Chapter III. Rhythmo-stratigraphy

III.1 Sequence analysis

Sequence stratigraphy or allostratigraphy is a method of studying stratigraphy based on the recognition of geological depositional sequences (marine regressions and transgressions) and sedimentary processes observed by seismic stratigraphy, correlated by field surveys and drilling.

- It is a scientific discipline that studies the relationships between the textural framework of facies and the structural arrangement of sequences.

- It appears as a method of processing information recorded over time, the aim of which is to establish the natural series. The information may be lithological, paleontological, geochemical, etc., in a general sense.

- The notion of facies is therefore essential, and its rich, concise description can provide vital and important information for a precise sequential response.

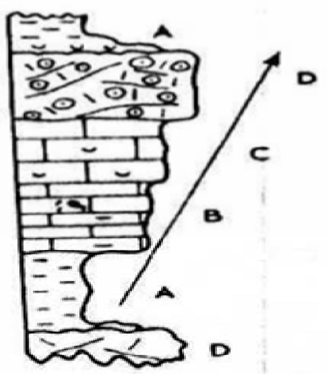
1. Facies:

Is a sum of parameters described or measured in a deposit. The choice of facies observation scale is correlatively proportional to the order of the sequences studied.

2. Sequence:

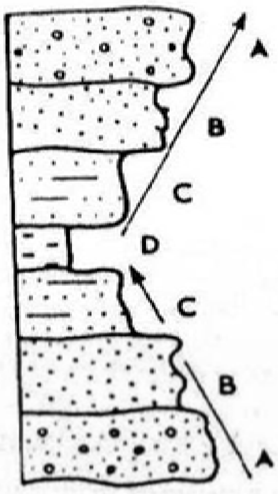
A sequence is an ordered succession of several facies. The scale of the sequence depends on the scale of the facies under consideration. Each sequence can be considered as an elementary facies within the higher-order sequence. Sequences are separated by discontinuities

Lithological sequence: single evolutionary succession of related lithological terms, vertical or horizontal.



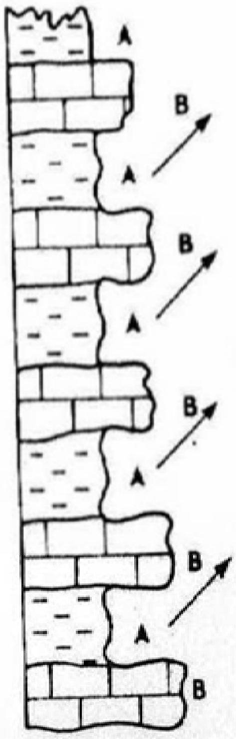
- Séquence lithologique

Sedimentary cycle: progressive succession of lithological terms with a return to the initial term.



- Cycle sédimentaire

Rhythm: natural succession of facies in which there is regular repetition of terms.

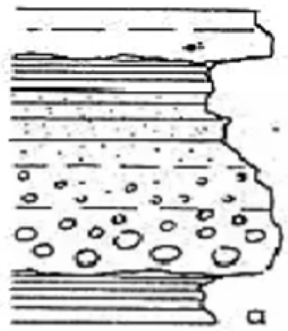


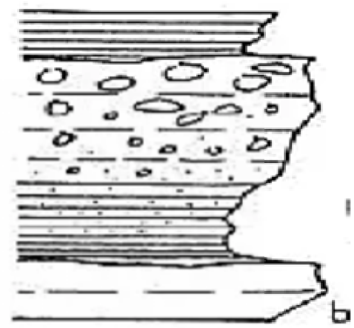
- Rythmes

Positive or negative sequence: lithological sequence showing a clear change in emplacement energy at the moment of deposition.

