Università degli studi di Trieste

LAUREA MAGISTRALE IN GEOSCIENZE

Classe Scienze e Tecnologie Geologiche

Curriculum: Esplorazione Geologica

Anno accademico 2022 - 2023

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

Docente: **Michele Rebesco**

Corso di Analisi di Bacino e Stratigrafia Sequenziale

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

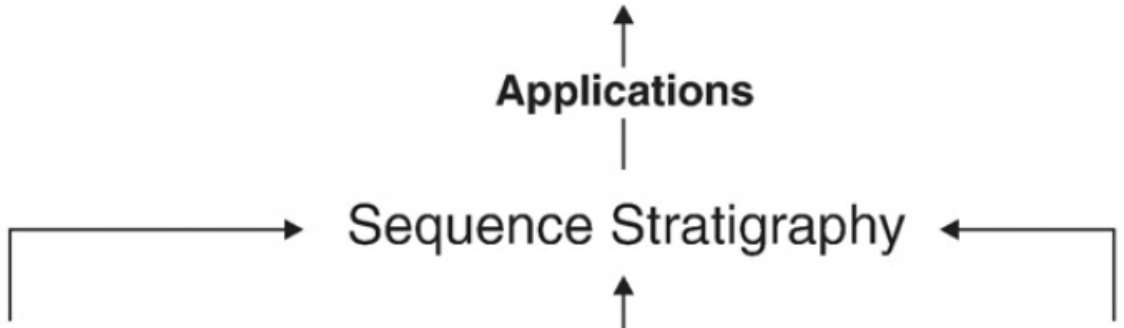
Unit	Topic	Teacher	Date
1.1	Introduction to the course	Rebesco	03/10/22
1.2	Methods (geophysics, but not only)	Volpi/Rebesco	06/10/22
6.1	Visit to the icebreaker Laura Bassi (along with Geologia Marina)	Rebesco	10/10/22
1.3	Mechanisms of basin formation (geodynamics, tectonics…)	Lodolo	13/10/22
1.4	Seismic interpretation, facies and primary structures	Rebesco	17/10/22
	No lesson: 20th October		
2.1	Sedimentary processes in river & deltas	Rebesco	24/10/22
	No lesson: 27th		
2.2	Action of tides and waves, wind and ice	Rebesco	31/10/22
	No lesson: 3rd November		
2.3	Density currents, bottom currents and mass transport	Lucchi/Rebesco	07/11/22
1.5	Energy storage & CCUS	Volpi/Donda	10/10/22
3.1	Alluvial deposits, lakes and deserts	Rebesco	11/11/22
	No lesson: 14th November		
3.2	Barrier systems and incised valleys	Rebesco	17/11/22
3.3	Continental shelves (wases, storms, tsunamis)	Rebesco	21/11/22
3.4	Mass transport deposits	Ford	24/11/22
3.5	Abyssal plains (hemipelagic fallout) and continental margins	Rebesco	28/11/22
3.6	Submarine fans (gravity flows on the continental slope)	Lucchi	01/12/22
3.7	Sediment drifts (bottom currents along the continental slope)	Rebesco	05/12/22
	No lesson on Thursday 8 th December		
3.8	Glacial depositional systems	De Santis	12/12/22
3.9	Carbonatic environments, faults, volcans	Rebesco	15/12/22
4.1	Sequence stratigraphy: introduction	Rebesco	19/12/22
	No lesson 22nd December till 8 th January		
4.2	Sequence stratigraphy: closer view	Rebesco	09/01/23
4.3	Sequence stratigraphy: applications (e.g. hydrocarbon reservoirs)	Rebesco	12/01/23
5	Excercise	Rebesco	13/01/23
6.2	Visit to OGS and SEISLAB (along with Geologia Marina)	Rebesco	20/01/23
6.3	Visit to CoreLoggingLAB (along with Geologia Marina)	Rebesco	24/02/??

Modulo 4.1
Sequence stratigraphy - introduction

Outline:

- General concepts
- Stratigraphic surfaces
- System Tracts

- **Academia:** genesis, evolution and internal architecture of sedimentary-basin fills
- **Government:** mapping and correlation on a regional to basin scale
- **Industry:** exploration and production - petroleum plays, coal, mineral resources



Integrated disciplines:

- Sedimentology
- Stratigraphy
- Geophysics
- Geomorphology
- Isotope Geochemistry
- Structural Geology
- Basin Analysis

Integrated data:

- seismic
- outcrop
- core
- well-log
- biostratigraphic
- geochemical

Main controls:

- sea-level change
- subsidence, uplift
- climate
- sediment supply
- basin physiography
- environmental energy
- biota

Historical development

Sequences
Sloss et al. (1949)

Depositional Sequence I
(Seismic Stratigraphy)
Mitchum et al. (1977)

Sequence Stratigraphy

Depositional Sequence II
Haq et al. (1987)
Posamentier et al. (1988)

Depositional Sequence III
Van Wagoner et al. (1988, 1990)
Christie-Blick (1991)

Depositional Sequence IV
Hunt & Tucker (1992, 1995)
Helland-Hansen & Gjelberg (1994)

Genetic Sequences
Frazier (1974)
Galloway (1989)

T-R Sequences
Johnson & Murphy (1984)
Embry & Johannessen (1992)

Definitions

Sequence stratigraphy (Posamentier et al., 1988; Van Wagoner, 1995): the study of rock relationships within a time-stratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or nondeposition, or their correlative conformities.

Sequence stratigraphy (Galloway, 1989): the analysis of repetitive genetically related depositional units bounded in part by surfaces of nondeposition or erosion.

Sequence stratigraphy (Posamentier and Allen, 1999): the analysis of cyclic sedimentation patterns that are present in stratigraphic successions, as they develop in response to variations in sediment supply and space available for sediment to accumulate.

Sequence stratigraphy (Catuneanu, 2006): the analysis of the sedimentary response to changes in base level, and the depositional trends that emerge from the interplay of accommodation (space available for sediments to fill) and sedimentation.

Sequence (Mitchum, 1977): a relatively conformable succession of genetically related strata bounded by unconformities or their correlative conformities.

Systems tract (Brown and Fisher, 1977): a linkage of contemporaneous depositional systems, forming the subdivision of a sequence.

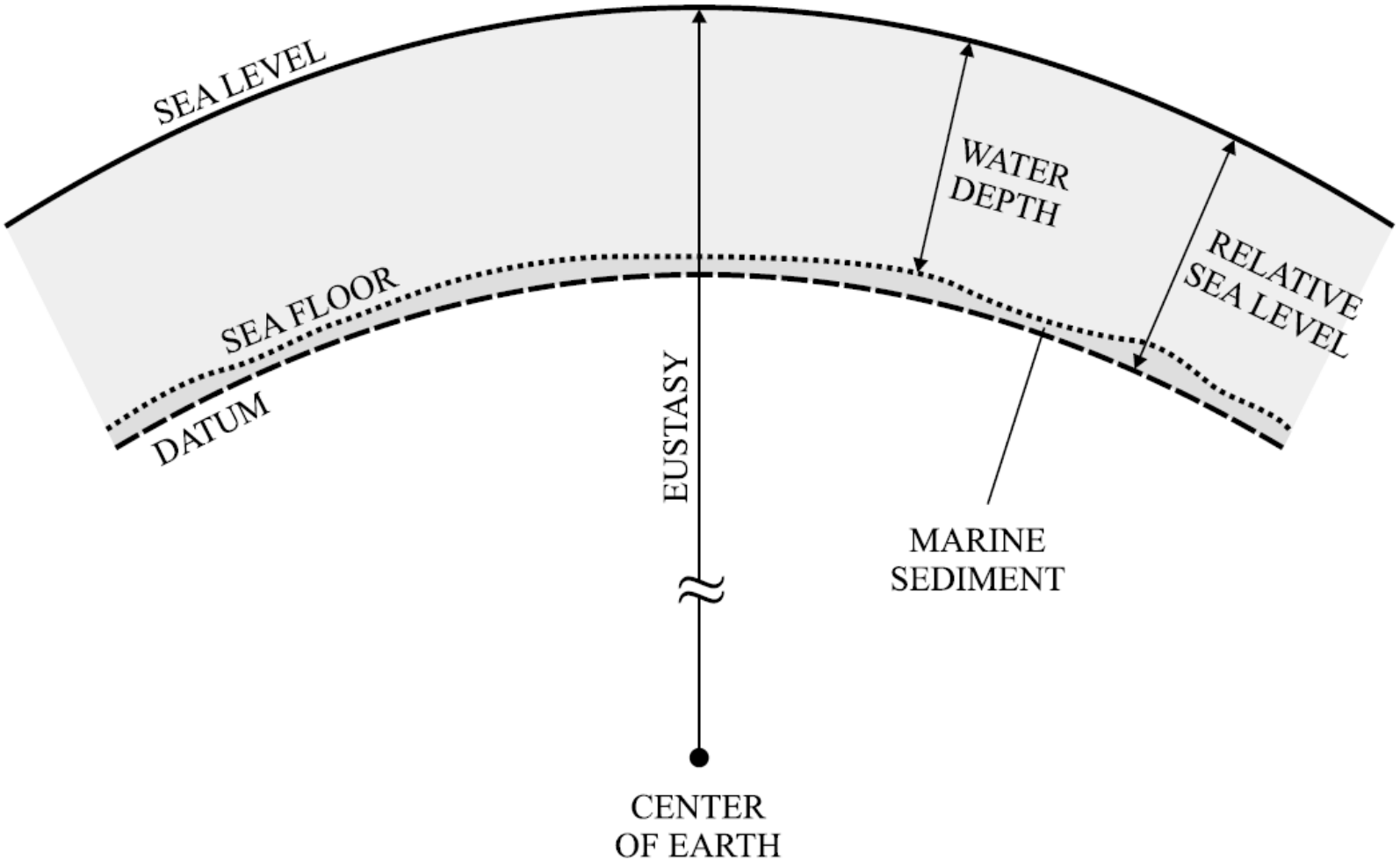
Key concepts

Relative sea-level: sea level relative to an immaginary reference horizon called 'datum' (Posamentier et al., 1988; Catuneanu, 2002).

