Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

Università degli studi di Trieste

LAUREA MAGISTRALE IN GEOSCIENZE

Classe Scienze e Tecnologie Geologiche

Curriculum: Esplorazione Geologica

Anno accademico 2021 - 2022

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

Docente: **Michele Rebesco**

Modulo 4.2
Sequence stratigraphy – closer view

Docente: Massimo Zecchin

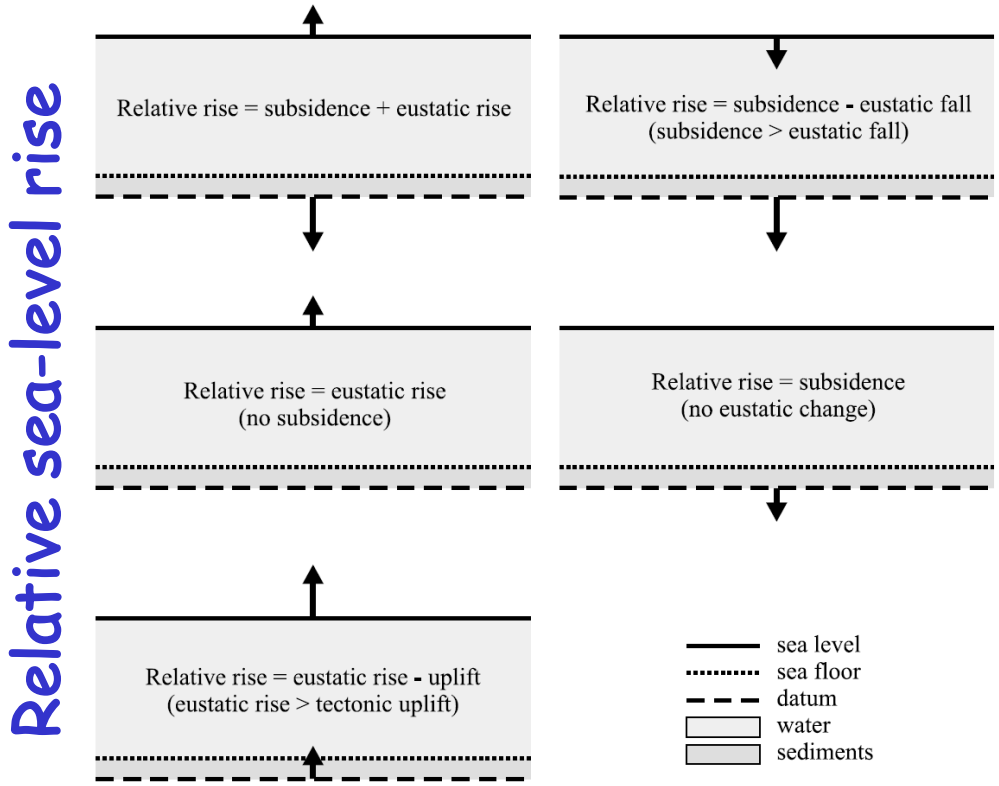
Outline:
- Questions and Answers
- Stratigraphic sequences within System Tracts
- Wheeler diagram of stratigraphic sequences
- exercise based on the Venice example

Modulo	Argomento	Docente	Data
1.1	introduzione al corso e argomenti	Rebesco	05/10/21
1.2	metodi (geofisica, affioramenti, geologia marina, ambienti attuali)	Volpi/Rebesco	06/10/21
1.3	meccanismi di formazione dei bacini (geodinamica, tettonica…)	Lodolo	12/10/21
1.4	Interpretazione sismica, facies e strutture primarie	Rebesco	13/10/21
6.1	visita a Rompighiaccio Laura Bassi (assieme a Geologia Marina)	Rebesco	15/10/22
	Martedì 19 Ottobre non c'è lezione		
1.5	Energy storage e CCS	Volpi/Donda	20/10/21
2.1	Processi sedimentari nei fiumi e nei delta	Rebesco	26/10/21
2.2	Azione di maree e onde, del ghiaccio e del vento	Rebesco	27/10/21
	Martedì 2 Novembre non c'è lezione		
	Mercoledì 3 Novembre non c'è lezione		
2.3	Correnti di densità e correnti di fondo, trasporto di massa	Lucchi/Rebesco	09/11/21
3.1	pianure abissali (decantazione emipelagica) e margini continentali	Rebesco	10/11/21
3.2	Conoidi sottomarine (flussi gravitativi dalla scarpata continentale)	Lucchi/Rebesco	16/11/21
3.3	Sediment drifts (correnti di fondo lungo la scarpata continentale)	Rebesco	17/11/21
3.4	Mass transport deposits (accenni a risoluzione/penetrazione)	Ford	23/11/21
3.5	Piattaforme continentali (onde, tempeste, tsunami)	Rebesco	24/11/21
3.6	Sistemi deposizionali in ambiente polare	De Santis	30/11/21
3.7	Sistema di barriera	Rebesco	01/12/21
3.8	Depositi alluvionali	Rebesco	07/12/21
	Mercoledì 8 e martedì 14 Dicembre non c'è lezione		
3.9	Laghi, deserti e ambienti carbonartici	Rebesco	15/12/21
3.10	faglie, vulcani e approfondimento conoidi	Rebesco	21/12/21
4.1	stratigrafia sequenziale: introduction	Rebesco	22/12/21
	Dal 23 Dicembre al 9 Gennaio non c'è lezione		
4.2	stratigrafia sequenziale: closer view	Rebesco	11/01/22
4.3	stratigrafia sequenziale: applicazioni (es. reservoirs di idrocarburi)	Rebesco	12/01/22
5	esercitazione	Rebesco	18/01/22
6.2	visita a CoreLoggingLAB (assieme a Geologia Marina)	Rebesco	19/01/22
6.3	visita a OGS e SEISLAB (assieme a Geologia Marina)	Rebesco	21/01/22

Question: Trasgressione (regressione): non solo legate a variazioni eustatiche? Può essere anche tettonica e basta?

Transgression: the landward migration of the shoreline
It's an interplay between **accommodation** and **sedimentation**.
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

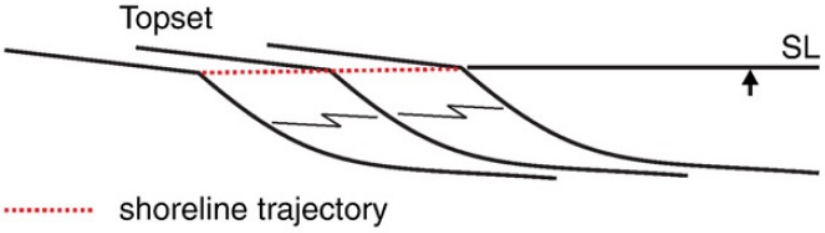


Answer: **Certo, oltre che a variazioni del tasso di sedimentazione**

Question: Come distinguere normal vs forced regression? chiarimenti ed esempi grafici e naturali (slide 14 e 15)

Answer: La traiettoria della linea di costa è verso mare (prograding) e leggermente ascendente nella normal regression (also aggrading), mentre è discendente nella forced regression (also degrading or downstepping)

Normal regression

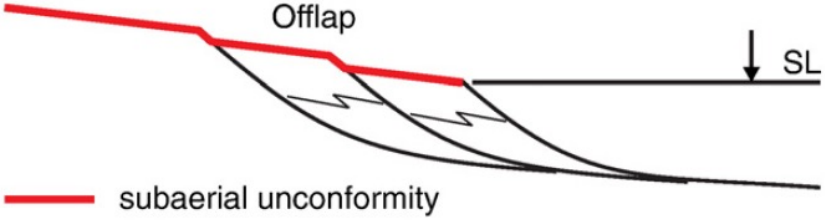


Definition: progradation driven by sediment supply. Sedimentation rates outpace the rates of base-level rise at the coastline.

Depositional trend: progradation with aggradation.

«Slide 14»

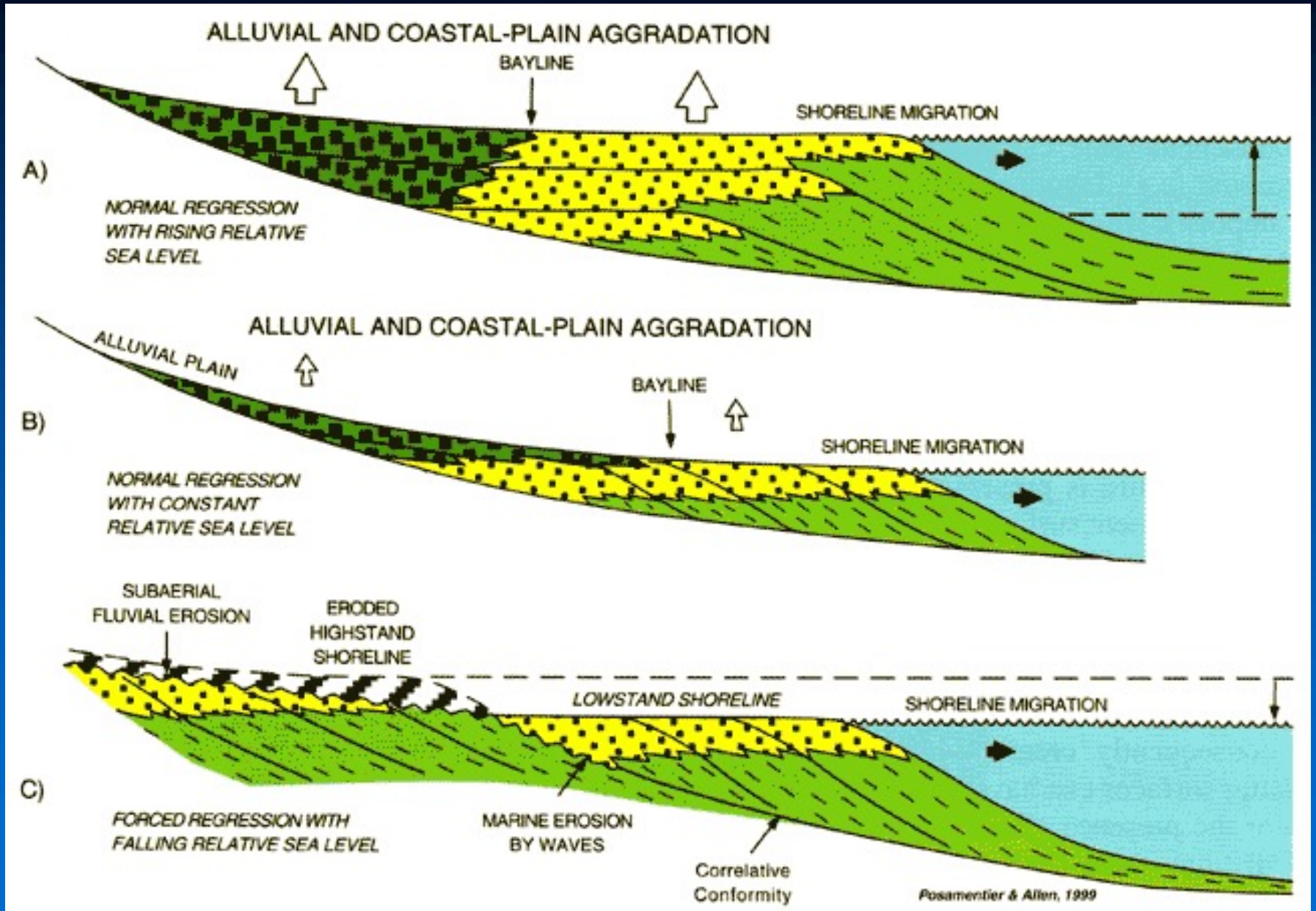
Forced regression



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

Depositional trend: progradation with downstepping.

