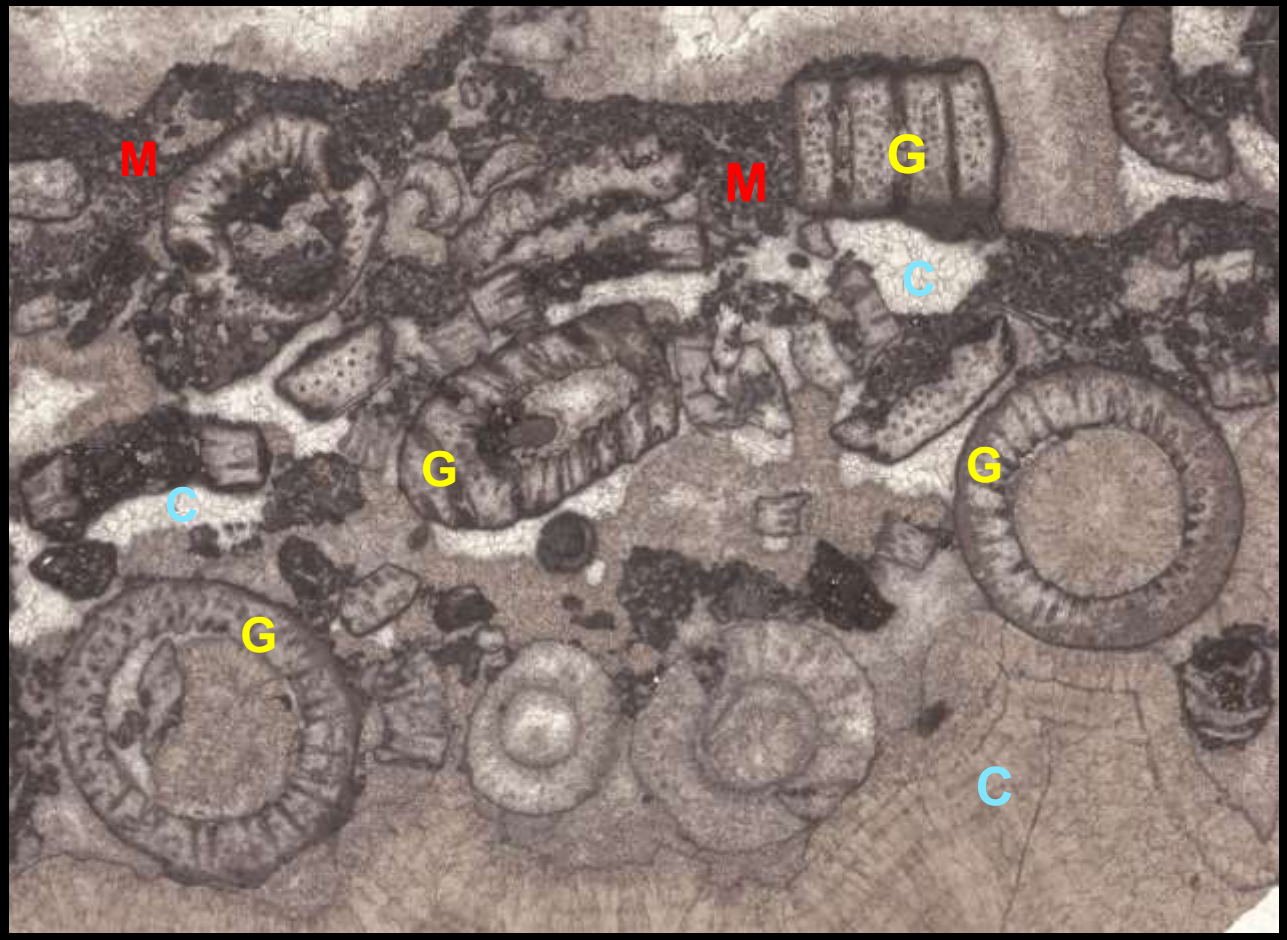
Carbonate rocks.
How do we look at them and what may we see in them?
(continued)

What is left? Micrite and Cements



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

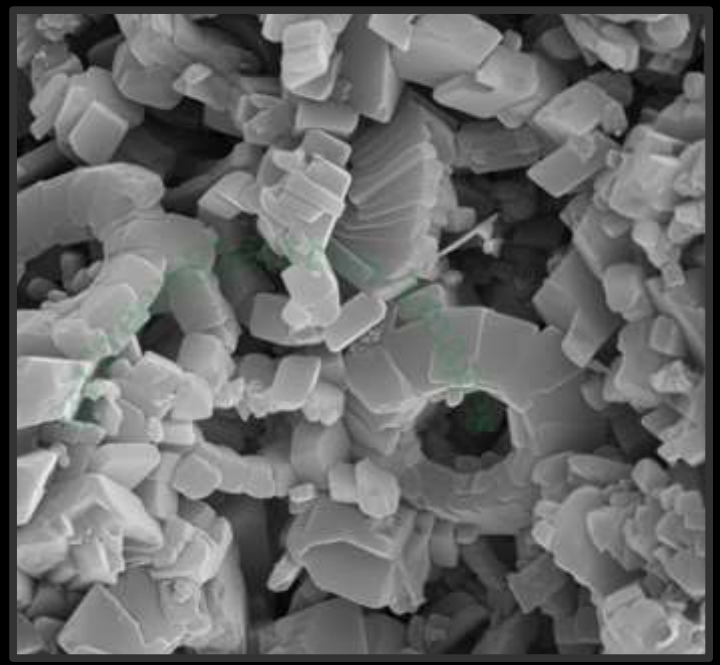
Micrite: fine grained carbonate mud that it indistinguishable observing hand samples and even at the optical microscope is difficult to characterize

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:

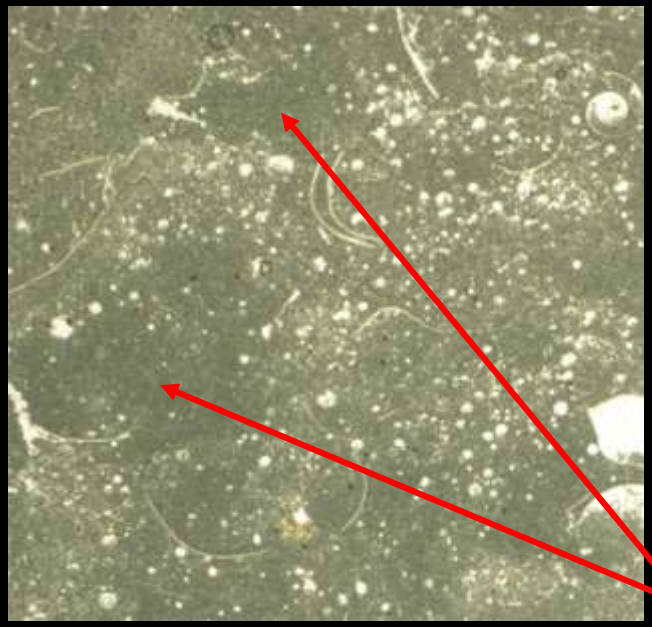
- **Abiotic** precipitation from highly supersaturated seawater (whitings)
- Precipitation **induced by microbial activity**
- Frantumation of **calcareous algae** (e.g., *Halimeda*, *Penicillus*)
- **Bioerosion**: the activity of borers, as fungi or sponge, on carbonate substrates
- **Mechanical erosion**,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

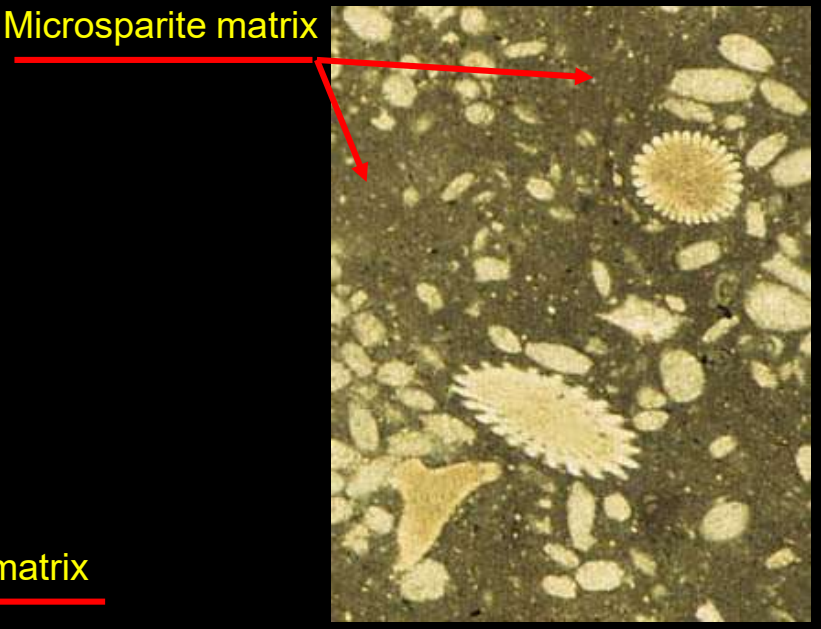


Definitions:

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

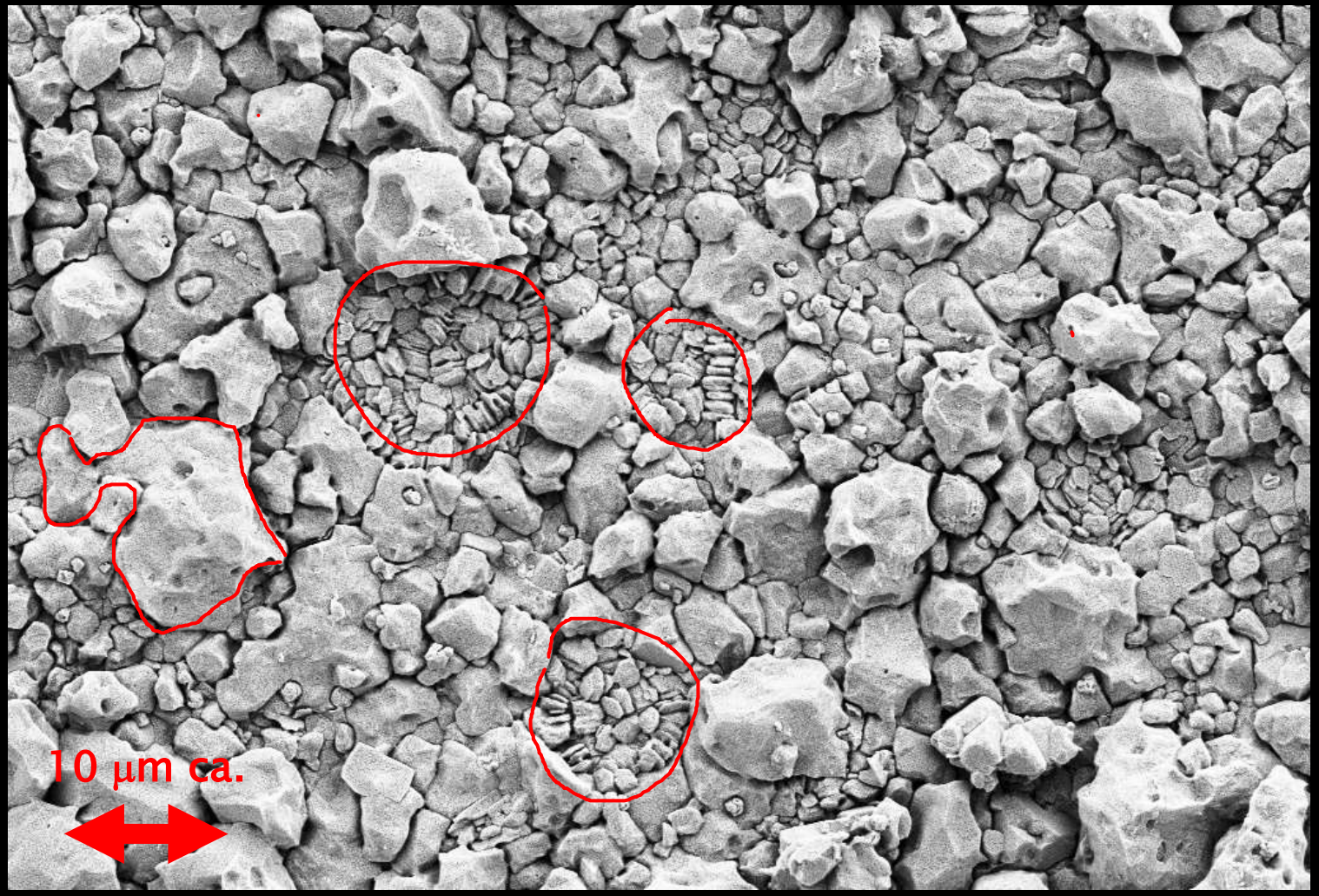
- **Microsparite**: interstitial carbonate with average diameters within 5 - 30 μm. Often identical to micrite under a microscope, the term is strictly descriptive, however, micrite and microsparite are often formed by distinct diagenetic processes.





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

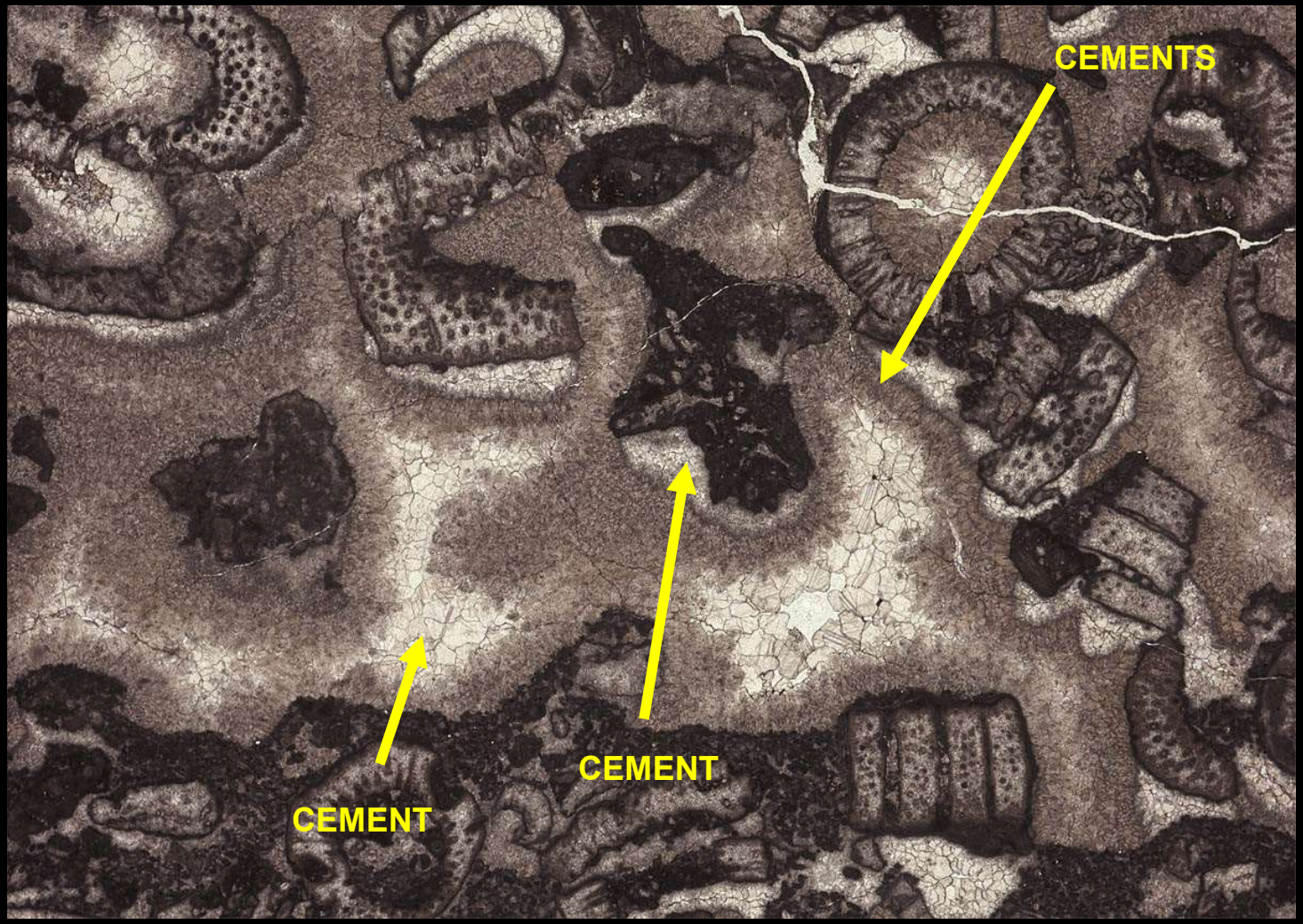


In this late Norian hemipelagic limestone of the Lagonegro Basin (Southern Apennines) the micrite component is nannofossils (*Prinsiosphaera* sp.). The rest is microsparite.

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

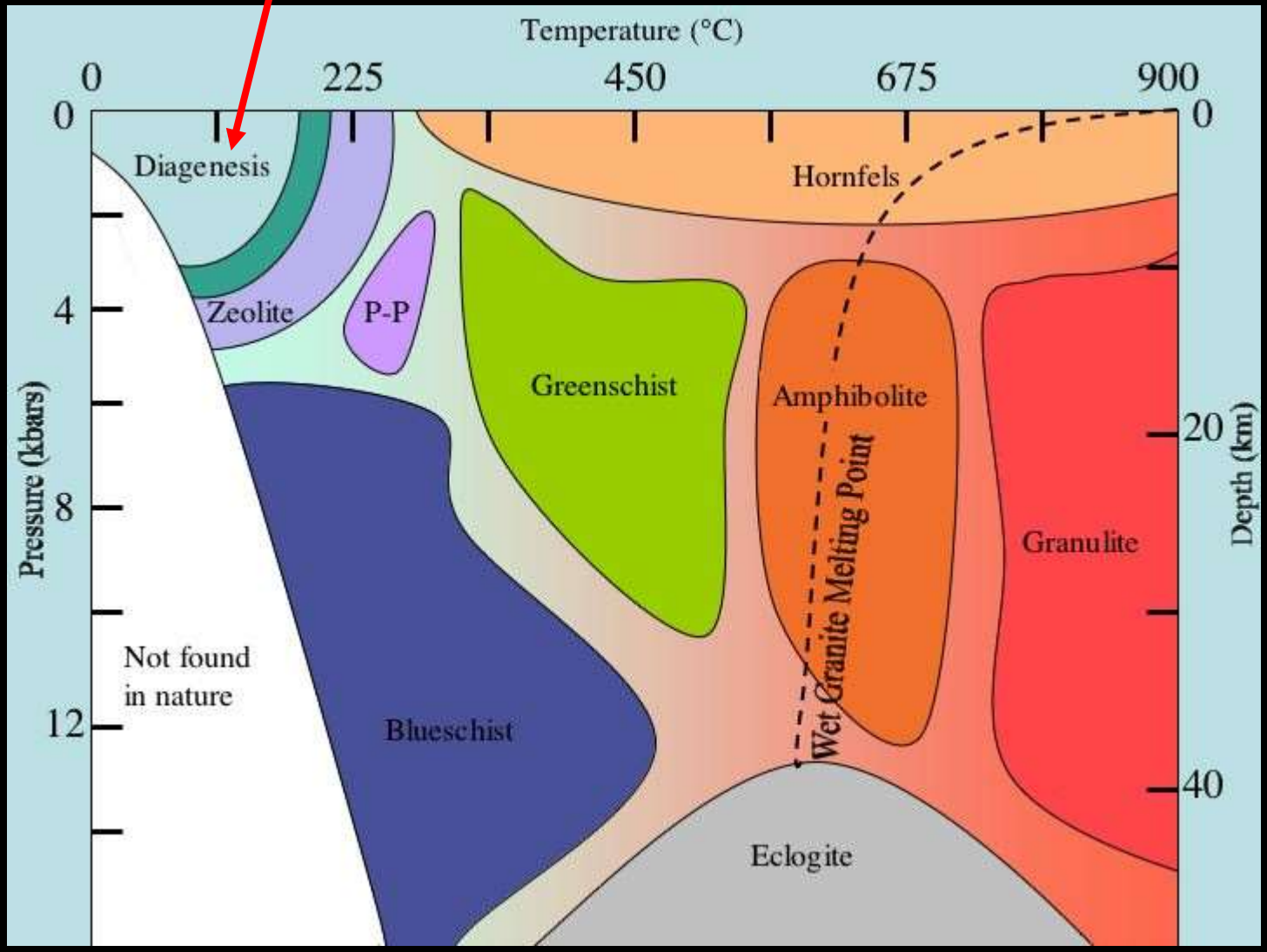
Diagenesis is a process that involves physical and chemical changes in sediments that start once it is deposited.
These changes are induced by increasing temperature and pressure during burial and may involve the circulation of fluids.

Carbonate sediments are particularly prone to diagenesis.

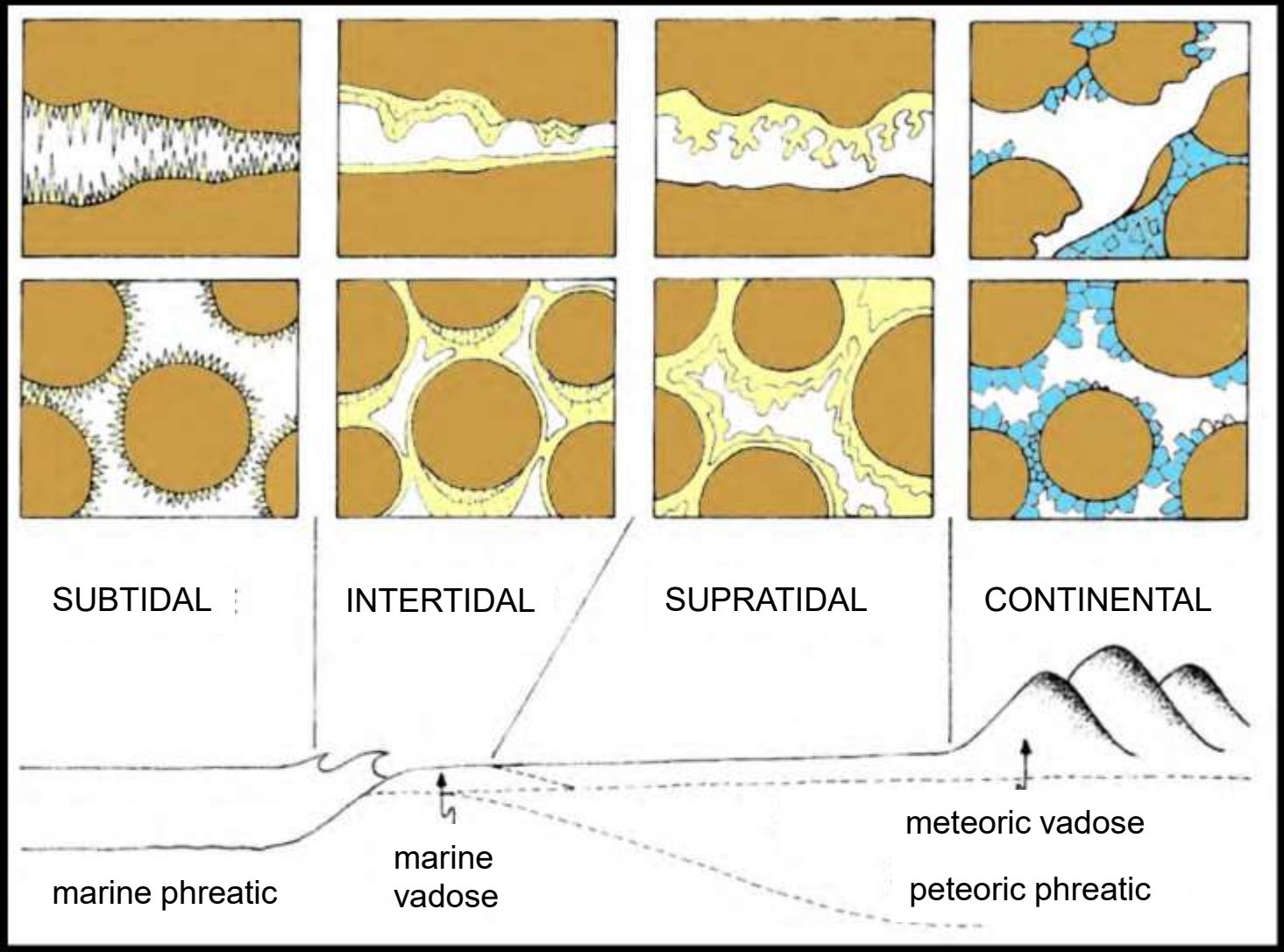
- compaction (under the load of overlying sediment)
- progressive pore occlusion
- **dissolution**
- **cementation**
- transformation of metastable carbonates (aragonite and high-Mg calcite) into low magnesium calcite (and dolomite)
- dolomitization*

