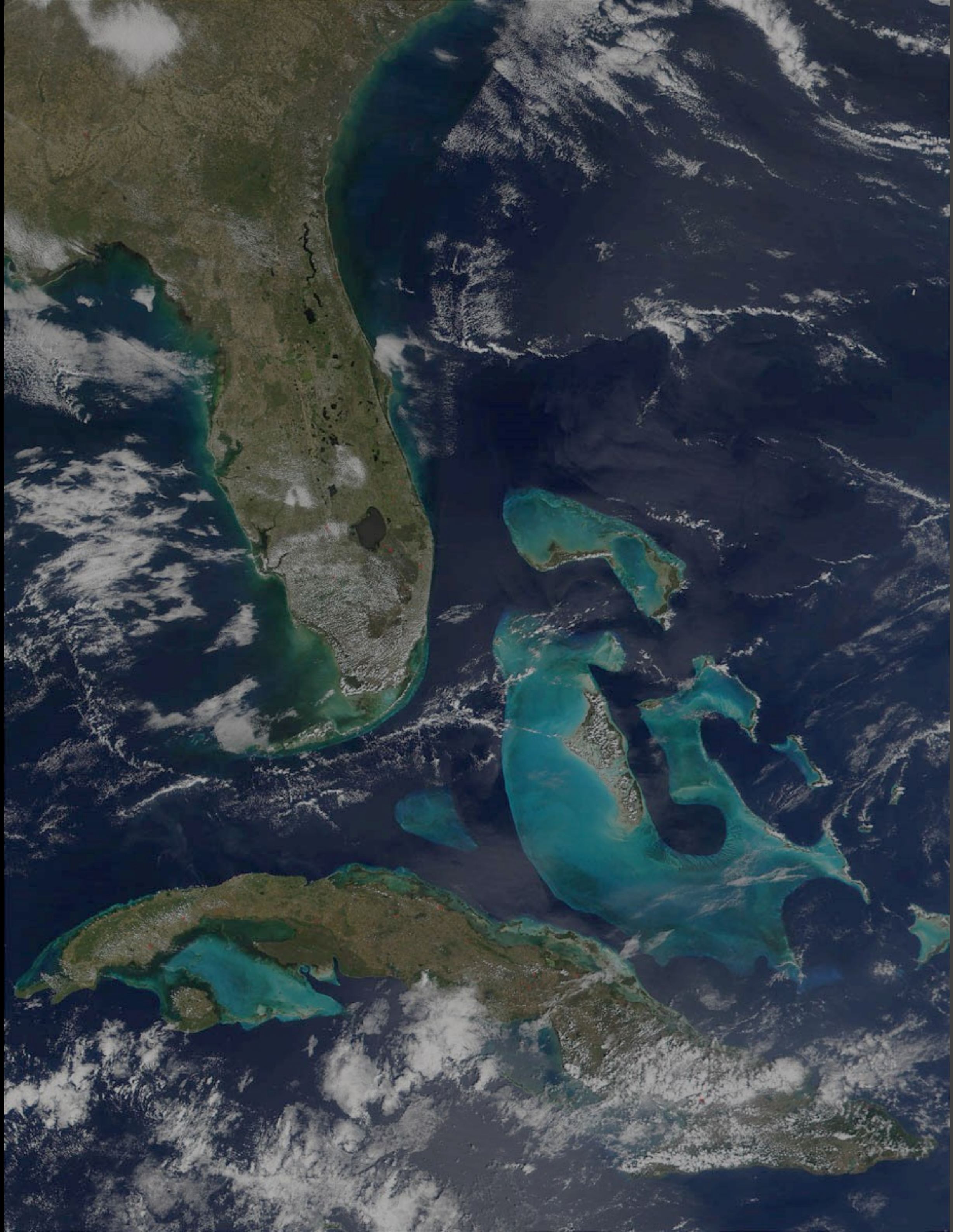
Shallow water carbonates

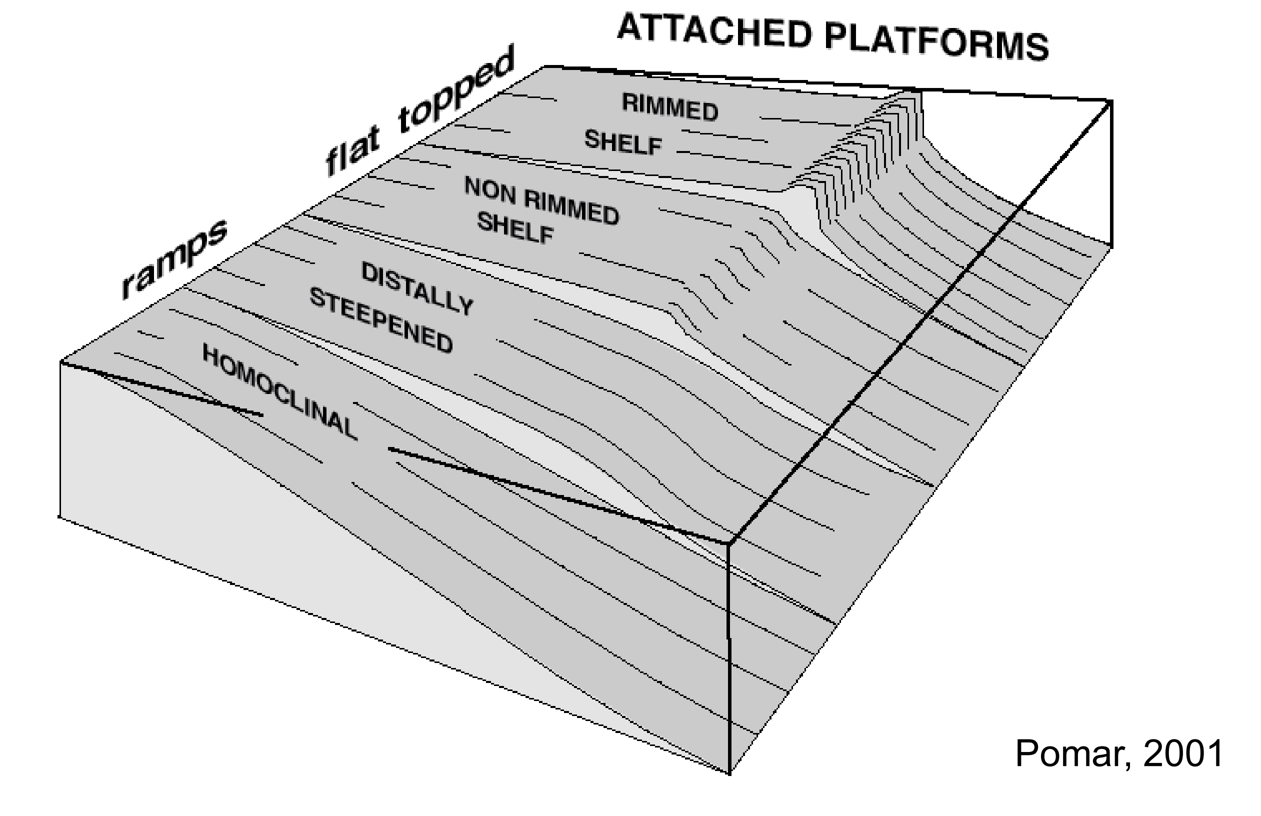


Shallow water carbonates

Carbonate platform:

A geological object that possesses topographic relief and is made of **parautochtonous carbonate deposits.**
A carbonate platform can be the product of benthic carbonate precipitation.

"Many types of carbonate platforms have been described, from homoclinal ramps to rimmed shelves and a full spectrum of variations in between; the distinction between these different types can be problematic. Nevertheless, **classification of carbonate platforms is not just a semantic issue.**" *(Luis Pomar, 2001)*



Some examples of carbonate platform

Carbonate platforms

Some modern examples of carbonate platform

Carbonate platforms

Isolated carbonate platform:

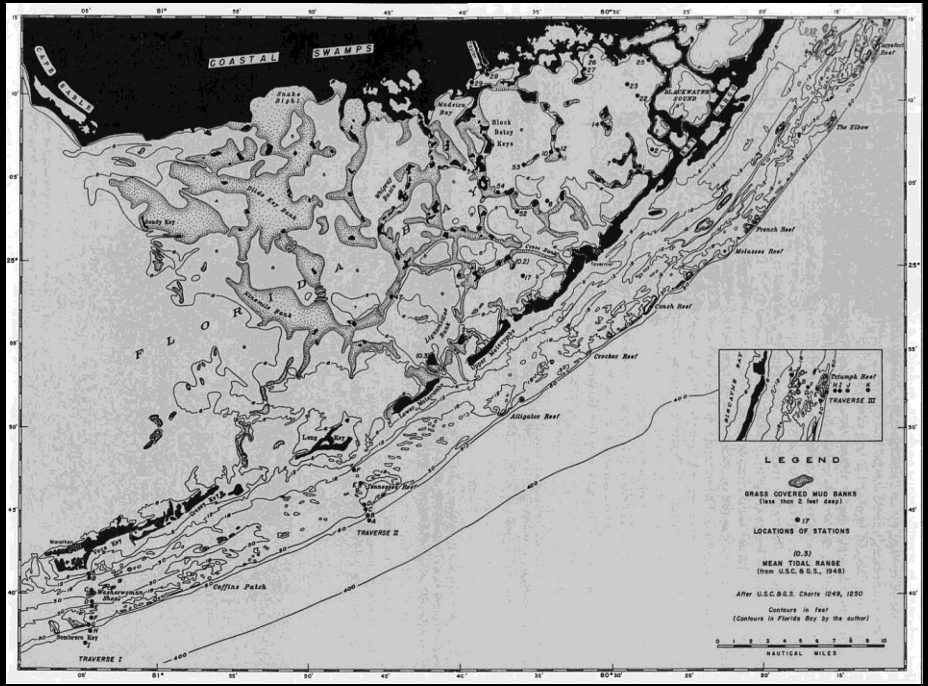
- one that is not connected to a continent or emerged land.

Examples: Bahamas, Maldives

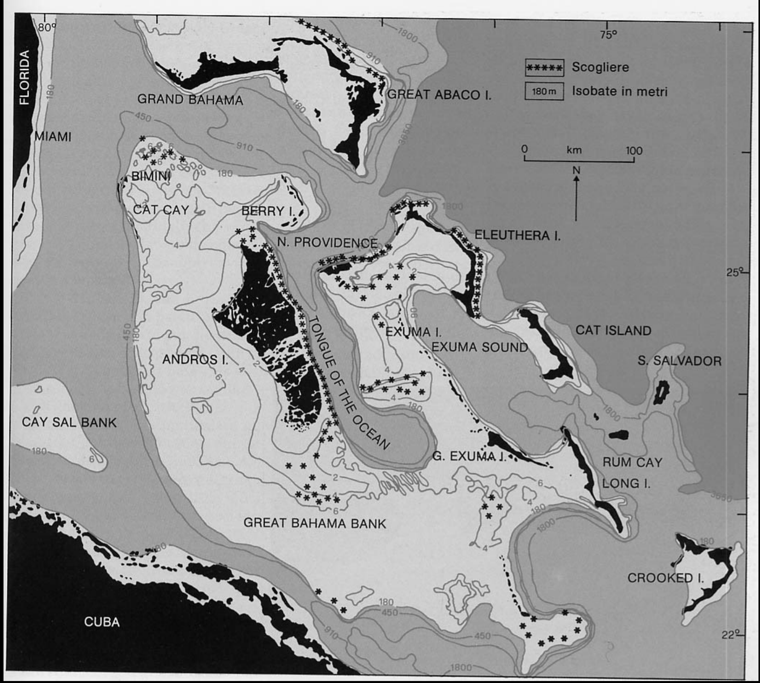
Epicontinental (or attached) carbonate platform:

- one that is connected to a continent or emerged land.

