Role of Incised Valley Systems in Source-to-Sink Sediment Routing and Storage: Examples from the Late Quaternary Northern Gulf of Mexico Margin*

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Search and Discovery Article #50248 (2010)
Posted February 24, 2010

*Adapted from oral presentation at AAPG Annual Convention, Denver, Colorado, June 7-10, 2009.
Please refer to related article by the senior author, entitled "High Frequency Cyclical Isostatic Adjustments: Significance for Incised Valleys," Search and Discovery Article #30079 (2009) (http://www.searchanddiscovery.net/documents/2009/30079blum/ndx_blum.pdf)

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Abstract

Incised-valley systems form in response to sea-level fall, as fluvial systems extend across newly subaerial shelves to the lowstand shoreline and shelf margin. Recent work on Late Quaternary systems of the Gulf of Mexico passive margin illustrate how sediment supply might change over the course of a glacio-eustatic cycle, and how the evolution of incised-valley systems modulates source-to-sink sediment routing to deepwater environments through processes of storage and export of sediments on the coastal plain and inner shelf.
First, empirical data on links between sediment supply and climate suggests supply from the hinterlands should decrease during glacio-eustatic sea-level fall and lowstand due to temperature depression. Hence, total supply from the hinterland may be (a) at a maximum when river mouths reside in highstand positions, and sediment storage takes place on the coastal plain and inner shelf, and (b) at a minimum during time periods when river systems are extended to the shelf margin lowstand shoreline and directly feeding the slope and basin floor. Second, incised valleys form in a step-wise manner, with short periods of incision punctuated by extended periods of lateral channel migration and valley widening, and with contemporaneous deposition of channel-belt sands. The total volume of sediment exported during the period of incised-valley formation is a relatively small value compared to the ongoing flux from the hinterlands, and short periods of incision likely produce an insignificant amount. However, periods of lateral channel migration and valley widening significantly increase the export of sediment, perhaps by 25% or more, such that falling-stage fluvial deposition corresponds to increased sediment delivery to the shelf margin and beyond. Finally, for low-gradient continental margins with broad shelves, like those of the Late Quaternary Gulf of Mexico, drainage basins merge as channels extend across the shelf, which will in turn result in increases in the drainage areas that contribute to single point sources at the shelf margin. Apparent signals of increased or decreased flux of sediment to the shelf margin and beyond may therefore reflect geomorphic response to sea-level change - the merging of drainages as they transit a broad shelf - rather than changes in sediment supply from the hinterland.

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ROLE OF INCISED-VALLEY SYSTEMS IN SOURCE-TO-SINK SEDIMENT ROUTING AND STORAGE