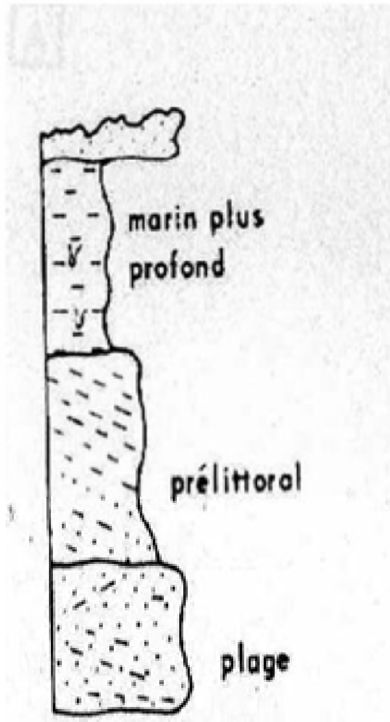
<u>a. Positive sequence:</u> detrital sedimentation at the base, chemical sedimentation at the top. From larger to smaller grains.

<u>b. Negative sequence:</u> from smaller to larger grains.



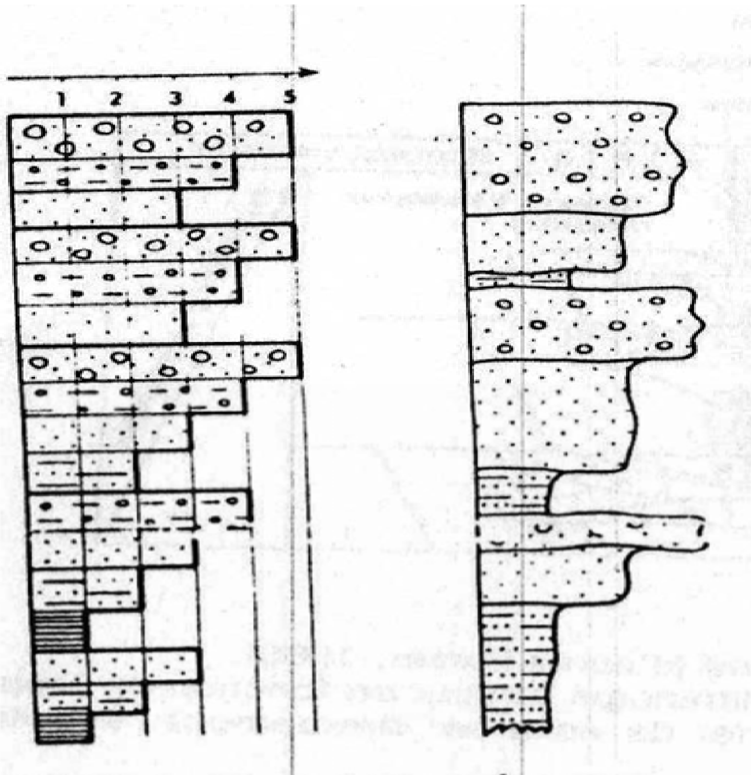


Transgressive or regressive sequence: evolutionary succession of lithological terms vertically translating a transgression or regression.



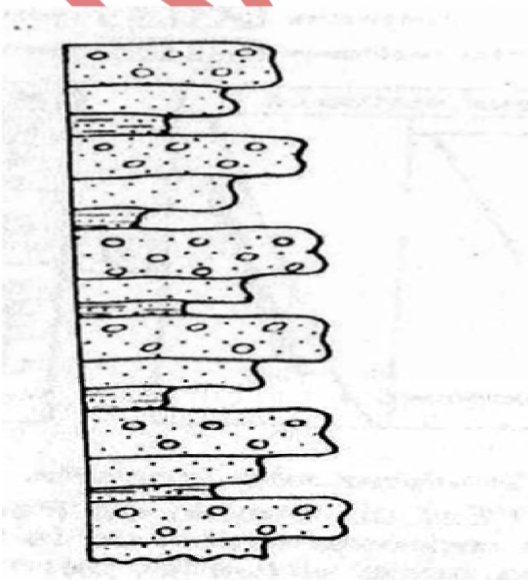
- Séquence transgressive

Mega sequence: corresponds to a sequence of higher order



Deux Types de Megaséquences

Rhythmic sequence: monotonous repetition of cycles or sequence without coherent variation of terms.



