Another Look at Fluvial Sequence Stratigraphy*

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Abstract

Vertical changes in fluvial deposit net/gross over 10’s to 100’s of meters and associated changes in depositional style and channel belt connectivity are widely observed within thick alluvial successions. It is popular to interpret these variations in terms of allogenic accommodation variations defined under a fluvial equilibrium profile of fixed geometry that is coupled to shoreline position. These interpretations generally infer that fluvial gradients steepen during sea-level fall, leading to declining accumulation rates (and eventual channel incision), floodplain narrowing, preferential preservation of channel relative to overbank deposits, and internally sandy channel belts. Sea-level rise is inferred to decrease fluvial gradients and widen floodplains as sediment aggradation accelerates and river incisions fill, leading to greater preservation of floodplain deposits and more internally heterolithic channel belts. Despite their popularity, we suggest current sequence stratigraphic models for fluvial systems based on these ideas are too simplistic and in many cases the underlying assumptions may be wrong. Fluvial stratigraphic interpretations commonly reverse cause and effect on alluvial architecture variables, wrongly predict that most large-scale fluvial successions fine upward, and over-emphasize accommodation controls and the ability of coastlines to buttress fluvial aggradation during relative sea-level rise. As an alternative, we interpret fluvial successions as regionally and locally prograding sediment wedges that initially expand as rates of downstream slope decline gradually decay over time and then back-step as sediment aggradation rates locally fall below subsidence rates (c.f., Autoretreat of Muto & Steel, 1997). Progradation can be initiated by allogenic changes or by autocyclic avulsions of sediment supply to areas that have previously undergone gradual subsidence. Sea level is inferred to have little influence on alluvial slopes and rates of sediment progradation, except perhaps in some areas directly adjacent to the coast. The idea that fluvial deposits are composed of prograding and retrograding units (at multiple scales) is used to interpret variations within several thick alluvial successions that gradually coarsen upward as channel belts progressively become larger and more obviously clustered. These successions tend to be capped by a relatively thin, erosionally-based sand-dominated interval, before fairly abruptly fining upsection.

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Another Look at Fluvial Sequence Stratgraphy

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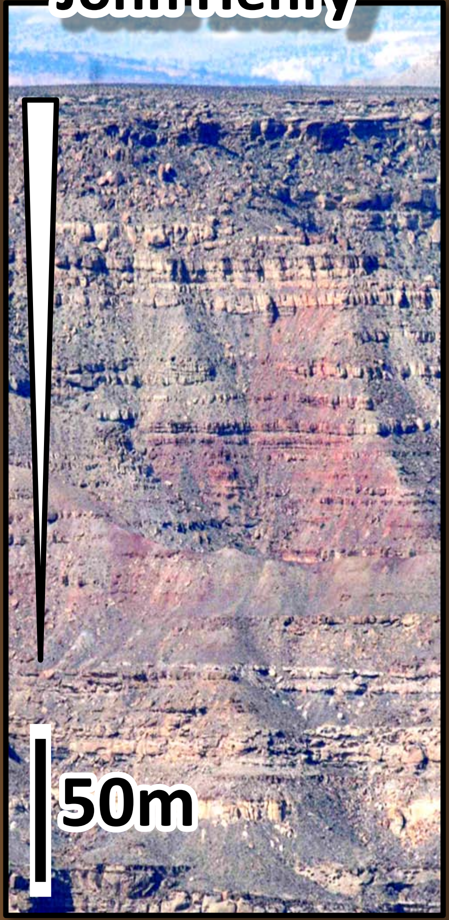
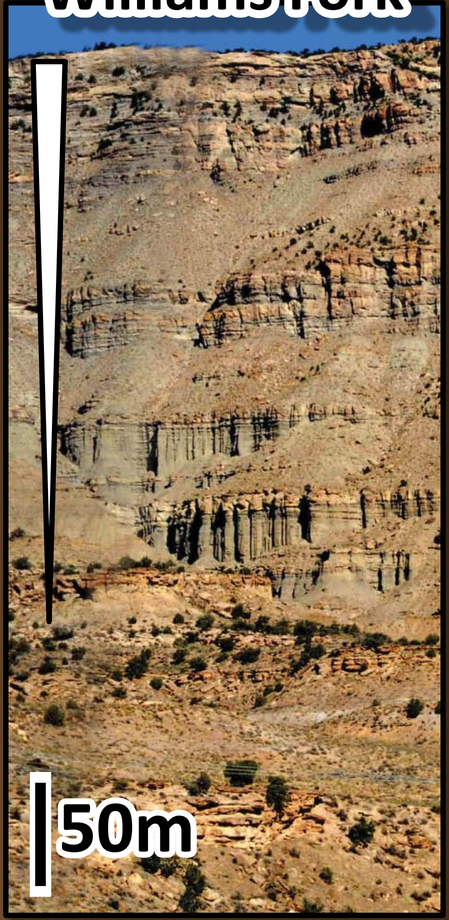
John Henry



Castlegate

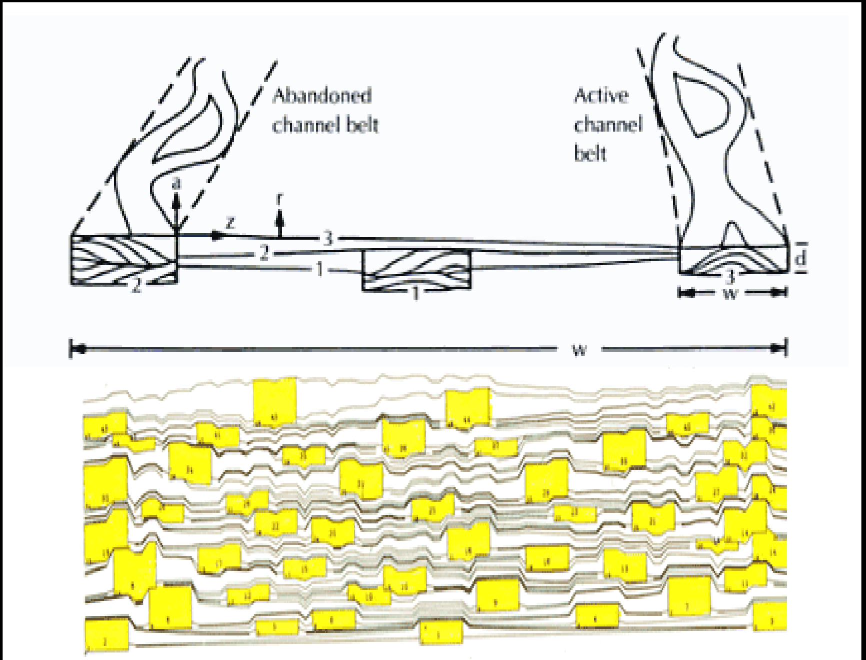
Price River

Williams Fork

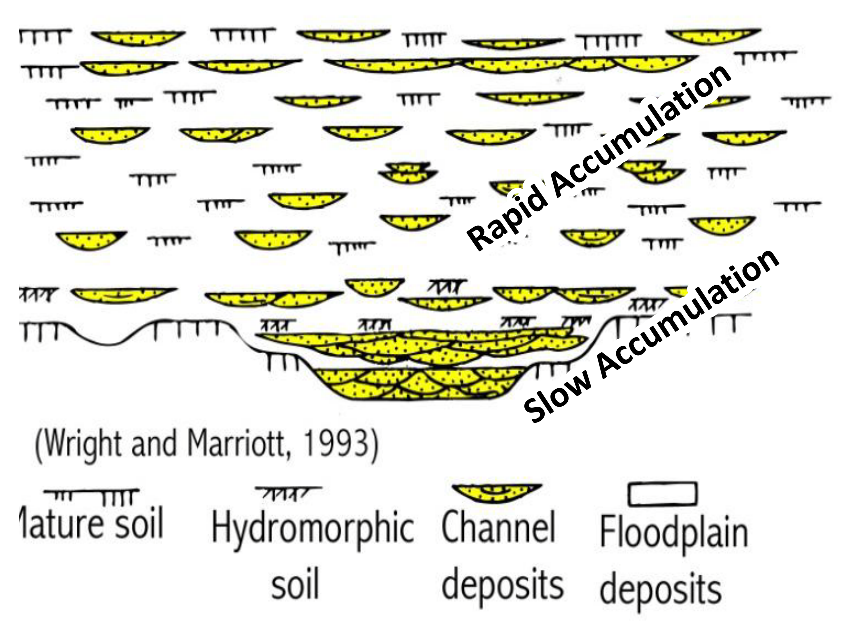


Popular Concept 1

Proportion of channel belt deposits within a succession is inversely related to aggradation rate. If all other variables are assumed constant!