Examples: Florida Bay, Great Barrier Reef



Florida Bay (attached), from Bosellini, 1991



Bahamas (isolated), from Bosellini, 1991

Carbonate platforms

Let's recall some important concepts:

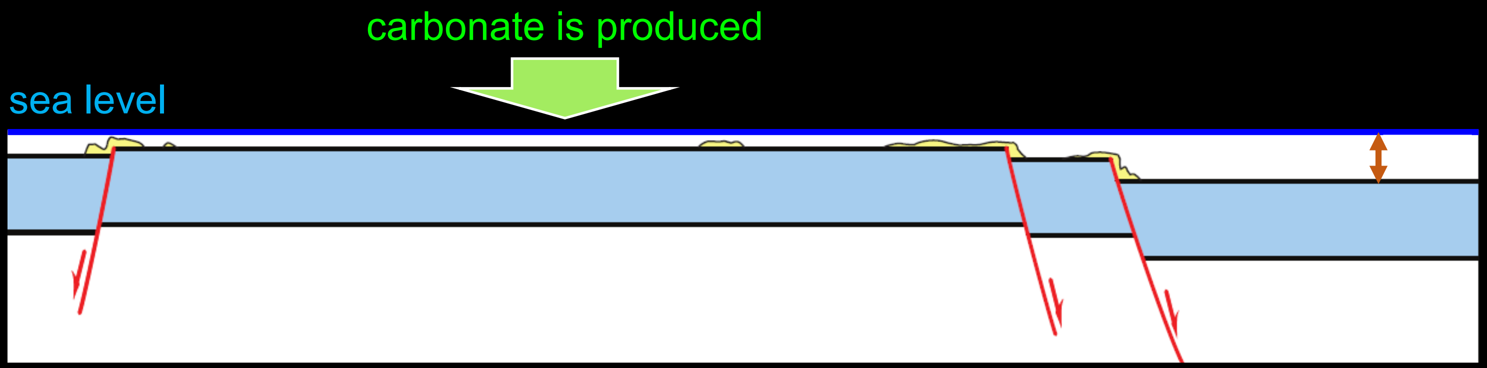
- Sediment supply. Is the amount of sediment that is produced. As mentioned, in the case of carbonates, sediment supply is given mostly (but not exclusively) by in situ production

- Accommodation. Is the physical space available for sediment accumulation. Accommodation is created below the base-level

- Sea level change. Sea level can experience positive and negative variations. These occur of very different time scales (daily or even on million years) that can be local or global.

Carbonate platforms

A carbonate platform is the product of the accumulation of benthic carbonate sediment.
The sediment accumulation occurs where accommodation is created and this depends on the interaction between the sediment supply and the relative sea level change.



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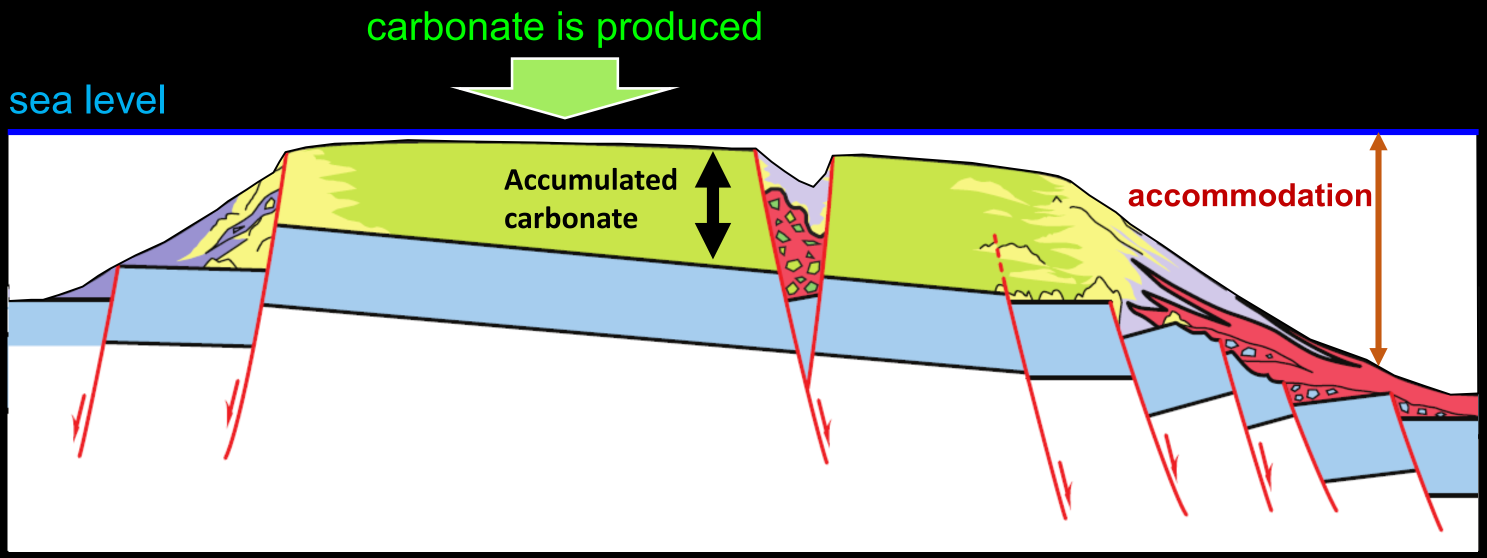

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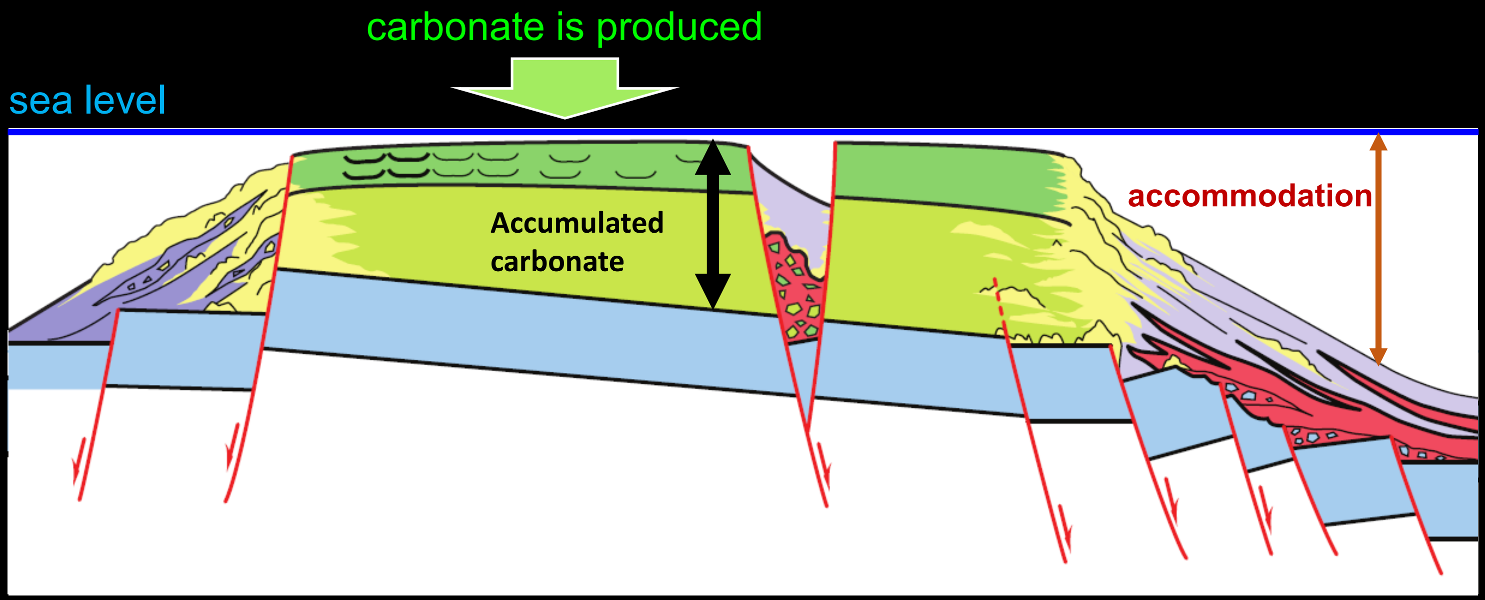

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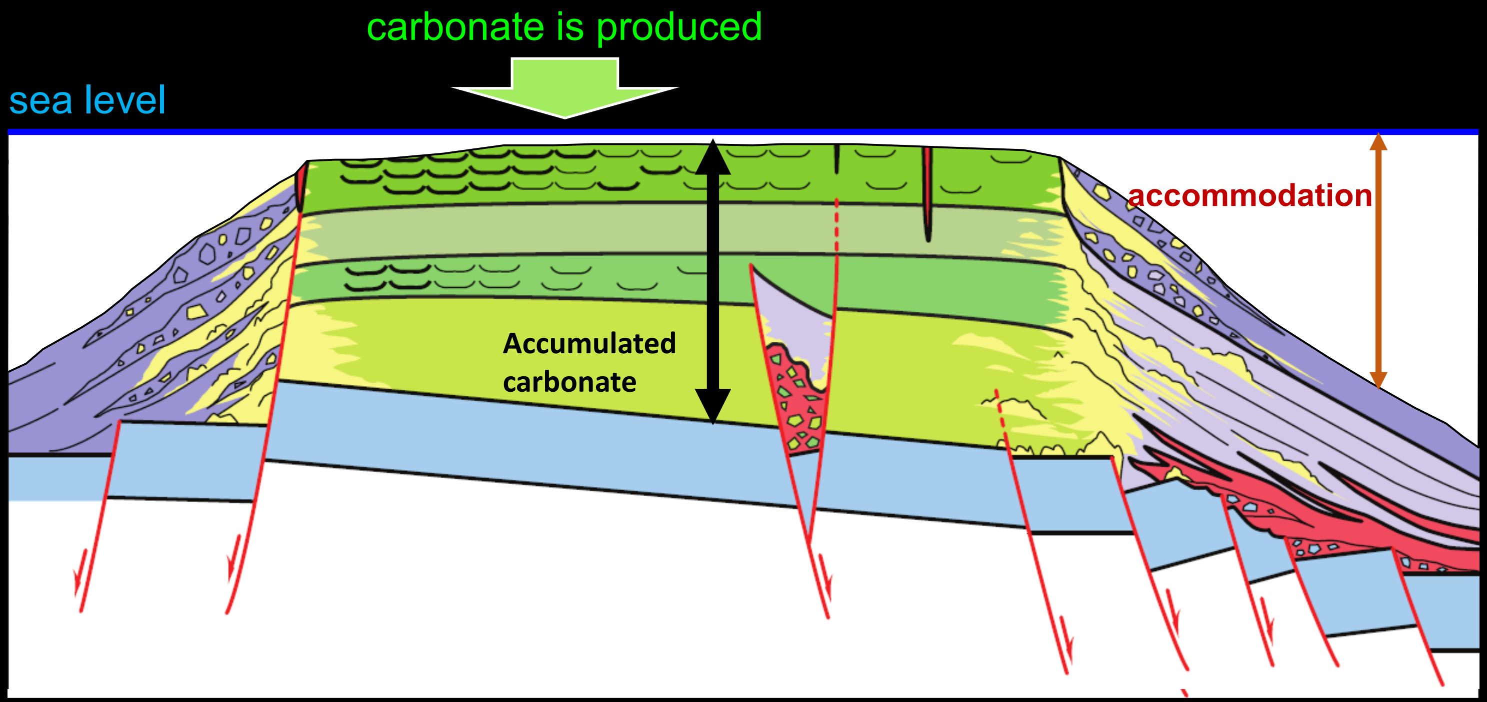
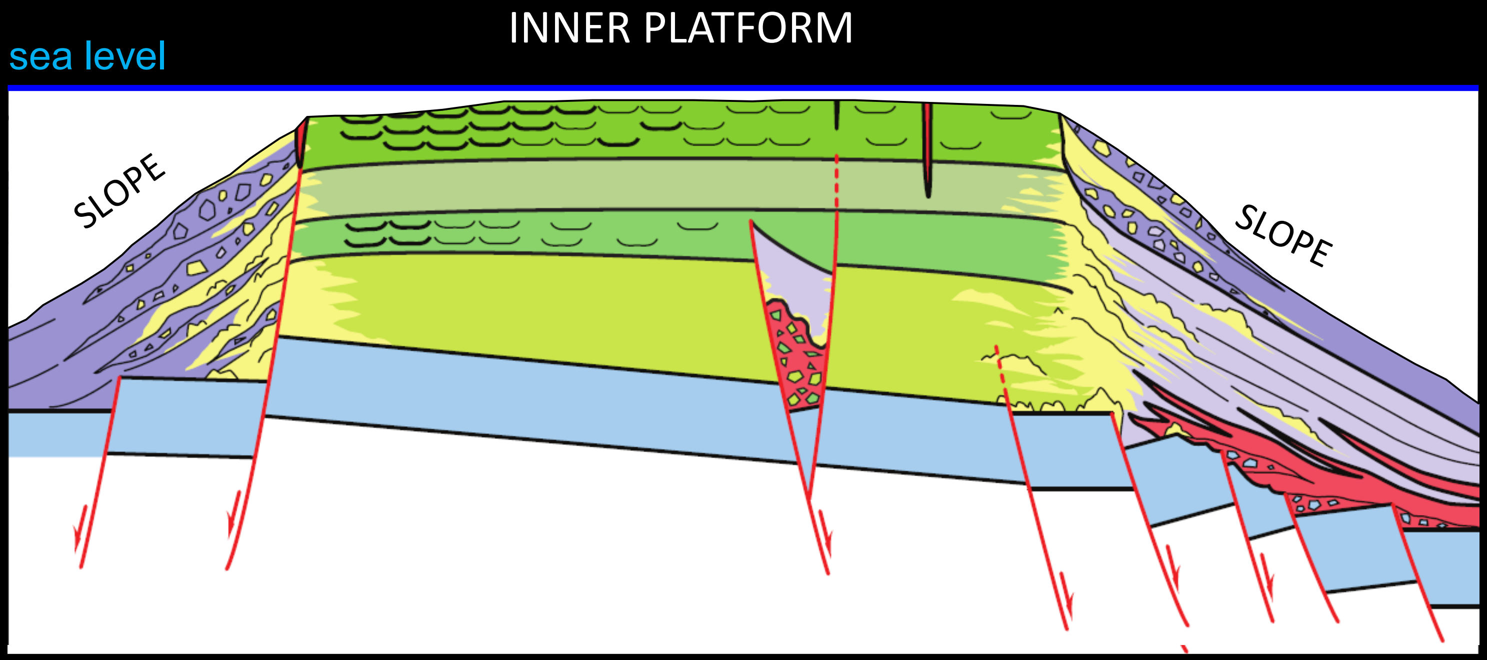


