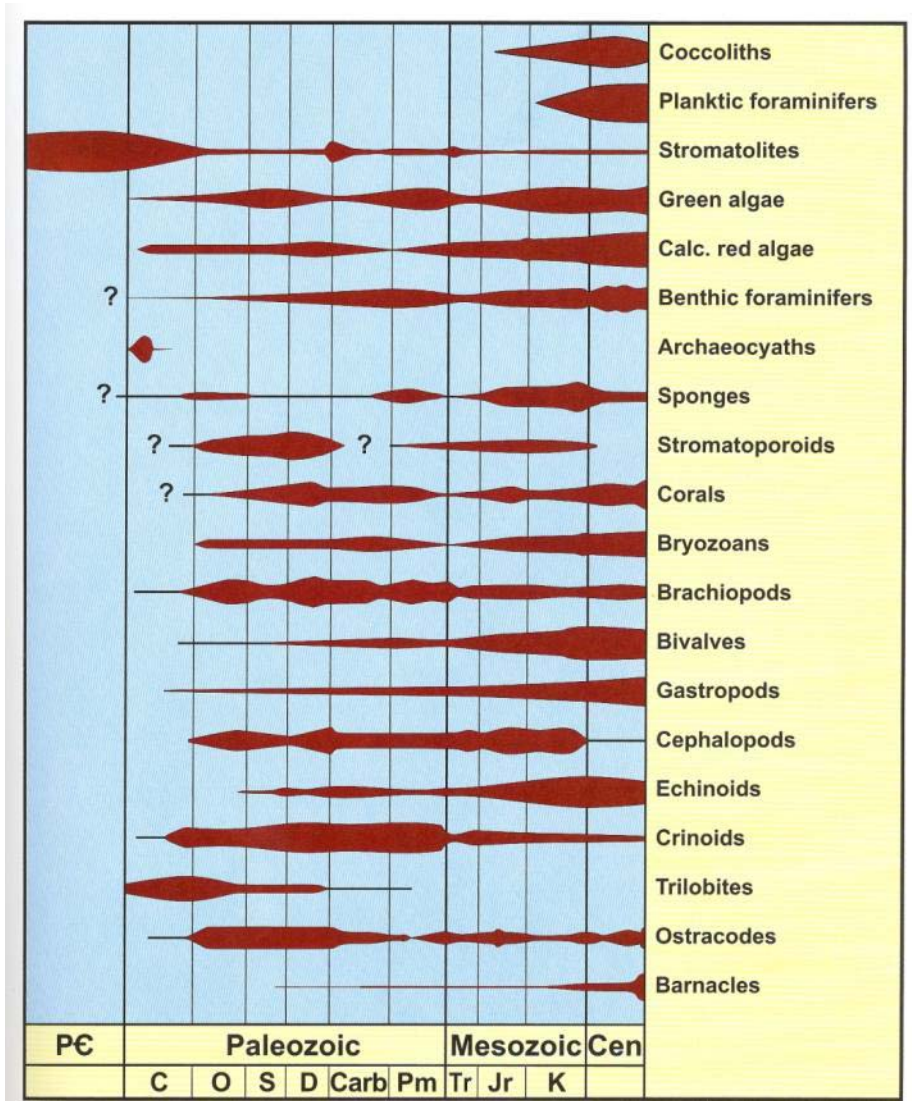


Up. Permian (Ufimian) Top Solikamskaya Suite, Perm Region, Russia
Extraclasts in a calclithite. The highly polymict nature of the clasts and the significant rounding of even the very hard chert fragments both are clues to an extraclastic origin of grains.

Skeletal particles

- Most common kind of grains
- Calcareous marine invertebrates
  - Whole microfossils
  - Whole larger fossils
  - Broken fragments of larger fossils
  - Specific kinds depend upon the age and the depositional environment

Major groups of marine carbonate-producing organisms through time



Calcimicrobes and cyanobacteria

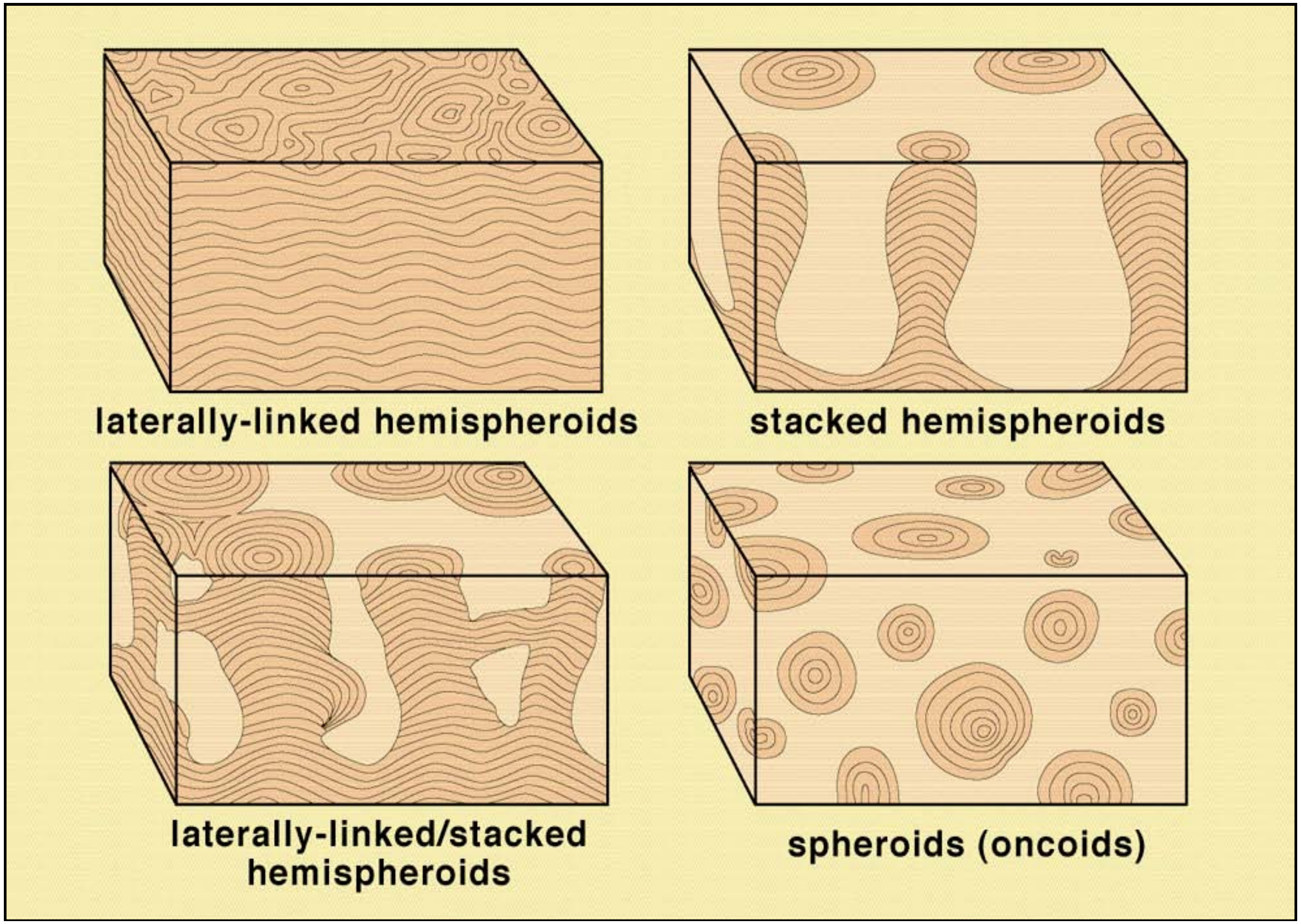
Intro

- **Cyanobacterial stromatolites usually are grouped in the Phylum Cyanophyta — Precambrian (Archean)-Recent**
- **Classification of other microbes is complex, uncertain, and ever changing (generally placed under the Prokaryotes**

Morphology

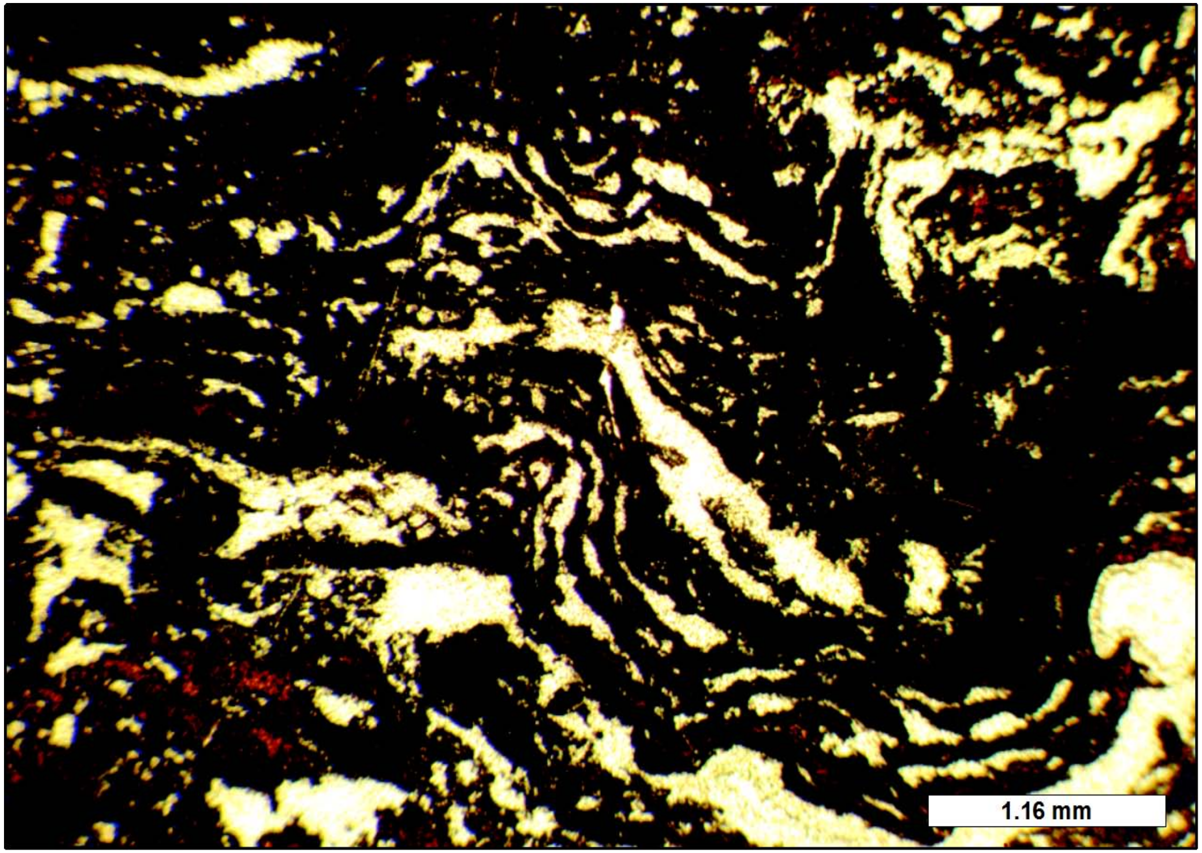
- **Lamination in stromatolites reflects microbial growth through day-night cycles and tidal cycles; those organic laminae commonly are interspersed with micritic or peloidal carbonate or terrigenous detritus that was deposited during episodic storms.**
- **Non-stromatolitic calcimicrobes typically form lumpy encrustations or small upright “shrubs”.**

Microbial Stromatolite Growth Forms



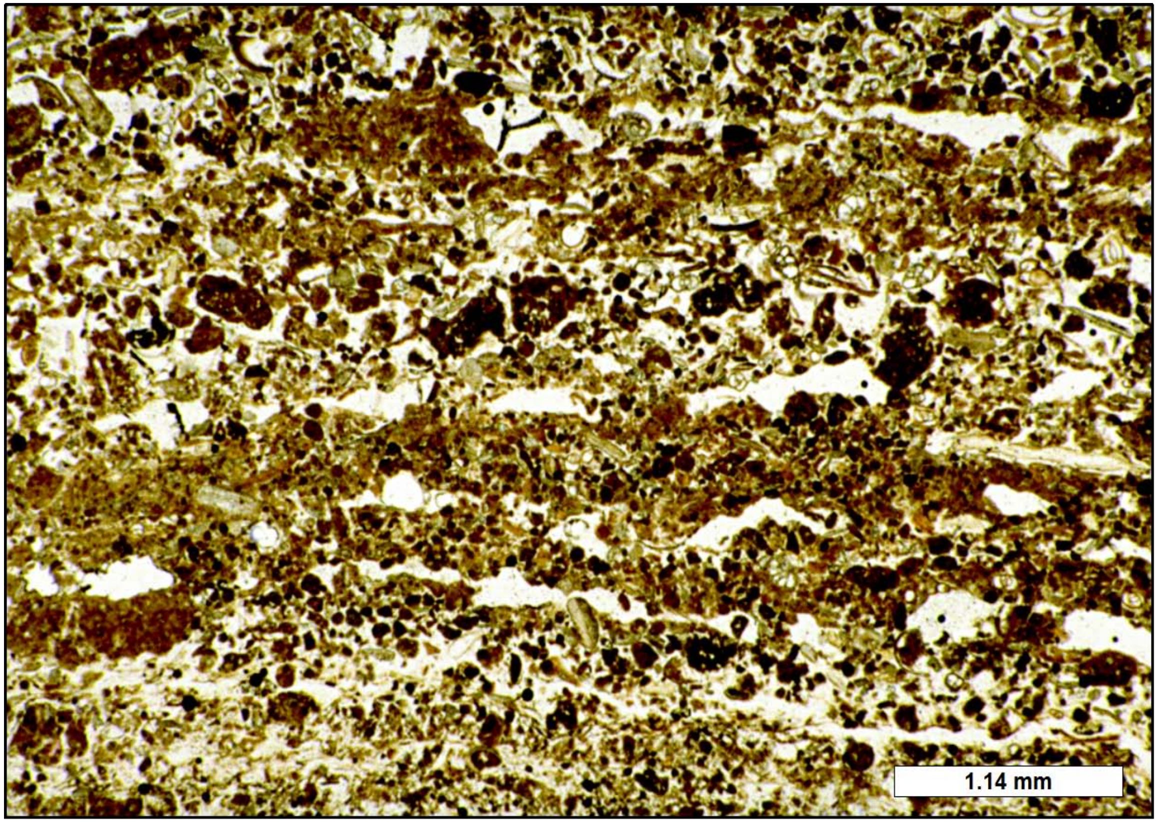
Most stromatolites are composed of laminae of trapped carbonate and/or terrigenous sediment

Example

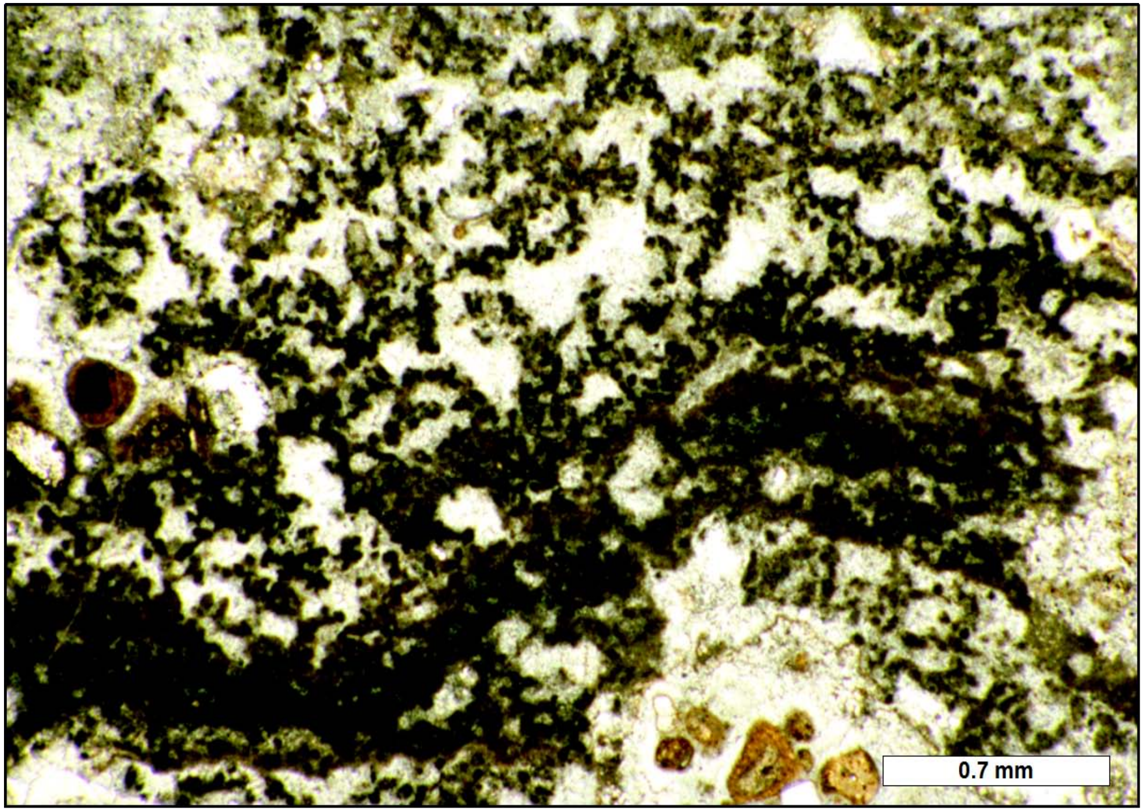


Triassic Dachstein Ls., Lofer facies, Tirol, Austria
A well developed ancient example of a laminated and contorted stromatolite (loferite).

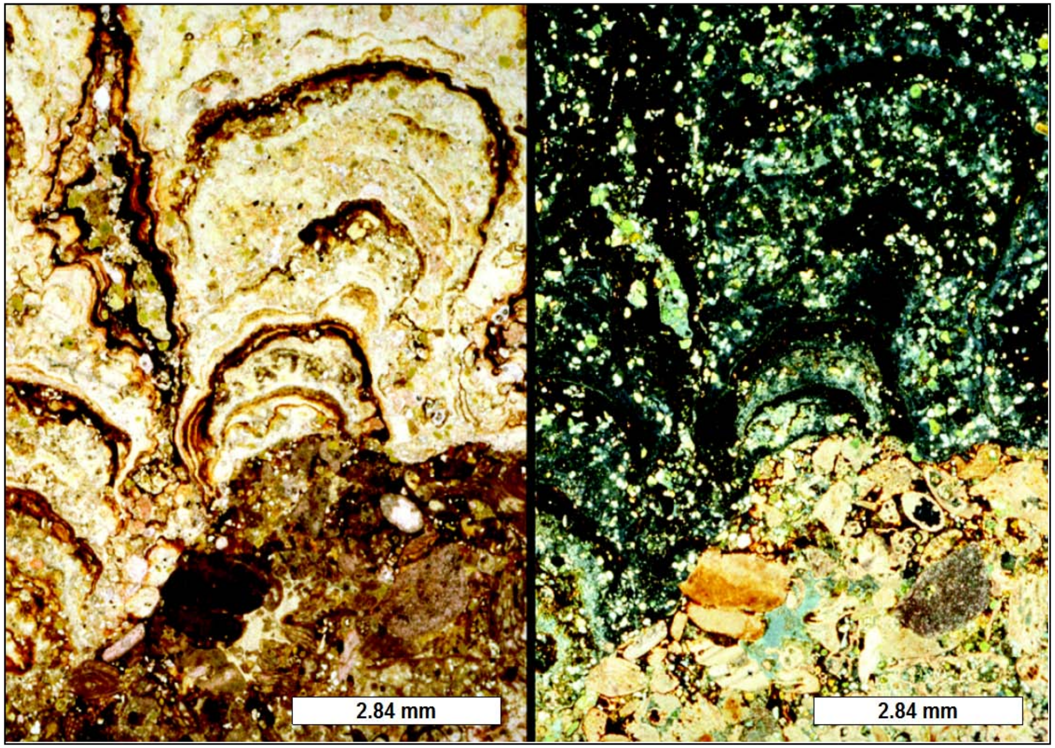
Example



Recent sediment, Crane Key, Florida Bay, Florida
Detailed texture of a typical intertidal stromatolite with interlamination of organic zones (cyanobacterial filaments, mangrove remains, and other organic detritus) and zones of transported and trapped detritus.



Recent sediment Deep Lake, Yorke Peninsula, South Australia
A stromatolite from a hypersaline lake (a coastal salina). Note microbial peloids and encrusted filaments forming small, incipient branching structures.

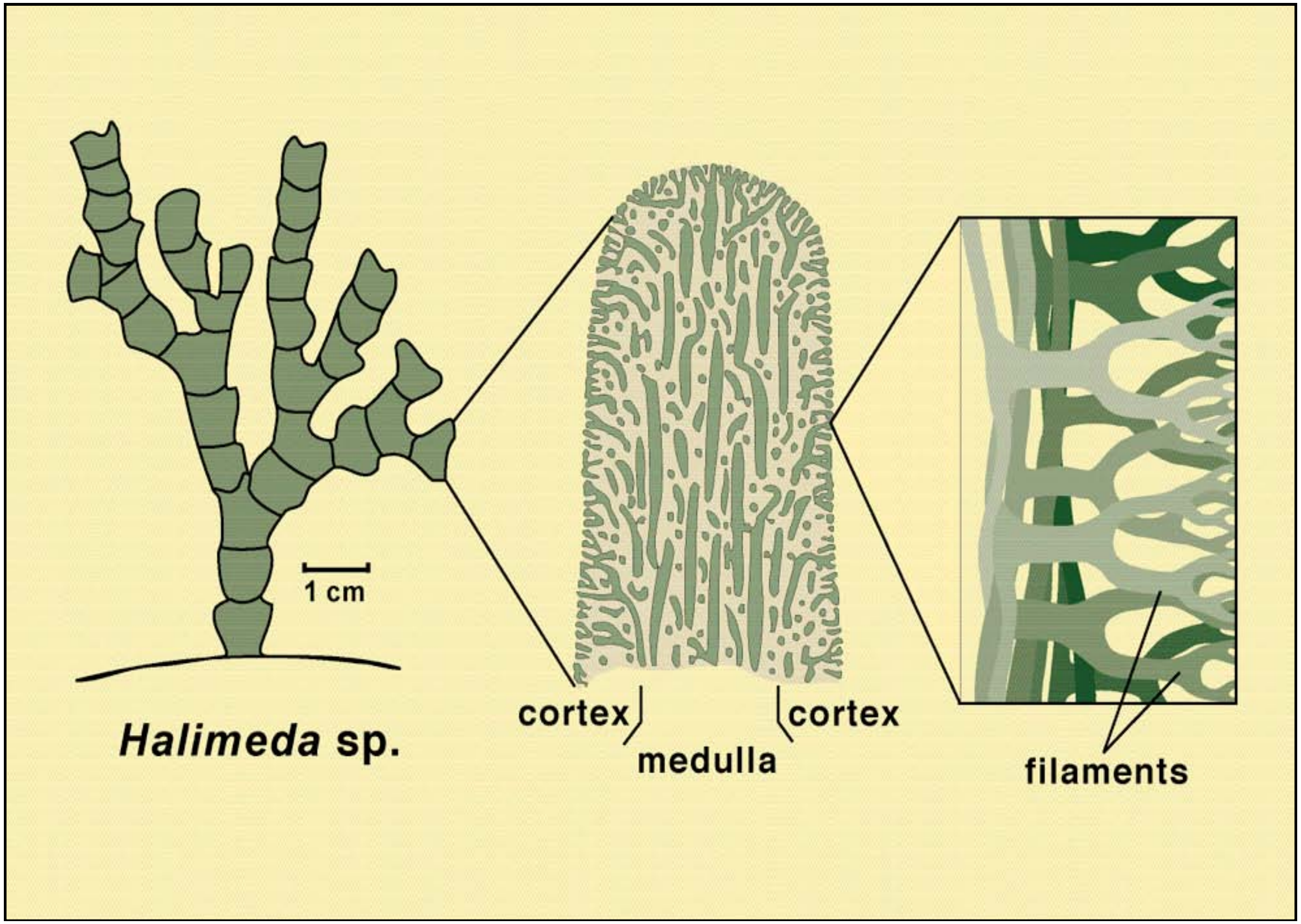


Oligocene-Miocene hardground, Oamaru, Otago, New Zealand
A stromatolitic crust atop a marine hardground. The lumpy, digitate, laminated crust is largely phosphatic, hence the brownish color in plane-polarized light and the nearly isotropic appearance in cross-polarized light.

Green algae

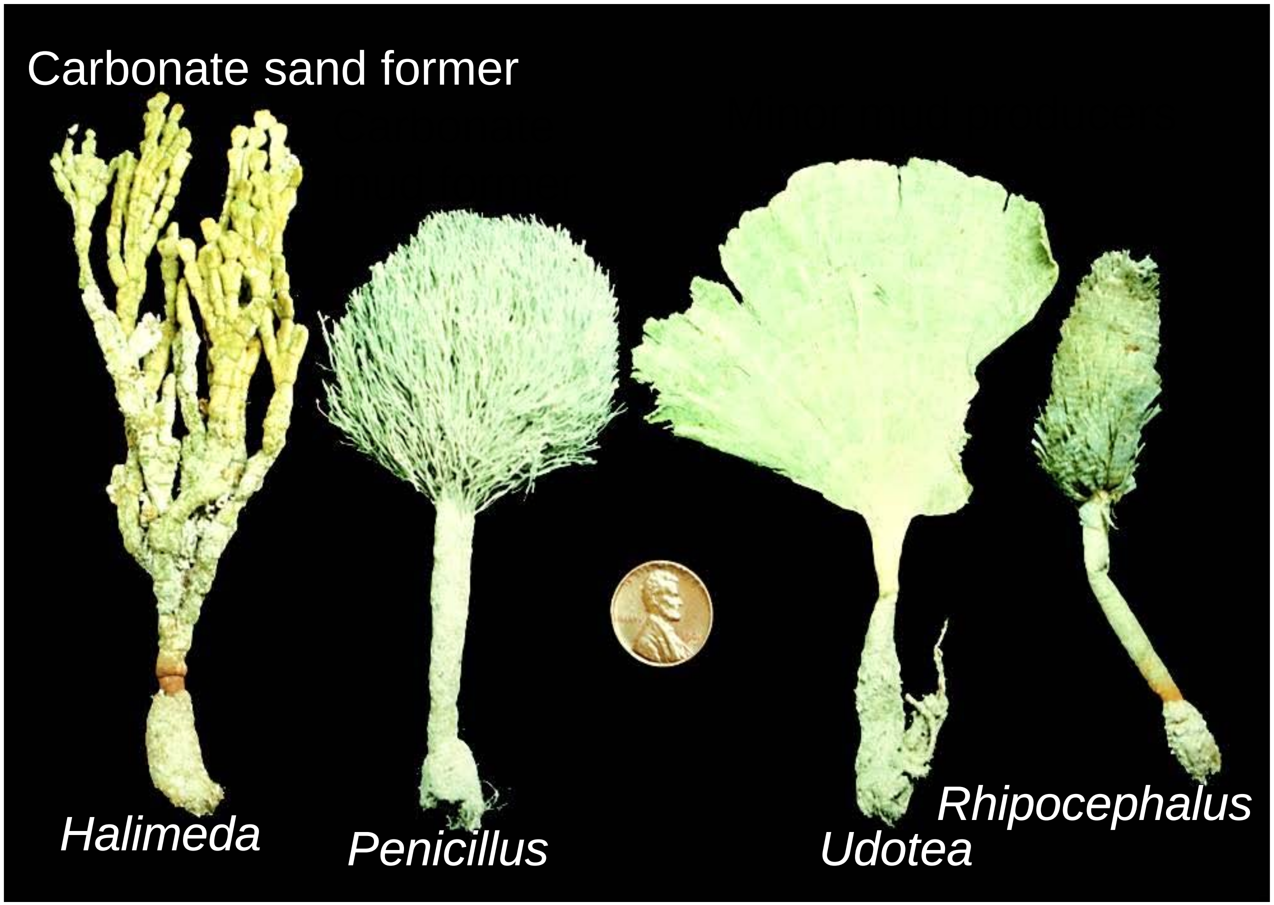
- **Modern green algae form upright, typically segmented, shrubby plants about 5-15 cm high**
    - **Source of carbonate mud (micrite)**
    - **Elongate plates with organized tubular or filamentous structure that may or may not be preserved after diagenesis**

Typical codiacean green algal structure



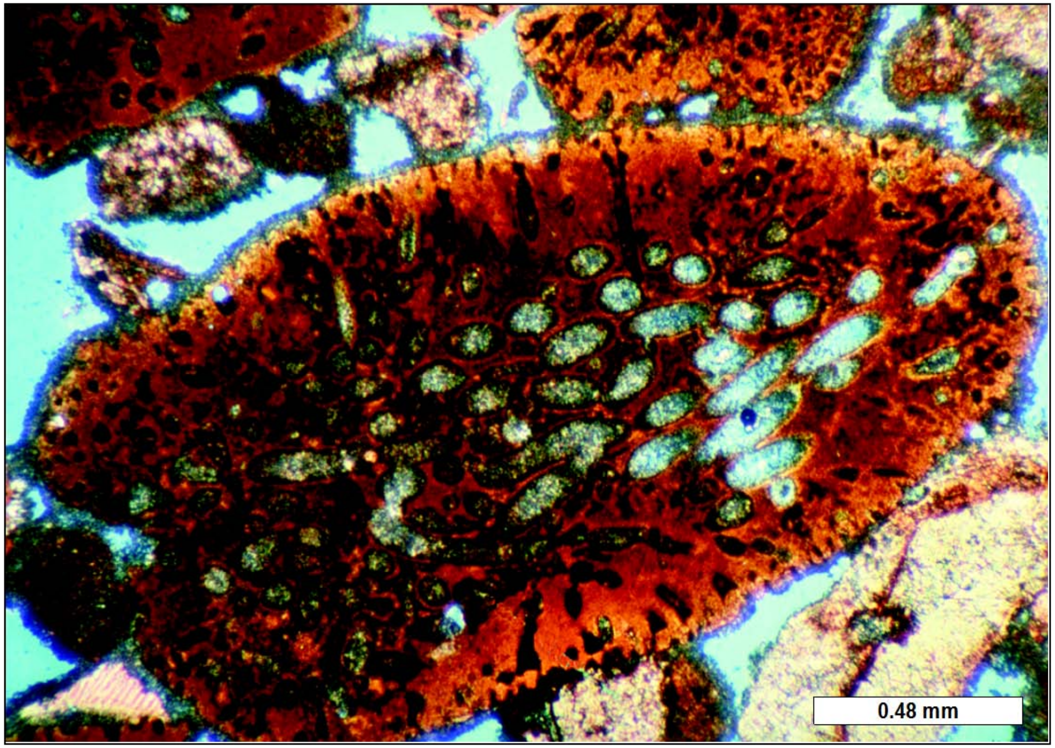
An individual plate segment and its relationship to the full plant.

Common green algae



Recent sediment, Florida reef tract, southern Florida
Dried samples of four common green algae that are significant sediment producers in modern Caribbean shelf settings.