Bridge and Mackey, 1995

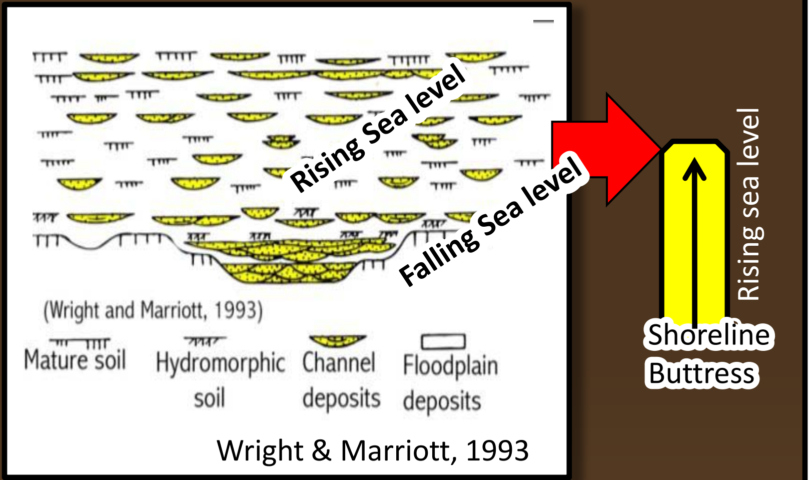


Wright & Marriott, 1993

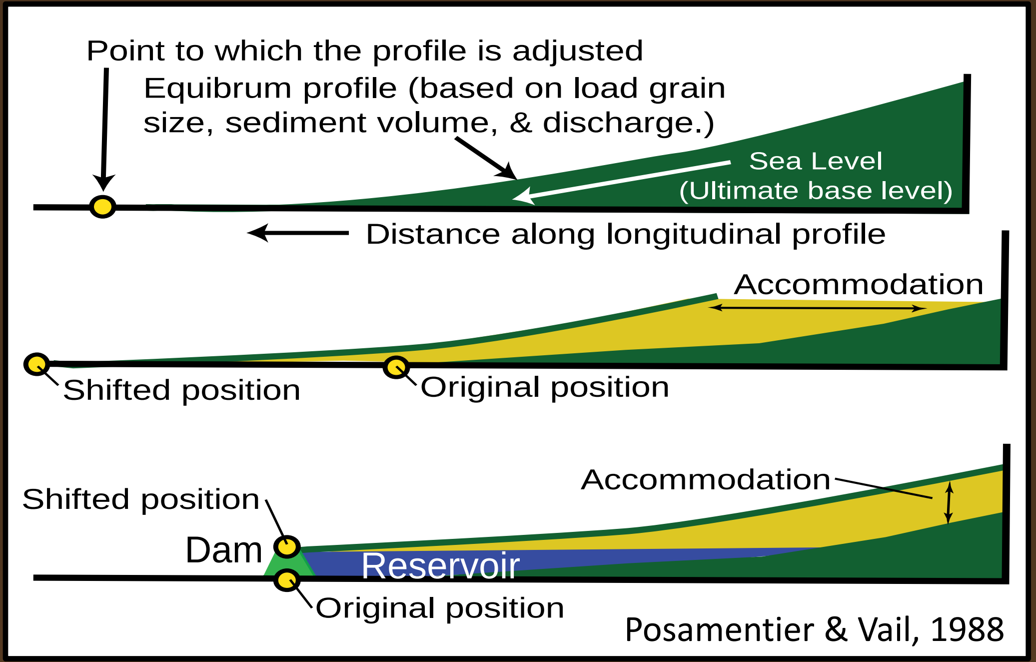
The LAB alluvial architecture models define the variables that account for variations in deposit net/gross, but they do not explicitly define relationships between these variables, nor allocyclic process that **control** changes in these variables.

Popular Concept 2

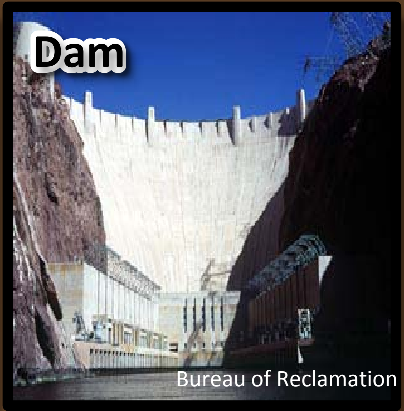
Fluvial accommodation can be defined by reference to a graded profile, fixed in shape, that is coupled the coast.