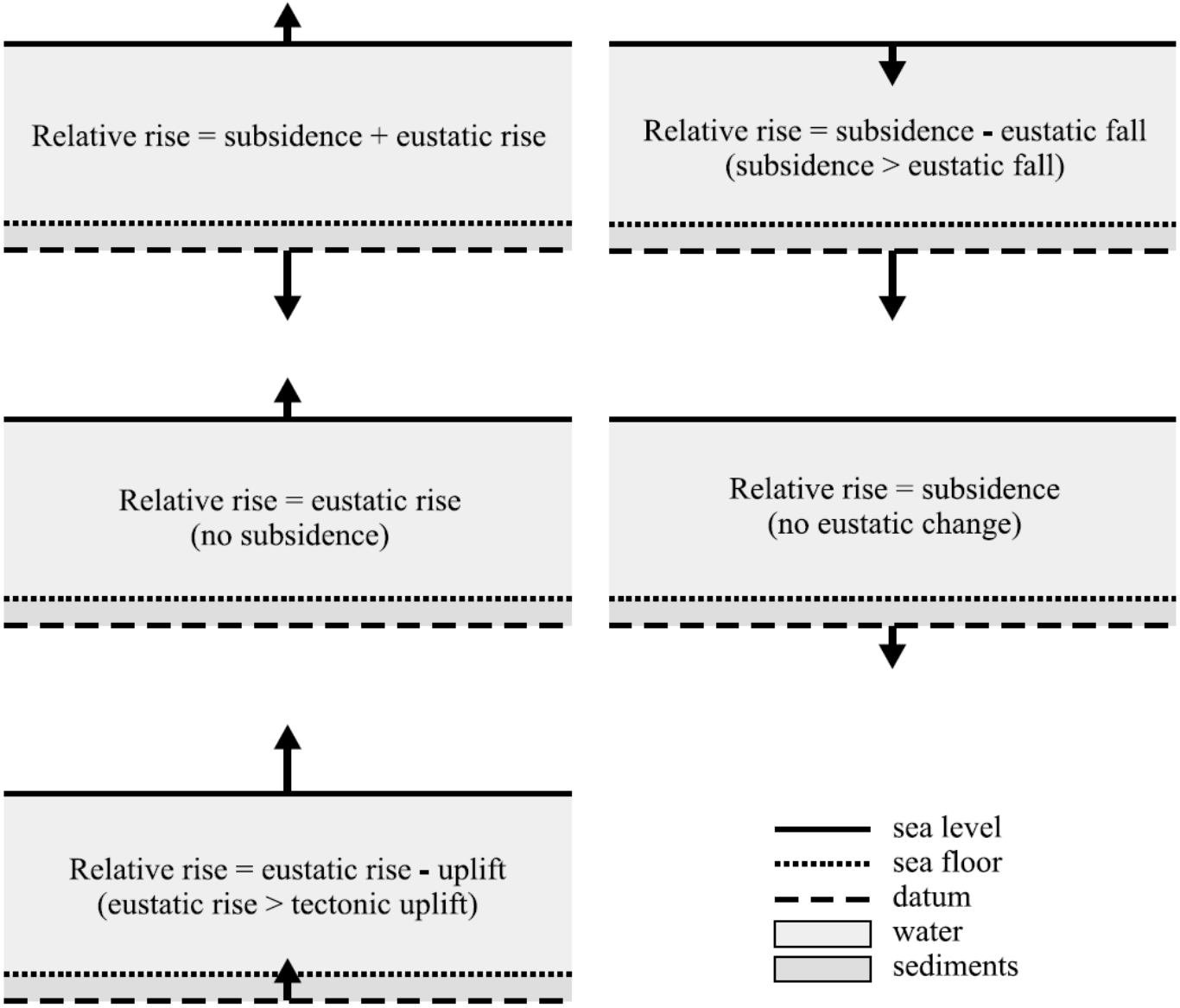
Base level: a surface of equilibrium which sedimentary processes strive to attain, at which neither erosion nor deposition takes place (Barrell, 1917).
Temporary base level: a surface of temporary equilibrium between sediment supply and energy (examples: seafloor, river bed)
Ultimate base level = sea level

Accommodation (space): the space available for the accumulation of sediment (Jervey, 1988). It can be created or destroyed by variations of relative sea level.