Séquences rythmiques

III.2 Eustatism and eustatic cycles

Eustatism is the variation in mean sea level (in relation to the continents) "This factor controls the thickness of the water level (relative level) and therefore the lateral extension of the basin". It's a cyclical phenomenon of slow rises and falls in sea level (on the order of mm/year). e.g.: the formation of ice caps has a eustatic effect, resulting in a drop in sea level (eustatic regression), which can reach a hundred meters. Understanding this phenomenon has enabled us to better explain the history of paleo-environments and organisms over time. The study of eustatism requires paleoenvironmental data. This data comes from petrography, paleontology, stratigraphy and the study of the isotopic composition of the sedimentary rock concerned. The effects of eustatism can be directly observed in stratigraphic series

Relative variations in sea level

These are processes that take the form of landward or seaward displacement of the shoreline (transgressions and regressions). These movements (on a global scale) derive from the relative rise or fall in sea level. As a result of these movements, the various erosion or sedimentation media move in one direction or the other. This leads to lateral displacement and the superimposition of different environments. A regression can also be caused ⇒ by simple progradation of laterally-increasing sedimentary bodies (delta, reef) without any relative variation in sea level (forced regression) ⇒ by tectonic movements on continental margins (uplift). A transgression can also be caused by tectonic movements on the continental margins (subsidence). During a transgression, lithology and fossils indicate increasingly deep environments from the base to the top of the series (deepening mesosequence). During a regression, they become shallower from bottom to top (filling mesosequence).

Eustatic factors :

They are multiple and interfere ("combined effects"). They are mainly tectono-eustatism (variations in the volume of ocean basins), which explains the cycles of low-frequency sea-level variations Ex. plate tectonics

glacio-eustatism (variations in the mass of water in ocean basins), which explains cycles of higher-frequency sea-level variations.

<u>For example:</u>

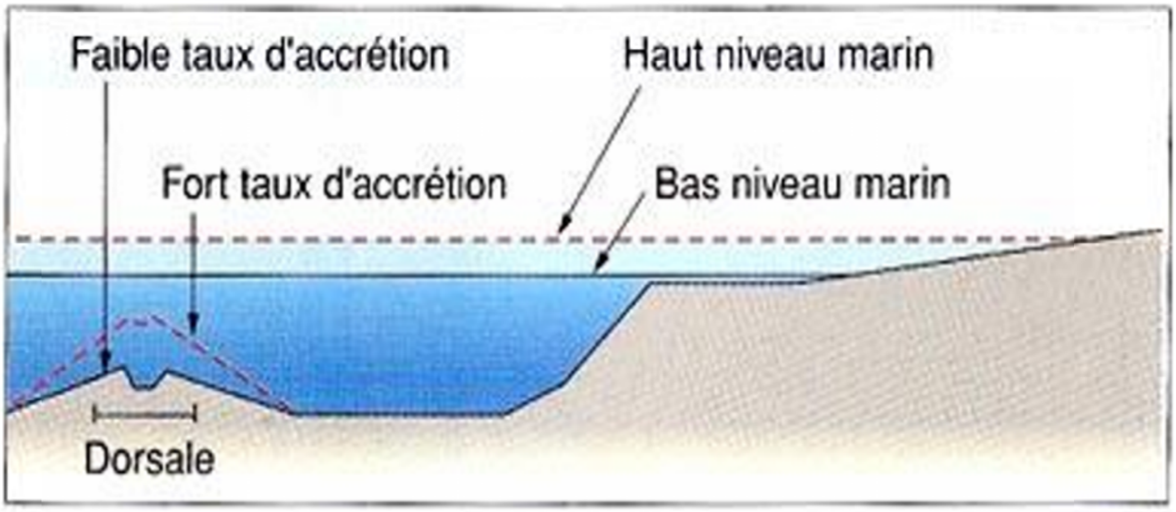
Glaciations: lowering of sea level and deglaciation: melting of ice which implies a rise in sea level

<u>Example:</u>

During the last deglaciation (which began 21,000 years ago), sea level rose by around 120-130 m, stabilizing at its current level 6,000 years ago. The ice caps that covered North America and Europe disappeared in almost 15,000 years.

