

# Introdução à Estratigrafia de Sequências: o modelo da Exxon

## **Estilos de preenchimento de bacias sedimentares**

- Controles na arquitetura de posicional de grande escala:

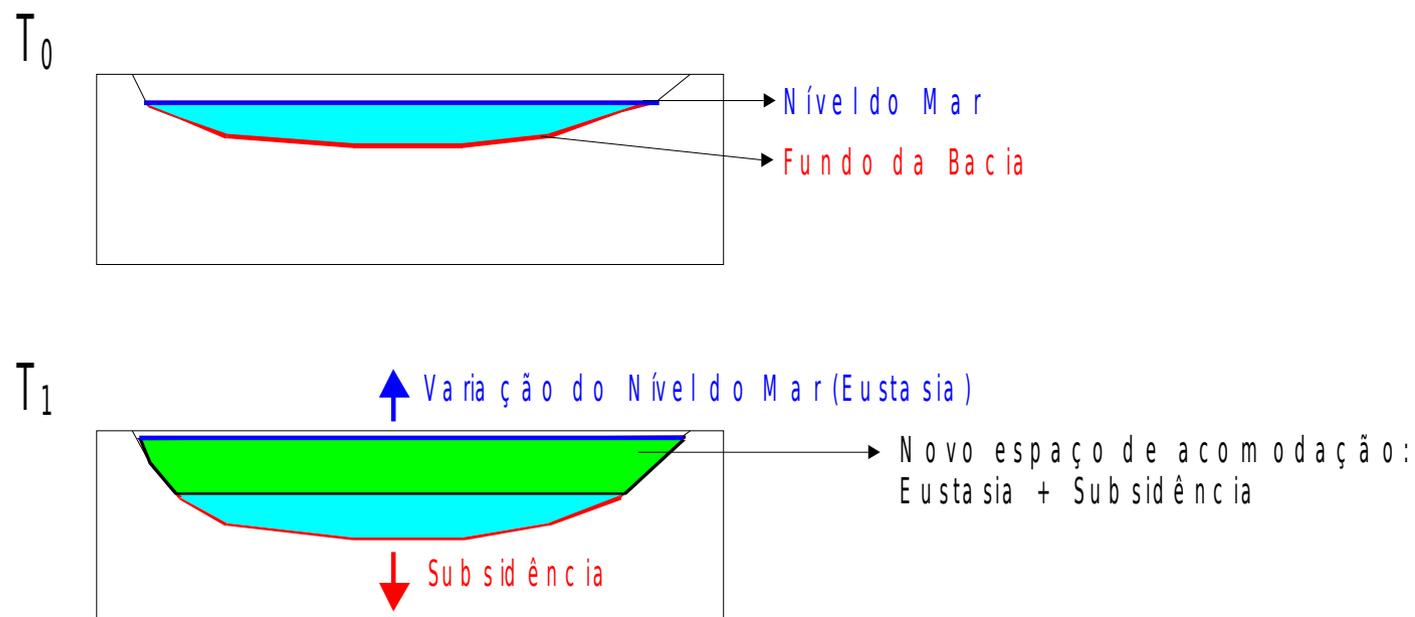
- Aporte sedimentar

- Espaço de acomodação

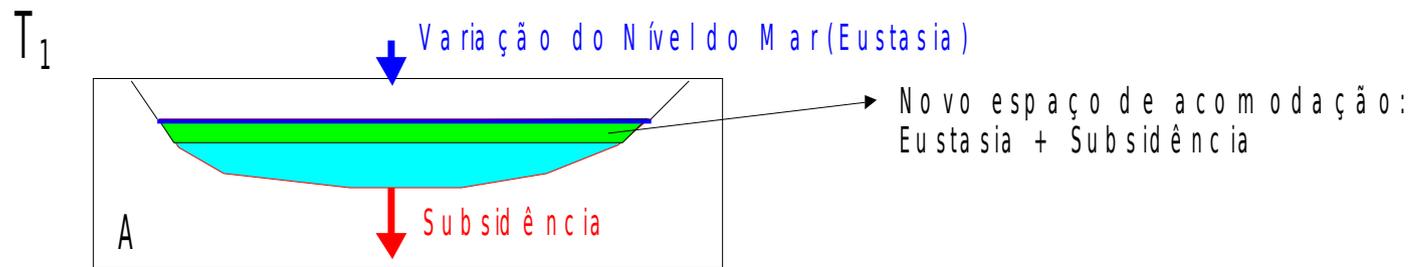
Subsidência

Eustasia

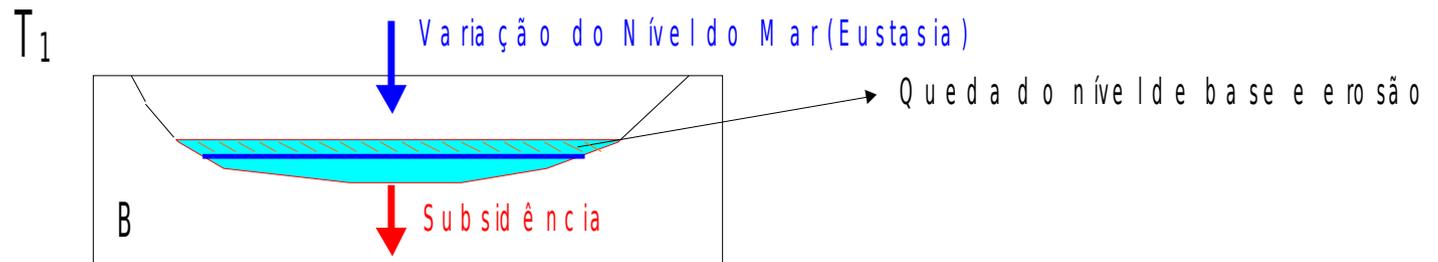
## Espaço de acomodação



Mesmo uma queda do nível do mar não implica em erosão se a taxa de subsidência for maior que a taxa de queda eustática.

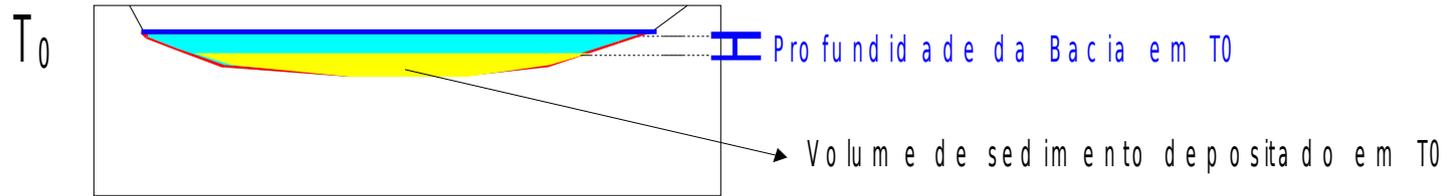


Apenas os eventos de rápida queda eustática resultam em erosão da bacia.

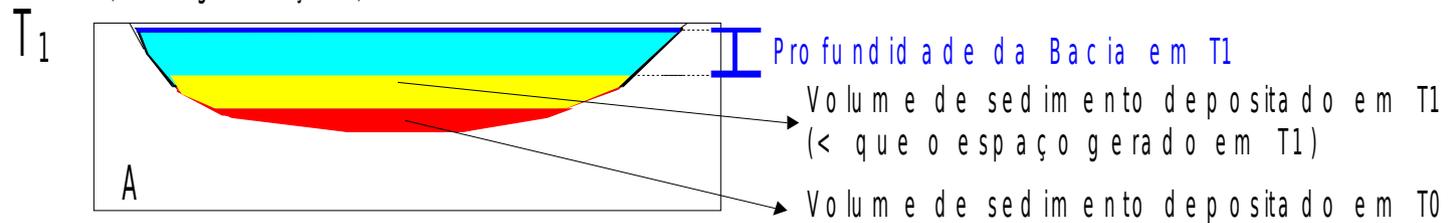


## Aporte X Espaço de acomodação

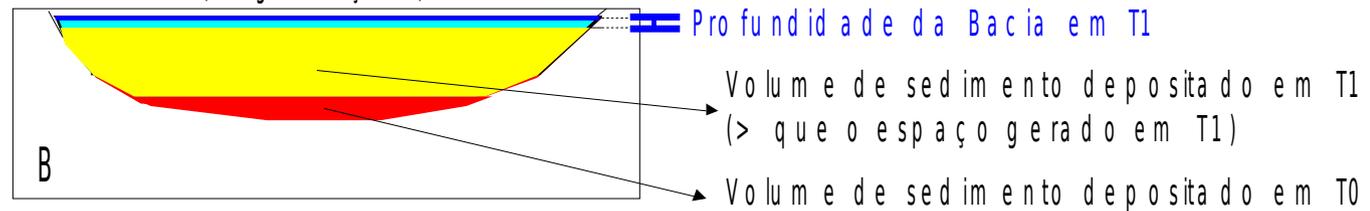
A profundidade da bacia (espessura da lâmina d'água) controla os sistemas deposicionais e é determinada pelo espaço entre o preenchimento sedimentar e o nível do mar.



Se o volume de sedimento que chega à bacia por intervalo de tempo for menor que o espaço de acomodação gerado, a bacia fica mais profunda (Retrogradação).



Se o volume de sedimento for maior que o espaço gerado, a bacia fica mais rasa (Progradação).



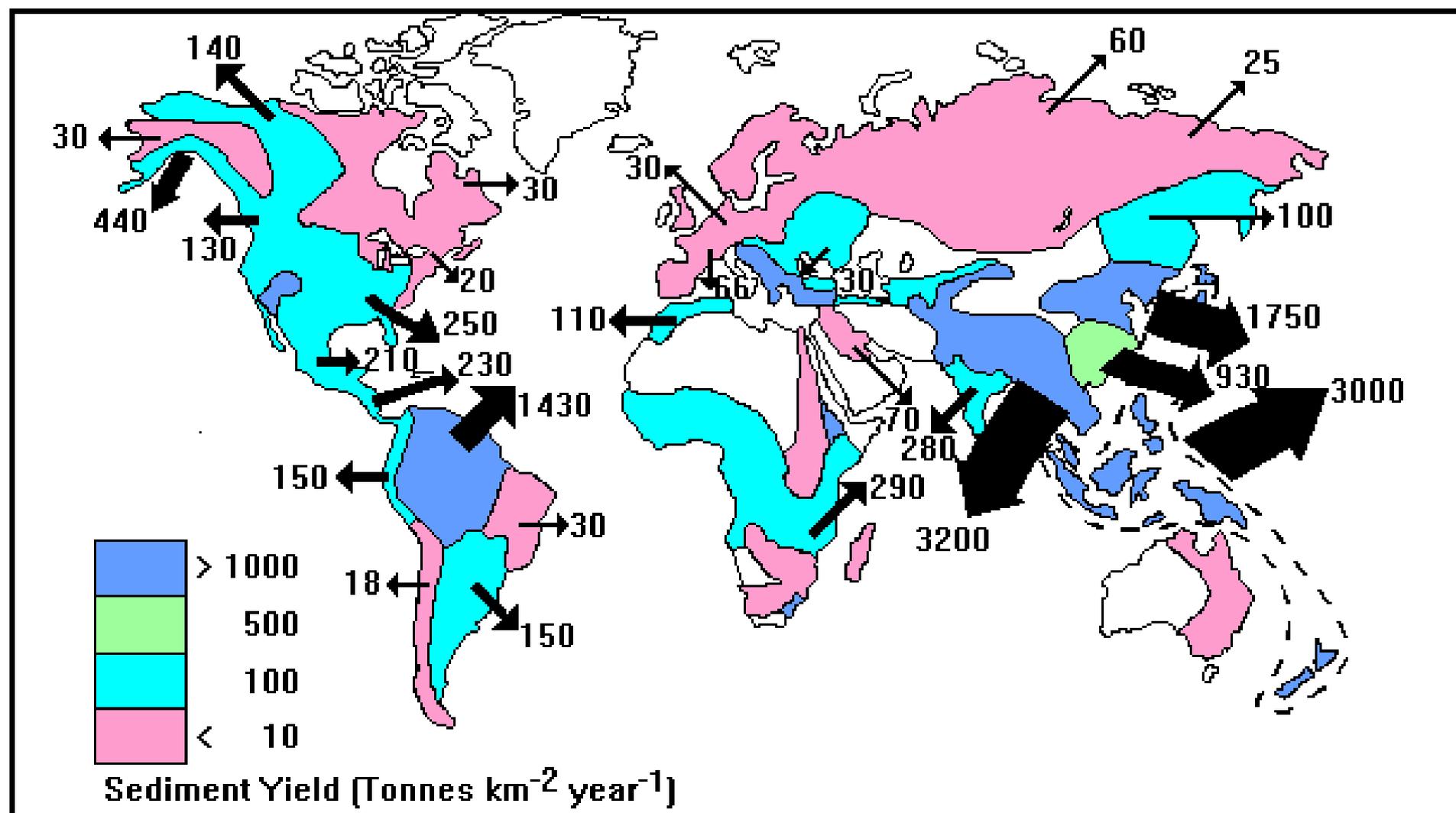
## Aporte X Espaço de acomodação

- O conceito de nível de base
- Transgressão – regressão X mar alto - mar baixo
- Espaço de acomodação: variações do nível de base + taxa de subsidência.
- Relações entre TAXAS e não entre picos.
- Padrões de empilhamento em função do equilíbrio entre aporte sedimentar e espaço de acomodação.

### **Fatores que controlam o aporte sedimentar:**

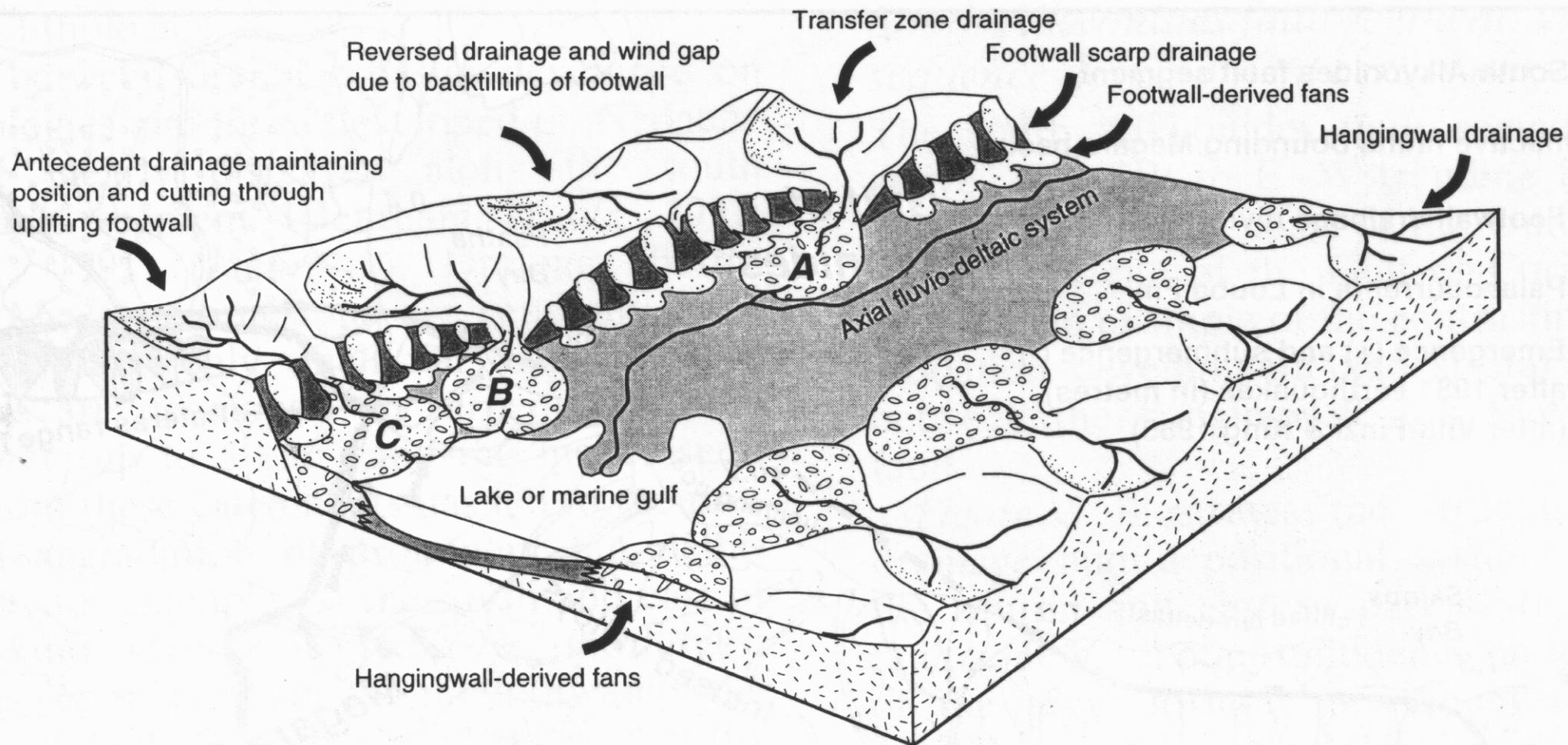
- Regime hidrológico e alteração de áreas-fonte – clima global e local.
- Tectônica local – elevação de áreas-fonte
- Feições geográficas locais – geometria e área da bacia, topografia dos limites – área de drenagem.
- Elevação média dos continentes.

## Produção sedimentar – distribuição global



**Figure 5** Global pattern of sediment yield, with river output of sediment to the oceans (tonnes  $\times 10^6$ ) (Ref. 6). (Reproduced by permission)

## Fatores fisiográficos locais



## Fatores que controlam a Eustasia

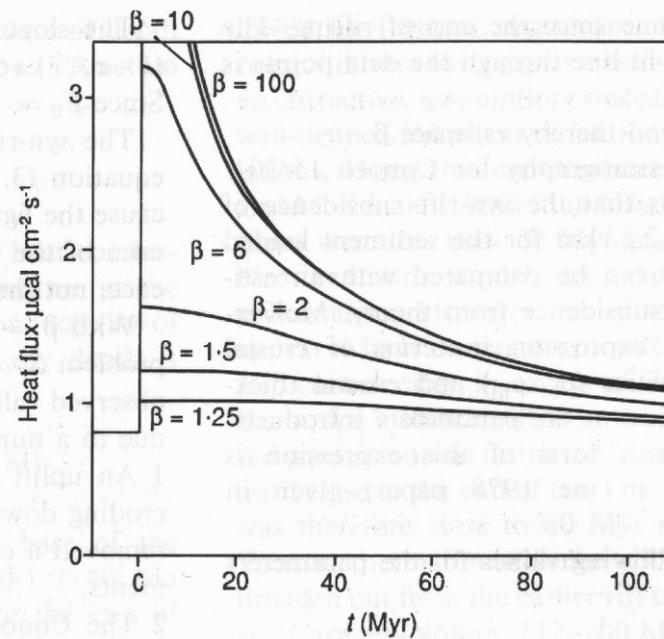
**Table 9.1.** Rates and magnitudes of processes affecting sea-level

Process	Region affected	Type of result	Rate (m/ka)	Duration (m.y.)	Total possible change (m)
<b>Eustatic process</b>					
Age distribution of earth's oceanic crust	Global	Eustasy	0.001	100+	100
Sea-floor ridge volume changes	Global	Eustasy	0.002-0.01	50-100	300
Density changes associated with intraplate stress	Global	Eustasy	1	0.05	50
Continental ice formation	Global	Eustatic fall	1.5	0.1	150
Continental ice melting	Global	Eustatic rise	4-10	0.02-0.04	80-400
Marine ice-sheet decoupling	Global	Eustatic rise	30-50	0.002	6-10

## Subsidência

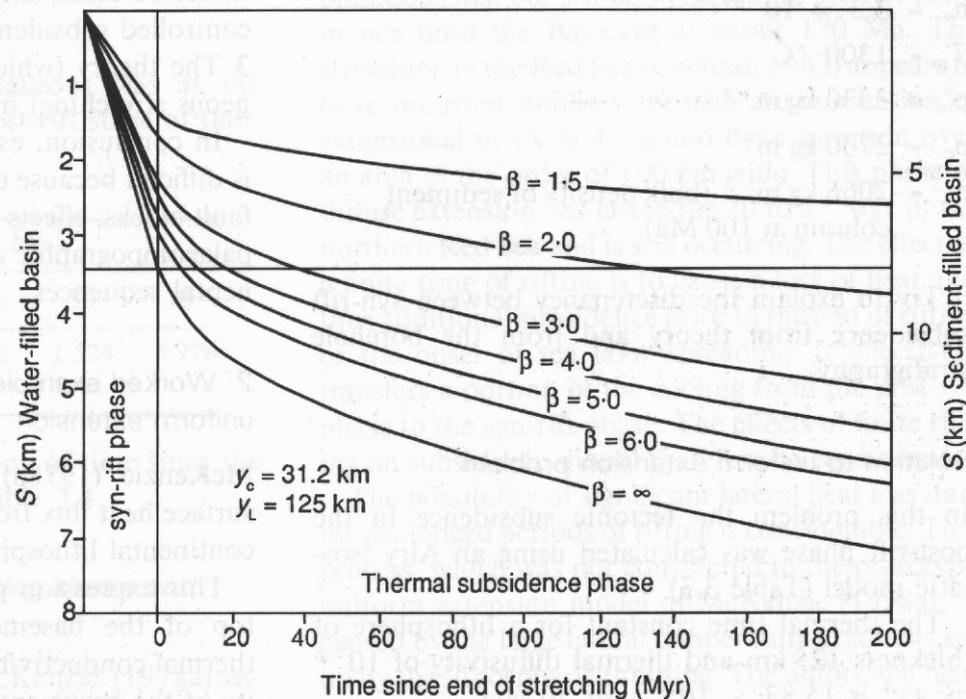
### **Bacias de subsidência térmica**

- Taxa de subsidência declinante
- Grande influência relativa da eustasia
- Controle de clima e elevação de áreas-fonte regionais.
- Geometria em plataforma – talude – sopé: Cliniformas.



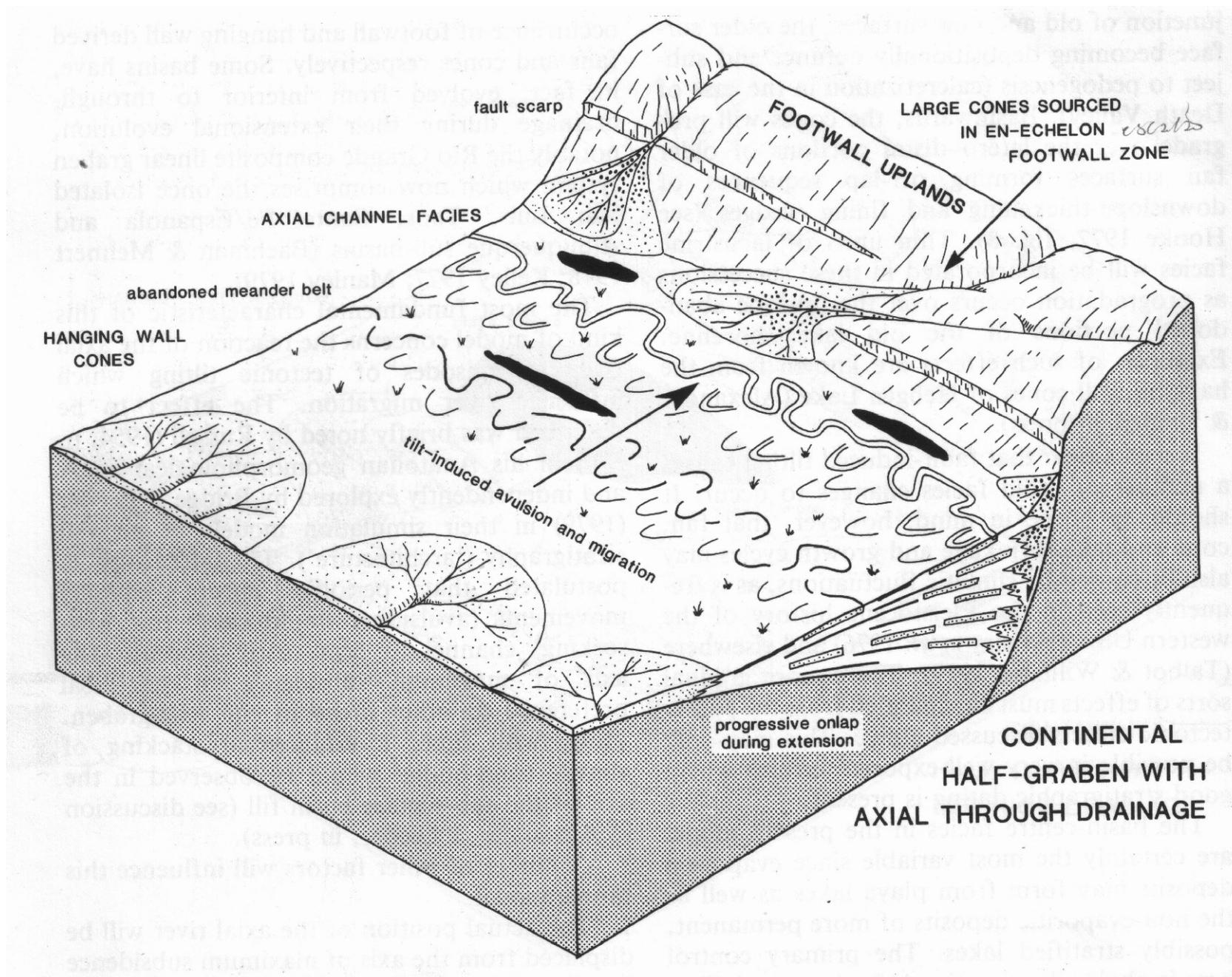
**Fig. 3.12a.** Heat flux as a function of time for various values of the stretch factor  $\beta$ , obtained using an equation of the form given in equation (3.17). The magnitude of the stretching-related heat flux is dependent on the stretch factor, but at long periods after the cessation of stretching, the heat fluxes are very similar irrespective of the initial amount of stretching (after McKenzie 1978a, p. 28).