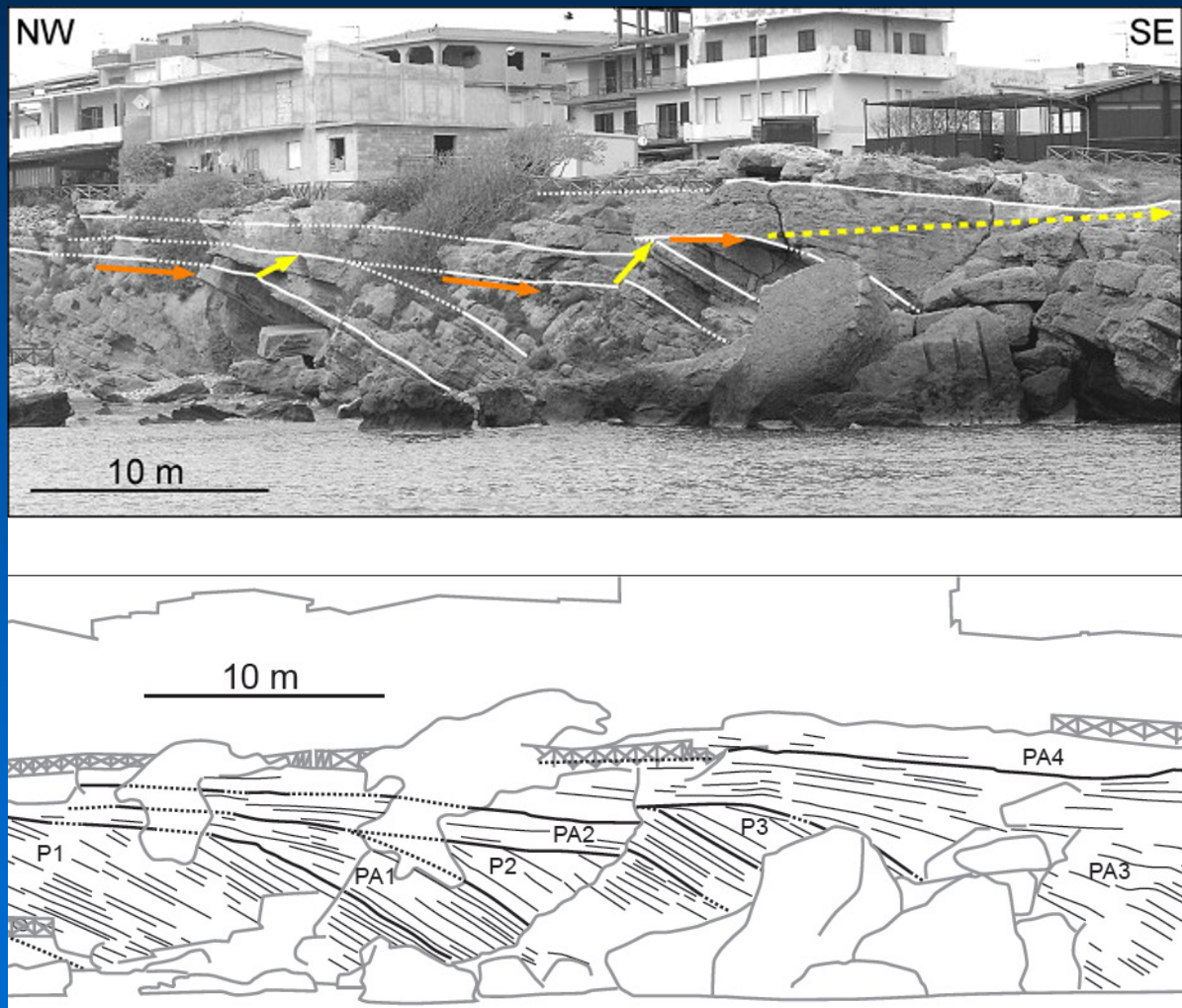
Esempio grafico



Esempio naturale (eccezione)

Zecchin et al., 2010. Le Castella clinoform. Sedimentary Geology. Alternating prograding and prograding/ aggrading elementary units, thought to be linked to high-frequency base-level changes during overall forced regressive conditions

Relative sea-level changes may be erratic and poorly predictable, and the expected complete succession of systems tracts doesn't form in all cases.



Question: **- Una trasgressione forzata e' distinguibile dalla trasgressione normale dalla granulometria dei sedimenti? Assomiglia a quella della regressione, ma al contrario dalla trasgressione forzata?**

Answer:

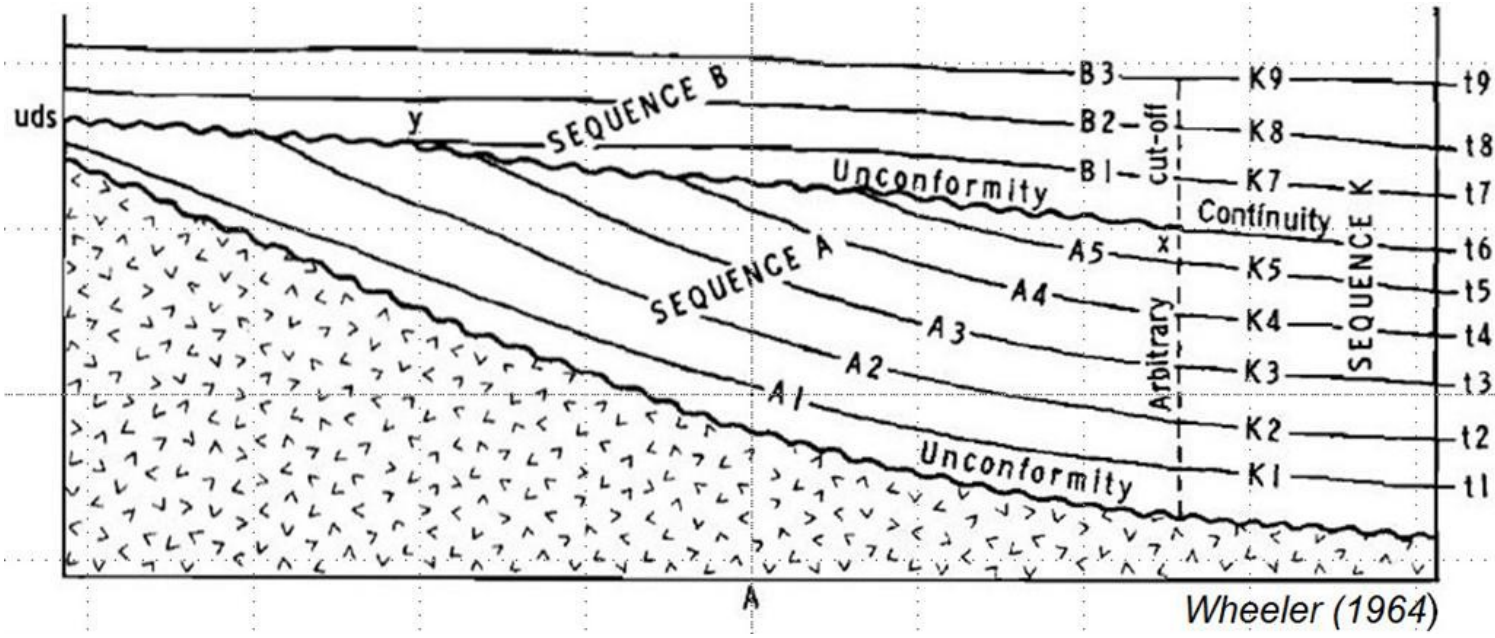
Trasgressione forzata? Da dove viene questo termine?
La trasgressione avviene quando il tasso di sedimentazione non tiene il passo con quello del relative sea-level rise, e questo può avvenire, oltre che per un aumento di quest'ultimo, anche per una diminuzione dell'apporto sedimentario.

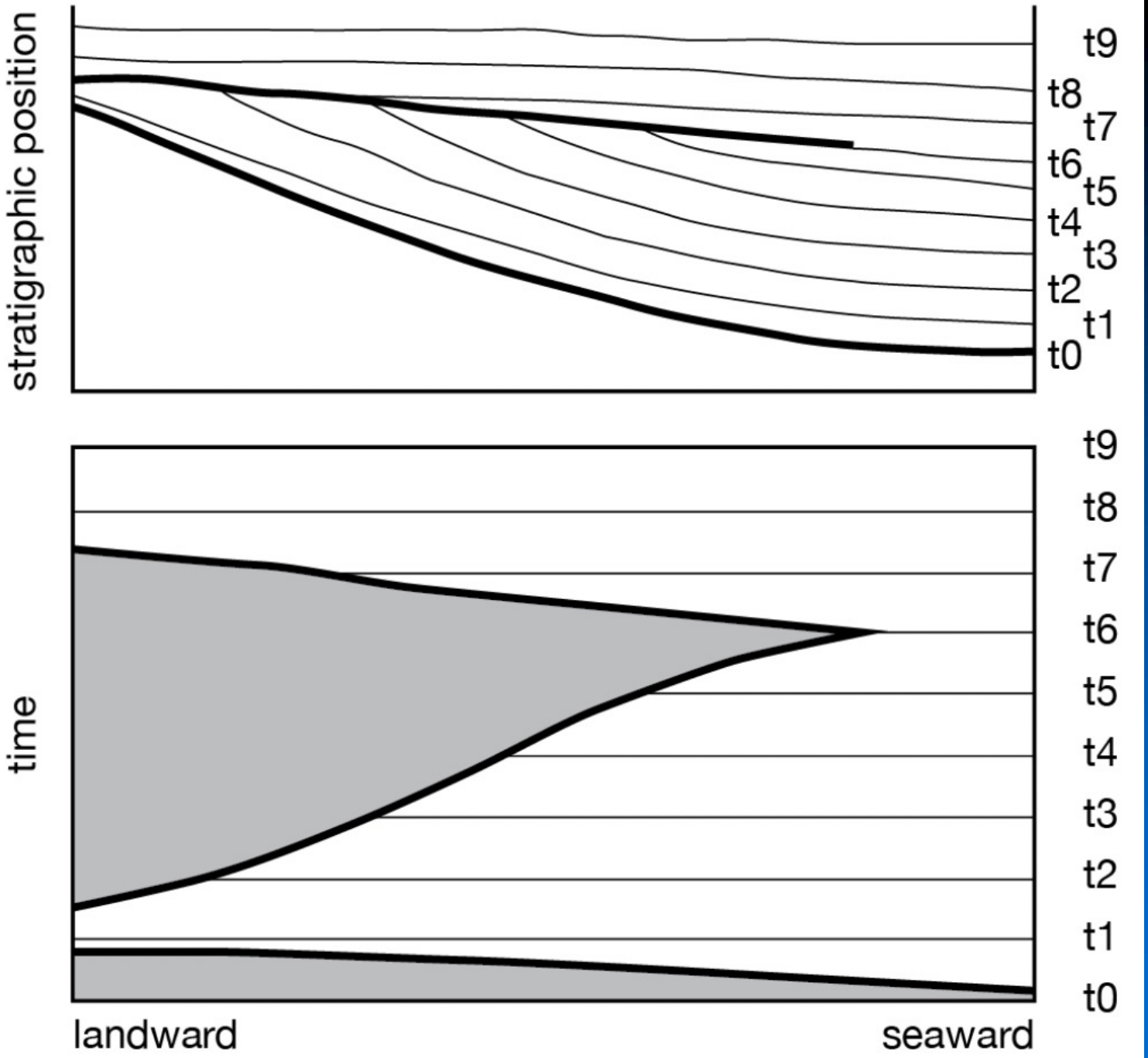
La granulometria dipende dal tipo di substrato che viene eroso, dall'energia locale, dal gradiente della costa e dal tasso di risalita del livello del mare.
Vedi anche successioni fining/coarsening upward nel diagramma di Wheeler

Question: Chiarimenti sullo hiatus, dove si puo' trovare e motivi per i quali avviene

A cessation in deposition of sediments during which no strata form or an erosional surface forms on the underlying strata; a **gap in the rock record**. This period might be marked by development of a lithified sediment (hardground) or burrowed surface. A disconformity (surface that represents a time of nondeposition, possibly combined with erosion) can result from a hiatus.

