Sediment diagenesis

I_ Introduction

Diagenesis is the set of physical and chemical processes that affect a sediment, between its deposition and its entry into the realm of metamorphism or meteoric alteration, by modifying its mineralogy, chemistry, and texture. It stops where metamorphism begins (<200°C and between 6 and 7 km depth).

Sediments can either originate from detrital sources (= resulting from weathering and erosion processes) or organic sources. Additionally, certain rocks form through chemical precipitation. The primary categories of sedimentary rocks include detrital rocks, the most prevalent, as well as biogenic or physico-chemical rocks, which involve chemical equilibria under external temperature and pressure conditions, whether on continental surfaces or in the depths of seas and oceans. While sedimentary rocks are visible in 73% of cases on continental surfaces, when considering the entirety of the Earth's crust (from the surface down to 35 km beneath a flat relief), they constitute merely 8% of its total volume.

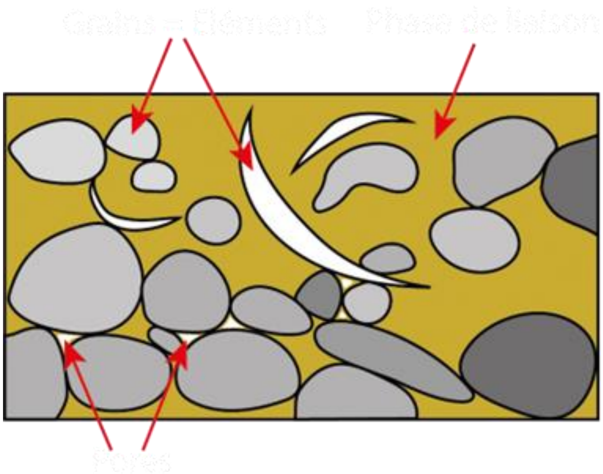
They remain highly diverse due to the multitude of factors influencing their formation: nature of disintegrated and altered materials, mode and type of weathering and erosion, transport methods, deposition zones or sedimentary basins, diagenesis processes, and more.

Within a sedimentary rock, one may observe:

_ Grains or clasts: comprising minerals, fossils (bioclasts), or fragments of rocks (lithoclasts)

_ A binding phase: responsible for the rock's cohesion, which could manifest as a matrix (synsedimentary) or a cement (diagenetically derived)

_ Pores: present in varying quantities and capable of holding gases or fluids (such as water or hydrocarbons).



II - Diagenetic Environments

There are two types of diagenetic environments:

Superficial diagenetic environments

Deep diagenetic environments

These two parameters can be combined to differentiate various superficial diagenetic environments:

<u>A - Superficial Diagenetic Environments</u>

Superficial diagenetic environments (in contact with water) can be categorized according to:

Water chemistry, which allows for the differentiation of three compositions:

Fresh continental water

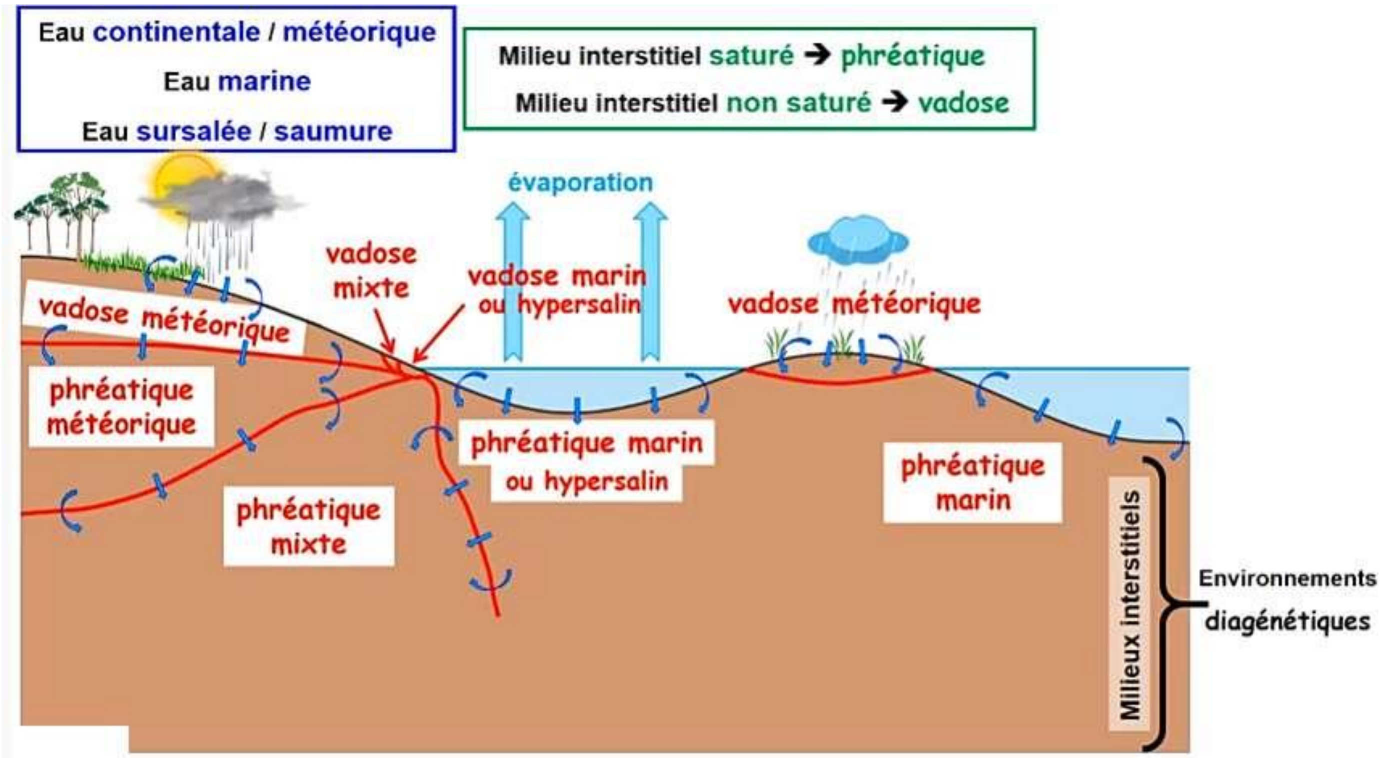
Saline marine water

Brackish water from mixed environments.

Water saturation, which distinguishes between two types of zones:

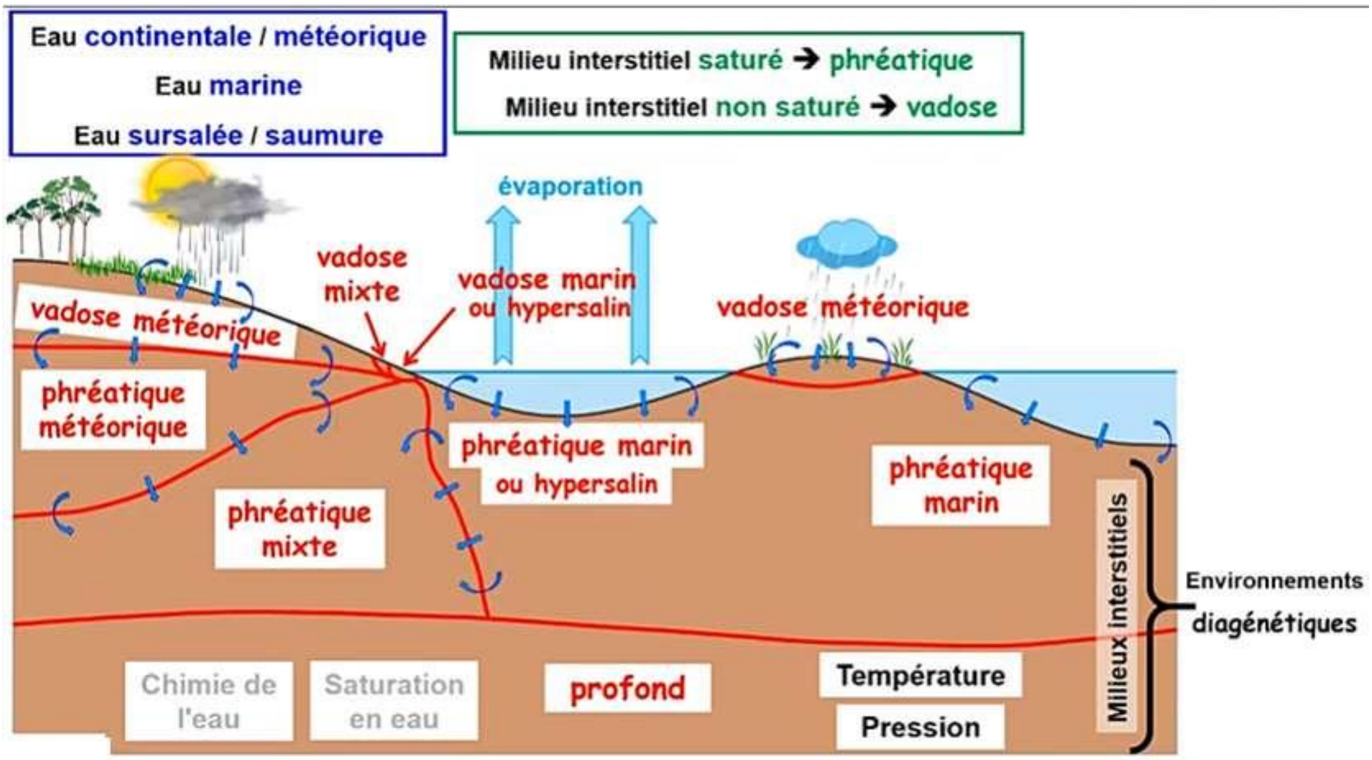
Water-saturated phreatic zone

Water-unsaturated vadose zone.



B - Deep Diagenetic Environments

Within deep environments, porosity is generally reduced, and the interstitial water frequently reaches chemical equilibrium with the surrounding sedimentary host. Pressure and temperature assume greater importance within these settings.

