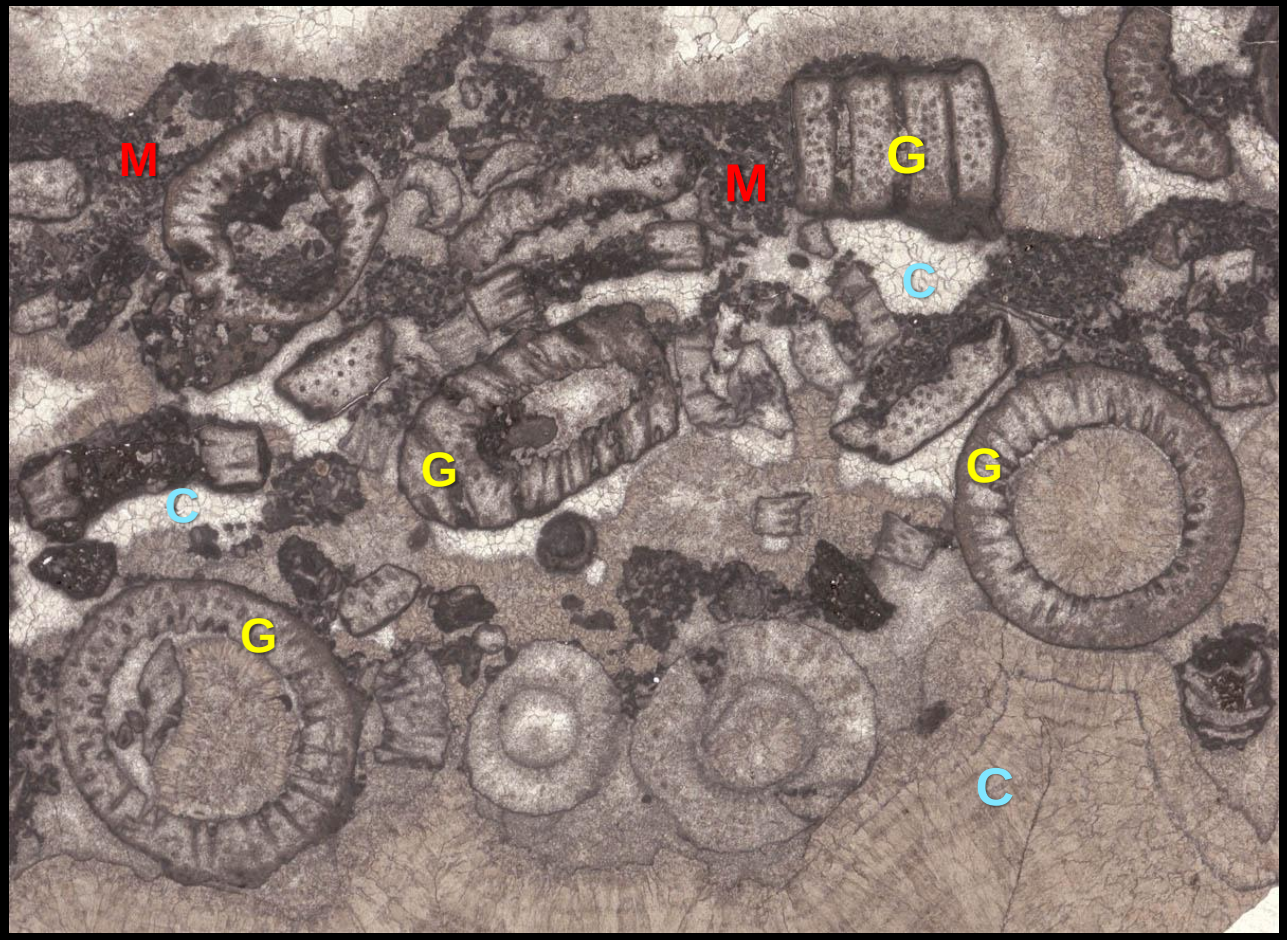
Carbonate rocks.
How do we look at them and what may we see in them?
(continued)

What is left? Micrite and Cements



What is not grains in a carbonate rock, i.e. the matrix, can be made of two elements

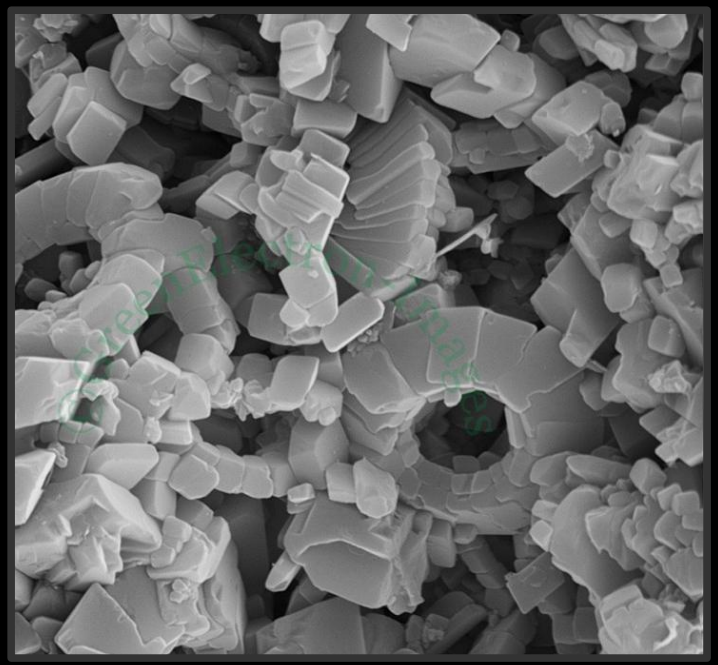
Micrite: fine grained carbonate mud that it indistinguishable observing hand samples and even at the optical microscope is difficult to characterize

Cements: Cements are the result of the diagenetic history of the carbonate rock

The origin of micrite

Carbonate mud may originate through several processes, including:

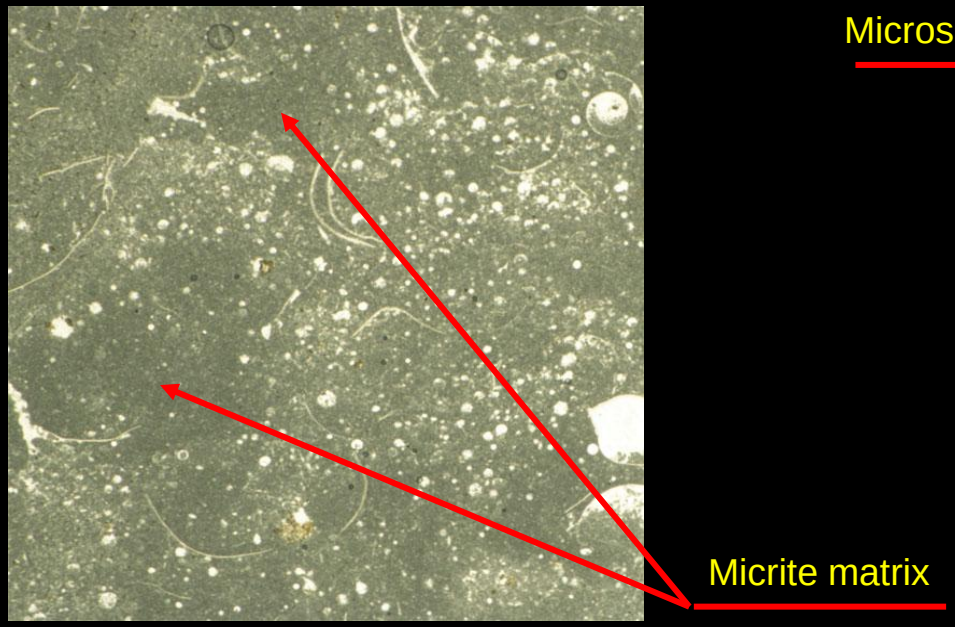
- **Abiotic** precipitation from highly supersaturated seawater (whitings)
- Precipitation **induced by microbial activity**
- Frantumation of **calcareous algae** (e.g., *Halimeda*, *Penicillus*)
- **Bioerosion**: the activity of borers, as fungi or sponge, on carbonate substrates
- **Mechanical erosion**, or abrasion, of carbonate grains or rocks by waves and currents
- Accumulation of **calcareous nannofossils**

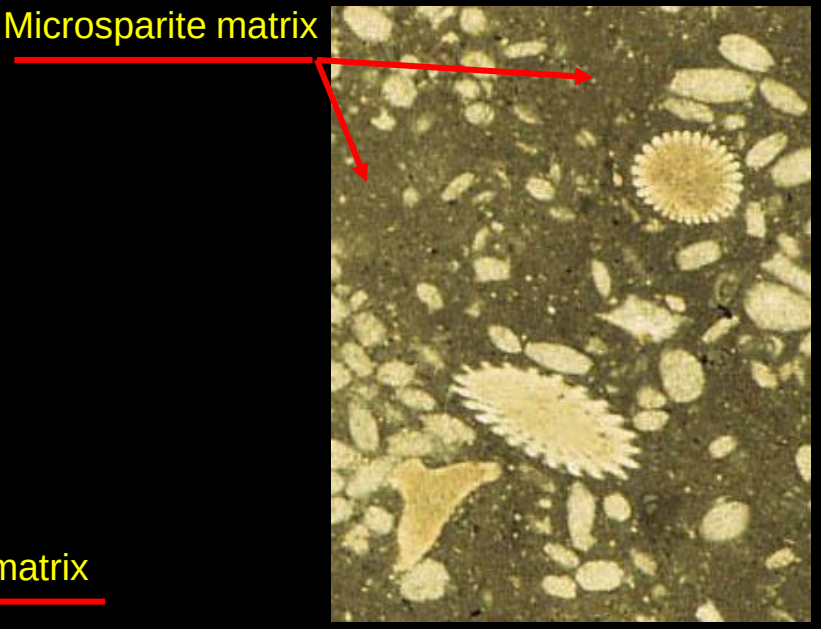


Definitions:

- **Micrite**: As in *Microcrystalline calcite*, refers to fine carbonate which crystals are less than 4 μm on average (Folk, 1959).