Answer:
diagramma di Wheeler



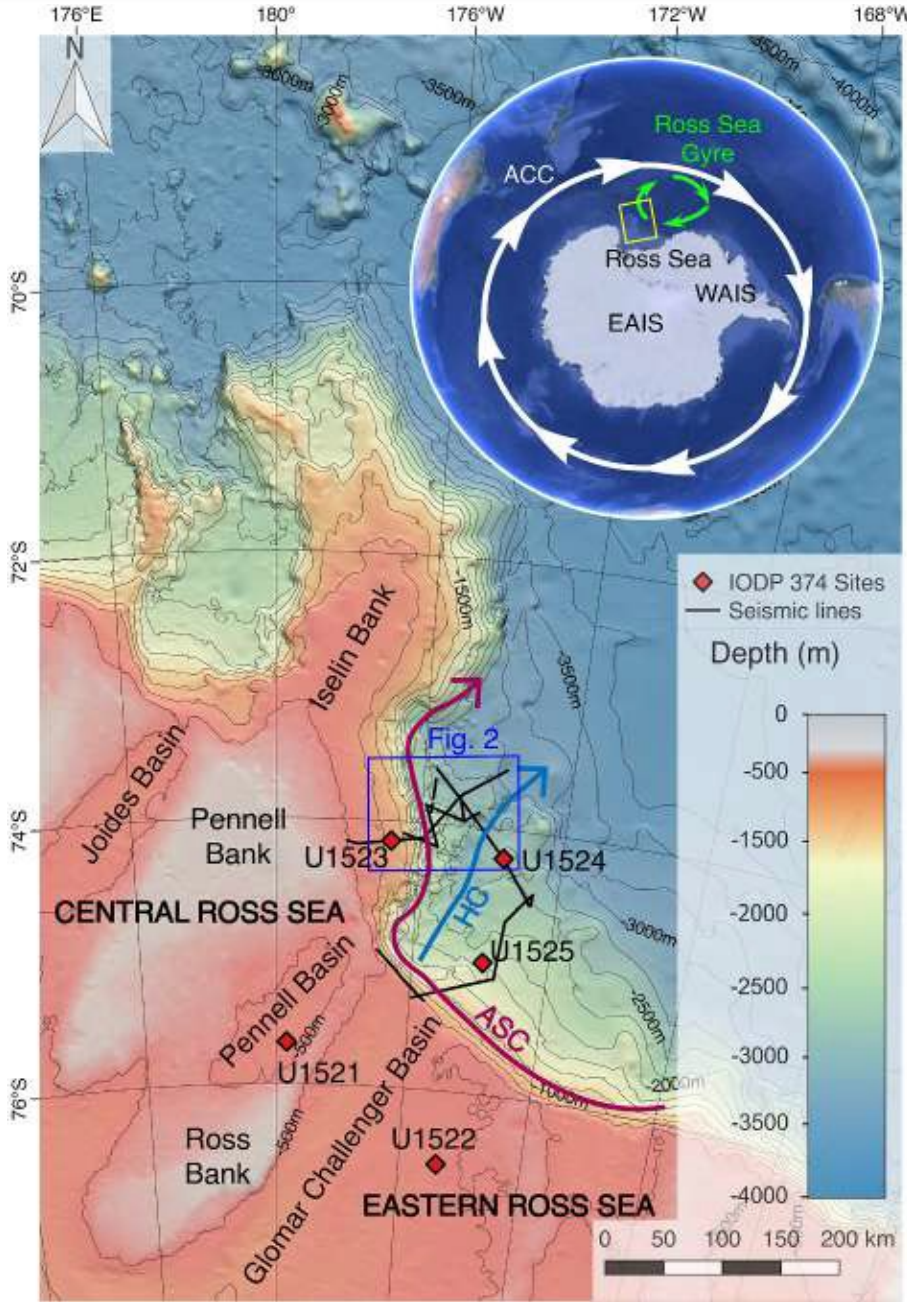


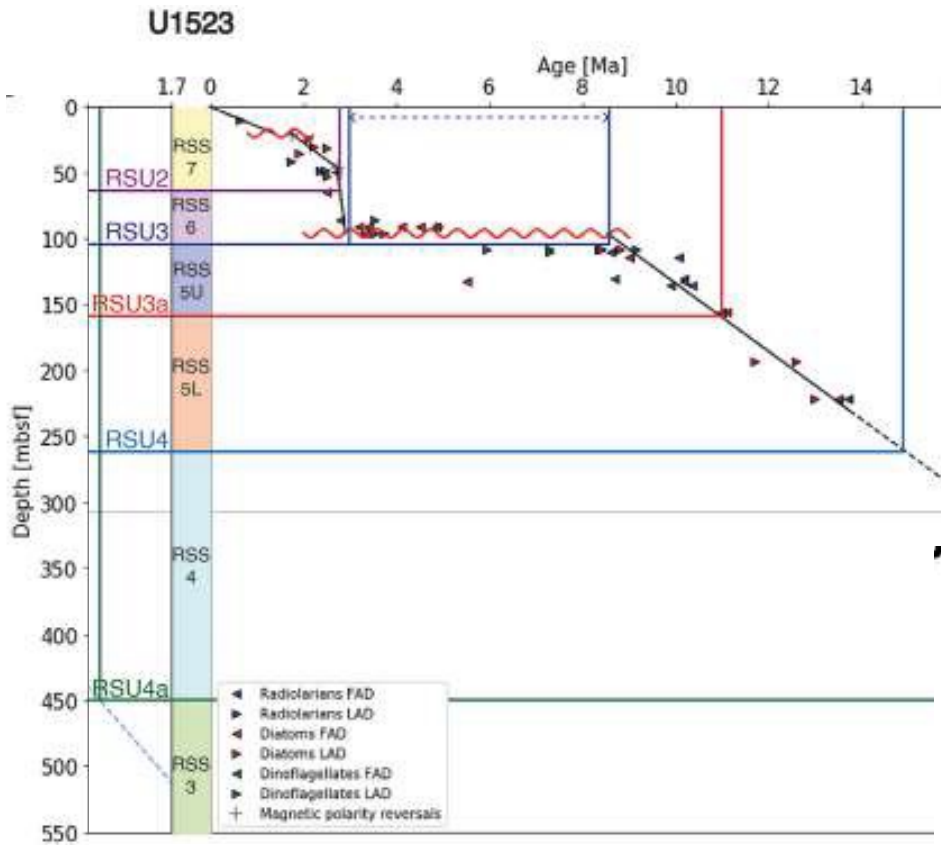
Wheeler diagram

Stratigraphic cross-section (upper) and chrono-stratigraphic (Wheeler) diagram lower, illustrating the chrono-stratigraphic potential of a subaerial unconformity

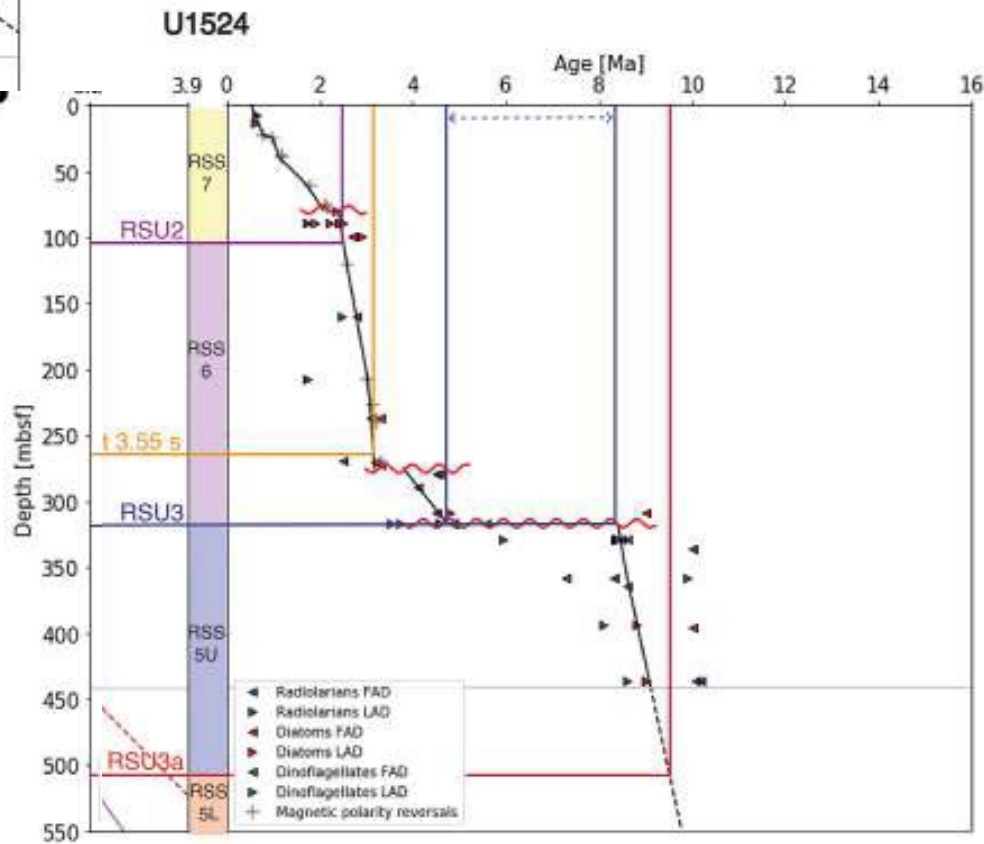
Conte et al., 2021 Bottom current control … (Antarctica). *Deep–Sea Research I 176, 103606*

Bathymetry including the study area with location of newly acquired seismic lines (ANTSSS and ODYSSEA projects) and International Ocean Discovery Program (IODP) Expedition 374 drilling sites (red diamonds). Isobaths every 500 m. The arrows are showing the approximate directions of Hillary Canyon (HC) (blue arrow) and of the core of the Antarctic Slope Current (ASC, purple arrow).