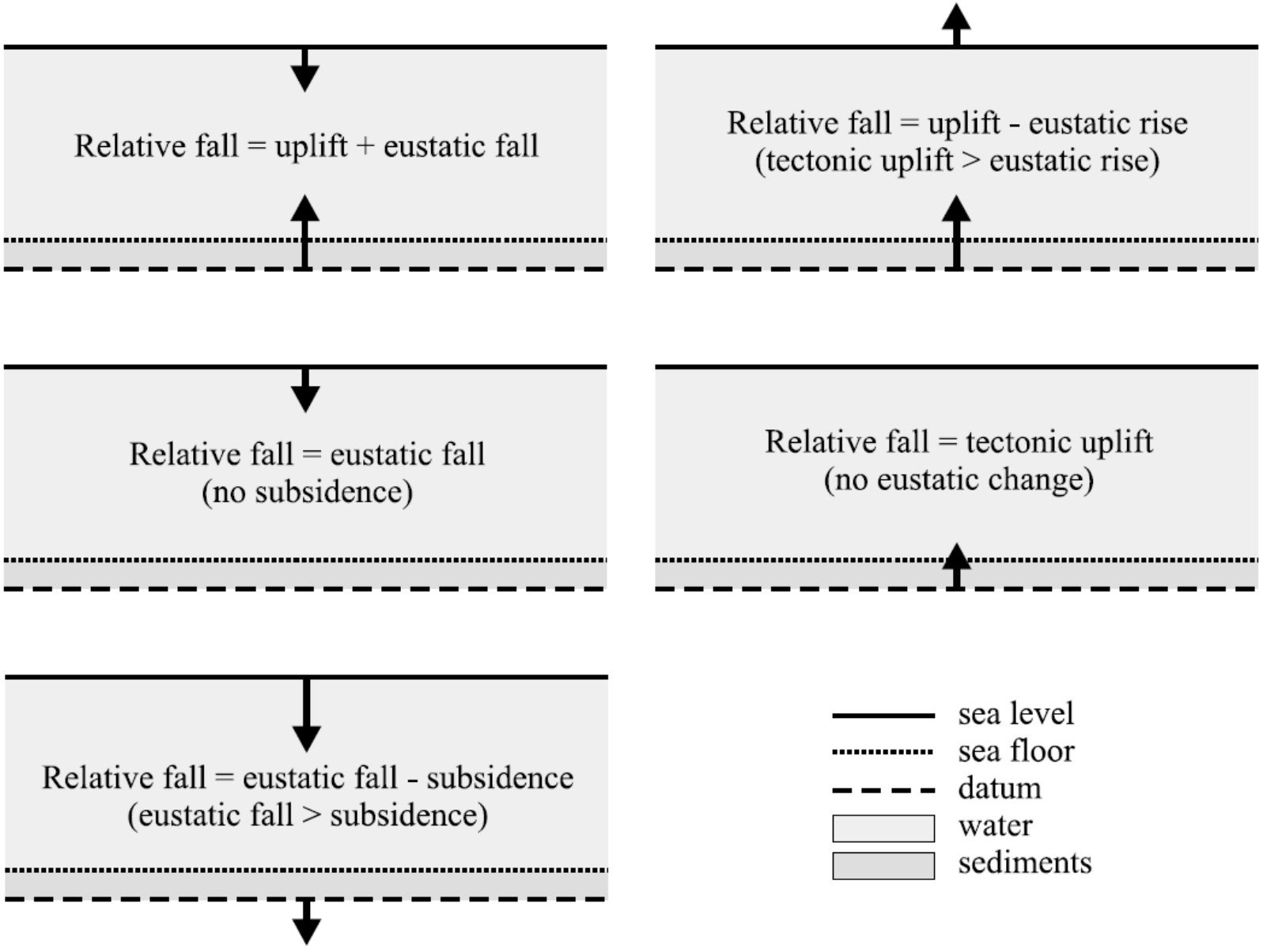
Relative sea level



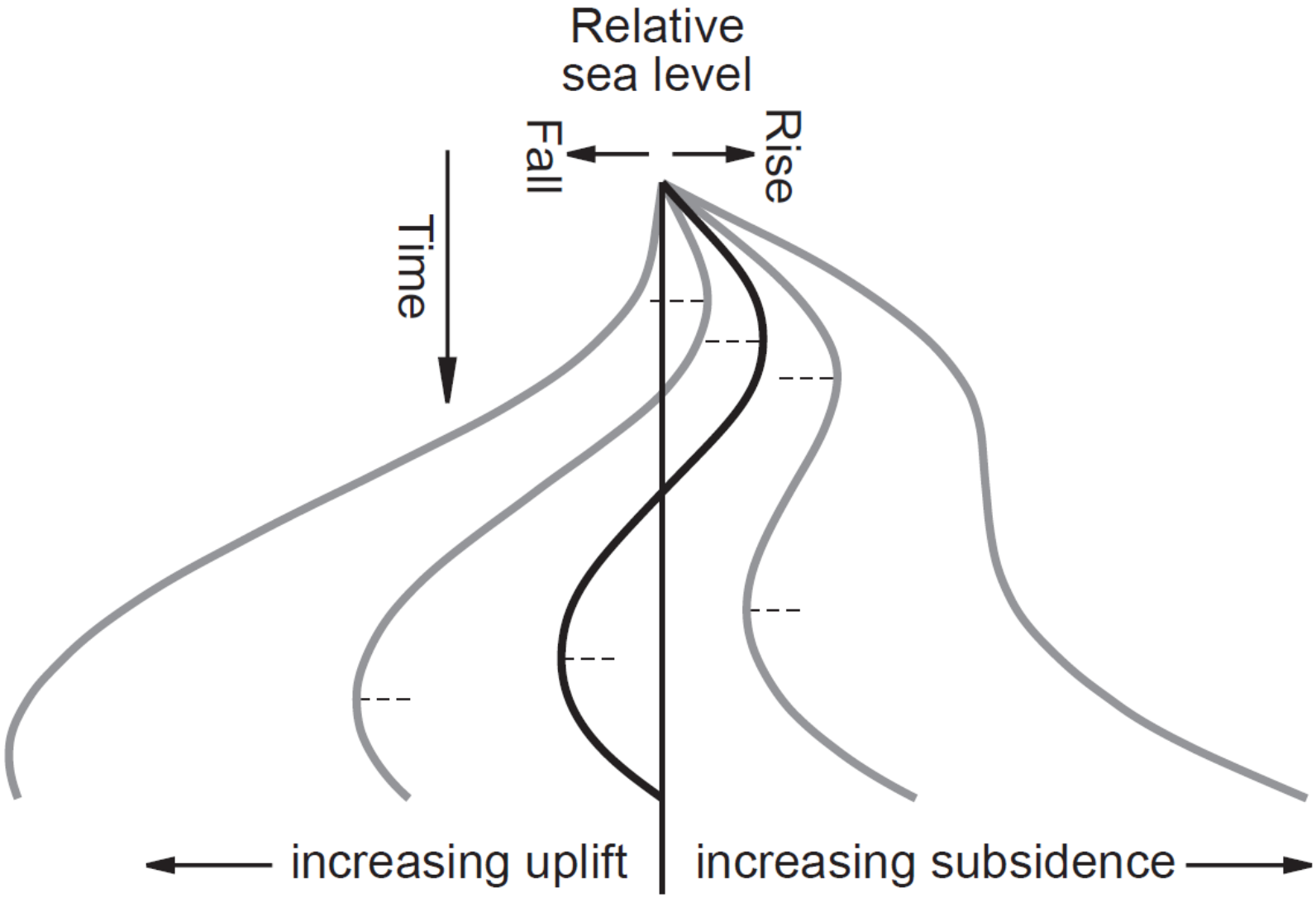
Relative sea-level rise



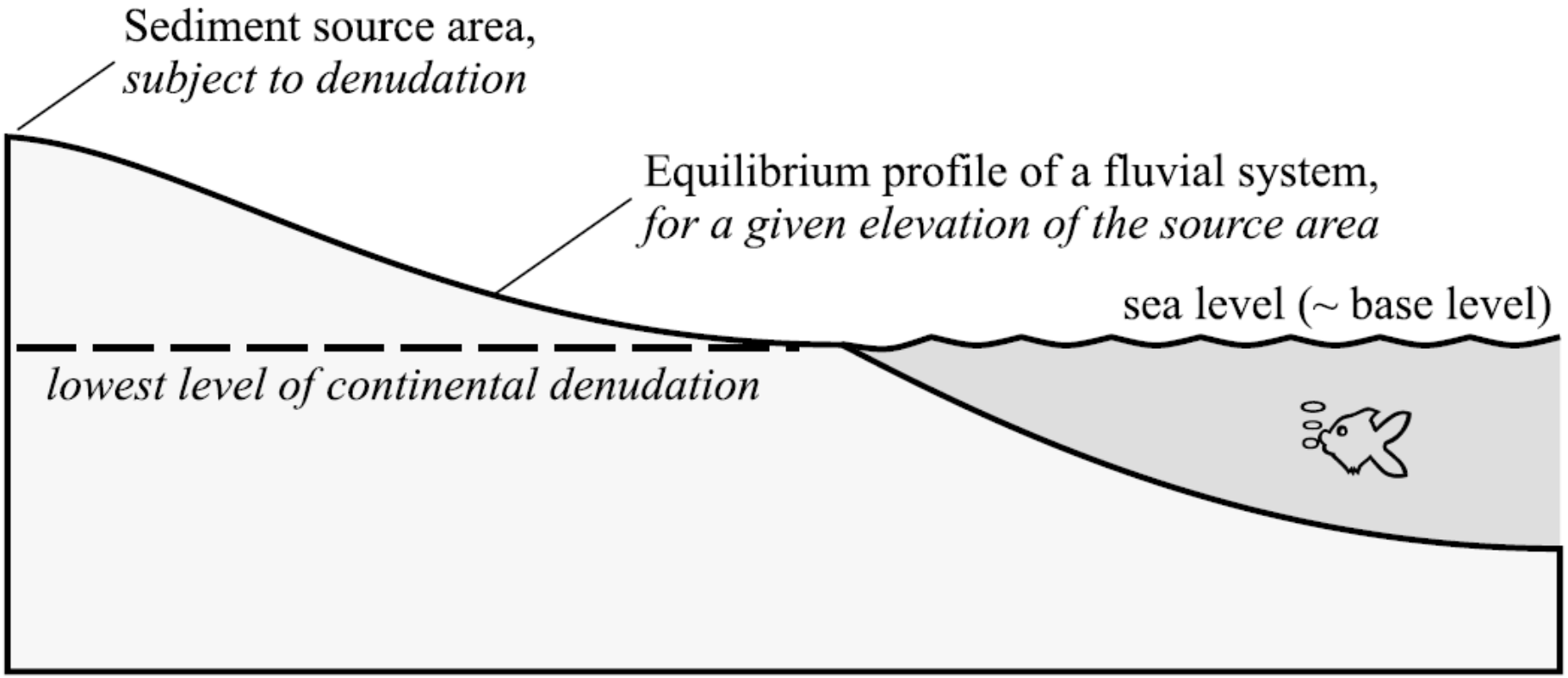
Relative sea-level fall



Relative sea-level changes



Base level


Sediment source area,
subject to denudation
Equilibrium profile of a fluvial system,
for a given elevation of the source area
sea level (~ base level)
lowest level of continental denudation

Interplay between accommodation and sedimentation

Transgression: the landward migration of the shoreline

It occurs if the rate of accommodation creation (relative sea-level rise) outpaces the sedimentation rate at the shoreline

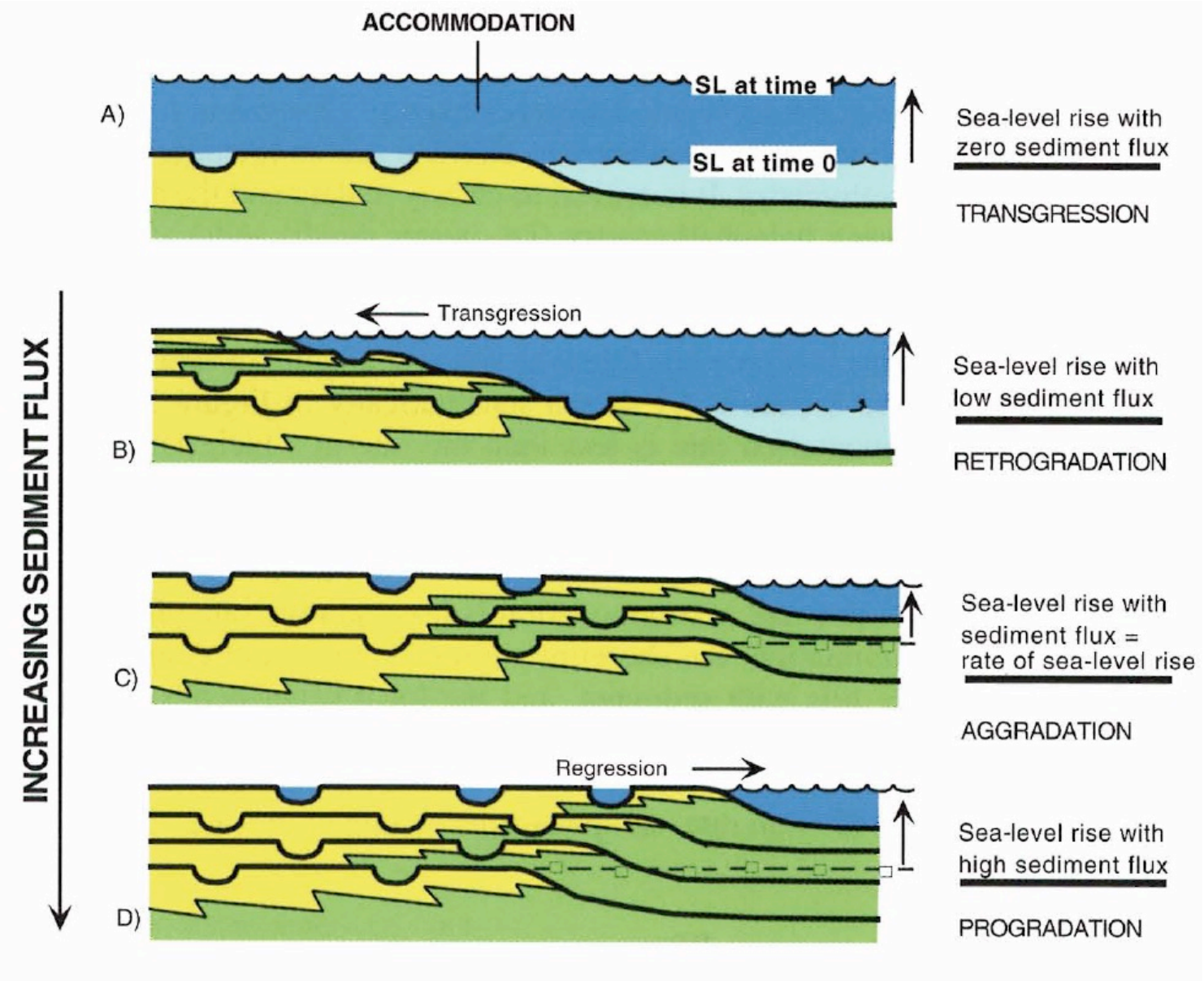
- Landward facies shift
- Deepening of the shallow-marine area
- Retrogradational stacking pattern