Tecto-eustatism: Change in ocean basin volume

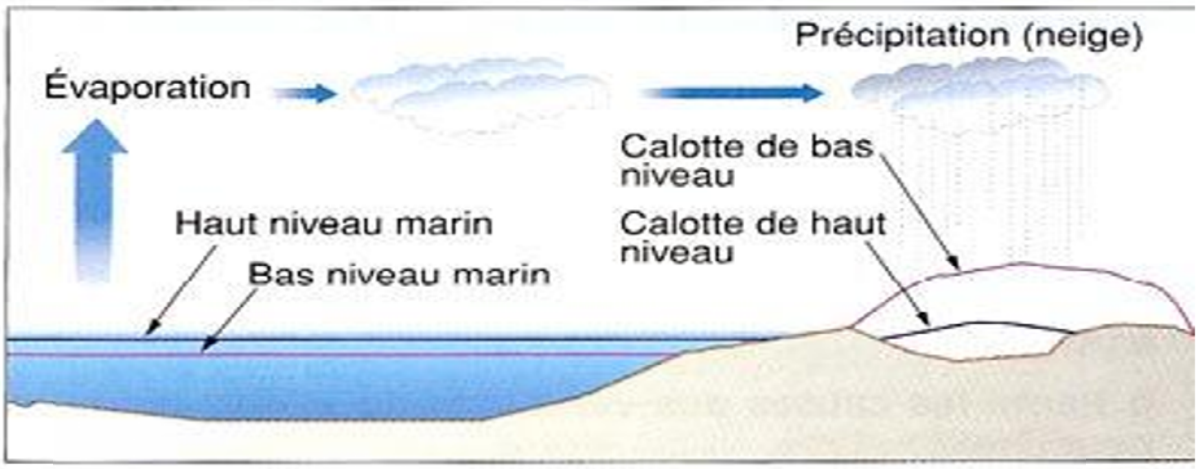
Changes in global ocean volume are linked to changes in the volume of mid-ocean ridges. In fact (and in general), the transition from a period of maximum collision (at super-continent/s) to a period of maximum break-up is accompanied by a progressive increase in the absolute length of the ridge system. The absolute length decreases steadily from a period of dislocation to a period of collision. Tecto-eustatism is therefore an important phenomenon. Studies have shown a certain parallelism between continental drift and the relative variations in long- and short-term sea level caused by plate tectonics.



4. Activités des dorsales et variation du niveau marin.

Glacio-eustatism: changes in the volume of water contained in the oceans

Climate plays a key role in any variation in the volume of water contained in the world's oceans, causing positive or negative variations in sea level: this is glacio-eustatism. This type of eustatism is a rather special phenomenon, and for sea level to vary (rise or fall) due to this phenomenon, climatic cooling (or warming) must occur, and significant land masses must be present at or near the poles. Glacio-eustatism causes major regressions and transgressions linked respectively to climatic cooling (with the formation of polar ice caps) or climatic warming (melting of polar ice caps).



3. Formation et destruction des calottes glaciaires et variation du niveau marin.

Consequences of eustatism

Continental drift causes significant relative changes in the surface area of the marine and continental domains, with the maximum change occurring on continental shelves. During periods of maximum dislocation, the surface area occupied by the platforms is significantly greater than during periods of super-continental drift. This is related to the decrease or increase in the distribution of the continental masses to which the platforms are strictly linked. Transgressions and regressions caused by tecto-eustatism, glacio-eustatism or a combination of the two lead to an increase or decrease in the absolute surface area of the marine and continental domains.

