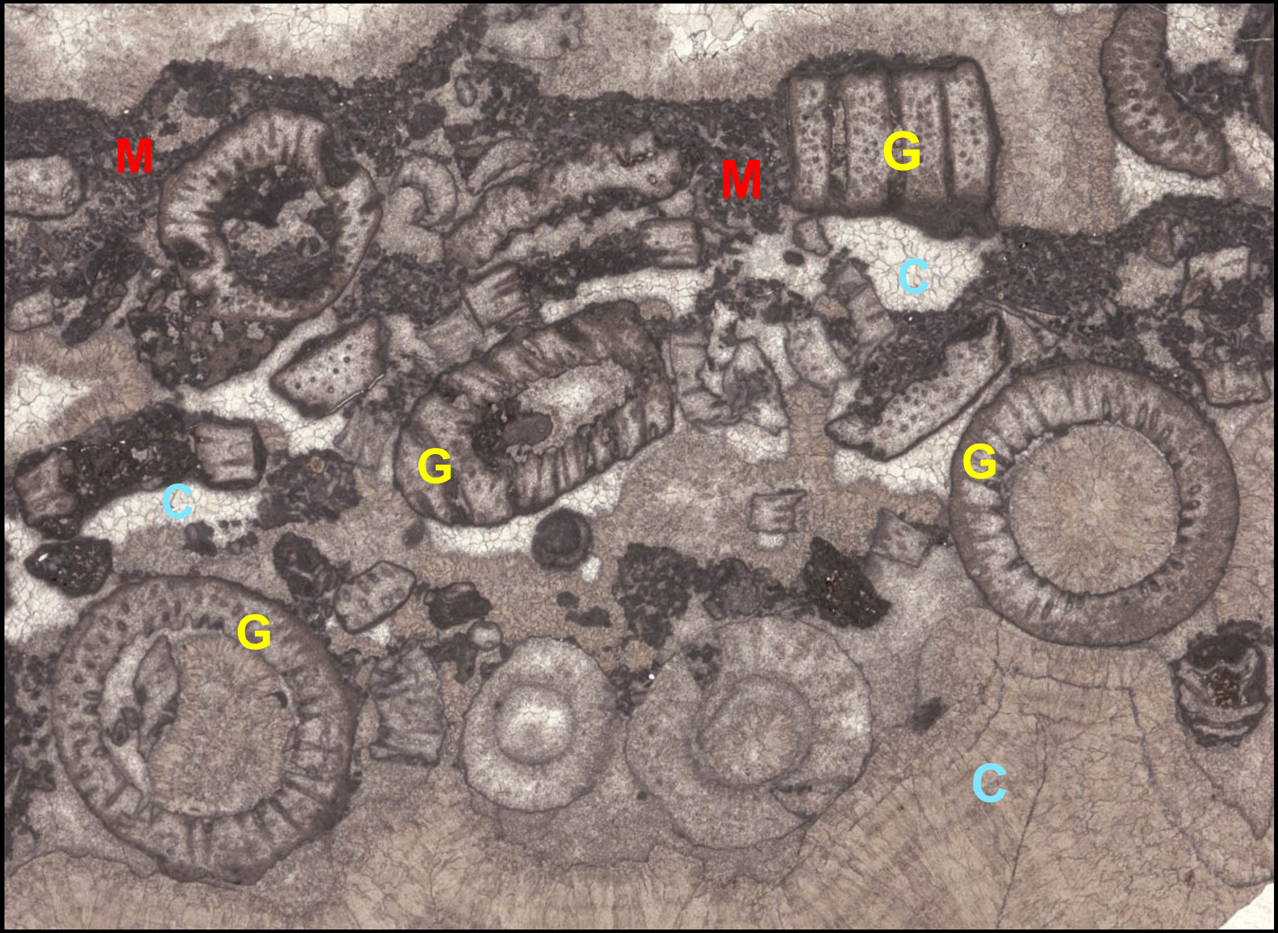
Sedimentology and Stratigraphy, 2022-2023

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

dipartimento di matematica e geoscienze

What is left? Micrite and Cements



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

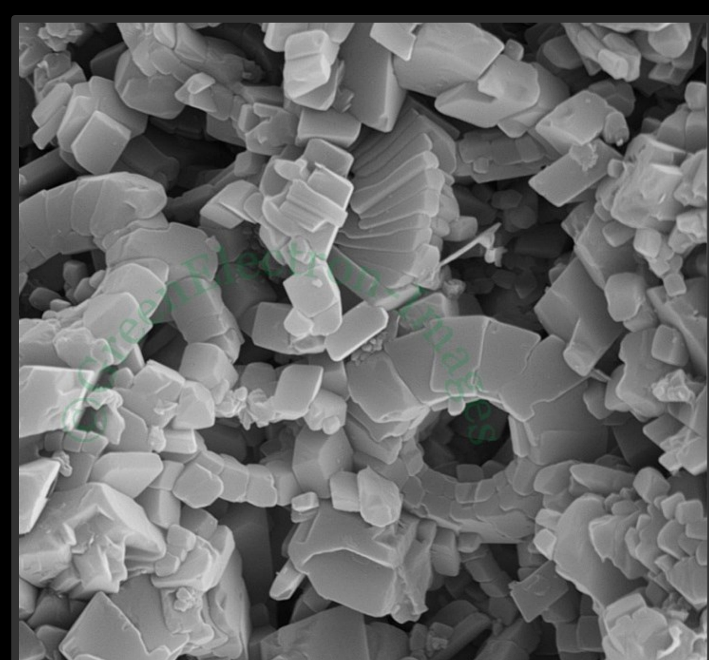
Mircite: fine grained carbonate mud that it indistinguishable observing hand samples and even at the optical microscope is difficult to characterize

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:

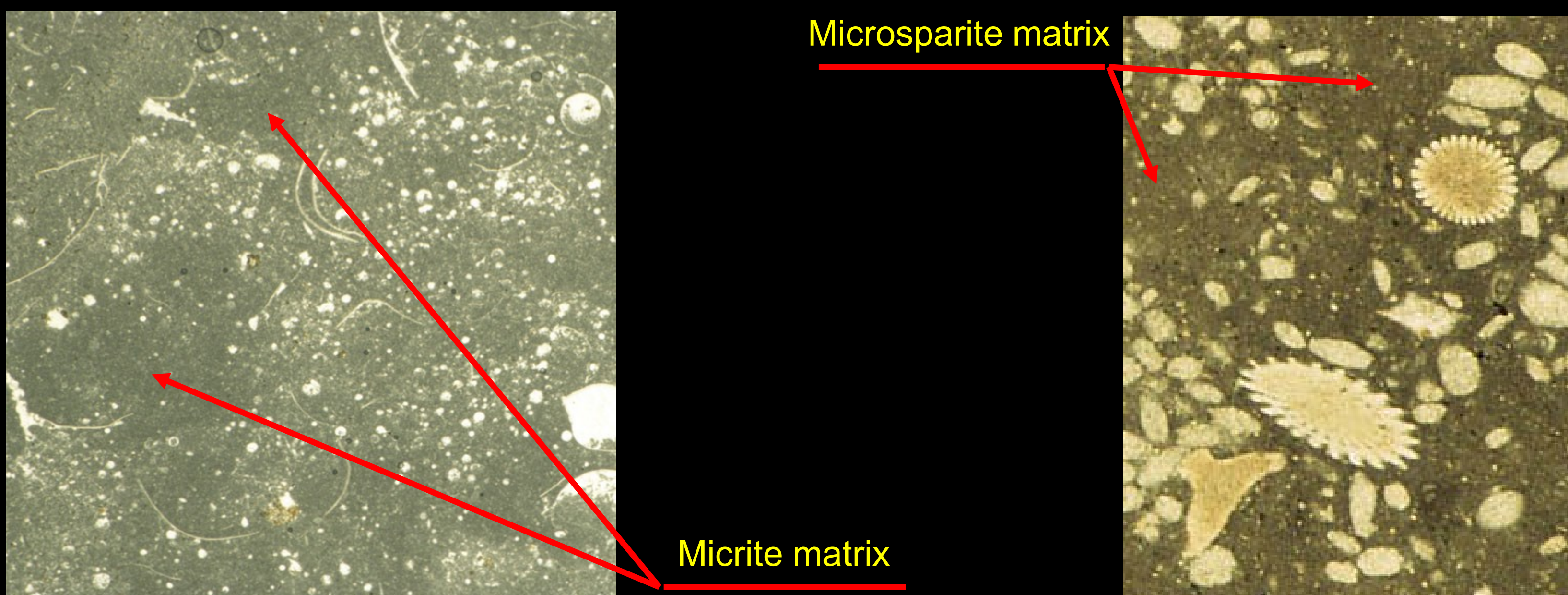
- **Abiotic** precipitation from highly supersaturated seawater (whitings)
- Precipitation **induced by microbial activity**
- Frantumation of **calcareous algae** (e.g., *Halimeda*, *Penicillus*)
- **Bioerosion**: the activity of borers, as fungi or sponge, on carbonate substrates
- **Mechanical erosion**,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



Definitions:

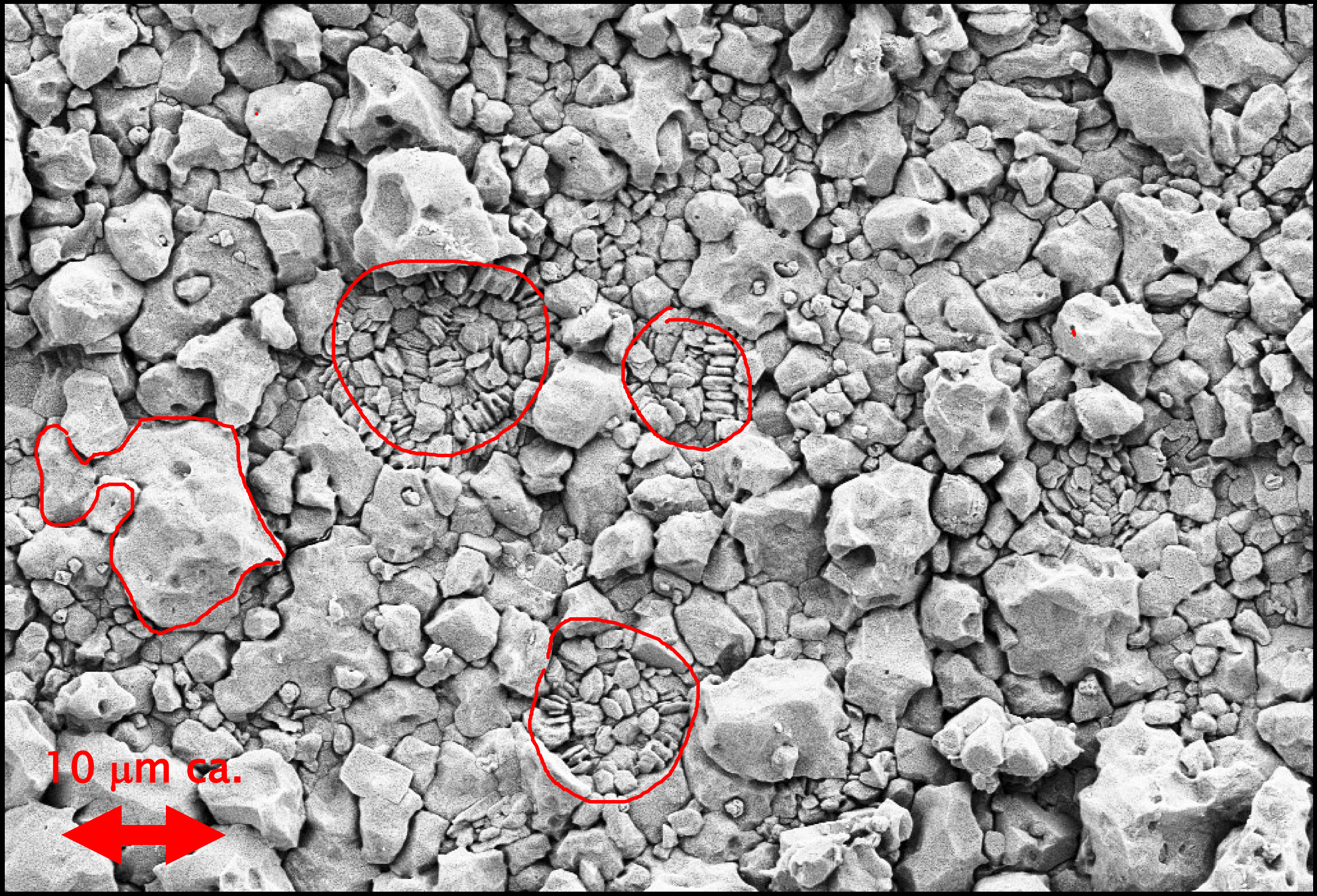
- **Micrite**: As in *Microcrystalline calcite*, refers to fine carbonate which crystals are less than 4 μm on average. This is a strictly descriptive term, and the 4 μm threshold (Folk, 1959) is arbitrary. Other authors go for 5 microns.

- **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

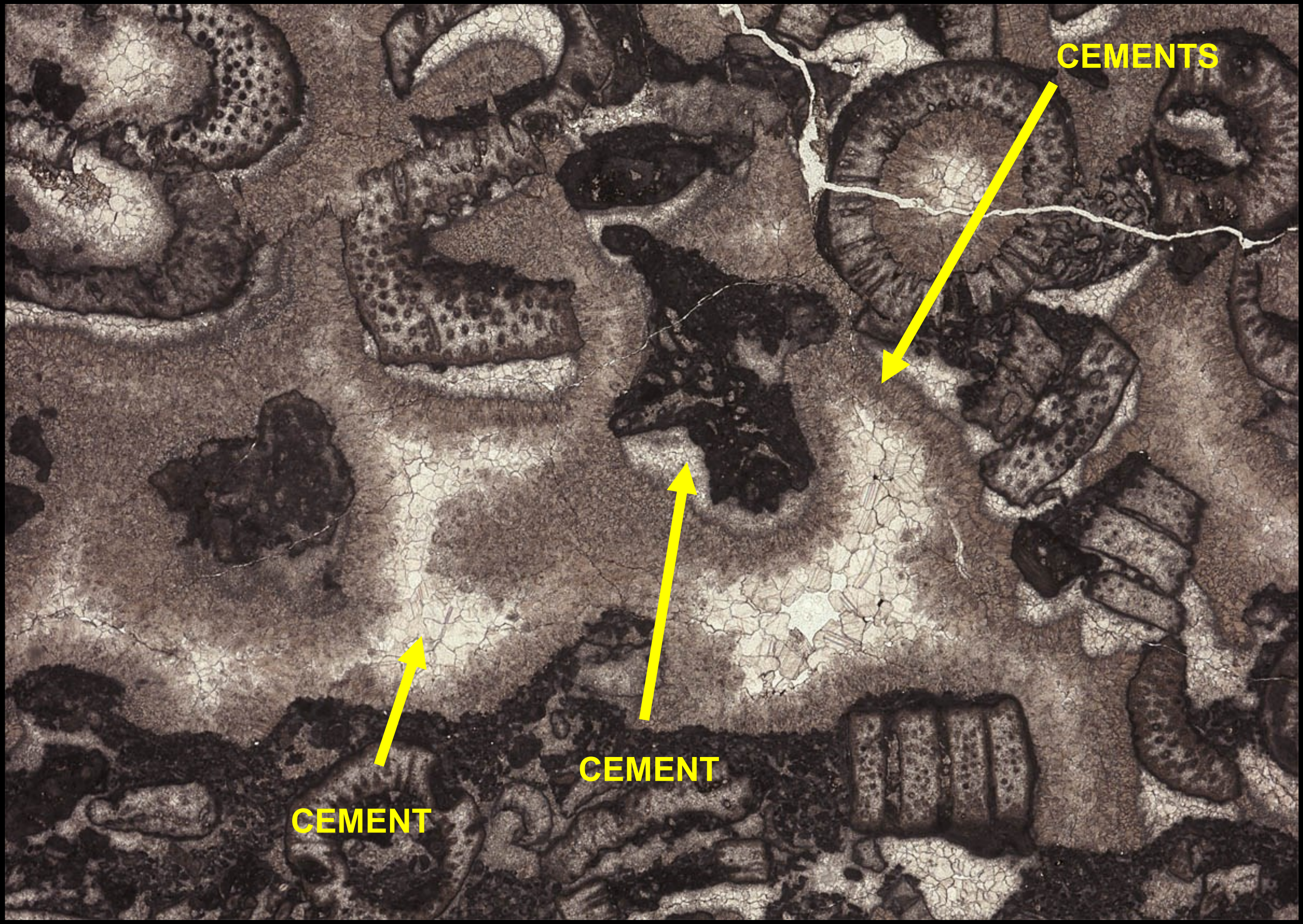


In this late Norian hemipelagic limestone of the Lagonegro Basin (Southern Apennines) the micrite component is nannofossils (*Prinsiosphaera* sp.). The rest is microsparite.

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

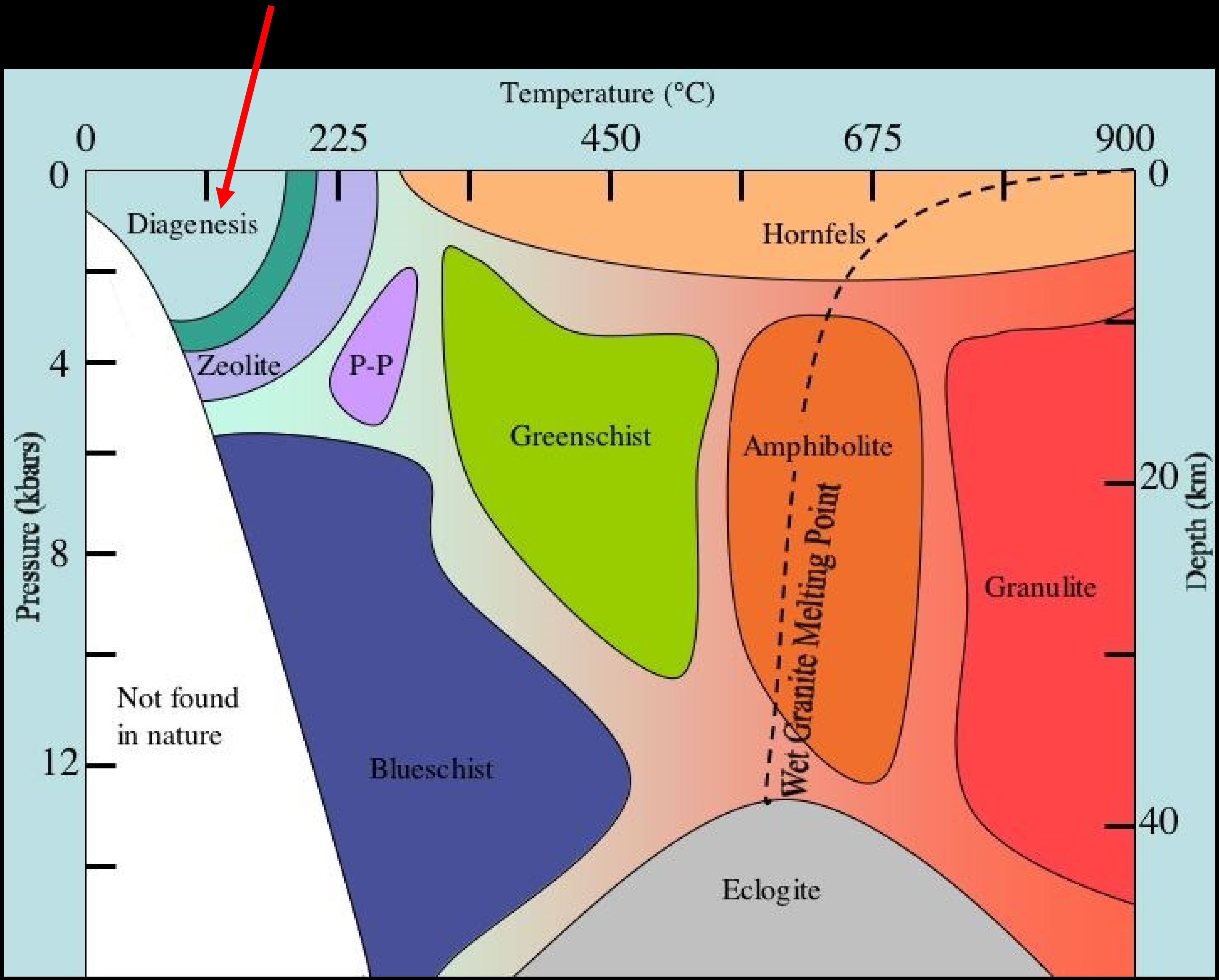
Diagenesis is a process that involves physical and chemical changes in sediments that start once it is deposited.
These changes are induced by increasing temperature and pressure during burial and may involve the circulation of fluids.

Carbonate sediments are particularly prone to diagenesis.

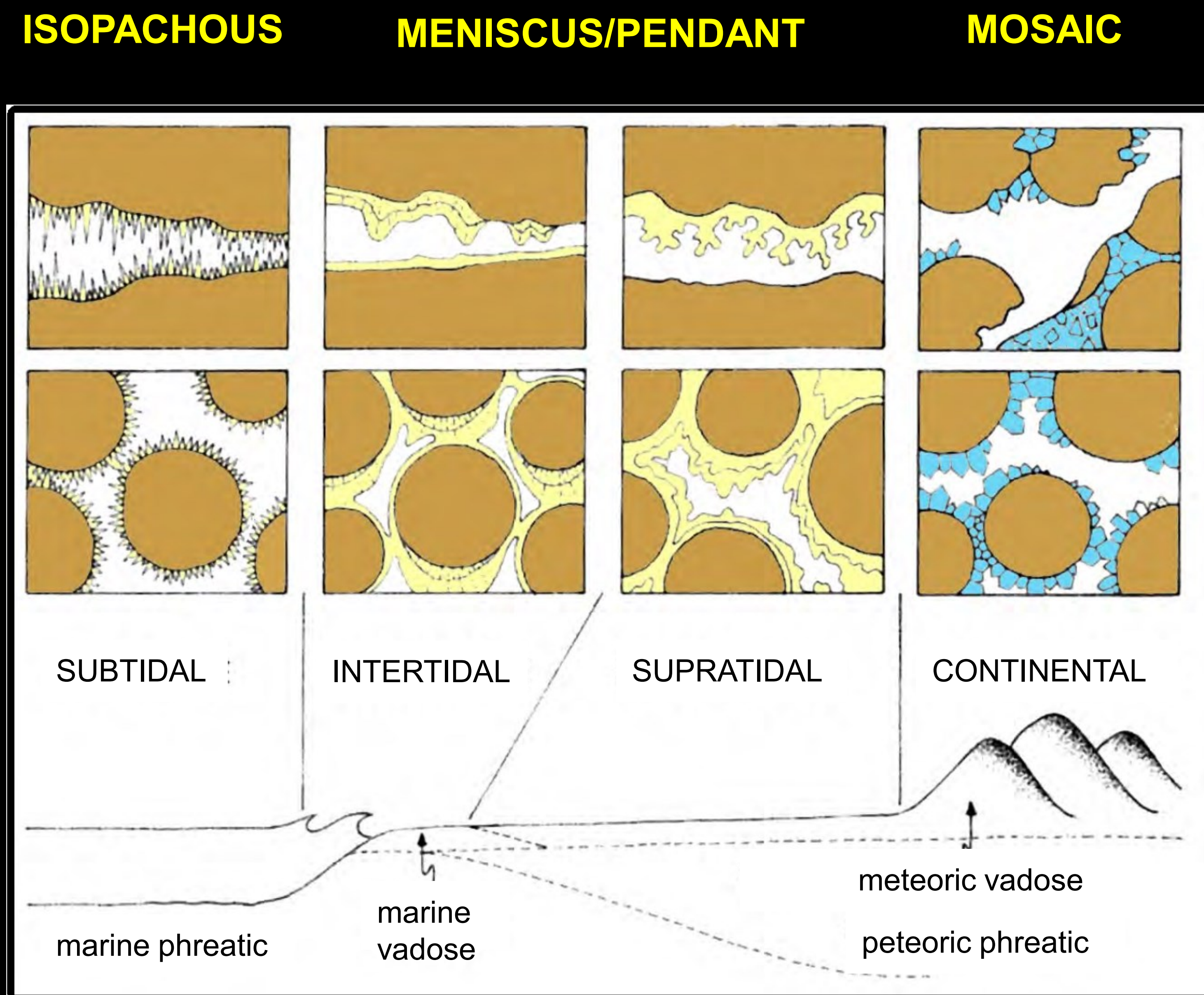
- compaction (under the load of overlying sediment)
- progressive pore occlusion
- **dissolution**
- **cementation**
- transformation of metastable carbonates (aragonite and high-Mg calcite) into low magnesium calcite (and dolomite)
- dolomitization*

