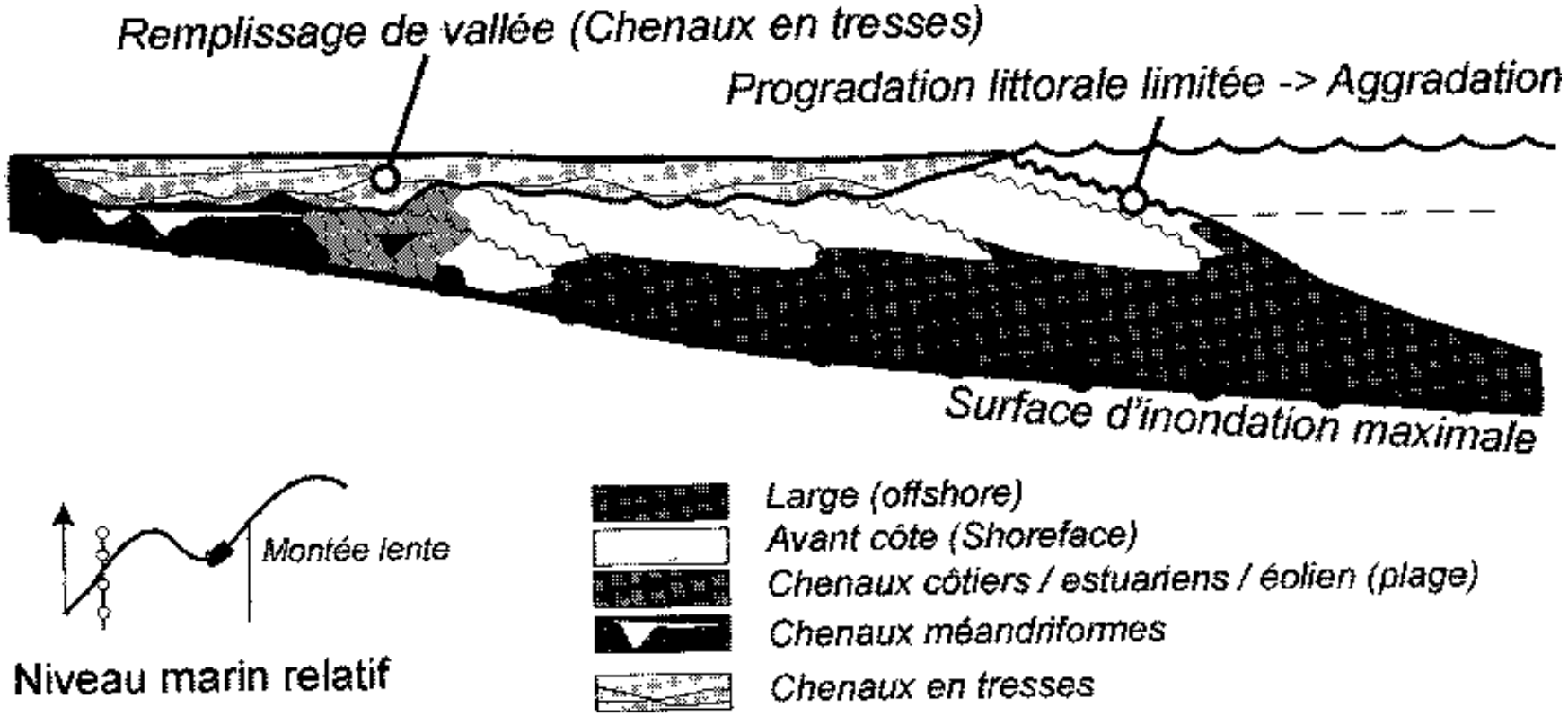


Figure 3.32. Montée lente du niveau marin relatif (fin de la phase régressive).

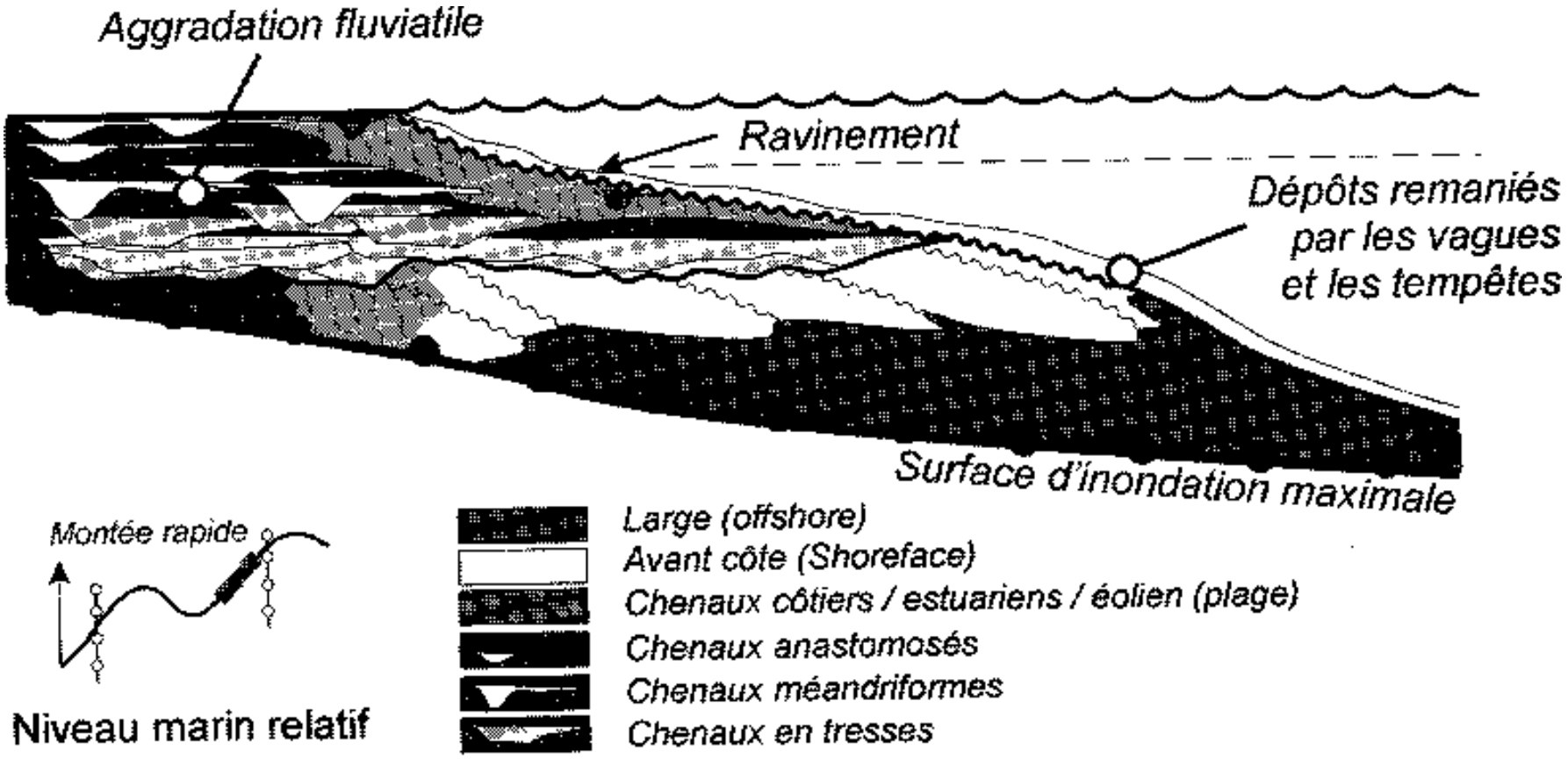


Figure 3.33. Montée rapide du niveau marin relatif (phase transgressive).

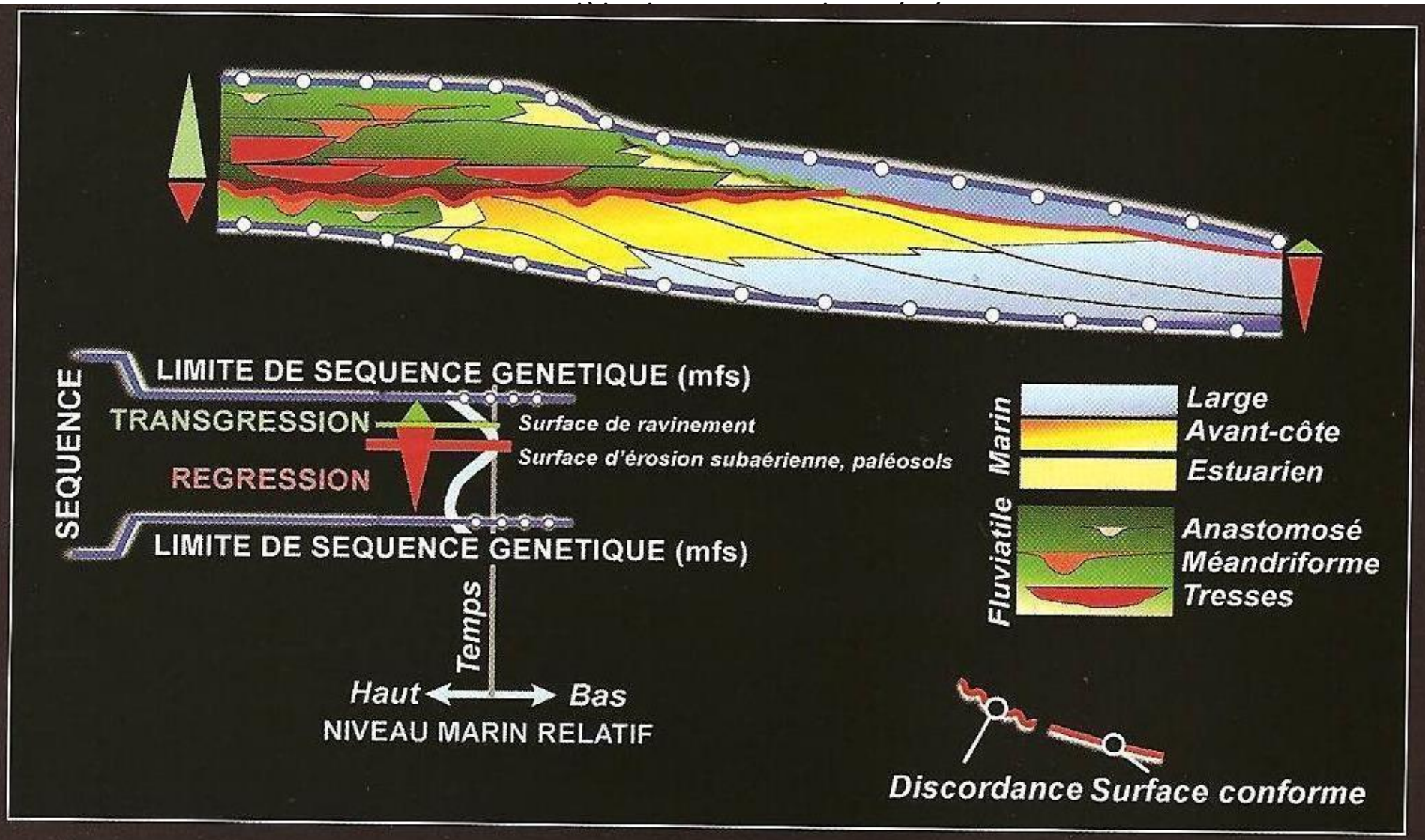


Planche V. Modèle de séquence génétique (d'après Homewood *et al.*, 1992 ; Merzeraud, 1992).