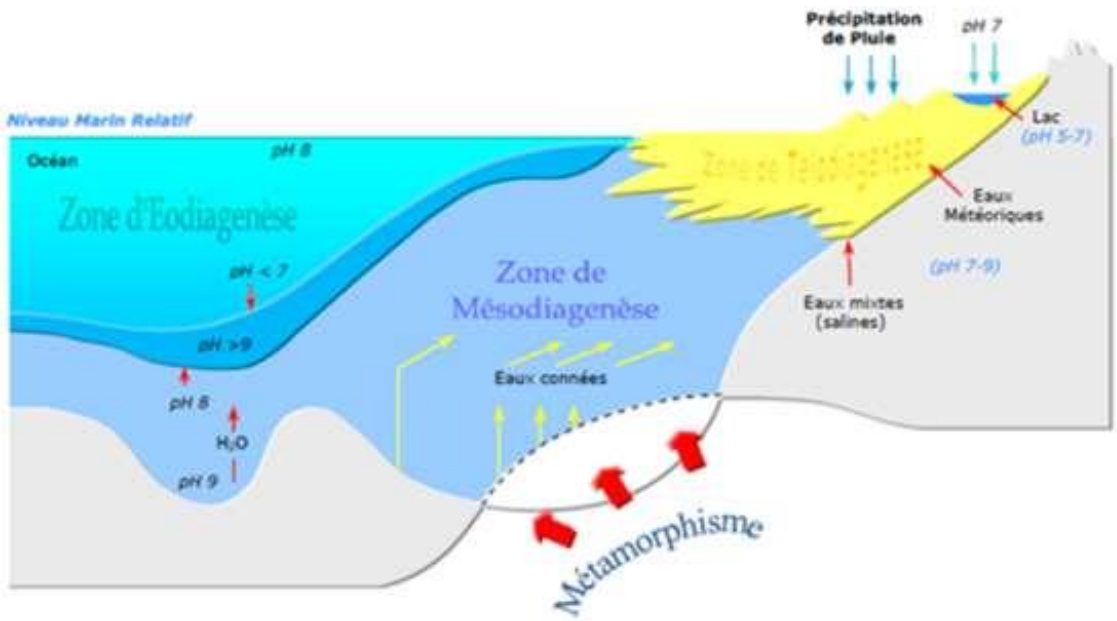


III - Diagenetic Zones

Eogenesis or early diagenesis: processes occurring in the shallow sediment layer affected by fluids in connection with the water layer.

Mesogenesis or burial diagenesis: processes occurring during burial, away from the zone where sediments and water interact.

Telogenesis or late diagenesis: processes occurring during the uplift of rocks to the surface, resulting from interaction between the rock and meteoric waters.



V - Diagenetic Stages

Throughout the diagenetic history of sediments, the various parameters and processes responsible for the diagenetic evolution of sediments are not randomly combined but follow a more or less precise order:

Temperature and pressure vary linearly with depth.

The redox potential sets clear boundaries between the oxidation zone and the reducing zone in early diagenesis.

The combinations of various parameters allow for distinguishing 4 major diagenetic stages, with their durations generally increasing.

Stage I

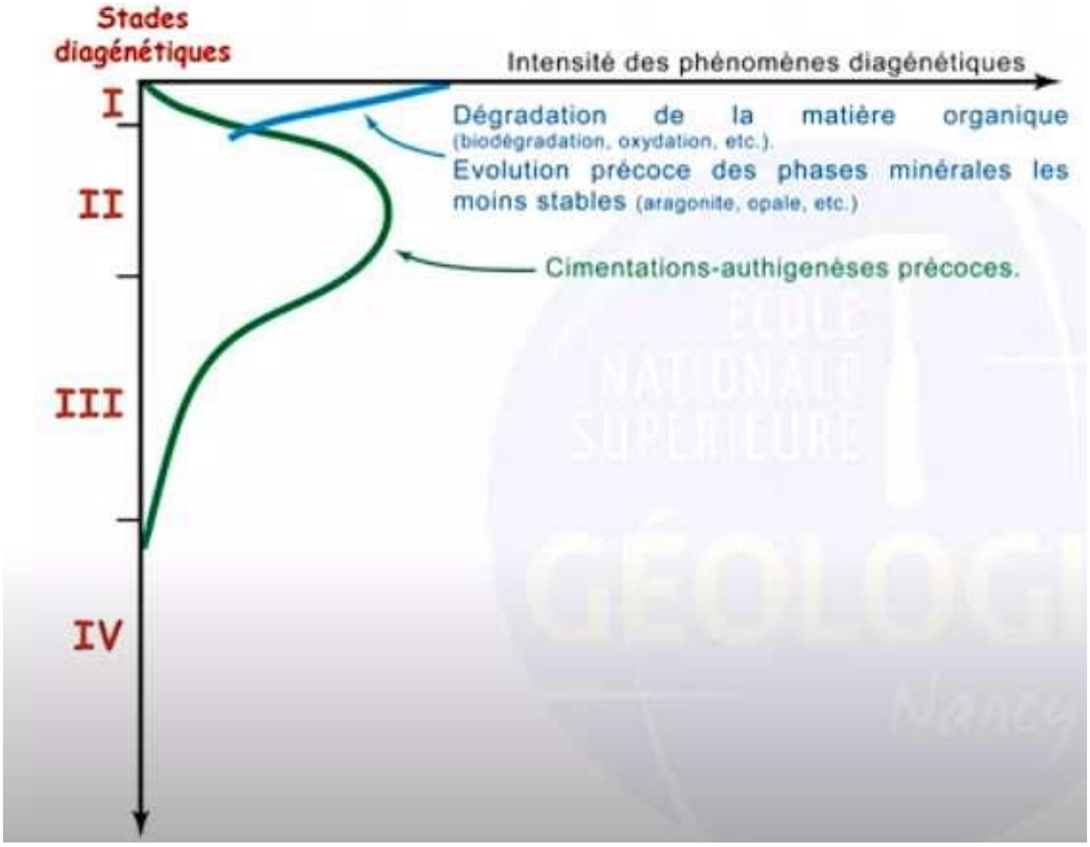
It is an oxidation zone (acidic pH) where bacterial activity is intense, and organic inputs are abundant.