This has an impact on:

The environment

Changes in the surface area of the marine and continental domains, caused by relative variations in sea level, influence the biotic and abiotic characteristics of the various environments:

- in transgressive periods, the large surface area of the marine domain increases evaporation, and hence cloud cover and precipitation. The climate will be humid, with little thermal variation. In the continental realm, epicontinental seas penetrate, sometimes deeply, into land masses. Relative elevation decreases. The climate is more oceanic, with little thermal variation.

- in regressive periods, rainfall decreases and the climate is dry. Epicontinental seas are reduced or even absent. The relative altitude of reliefs increases and the climate becomes more continental with a strong thermal difference.

Sedimentation

Progressive changes in the earth's configuration, caused by continental drift, lead to changes in the sediment regime and dynamics. This is related to the consequent modification of the river equilibrium curve profile.

a- Detrital:

- periods with super-continents (convergent tectonic phase) are characterized by an arid climate, unfavorable to vegetation (deforestation) and vast surfaces are thus delivered to mechanical and chemical erosion (rhexistasia). The lowering of the sea level (regression) also leads to the over sinking of rivers, resulting in significant terrigenous inputs into the basin.

- during periods of dislocation (divergent tectonic phase), epicontinental seas penetrate between separated continents. The oceanic climate favors the development of plant cover (biostasy) and mechanical erosion is low.

Marine advances (transgressions) gradually move the shoreline towards the continent. Terrigenous sediments, trapped near the shoreline, gradually move away from the center of the basin.

b- Carbonate:

Carbonate deposits are essentially formed by the accumulation of bioclasts. Carbonate sedimentation is therefore largely driven by biological factors, either directly (bioconstructions) or indirectly (accumulations).

Transgressions correspond to periods of high carbonate sedimentation, as they increase the surface area of biotopes favorable to the development of marine organisms (continental shelf).

During regressions, **terrigenous** sedimentation dominates.

c- Anoxic deposits (black shales):

These are black organic muds (fine detrital muds rich in organic matter), deposited in anoxic environments during periods of confinement (regressions) or slowing of oceanic circulation (transgressions) (figure1). Through diagenesis, these sapropelic muds become black shales, the source rocks of oil. During transgressive periods, all the conditions favorable to the development of this type of sedimentation are present:

- Basin deposits are clayey, slow-settling and may be loaded with organic matter.

- the shallow depth of the CCD (carbonate compensation limit) will restrict the range of carbonate sedimentation,

- the warm, humid climate (with low temperature differentials) accompanied by the disappearance of the polar ice caps means that during transgressions, marine temperatures are more homogeneous, so currents generated by temperature differentials will be less active.

FIG 1 : BLACK SHALE

Life

The influence of eustatism on life is very important, whether marine or continental.

a- Marine

Eustatism is said to have numerous consequences for marine life, through its impact on climate, the surface of the marine realm, sedimentation, and oxygen and carbon dioxide content.

Transgressive periods are characterized by the development of favorable conditions for marine life, with an enrichment of both species and individuals; certain groups evolve rapidly to colonize the new ecological niches created by rising sea levels.

During transgressions, the pelagic fauna developed rapidly, both in the basin (photic zone) and on the continental shelf. The benthic fauna, again during transgressive periods and following the development of large surfaces with low water levels (platforms), also undergoes great qualitative and quantitative development.

During regressions, surfaces favorable to benthic life (platforms) are drastically reduced, with a consequent reduction in populations.

b- Continental

Relative variations in sea level influence continental life through two factors:

- during regressive periods, the surface area of the continents increases, so the range of continental organisms theoretically becomes greater. However, regressions, by creating land bridges between previously separate continents, create competition between populations with identical biotopes, leading to numerous extinctions.

- lower sea levels lead to lower water tables and a subsequent lack of water for animals and plants. This is leading to increasing desertification in the center of continents, with a consequent reduction in areas suitable for life.