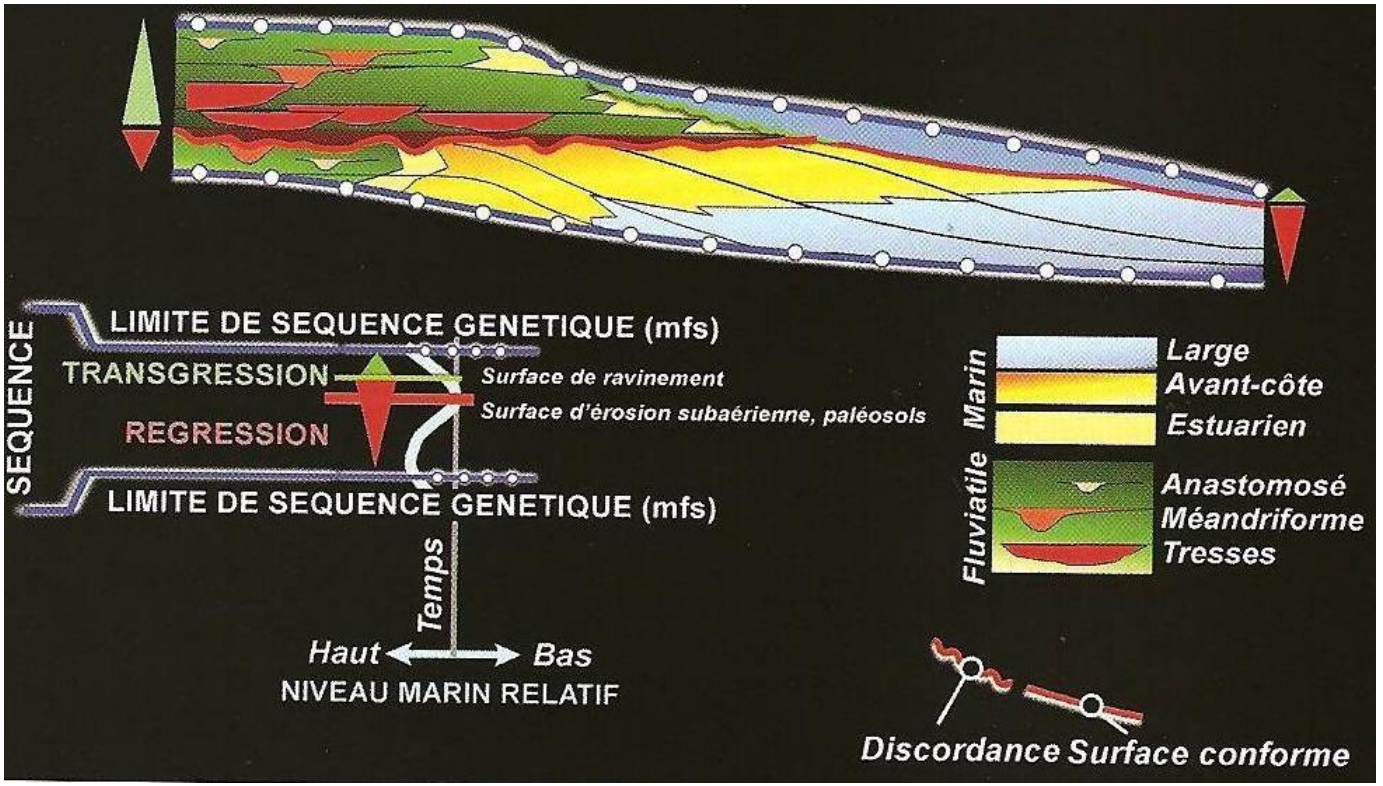
SYNTHESIS – pros and cons, genetic stratigraphy

- During transgression/sea level rise : river sedimentation/ lack of sediment in marine environment

- During regression/sea level fall : erosion at rivers/ high sedim rates in marine environment

- Sequence is bounded by two highstand discontinuities (hardgrounds)

- Only valuable for regional studies (sea level rise pattern is uneven at this time scale), but cannot be extrapolated to global scale



Tracking past sea level variations, at the geological time scale

Oblique stratifications + unconformity
Ypresian sandstones; Noirmoutiers, Vendée

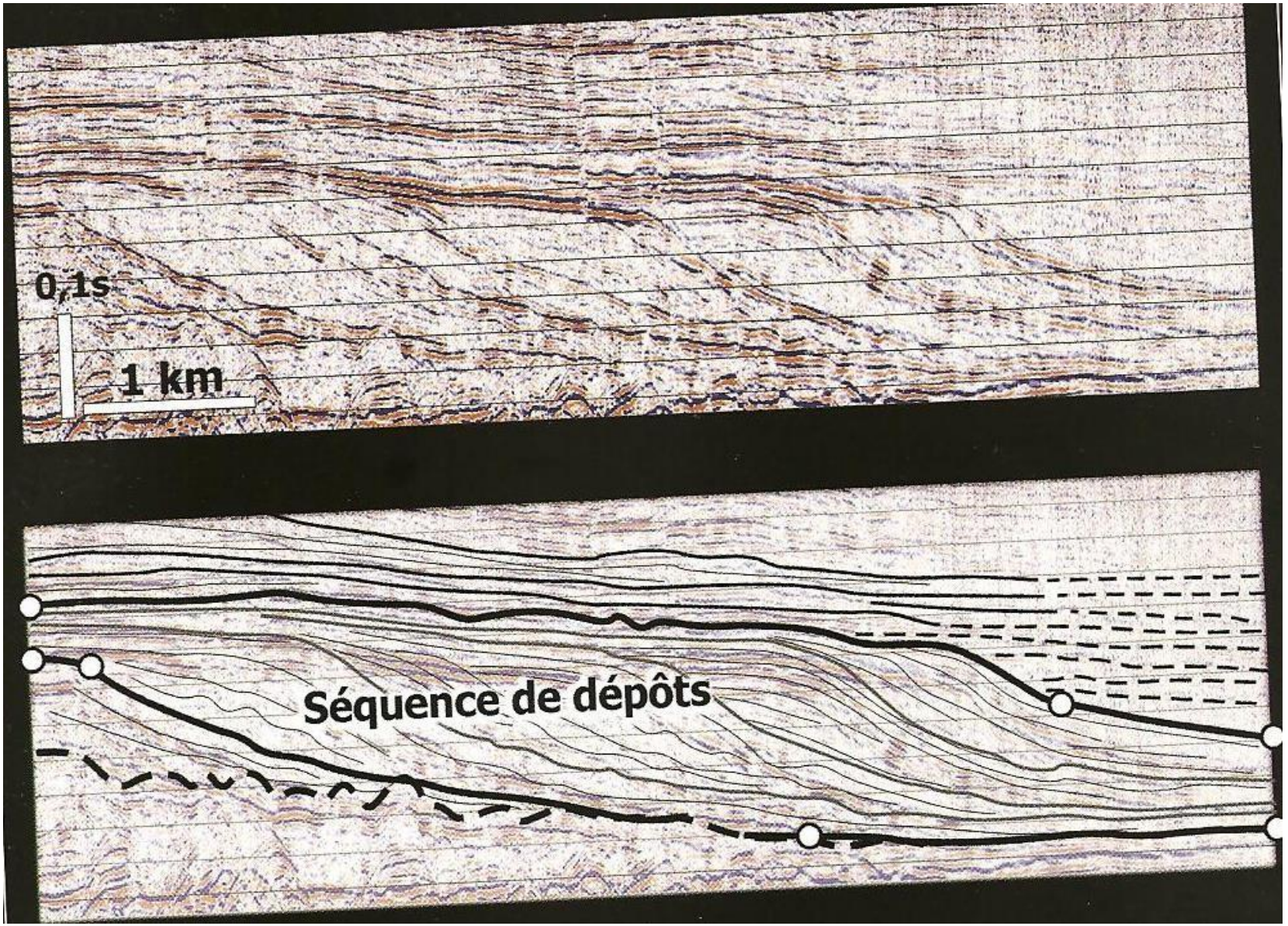
MAIN QUESTIONS

- How sea level variations are recorded in sediments?
- What is the time resolution of the record?
- How do we reconstruct past sea level curves from the sedimentary record?
- What do we learn from the sedimentary record in terms of past sea level variations?

OUTLINE

- The significance of the sedimentary record of sea level variations : an historical approach
- Tracking sea level variations at the 10^4-10^5 yrs time scale (genetic stratigraphy)
- **Tracking sea level variations at the 10^6 time scale (sequence stratigraphy)**
- Which processes control sea level variations at the geological time scale? A synthesis

Vail 's model of sequence stratigraphy, based on seismic lines

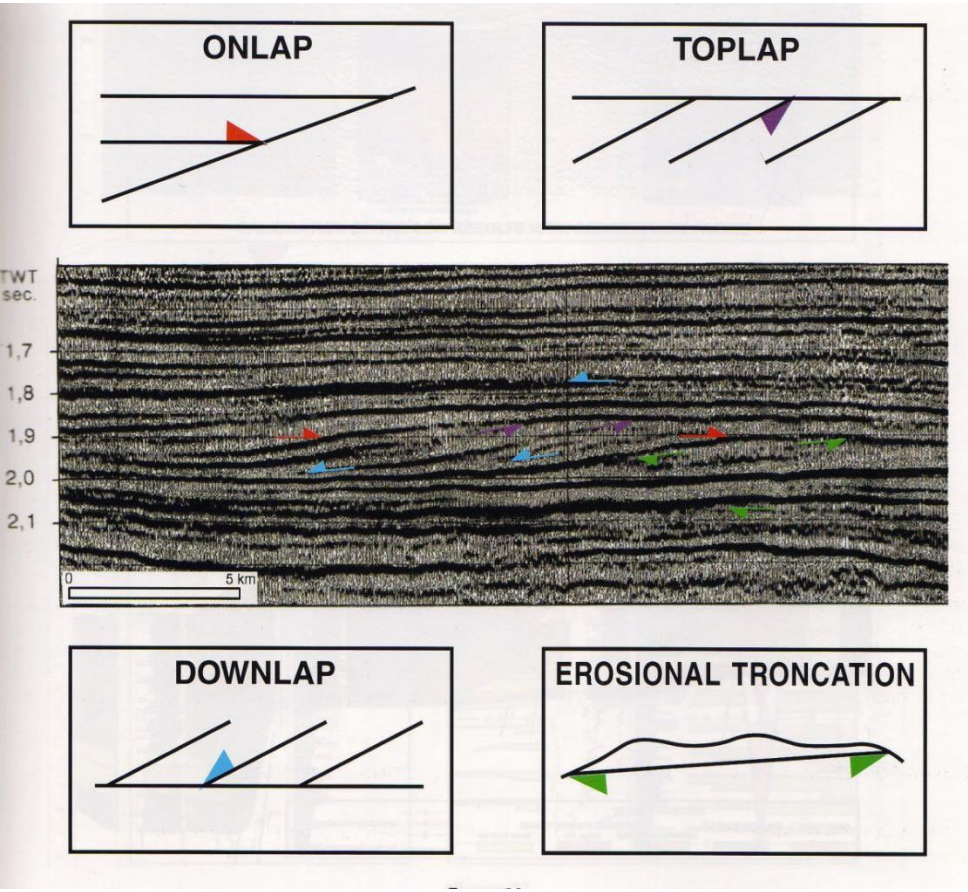


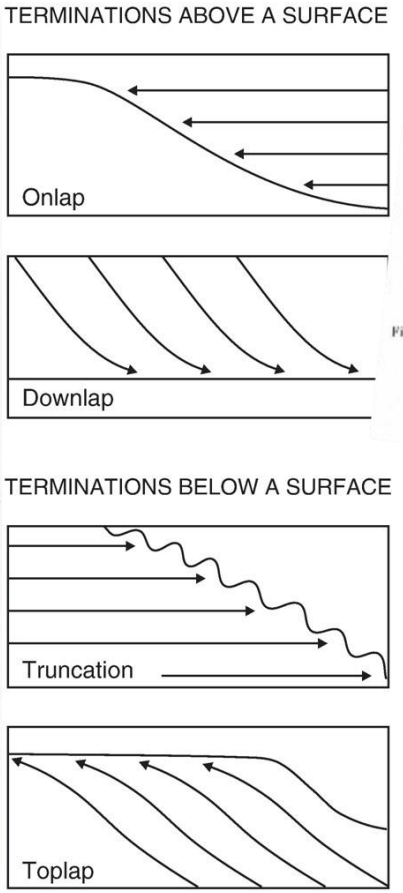
Same principle : identification of facies, major discontinuities, geometry/architecture of sedimentary bodies…

But the spatial relationships are investigated at the scale of the basin …and at the scale of the million year.