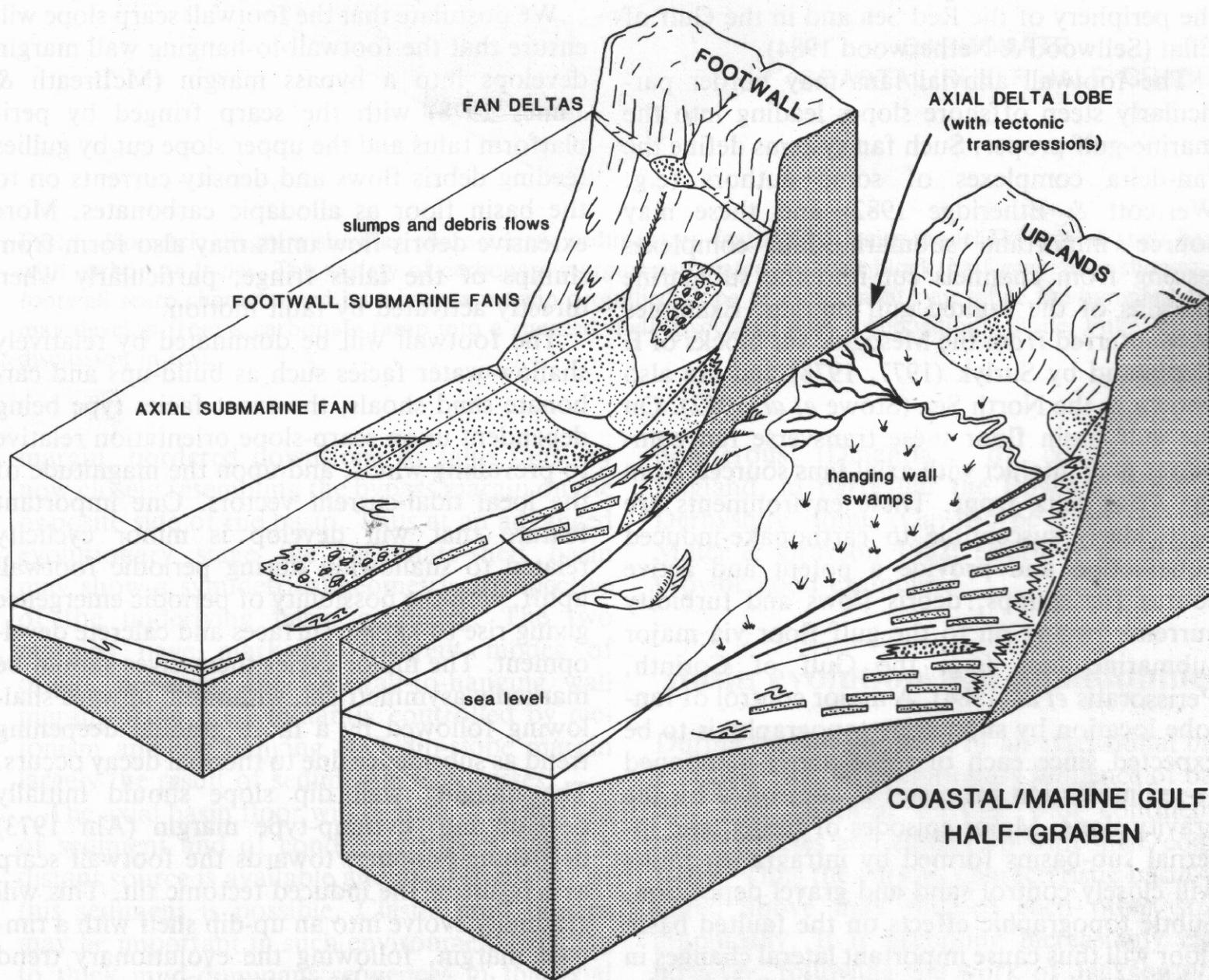
**Fig. 3.12b.** The elevation change (subsidence) resulting from the heat flux patterns in Fig. 3.12a, for various values of the stretch factor, obtained from equation (3.18). The rate of thermal subsidence decreases exponentially with time. The curves shown refer to a lithosphere with an initial thickness of 125 km and an initial crustal thickness of 31.2 km (following Slater, Jaupart and Gelson 1980). After Dewey (1982, p. 387).



## **Bacias de subsidência mecânica**

- Alta taxa de subsidência
- Menor influência relativa da eustasia
- Controle tectônico na distribuição da granulção





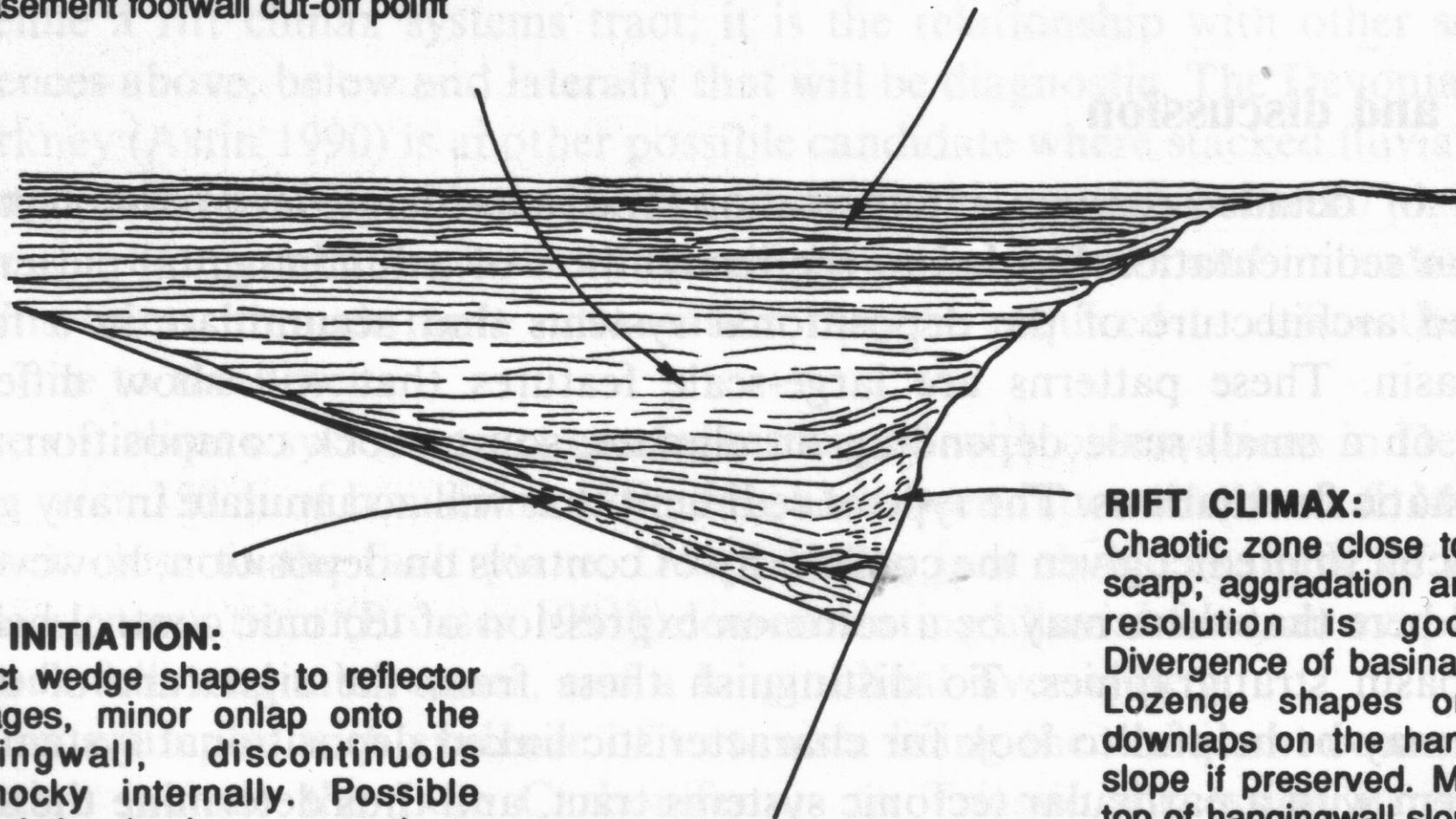


**IMMEDIATE POST-RIFT:**

Discontinuous parallel reflectors, with possible progradational and aggradational reflectors close to the footwall. Compaction syncline over the basement footwall cut-off point

**LATE POST-RIFT:**

Continuous parallel reflectors, less compaction induced deformation. Strong onlap and burial

**RIFT INITIATION:**

Perfect wedge shapes to reflector packages, minor onlap onto the hangingwall, discontinuous hummocky internally. Possible progradation (real or apparent), no evidence of important footwall derived sediments.

**RIFT CLIMAX:**

Chaotic zone close to the footwall scarp; aggradation and downlap if resolution is good enough. Divergence of basinal equivalents. Lozenge shapes or low angle downlaps on the hangingwall dip-slope if preserved. Minor onlap at top of hangingwall slope.

## **Bacias de subsidência flexural**

- Picos com alta taxa de subsidência
- Interação eustasia subsidência
- Controle tectônico na distribuição da granulção

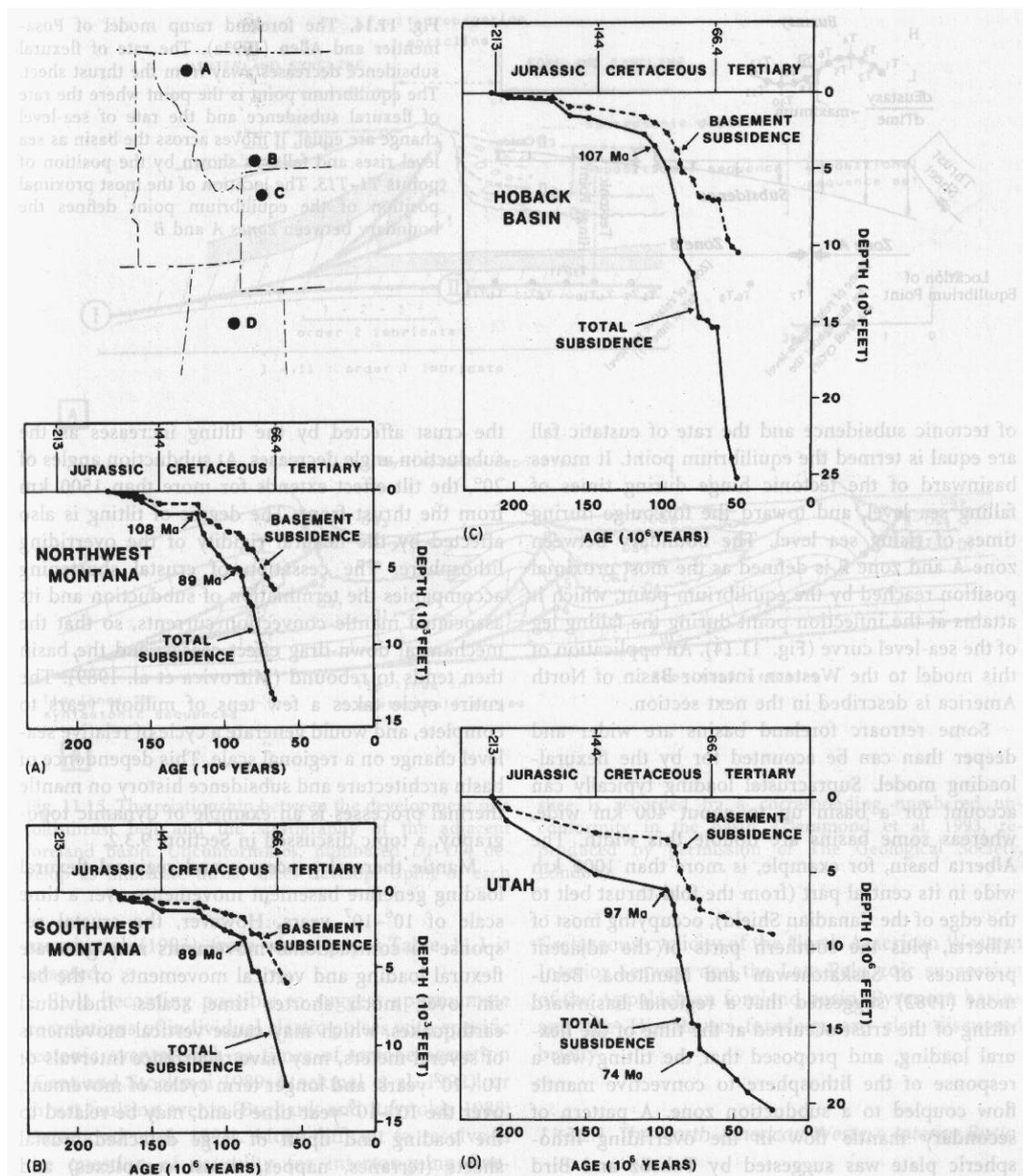
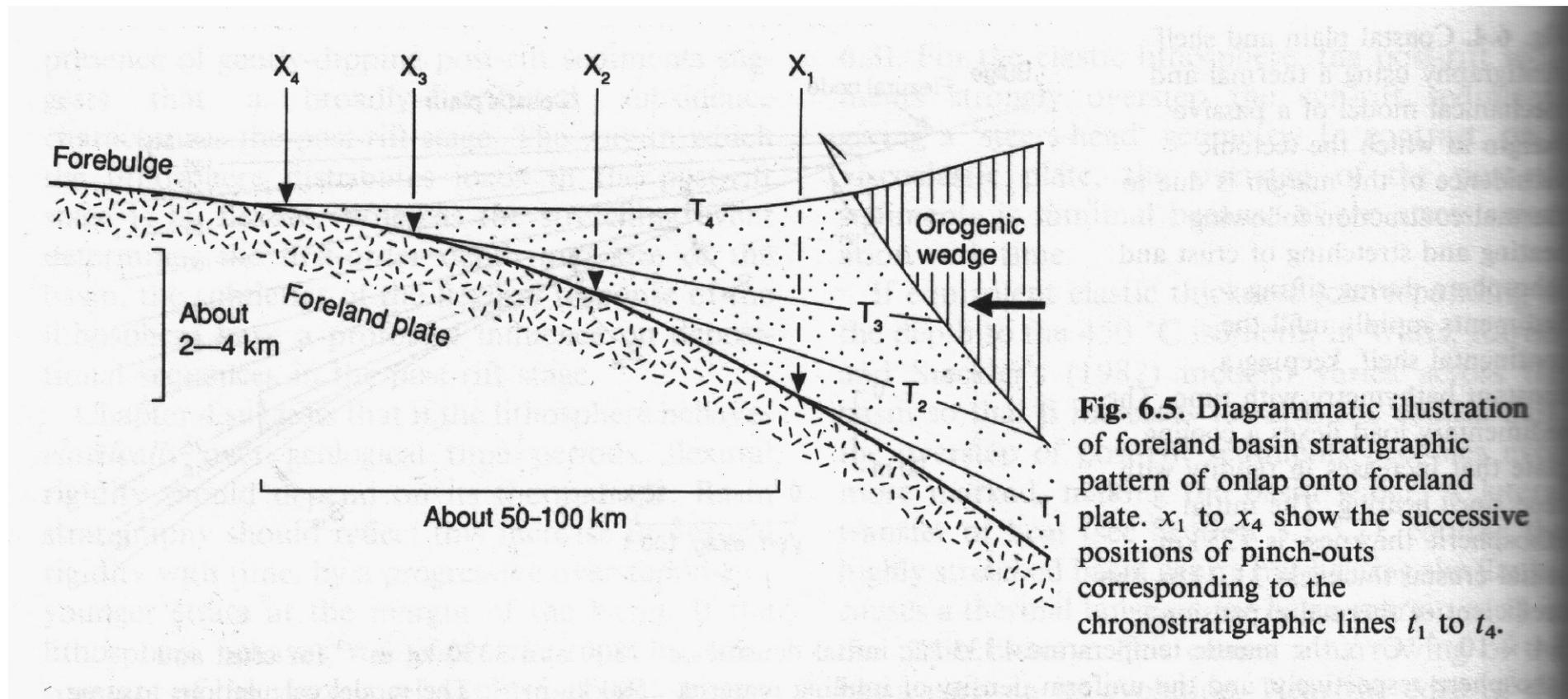
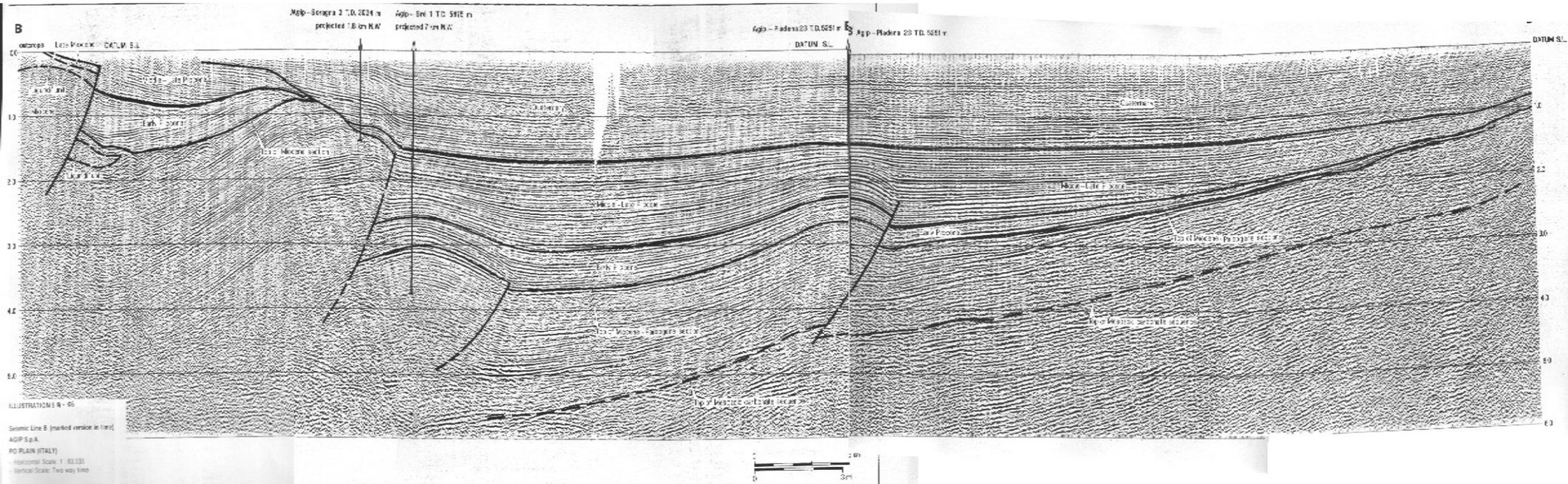


Fig. 11.13. Examples (A–D) of subsidence curves for the Rocky Mountain foreland basin, showing the characteristic convex-up shape, with inflexion points corresponding to thrust-loading events. This shape contrasts with the

concave-up shape of subsidence curves derived from extensional basins, such as is shown in Fig. 11.3. (Cross 1986)



# Bacia de antepaís



## Relação espaço - aporte

**Curvas de espaço de acomodação e aporte sedimentar:**  
**modelo de seqüências deposicionais**

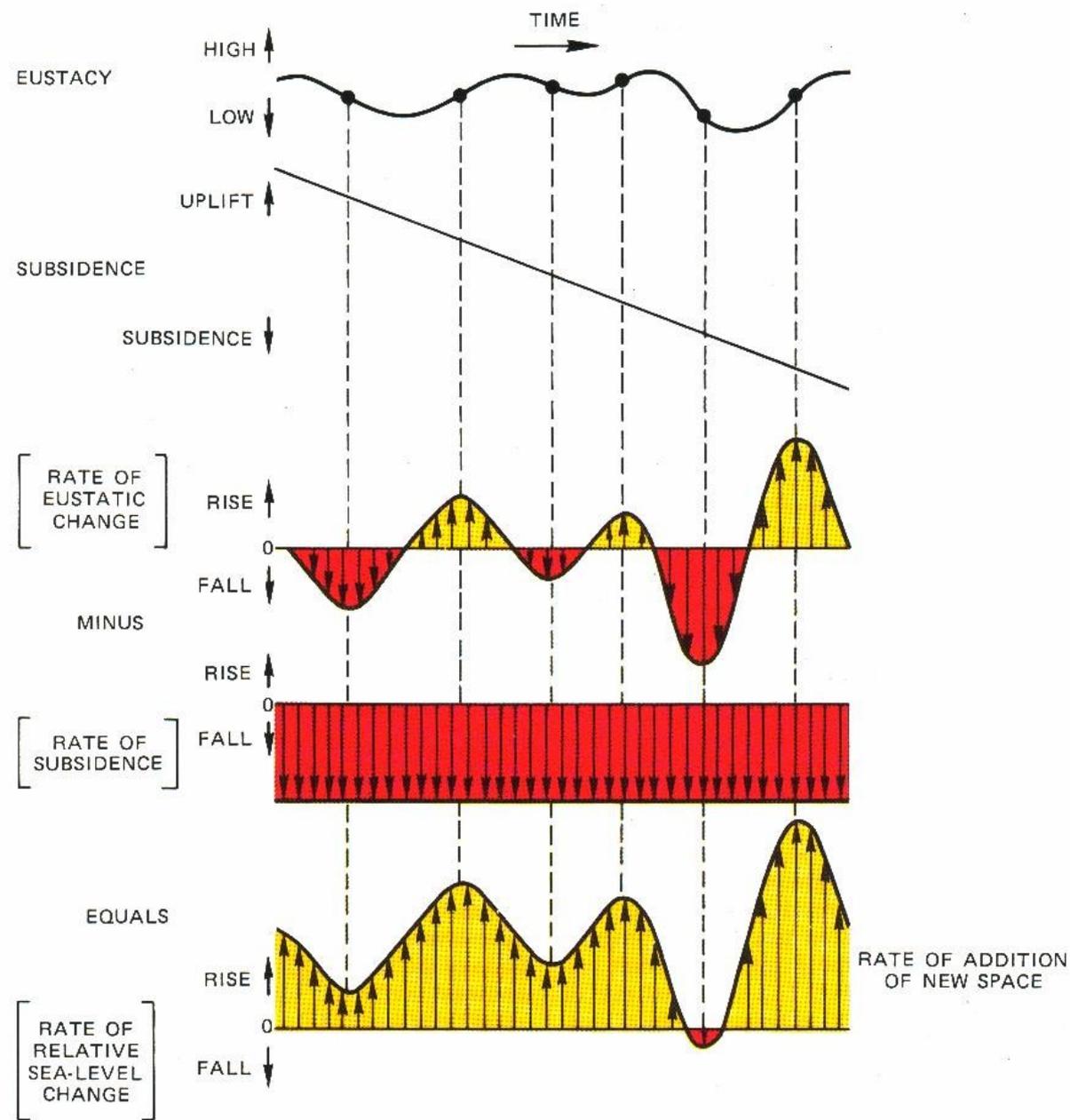
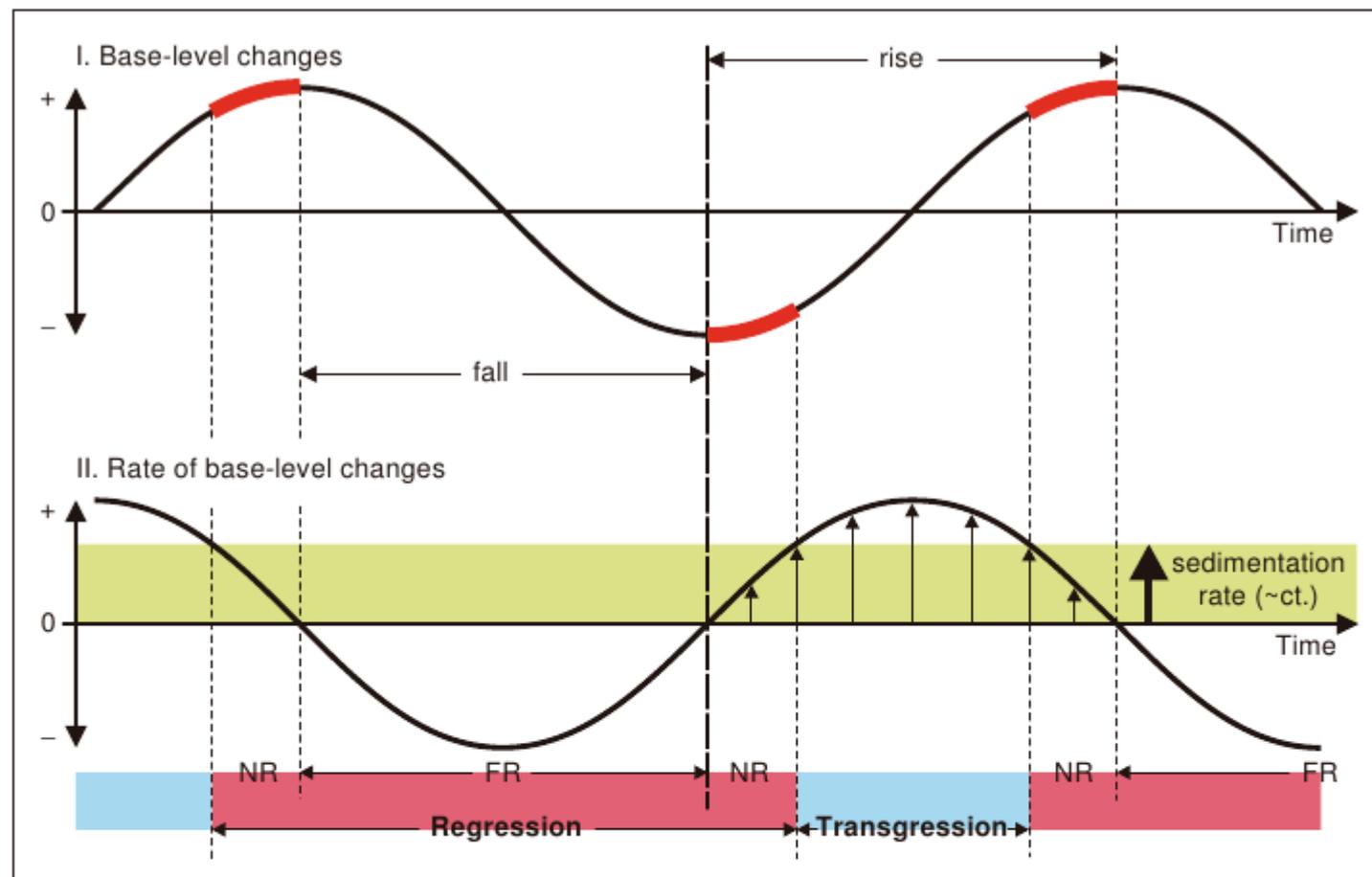


FIG. 10.—Relative sea level as a function of eustasy and subsidence.

Posamentier *et al.* (1988)

## Revisão Espaço e Sedimentação



**FIGURE 3.19** Concepts of transgression, normal regression, and forced regression, as defined by the interplay between base-level changes and sedimentation. The top sine curve shows the magnitude of base-level changes through time. The thicker portions on this curve indicate early and late stages of base-level rise, when the rates of base-level rise (increasing from zero and decreasing to zero, respectively) are outpaced by sedimentation rates. The sine curve below shows the rates of base-level changes. Note that the rates of base-level change are zero at the end of base-level rise and base-level fall stages (the change from rise to fall and from fall to rise requires the motion to cease). The rates of base-level change are the highest at the inflection points on the top curve. Transgressions occur when the rates of base-level rise outpace the sedimentation rates. For simplicity, the sedimentation rates are kept constant during the cycle of base-level shifts. The reference base-level curve is shown as a symmetrical sine curve for simplicity, but no inference is made that this should be the case in the geological record. In fact, asymmetrical shapes are more likely, as a function of particular circumstances in each case study (e.g., glacio-eustatic cycles are strongly asymmetrical, as ice melts quicker than it builds up), but this does not change the fundamental principles illustrated in this diagram. Abbreviations: FR—forced regression; NR—normal regression.