Carbonate platforms

Some notable sedimentary environments can be identified on a carbonate platform:

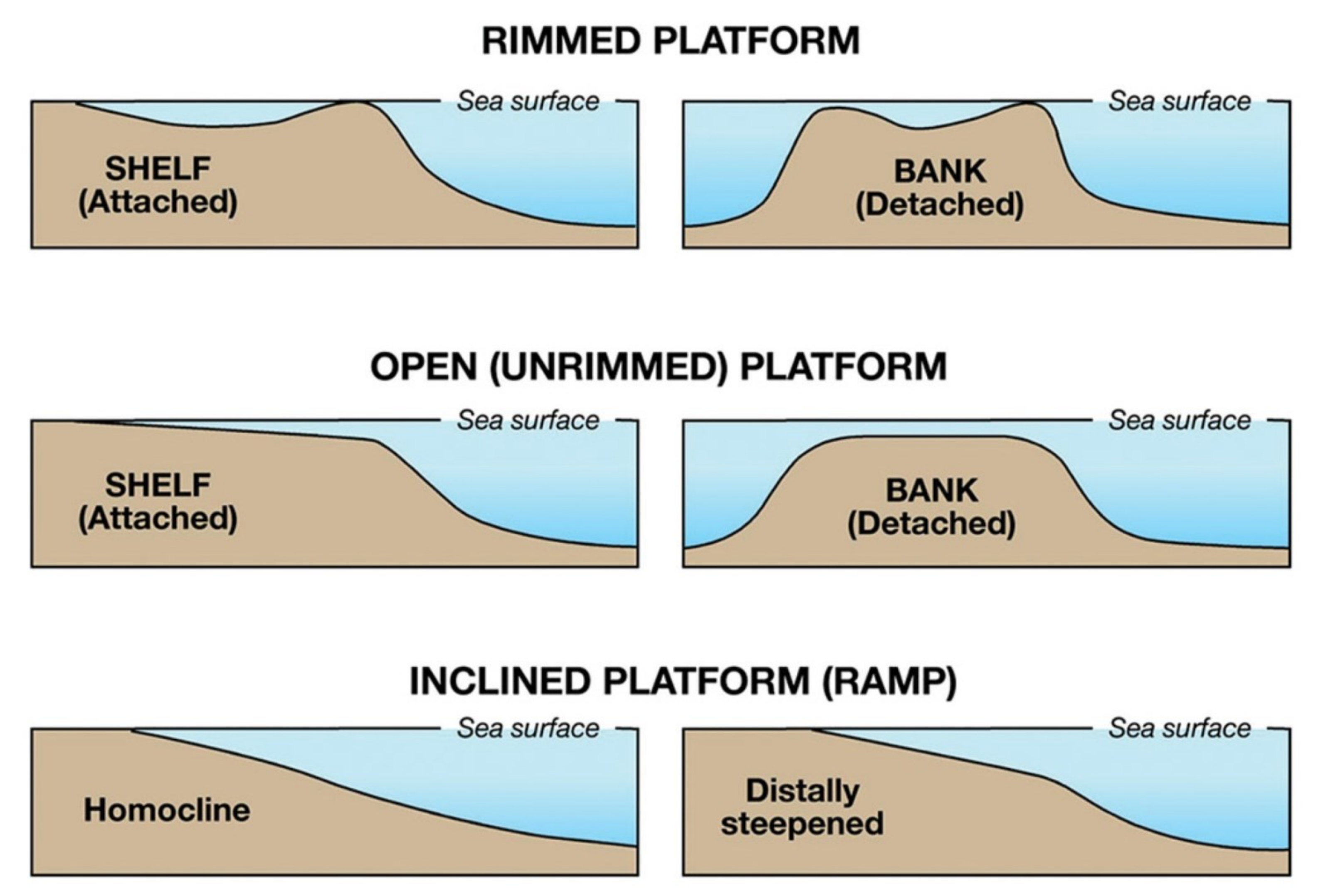
- Inner platform (sometimes referred to as lagoon or platform interior). Is an area characterized by a relatively low hydrodynamic regime
- Slope. Is an area characterized by a primary inclination that links the platform top to the adjacent areas of deeper waters.



from Preto et al., 2011, modified

Note that in this cartoon the inner platform area stays always approximately at the same depth, close to sea level. In order to do so, the carbonate production must match the rate of the creation of accommodation.