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

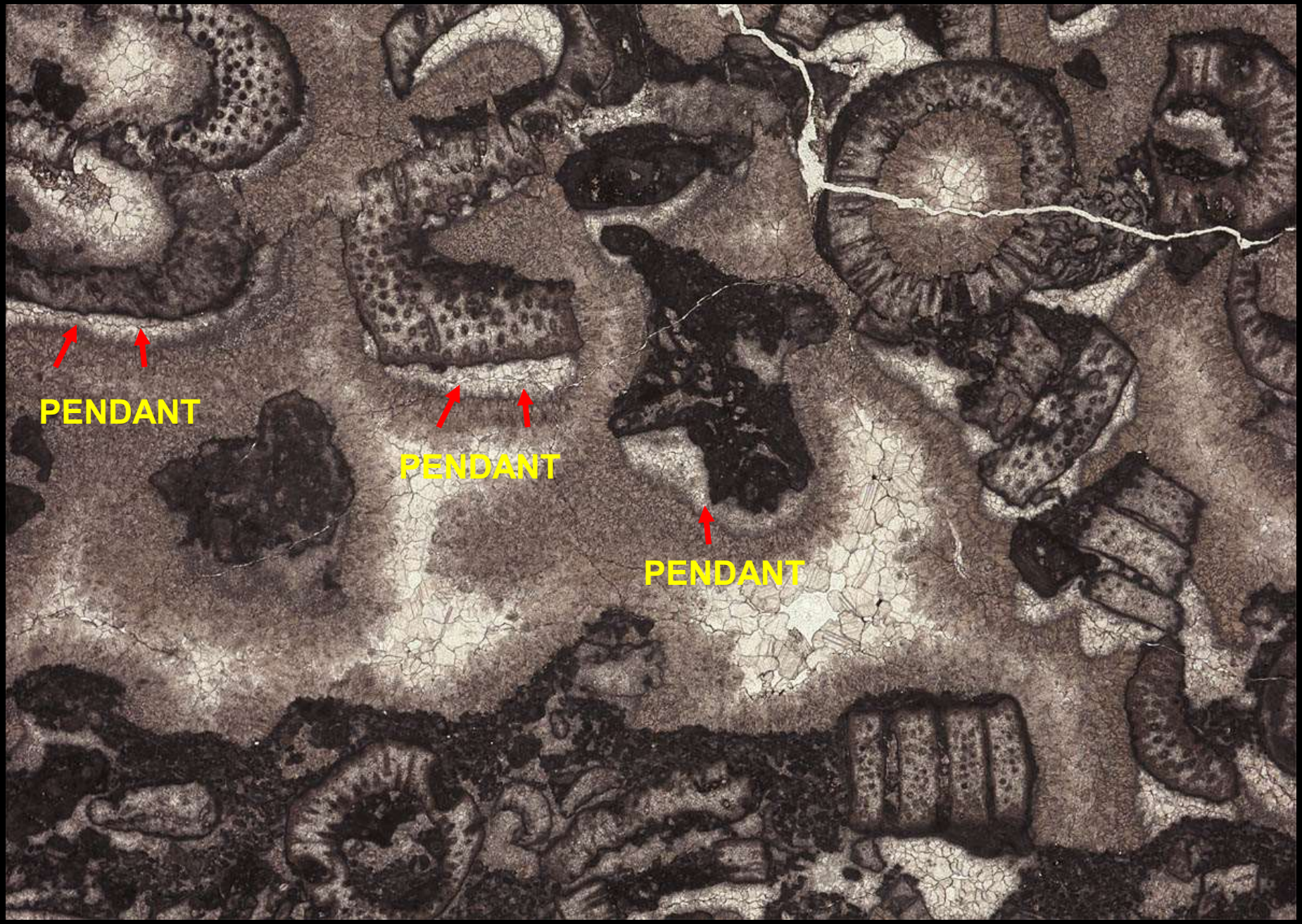


from Wikipedia

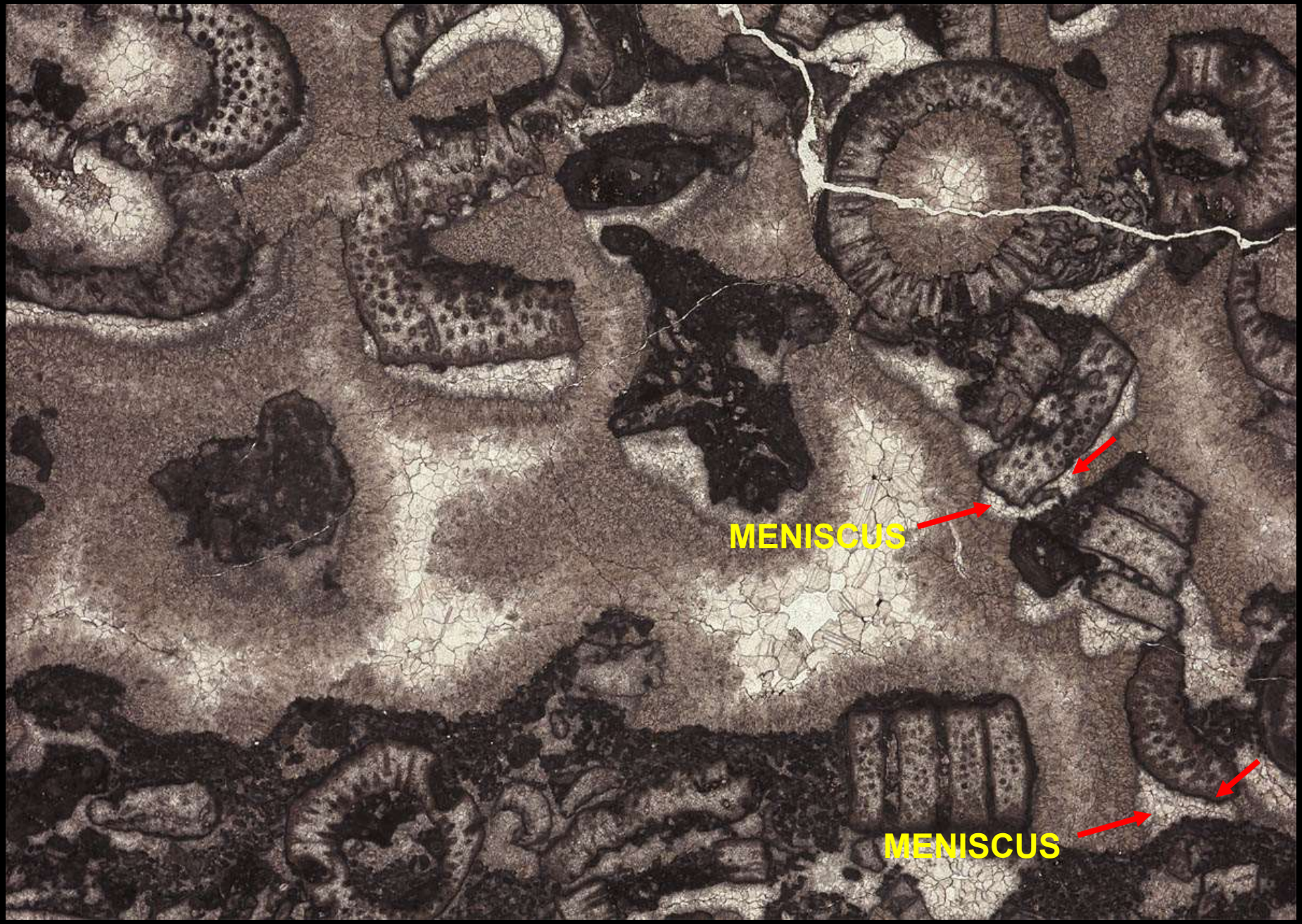


Different types of cement form in specific diagenetic environments. Characterizing the cements of a carbonate rock can help reconstructing its **diagenetic history**.

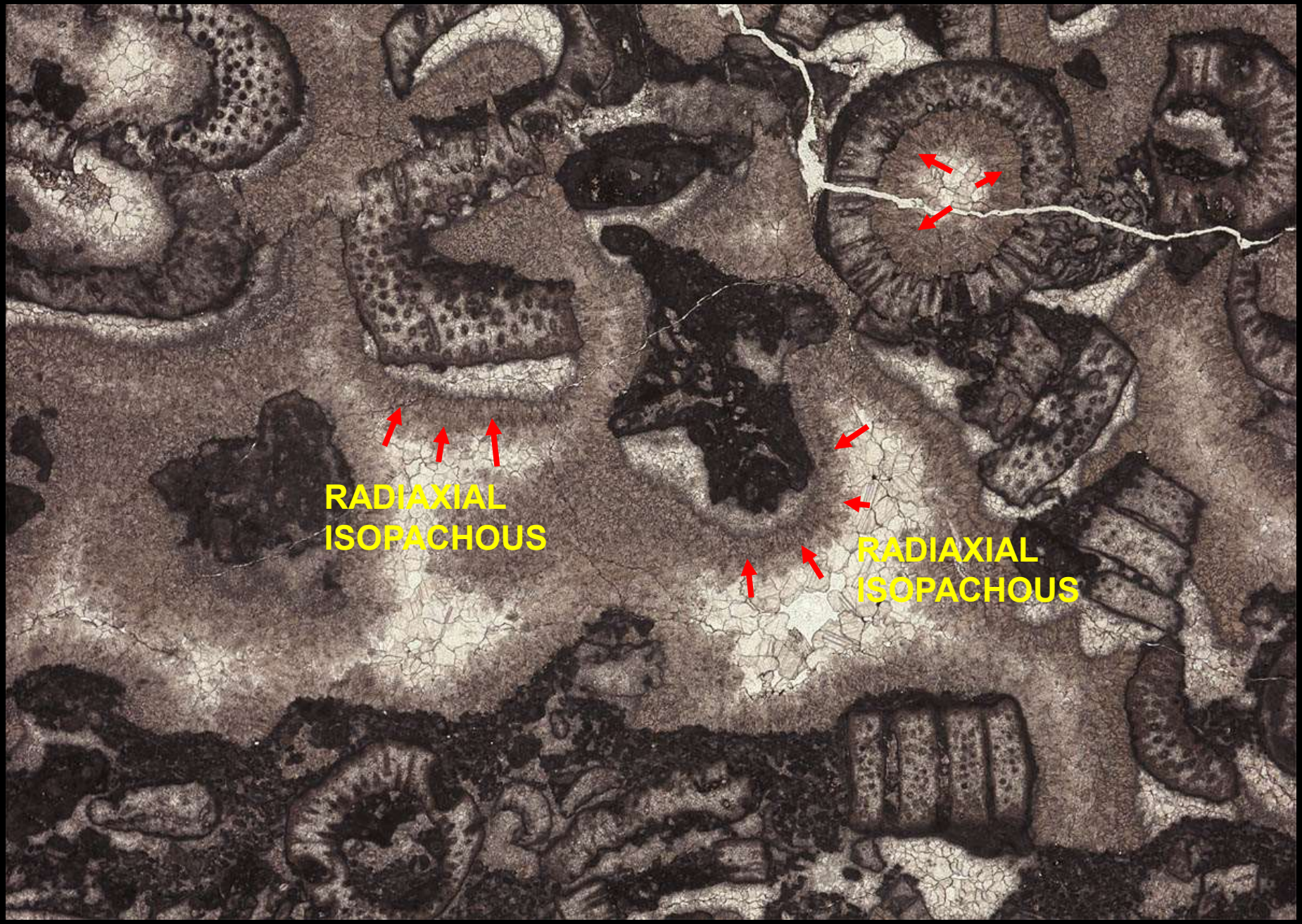
Some types of cements under the optical microscope



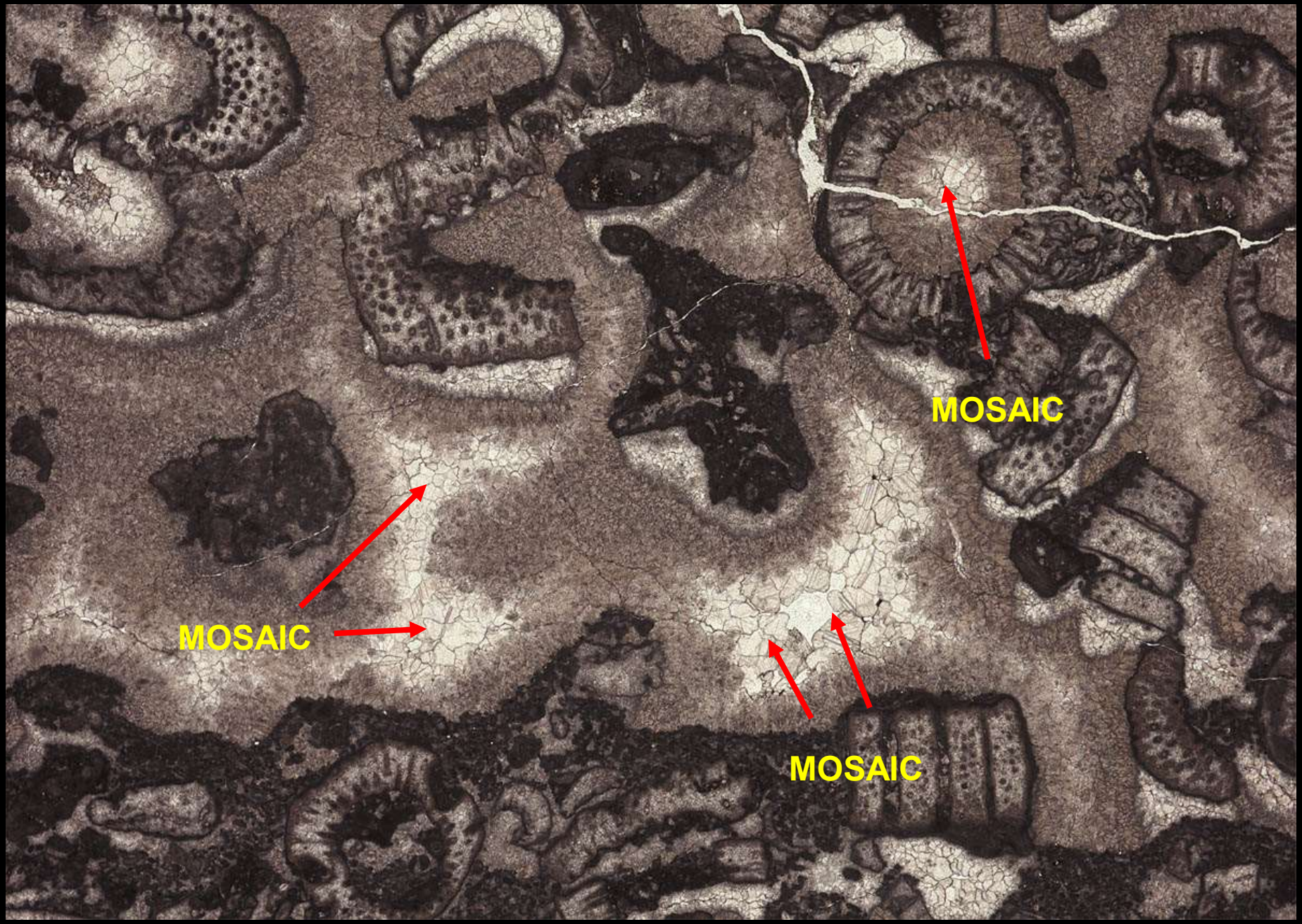
Some types of cements under the optical microscope



Some types of cements under the optical microscope



Some types of cements under the optical microscope

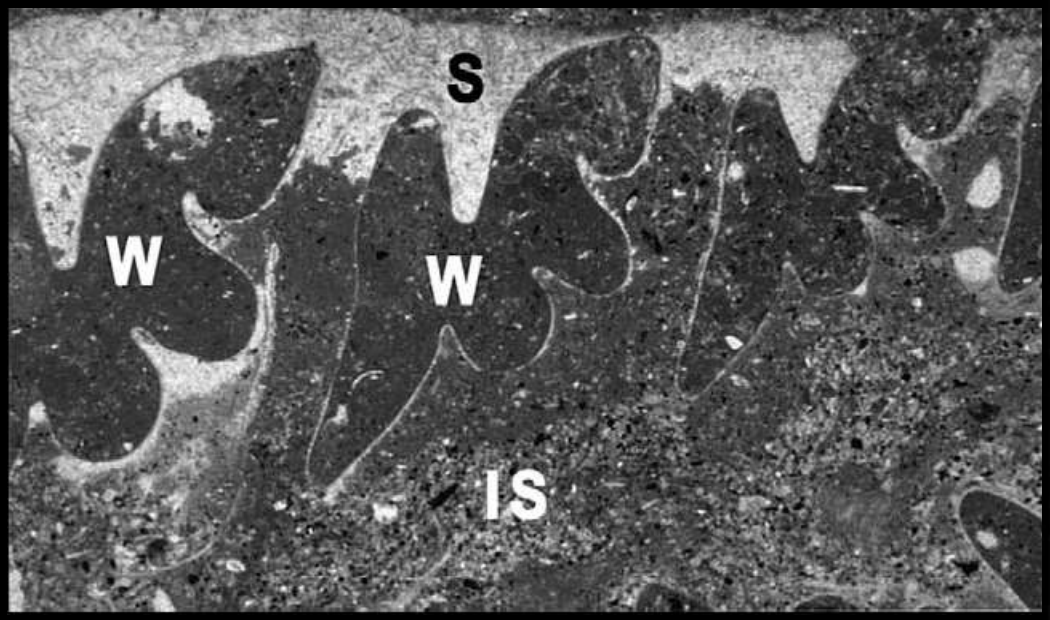


Some types of cements under the optical microscope

Syndepositional dissolution

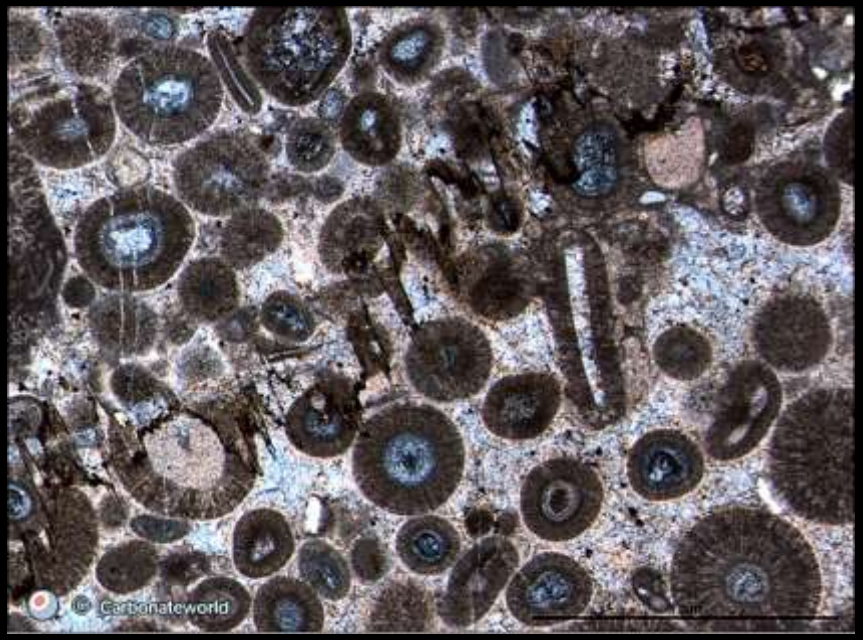
Carbonates can undergo syn-depositional modification. Dissolution is one of these processes and is caused by processes that may occur within the sediment right after burial (e.g. organic matter oxidation) that cause a local CaCO3 undersaturation.

Shallow water dissolution of a *Nerinea* shell (shallow water gas
the preserved specimen (right) the shell (S) completely surrou
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.



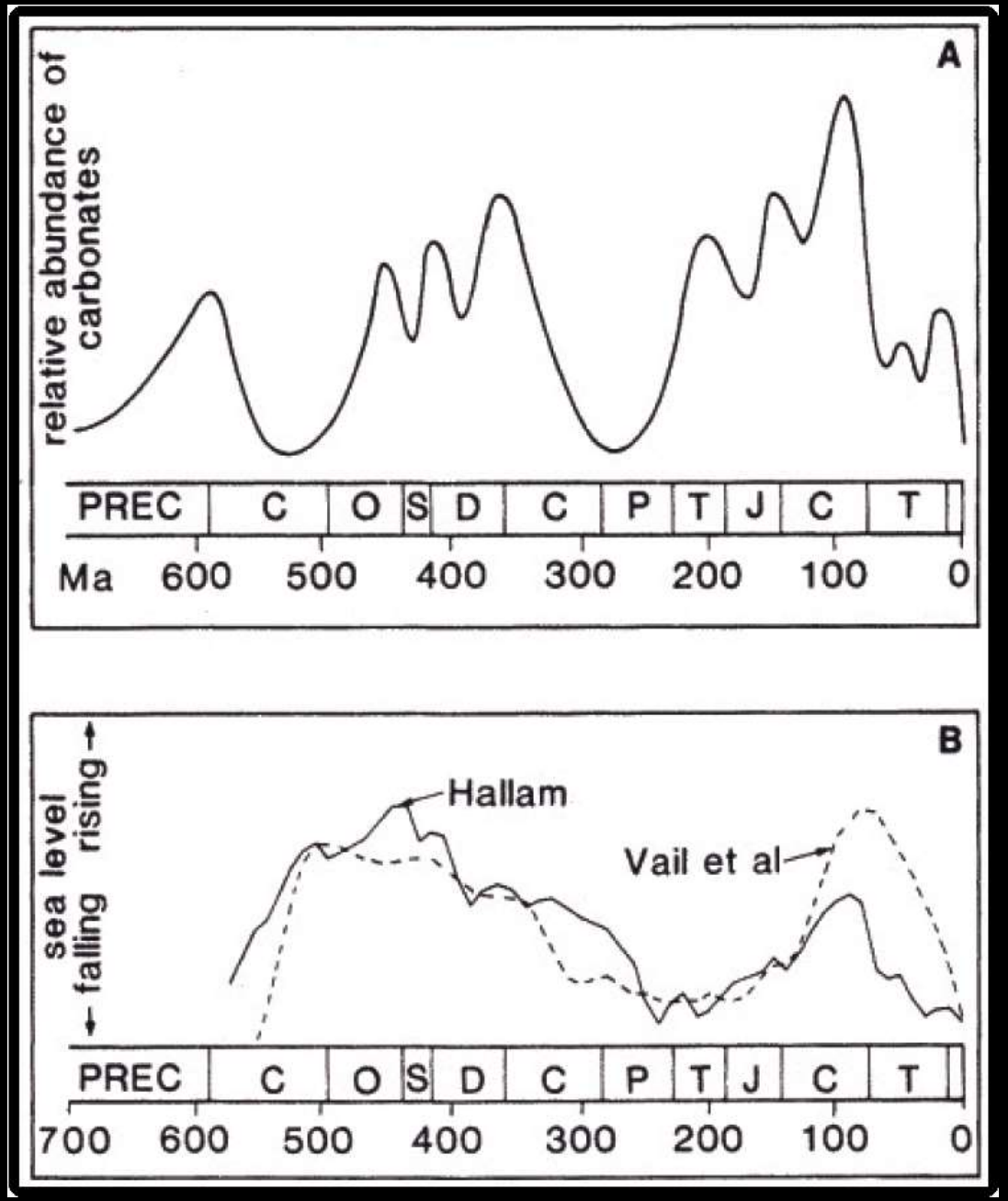
Stylolite in thin section (Carboniferous of Asturias). From www.carbonateworld.com

Sedimentology and Stratigraphy, 2021-2022

Carbonates through geological time

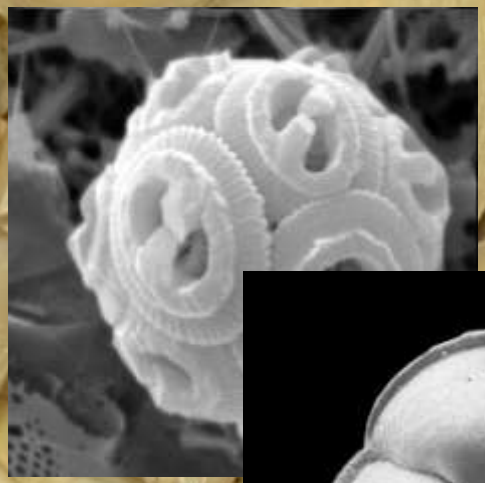
Carbonates aboundance fluctuated through geological times and a broad correspondence is seen with large scale **osciallation of sea level**.

