Stratigraphic Architecture of Fluvial Distributive Systems in Basins of Internal Drainage*

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Abstract

Stratigraphic models of fluvial successions tend to focus on the 'incised valley' model, which assumes that a marine base level exerts a strong control on the distribution of sandstones deposited by river channels. However, not all rivers flow to the sea and in basins of internal drainage there is no control exerted on river profiles by fluctuations in marine base level. Internal drainage basins are the sites of approximately half of the actively depositing fluvial systems today, and during periods of continental amalgamation, there would have been significant accumulations of continental successions in these endorheic basins. In relatively humid endorheic basins a deep basin-center lake may act as a partial downstream control on fluvial successions. However, in temperate through to arid settings, rivers terminate in a shallow, perhaps ephemeral lake, dry out on an alluvial plain or interfinger with aeolian environments. In these settings the level of the downstream termination is related to aggradation in the basin, which is itself determined by sediment supply via the rivers. The fluvial system, its depositional patterns, and the stratigraphic architecture are hence controlled by just discharge and sediment supply. A distributive fluvial pattern seems to be dominant in modern and modern and ancient endorheic basins. The fluvial successions formed by these systems in endorheic basins have a fundamentally different architecture to the 'incised valley fill' model commonly used in fluvial stratigraphy. Case studies from Miocene strata in northern Spain illustrate the stratigraphic relationships between fluvial channel and overbank successions in an endorheic basin.

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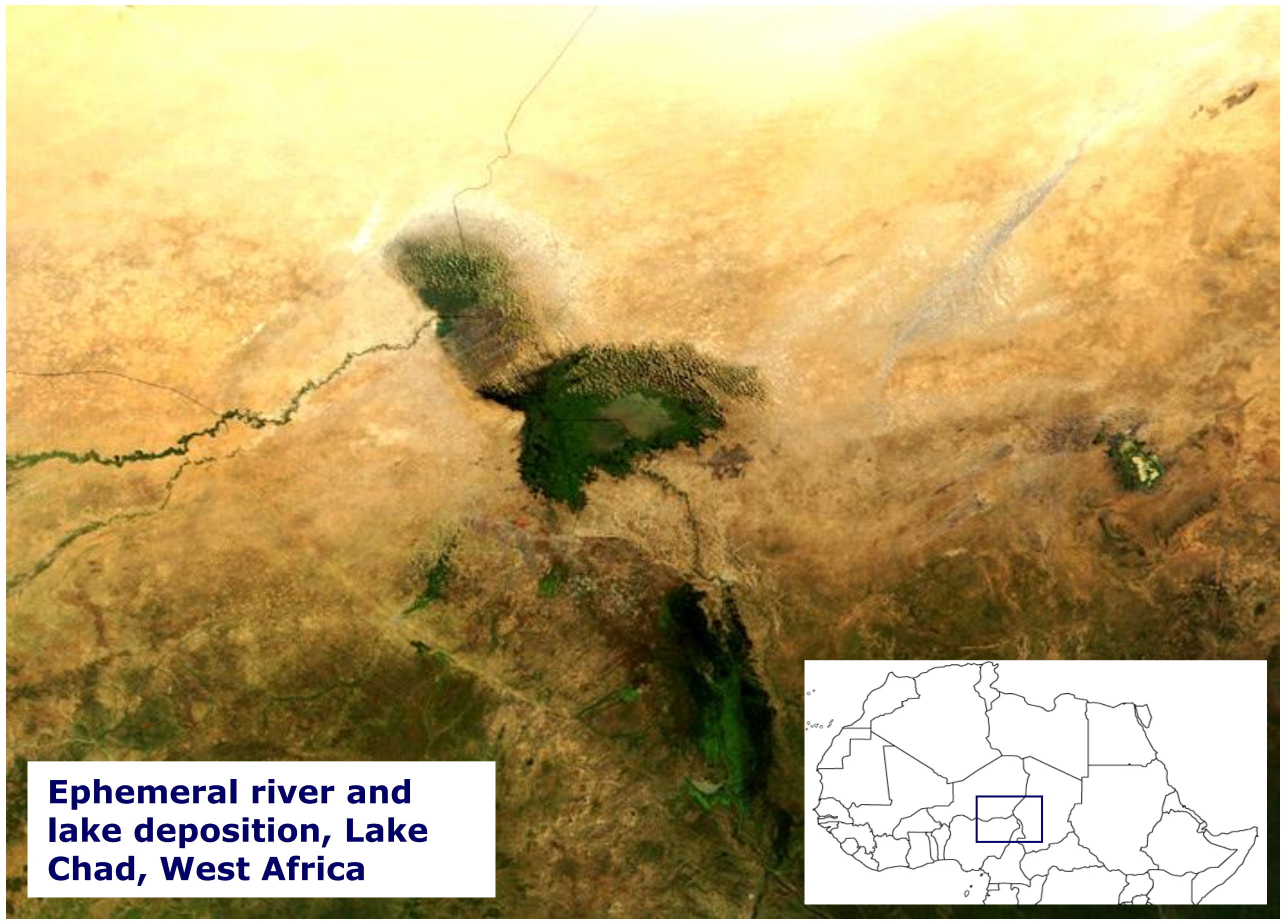

Ephemeral river and lake deposition, Lake Chad, West Africa

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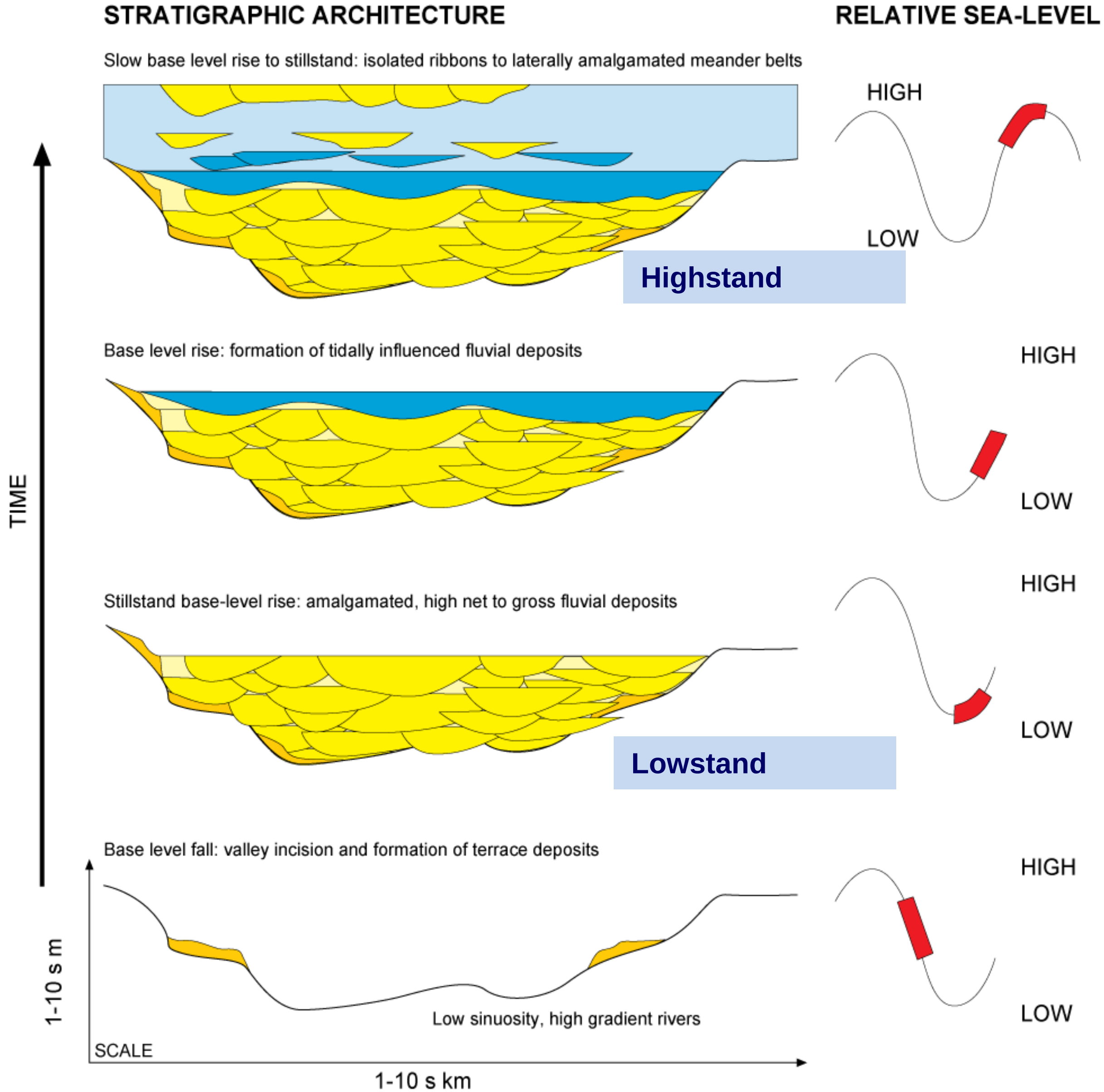
Stratigraphic Architecture in Endorheic Basins

River systems connected to the sea

The Shanley & McCabe (1993, 1994) model describes fluvial facies architecture in terms of relative sea level.

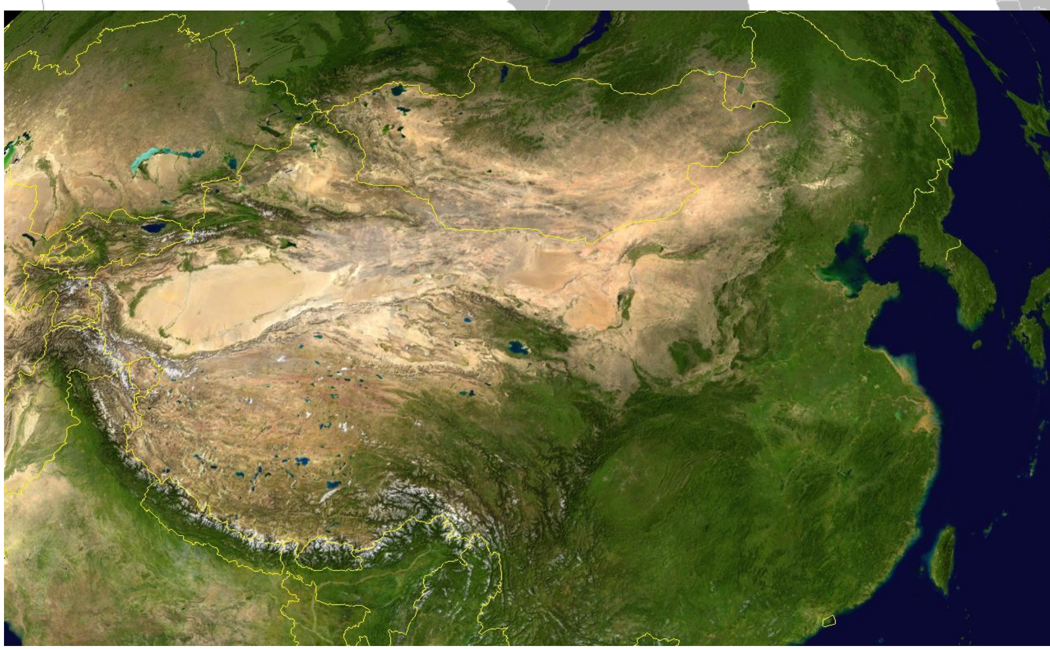
This model cannot be applied to river systems that do not terminate at a coastline

However, deposition in basins of internal drainage (endorheic basins) is widespread on several continents today



Modern Endorheic Basins

Examples



About half of modern continental basins (where there is current aggradation) have no drainage connection to sea

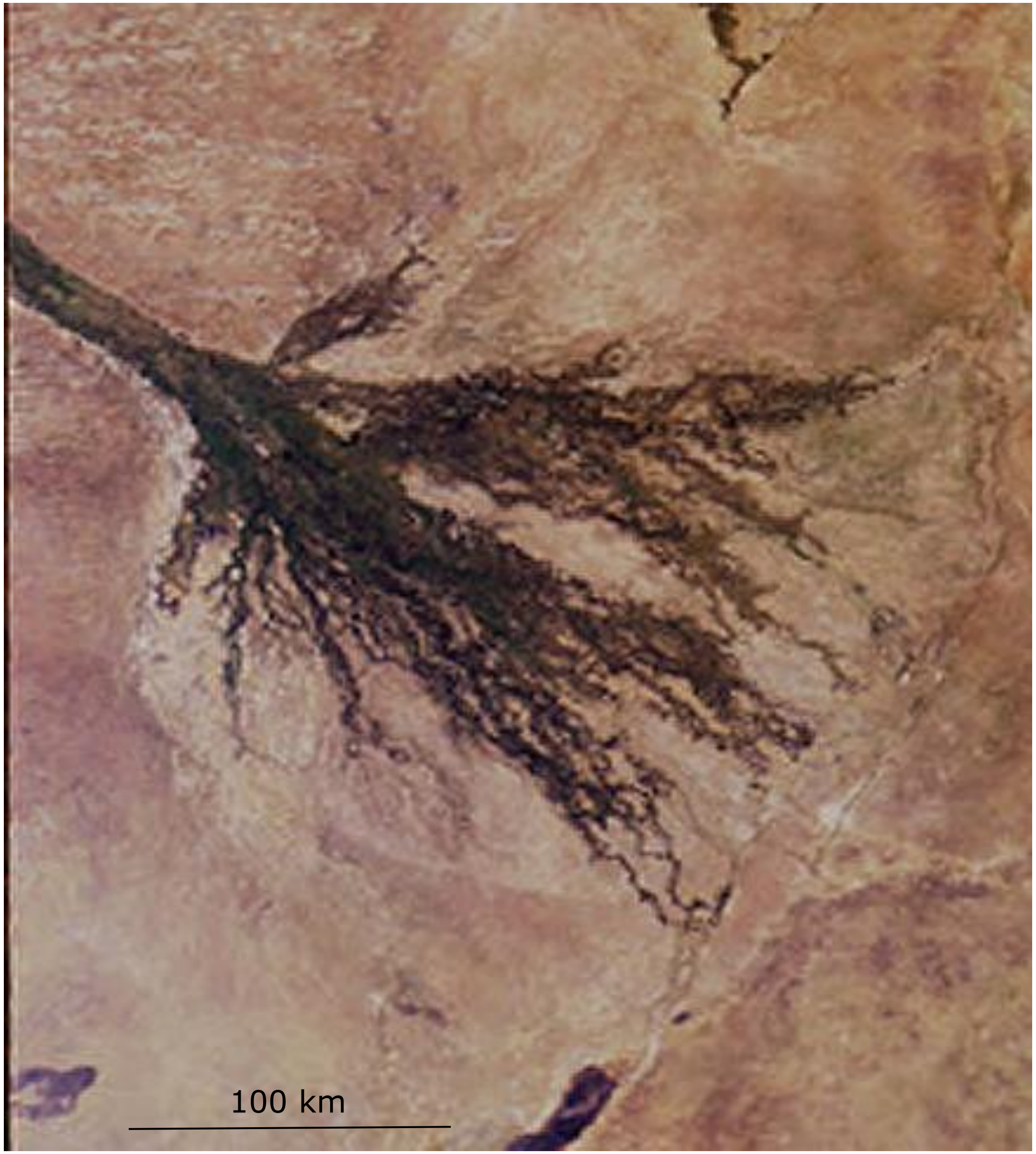
Modern Endorheic Basins

Example: Lake Eyre Basin, Central Australia

Covers 1,200,000 km^2 - a sixth of the continent

In endorheic basins marine base level is not a control, and sea level fluctuations do not influence the river systems