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

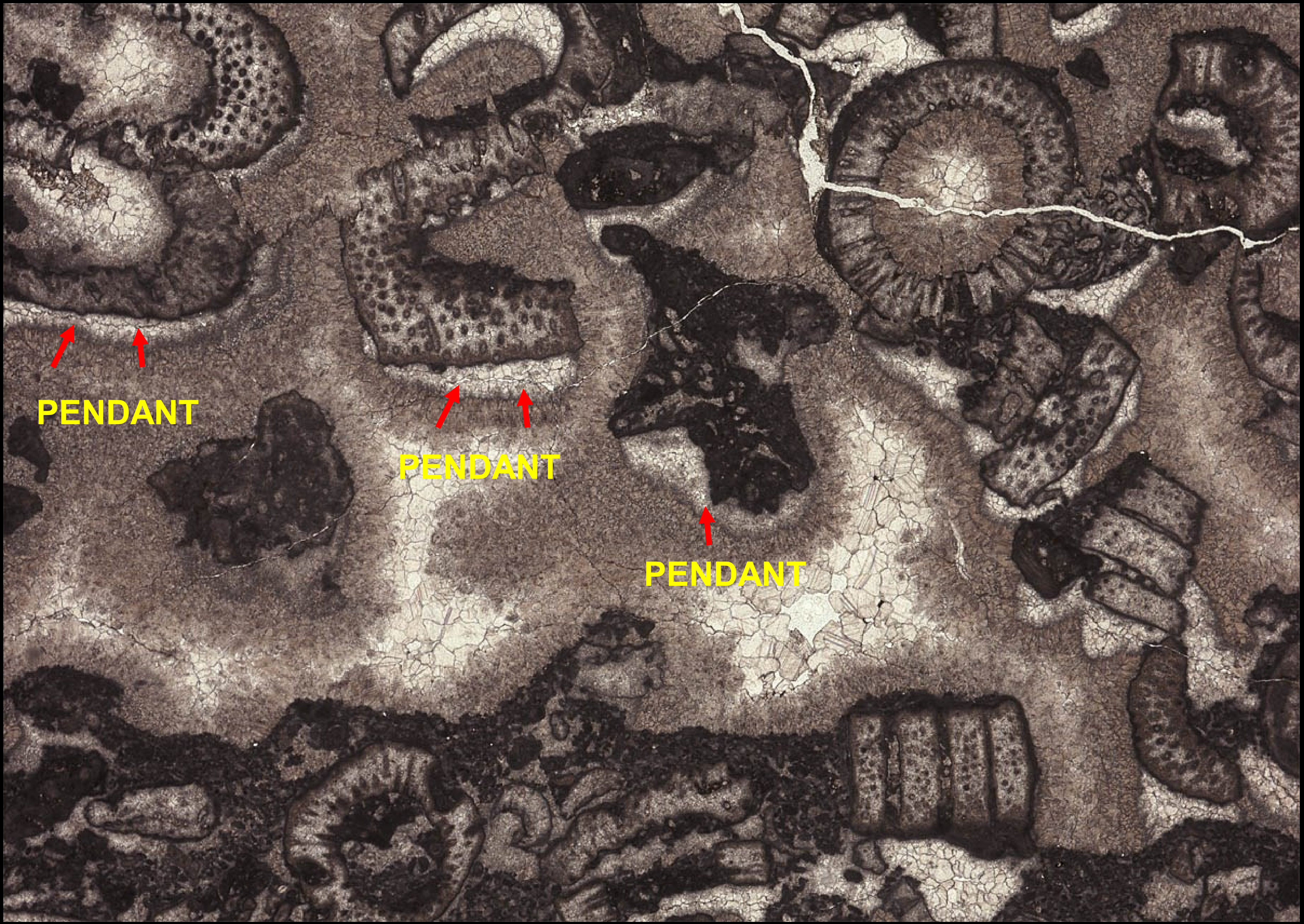


from Wikipedia

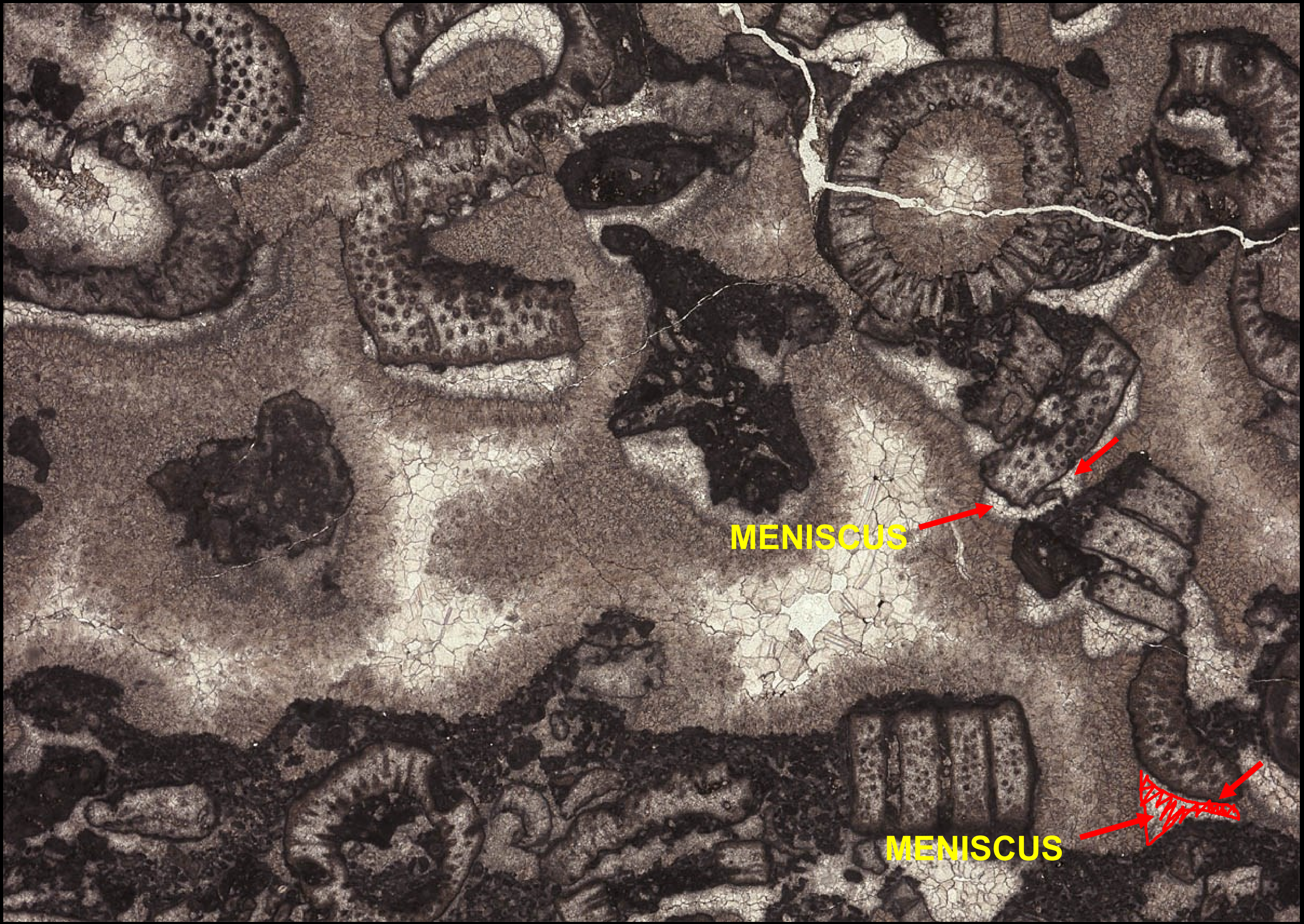


Different types of cement form in specific diagenetic environments. Characterizing the cements of a carbonate rock can help reconstructing its **diagenetic history**.

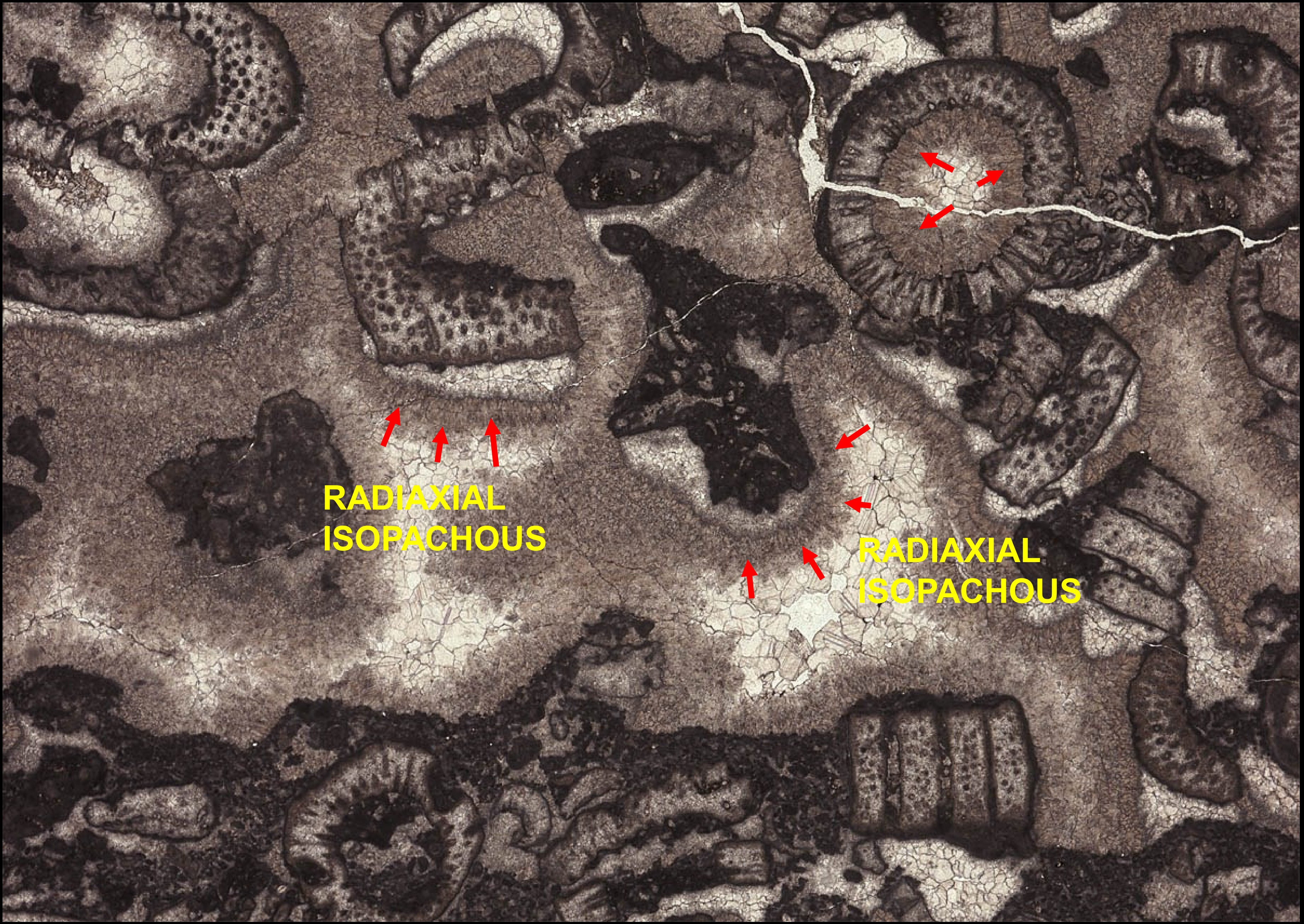
Some types of cements under the optical microscope



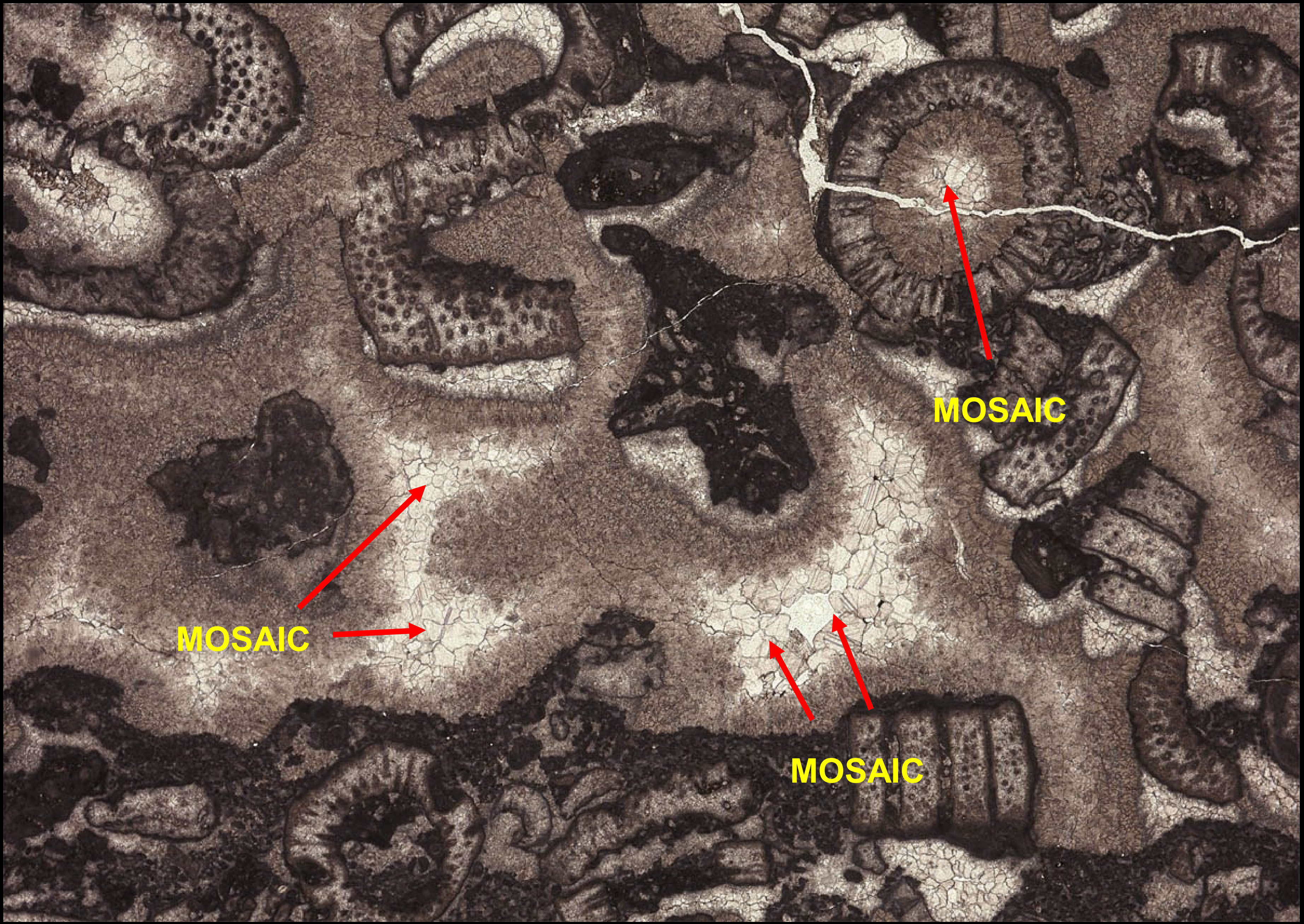
Some types of cements under the optical microscope



Some types of cements under the optical microscope



Some types of cements under the optical microscope

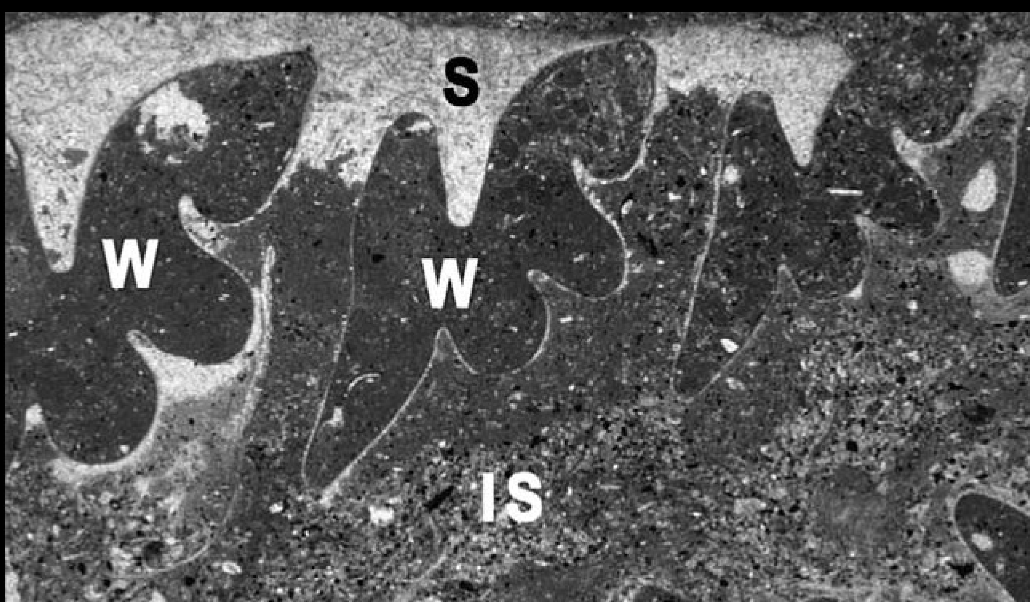


Some types of cements under the optical microscope

Syndepositional dissolution

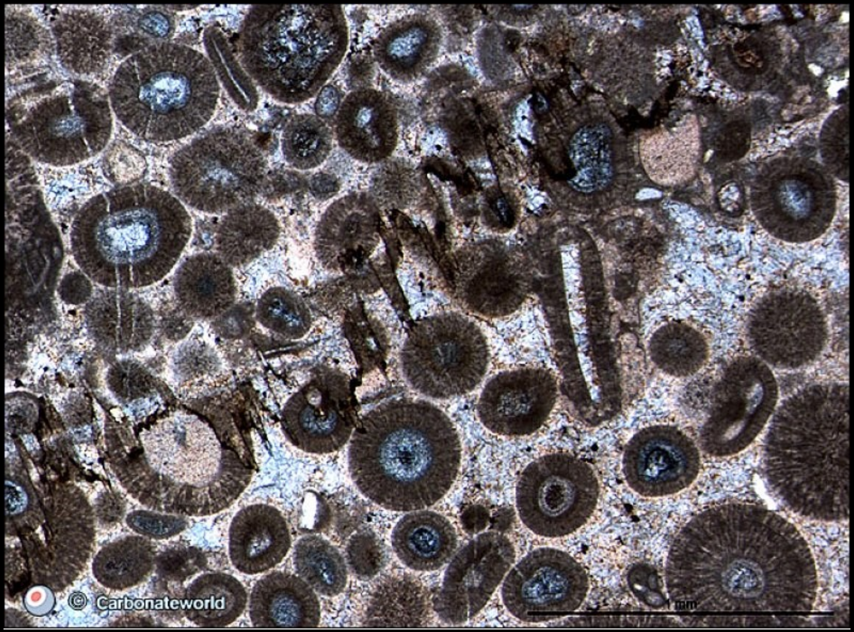
Carbonates can undergo syn-depositional modification. Dissolution is one of these processes and is caused by processes that may occur within the sediment right after burial (e.g. organic matter oxidation) that cause a local CaCO3 undersaturation.

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

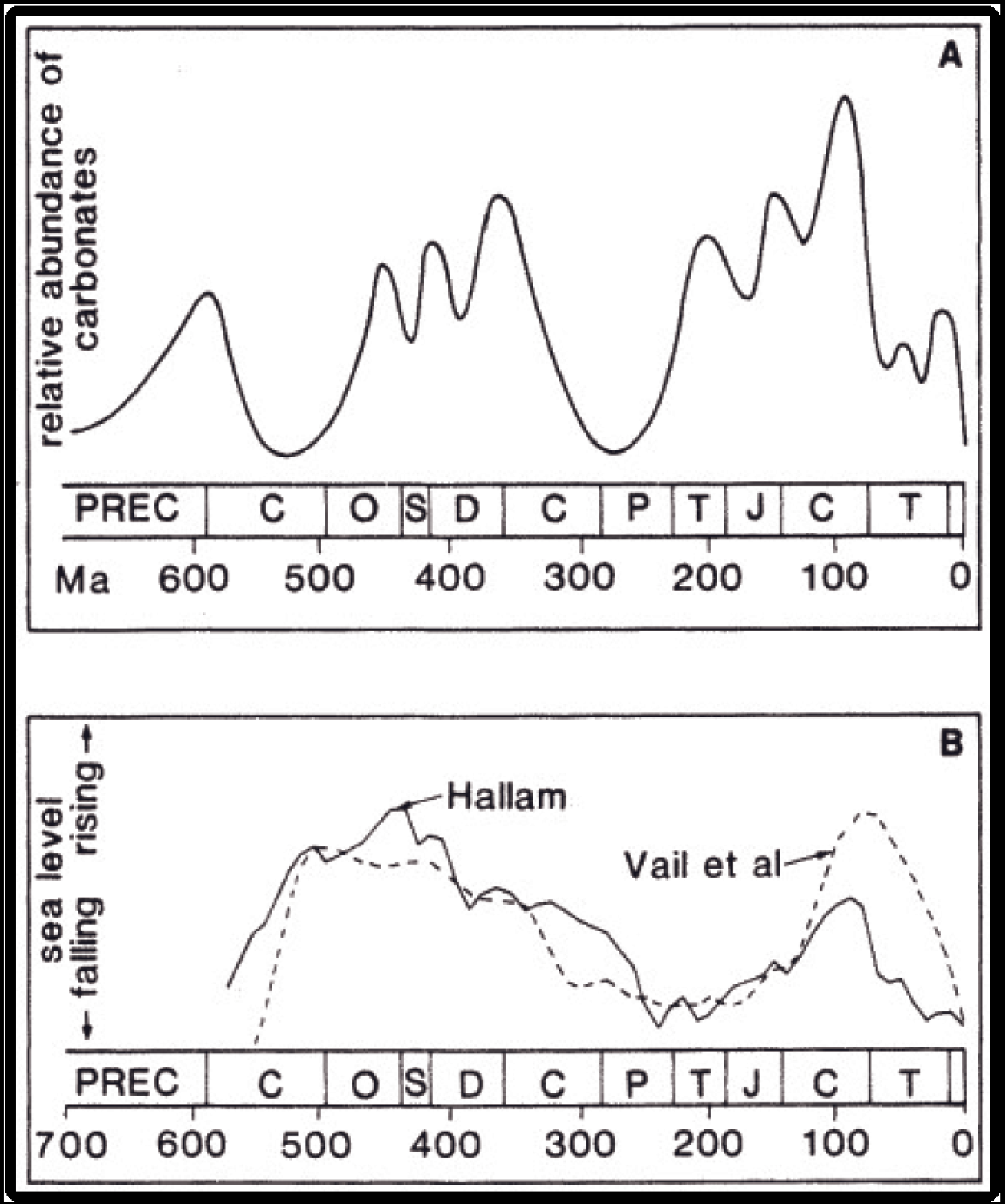
Carbonates through geological time

UNIVERSITAS STVDIORVM TERGESTVM MCMXXIV

DMG dipartimento di matematica e geoscienze

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

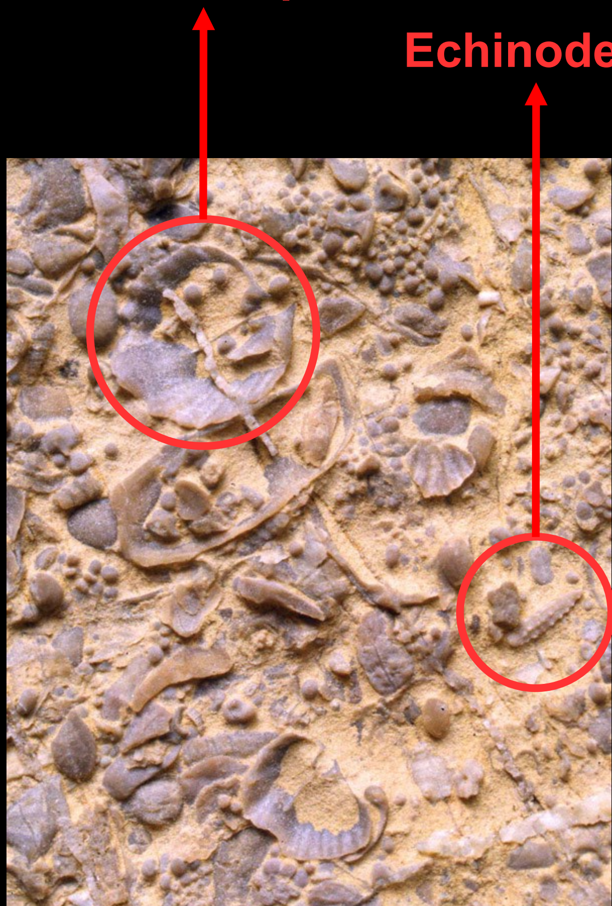


Tucker and Wright, 1990

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

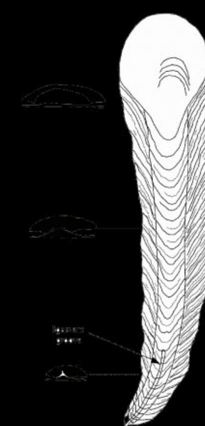
Carbonates:
the biological factor

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



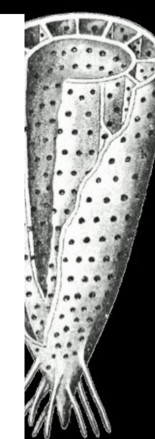
Carbonate rocks may contain skeletal grains