Allowed by the seismic profiles

Interpretation of seismic reflectors





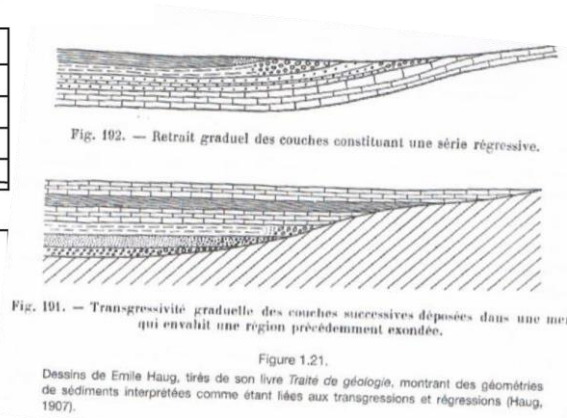


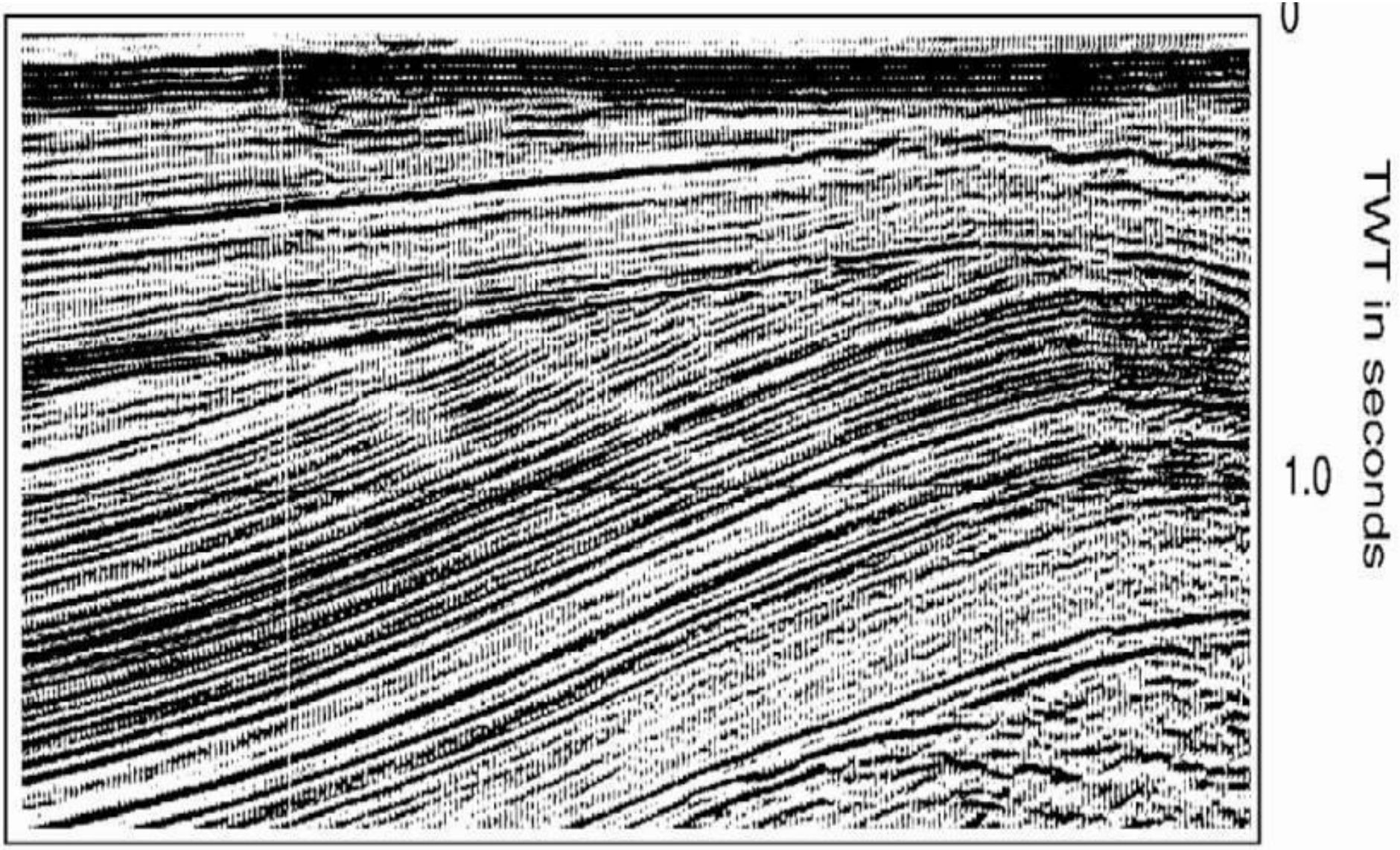
Fig. 192. — Retrait graduel des couches constituant une série régressive.

Fig. 191. — Transgressivité graduelle des couches successives déposées dans une mer qui envahit une région précédemment exondée.

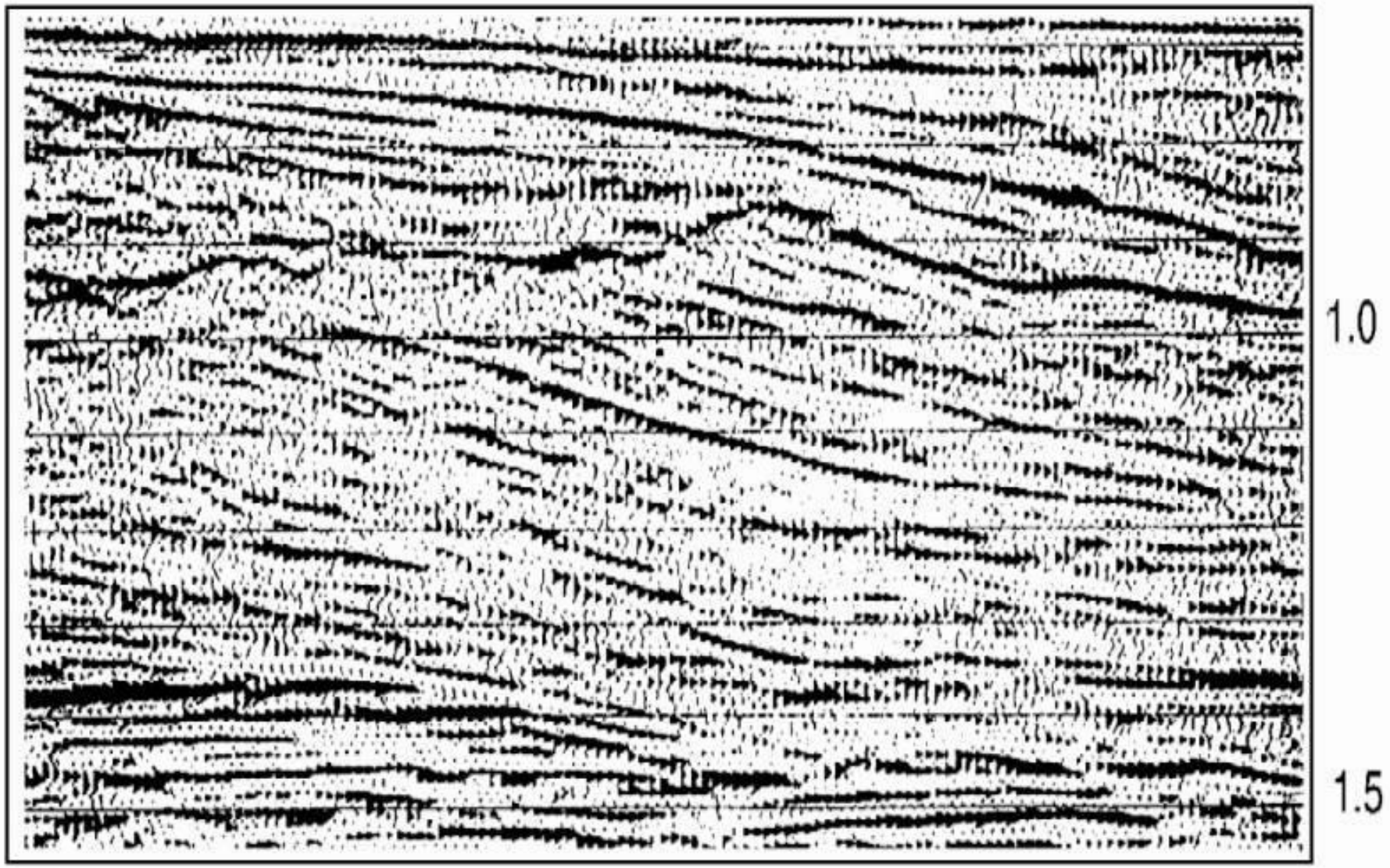
Figure 1.21.
Dessins de Emile Haug, tirés de son livre *Traité de géologie*, montrant des géométries de sédiments interprétées comme étant liées aux transgressions et régressions (Haug, 1907).

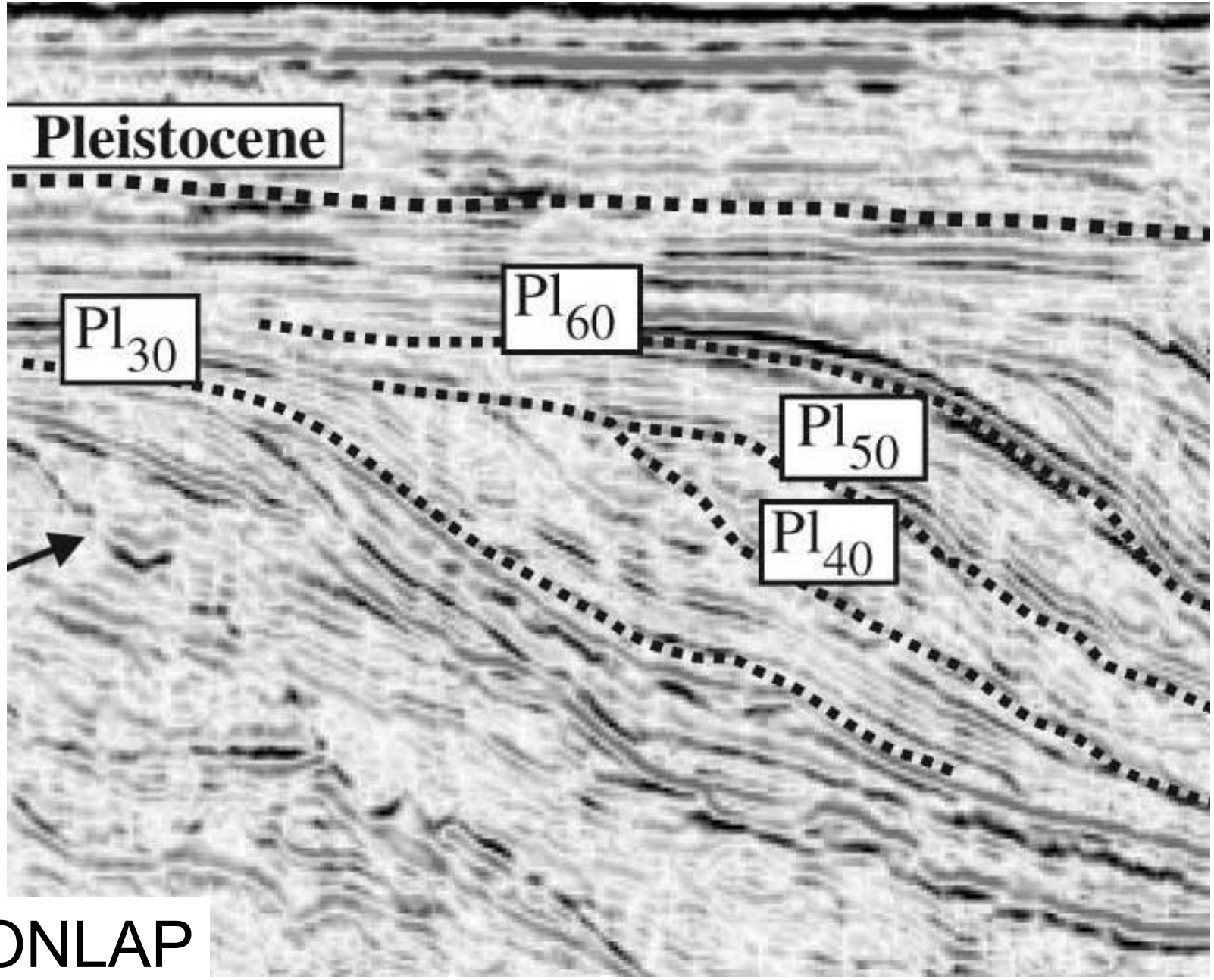
To characterize major discontinuities and geometries, we need to identify reflector terminations

Specific nomenclature for reflector terminations => description of the sedimentary bodies