Modern Endorheic Basins: River systems

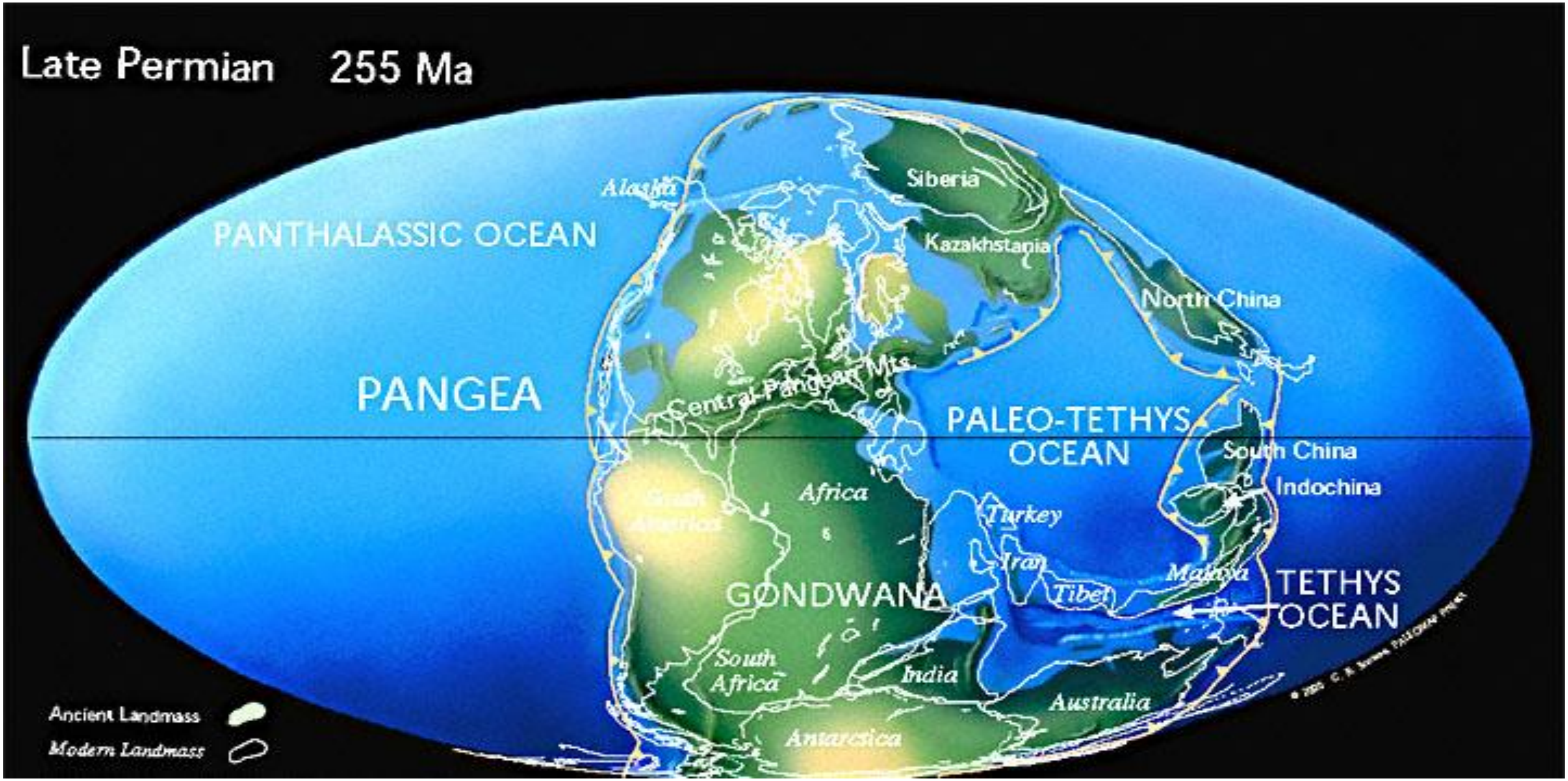


Today, approximately half of the river systems that are depositing are in basins of internal drainage

All of these river systems display a Distributive Fluvial pattern

Example: the Okavango River system, Southern Africa

Ancient Endorheic Basins



Endorheic basins may have been more common at times of continental amalgamation when there were larger areas of internal drainage

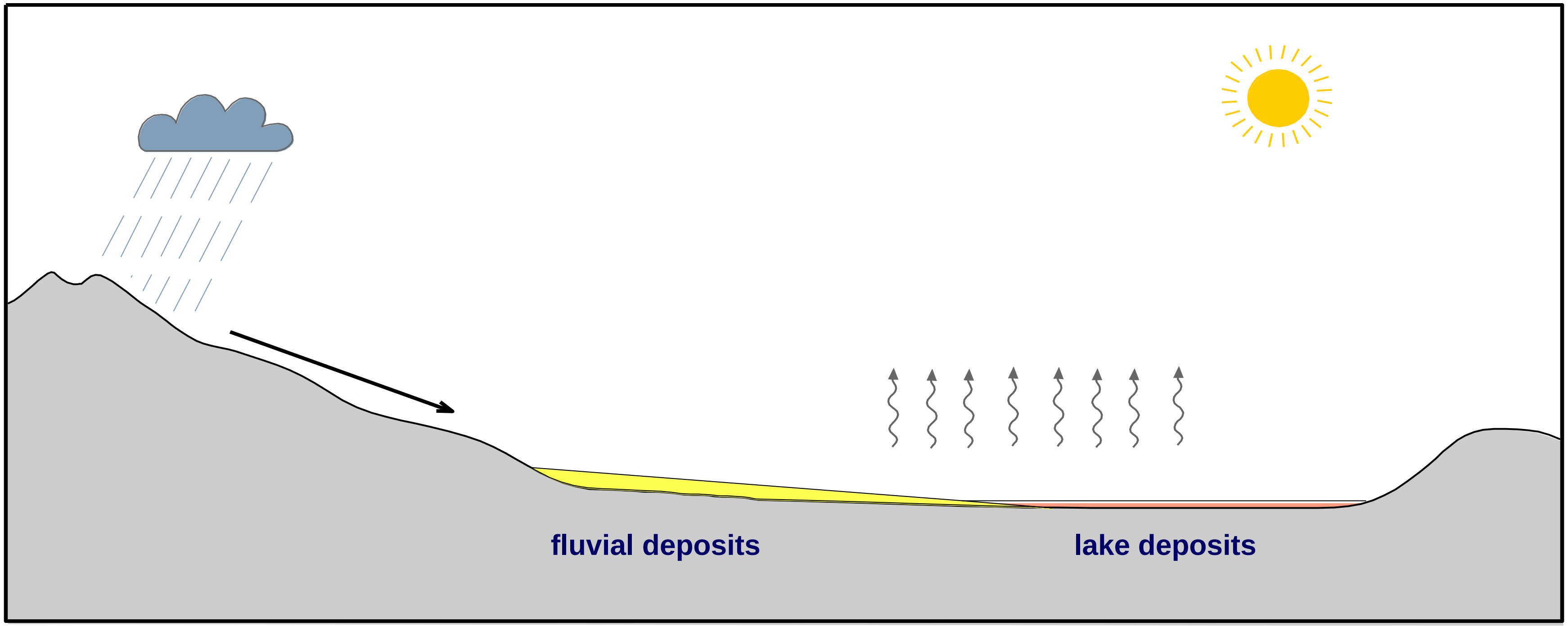
River systems in Ancient Endorheic Basins

To consider:

A significant proportion (half?) of fluvial successions in the stratigraphic record were deposited by Distributive Fluvial Systems in basins of internal drainage

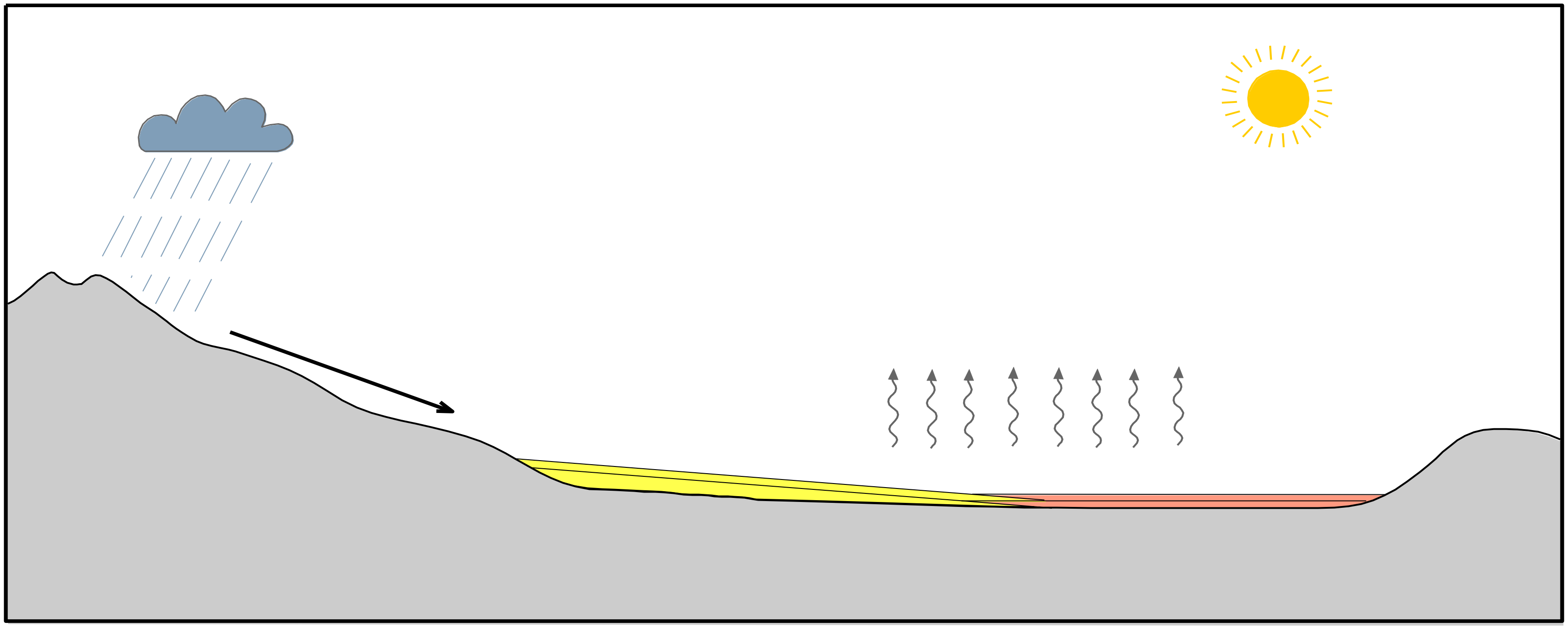
So what controls the stratigraphic architecture of these fluvial successions?

Endorheic Basin Sedimentation



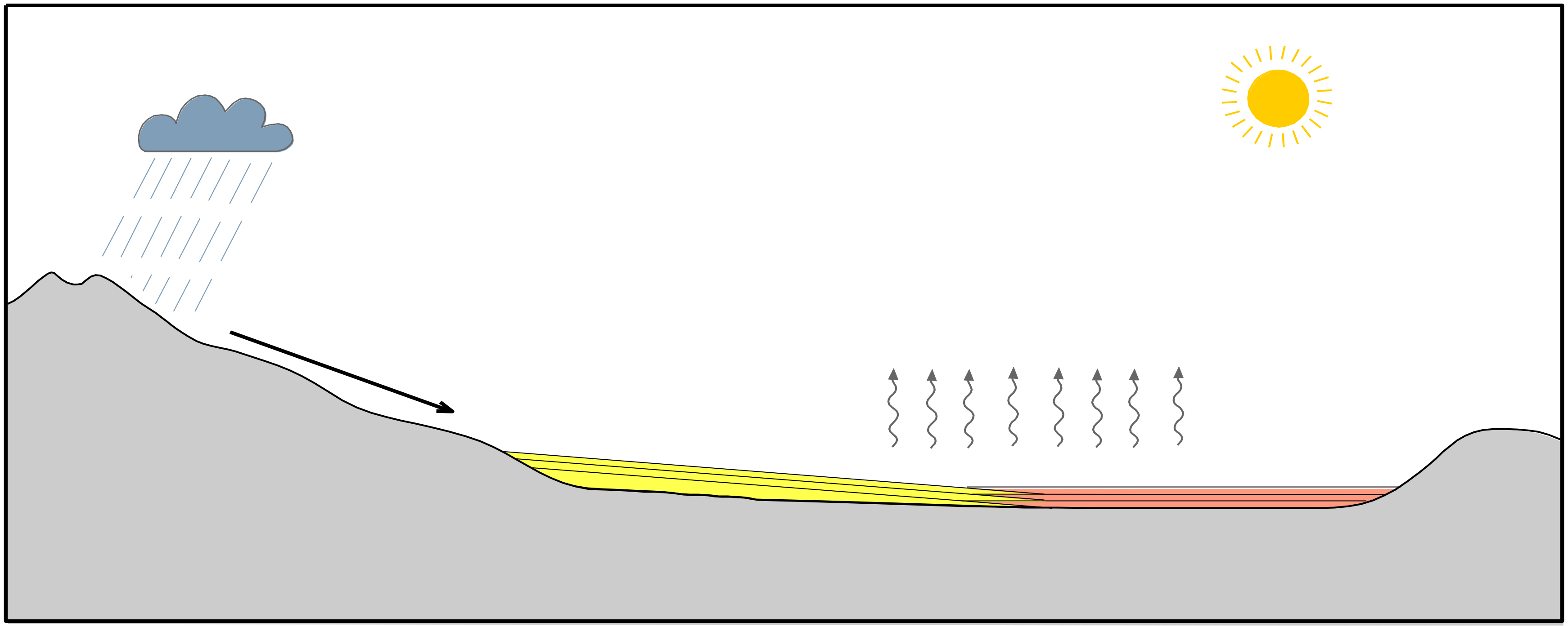
Water and sediment from adjacent hinterland supplies basin

Endorheic Basin Sedimentation



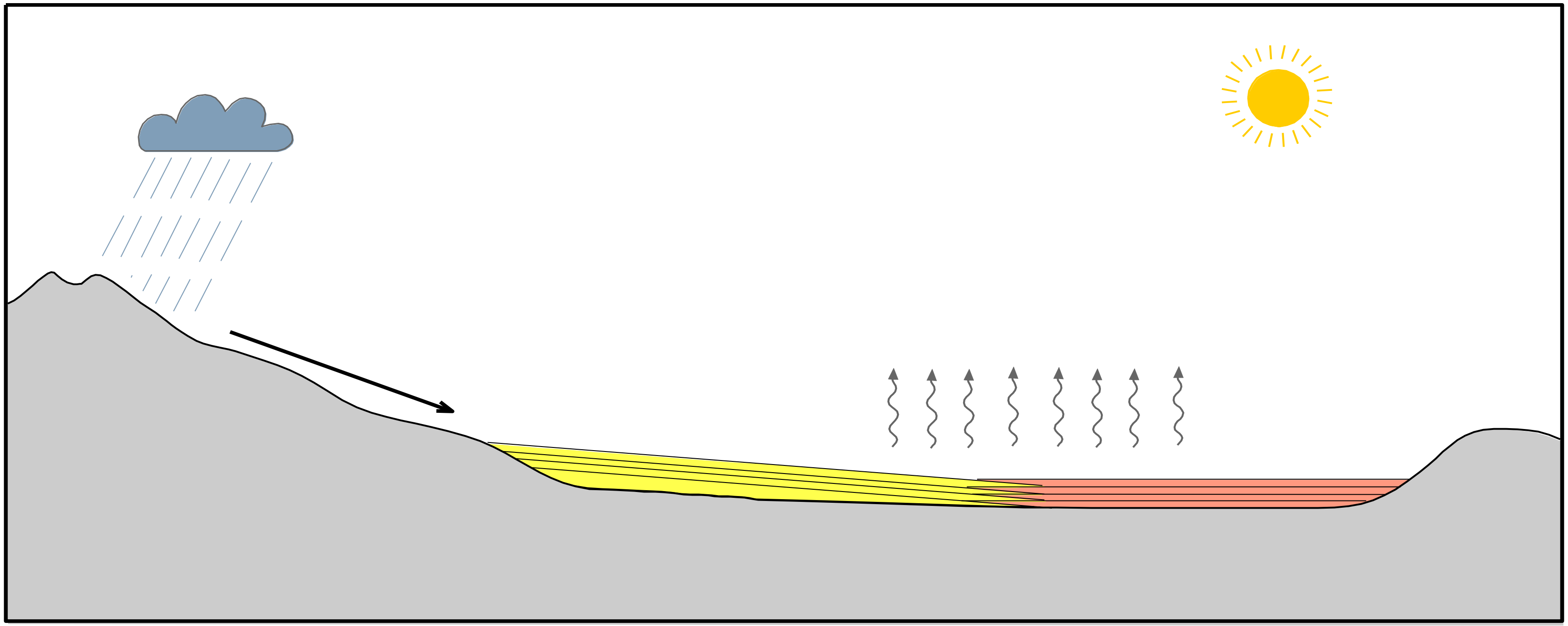
Loss of water by evaporation and soak away exceeds water supply