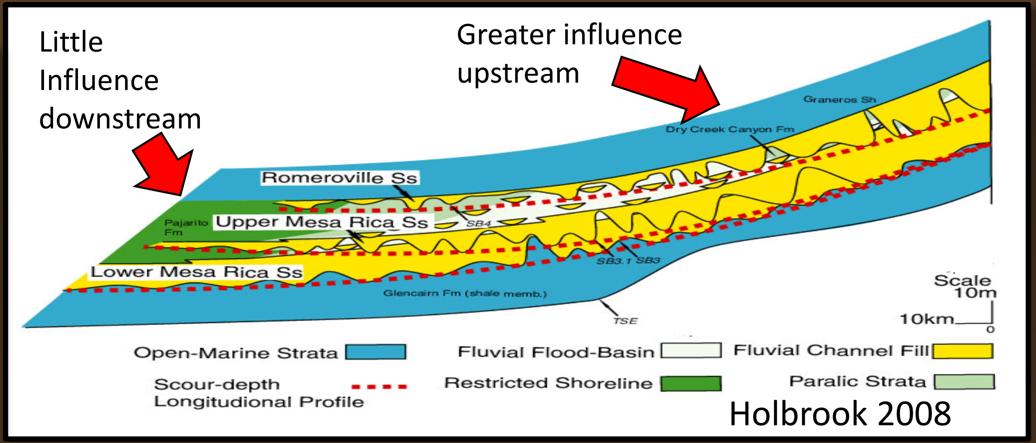
Wright & Marriott, 1993



Posamentier & Vail, 1988



Bureau of Reclamation



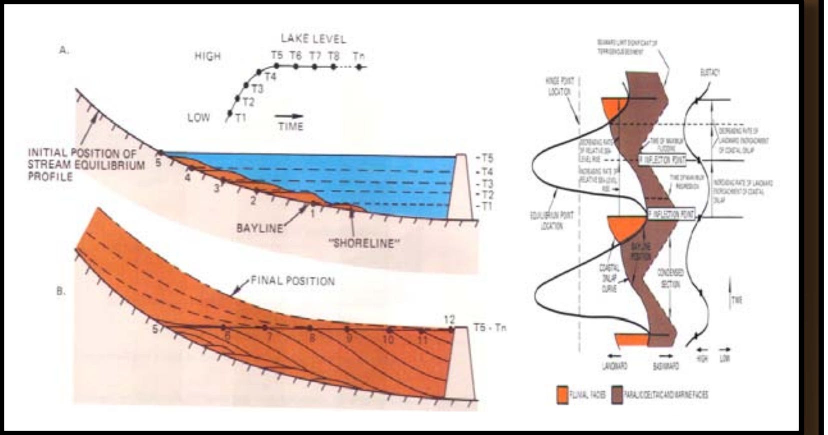
Holbrook 2008

Unlike dams, shorelines are not locked in position along a fluvial profile

Popular Concept 3

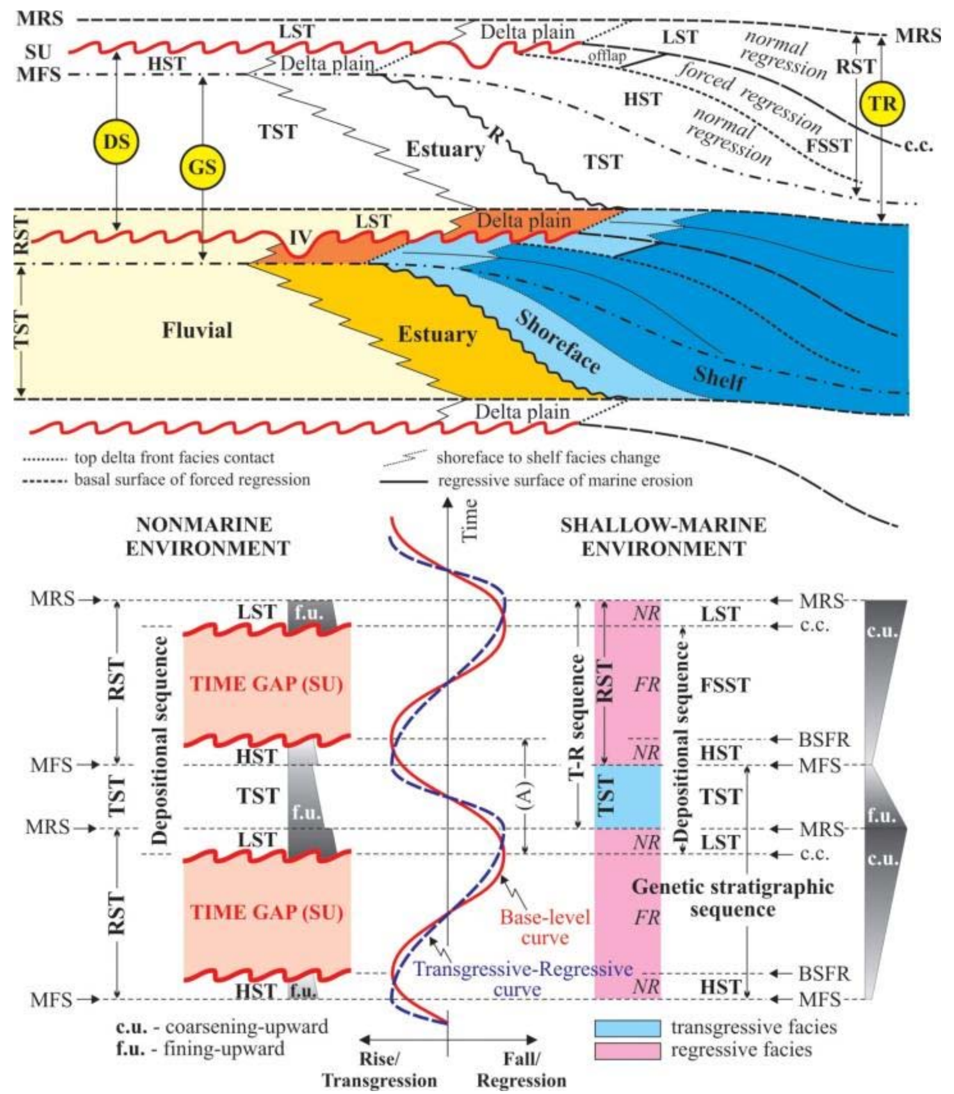
Upward fining major fluvial depositional cycles

In Posamentier & Vail (1988) most fluvial deposition was predicted to occur in the early highstand when shorelines moved basinward .



"It is now widely understood that fluvial aggradation and coastal onlap occur on the rising limb of a relative sea-level curve"

From Aitken and Howell (1996) Introduction to the volume ***High Resolution Sequence Stratigraphy*** (Geological Society, London, Sp 104)



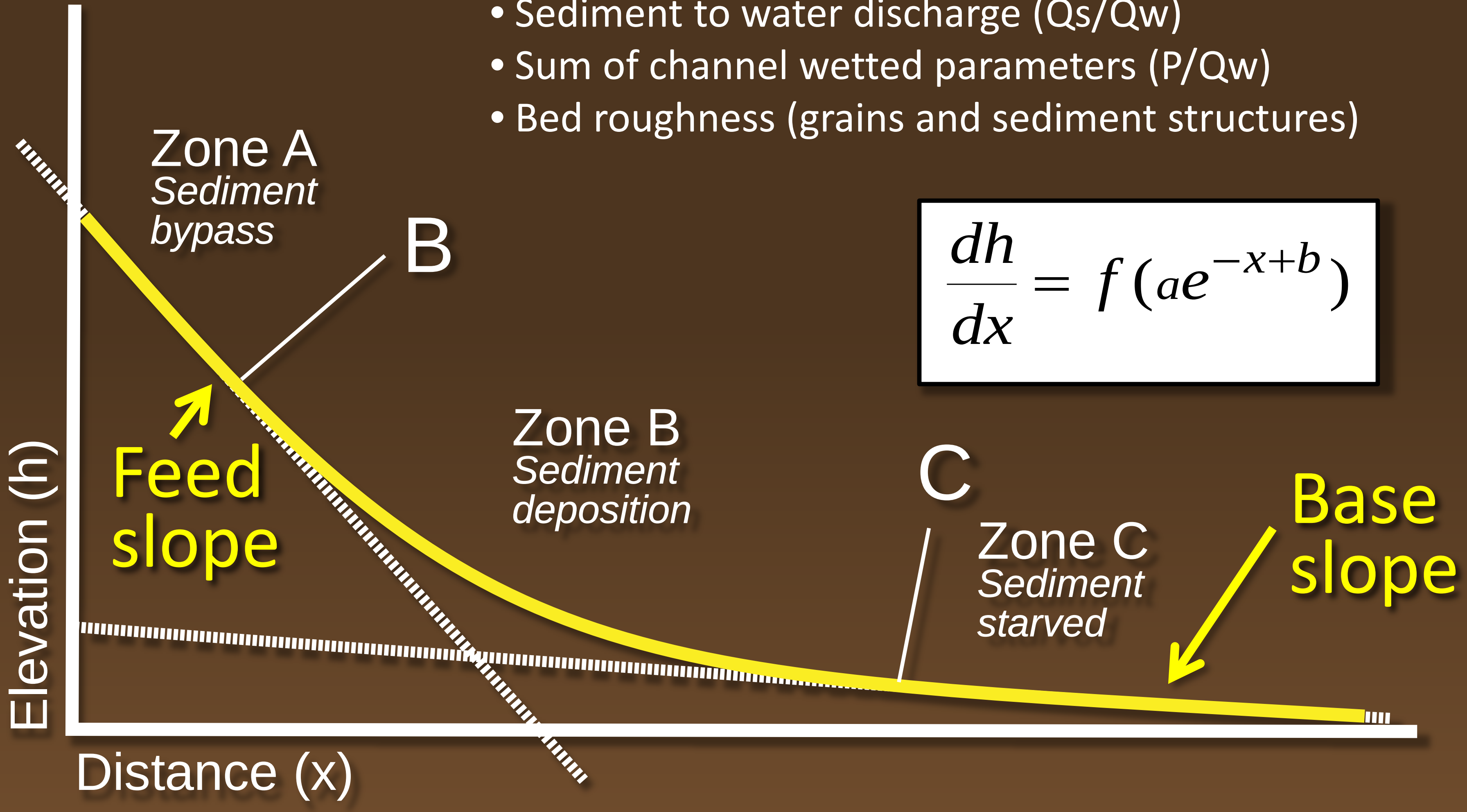
Canuneanu 2006

Downstream Slope

Rate of downstream slope change depends on:

- Sediment to water discharge (Qs/Qw)
- Sum of channel wetted parameters (P/Qw)
- Bed roughness (grains and sediment structures)