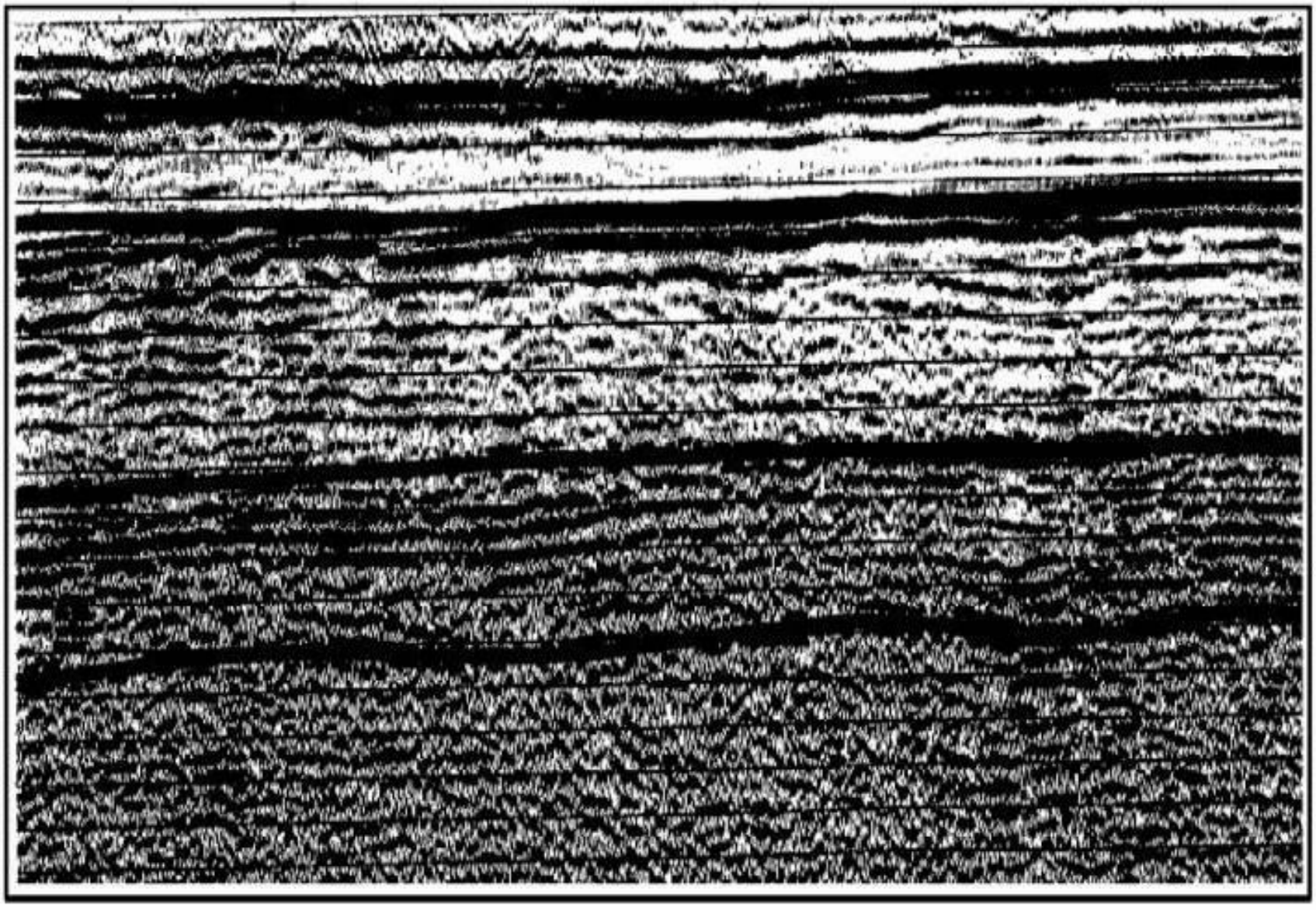


Erosional truncation


TWT in seconds
1.0
1.5
Top lap

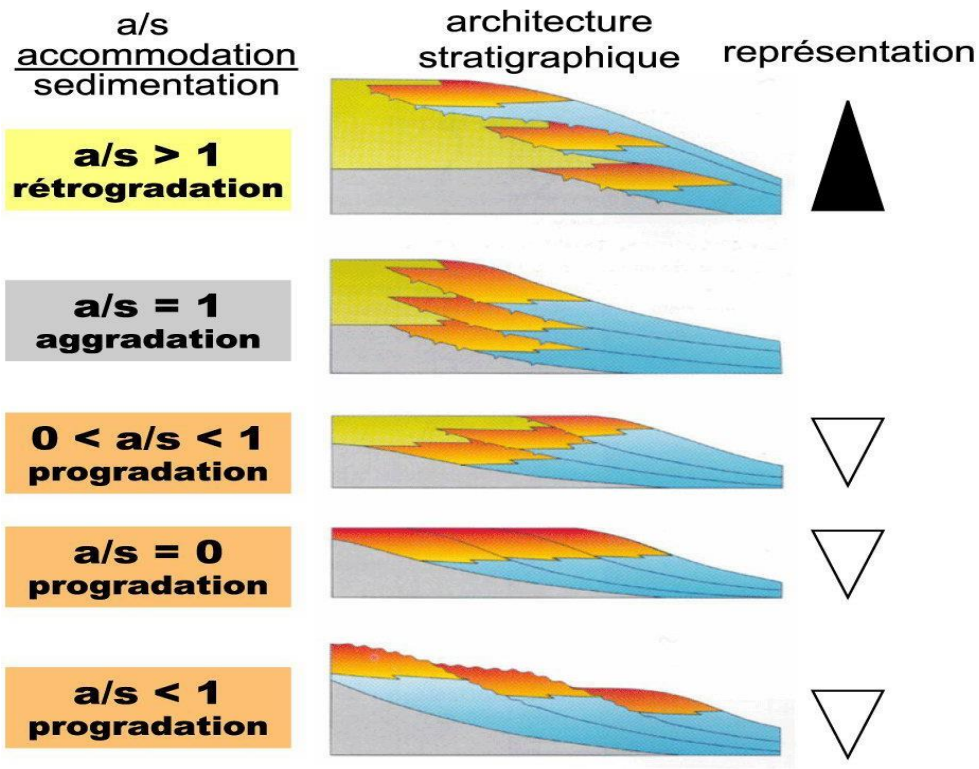


ONLAP

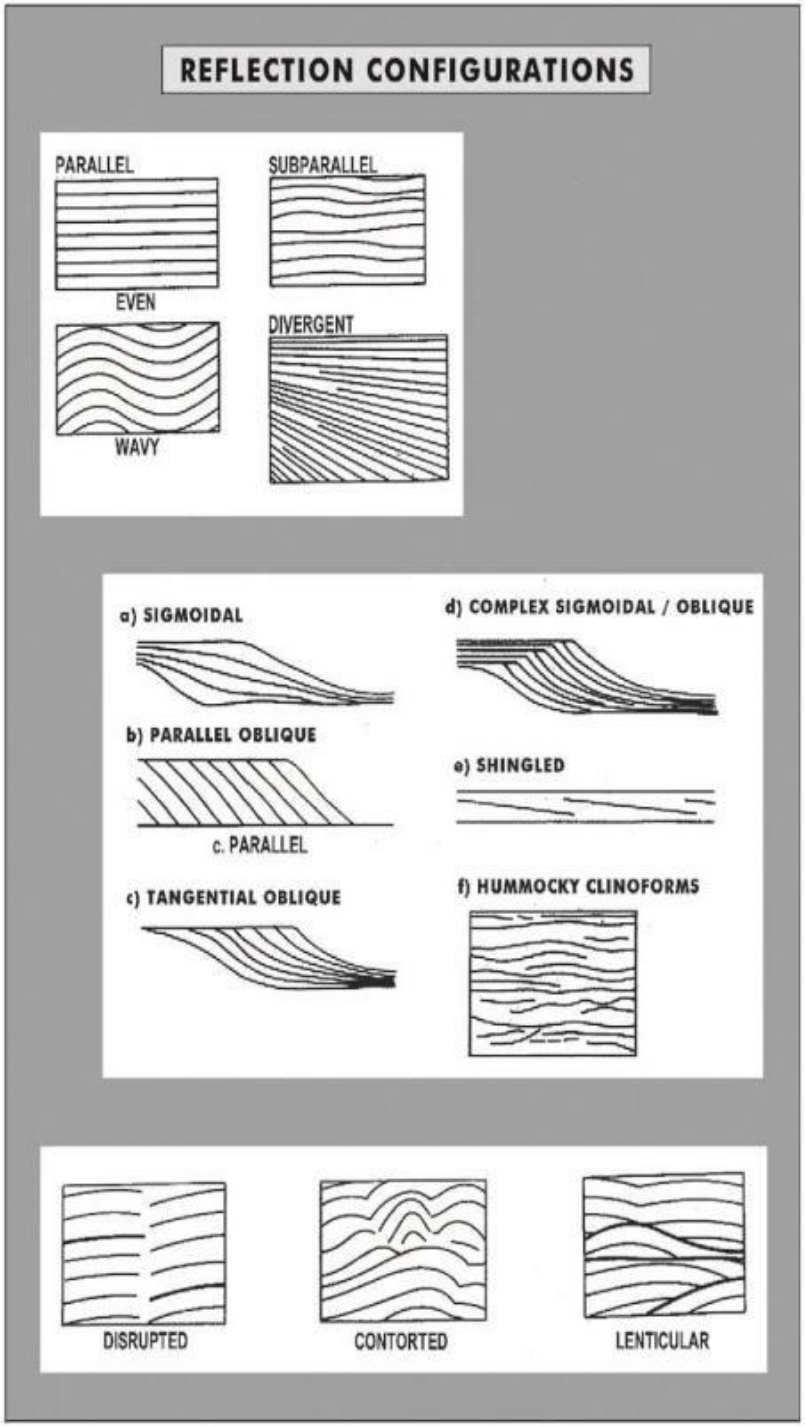


Concordance with subtle indications for sediment bypass

Description of the geometry of sedimentary bodies



Prograding wedge, aggrading wedge, retrograding wedge…



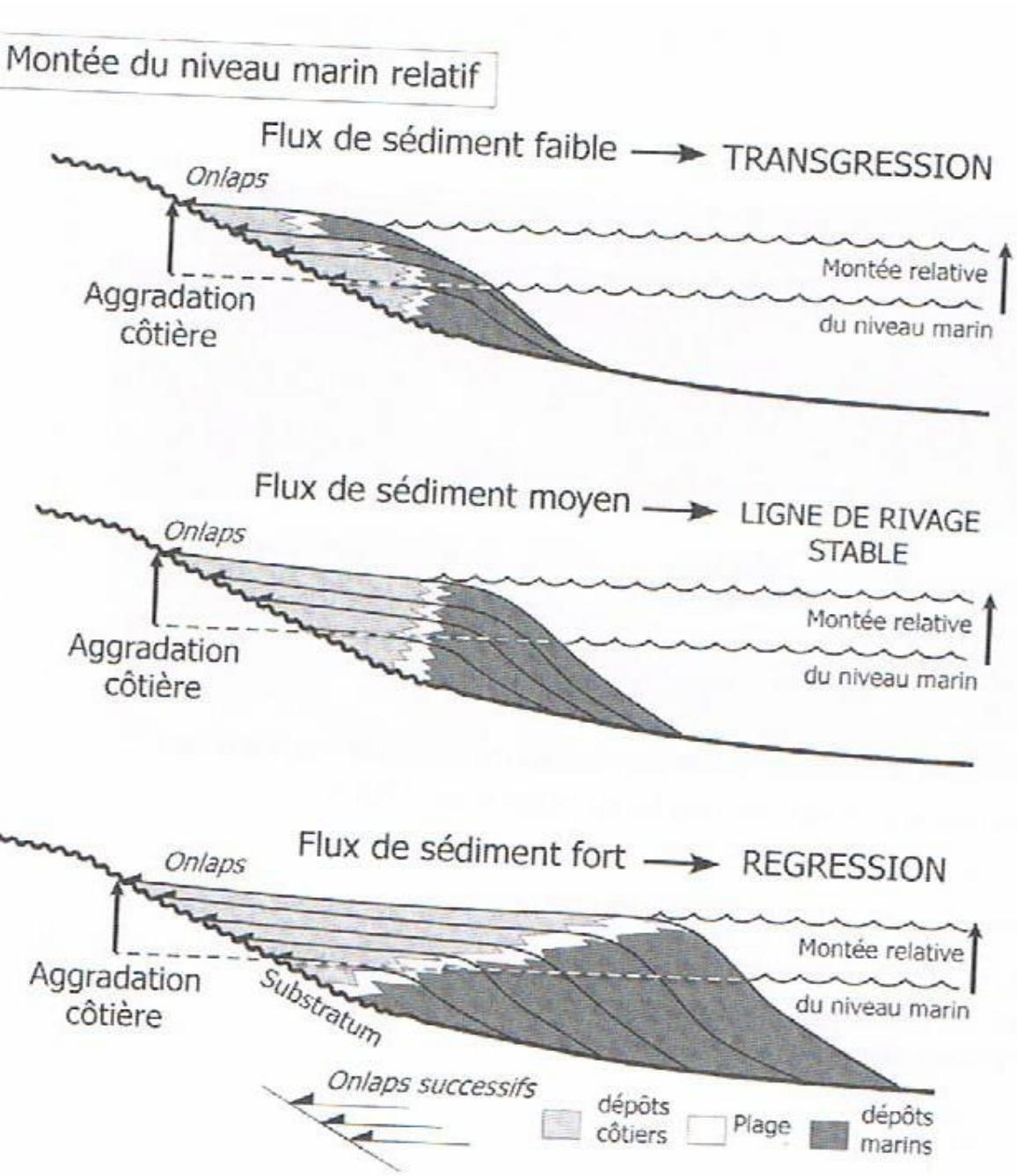


Figure 2.11. Effet de la montée du niveau marin relatif sur l'aggradation côtière et relation avec les transgressions/ régressions.

L'aggradation côtière, marquée par la superposition des *onlaps*, est la seule à pouvoir être reliée directement au niveau marin relatif, indépendamment des transgressions/régressions. Ces dernières dépendent en fait de l'interaction entre le flux sédimentaire et le niveau marin relatif. Si le flux sédimentaire est plus lent que la montée du niveau marin, la tranche d'eau augmente plus vite que les sédiments ne se déposent : il y a transgression. Si le flux de sédiments équivaut à la vitesse de montée du niveau marin, il y a équilibre et la ligne de rivage se stabilise. Si, enfin, les sédiments comblent la tranche d'eau plus vite que la montée du niveau marin, il y a régression. Dans tous les cas, on observera une aggradation côtière et une superposition d'onlaps qui caractérisent la montée du niveau marin (d'après Vail *et al.*, 1977, modifié).

Reconstruction of sea level curve :
tracking the aggradation of the coastline by picking successive onlaps

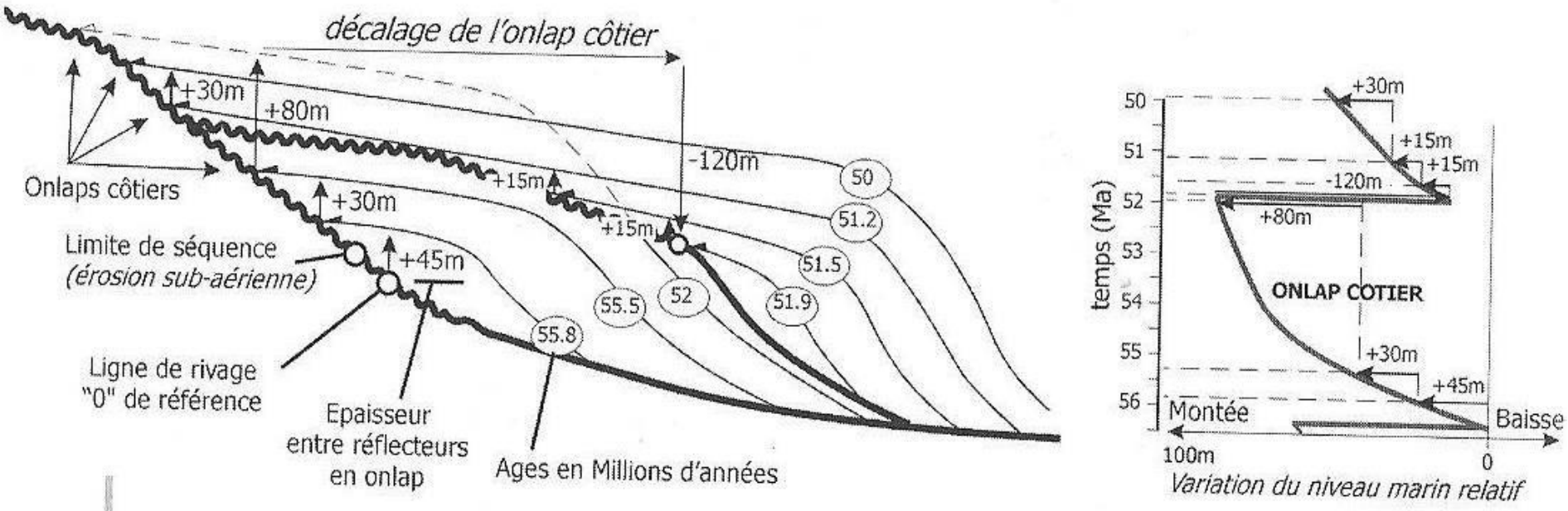


Figure 2.13.