Examples from the Late Quaternary Gulf of Mexico Margin

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Houston, Texas

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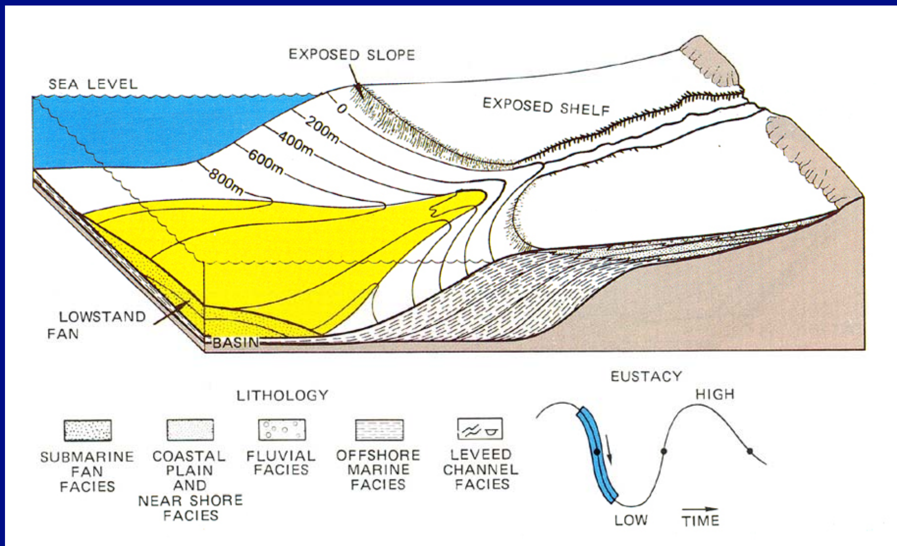
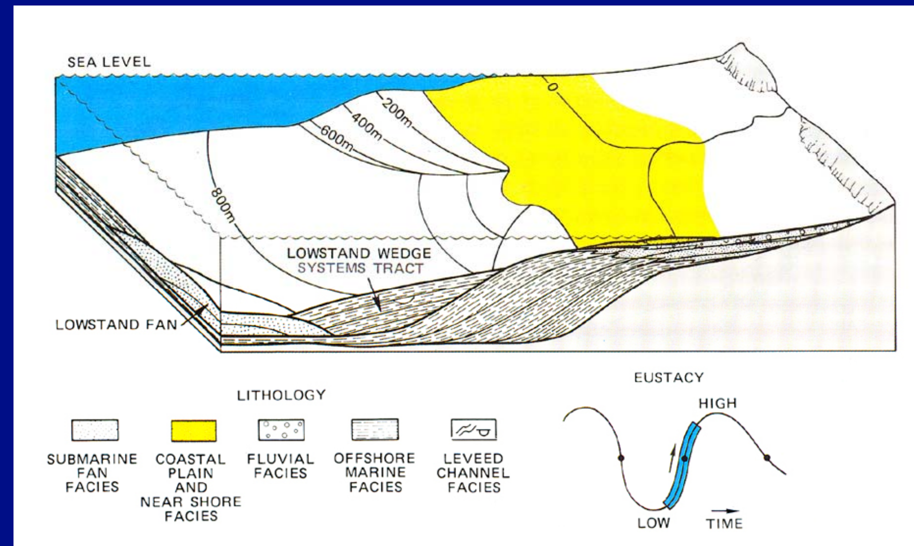
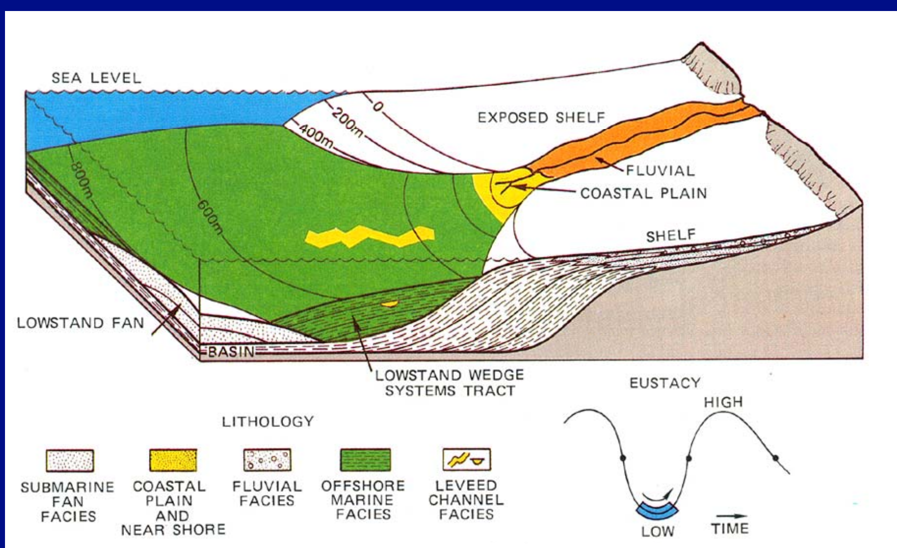
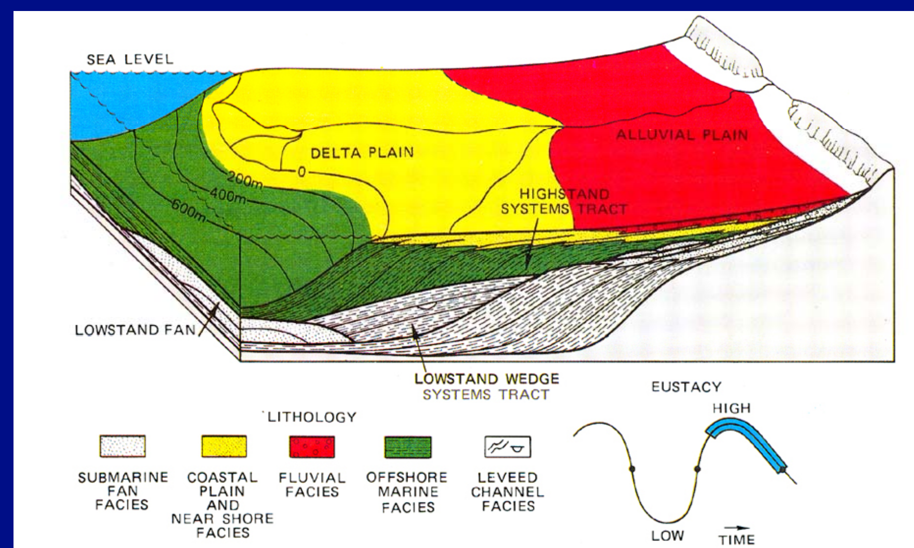
FIRST-GENERATION EXXON MODELS