Mid Cambrian
to present

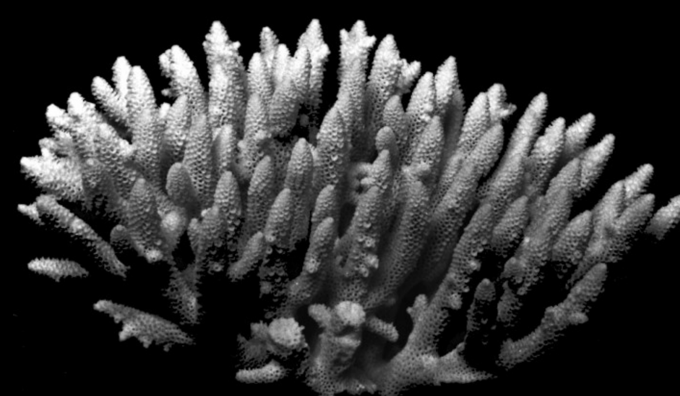


Lithiotis sp.
Early Jurassic

Rudist
Cretaceous



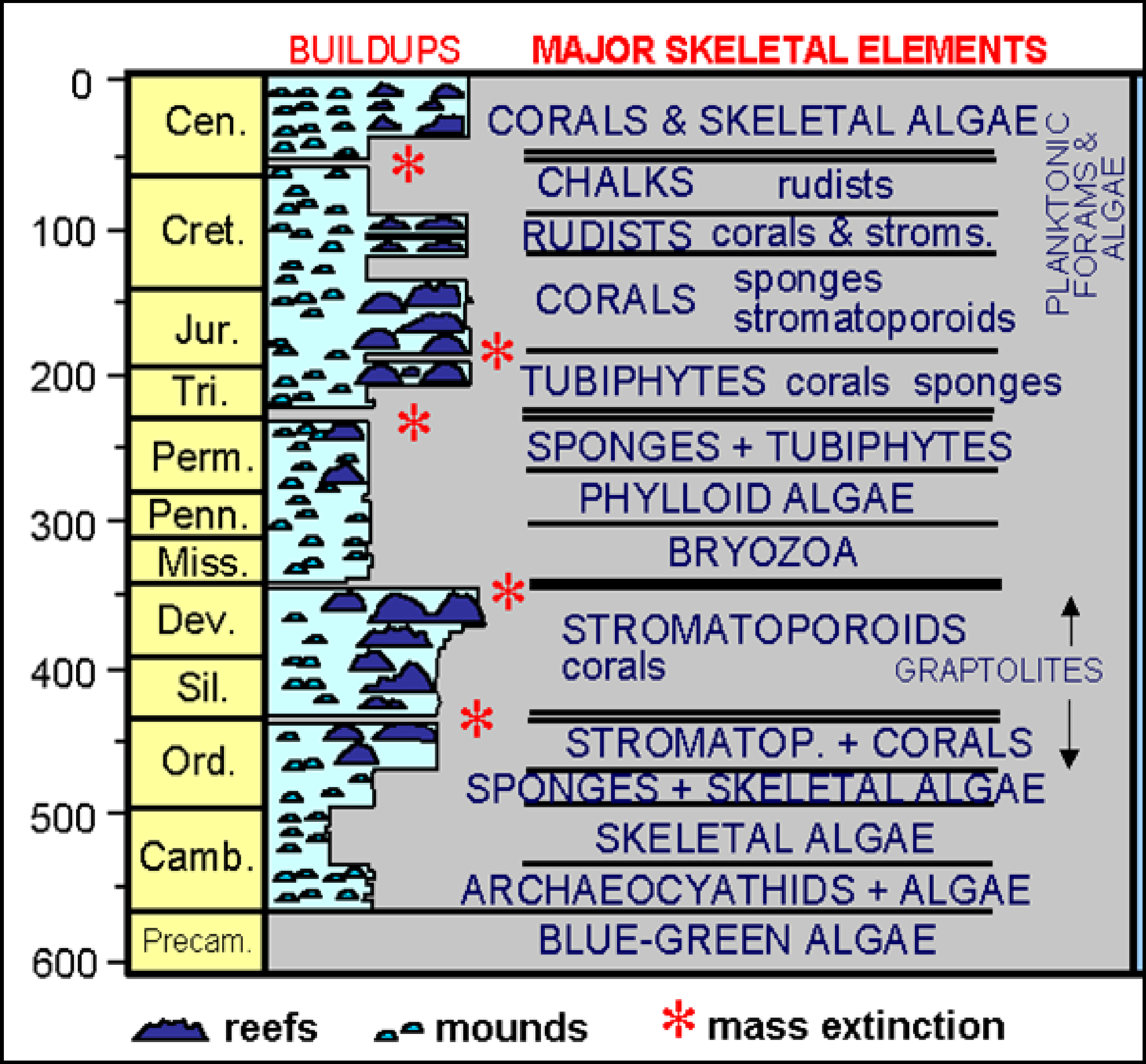
Archaeocyatha
Cambrian



Scleractinian coral
Cenozoic to present

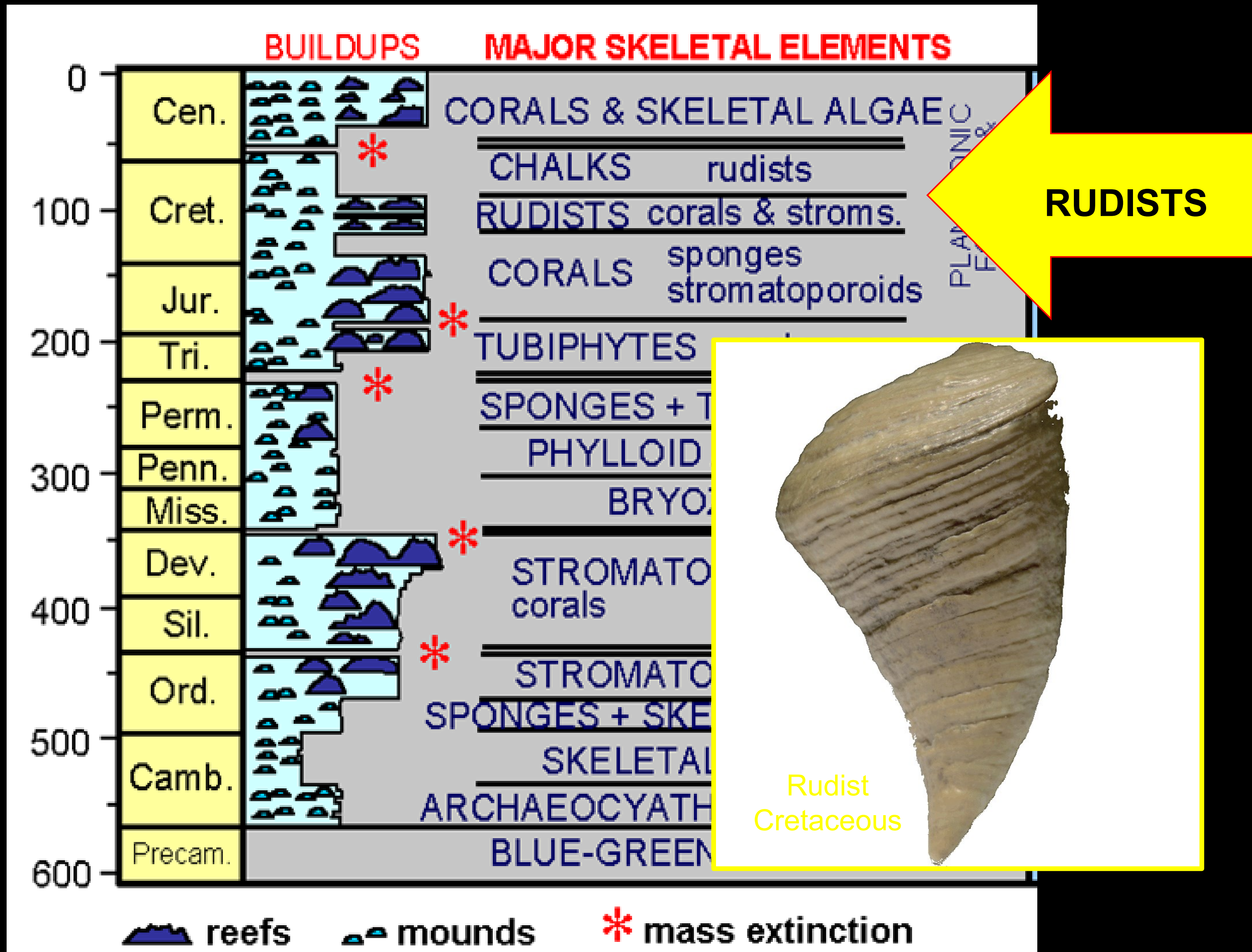
Stromatolite
Precambrian

Reef building organisms changed through geological times



Redrawn from James, 1983.

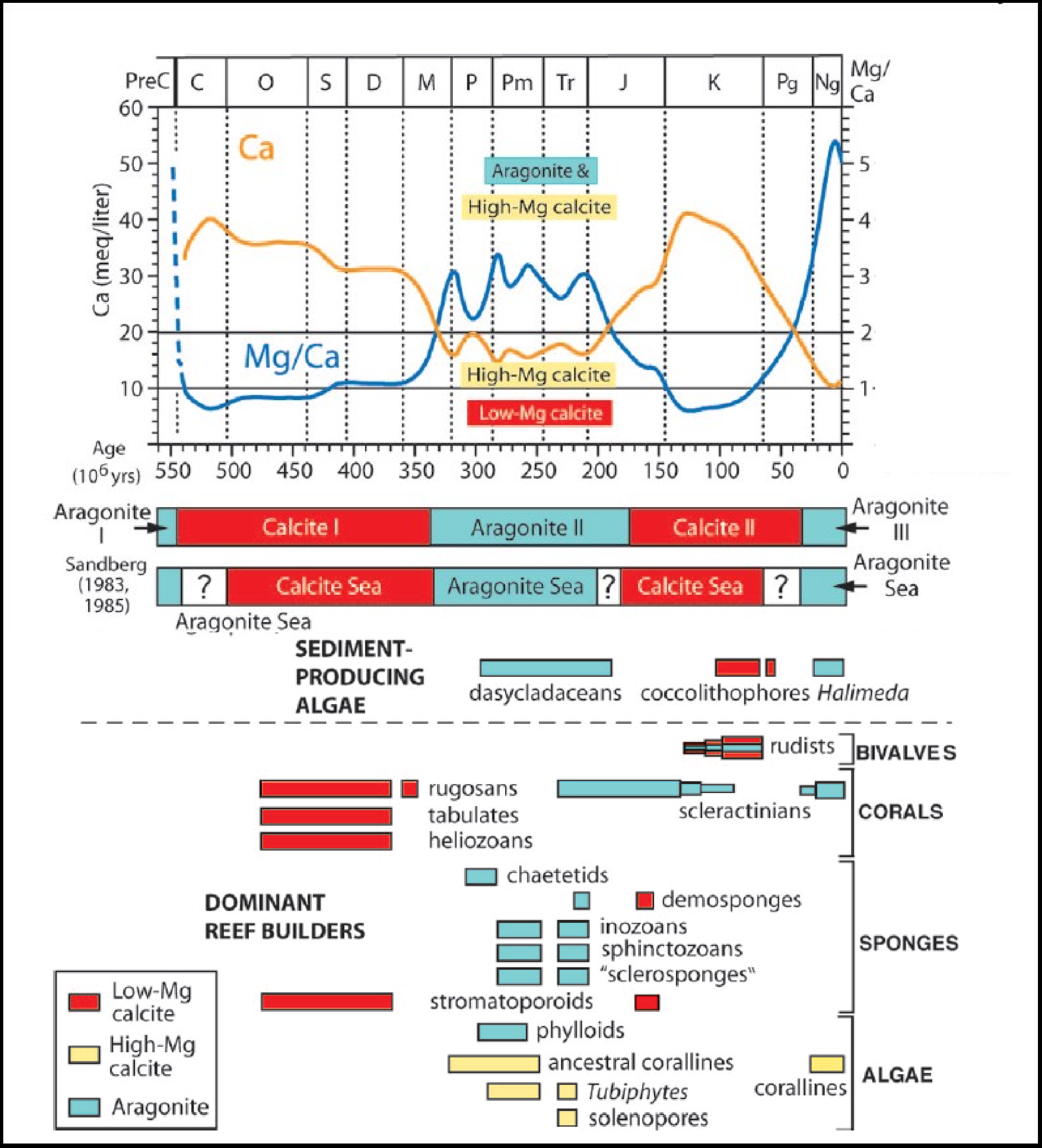
Reef building organisms changed through geological times



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.

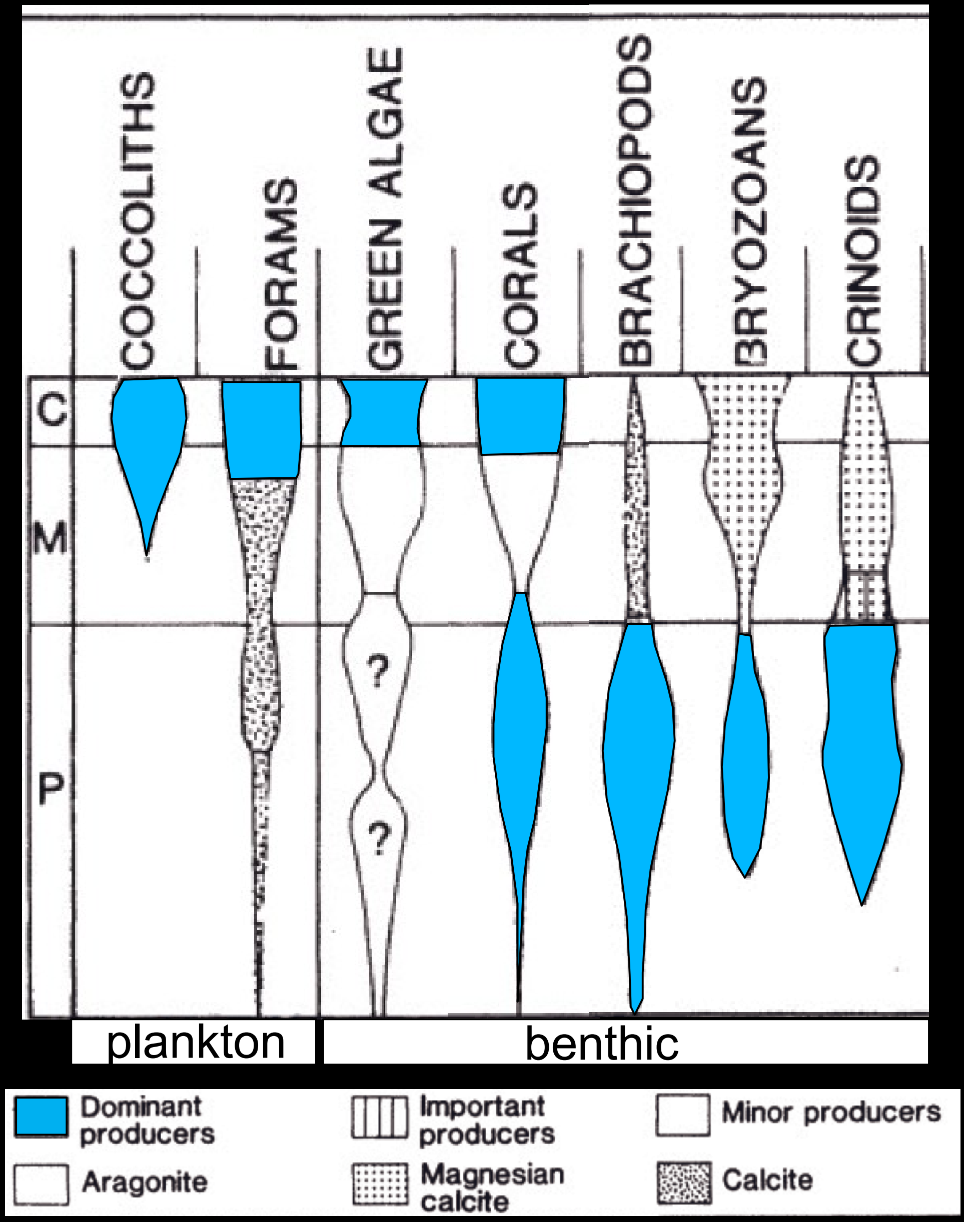


Stanley, 2004 modified

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

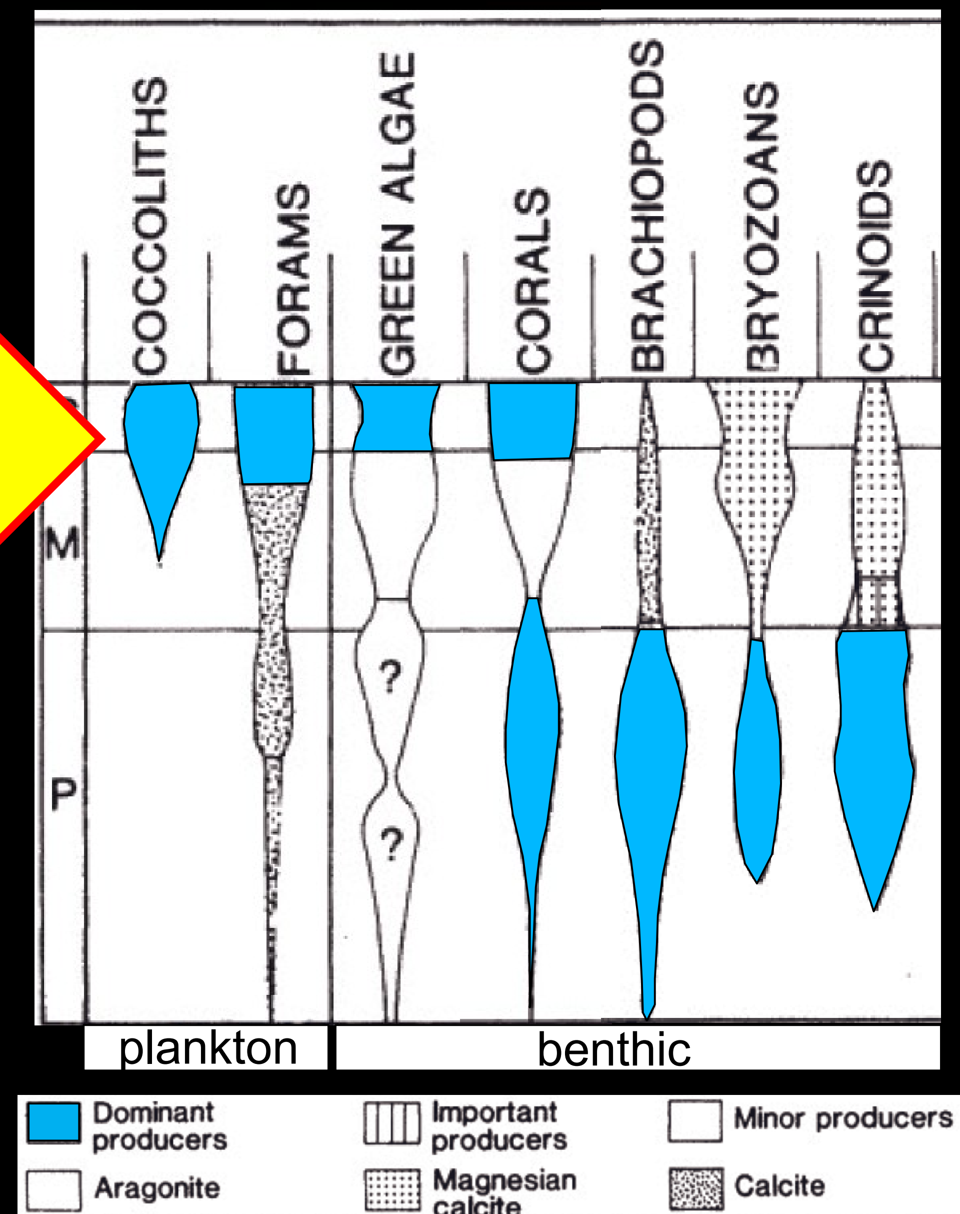


Tucker and Wright, 1990 modified

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

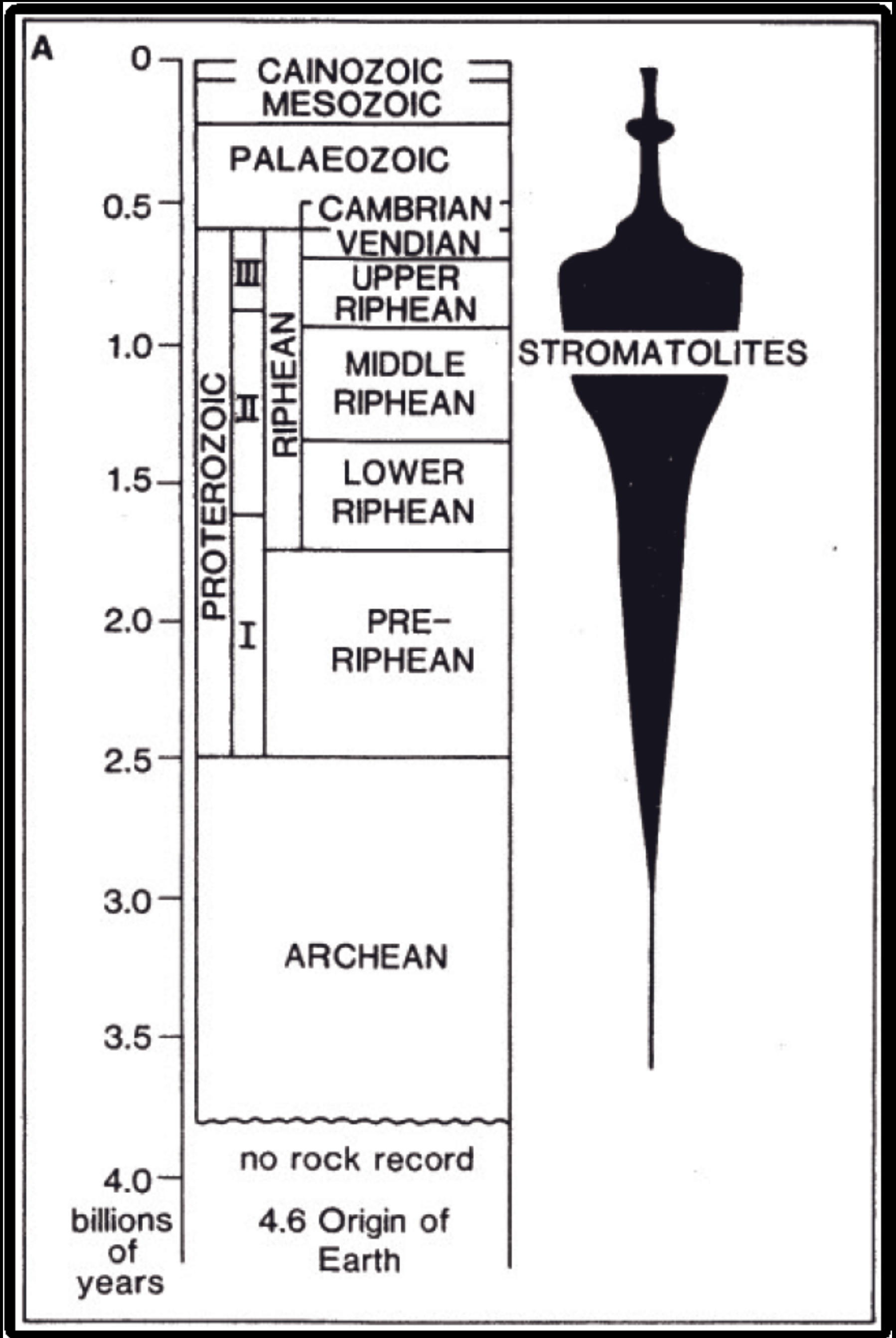
When did carbonate apper in the geological record?

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)