Méthode de construction de la courbe d'aggradation côtière permettant de représenter les variations du niveau marin relatif, d'après l'étude des onlaps côtiers observés sur des séquences de dépôts en sismique. Le schéma de gauche représente un dessin des réflecteurs sismiques au niveau d'une succession incomplète de séquences de dépôts. Le diagramme de droite est la courbe d'aggradation côtière traduite en termes de variations du niveau marin relatif.

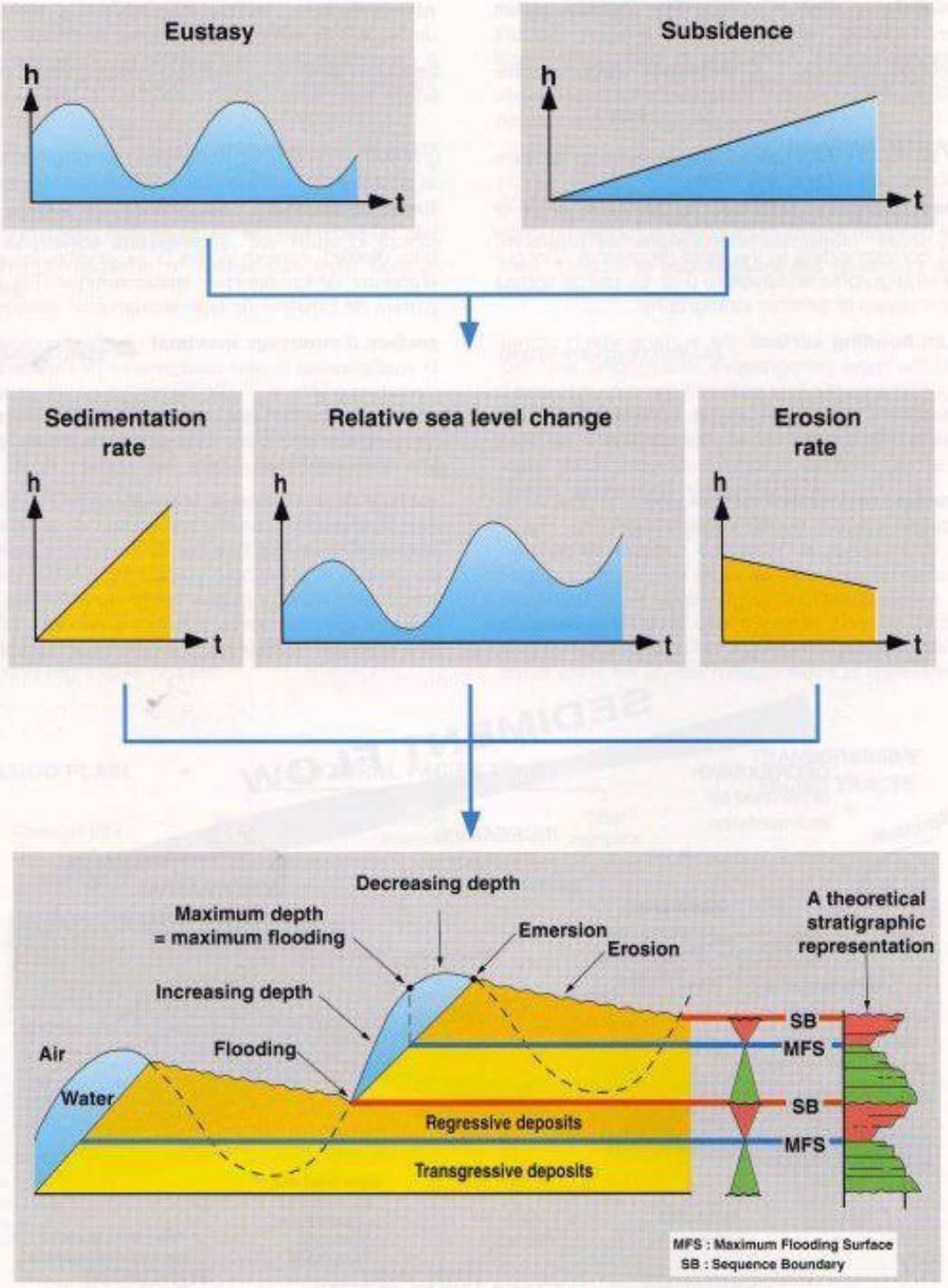
How to build a model of sedimentary evolution of margins integrating sea level variations?

Model input:

Regional geology

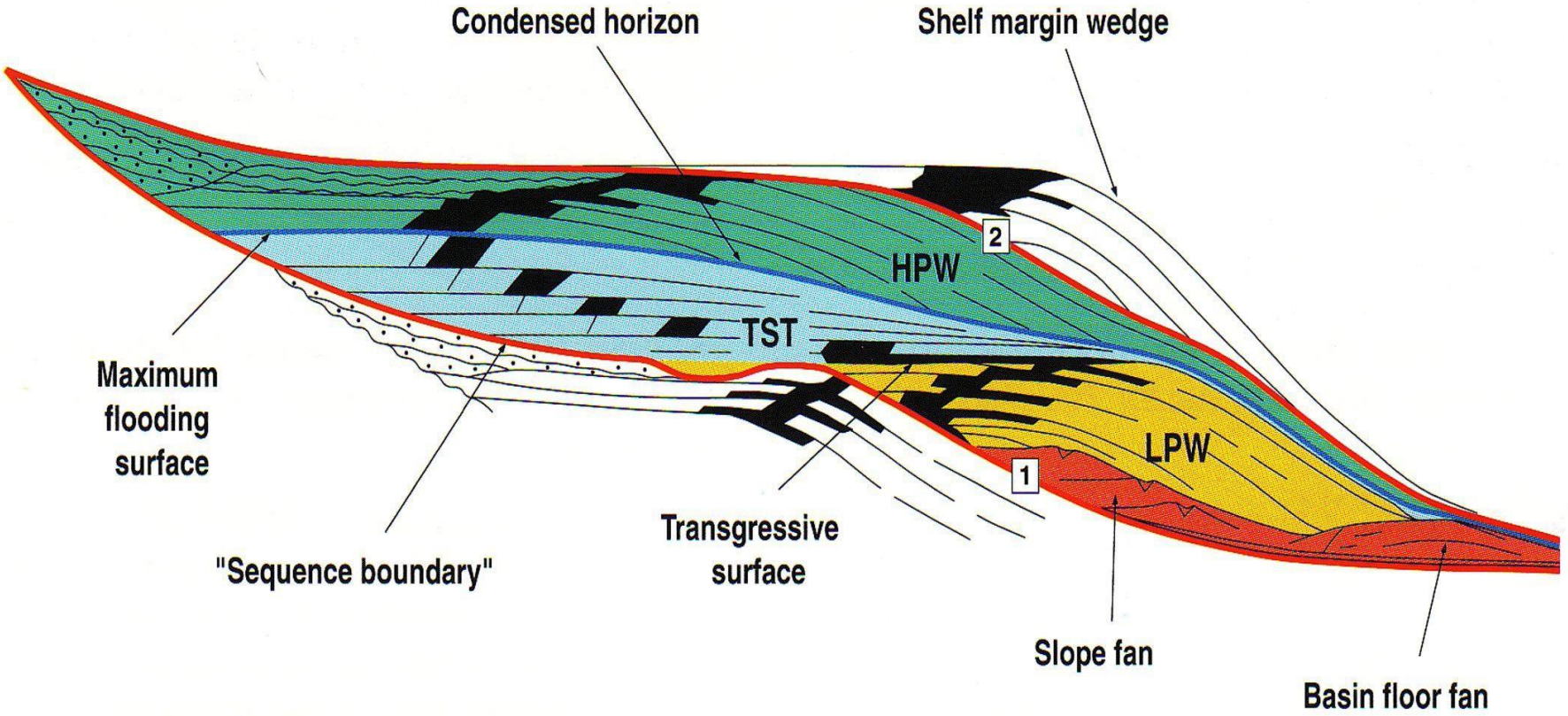
Eustatism, subsidence, sediment supply

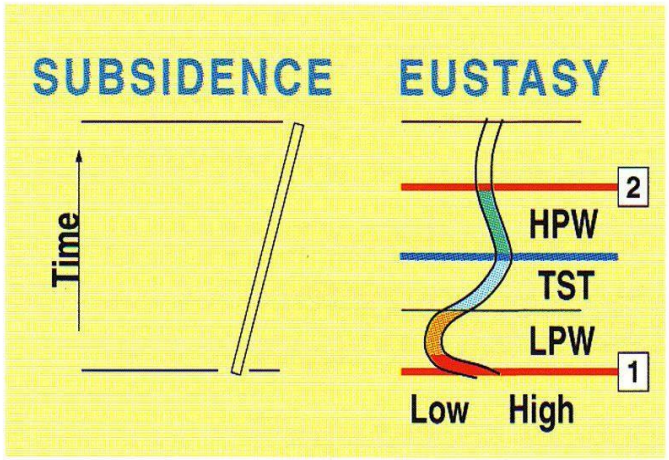
Cyclicity of sea level variations



Homewood 1999

VAIL'S MODEL-SEQUENCE STRATIGRAPHY (detritic environments)

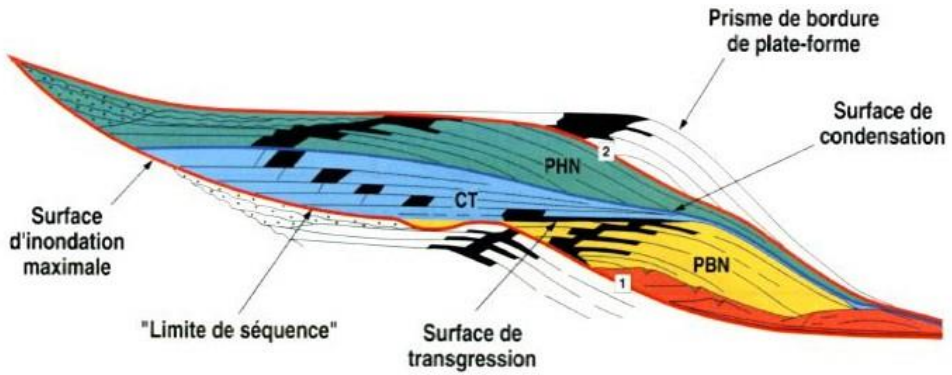


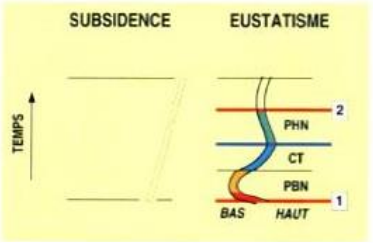


HPW : Highstand Prograding Wedge
TST : Transgressive Systems Tract
LPW : Lowstand Prograding Wedge