Detrital organic matter mineralizes rapidly through biodegradation and oxidation.

Release of gases such as CO2, H2S (hydrogen sulfide), and NH3 (ammonia).

The least stable mineral phases either dissolve or get replaced by more stable minerals such as calcite and chalcedony.

Initiation of authigenesis (local formation of minerals like gypsum).



Stage II:

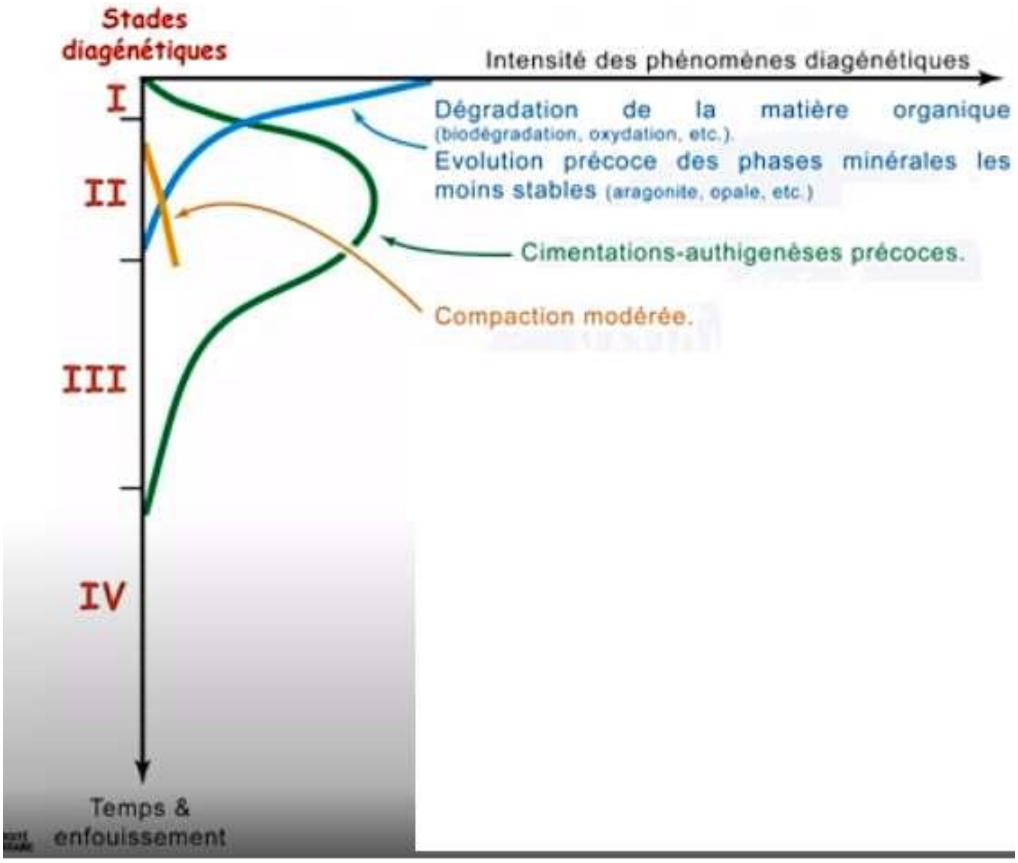
It is a reducing zone where anaerobic life dominates.

It is a zone where pH can reach values that allow for the dissolution of silica (basic pH).

During Stage I and especially in Stage II, the first cementations will occur in the sedimentary material.