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



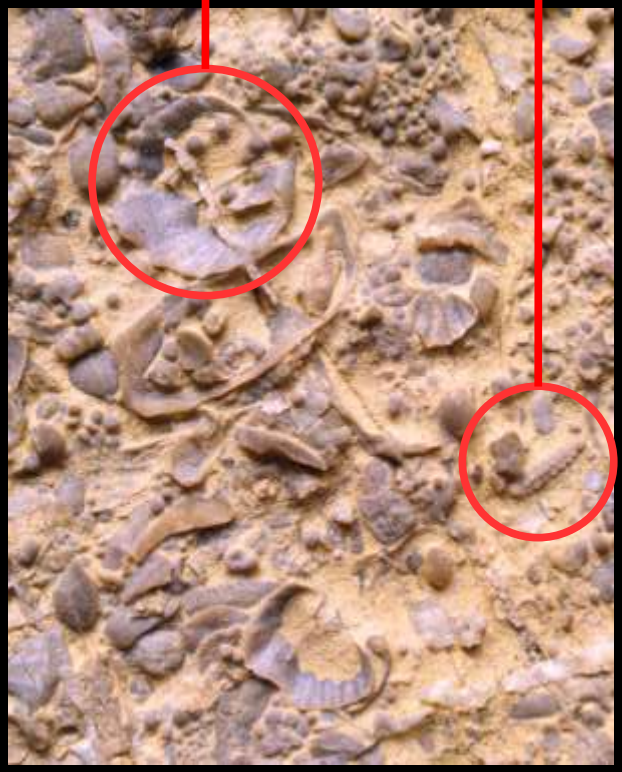
Tucker and Wright, 1990

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



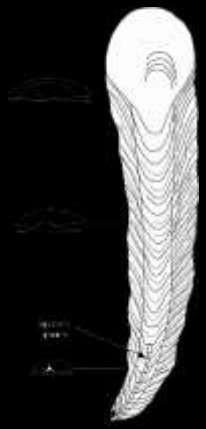
Carbonates: the biological factor

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

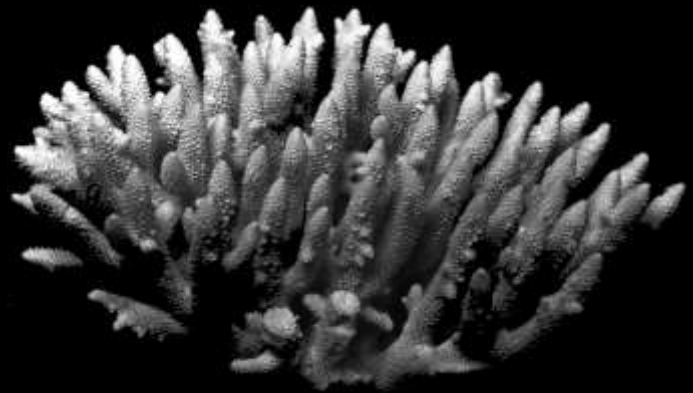
Mid Cambrian
to present



Lithiotis sp.
Early Jurassic

Rudist
Cretaceous

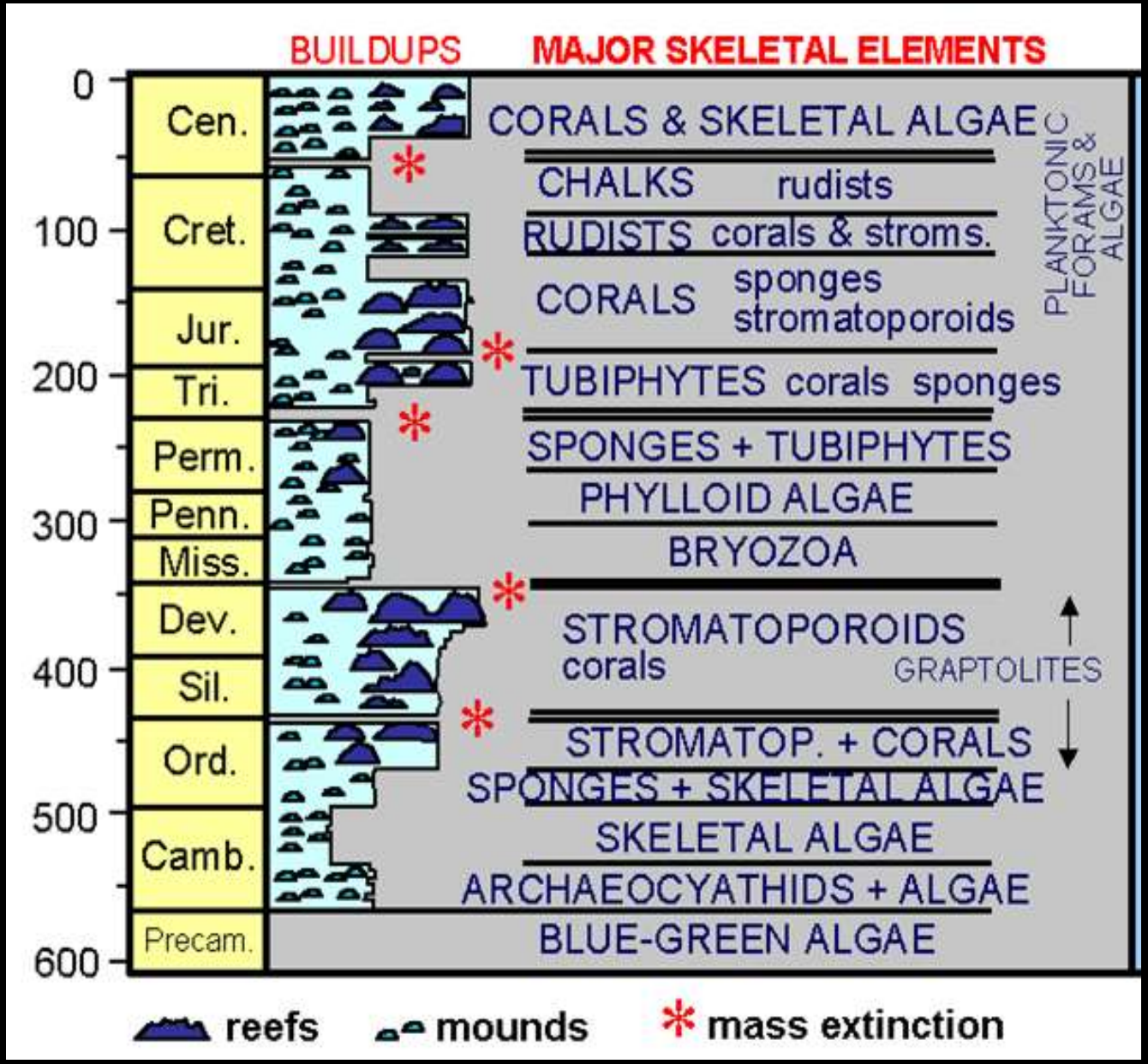
Archaeocyatha
Cambrian



Scleractinian coral
Cenozoic to present

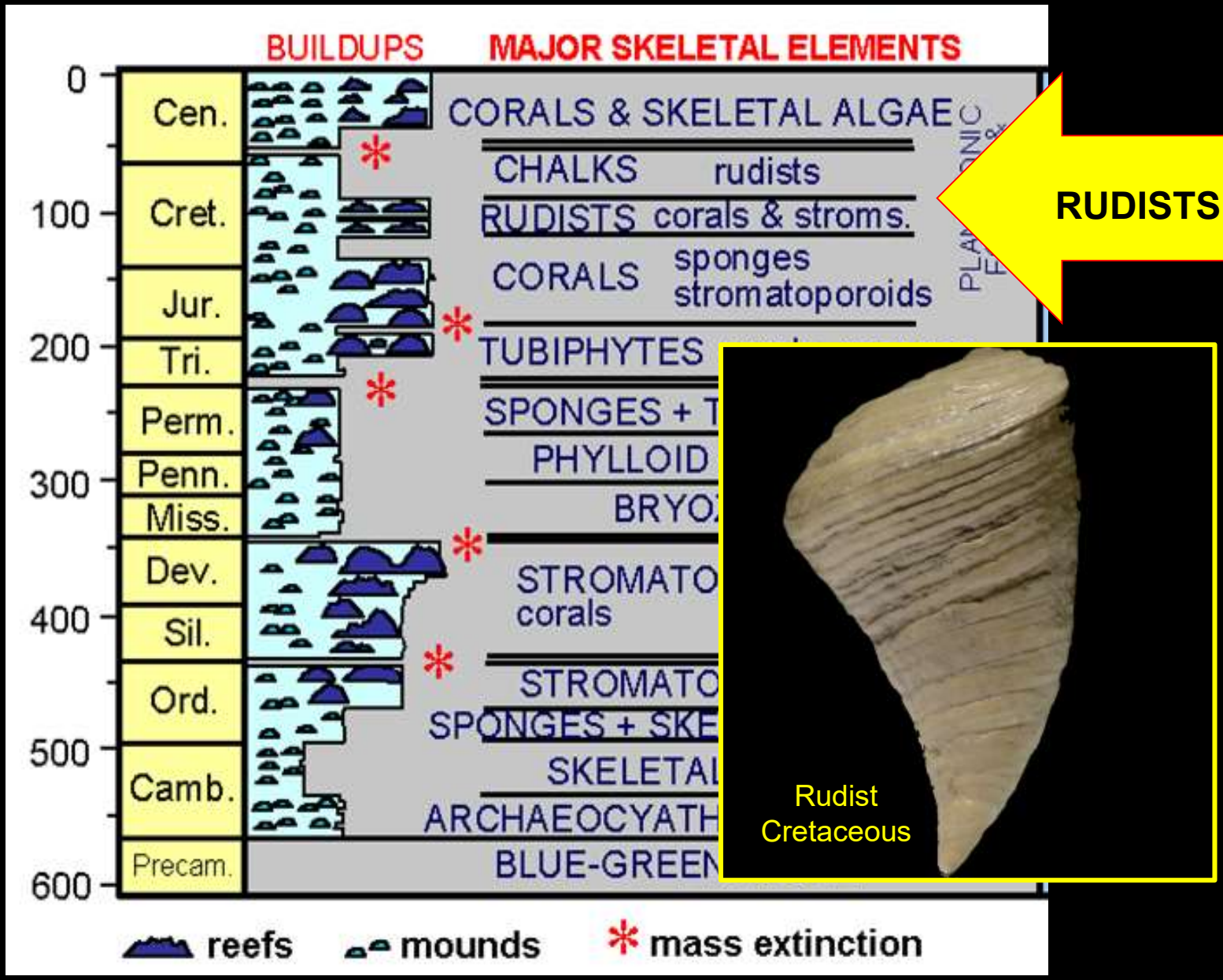
Stromatolite
Precambrian

Reef building organisms changed through geological times



Redrawn from James, 1983.

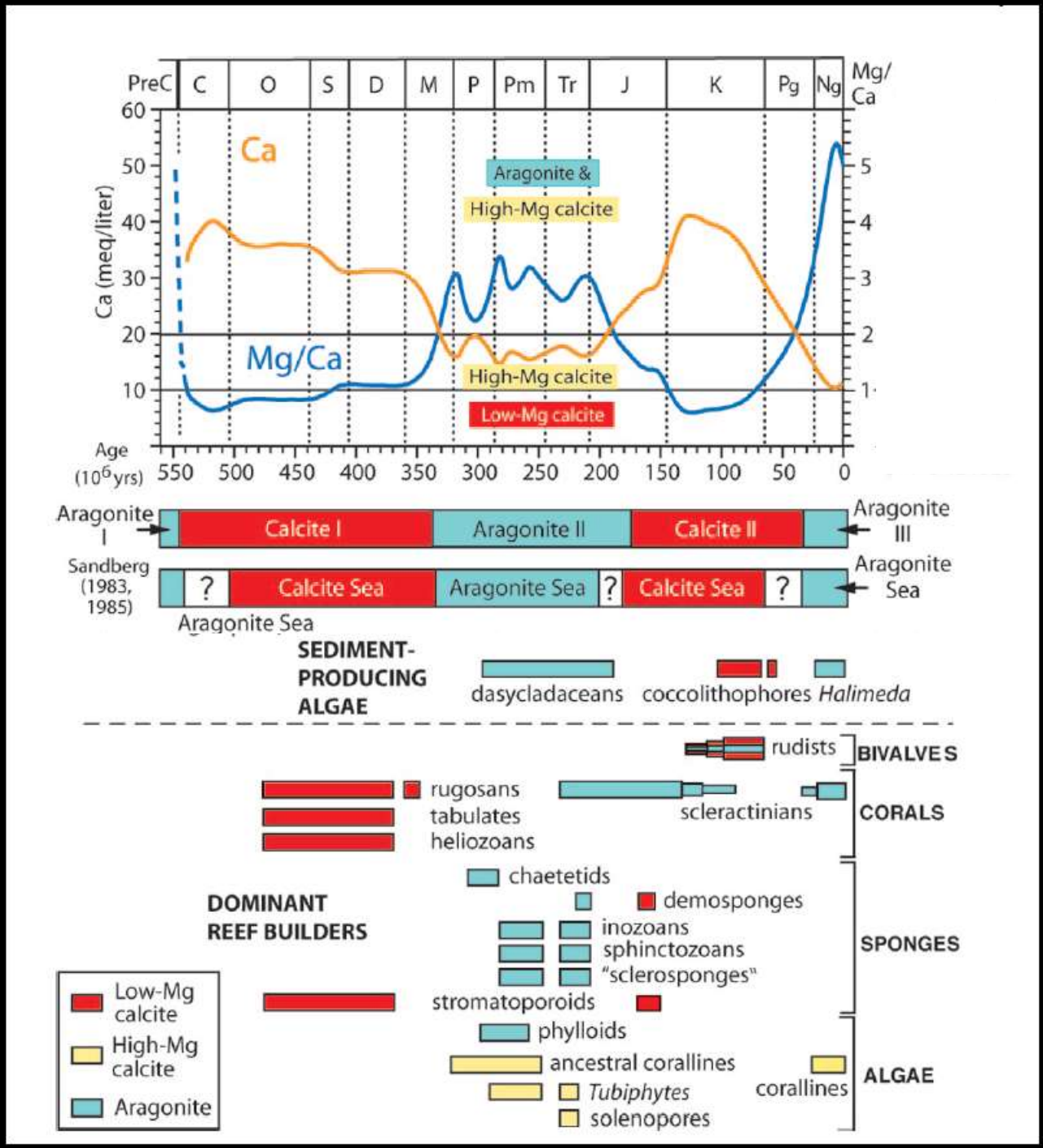
Reef building organisms changed through geological times



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.

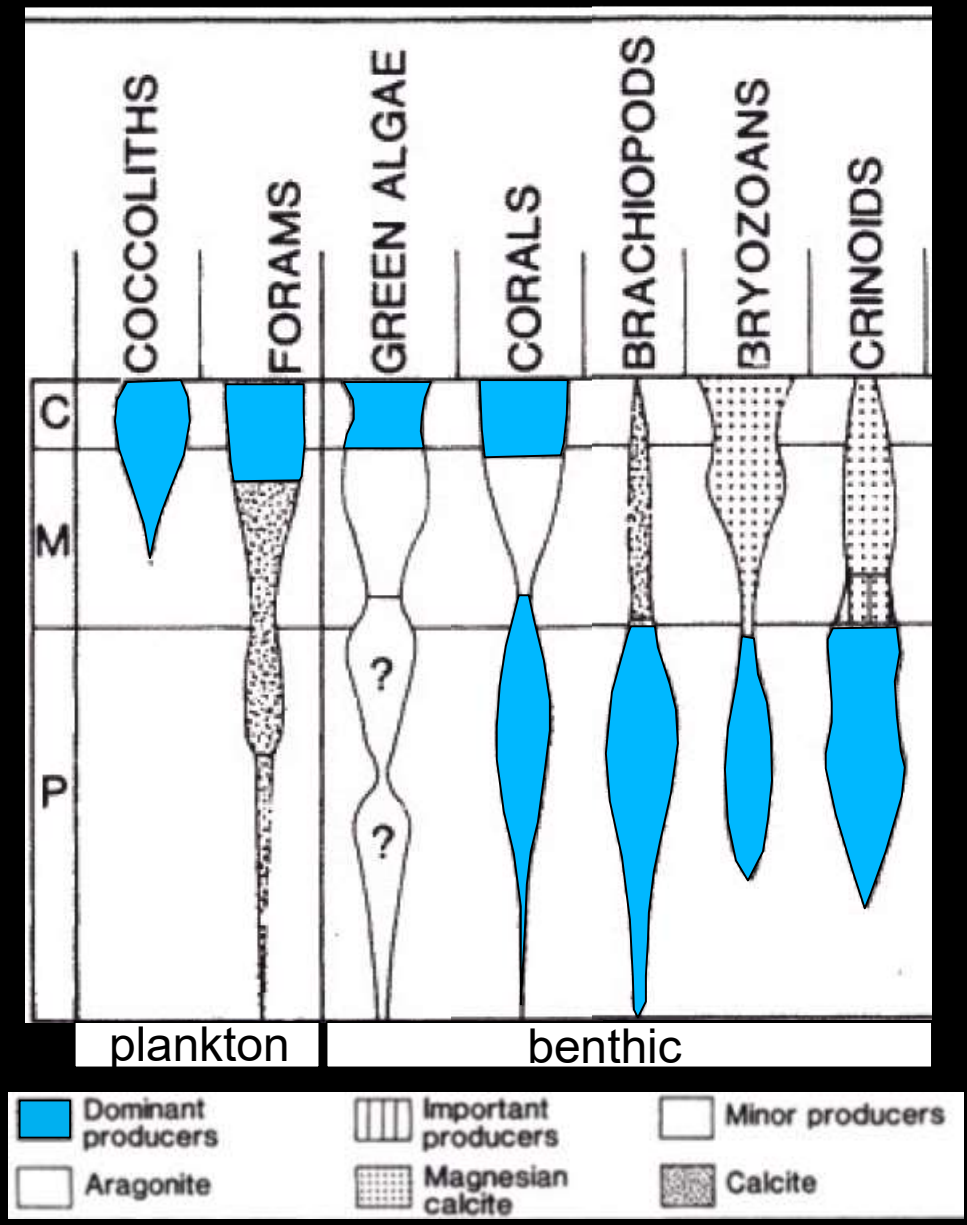


Stanley, 2004 modified

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

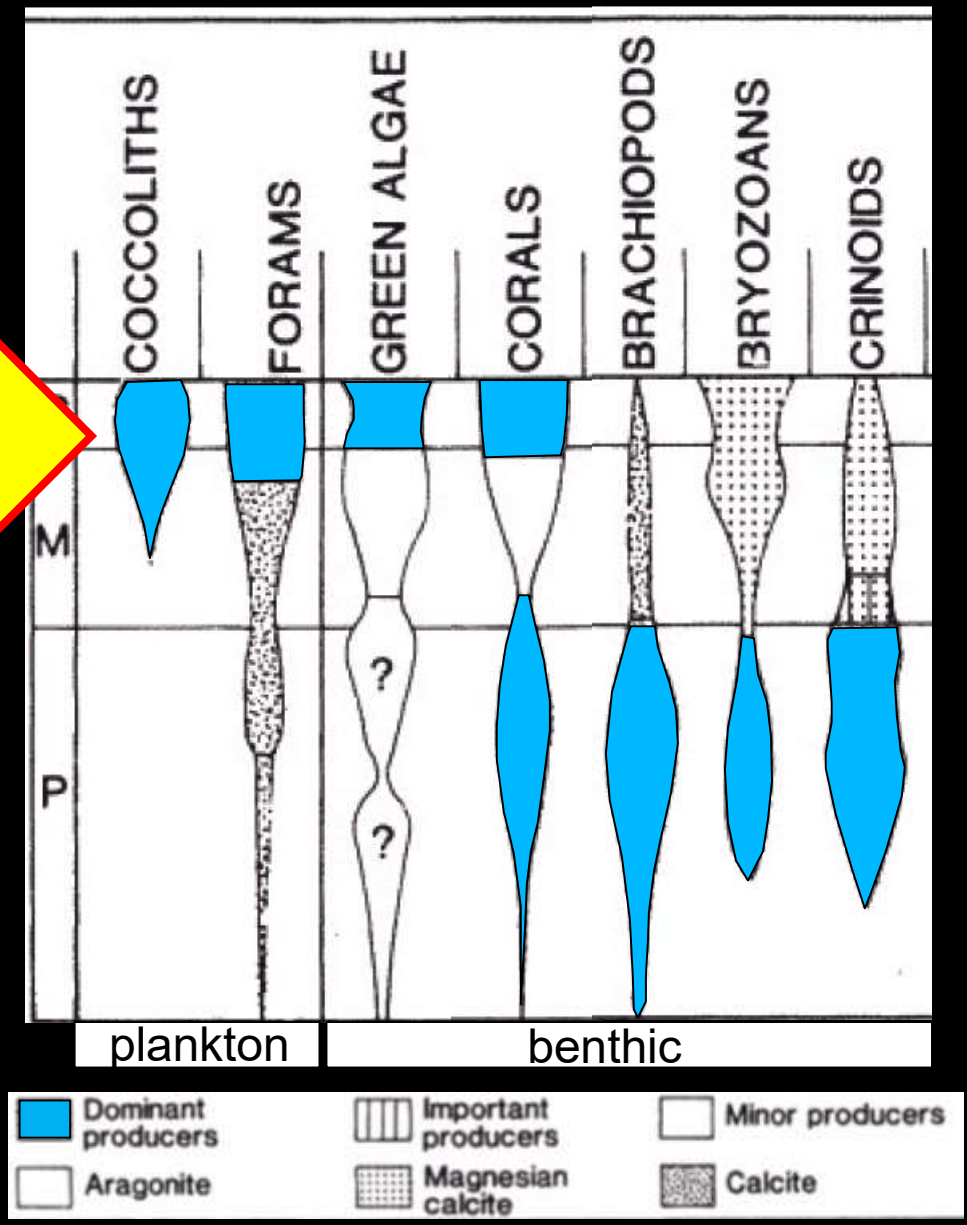


Tucker and Wright, 1990 modified

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

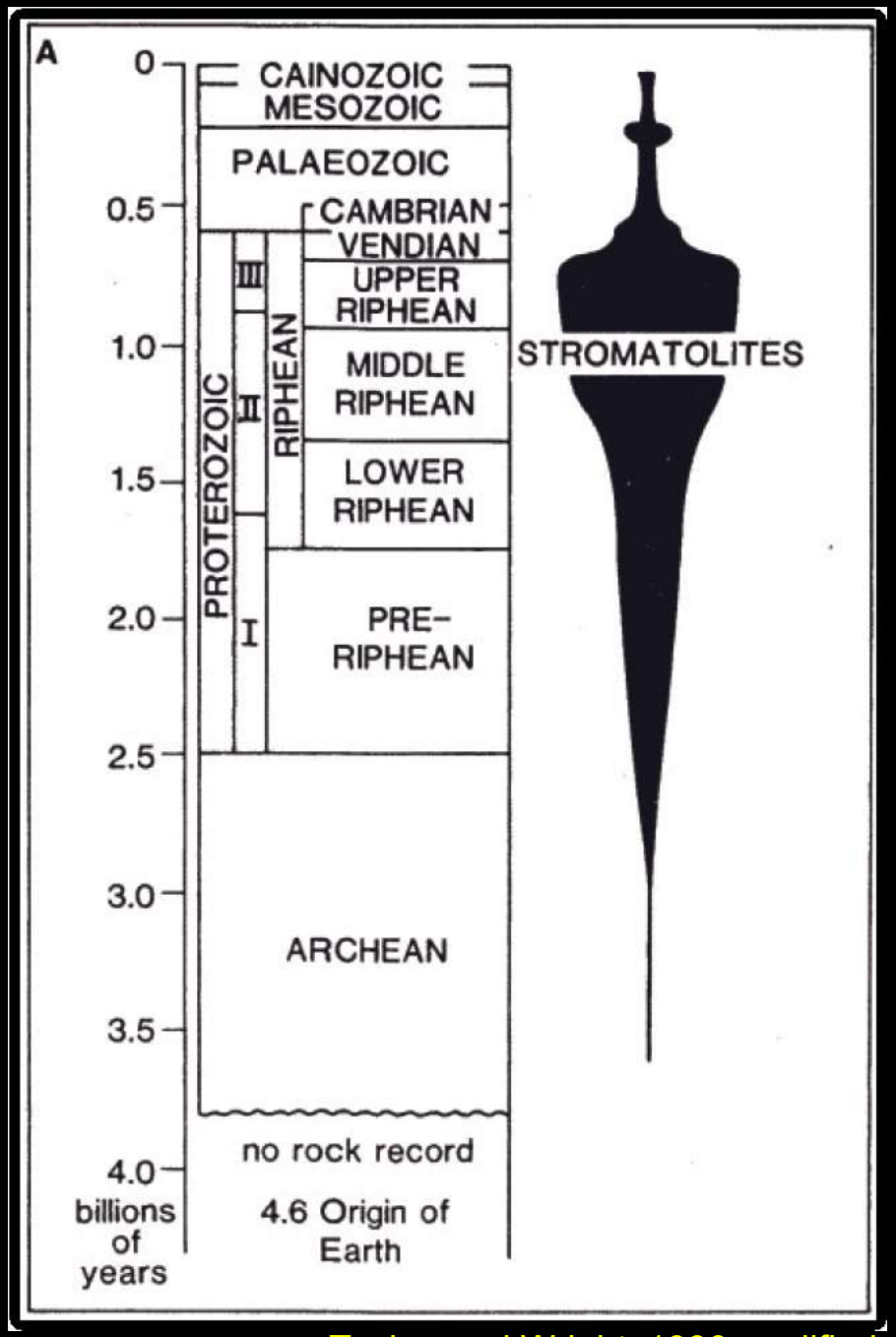
When did carbonate apper in the geological record?

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)

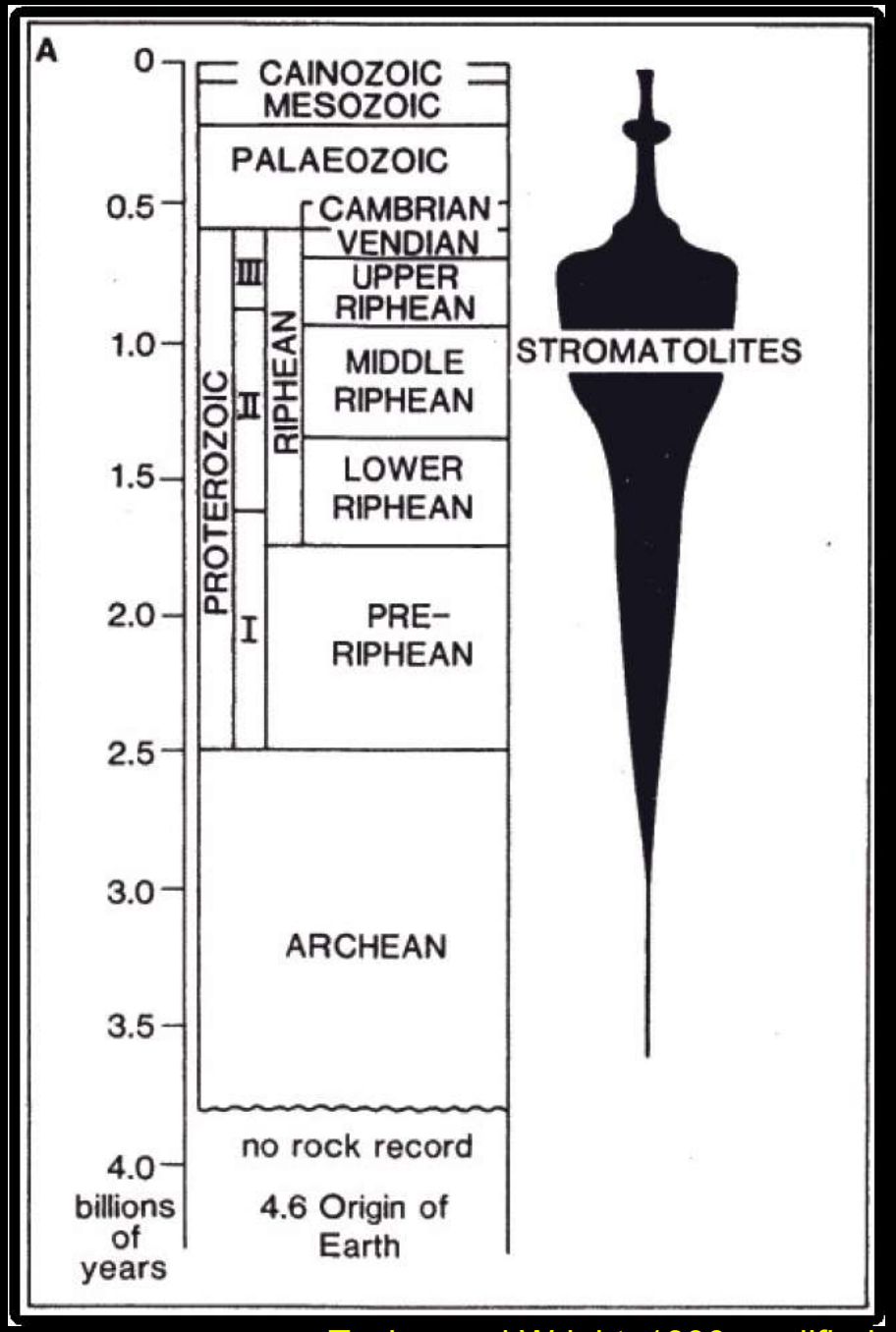


Tucker and Wright, 1990 modified

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

Brief introduction to the stratigraphic succession in the Trieste area

Fm . di Trieste

marne di San Lorenzo

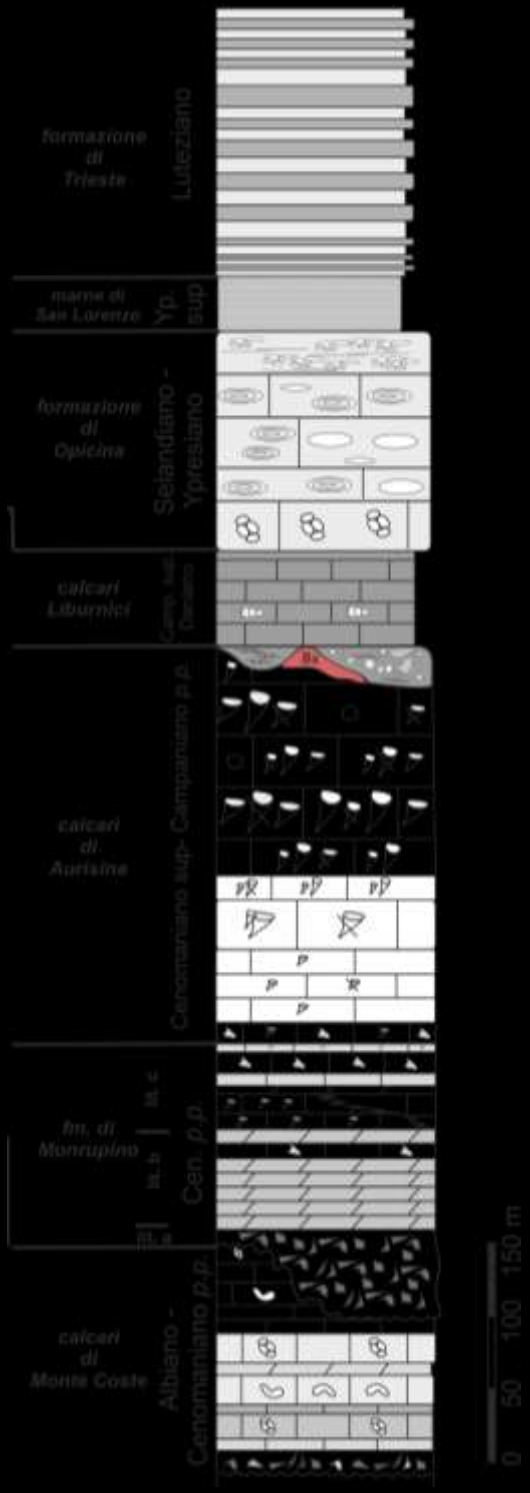
fm. di Opicina

Calcari Liburnici

Calcari di Aurisina

fm. di Monrupino

calcari di M. Coste



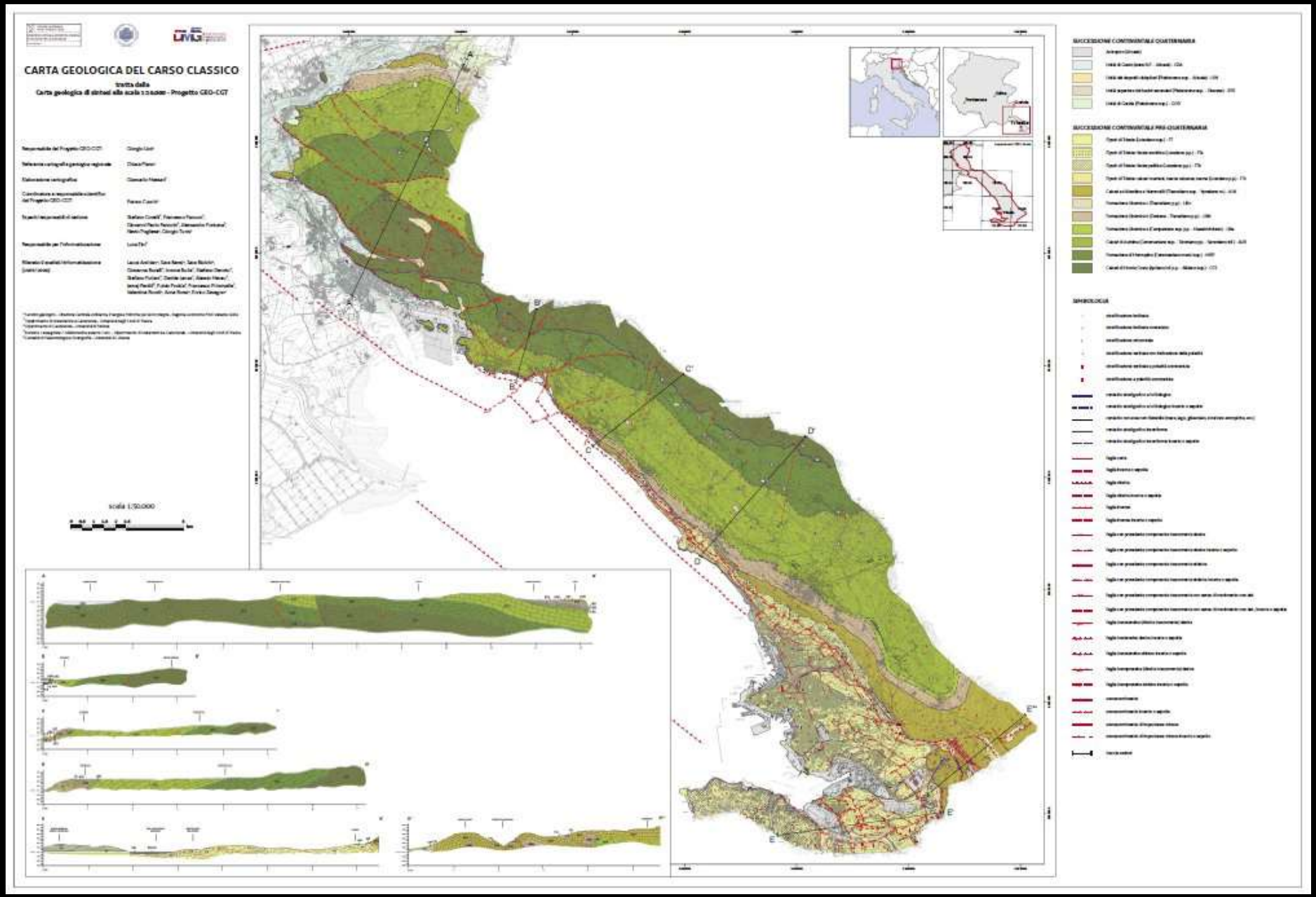
LA SUCCESSIONE STRATIGRAFICA DEL CARSO

Le rocce che costituiscono l'ossatura del Carso sono rocce sedimentarie di età Mesozoica e Cenozoica.