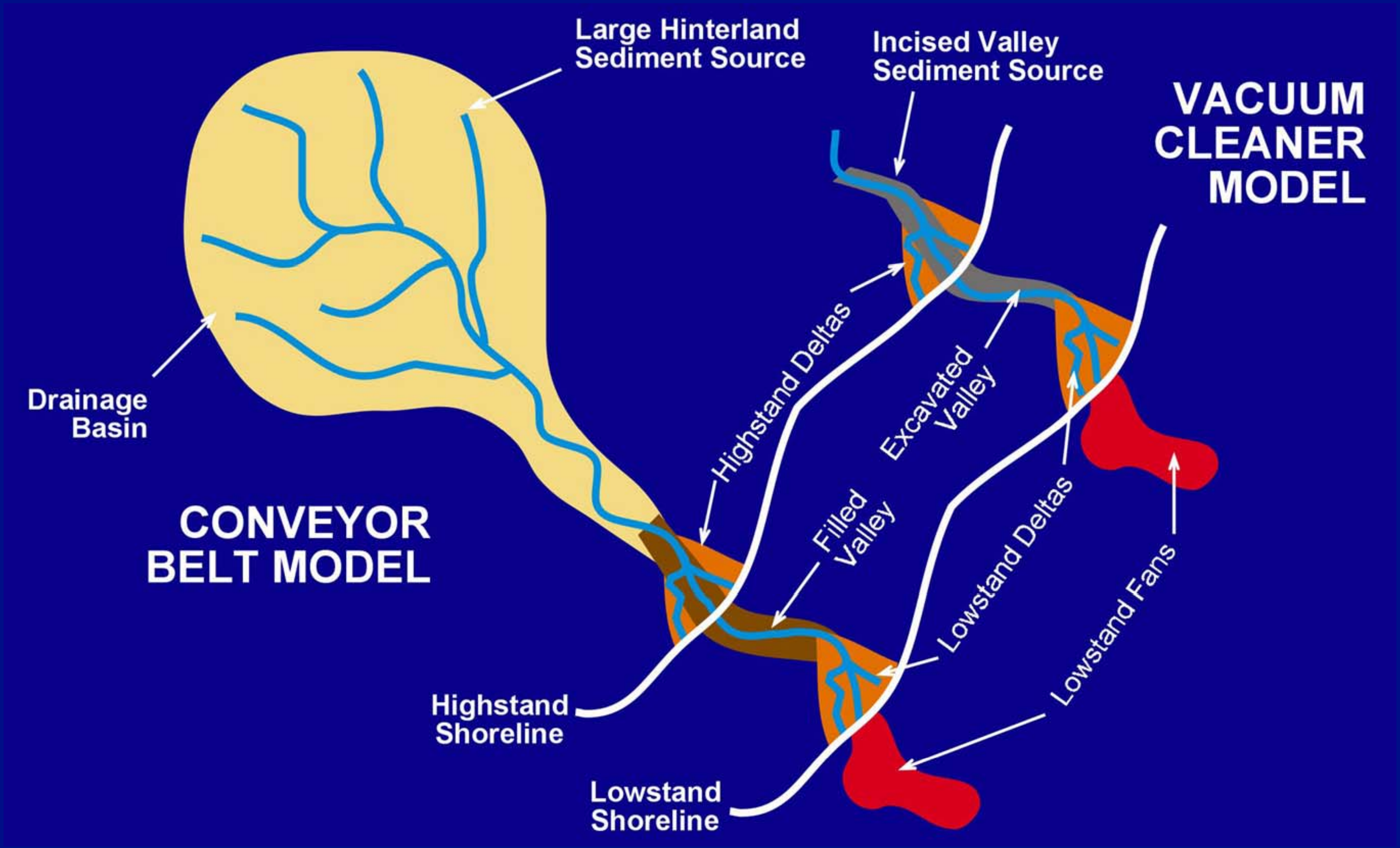


- *incision and sediment bypass during relative sea-level fall with no fluvial deposition*
- *excavation of valley was seen as an important sediment source to lowstand fans*