**Curvas de espaço de acomodação e aporte sedimentar:**  
**modelo de seqüências deposicionais**

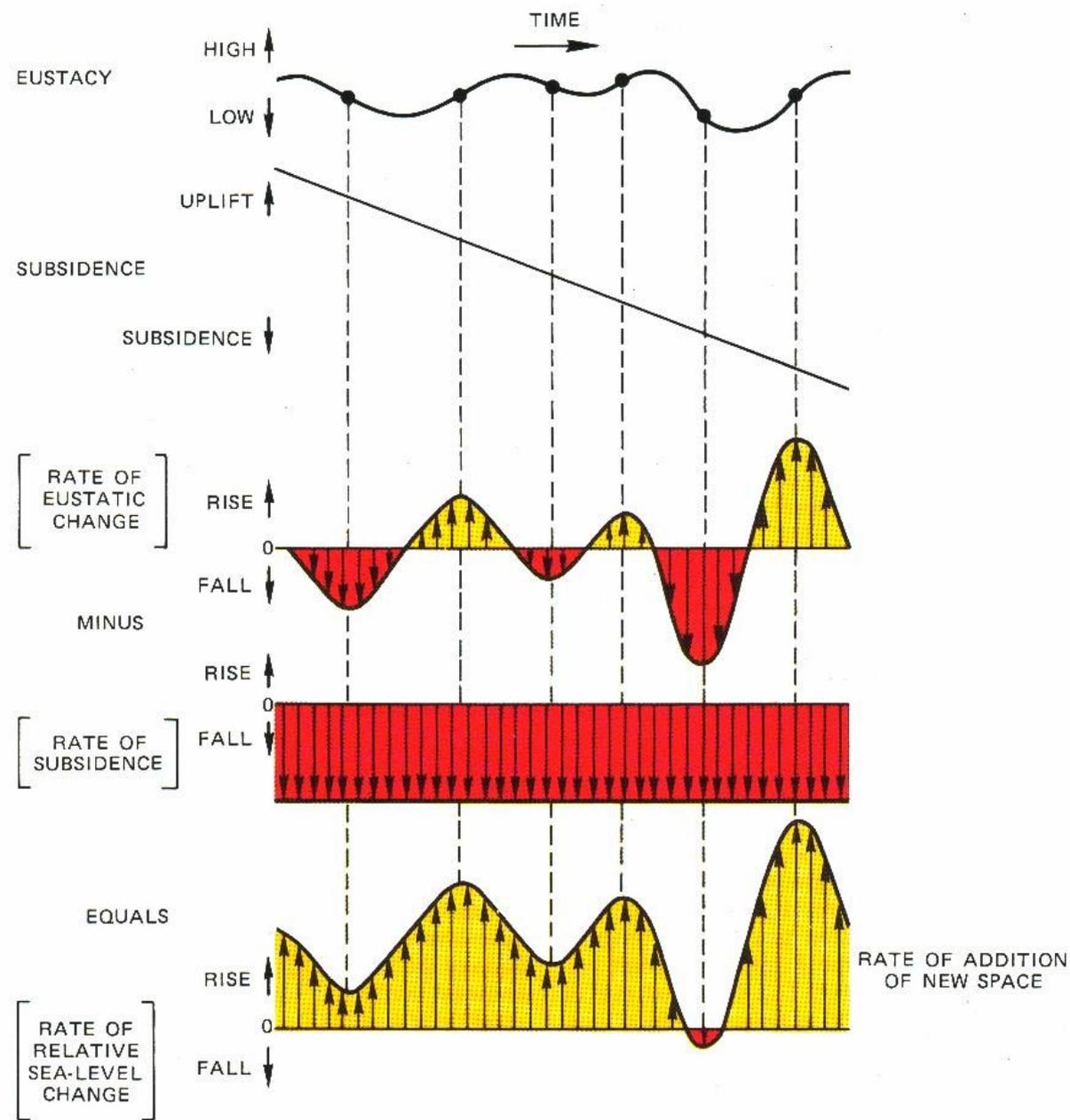


FIG. 10.—Relative sea level as a function of eustasy and subsidence.

Posamentier *et al.* (1988)

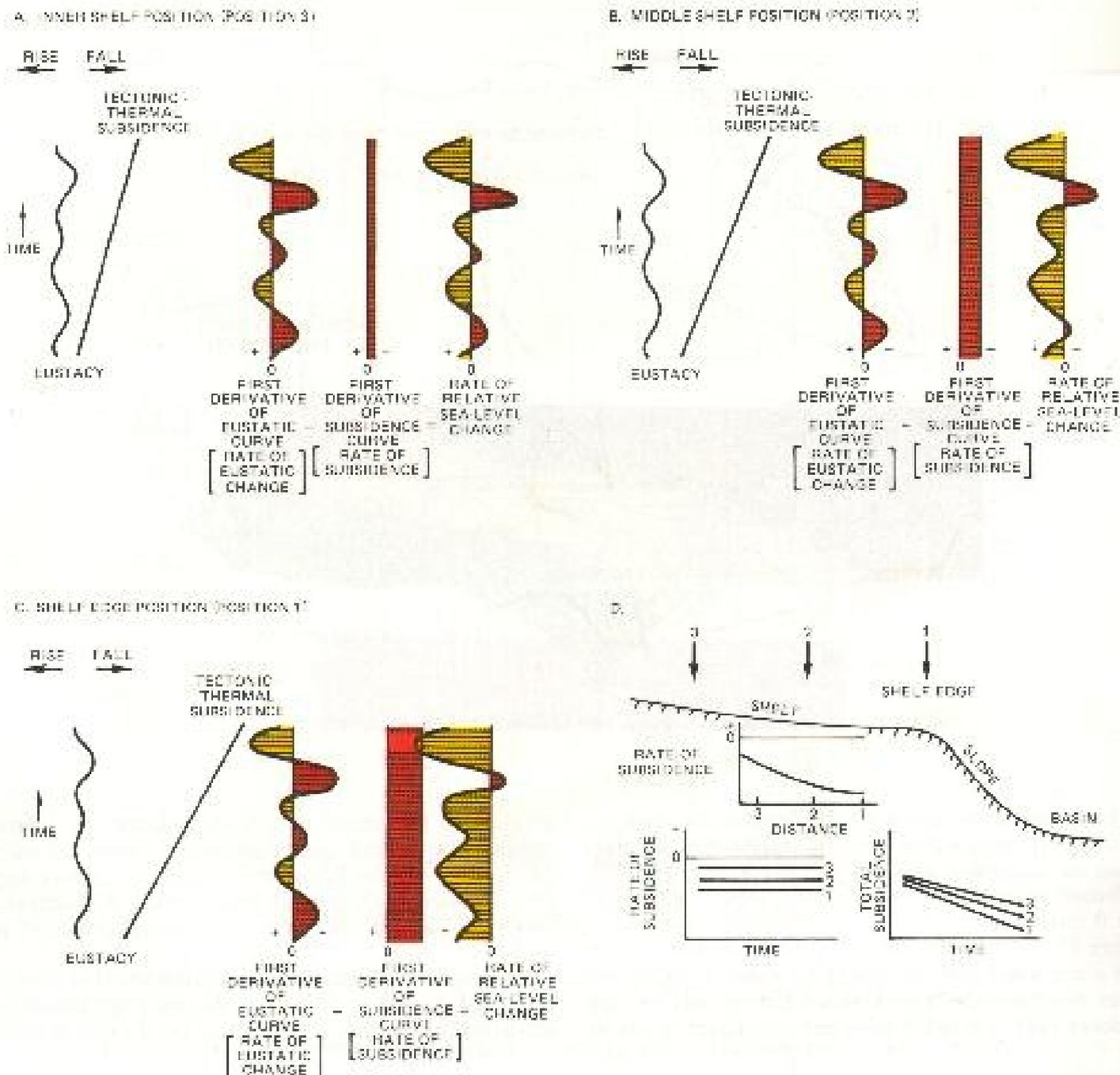
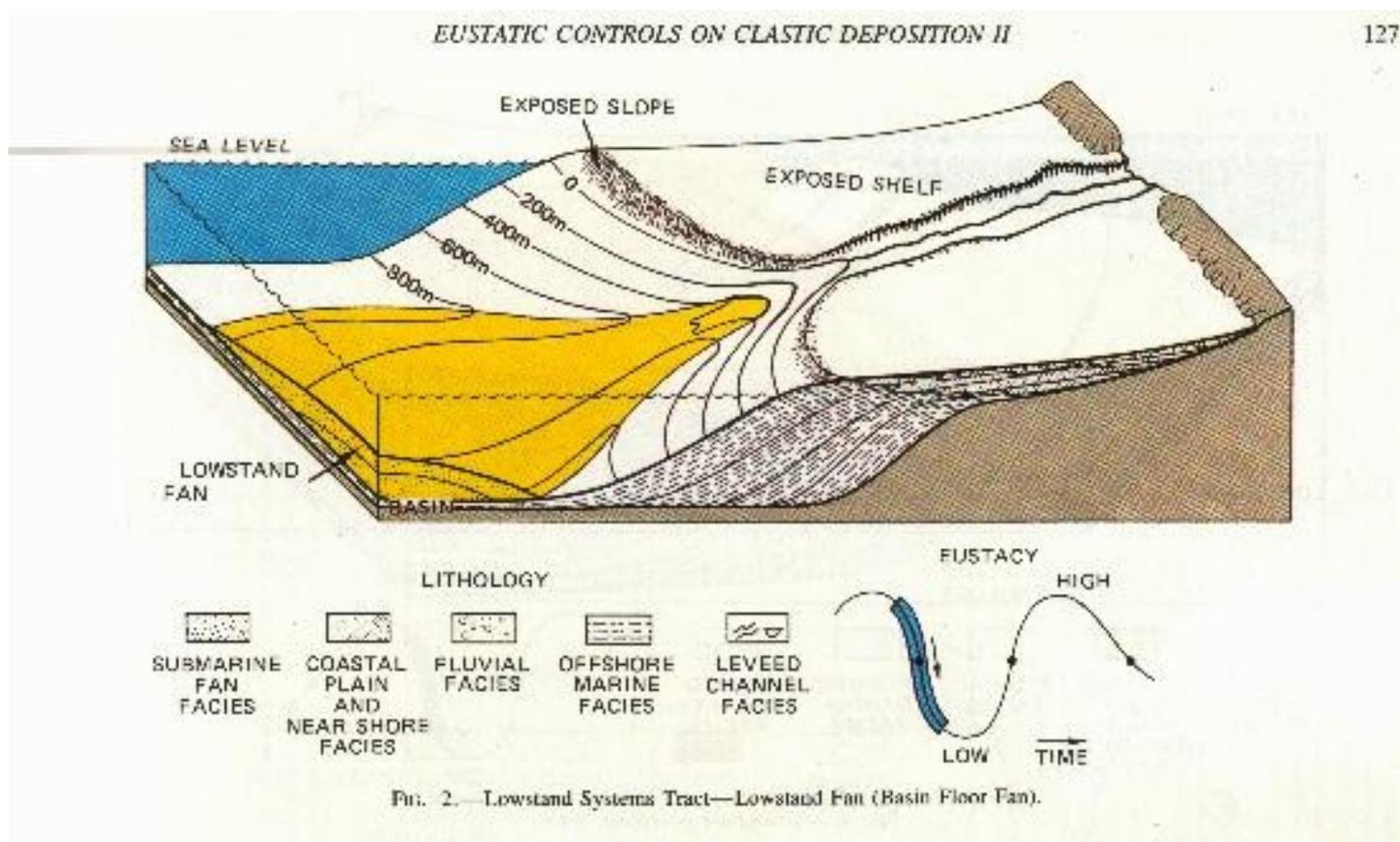


Fig. 13.—Response of relative sea level to differential tectonic thermal subsidence.

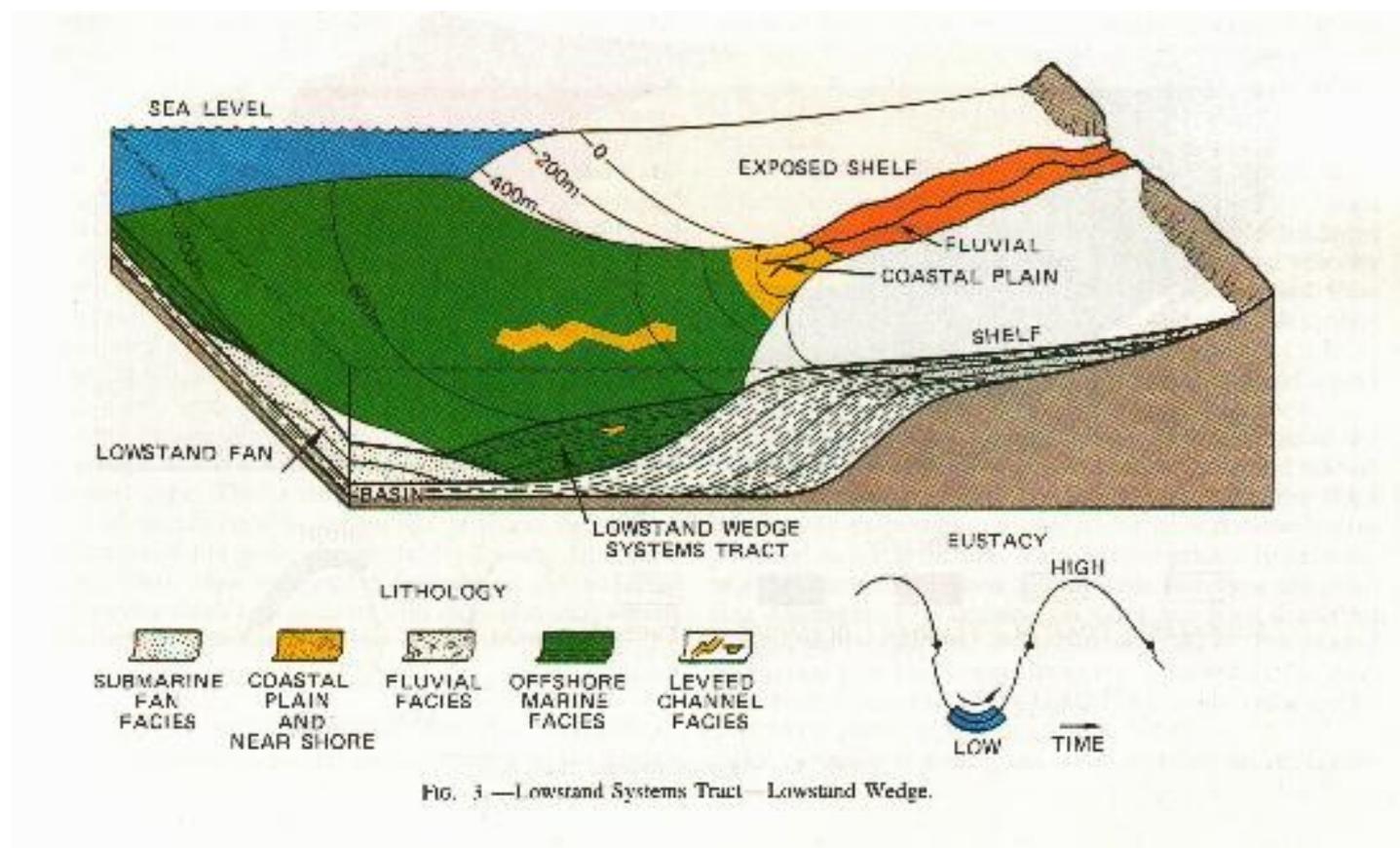
## Padrões de preenchimento – tratos de sistemas deposicionais

### Trato de Mar Baixo



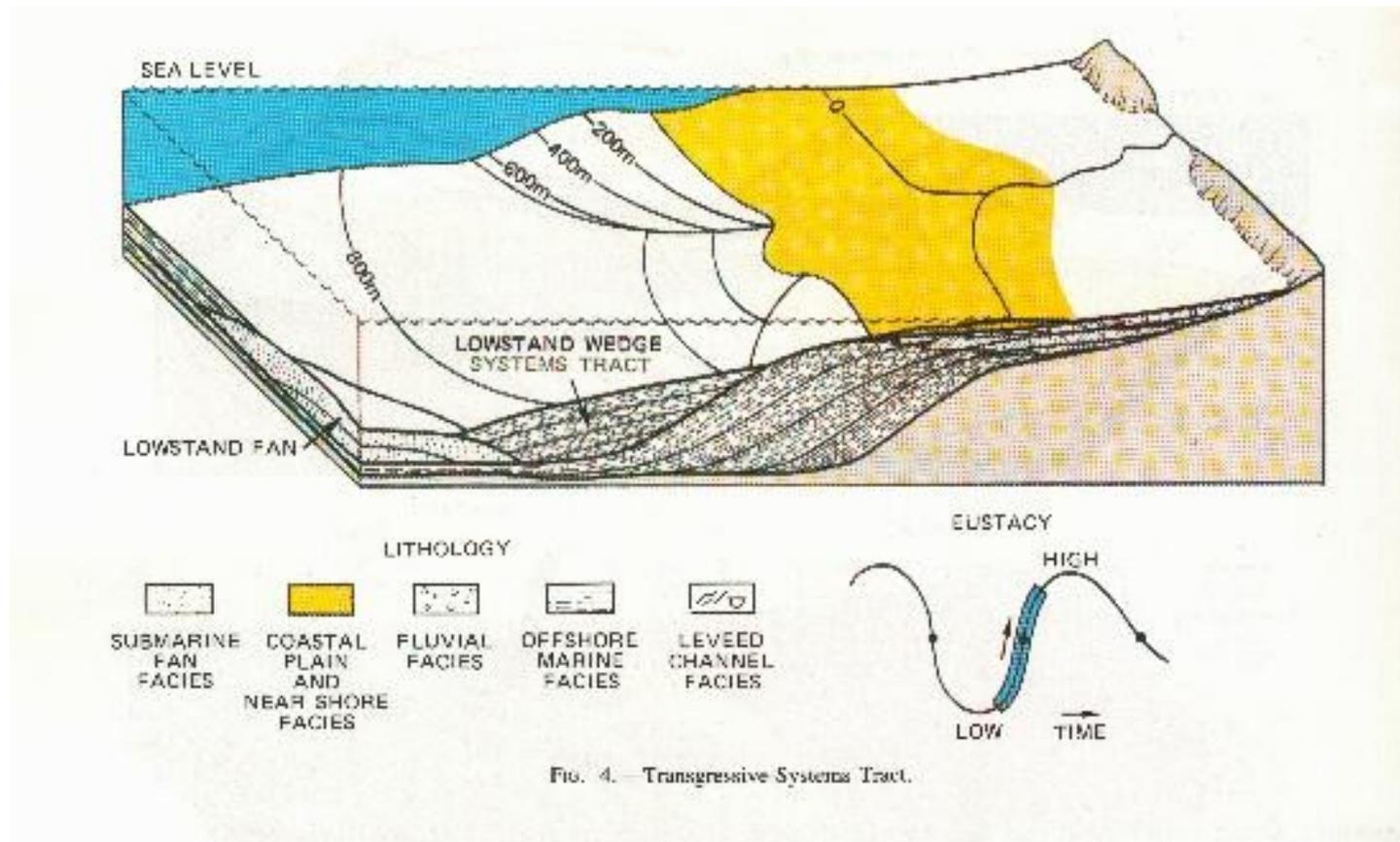
## Padrões de preenchimento – tratos de sistemas deposicionais

### Trato de Mar Baixo II



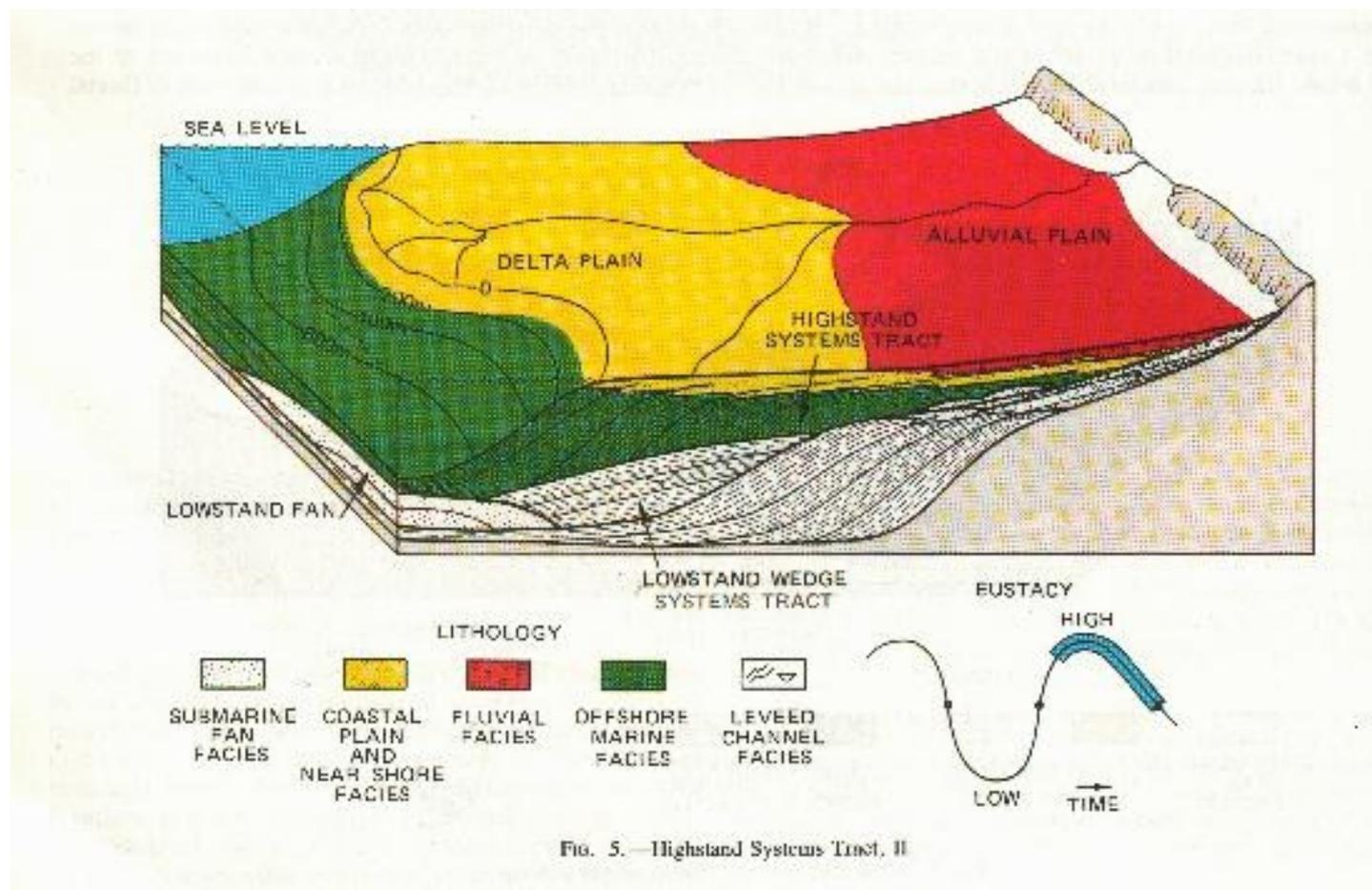
## Padrões de preenchimento – tratos de sistemas deposicionais

### Trato Transgressivo



## Padrões de preenchimento – tratos de sistemas deposicionais

### Trato de Mar Alto

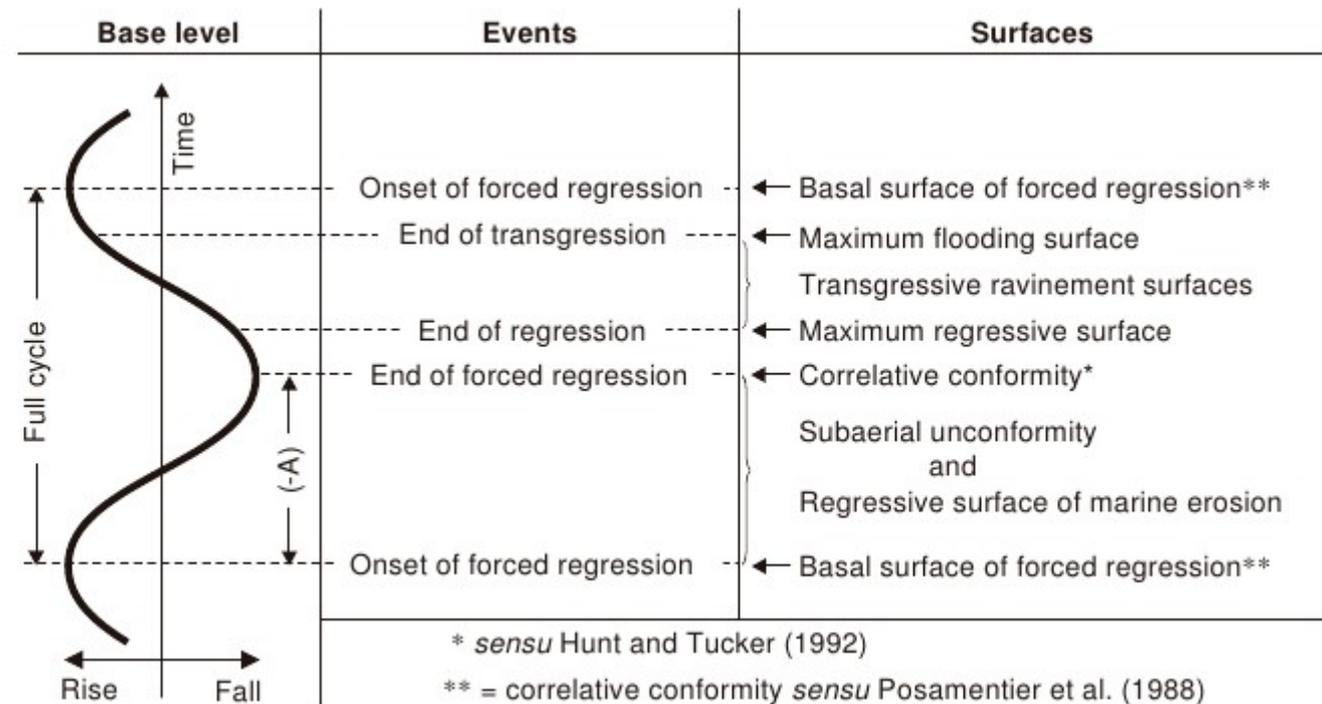


Posamentier & Vail (1988)

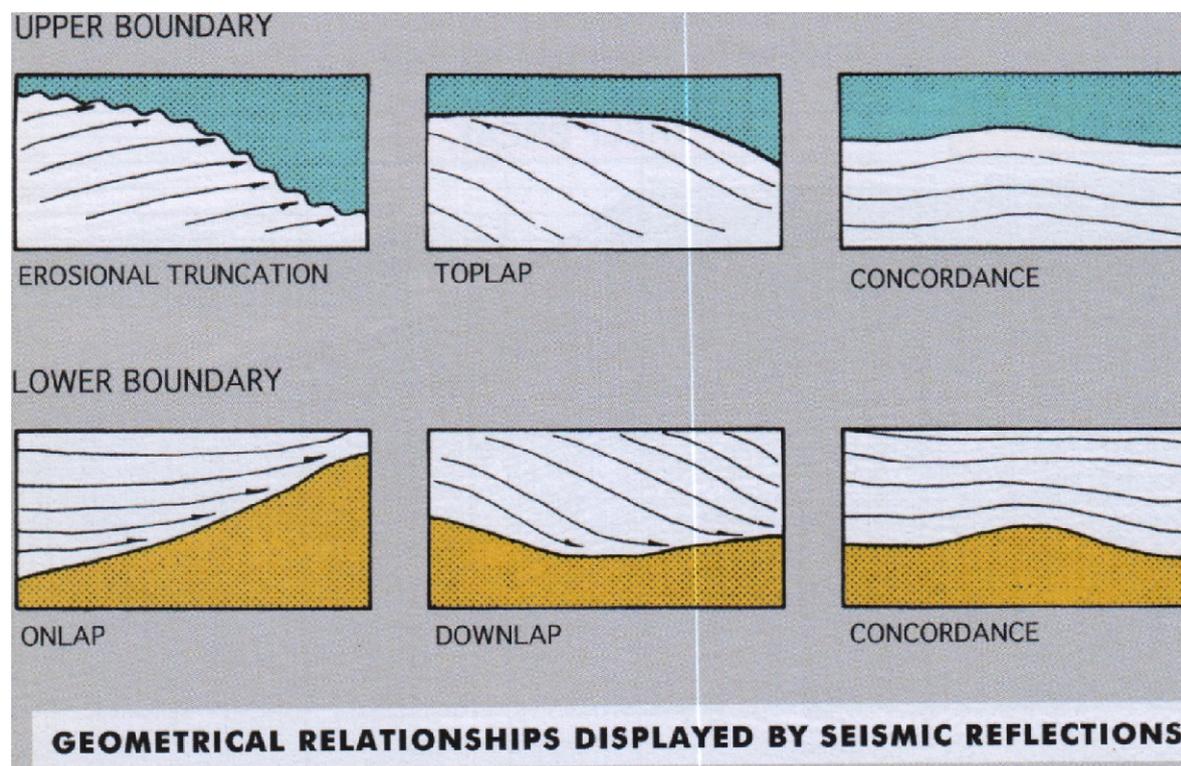
## **Superfícies limitantes principais**

- Limite de seqüências deposicionais: superfície erosiva e correlatos laterais
- Superfície transgressiva
- Superfície de inundação máxima: sup. condensada, hard ground, firm ground
- Geometrias e padrões de terminação de refletores sísmicos

**FIGURE 4.7** Timing of sequence stratigraphic surfaces relative to the main events of the base-level cycle (modified from Catuneanu *et al.*, 1998b, and Embry and Catuneanu, 2002). (-A)—negative accommodation. Each of these seven surfaces of sequence stratigraphy can serve, at least in part, as systems tract boundaries. The 'transgressive ravinement surfaces' include a pair of *wave-* and *tidal-*ravinement surfaces, which are often superimposed, especially in open shoreline settings. In river-mouth settings, the two transgressive ravinement surfaces may be separated by estuary-mouth complex deposits.