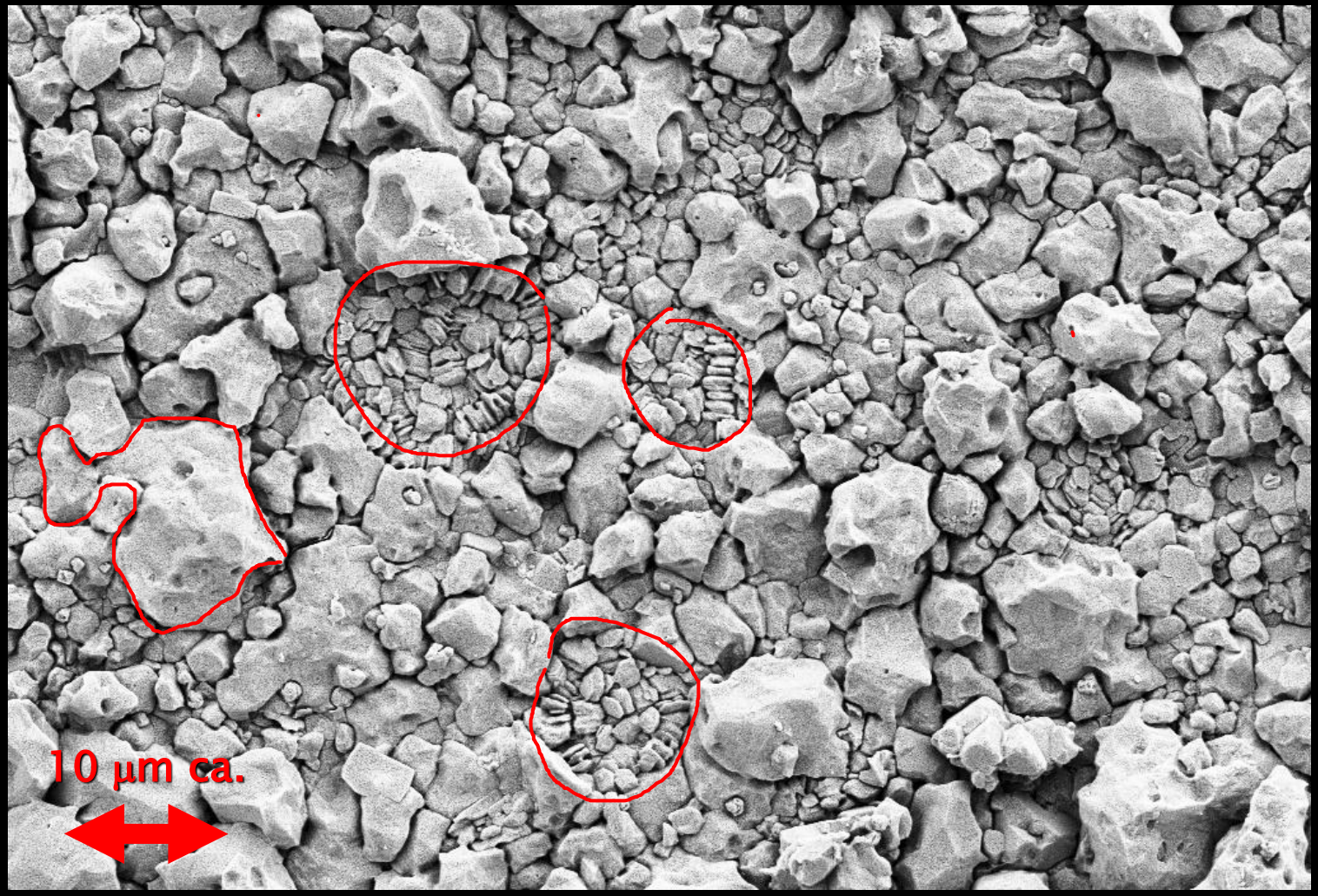
- **Microsparite**: interstitial carbonate with average diameters within 5 - 30 μm. Often identical to micrite under a microscope, the term is strictly descriptive, however, micrite and microsparite are often formed by distinct diagenetic processes.





Micrite and microsparite are hard to distinguish at the optical microscope. They are normally observed using a Scanning Electron Microscope

Micrite under the scanning electron microscope

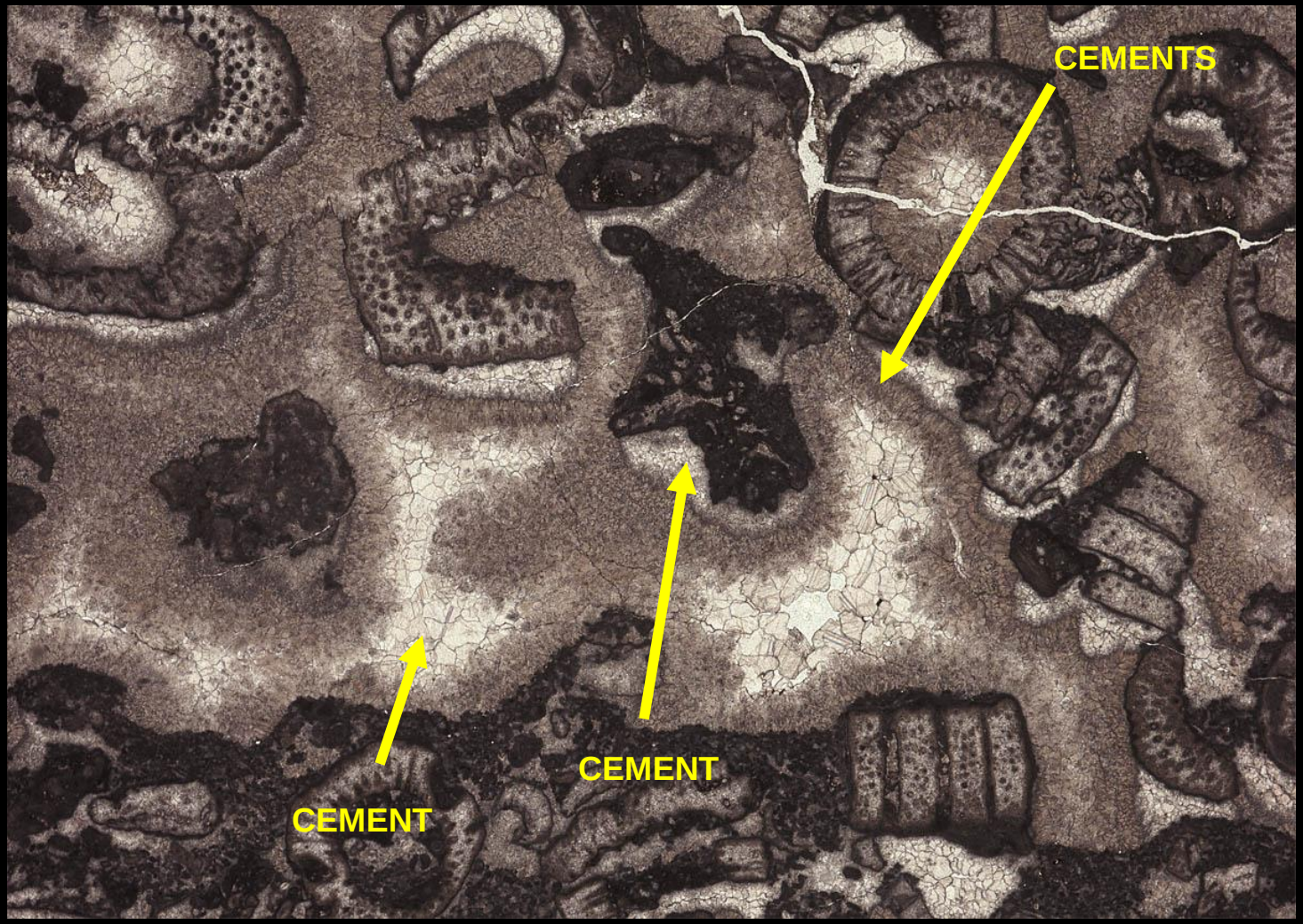


In this late Norian hemipelagic limestone of the Lagonegro Basin (Southern Apennines) the micrite component is nannofossils (*Prinsiosphaera* sp.). The rest is microsparite.

Cements

Cements in carbonate rocks are mainly a product of **diagenesis**.
Keep in mind that diagenesis is a very important phenomenon for carbonate rocks.

Diagenesis starts immediately after carbonate precipitated. Virtually **all carbonate rocks show signs of diagenesis at various degrees.**



Diagenesis

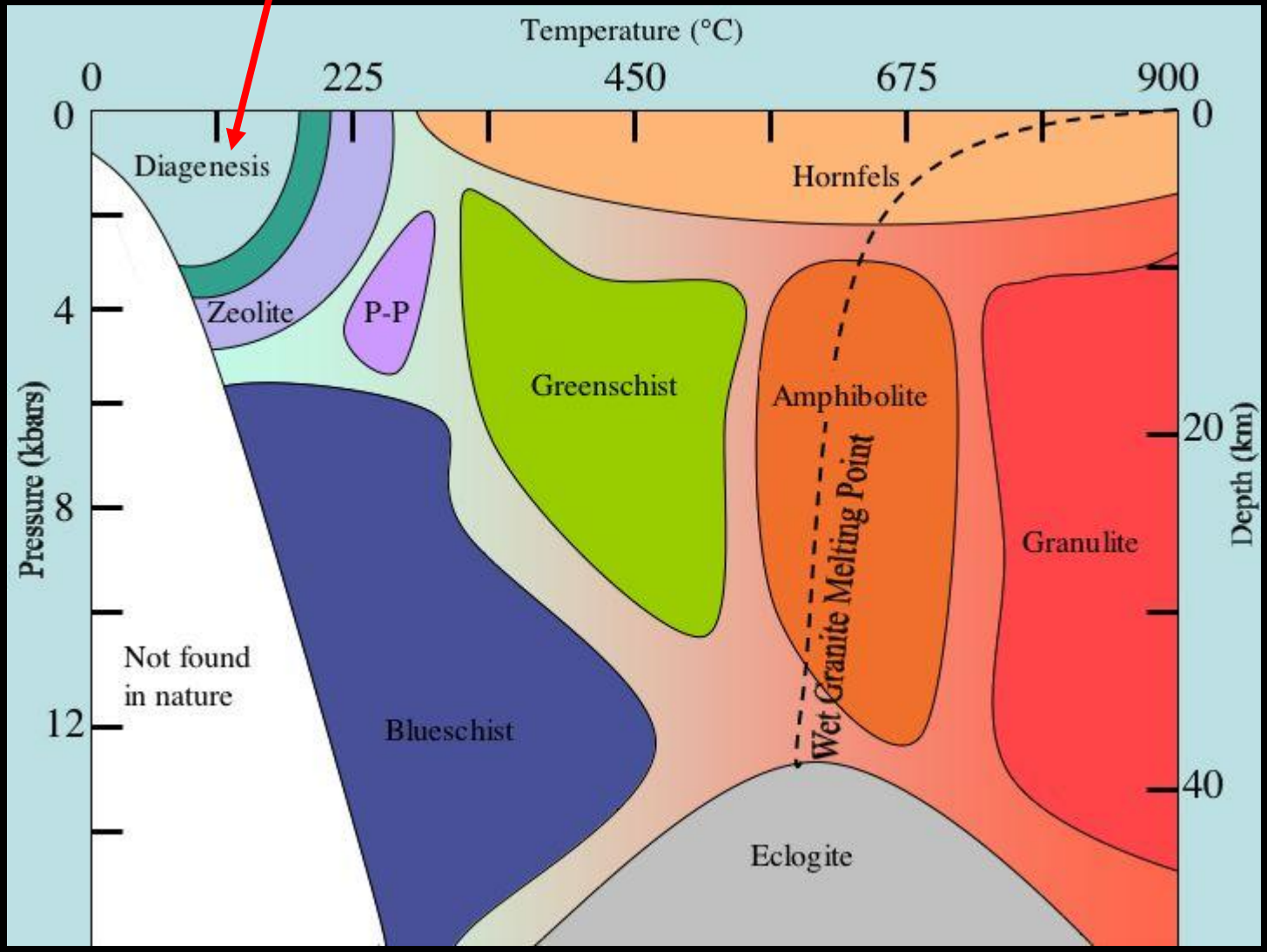
Diagenesis is a process that involves physical and chemical changes in sediments that start once it is deposited.
These changes are induced by increasing temperature and pressure during burial and may involve the circulation of fluids.

Carbonate sediments are particularly prone to diagenesis.