after Posamentier and Vail, 1988

FLUVIAL SYSTEMS AND SEDIMENT SUPPLY

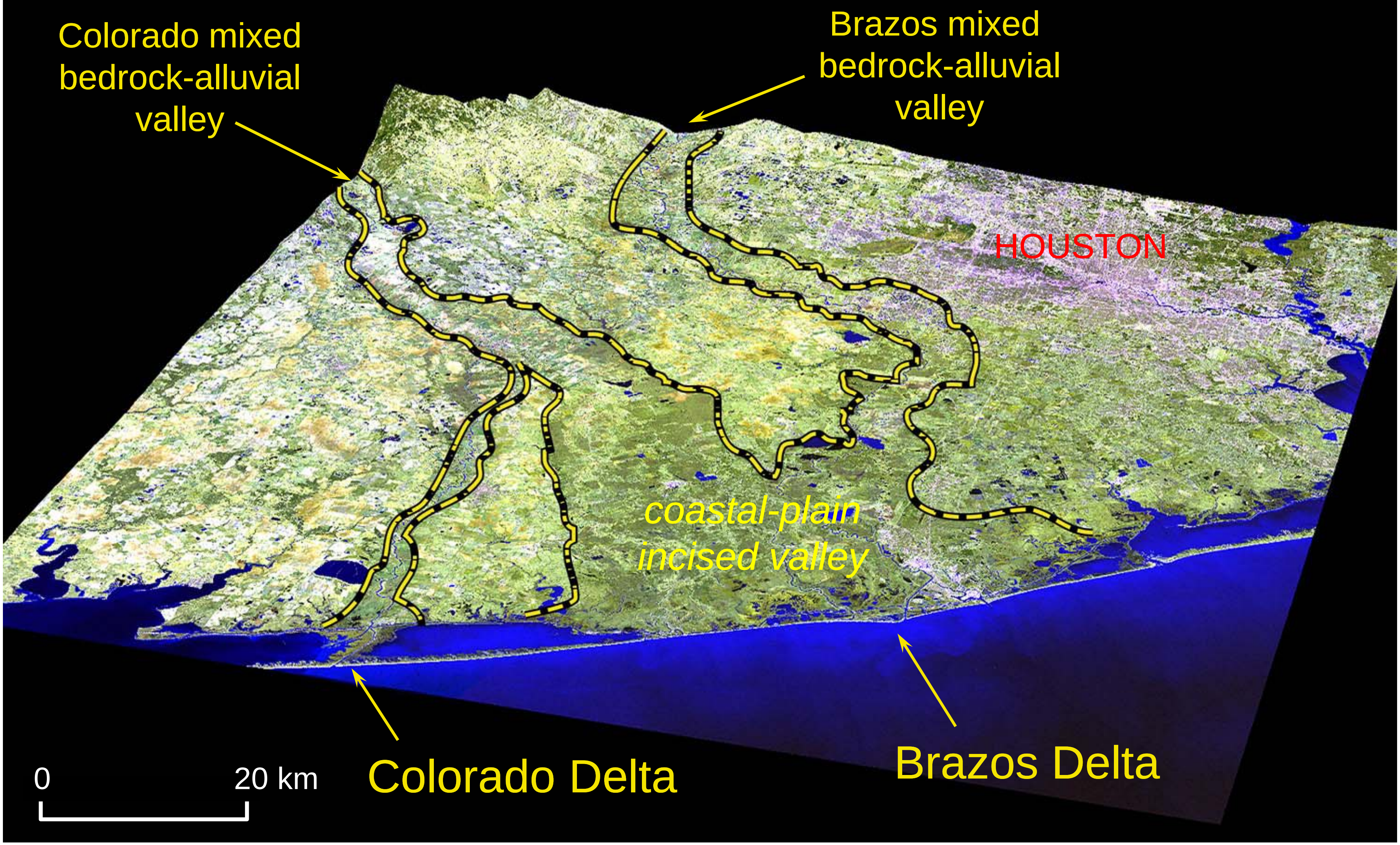
Incised Valleys as Conveyor Belts or Vacuum Cleaners



after Blum and Törnqvist (2000)