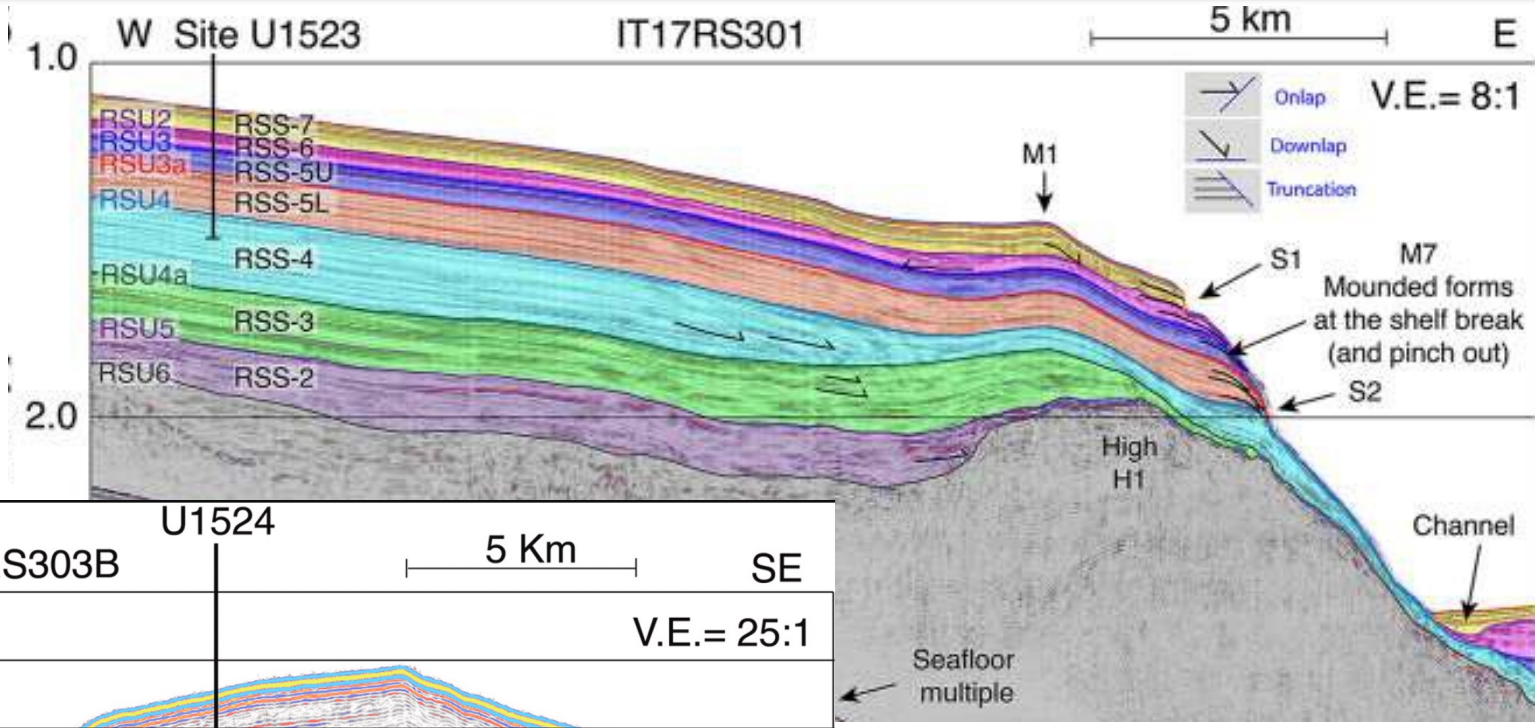


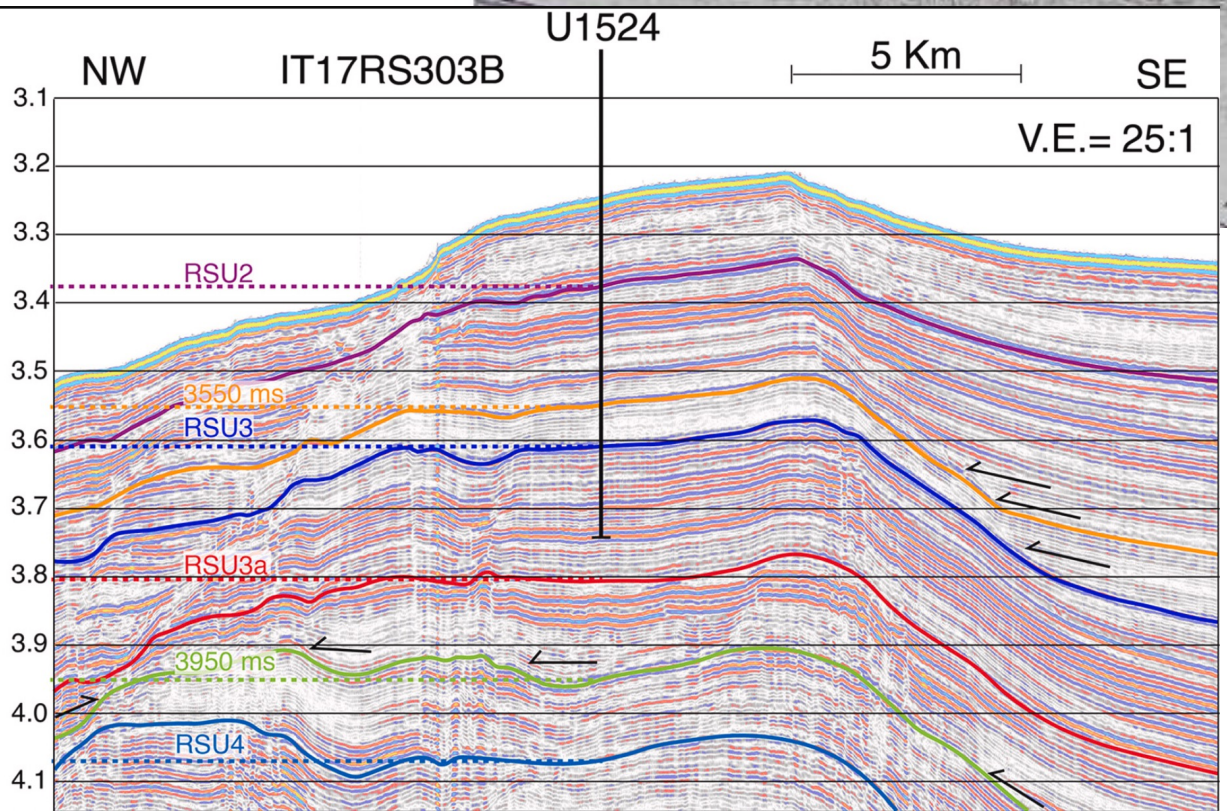


Age models for U1523 and U1524 faunas



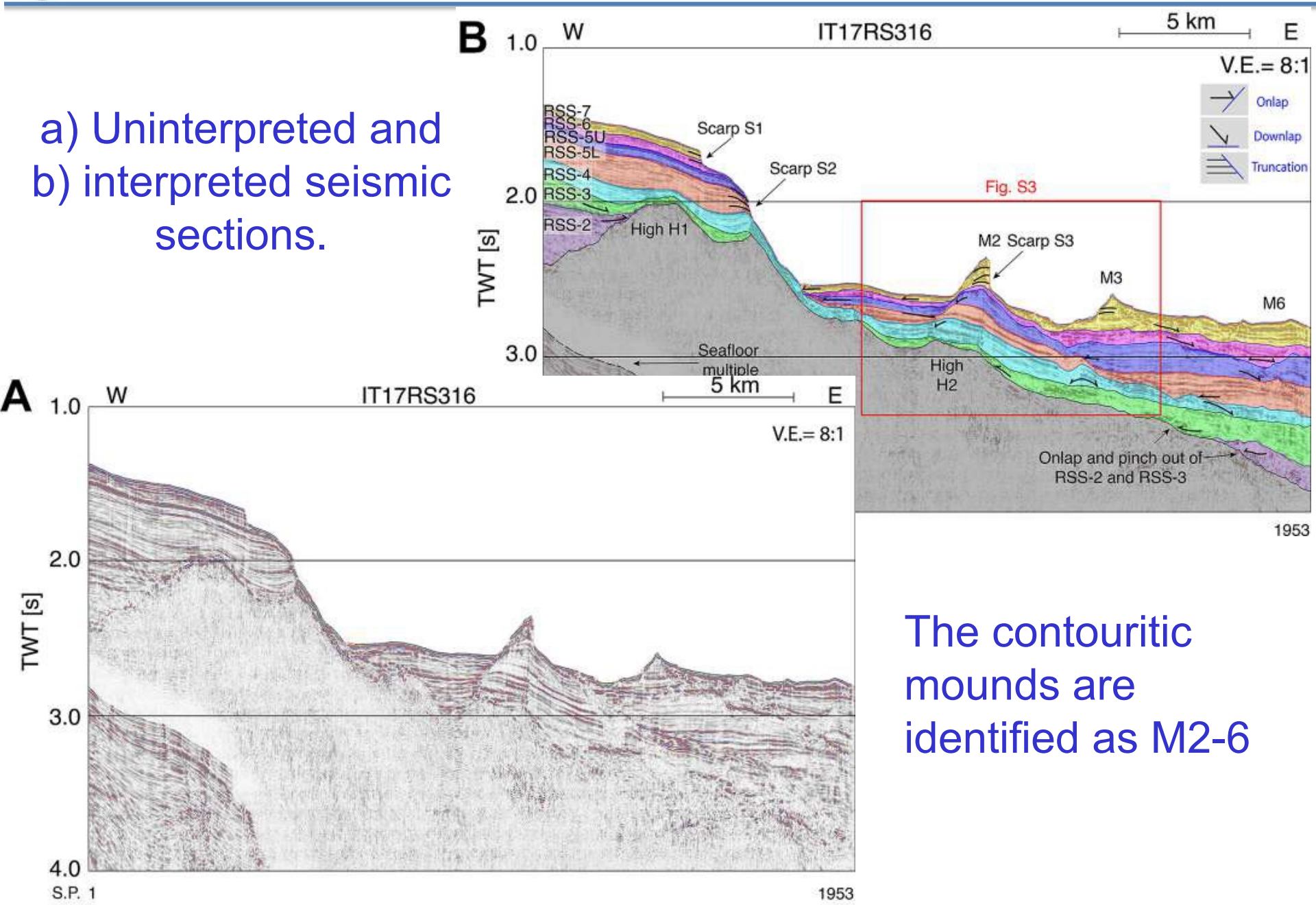
from IODP Expedition 374 Proceeding (McKay et al., 2019)