- compaction (under the load of overlying sediment)
- progressive pore occlusion
- **dissolution**
- **cementation**
- transformation of metastable carbonates (aragonite and high-Mg calcite) into low magnesium calcite (and dolomite)
- dolomitization*

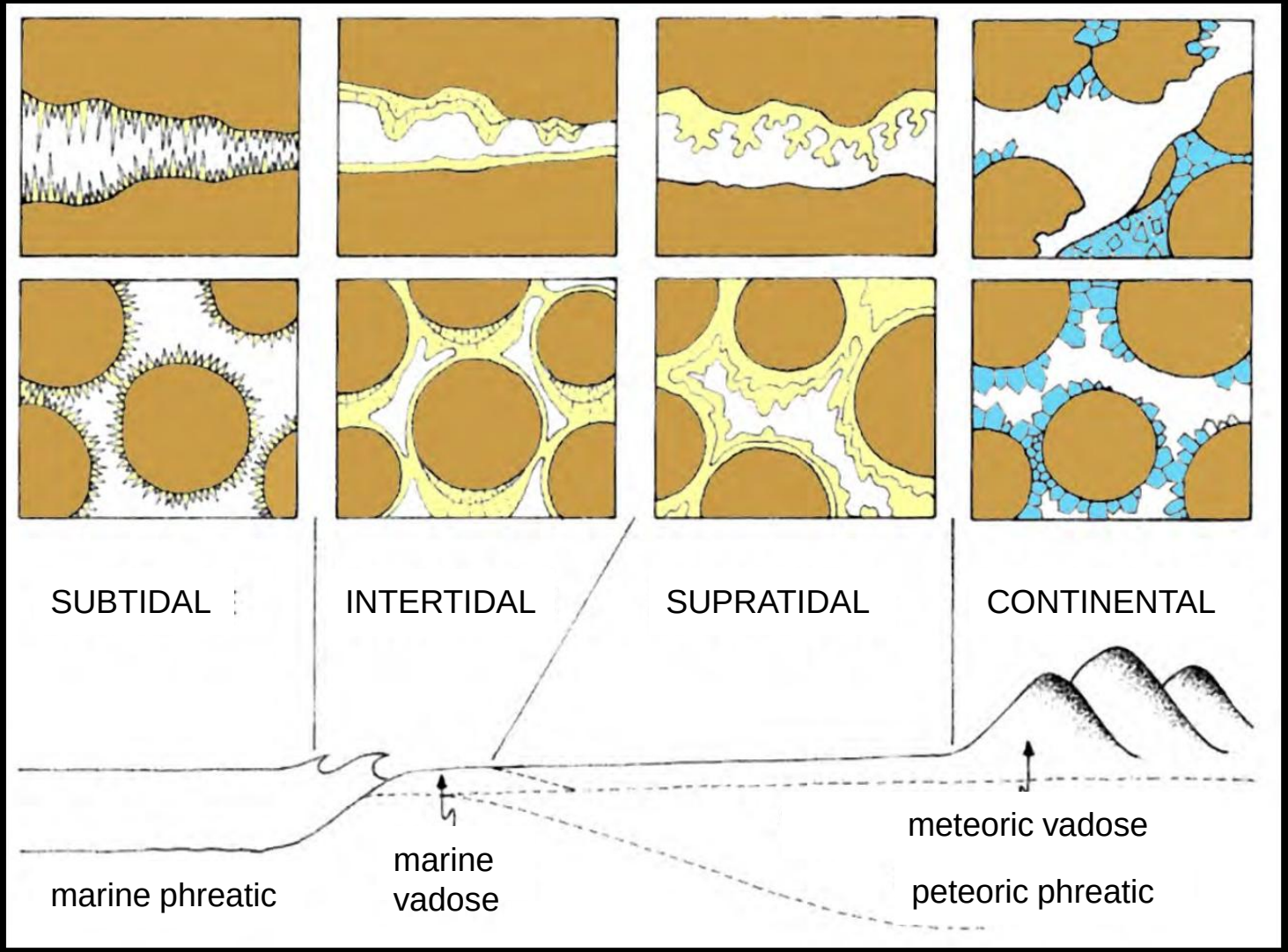
Normally, a diagenized limestone is **only made of low magnesium calcite**.
High magnesium calcite and aragonite are present in limestones only in cases of exceptional preservation.

The realm of **diagenesis**: between deposition and metamorphism



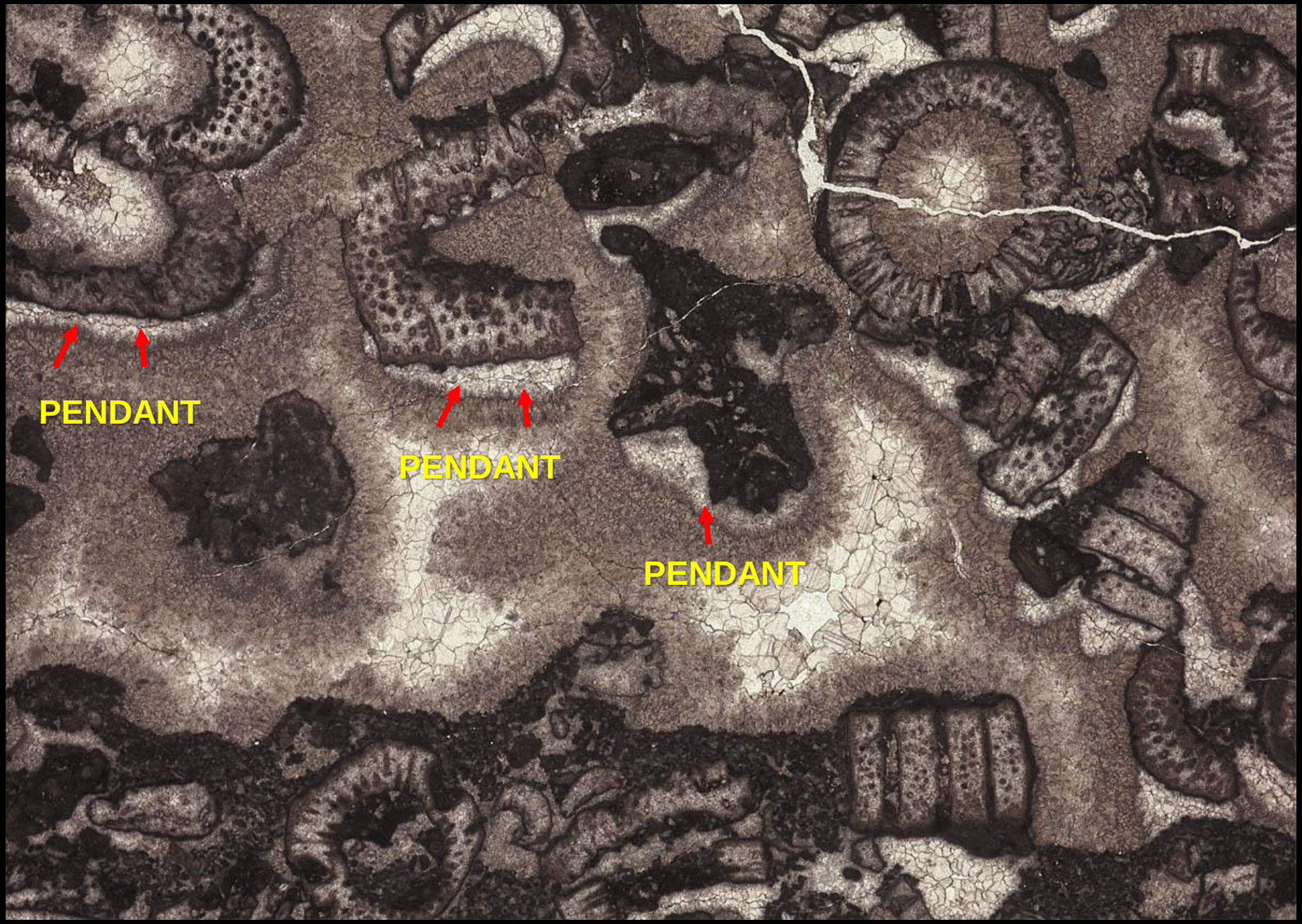
from Wikipedia

ISOPACHOUS **MENISCUS/PENDANT** **MOSAIC**

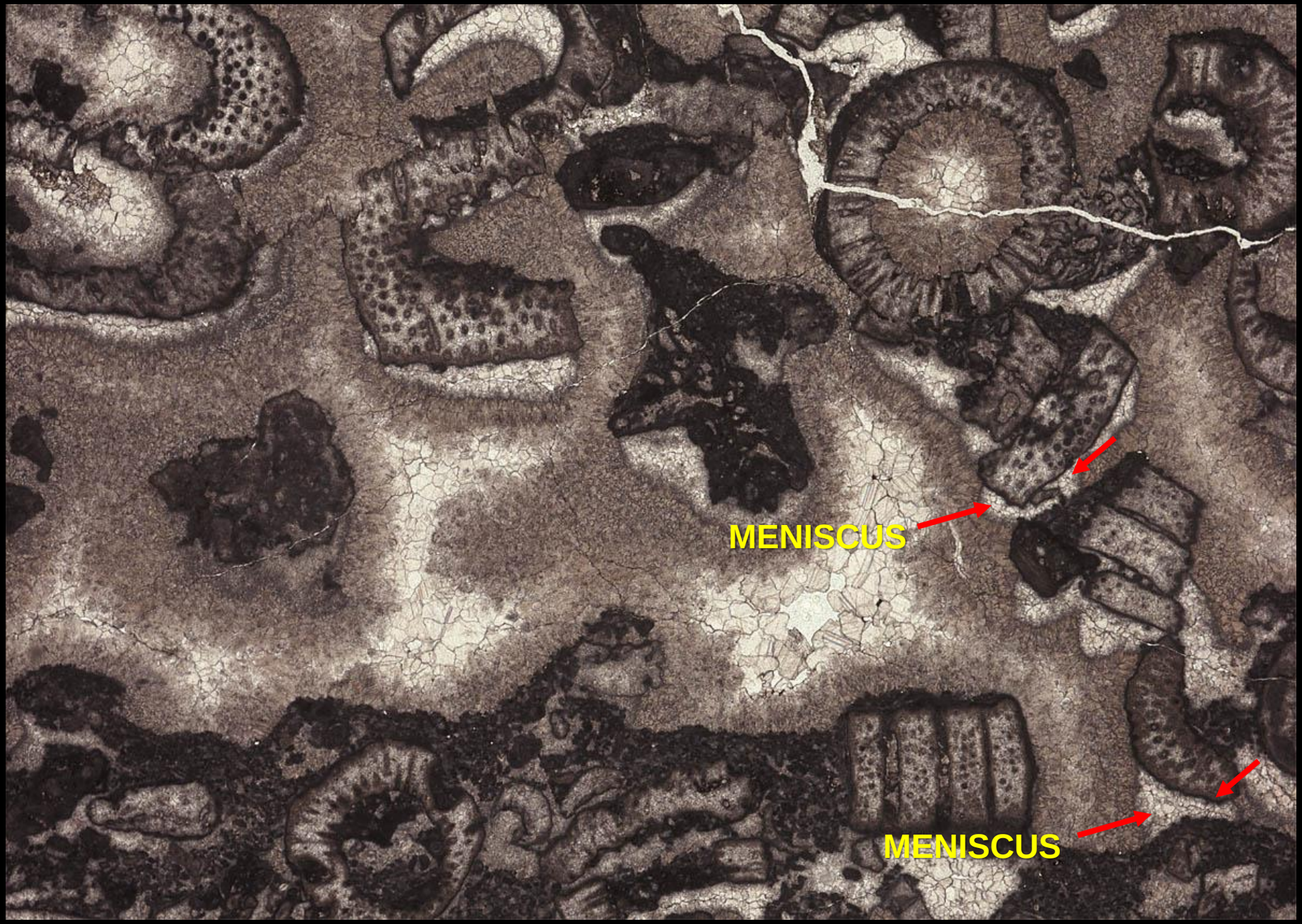


Different types of cement form in specific diagenetic environments. Characterizing the cements of a carbonate rock can help reconstructing its **diagenetic history**.