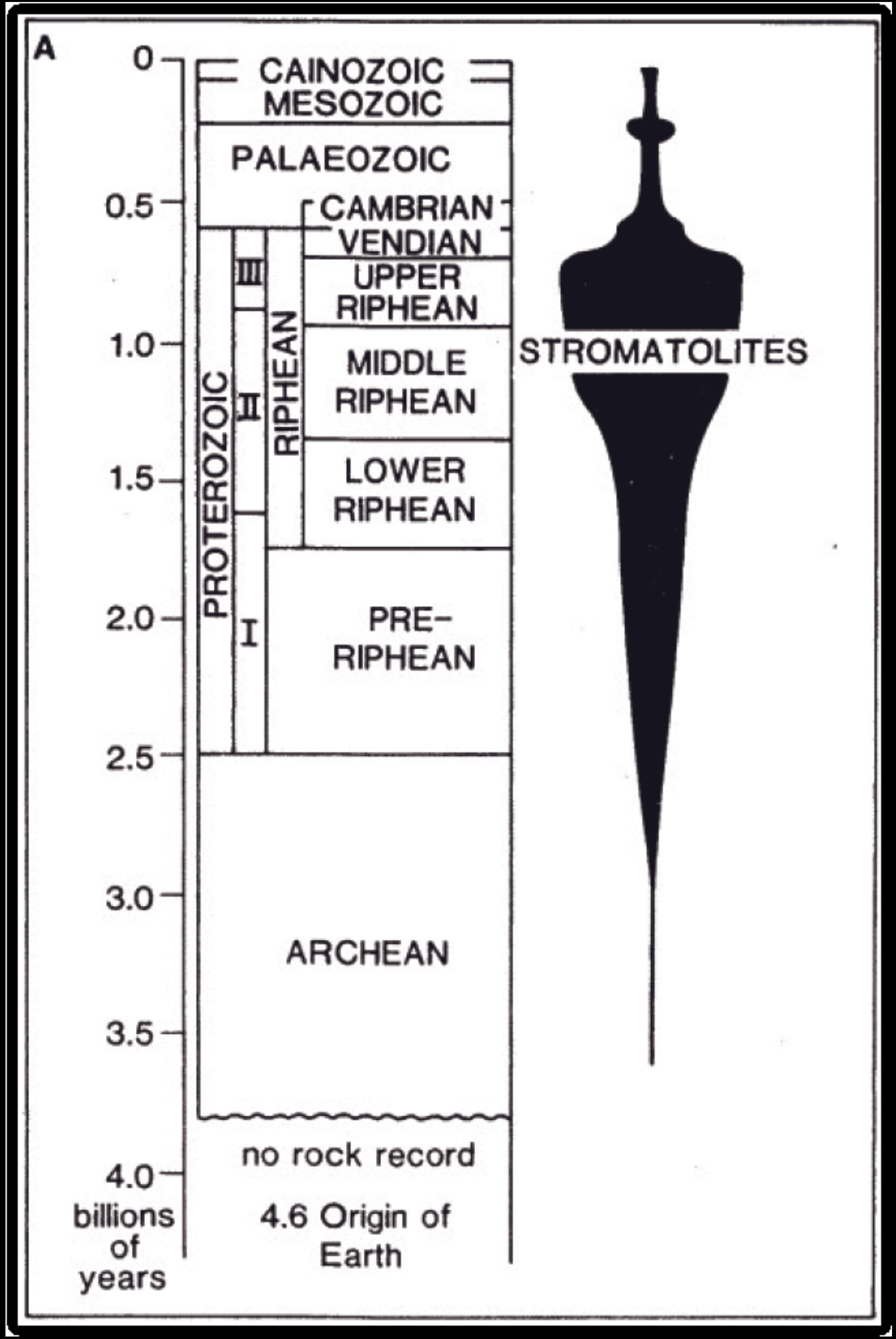


Tucker and Wright, 1990 modified

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

Sedimentology and Stratigraphy, 2021-2022

Breve introduzione alla successione stratigrafica dell'area di Trieste

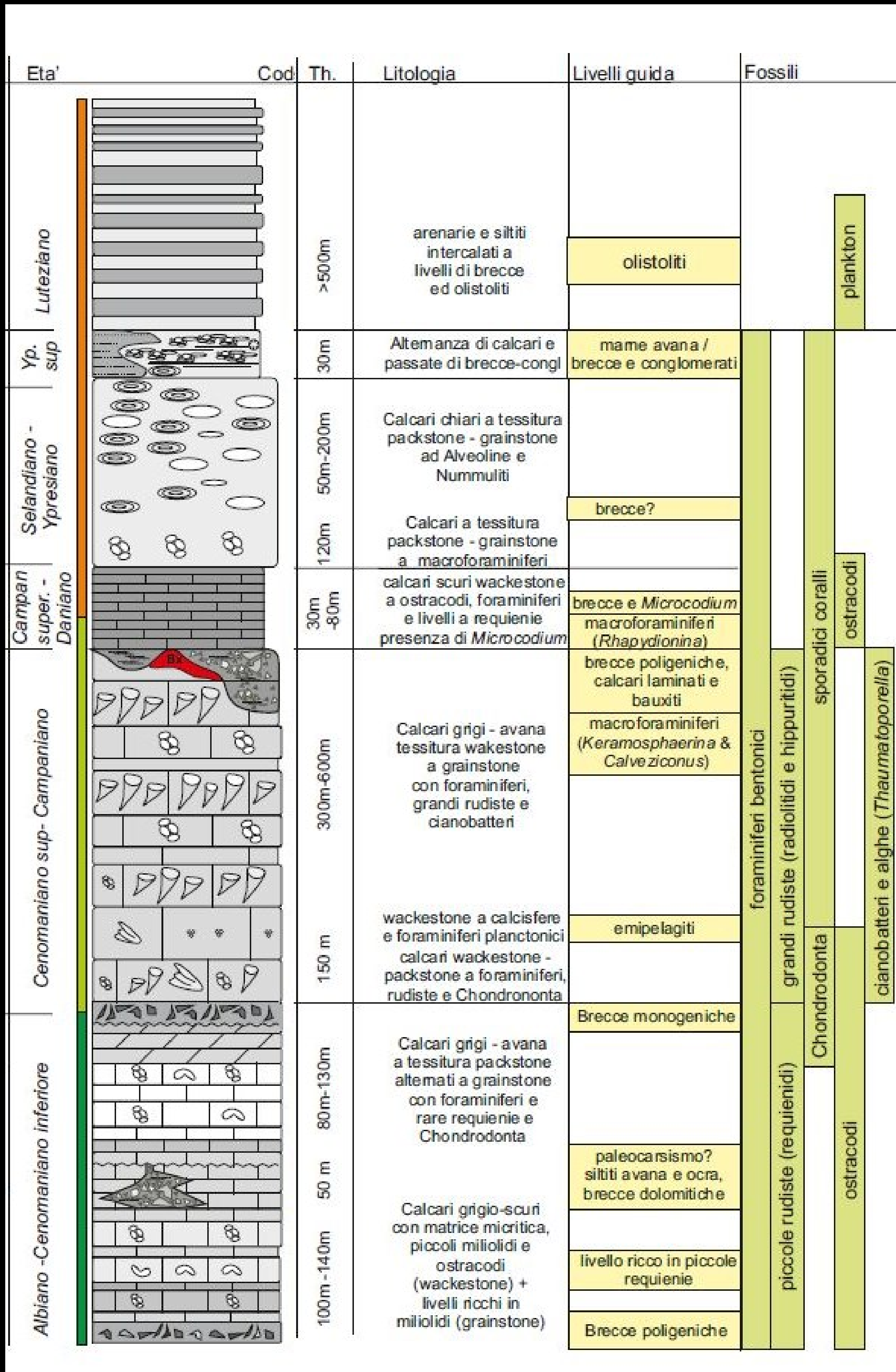
Flysch di Trieste

Calcari a Alveoline Nummuliti

C. Liburnici

Calcari di Aurisina

Calcari di M. Coste



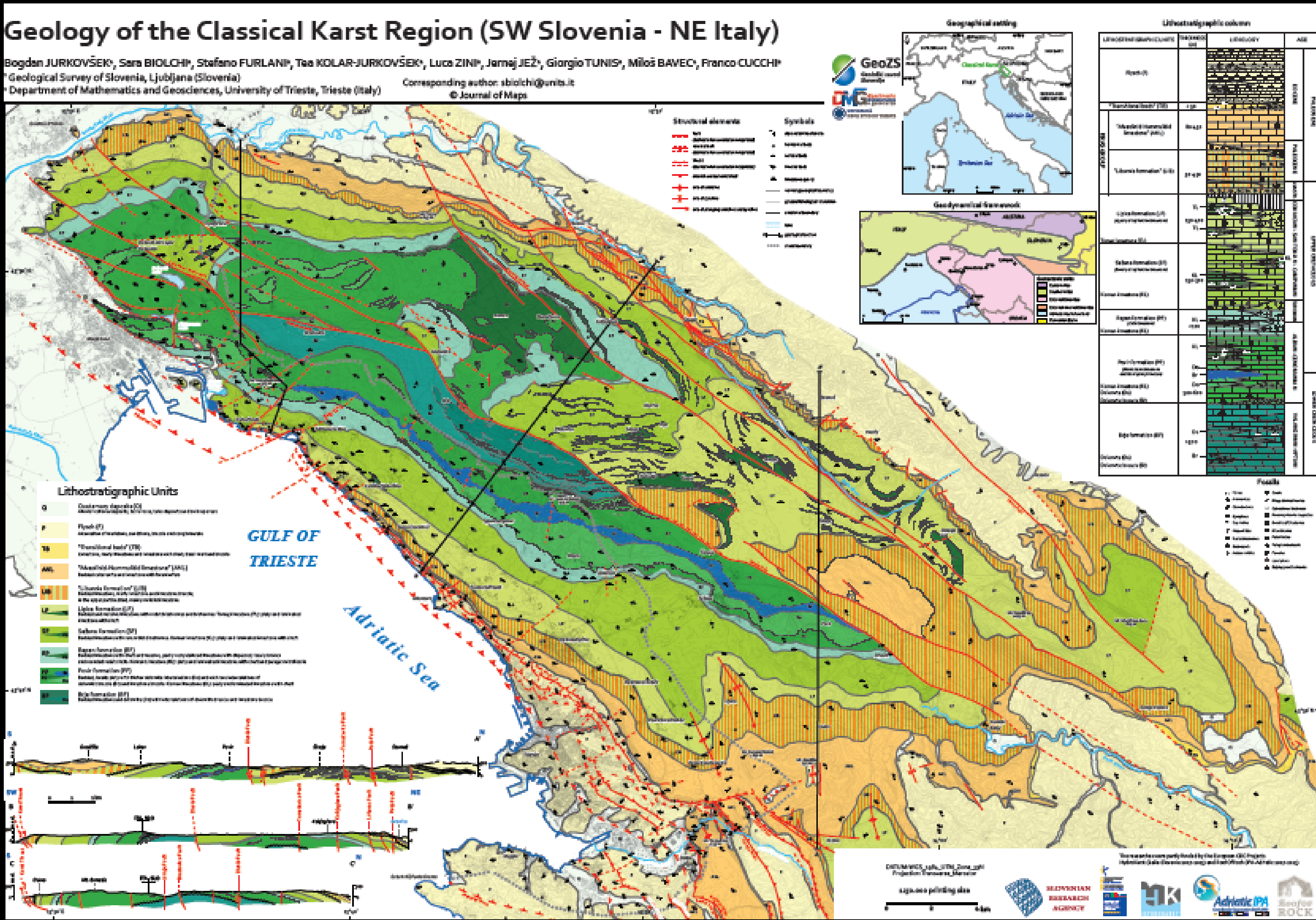
LA SUCCESSIONE STRATIGRAFICA DEL CARSO

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

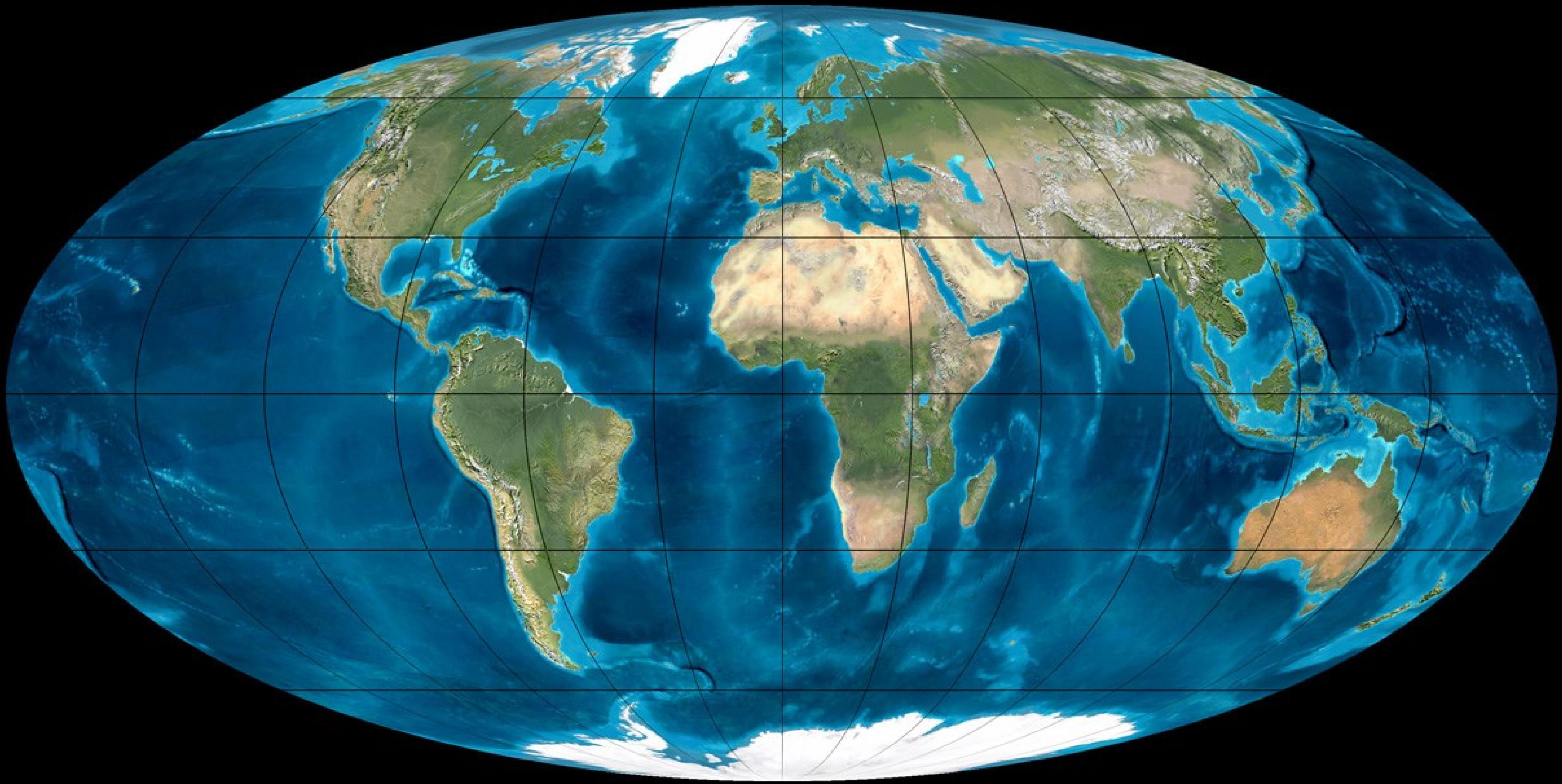
E' possibile riconoscere diverse unità stratigrafiche, ossia "pacchetti" di rocce stratificate che possiedono caratteristiche che le accomunano e che ci parlano degli ambienti in cui si sono formate.

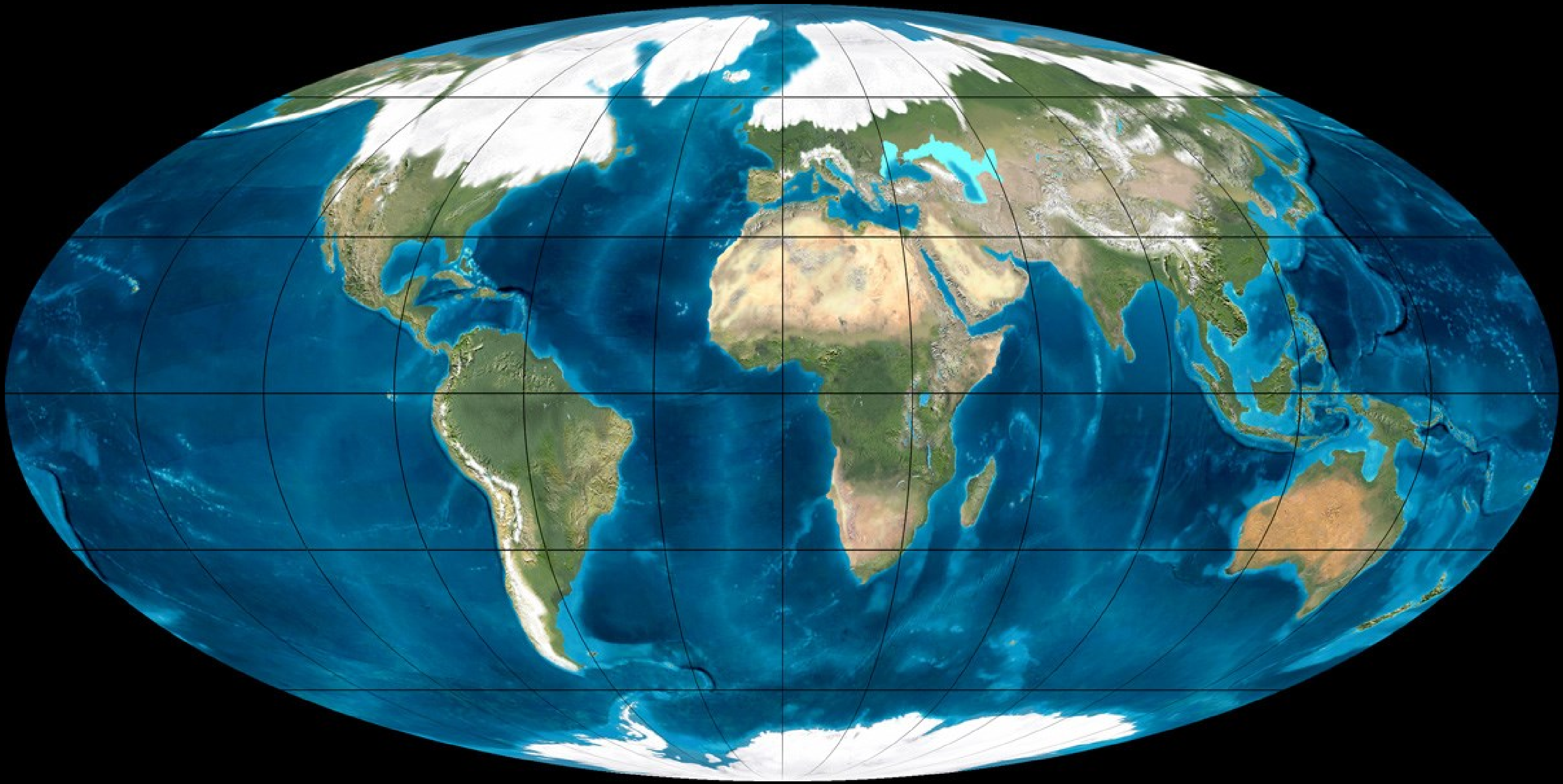
Il susseguirsi delle rocce della successione stratigrafica ci parla di come questi ambienti sono cambiati nel tempo e dei mutamenti climatici e ambientali avvenuti nel passato