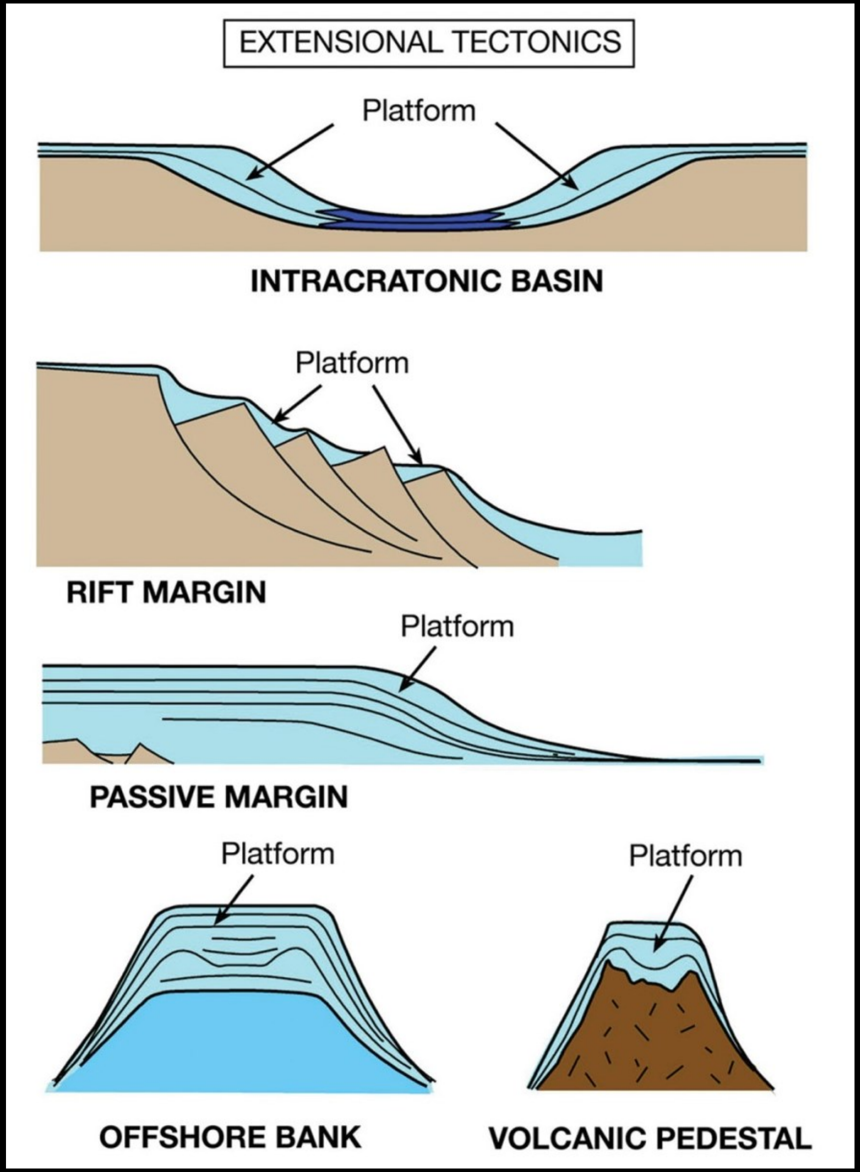
Carbonate platforms

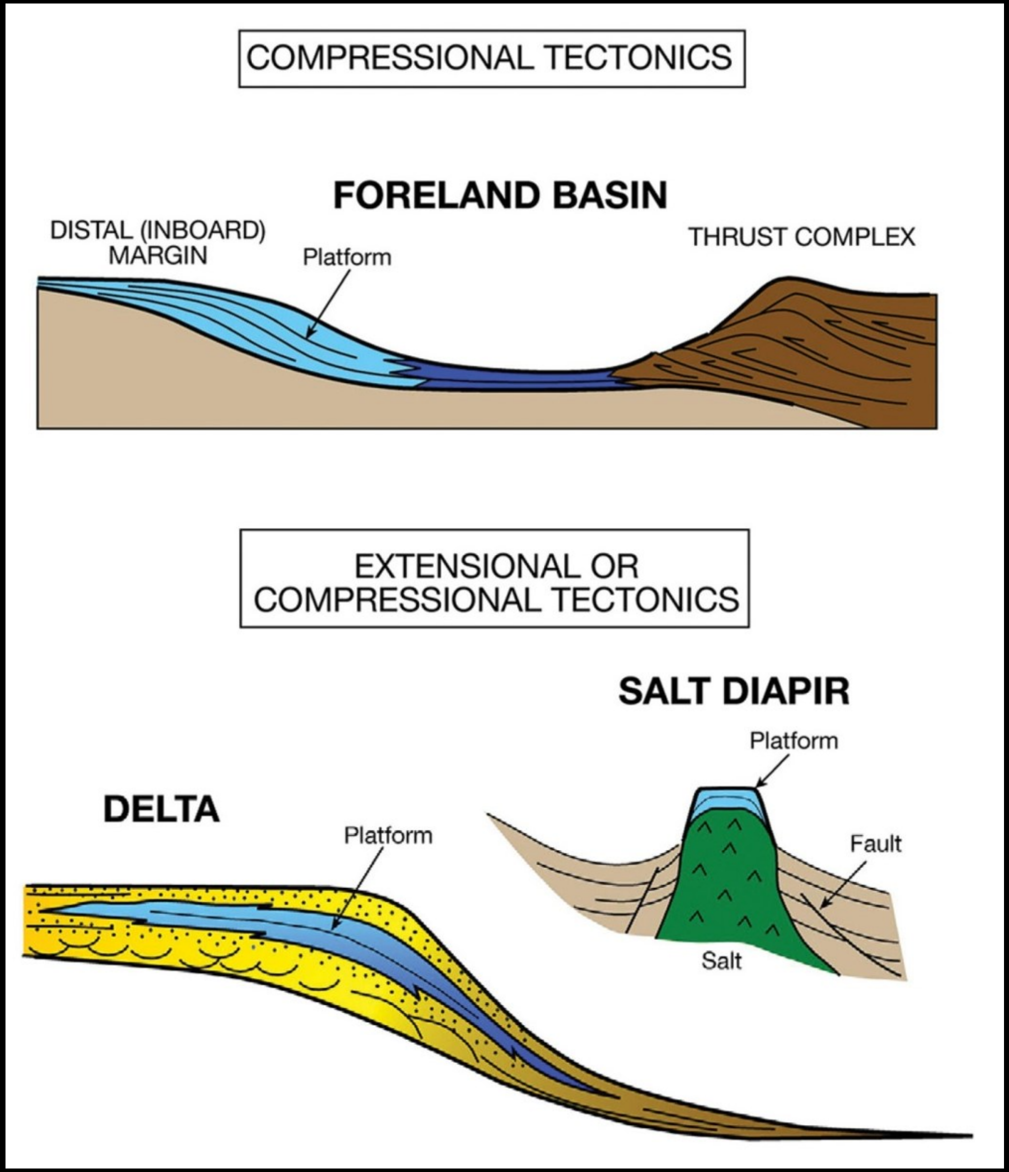


James and Jones, 2016

Carbonate platforms

Carbonate platforms in different tectonic regimens





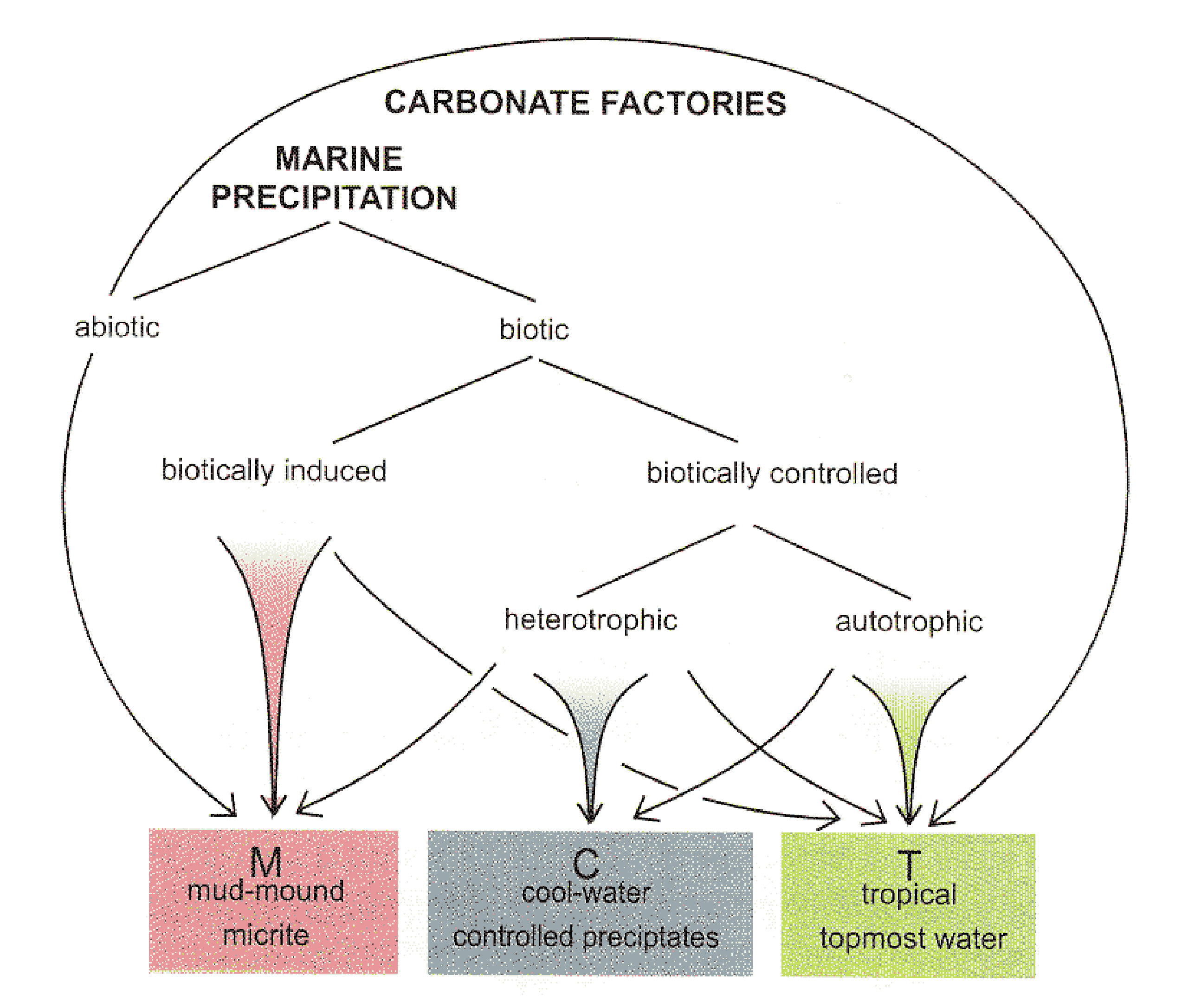
James and Jones, 2016

Carbonate factories

A **carbonate factory** is benthic carbonate association dominated by a specific mode of precipitation. (Schlager, 2000)

This term is linked to carbonate platforms as it specifically refers to a shallow (or relatively shallow) submerged area where carbonate precipitation occurs.

- **Carannante et al., 1988** - Carbonate lithofacies as paleolatitude indicators: problems and limitations. Sedimentary Geology, vol. 60, pp. 333-346
- **Pomar L., 2001** - Types of carbonate platforms: a genetic approach. Basin Research, v. 13, pp. 313-334
- **Schlager W., 2003** - Benthic carbonate factories of the Phanerozoic. International Journal of Earth Sciences, v. 92, pp. 445-464



Schlager, 2005

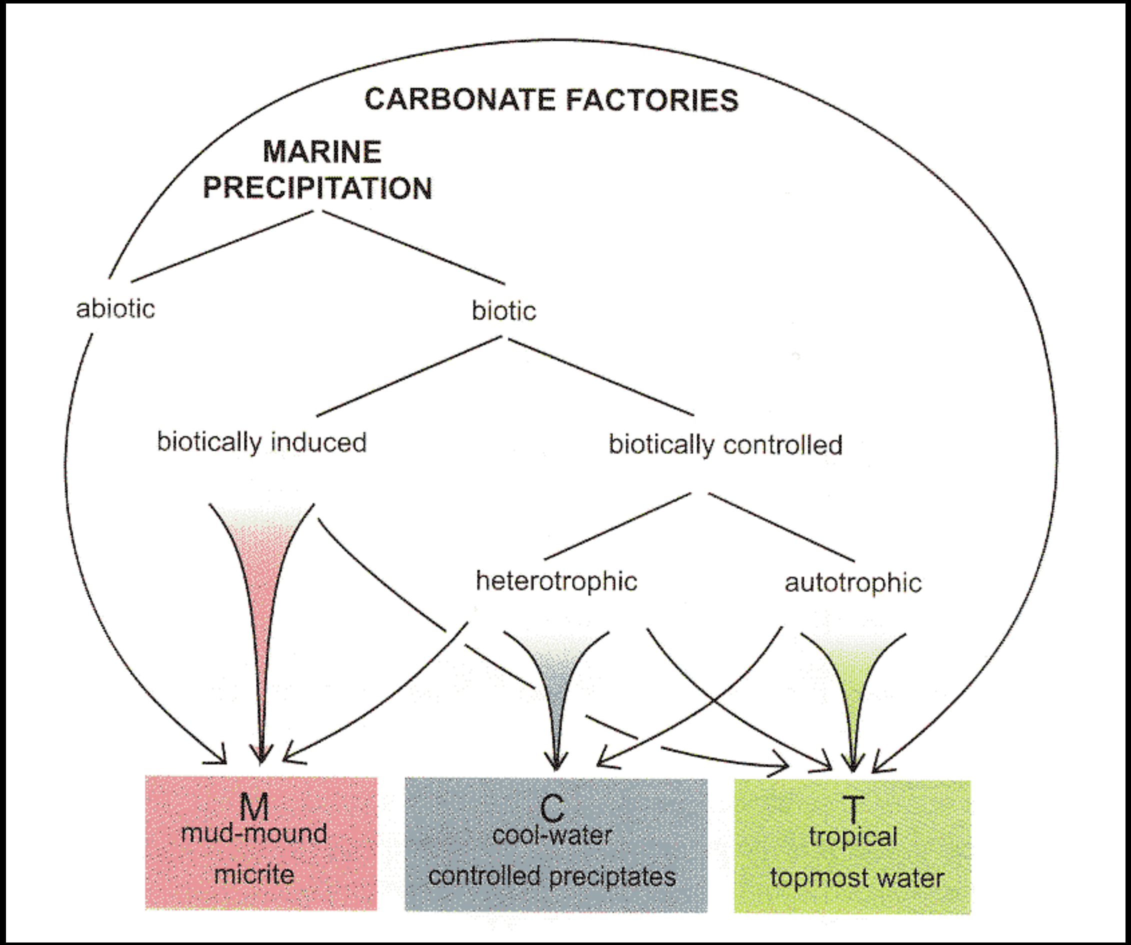
Carbonate platforms

Schlager (2003) proposed a genetic classification of carbonate factories that is based on the predominant mode of precipitation.
Three main types of carbonate factories have been defined:

T-factory – dominated by biotically controlled precipitation by autotrophs

C-factory – dominated by biotically controlled precipitation by heterotrophs

M-factory – dominated by biotically induced precipitation



Carbonate factories

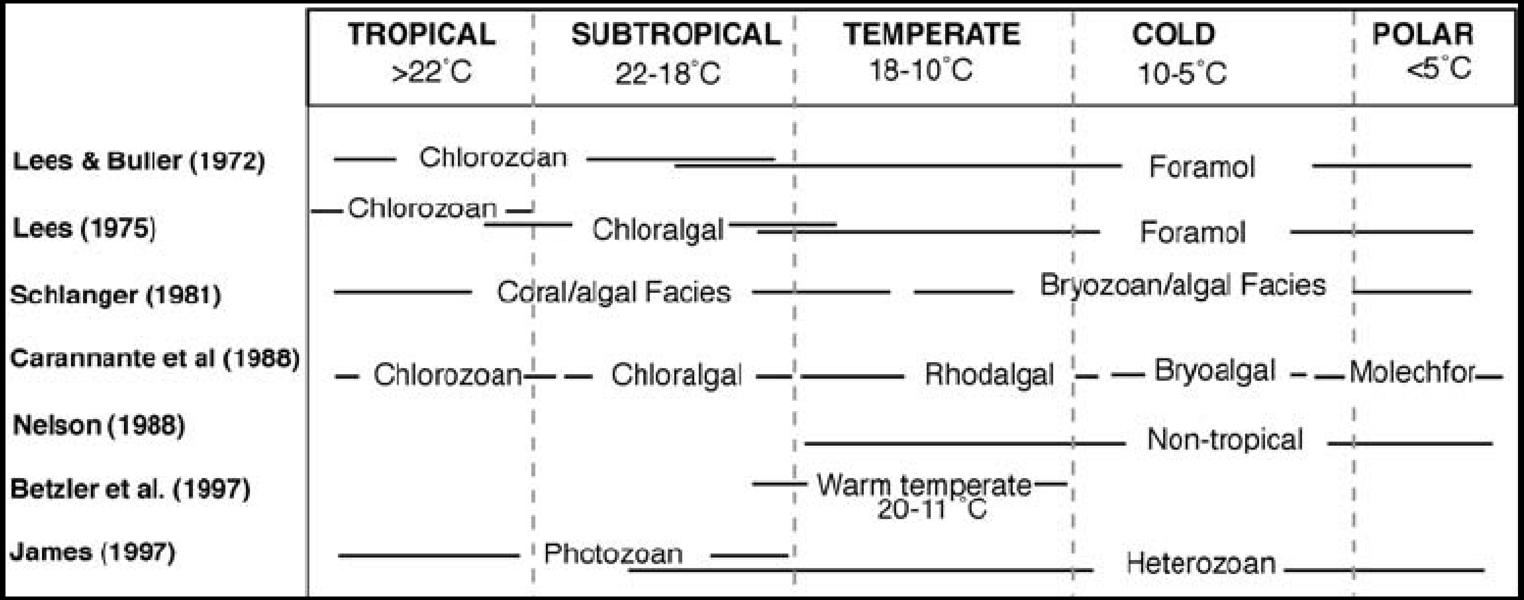
Carbonate factories can be characterized by specific **skeletal associations** that strongly depend on environmental conditions. They repeat so systematically in the sedimentary record (in the Cenozoic and Recent, mostly) that were given specific names, e.g.:

- Chlorozoan = Chlorophyta + Zoantharia (Green algae, corals)
- Chloralgal = Chlorophycean algae
- Foramol = Foraminifera + Molluscs
  - Rhodalgal = Rhodophycean algae
  - Molechfor = Molluscs + Echinoderms + Foraminifera
  - Foralgal = Foraminifera + Algae (red or green)
- Bryomol = Bryozoans + Molluscs

Bryomol with echinoderm plates and spines - Mauritania

Chlorozoan with mollusks - Okinawa

Carbonate factories

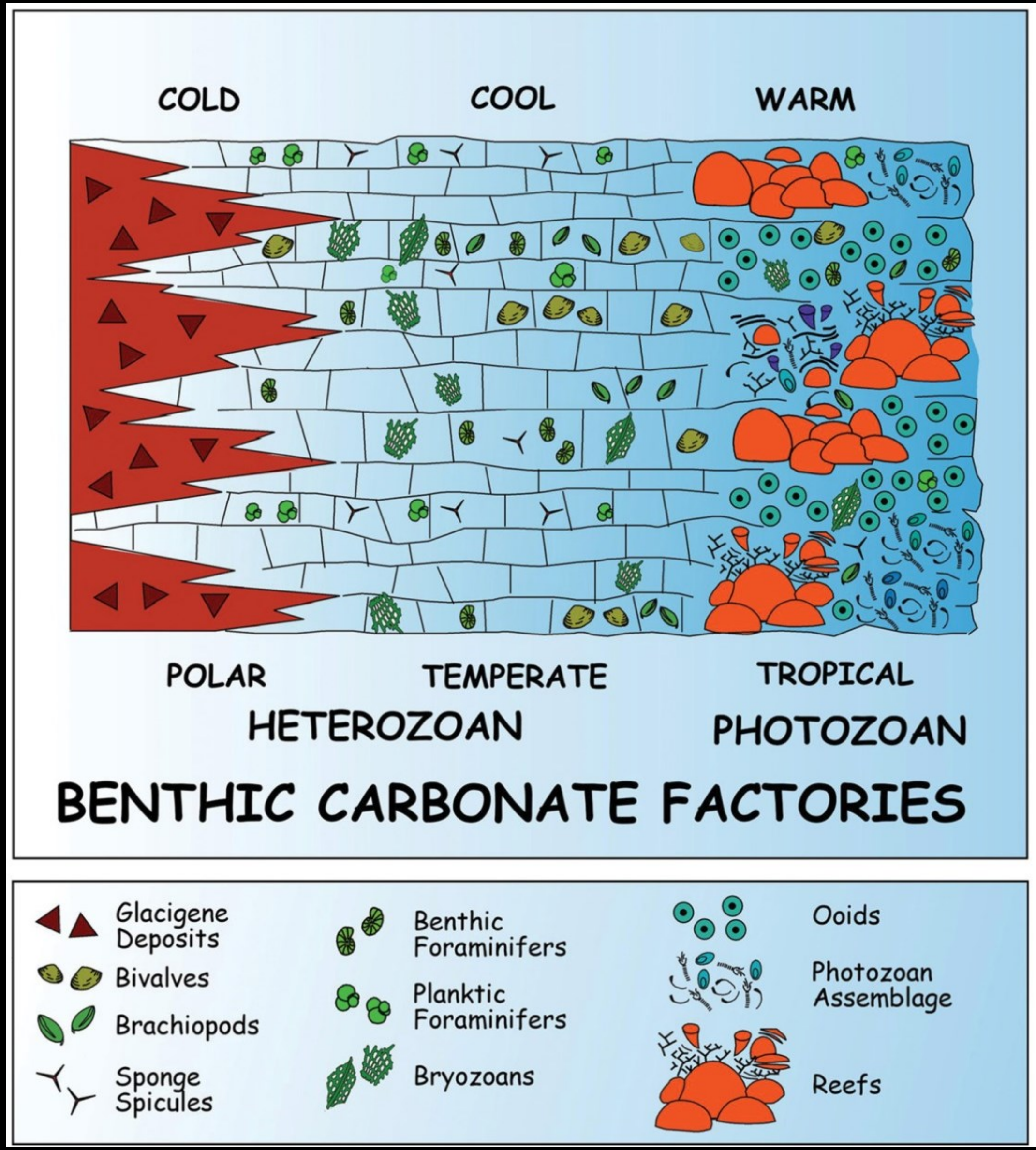


From Mutti and Hallock, 2003

Bryomol with echinoderm plates and spines - Mauritania

A connection between temperature and skeletal associations has been observed, however things are more complex.

Carbonate factories

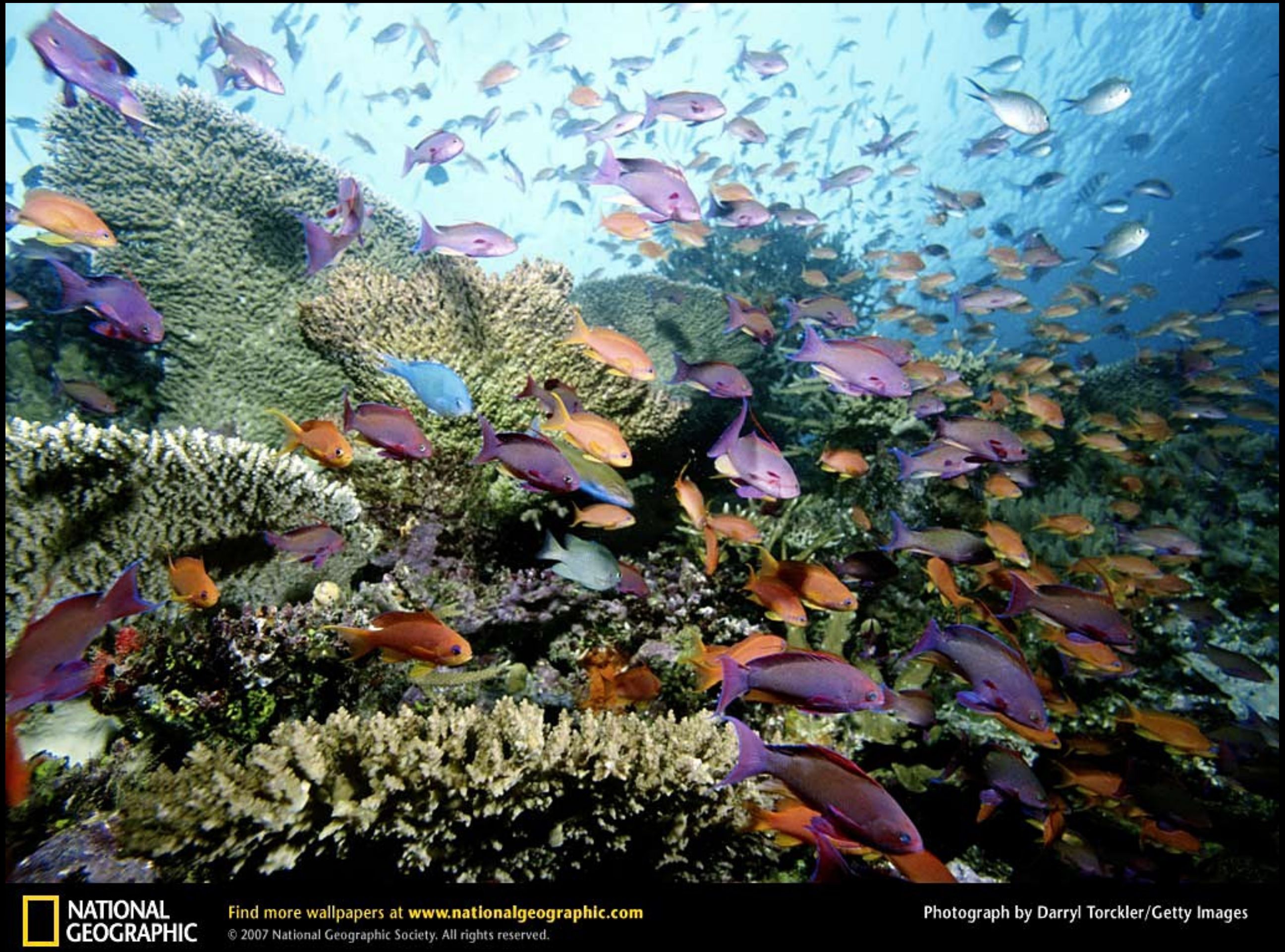


James and Jones, 2016

Carbonate factories

T-factory-dominated platforms (tropical platforms):

- **chlorozoan** skeletal associations
- carbonate precipitation is **controlled by autotrophs**
- secondarily, abiotic and biotically induced precipitation
- early lithification is common