Regression: the seaward migration of the shoreline

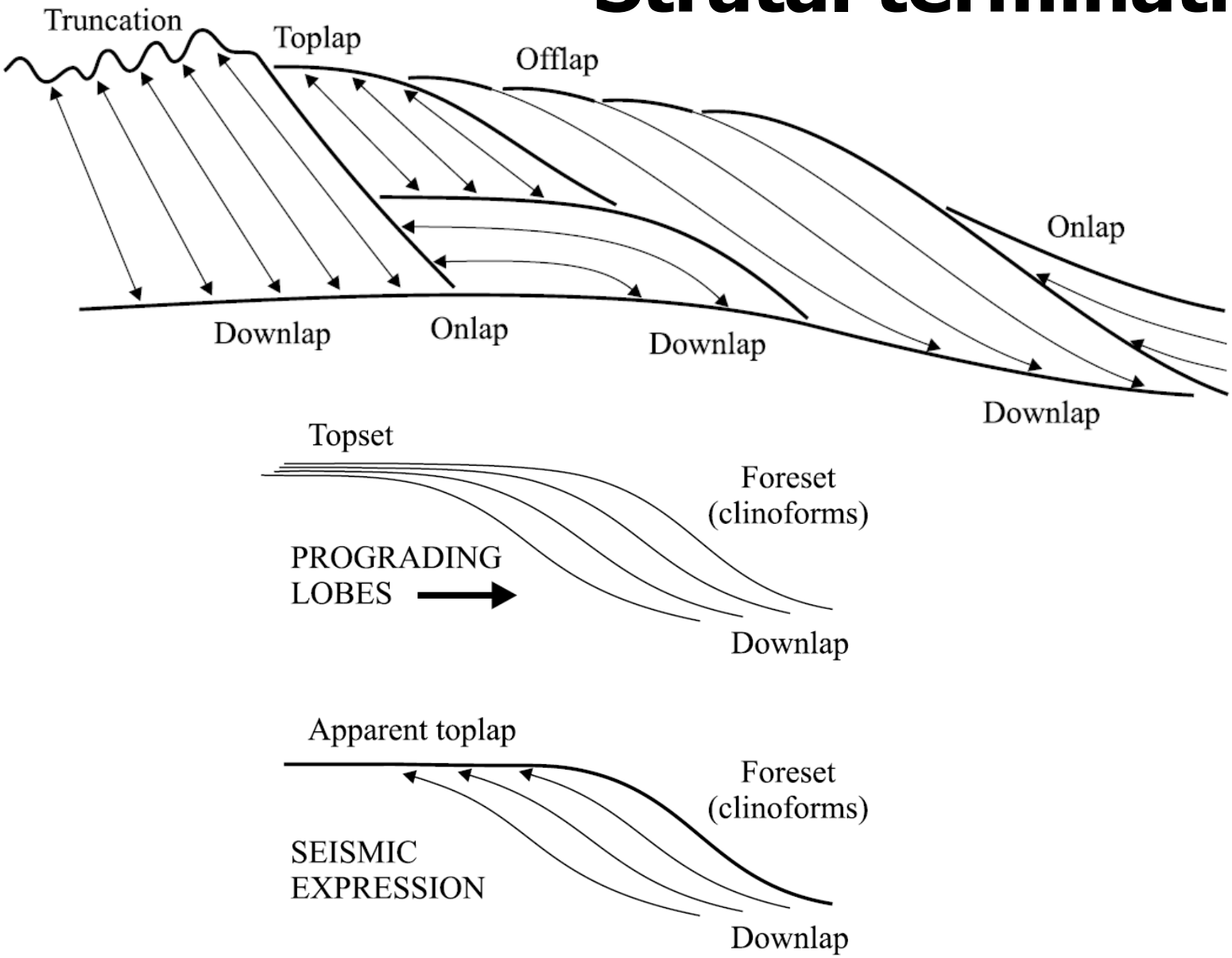
It occurs if the sedimentation rate outpaces the rate of accommodation creation at the shoreline (normal regression) or during relative sea-level fall (loss of accommodation) (forced regression)

- Seaward facies shift
- Shallowing of the shallow-marine area
- Progradational stacking pattern

Accommodation and sedimentation



Stratal terminations



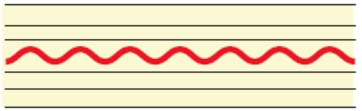
Unconformities

Unconformity = hiatus ± erosion

A break in the geological record, whatever its cause and magnitude, with or without accompanying erosion.
Types of unconformity:

- **Disconformity** = hiatus + erosion

  An unconformity in which the bedding planes above and below the break are essentially parallel, ...and usually marked by a visible and uneven erosion surface of appreciable relief.

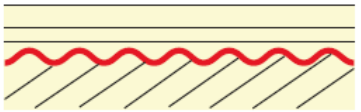


- **Paraconformity** = hiatus ± erosion

  An obscure or uncertain unconformity with no discernable erosion, in which the beds above and below the break are parallel to each other. 'Minor' paraconformities are also referred to as 'diastems'.

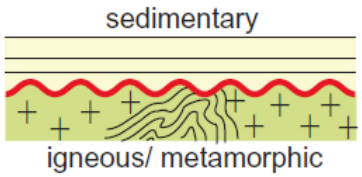
- **Angular unconformity** = hiatus, erosion, and tilt

  An unconformity between two groups of rocks whose bedding planes are not parallel or in which the older, underlying rocks dip at a different angle (usually steeper) than the younger, overlying strata.



- **Nonconformity** = top of basement rocks

  An unconformity developed between sedimentary rocks and older basement rocks that had been exposed to erosion before the overlying sediments covered them.

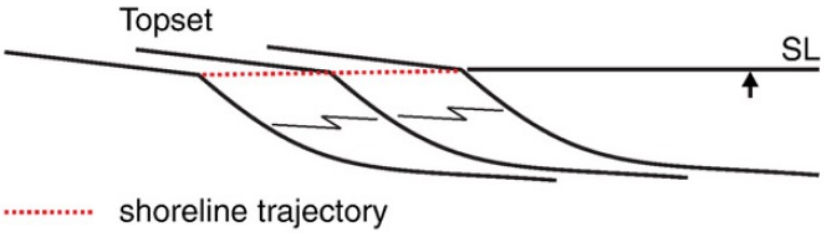


Conformity = no hiatus

Undisturbed relationship between adjacent sedimentary strata that have been deposited in orderly sequence.
True stratigraphic continuity in the succession of beds.

Genetic types of deposits

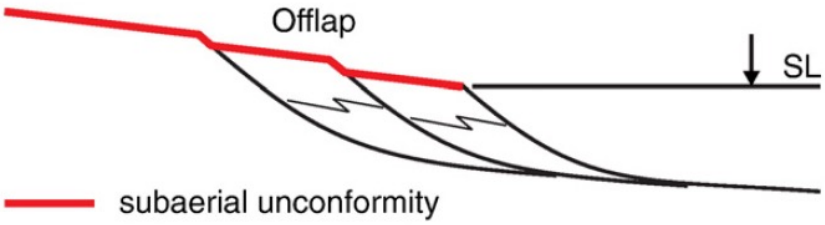
Normal regression



Definition: progradation driven by sediment supply. Sedimentation rates outpace the rates of base-level rise at the coastline.

Depositional trend: progradation with aggradation.