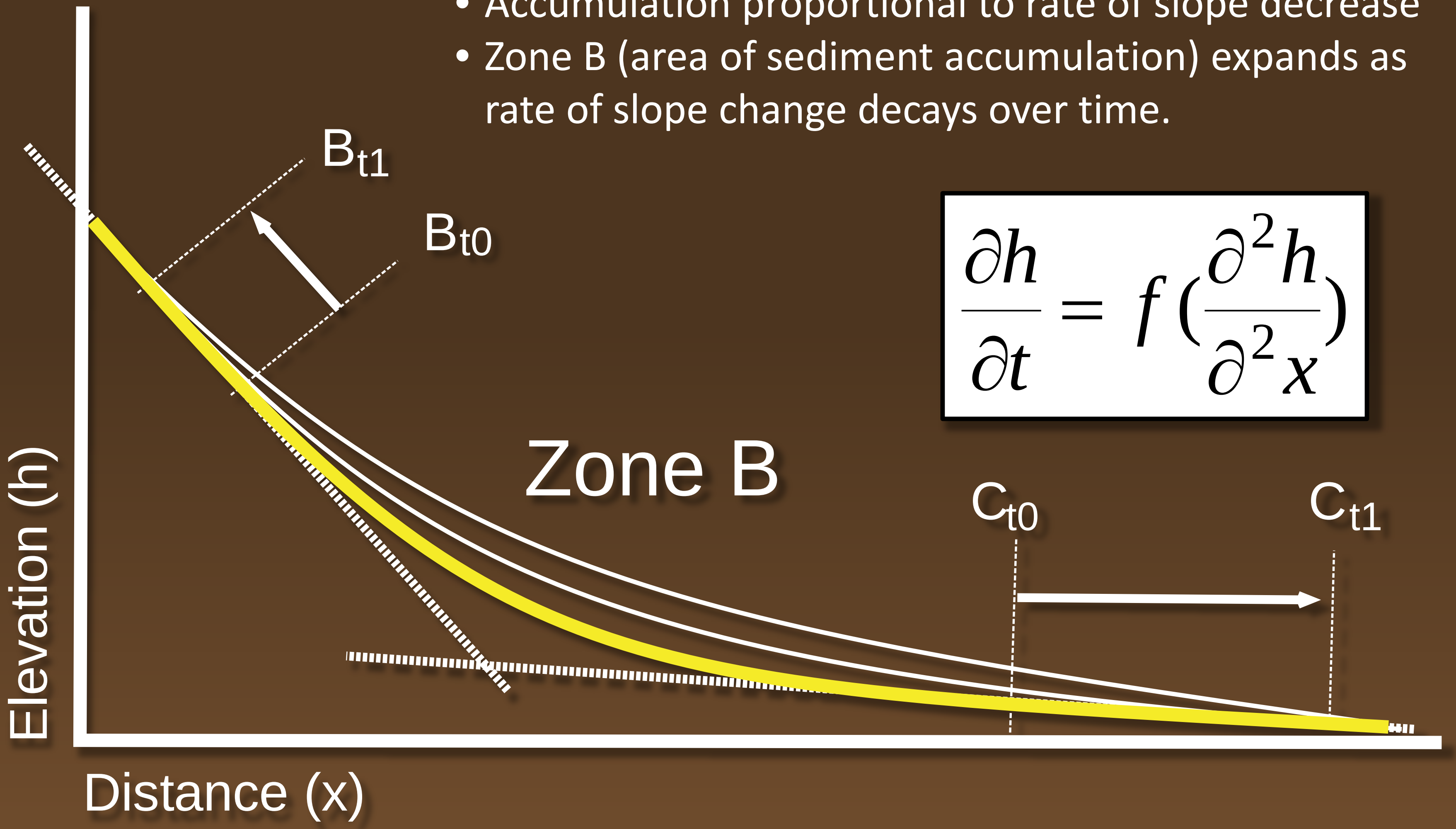
$$\frac{dh}{dx} = f\left(ae^{-x+b}\right)$$



Accumulation

All else constant (no subsidence):

- Accumulation proportional to rate of slope decrease
- Zone B (area of sediment accumulation) expands as rate of slope change decays over time.

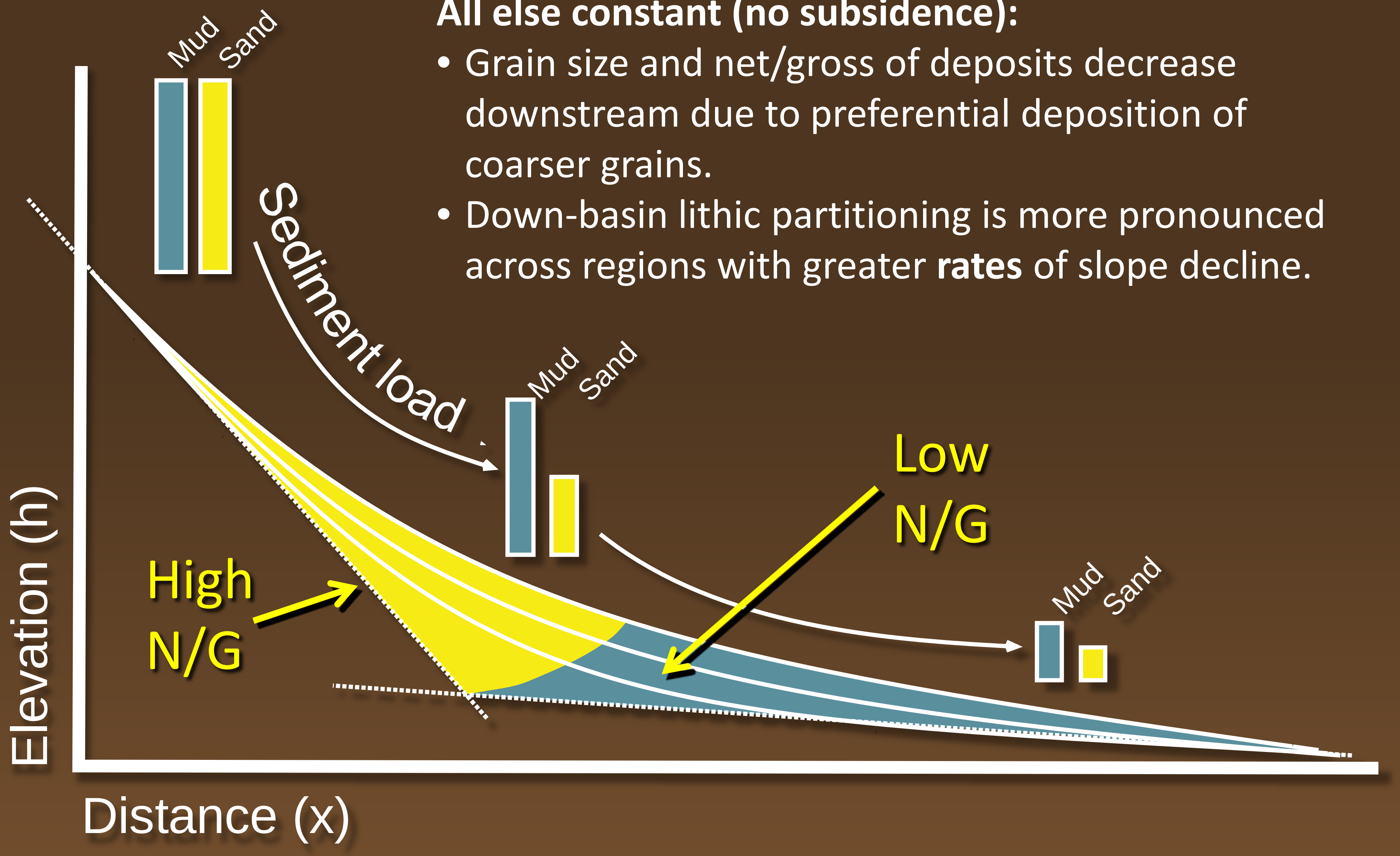


$$\frac{\partial h}{\partial t} = f\left(\frac{\partial^2 h}{\partial^2 x}\right)$$

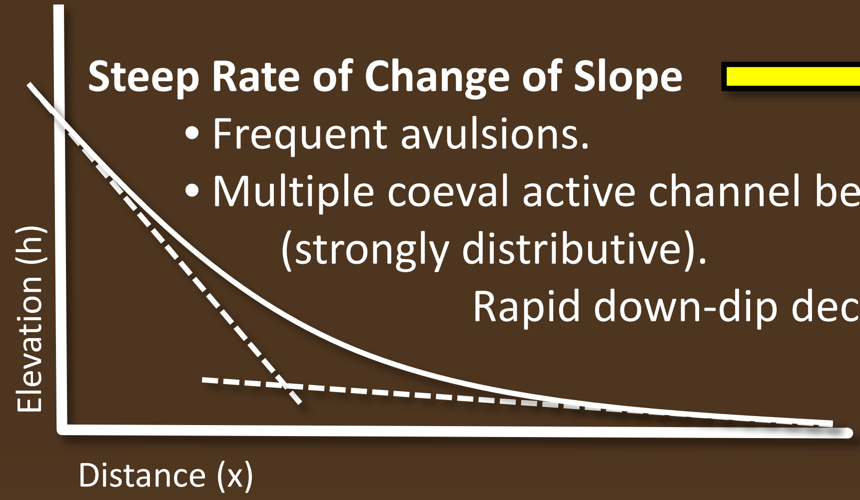
Sediment Partitioning

All else constant (no subsidence):

- Grain size and net/gross of deposits decrease downstream due to preferential deposition of coarser grains.
- Down-basin lithic partitioning is more pronounced across regions with greater **rates** of slope decline.