Example



Holocene sediment (beachrock), Grand Cayman, Cayman Islands, B.W.I. A complete single plate shed by *Halimeda* sp., a green algae (left side in picture above). Note the characteristic yellowish to reddish-colored material that is filled with minute aragonite needles and a series of tubules (utricles)

Foraminifers

Intro - forams

Benthic foraminifers: Cambrian-Recent (early forms were exclusively agglutinating)

Calcareous benthic foraminifers — Ordovician-Recent; large forms from Late Carboniferous-Recent

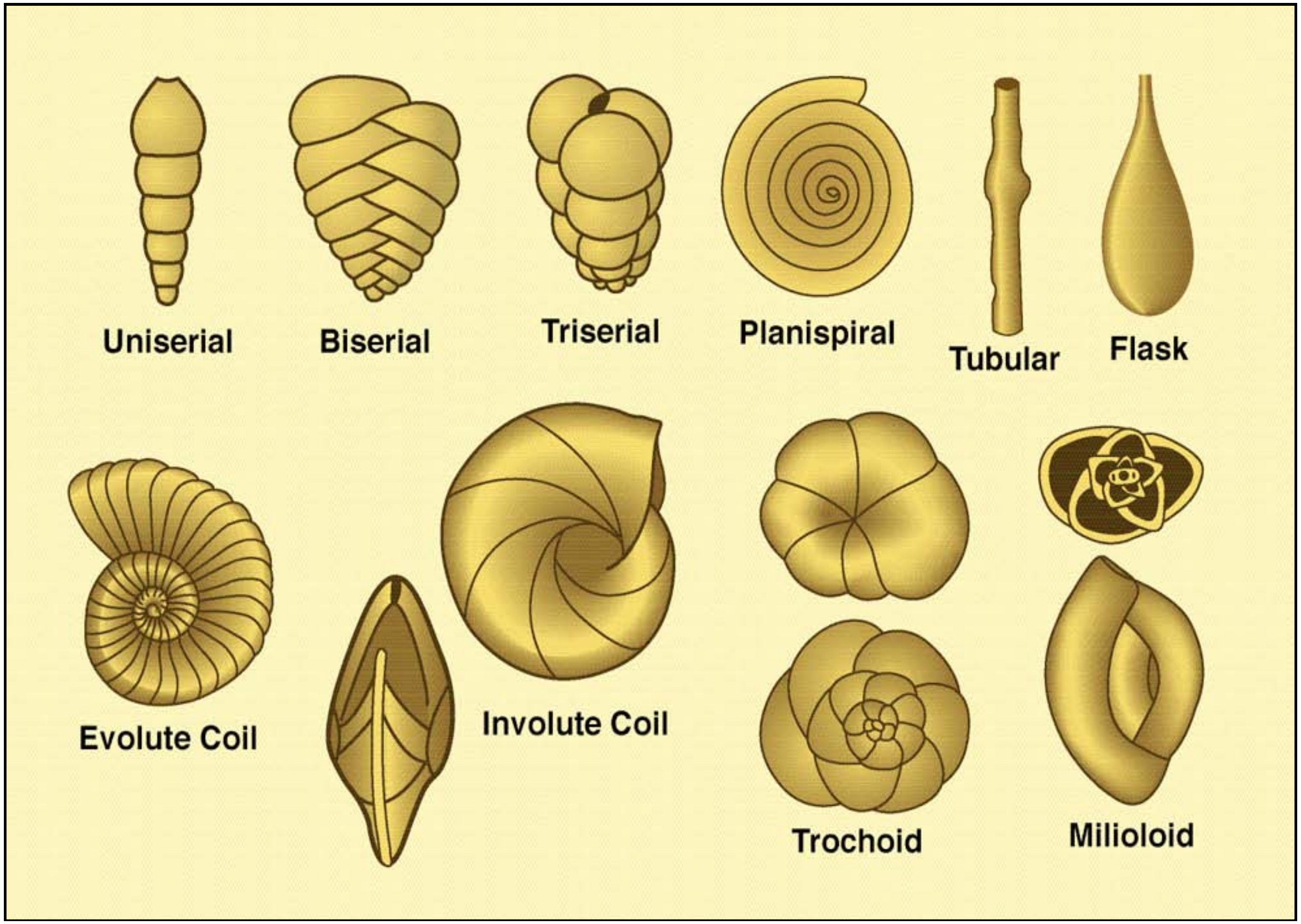
Planktic foraminifers: Middle Jurassic-Recent

- **Despite being single-celled protozoans**
  - **A very complex group of organisms, with 12 suborders and some 60-80,000 species identified from Phanerozoic strata.**

Skeletal Morphology

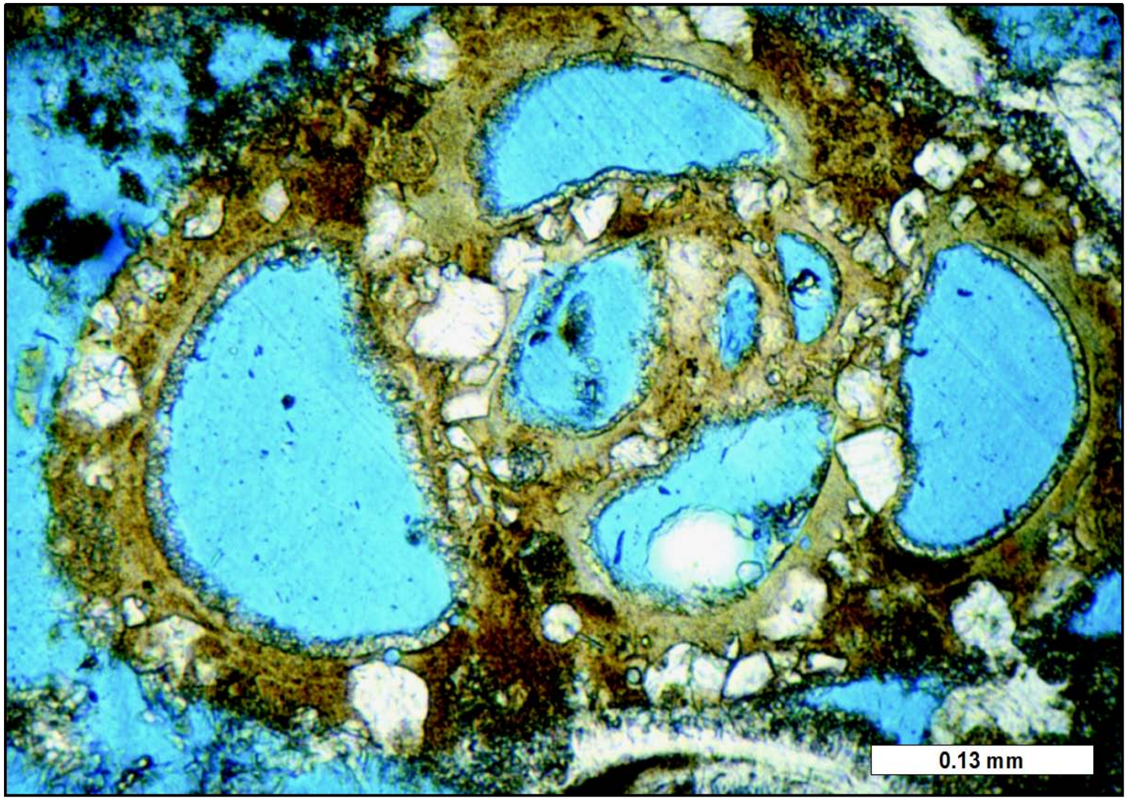
- Foraminiferal tests typically range in size from less than 0.1 mm to 1 mm; the largest fossil forms reach nearly 20 cm in length.
- Tests consist of hollow chambers, separated from each other by partitions with small openings (foramina). The last chamber has one or more exterior openings (apertures).

Common test morphologies

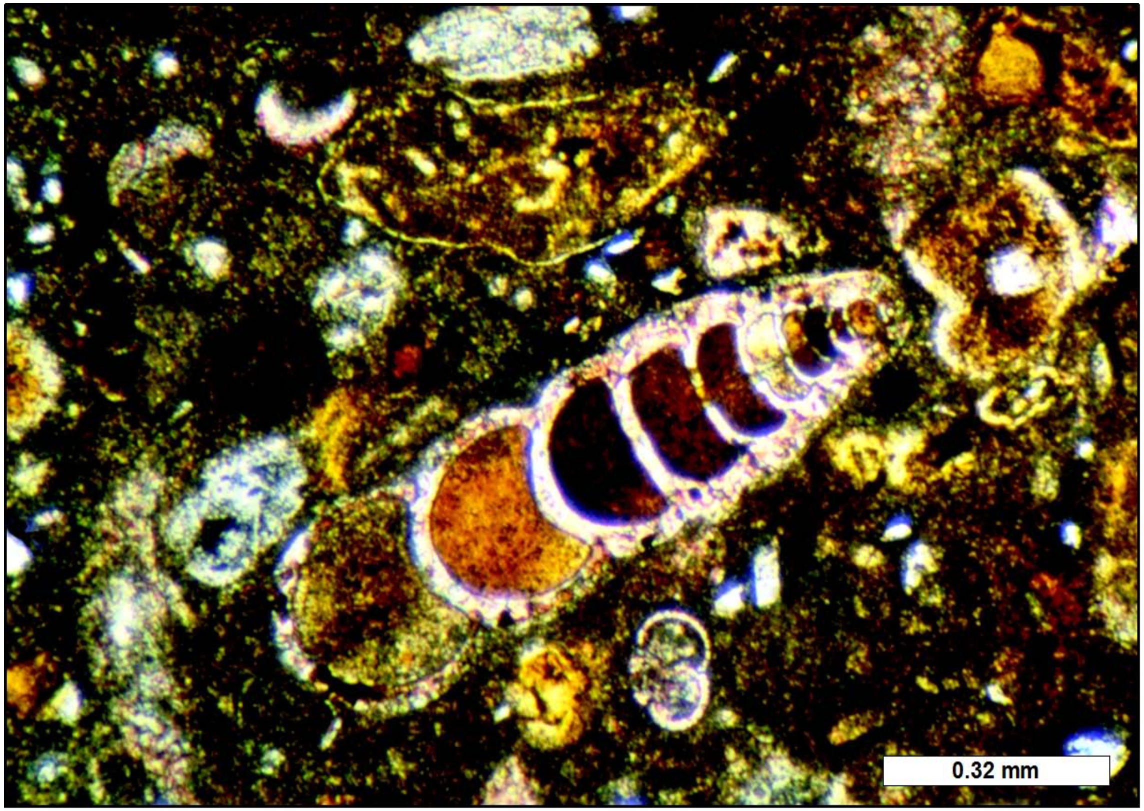


Modern examples

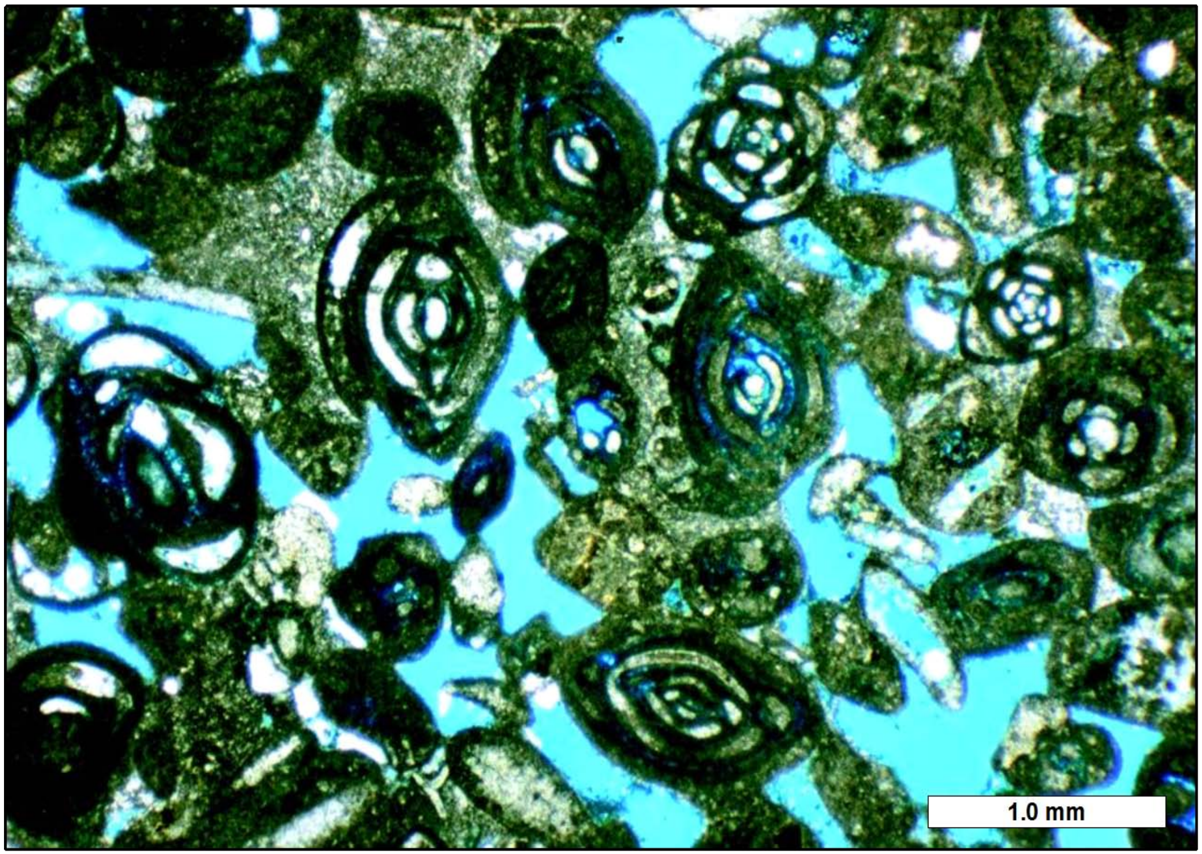
Up. Cretaceous (Cenomanian) Del Rio Fm., Big Bend area, west Texas
A limestone packed with multilocular, uniserial, agglutinated (arenaceous) foraminifers



Recent sediment, Grand Cayman, Cayman Islands, B.W.I.
This example (benthic foram) shows a dominantly calcareous (porcelaneous) wall incorporating scattered agglutinated quartz and other grains.



Oligocene-Miocene, Top McDonald Ls., northern Otago, New Zealand
An example of a calcareous uniserial benthic foraminifer in a ferruginous hardground. In this example, the chambers are easily seen because they have been filled with precipitated, very finely crystalline phosphatic cements.

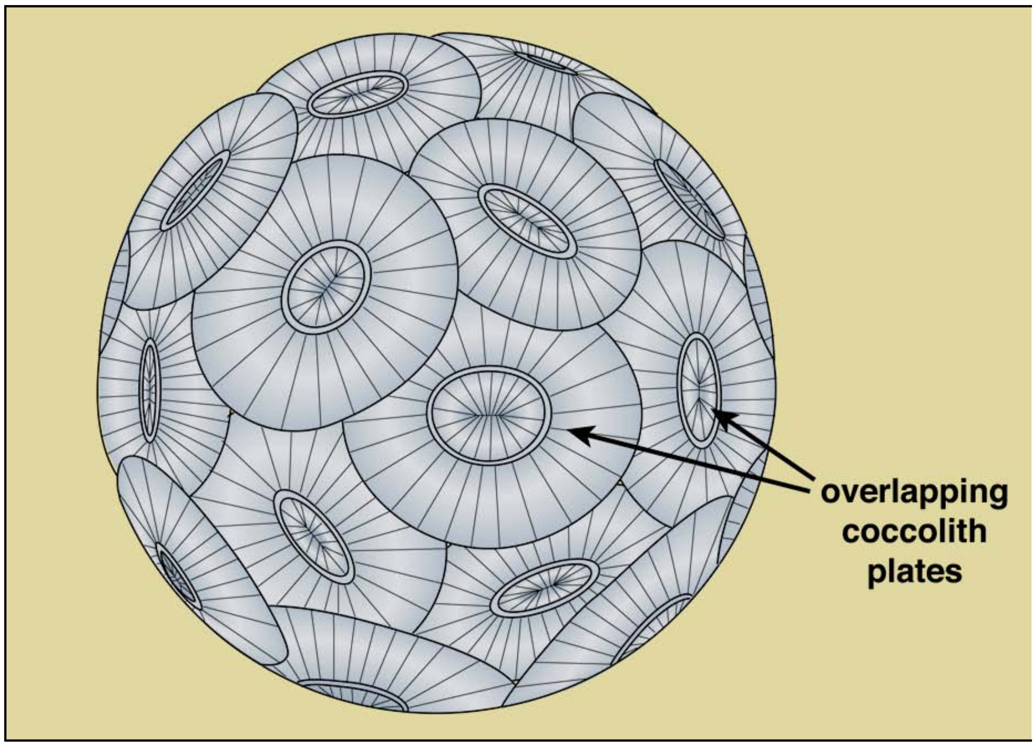


Eocene Ocala Gp., Inglis Fm., Levy Co., Florida

A limestone (packstone) in which miliolid foraminifers are a major component of the total sediment. The tests have non-laminar, porcelaneous calcareous walls and complex (miliolid) chamber coiling patterns.

Nannoplanktons

Coccolithophores

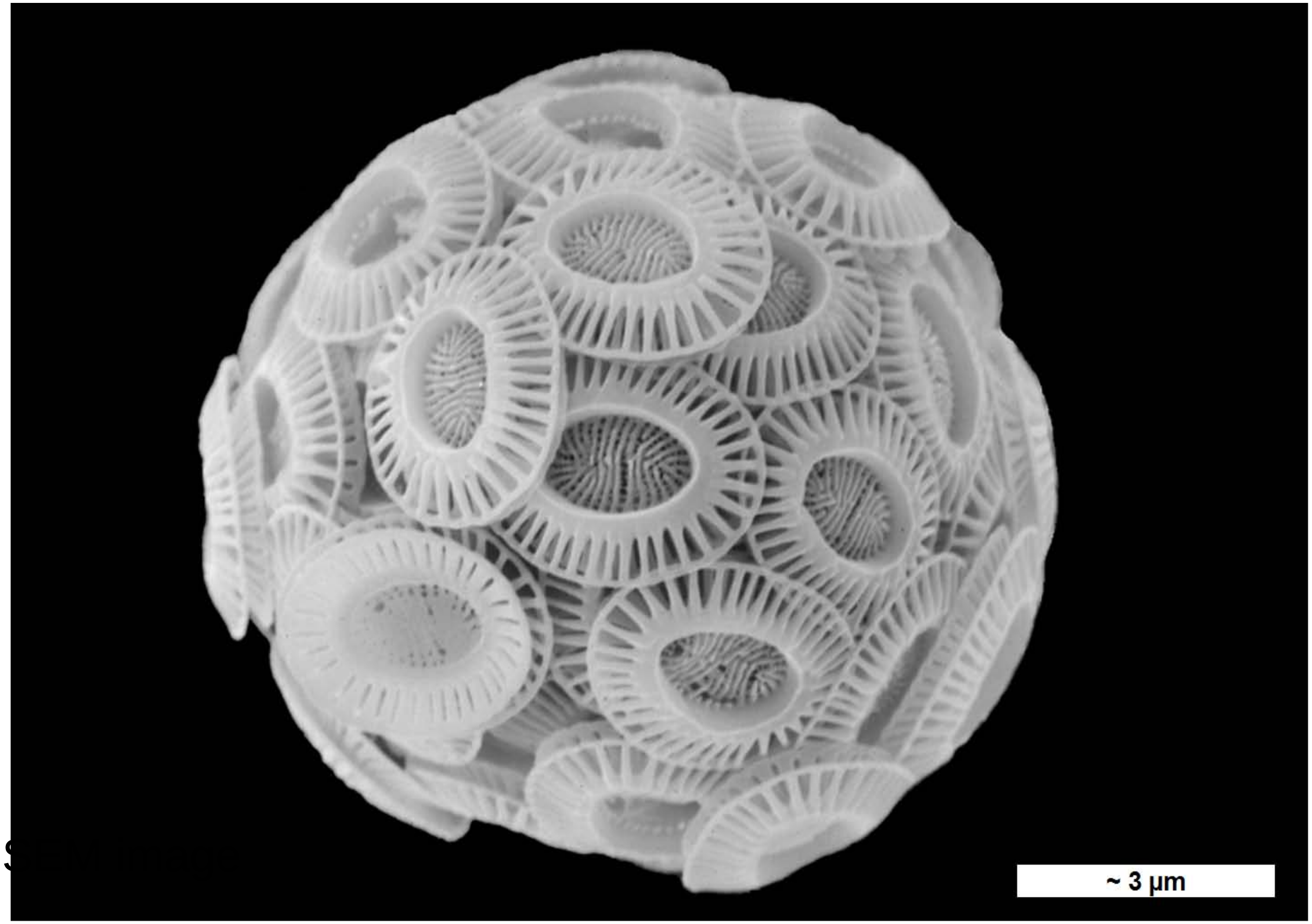


Coccospheres consist of a variable number of overlapping calcite shields that, in turn, are composed of a large number of radiating single crystals of calcite. Coccospheres are only rarely found in sedi-ments because they typically disaggregate into their individual shields or constituent crystals. Typical coccospheres are between 5 and 25 µm in diameter.

planktic unicellular algae

First occur in the Late Triassic and are abundant from the Early Jurassic to the Recent

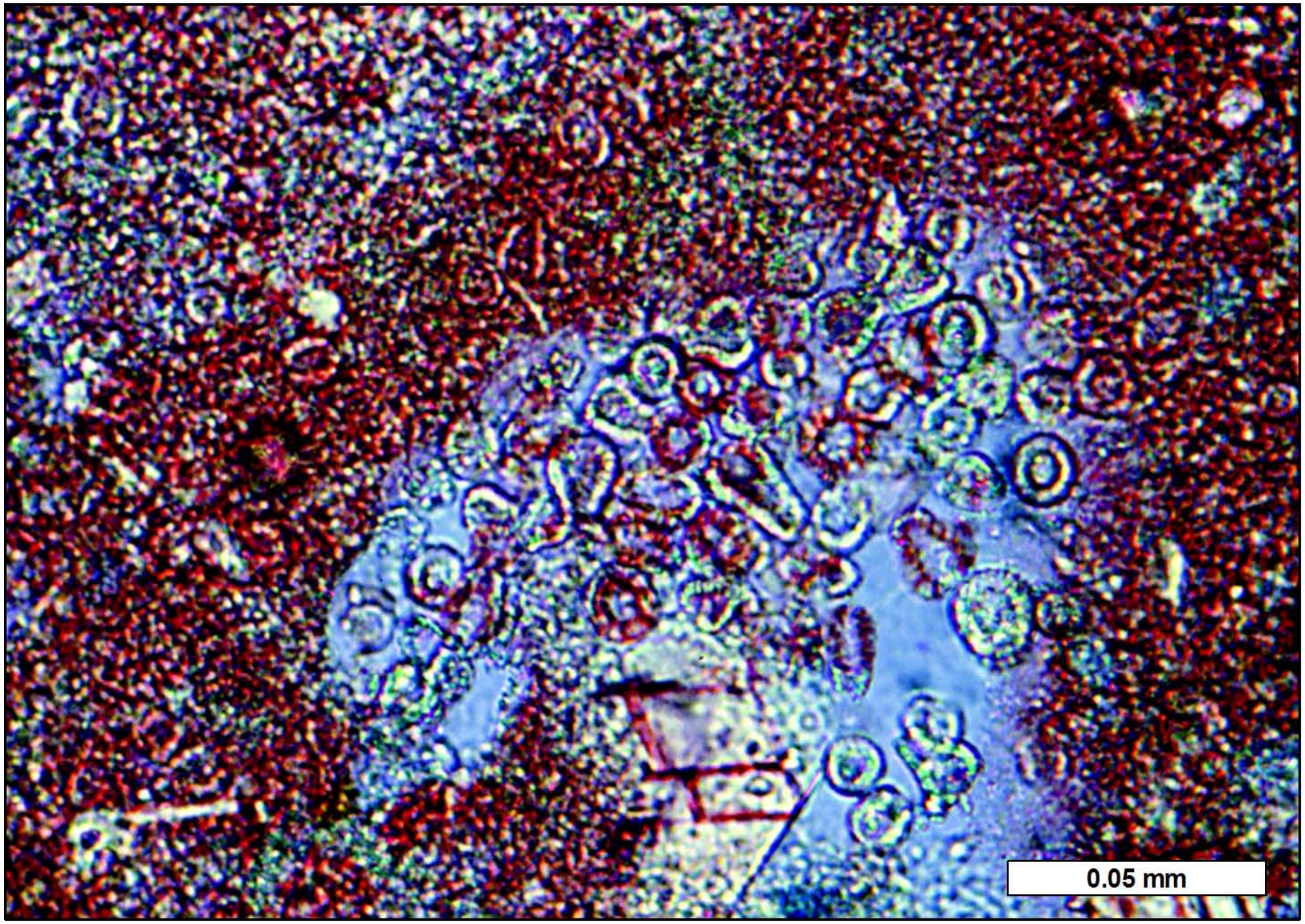
Example



SEM image

Recent sediment, North Atlantic Ocean, 26°N

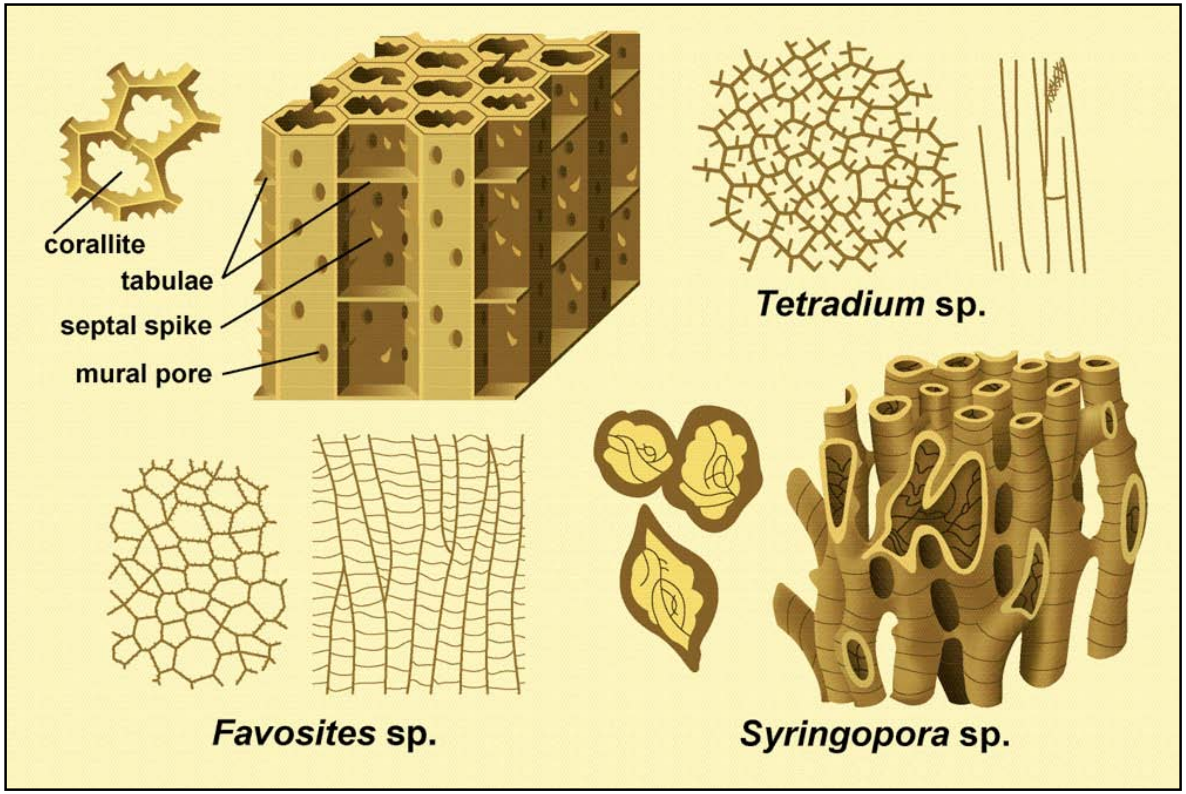
Example



Lo. Cretaceous (Aptian) Shuaiba Fm., offshore Qatar
A shallow shelf chalky micrite with high concentrations of nannoconids