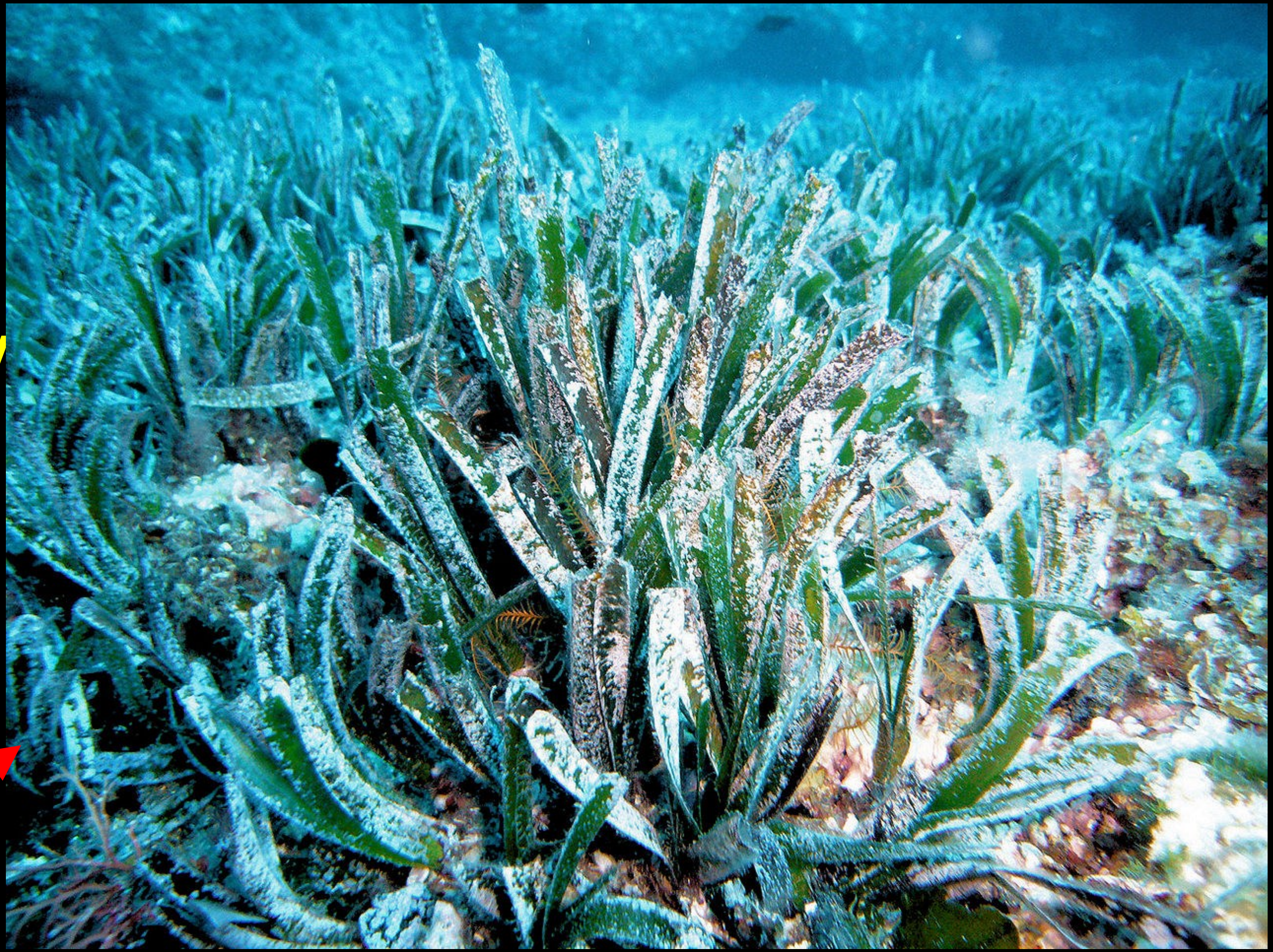


An example of T-factory-dominated platform. A tropical atoll

Carbonate factories

C-factory-dominated platforms
(temperate or cool-water platforms):

- **foramol** skeletal associations
- carbonate precipitation is **controlled by heterotrophs** abiotic precipitation is substantially absent
- thus, **no early lithification**



A submarine prairie of *Posidonia oceanica. Posidonia* and its likes are angiosperm plants (i.e., flowering plants) that re-adapted to seawater and today form extensive meadows in shallow water marine environments. *Posidonia* does not calcify, but it sustains a rich ecosystem of heterotrophic calcifying organisms. White spots on the leaves in this photography are calcifying encrusters. From Wikimedia commons, by User:Yoruno.

Carbonate factories

M-factory-dominated platforms
(mud mounds):

no skeletal grains - microbialites prevail

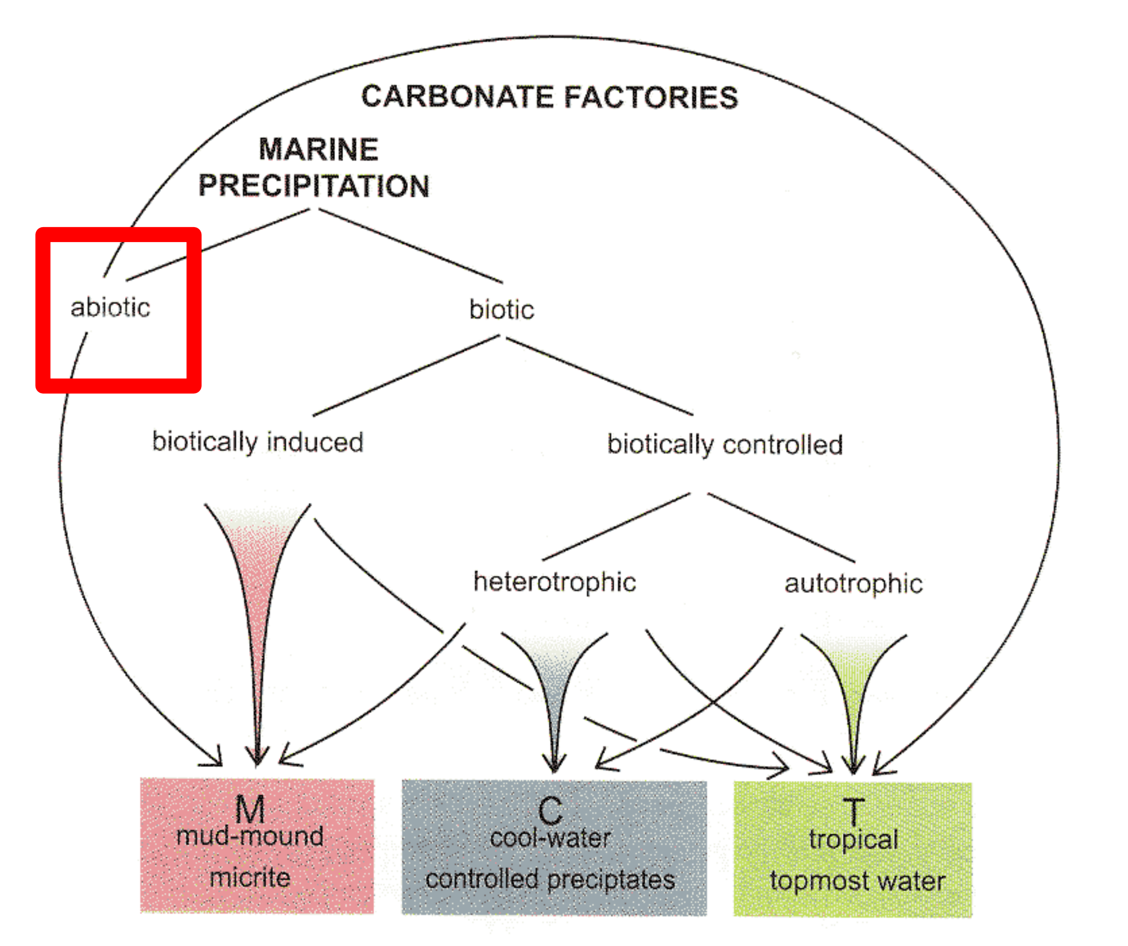
- **biotically induced** precipitation
- secondarily, abiotic precipitation
- strong early lithification

An example of M-factory carbonates (Kess Kess mounds, Devonian, Morocco)

Mono Lake in California hosts bacterial communities that promote precipitation of carbonate from its alkaline waters. These bacteria contribute to the formation of tufa towers, and those that formed in the past when lake levels were higher are now standing above the lake water.
Tufa is a type of continental carbonate that looks like travertines, but precipitated from waters at ambient temperatures, not from hydrothermal waters.
Marine analogs for the M factory are rare: e.g., Shark Bay or the subtidal stromatolites of Bahamas.
http://en.wikipedia.org/wiki/File:Mono_Lake_Reflections.jpg
by Henry Lydecker

Carbonate factories

Abiotic precipitation



abiotic precipitation is extremely uncommon *today*

Carbonate factories

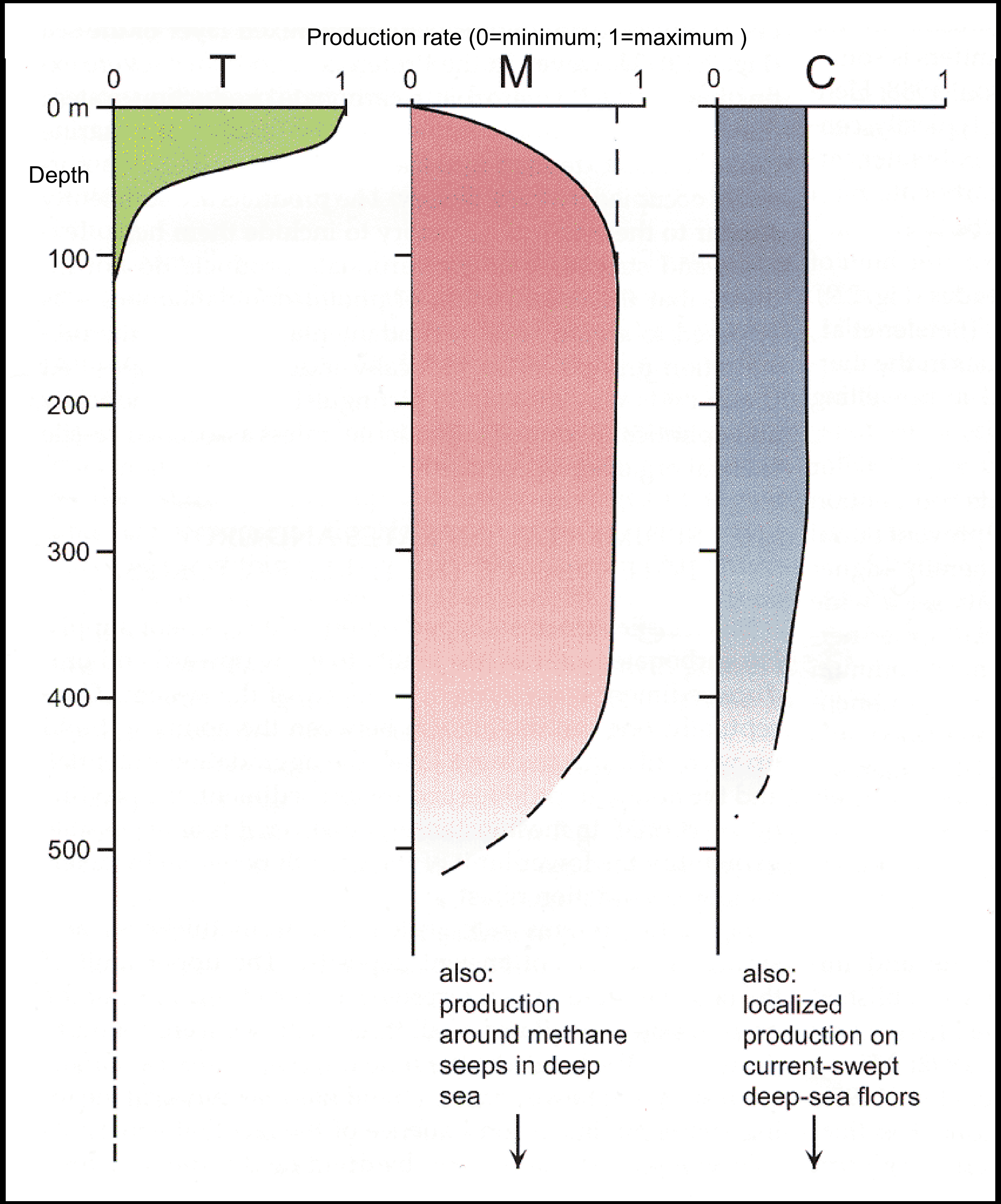
Production-to-depth profile

Carbonate factories are characterized by different production-to-depth profiles.

In the T-factory, being the majority of carbonate produced by photosynthesizing organisms, carbonate production is confined in the photic zone. It is highest in the first tens of meters and then sharply decreases with depth.