Endorheic Basin Sedimentation



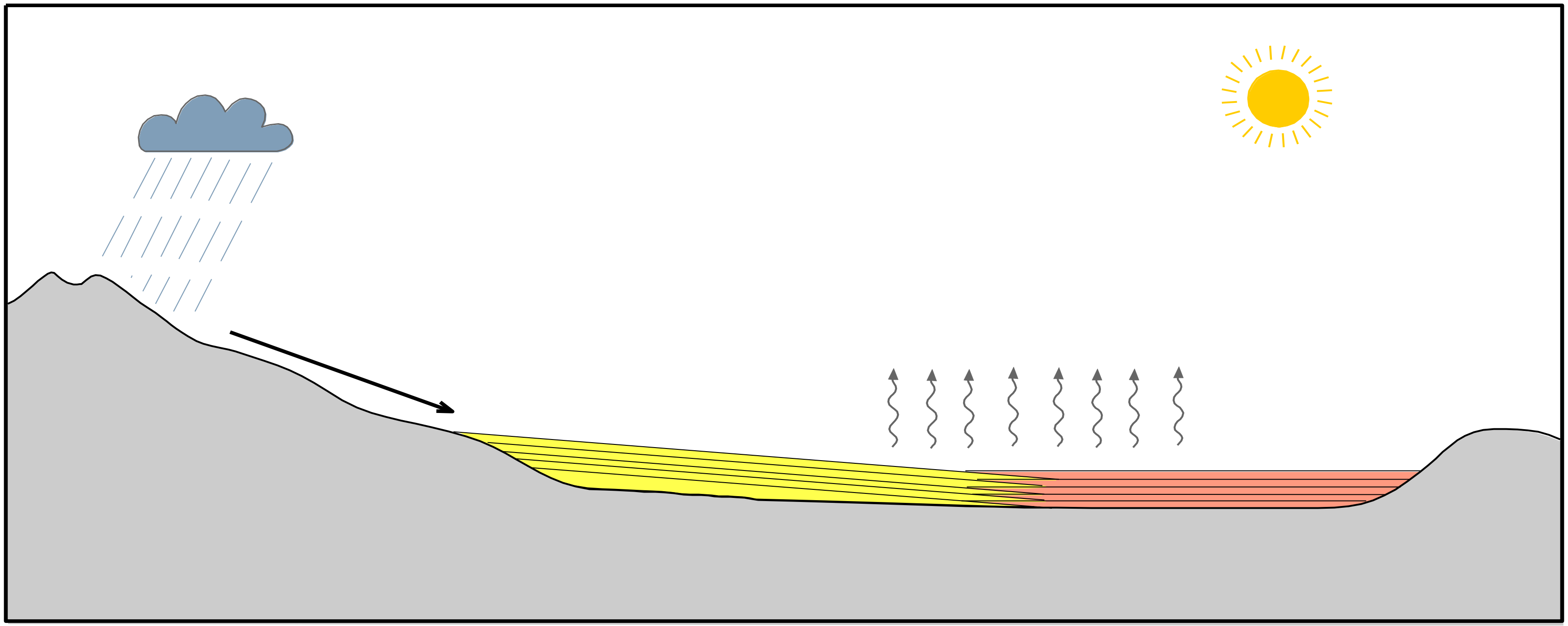
Fluvial and lacustrine deposits aggrade in the basin

Endorheic Basin Sedimentation



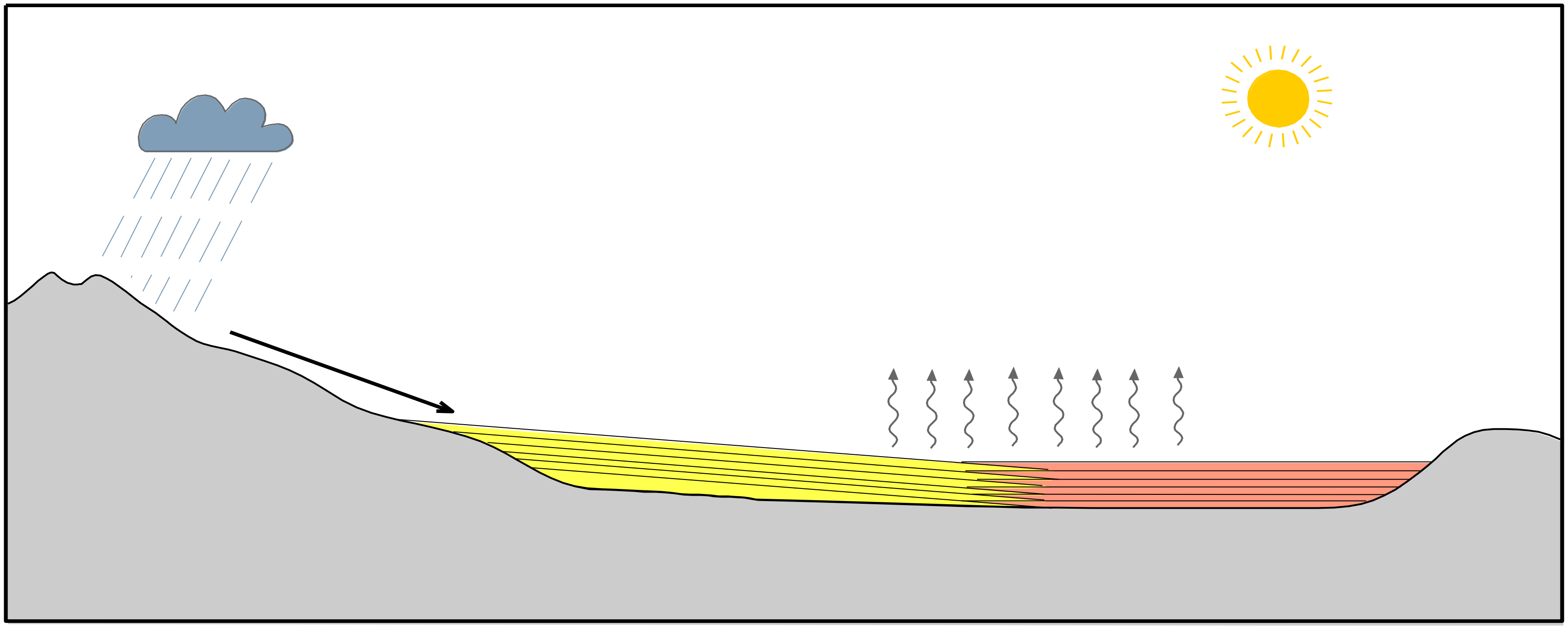
Style of river deposition – Distributive Fluvial Systems (DFS)

Endorheic Basin Sedimentation



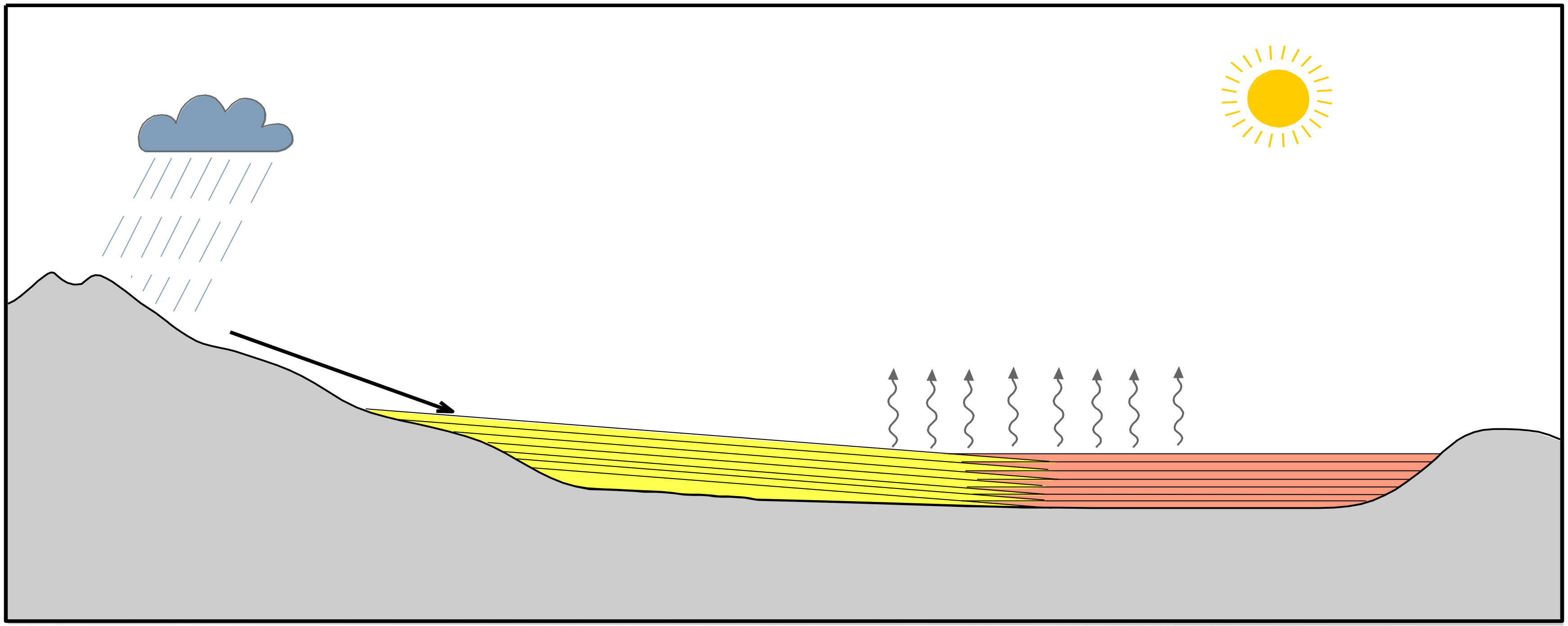
Sediment onlaps onto basin margin, back-filling valleys

Endorheic Basin Sedimentation



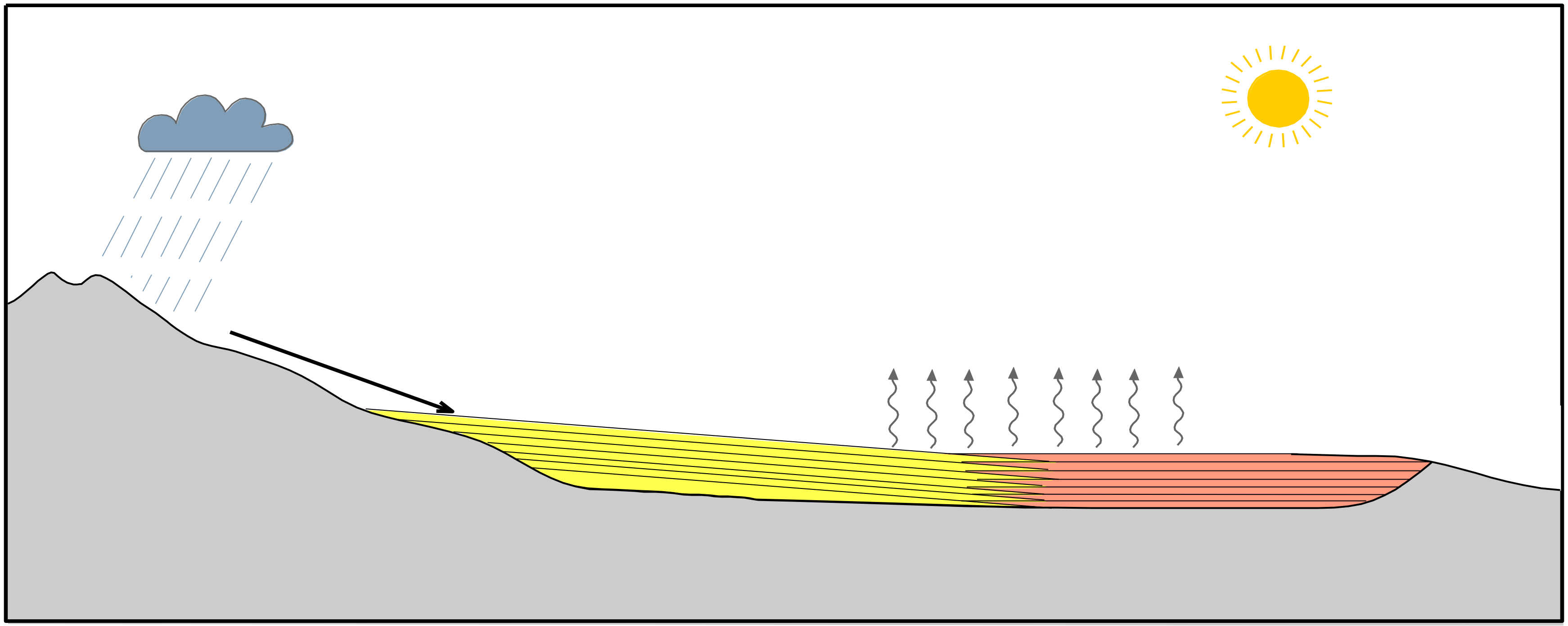
Succession builds up without need for subsidence to create accommodation

Endorheic Basin Sedimentation



Aggradation in basin continues until the basin margin is over-spilled or is breached

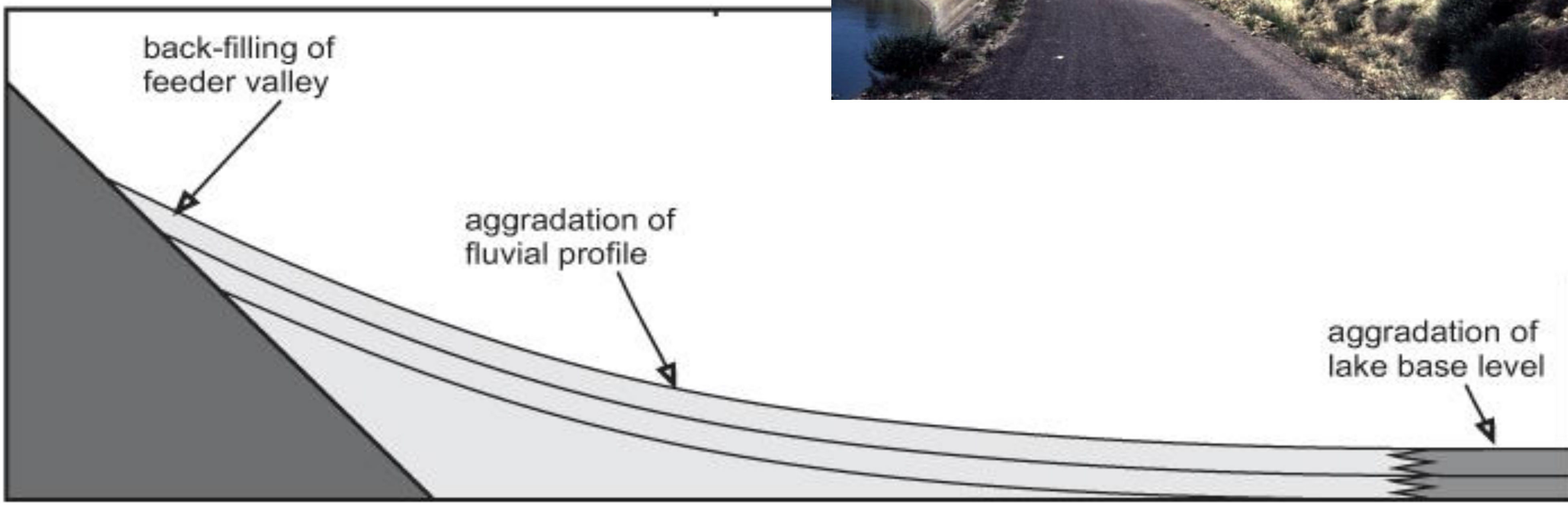
Endorheic Basin Sedimentation



Once breach has occurred, basin is no longer endorheic and drainage systems respond to new, lower base level