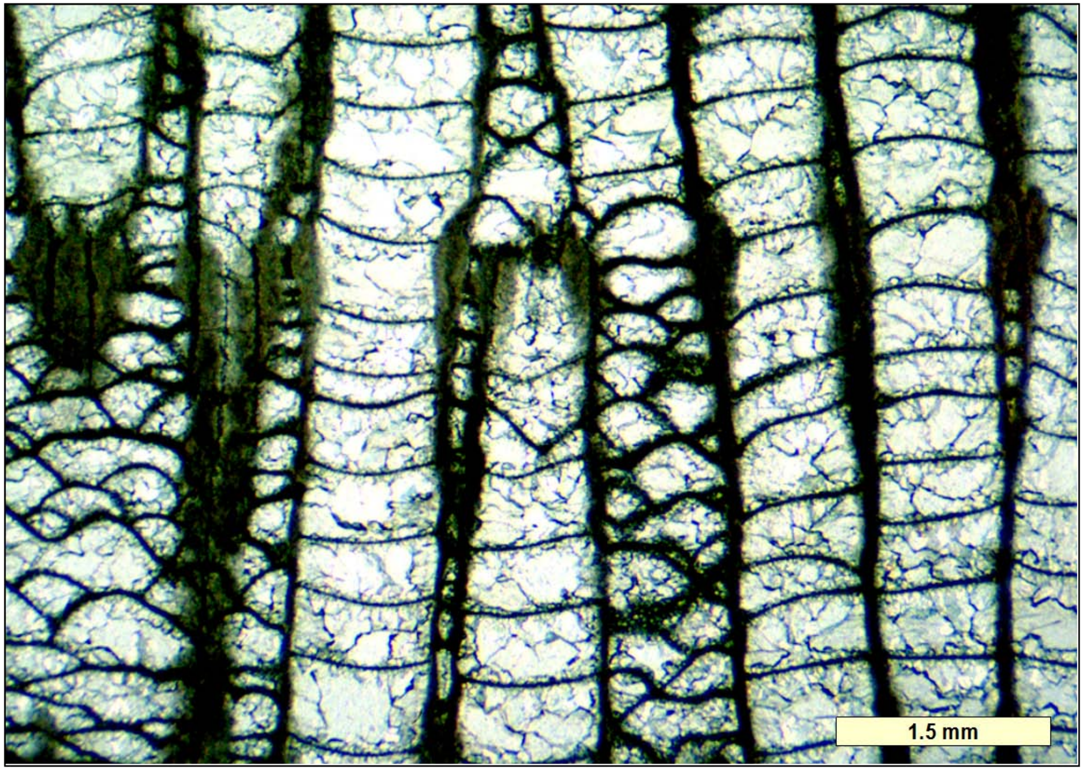
Corals

Tabular corals



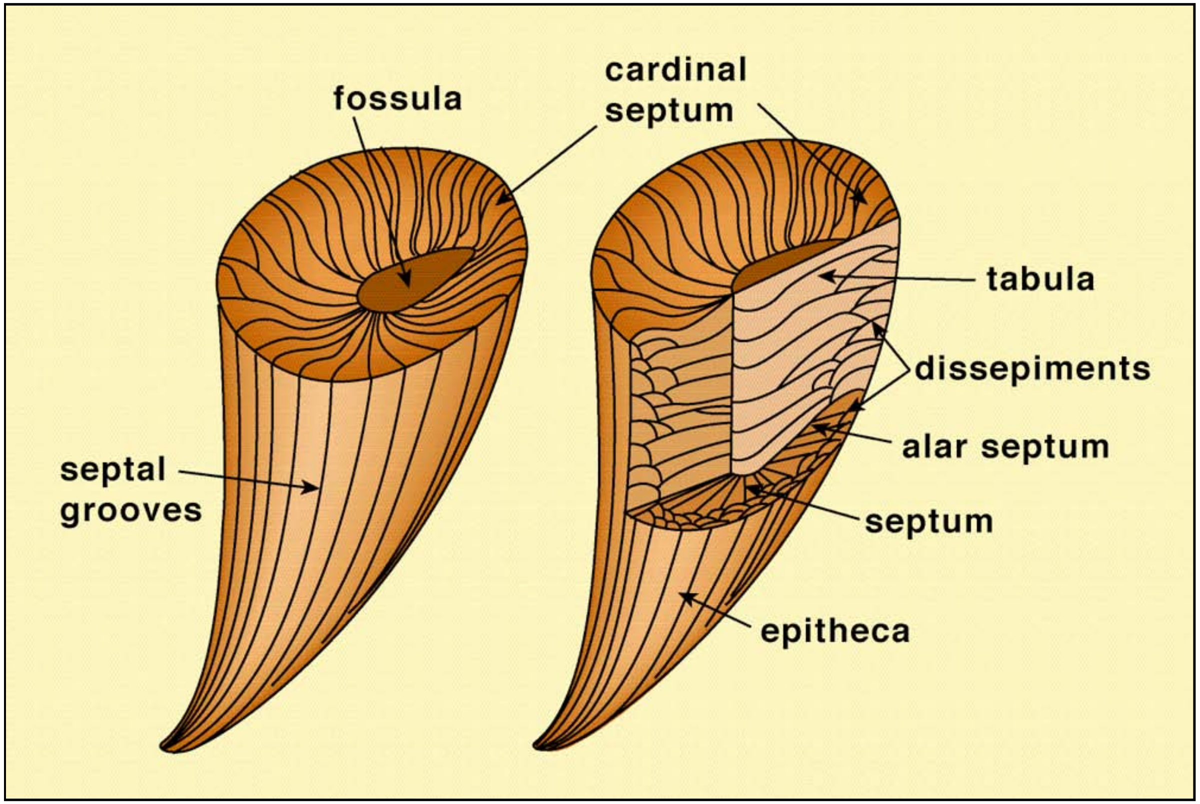
•**Exclusively colonial; slender corallite tubes that are commonly closely packed and have circular, oval, or polygonal shapes in transverse sections**

Example



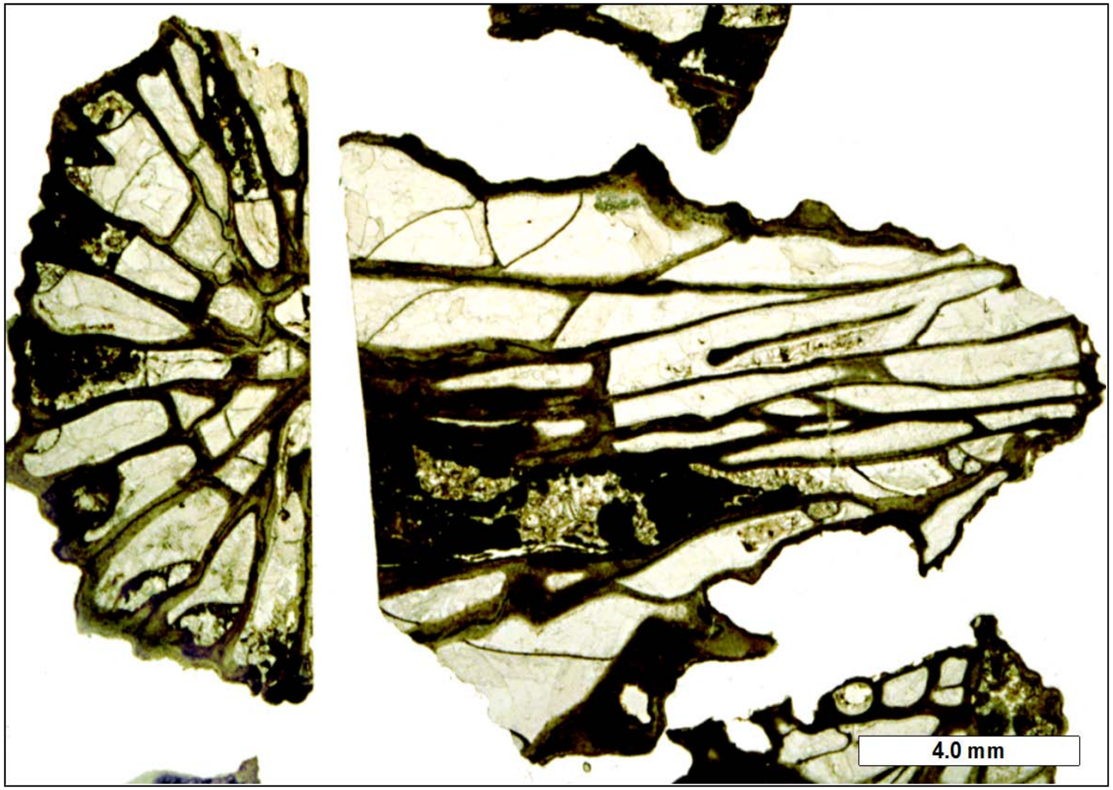
Up. Ordovician Keel Fm., Pontotoc Co., Oklahoma

Rugose corals



Major morphologic features of a typical rugose coral

Example



Pennsylvanian limestone, north-central Texas
Longitudinal and transverse sections through a solitary rugose coral

Bryozoans

Bryozoans

Three Kings platform, northern New Zealand
Underwater view of branching bryozoan colonies (the fawn-green “bushes”), 20 m water depth

Bryozoans

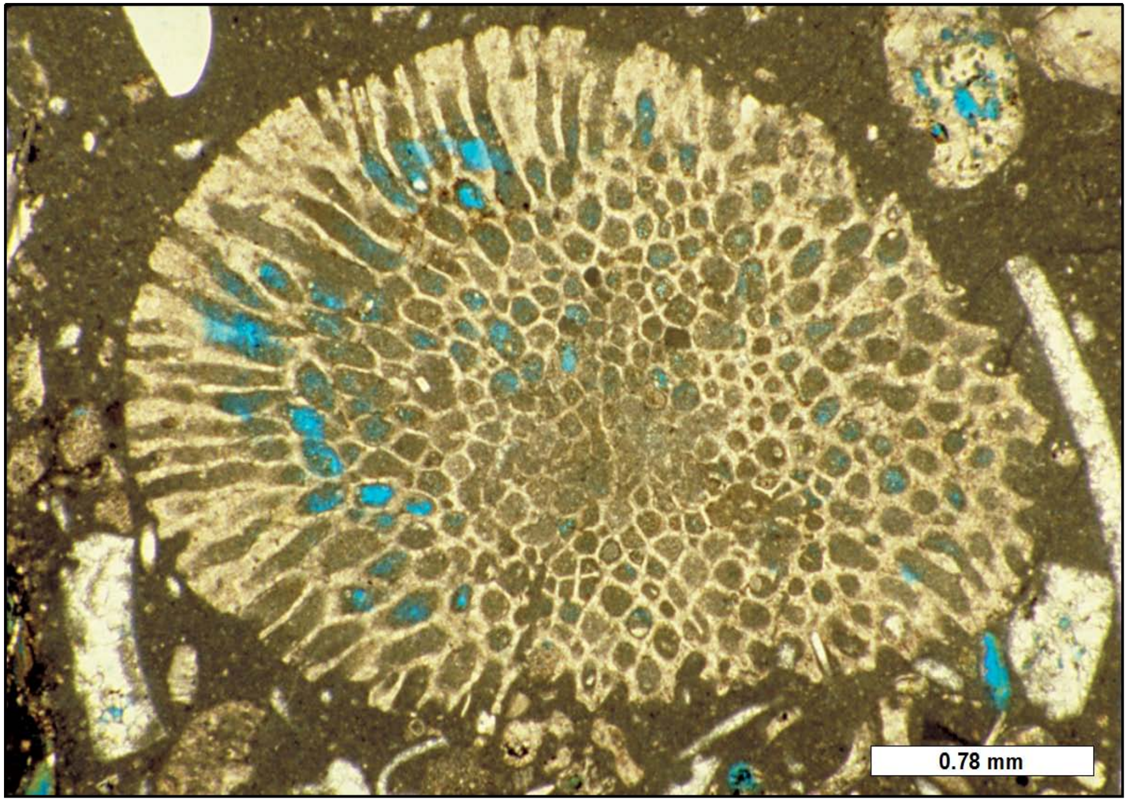
The main distinguishing differences between bryozoans and corals are the typically smaller size of bryozoan colonies and individual living chambers, and the outward thickening of bryozoan living chamber (zooecial) walls

Bryozoan-rich, gravel-sized fraction of Holocene skeletal carbonate sediment, 122 m water depth (New Zealand)

Example

Oligocene Nile Gp., Karamea, Westland, New Zealand
This longitudinal section through a cyclostome (a cerioporoid) bryozoan branch

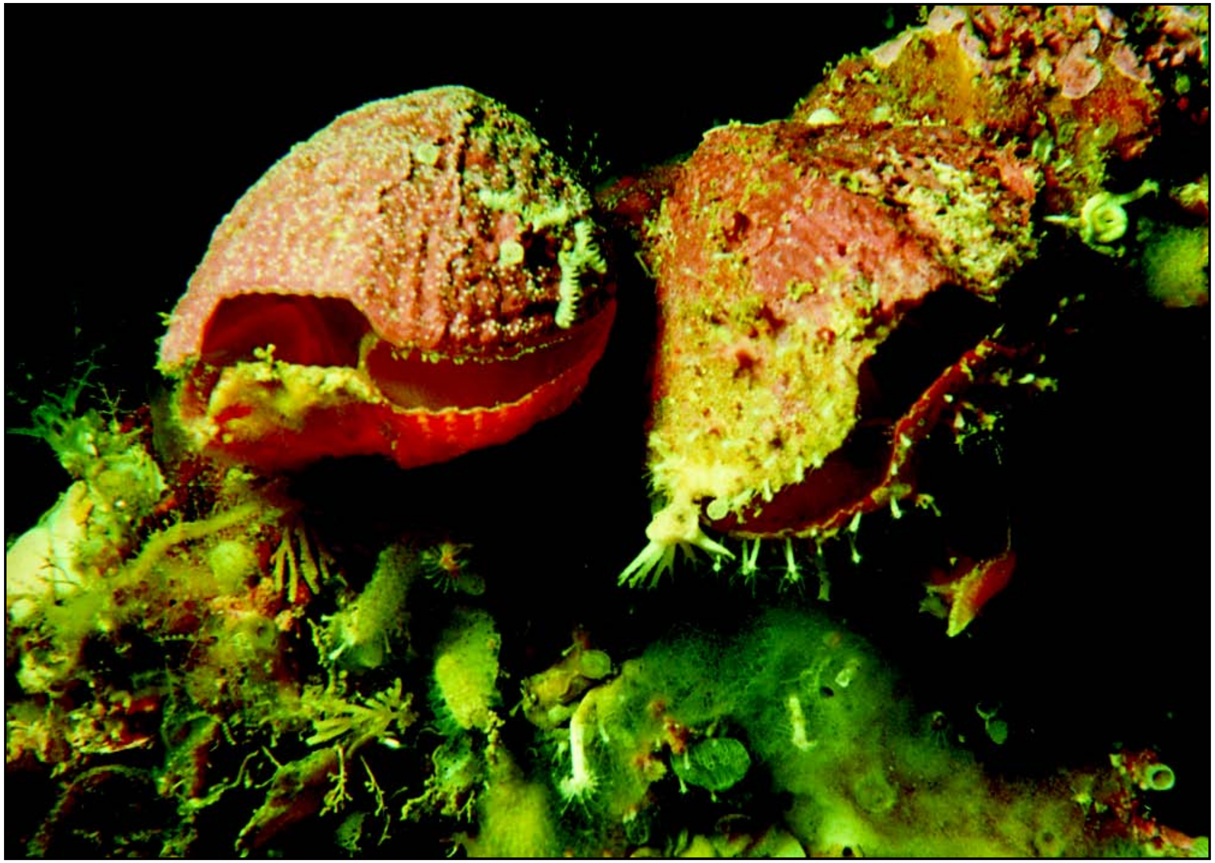
Example



Oligocene Nile Gp., Karamea, Westland, New Zealand
A transverse section through a cerioporoid cyclostome bryozoan.

Brachiopods

Brachiopods

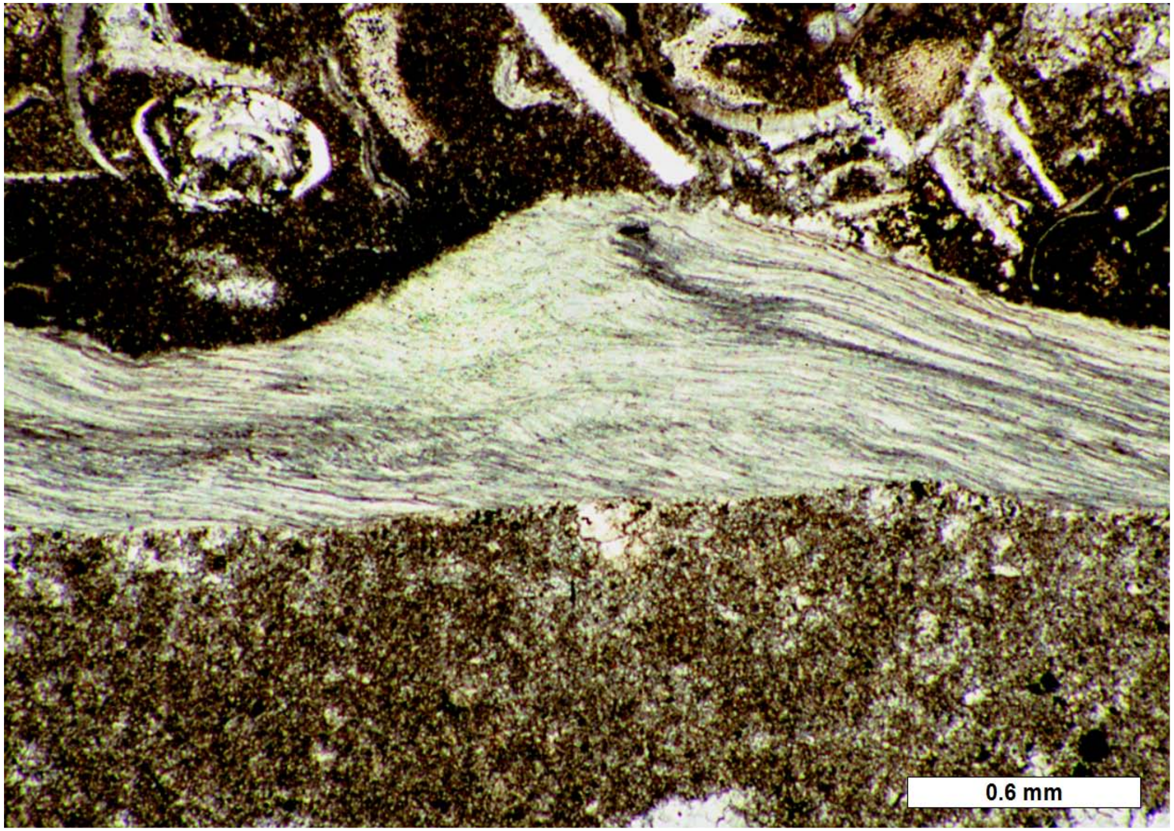


Underwater view of two examples of a brachiopod, *Terebratella sanguinea*, living on fjord walls at 20 m (60 ft) depth in Doubtful Sound, Westland, New Zealand

Brachiopods

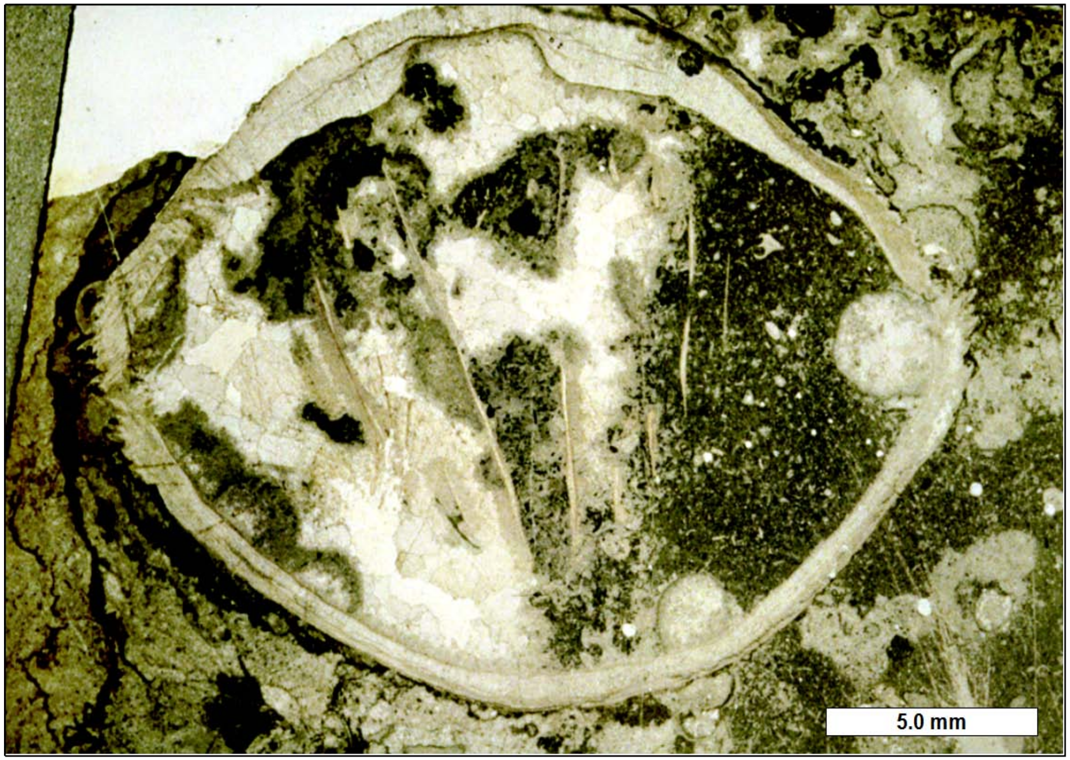
A selectively silicified spiriferid brachiopod from Permian (Leonardian) lower slope deposits from the Glass Mountains, of west Texas

Example



An example of an impunctate shell wall in a brachiopod. Note the typical low-angle fibrous structure and the substantial lateral variations in shell thickness

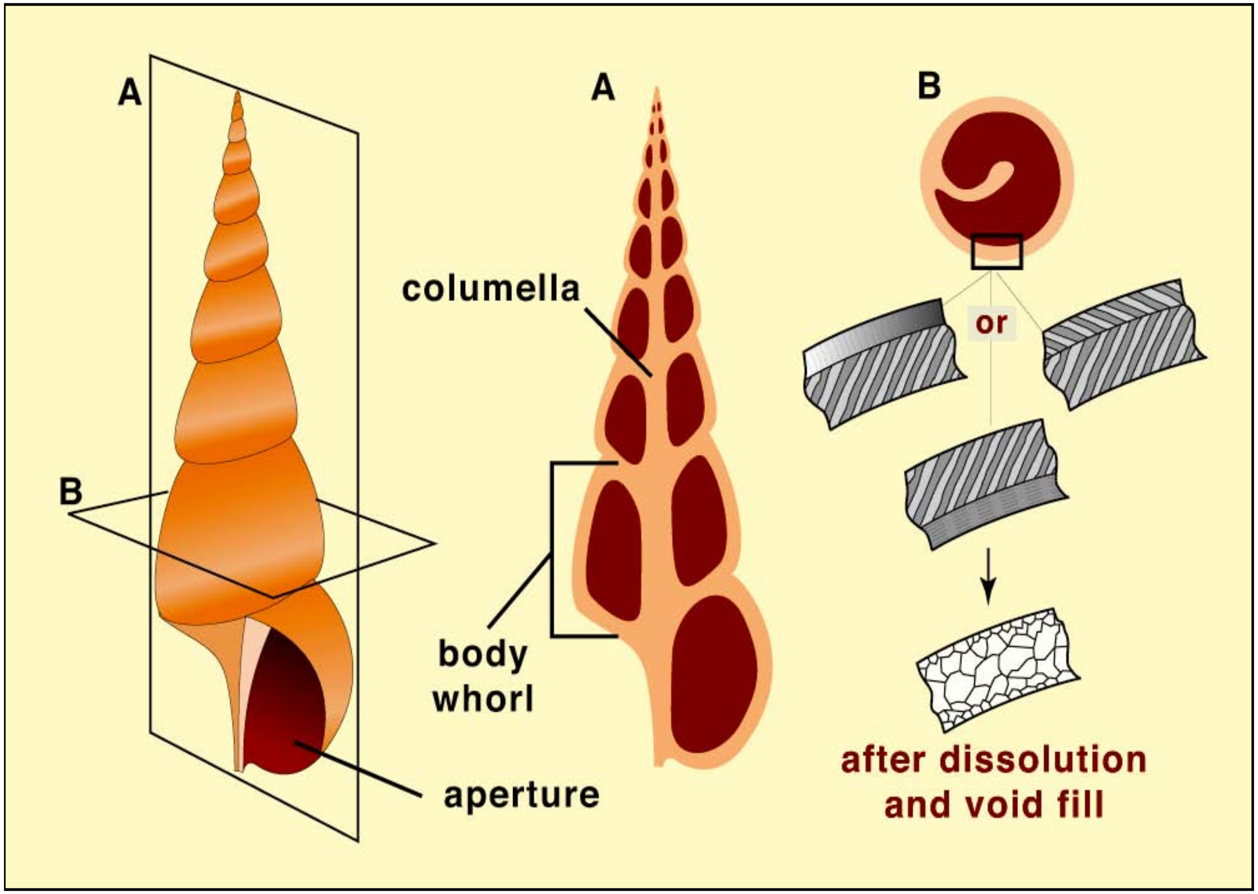
Example



Up. Permian (Guadalupian) Capitan Fm., Eddy Co., New Mexico
A transverse section through a complete spiriferid brachiopod showing slightly V-shaped lines of shell material within the internal cavity. These spiral-shaped calcareous growths served as internal supports for the organisms feeding structure (termed the lophophore).

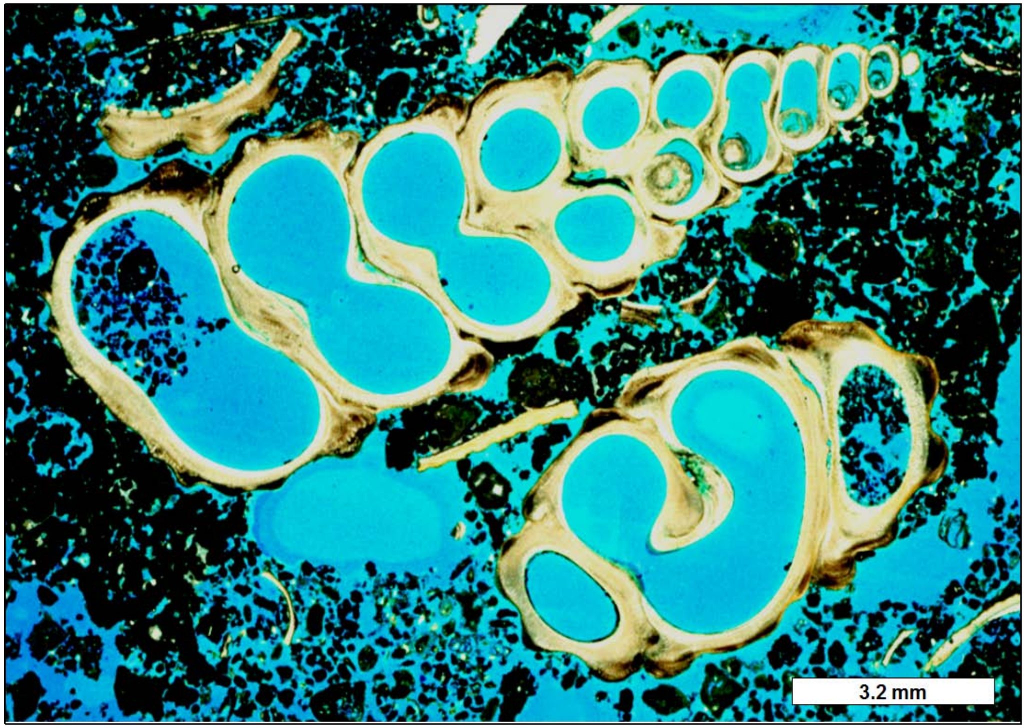
Mollusks

Gastropods



Gastropods are the largest class of both living and fossil mollusks (with nearly 8,000 genera), although they are rarely major rock-forming organisms

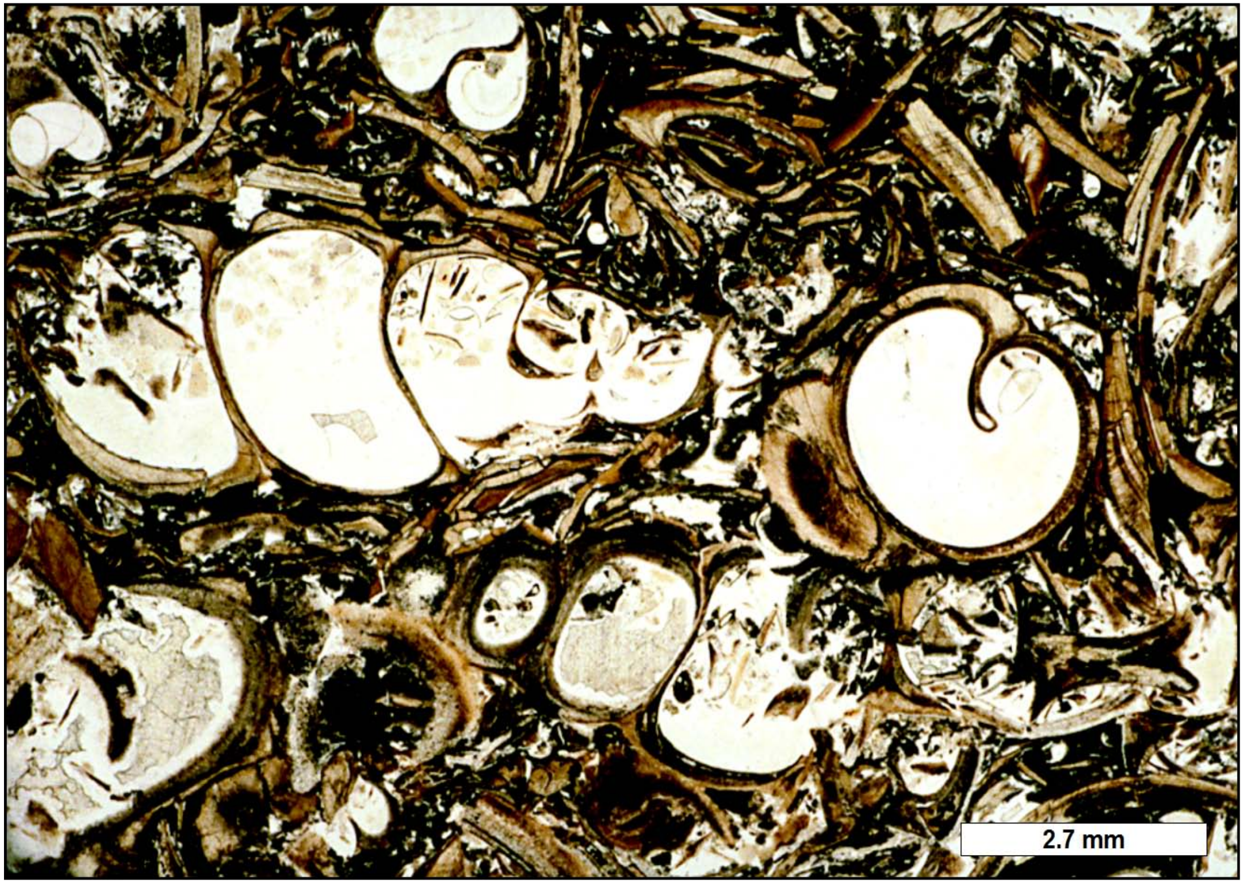
Example



Recent sediment, Abu Dhabi, coastal United Arab Emirates
Oblique and longitudinal sections through modern high-spired cerithid gastropods in a hardground.

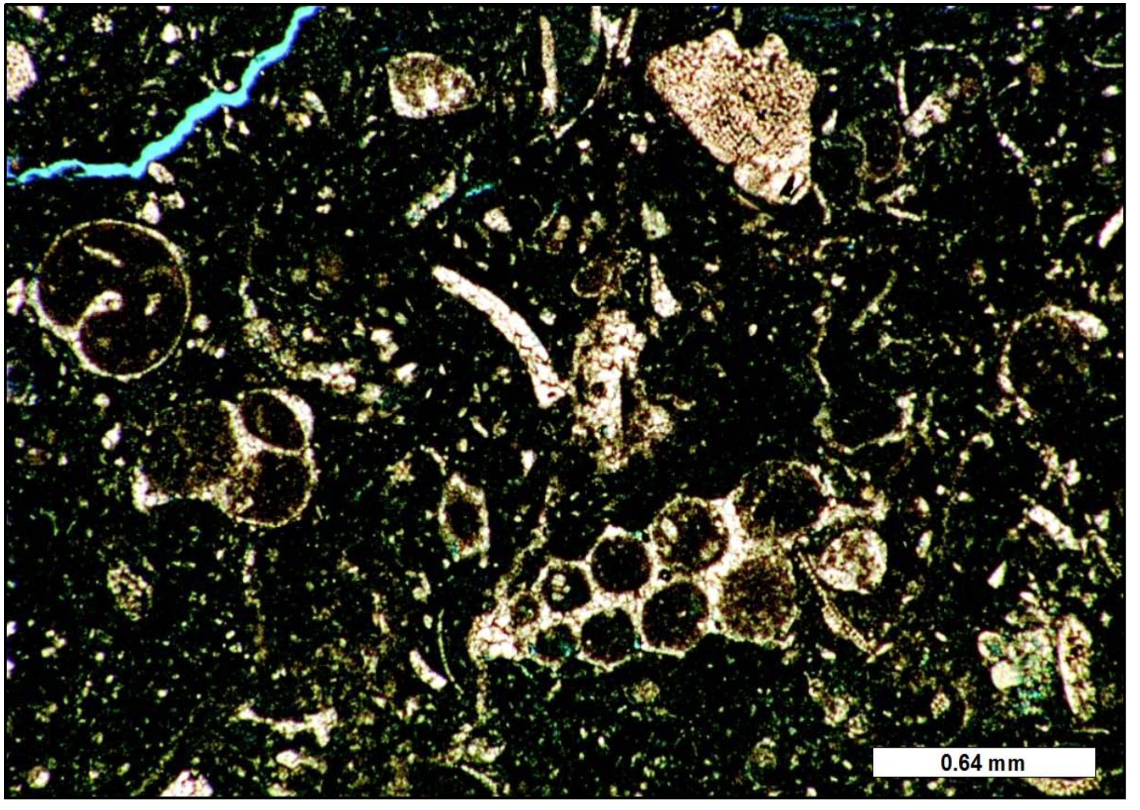
This genus of gastropods is well adapted to variable and high salinity environments and is a dominant faunal element in many lagoonal deposits.