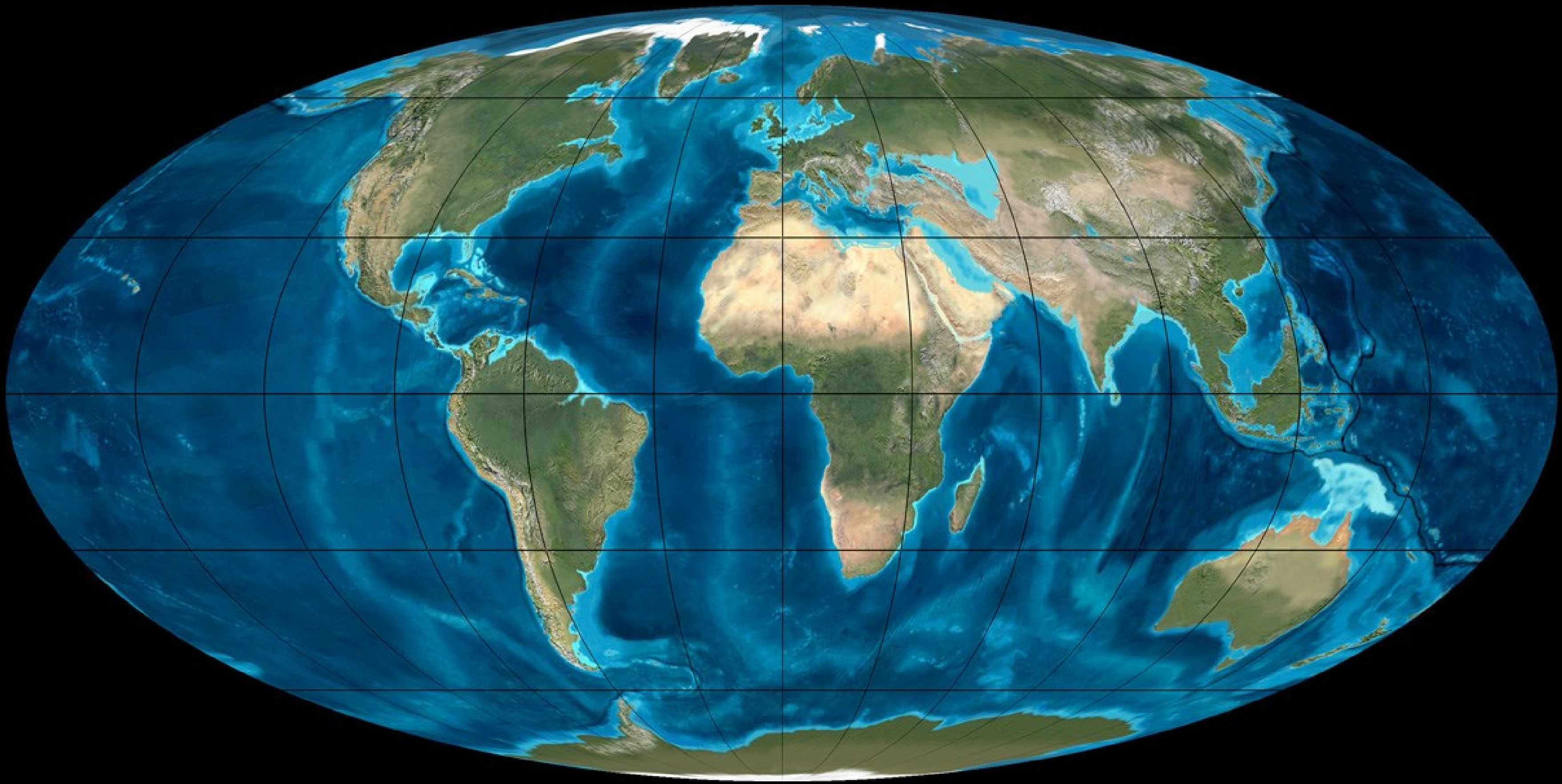


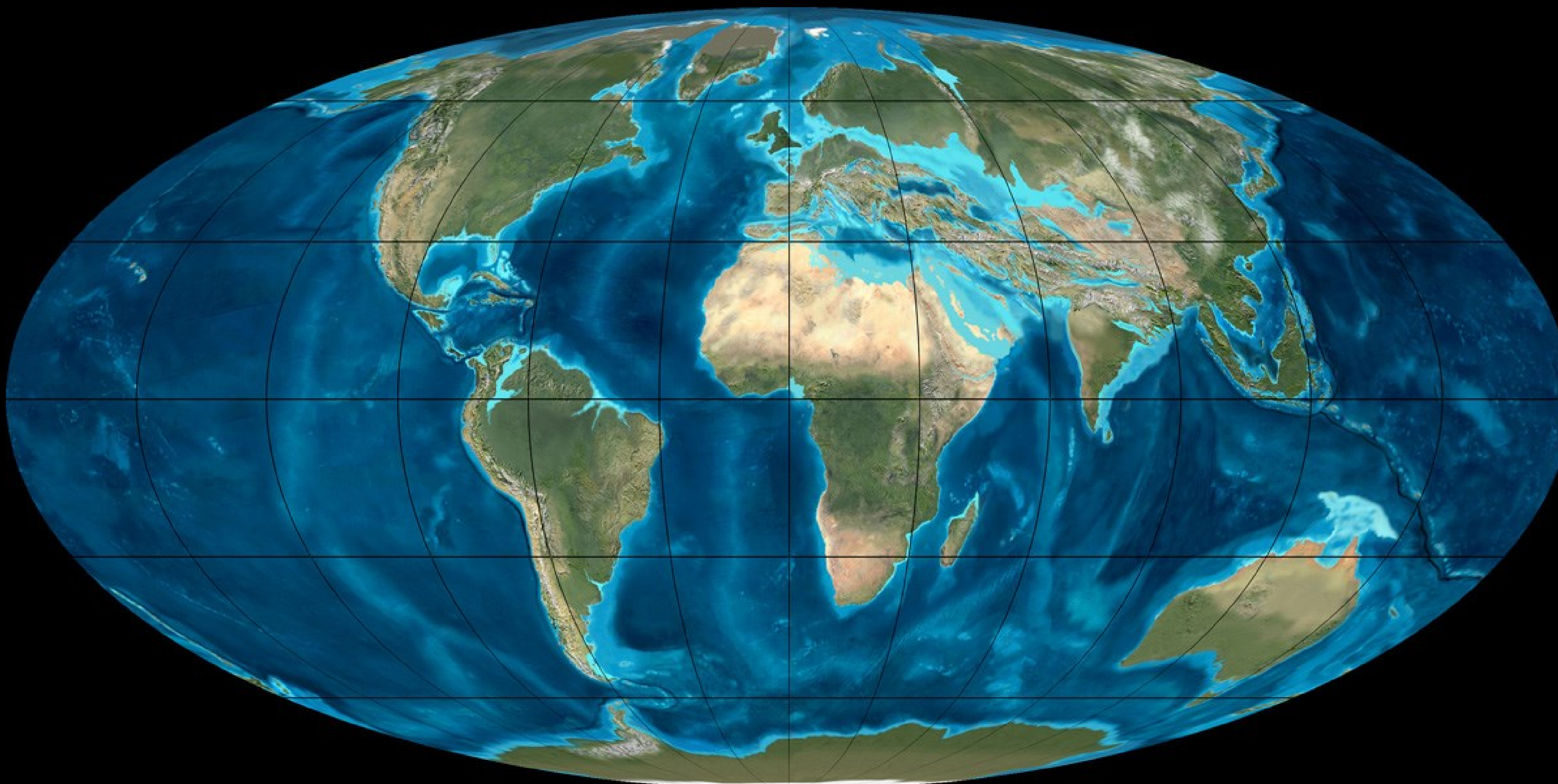
Jurkovšek et al., 2016

Oggi

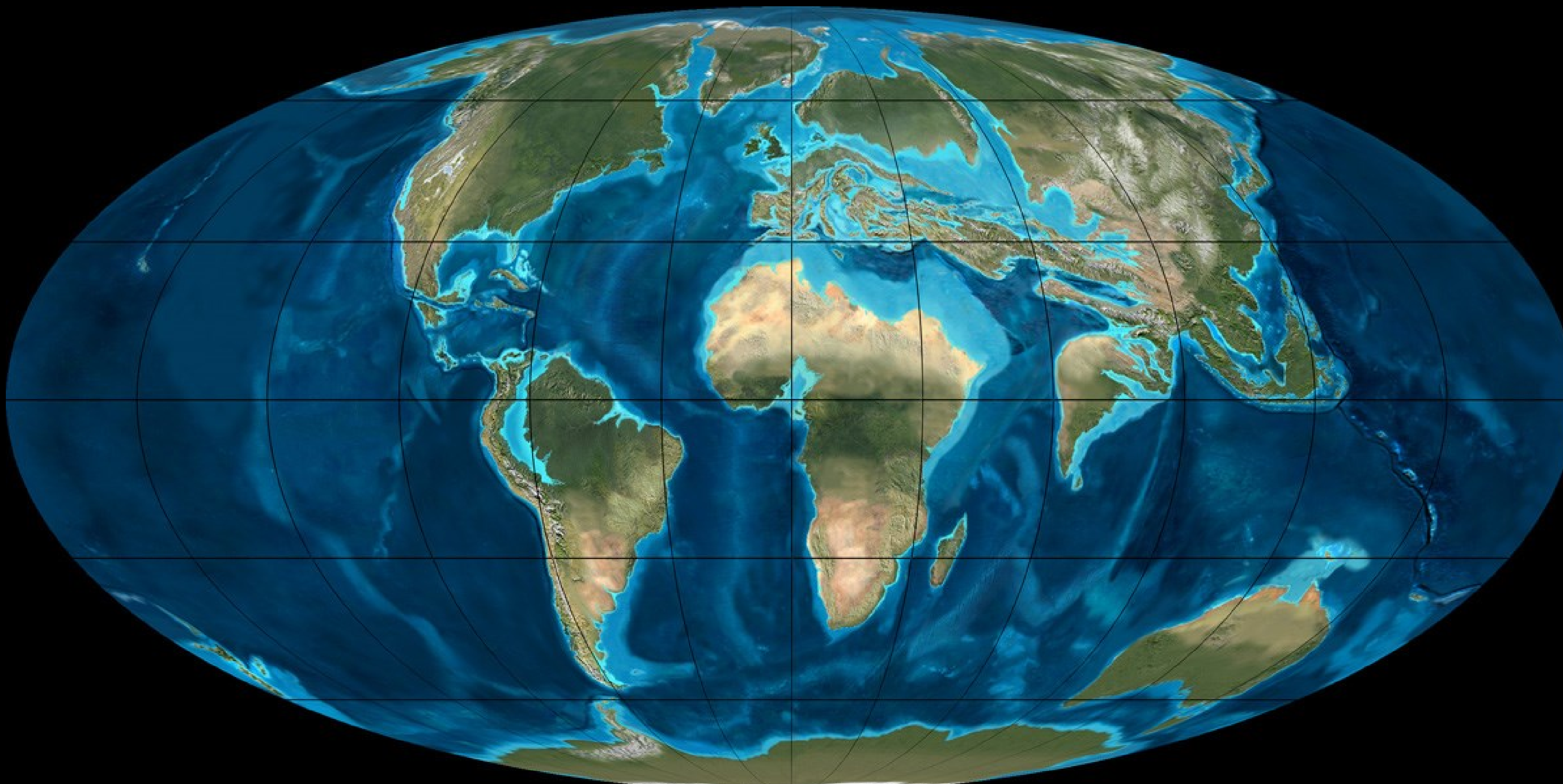


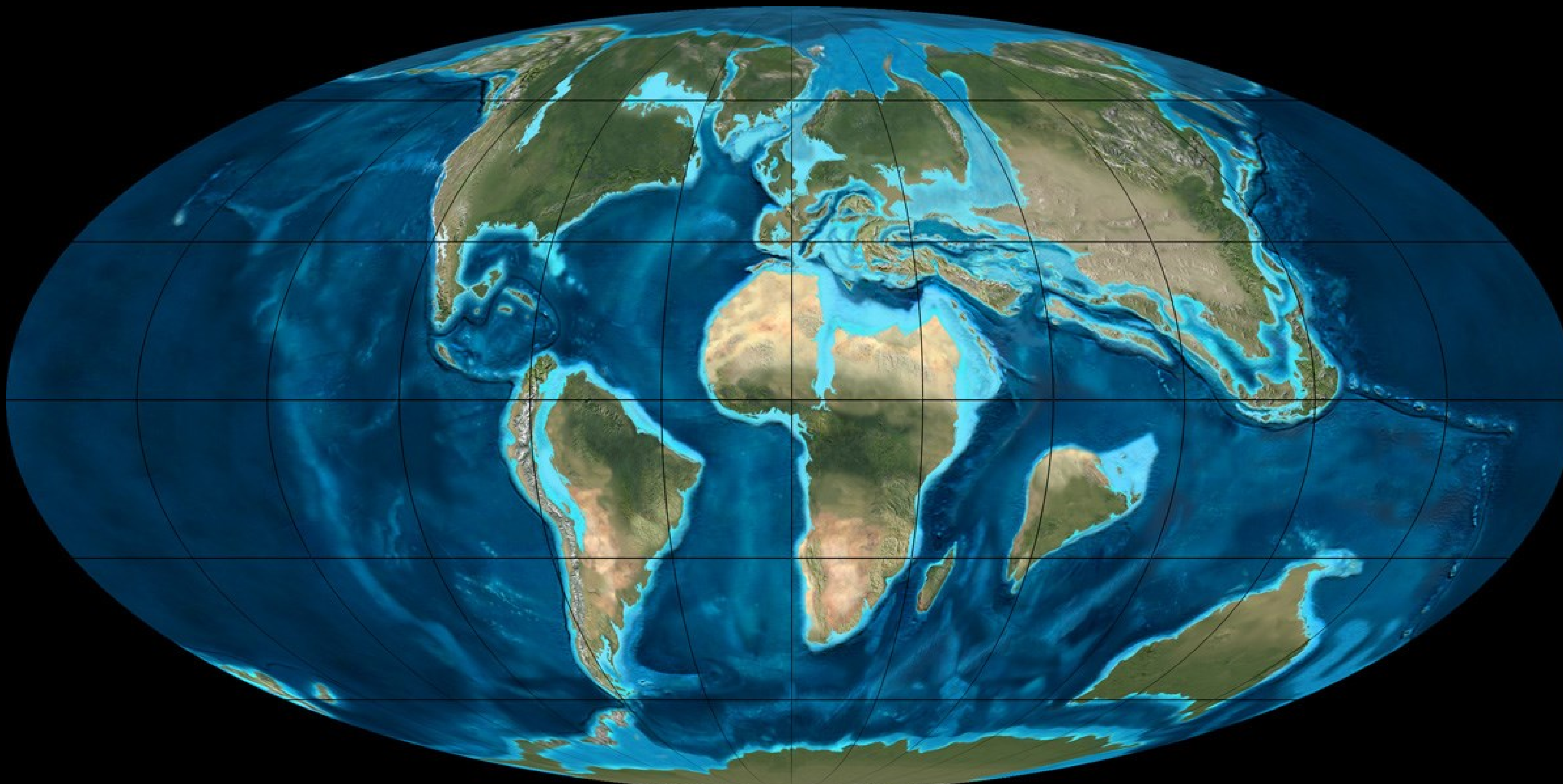


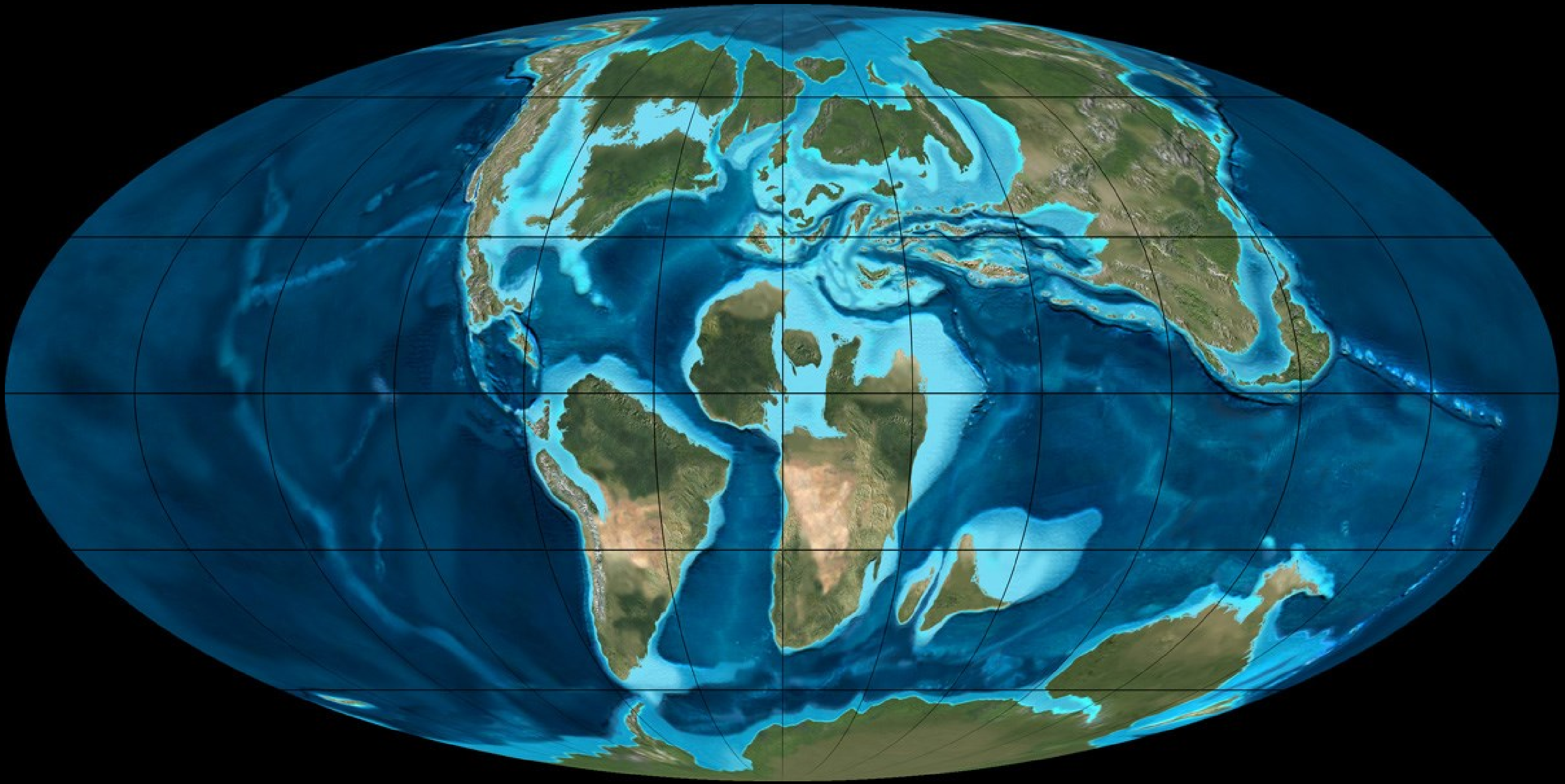




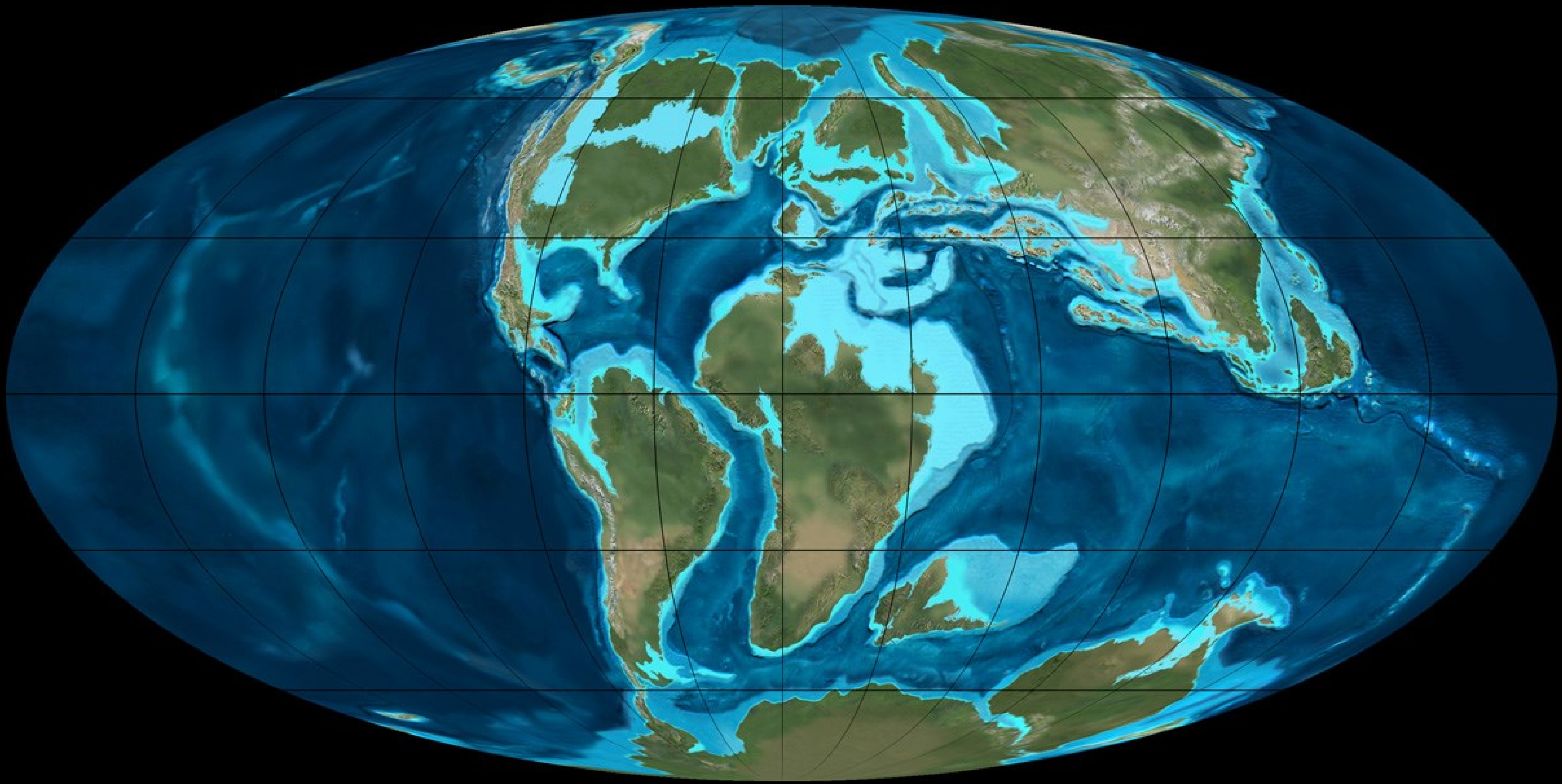
DOLOMITES GEODIVERSITY

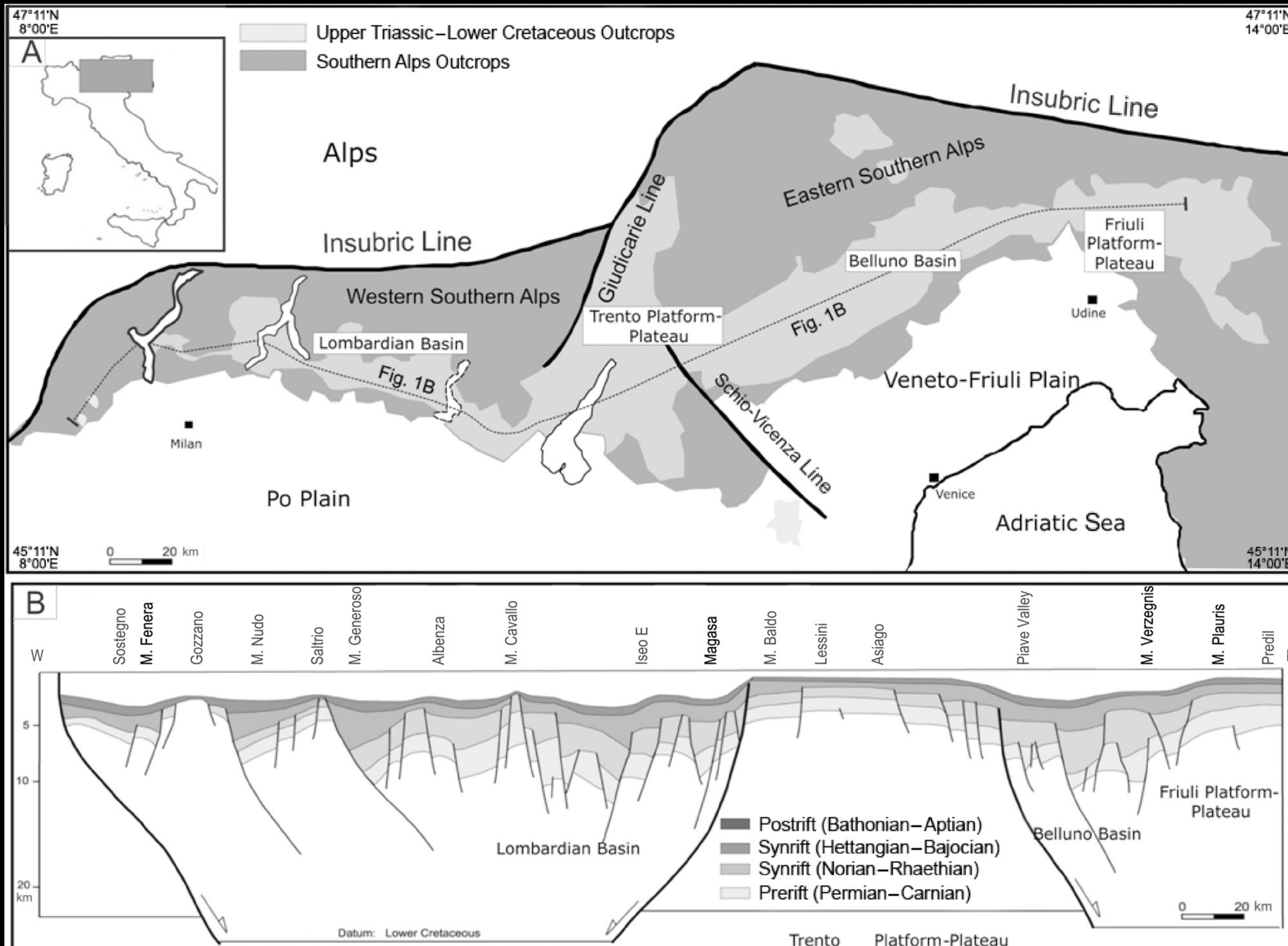




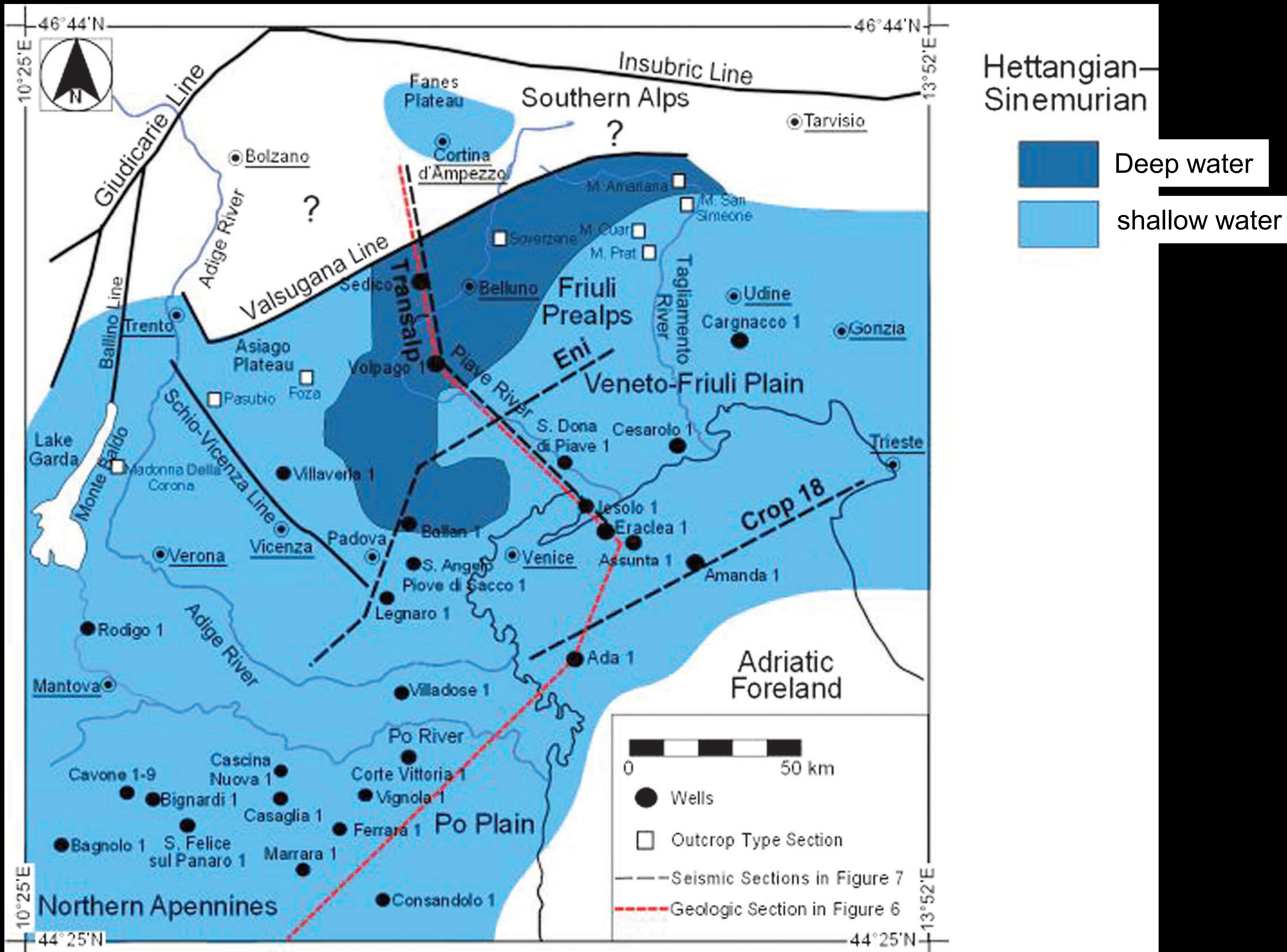


Circa 100 milioni di anni fa

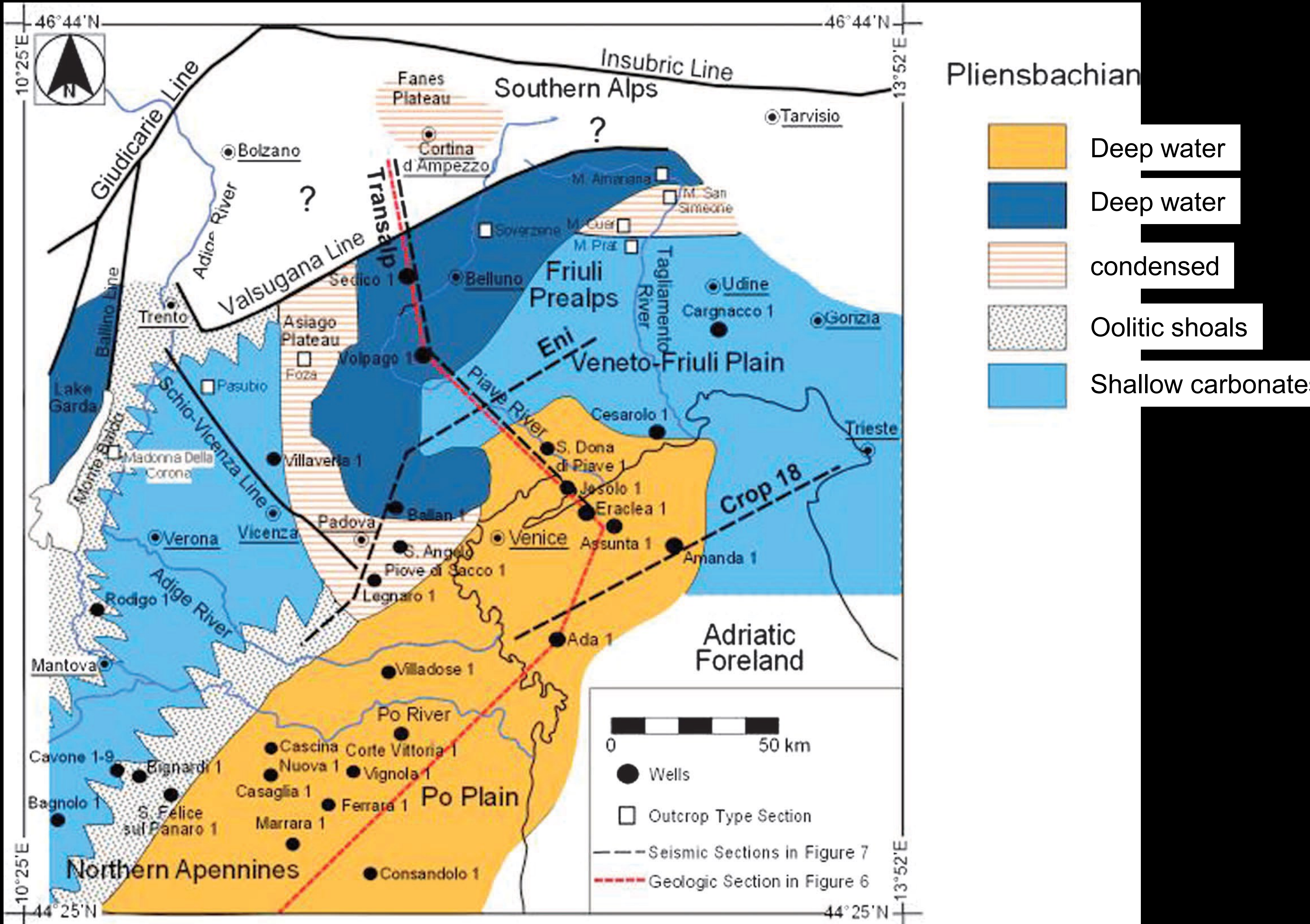




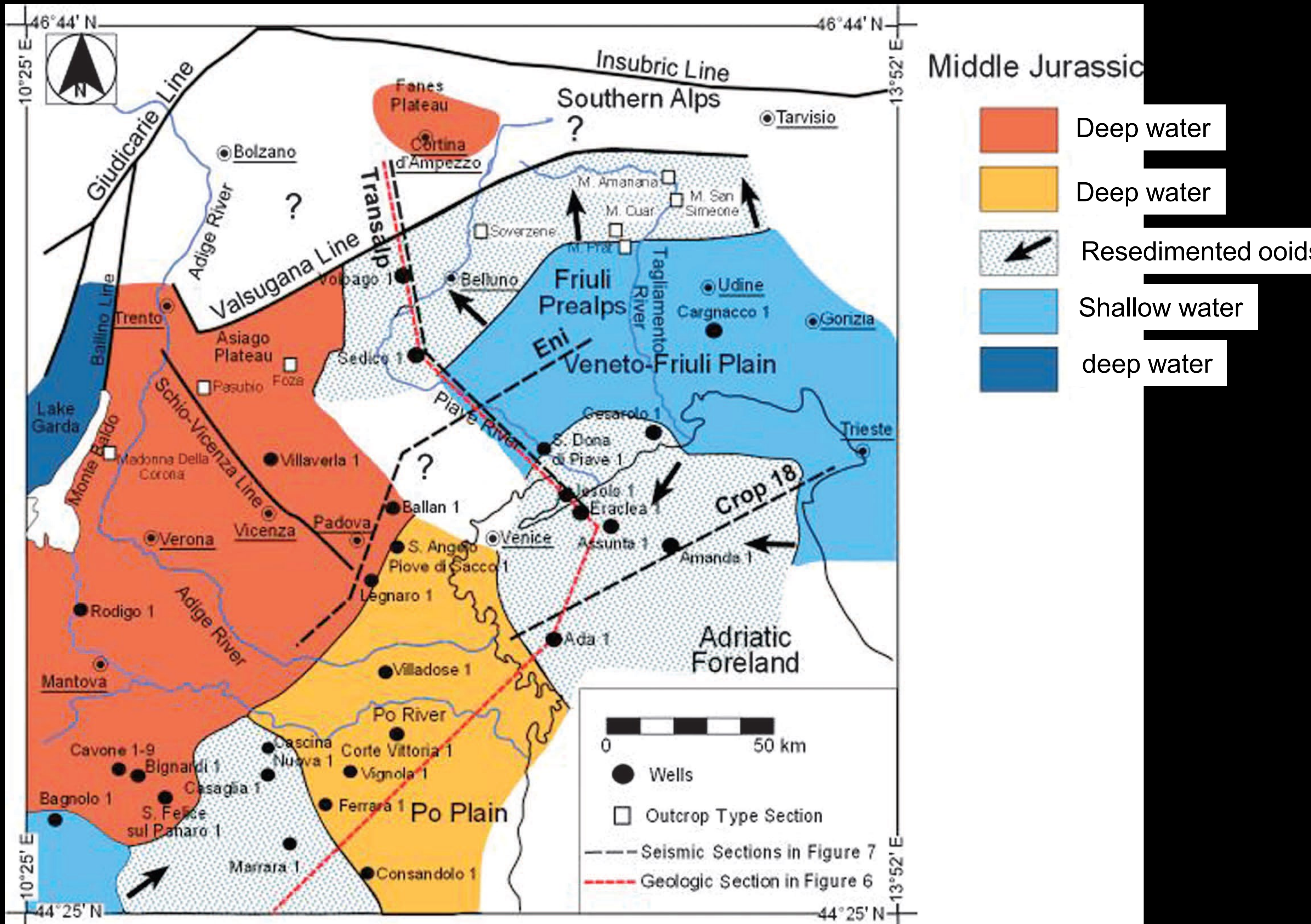
47°11'N 8°00'E
47°11'N 14°00'E
45°11'N 8°00'E
45°11'N 14°00'E
A
Upper Triassic–Lower Cretaceous Outcrops
Southern Alps Outcrops
Alps
Insubric Line
Insubric Line
Eastern Southern Alps
Western Southern Alps
Giudicarie Line
Friuli Platform-Plateau
Belluno Basin
Trento Platform-Plateau
Lombardian Basin
Fig. 1B
Fig. 1B
Udine
Milan
Veneto-Friuli Plain
Schio-Vicenza Line
Venice
Po Plain
Adriatic Sea
0 20 km
B
W
Sostegno
M. Fenera
Gozzano
M. Nudo
Saltrio
M. Generoso
Albenza
M. Cavallo
Iseo E
Magasa
M. Baldo
Lessini
Asiago
Piave Valley
M. Verzegnis
M. Plauris
Predil
E
5
10
20 km
Postrift (Bathonian–Aptian)
Synrift (Hettangian–Bajocian)
Synrift (Norian–Rhaethian)
Prerift (Permian–Carnian)
Lombardian Basin
Belluno Basin
Friuli Platform-Plateau
0 20 km
Datum: Lower Cretaceous
Trento Platform-Plateau