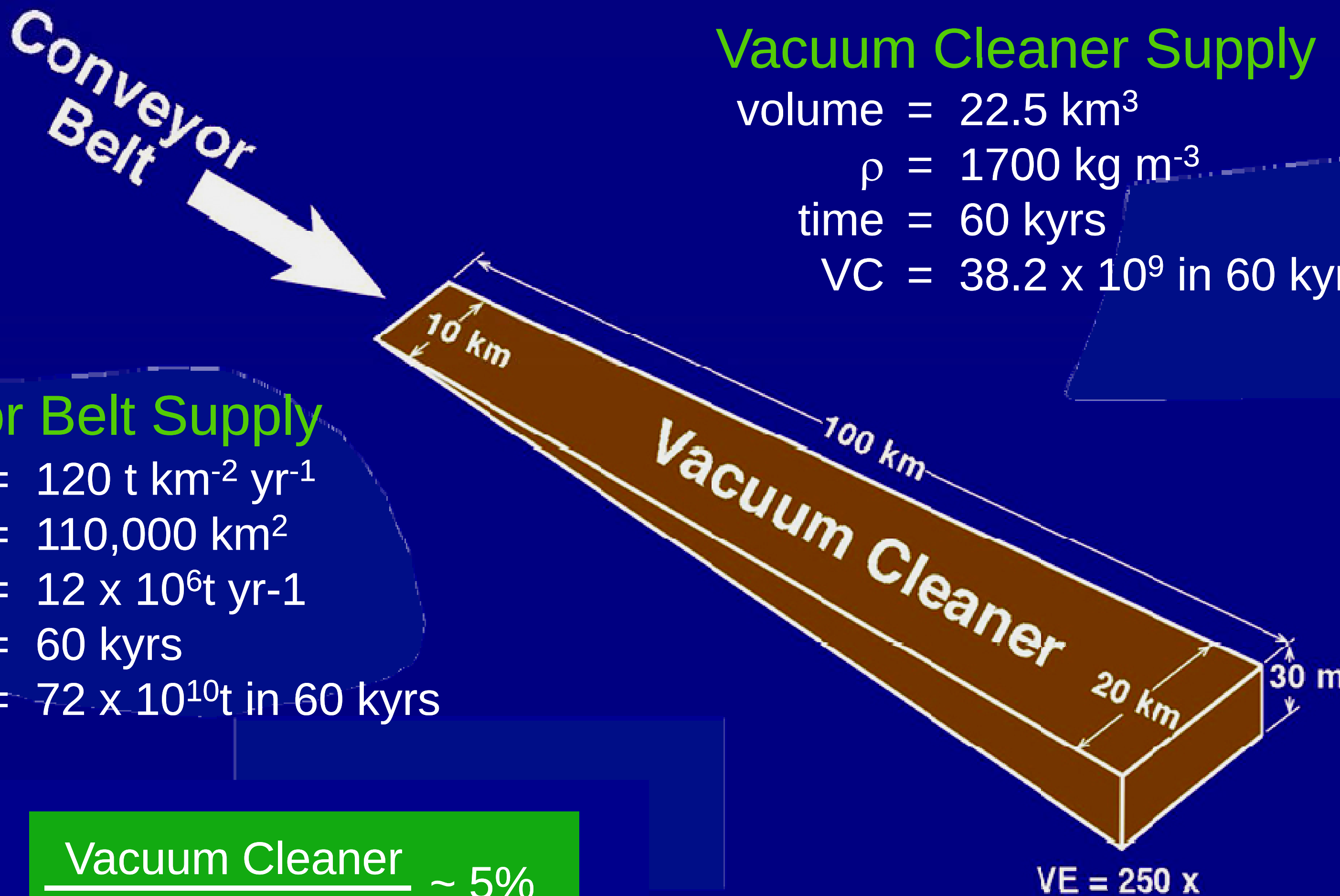
COLORADO-BRAZOS INCISED VALLEY

Last 100 kyr Glacial-Interglacial Cycle



FLUVIAL SYSTEMS AND SEDIMENT SUPPLY

Relative Importance of Conveyor Belts and Vacuum Cleaners



Vacuum Cleaner Supply

volume = 22.5 km^3
ρ = 1700 kg m^{-3}
time = 60 kyrs
VC = 38.2 x 10^9 in 60 kyrs