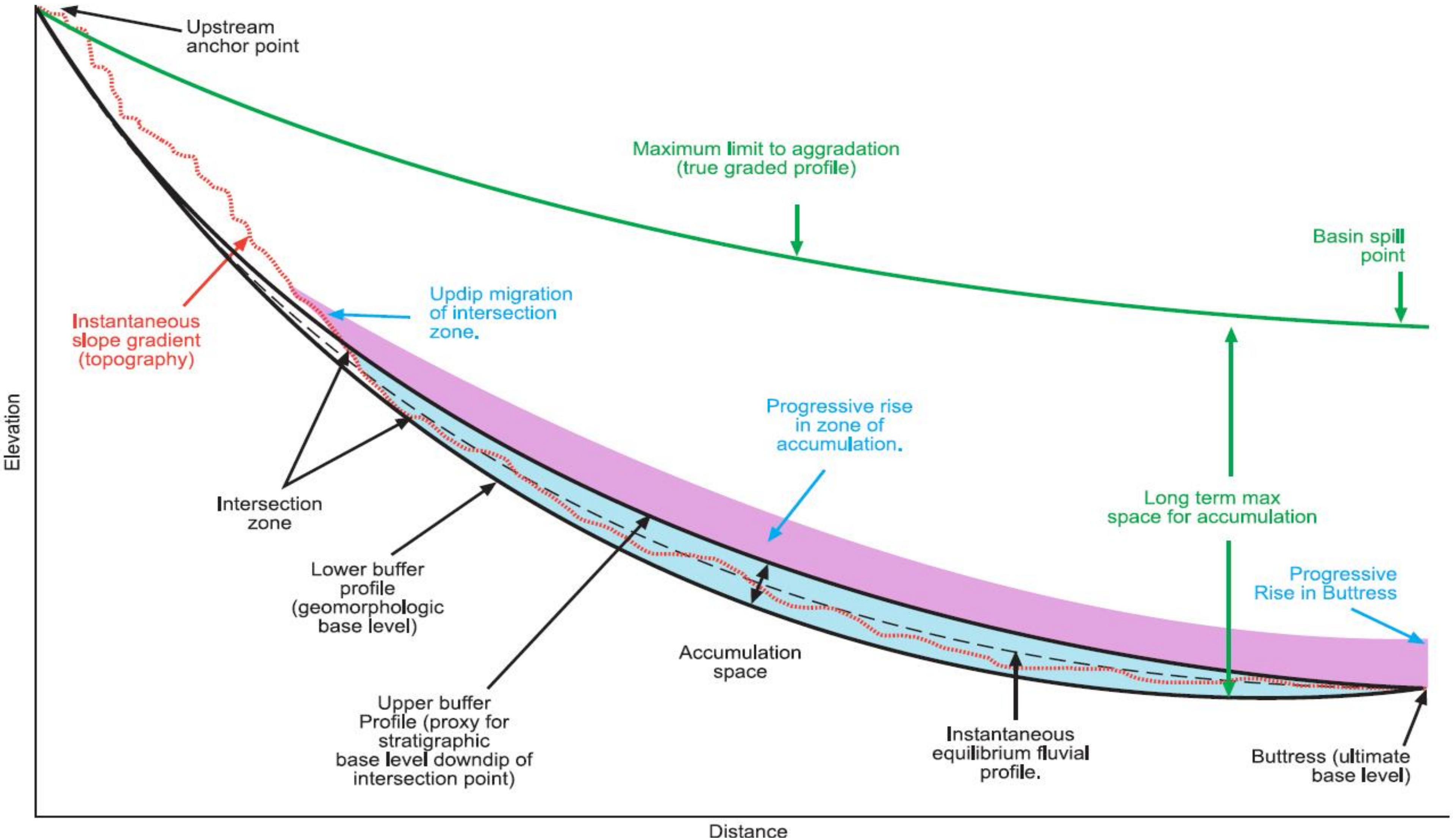
Fluvial Profile in an Endorheic Basin

Basin aggradation results in a vertical stacking of facies belts and the aggradation of the fluvial profile



Fluvial Profile in an Endorheic Basin

Buffers and buttresses: controls on fluvial systems (Holbrook et al 2006)



Fluvial Profile in an Endorheic Basin

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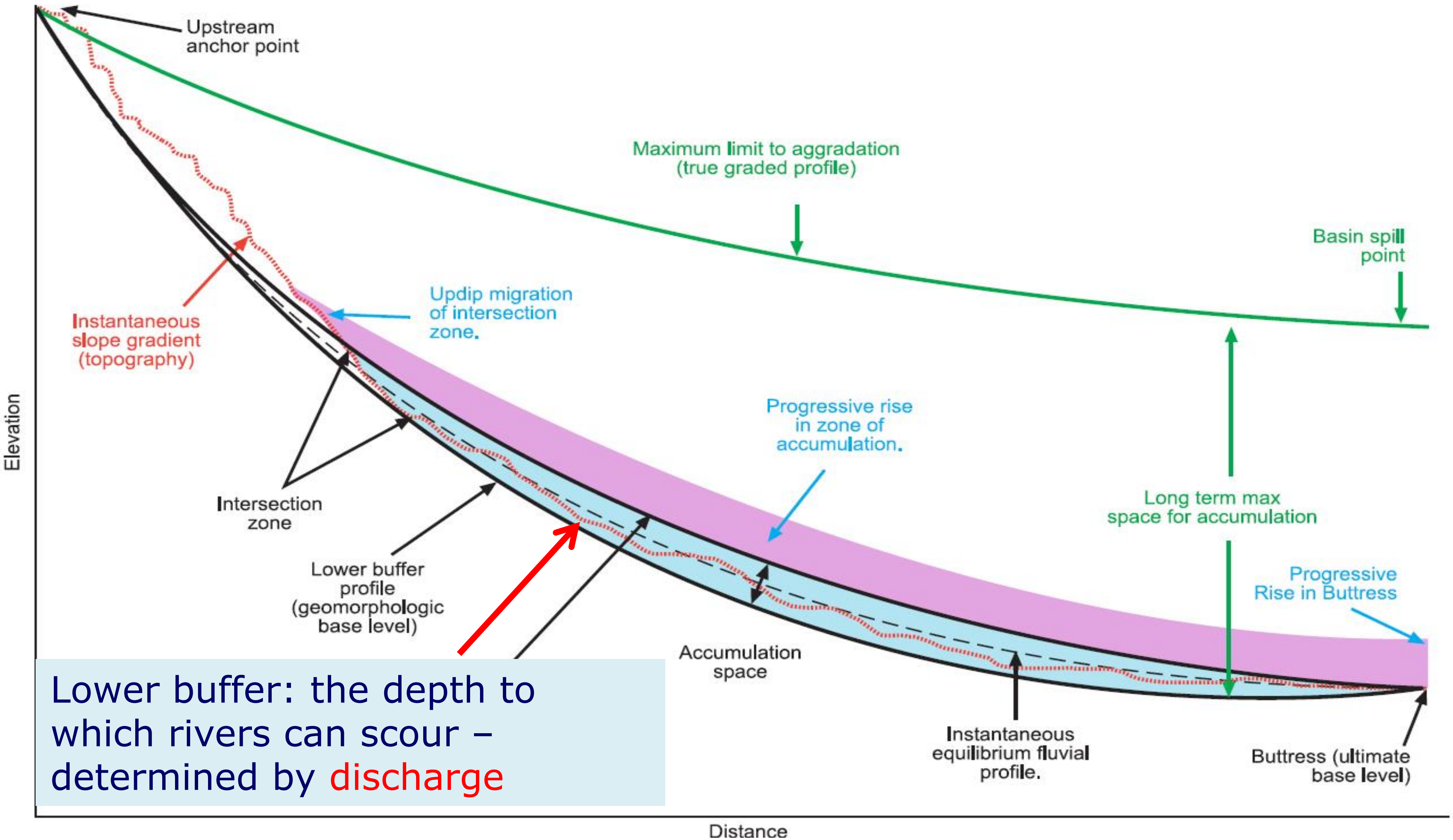
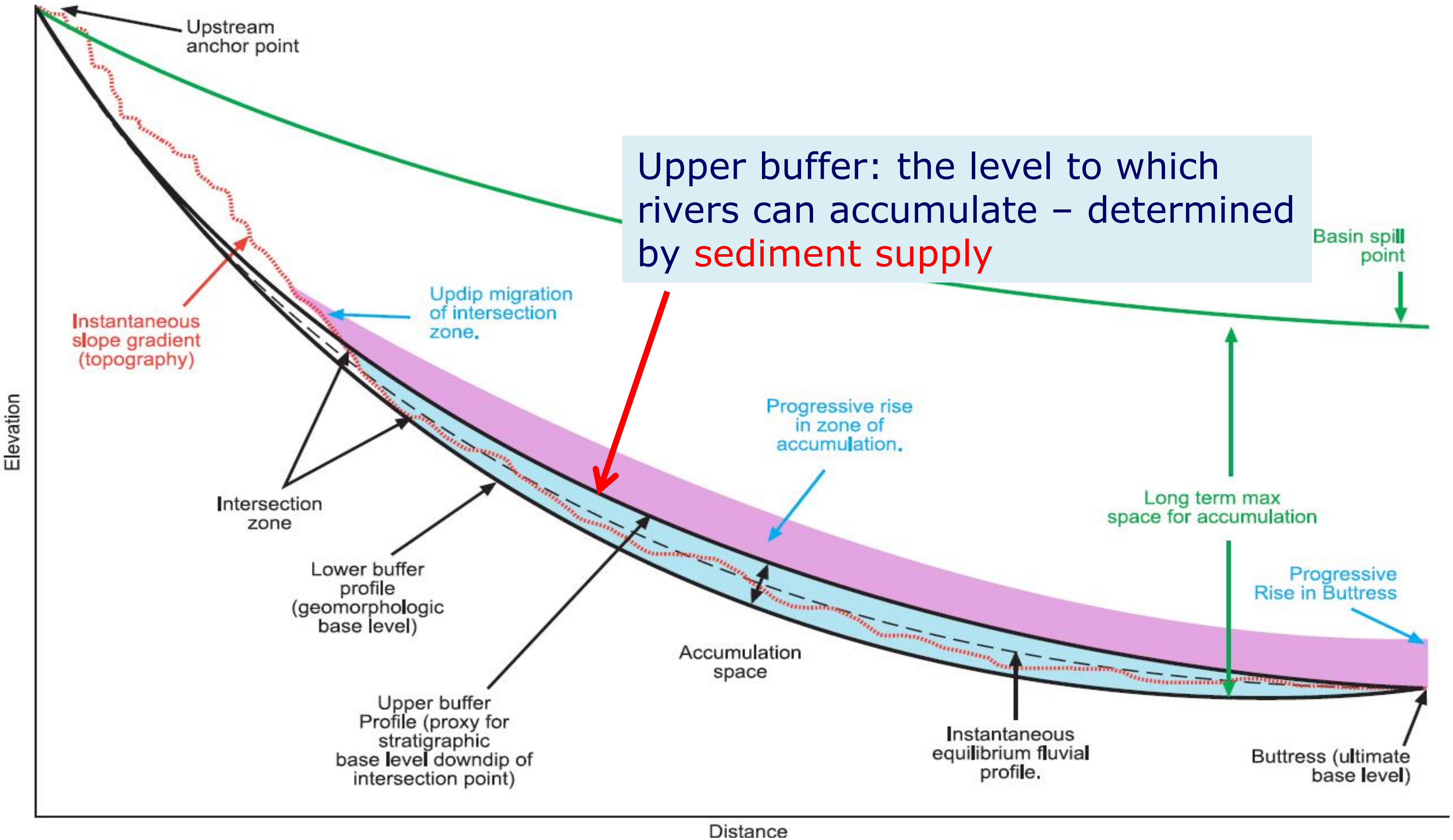


Lower buffer: the depth to which rivers can scour – determined by discharge

Fluvial Profile in an Endorheic Basin

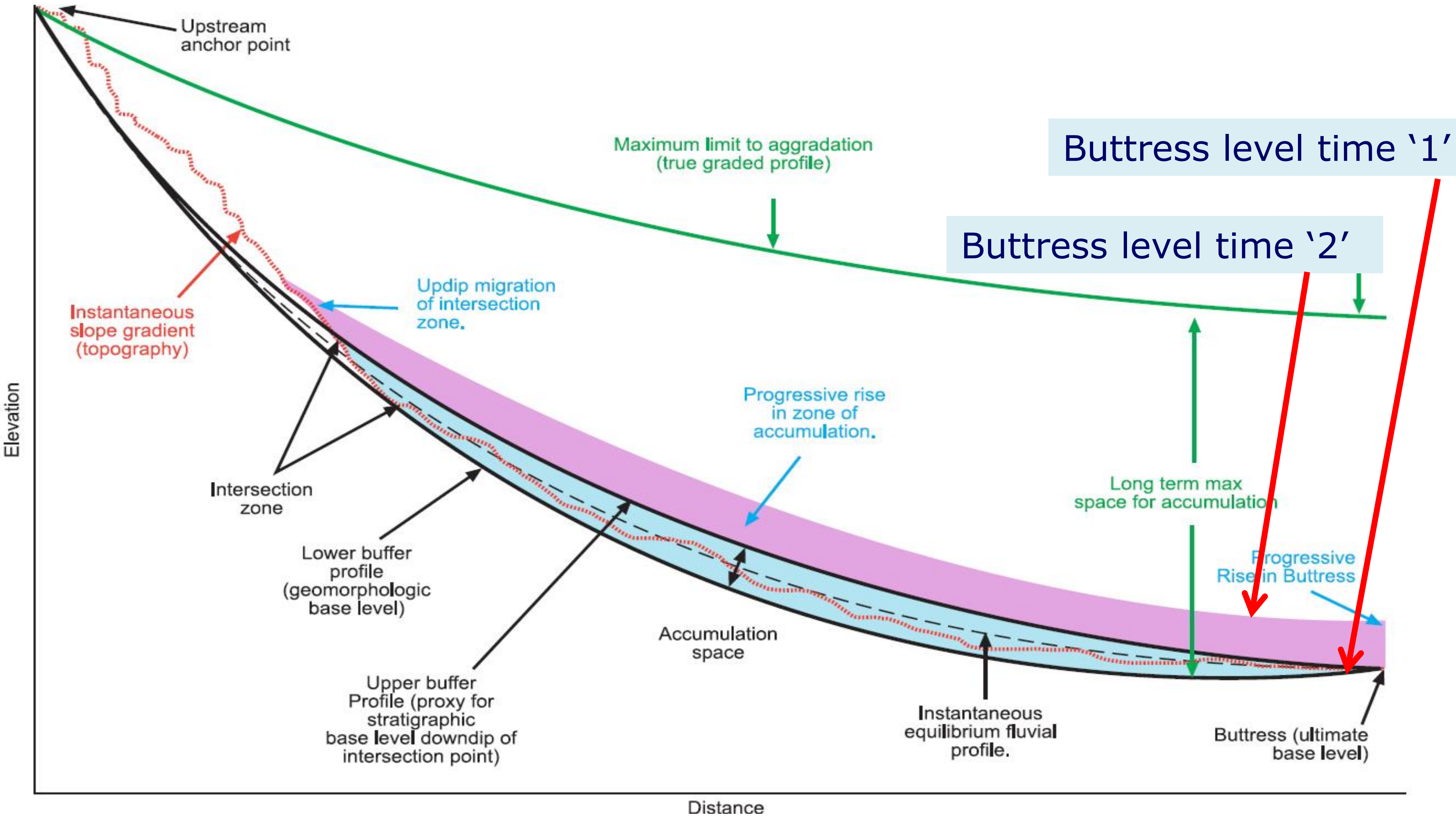
Buffers and buttresses: controls on fluvial systems (Holbrook et al 2006)



Upper buffer: the level to which rivers can accumulate – determined by sediment supply