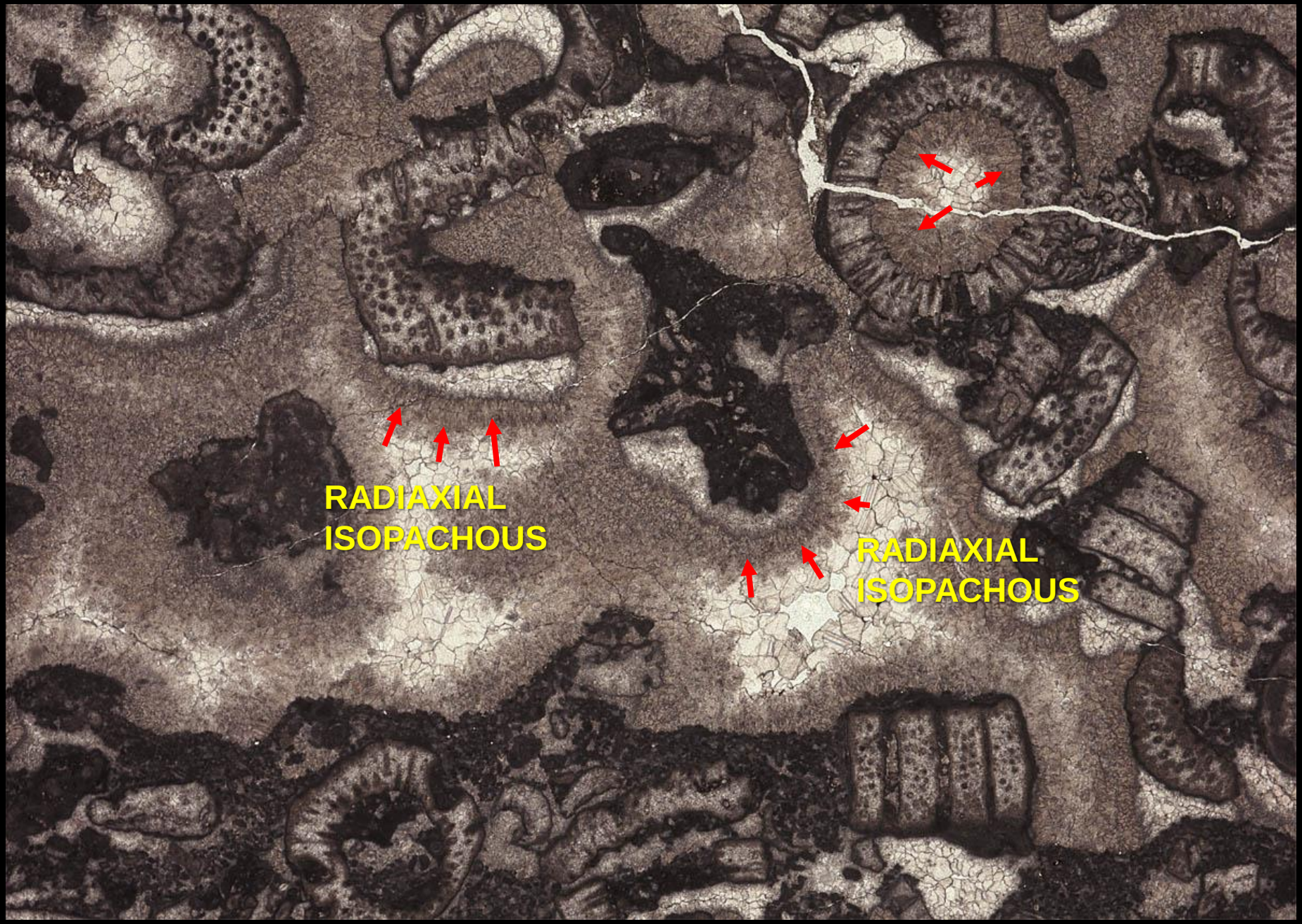
Some types of cements under the optical microscope



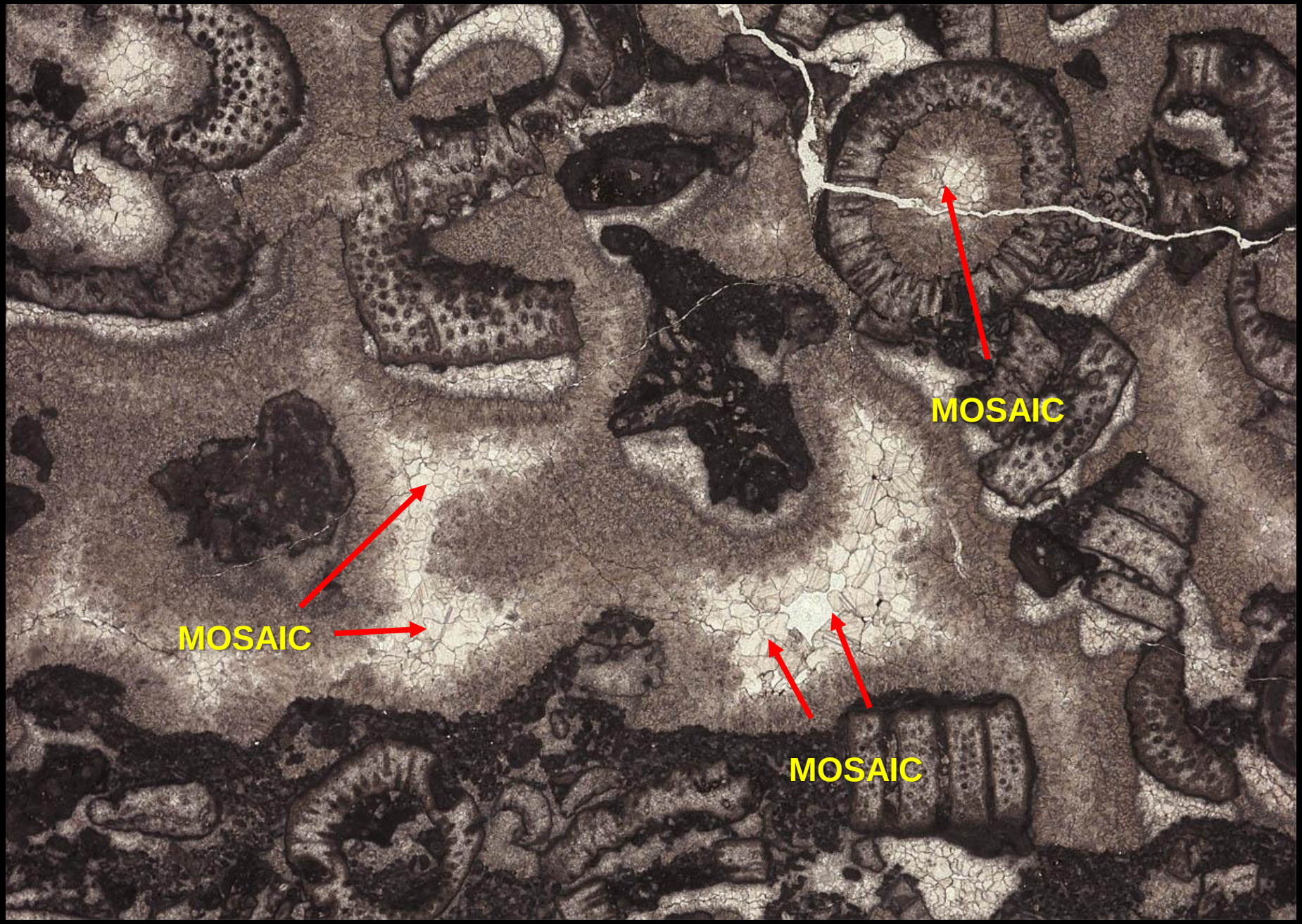
Some types of cements under the optical microscope