Example



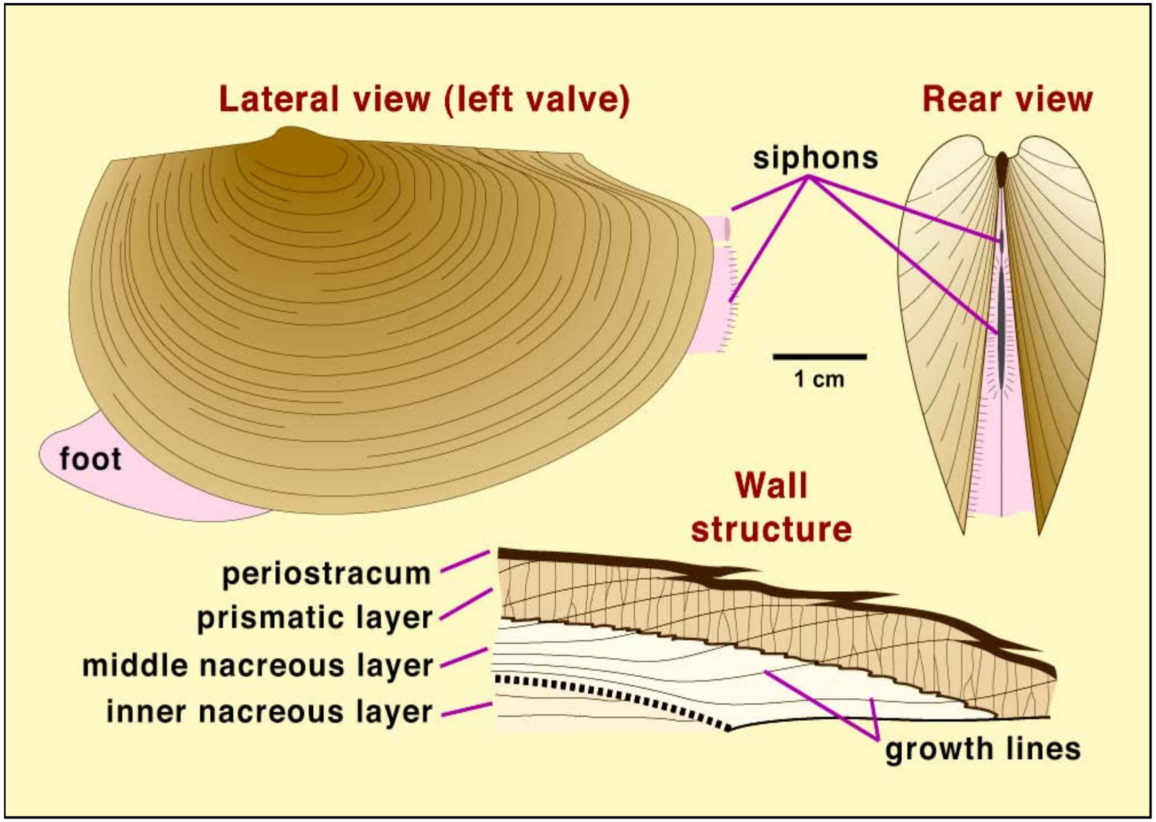
Eocene Green River Fm., Laney Mbr., Sweetwater Co., Wyoming
Large numbers of a single species of gastropod from a lacustrine environment. These thin-walled organisms dominated the fauna in this restricted, freshwater setting.

Example



Lo. Cretaceous (Aptian) Shuaiba Fm., offshore Qatar
A molluscan packstone in which gastropods are a major sediment contributor. This shows some of the wide variety of geometrical shapes that can be generated by random cuts through complicated shell forms.

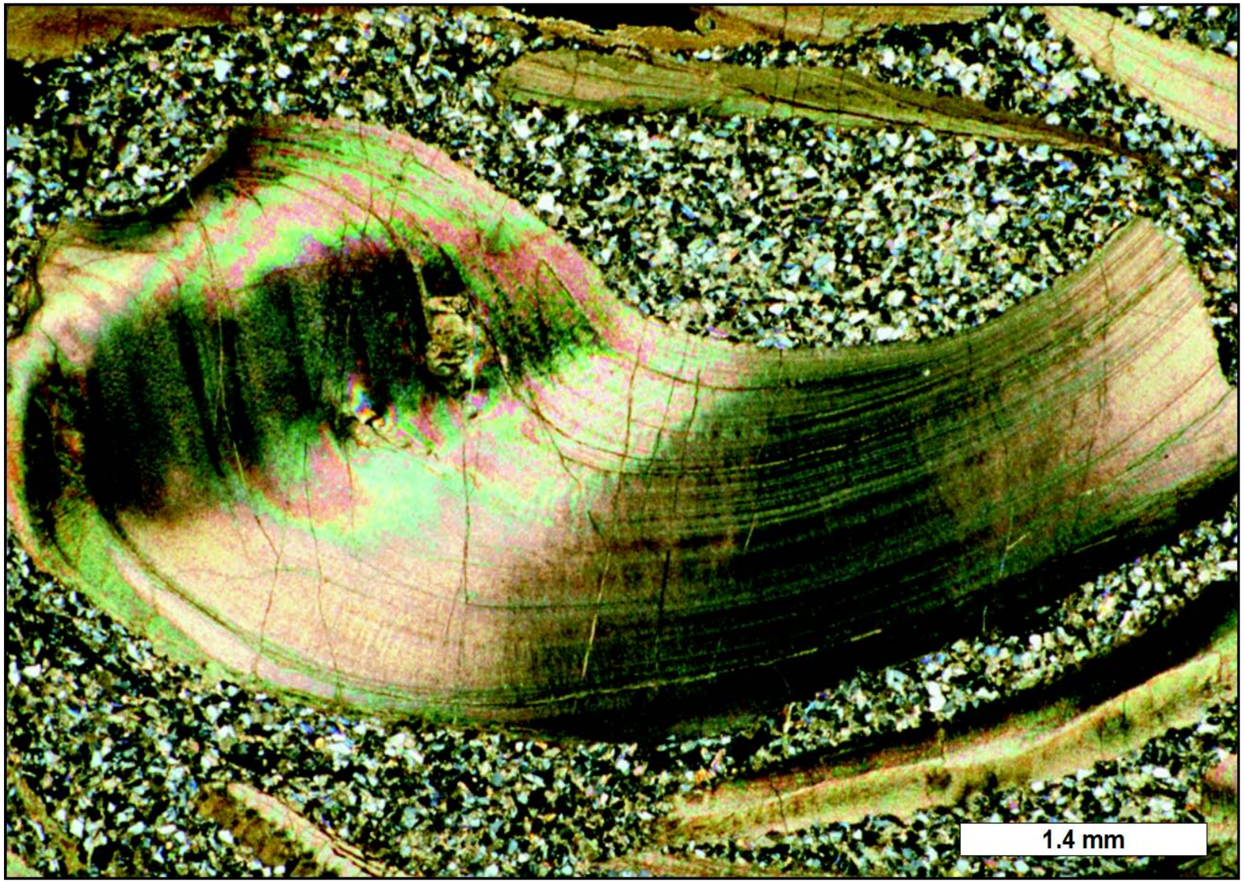
Bivalves (pelecypods)



Morphology and wall structure of a typical bivalve, based on the freshwater clam. Note how the shell symmetry differs from that of the brachiopods shown earlier (useful when examining sections that include articulate shell pairs).

Example

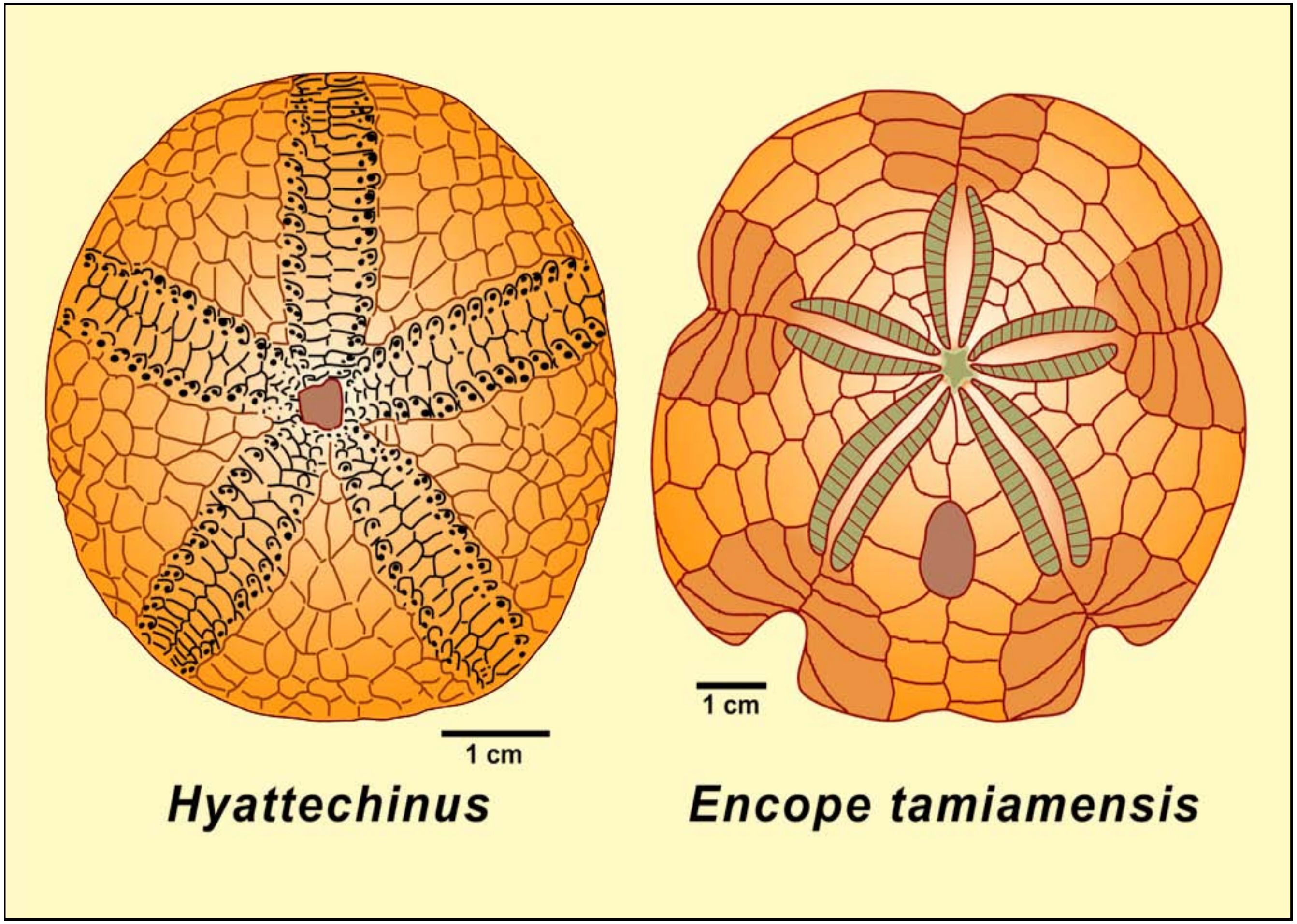
Mid. Triassic Muschelkalk, Western Silesia, Poland
The bivalve shells were dissolved and the molds were later filled with sparry calcite. The bivalve origins remain clear, however, based on shell shapes — smoothly curved and thickening toward the still discernible hinge structures.



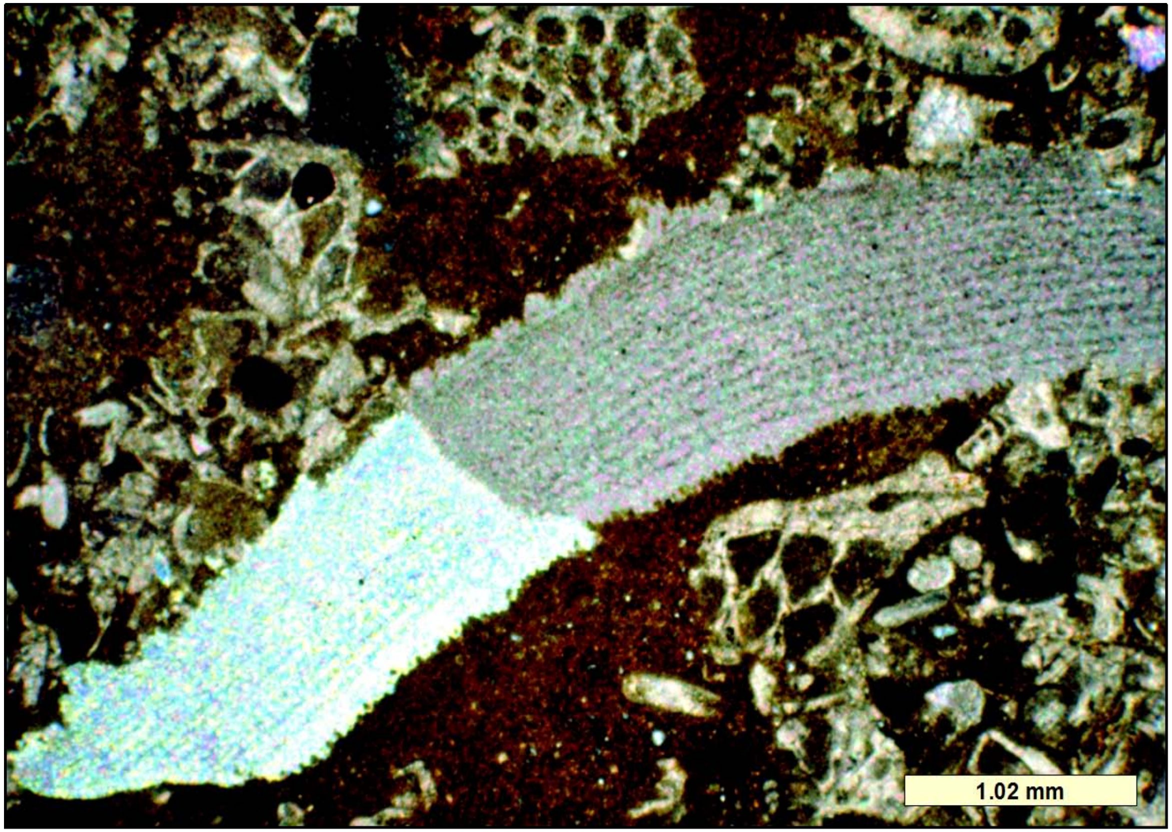
Up. Oligocene (Chattian) Molasse, Bavaria, Germany
Part of a large *Cyrenia* shell easily recognizable as a bivalve by its shell shape.

Echinoids

Typical Echinoids

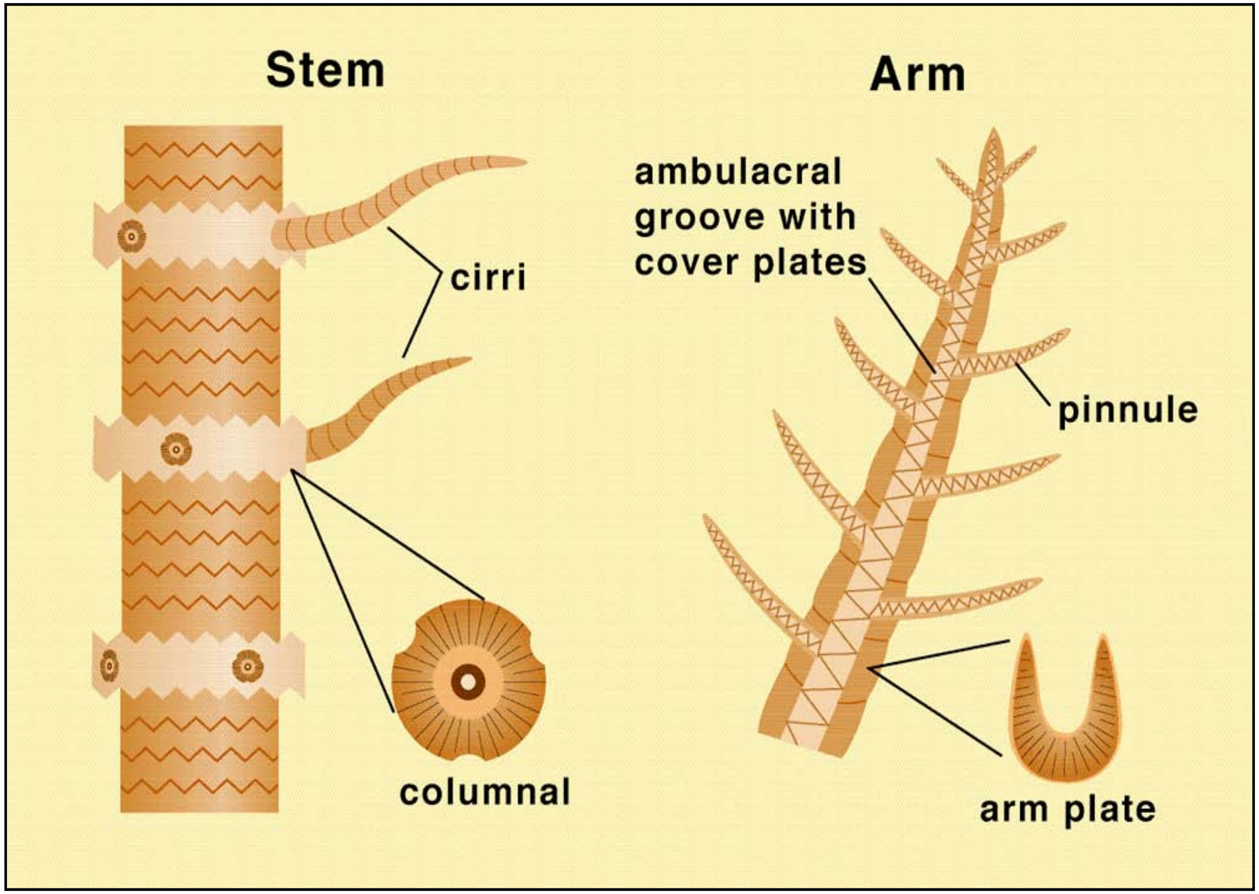


Example



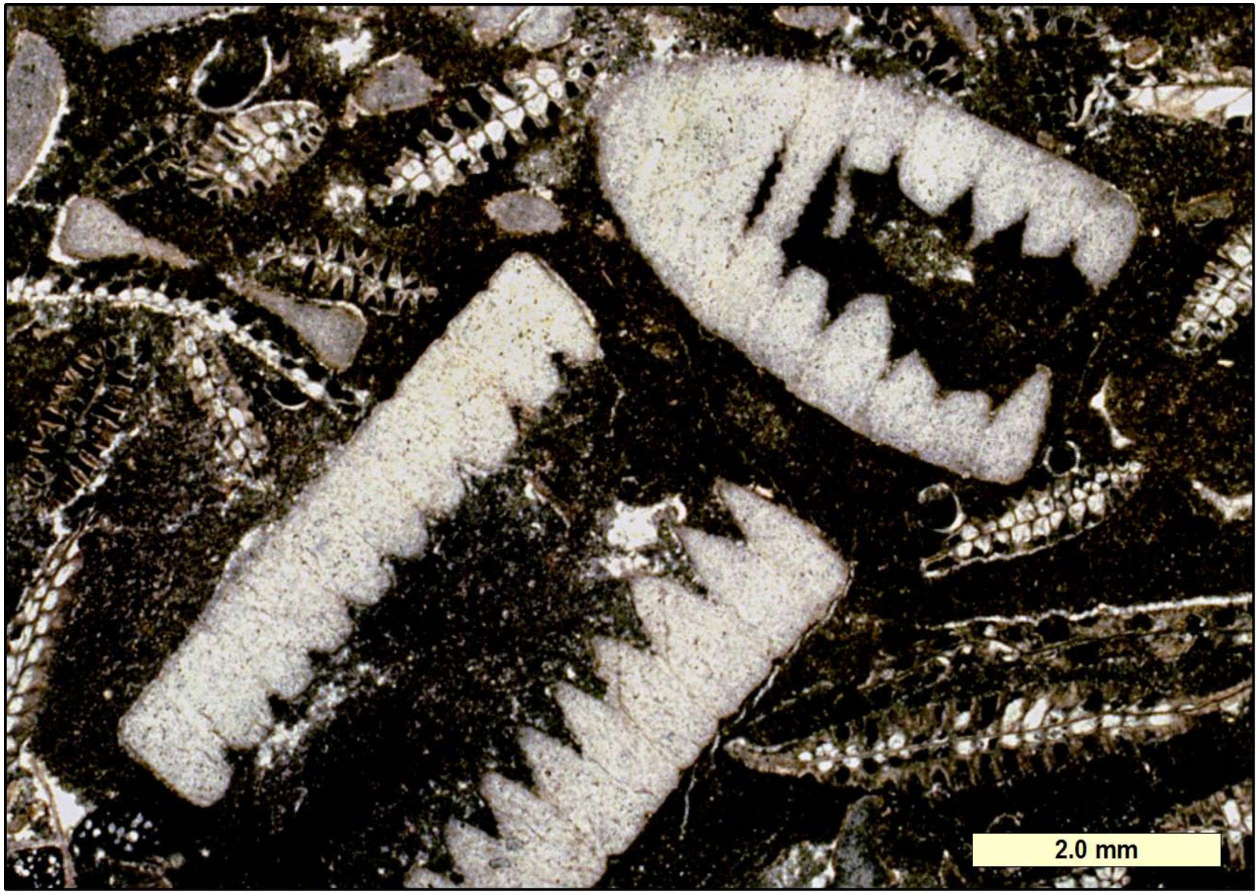
Oligocene Thomas Fm., western Canterbury, New Zealand
Two joined plates from a fragmented echinoid corona. Note the fact that each plate has separate unit extinction and shows (weakly in this case) the regular pattern of intraplate pores that permeate all echinoid material.

Crinoids



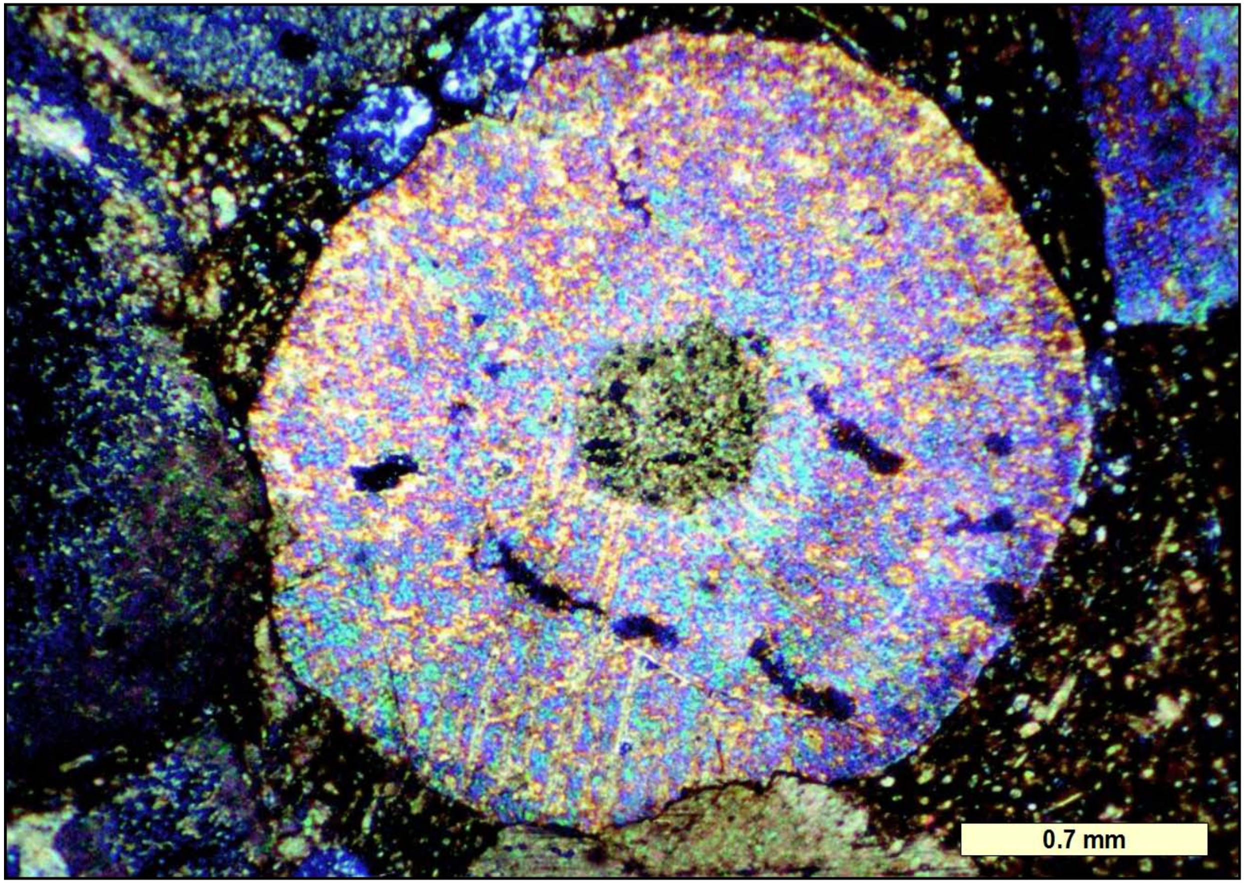
Crinoid stems consist of a series of corrugated circular or pentagonal plates (columnals) that resemble a stack of poker chips and easily disarticulate upon death of the crinoid.

Example



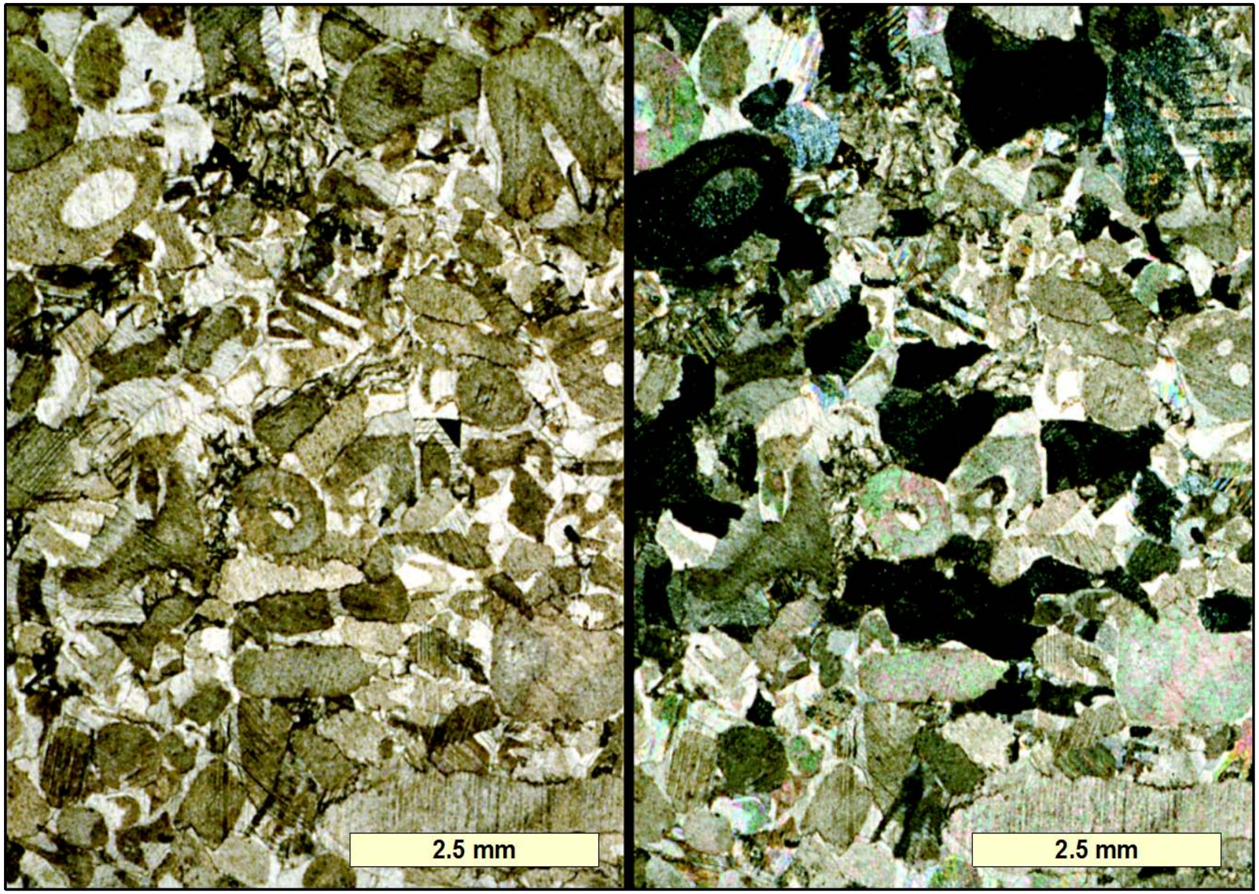
Mid. Ordovician Black River Gp., Lowville Fm., Kingston, Ontario, Canada
Random cuts through stacks of crinoid columnals with large lumens.

Example



Pennsylvanian Marble Falls Ls., Burnet Co., Texas
A crinoid showing the unit extinction (single-crystal extinction), traces of pore structure, and the axial canal common to this group.