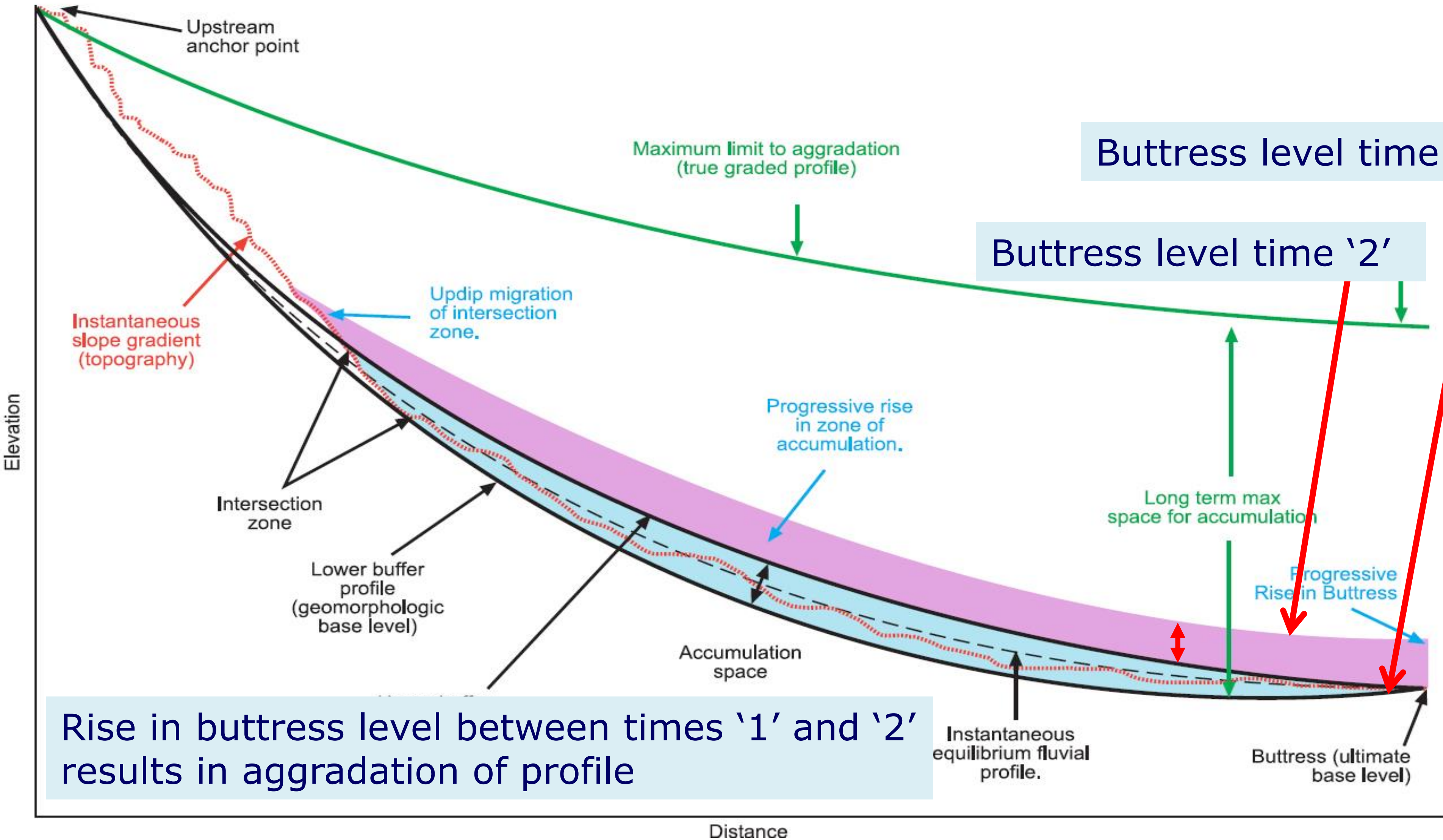
Fluvial Profile in an Endorheic Basin

Buffers and buttresses: controls on fluvial systems (Holbrook et al 2006)



Fluvial Profile in an Endorheic Basin

Buffers and buttresses: controls on fluvial systems (Holbrook et al 2006)



Buttress level time ‘1’

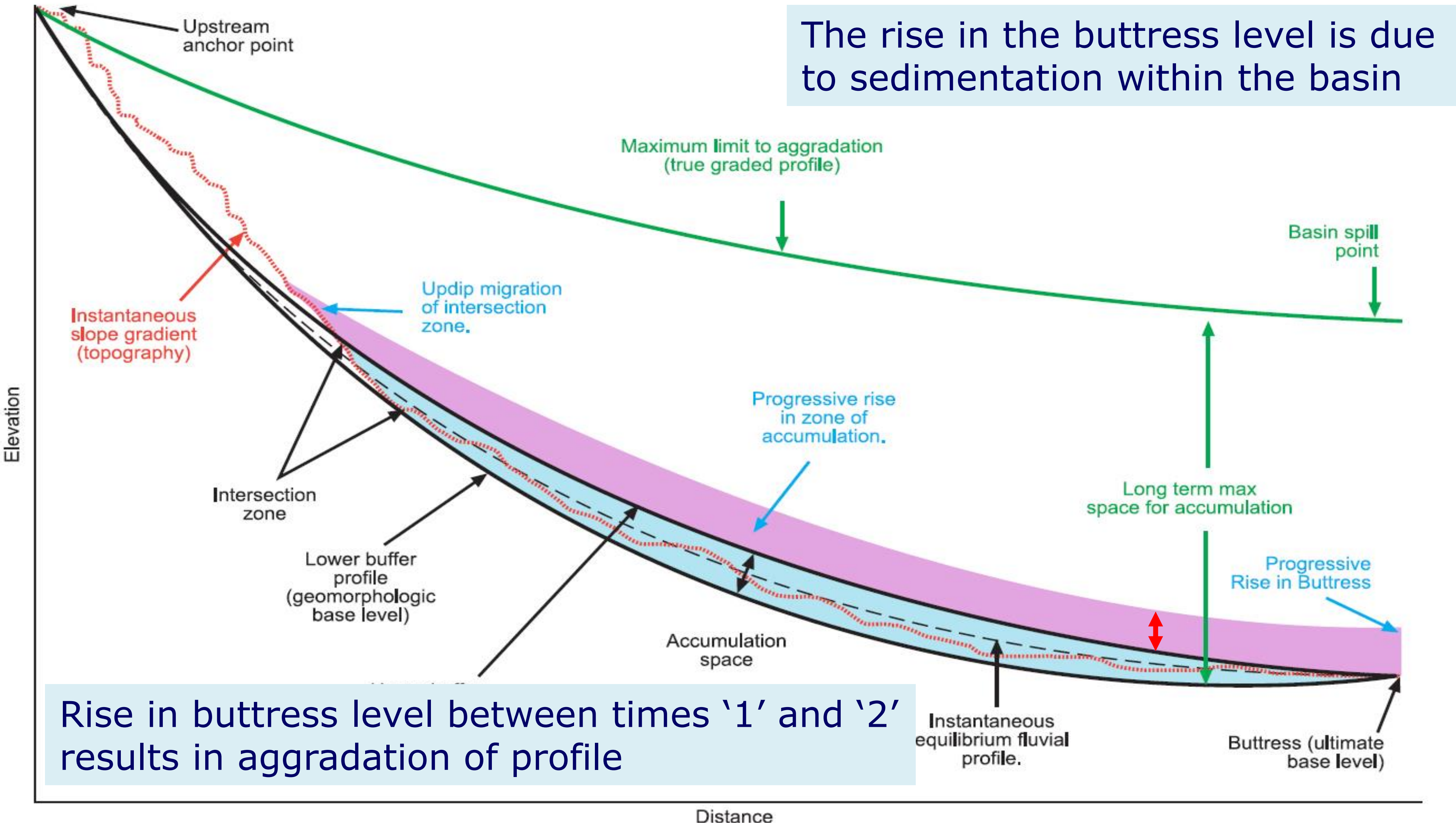
Buttress level time ‘2’

Rise in buttress level between times ‘1’ and ‘2’ results in aggradation of profile

Fluvial Profile in an Endorheic Basin

Buffers and buttresses: controls on fluvial systems (Holbrook et al 2006)

The rise in the buttress level is due to sedimentation within the basin

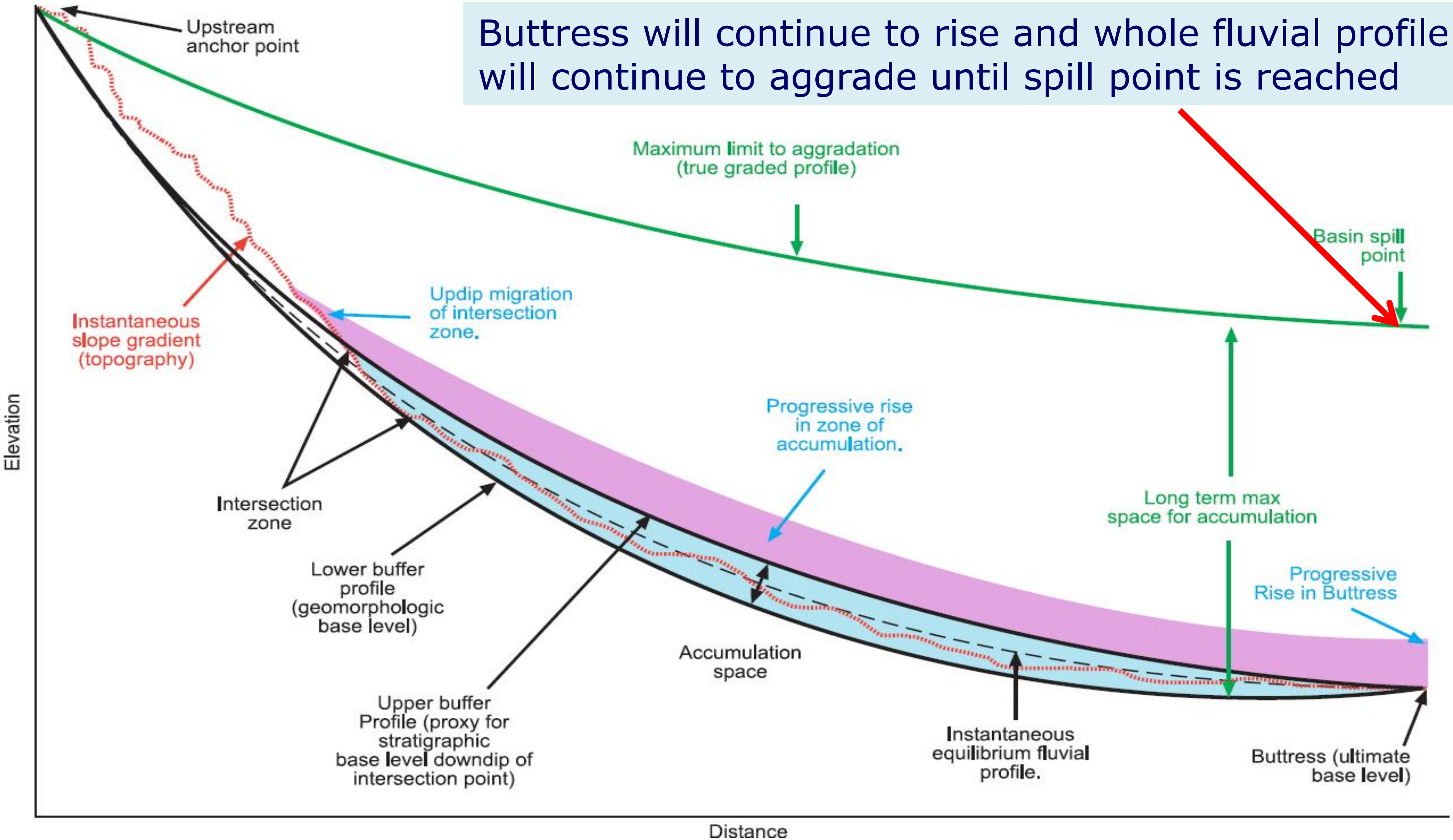


Rise in buttress level between times '1' and '2' results in aggradation of profile

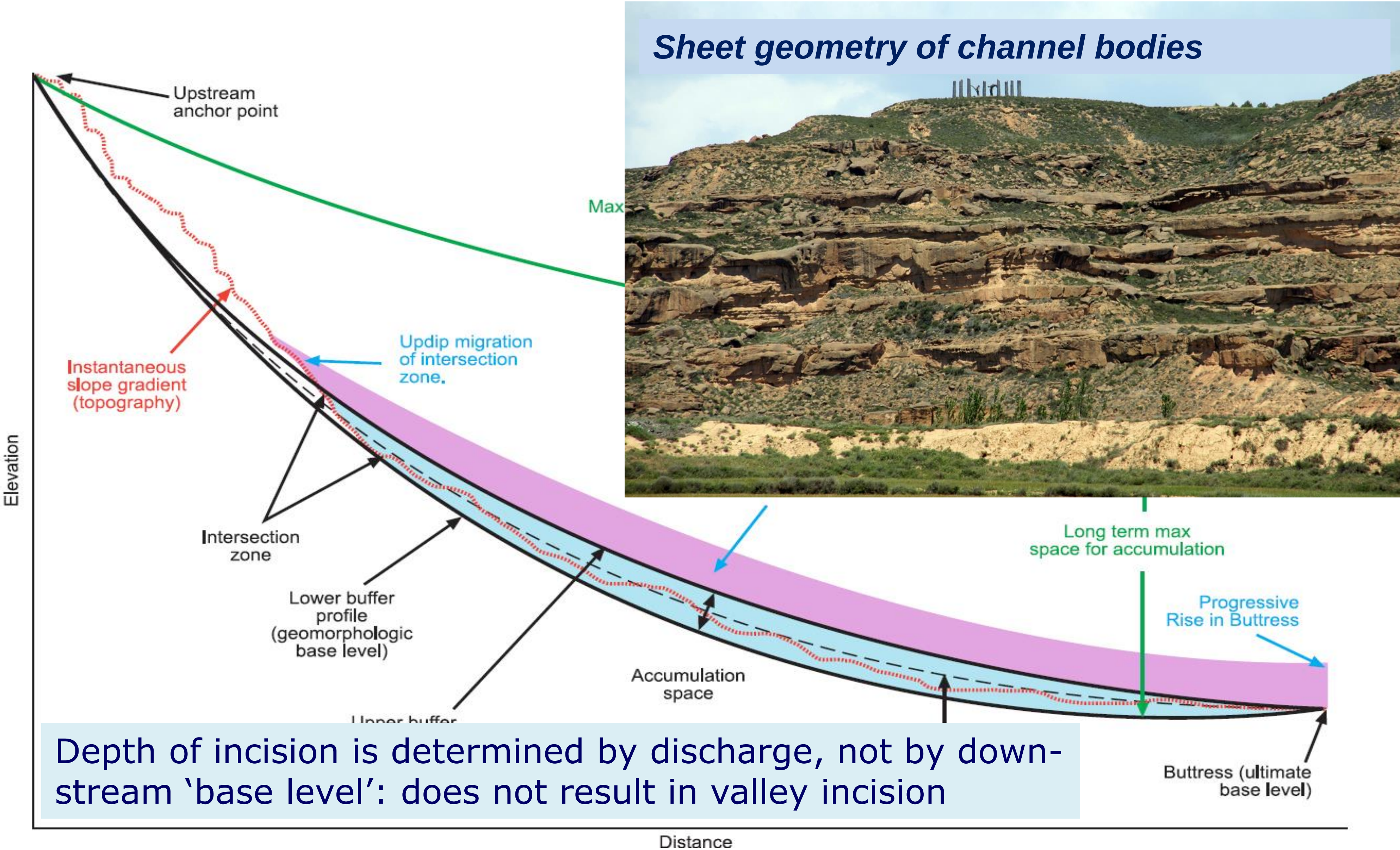
Fluvial Profile in an Endorheic Basin

Buffers and buttresses: controls on fluvial systems (Holbrook et al 2006)

Buttress will continue to rise and whole fluvial profile will continue to aggrade until spill point is reached



Fluvial Profile in an Endorheic Basin



Sheet geometry of channel bodies

Depth of incision is determined by discharge, not by down-stream 'base level': does not result in valley incision

Stratigraphy in an Endorheic Basin

Successions in fluvially-dominated endorheic basins will only show aggradational stratigraphic patterns.