46°44'N
10°25'E
13°52'E
44°25'N
N
Insubric Line
Southern Alps
Giudicarie Line
Fanes Plateau
Cortina d'Ampezzo
Bolzano
Tarvisio
Adige River
Valsugana Line
M. Amariana
M. San Simeone
Soverzene
M. Cuar
M. Prat
Sedico
Transalp
Belluno
Friuli Prealps
Tagliamento River
Udine
Cargnacco 1
Gonzia
Ballino Line
Trento
Asiago Plateau
Foza
Pasubio
Volpago 1
Piave River
Eni
Veneto-Friuli Plain
Lake Garda
Monte Baldo
Madonna Della Corona
Schio-Vicenza Line
Villaverla 1
S. Dona di Piave 1
Cesarolo 1
Trieste
Jesolo 1
Eraclea 1
Crop 18
Ballan 1
Padova
Vicenza
Verona
S. Angelo Piove di Sacco 1
Venice
Assunta 1
Amanda 1
Legnaro 1
Rodigo 1
Adige River
Ada 1
Adriatic Foreland
Mantova
Villadose 1
Po River
Cascina Nuova 1
Cavone 1-9
Bignardi 1
Casaglia 1
Corte Vittoria 1
Vignola 1
Ferrara 1
Po Plain
Bagnolo 1
S. Felice sul Panaro 1
Marrara 1
Consandolo 1
Northern Apennines
0
50 km
Wells
Outcrop Type Section
Seismic Sections in Figure 7
Geologic Section in Figure 6
Hettangian–Sinemurian
Deep water
shallow water

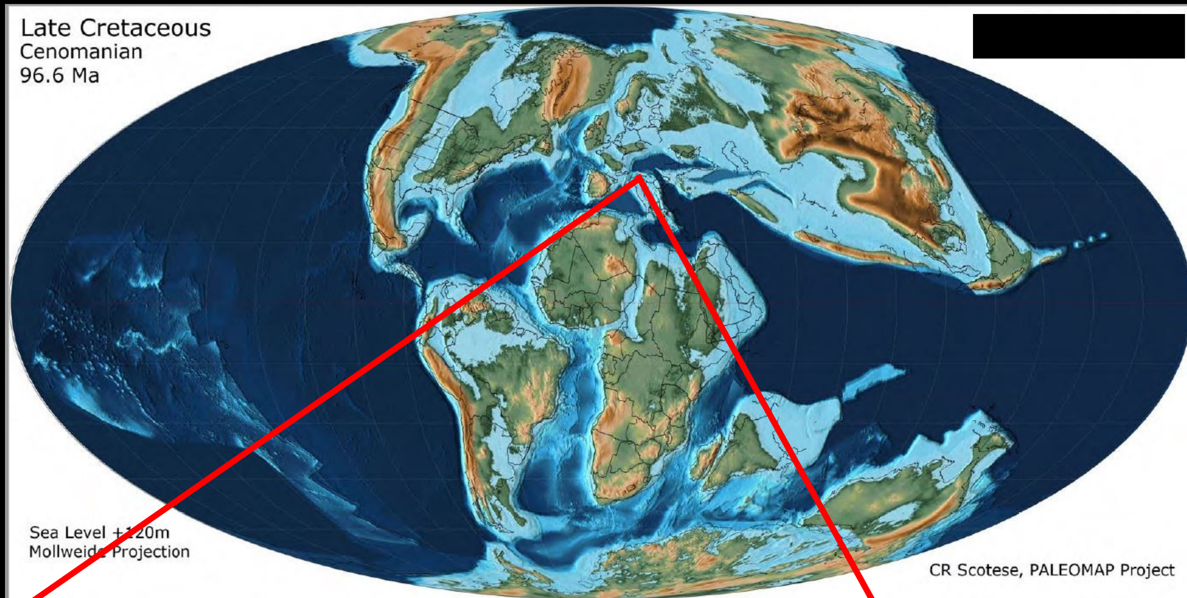


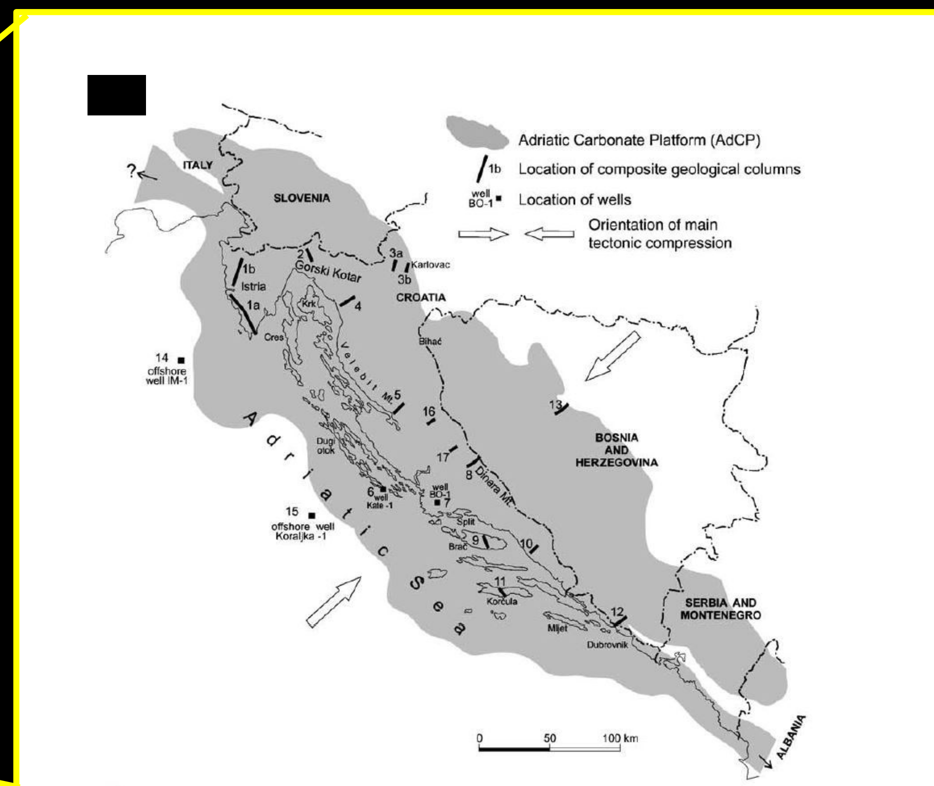
Pliensbachian
Deep water
Deep water
condensed
Oolitic shoals
Shallow carbonates
46°44'N
46°44'N
44°25'N
44°25'N
10°25'E
10°25'E
13°52'E
13°52'E
N
Insubric Line
Southern Alps
Fanes Plateau
Cortina d'Ampezzo
Tarvisio
Giudicarie Line
Bolzano
Adige River
Transalp
Valsugana Line
?
?
Sedico 1
Belluno
Friuli Prealps
Tagliamento River
Udine
Cargnacco 1
Gorizia
Trento
Ballino Line
Asiago Plateau
Foza
Volpago 1
Eni
Veneto-Friuli Plain
Lake Garda
Pasubio
Schio-Vicenza Line
Piave River
Cesarolo 1
Trieste
Monte Baldo
Madonna Della Corona
Villaverla 1
S. Dona di Piave 1
Jesolo 1
Eraclea 1
Crop 18
Ballan 1
Padova
Vicenza
Verona
Venice
Assunta 1
Amanda 1
S. Angelo
Piove di Sacco 1
Legnaro 1
Rodigo 1
Adige River
Adriatic Foreland
Ada 1
Mantova
Villadose 1
Po River
Cascina Nuova 1
Corte Vittoria 1
Cavone 1-9
Bignardi 1
Vignola 1
Casaglia 1
Po Plain
Bagnolo 1
S. Felice sul Panaro 1
Ferrara 1
Marrara 1
Northern Apennines
Consandolo 1
0
50 km
Wells
Outcrop Type Section
Seismic Sections in Figure 7
Geologic Section in Figure 6



Middle Jurassic
Deep water
Deep water
Resedimented ooids
Shallow water
deep water
46°44' N
10°25' E
13°52' E
44°25' N
Insubric Line
Southern Alps
Giudicarie Line
Valsugana Line
Transalp
Fanes Plateau
Cortina d'Ampezzo
Tarvisio
Bolzano
Adige River
M. Amariana
M. San Simeone
M. Cuar
M. Prat
Soverzene
Friuli Prealps
Tagliamento River
Udine
Cargnacco 1
Gorizia
Belluno
Volpago 1
Sedico 1
Eni
Veneto-Friuli Plain
Piave River
Ballino Line
Trento
Asiago Plateau
Foza
Pasubio
Lake Garda
Monte Baldo
Madonna Della Corona
Schio-Vicenza Line
Villaverla 1
Vicenza
Padova
Verona
Ballan 1
Cesarolo 1
S. Dona di Piave 1
Jesolo 1
Eraclea 1
Assunta 1
Amanda 1
Crop 18
Trieste
Venice
S. Angelo Piove di Sacco 1
Legnaro 1
Rodigo 1
Adige River
Mantova
Ada 1
Adriatic Foreland
Villadose 1
Po River
Cascina Nuova 1
Corte Vittoria 1
Vignola 1
Cavone 1-9
Bignardi 1
Casaglia 1
Bagnolo 1
S. Felice sul Panaro 1
Ferrara 1
Po Plain
Marrara 1
Consandolo 1
0
50 km
Wells
Outcrop Type Section
Seismic Sections in Figure 7
Geologic Section in Figure 6

LA PIATTAFORMA CARBONATICA ADRIATICA

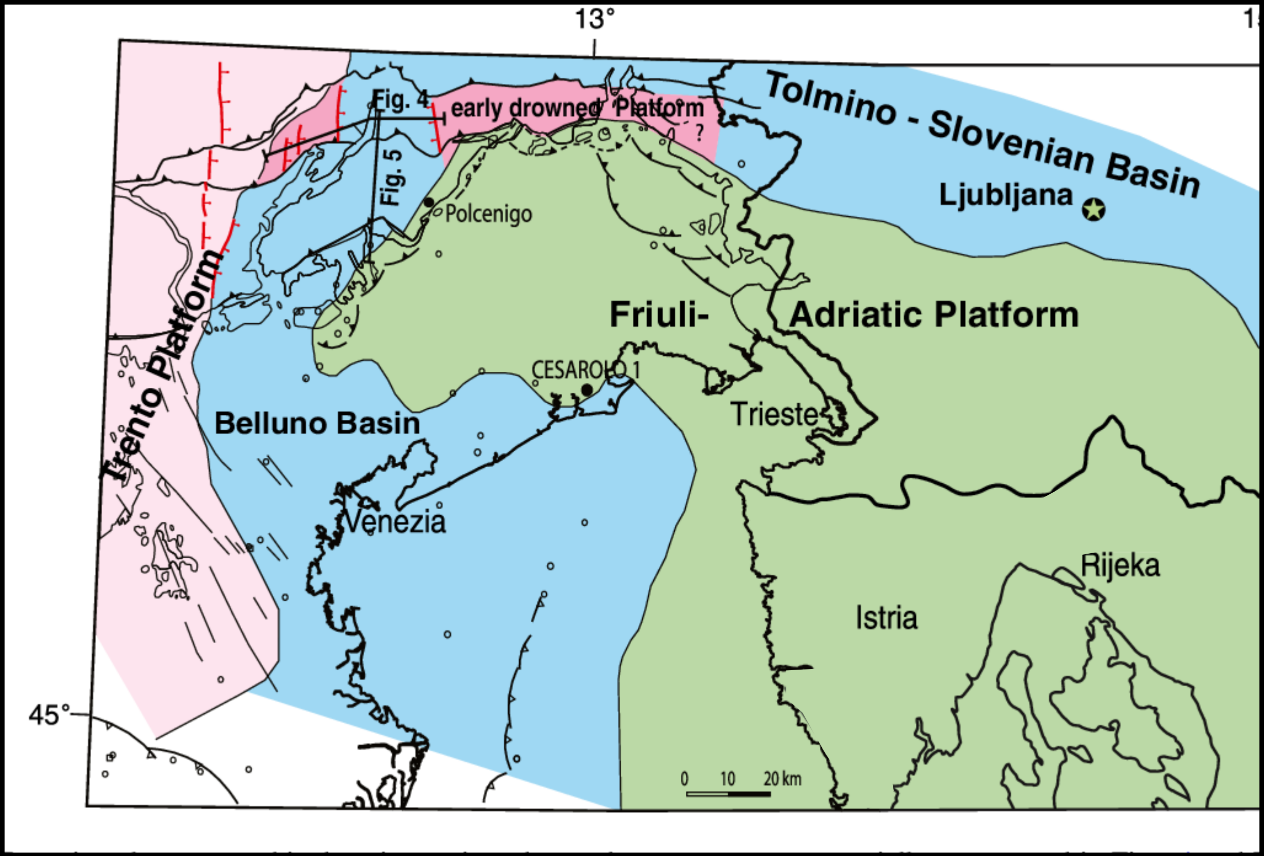




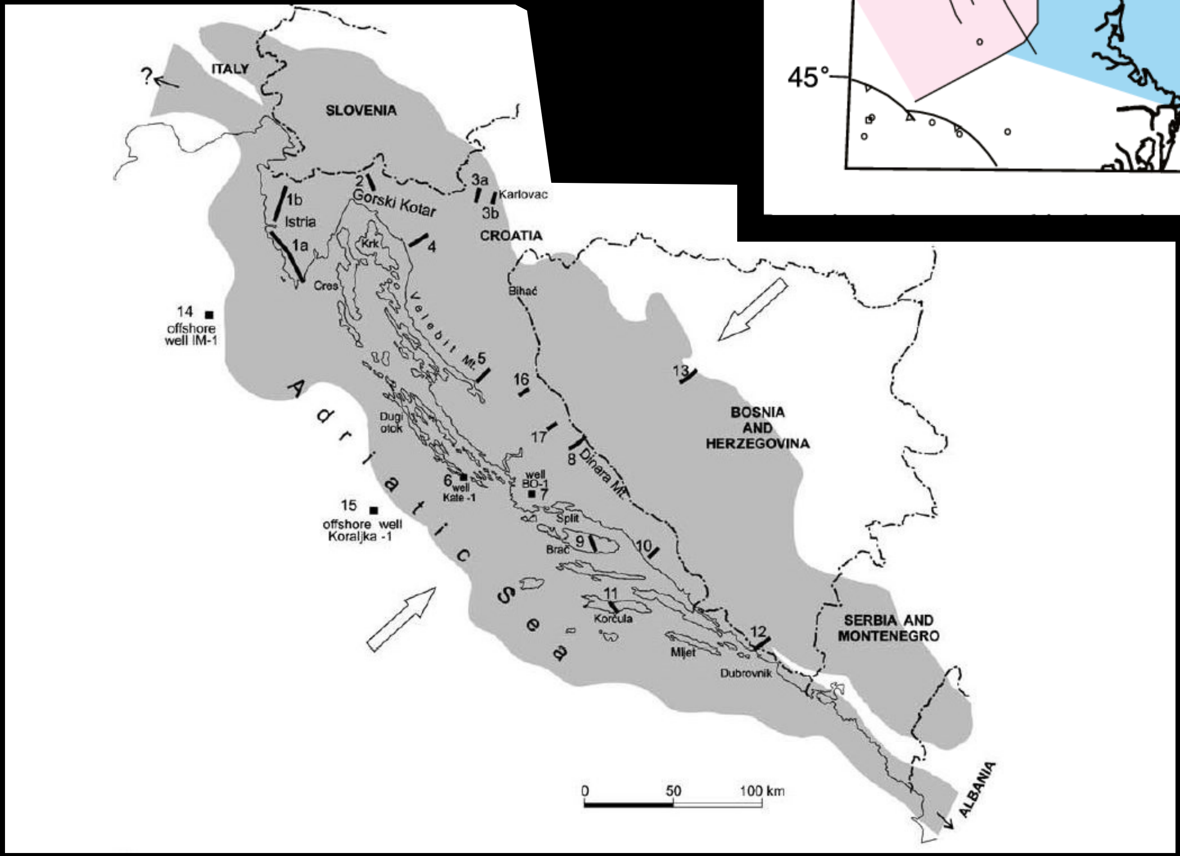
LA PIATTAFORMA CARBONATICA ADRIATICA

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**



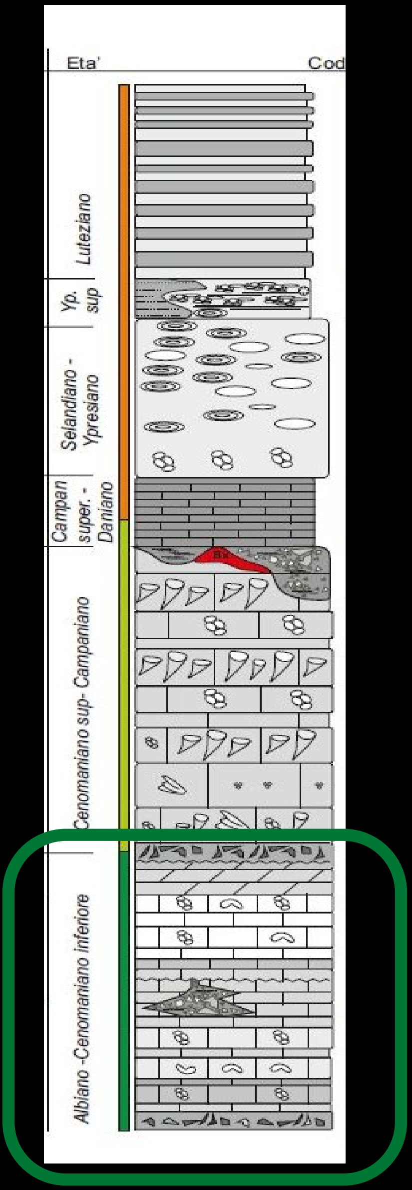
Modificato da Picotti e Cobianchi, 2017



da Vlahovic et al., 2005

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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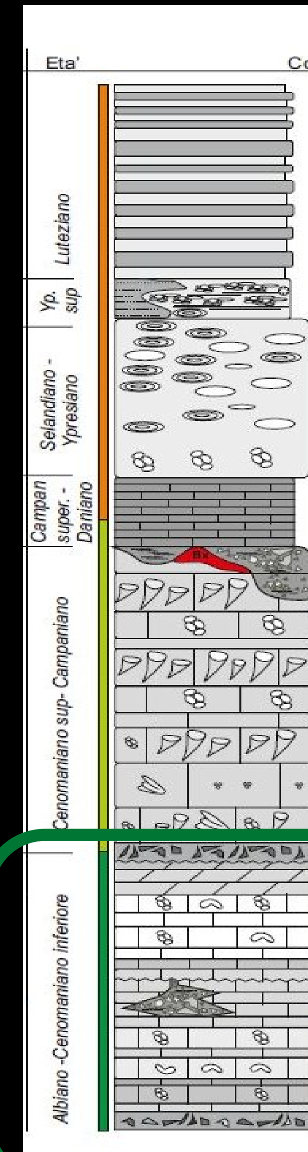

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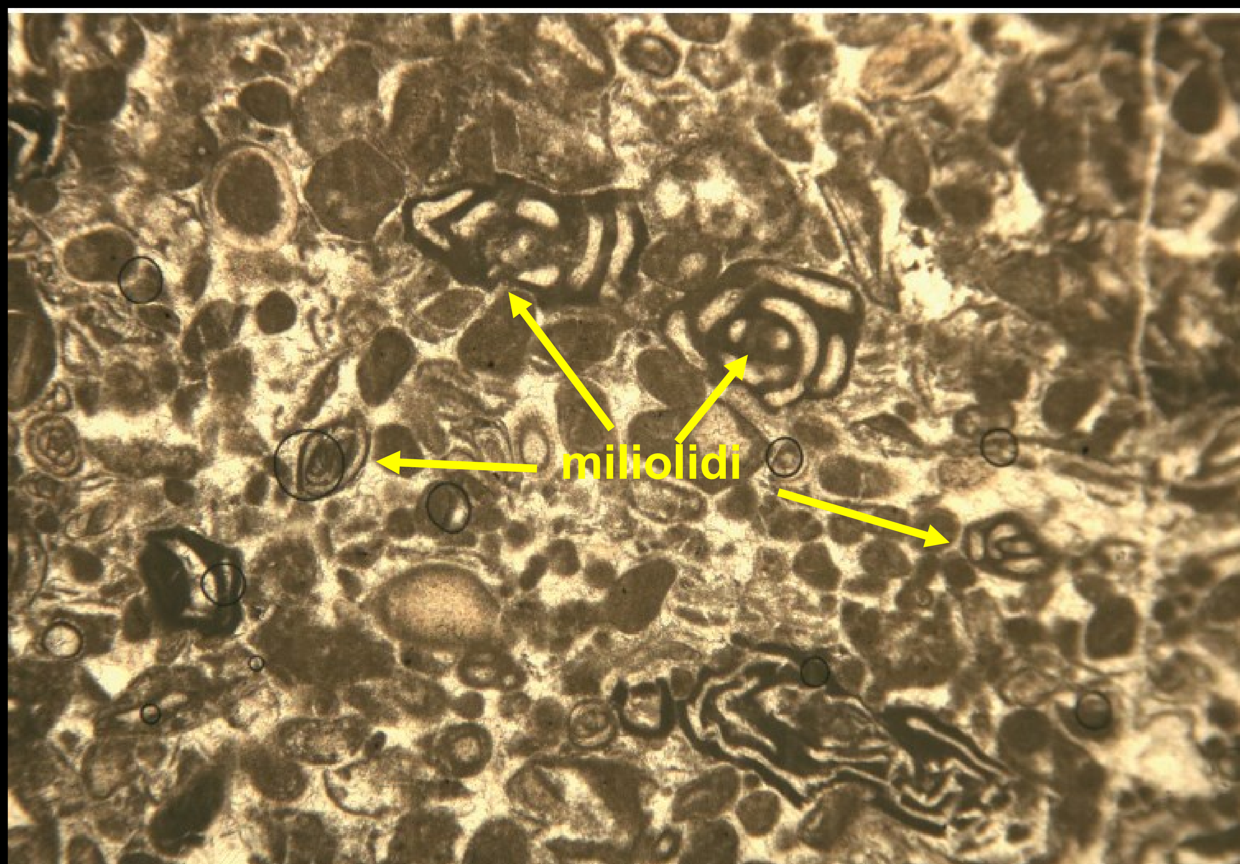

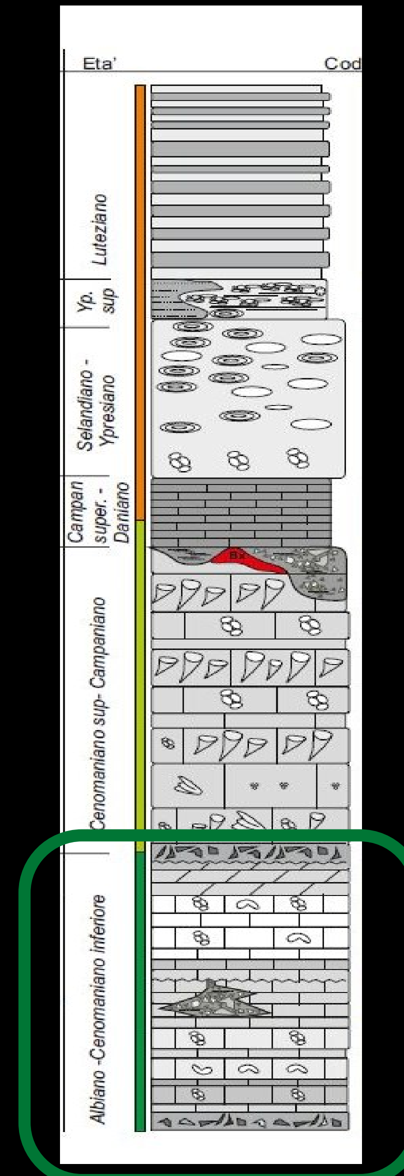

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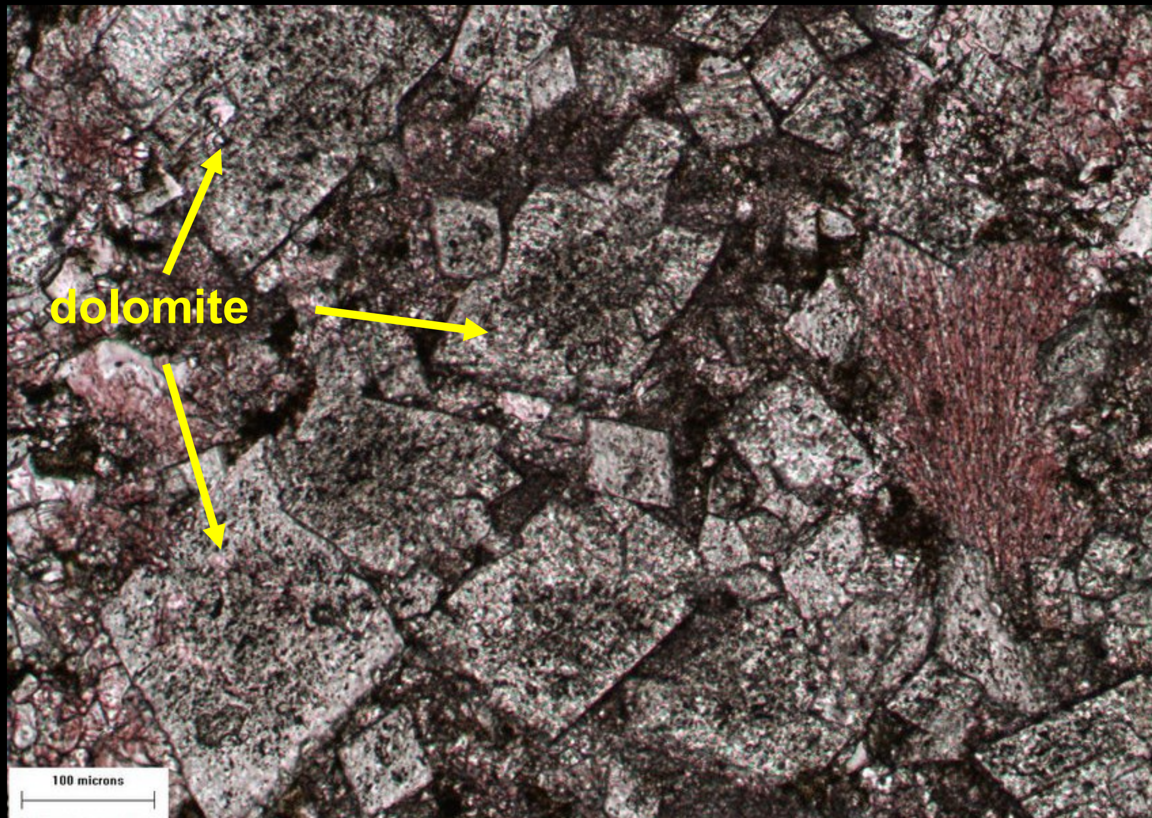
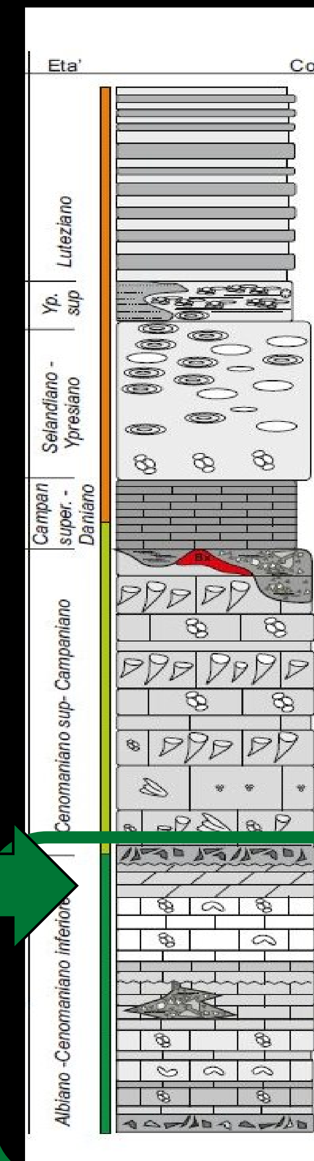