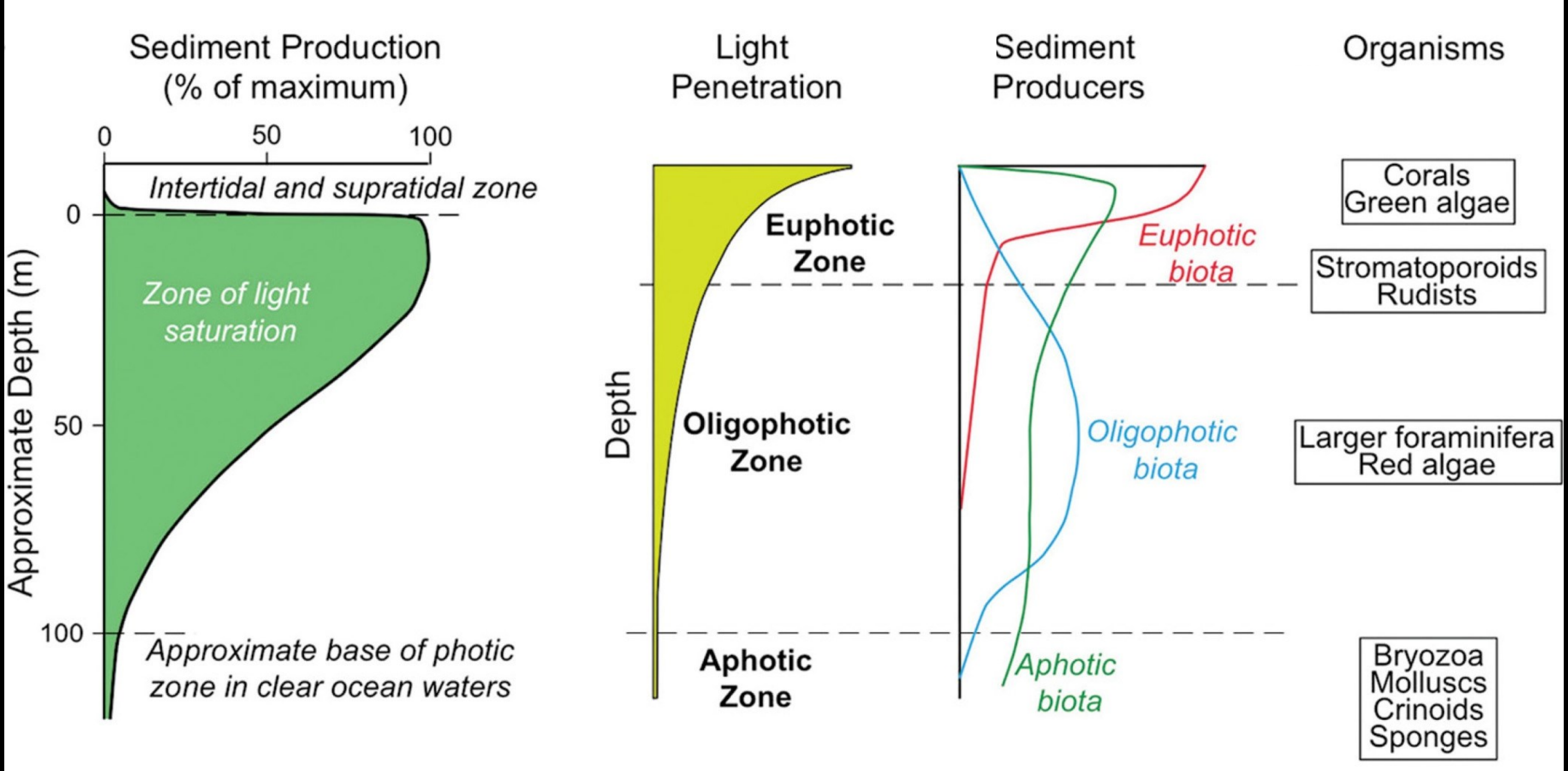
Note how, in contrast, carbonate production in the M-factory can occur at high rates also at considerable depths.

Lowest production rates are those of the C-factory, although by autotrophs can be active at depths as high as those of the M-factory.



Schlager, 2005

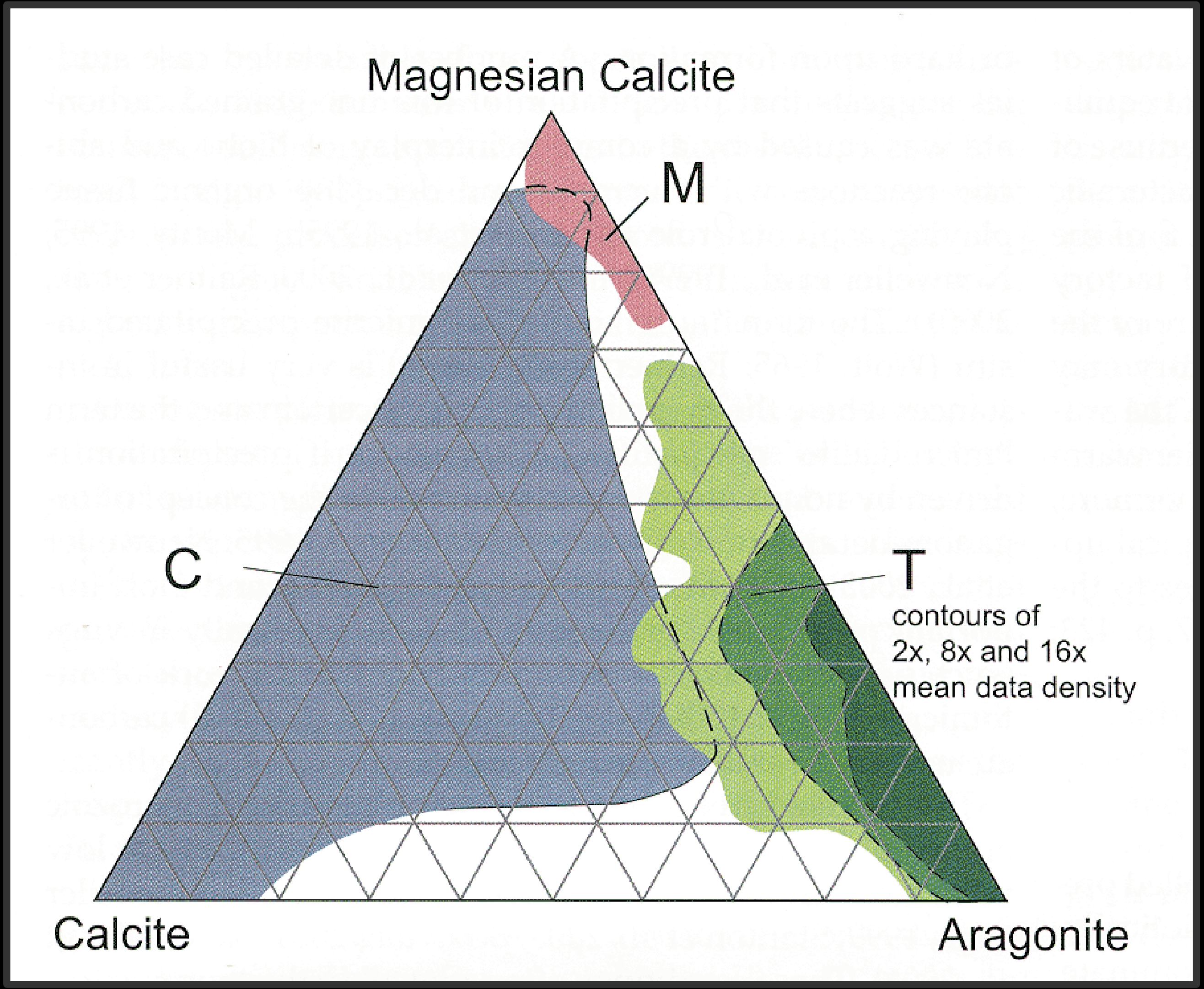
Carbonate factories



Carbonate sediment production, light penetration and different producing organisms of T and C factories against water depth. James and Jones, 2016

Carbonate factories

Carbonate factories differ also for the **mineralogy** of precipitated carbonates.



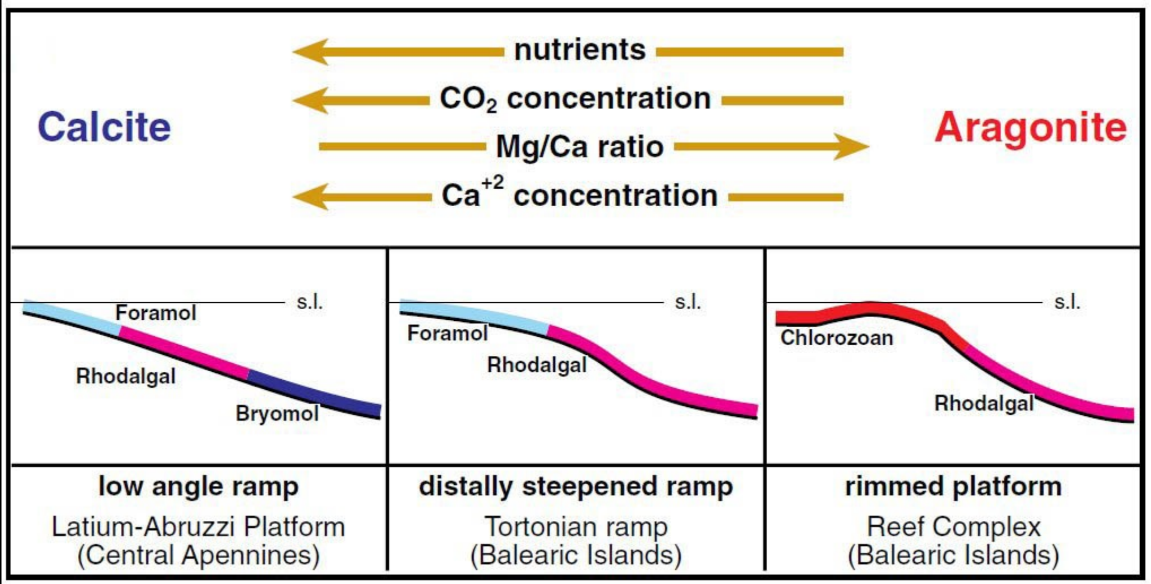
Schlager, 2005

Diagram showing dominant mineralogy of carbonate precipitated by different carbonate factories.
C-factory precipitates carbonate with a wider range mineralogy, but prevailingly calcite or magnesian calcite.
The T-factory tends to precipitate prevailingly aragonite,
The M-factory precipitates essentially magnesian calcite.
Different mineralogy of the precipitate can have a strong impact on diagenetic transformations.
Aragonite, being metastable, undergoes recrystallization much more easily than calcite.

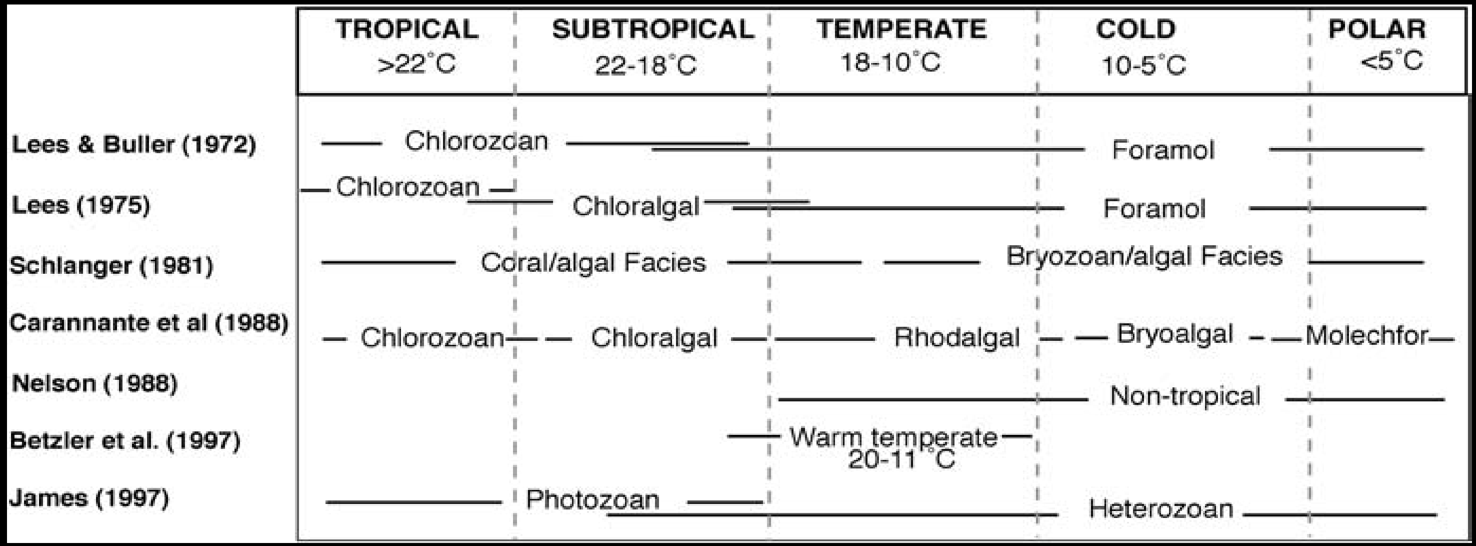
Carbonate factories

Many more factors determine skeletal associations

Pomar et al. (2004) studied the case of Miocene carbonates of the Mediterranean region. They show that skeletal associations, types of carbonate factories and depositional geometries are driven by many environmental factors, among which seawater geochemistry is one major driver.