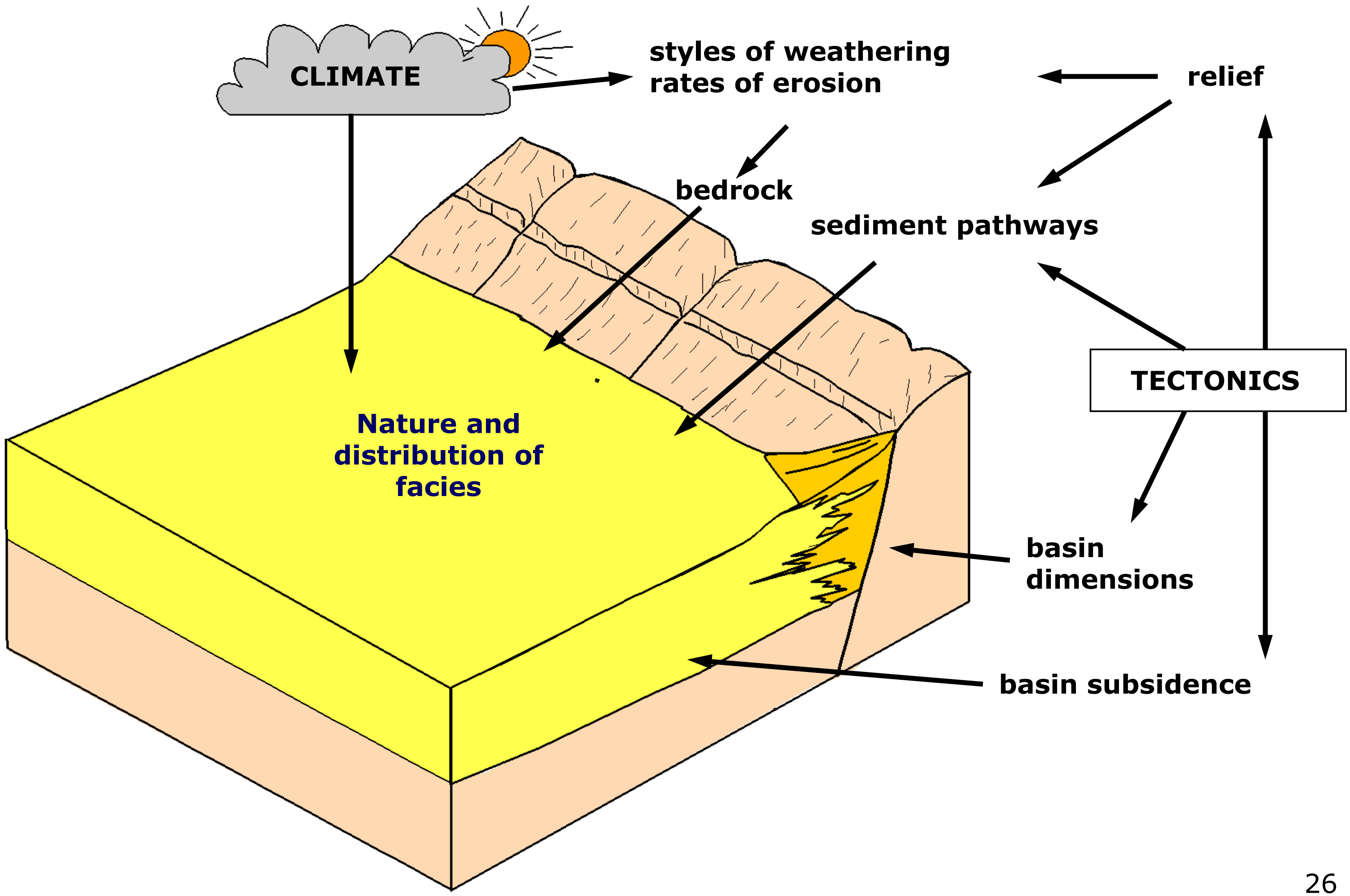
Base-level driven reduction in accommodation does not occur in most cases

Concepts of systems tracts (HST, LST, TST) do not apply

What are the controls on the facies and stratigraphy in a fluvially-dominated endorheic basin?

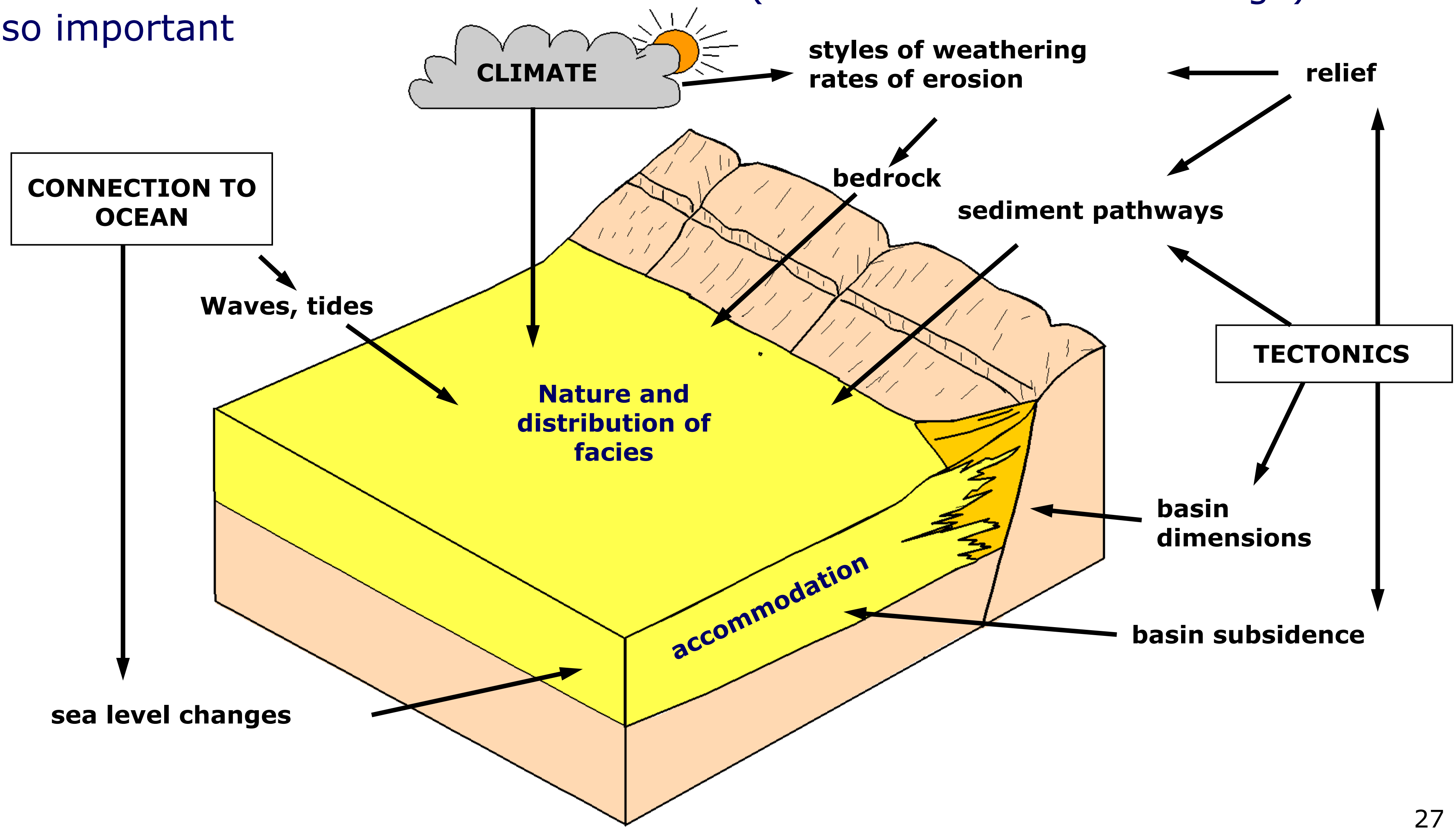
Accommodation in an Endorheic Basin

Facies distributions in basins are typically considered in terms of tectonic and climatic controls



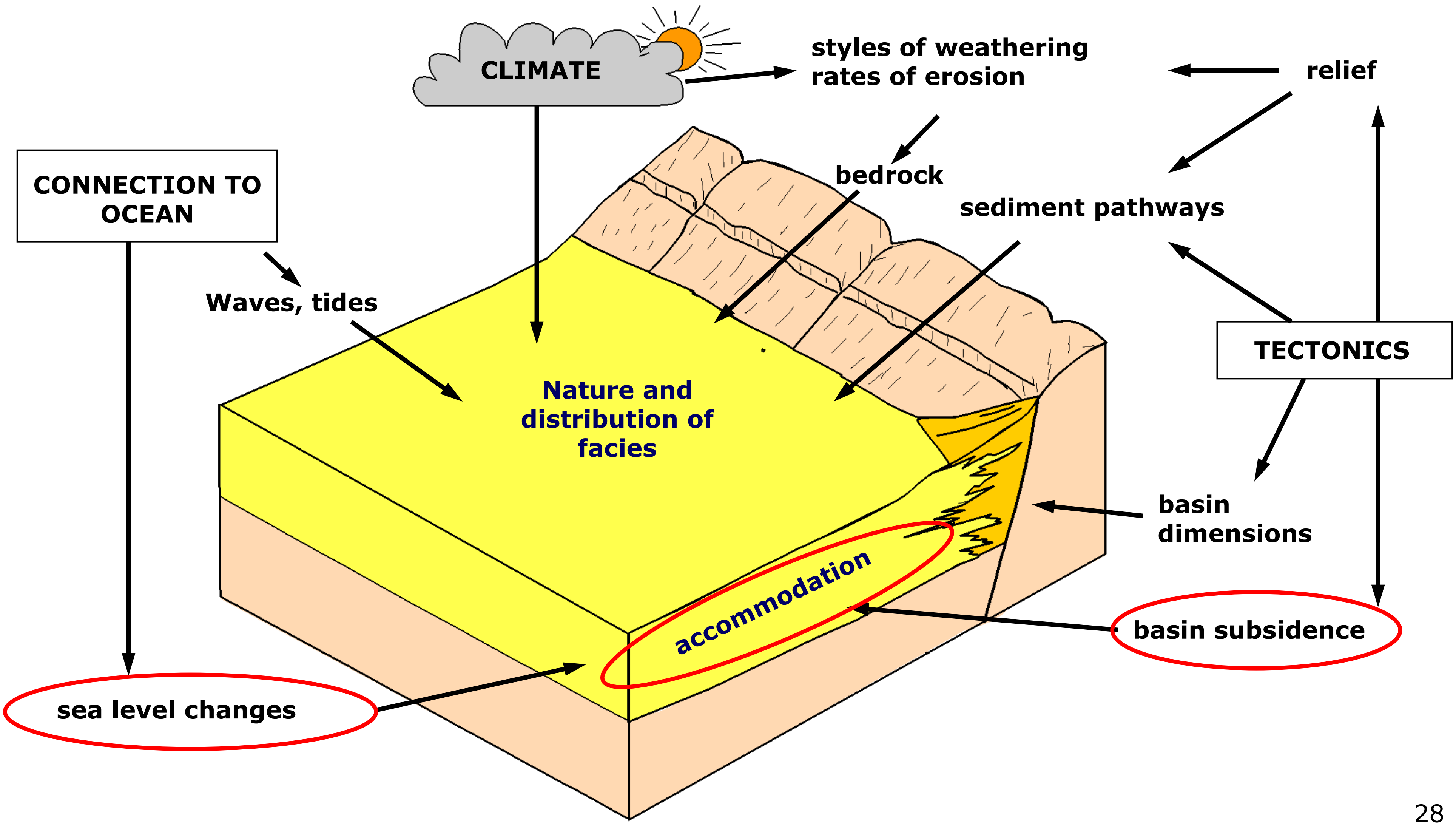
Accommodation in an Endorheic Basin

Facies distributions in basins are typically considered in terms of tectonic and climatic controls: connection to the ocean (external vs internal drainage) is also important



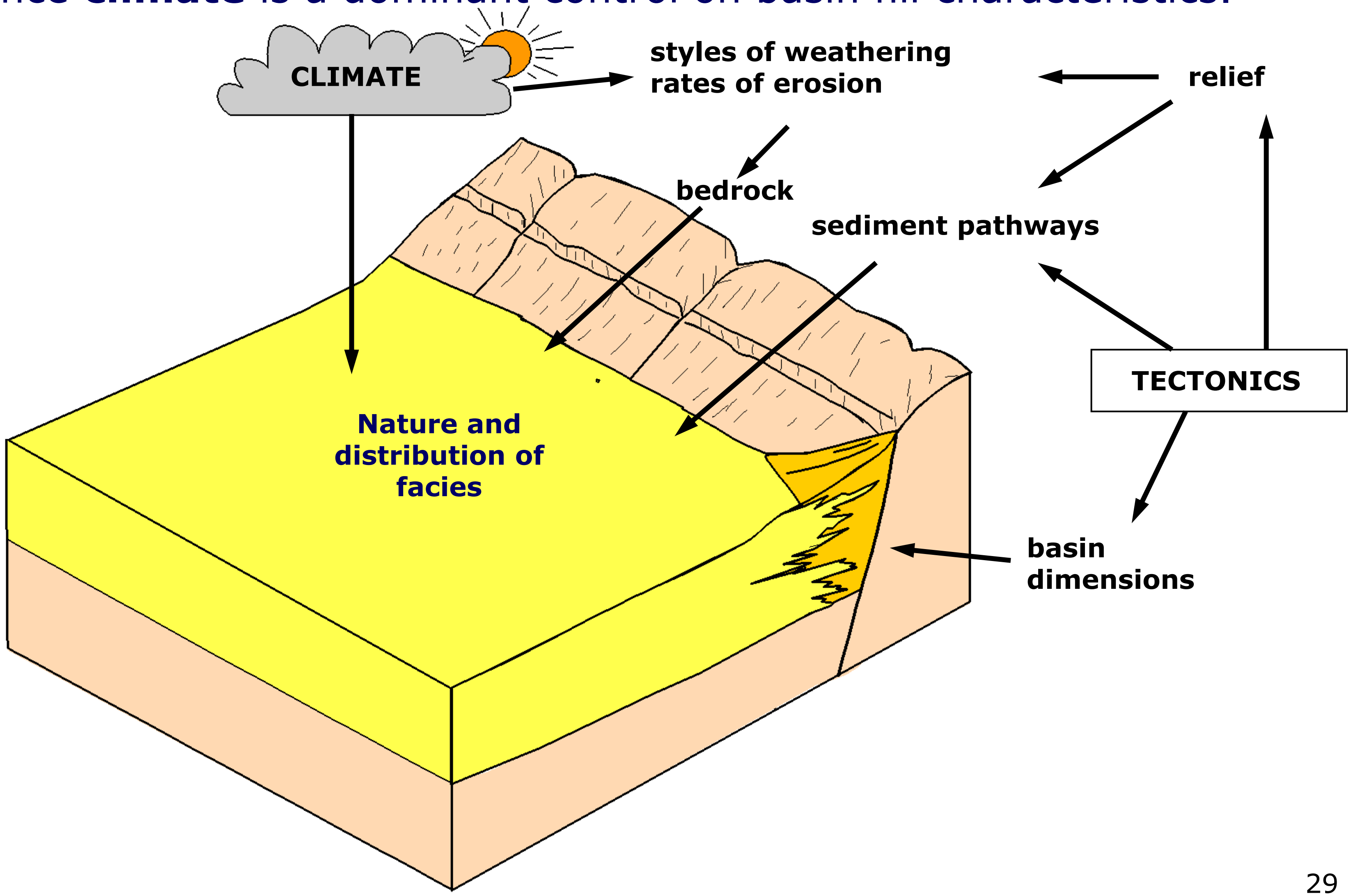
Accommodation in an Endorheic Basin

Accommodation is determined by sea level and subsidence controls, but....



Accommodation in an Endorheic Basin

Accommodation is determined by sea level and subsidence controls, but.... in their absence **climate** is a dominant control on basin fill characteristics.