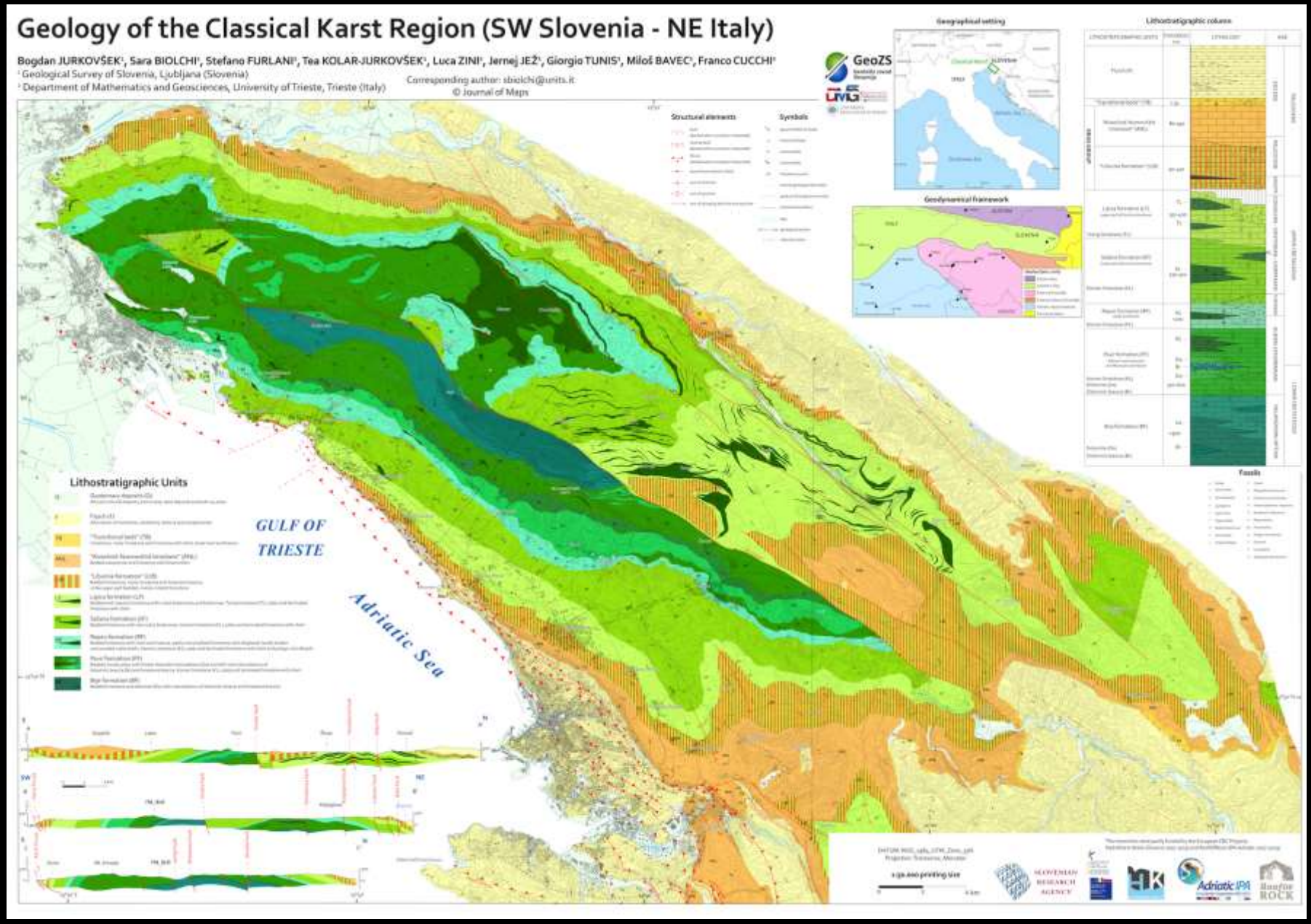
Rocce diverse si sono sovrapposte nel tempo dando luogo alla successione stratigrafica che caratterizza il Carso

E' possible riconoscere diverse formazioni, ossia "pacchetti" di rocce stratificate che possiedono caratteristiche che le accomunano e che ci parlano degli ambienti in cui si sono formate.

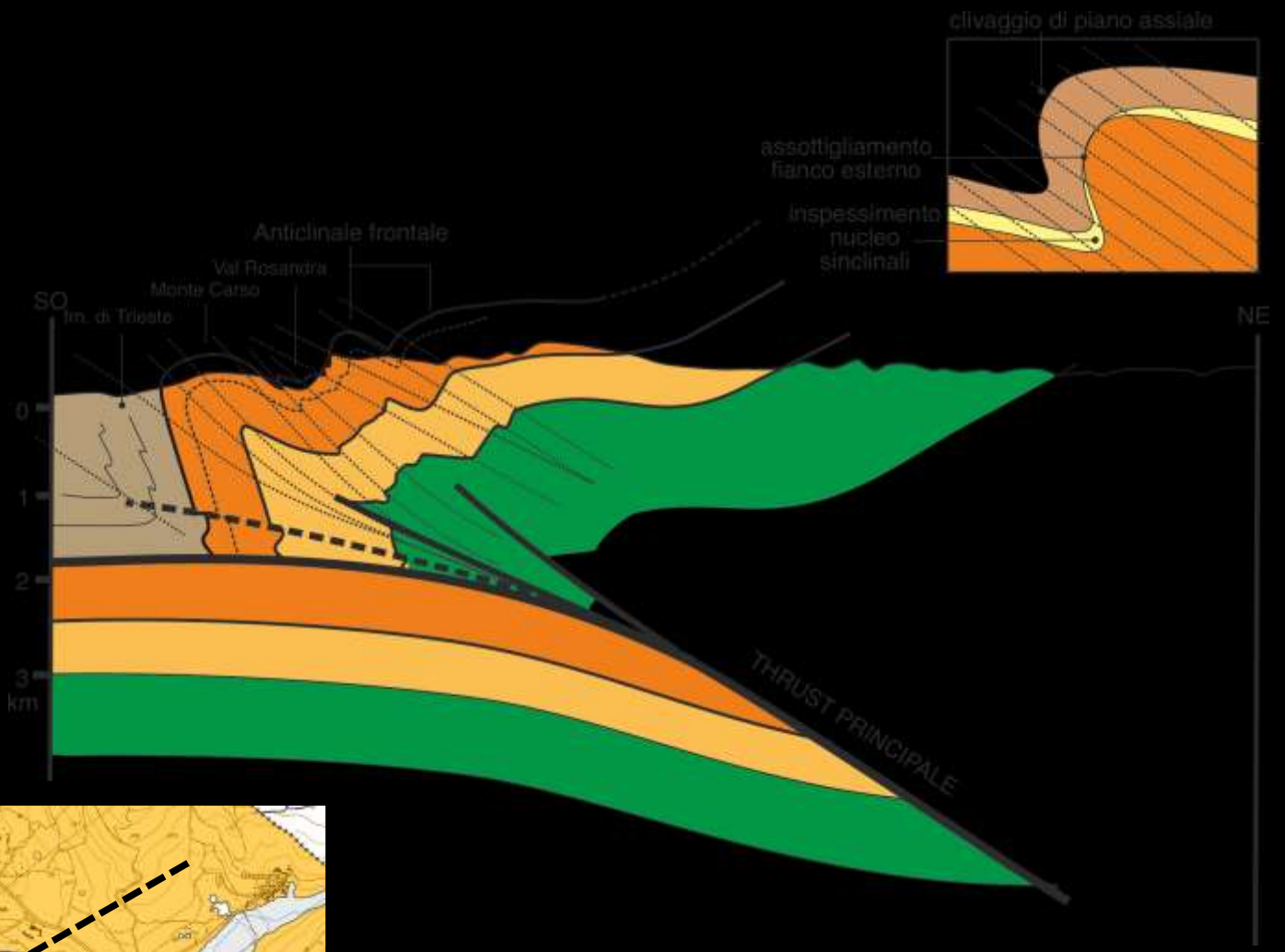
Il susseguirsi delle rocce della successione stratigrafica ci parla di come questi ambienti sono cambiati nel tempo e dei mutamenti climatici e ambientali avvenuti nel passato

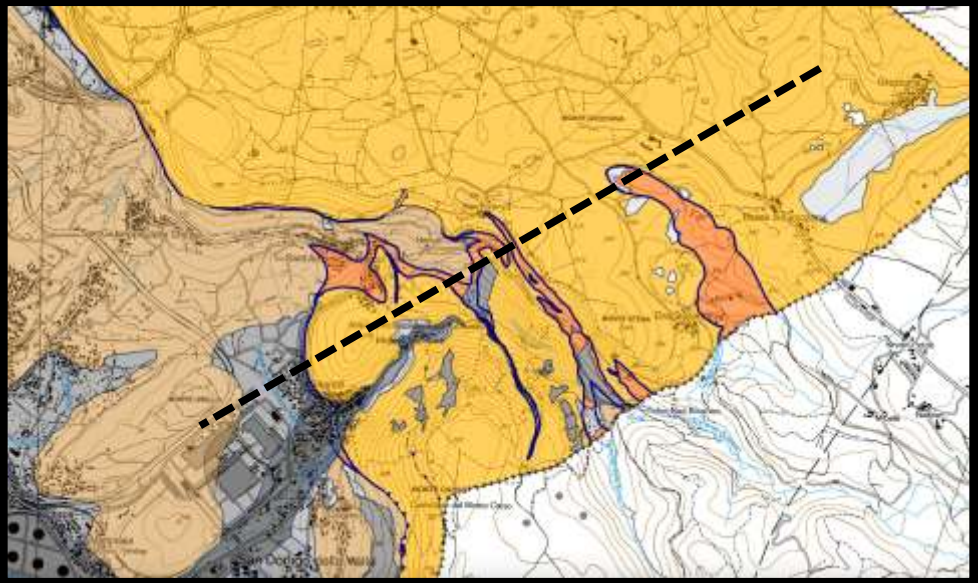


Cucchi et al., 2013



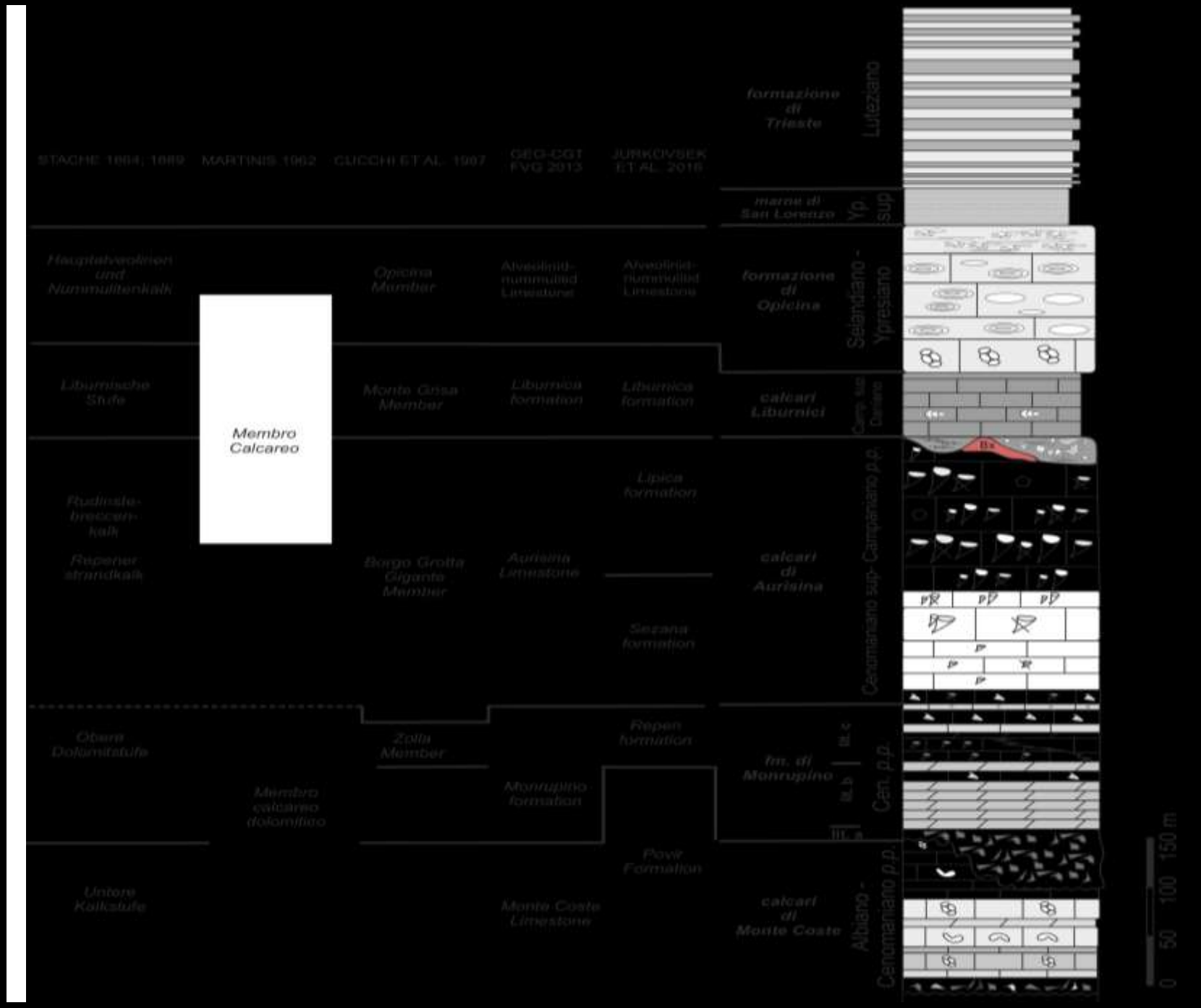
Jurkovšek et al., 2016



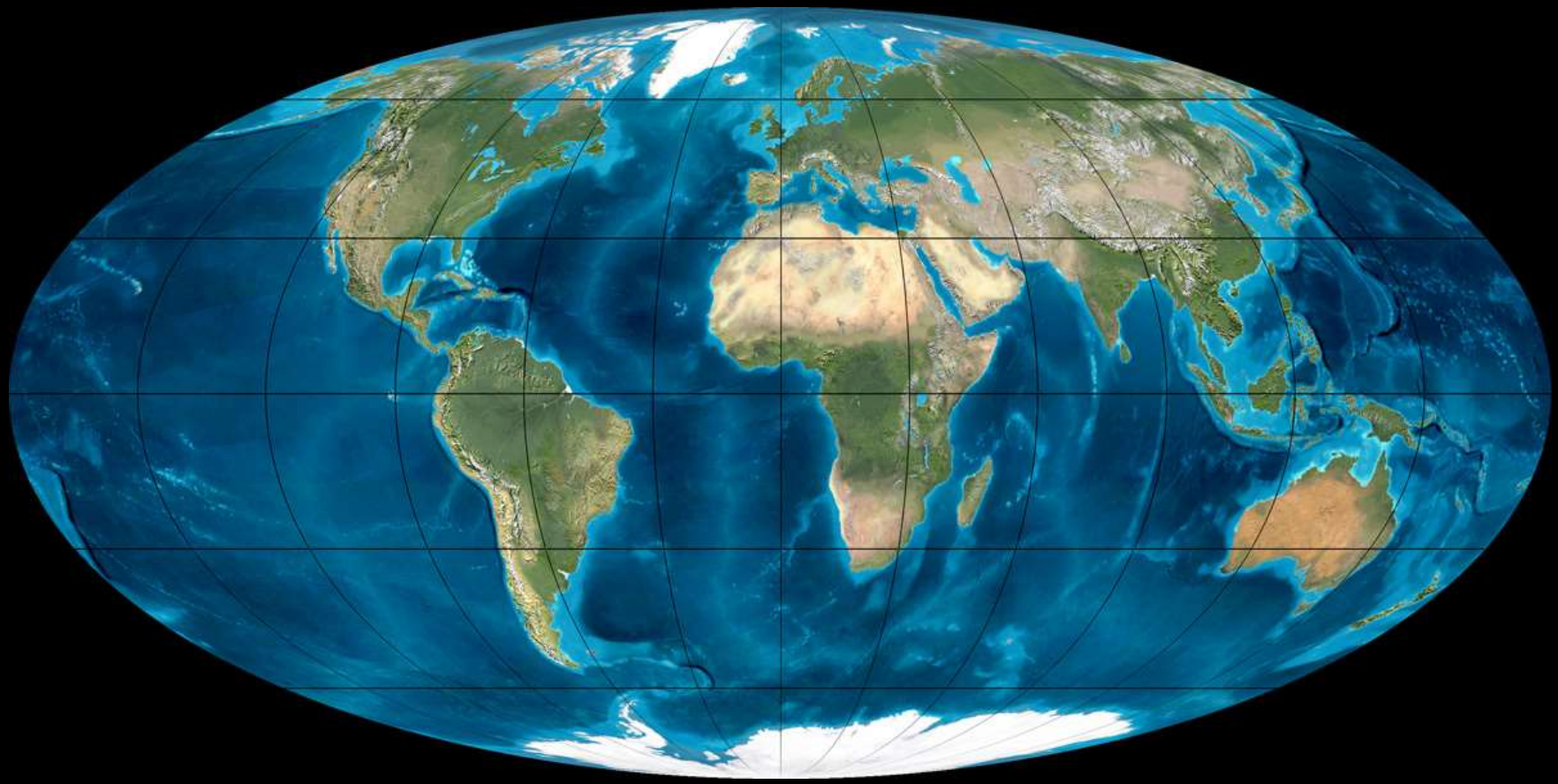


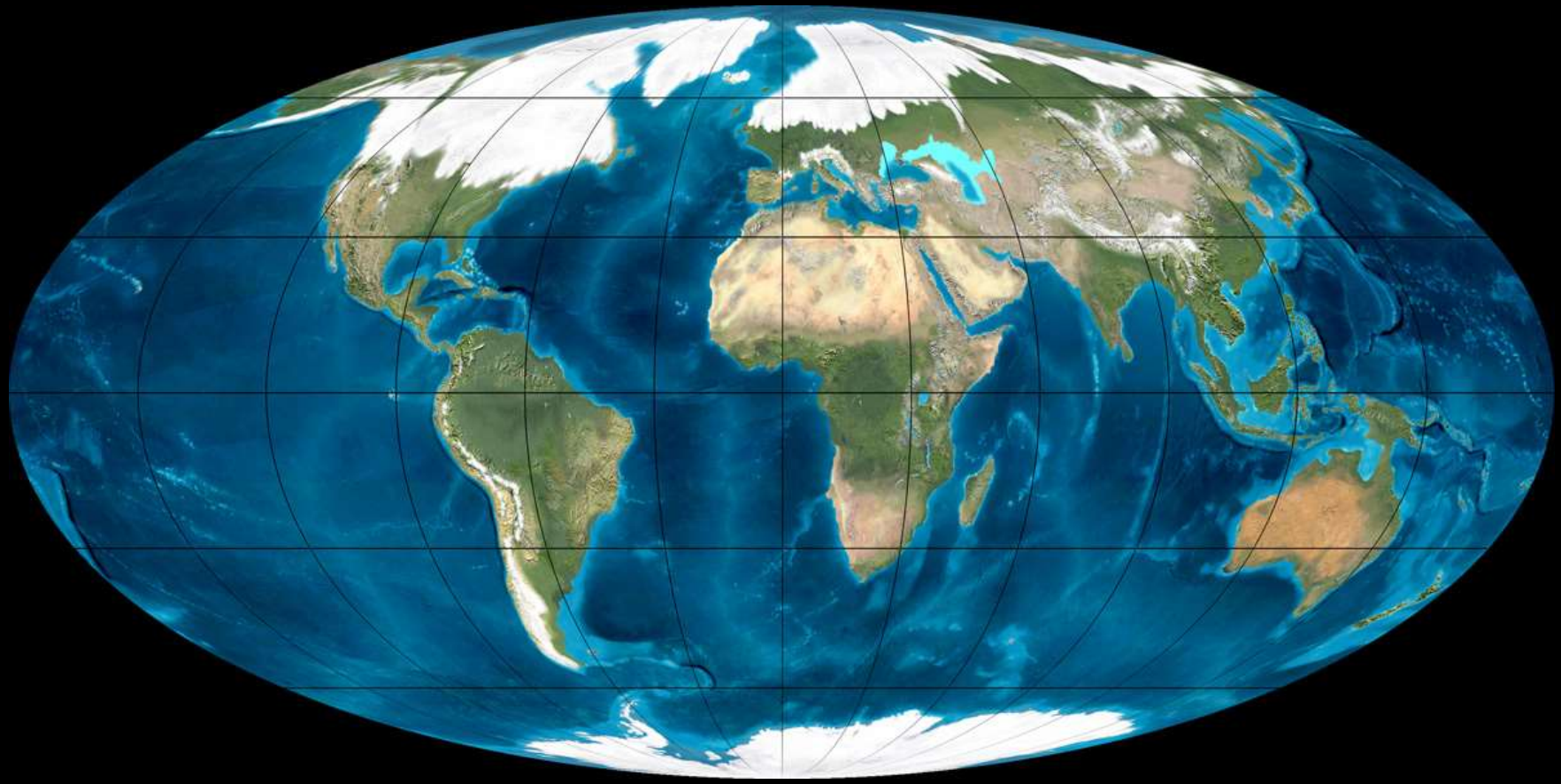
L’altiopiano del Carso è stato sollevato dall’Orogenesi Alpina (fase Dinarica) che ha deformato la successione sedimentaria piegandola

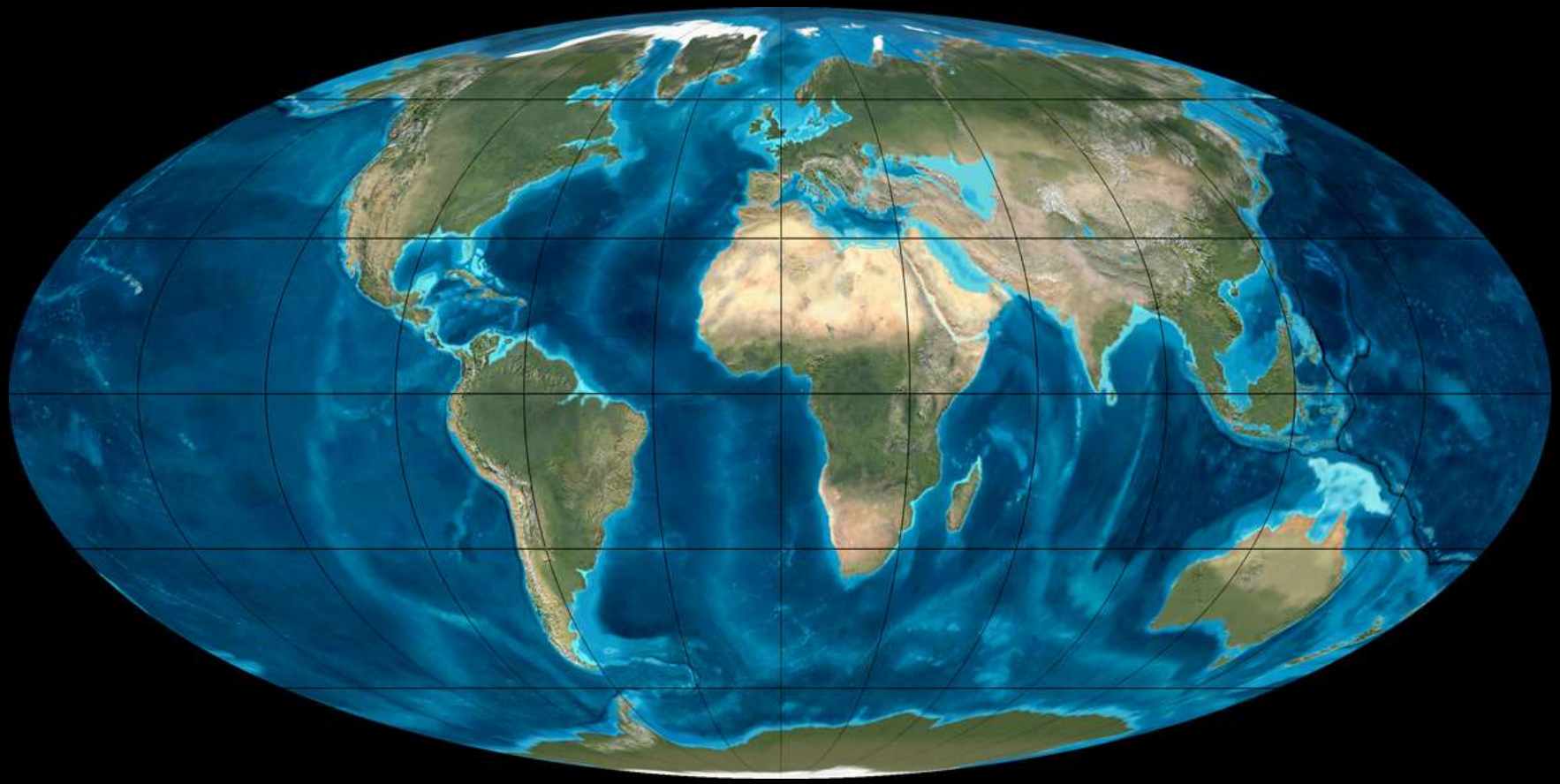
Nel 2023 è stata definite la nomenclatura delle unità stratigrafiche per il fogli geologici “Trieste” e “Caresana” della Carta Geologica d’Italia a scalal 1:50000