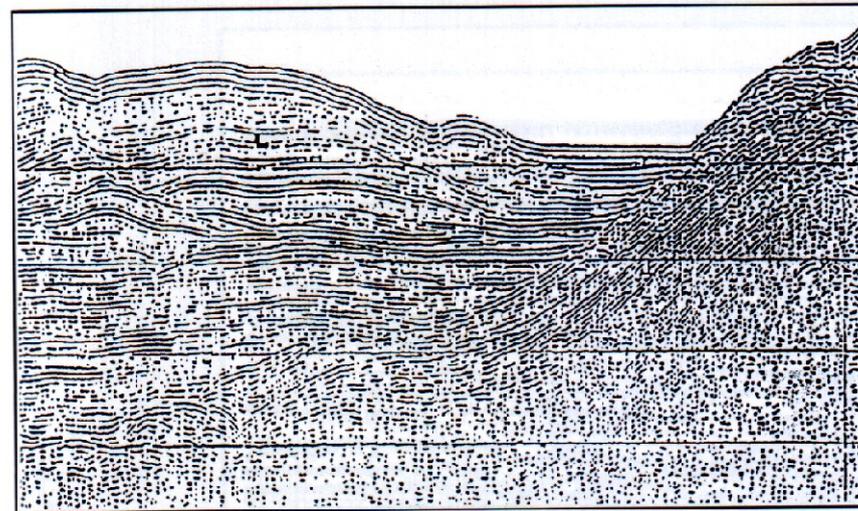


## Padrões de terminação de refletores



Veeken, P.C.H . 2007. SEISMIC STRATIGRAPHY, BASIN ANALYSIS AND RESERVOIR CHARACTERISATION. HANDBOOK OF GEOPHYSICAL EXPLORATION SEISMIC EXPLORATION VOLUME 37. Elsevier. 509 pp.

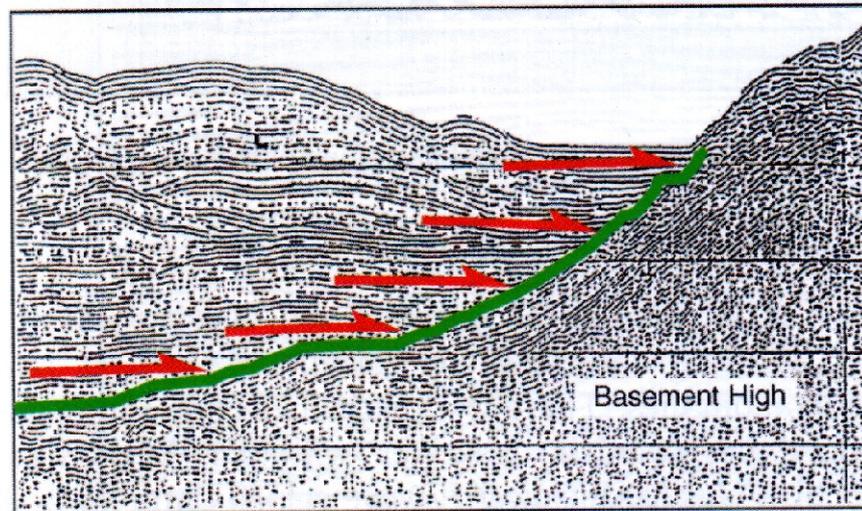
# Onlap



TWT in seconds  
4.0  
5.0

Onlap

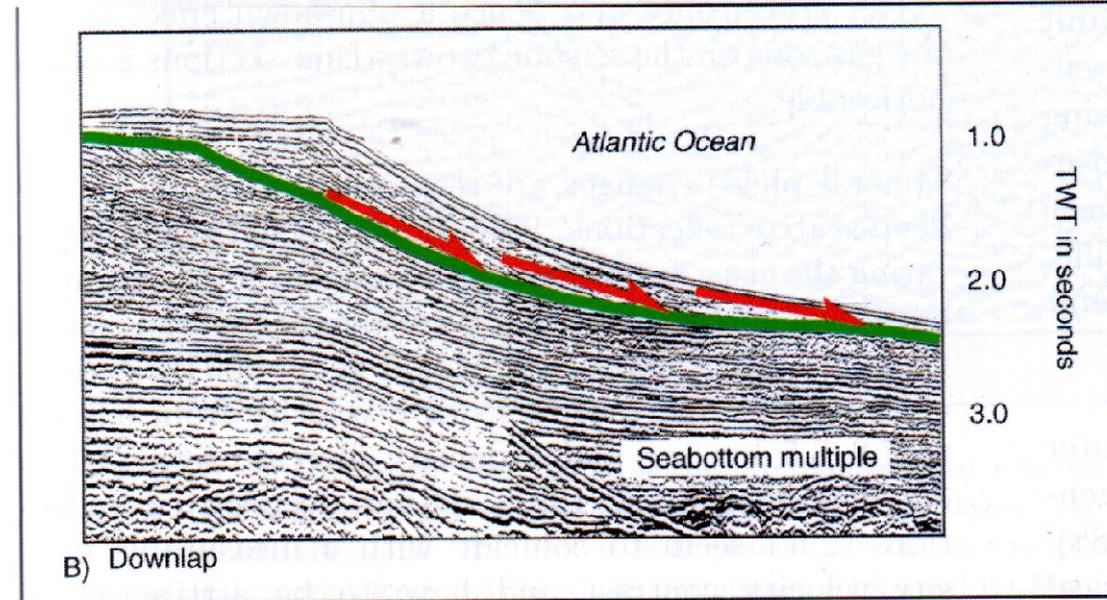
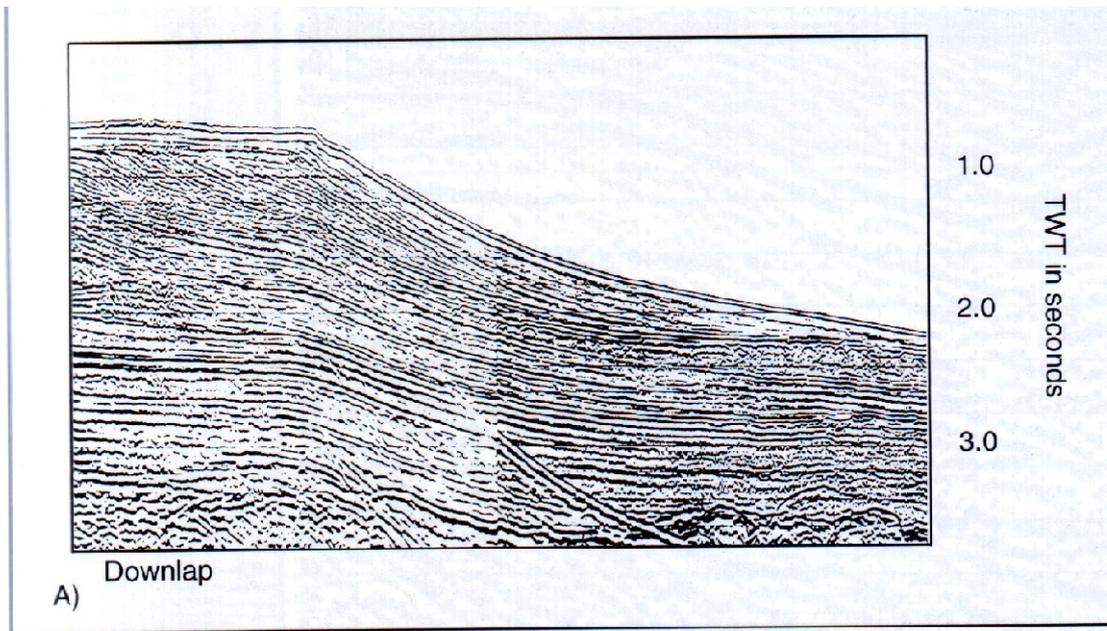
P



TWT in seconds  
4.0  
5.0

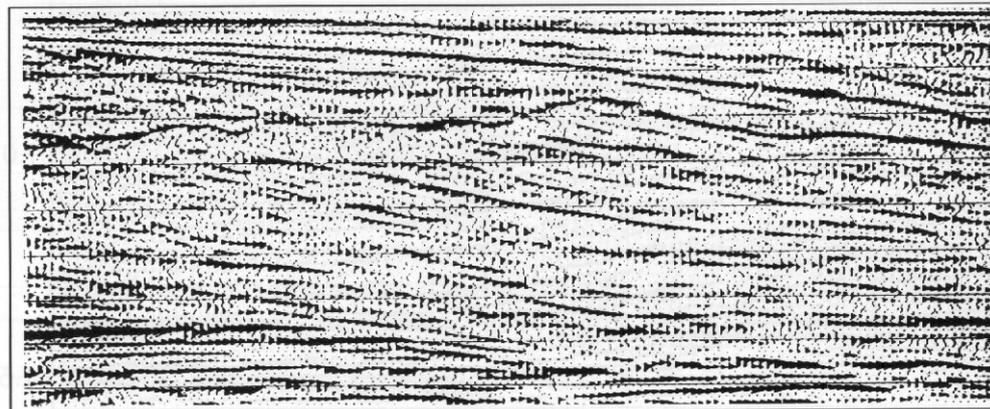
Onlap

# Donwlap

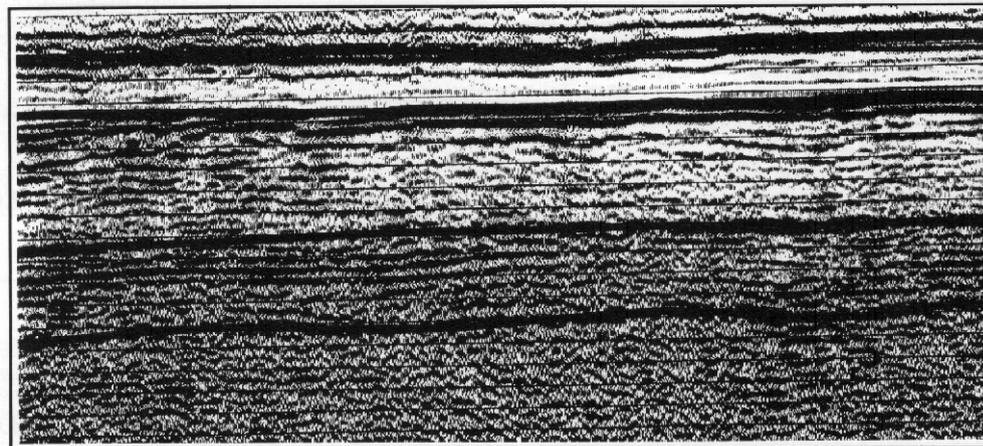




Top lap



Erosional truncation



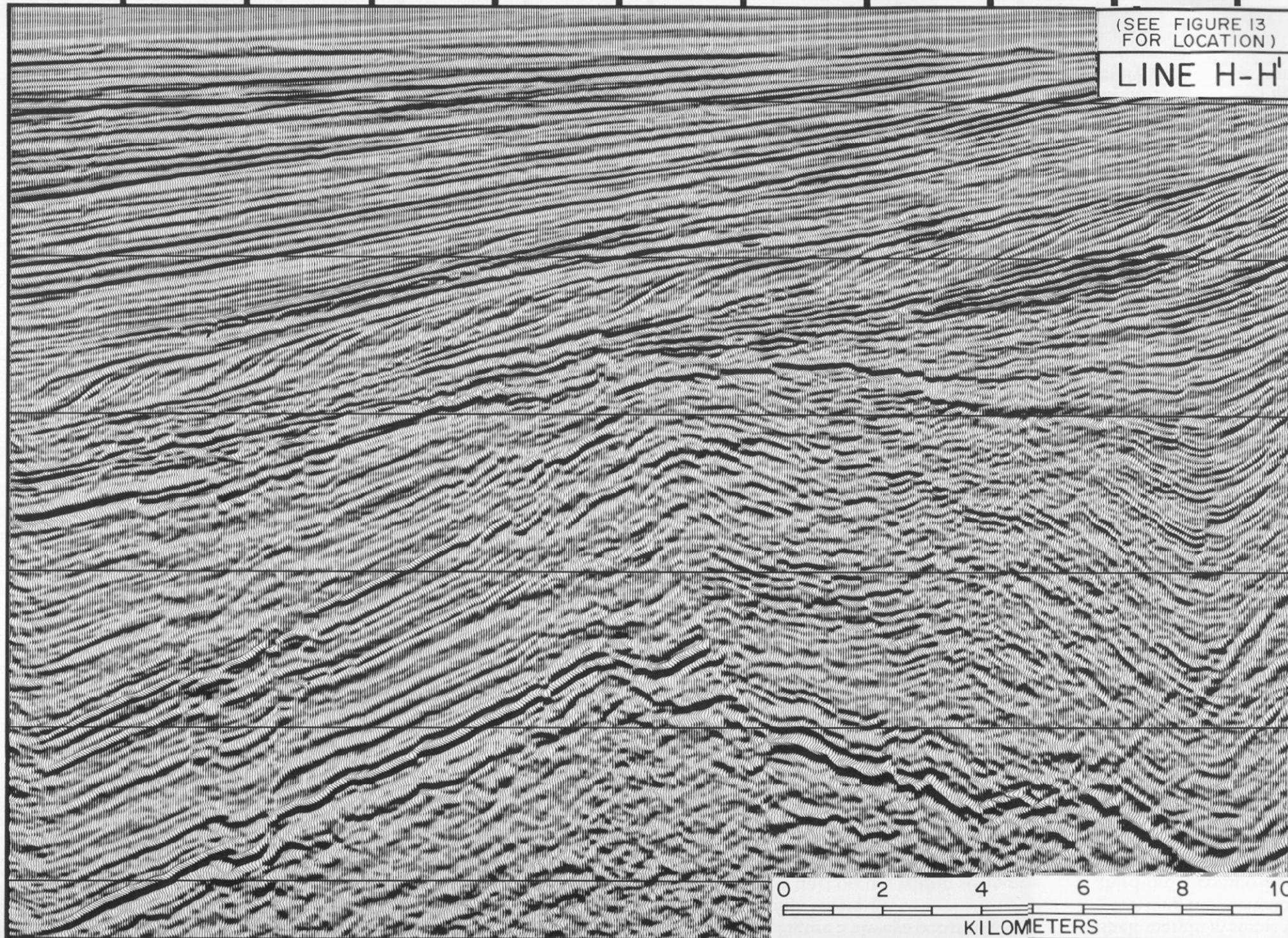
Concordance with subtle indications for sediment bypass

SSW

NNE

(SEE FIGURE 13  
FOR LOCATION)

LINE H-H'



0 2 4 6 8 10  
KILOMETERS

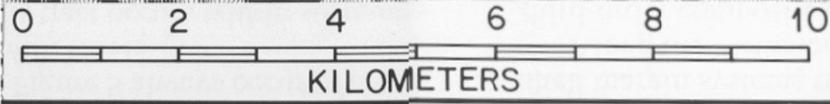
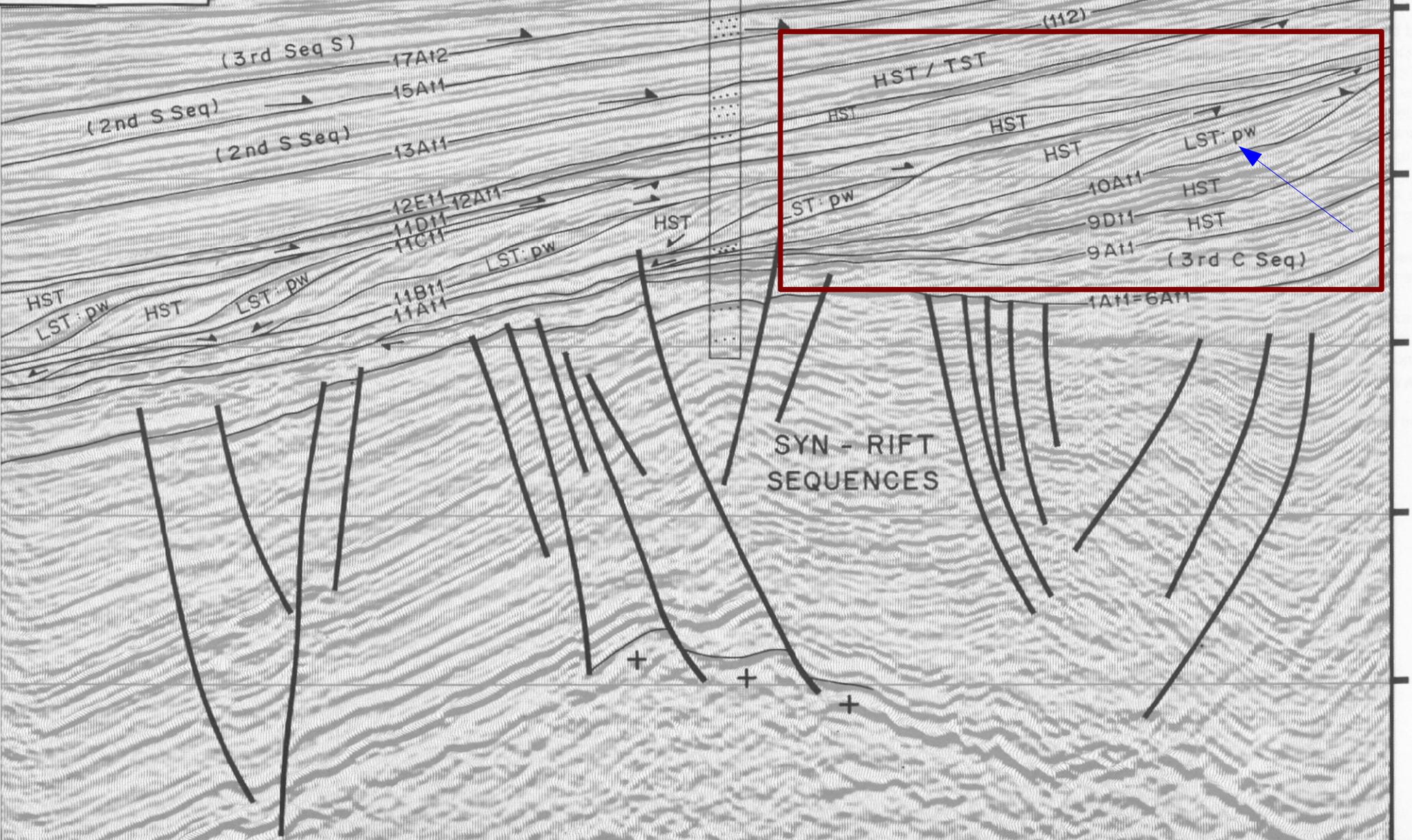
SSW

G-G' 7

NNE

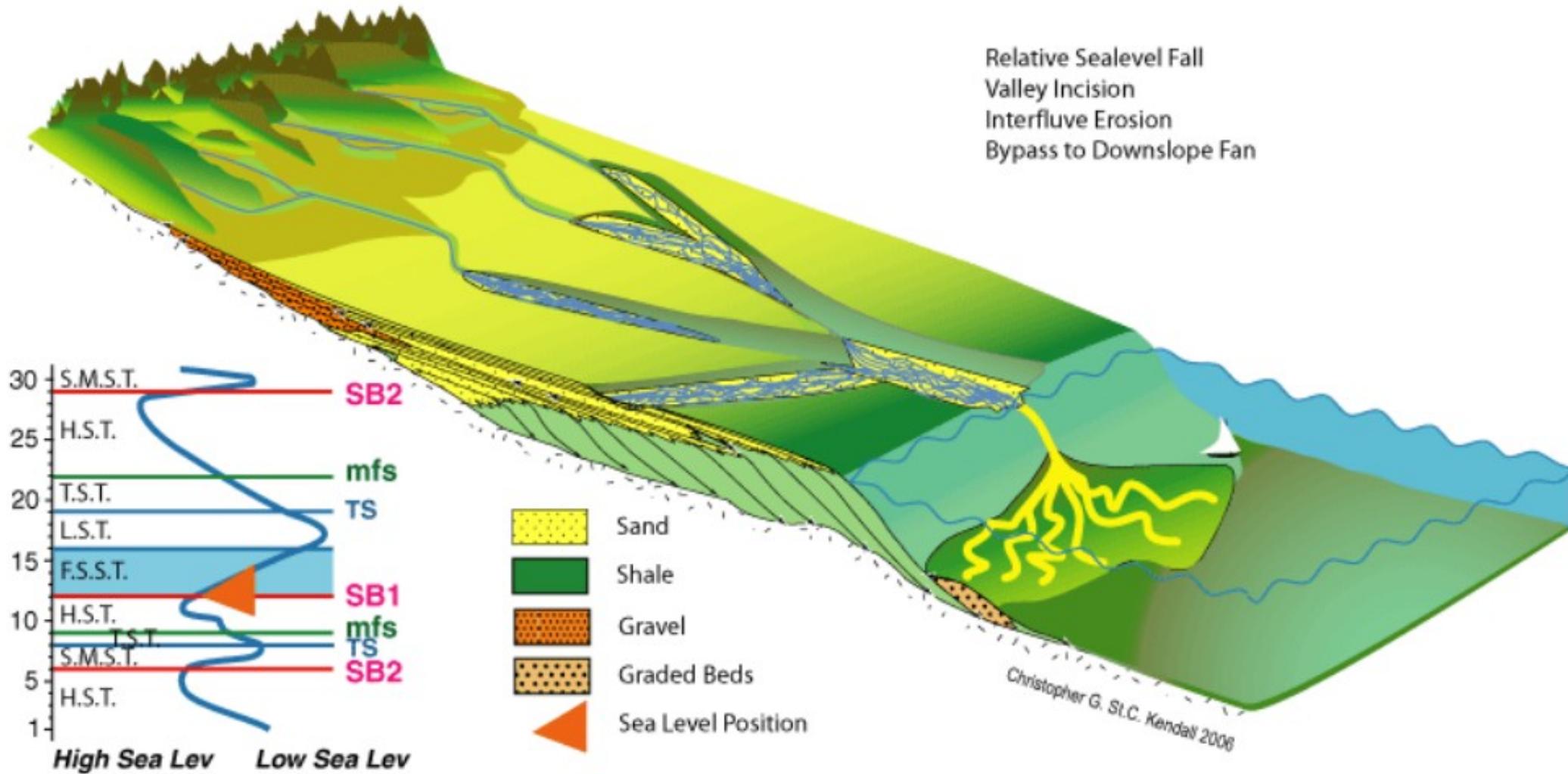
(SEE FIGURE 13 FOR LOCATION)

LINE H-H'



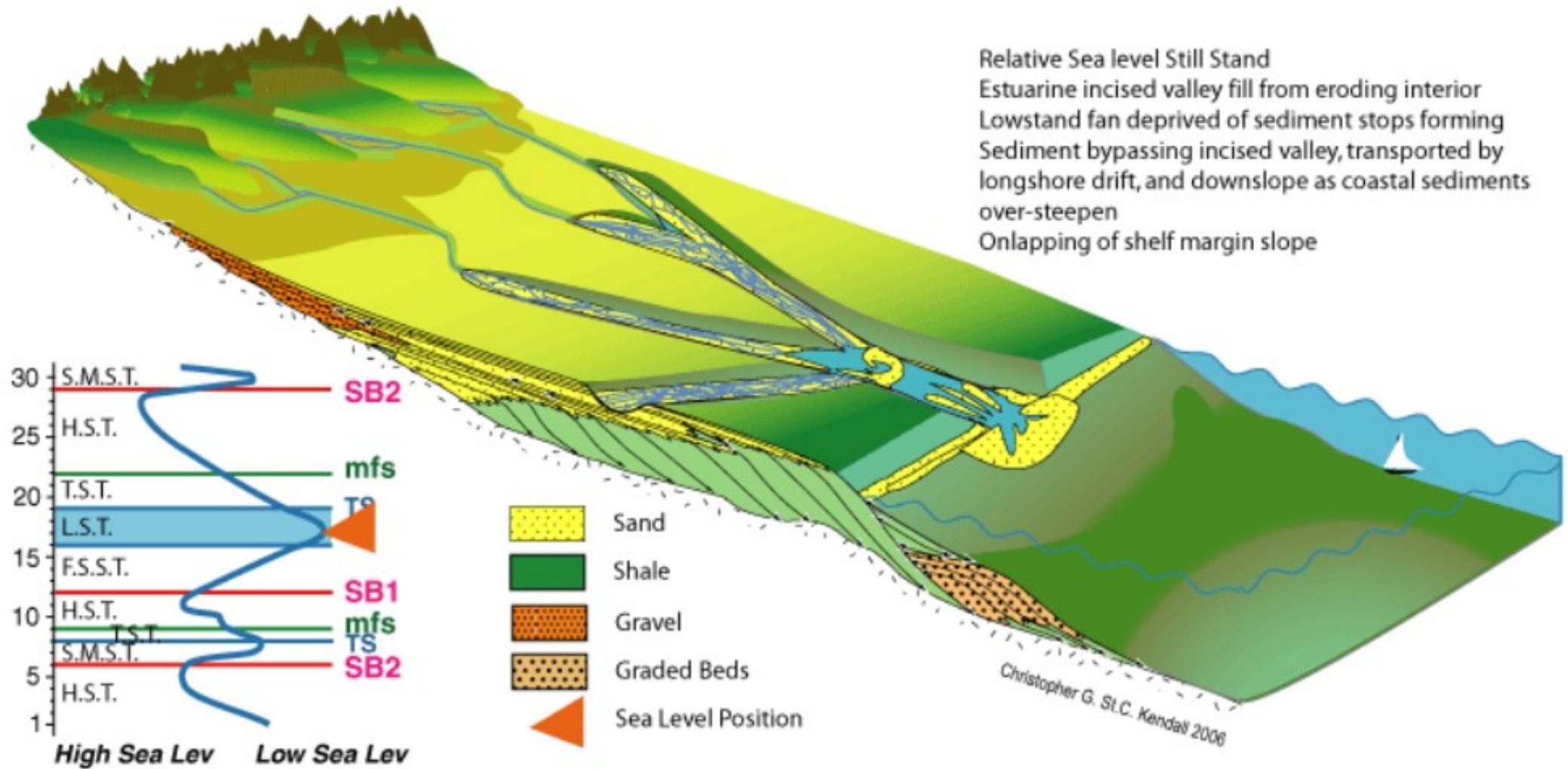
# Padrões de preenchimento – tratos de sistemas deposicionais