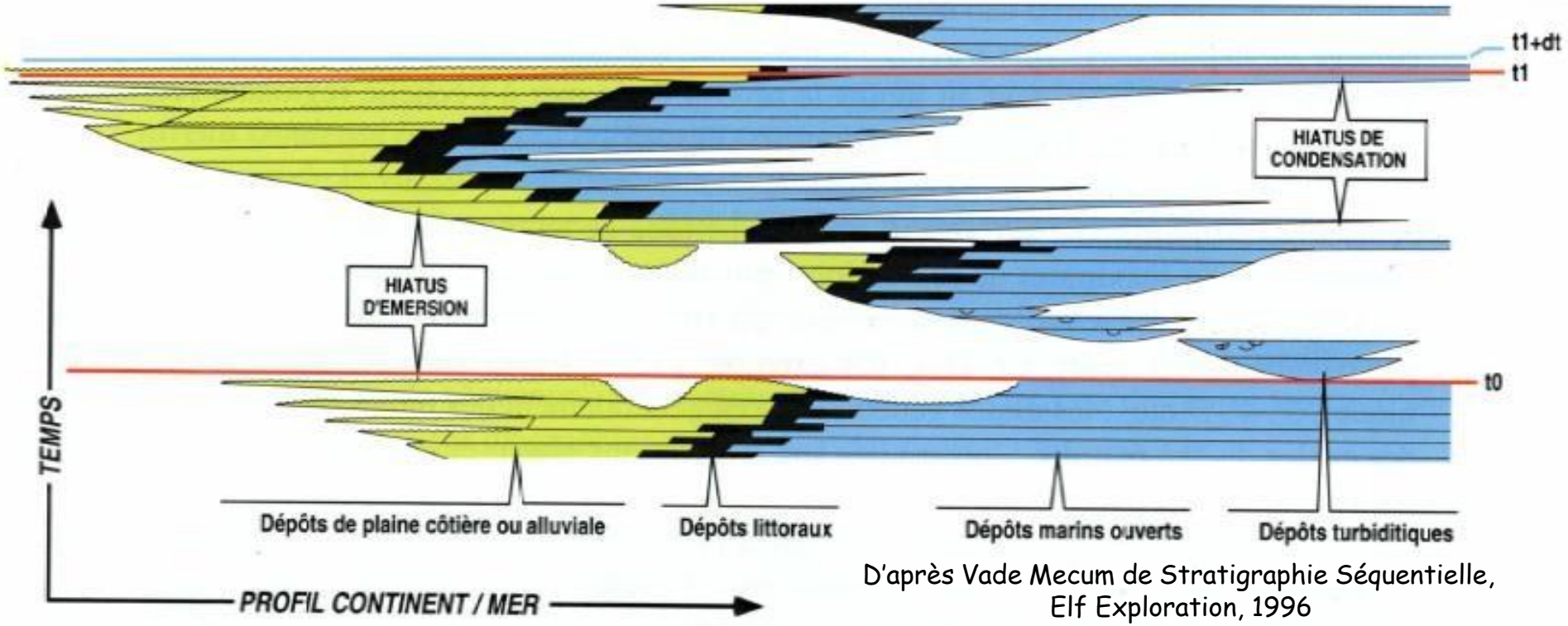
The model is more a guideline for interpretation that something you can observe in nature

How time is recorded in the model?
Back to Wheeler diagram…

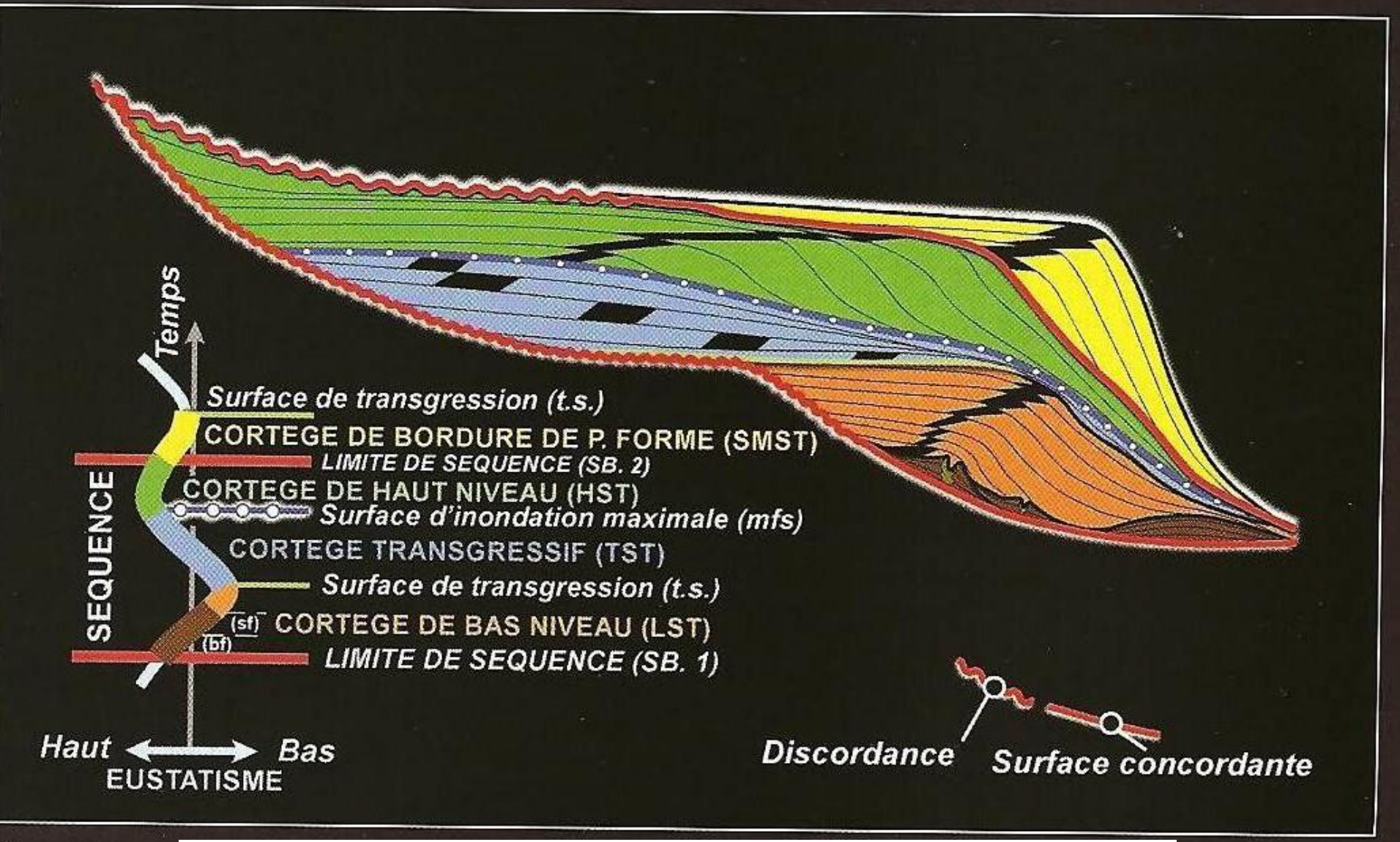




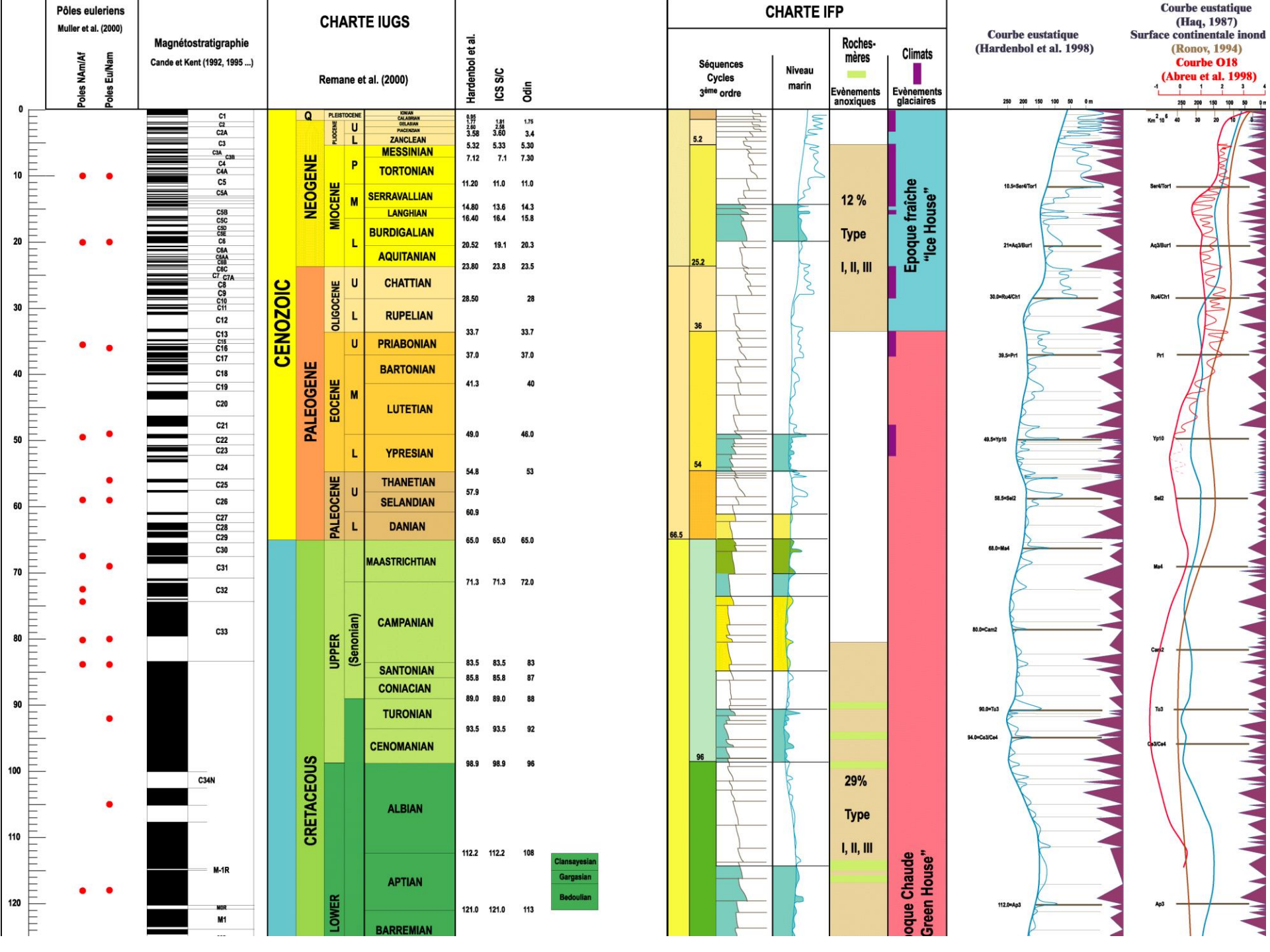
PBN : Prisme de Bas Niveau
CT : Cortège Transgressif
PHN : Prisme de Haut Niveau



D'après Vade Mecum de Stratigraphie Séquentielle, Elf Exploration, 1996



The model has been challenged and improved since the 70's… see Catuneanu et al 2009 and others…


Pôles euleriens
Muller et al. (2000)
Poles NAm/Af
Poles Eu/Nam
Magnétostratigraphie
Cande et Kent (1992, 1995 ...)
CHARTE IUGS
Remane et al. (2000)
Hardenbol et al.
ICS S/C
Odin
CHARTE IFP
Séquences Cycles 3ème ordre
Niveau marin
Roches-mères
Evènements anoxiques
Climats
Evènements glaciaires
Courbe eustatique (Hardenbol et al. 1998)
Courbe eustatique (Haq, 1987)
Surface continentale inond (Ronov, 1994)
Courbe O18 (Abreu et al. 1998)
CENOZOIC
PALEOGENE
NEOGENE
CRETACEOUS
Q
PLEISTOCENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
UPPER
(Senonian)
LOWER
IONIAN
CALABRIAN
GELASIAN
PIACENZIAN
ZANCLEAN
MESSINIAN
TORTONIAN
SERRAVALLIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
CHATTIAN
RUPELIAN
PRIABONIAN
BARTONIAN
LUTETIAN
YPRESIAN
THANETIAN
SELANDIAN
DANIAN
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
Clansayesian
Gargasian
Bedoulian
12 %
Type
I, II, III
29%
Type
I, II, III
Epoque fraîche "Ice House"
Epoque Chaude "Green House"
C34N
M-1R
M1

Tracking past sea level variations, at the geological time scale

Oblique stratifications + unconformity
Ypresian sandstones; Noirmoutiers, Vendée

MAIN QUESTIONS

- How sea level variations are recorded in sediments?
- What is the time resolution of the record?
- How do we reconstruct past sea level curves from the sedimentary record?
- What do we learn from the sedimentary record in terms of past sea level variations?