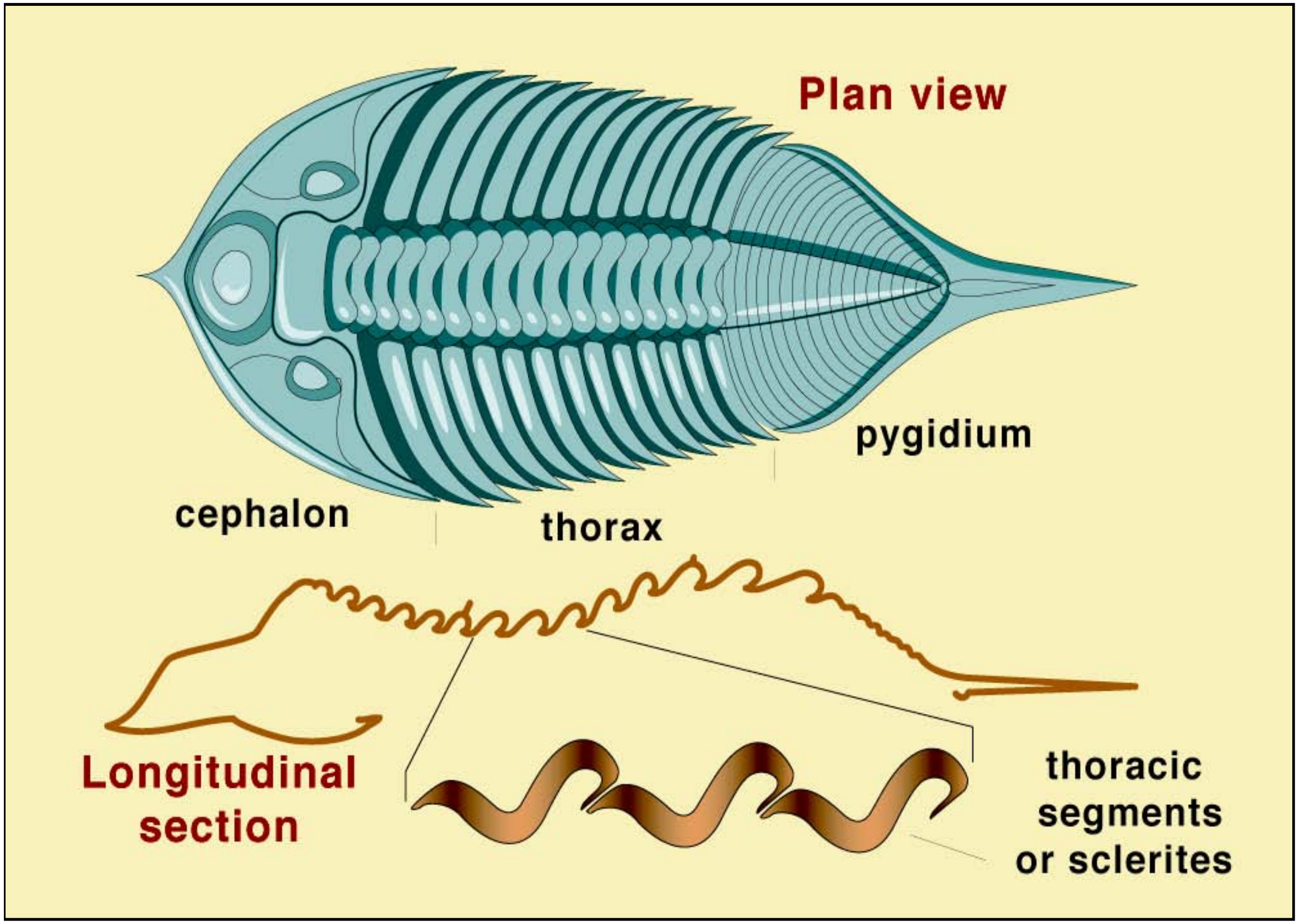
Example



Up. Silurian Tonoloway-Keyser Ls., Mifflin Co., Pennsylvania
Plane- and cross-polarized views of a crinoidal grainstone (encrinite) fully cemented with syntaxial calcite overgrowths.

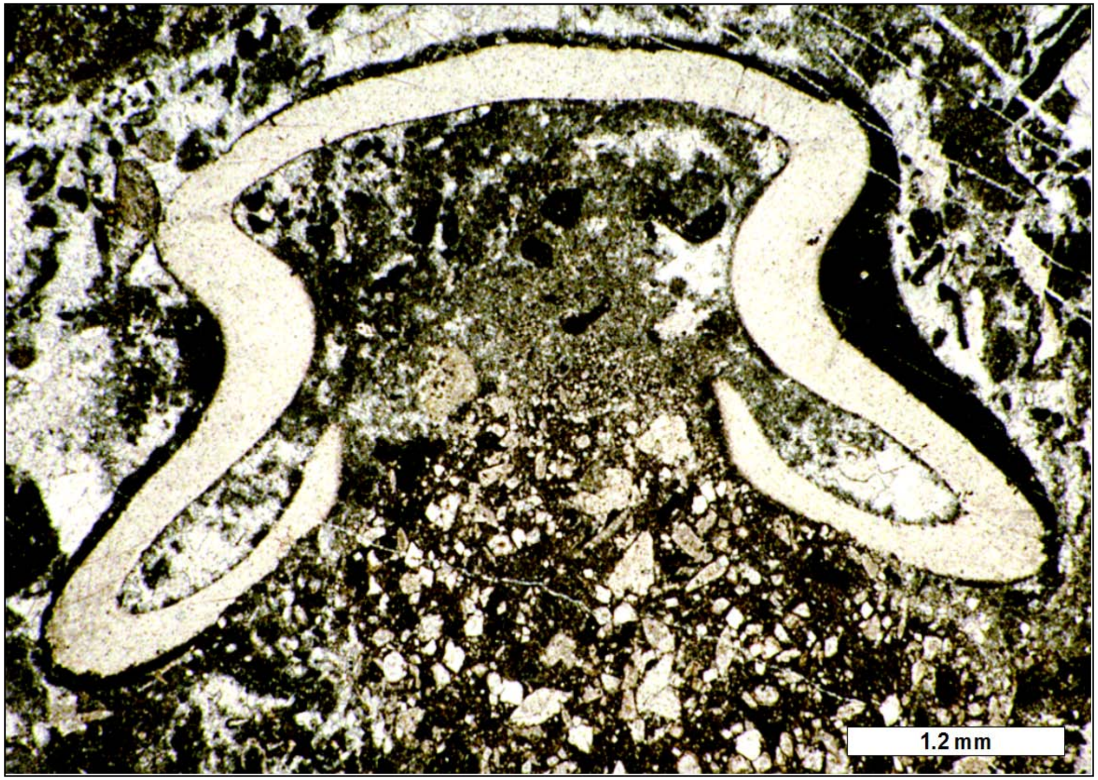
Arthropods

Trilobites



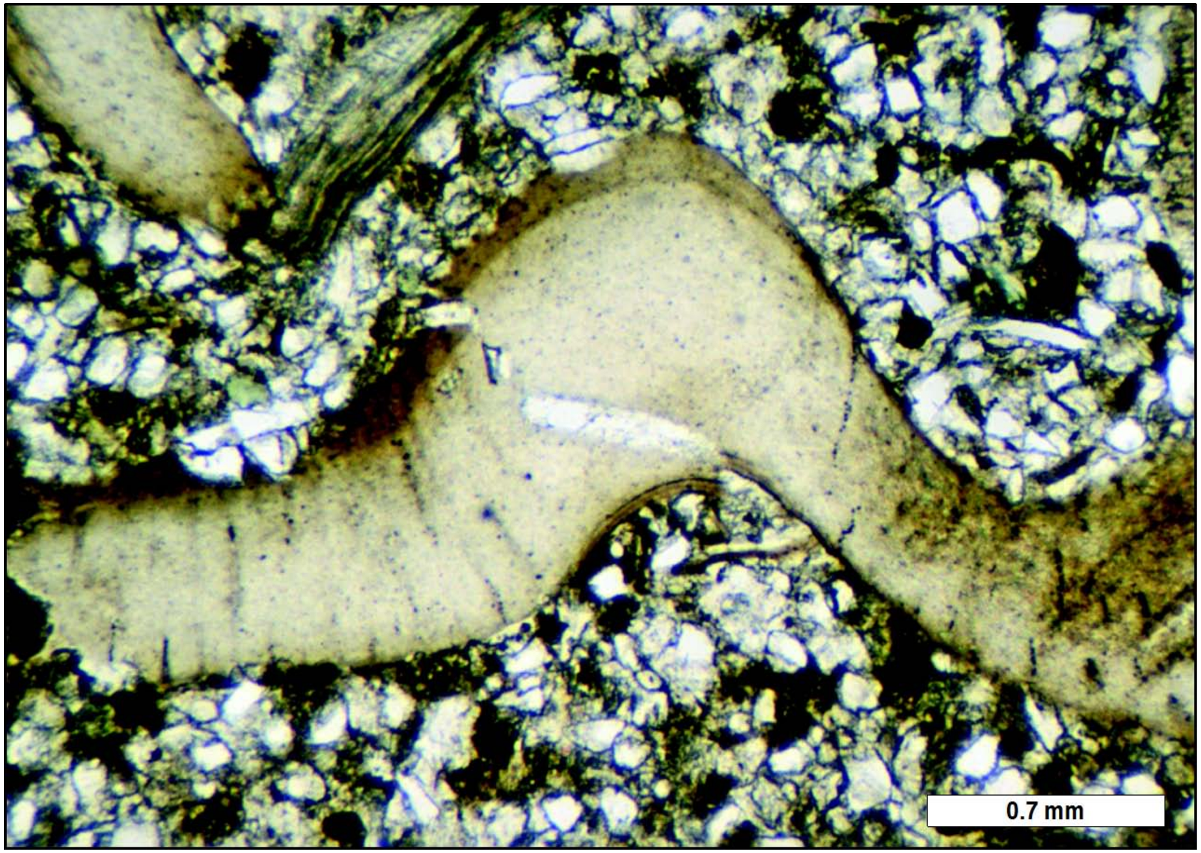
Plan view
pygidium
cephalon
thorax
Longitudinal section
thoracic segments or sclerites

Example



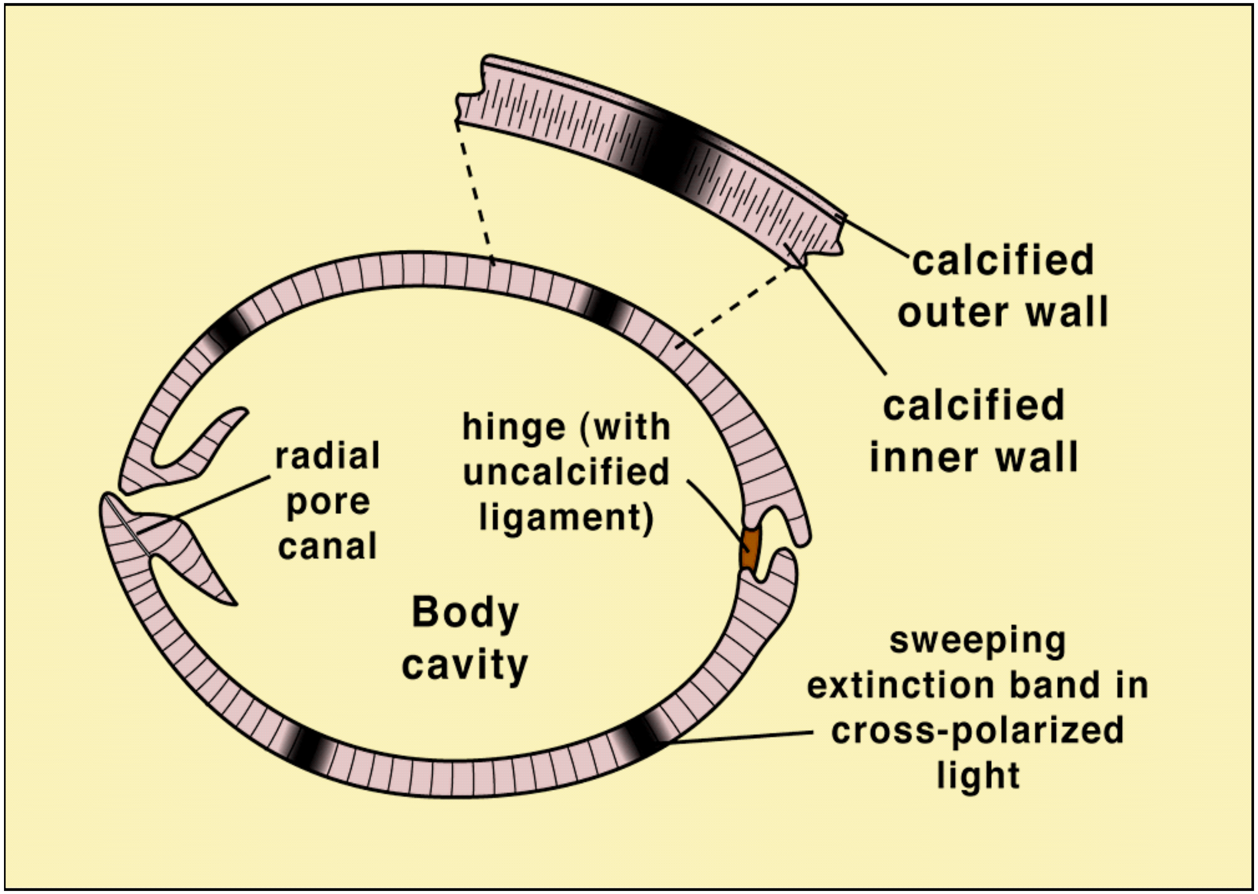
Lo. Ordovician El Paso Gp., Franklin Mountains, Texas
A transverse cut through an unusually complete trilobite carapace showing the highly recurved nature of the calcitic skeleton. These fossils are more commonly found broken into smaller fragments that show shapes like boomerangs or shepherd's crooks.

Example



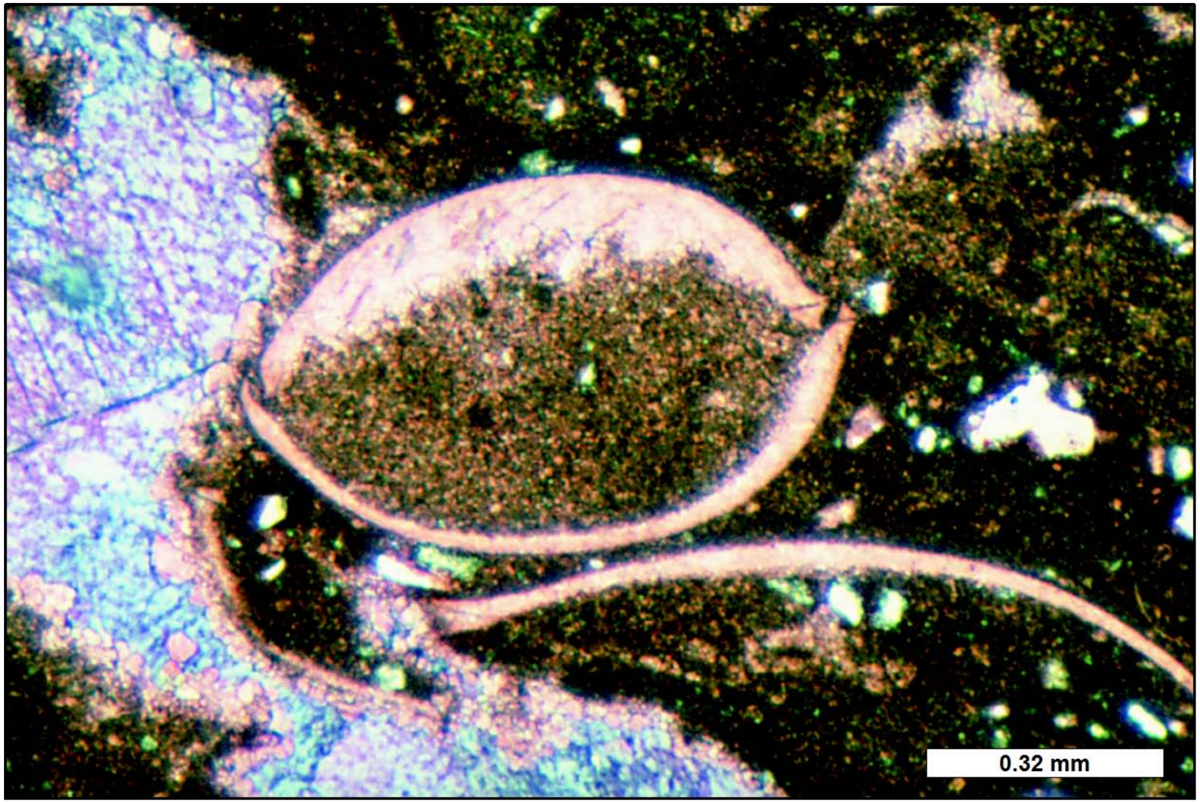
Mid, Ordovician Reedsville Fm., Mifflin Co., Pennsylvania
This trilobite fragment shows characteristic complex curvature of the shell and homogeneous prismatic shell structure (essentially showing no visible crystal structure at this magnification).

Ostracods



characteristic features of the overlapping carapace valves and multilayered shell walls as well as the extinction banding visible under cross-polarized light.

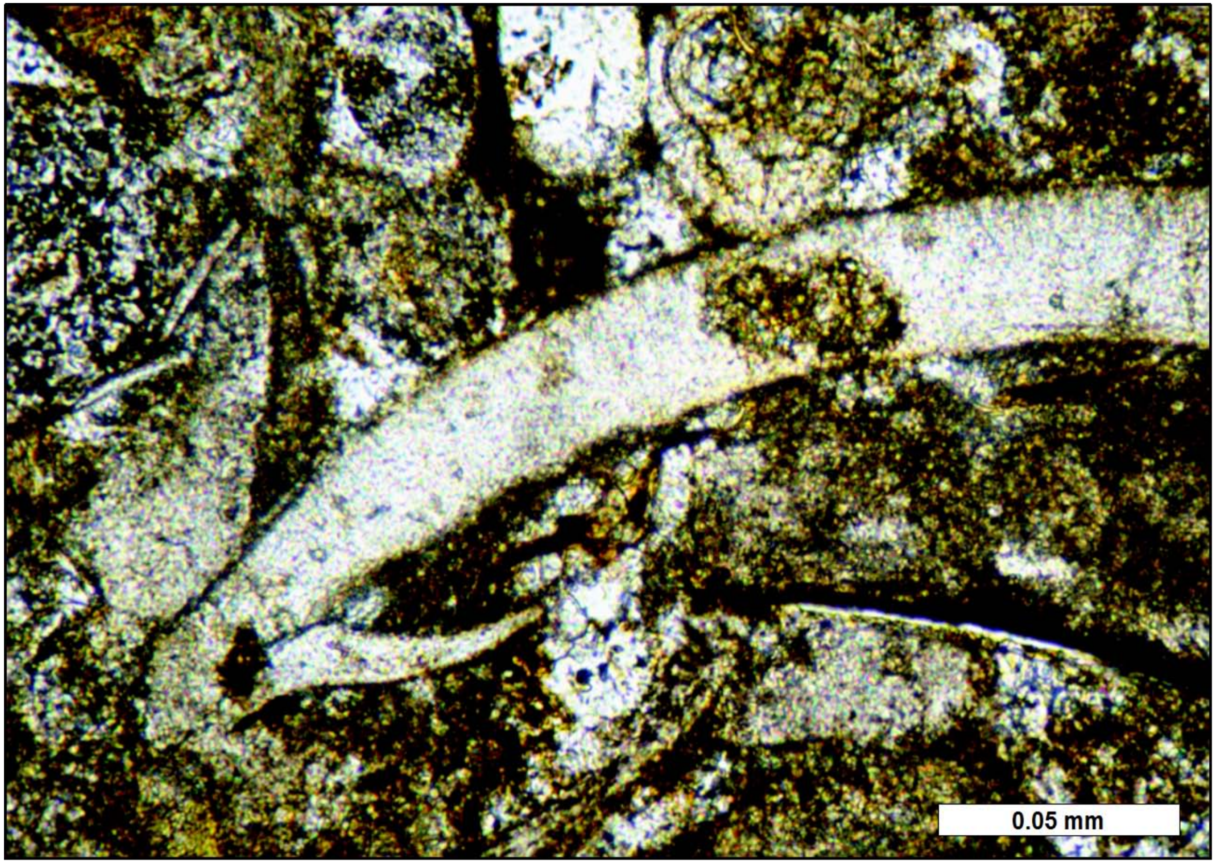
Example



Ostracode valves, unlike bivalve shells, have recurved (fish-hook-like) edges and one valve commonly overlaps the other along one or more margins

Up. Permian Zechstein Z1, Bolechowice, Poland
Ostracode carapaces from a marginal marine setting. The complete ostracode shows overlap of valves and a geopetal internal sediment fill

Example



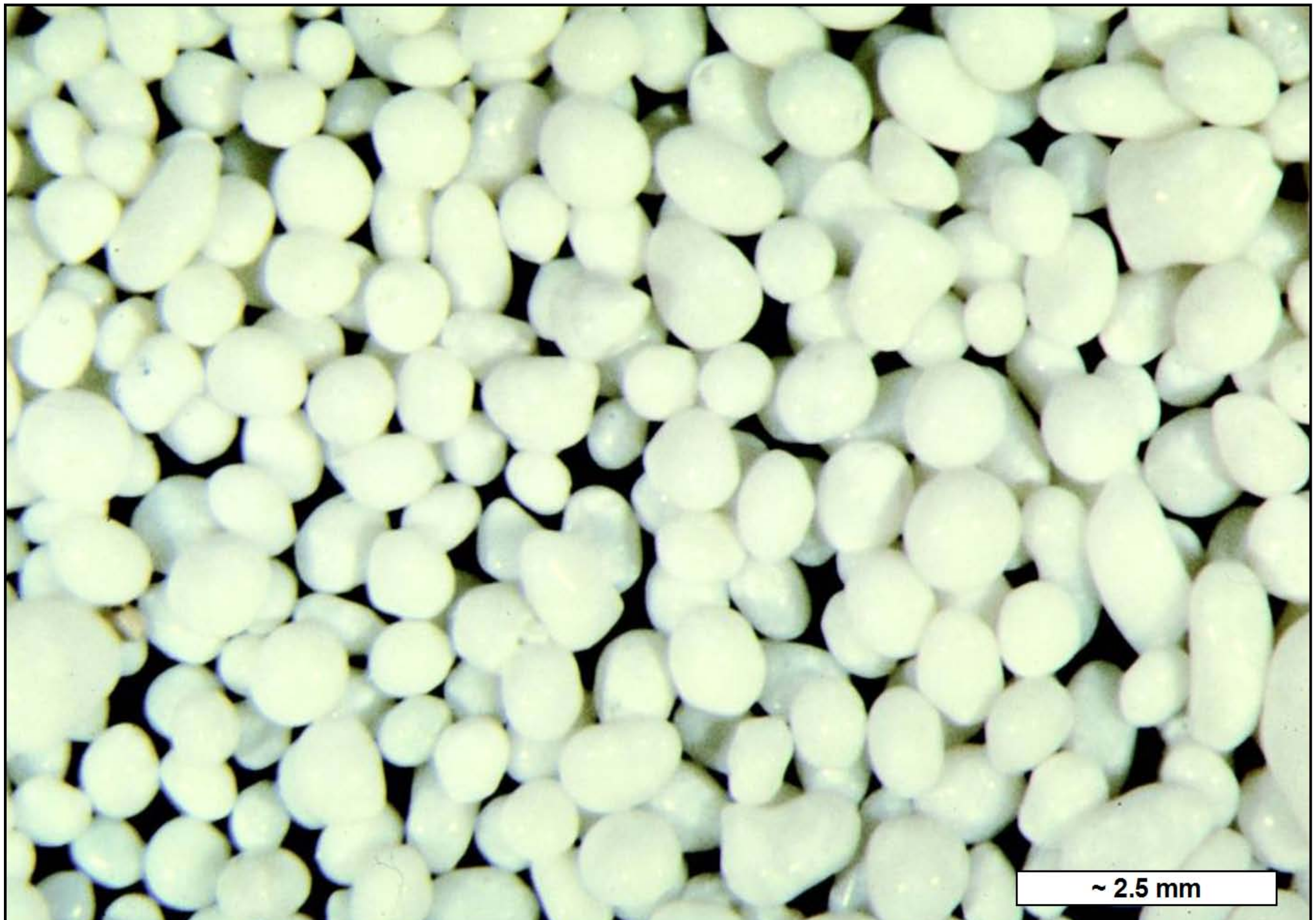
Lo. Miocene Lower Otekaike Ls., northern Otago, New Zealand
A fish-hook-like termination of a single ostracode valve. These terminations are distinctive and, in combination with carapace size, structure, and wall morphology, help to reliably identify ostracode remains

Ooids, peloids

Definitions

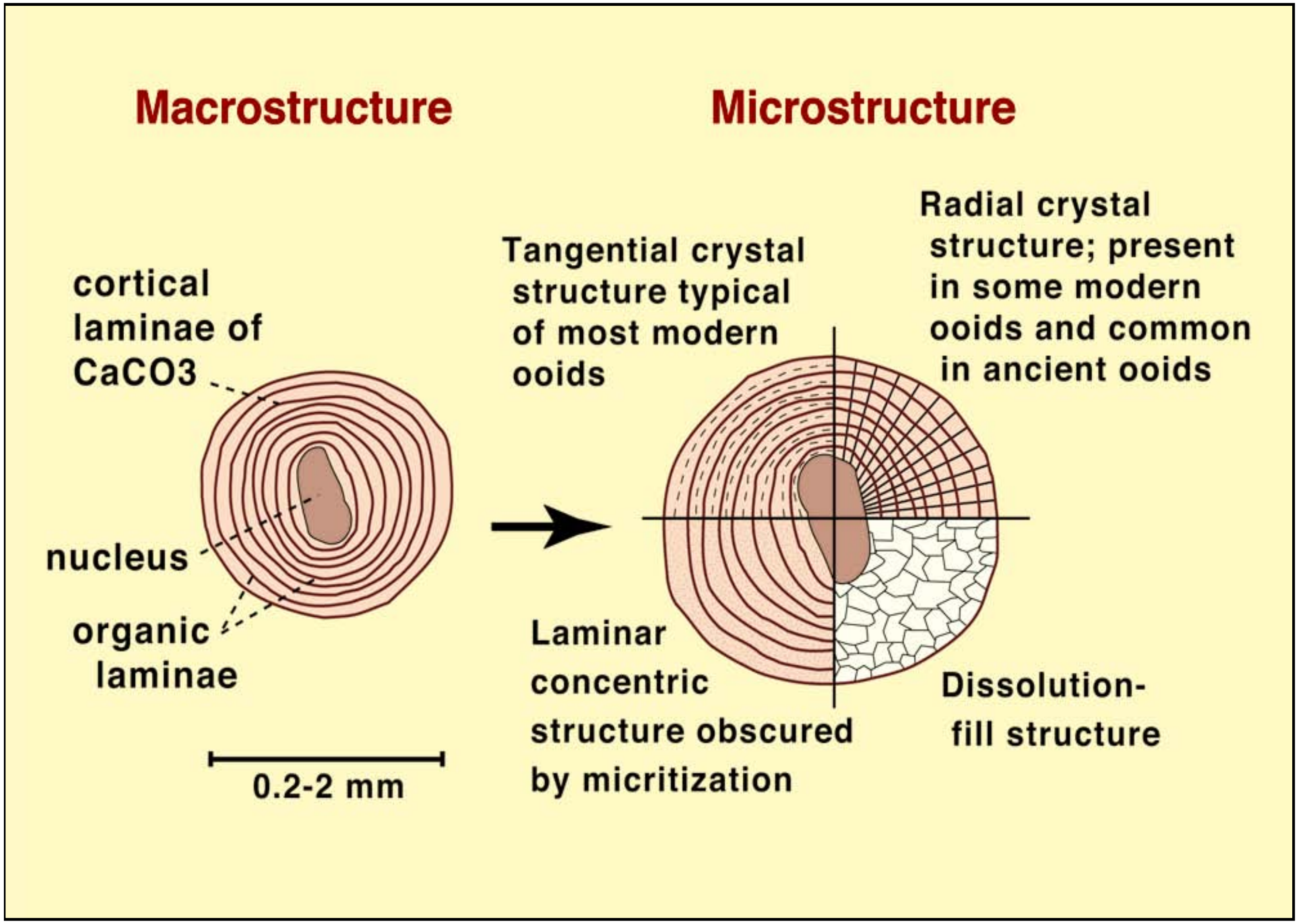
- **Ooid -** A spherical to ellipsoidal grain, 0.25 to 2.00 mm in diameter, with a nucleus covered by one or more precipitated concentric coatings (cortical layers) with radial and/or concentric orientation of constituent crystals.
- **Pisoid -** A small spheroidal particle with concentrically laminated internal structure, larger than 2 mm and and less than 10 mm in diameter.