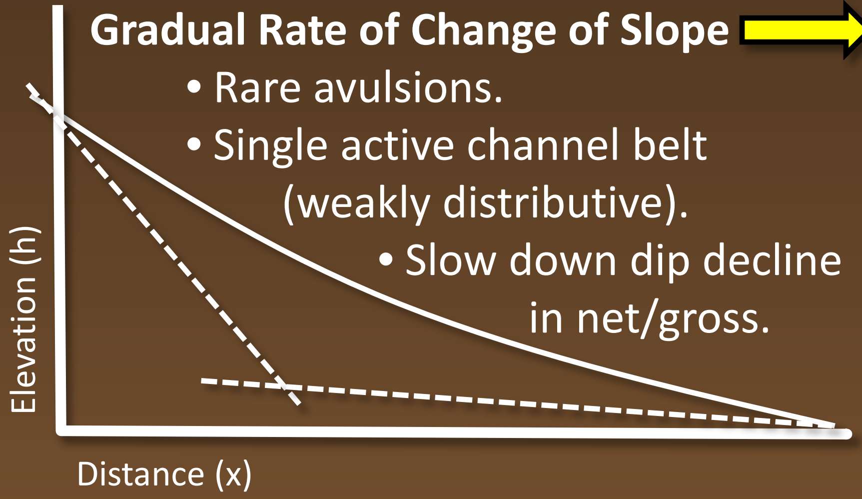
Channel Belt Patterns & Avulsion Behavior



Steep Rate of Change of Slope

- Frequent avulsions.
- Multiple coeval active channel belts (strongly distributive).

Rapid down-dip decline in net/gross.



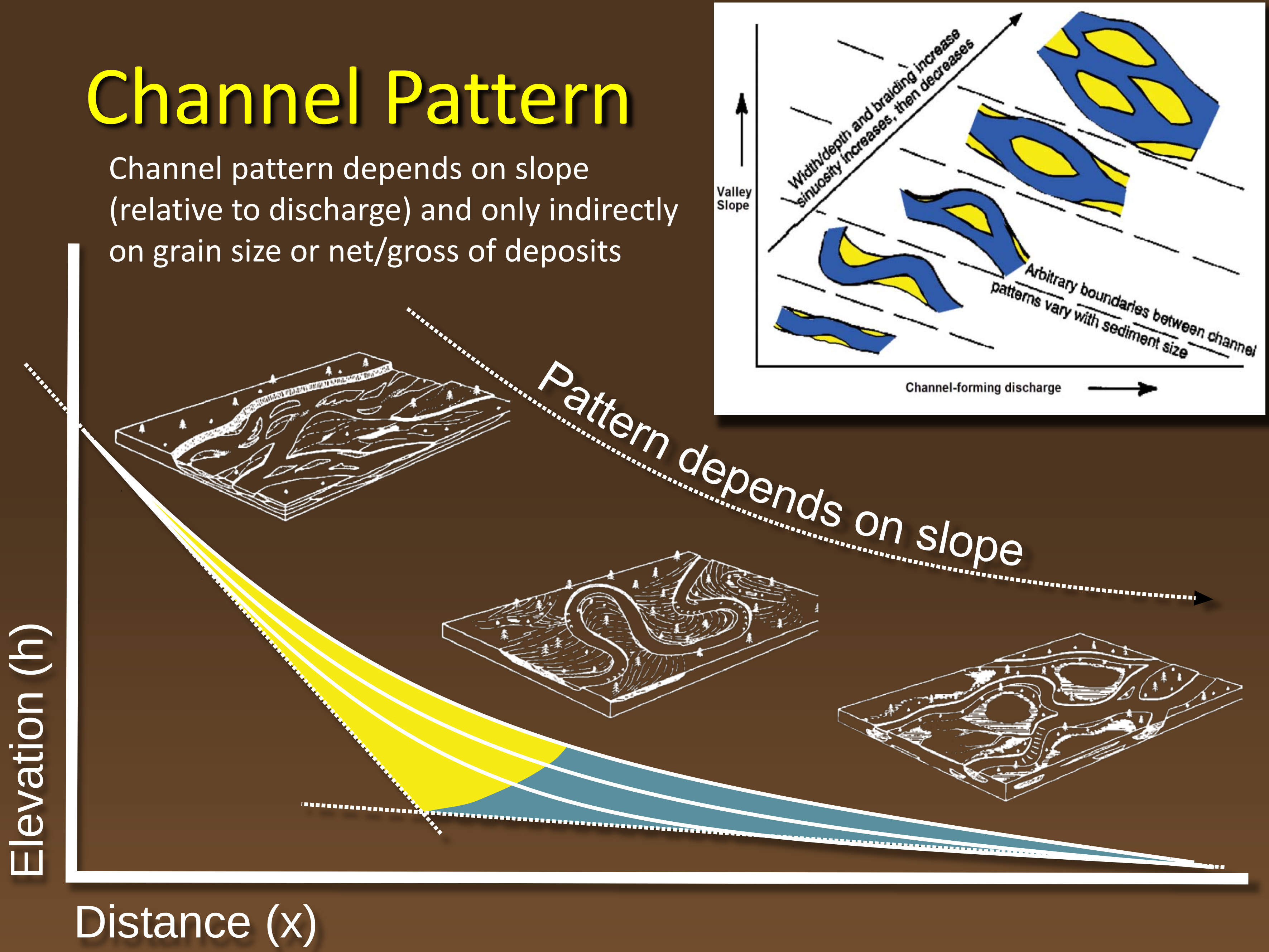
Gradual Rate of Change of Slope

- Rare avulsions.
- Single active channel belt (weakly distributive).
  - Slow down dip decline in net/gross.

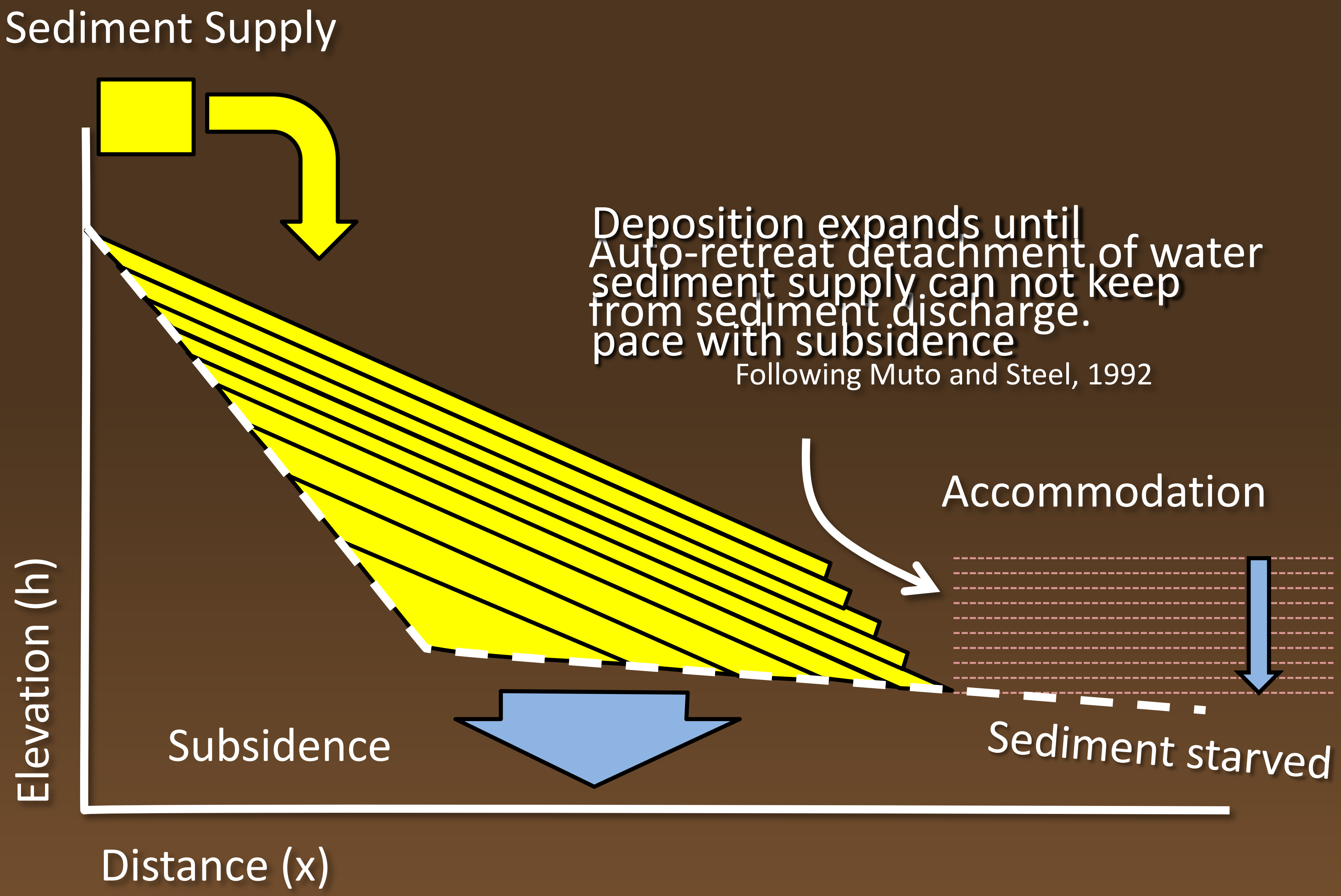
Images from Google Earth

Channel Pattern

Channel pattern depends on slope (relative to discharge) and only indirectly on grain size or net/gross of deposits