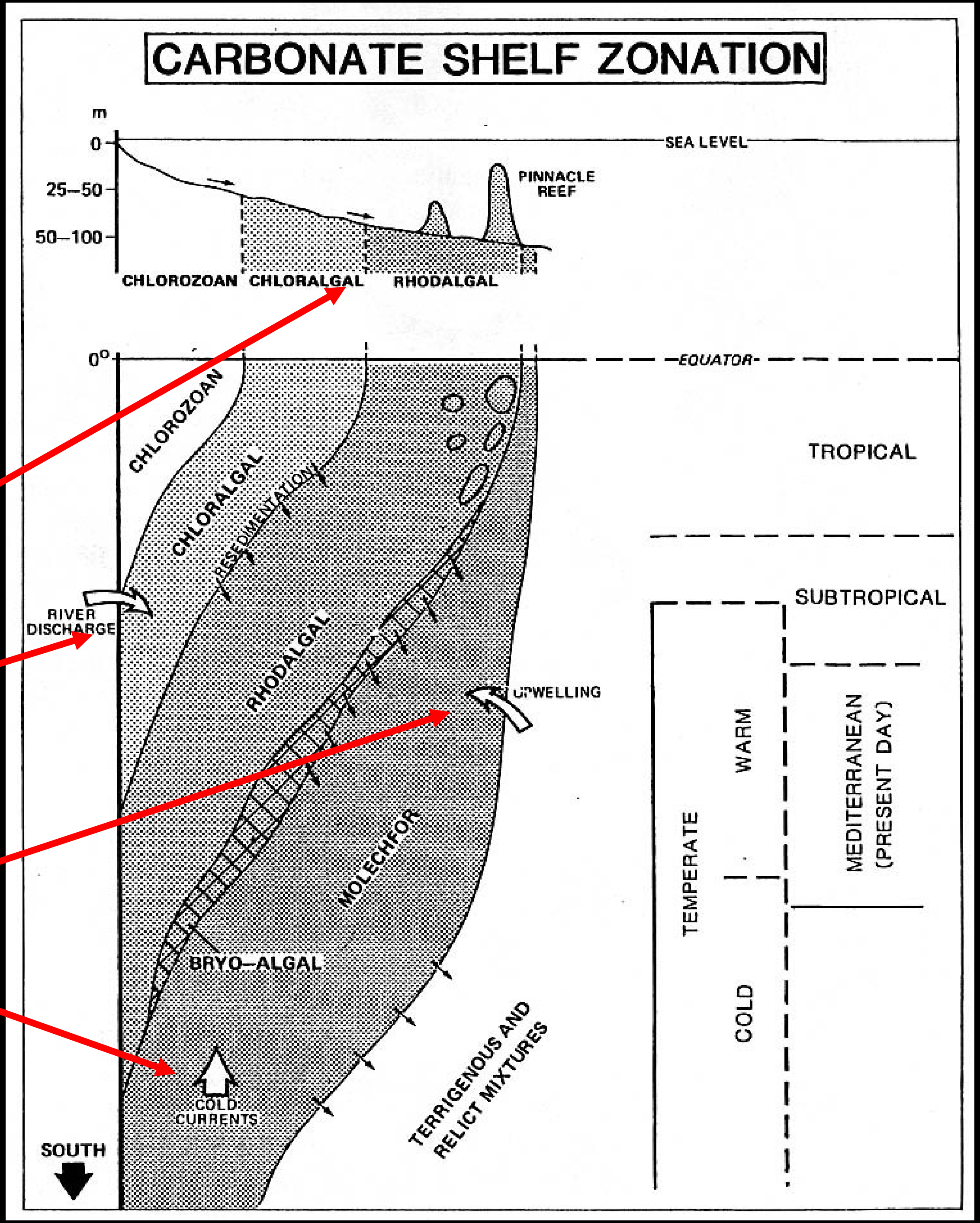
Mutti and Hallock (2003) summarize the classifications of skeletal associations proposed by various authors, and highlight the main controlling factor used to be considered to be temperature. They believe nutrients, rather than temperature, play the leading role.



Carbonate factories

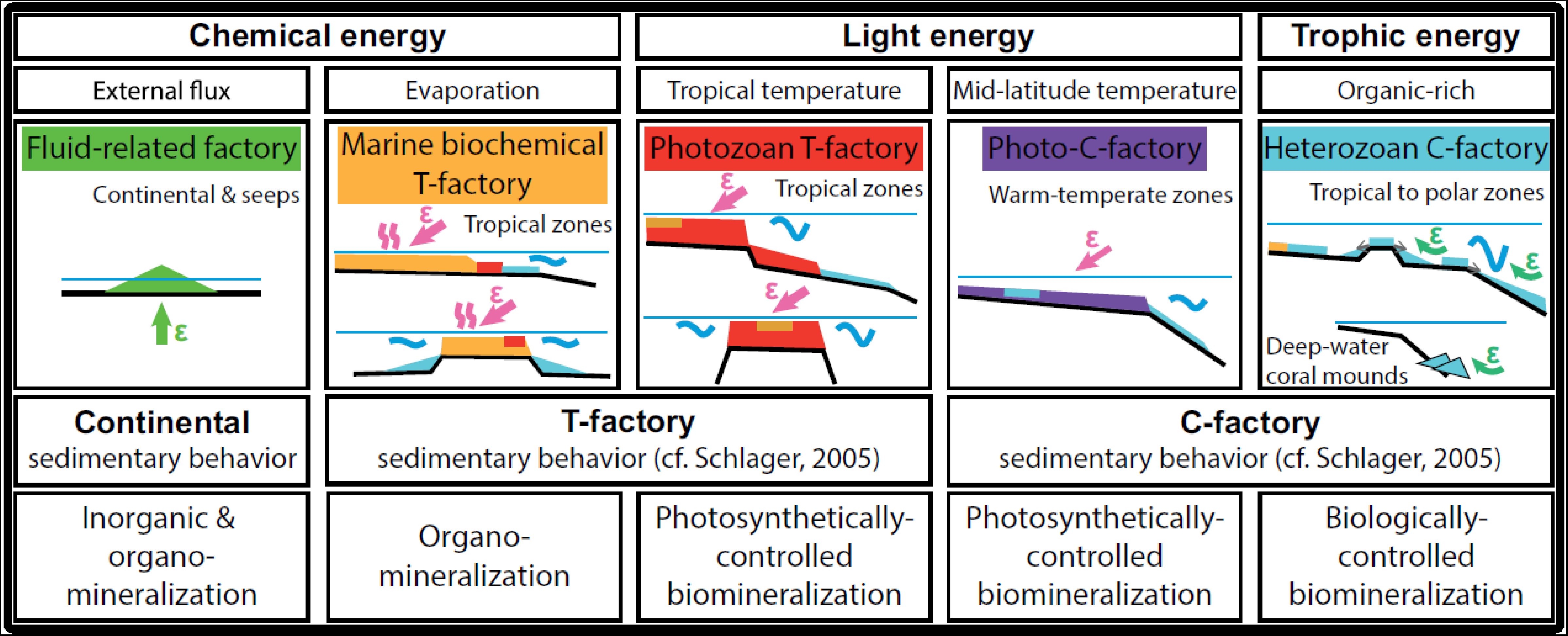
Carannante et al. (1988) already noticed that...

- Tropical carbonate platforms are associated to foramol skeletal associations (C-factory) **in the deepest portions**.
- Within the tropics, **terrigenous** or freshwater input can trigger a switch from T- to C-factories.
- The **upwelling** of cold and nutrient-rich deep waters has the same effects.



Carbonate factories

Michel et al., recently proposed another classification for neritic carbonate factories that relies on oceanographic, environmental and climatic parameters



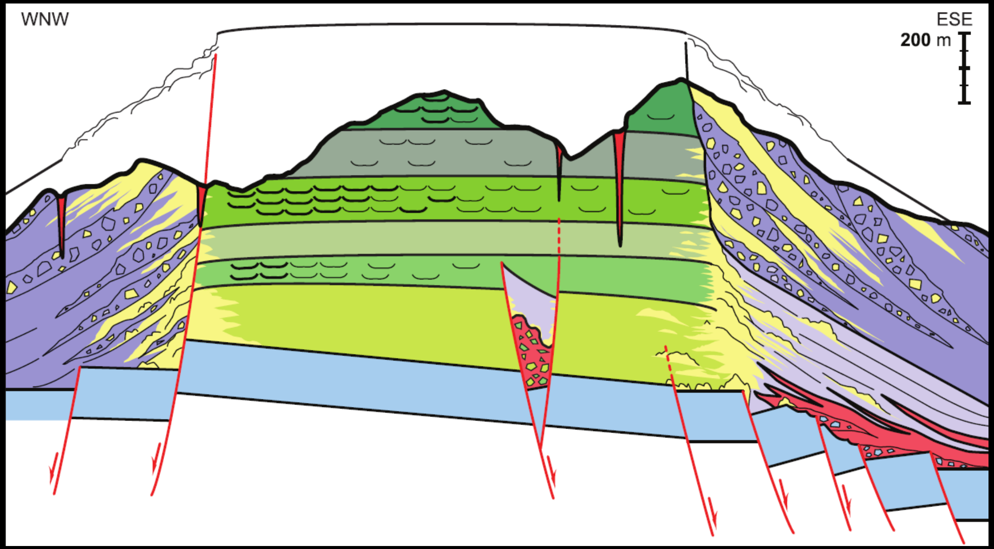
Michel et al., 2019

Carbonate factories and depositional geometries

We have mentioned that T and M type factories are characterized by enhanced early lithification. This phenomenon is less pronounced in C factories.
This difference has a direct consequence on the depositional geometries that carbonate platforms generated by the different carbonate factories can produce

T and M factories can produce high-relief carbonate platforms.

C factories cannot produce high-relief carbonate platform and their depositional profile is closer to that of clastic systems.



A high-relief carbonate platform can be produced when the dominant carbonate factory is of type T or M.

Take home messages for today

- a carbonate platform is a sedimentary body that possesses topographic relief and is made of parautochtonous carbonate deposits

- the formation of a carbonate platform is influenced by numerous factors and the accumulation of carbonate is controlled by the availability of accommodation

- a carbonate factory is benthic carbonate association dominated by a specific mode of precipitation

- three carbonate factories has been defined by Schlager: T-factory, M-factory and C-factory. Differences in the factories can determine depositional geometries.

- numerous environmental parameters (seawater geochemistry, nutrients availability, depth, temperature…) exert a control in determining the dominant carbonate factory in a carbonate platform