Some types of cements under the optical microscope



Some types of cements under the optical microscope

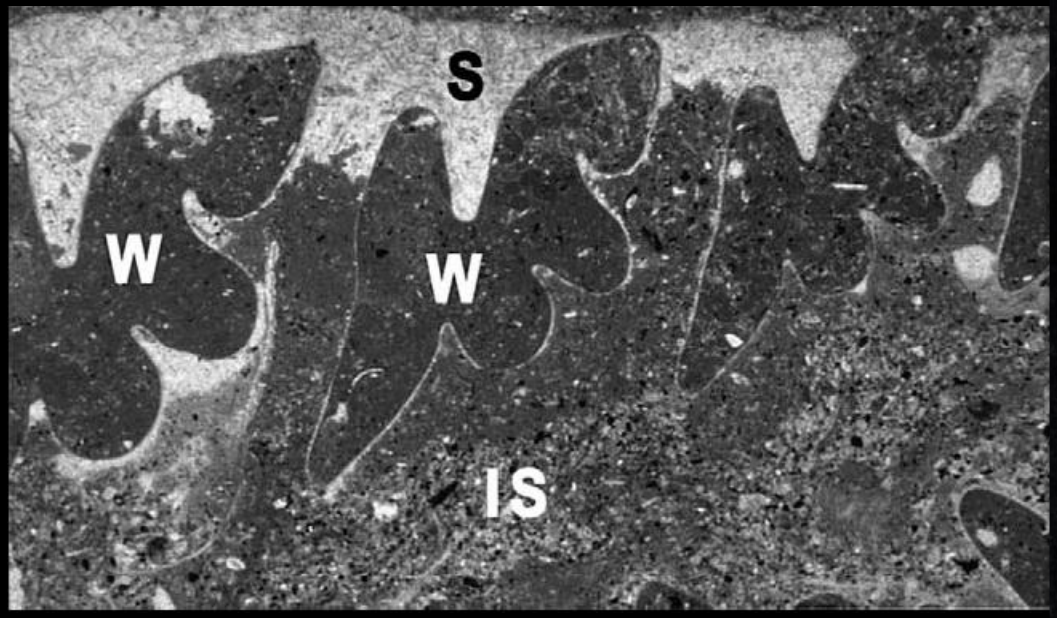


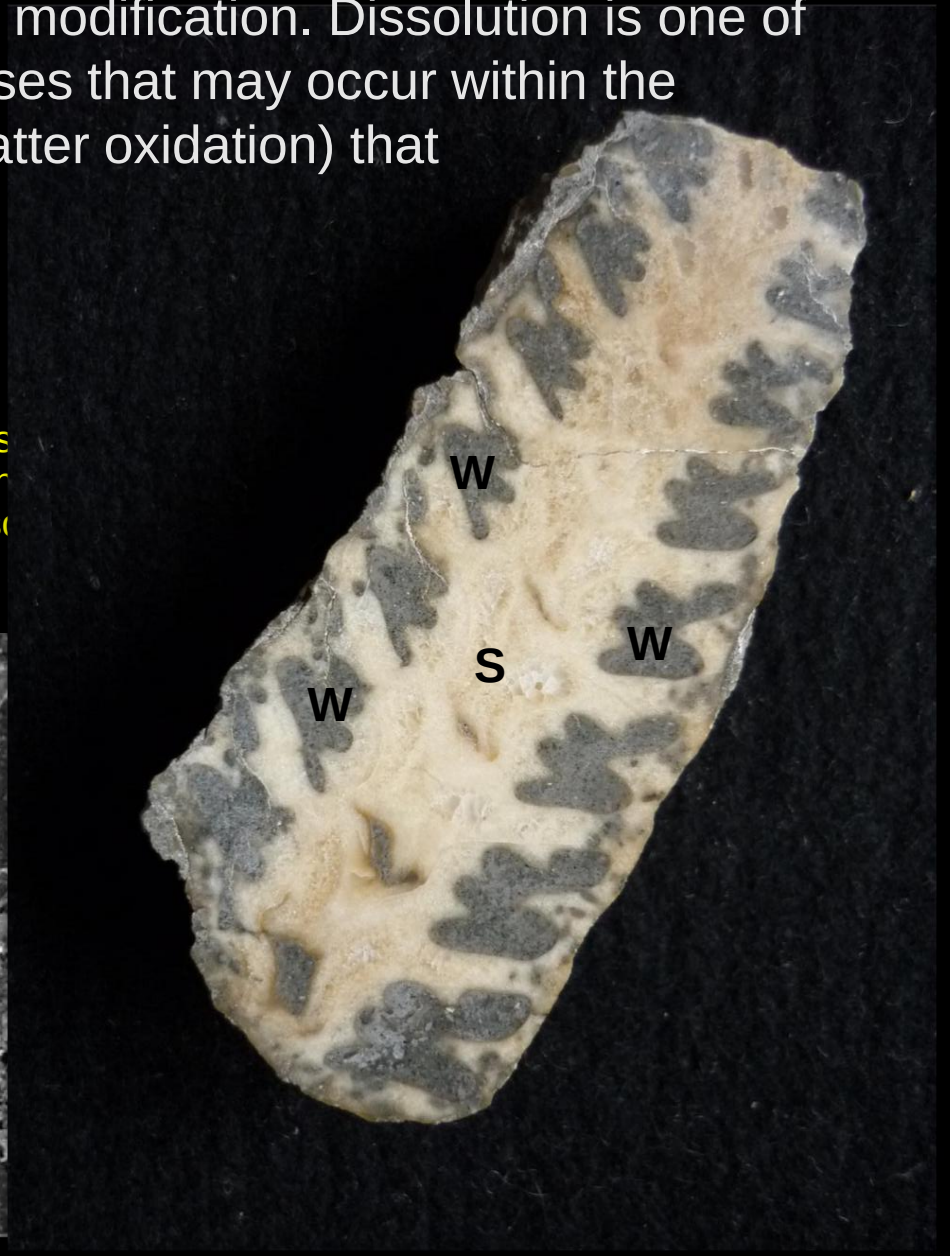
Some types of cements under the optical microscope

Syndepositional dissolution

Carbonates can undergo syn-depositional modification. Dissolution is one of these processes and is caused by processes that may occur within the sediment right after burial (e.g. organic matter oxidation) that cause a local CaCO3 undersaturation.

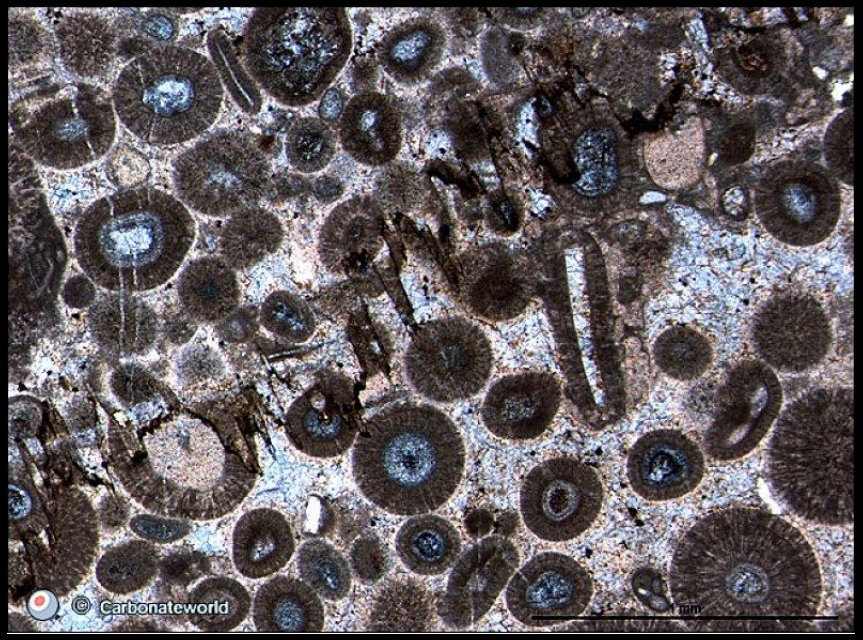
Shallow water dissolution of a *Nerinea* shell (shallow water gas
the preserved specimen (right) the shell (S) completely surrour
wohrls (W). In the dissolved one (below) the shell is partly diss
partially substituted by sediment (IS). From Sanders, 2003.



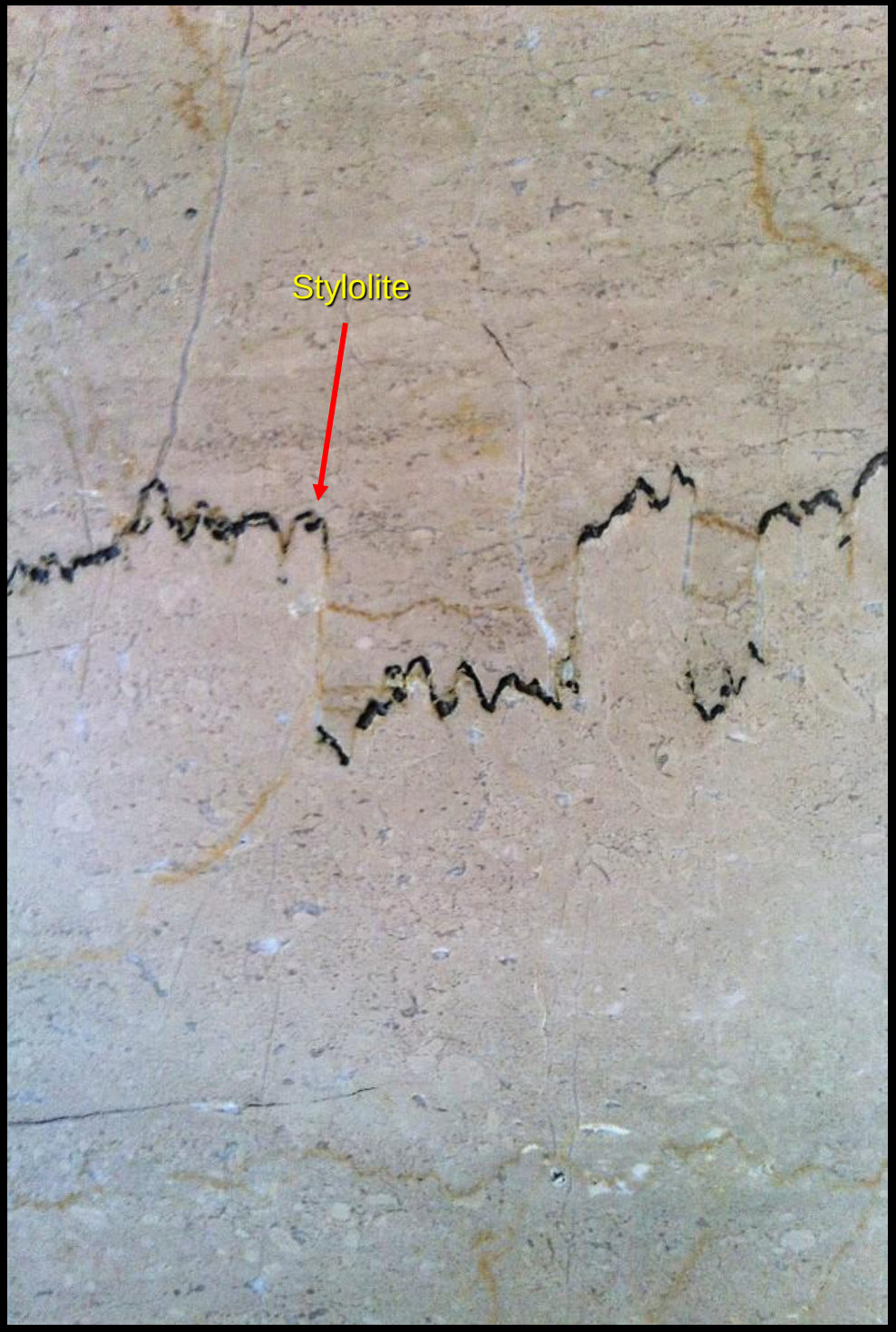


Burial diagenesis

A typical process of burial diagenesis is also **pressure solution**, and the consequent formation of **stylolites**. The amplitude of stylolites gives a minimum estimate of sediment loss by chemical (pressure) compaction.



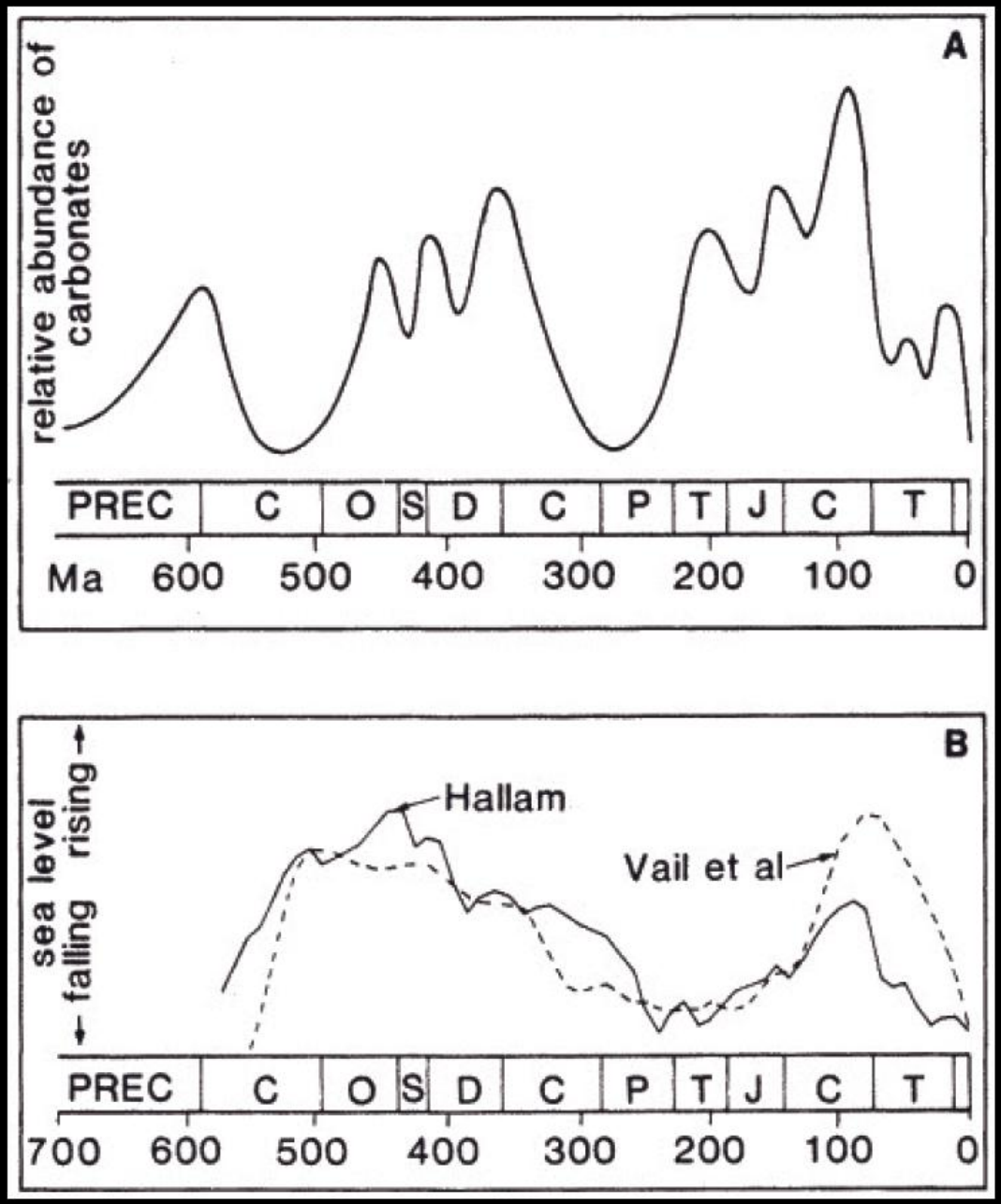
Stylolite in thin section (Carboniferous of Asturias). From www.carbonateworld.com