Subsidence

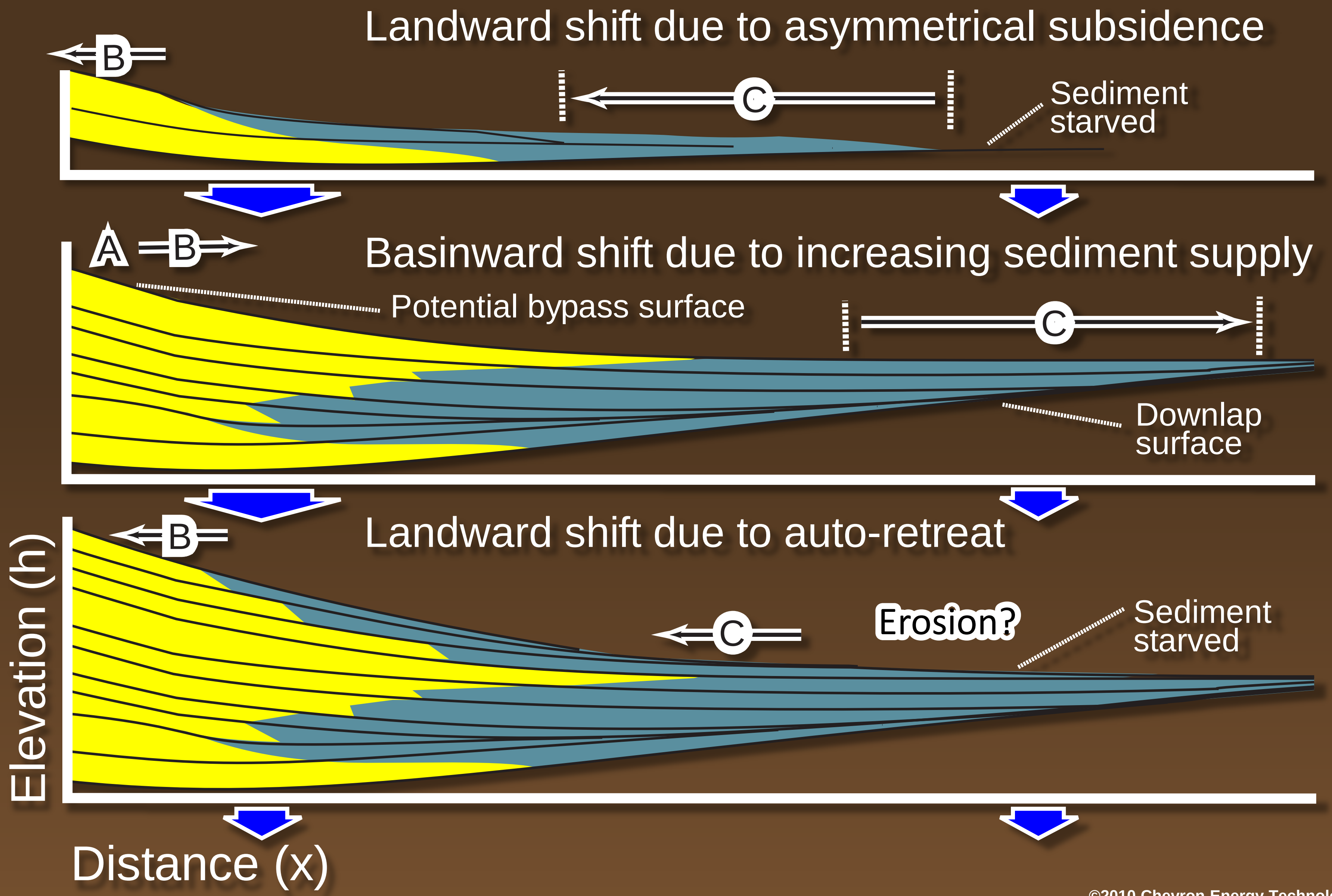


Deposition expands until sediment supply can not keep pace with subsidence

Auto-retreat detachment of water from sediment discharge.

Following Muto and Steel, 1992

Tectonic Fluvial Depositional Cycle



Landward shift due to asymmetrical subsidence

B

C

Sediment starved

A B

Basinward shift due to increasing sediment supply

Potential bypass surface

C

Downlap surface

Landward shift due to auto-retreat

B

C

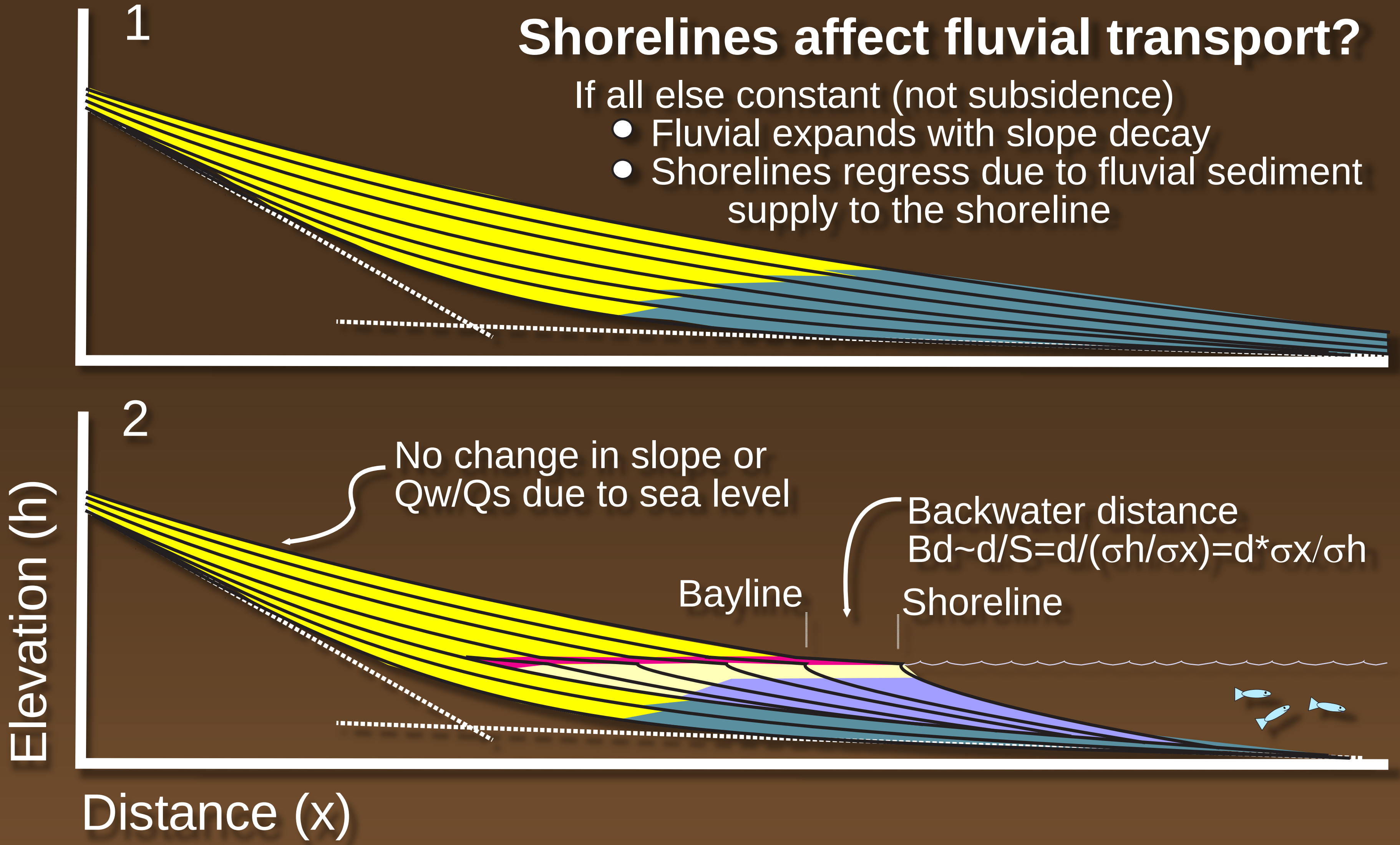
Erosion?

Sediment starved

Elevation (h)

Distance (x)

Sea Level: Shoreline Regression



Shorelines affect fluvial transport?