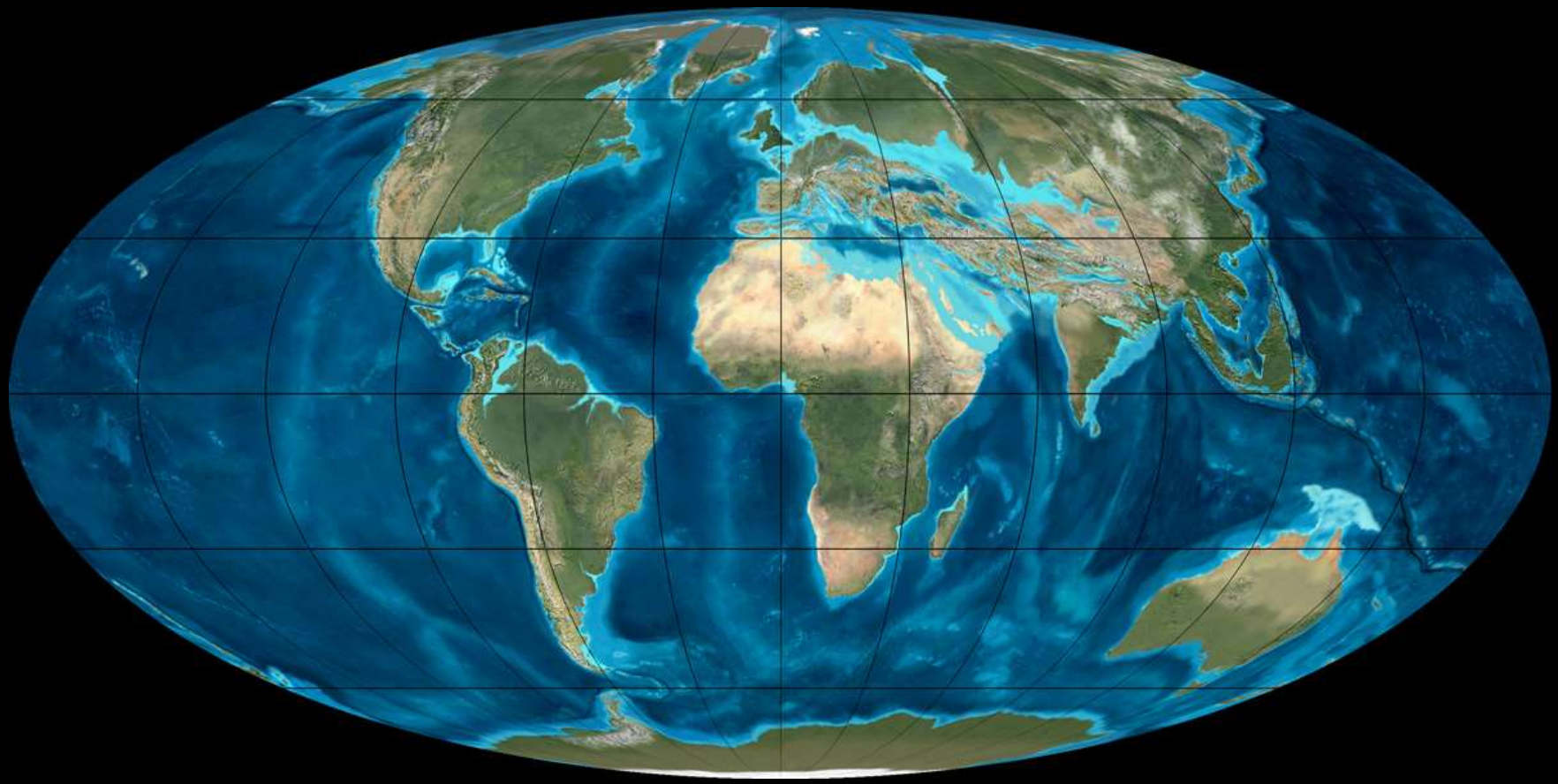


Oggi

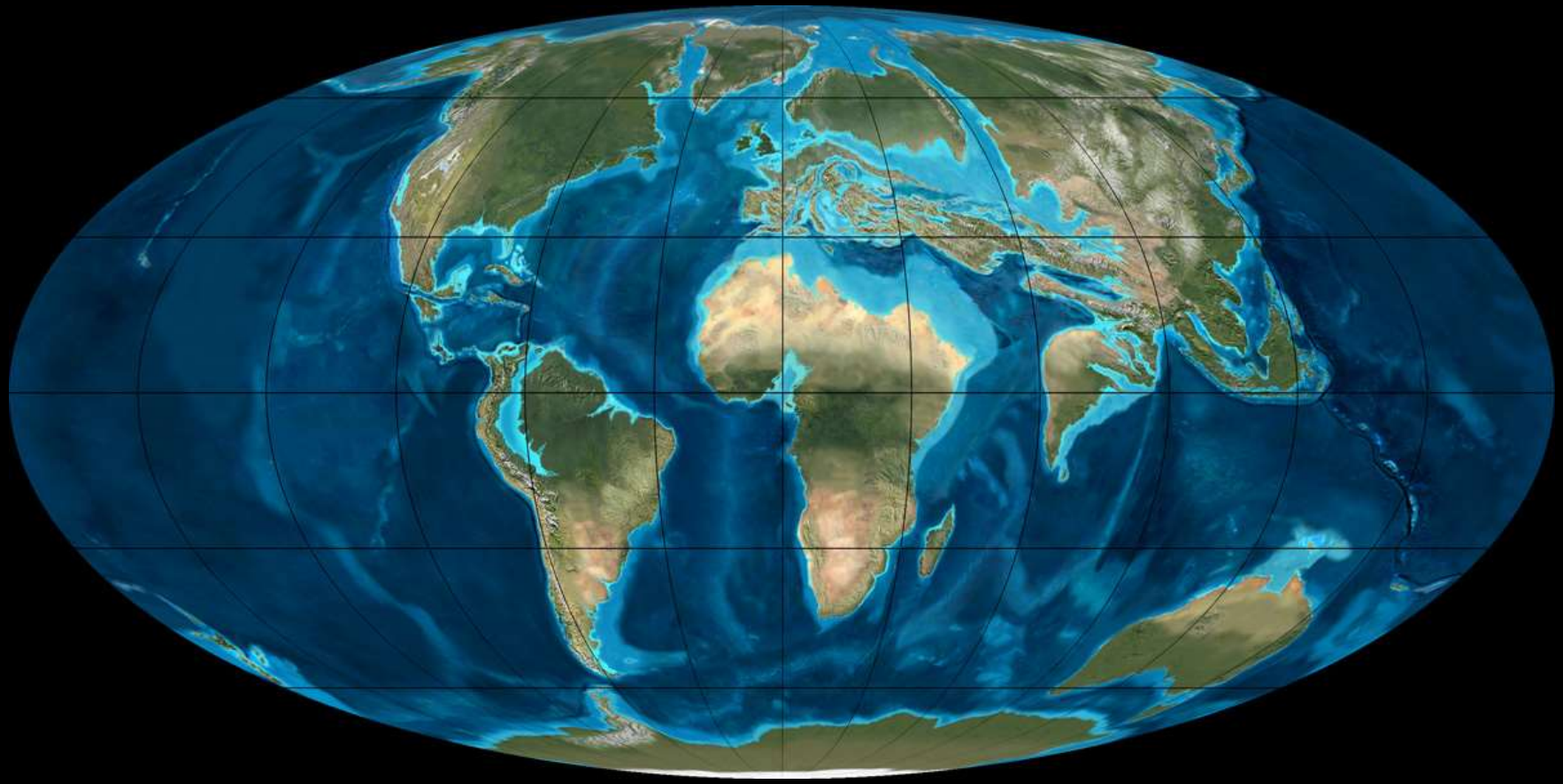


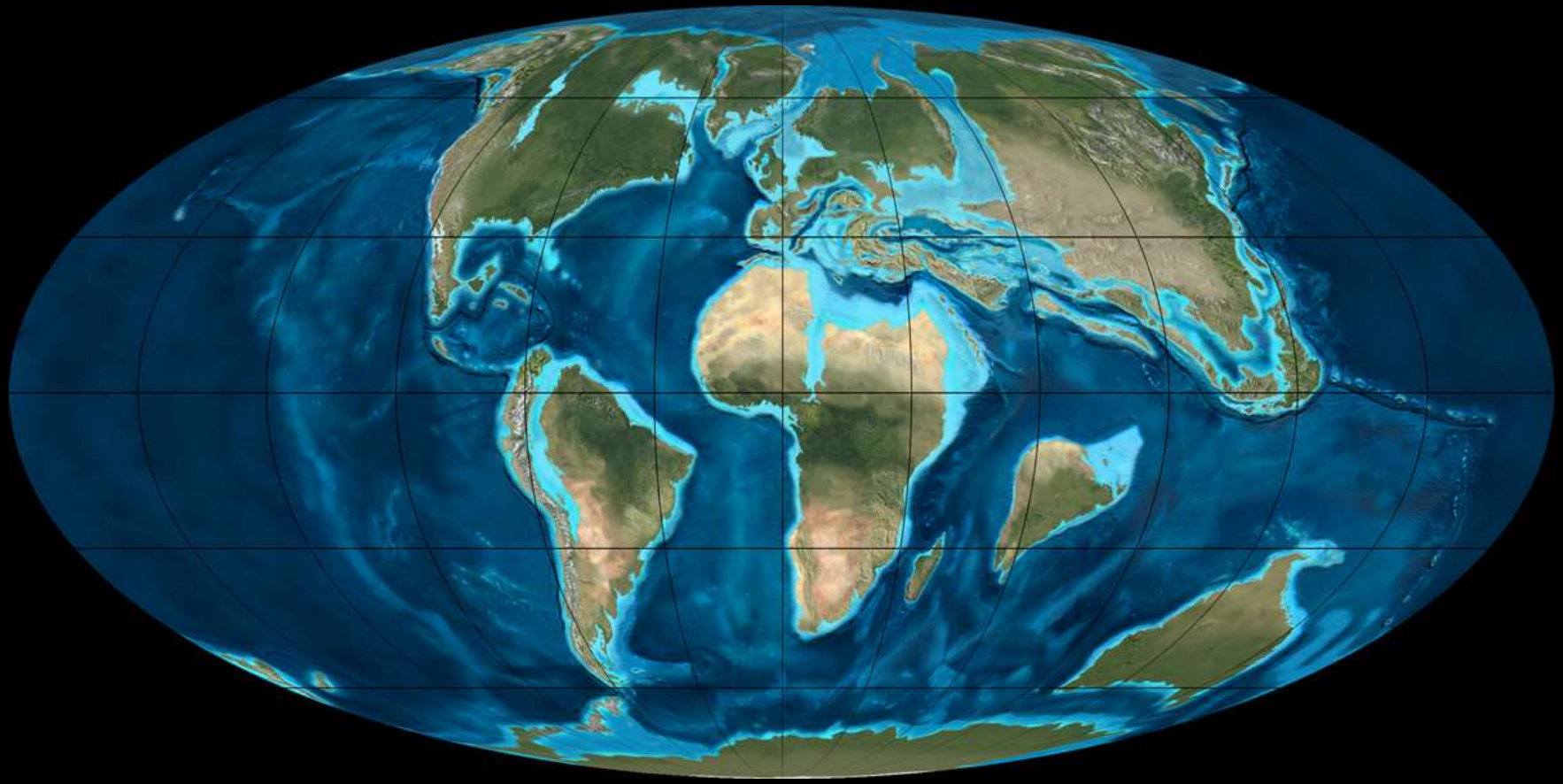


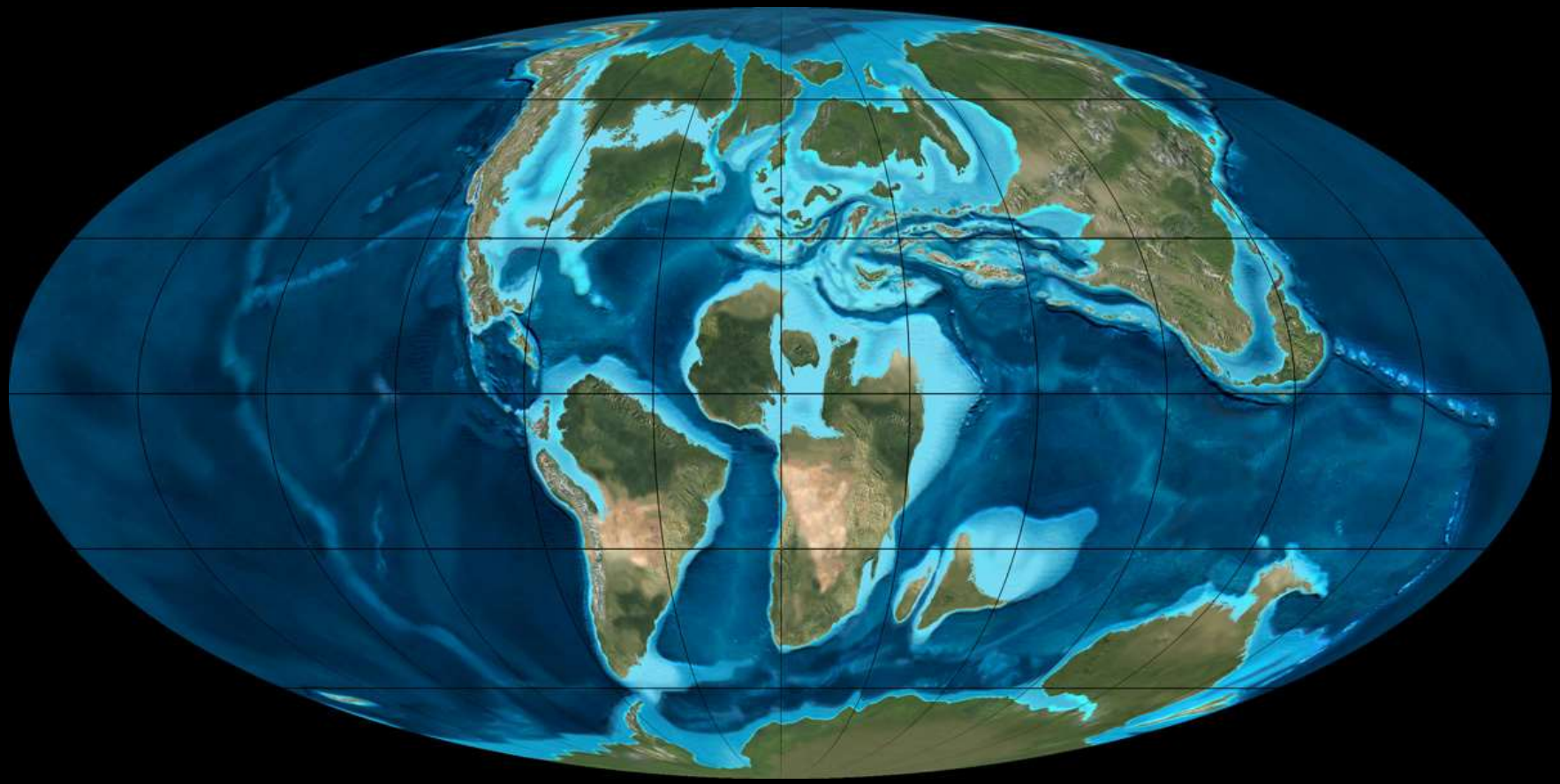




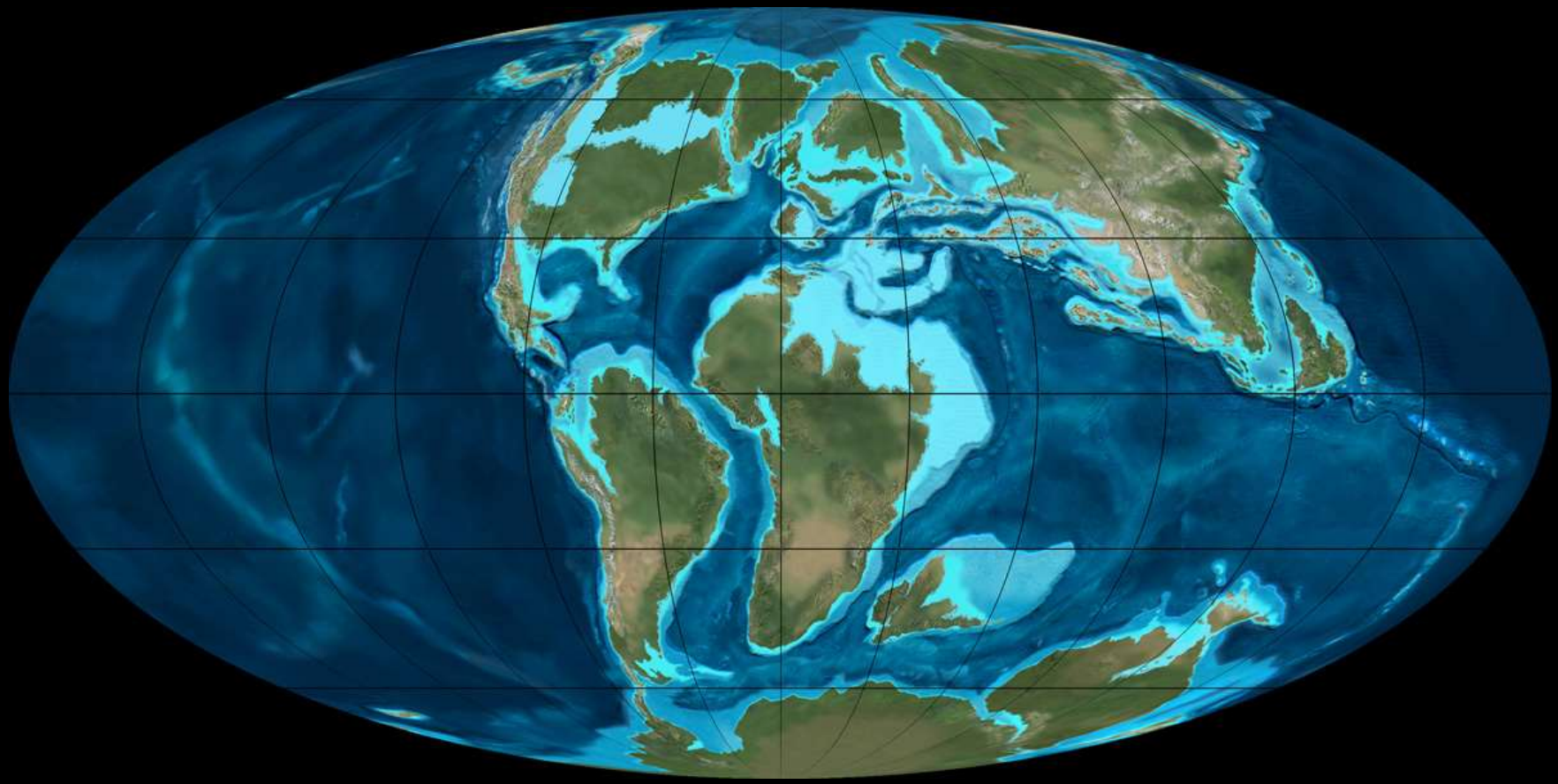
DOLOMITES GEODIVERSITY

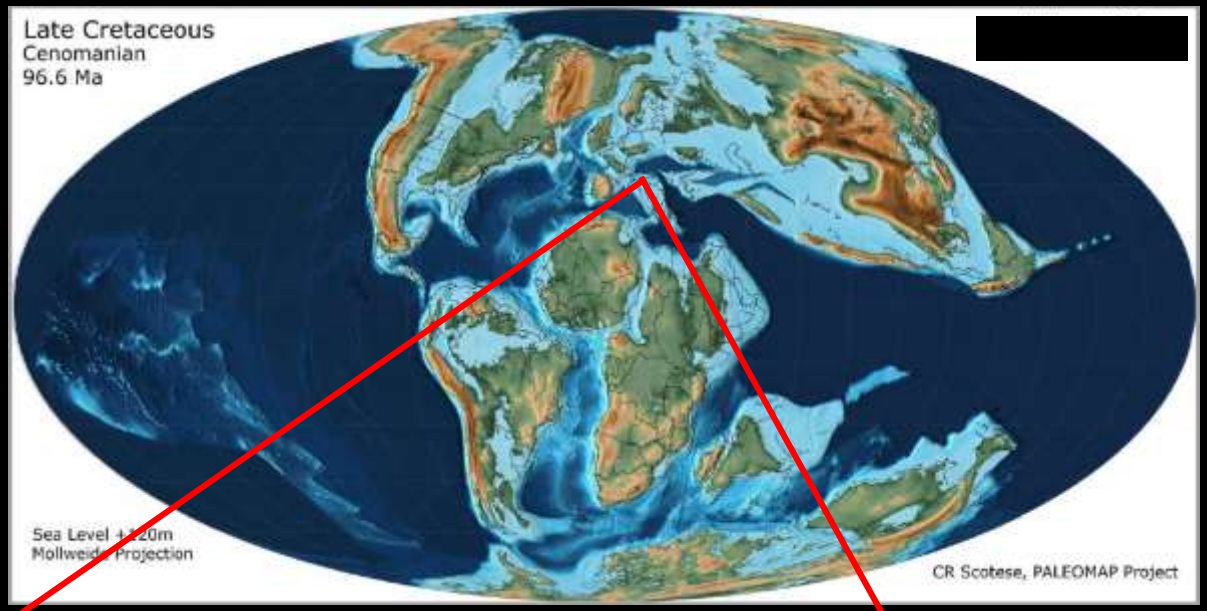




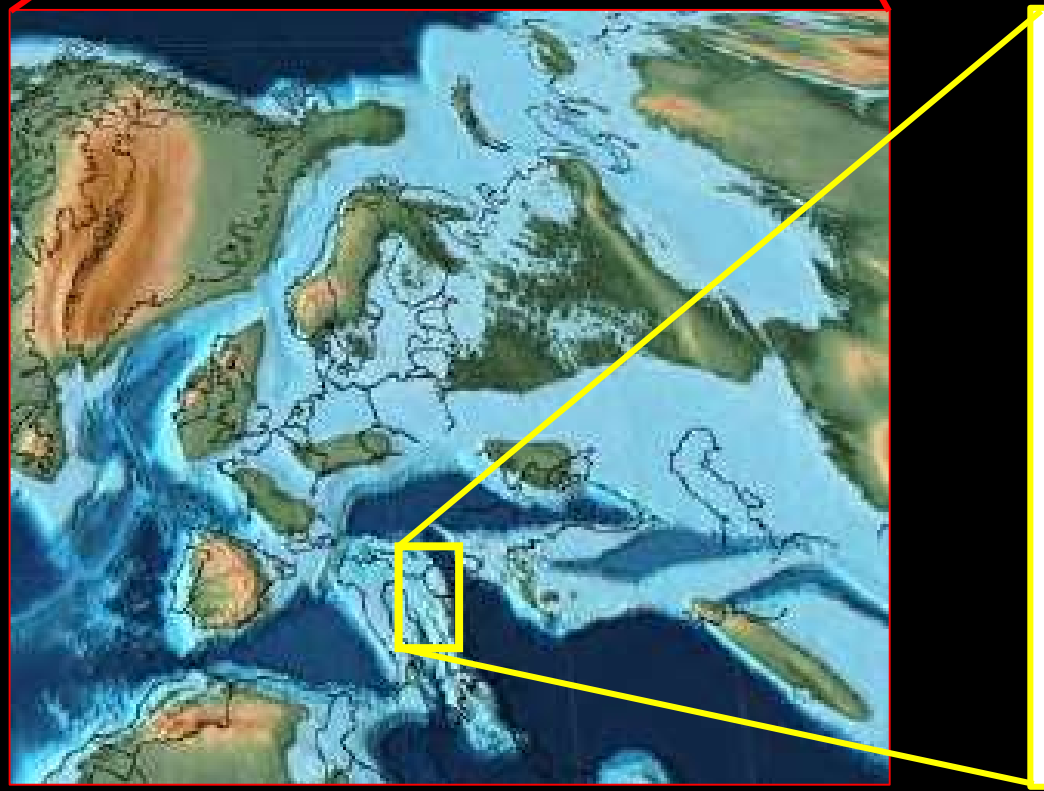


Circa 100 milioni di anni fa





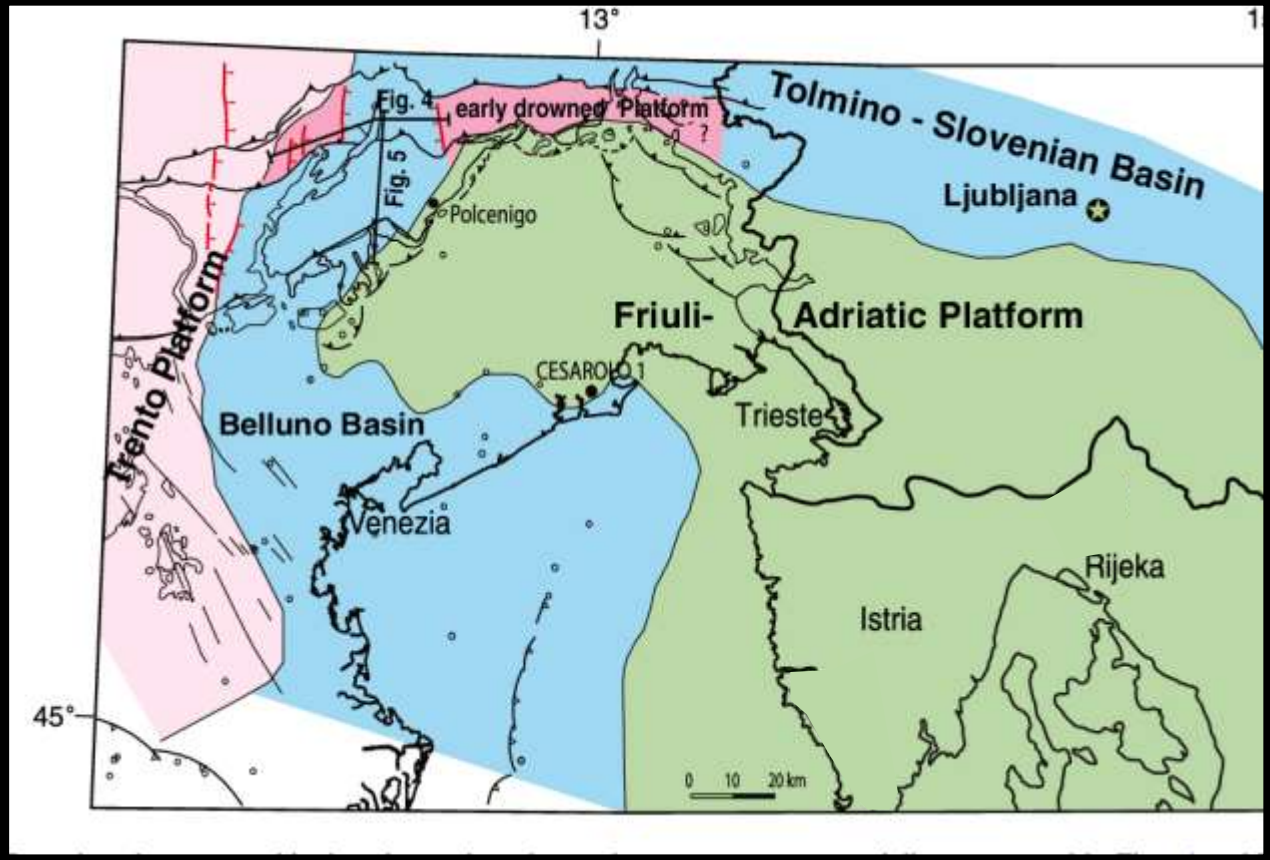
LA PIATTAFORMA CARBONATICA ADRIATICA



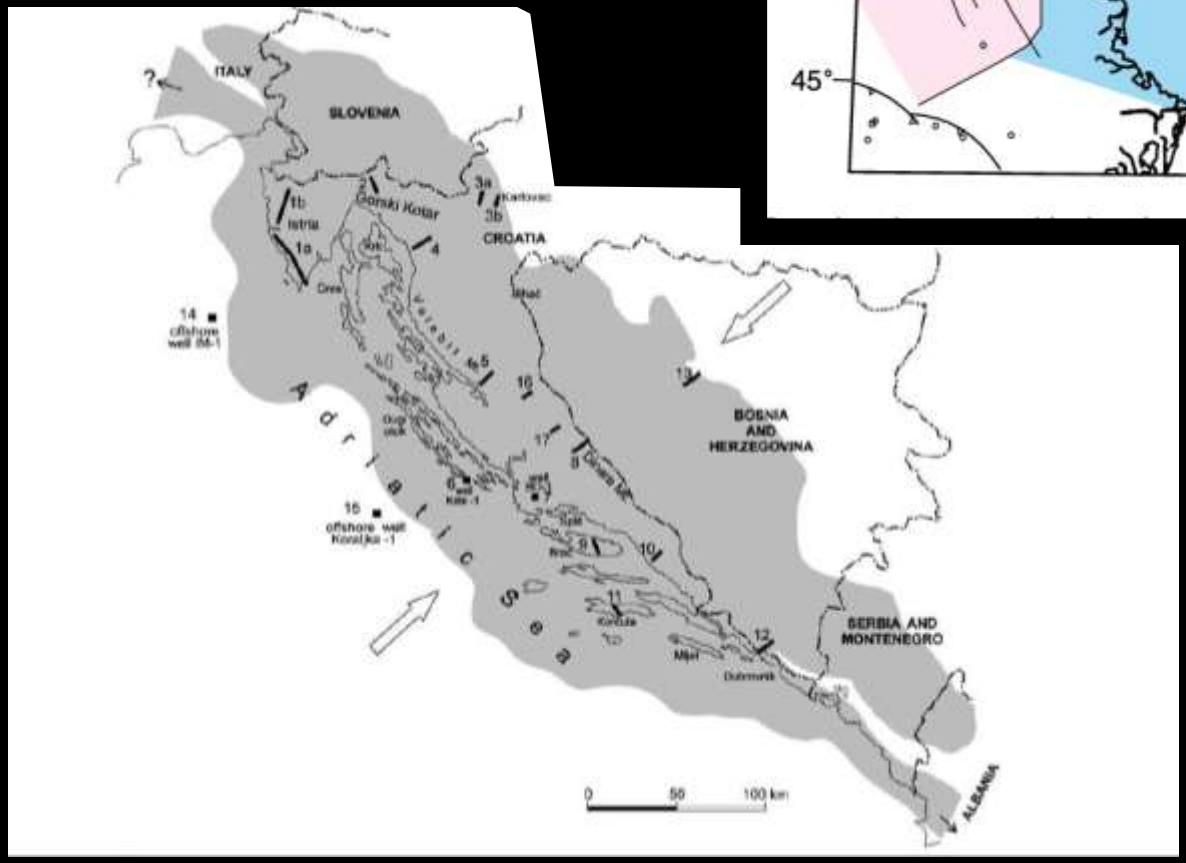
LA PIATTAFORMA CARBONATICA ADRIATICA

una grande piattaforma carbonatica che si sviluppo a partire dal Triassico sul margine passivo della Placca Africana