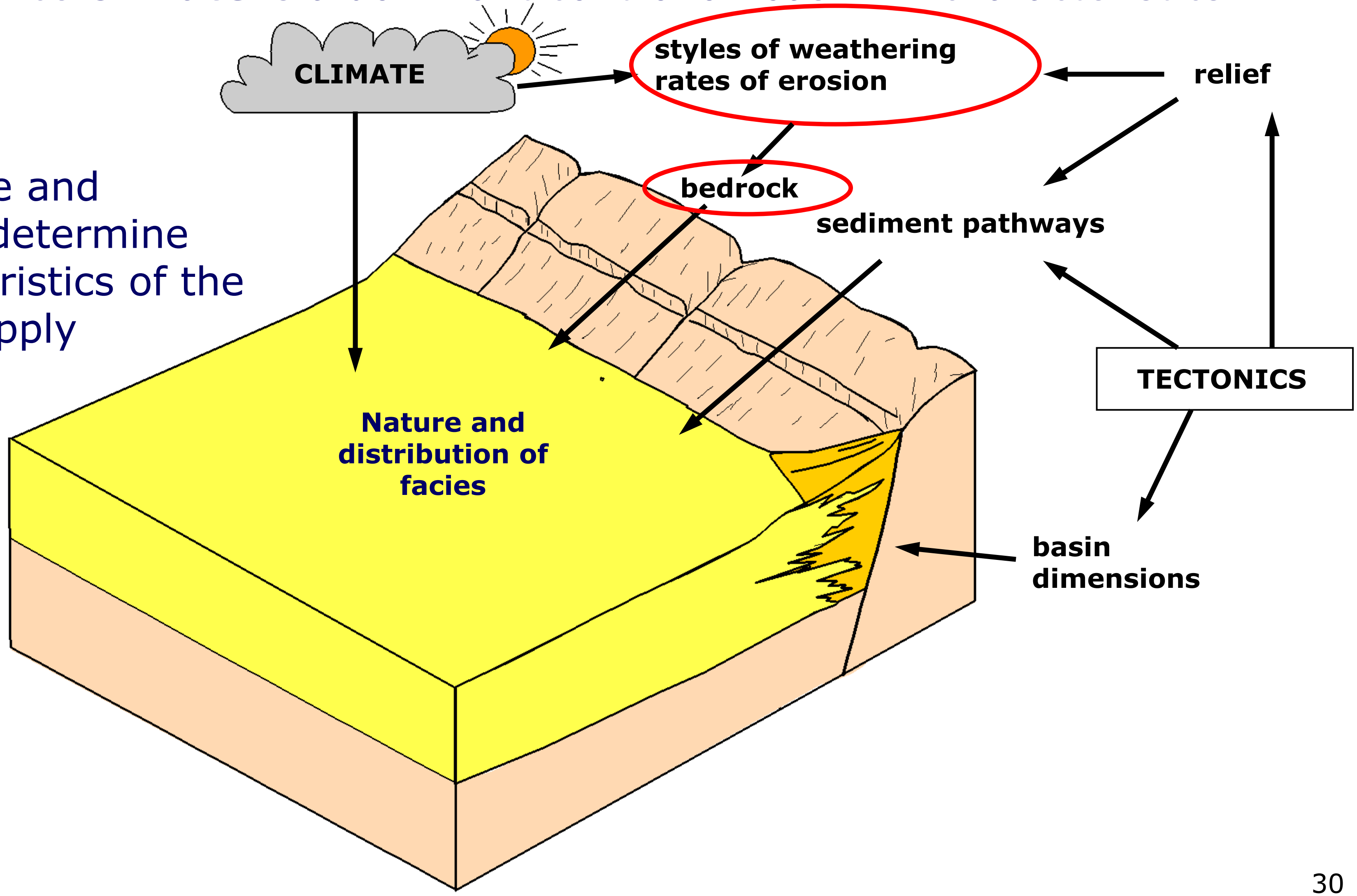


Accommodation in an Endorheic Basin

Accommodation is determined by sea level and subsidence controls, but.... in their absence **climate** is a dominant control on basin fill characteristics.

Or is it?

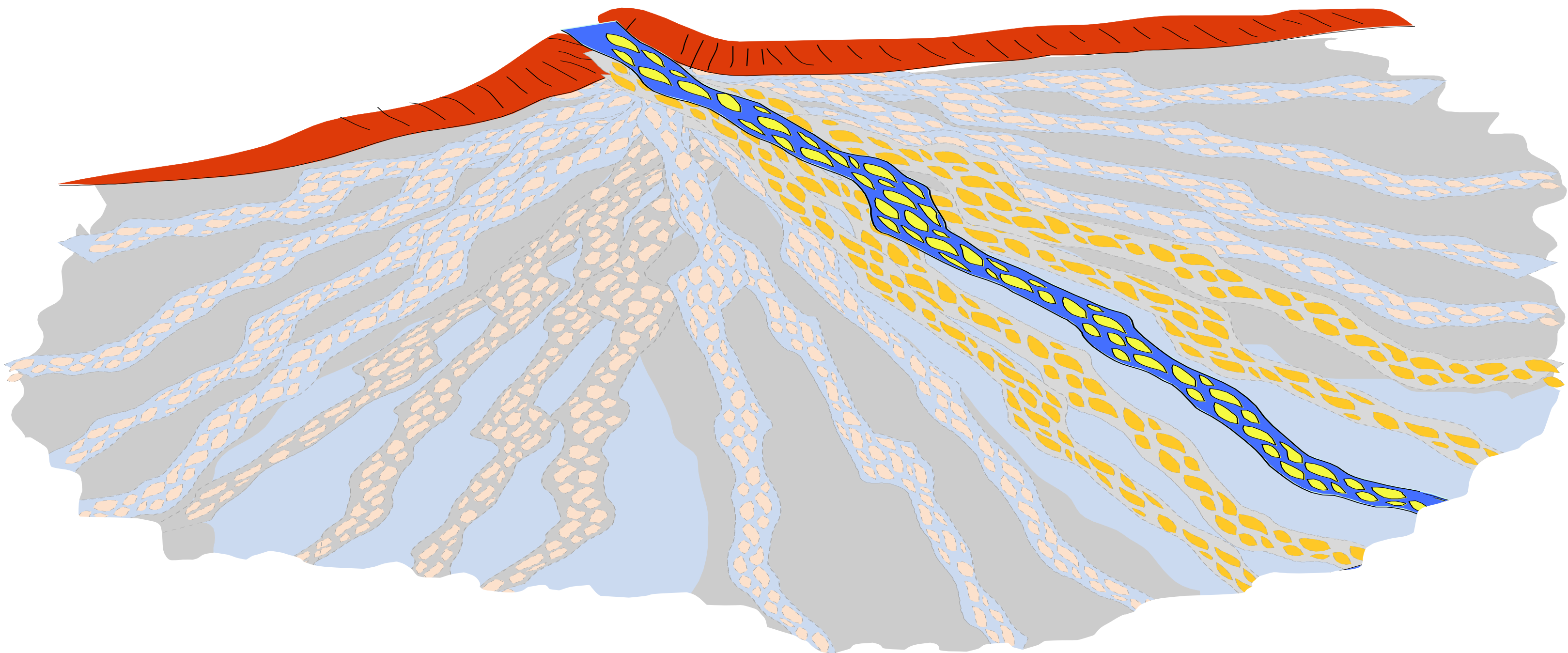
Bedrock type and weathering determine the characteristics of the sediment supply



Sediment supply controls

The characteristics of the sediment supplied to the fluvial system will largely determine the facies and stratigraphic architecture of the succession

Two scenarios

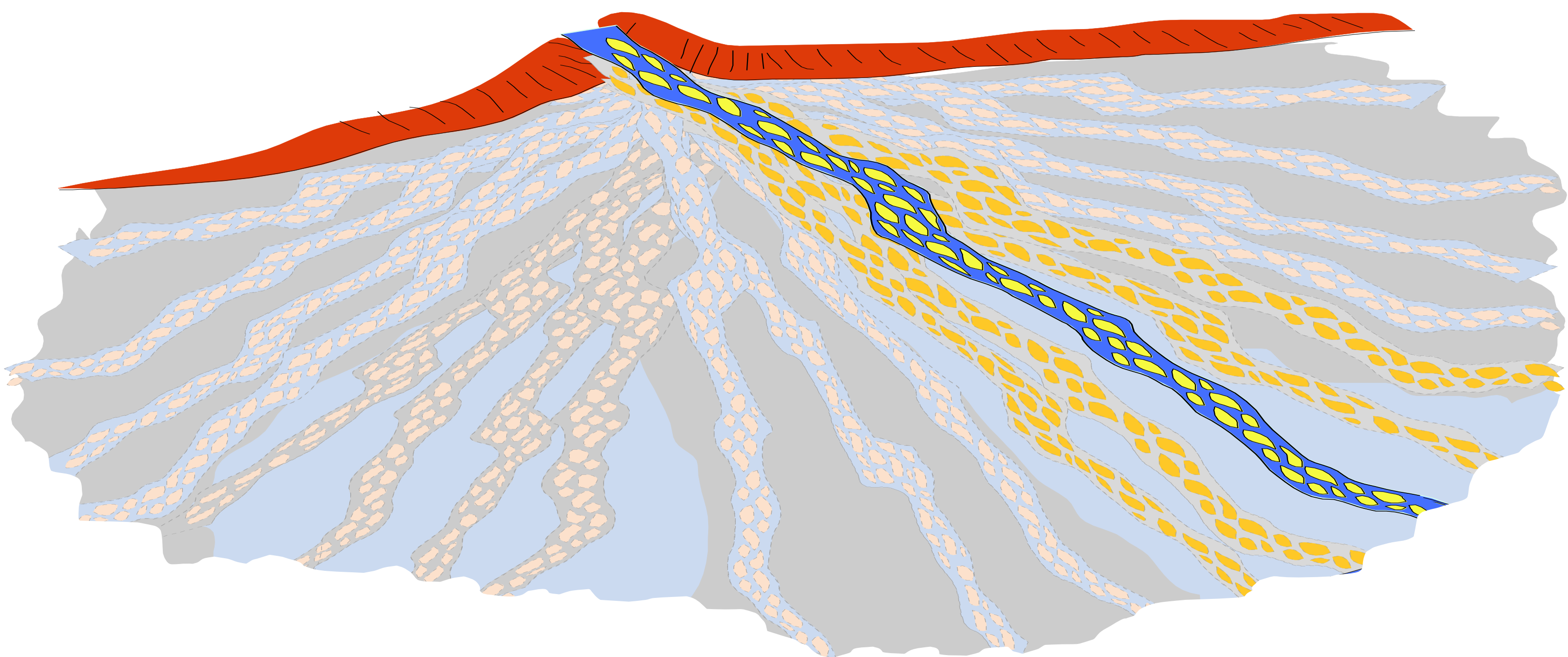


1. Bedload dominated

Sediment supply controls

A river carrying mostly sand and gravel will deposit in channels that move by avulsion across the surface of the distributive system.

This will deposit a broad sheet of sand and/or gravel, with little preservation of any finer overbank material



1. Bedload dominated

Sediment supply controls

The Okavango River system in Botswana is a modern example.

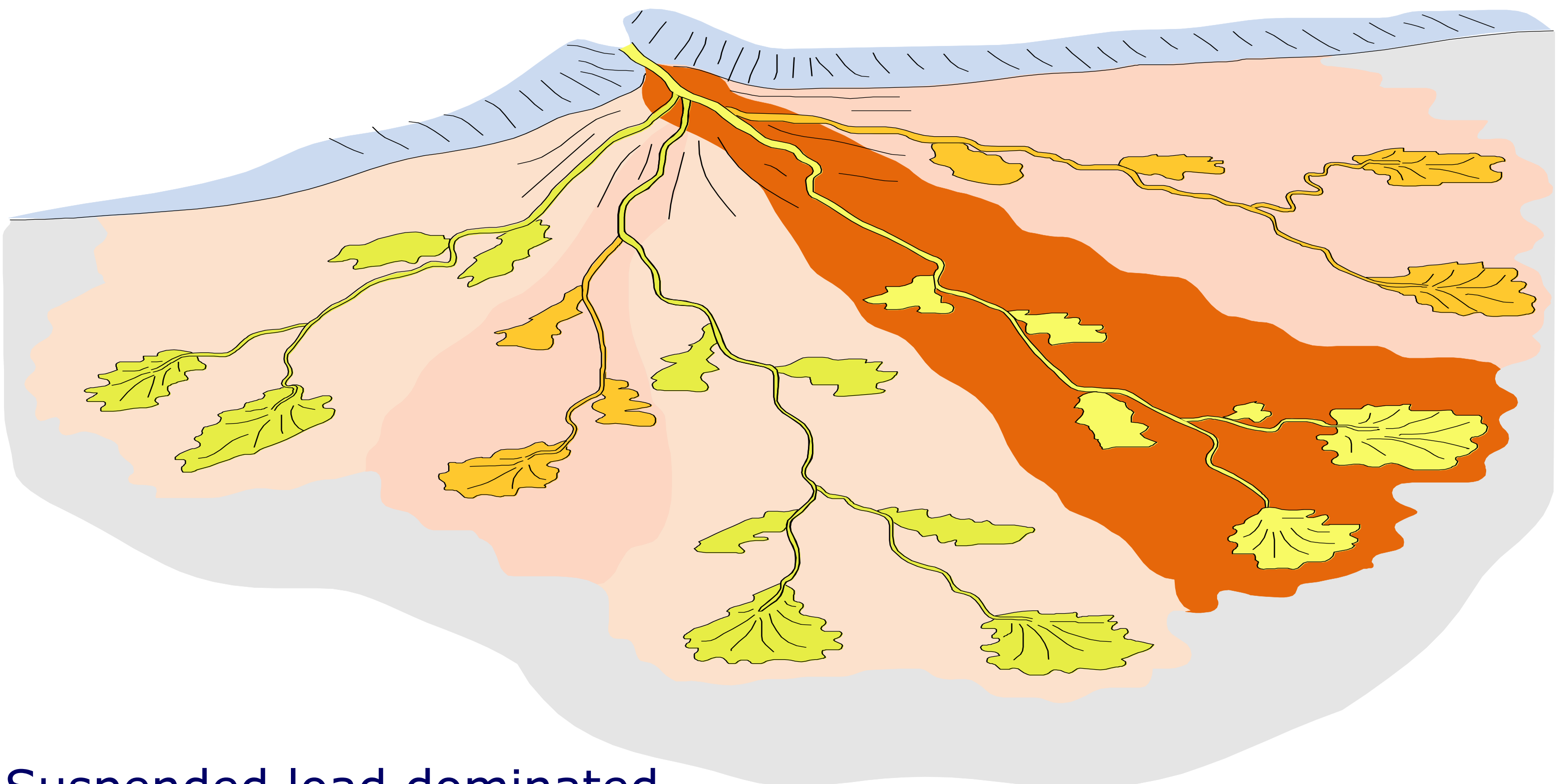
Over 90% of the sediment carried by the rivers is sandy bedload. There is little preservation of any fine-grained material.

1. Bedload dominated

Sediment supply controls

A river carrying mostly suspended and dissolved load will deposit in he overbank areas and in abandoned channels.

This will form successions dominated by mudrocks



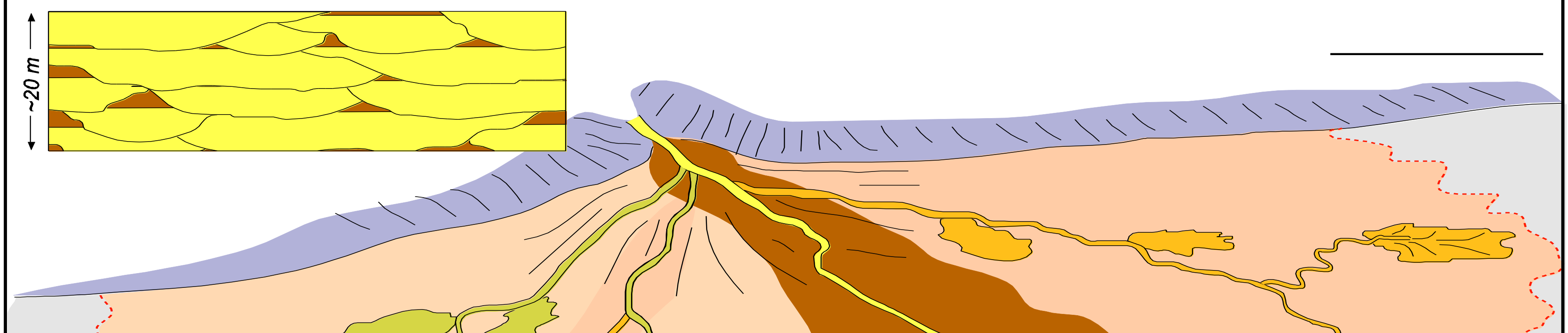
1. Suspended load dominated

Sediment supply controls

A mudrock-dominated succession, Cenozoic of Wyoming. Both the overbank succession and the channel-fill deposits are fine-grained.