OUTLINE

- The significance of the sedimentary record of sea level variations : an historical approach
- Tracking sea level variations at the 10^4-10^5 yrs time scale (genetic stratigraphy)
- Tracking sea level variations at the 10^6 time scale (sequence stratigraphy)
- **Which processes control sea level variations at the geological time scale? A synthesis**

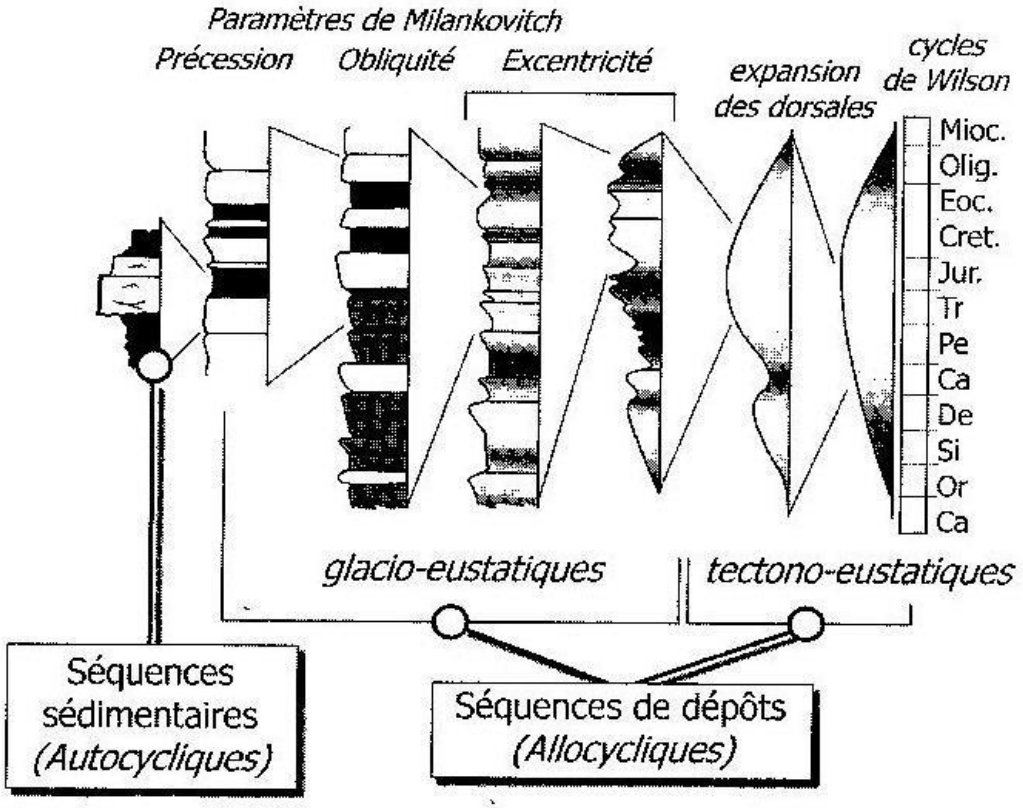
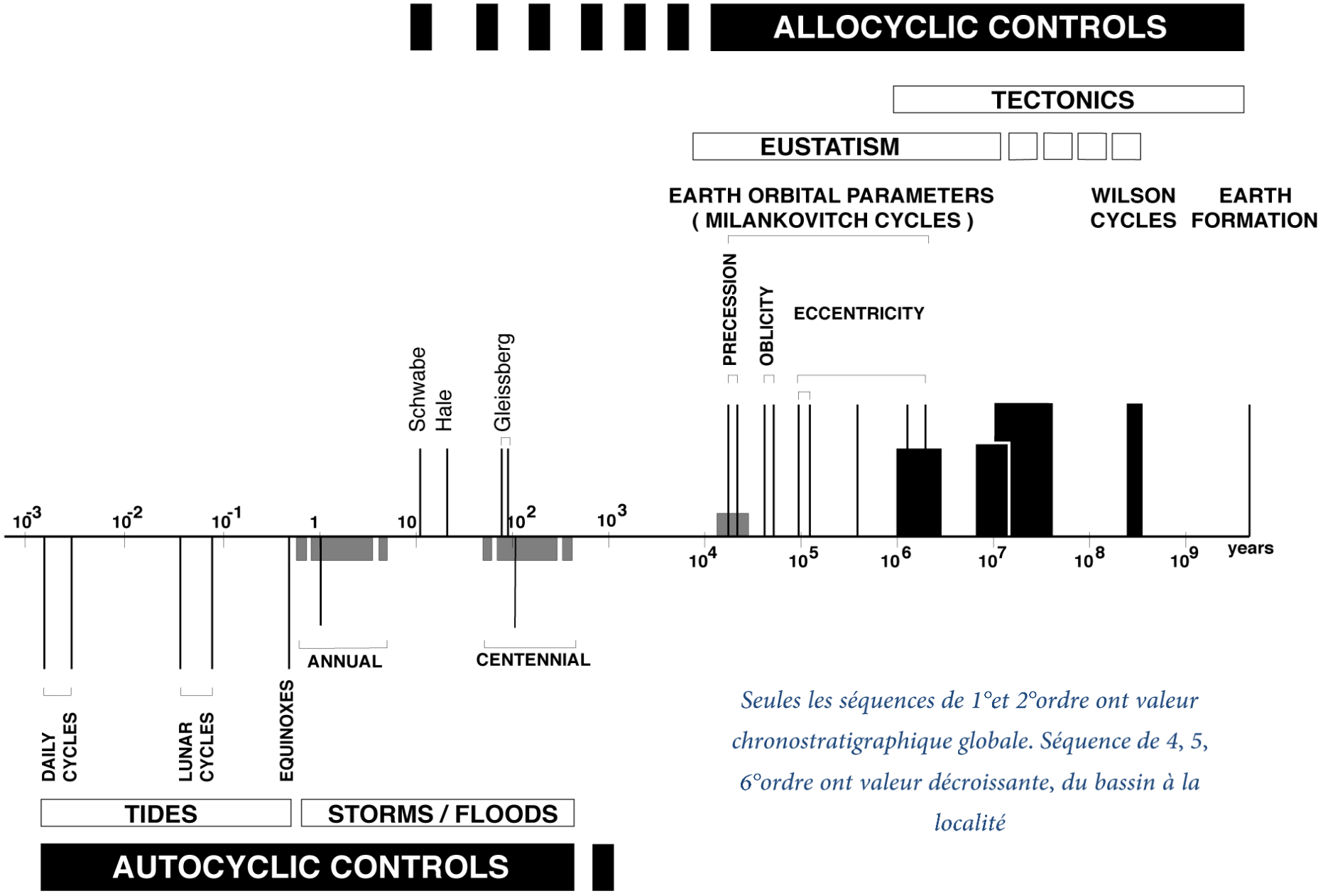


Figure 1.28. Les différents types de séquences emboîtées et leurs causes (d'après Einsele *et al.* 1991, modifié).

La stratigraphie séquentielle va s'intéresser à ces séquences allocycliques que l'on retrouve à l'échelle des bassins sédimentaires. Elles sont regroupées en deux familles suivant leur durée et leur origine ; celles de plus courte durée (< 1 Ma) sont attribuées au glacio-eustatisme et celles de plus longue durée (> 1 Ma) au tectono-eustatisme (figure 1.28).

Merzeraud, 2009



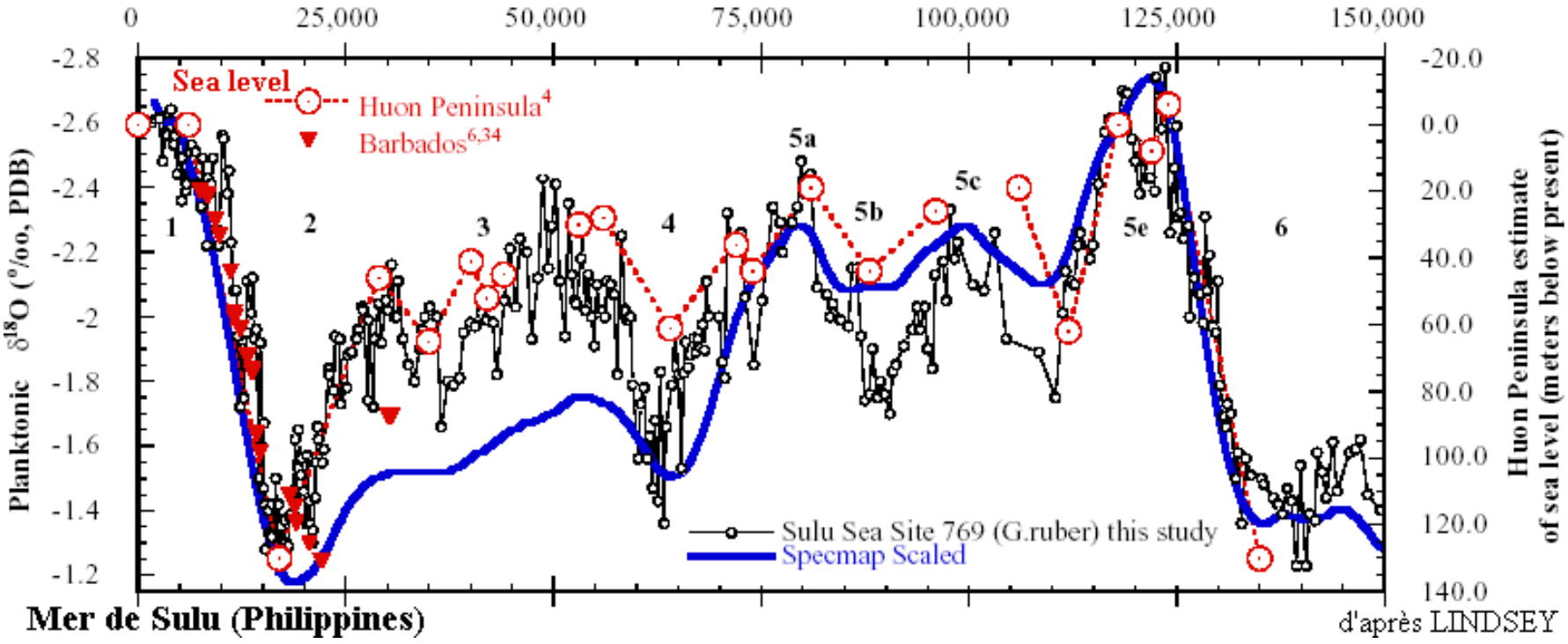
Seules les séquences de 1°et 2°ordre ont valeur chronostratigraphique globale. Séquence de 4, 5, 6°ordre ont valeur décroissante, du bassin à la localité

Not really captured at the time scale of the sequence stratigraphy…

(Guillocheau, 1995)

Sea level variations during the Quaternary

Role of ice sheets



Variations according to the record and its location…but the general trend is well identified

Only a few Ice periods during Earth history…

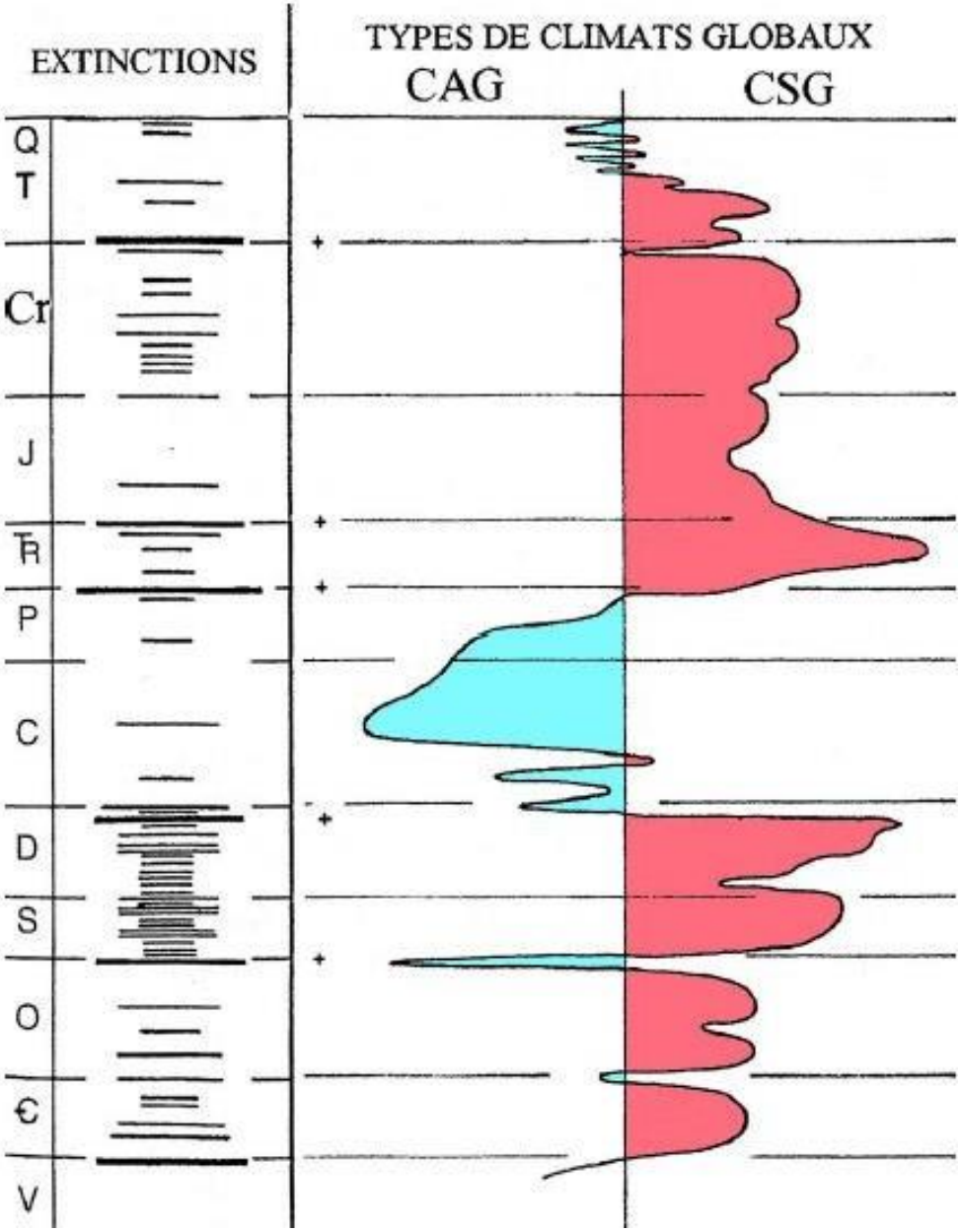
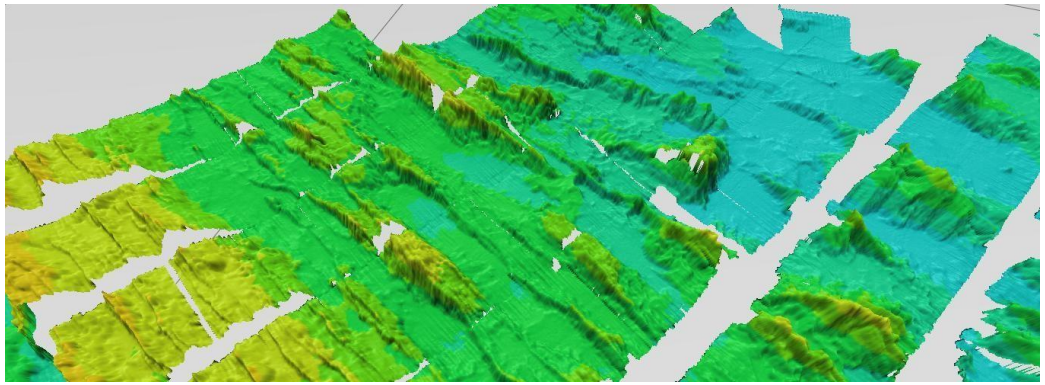


Figure 6 : Variation du climat global au cours du Phanérozoïque et périodes d'extinction. Les + : les 5 crises biologiques majeures. CSG : climat global sans glaciation, CAG : climat global avec glaciation. Plus la courbe pointe vers la gauche plus les calottes glaciaires sont étendues et plus le gradient thermique latitudinal est élevé. Plus une extinction est sévère et plus le trait est long. Ceux correspondant aux cinq crises majeures sont en gras (d'après Lethiers, 2004).