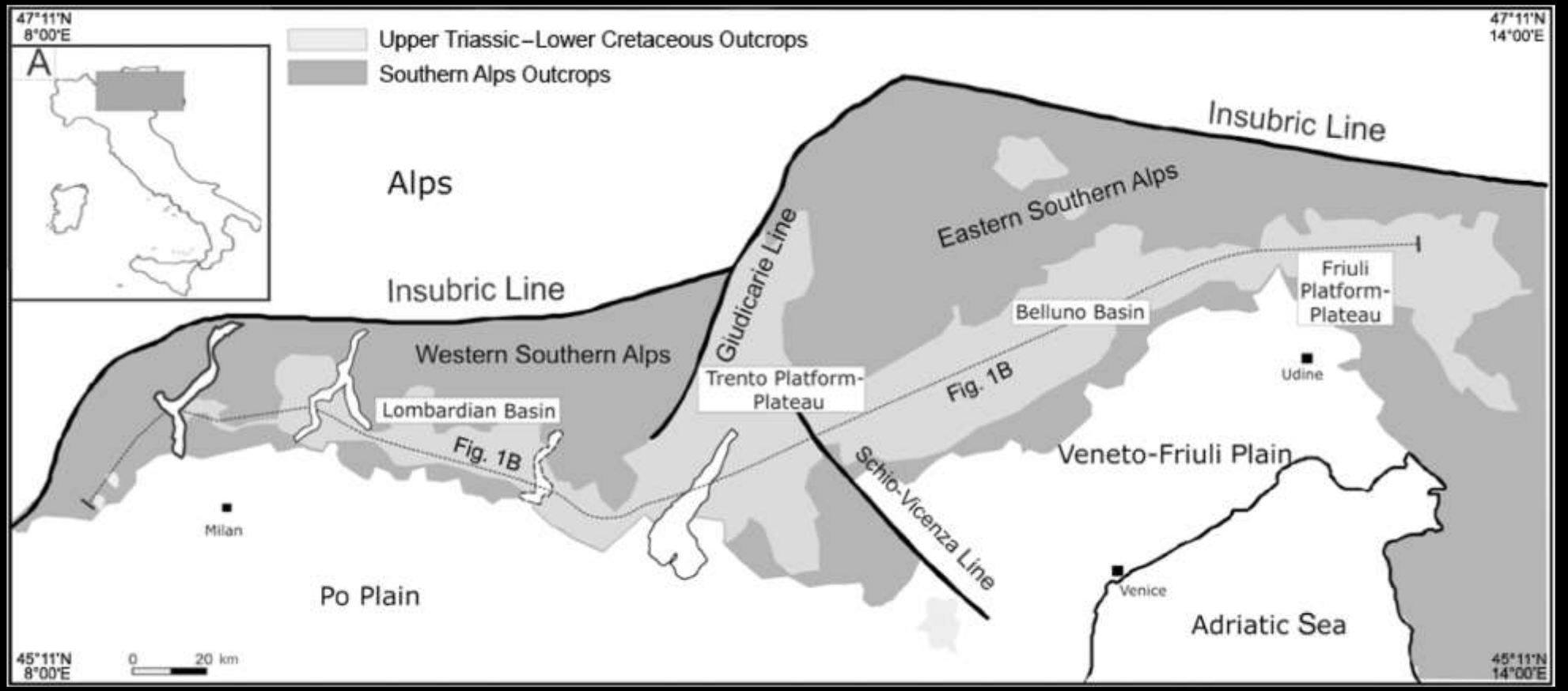
L'estremità nord-occidentale della Piattaforma Adriatica è chiamato anche **Piattaforma Friulana**

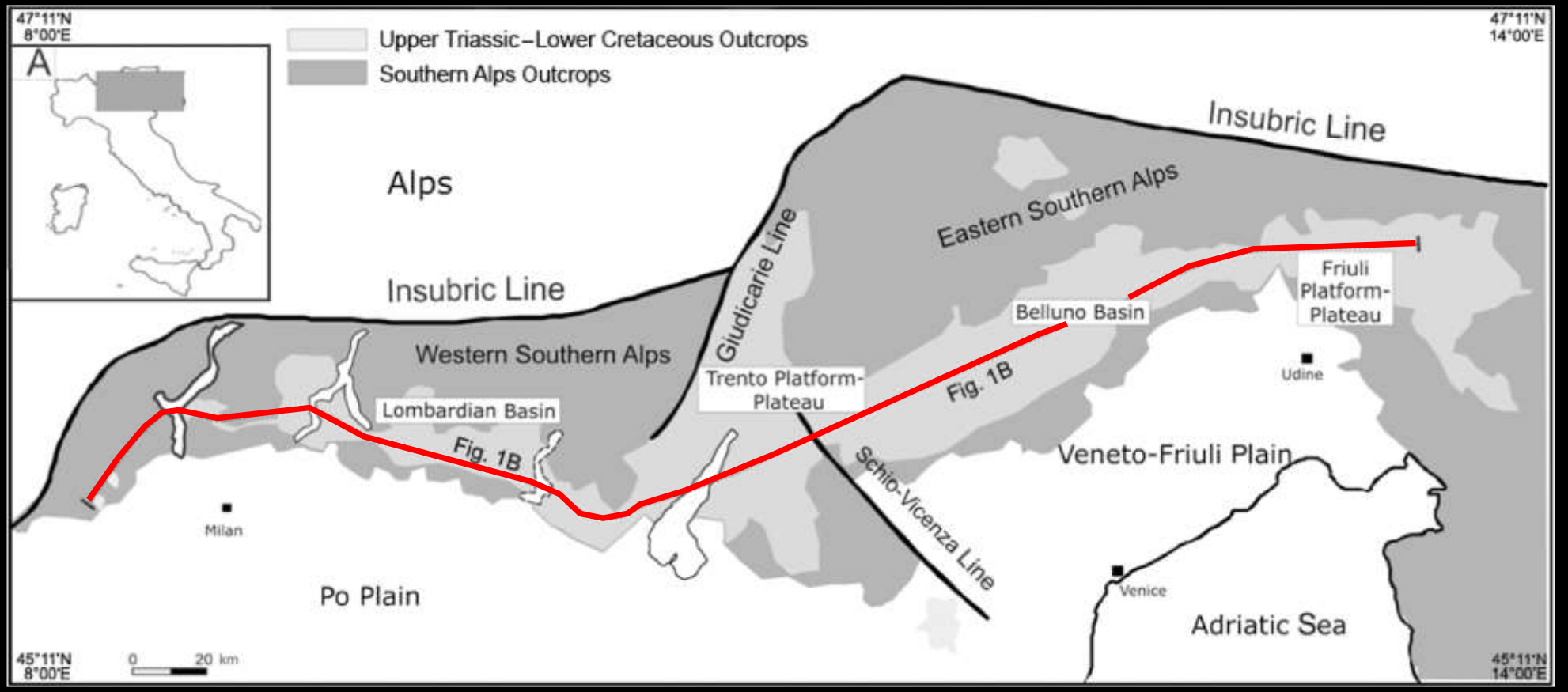


Modificato da Picotti e Cobianchi, 2017



da Vlahovic et al., 2005


47°11'N
8°00'E
47°11'N
14°00'E
A
Upper Triassic–Lower Cretaceous Outcrops
Southern Alps Outcrops
Alps
Insubric Line
Insubric Line
Eastern Southern Alps
Giudicarie Line
Friuli
Platform-
Plateau
Belluno Basin
Western Southern Alps
Trento Platform-
Plateau
Fig. 1B
Udine
Lombardian Basin
Fig. 1B
Veneto-Friuli Plain
Schio-Vicenza Line
Milan
Venice
Po Plain
Adriatic Sea
45°11'N
8°00'E
0
20 km
45°11'N
14°00'E


47°11'N
8°00'E
47°11'N
14°00'E
A
Upper Triassic–Lower Cretaceous Outcrops
Southern Alps Outcrops
Alps
Insubric Line
Insubric Line
Eastern Southern Alps
Giudicarie Line
Western Southern Alps
Belluno Basin
Friuli
Platform-
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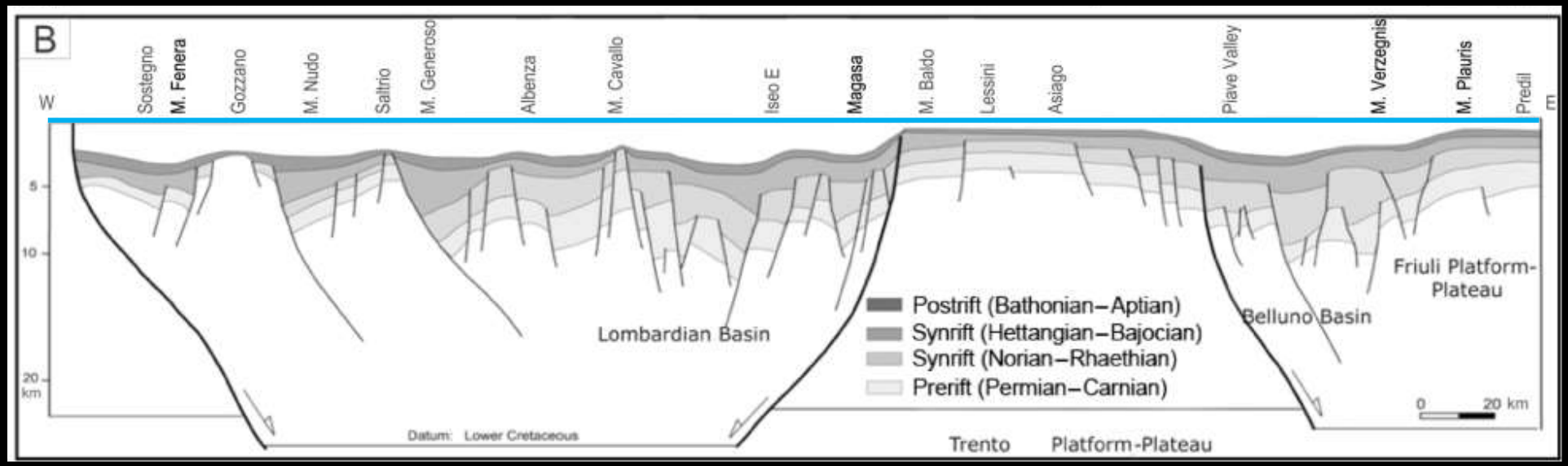
0
20 km
45°11'N
14°00'E

Bacino Lombardo

Piattaforma di Trento

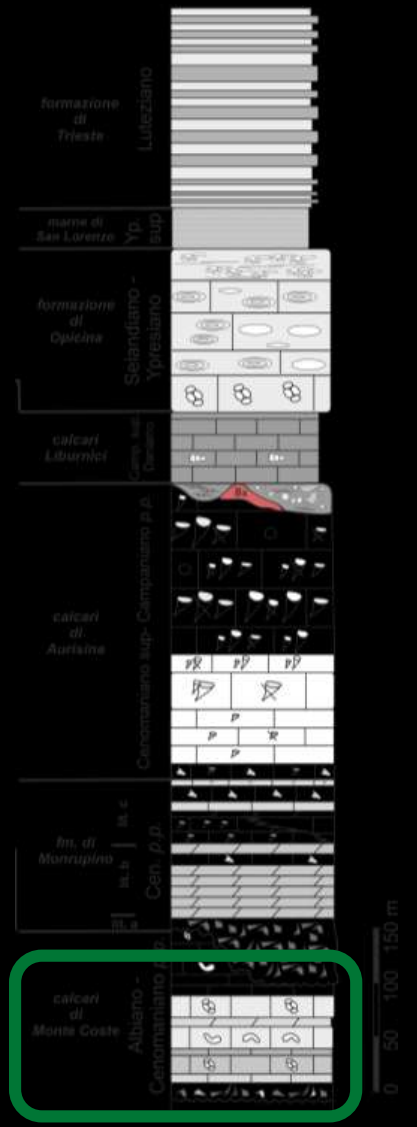
Bacino di Belluno

Piattaforma Friulana



CALCARI DI MONTE COSTE

calcari da grigio a grigio-scuro e nerastri, a matrice fangosa in facies prevalentemente di tipo wackestone, caratterizzati da frequenti **accumuli di piccoli foraminiferi bentonici (miliolidi)** depositati in un ambiente lagunare nella piattaforma interna della Piattaforma Adriatica



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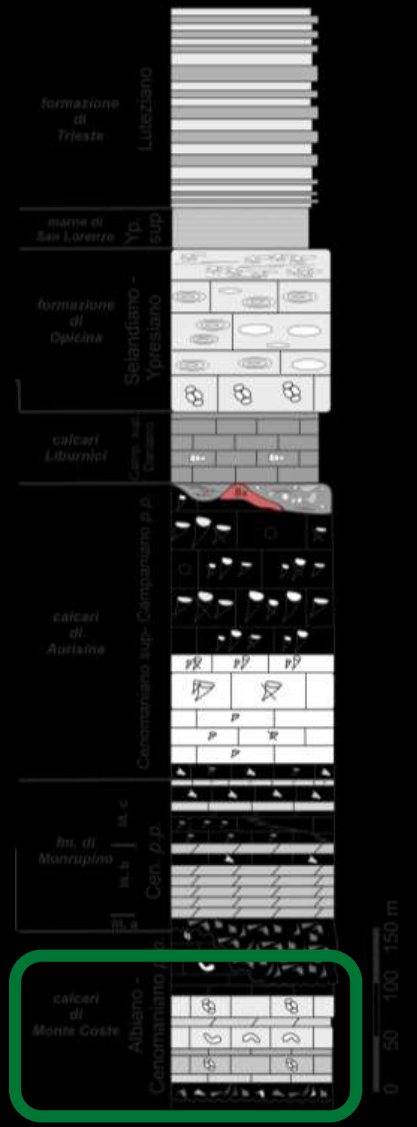

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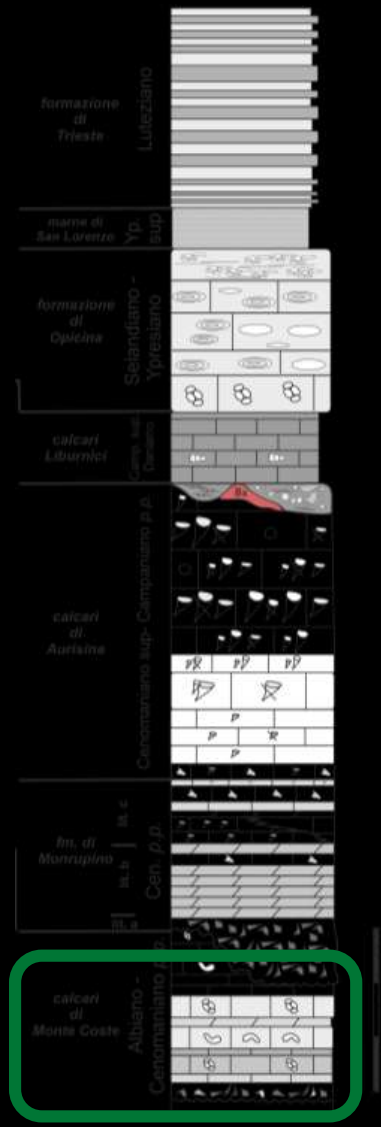
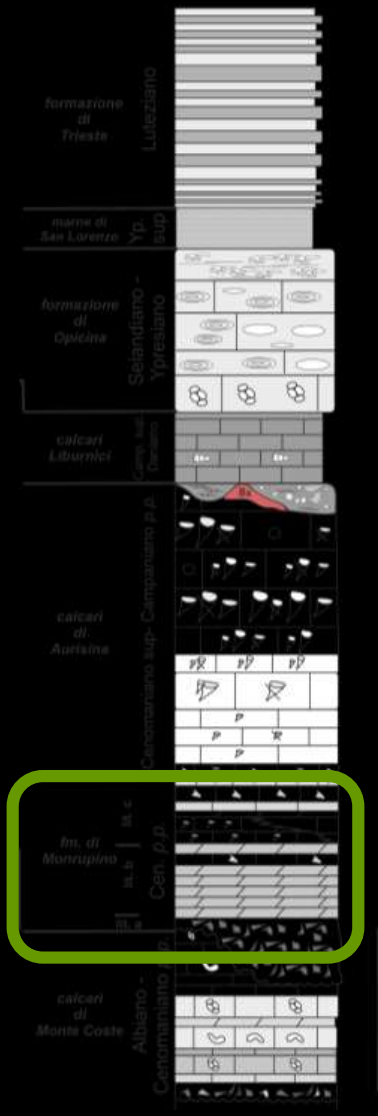
Sezione sottile di calcari di Monte Coste in cui si nota l'abbondanza di foraminiferi miliolidi

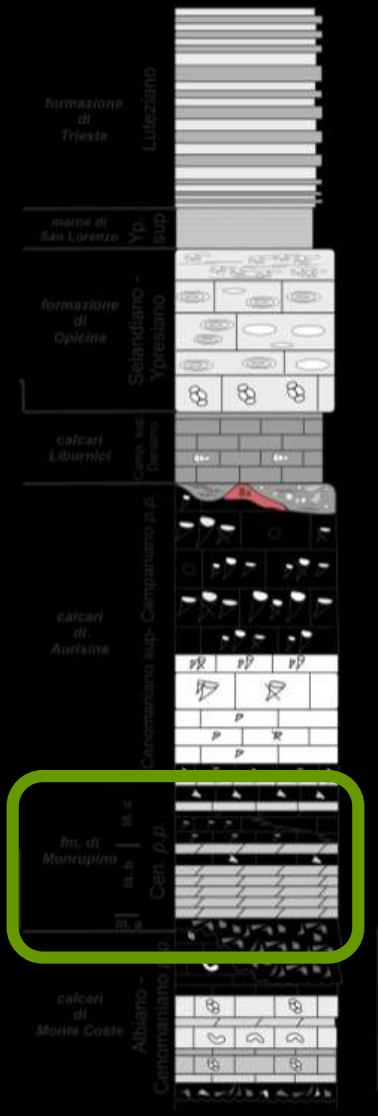


FM. DI MONRUPINO

La base della fm. di Monrupino è caratterizzata da un potente intervallo costituito da brecce dolomitiche mongeniche e poligeniche.
Testimoniano un importante evento di esposizione subaerea della piattaforma carbonatica

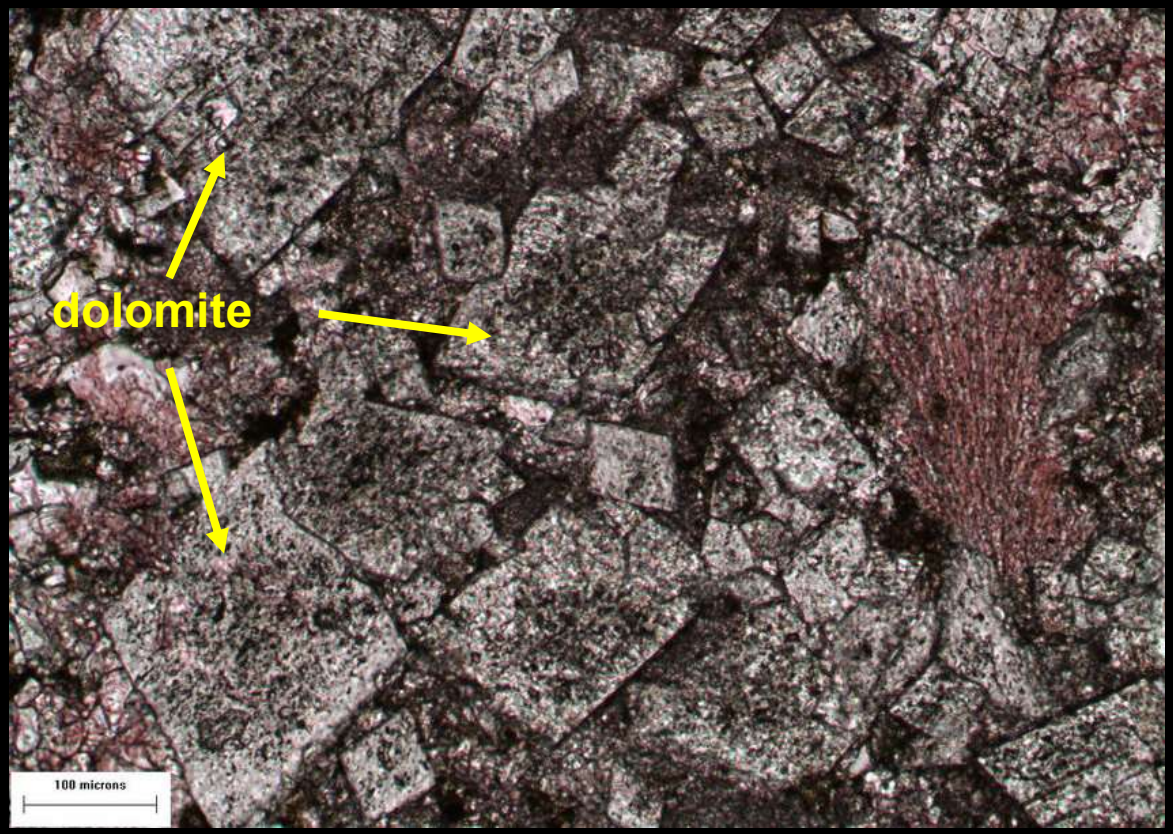


FM. DI MONRUPINO

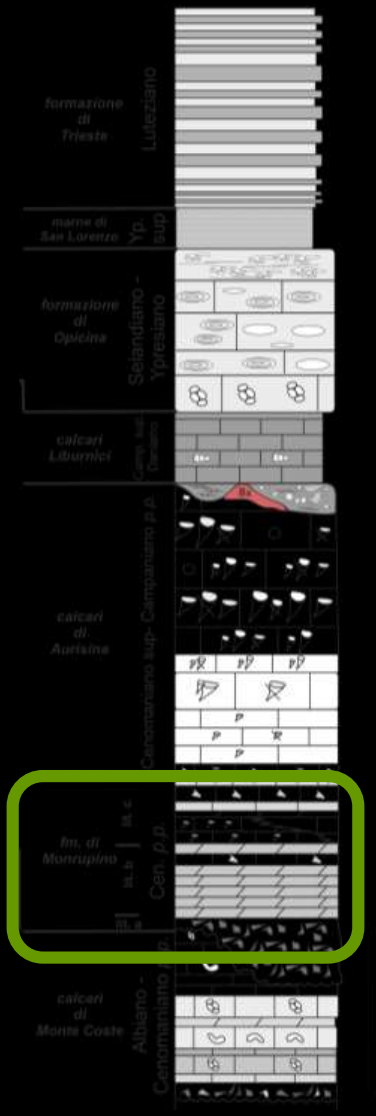


Brecce poligeniche alla base della fm. di Monrupino intercettate in un pozzo perforato nei pressi di Jamiano.

FM. DI MONRUPINO



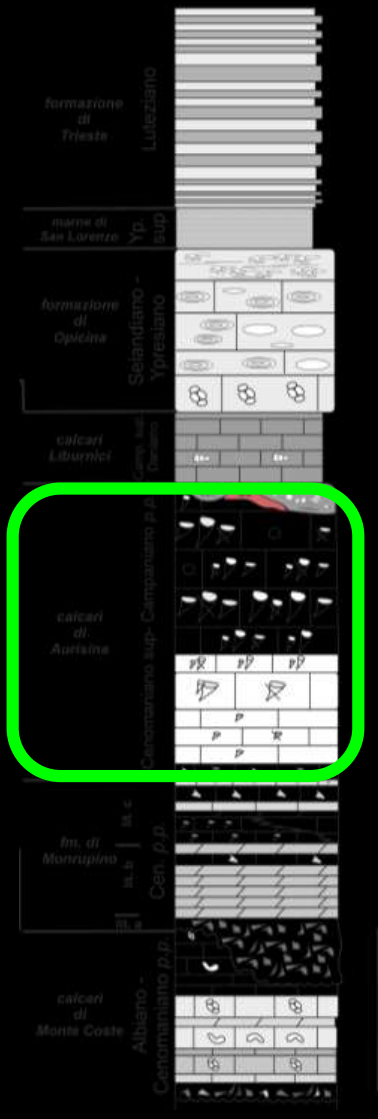
La parte sommitale dei Calcari di Monte Coste è in realtà costituita da un potente livello di calcari dolomitici e dolomie (in letteratura deominate Formazione di Monrupino)



CALCARI DI AURISINA

calcari bioclastici da grigio-chiari a grigio-scuri, in facies prevalente di tipo packstone o floatstone. Caratteristici sono i gusci appartenenti a **grandi bivalvi tipo rudiste.**

I C. di Aurisina rappresentano ancora la deposizione carbonatica in ambiente di piattaforma interna, caratterizzato da frequenti eventi di tempesta che portavano alla formazione di accumuli bioclastici.