Seoismic sections crossing U1523 and U1524

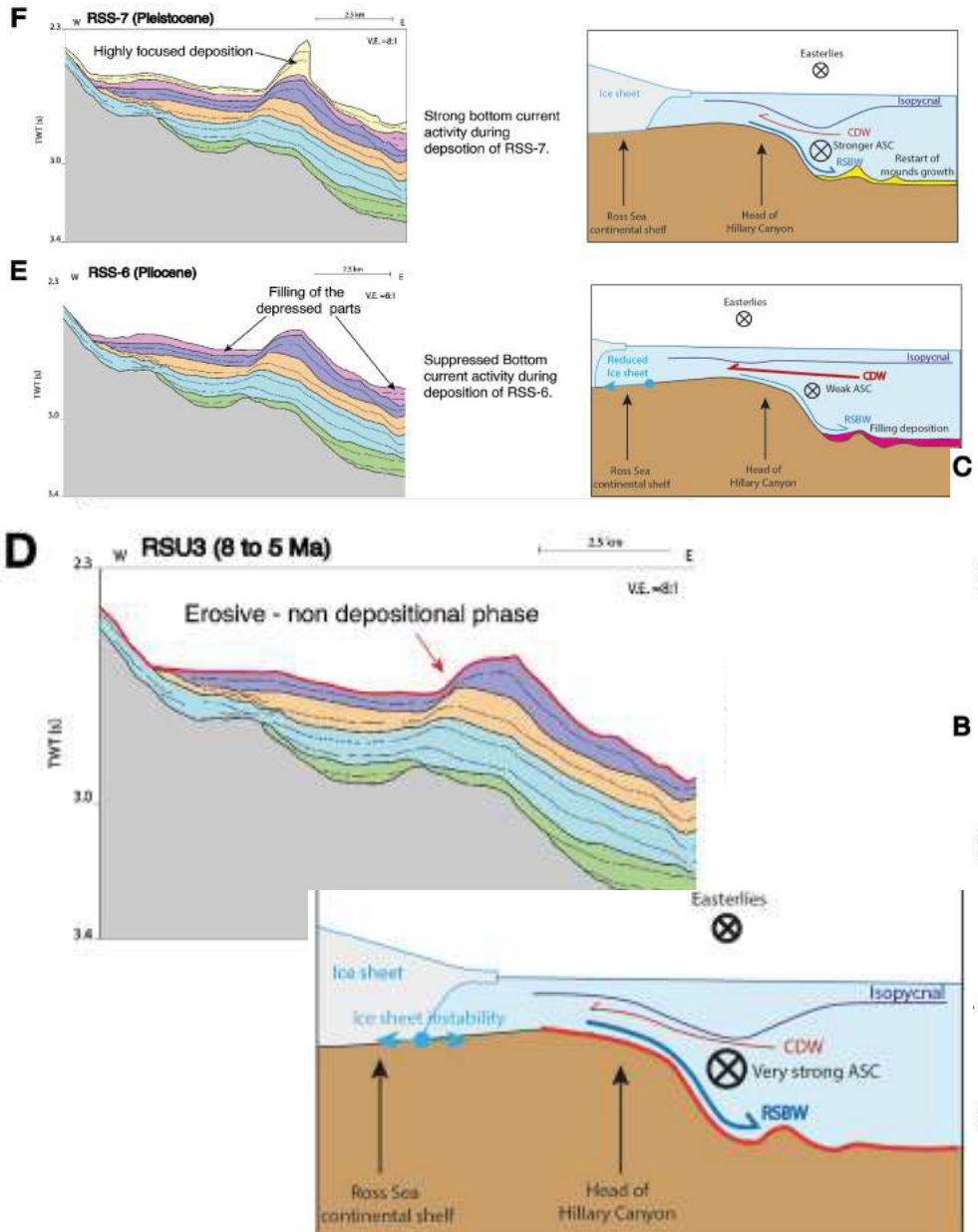
a) Uninterpreted and
b) interpreted seismic sections.



The contouritic mounds are identified as M2-6

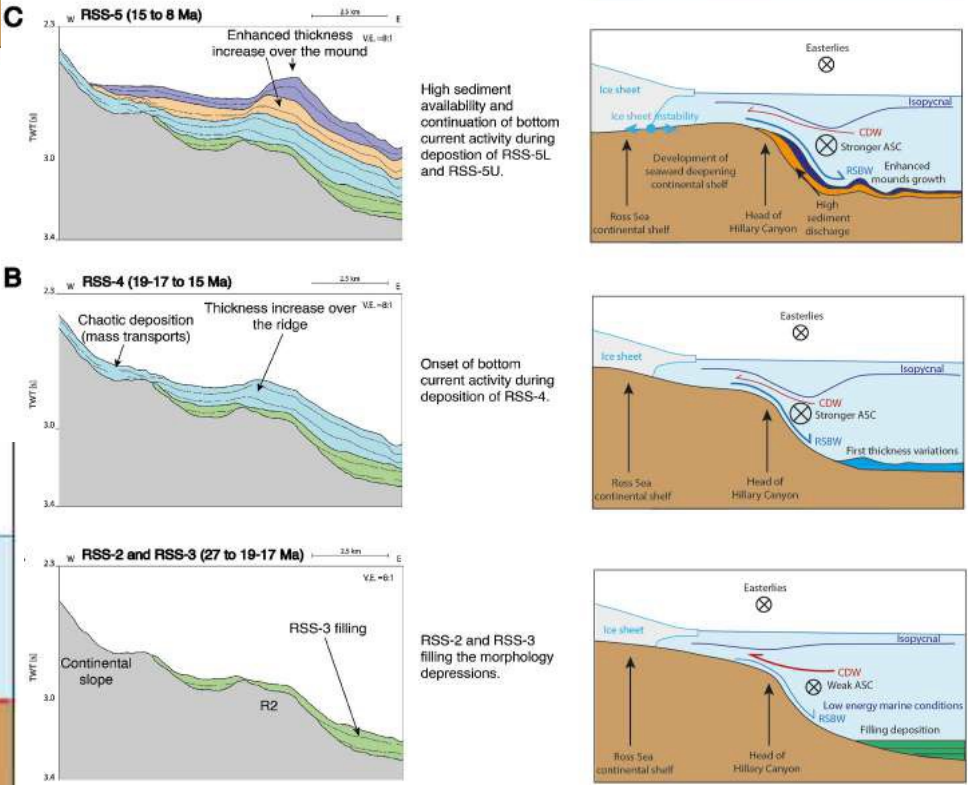
Evolution of mound M2

Prevailing oceanic condition



Evolution of the mound M2 (left) and associated prevailing oceanic conditions (right).

ASC: Antarctic Slope Current.
CDW: Circumpolar Deep Water.
RSBW: Ross Sea Bottom Water



Diverse domande sulle Sequence stratigraphic surfaces

Relative sea-level fall

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

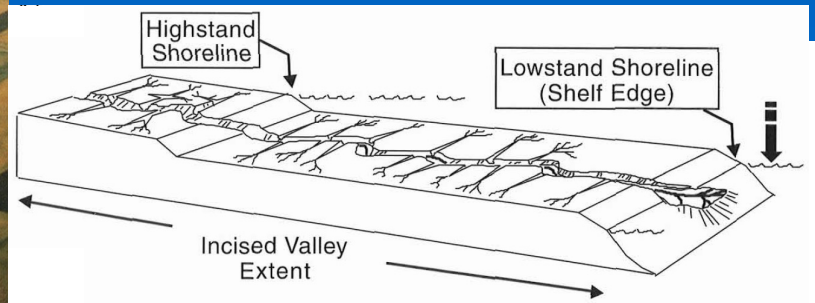
Relative sea-level rise

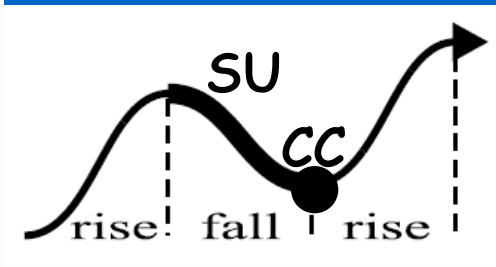
- Maximum regressive surface
- Maximum flooding surface
- Ravinement surface

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)

Cosa vogliono dire le linee spesse e i punti sulla curva del livello del mare?





Question: Basal Surface of Forced Regression?

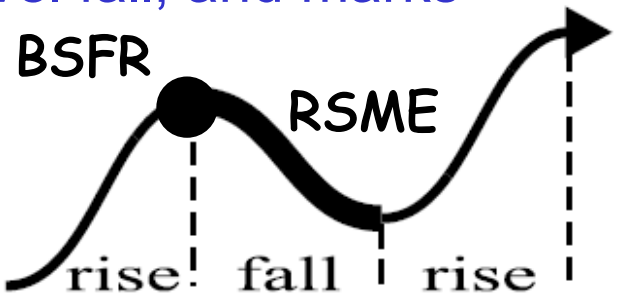
Answer: **base dei depositi di regressione forzata = fondo mare all'inizio del RSL fall. Può essere rimaneggiata dalla RSME, alla base della shoreface.**

Question: **RMSE si sposta con la regressione marina?**

Answer: **Più che spostarsi, si espande, e diventa più giovane procedendo verso mare**

The Basal Surface of Forced Regression (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 Regressive Rurface of Marine Erosion (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

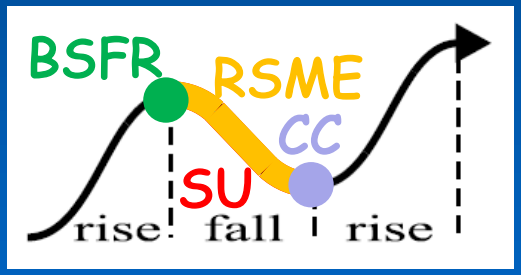


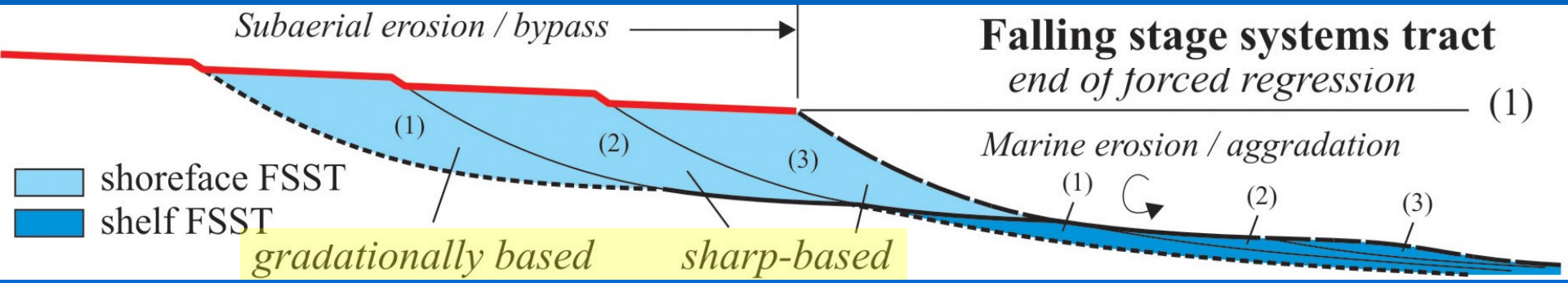
basal surface of forced regression BSFR is to the paleo-seafloor at the onset of forced regression and lies at the base of all marine deposits accumulated during relative sea-level fall.

regressive surface of marine erosion RSME is cut by waves in the shoreface during relative sea-level fall, and marks the base of forced regressive shorefaces.