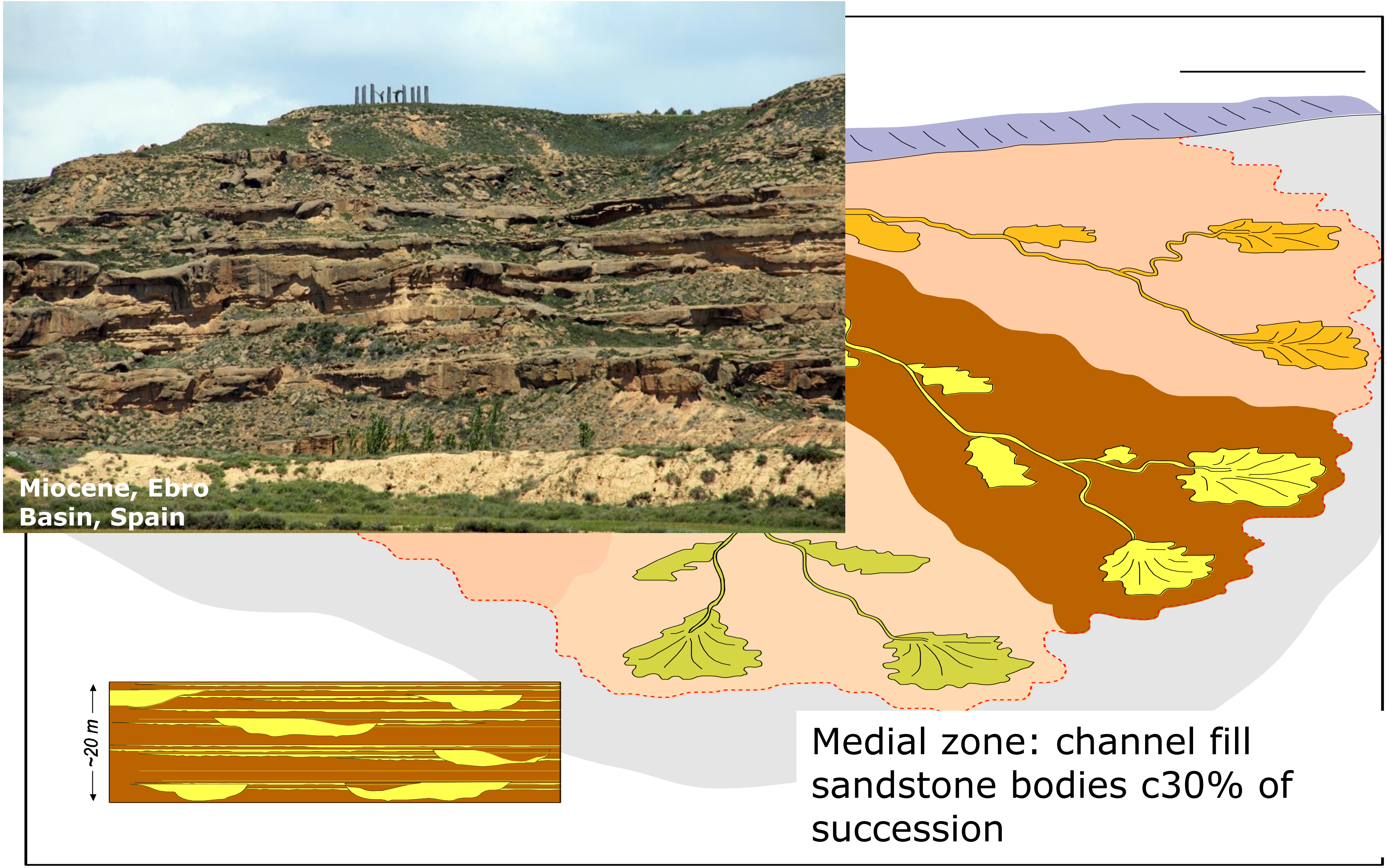
1. Suspended load dominated

Sediment supply controls: mixed loads



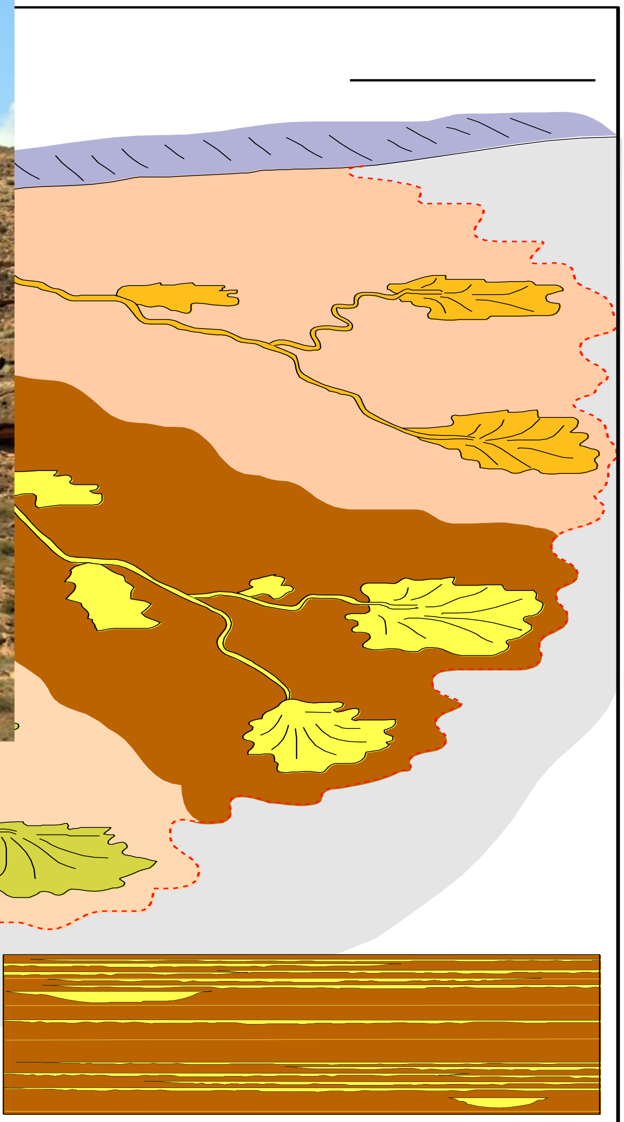
Proximal zone: channel fill sandstone bodies >50% of succession

Sediment supply controls: mixed loads



Medial zone: channel fill sandstone bodies c30% of succession

Sediment supply controls: mixed loads

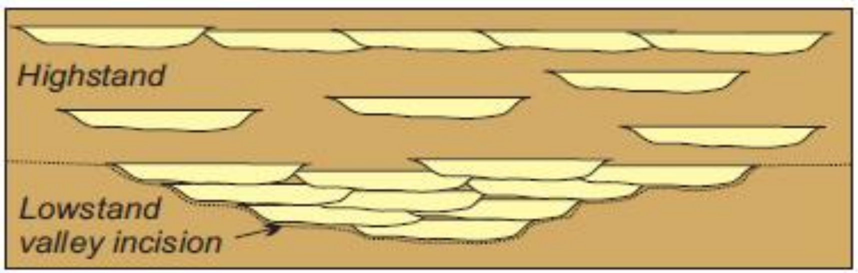


Distal zone: isolated channel fill sandstone bodies <10% of succession

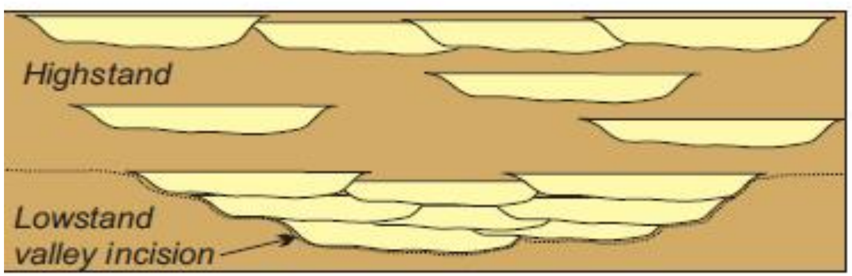
Stratigraphic models for fluvial systems

Conceptual model assuming that rivers are influenced by changes in sea level

Conceptual model for a tributary river system influenced by relative sea level (after Shanley and McCabe 1993)



↓ Increase in channel body size down system

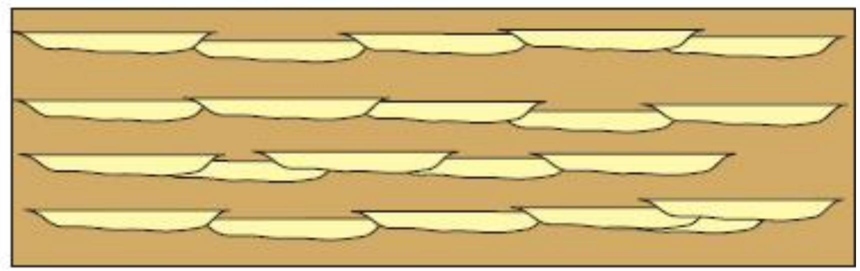


Degree of amalgamation varies between relative low stand and high stand

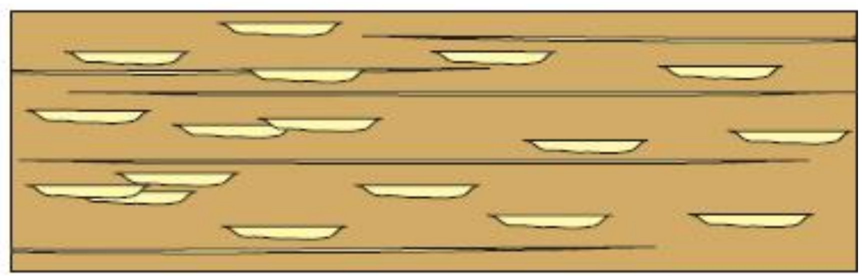
Increasing distance down-systm ↓

Conceptual model assuming that rivers are distributive and independent of sea level changes

Conceptual model for a terminal distributive river system in a basin of internal drainage (after Nichols and Fisher 2007)



↓ Decrease in channel body size down system

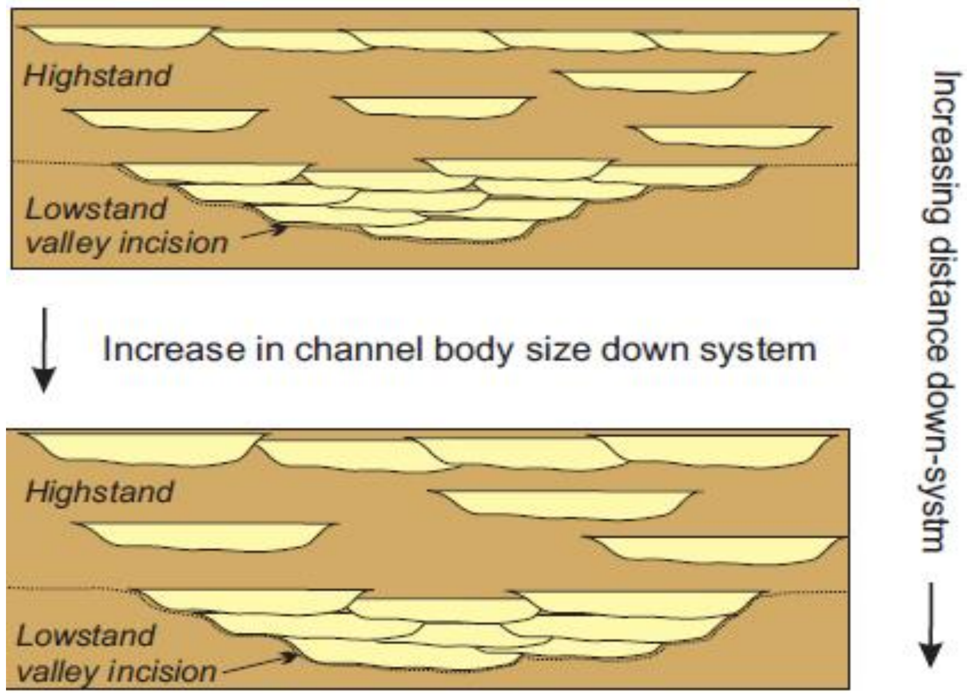


Degree of amalgamation shows little variation with time

Stratigraphic models for fluvial systems

Conceptual model assuming that rivers are influenced by changes in sea level

Conceptual model for a tributary river system influenced by relative sea level (after Shanley and McCabe 1993)



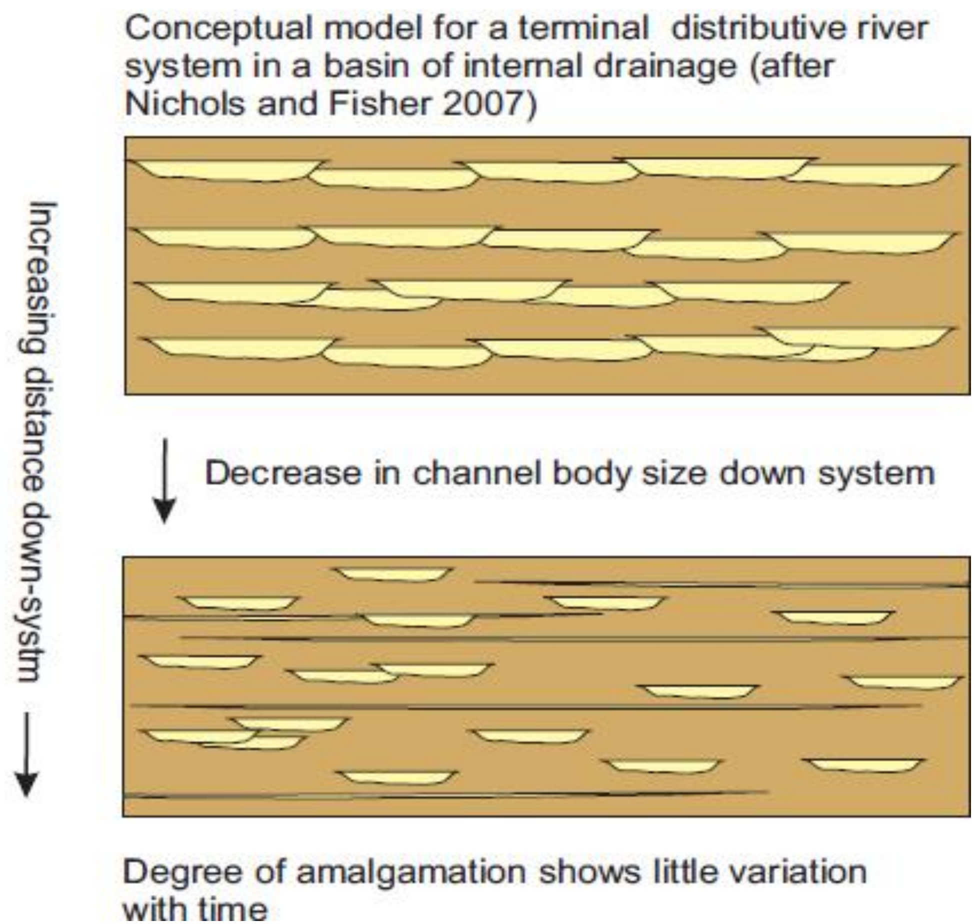
Degree of amalgamation varies between relative low stand and high stand

This model has limited application. It does not apply to distributive fluvial systems in endorheic basins – which are c. 50% continental basins in the stratigraphic record

Stratigraphic models for fluvial systems

Conceptual model assuming that rivers are distributive and independent of sea level changes

This model may have more widespread application and be a better predictor of the distribution of reservoir sandstone bodies in fluvial successions. However, it is currently based on a limited number of case studies from the stratigraphic record.



Conclusions

Basins of internal drainage are important sites of deposition of Distributive Fluvial Systems and may show distinctive features

- There are limitations of a sequence stratigraphic approach:
  - Sediment supply and accommodation are not independent
  - Subsidence is not required to create short-term accommodation.
  - Concepts of 'highstand' and 'lowstand' do not apply
  - 'Incised valleys' do not occur
- Primary controlling factors on channel architecture:
  - The proportion of bedload and suspended load/dissolved load in the sediment supply
  - The distributive character of the fluvial system