Carbonates through geological time

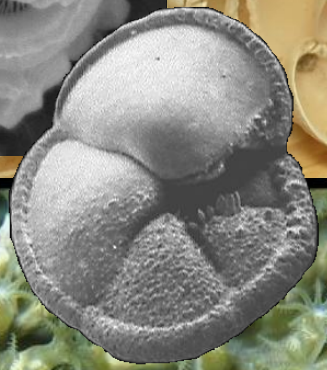
Carbonates aboundance fluctuated through geological times and a broad correspondence is seen with large scale **osciallation of sea level**.

Carbonate abundance was high during times of high sea level and low in times of low sea level



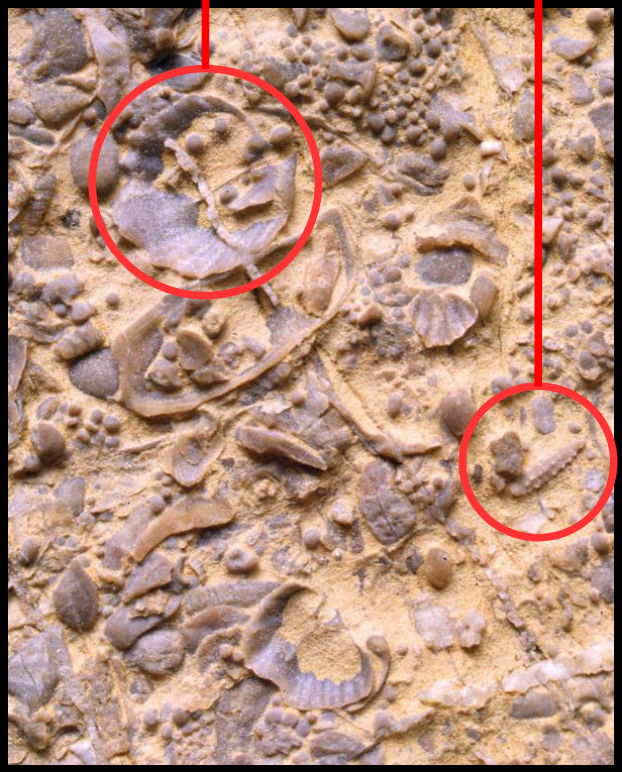
Tucker and Wright, 1990

Remember that carbonates are formed with the **mediation of living organisms** (up to 90-95% grains are biogenic in origin)



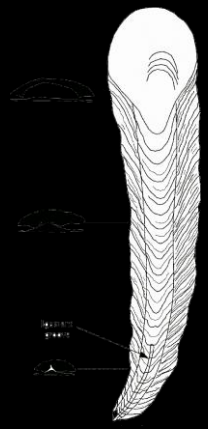
Carbonates: the biological factor

Reef-building organisms with carbonate shells or skeletons were there since the Precambrian.
Each may have had **specific ecological preferences**.



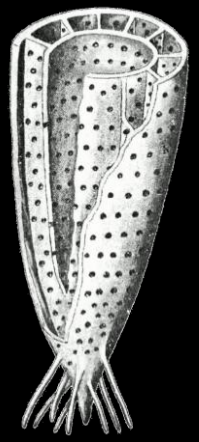
Carbonate rocks may contain skeletal grains