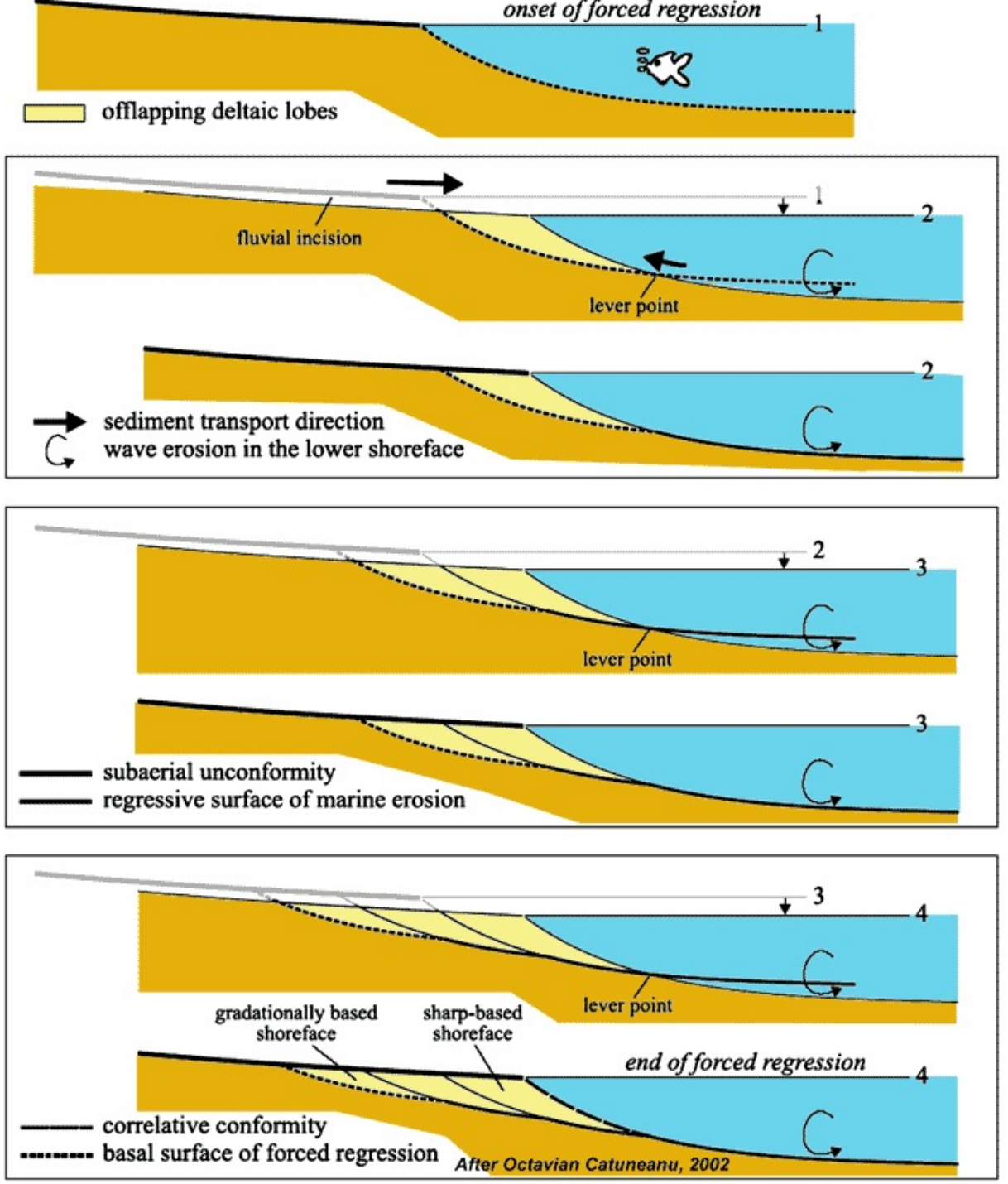
correlative conformity CC corresponds to the seafloor at the end of relative sea-level fall and is connected to SU basinward termination.

subaerial unconformity SU develops during relative sea-level fall and progressively extends basinwards.





How the Regressive Surface of Marine Erosion reworks the Basal Surface of Forced Regression during the Falling Stage System Tract



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

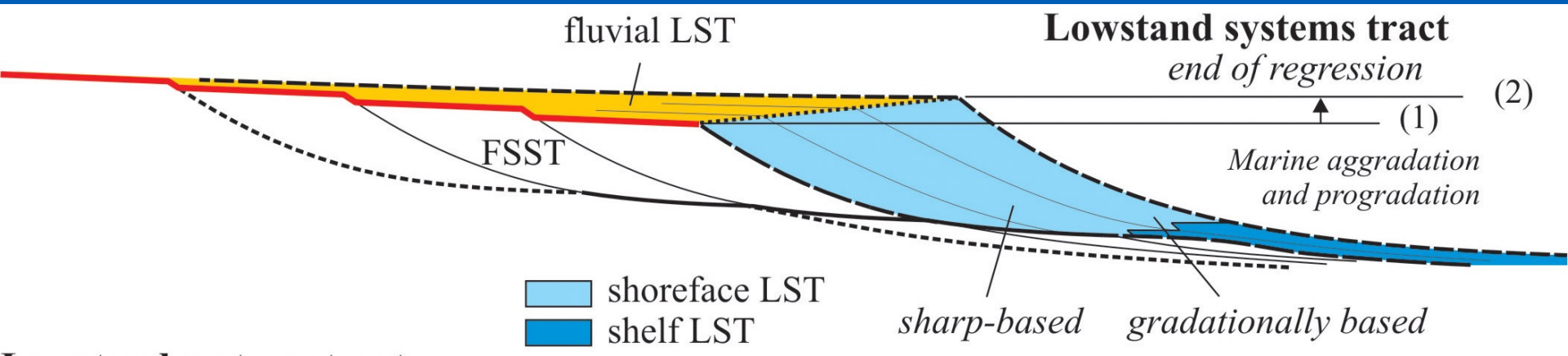
maximum regressive surface

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.

within-trend normal regressive surface

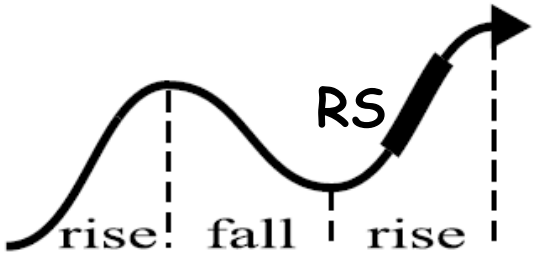
lateral shifts of facies



Question: RS a contatto con MSR? (MRS)

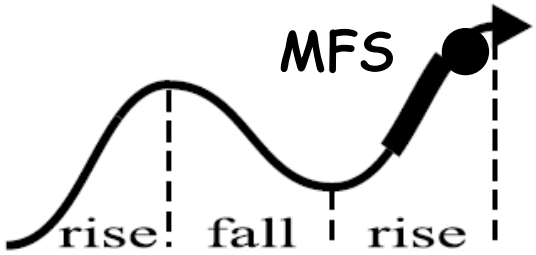
The RS is a diachronous erosional surface cut by waves (WRS) or tidal currents (TRS) in the shoreface and coastal settings during transgression (RSL rise). It is associated with transgressive lags or condensed bioclastic deposits. It climbs toward the basin margin. Its formation depends on wave energy, slope and rates of RSL rise and sediment supply

Answer: la RS può rimaneggiare la MRS



Question: **Come MFS si intende la zona/superficie dove in un'intera sequenza c'era la trasgressione maggiore, la trasgressione maggiore assoluta in una seguenza progradante in un periodo definito o solamente per la parte che si sta osservando/studiando?**

The MFS marks the end of the shoreline transgression. It separates retrograding (transgressive) strata below from prograding (regressive) strata above. In seismic it is a downlap surface. It is commonly associated with a condensed section. It is formed when the sedimentation rates start to outpace the rates of creation of accommodation (relative sea-level rise).



Answer: **La MFS in ogni singola sequenza si identifica con il fondo mare almomento della massima ingressione marina (fine della trasgressione). Se c'è una gerarchia di sequenze, anche le MFSs potranno essere definite a varie scale.**

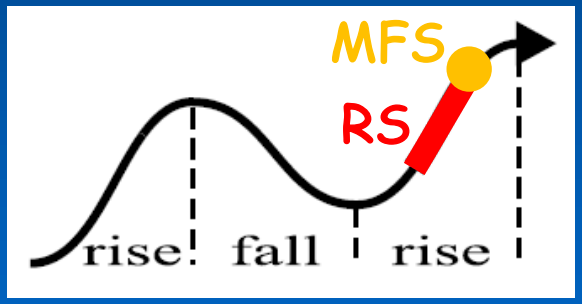
ravinement surface

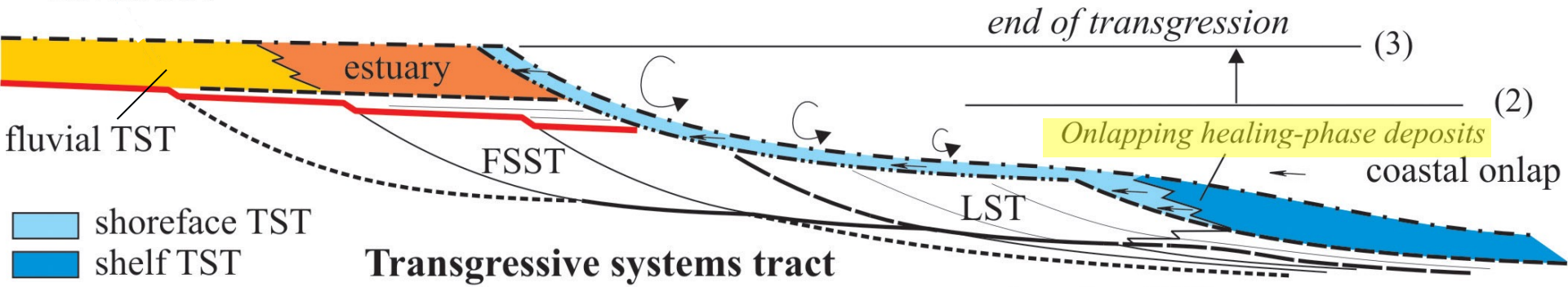
RS is a diachronous erosional surface cut by waves or tidal currents in the shoreface and coastal settings during transgression (RSL rise). It is associated with transgressive lags or condensed bioclastic deposits.

maximum flooding surface

MFS marks the end of the shoreline transgression. It separates retrograding (transgressive) strata below from prograding (regressive) strata above. In seismic it is a downlap surface. It is commonly associated with a condensed section.