Ooids

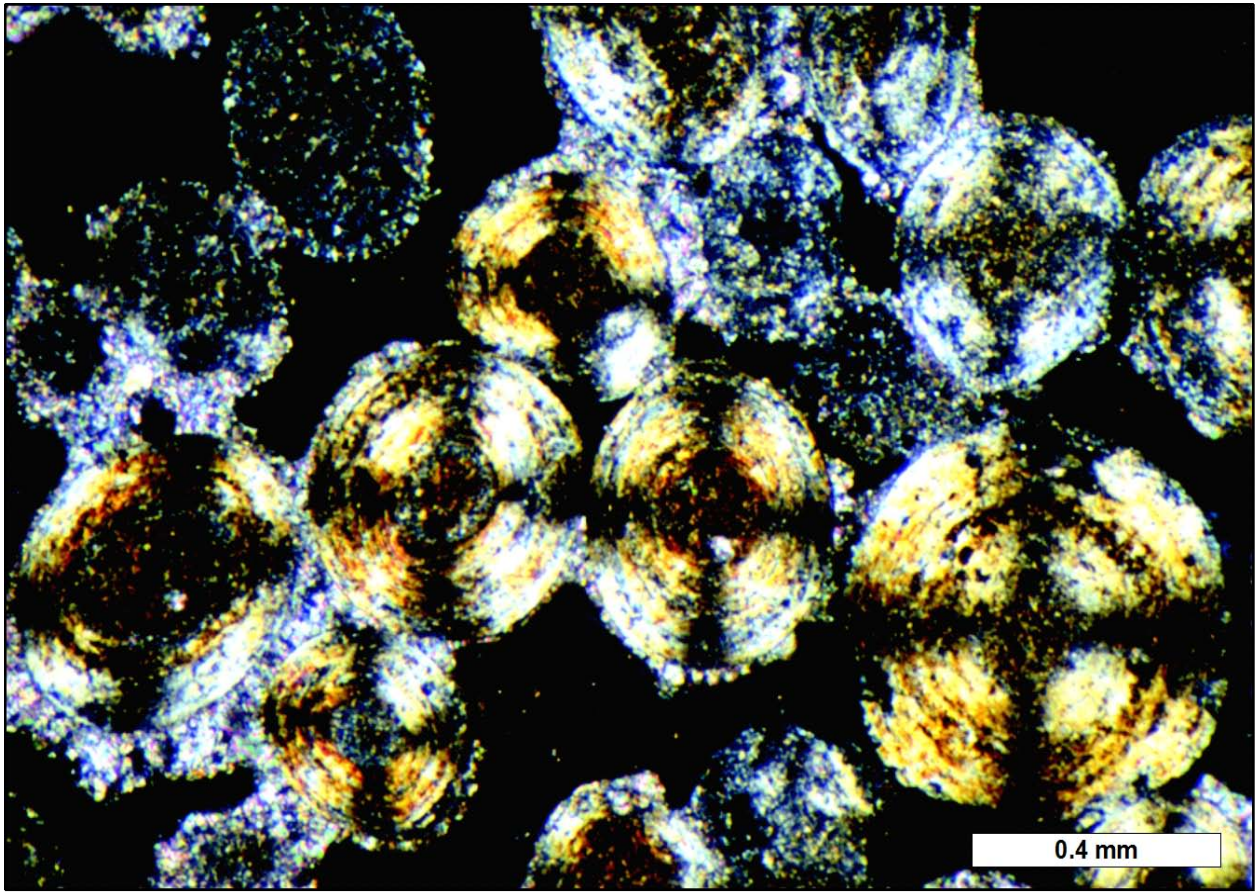


Macrophotograph of modern ooids from Cat Cay, Great Bahama Banks, Bahamas

Ooid structure

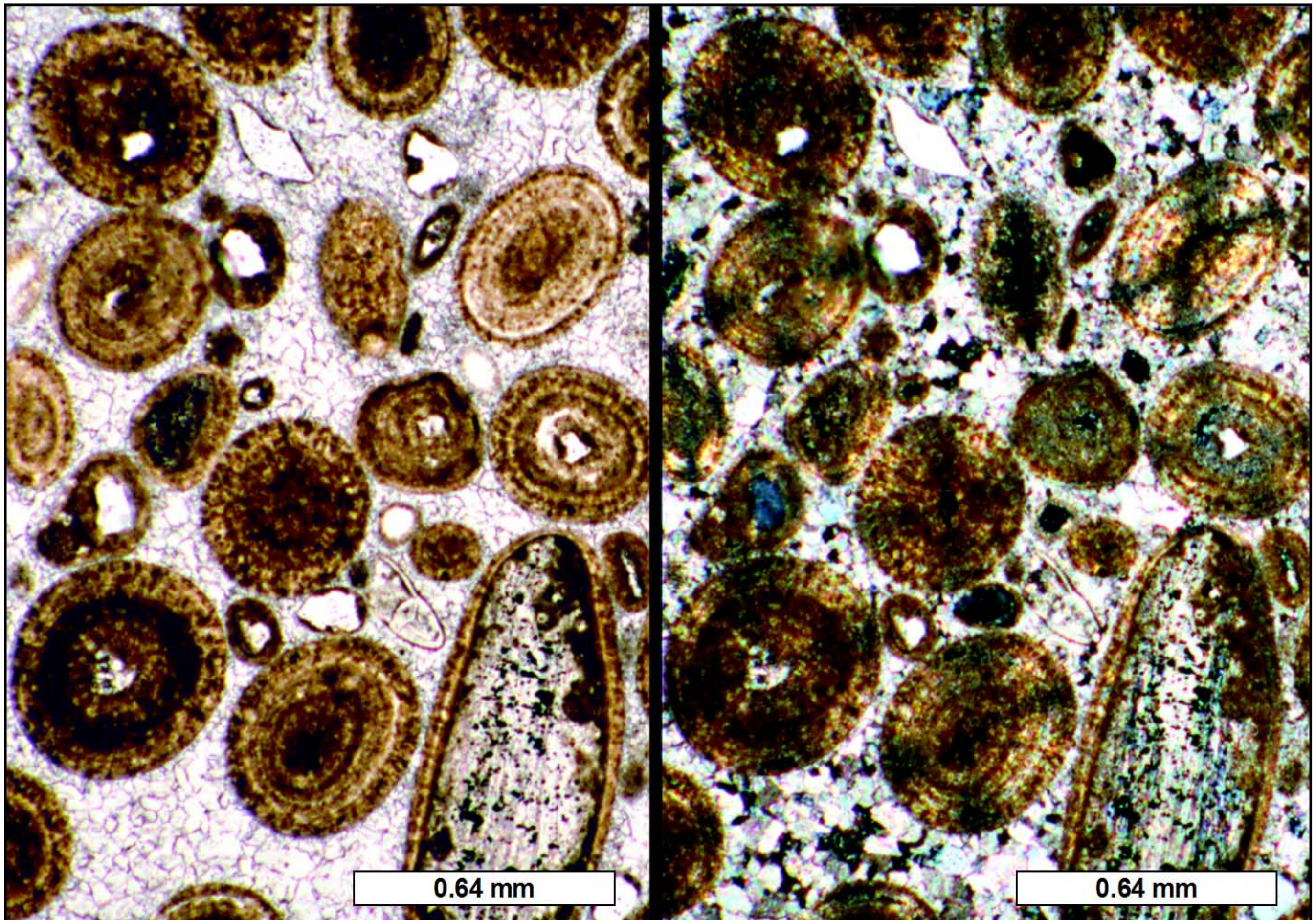


Example



Holocene, Joulters Cay, Great Bahama Bank, Bahamas
These are sub-Recent and slightly cemented aragonitic ooids that show strong pseudo-uniaxial crosses

Example



Jurassic (Corallian) Lo. Osmington Oolite, Dorset, England, U.K.

Inorganic precipitation

- **Ooids** provide an example of inorganic precipitation
- They form mainly under **high-energy**, agitated-water conditions in **warm waters** that are **supersaturated** with calcium carbonate
  - Currents and waves keep the grains moving (+intermittent burial and resuspension)
    - Allows ± even precipitation of calcium carbonate (pref. aragonite) on all sides of the grains

Inorganic precipitation

- pCO$_2$ exerts a major control on calcium carbonate precipitation…
  - Loss of CO_2 from water favors precipitation
    - Increase in **<u>temperature</u>**
      - ↓ in the solubility of CO_2 in water (escape of CO_2)
        - » ↑ in pH
      - ↓ in the solubility of calcium carbonate minerals
        - » more likely to precipitate…
    - Decrease in **<u>water pressure</u>**
      - Storm activity (wave agitation)
- Decrease in **<u>salinity</u>**
  - **Ionic strength ↓ = less foreign ions (e.g. Mg^{2+})**

Calcium carbonate deposition is favored in the more <u>tropical and shallower areas</u> of the ocean

Pellets

Pellets are the fecal products of invertebrate organisms

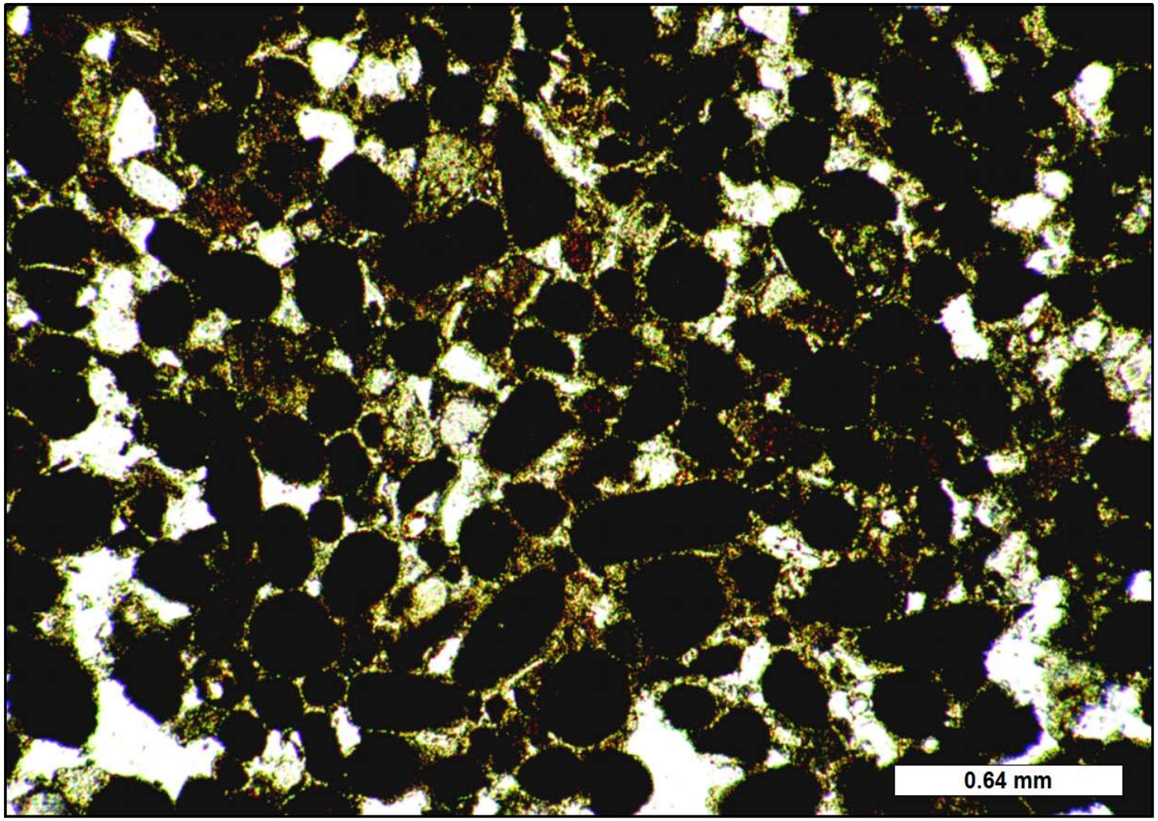
Close-up view

San Salvador Island, Bahamas

View of tidal flat with numerous pellet-covered mounds of a burrowing shrimp

Peloids

- **Allows reference to grains composed of micritic material without the need to imply any particular mode of origin**
  - **possible pellets, indistinct intraclasts, micritized ooids or fossil fragments**



Recent sediment, Coorong Lagoon, South Australia
An example of modern (crustacean?) fecal pellets from a variable salinity (hypersaline to subsaline) carbonate lagoon

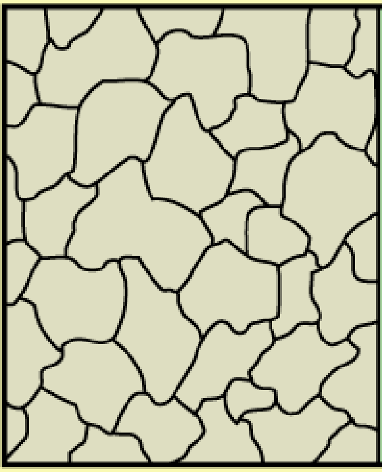
Dolostone textures

Dolostone

- Composed mainly of the mineral dolomite
- Texture is largely crystalline (granular)
  - Crystal shape
    - Planar (idiotopic) dolomite
      - Rhombic, euhedral to subhedral crystals
    - Nonplanar (xenotopic) dolomite
      - Anhedral crystals
- Many dolomites form by <u>replacement</u> of a precursor limestone

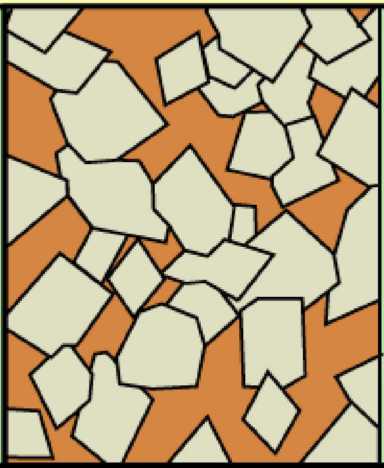
Sibley & Gregg (1987) Dolomite Classification

NONPLANAR FABRICS

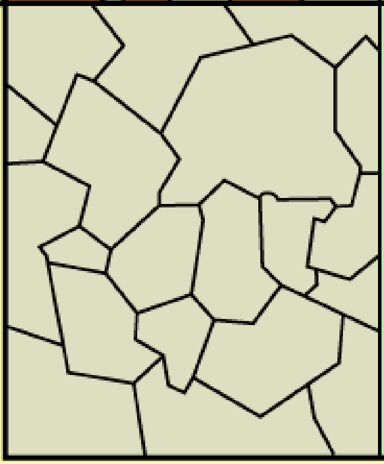


Nonplanar: closely packed anhedral crystals; mostly curved, lobate, serrated or irregular inter-crystalline boundaries. Preserved crystal-face junctions rare; crystals often show undulatory extinction in cross-polarized light.

PLANAR FABRICS

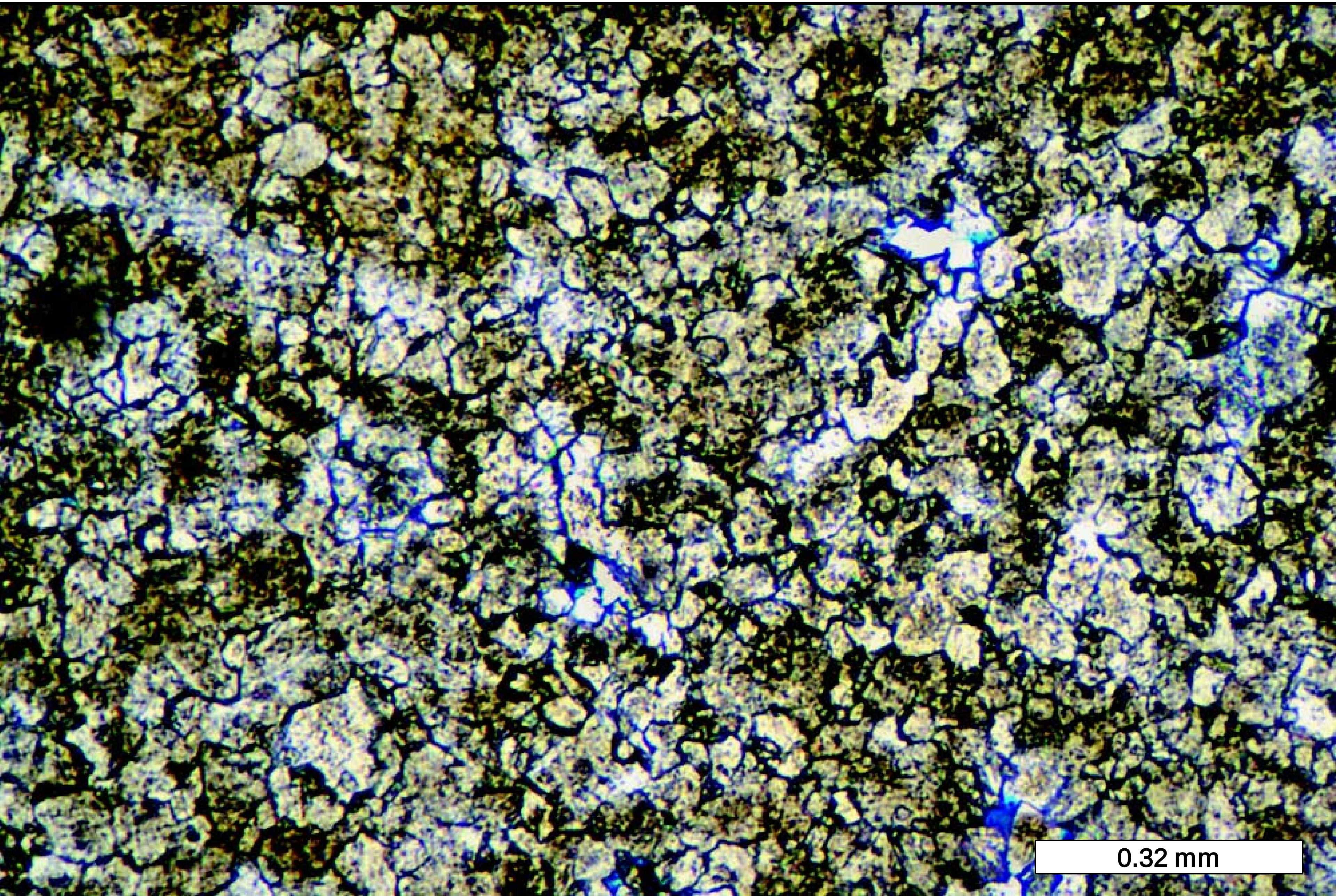


Planar-e (euhedral): most dolomite crystals are euhedral rhombs; crystal-supported; inter-crystalline areas filled by another mineral or porous.

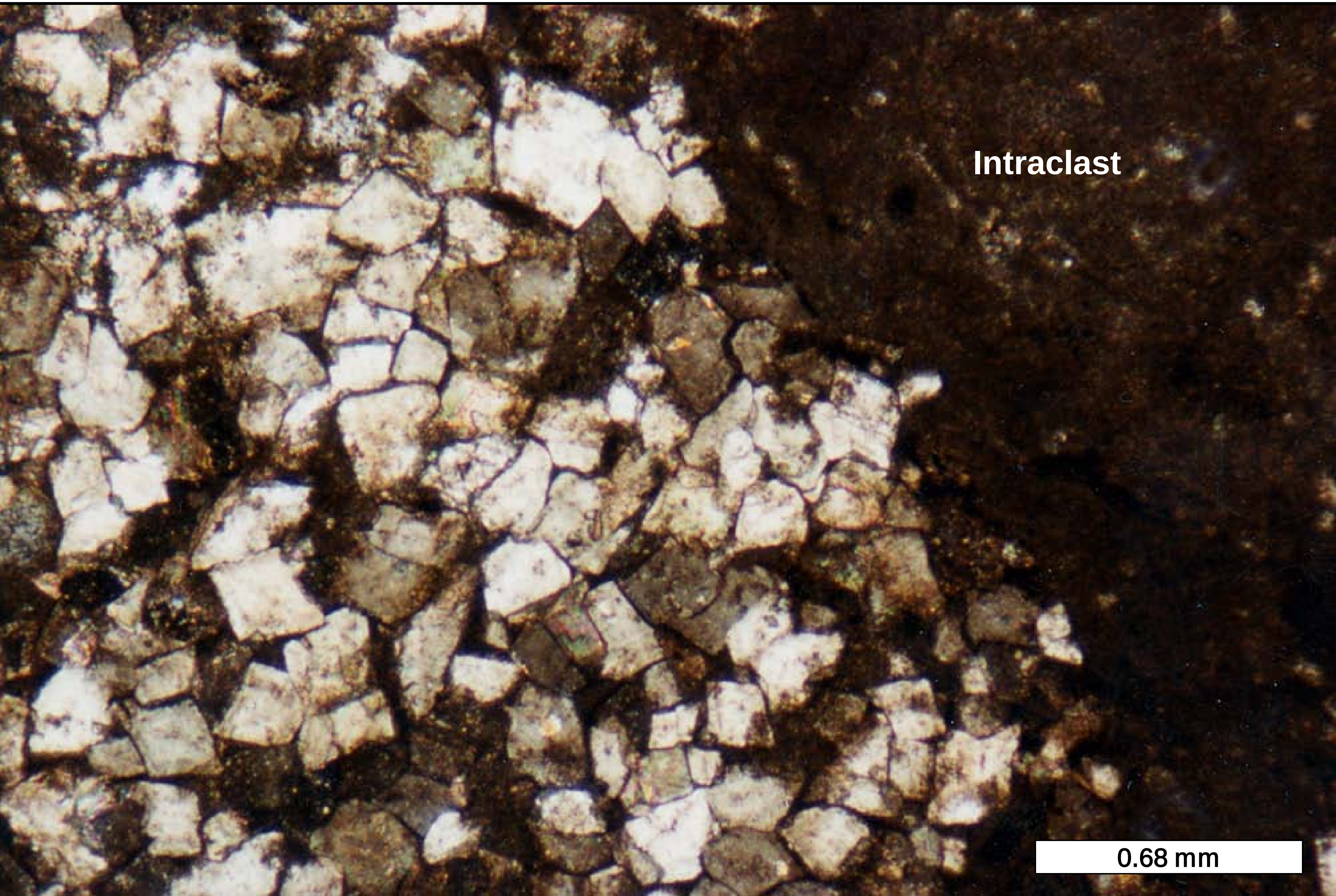


Planar-s (subhedral): most dolomite crystals subhedral to anhedral with straight, compro-mise boundaries and many crystal-face junctions. Low porosity and/or low intercrys-talline matrix content.

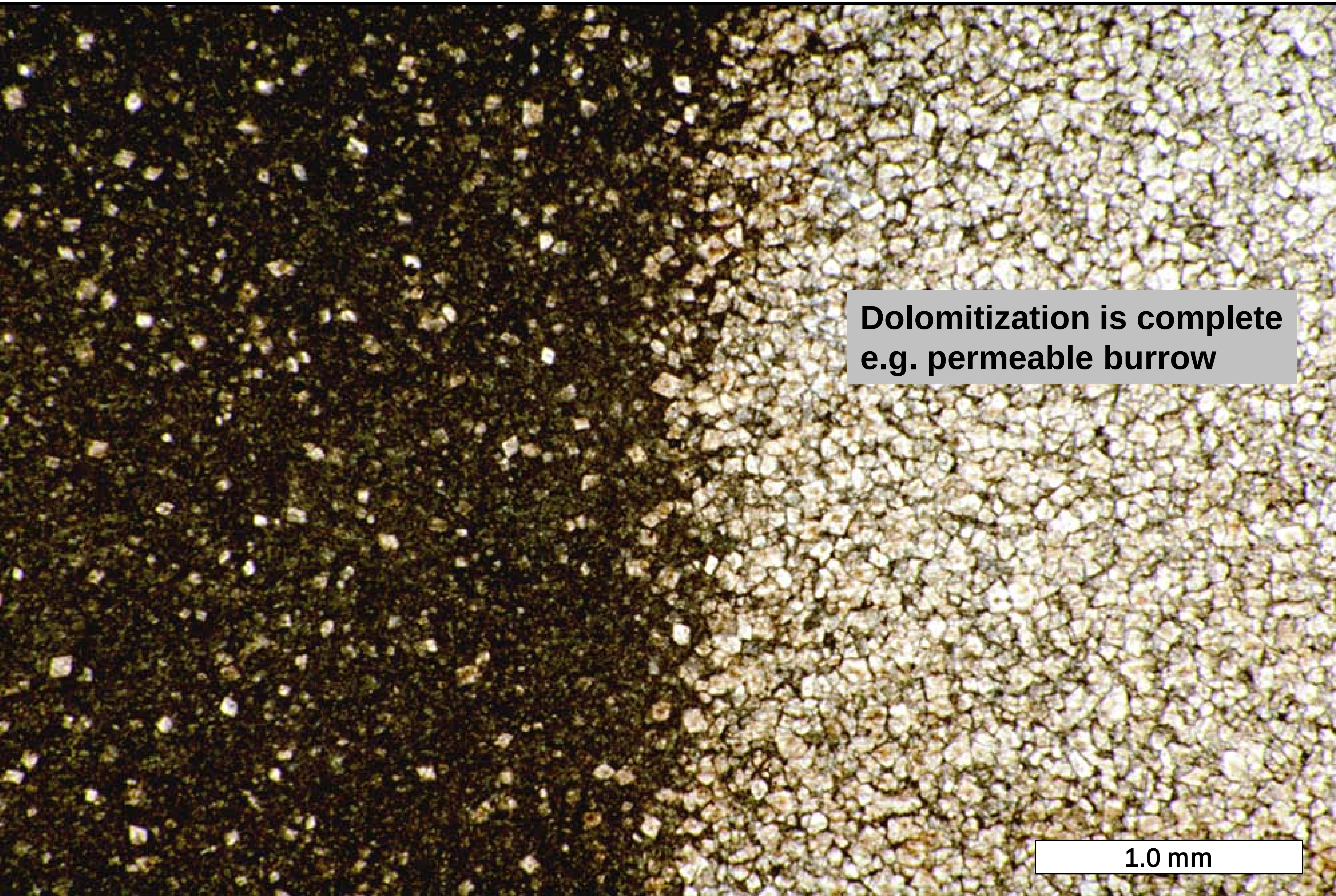
Nonplanar fabric



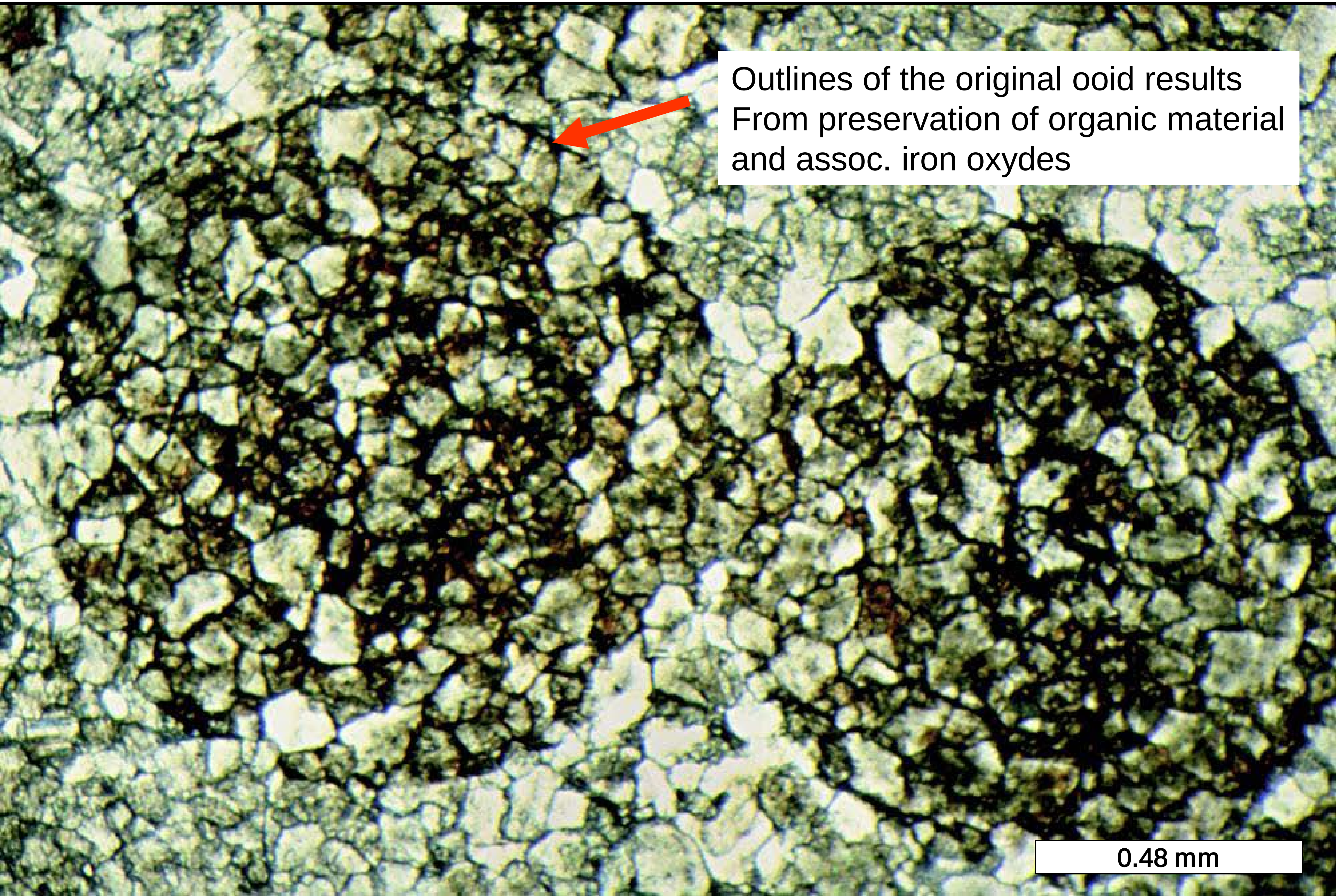
Nonmimic planars to planar-e



Dolomitization front



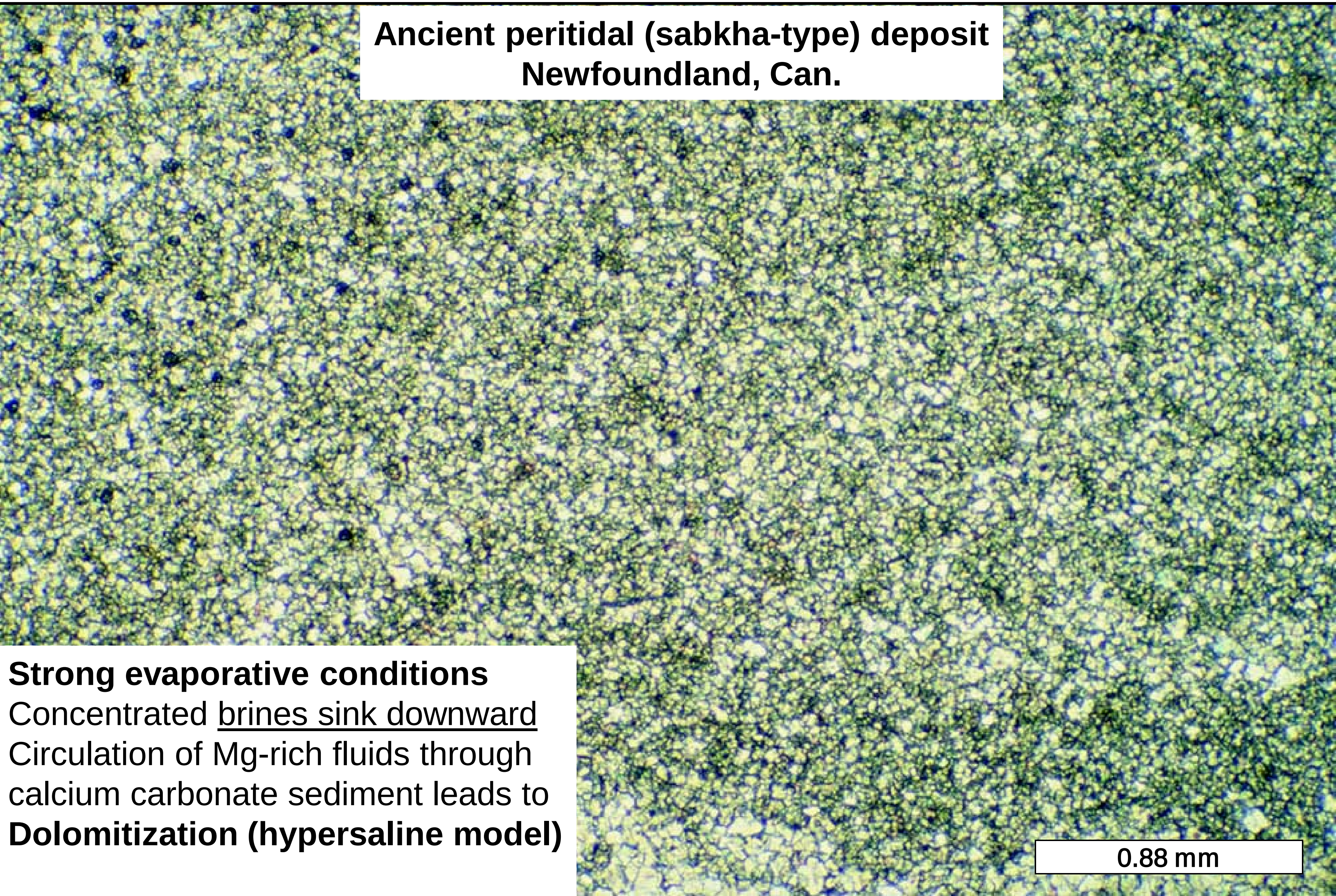
Mimicking replacement



Dolomite precipitation vs. replacement

Nearly abandoned tidal channel on Andros Island (Bahamas).