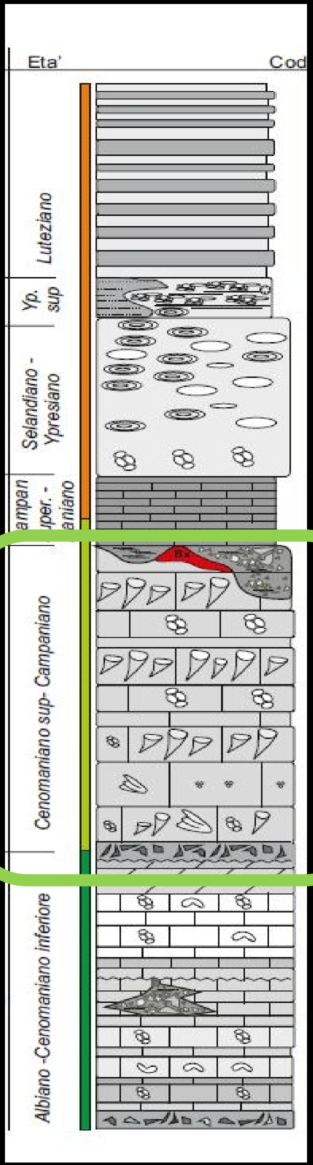


La parte sommitale dei Calcari di Monte Coste è in realtà costituita da un potente livello di calcari dolomitici e dolomie (in letteratura deominate Formazione di Monrupino)

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 e Chondrodonta**

Il C. di Aurisina rappresenta 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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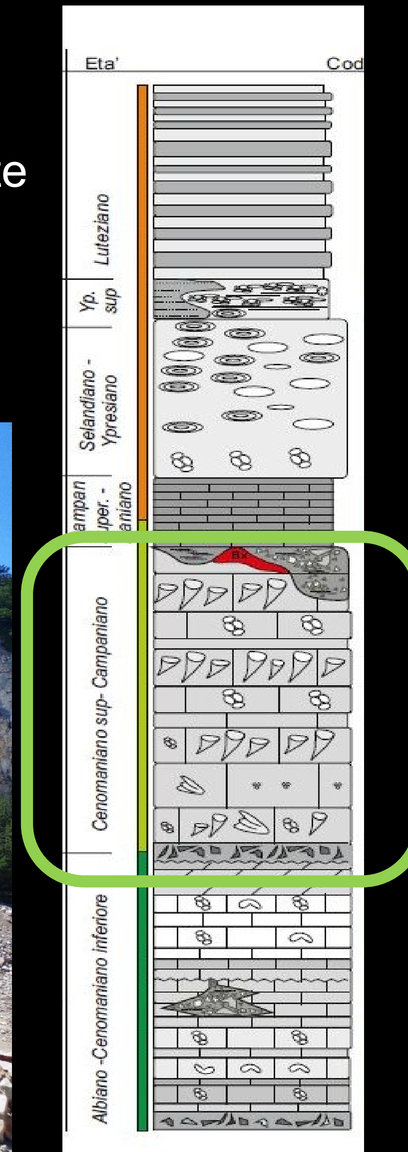

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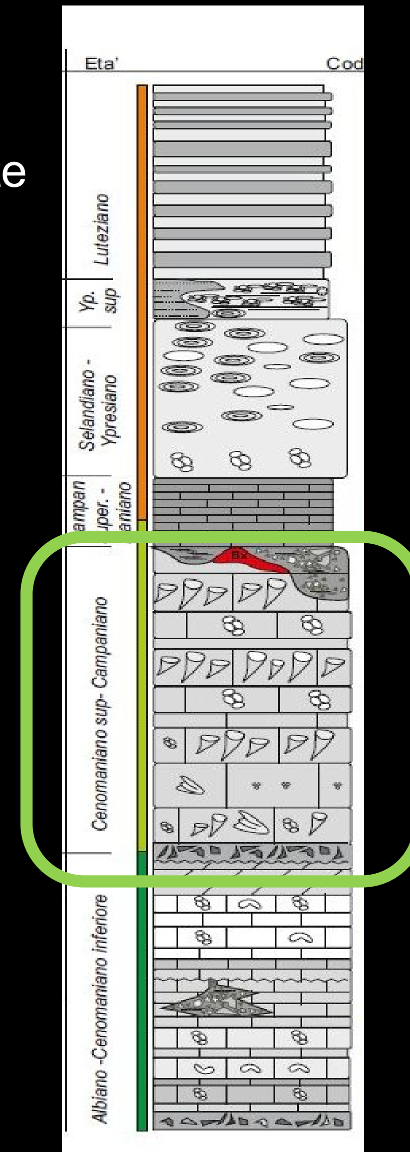

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CALCARI LIBURNICI

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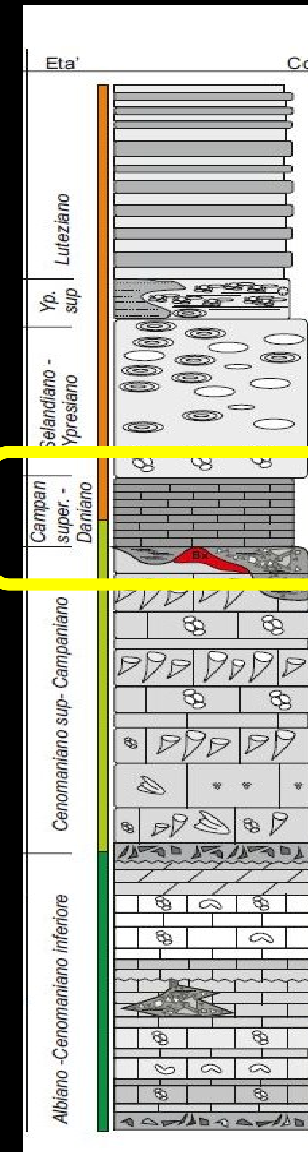

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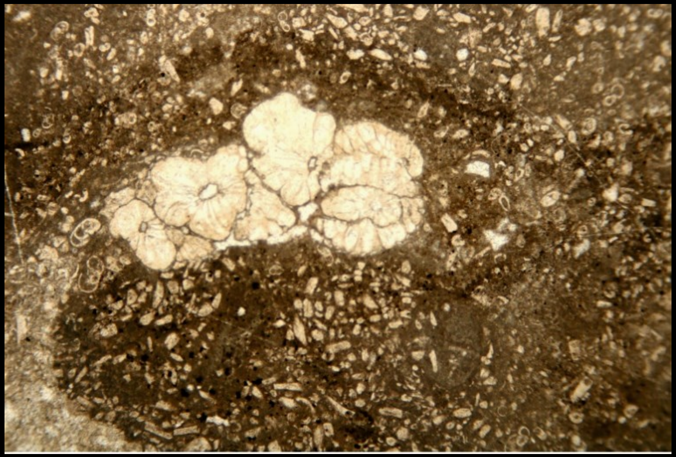

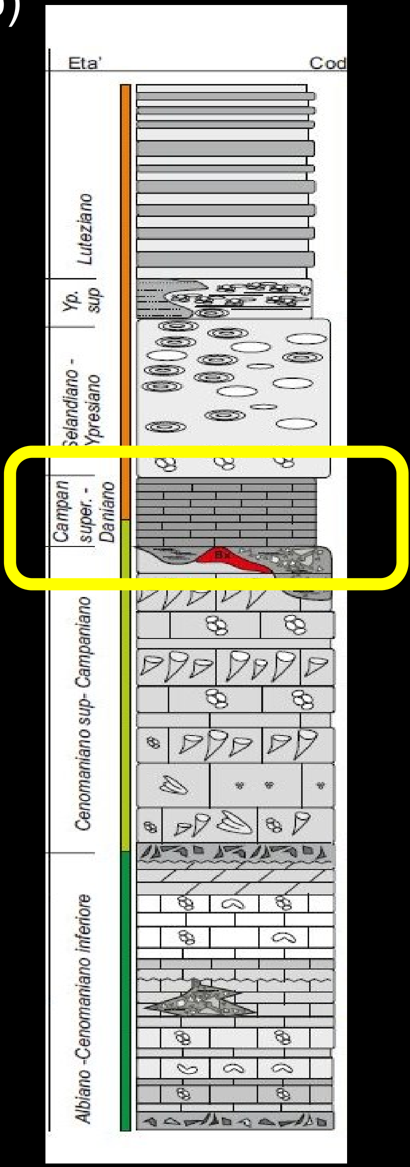

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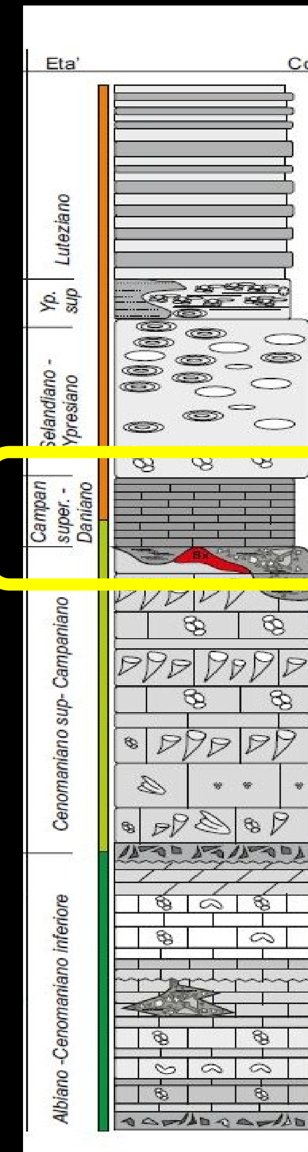
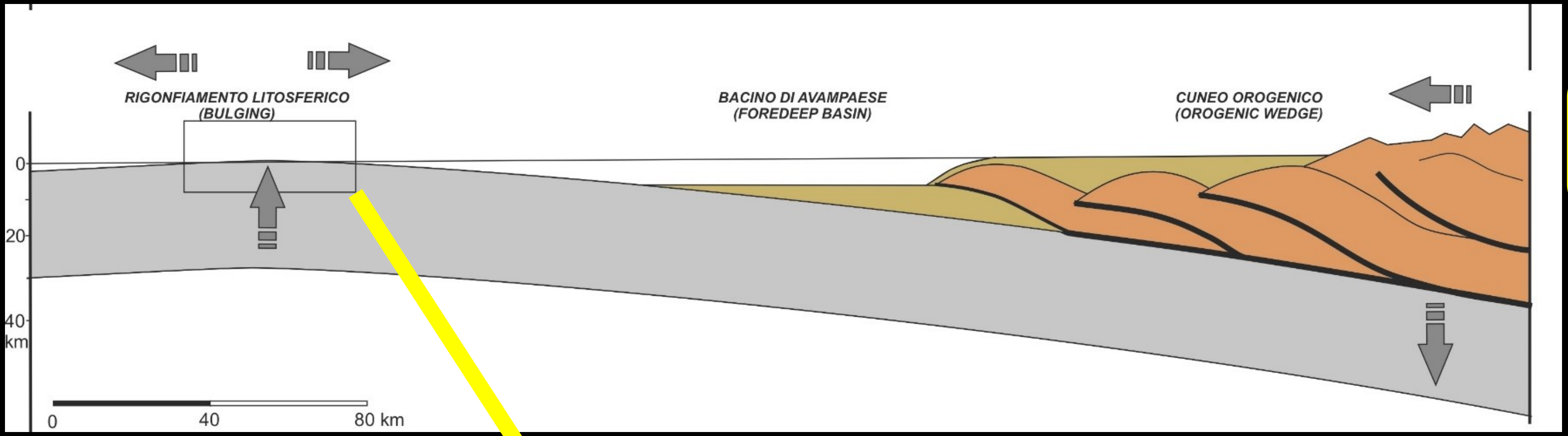
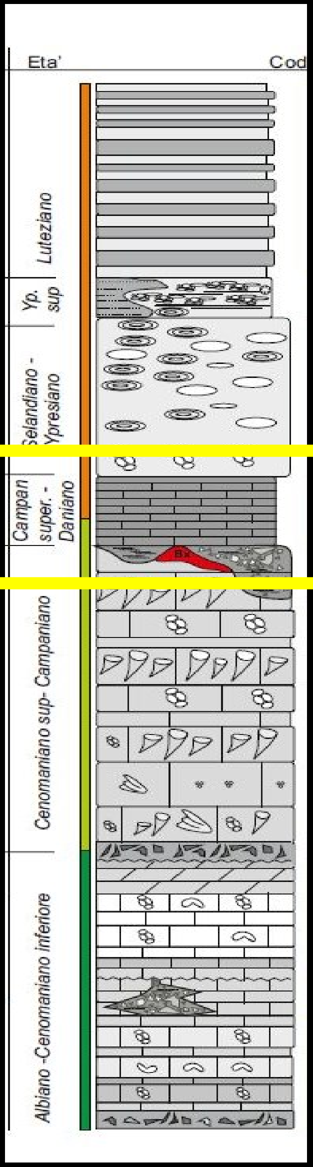


CALCARI LIBURNICI

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.

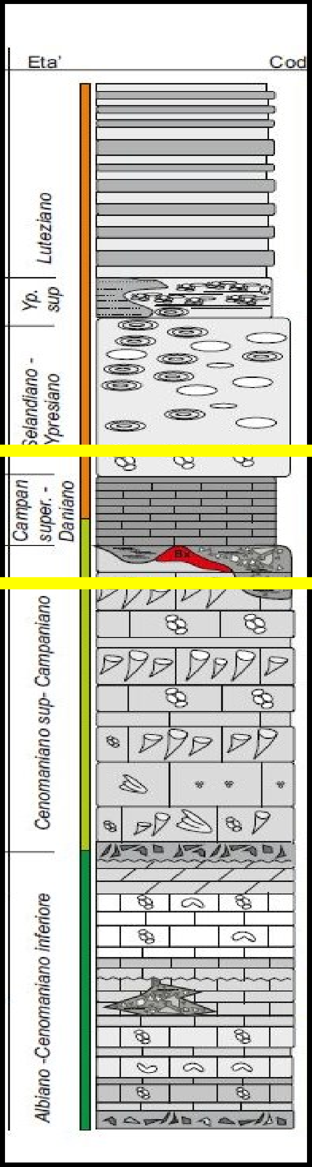




Deposizione dei C. Liburnici

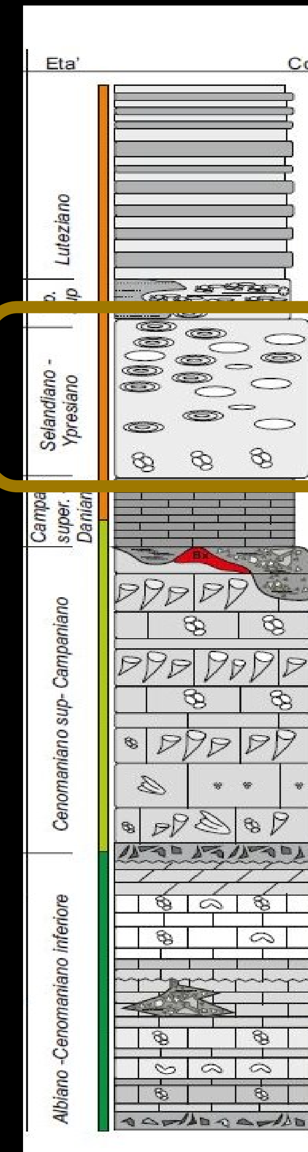
CALCARI LIBURNICI

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)



CALCARI AD ALVEOLINE E NUMMULITI

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.



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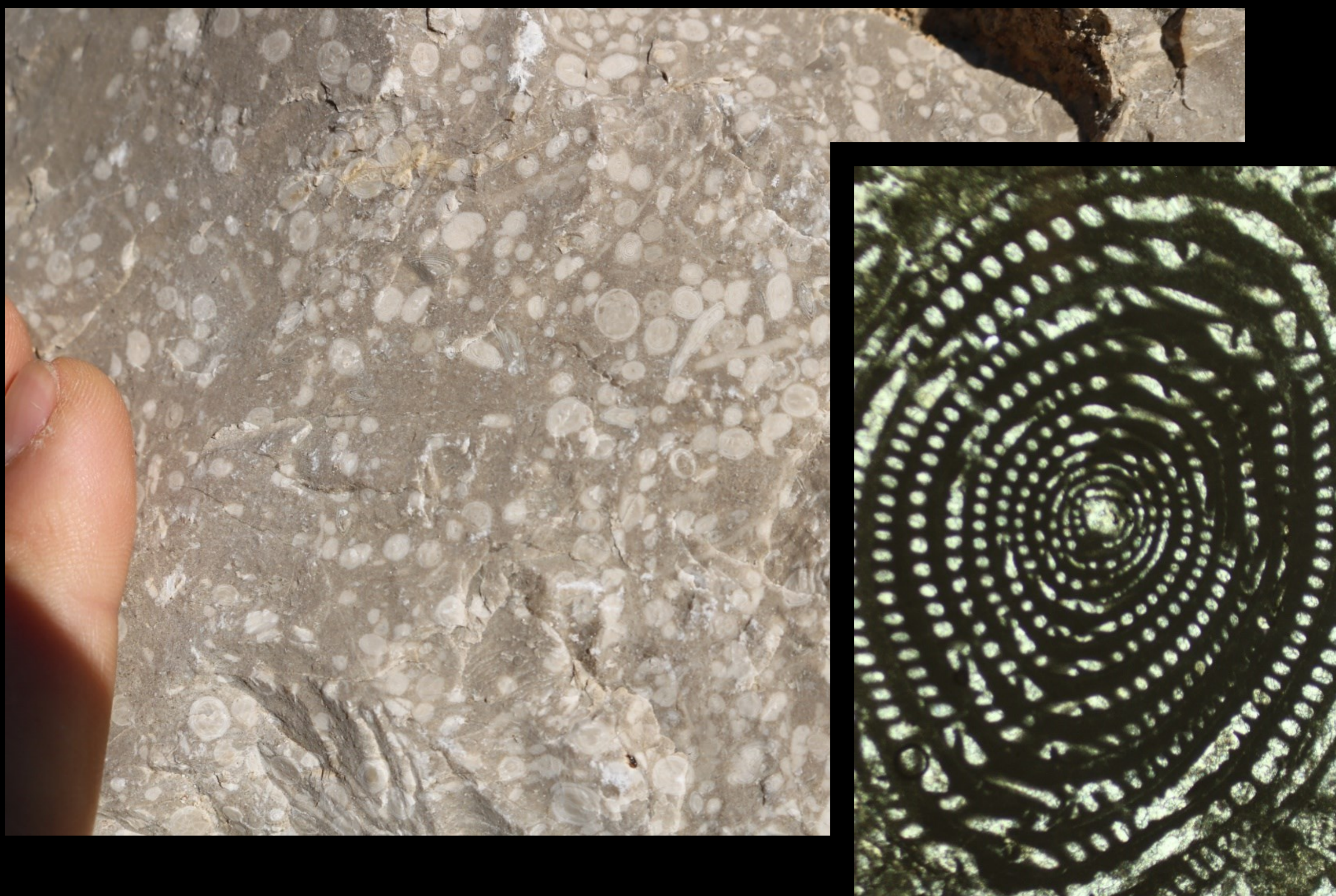

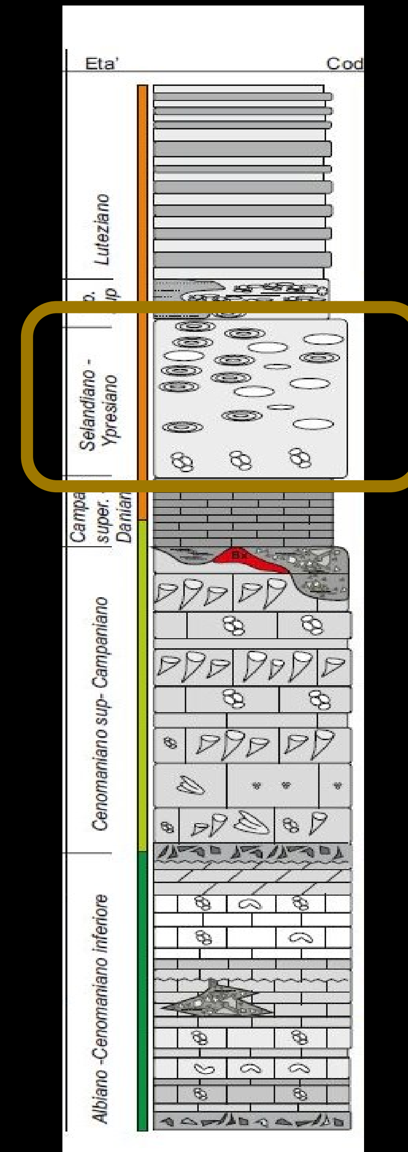

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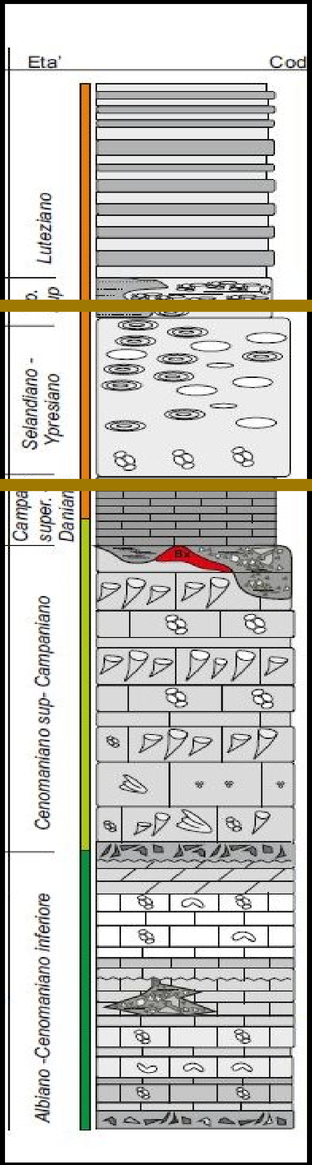
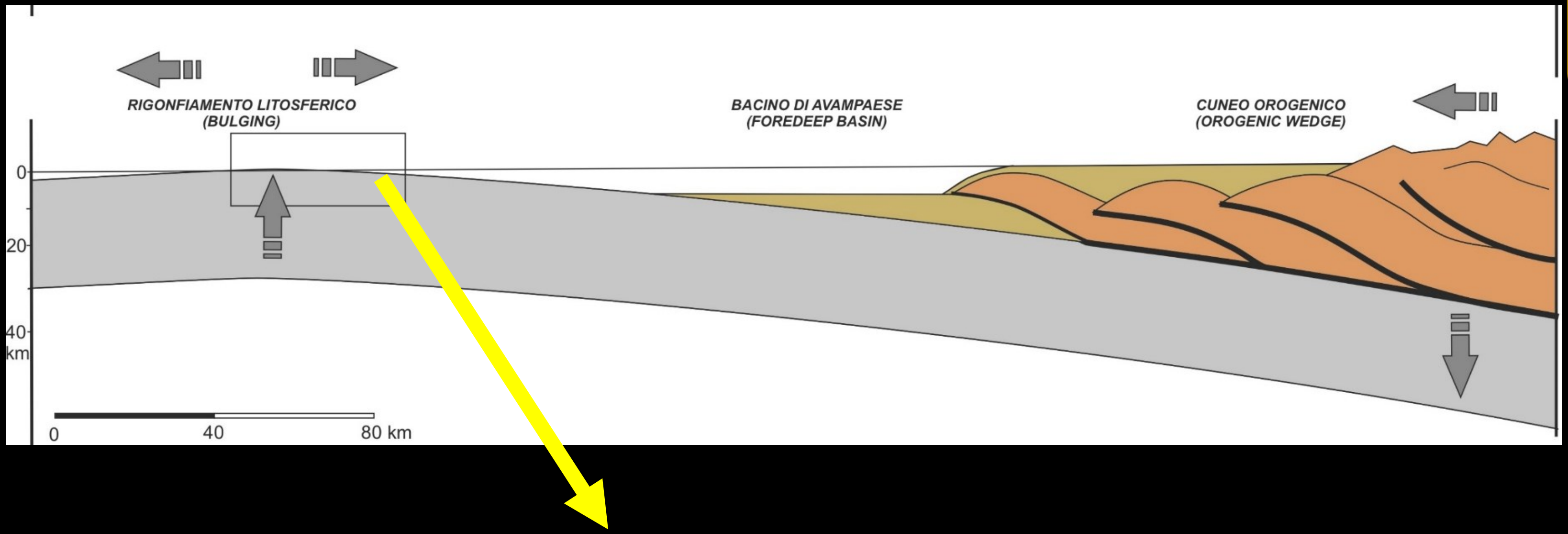


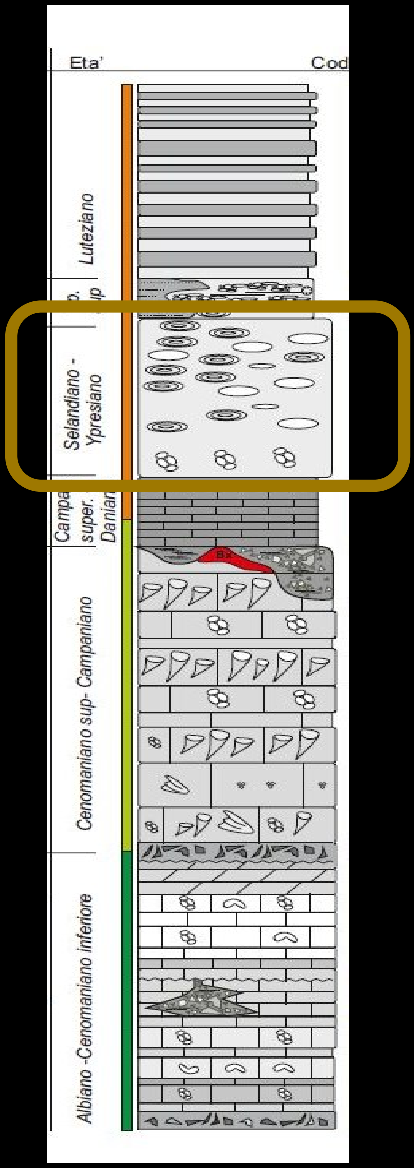
CALCARI AD ALVEOLINE E NUMMULITI

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.