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





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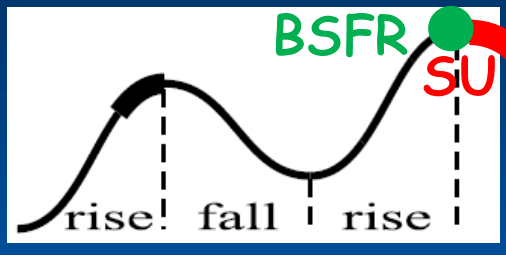
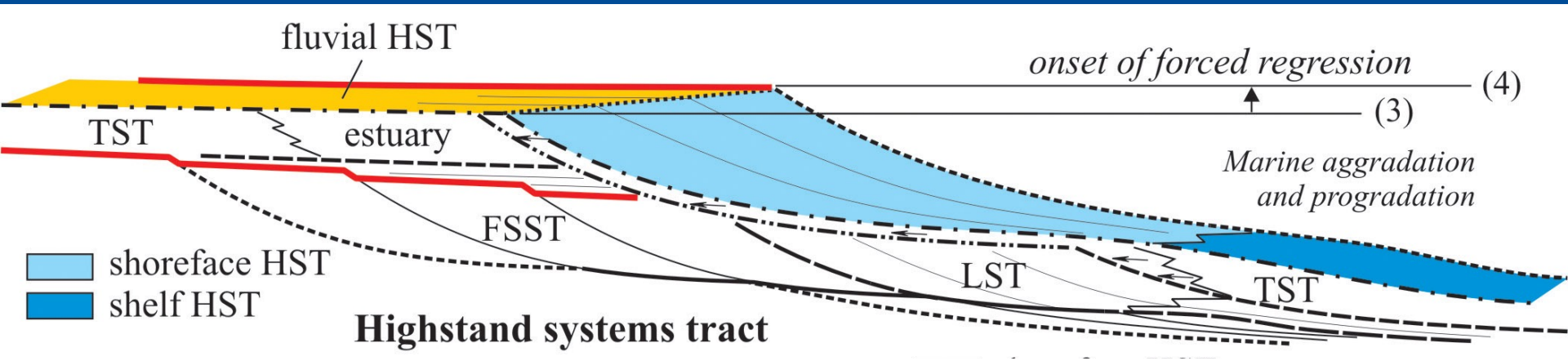
subaerial unconformity SU develops during relative sea-level fall and progressively extends basinwards.





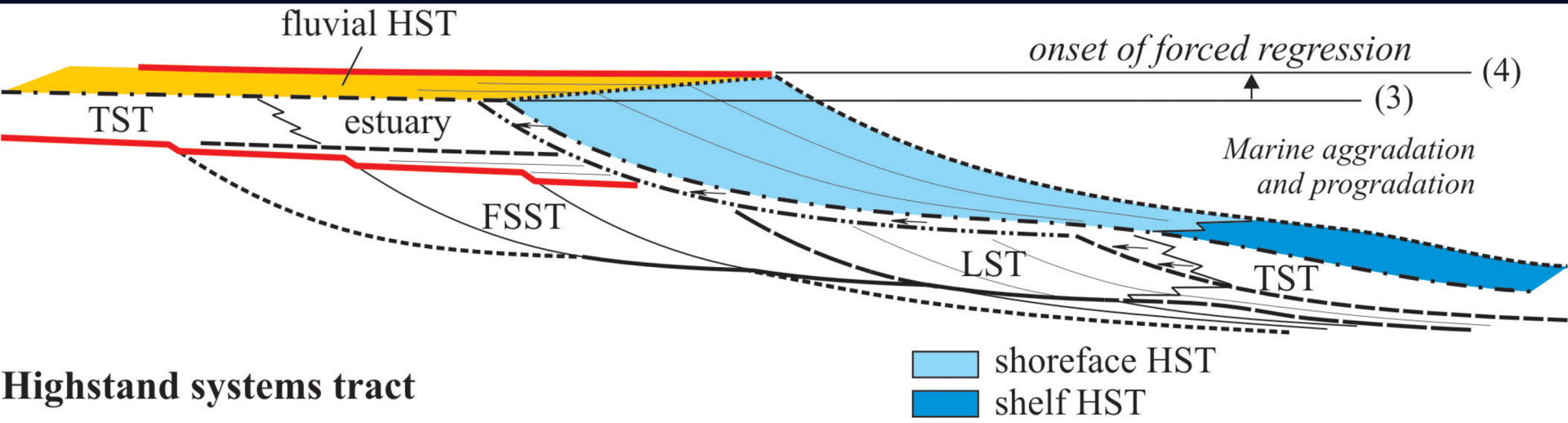
subaerial unconformity
correlative conformity
basal surface of forced regression
regressive surface of marine erosion
ravinement surface

maximum regressive surface
maximum flooding surface
within-trend normal regressive surface
lateral shifts of facies
coastal onlap (healing phase deposits)

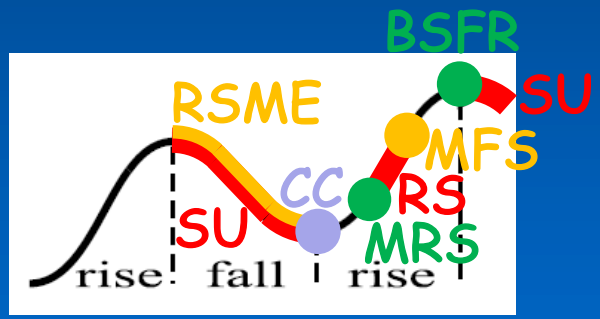
Question: **Si potrebbero aggiungere per piacere più rappresentazioni visive dei vari tratti sistematici ed i loro rispettivi grafici in una sequenza in modo da poter confrontare la granulometria e caratteristiche dei sedimenti che li compongono?**

Answer: **granulometria e caratteristiche dei sedimenti che compongono i diversi apparati deposizionali (system tract) dipendono da tanti fattori (tipo di substrato che viene eroso, dall'energia locale, dal gradiente della costa, etc.). Quello che caratterizza i diversi system tracts sono i diversi ambienti deposizionali, ad es. estuario, piuttosto che shoreface (spiaggia sommersa). Approfondiamo in «Application to reservoir geology». Vediamo ora system tracts e curve del RSL in sequenza.**

System tracts & stratigraphic surfaces



Highstand systems tract



subaerial unconformity
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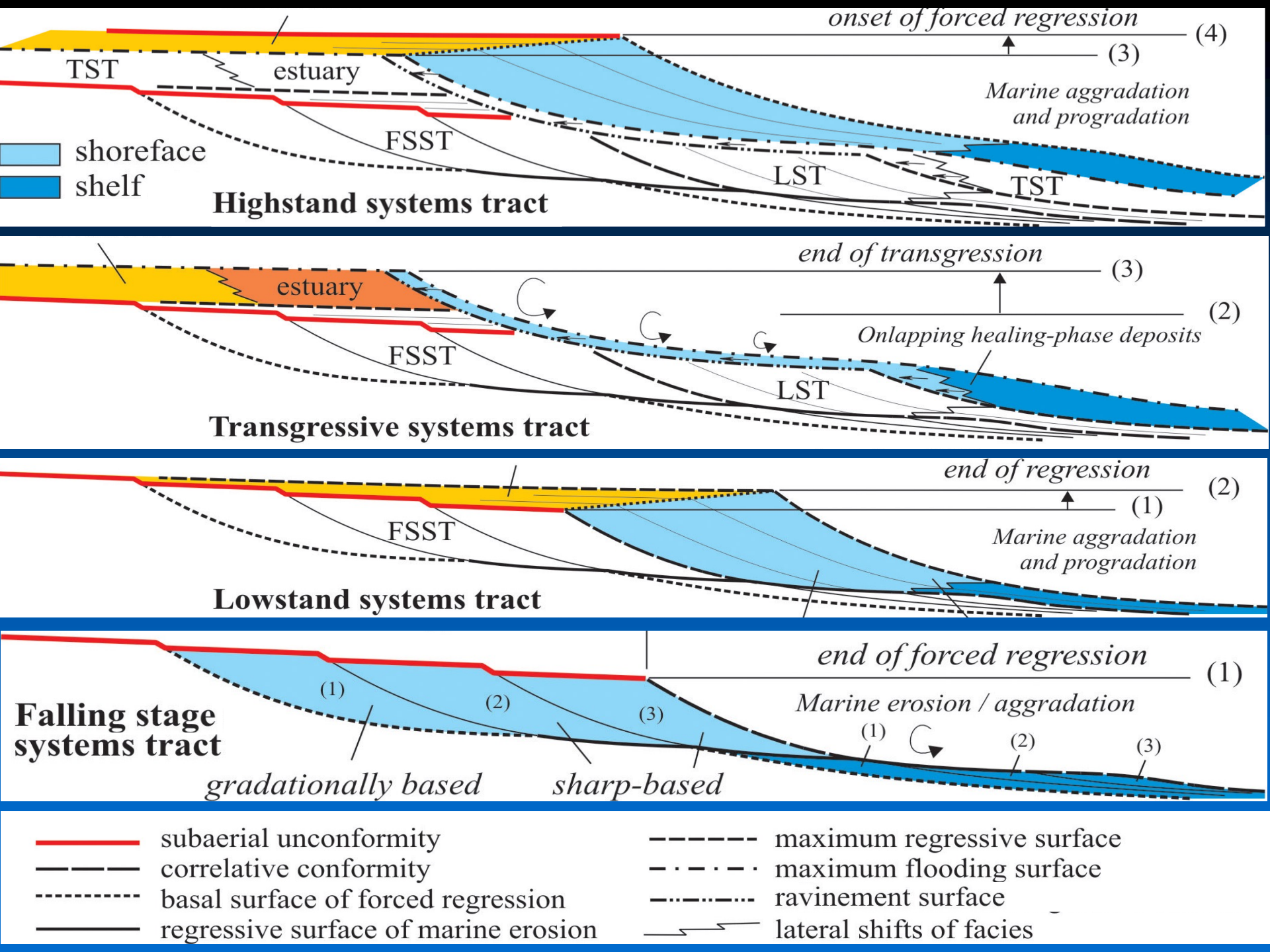
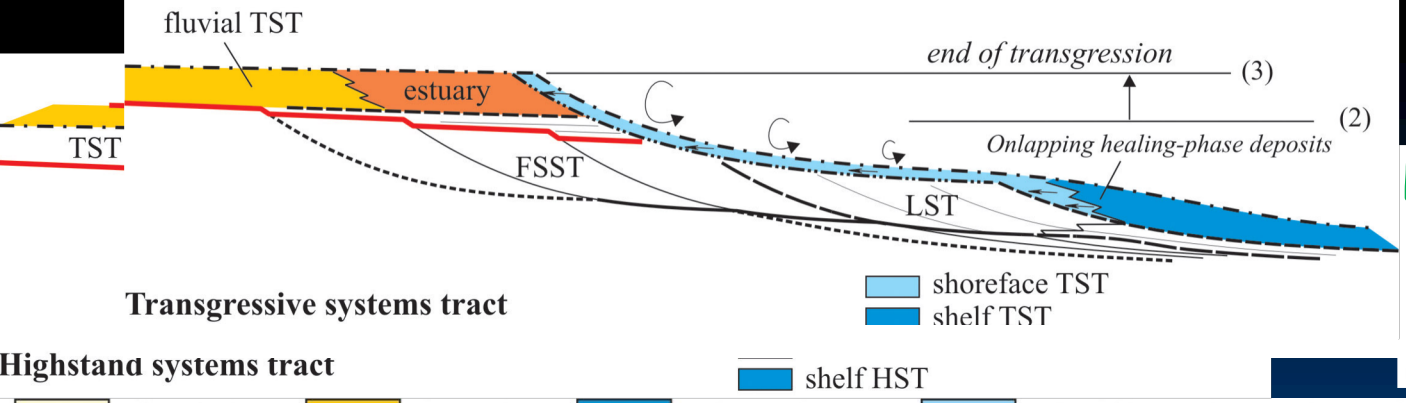
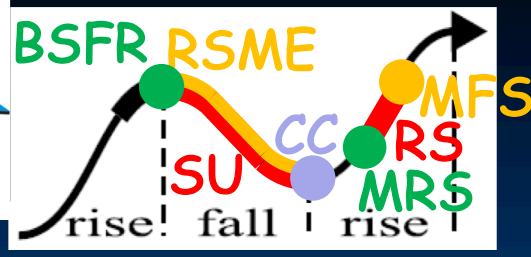
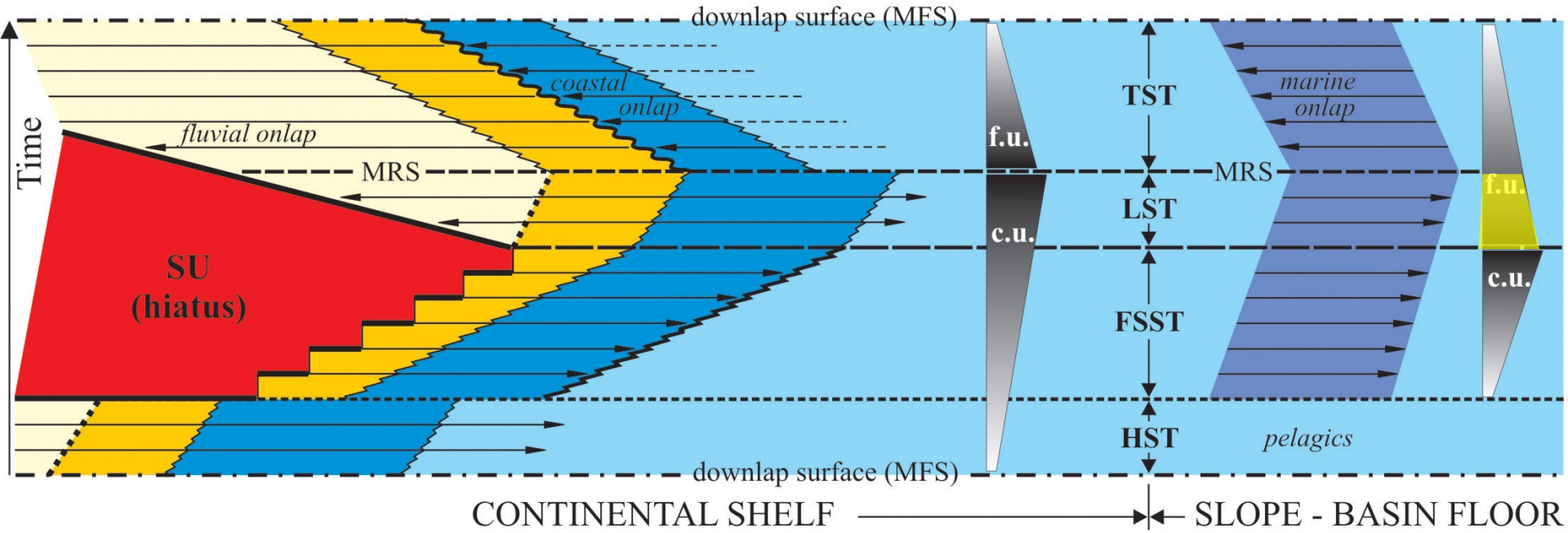