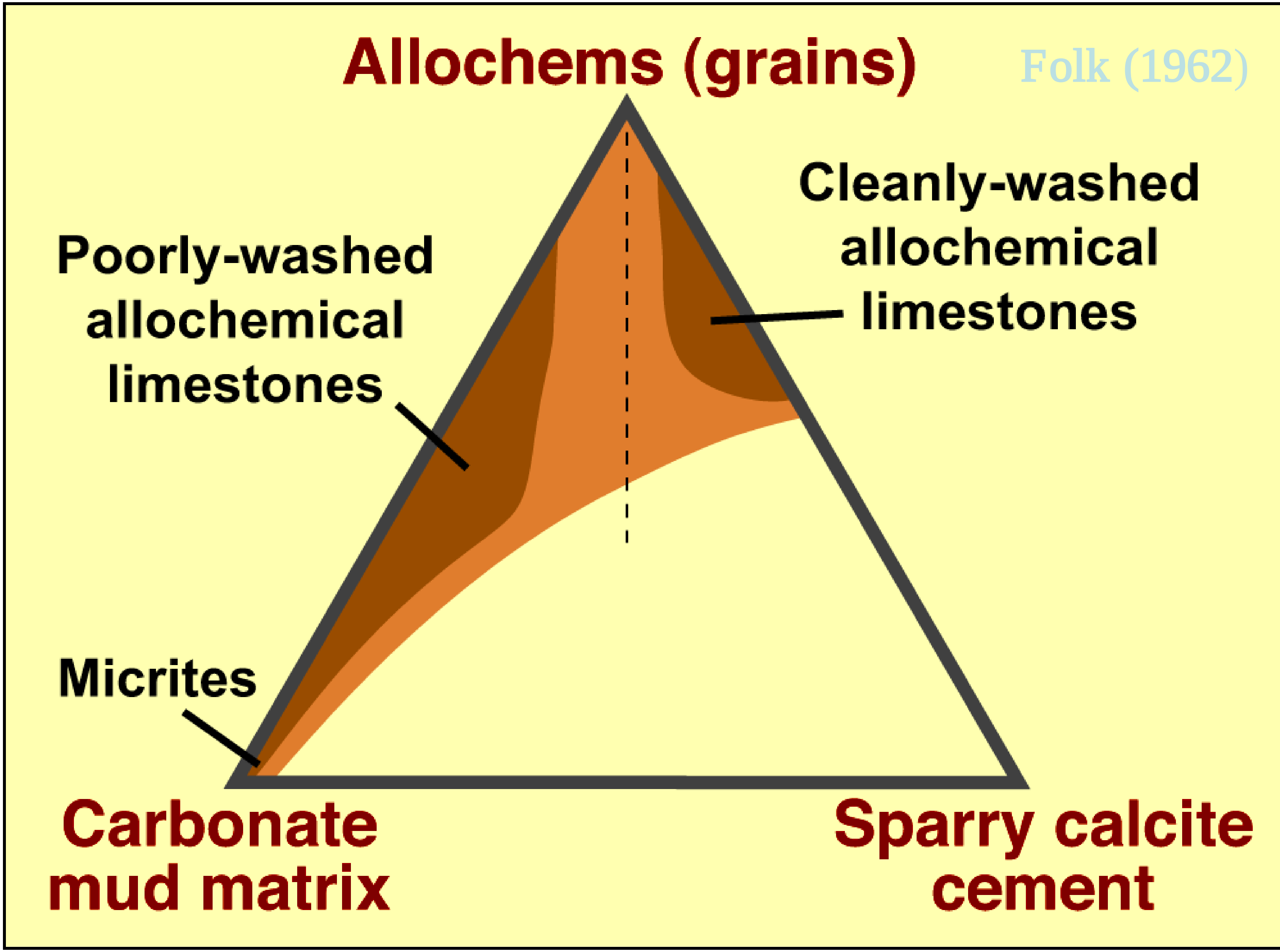
Finely crystalline dolomite



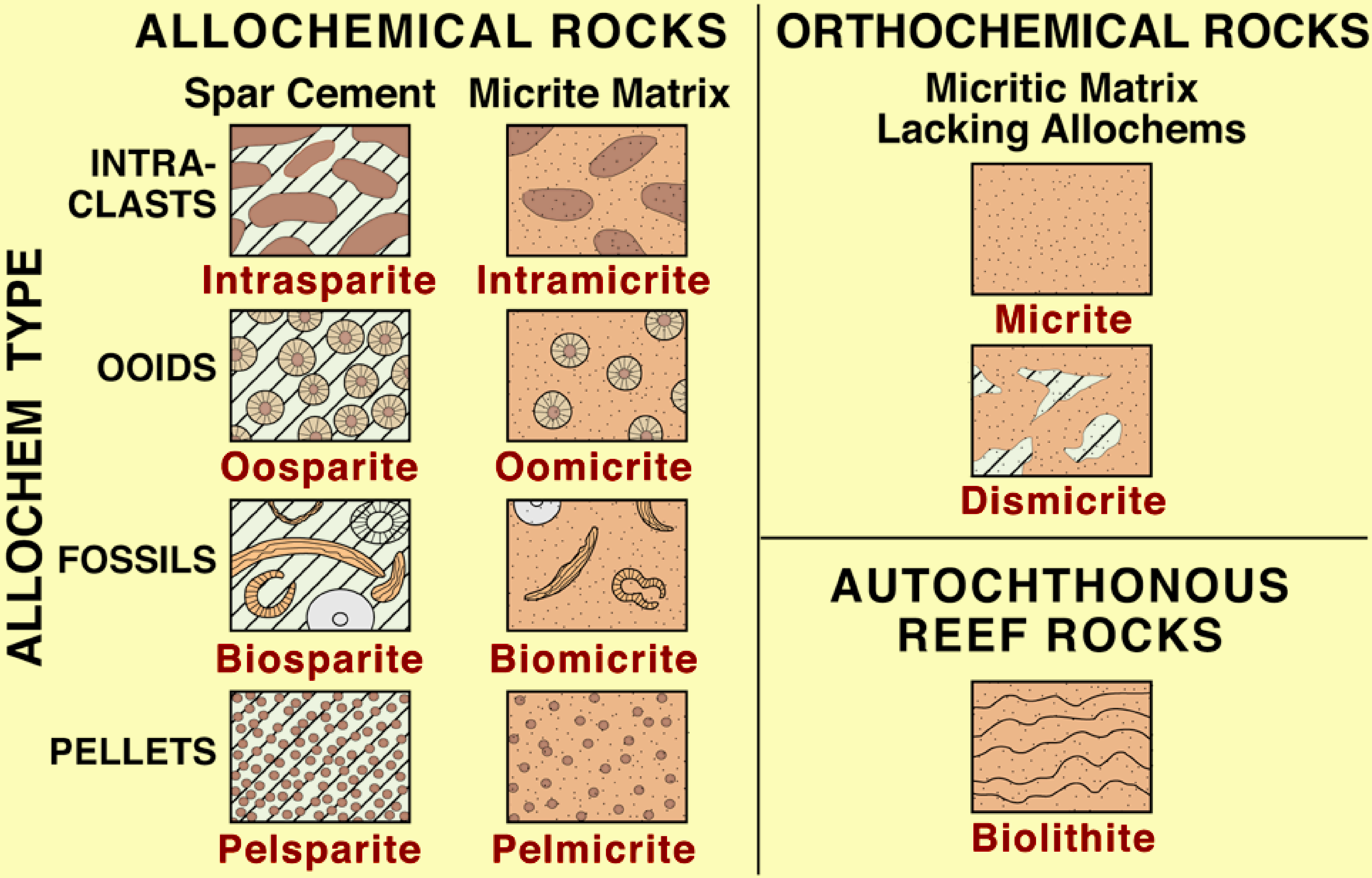
Ancient peritidal (sabkha-type) deposit
Newfoundland, Can.

Strong evaporative conditions
Concentrated brines sink downward
Circulation of Mg-rich fluids through calcium carbonate sediment leads to
Dolomitization (hypersaline model)

Ternary Plot of Major Limestone Constituents

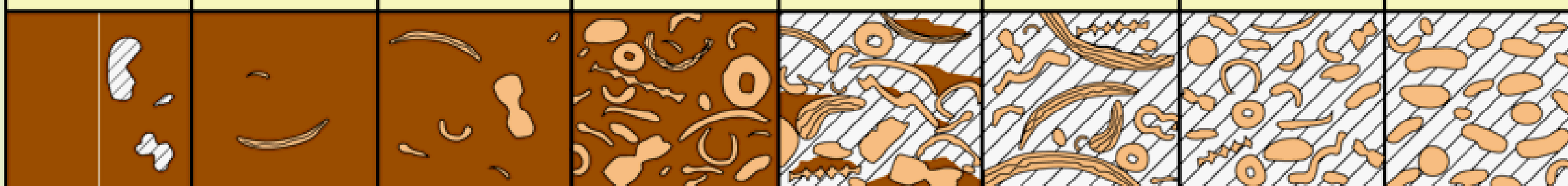


Folk (1962) Limestone Classification



Textural Spectrum of Carbonate Rocks (Folk, 1962)

Low energy settings — **High energy settings**

	> 2/3 LIME MUD MATRIX				SUBEQUAL SPAR and LIME MUD	> 2/3 LIME SPAR CEMENT		
Percent allochems	0-1%	1-10%	10-50%	> 50%		SORTING POOR	SORTING GOOD	ROUNDED and ABRADED
Textural name	MICRITE and DIS-MICRITE	FOSSILI-FEROUS MICRITE	SPARSE BIO-MICRITE	PACKED BIO-MICRITE	POORLY-WASHED BIO-SPARITE	UN-SORTED BIO-SPARITE	SORTED BIO-SPARITE	ROUNDED BIO-SPARITE
Typical fabric								
Terri-genous analogs	Claystone		Sandy clay-stone	Clayey or immature sandstone		Sub-mature sand-stone	Mature sand-stone	Super-mature sand-stone

Grain and Crystal Size Scales (Folk, 1962)

Grain size	Transported Constituents	Authigenic Constituents	Crystal size
	Very coarse calcirudite	Extremely coarsely crystalline	
64 mm			
	Coarse calcirudite		
16 mm			
	Medium calcirudite		
4 mm			4 mm
	Fine calcirudite	Very coarsely crystalline	
1 mm			1 mm
	Coarse calcarenite	Coarsely crystalline	
0.5 mm			
	Medium calcarenite		
0.25 mm			0.25 mm
	Fine calcarenite	Medium crystalline	
0.125 mm			
	Very fine calcarenite		
0.062 mm			0.062 mm
	Coarse calcilutite	Finely crystalline	
0.031 mm			
	Medium calcilutite		
0.016 mm			0.016 mm
	Fine calcilutite	Very finely crystalline	
0.008 mm			
	Very fine calcilutite		
			0.004 mm
		Aphanocrystalline	

Dunham (1962) Limestone Classification

<table>
<tr><td colspan="5">DEPOSITIONAL TEXTURE RECOGNIZABLE</td><td rowspan="6">DEPOSITIONAL TEXTURE NOT RECOGNIZABLE

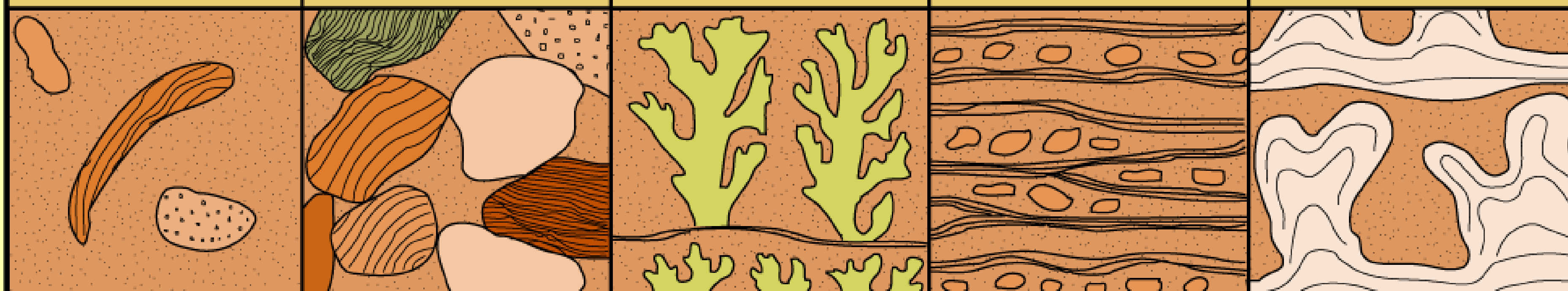
Crystalline carbonate

(Subdivisions based on texture or diagenesis)</td></tr>
<tr><td colspan="4">Original Components Not Bound Together During Deposition</td><td rowspan="4">Original Components Bound Together During Deposition</td></tr>
<tr><td colspan="3">Contains mud</td><td rowspan="3">Lacks mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>< 10% grains</td><td>> 10% grains</td></tr>
<tr><td>Mud-stone</td><td>Wacke-stone</td><td>Packstone</td><td>Grain-stone</td><td>Boundstone</td></tr>
</table>

The distinction as to whether a rock is supported by matrix (mud) or framework (grains) is fundamental to this scheme

Embry& Klovan (1971) Limestone Classification

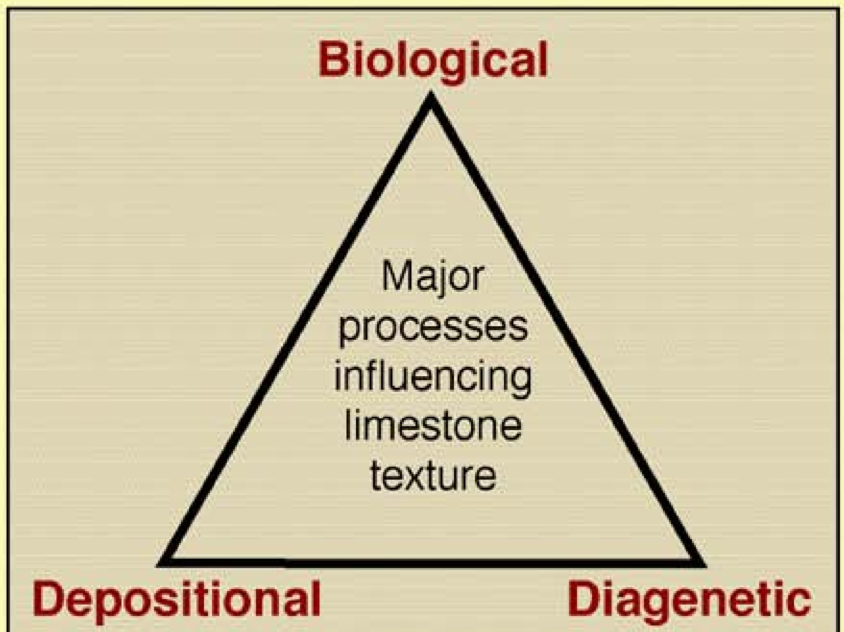
Original Components Not Organically Bound During Deposition		Original Components Organically Bound During Deposition		
> 10% grains >2 mm				
Matrix-supported	Supported by components larger than 2 mm	Organisms acted as baffles	Organisms encrusted and bound	Organisms built a rigid framework
Floatstone	**Rudstone**	**Bafflestone**	**Bindstone**	**Framestone**



Widely adopted by those working on reefs, bioherms, and other biogenic carbonates

Wright (1992) Limestone Classification

DEPOSITIONAL				BIOLOGICAL			DIAGENETIC			
Matrix-supported (clay & silt grade)		Grain-supported		In-situ organisms			Non-obliterative			Obliter-ative
< 10% grains	> 10% grains	with matrix	no matrix	Encrusting binding organisms	Organisms acted to baffle	Rigid organisms dominant	Main component is cement	Many micro-stylolitic grain contacts	Mostly micro-stylolitic grain contacts	Crystals > 10 μm
Calci-mudstone	Wacke-stone	Pack-stone	Grain-stone	Bound-stone	Baffle-stone	Frame-stone	Cement-stone	Condensed grainstone	Fitted grainstone	Spar-stone
	Float-stone	Rud-stone								Crystals < 10 μm Microspar-stone
	Grains > 2mm									

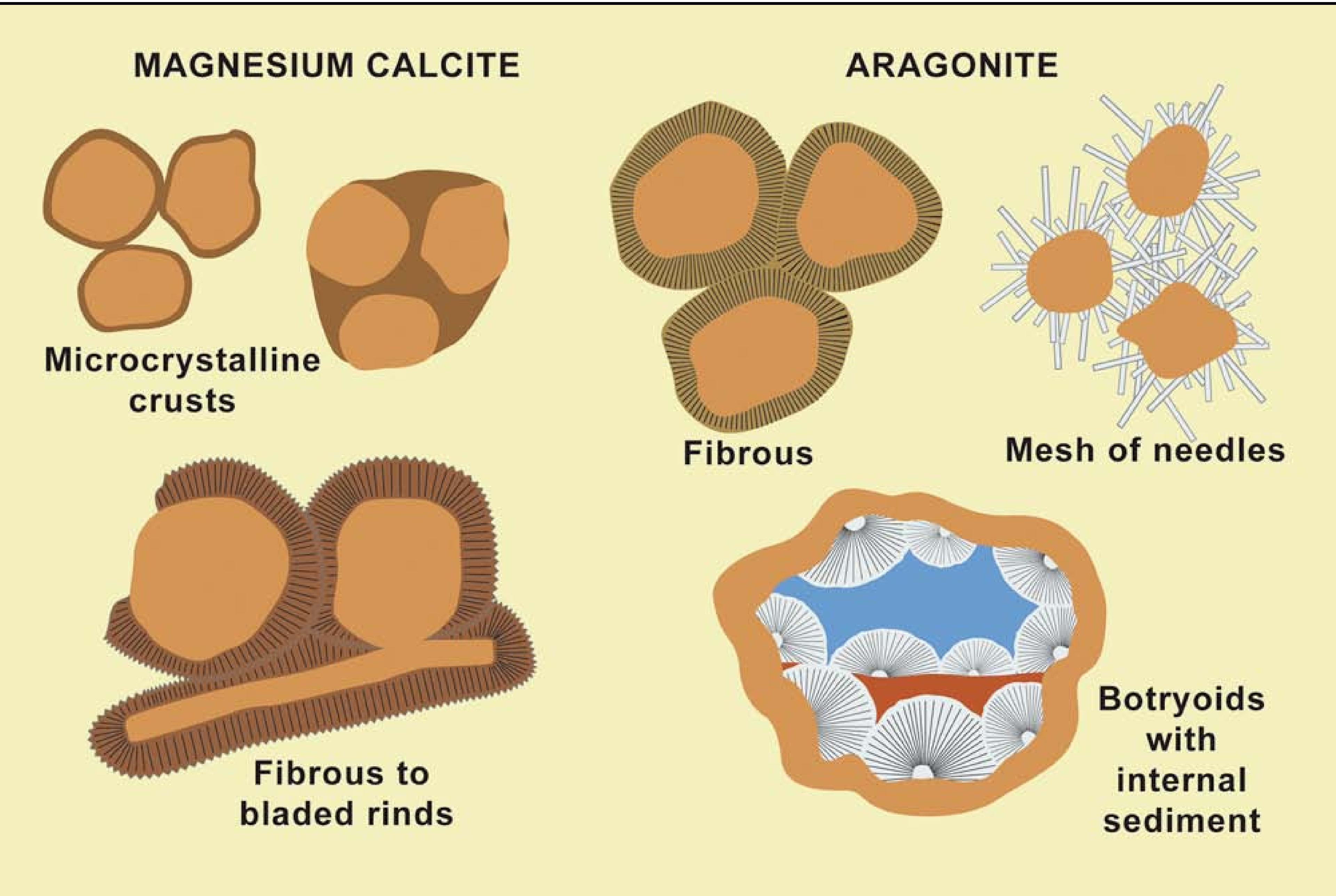


Carbonate diagenesis

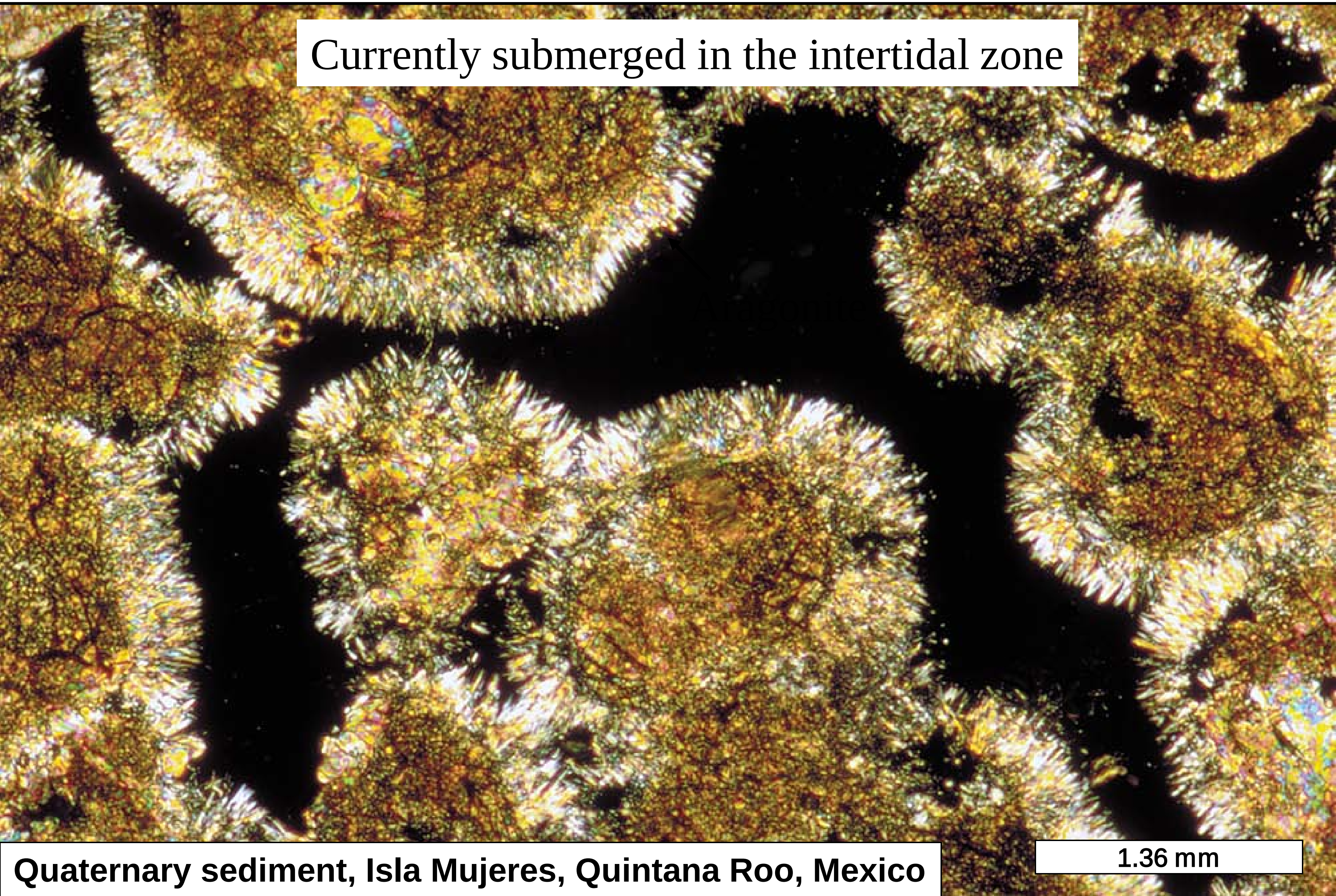
Regimes of carbonate diagenesis

- Marine realm
  - Seafloor and its near-subsurface
    - Bioturbation
    - Modifications by boring organisms
    - Cementation of grains in warm-water areas
      - Reefs, platform-margin sand shoals, beachrock
- Meteoric realm
  - Presence of CO_2-rich freshwater
    - Vadose zone, phreatic zone
    - Dissolution reprecipitation process
- Subsurface realm
  - Increase pressure and temp. and chemical changes (pore fluids)
    - Physical compaction
    - Chemical compaction
    - Other chemical changes (e.g. dolomitization)