Attecchimento della piattaforma dei C. a Nummuliti e Alveoline



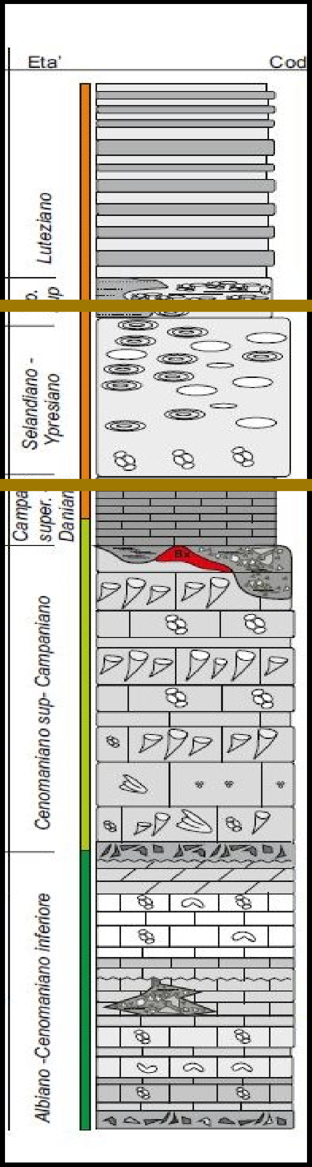
CALCARI AD ALVEOLINE E NUMMULITI

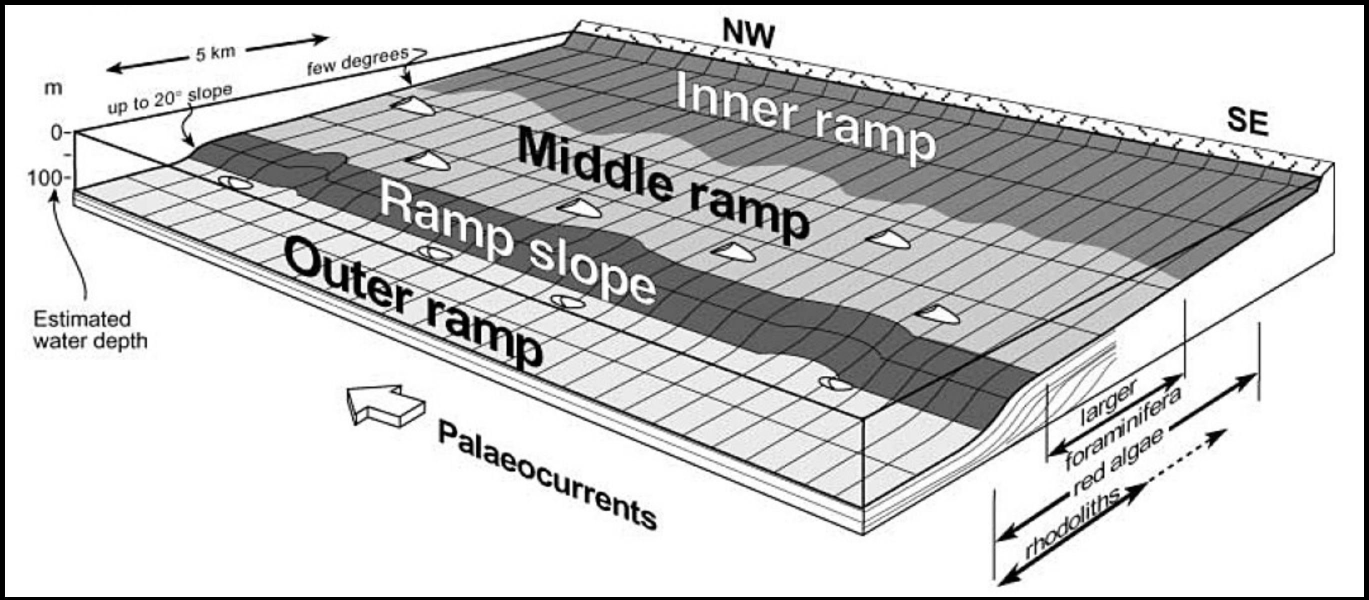
ATTENZIONE

La carbonate factory nella piattaforma dei C. ad Alveoline e Nummuliti 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’



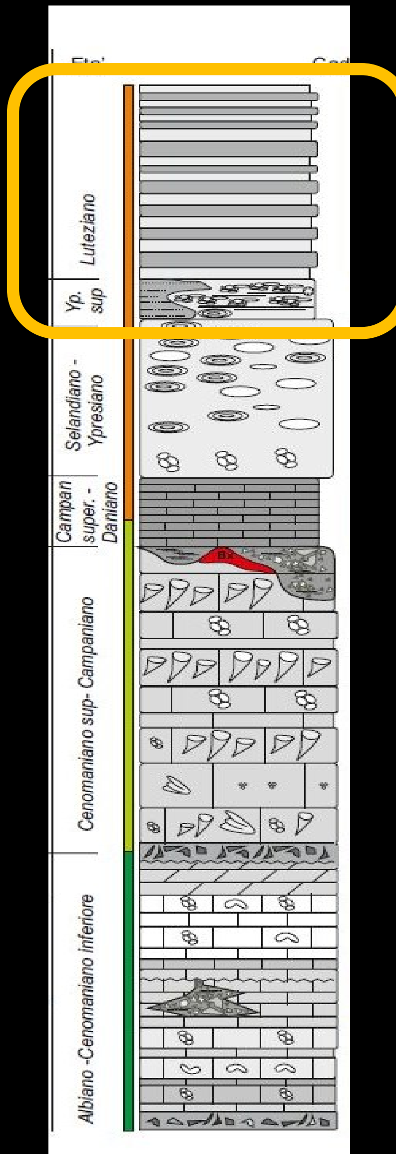


FLYSCH DI TRIESTE

Questa unità può essere divisa in due parti.

Prima, a contatto con i C. a Nummuliti e Alveoline brecce a clasti calcarei da angolosi a sub-arrotondati a cui seguono marne e calcari marnosi con foraminiferi planctonici globigerinidi e calcareniti.

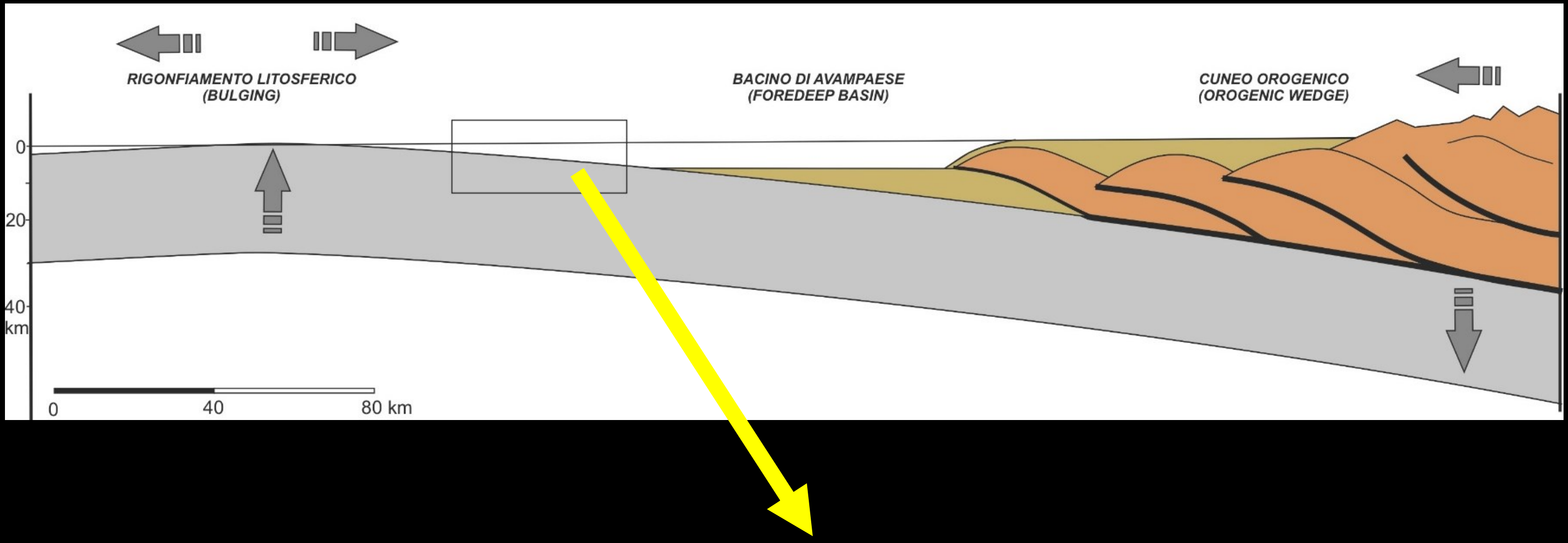
Poi, il flysch vero e proprio, comprendente areniti da grossolane a fini, siltiti e argilliti siltose con strutture sedimentarie quali laminazioni, flute casts e groove casts tipici delle successioni torbiditiche

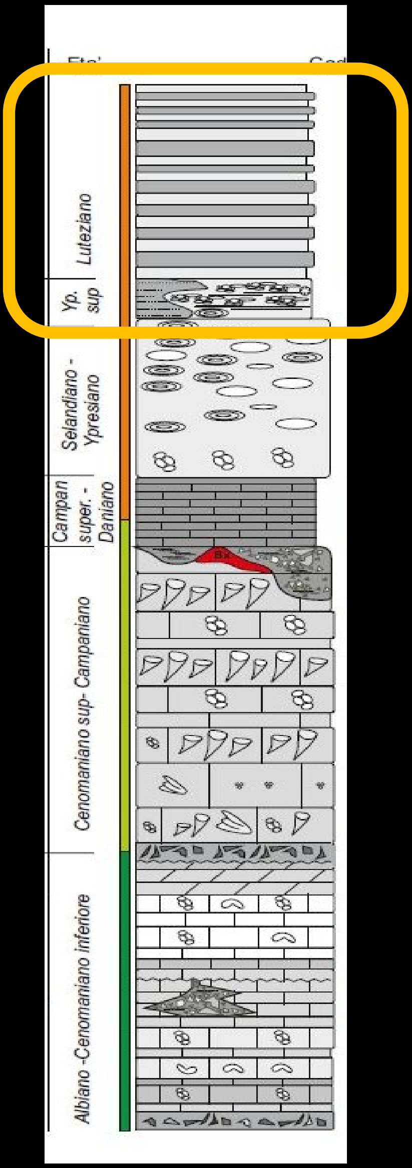


FLYSCH DI TRIESTE

Il contatto tra i calcari marnosi e le marne a globigerine e la sottostante piattaforma ad Alveoline e Nummuliti è brusco e testimonia un netto approfondimento dell'ambiente sedimentario che passa da mare basso a mare profondo.
Questo testimonia l'annegamento della piattaforma dei C. a Alveoline e Nummuliti.

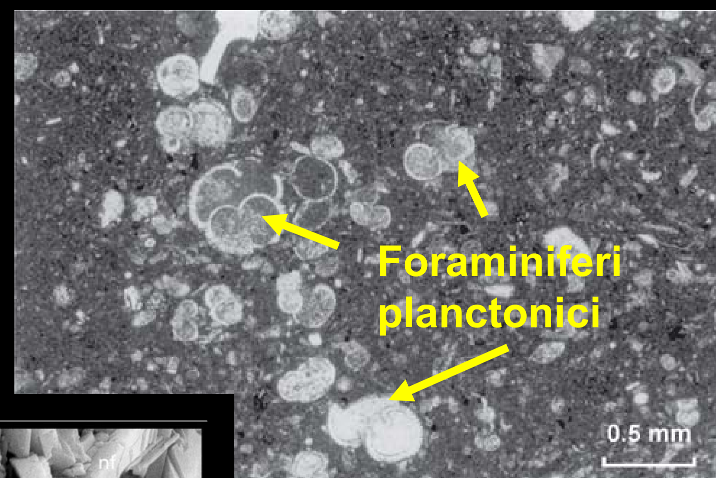
Una delle cause di questo annegamento è sicuramente il forte aumento della subsidenza dovuto all'approfondirsi dell'avanfossa dinarica

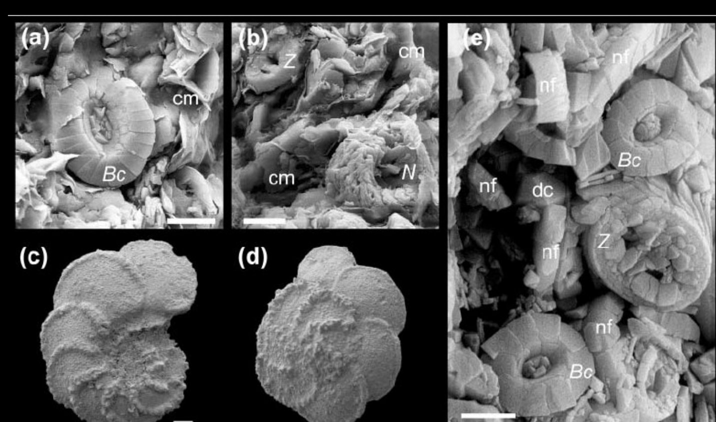




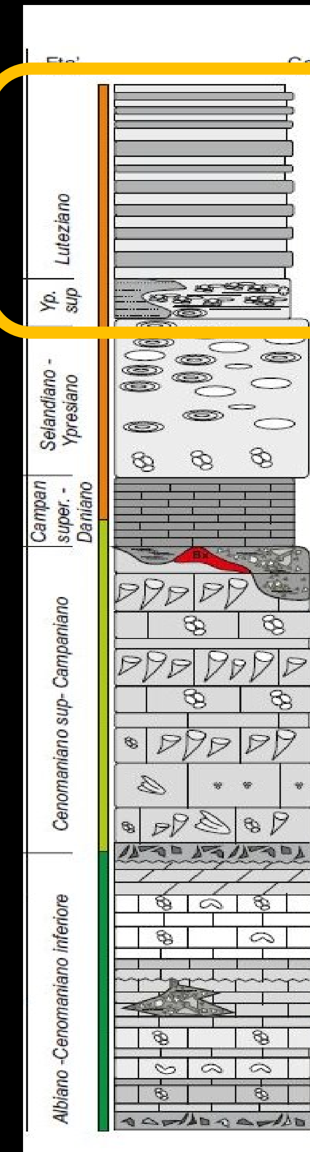
FLYSCH DI TRIESTE

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



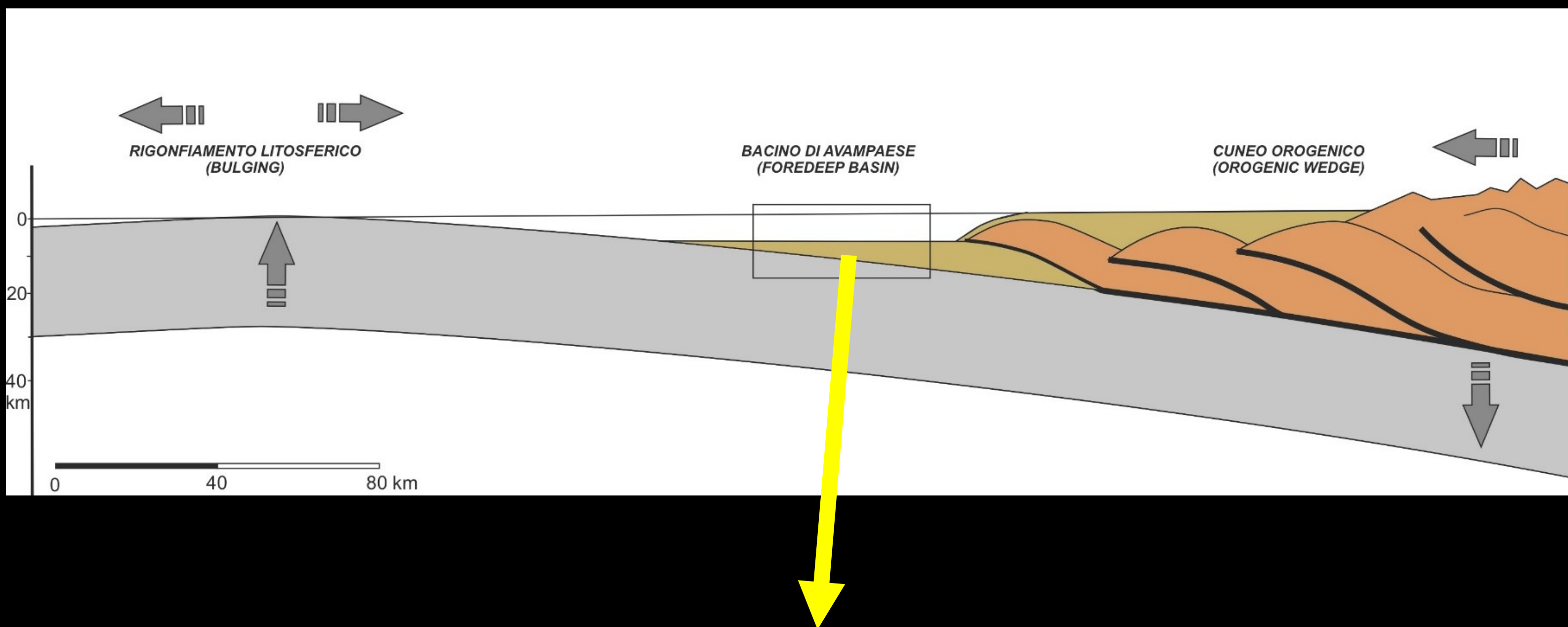


nannofossili

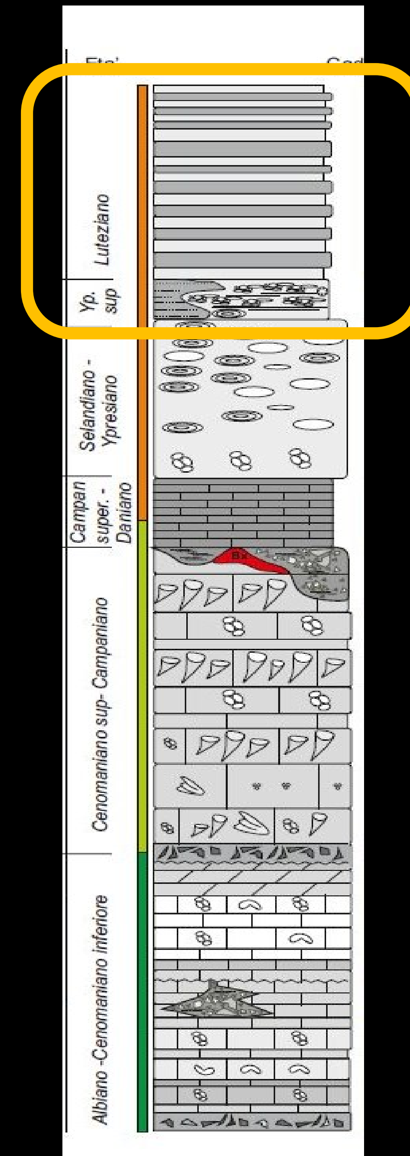


FLYSCH DI TRIESTE

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

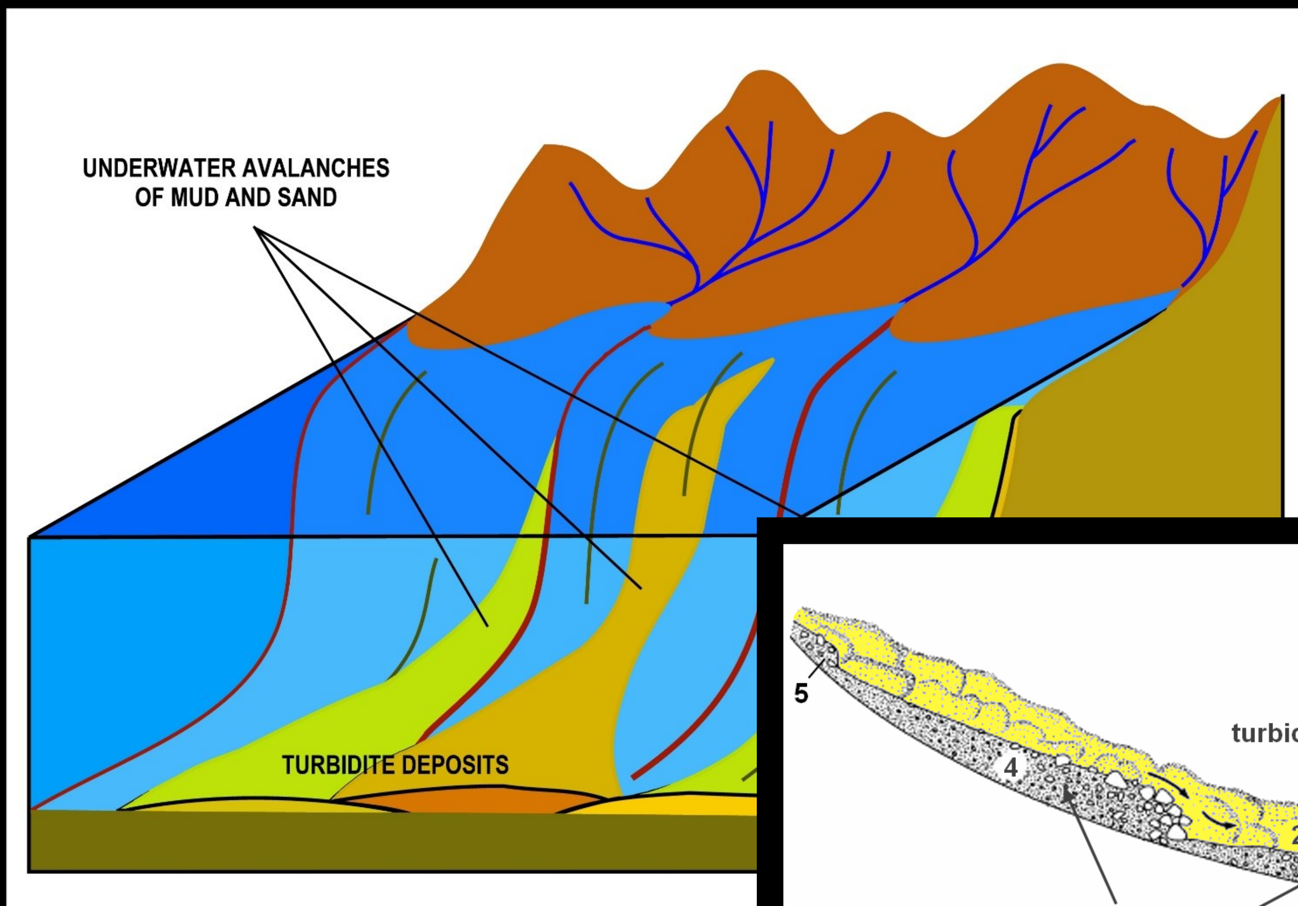


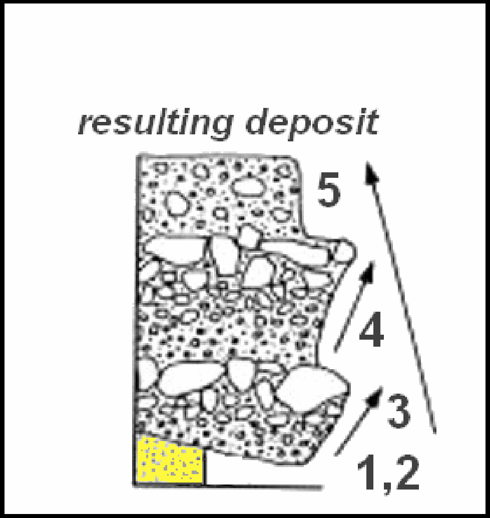
Deposizione di torbiditi

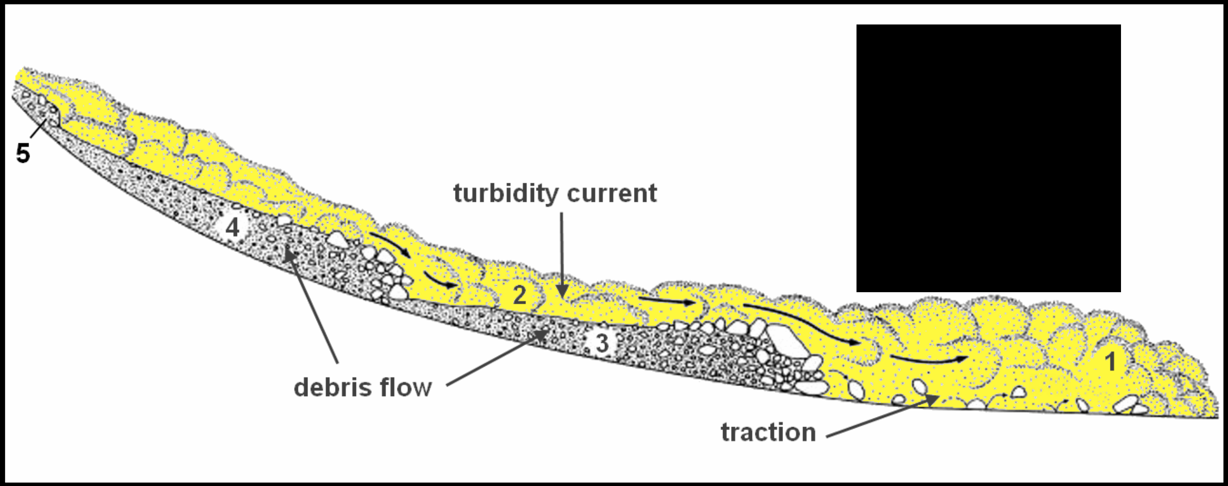


TORBIDITI

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

FLYSCH DI TRIESTE

Successione di areniti, peliti e argilliti nel Flysch di Trieste

Banchi arenitici nel Flysch di Trieste