onset of forced regression
(4)
(3)
TST
estuary
Marine aggradation
and progradation
shoreface
shelf
FSST
LST
TST
Highstand systems tract
end of transgression
(3)
estuary
(2)
FSST
Onlapping healing-phase deposits
LST
Transgressive systems tract
end of regression
(2)
(1)
FSST
Marine aggradation
and progradation
Lowstand systems tract
end of forced regression
(1)
Falling stage
systems tract
(1)
(2)
(3)
Marine erosion / aggradation
(1)
(2)
(3)
gradationally based
sharp-based
subaerial unconformity
correlative conformity
basal surface of forced regression
regressive surface of marine erosion
maximum regressive surface
maximum flooding surface
ravinement surface
lateral shifts of facies





fluvial | beach | shoreface | shelf/condensed section | submarine fans



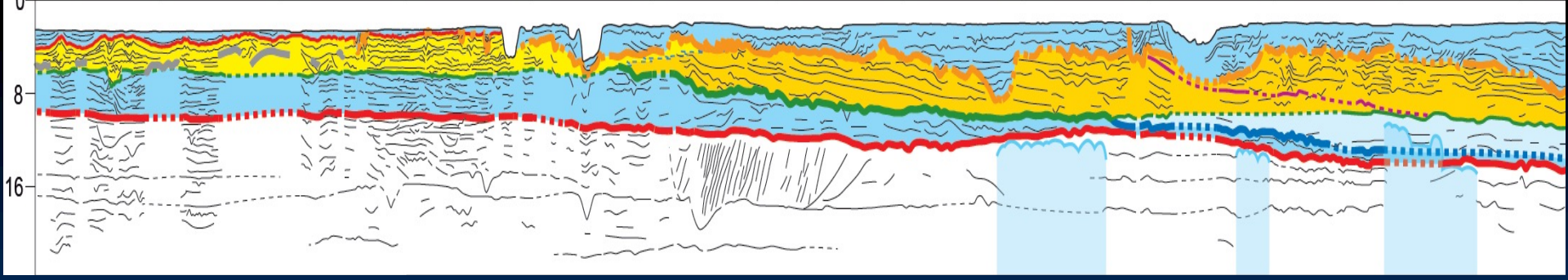
Wheeler diagram

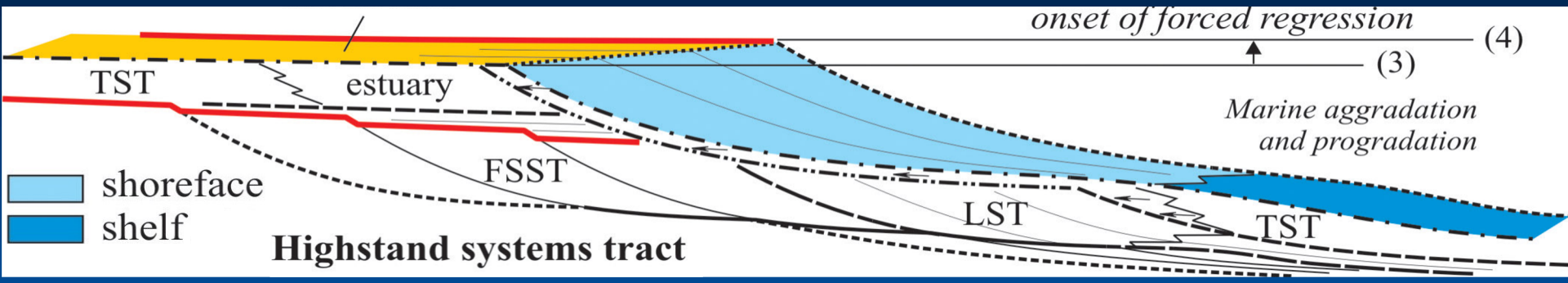
- subaerial unconformity
- correlative conformity
- regressive surface of marine erosion
- basal surface of forced regression
- onlap
- maximum regressive surface
- maximum flooding surface
- transgressive ravinement surface
- within-trend normal regressive surface
- downlap

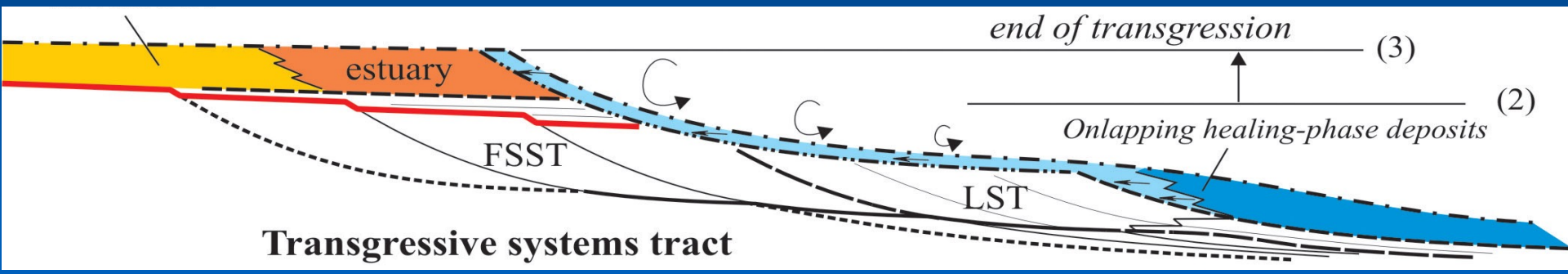
Question: **Qualche approfondimento in generale ed esempio grafico sulle varie sequenze stratigrafiche e se possiamo magari noi tentare di segnarle o disegnarle**

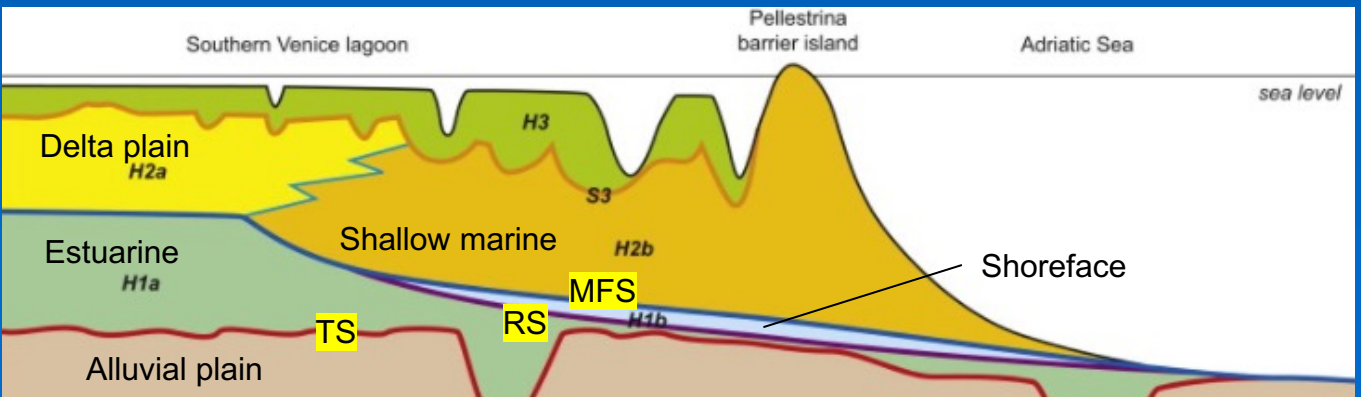
Answer: **Prima vi mostro tre diapositive di esempi, la spiegazione sui «diversi» limiti di sequenza,**

e poi la prossima volta un esercizio dove potete tentare voi di identificare i system tracts e segnare le superfici stratigrafiche









Guess the ST and surfaces !

From Zecchin et al. (2009) Venice lagoon. Continental Shelf Research 29, 1343-1359