Characteristic Morphologies of Marine Cements

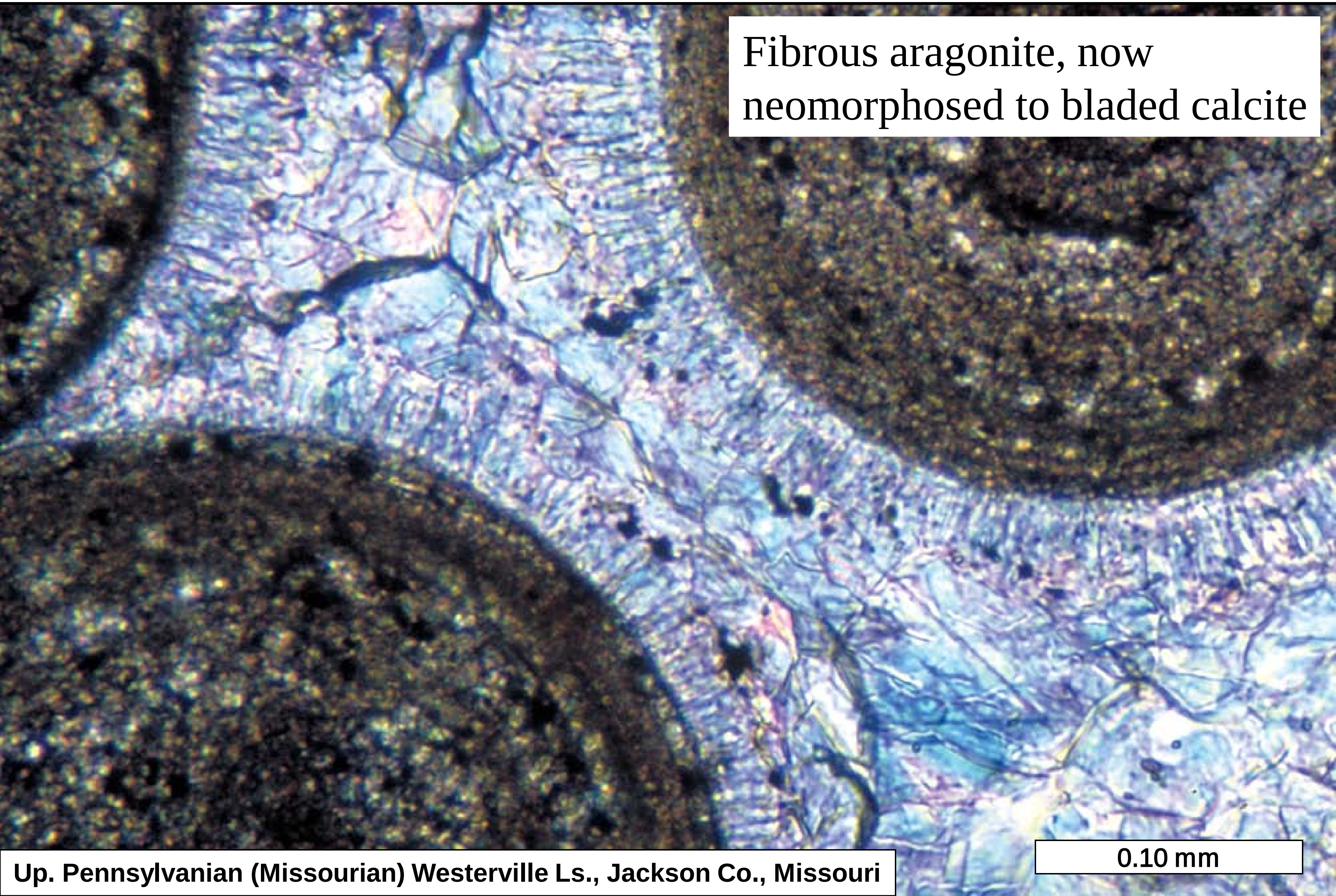


Weakly lithified Pleistocene <u>eolianite</u>

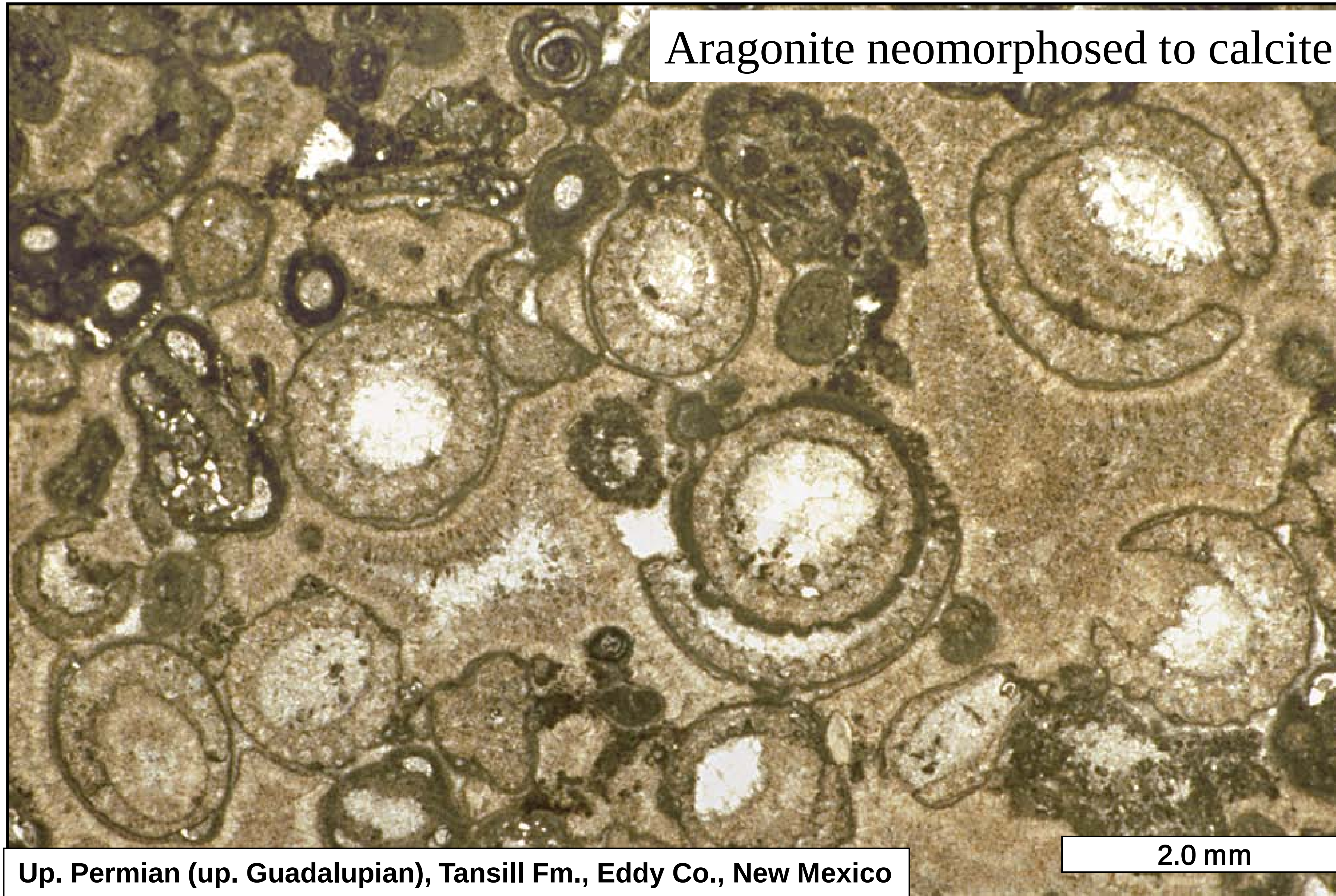


Quaternary sediment, Isla Mujeres, Quintana Roo, Mexico

Ancient oolitic grainstone

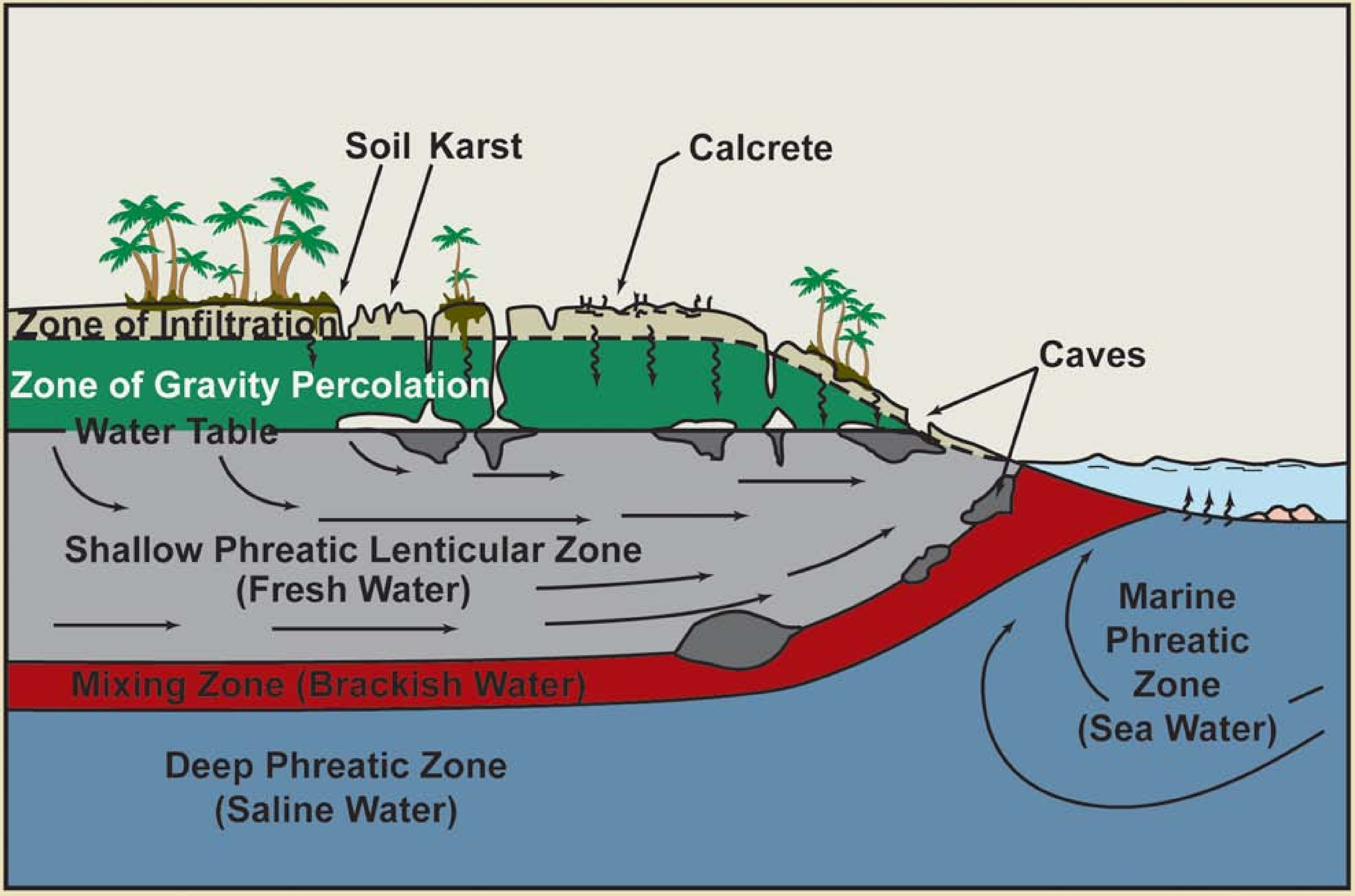


Cloudy (inclusion-rich), isopachous marine cements

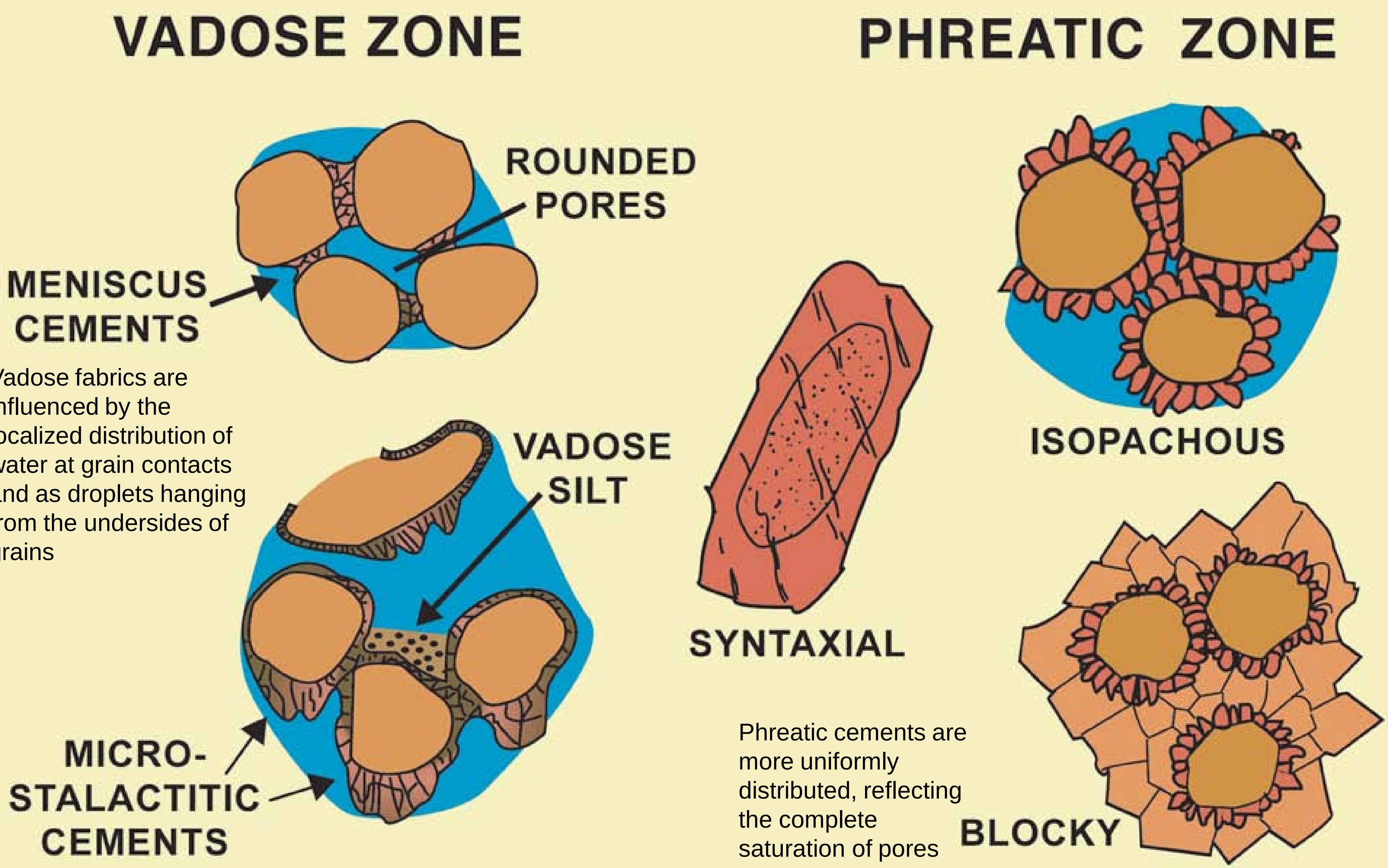


Up. Permian (up. Guadalupian), Tansill Fm., Eddy Co., New Mexico

The Coastal Meteoric Diagenetic Environment



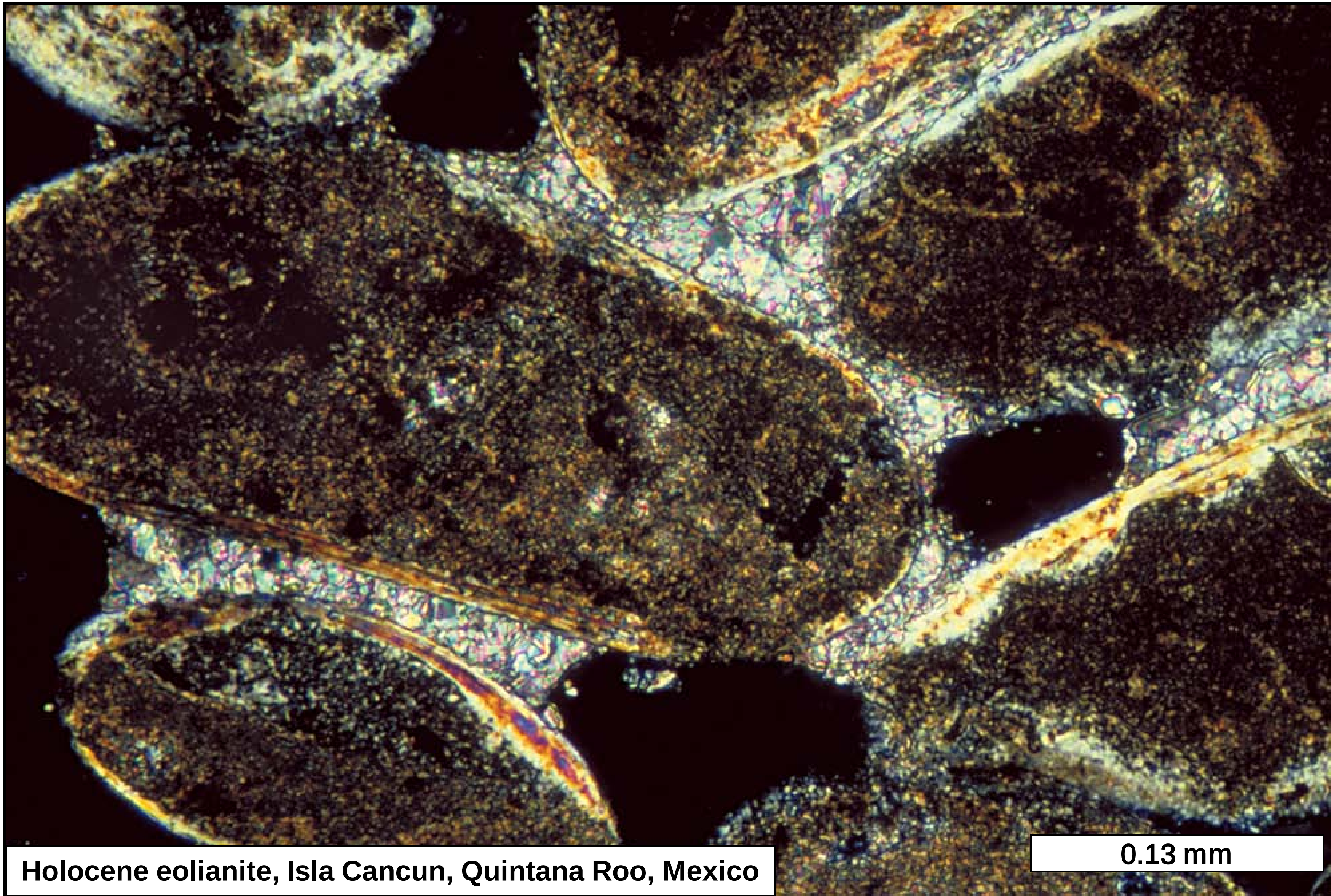
Common Meteoric Cement Morphologies



Vadose fabrics are influenced by the localized distribution of water at grain contacts and as droplets hanging from the undersides of grains

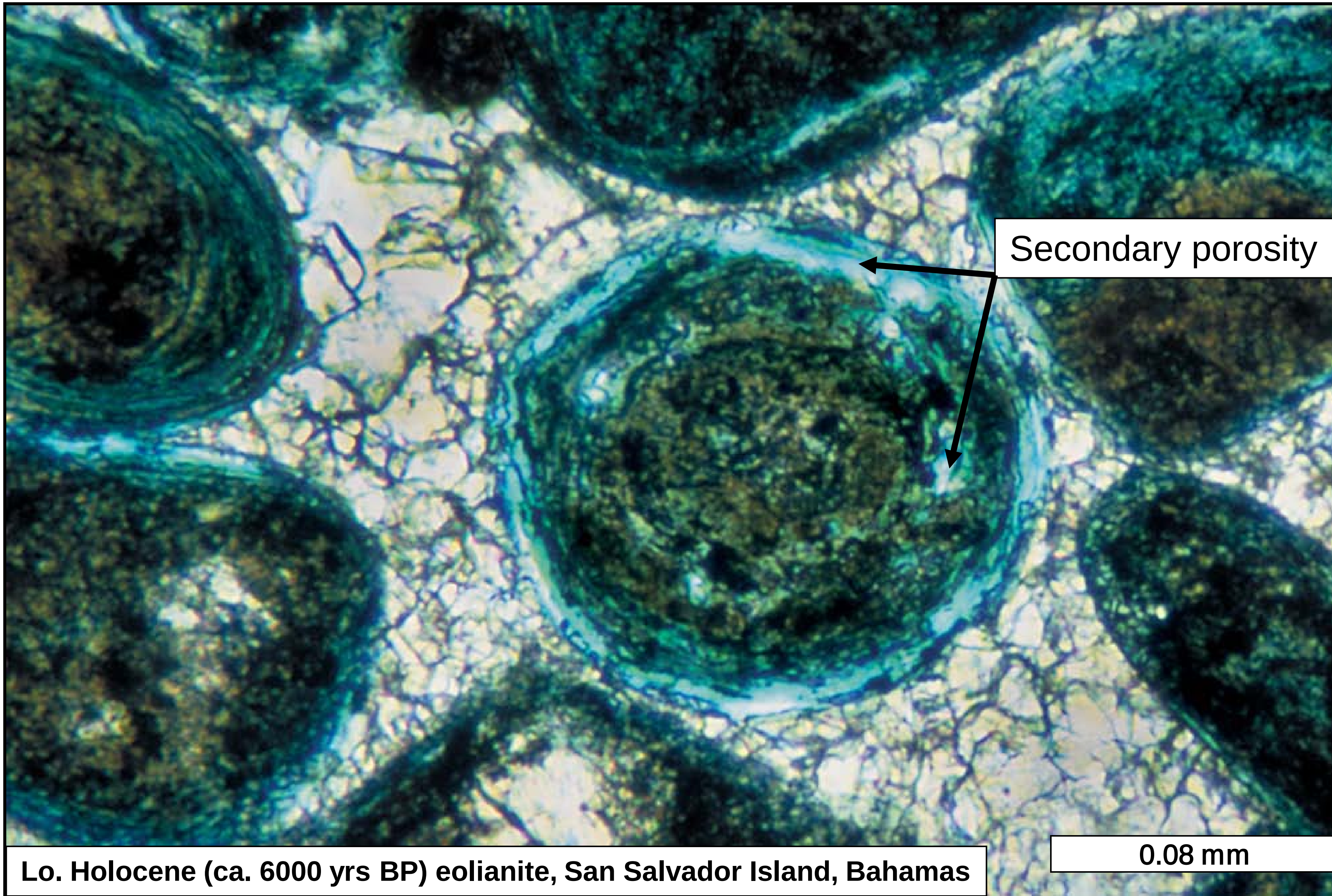
Phreatic cements are more uniformly distributed, reflecting the complete saturation of pores with water in that environment

Meniscus fabric that has formed rounded pores



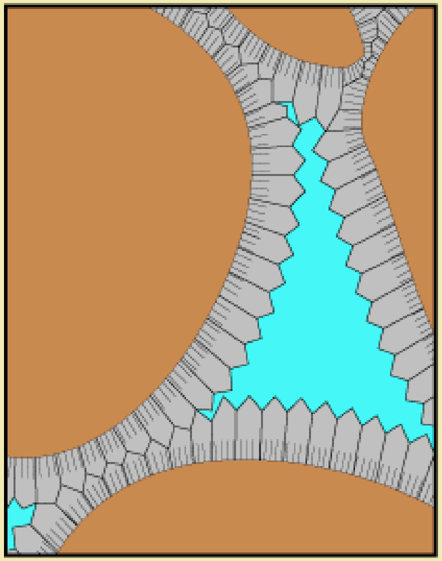
Holocene eolianite, Isla Cancun, Quintana Roo, Mexico

Sediment fully cemented by blocky, meteoric calcite spar

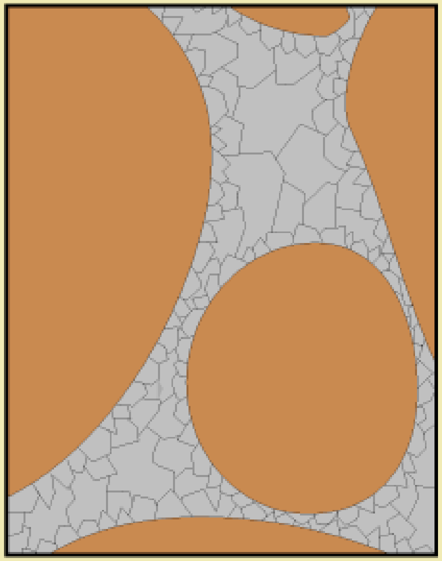


Lo. Holocene (ca. 6000 yrs BP) eolianite, San Salvador Island, Bahamas

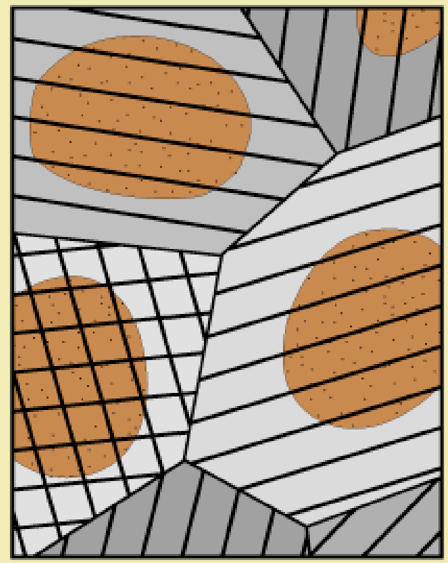
Common Burial-Stage Cement Fabrics



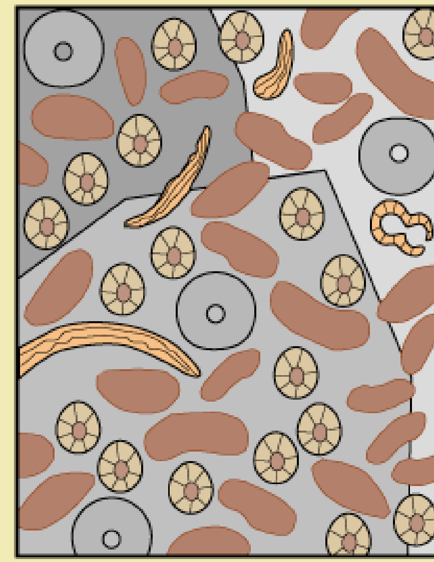
Prismatic spar overgrowing marine cement



Drusy mosaic of equant spar



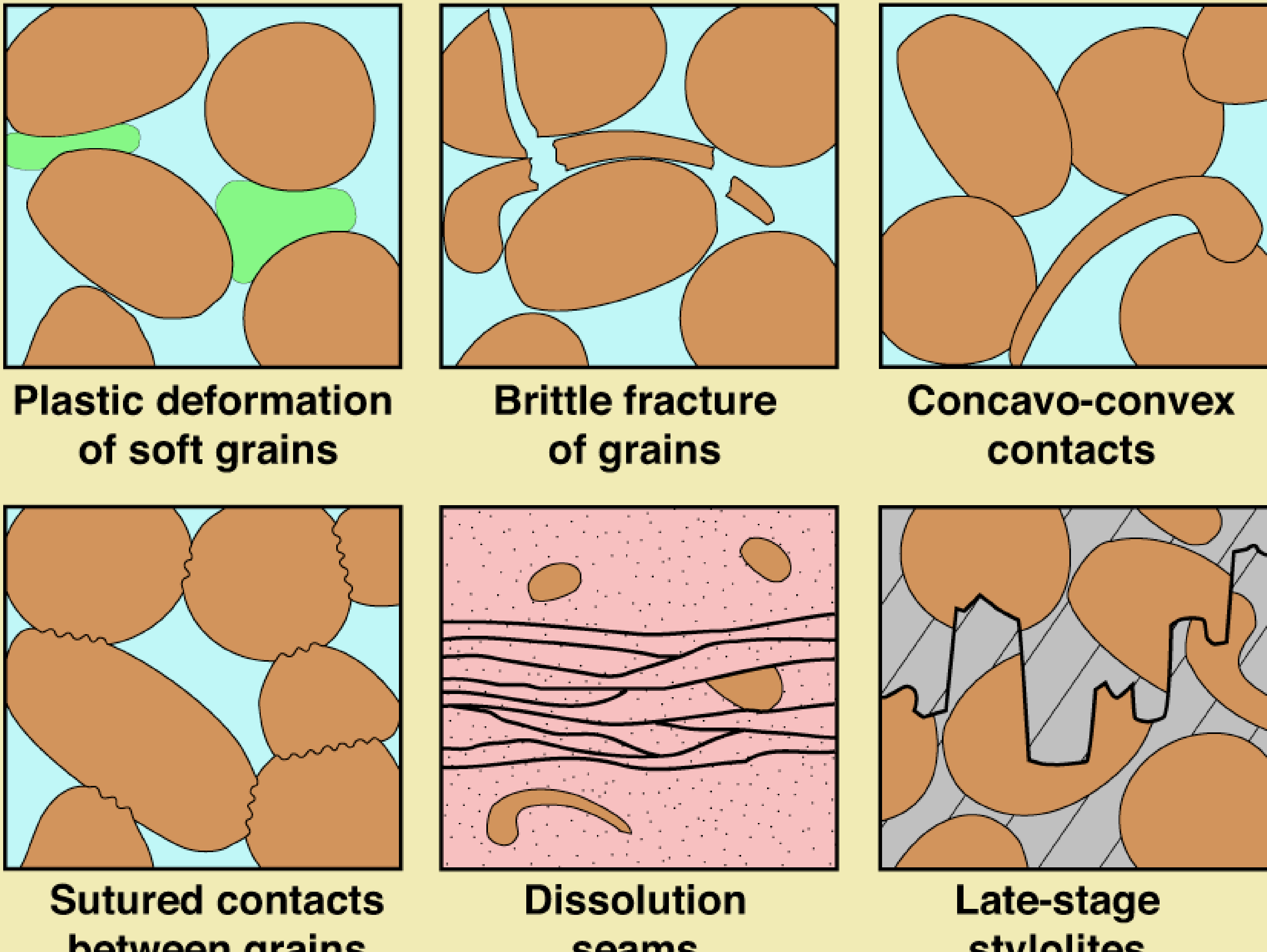
Syntaxial overgrowth of echinoderms



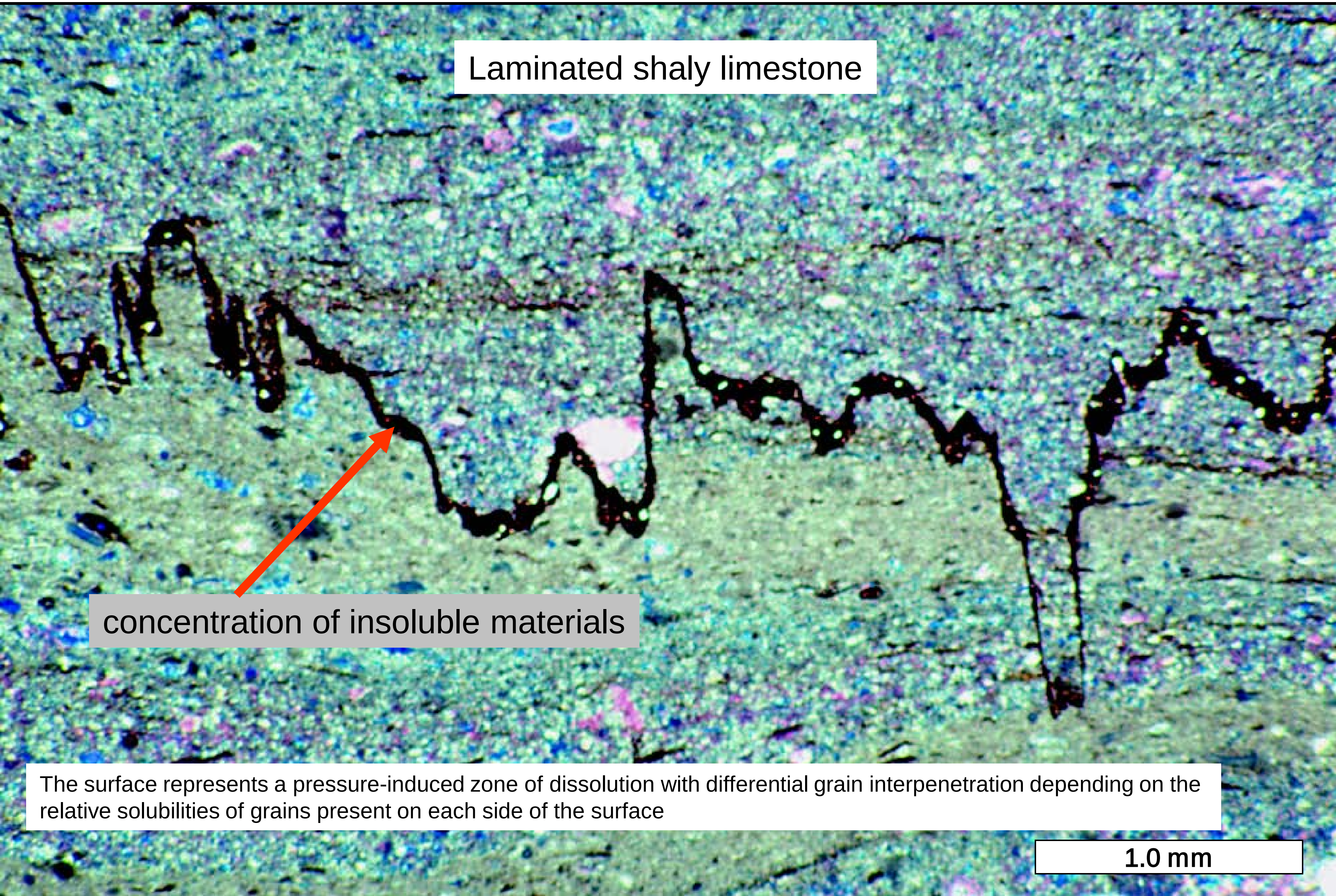
Poikilotopic spar

Unfortunately, none are completely diagnostic of burial cementation

Mechanical and Chemical Compaction Features

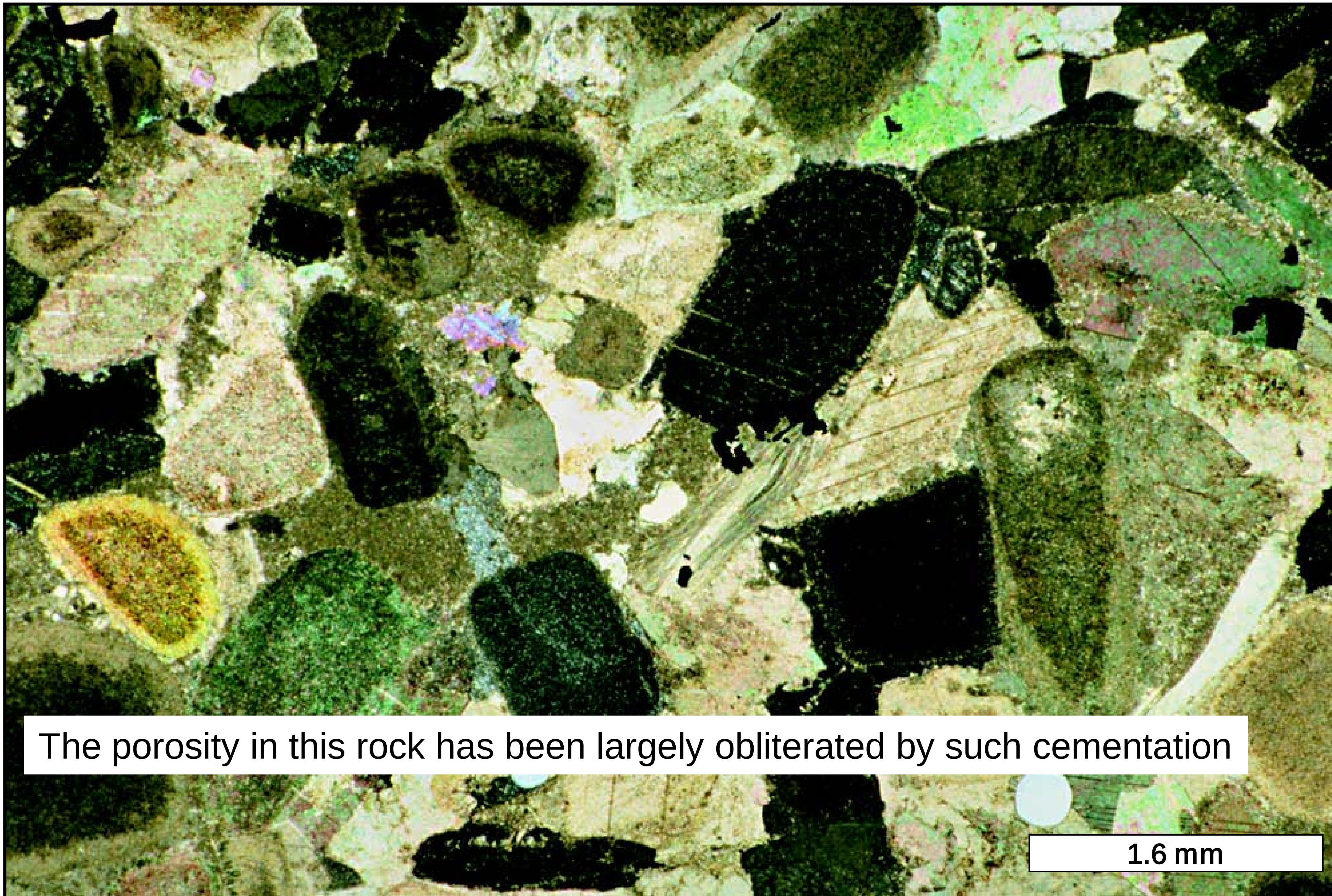


Stylolites



The surface represents a pressure-induced zone of dissolution with differential grain interpenetration depending on the relative solubilities of grains present on each side of the surface

Calcitic syntaxial overgrowth cements on crinoid fragments



Fibrous calcite + bladed blocky calcite