Mid Cambrian
to present

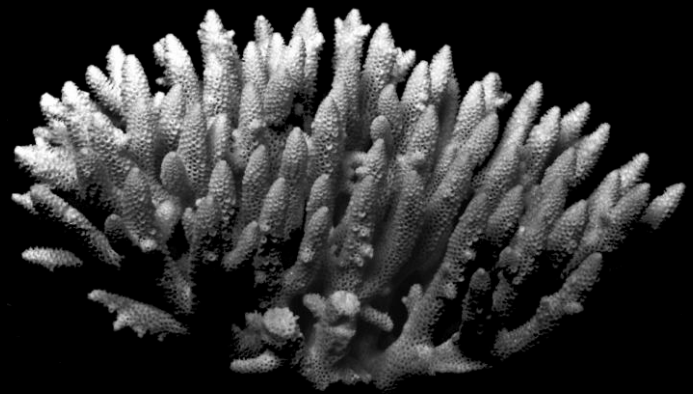


Lithiotis sp.
Early Jurassic

Rudist
Cretaceous



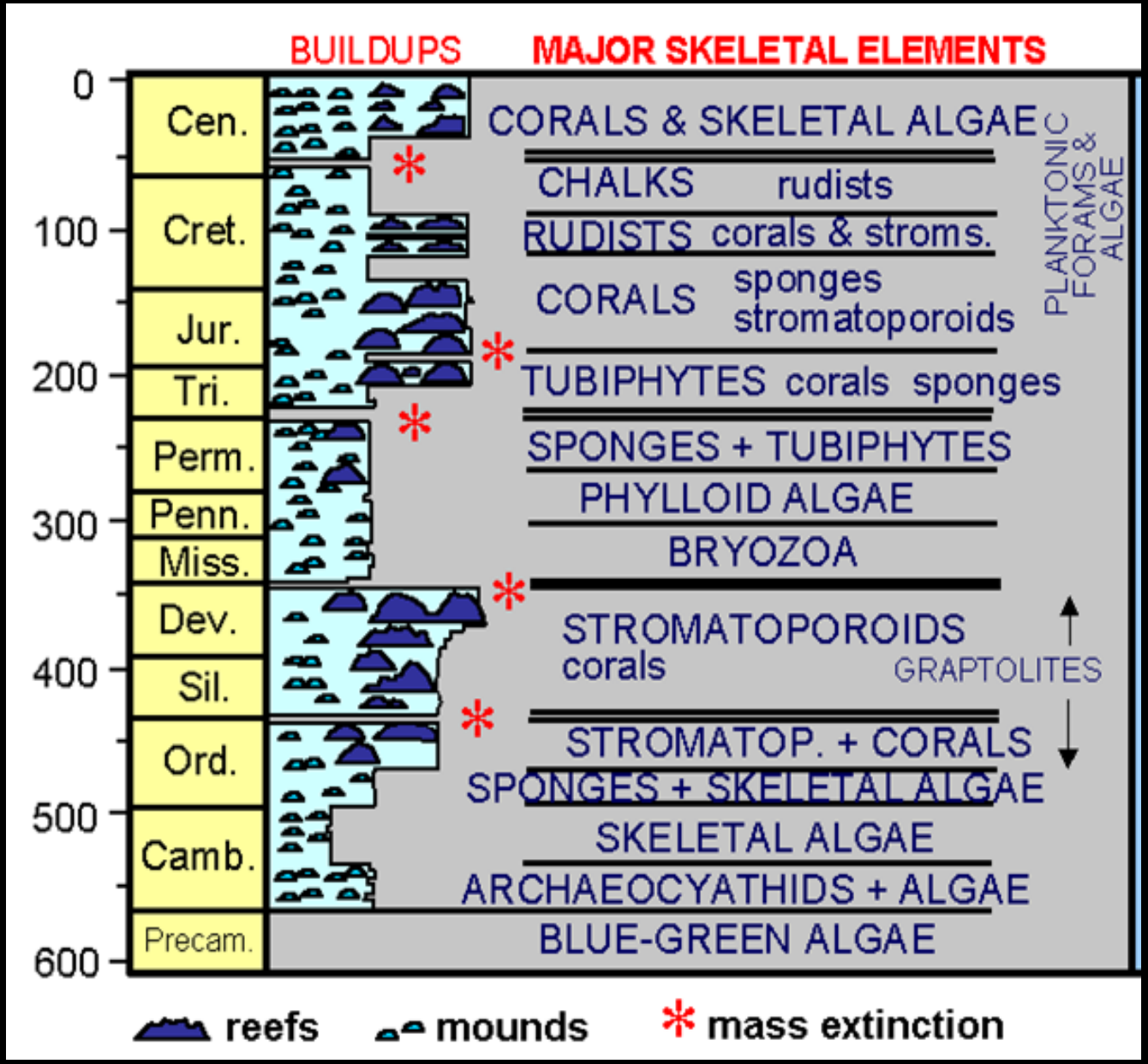
Archaeocyatha
Cambrian



Scleractinian coral
Cenozoic to present

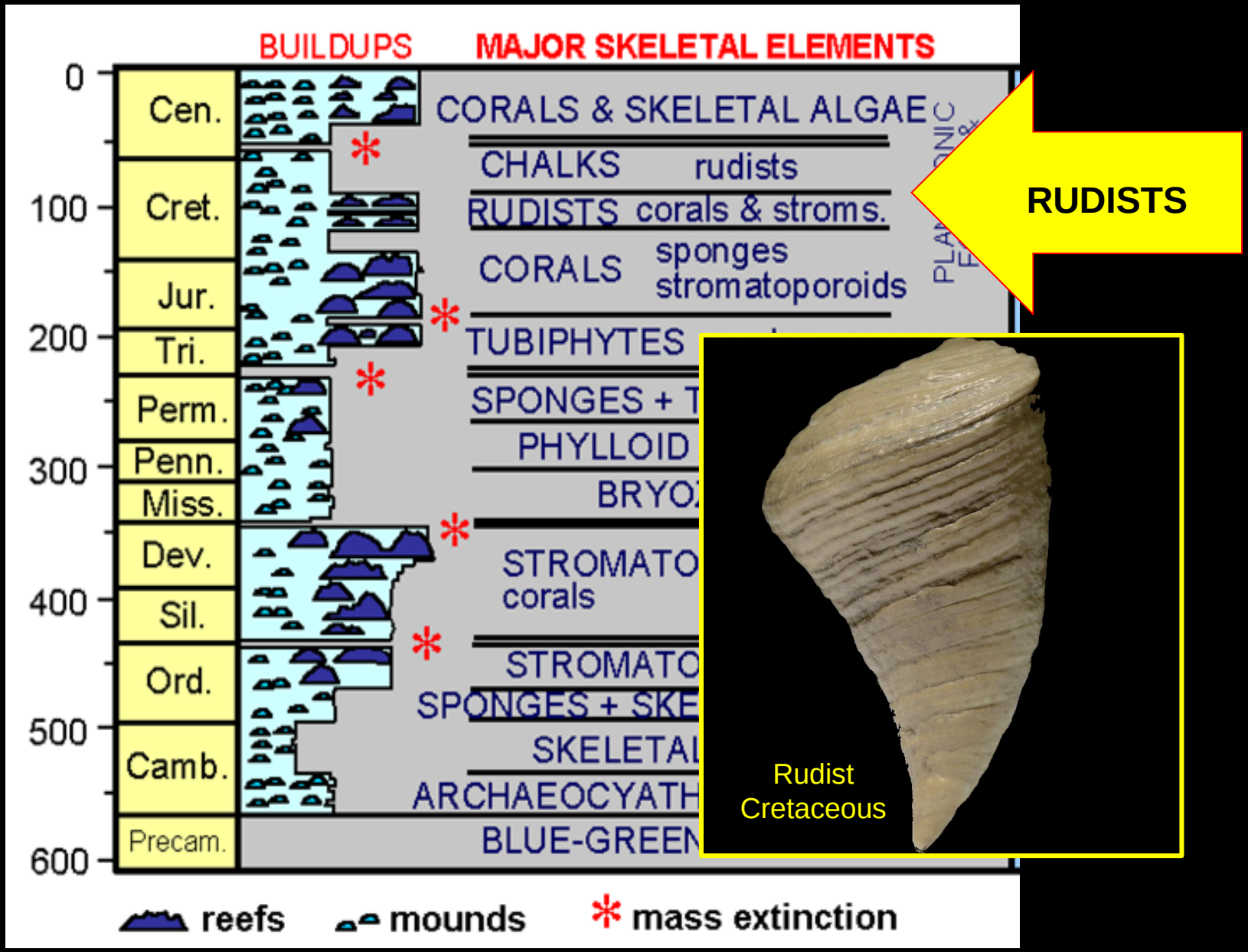
Stromatolite
Precambrian

Reef building organisms changed through geological times



Redrawn from James, 1983.

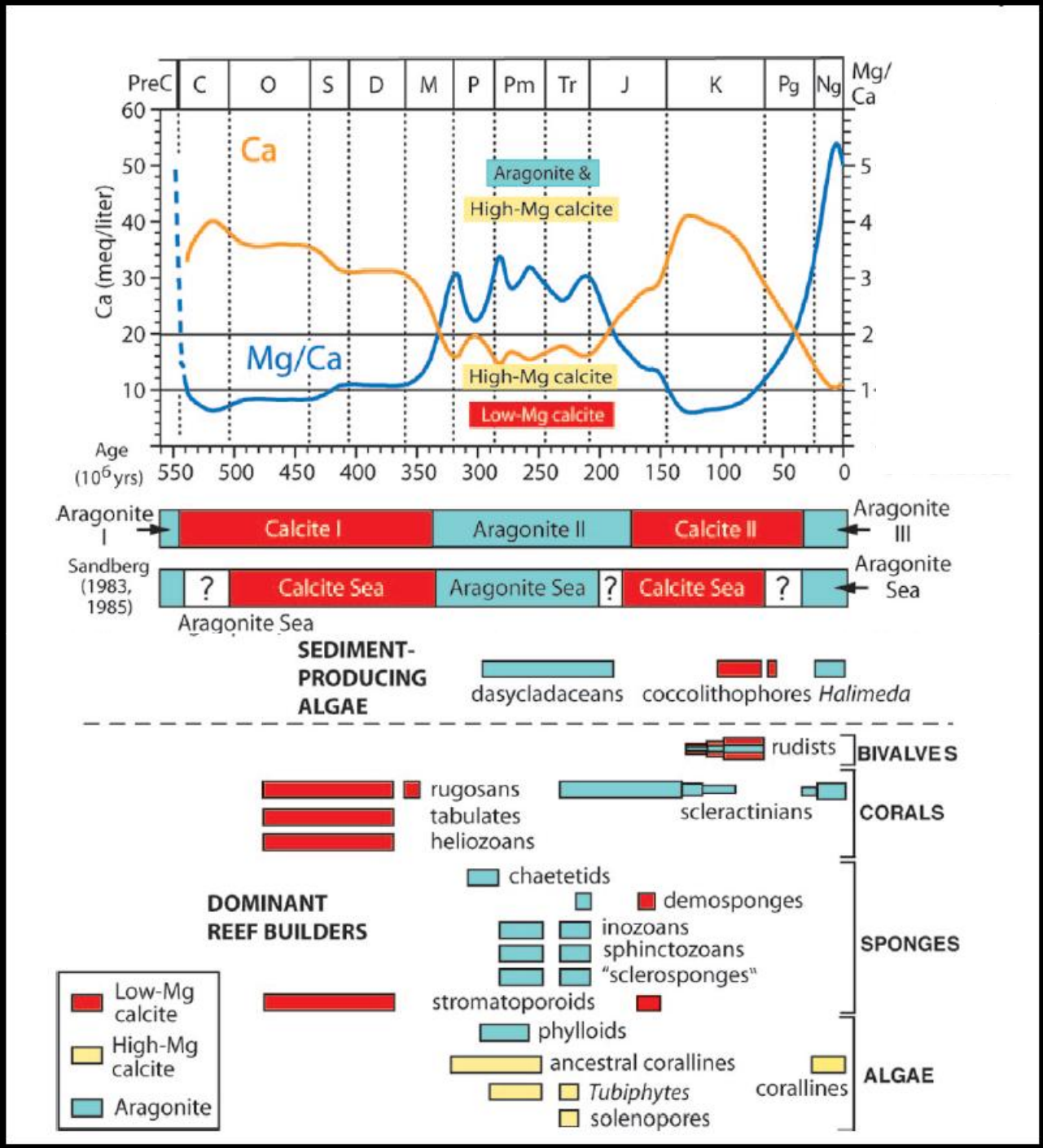
Reef building organisms changed through geological times



Redrawn from James, 1983.

Aragonite seas and Calcite seas

Carbonate precipitated by organisms changed through time. It was observed that there were periods in which calcite was prevailing precipitated (**calcite seas**), and others in whic aragonite was instead dominant (**aragonite seas**). **Modern ocean is an aragonite sea**.
This phenomenon is thought to be linked to variations in the availability of **Mg** in seawaters possibly related to phases of more pronounced or lesser activity of mid atlantic ridges.

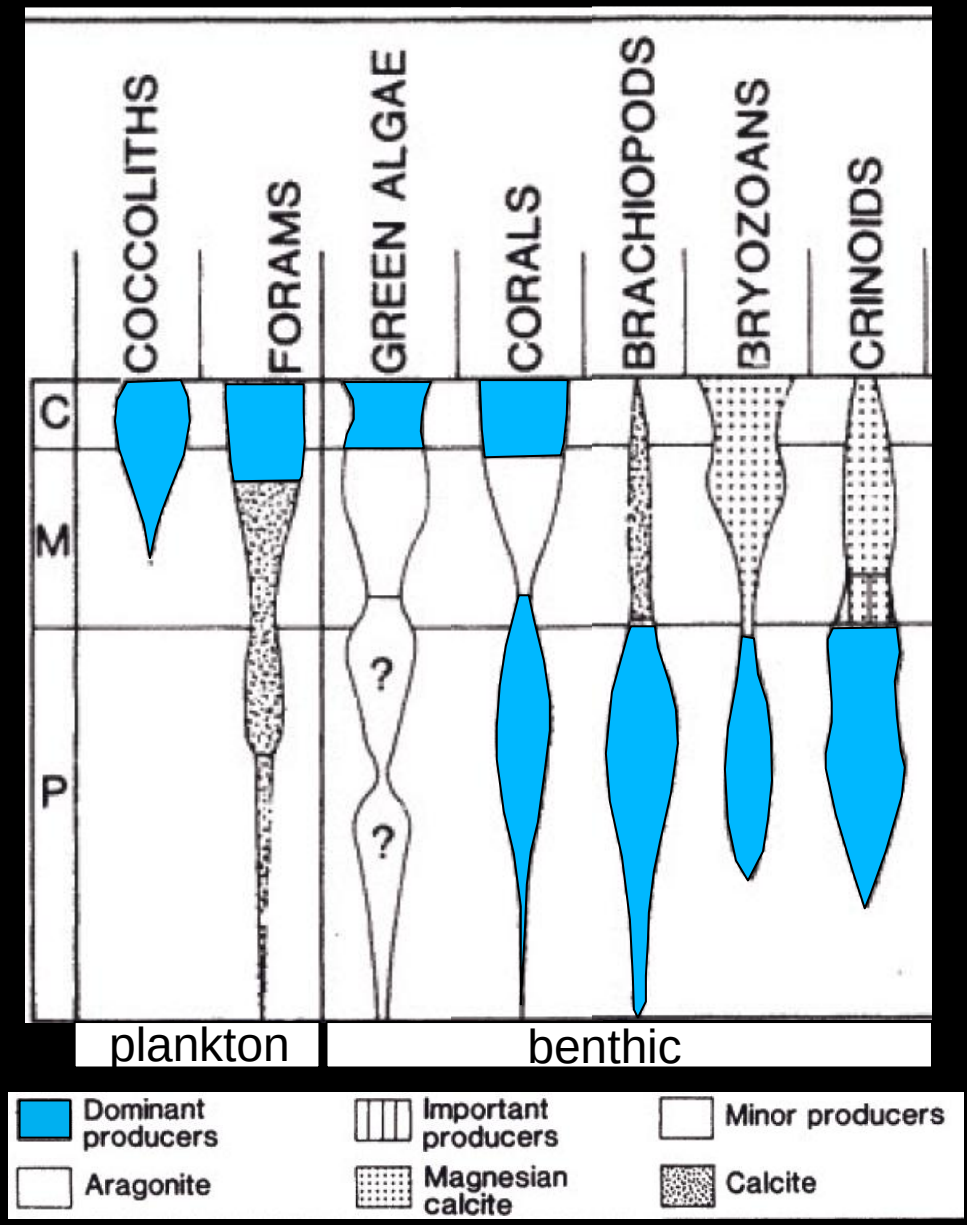


Stanley, 2004 modified

Major carbonate producers through time

Life evolved and so did carbonate producers

The importance of organisms that were main producers in some periods subsided and new ones appeared and became dominant