## Trato de Mar Baixo

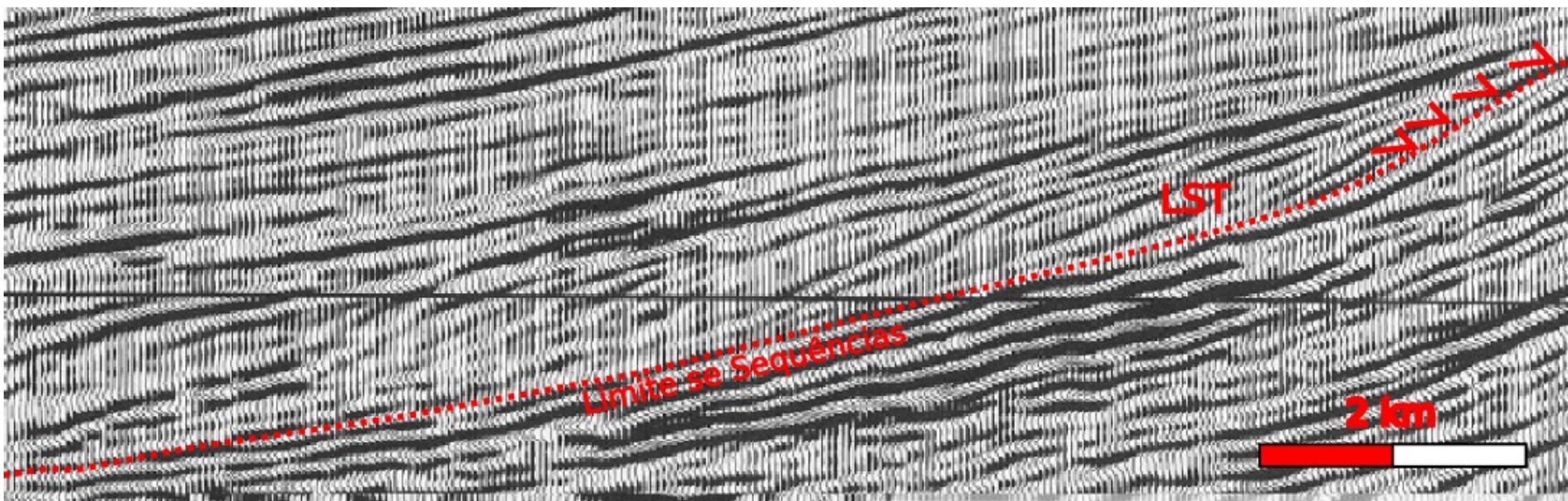
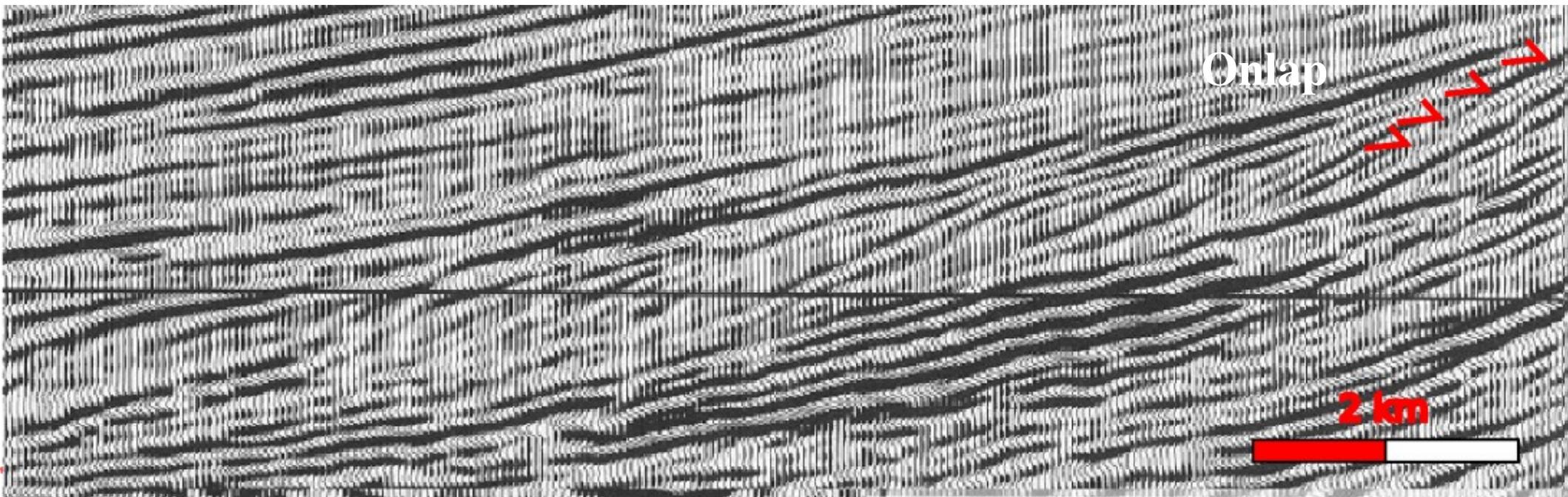


# Padrões de preenchimento – tratos de sistemas deposicionais

## Trato de Mar Baixo II



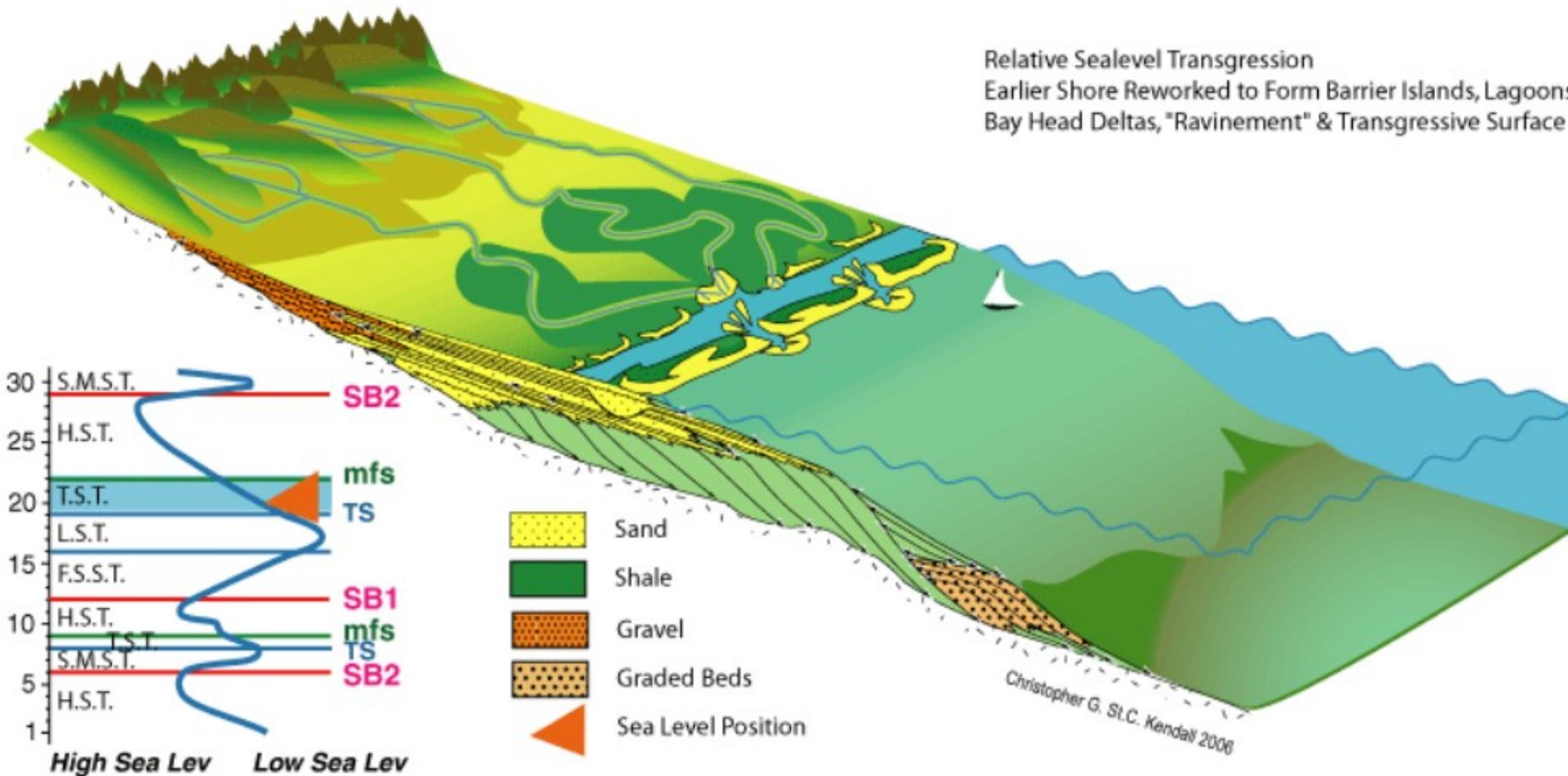
# Trato de Mar Baixo

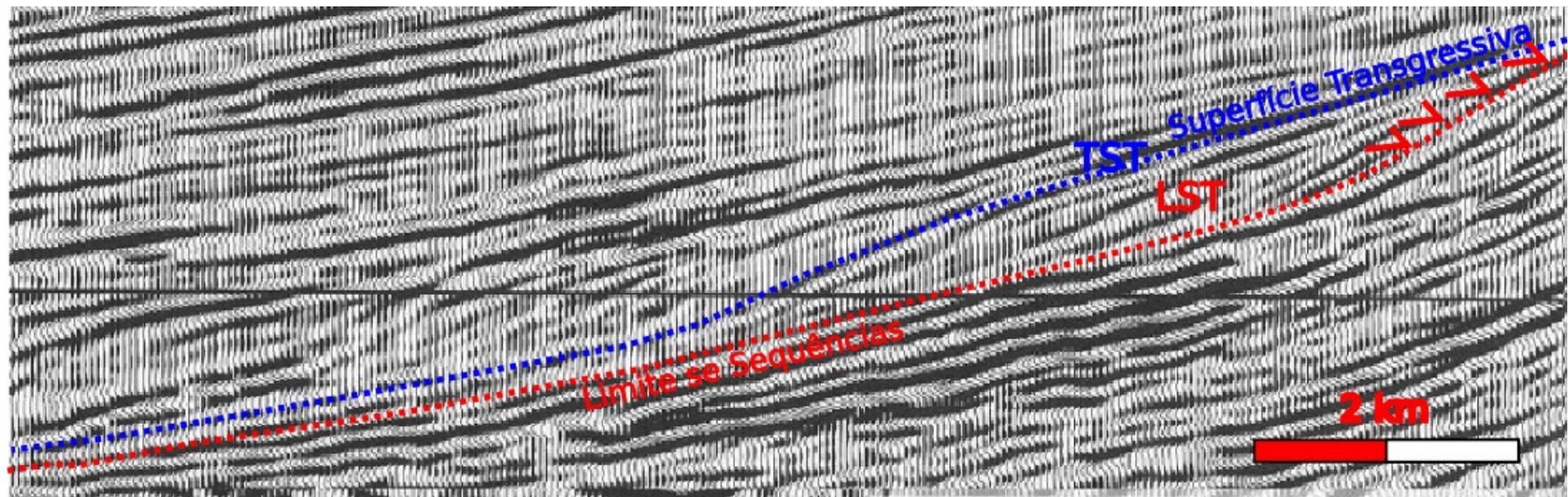


# Padrões de preenchimento – tratos de sistemas deposicionais

## Trato Transgressivo

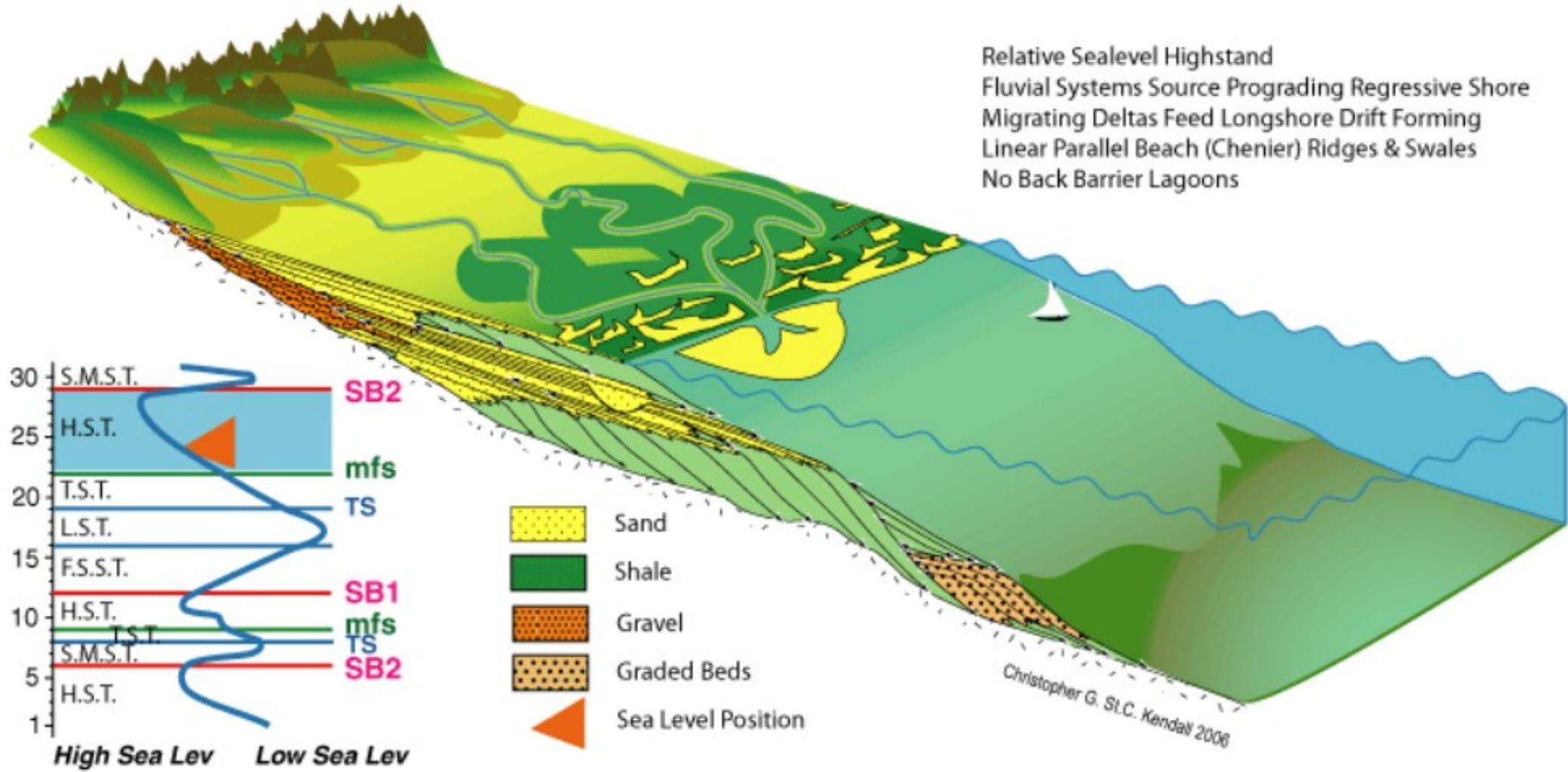
Relative Sealevel Transgression  
 Earlier Shore Reworked to Form Barrier Islands, Lagoons  
 Bay Head Deltas, "Ravinement" & Transgressive Surface





# Padrões de preenchimento – tratos de sistemas deposicionais

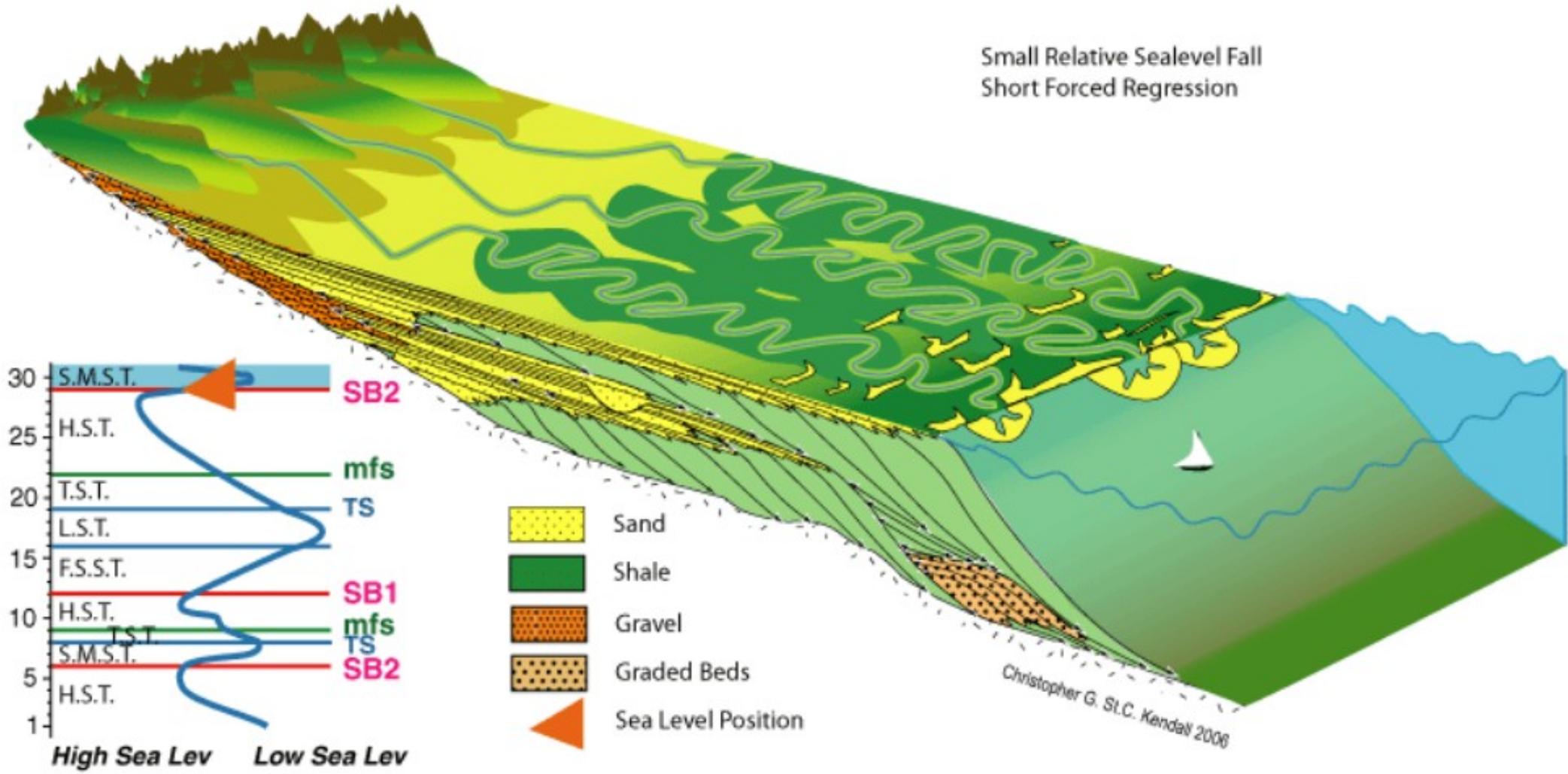
## Trato de Mar Alto

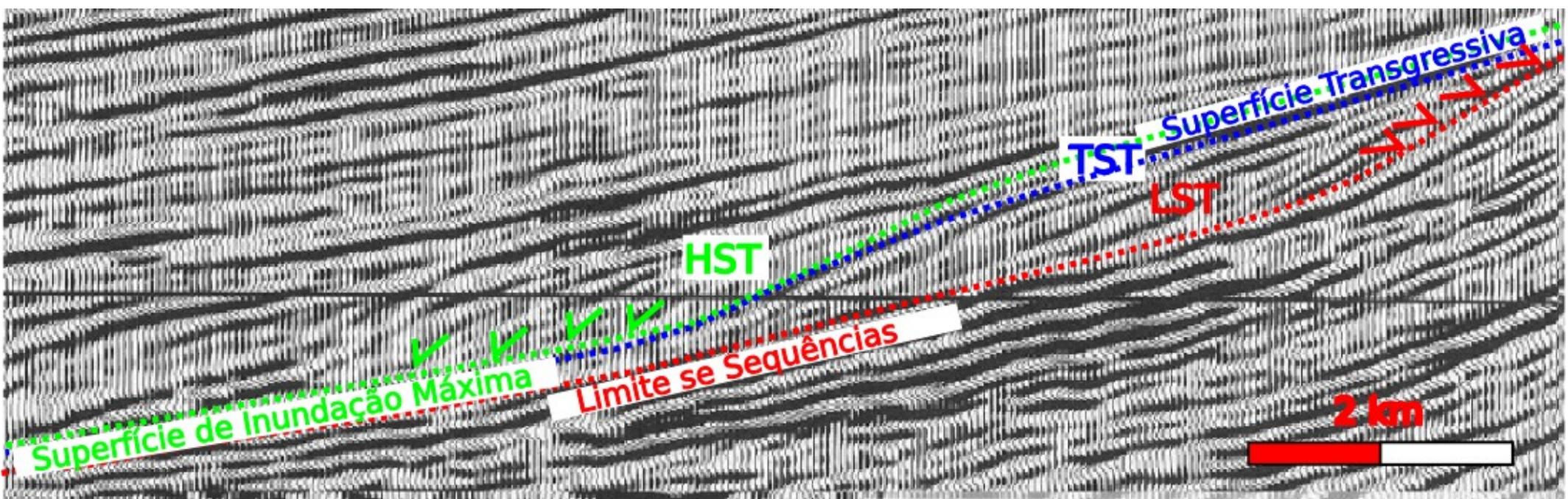
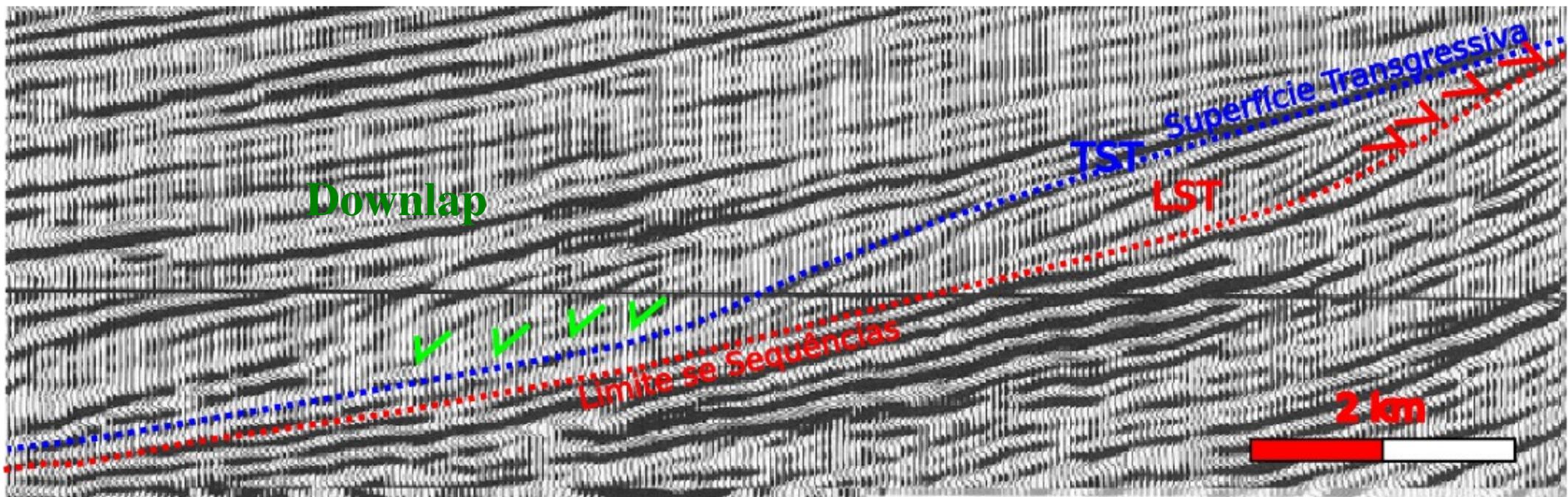


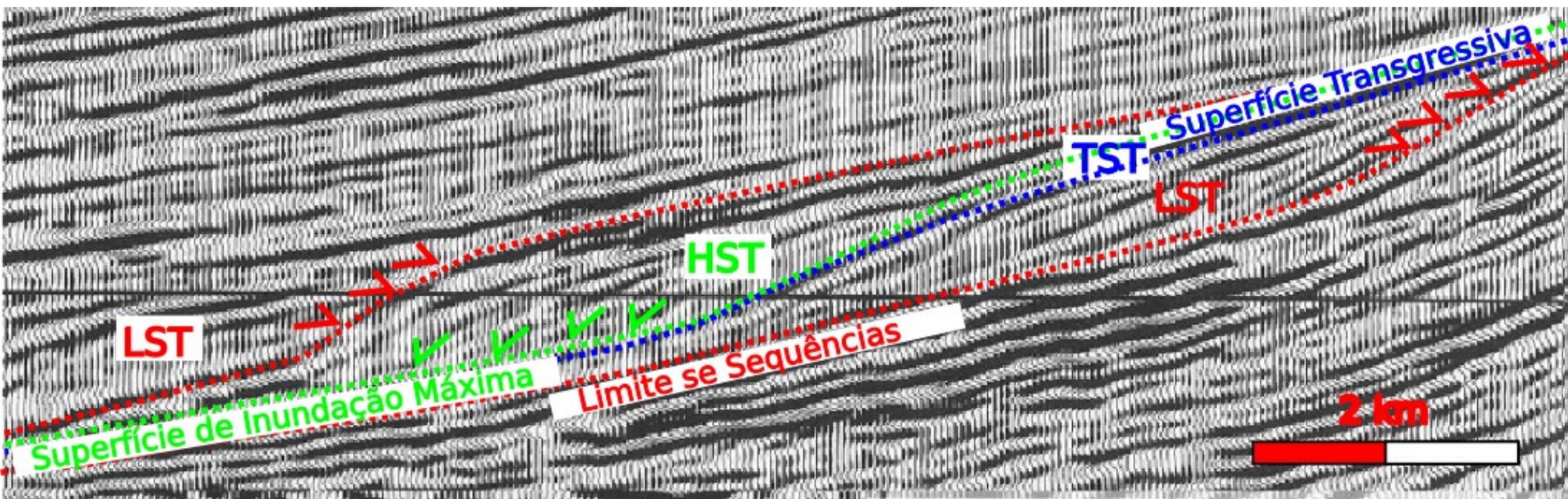
# Padrões de preenchimento – tratos de sistemas deposicionais