If all else constant (not subsidence)
- Fluvial expands with slope decay
- Shorelines regress due to fluvial sediment supply to the shoreline

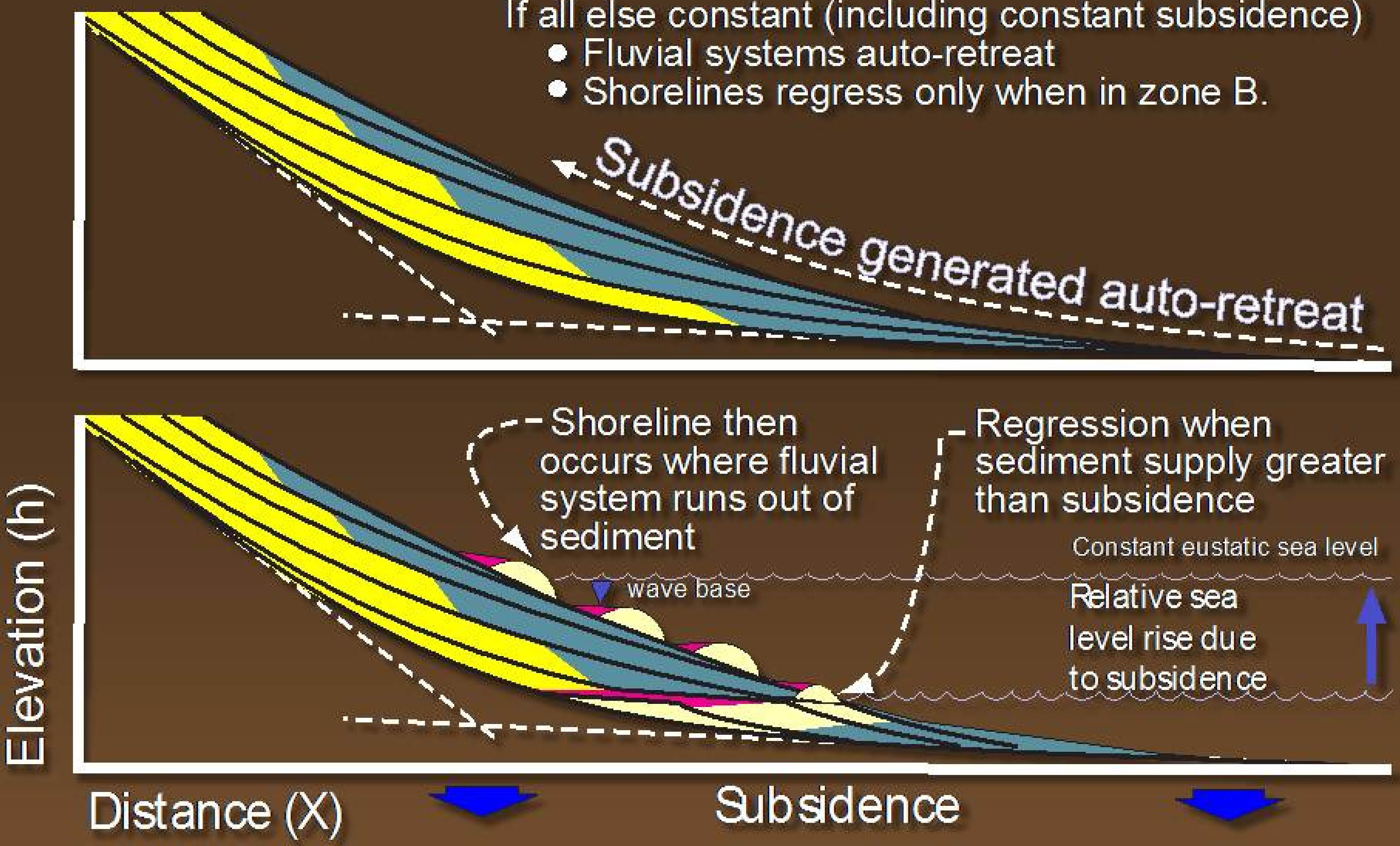
No change in slope or Qw/Qs due to sea level

Backwater distance
$Bd \sim d/S = d/(\sigma h/\sigma x) = d*\sigma x/\sigma h$

Bayline

Shoreline

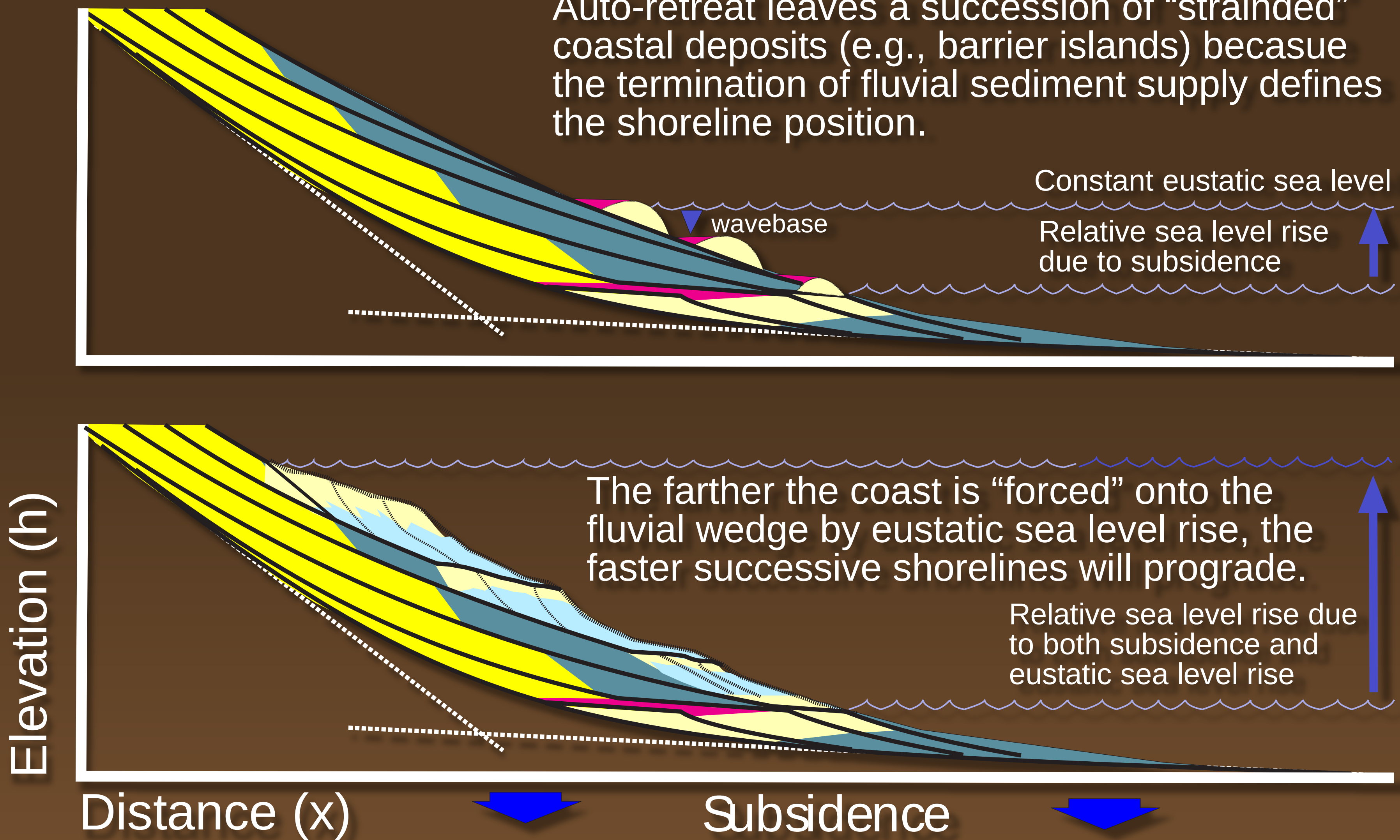
Sea Level: Transgression Due To Auto-Retreat



If all else constant (including constant subsidence)

- Fluvial systems auto-retreat
- Shorelines regress only when in zone B.

Eustatic Sea Level Rise



Auto-retreat leaves a succession of “strainded” coastal deposits (e.g., barrier islands) becasue the termination of fluvial sediment supply defines the shoreline position.

Constant eustatic sea level

wavebase

Relative sea level rise due to subsidence

The farther the coast is “forced” onto the fluvial wedge by eustatic sea level rise, the faster successive shorelines will prograde.