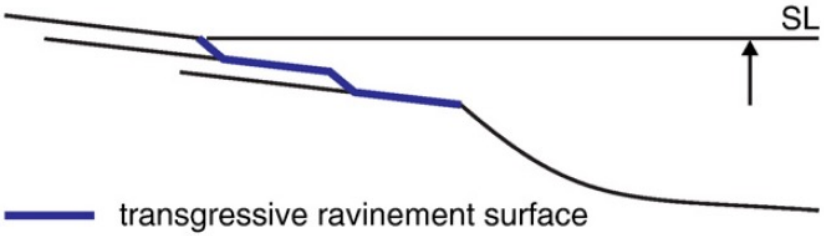
Forced regression



Definition: progradation driven by base-level fall. The coastline is forced to regress, irrespective of sediment supply.

Depositional trend: progradation with downstepping.

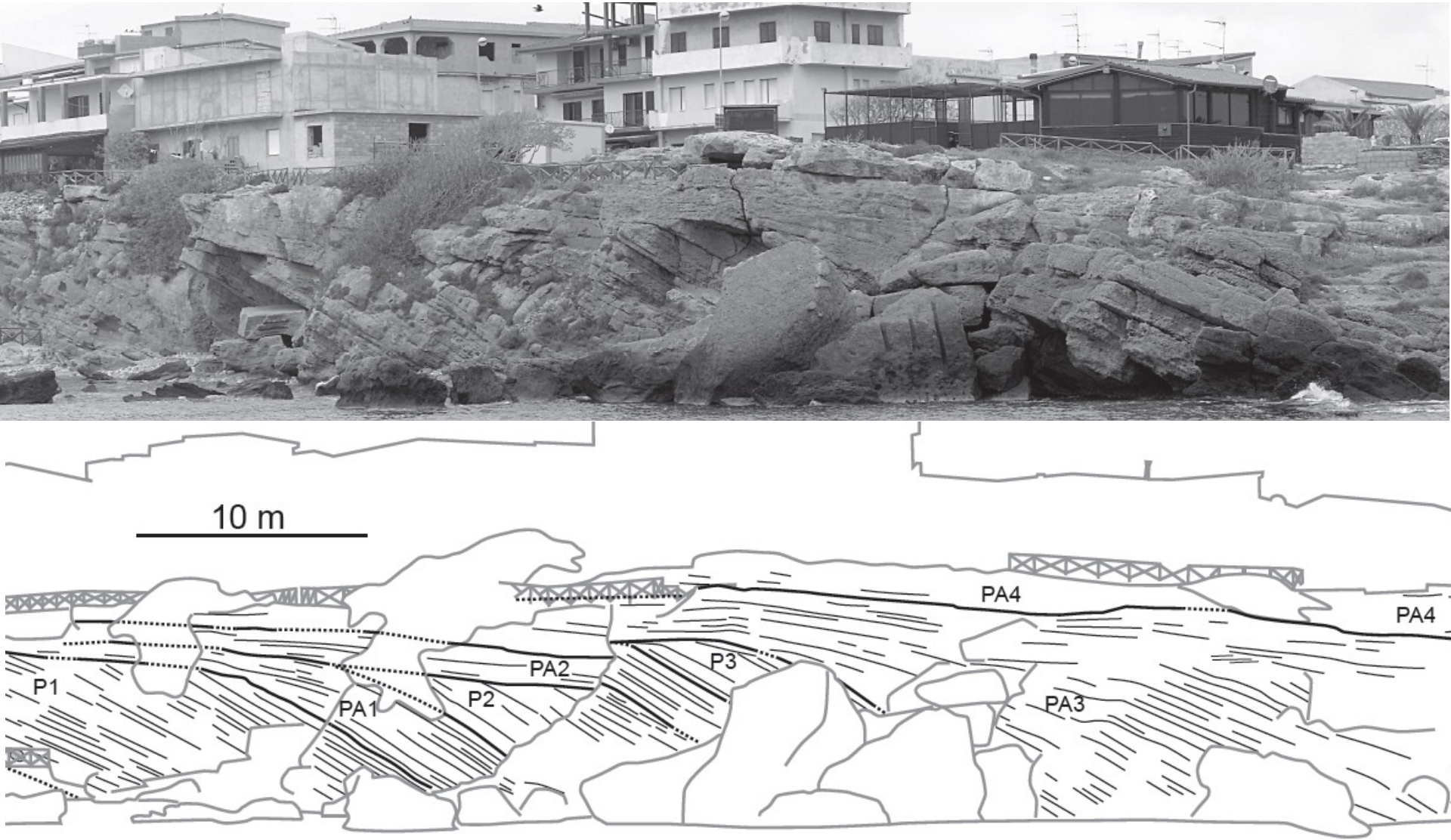
Transgression



Definition: retrogradation (backstepping) driven by base-level rise. The rates of base-level rise outpace the sedimentation rates at the coastline.

Depositional trend: retrogradation.

Normal and forced regressive deposits



Sequence stratigraphic surfaces

Relative sea-level fall

- Subaerial unconformity (and correlative conformity)
- Basal surface of forced regression
- Regressive surface of marine erosion

Relative sea-level rise

- Maximum regressive surface
- Maximum flooding surface
- Ravinement surface

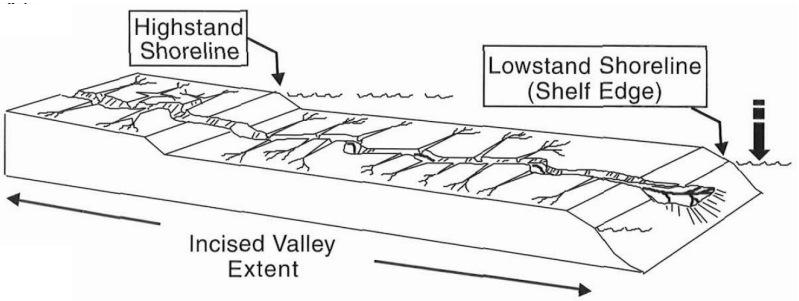
Subaerial unconformity (SU)

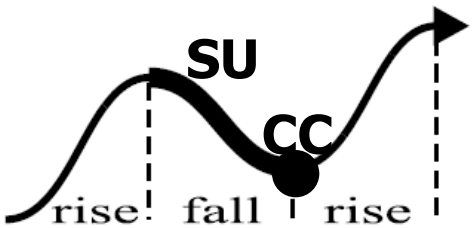
- The SU develops during relative sea-level fall

- It is associated with river incision and pedogenesis

- It progressively extends basinwards during the forced regression of the shoreline

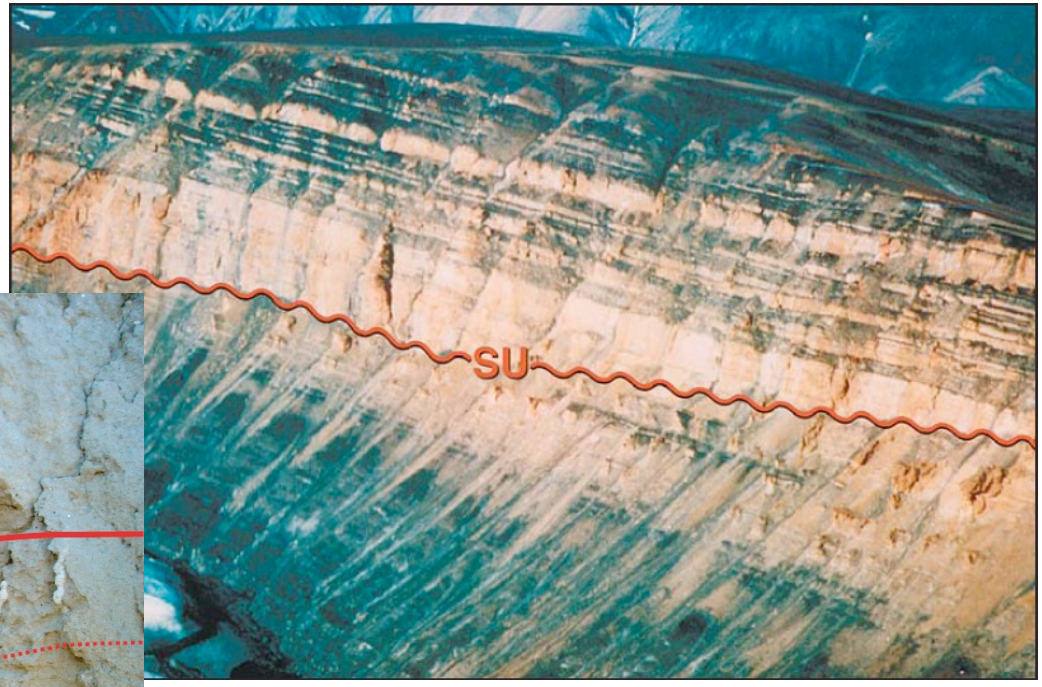
- It has a marine correlative conformity (CC) connected to its basinward termination (corresponding to the seafloor at the end of relative sea-level fall)