## Trato de Mar Alto

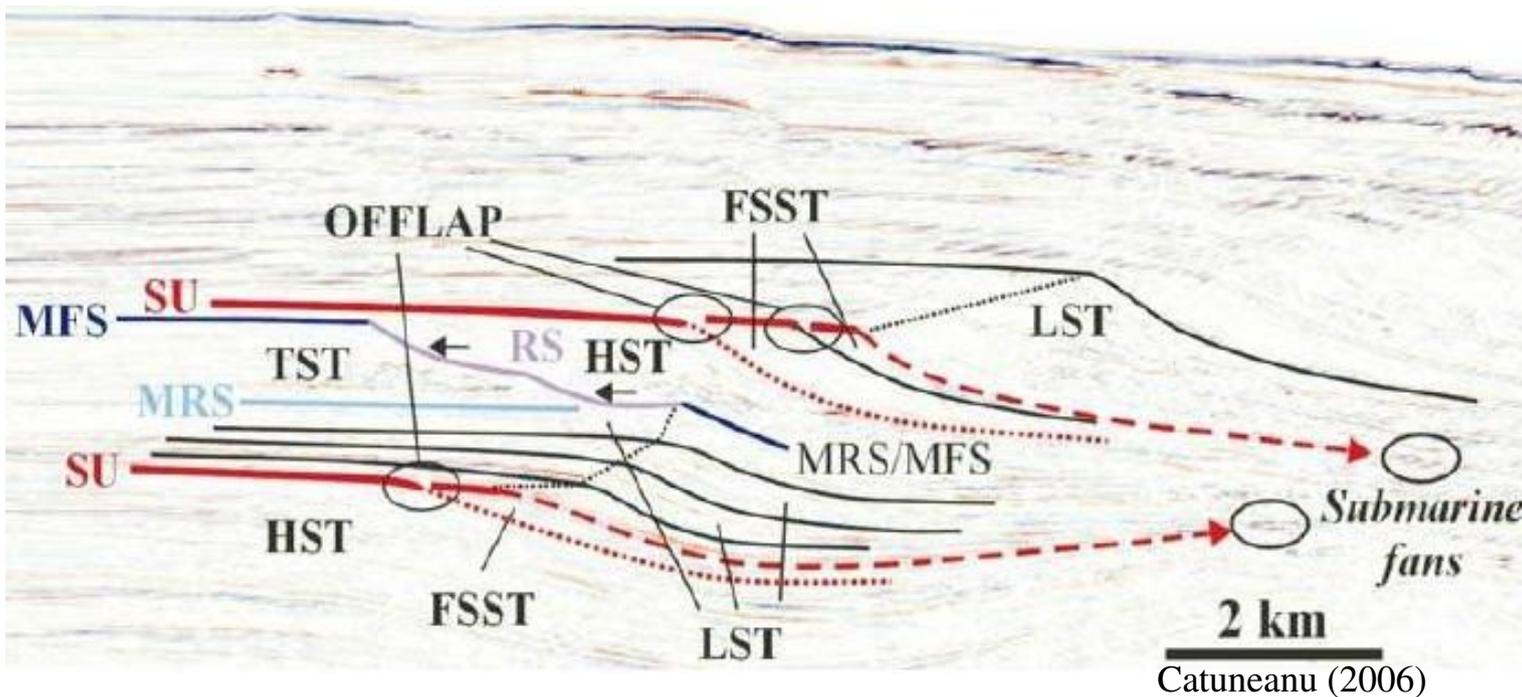
Small Relative Sealevel Fall  
Short Forced Regression







*Linha sísmica de uma sequência deposicional*

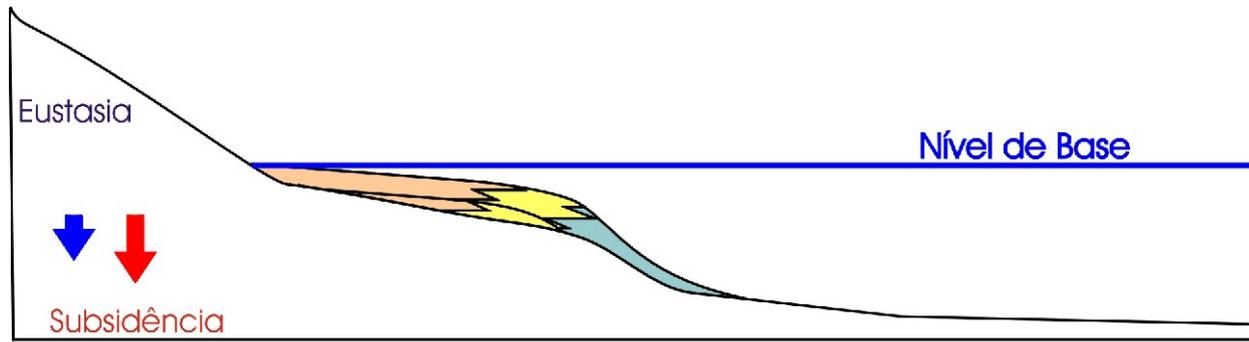


**Seqüência 1 - Trato de Mar Alto**

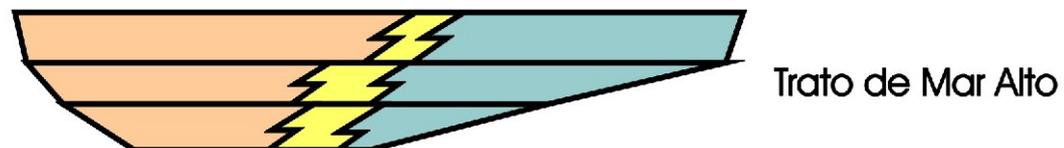
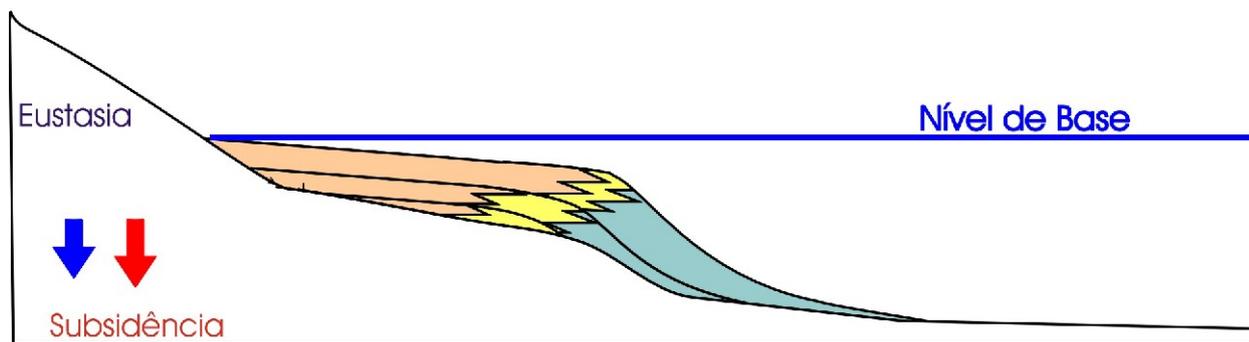


Trato de Mar Alto

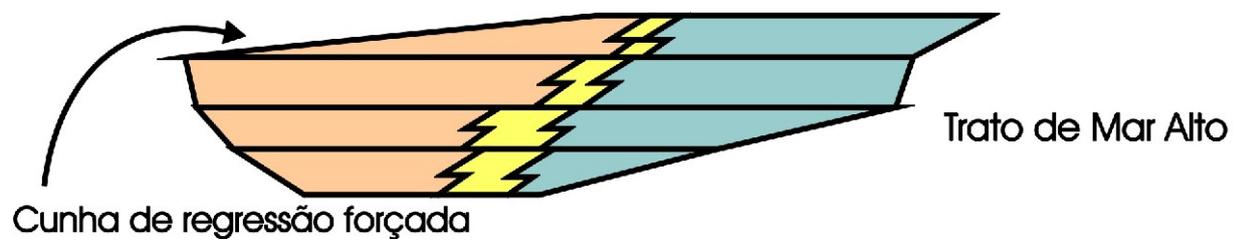
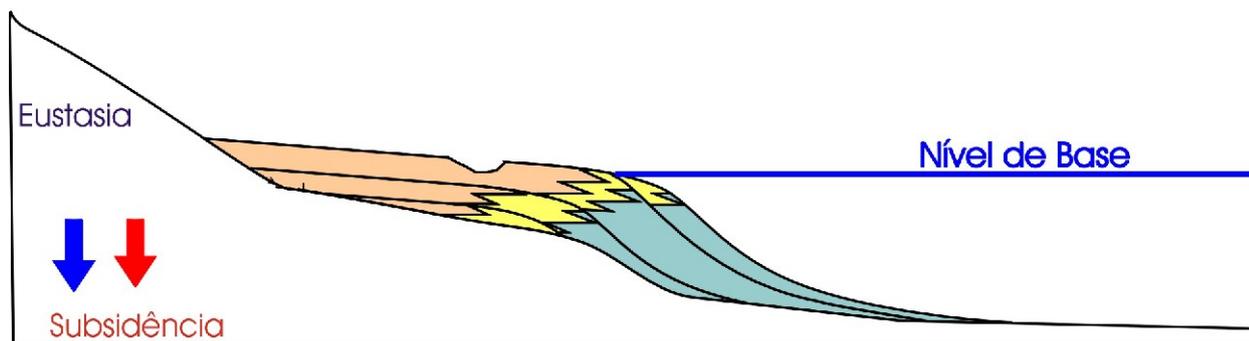
## Seqüência 1 - Trato de Mar Alto



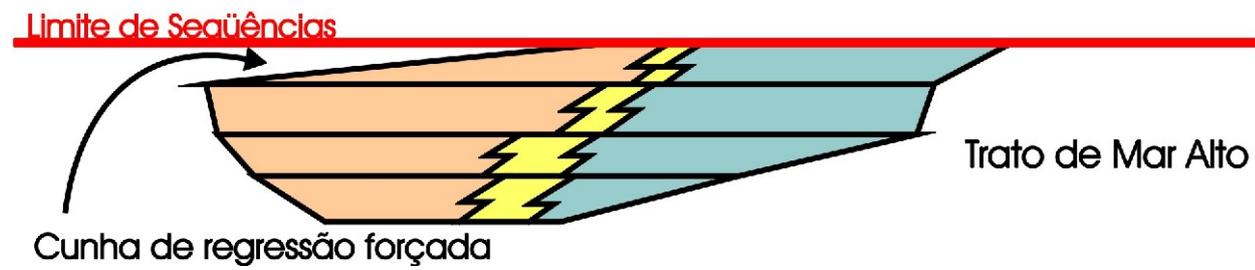
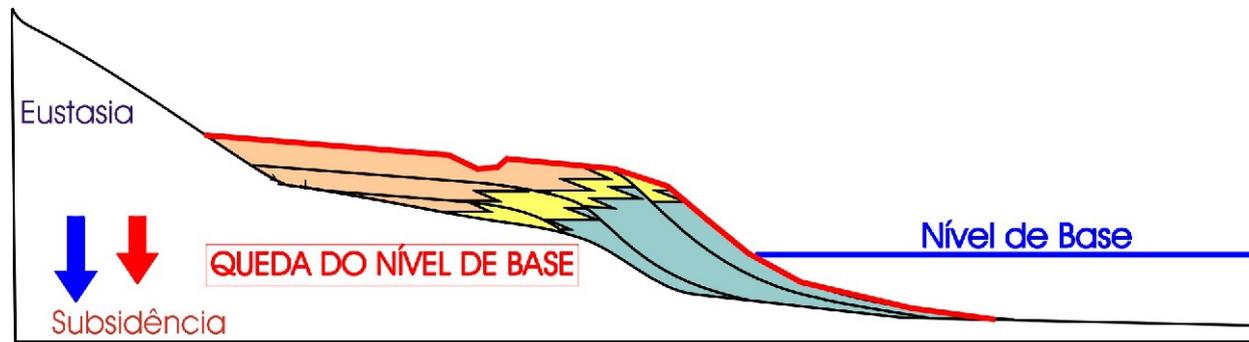
## Seqüência 1 - Trato de Mar Alto



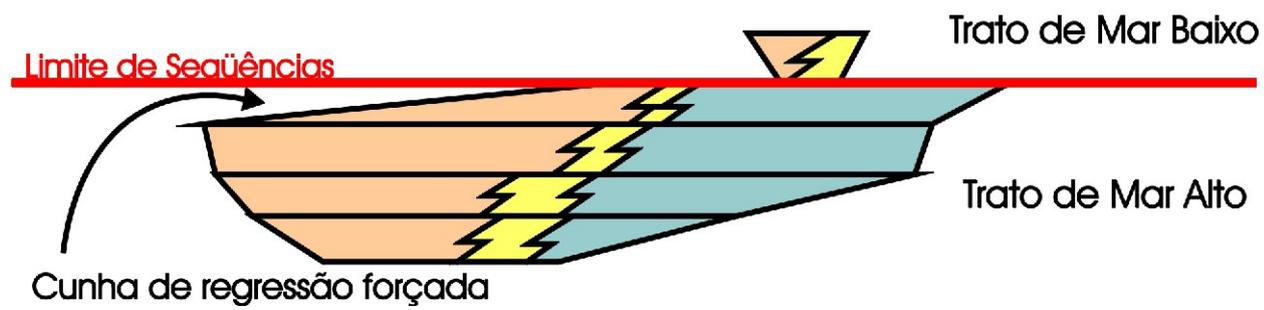
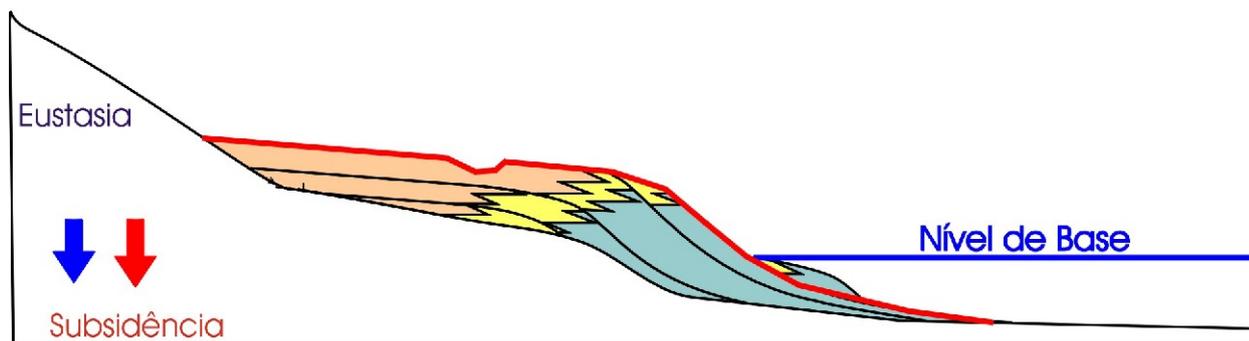
## Seqüência 1 - Cunha de regressão forçada



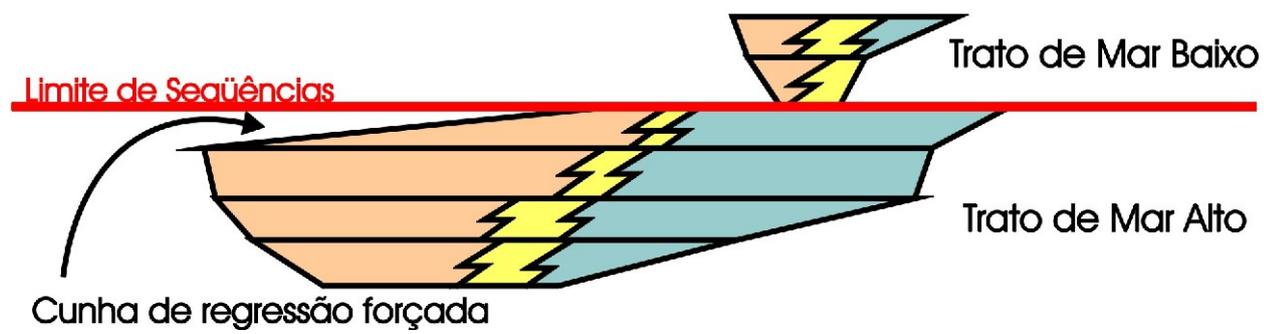
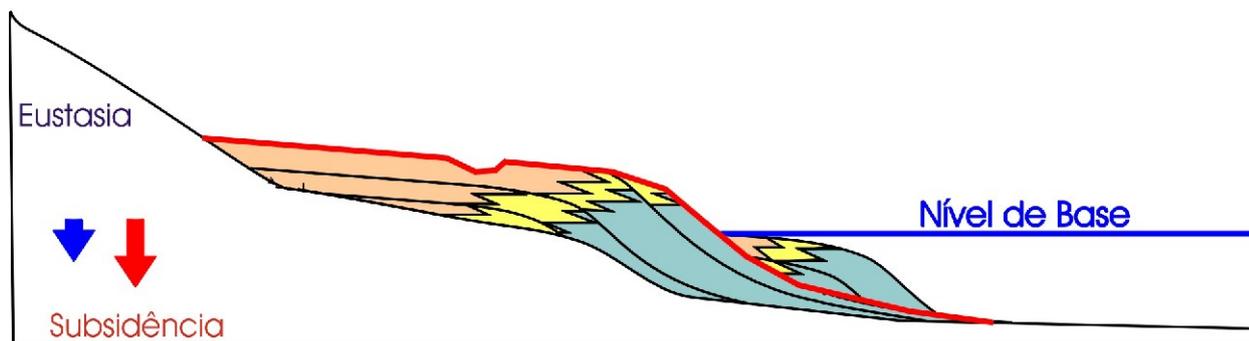
## Limite de Seqüências tipo 1



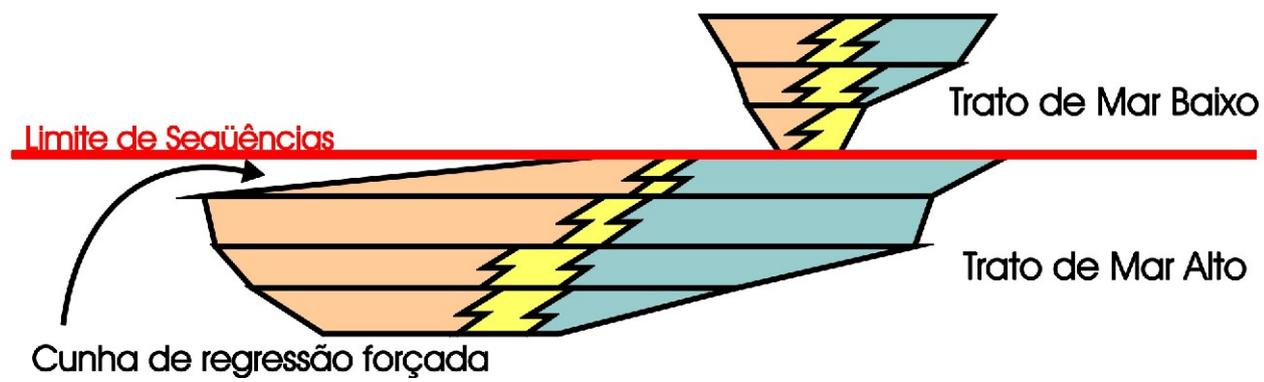
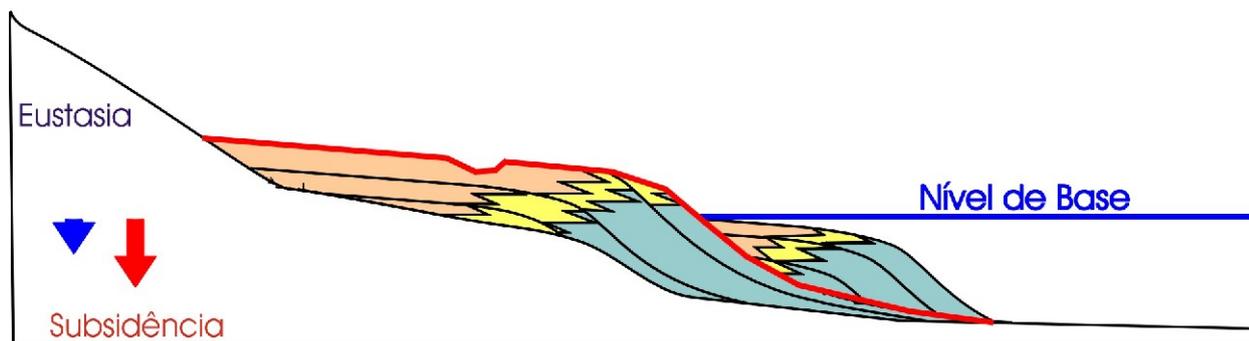
## Seqüência 2 - Trato de Mar Baixo



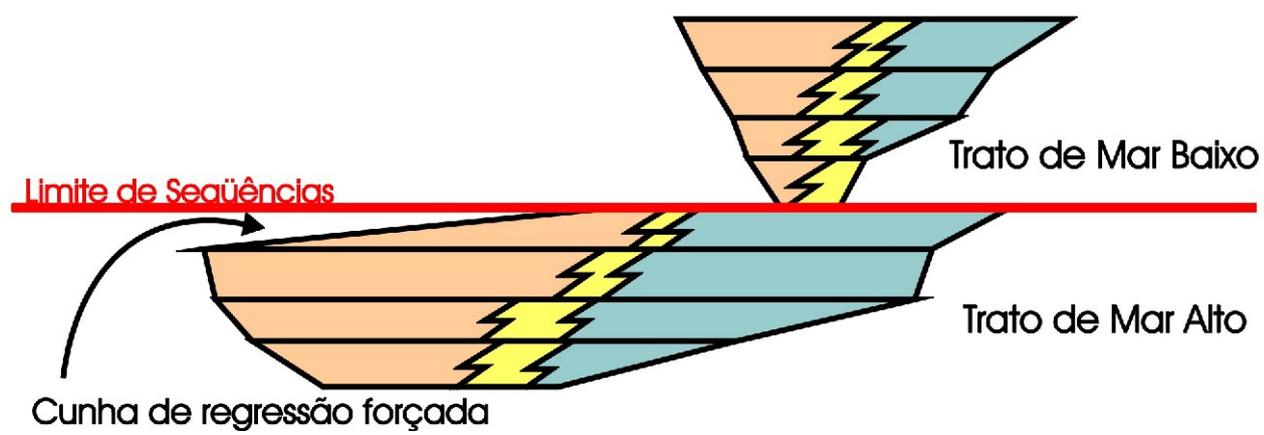
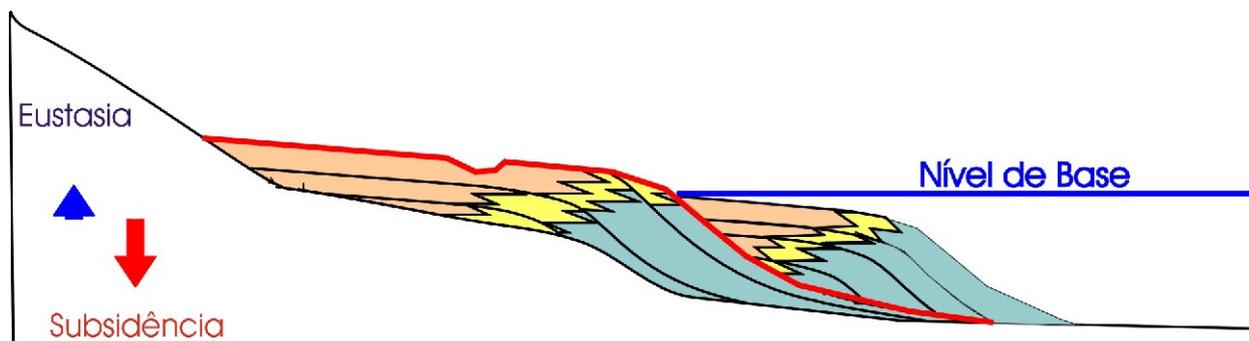
## Seqüência 2 - Trato de Mar Baixo



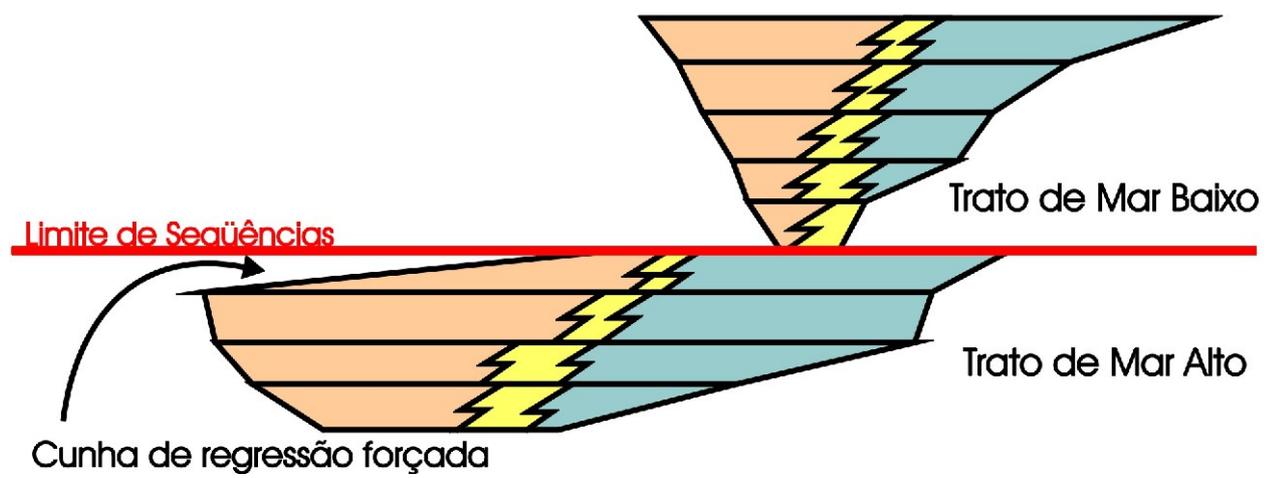
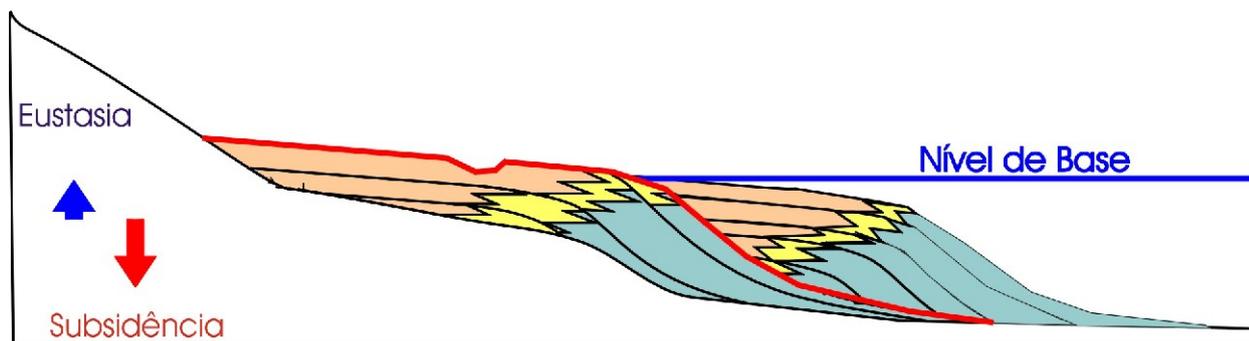
## Seqüência 2 - Trato de Mar Baixo