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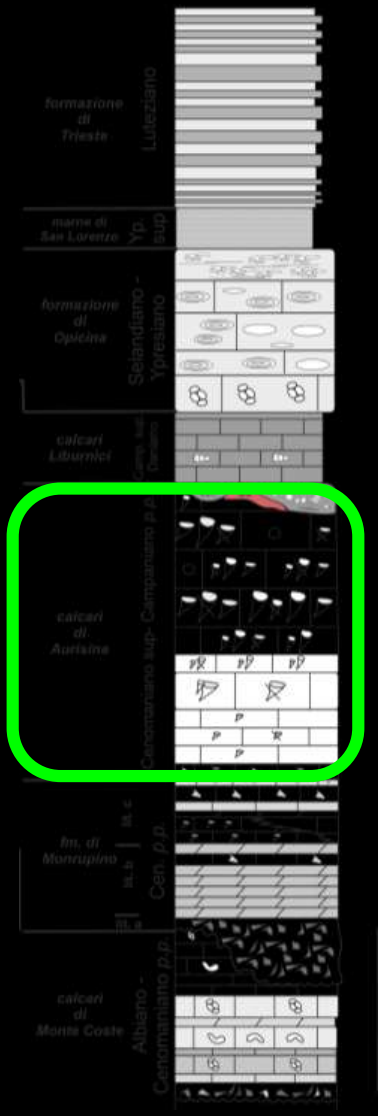

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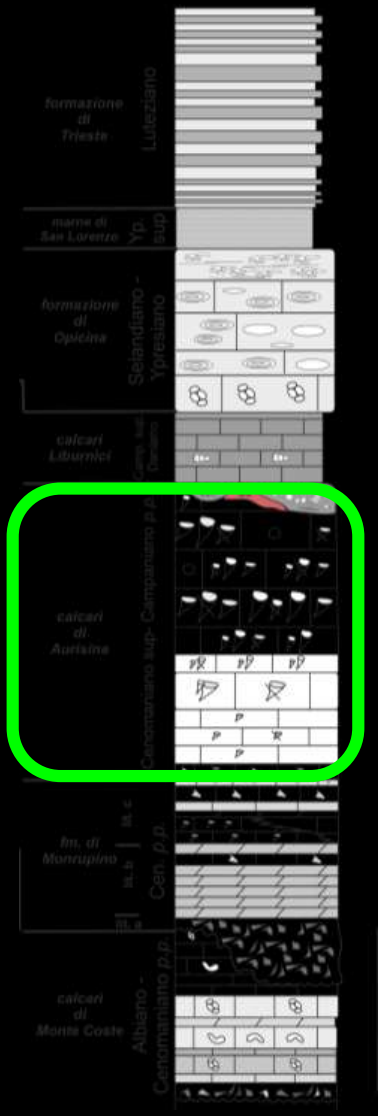

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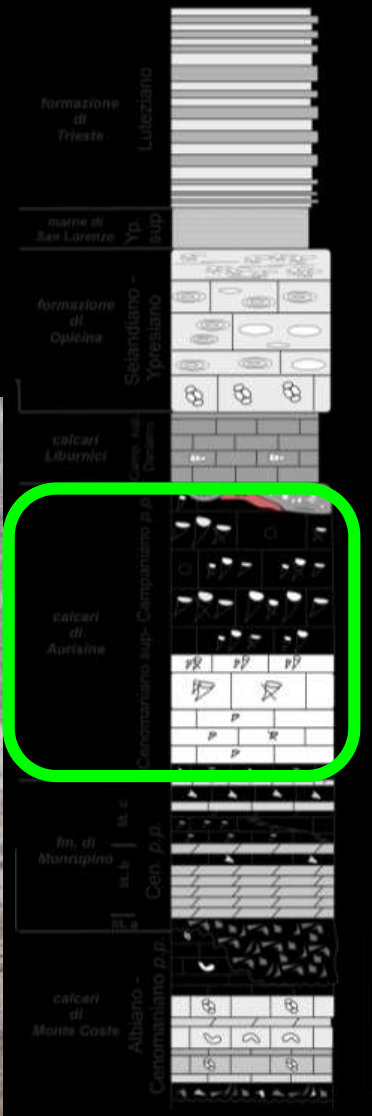
Rudista radiolitide

Chondrodonta

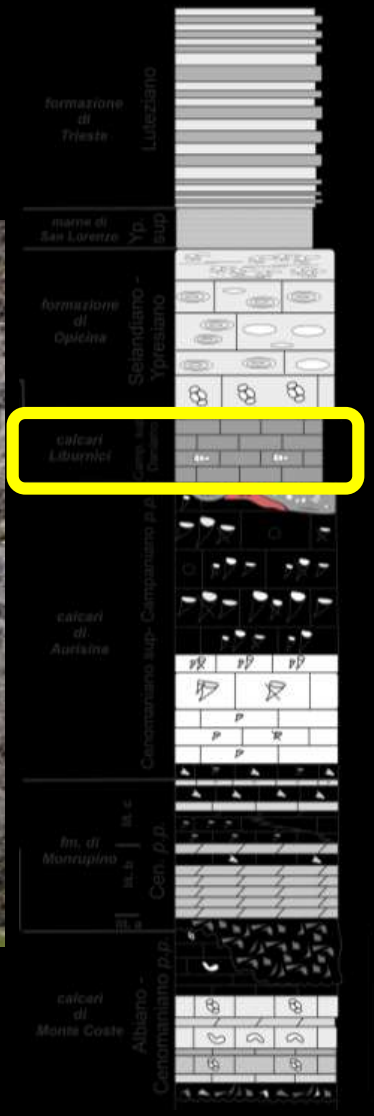
Rudista hippuritide



CALCARI LIBURNICI

calcari a matrice fangosa di colore molto scuro (dal marrone al grigio scuro) in facies tipo wackestone o mudstone. Frequenti sono gli accumuli di organismi bentonici (foraminiferi, ostracodi, gasteropodi, alghe dasicladali, coralli solitari) e le **evidenze di ambiente paralico quali presenza di Microcodium**.

Calcari Liburnici nella sezione di Padriciano



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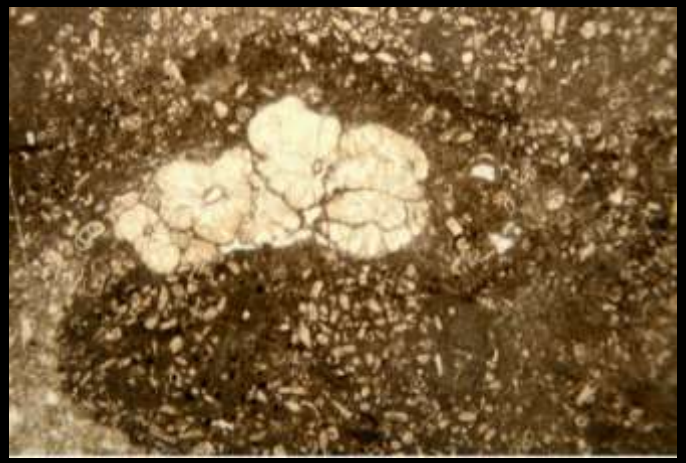
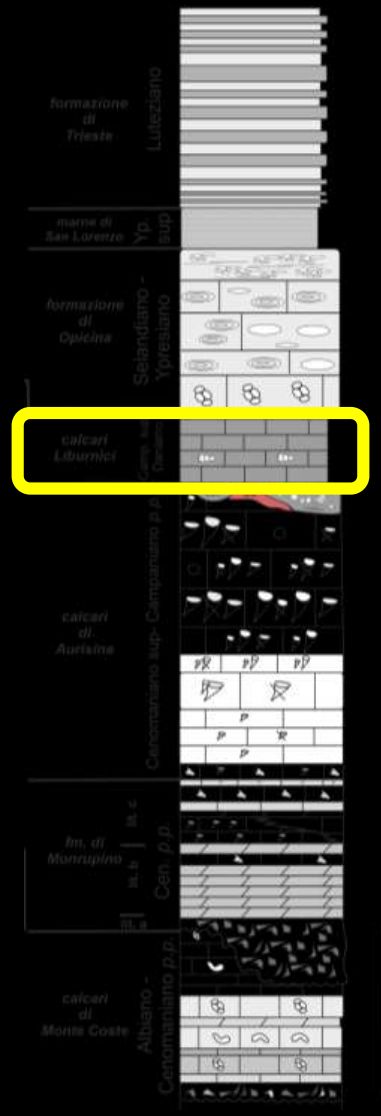


Microcodium nei C. Liburnici



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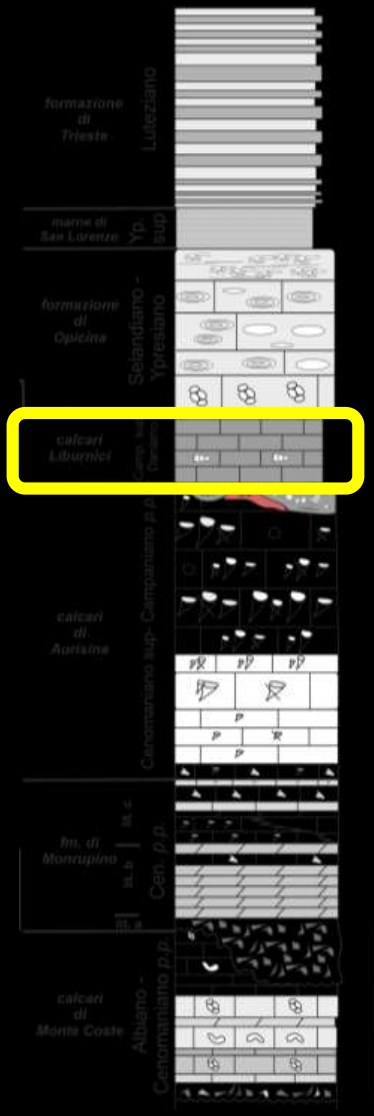
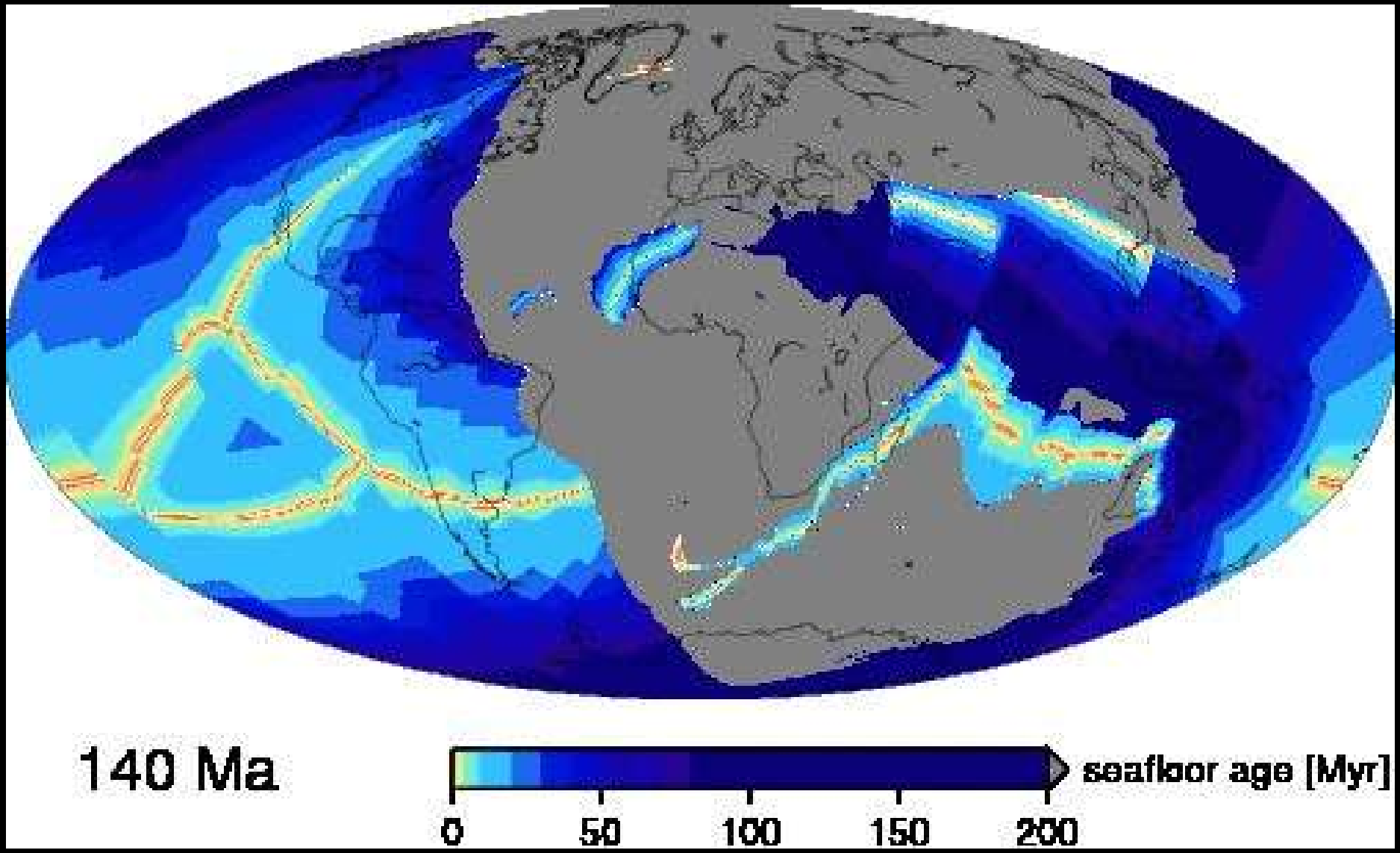
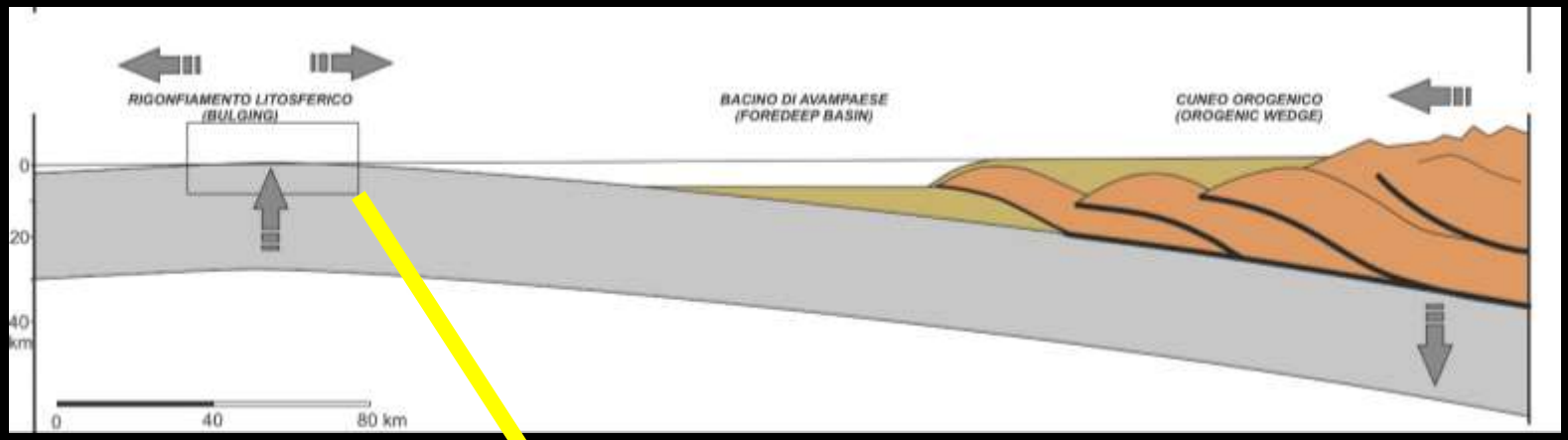


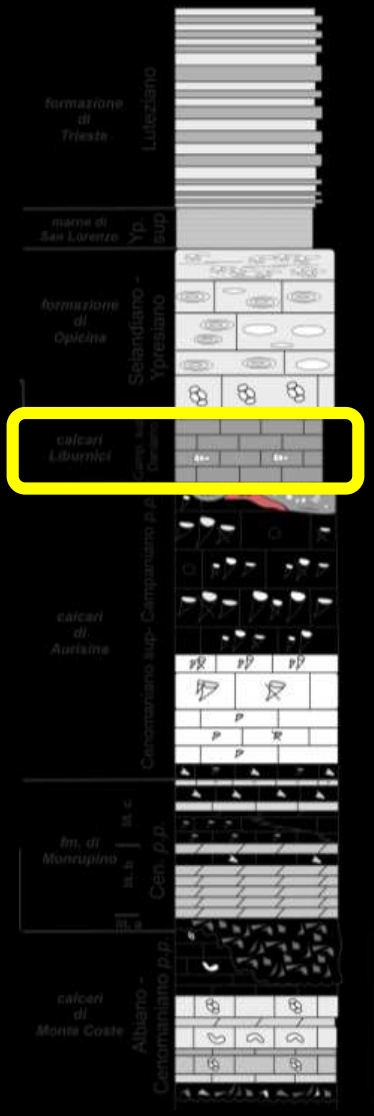

140 Ma
seafloor age [Myr]
0
50
100
150
200

CALCARI LIBURNICI

I Calcari Liburnici sono l'espressione di un significativo cambiamento nella sedimentazione carbonatica sulla Piattaforma Adriatica: un abbassamento del livello marino dovuto all'inizio della significativa influenza del sollevamento della Catena Dinarica.

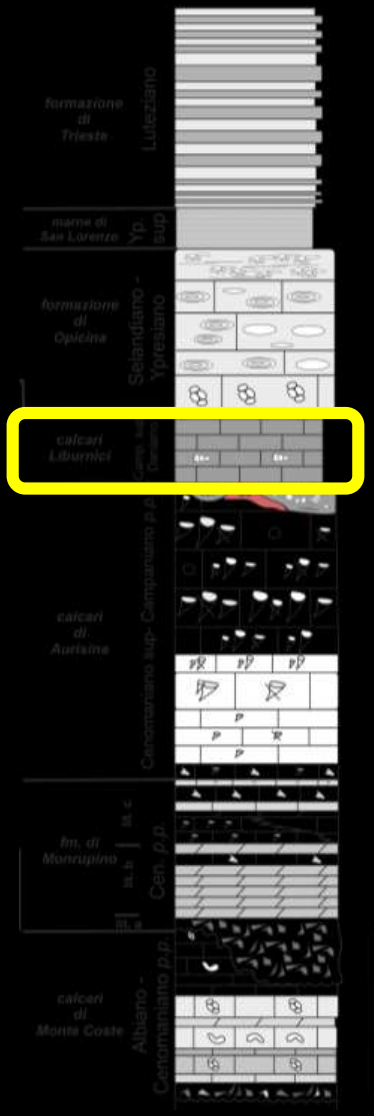


Deposizione dei C. Liburnici



CALCARI LIBURNICI

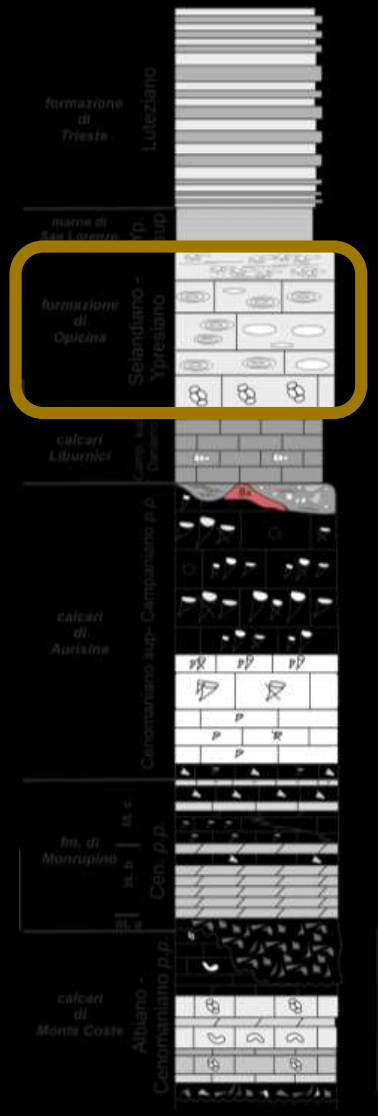
All’interno dei Calcari Liburnici è inoltre registrato il limite Cretaceo – Paleogene (K/Pg).
Questo momento della storia geologica è caratterizzato da una importante estinzione di massa di numerose forme terrestri (p.es. i dinosauri) e marine (p.es. le rudiste, ammoniti…)



FM. DI OPCINA

Calcari caratterizzati dalla presenza di **foraminiferi bentonici miliolidi, nummulitidi e alveolinidi**, a volte molto grandi e visibili a occhio nudo. Sporadici sono livelli di alghe dasicladali e coralli.

Fm. di Opicina nella Cava Scoria presso Trieste



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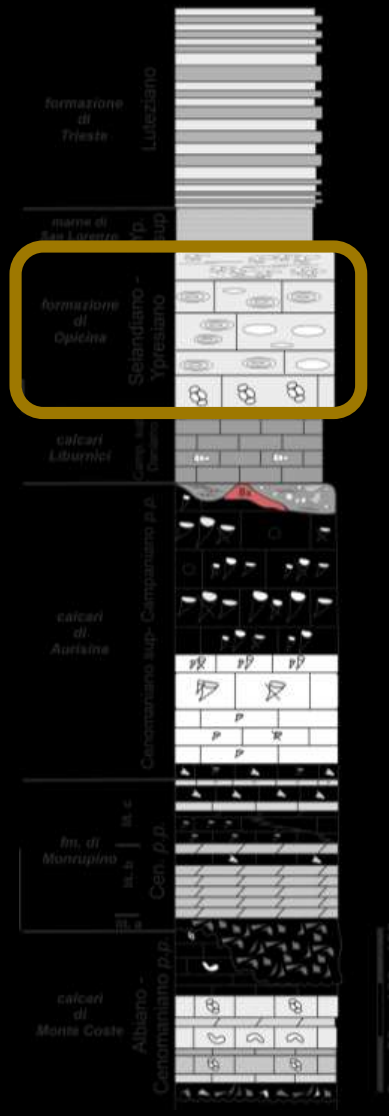

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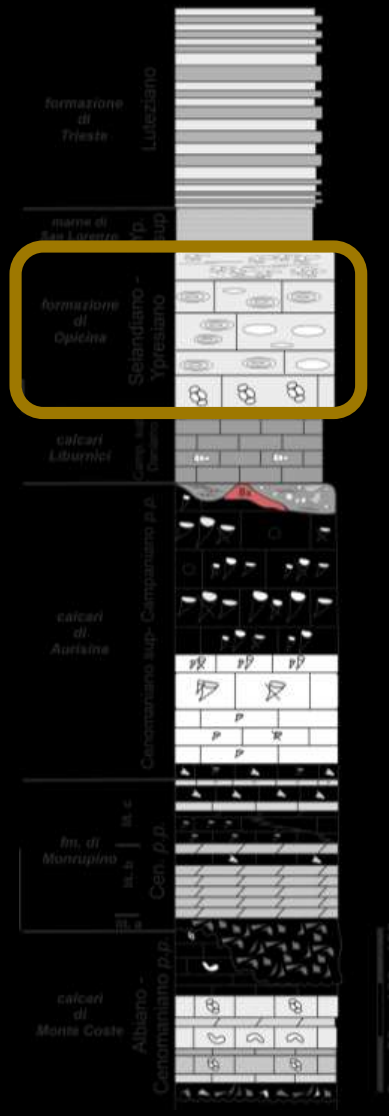
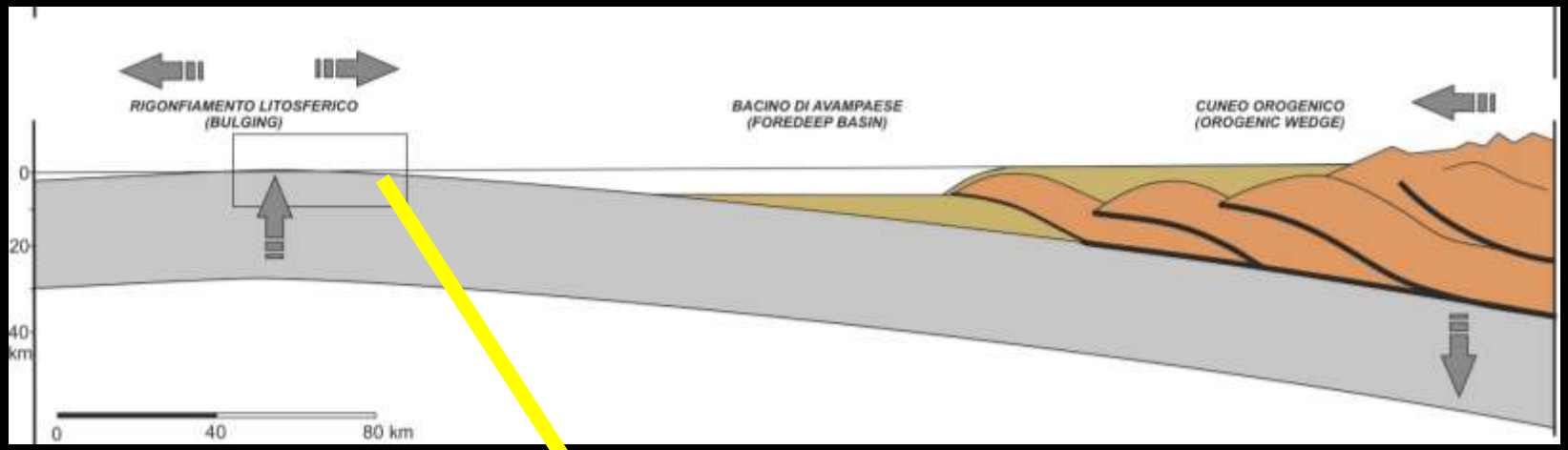


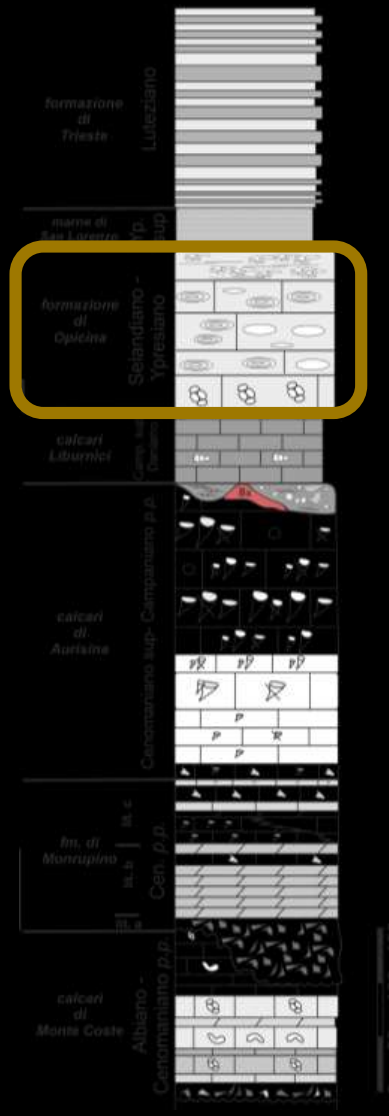
FM. DI OPCINA

I C. ad Alveoline e Nummuliti testimoniano una nuova fase dell'evoluzione sedimentaria.