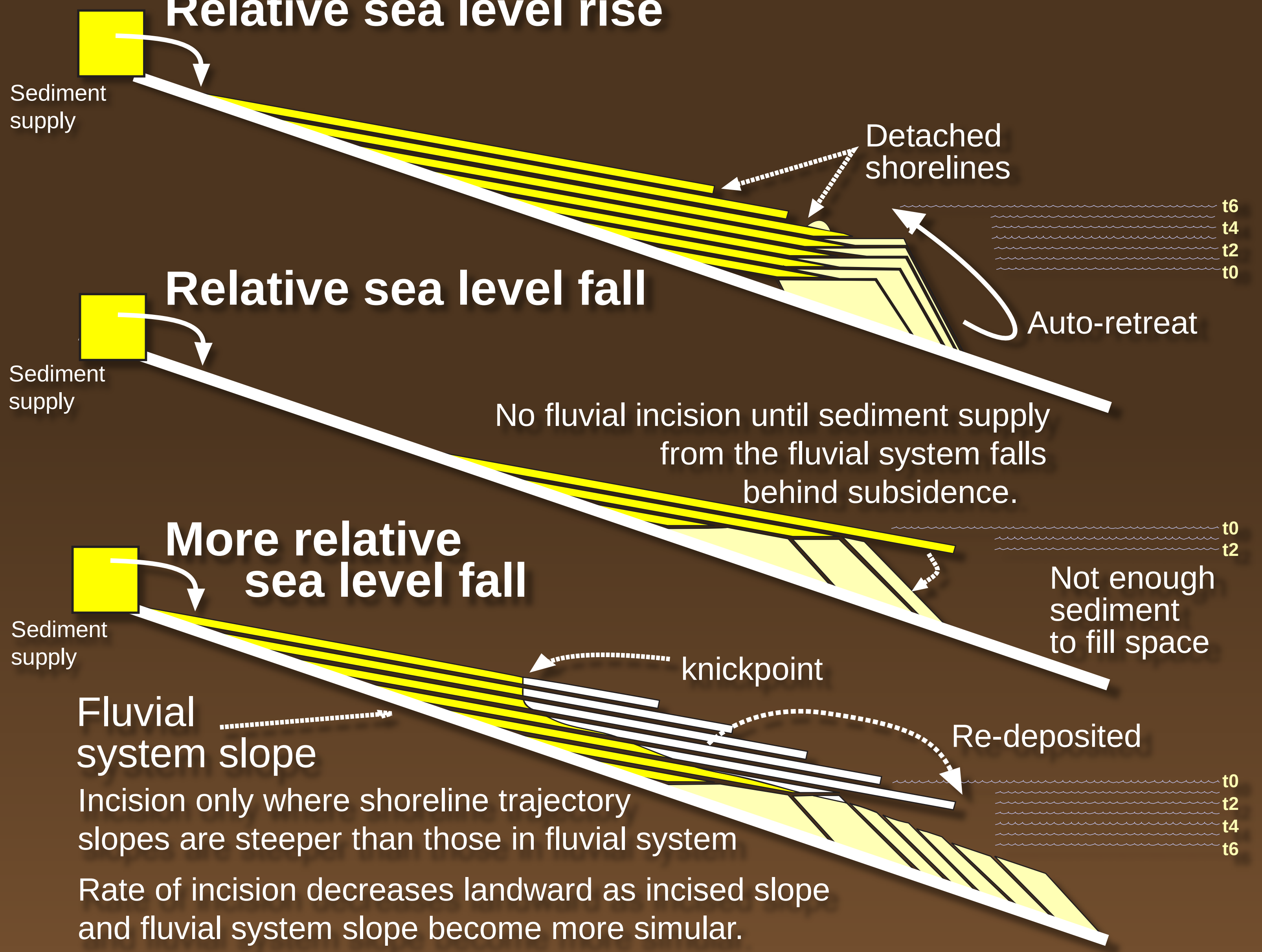
Relative sea level rise due to both subsidence and eustatic sea level rise

Elevation (h)

Distance (x)

Subsidence

Eustatic Sea level Change



Relative sea level rise

Relative sea level fall

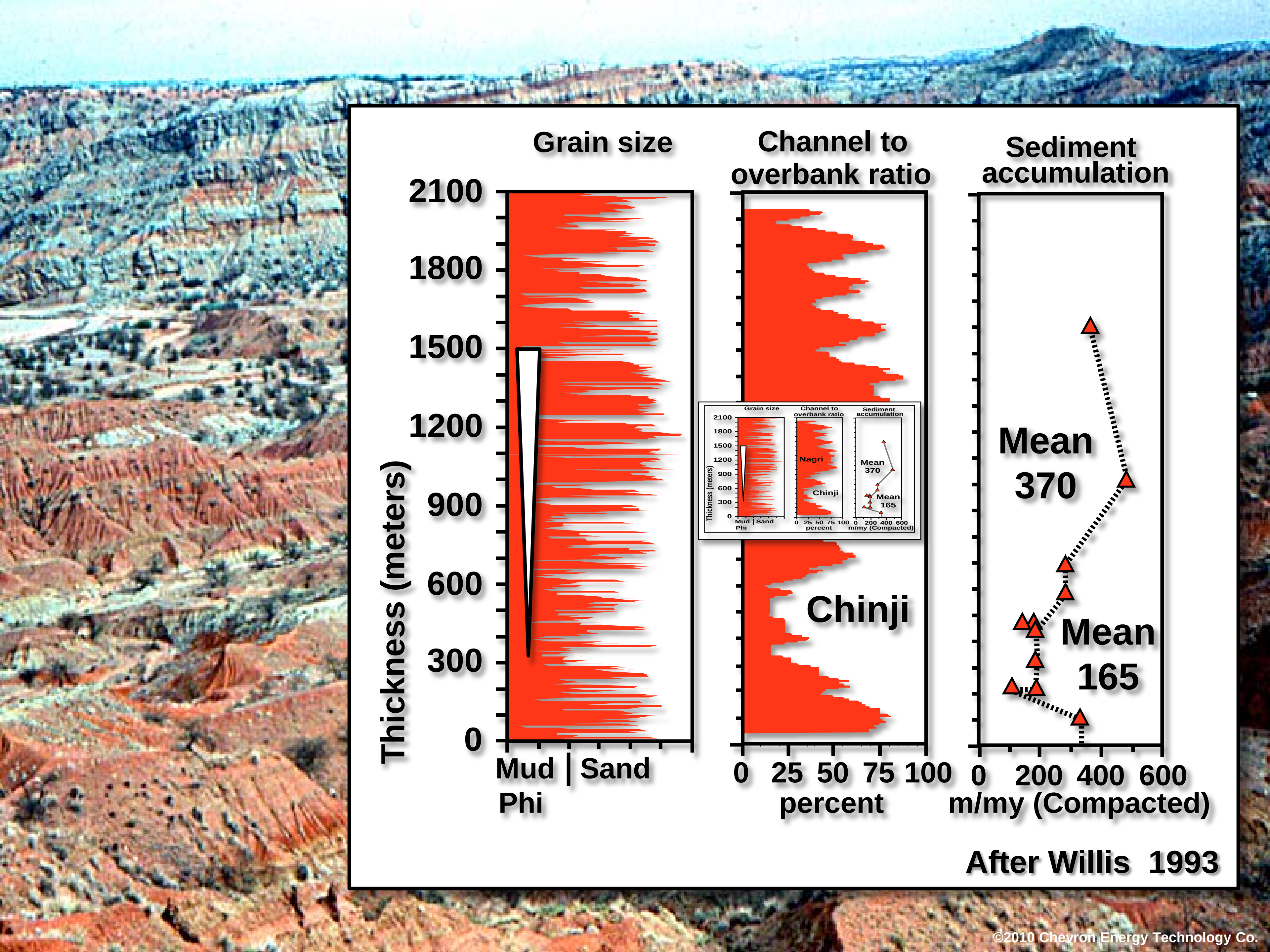
No fluvial incision until sediment supply from the fluvial system falls behind subsidence.

Not enough sediment to fill space

More relative sea level fall

Incision only where shoreline trajectory slopes are steeper than those in fluvial system

Rate of incision decreases landward as incised slope and fluvial system slope become more simular.



After Willis 1993

Conclusions

- Applying shoreline sequence stratigraphic concepts to fluvial systems puts the wrong emphasis on controlling processes.
- Concept of accommodation defined by a fixed fluvial profile linked to the coast is poorly developed and probably wrong for most large fluvial systems.

xec.xanga.com/abf88b2bc2230183988765/z19974.jpg

- Large-scale fluvial successions are better visualized as driven by changes in sediment supply relative to subsidence (probably related to tectonics or climate change) rather than by sea level driven changes in accommodation.