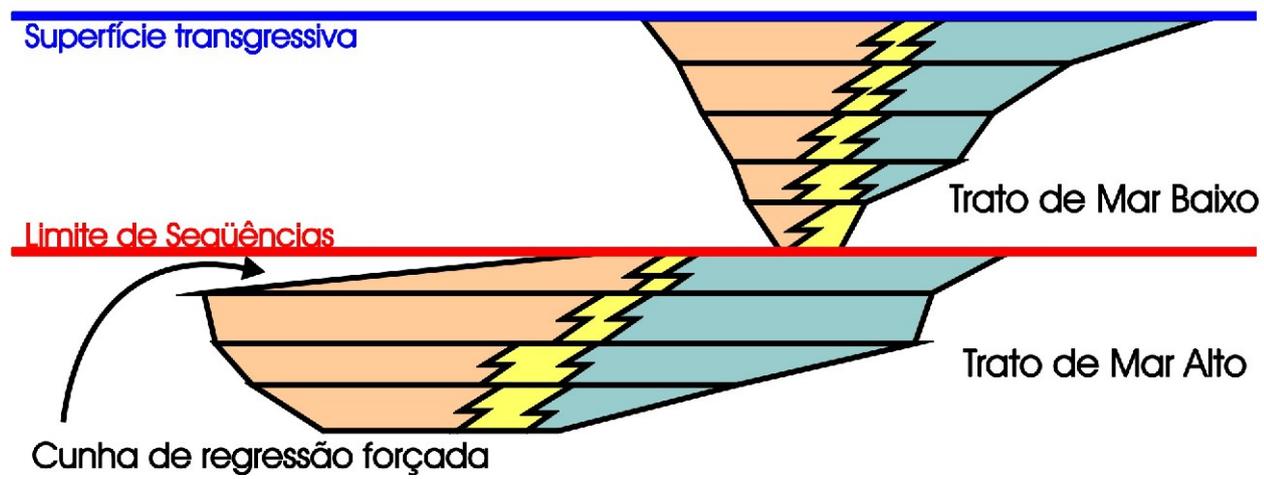
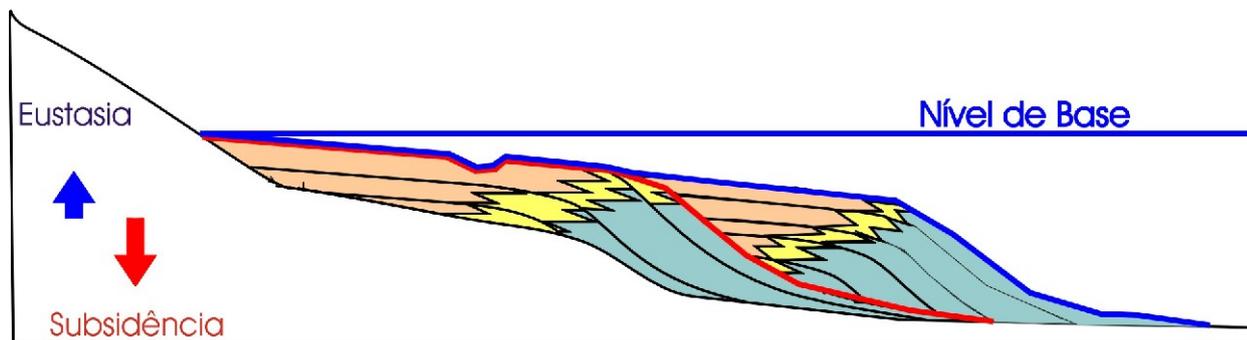
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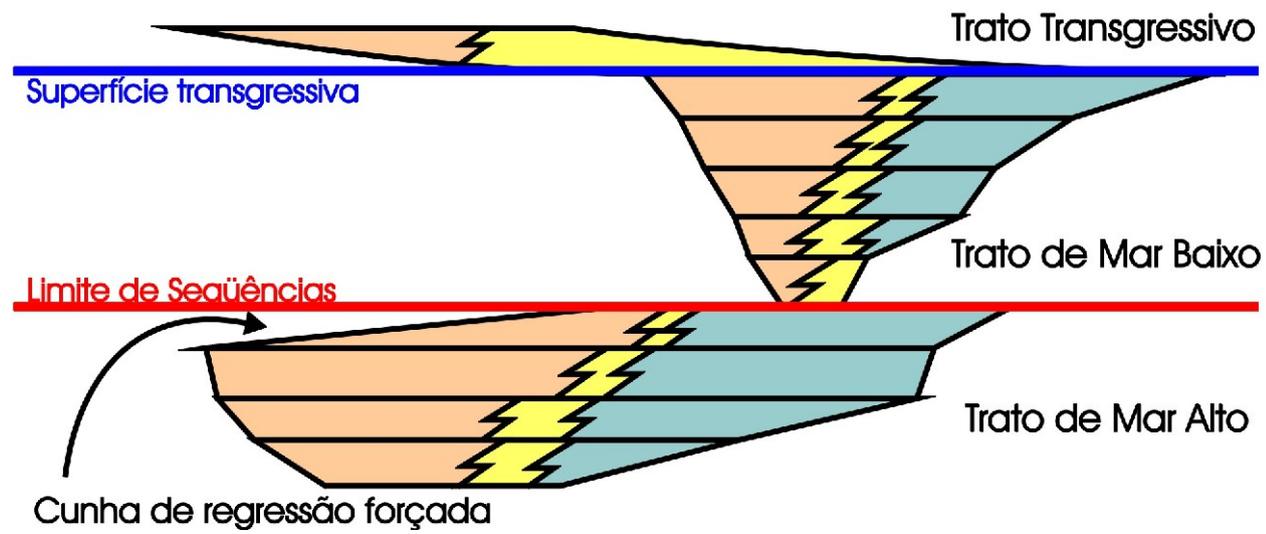
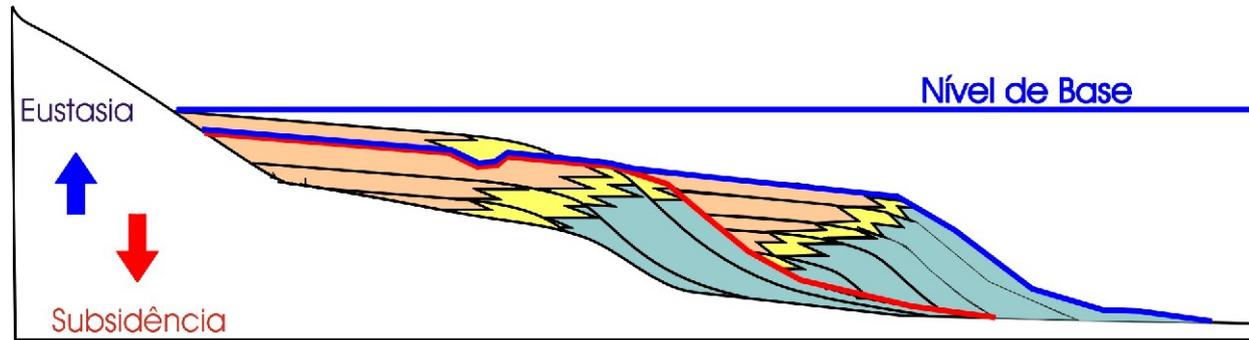
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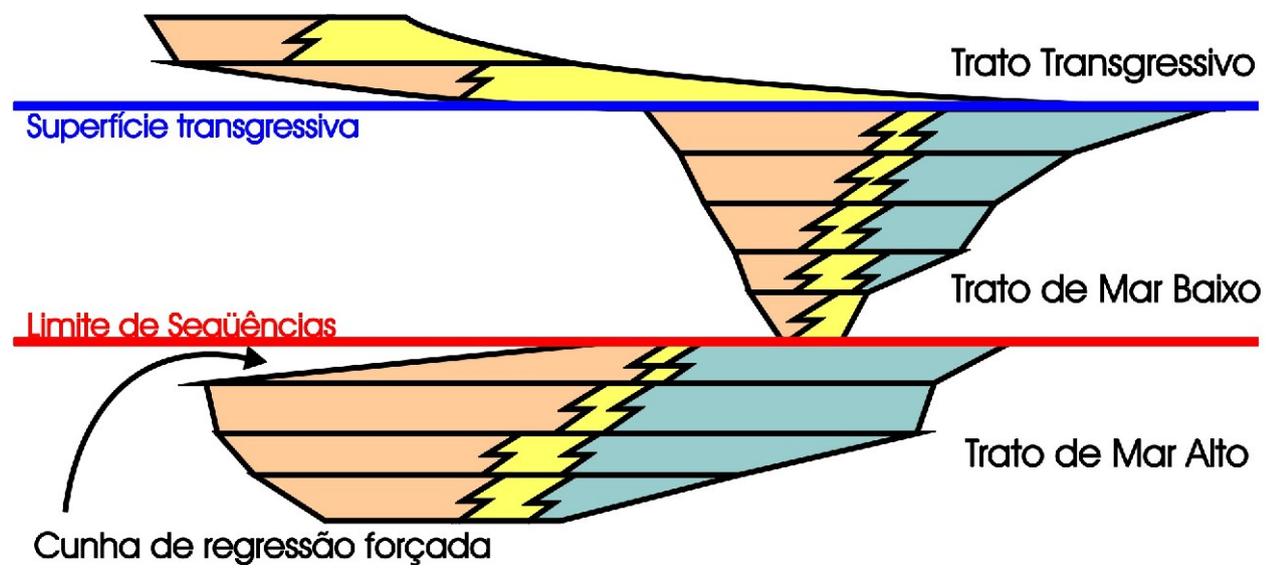
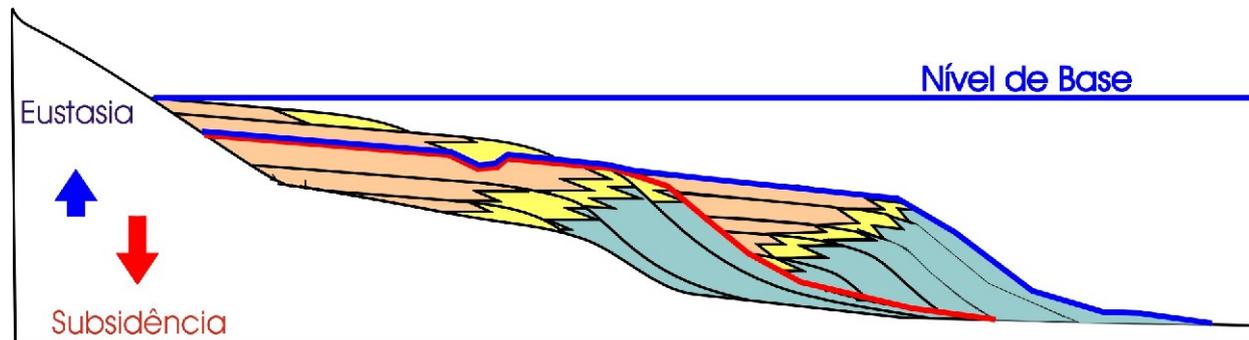
## Seqüência 2 - Superfície Transgressiva



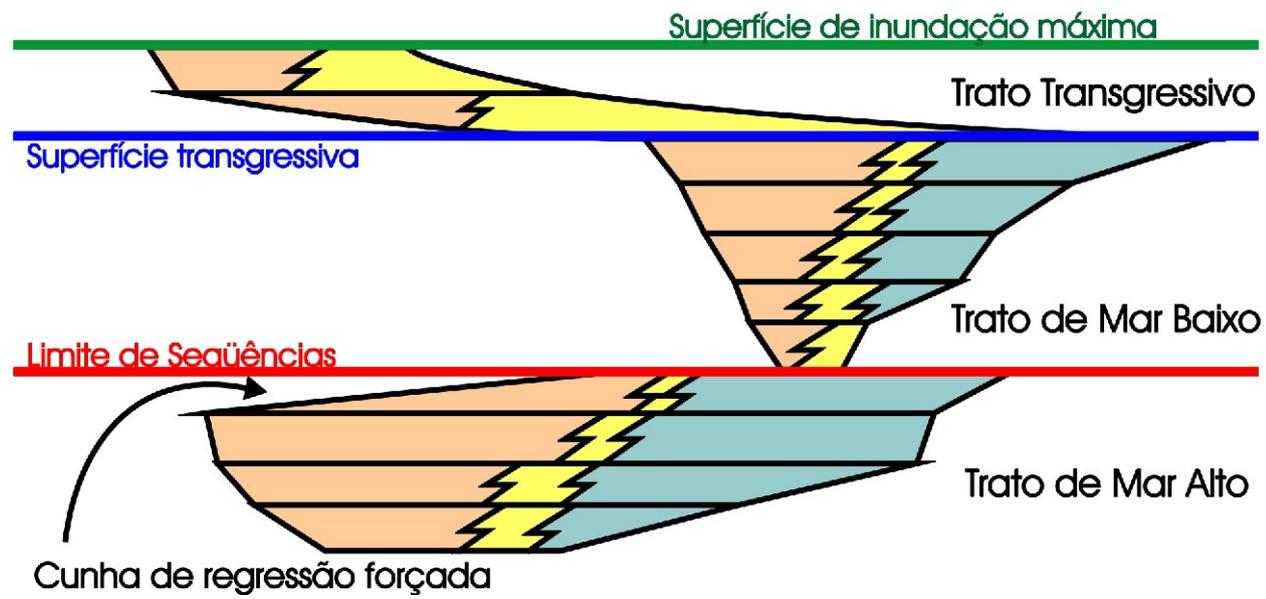
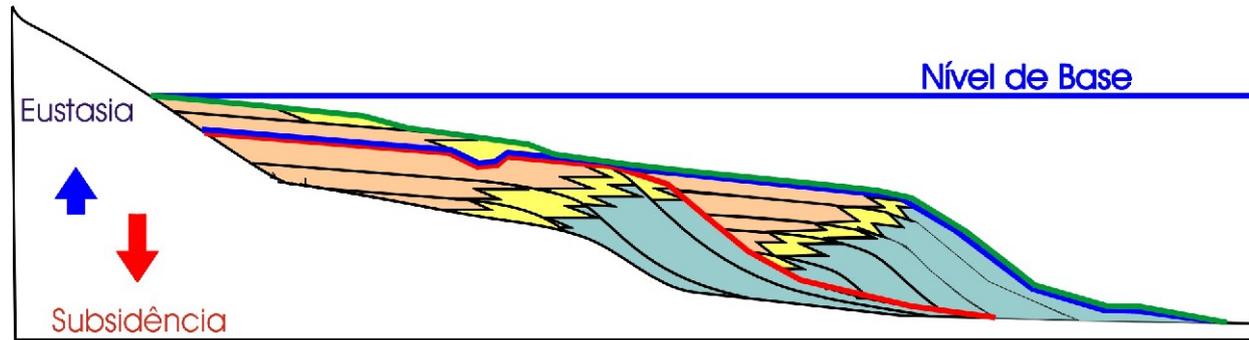
## Seqüência 2 - Trato Transgressivo



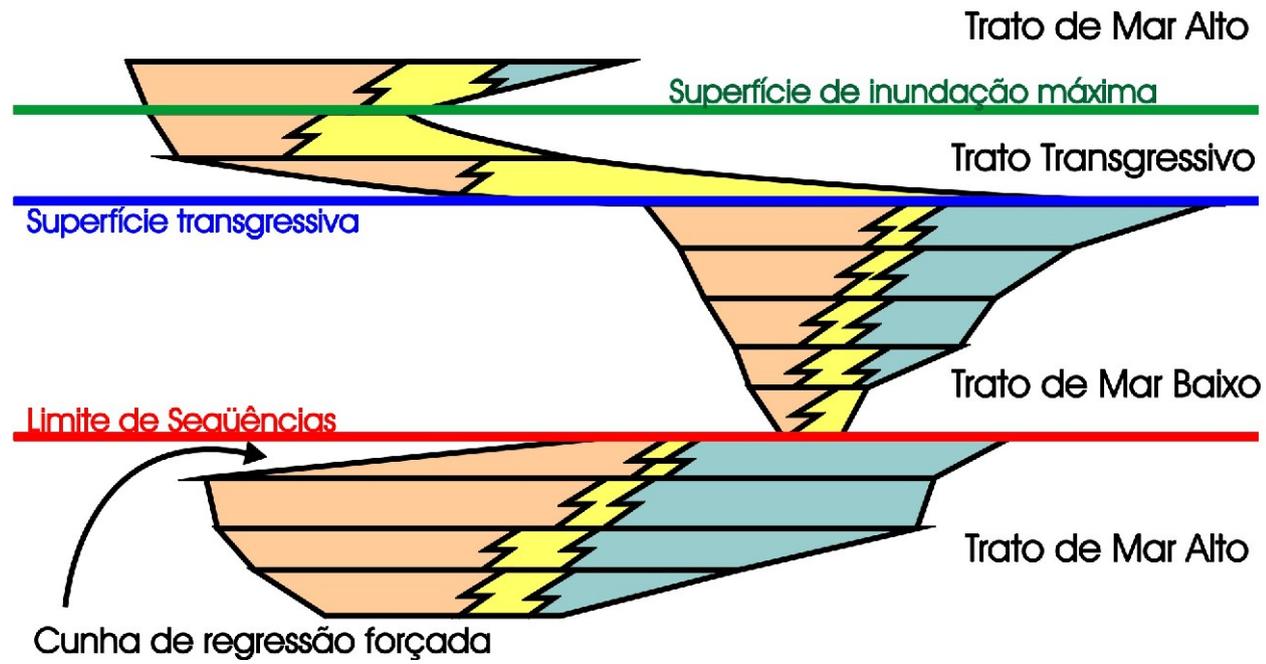
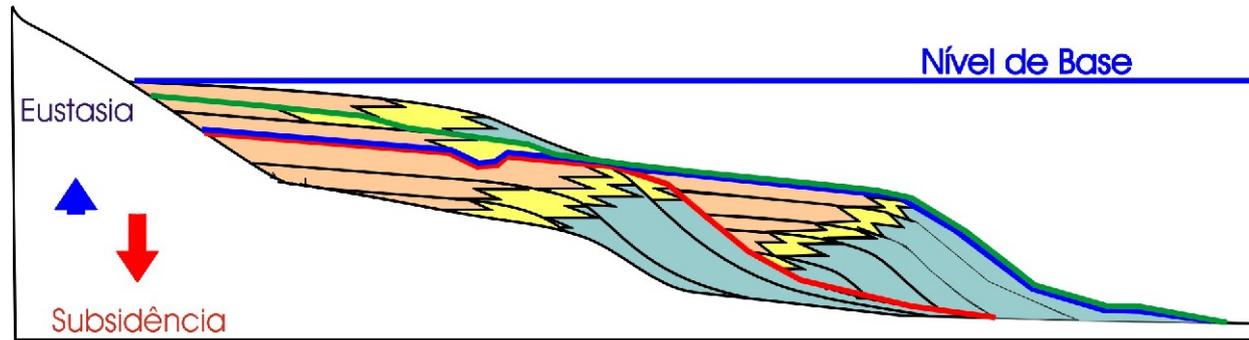
## Seqüência 2 - Trato Transgressivo



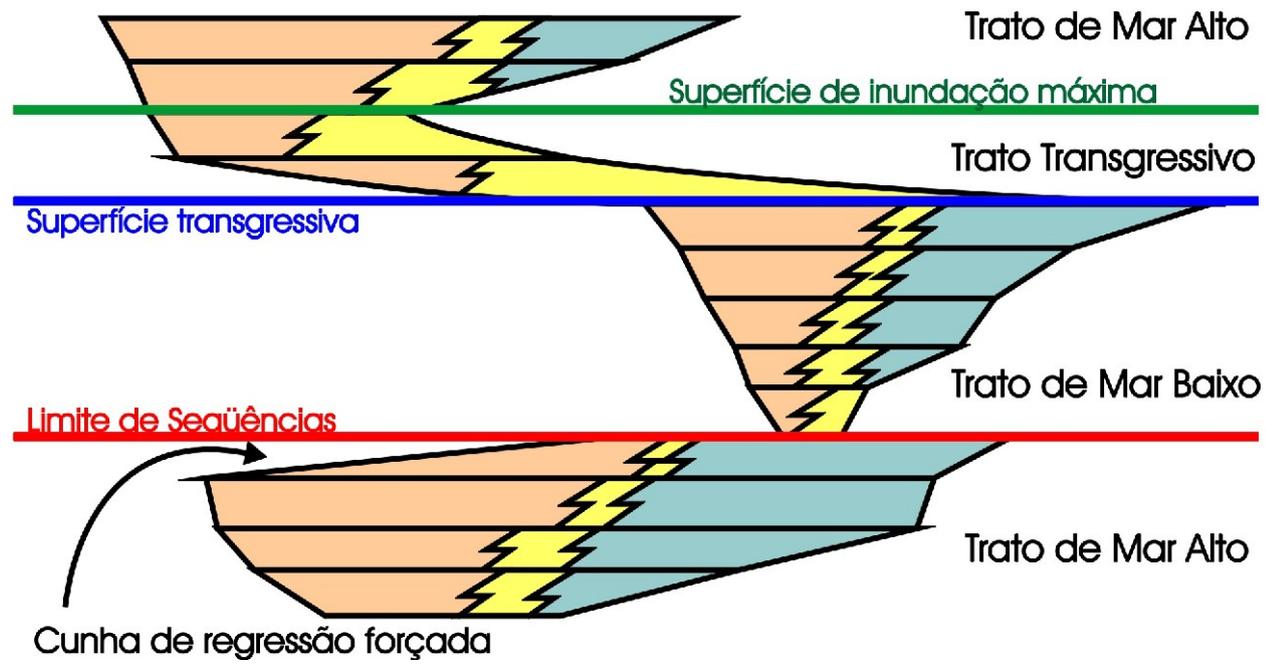
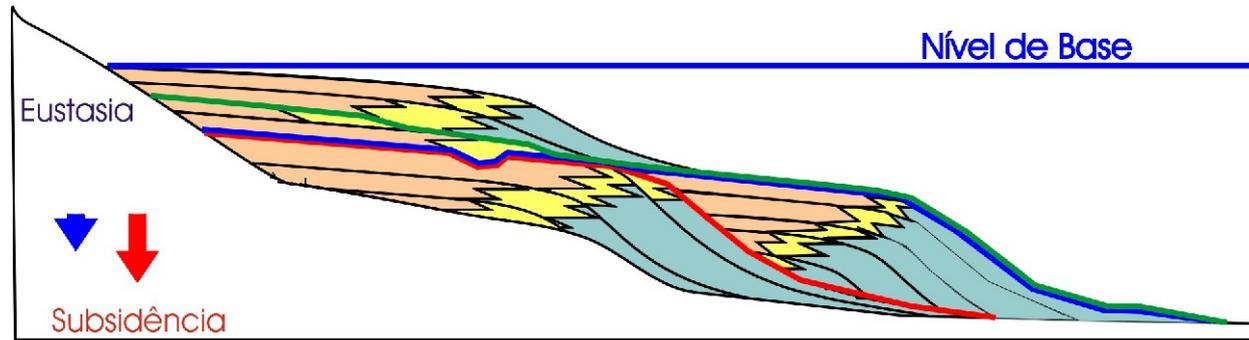
## Superfície de inundação máxima



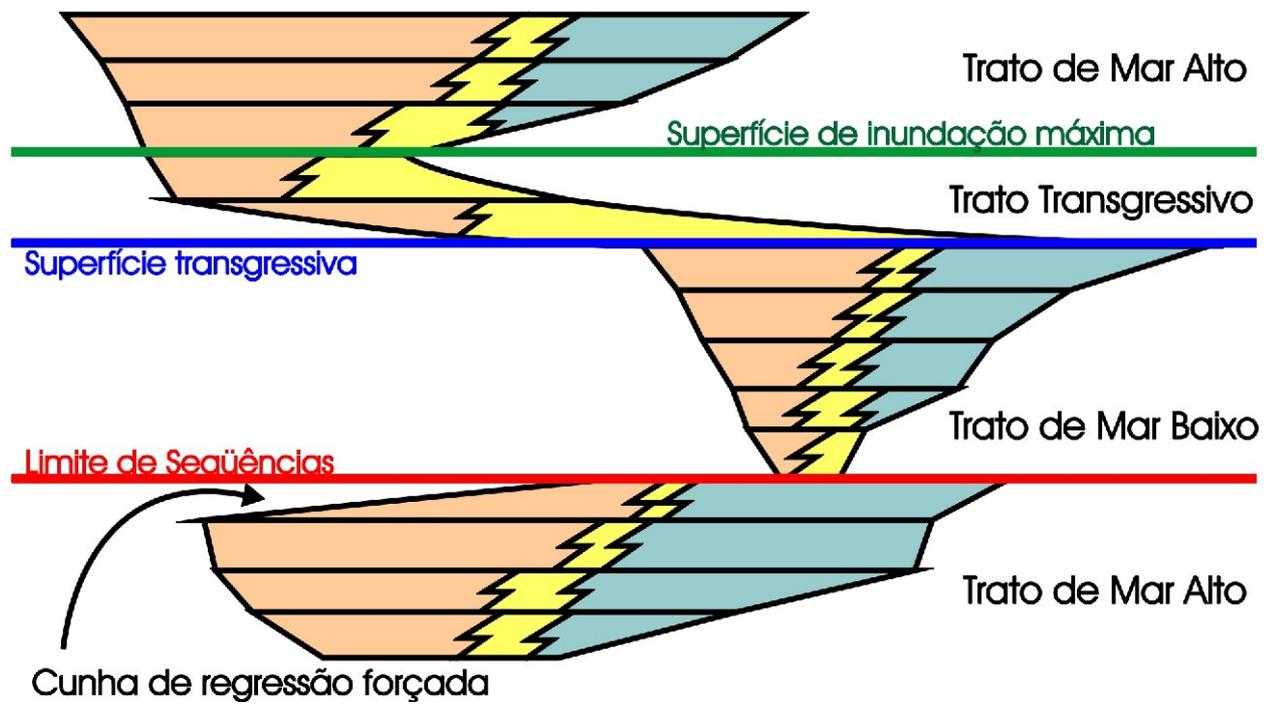
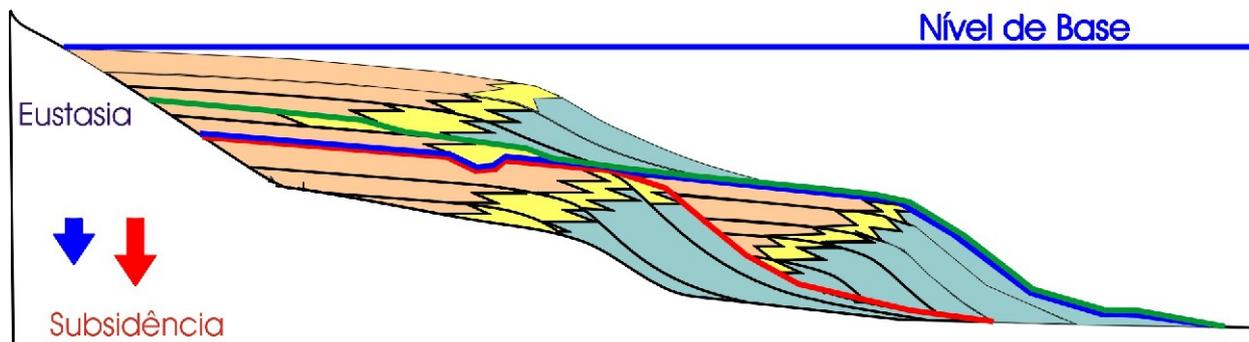
## Seqüência 2 - Trato de Mar Alto