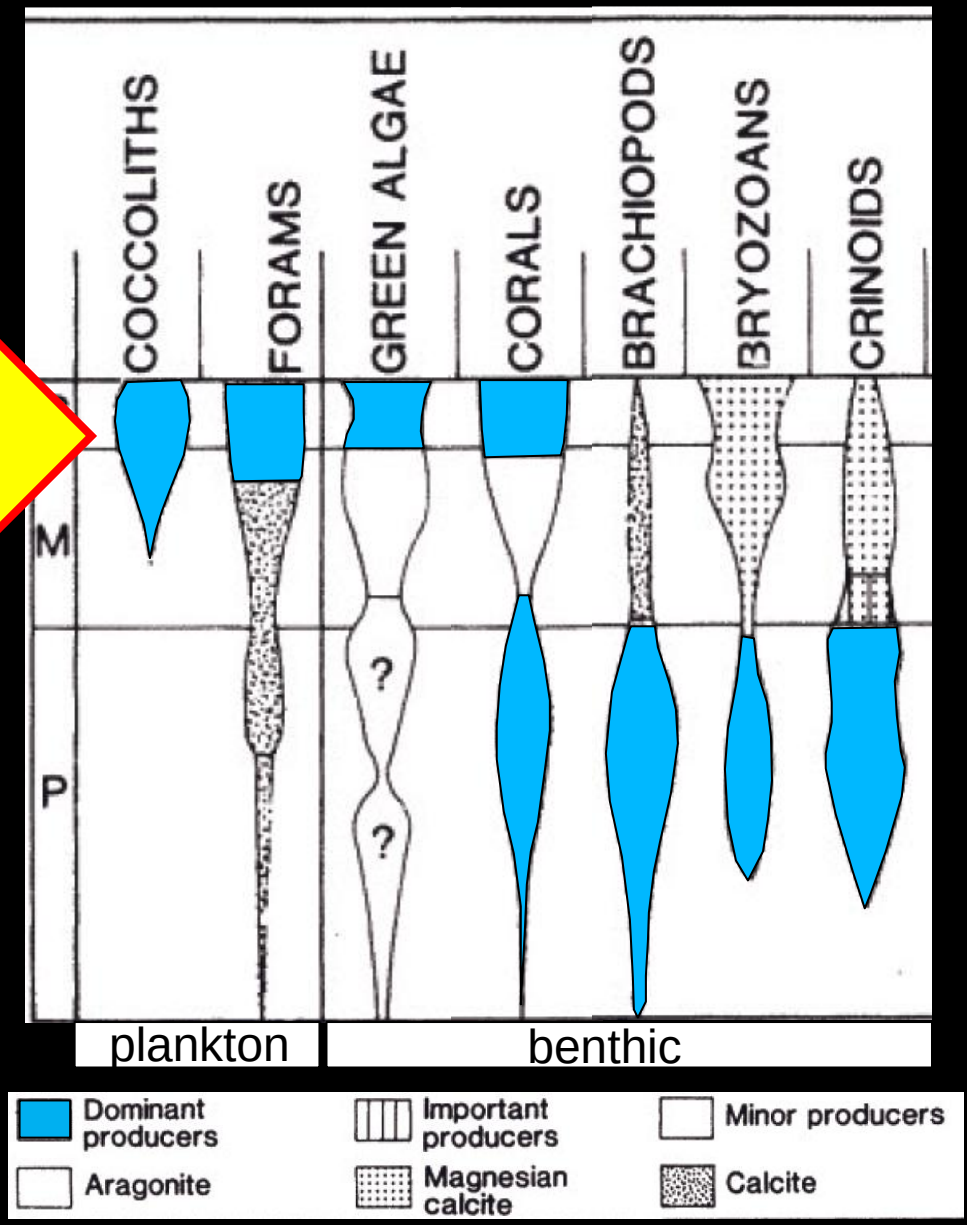


Tucker and Wright, 1990 modified

Major carbonate producers through time

Coccolithophores and forams became dominant only from the mid Mesozoic

Deep-water carbonate precipitation prior to mid Mesozoic was minor



Tucker and Wright, 1990 modified

Carbonate production through time

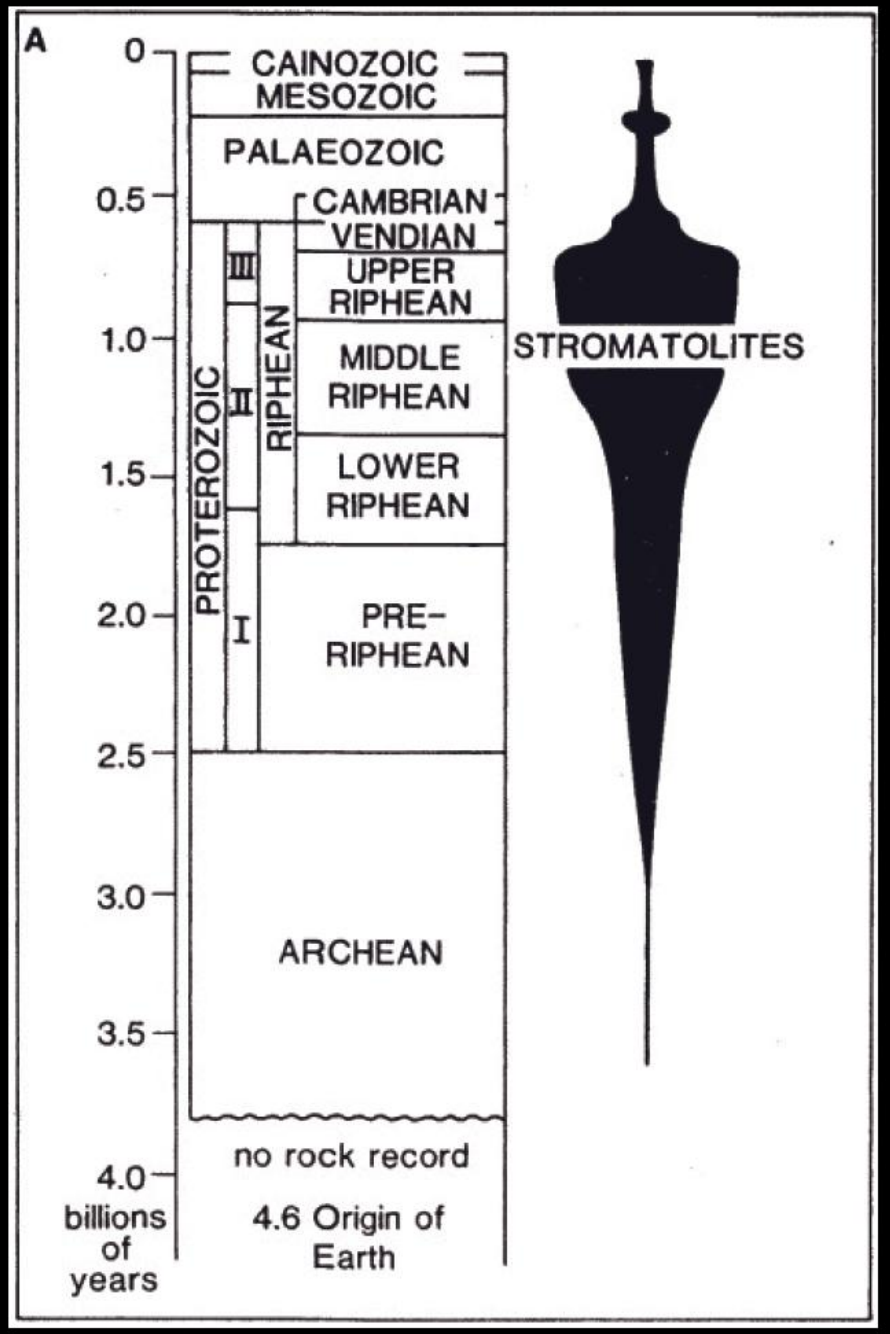
When did carbonate apper in the geological record?

Oldest carbonates date back to te Archean and one important type are **stromatolites**

Stromatolites are carbonate sedimentary structures that are interpreted as originated by the activity of bacteria.

They belong to an important family of carbonates: **microbial carbonates**

Precambrian of Mauritania (Photo A. Riva)

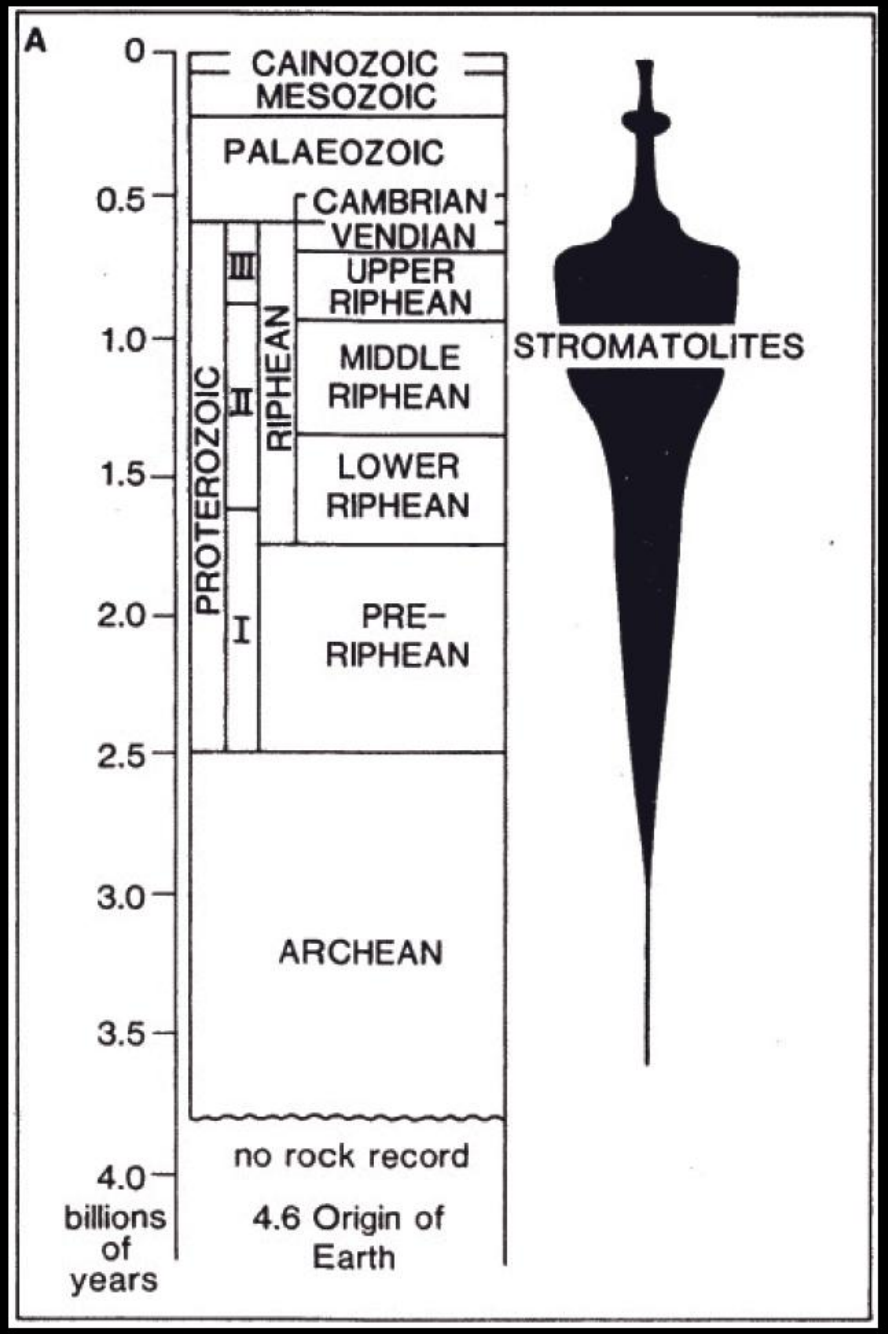


Tucker and Wright, 1990 modified

Carbonate production through time

Modern stromatolites in Shark Bay, Australia

Cambrian stromatolites, USA



Tucker and Wright, 1990 modified

Uniformitarianism

assumption that the same natural laws and processes that operate in our present-day scientific observations have always operated in the universe in the past and apply everywhere in the universe

In Geology this assumption is often experssed as «**The present is a key for the past»**

In these lessons, however, you have learned that carbonates are intimately linked to life and life changed through time. Carbonate producers changed, ecological characteristics of organisms may have changed…so:

In the study of carbonates, present is the key for…the Pleistocene