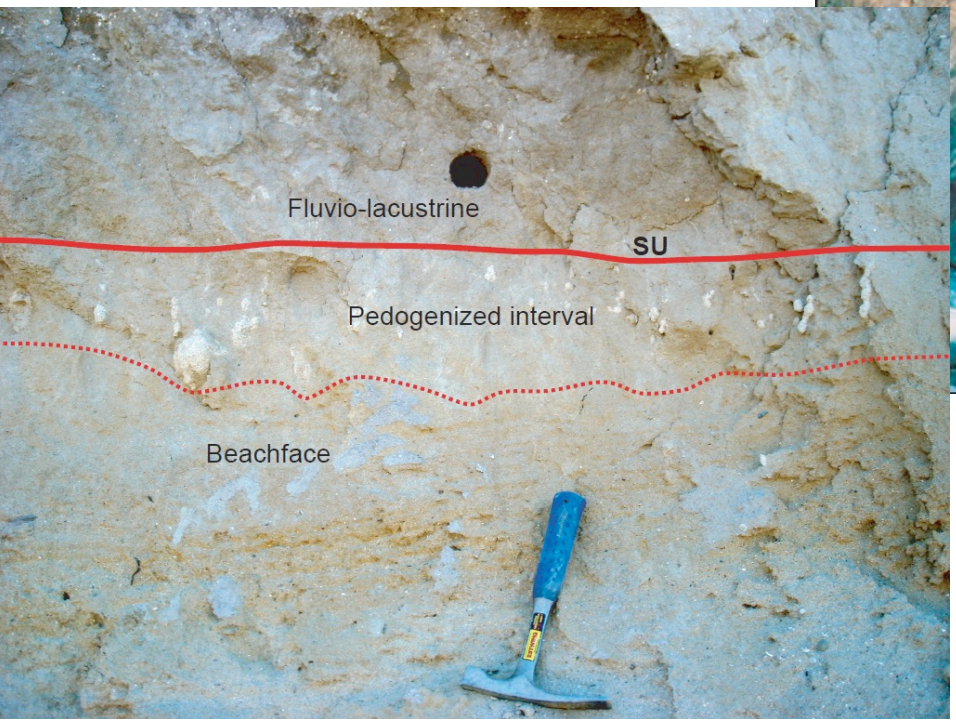


Subaerial unconformity (SU)

Lower Cretaceous –
Axel Heiberg Island



Middle Pleistocene – Crotone

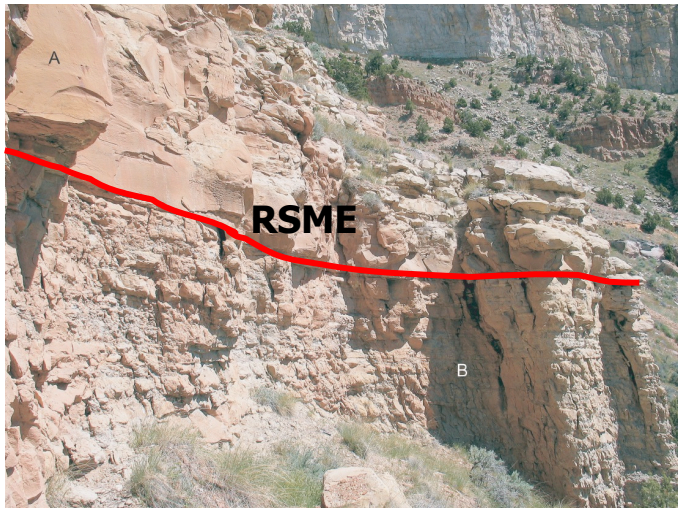


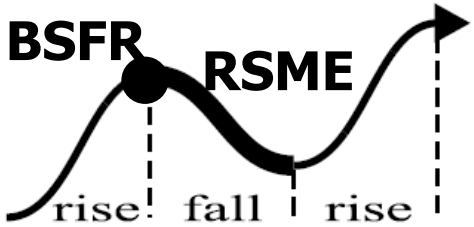
Basal surface of forced regression (BSFR) and regressive surface of marine erosion (RSME)

- The BSFR marks the base of all marine deposits accumulated during relative sea-level fall. It corresponds to the paleo-seafloor at the onset of forced regression

- The RSME is cut by waves in the shoreface during relative sea-level fall, and marks the base of forced regressive shorefaces. It easily reworks the BSFR in proximal settings. Its formation depends on wave energy, slope, and subsidence

Cretaceous – Blackhawk Fm., Utah



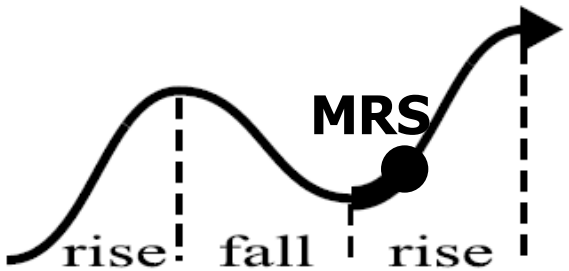


Maximum regressive surface (MRS) or transgressive surface (TS)

- The MRS marks the boundary bentween prograding (regressive) and subsequent retrograding (transgressive) deposits

- It is formed when the increasing rates of accommodation creation (relative sea-level rise) start to outpace the sedimentation rates.

Early and Middle Triassic – Ellesmere Island

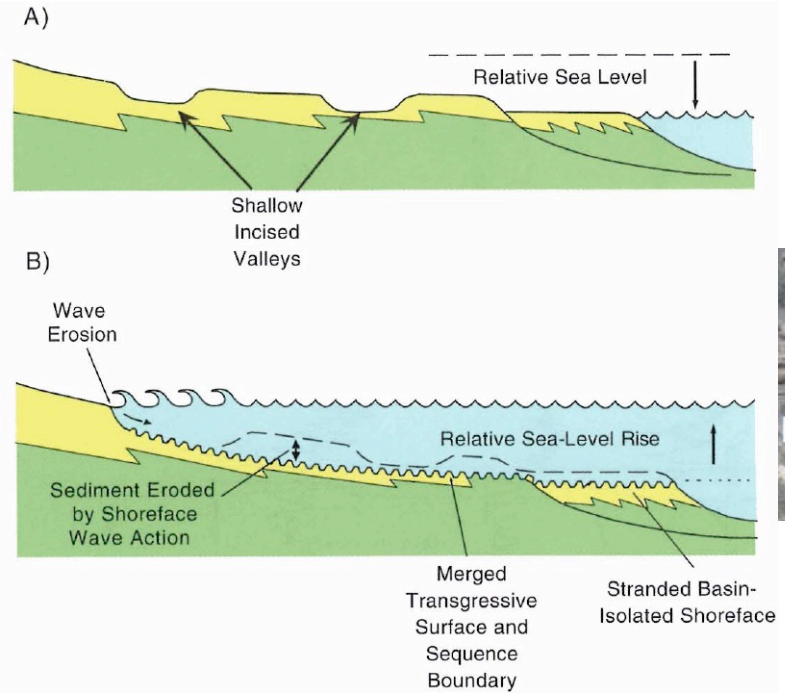


Ravinement surface (RS)

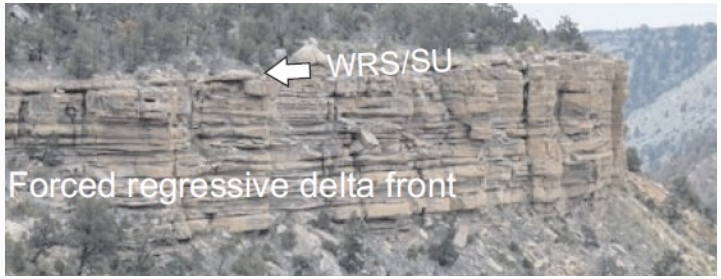
- The RS is a diachronous erosional surface cut by waves (WRS) or tidal currents (TRS) in the shoreface and coastal settings during transgression (relative sea-level rise)

- It is associated with transgressive lags or condensed bioclastic deposits

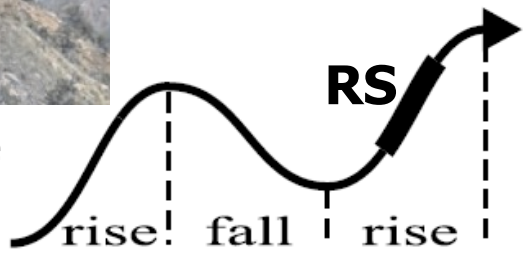
- It climbs toward the basin margin



- Its formation depends on wave energy, slope and rates of relative sea-level rise and sediment supply