Attecchisce una nuova generazione di piattaforme carbonatiche dovuto a un innalzamento del livello marino dovuto all'avanzare dell'avanfossa della Catena Dinarica.



piattaforma della fm. di Opicina



fm. di Opicina

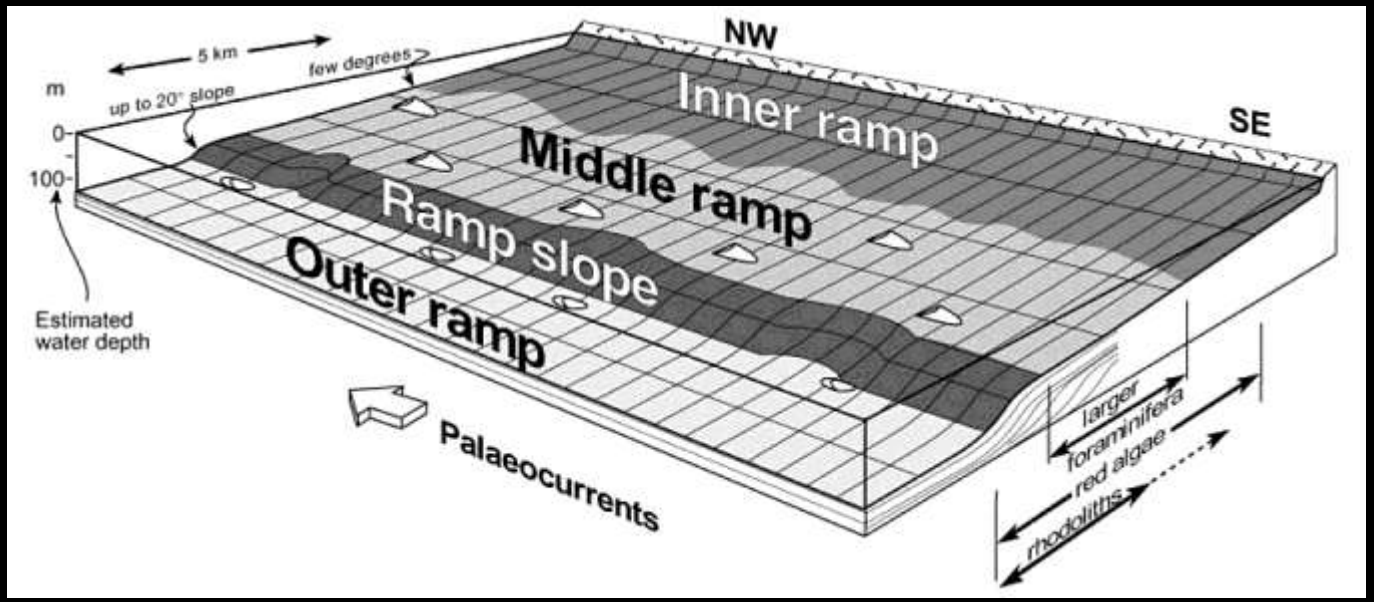
ATTENZIONE

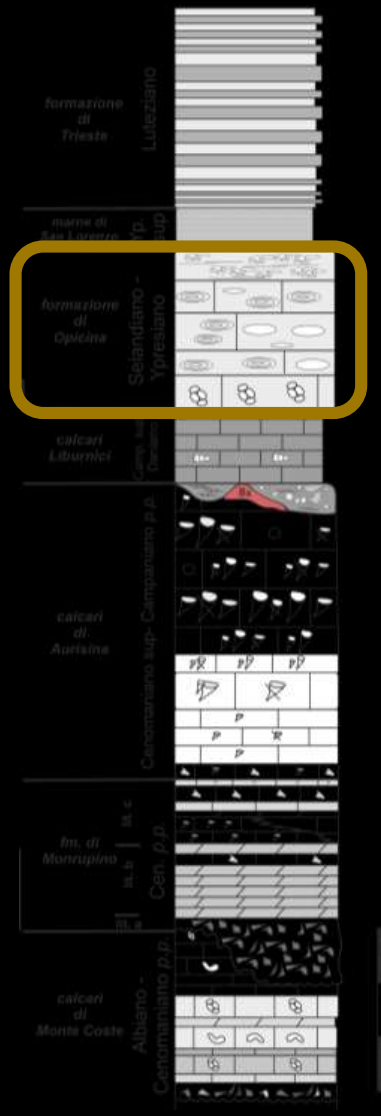
La *carbonate factory* nella piattaforma della fm. di Opicina era in prevalenza dominata da una precipitazione del carbonato ad opera di organismi eterotrofi (foraminiferi).

Una delle conseguenze di questa differenza è che la piattaforma:

- Produceva meno carbonato di quanto dominavano le rudiste

- Aveva geometria deposizionale cosiddetta ‘a rampa’





MARNE DI SAN LORENZO

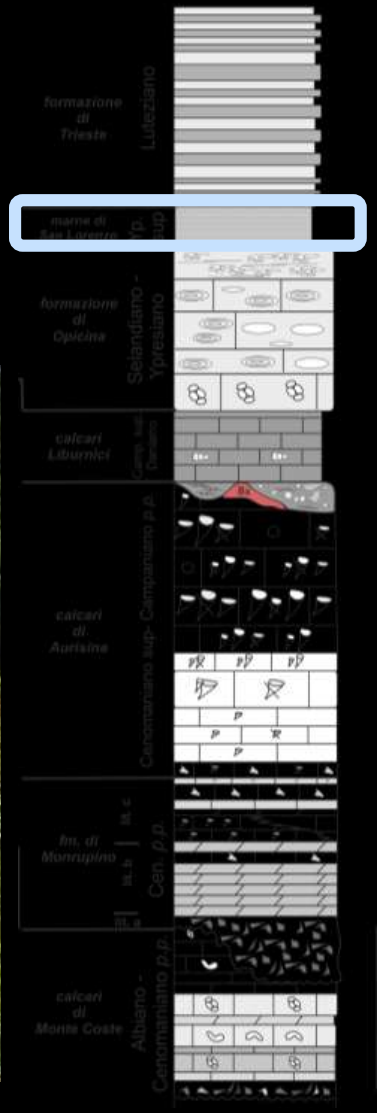
Questa unità può essere divisa in due parti.

Al tetto la fm. di Opicina si trovano brecce/conglomerati a clasti calcarei da angolosi a sub-arrotondati a cui seguono marne e calcari marnosi con foraminiferi planctonici globigerinidi e calcareniti.

Le marne sono riferibili ad un ambiente marino profondo caratterizzato da apporti terrigeni. Contengono nannofossili calcarei (ambiente pelagico).

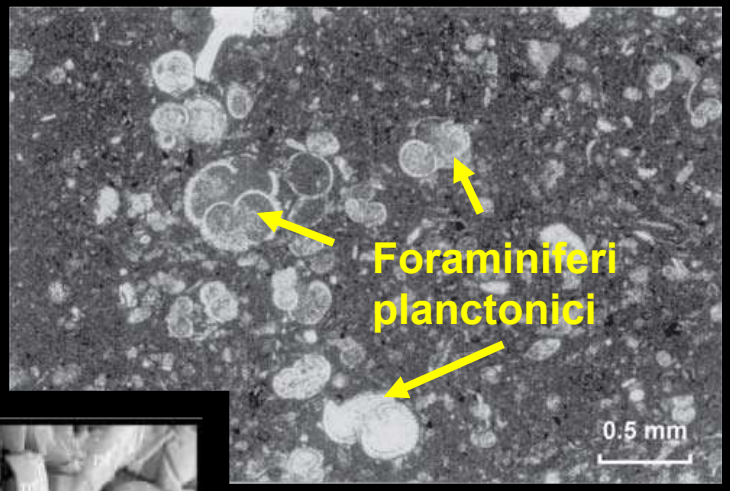
Conglomerati calcarei al tetto della fm di Opicina

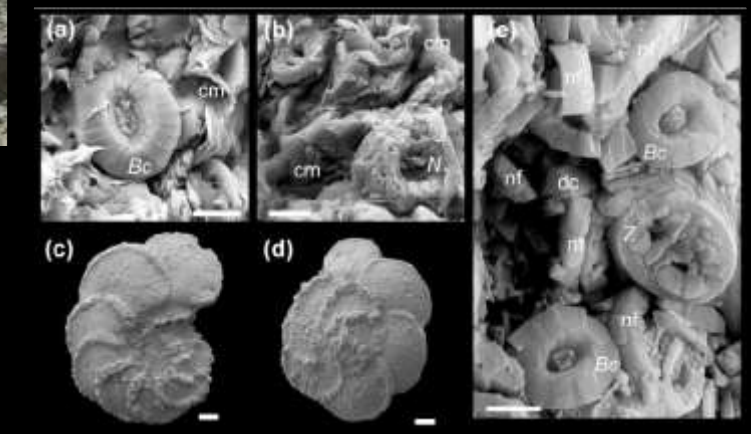
Marne di San Lorenzo



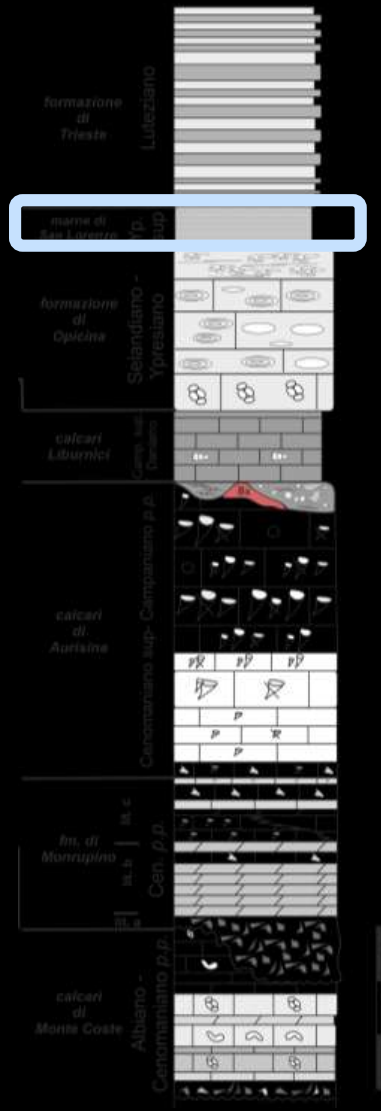
MARNE DI SAN LORENZO

Le marne contengono **foraminiferi planctonici e nannofossili**, a testimonianza di un netto approfondimento dell'ambiente sedimentario.





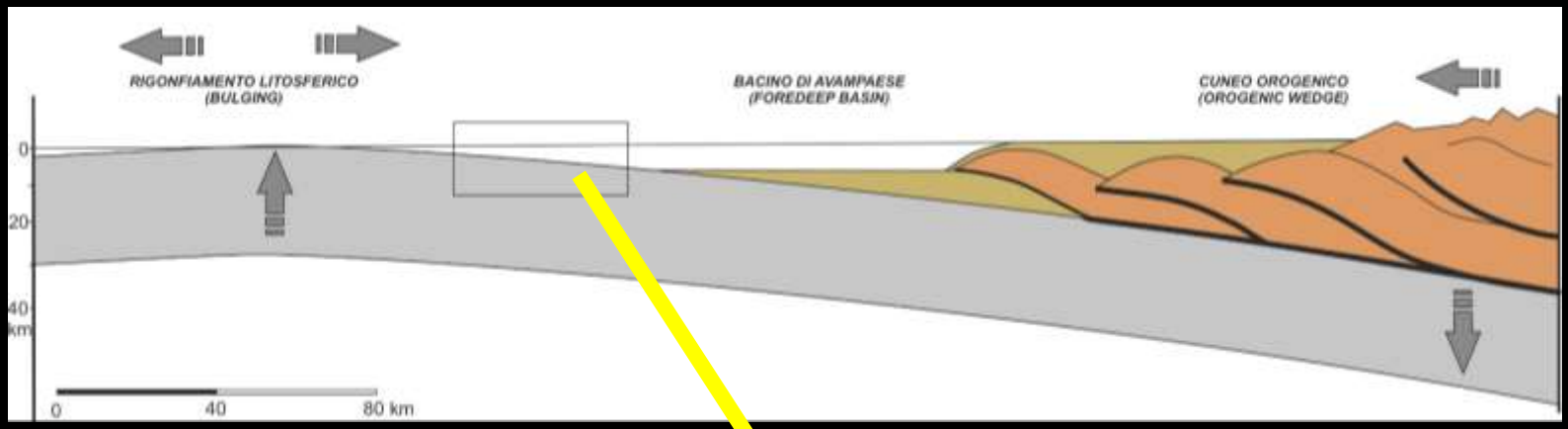
nannofossili



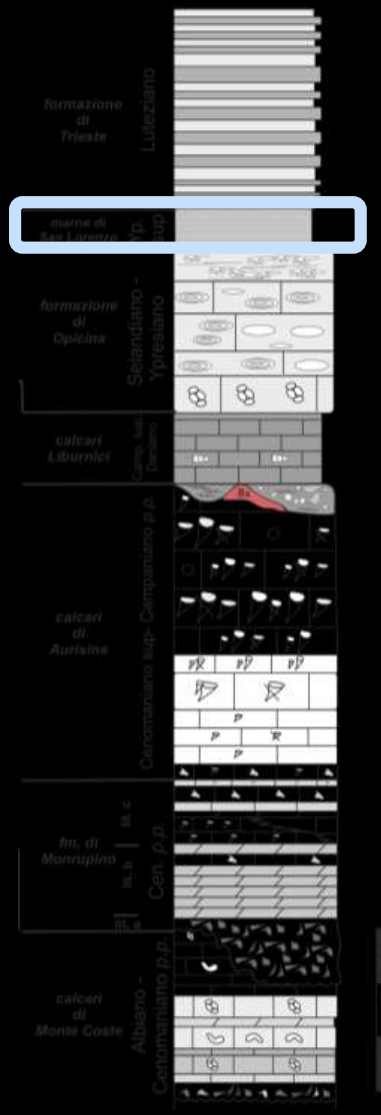
MARNE DI SAN LORENZO

Il contatto tra le marne di San Lorenzo e la fm. di Opicina è brusco e testimonia un netto approfondimento dell'ambiente sedimentario che passa da mare basso a mare profondo.
Questo testimonia l'annegamento della piattaforma dove depositavano i calcari della fm. di Opicina.

Una delle cause di questo annegamento è sicuramente il forte aumento della subsidenza dovuto all'approfondirsi dell'avanfossa dinarica

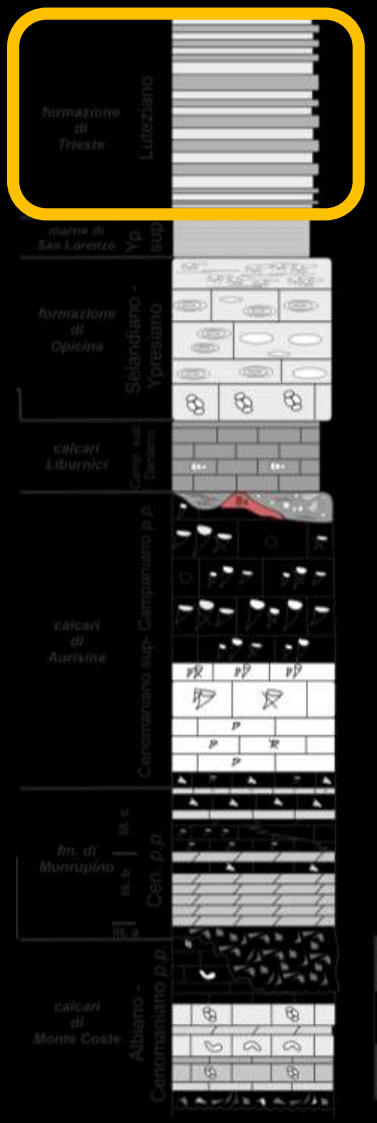


Deposizione delle marne di San Lorenzo



FORMAZIONE DI TRIESTE

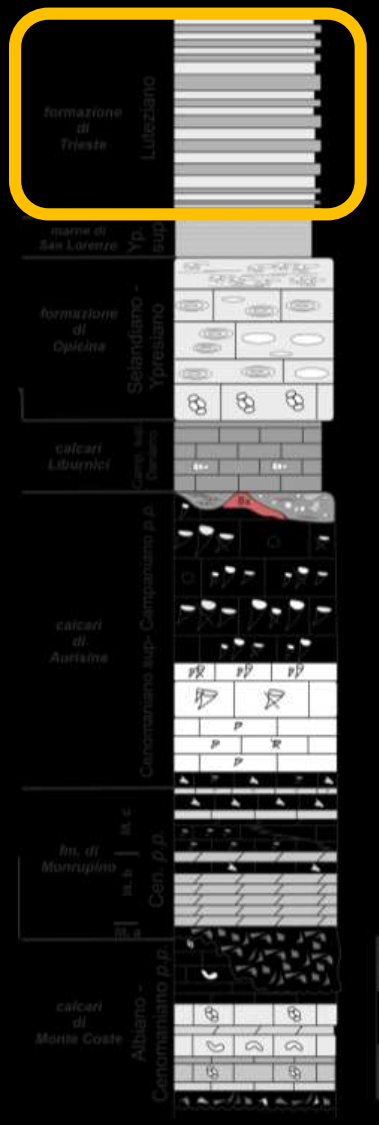
Alle marne di San Lorenzo si sovrappongono i depositi torbiditici della fm. di Trieste.
Si tratta di areniti ibride, marne e argilliti fittamente stratificate con strati di spessore generalmente centimetrico. In alcuni casi la frazione arenitica è preponderante e gli strati risultano amalgamanti e più spessi.
È presente abbondante bioturbazione e sono frequenti livelli ricchi in resti vegetali.



FORMAZIONE DI TRIESTE

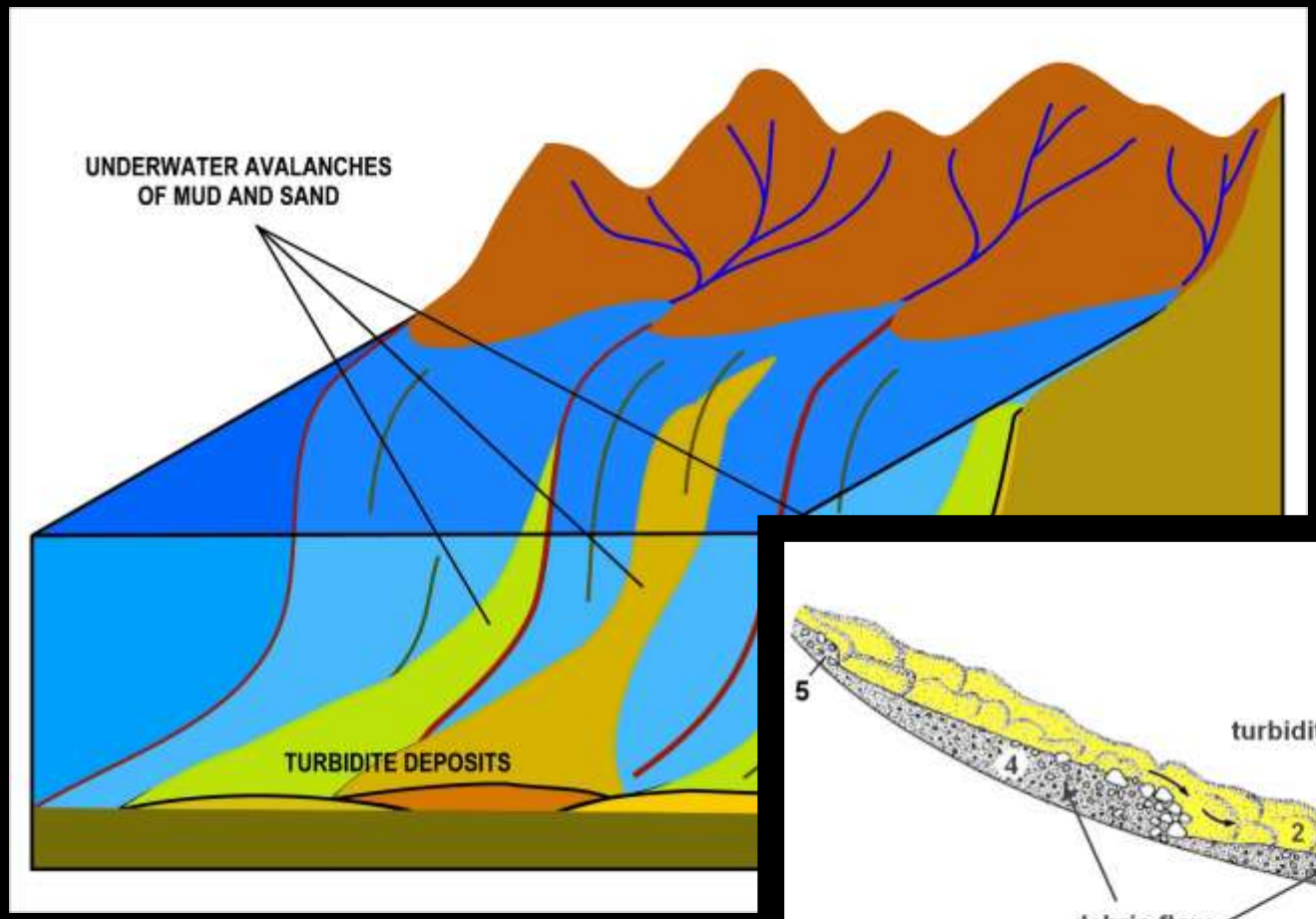
Successione di areniti, peliti e argilliti nella fm. di Trieste

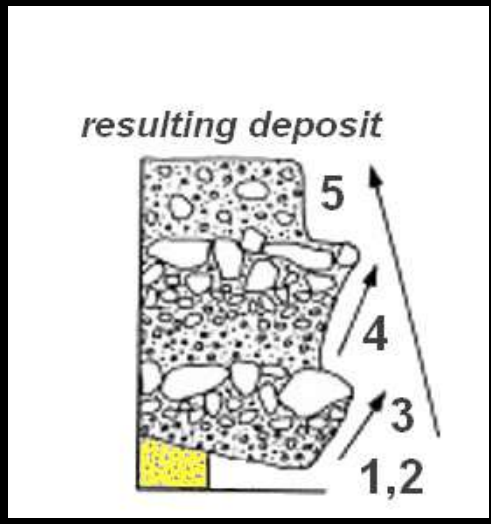
Banchi arenitici nella fm. di Trieste

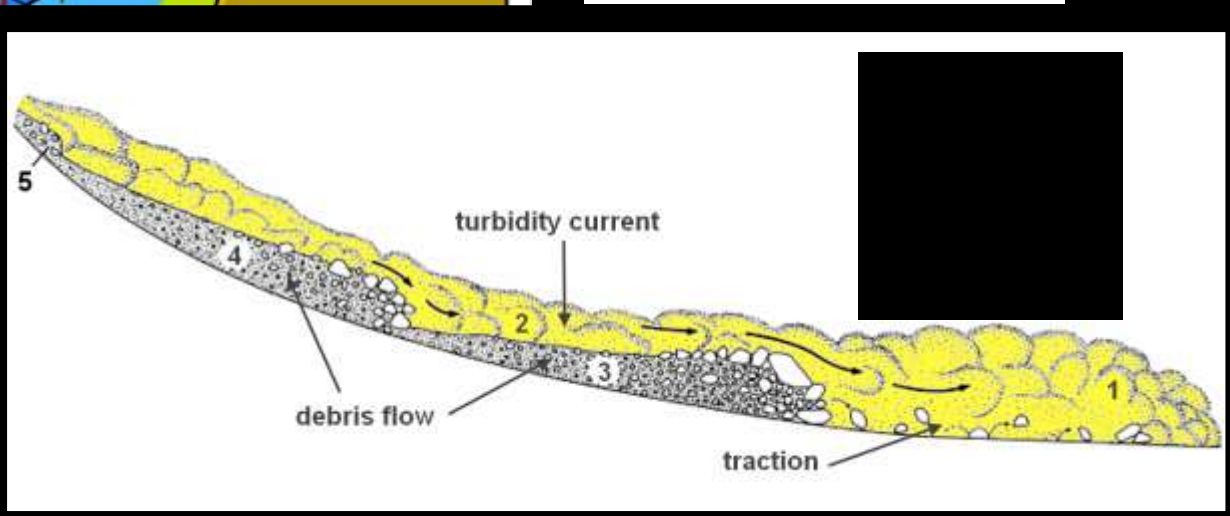


TORBIDITI

Le torbiditi sono sedimenti clastici. Sono prodotte dalla deposizione di sedimenti ad opera di correnti ricche di materiale in sospensione e notevolmente più dense della massa d'acqua in cui si muovono, definite "correnti di torbida".



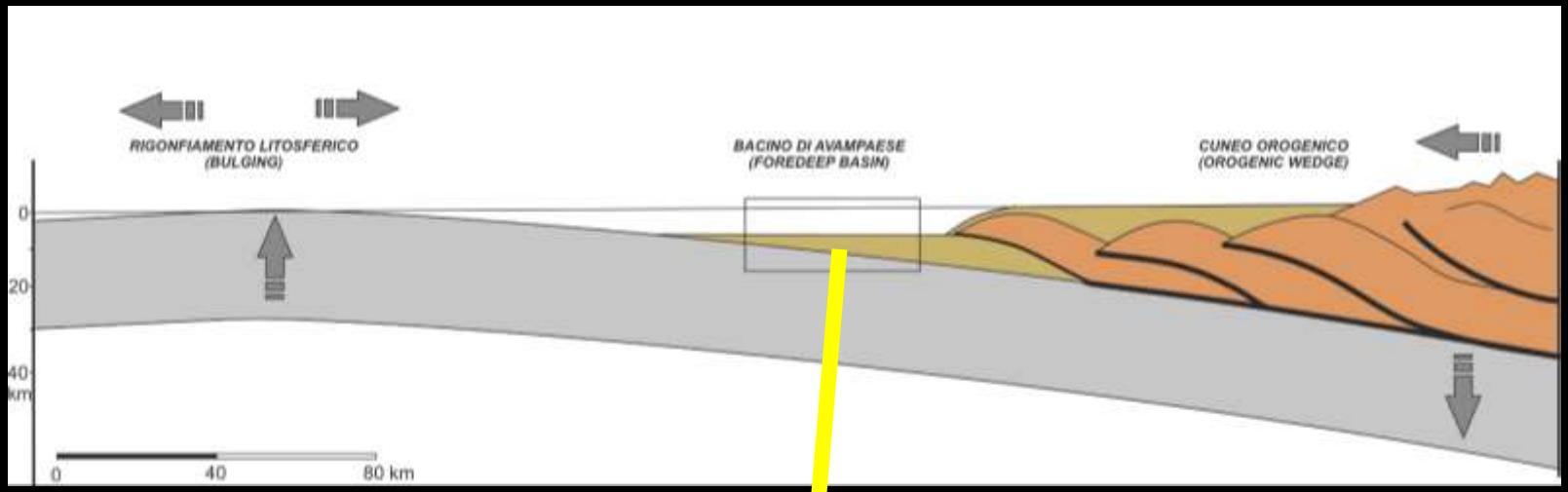




da Wikipedia.org

fm. di Trieste

Le areniti, siltiti e argillite del Flysch vero e proprio sono l'espressione del riempimento dell'avanfossa dinarica con laccumulo di una potente successione di depositi torbiditici



deposizione della fm. di Trieste