How to explain sea level rise during green house periods?

Cenomanian sea level rise + ~200m

Origin of 1st and 2nd order sequence?



Modelisation of the volume of mid oceanic ridges

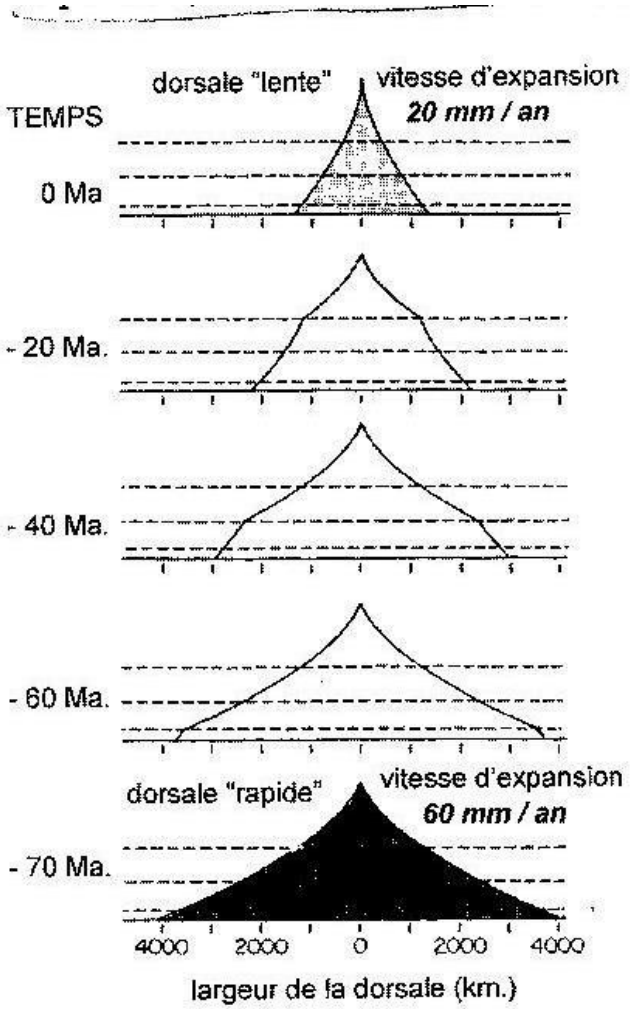


Figure 1.13. Modélisation de la variation de volume d'une dorsale océanique (Pitman, 1978).

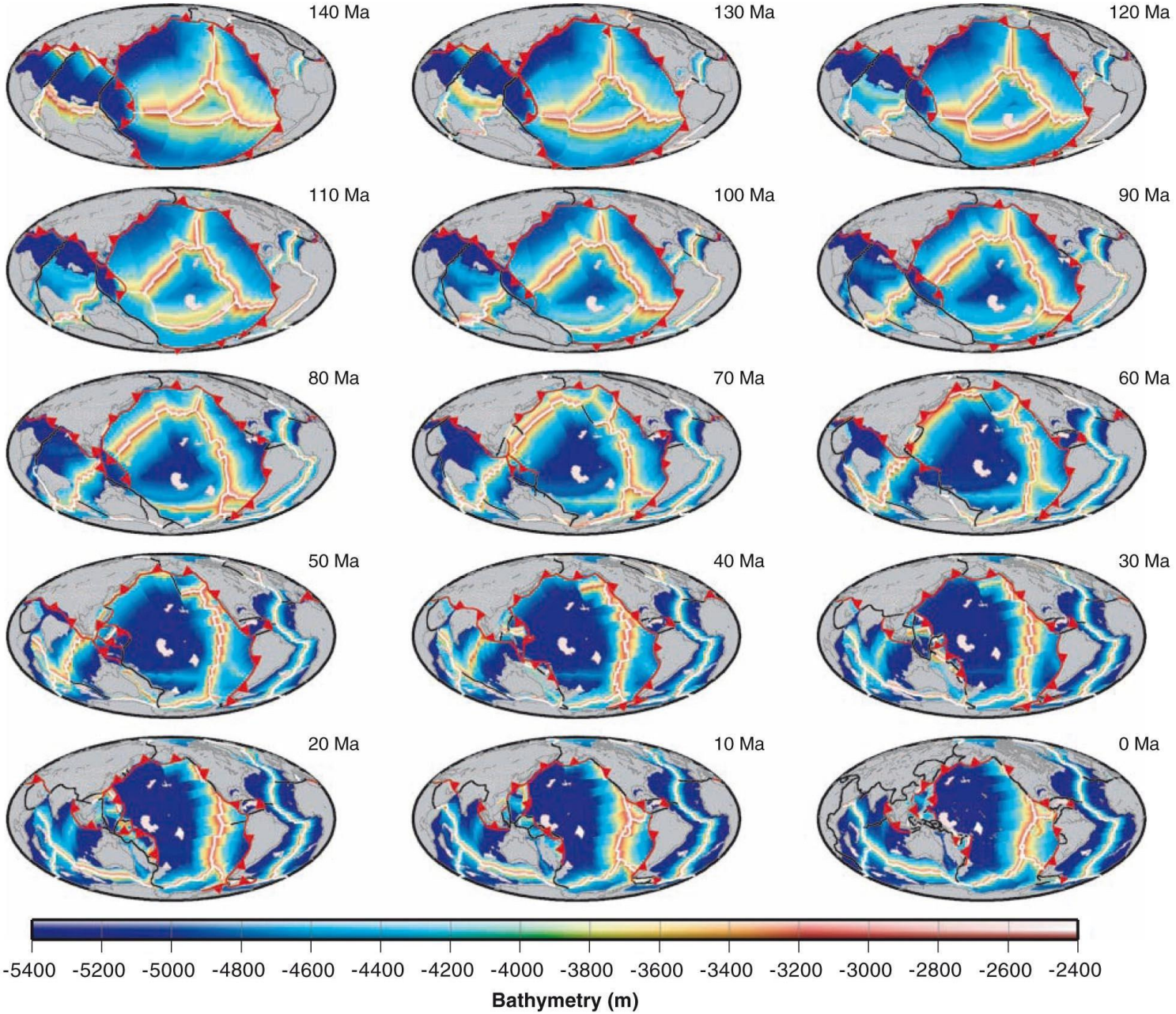


Fig. 3. Reconstructed bathymetry through time by combining basement depths derived from paleo-age grids (Fig. 1 and fig. S1) and the GDH-1 age-depth model (*26*) with estimates of sediment thickness through time (figs. S4 and S5) and inclusion of all major oceanic plateaus (table S1).

Estimation of the volume of oceanic basins… Need of precise paleogeographic + paleoclimatic reconstructions

Numerous uncertainties

and models…

+Thermic expansion of oceans…

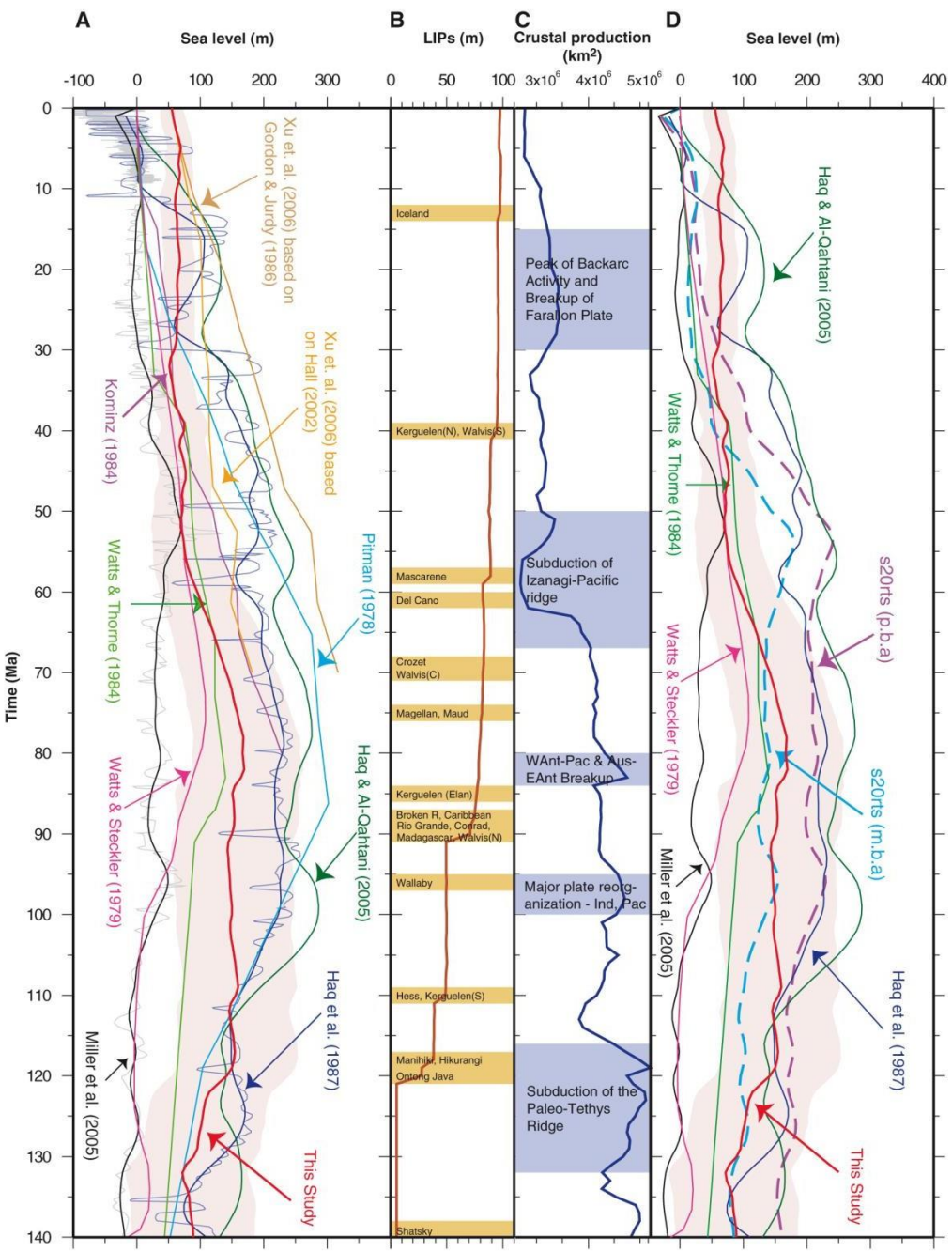


Fig. 4. (**A**) Predicted relative sea-level change (red) and error envelope (reflecting basement age-depth errors) (light pink) since 140 Ma based on changes in the average depth and area of the ocean basins using the GDH-1 plate model (*26*) age-depth conversion (Database S1) compared with the sea-level curves by Kominz (*7*) (magenta), Haq *et al.* (*9*) (dark blue), adjusted to the Berggren *et al.* time scale (*2*), Haq and Al-Qahtani (*43*) (dark green), Miller *et al.* (*2*) (black), Watts and Steckler (*11*) (pink), Watts and Thorne (*12*) (light green), Pitman (*5*) (light blue), and the two curves by Xu *et al.* (*8*) (light and dark orange). The Haq *et al.* (*9*), Haq and Al-Qahtani (*43*), and Miller *et al.* (*2*) curves have been smoothed by a 10-My cosine-arch low-pass filter (in bold), representing long-term sea-level change. The original curves from Haq *et al.* (*9*) and from Miller *et al.* (*2*) are shown as thin lines. (**B**) Sea-level effect of large igneous provinces (LIPs) (100 m cumulatively). (**C**) Total crustal production through time since 140 Ma with major tectonic events highlighted in blue. (**D**) Miller *et al.* (*2*) sea-level curve, uncorrected (black) and corrected for post–70 Ma modeled tectonic subsidence of the New Jersey margin based on the *s20rts* seismic tomography model (*39*) for the pure backward advection (p.b.a) (purple) and modified backward advection (m.b.a) (light blue) compared with long-term sea-level variation from our computation of the volume of the ocean basins through time (red), as well as with the models by Haq and co-workers (*9*, *43*) and Watts and co-workers (*11*, *12*).