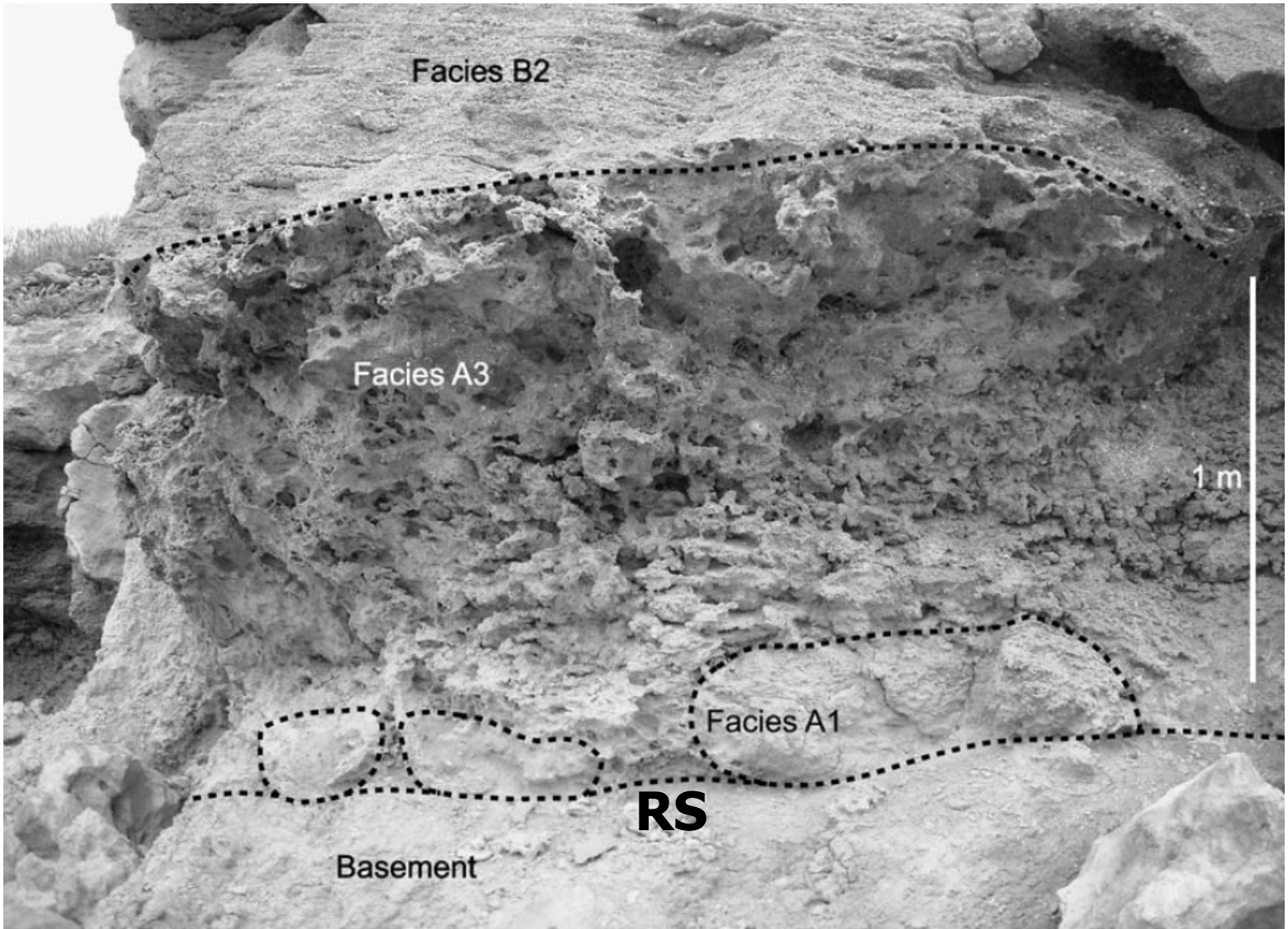


Upper Cretaceous – Panther Tongue Member, Star Point Fm., Utah



Ravinement surface (RS)

Late Pleistocene – Crotone



Maximum flooding surface (MFS)

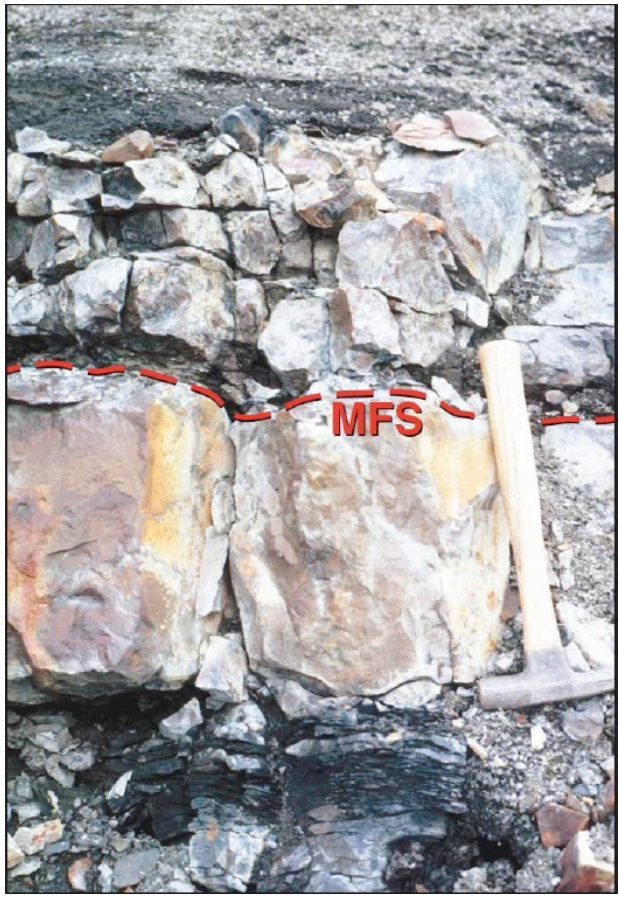
- The MFS marks the end of the shoreline transgression

- It separates retrograding (transgressive) strata below from prograding (regressive) strata above

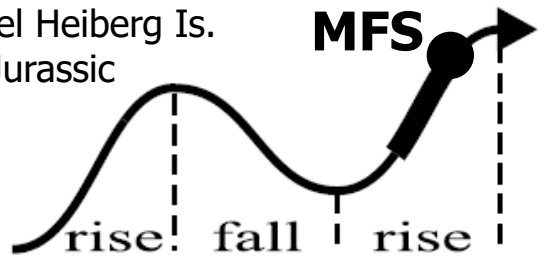
- It is formed when the sedimentation rates start to outpace the rates of creation of accommodation (relative sea-level rise)

- It is a downlap surface (in seismics)

- It is commonly associated with a condensed section

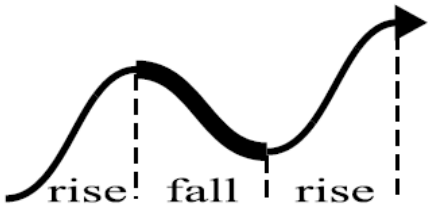


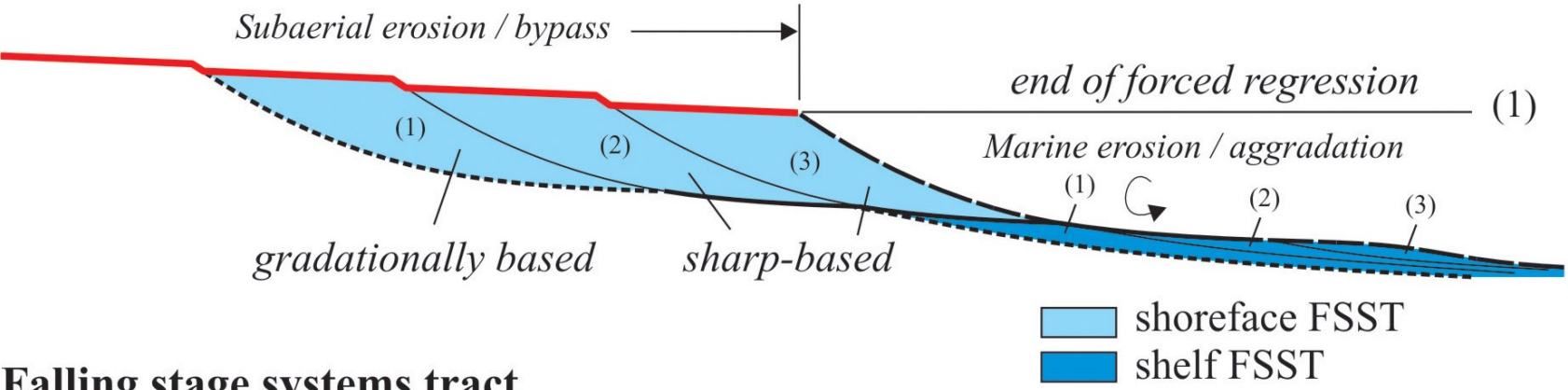
Axel Heiberg Is. – Jurassic



Systems tracts

Falling stage or forced regressive or early lowstand systems tract

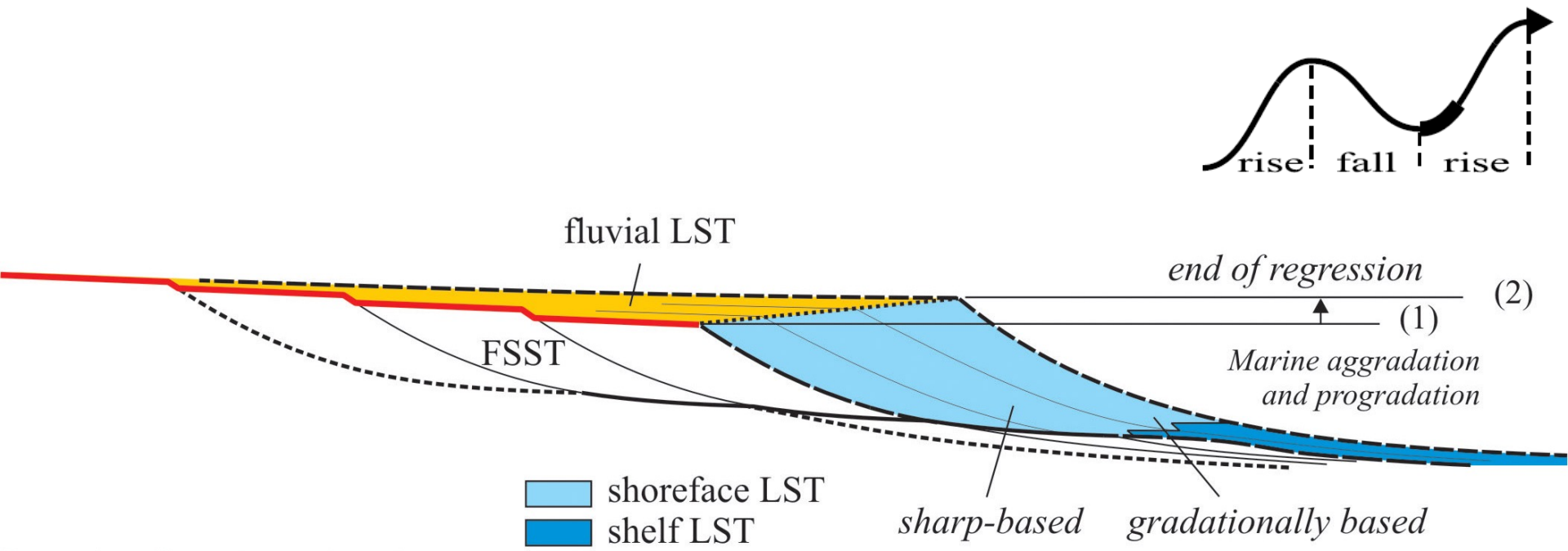




Falling stage systems tract

- subaerial unconformity
- correlative conformity
- basal surface of forced regression
- regressive surface of marine erosion
- ravinement surface
- maximum regressive surface
- maximum flooding surface
- within-trend normal regressive surface
- lateral shifts of facies
- coastal onlap (healing phase deposits)