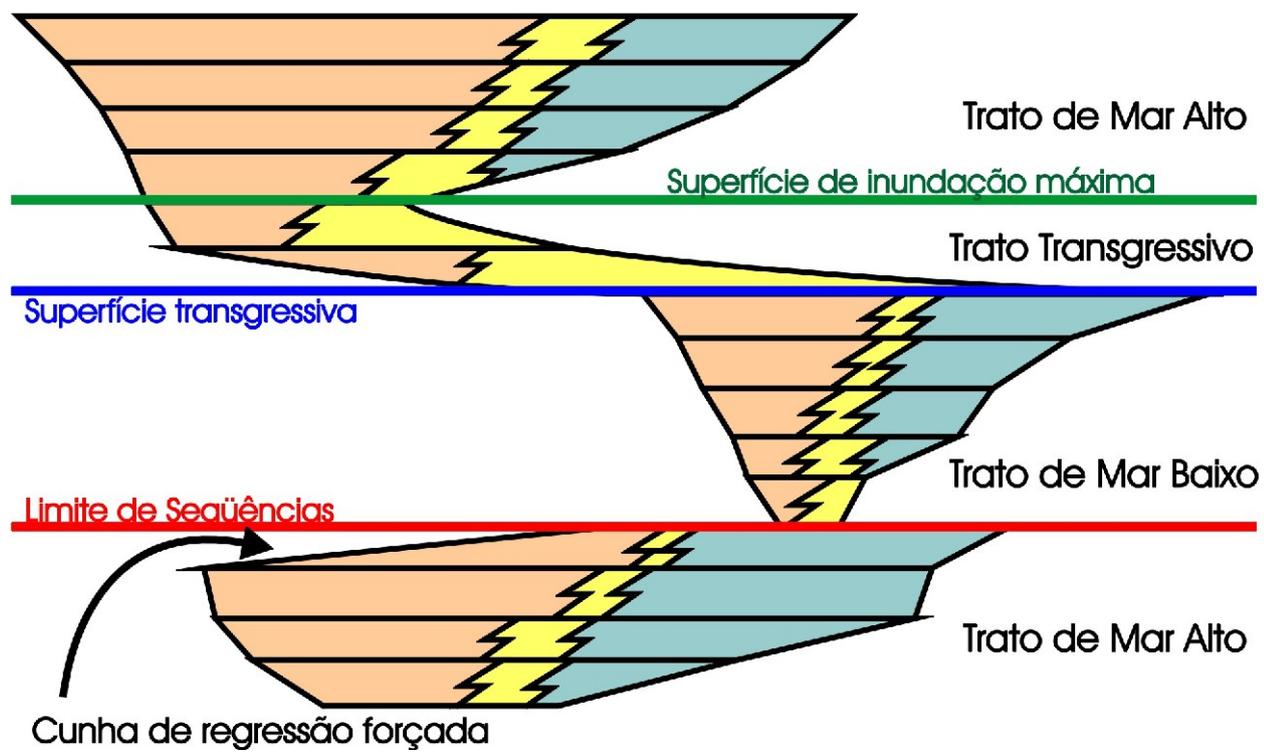
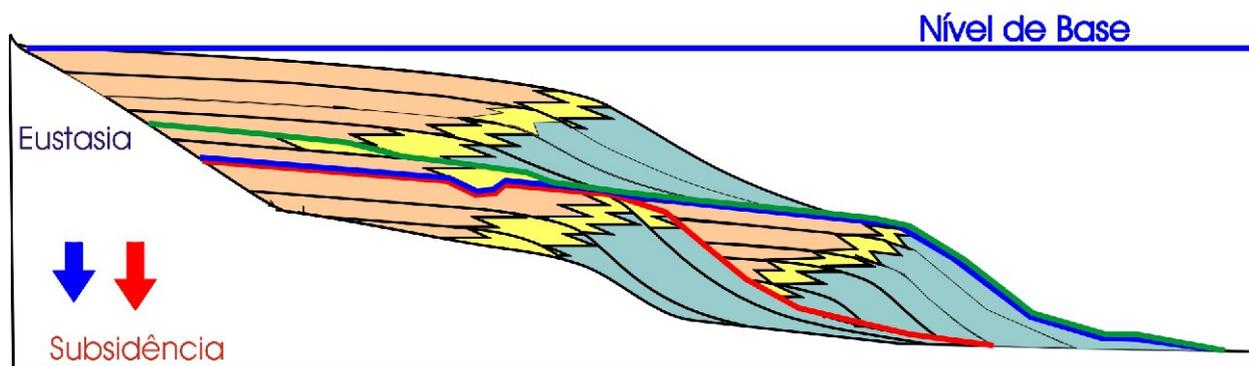
## Seqüência 2 - Trato de Mar Alto



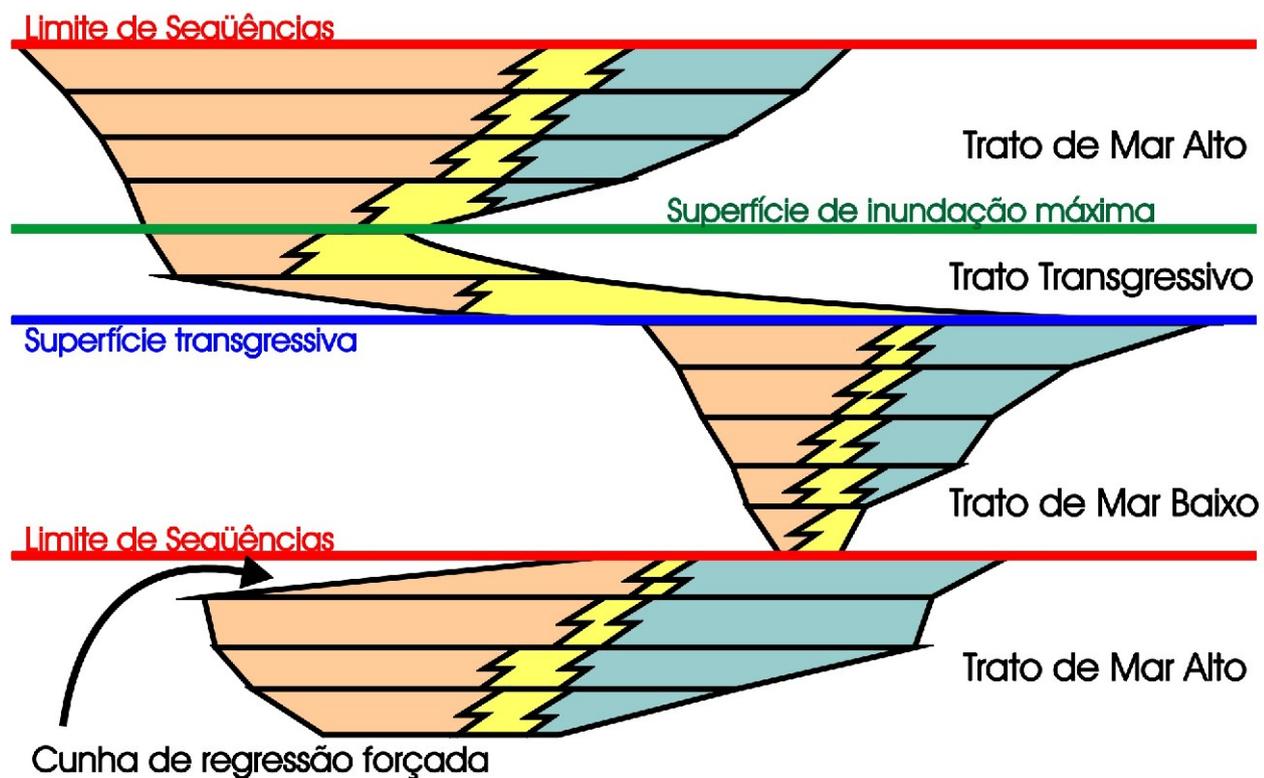
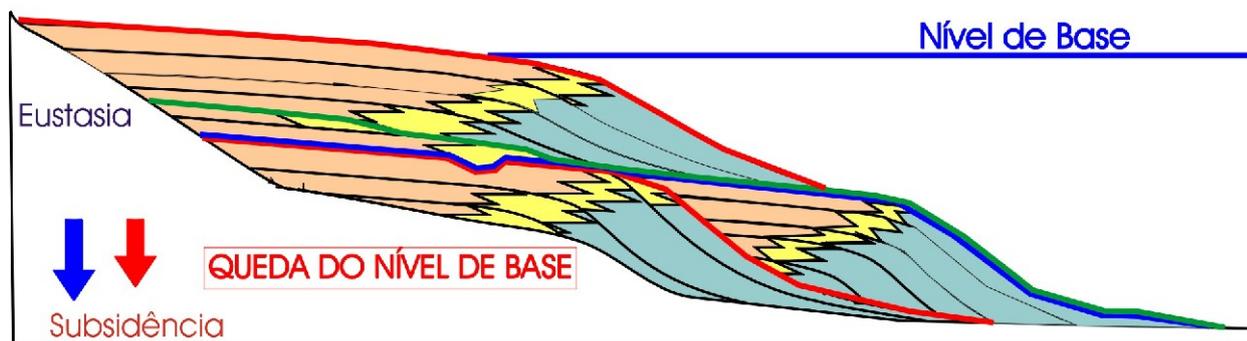
**Seqüência 2 - Trato de Mar Alto**



## Seqüência 2 - Trato de Mar Alto

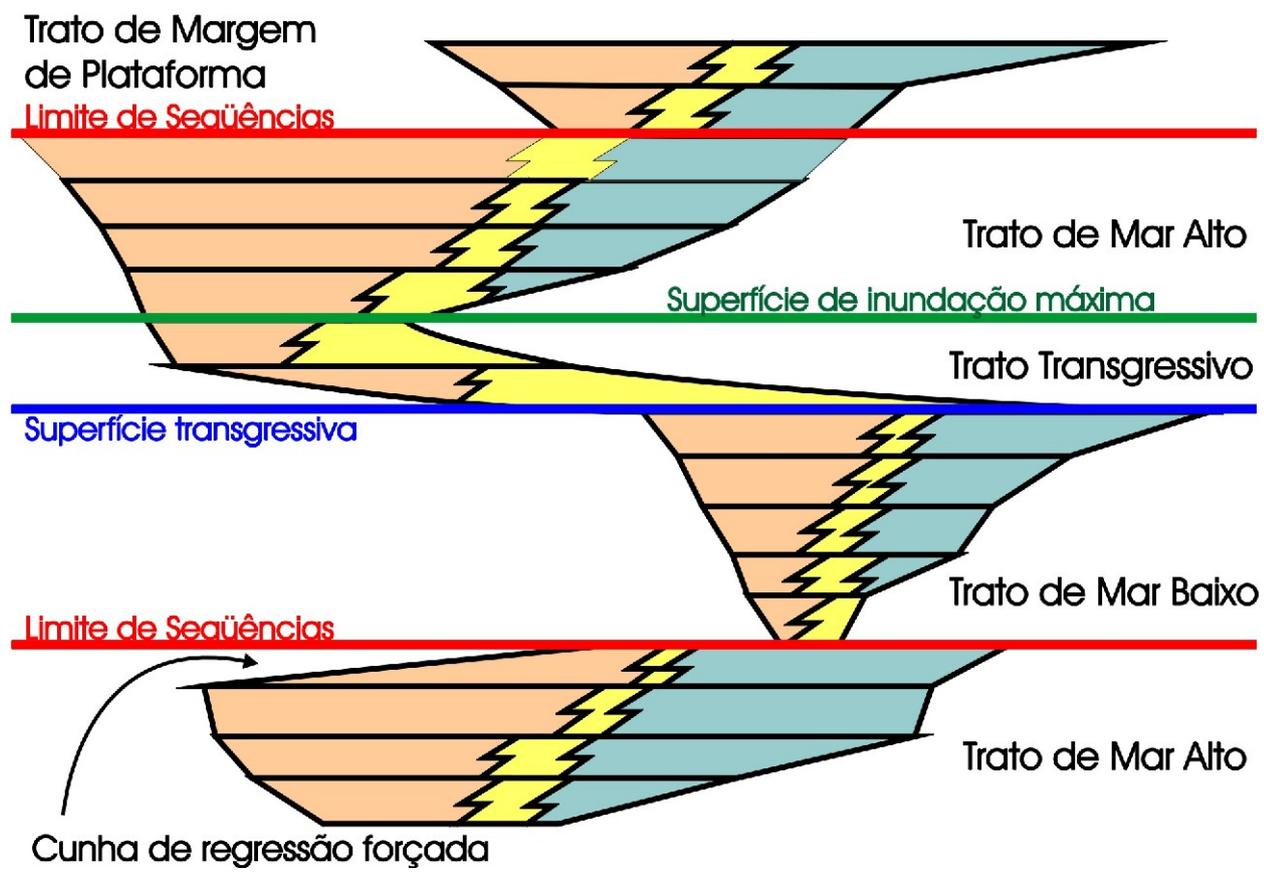
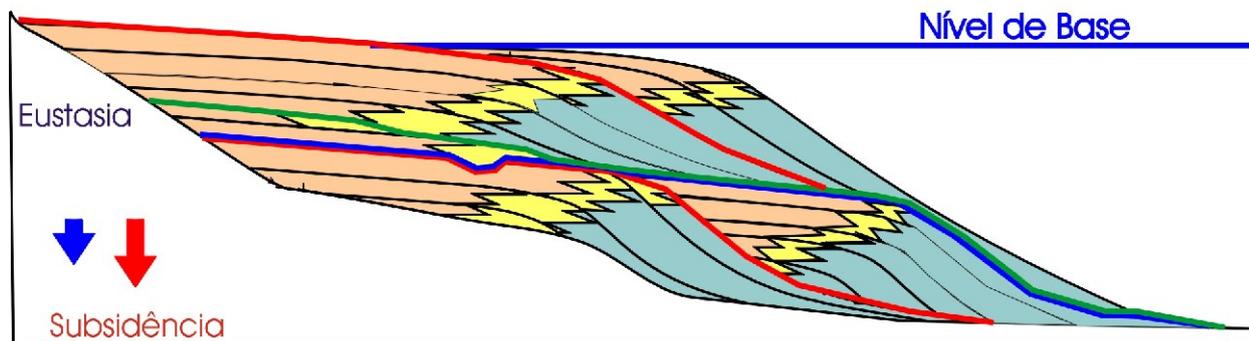


## Limite de seqüências tipo 2

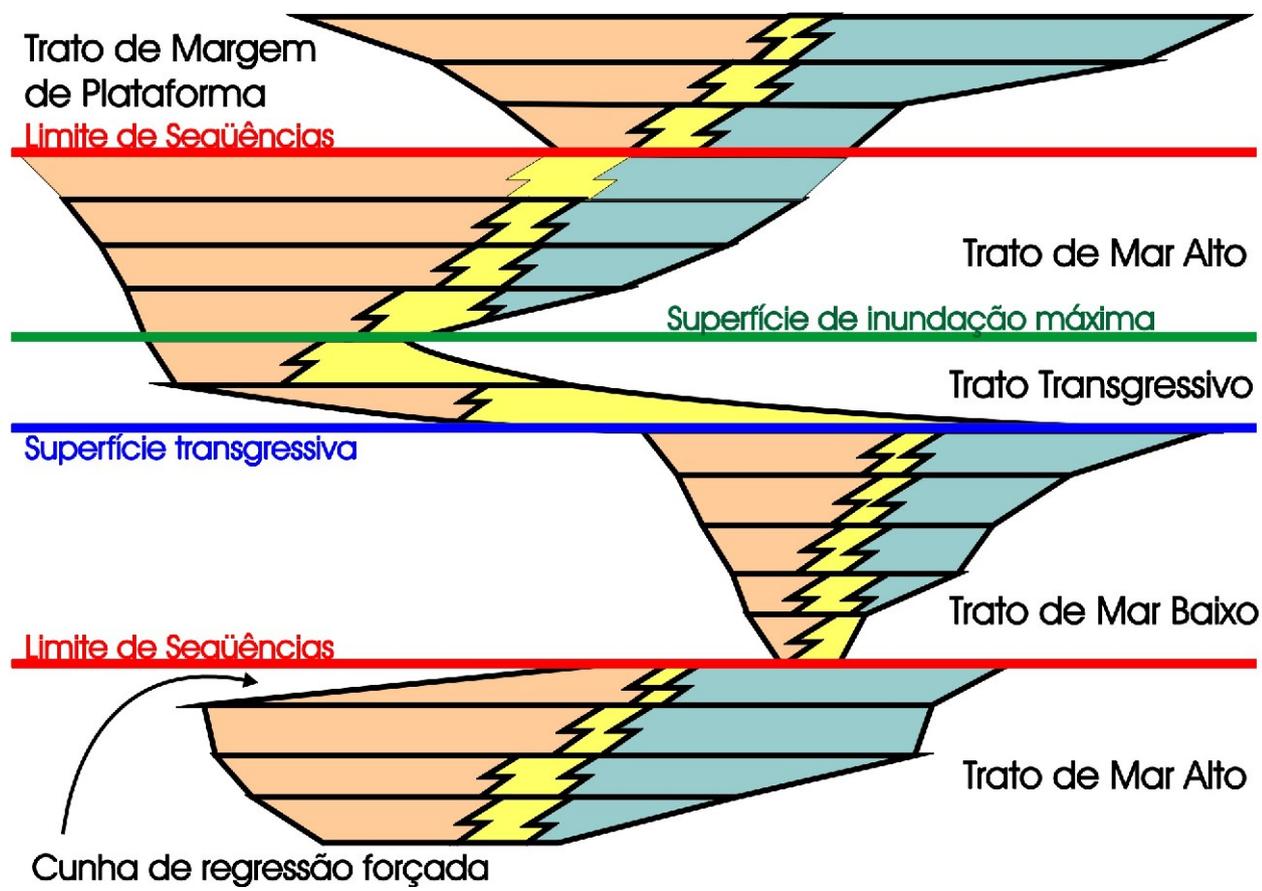
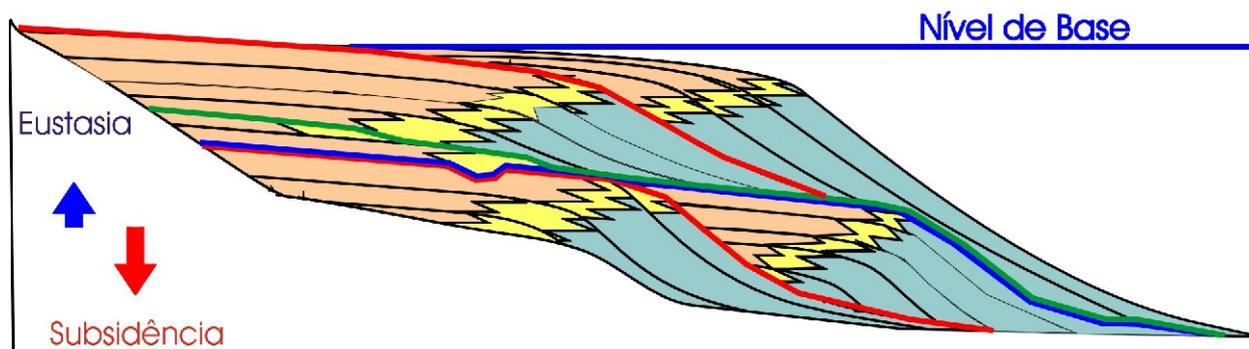




## Seqüência 3 - Trato de Margem de Plataforma

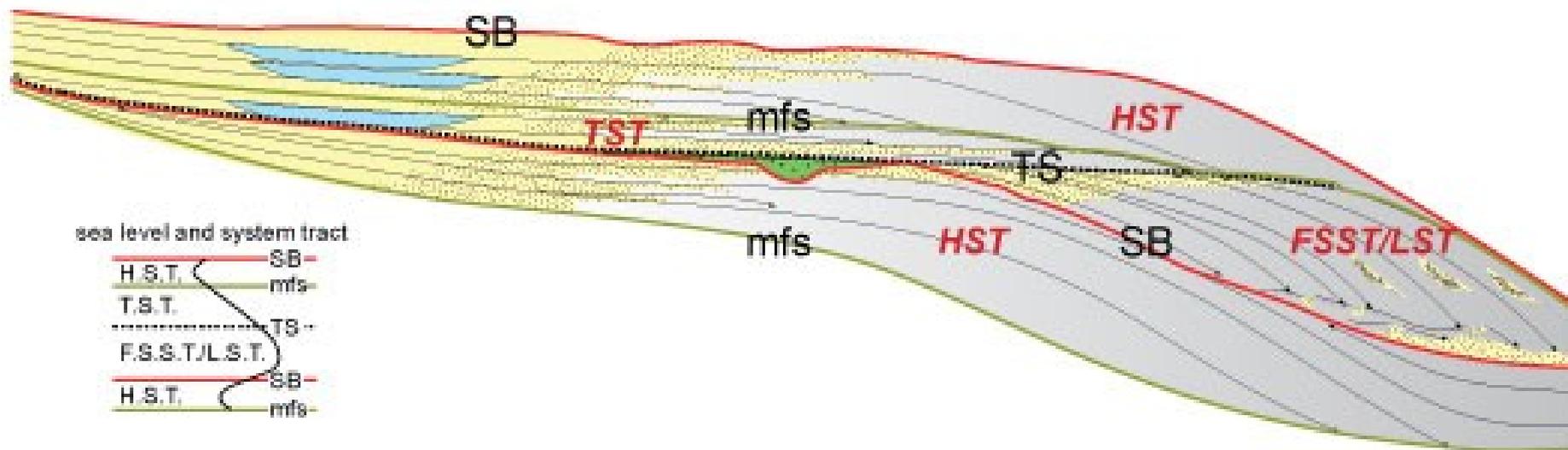


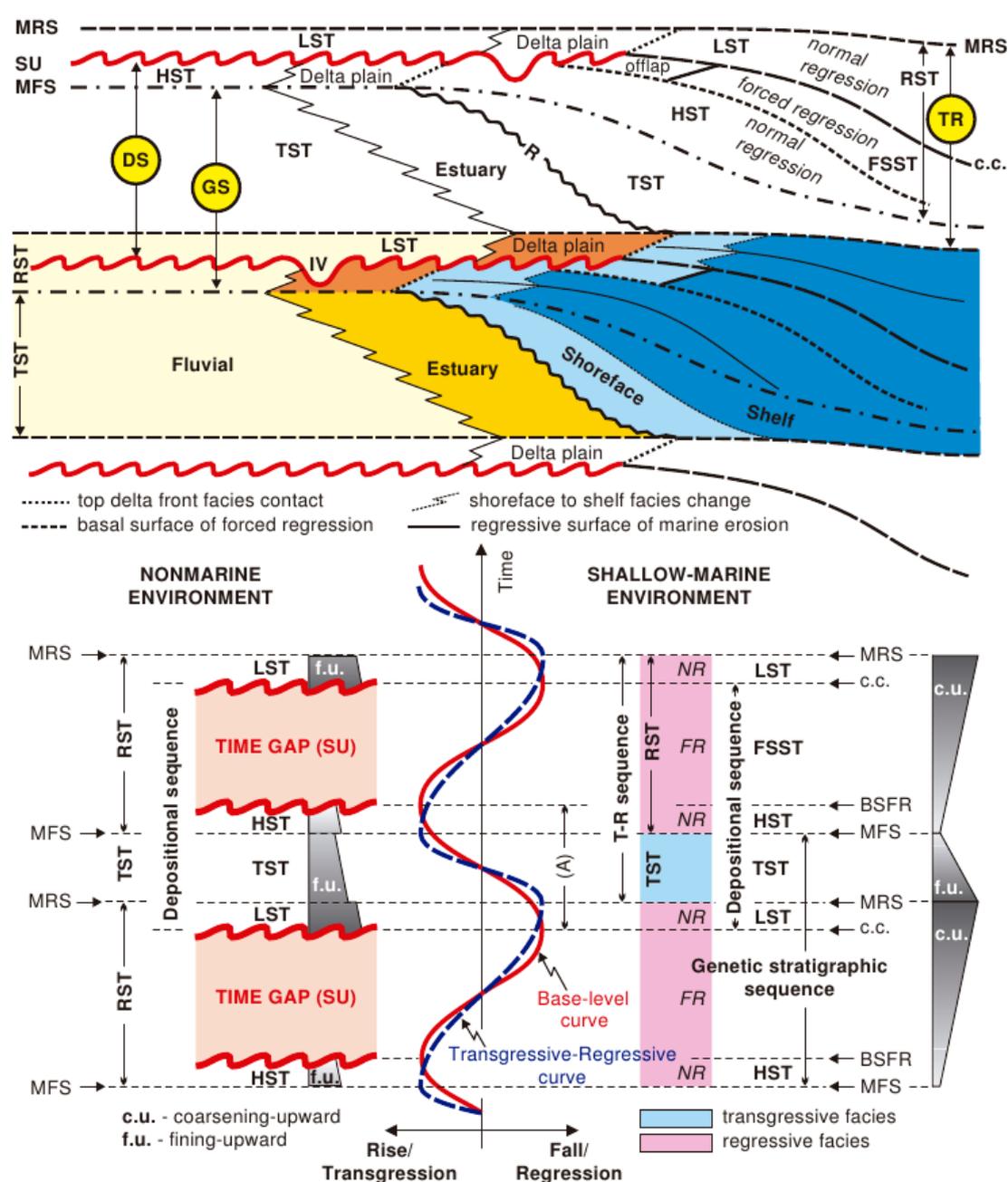
## Seqüência 3 - Trato de Margem de Plataforma



Distribuição dos sistemas deposicionais no modelo de seqüências:

- Colunas estratigráficas no sopé-talude: TMB (turbiditos) de várias seqüências separados por intervalos condensados (ST e SIM amalgamadas). LS não erosivo (base dos turbiditos).
- Colunas na margem da plataforma: deltas de TMB preenchimento de vales incisos no fim do TMB e no TT, deltas de TMA. LS erosivo ou não.
- Colunas de plataforma: TMB ausente fora de vales incisos profundos. LS erosivo amalgamado à ST. Ciclos transgressivo-regressivos (TT e TMA),
- Colunas de áreas continentais: LS erosivo de difícil reconhecimento em depósitos fluviais (só por paleossolos). Difícil distinção entre TMB (vales profundos) e TT (também fluvial). Superfície transgressiva marcada por aumento de depósitos de planícies aluviais.





**FIGURE 4.6** Sequences, systems tracts, and stratigraphic surfaces defined in relation to the base-level and the transgressive-regressive curves (modified from Catuneanu *et al.*, 1998b). Abbreviations: SU—subaerial unconformity; c.c.—correlative conformity (*sensu* Hunt and Tucker, 1992); BSFR—basal surface of forced regression (= correlative conformity *sensu* Posamentier *et al.*, 1988); MRS—maximum regressive surface; MFS—maximum flooding surface; R—transgressive wave-ravinement surface; IV—incised valley; (A)—positive accommodation (base-level rise); NR—normal regression; FR—forced regression; LST—lowstand systems tract (*sensu* Hunt and Tucker, 1992); TST—transgressive systems tract; HST—highstand systems tract; FSST—falling-stage systems tract; RST—regressive systems tract; DS—depositional sequence; GS—genetic stratigraphic sequence; TR—transgressive-regressive sequence.

## Escalas das Seqüências (Vail et al. 1977)

1ª ordem – Dezenas a centenas de Ma

2ª ordem – 10 a 18 Ma

3ª ordem – 1 a 10 Ma

4ª e 5ª ordens – Dezenas a centenas de Ka

- Controles na origem
- Características de cada ordem
- Arbitrariedade da hierarquização

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