The sediment will compact under the weight of overlying sediments.

The combination of Stages I and II forms the realm of early diagenesis, with its boundary located between 1 and 100 meters.

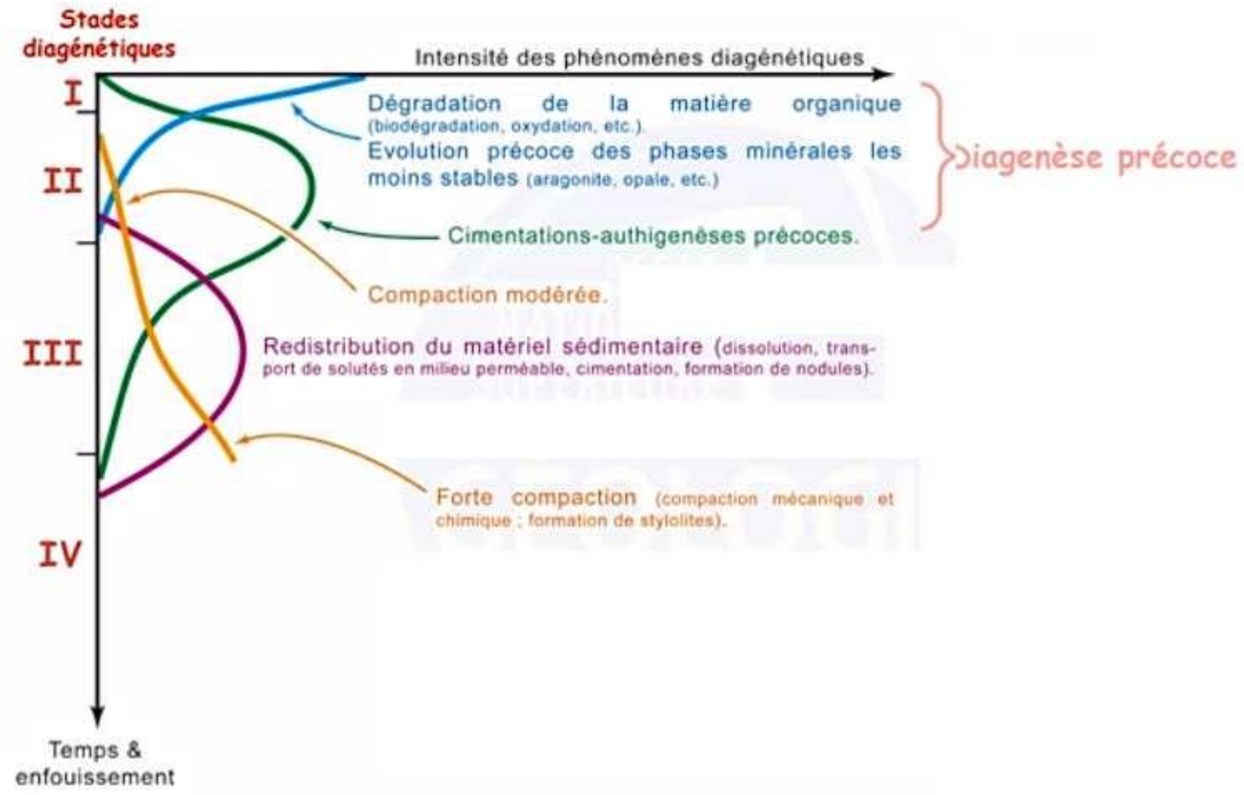


Stage III:

It is characterized by significant cementation in the pores and mineral phase replacements, sometimes in the form of nodules.

It marks the beginning of mechano-chemical compaction with material redistribution in the sediment.

Geothermal gradients (pressure and temperature) start to play a significant role in diagenetic transformations.



Stage IV:

The sediment undergoes strong compaction, leading to the expulsion of water tightly bound to minerals through capillarity. This causes significant dehydration of minerals, greatly reducing sediment porosity.

This stage is characterized by recrystallization and transitions into metamorphism beyond 1000 meters.