Lowstand or late lowstand Systems tract



Lowstand systems tract

- subaerial unconformity
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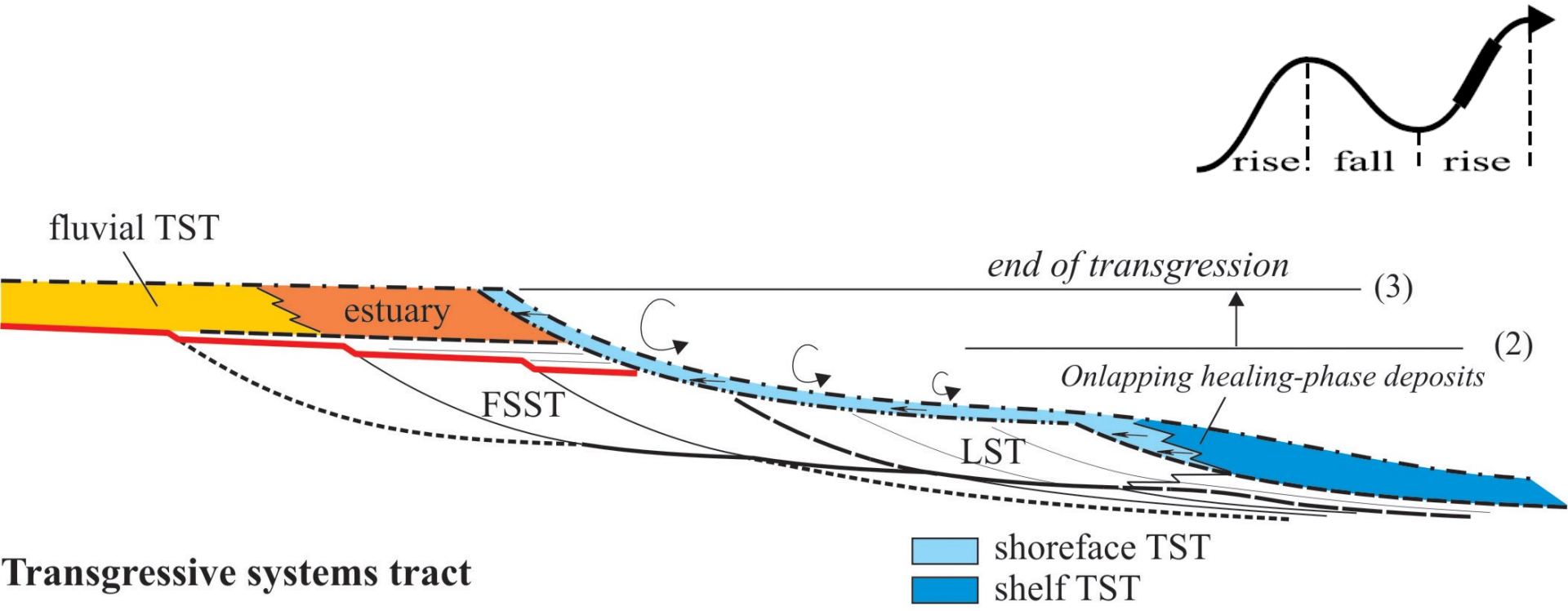
- regressive surface of marine erosion
- ravinement surface
- maximum regressive surface
- maximum flooding surface
- within-trend normal regressive surface
- lateral shifts of facies
- coastal onlap (healing phase deposits)

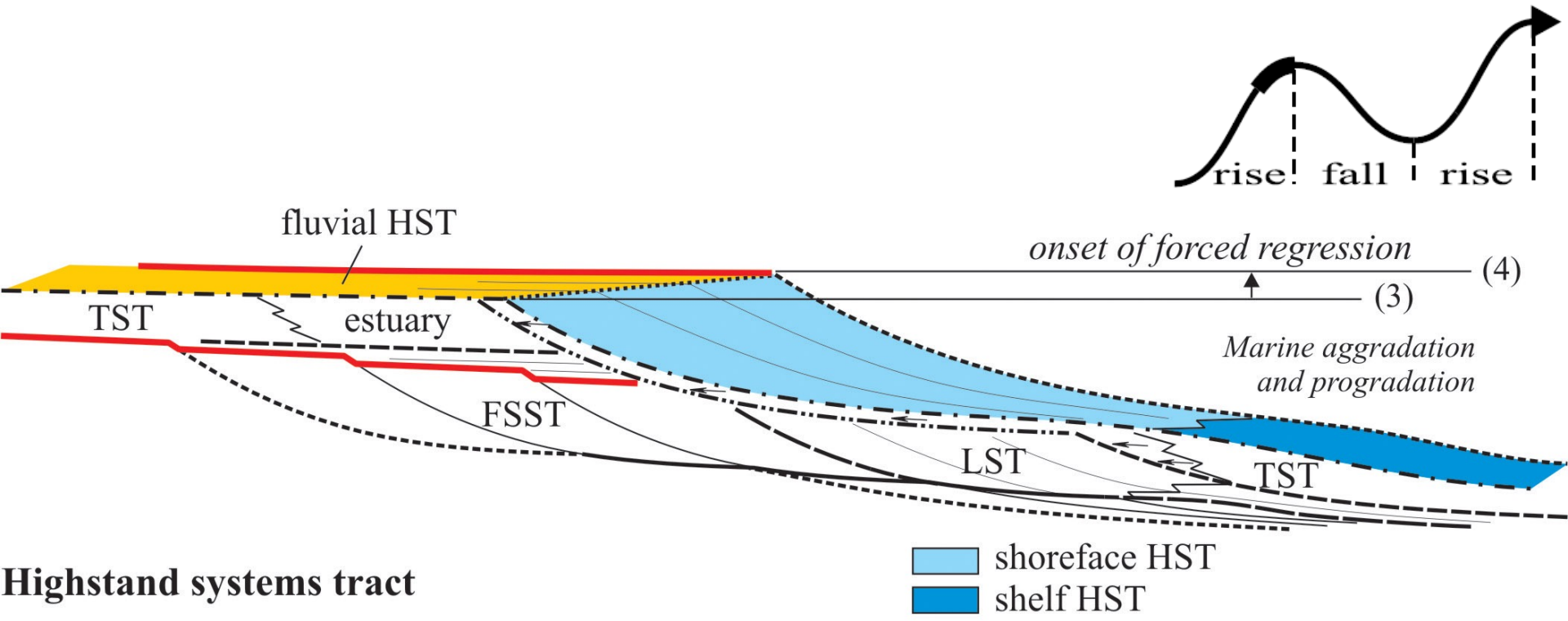
Transgressive systems tract



Transgressive systems tract

subaerial unconformity
correlative conformity
basal surface of forced regression
regressive surface of marine erosion
ravinement surface
maximum regressive surface
maximum flooding surface
within-trend normal regressive surface
lateral shifts of facies
coastal onlap (healing phase deposits)

Highstand systems tract



Highstand systems tract

subaerial unconformity
correlative conformity
basal surface of forced regression
regressive surface of marine erosion
ravinement surface
maximum regressive surface
maximum flooding surface
within-trend normal regressive surface
lateral shifts of facies
coastal onlap (healing phase deposits)

Sequence stratigraphic models

Events and stages / Sequence model	Mitchum et al. (1977) Depositional Sequence I	Posamentier et al. (1988) Depositional Sequence II	Van Wagoner et al. (1988) Depositional Sequence III	Hunt & Tucker (1992) Depositional Sequence IV	Galloway (1989) Genetic Sequence	Johnson & Murphy (1984) T-R Sequence
HNR		HST	early HST	HST	HST	RST
end of T					MFS	
T	Sequence	TST	TST	TST	TST	TST
end of R						MRS
LNR		late LST (wedge)	LST	LST	late LST (wedge)	
end of RSL fall				CC**		
FR		early LST (fan)	late HST	FSST	early LST (fan)	RST
onset of RSL fall	CC*	CC*				
HNR		HST	early HST	HST	HST	

time

sequence boundary
systems tract boundary
within-sequence surface
within-systems tract surface