Conveyor Belt Supply

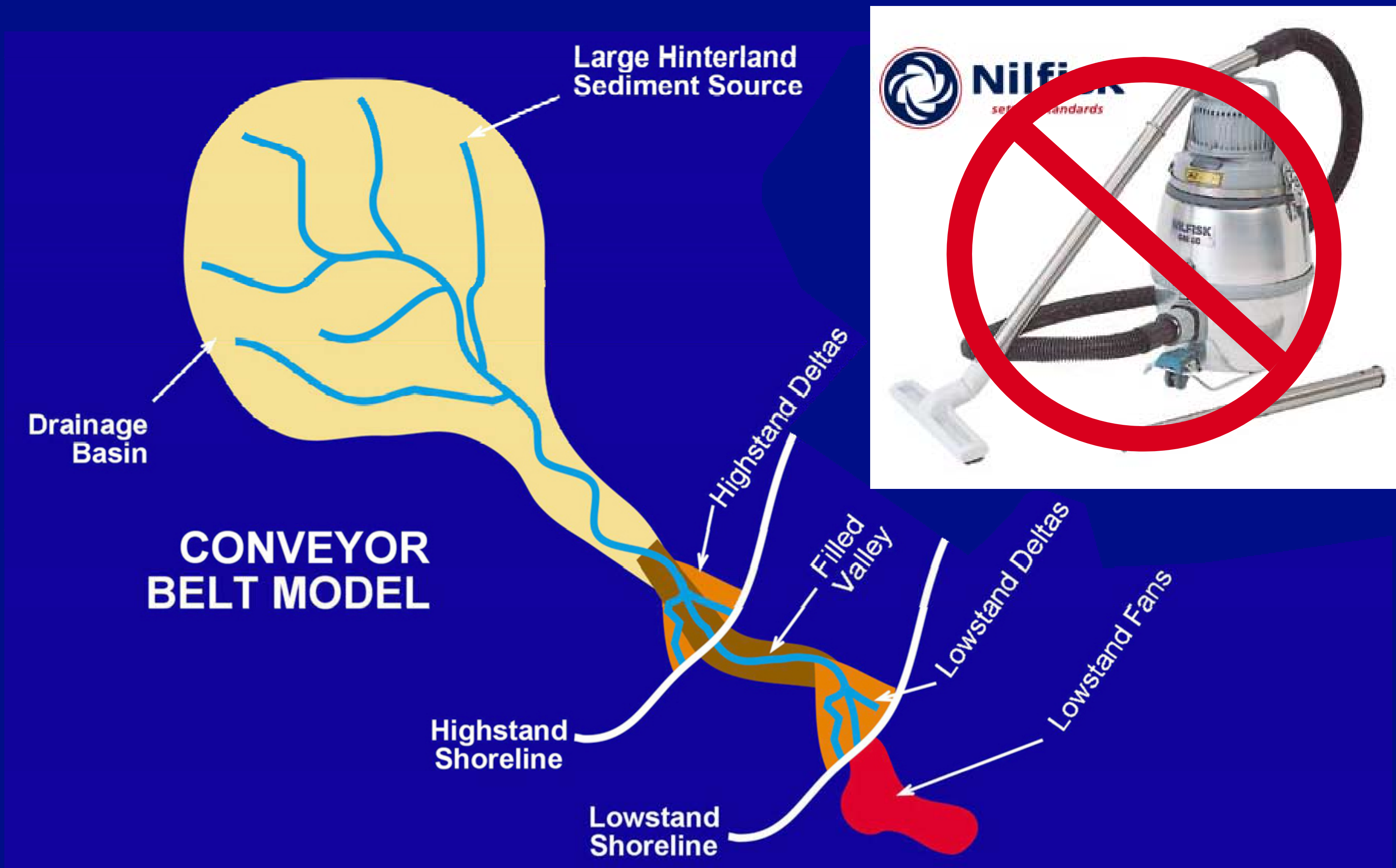
yield = 120 t km^{-2} yr^{-1}
area = 110,000 km^2
supply = 12 x 10^{6}t yr-1
time = 60 kyrs
CB = 72 x 10^{10}t in 60 kyrs

$$\frac{\text{Vacuum Cleaner}}{\text{Conveyor Belt}} \sim 5\%$$

after Blum and Törnqvist (2000)

FLUVIAL SYSTEMS AND SEDIMENT SUPPLY

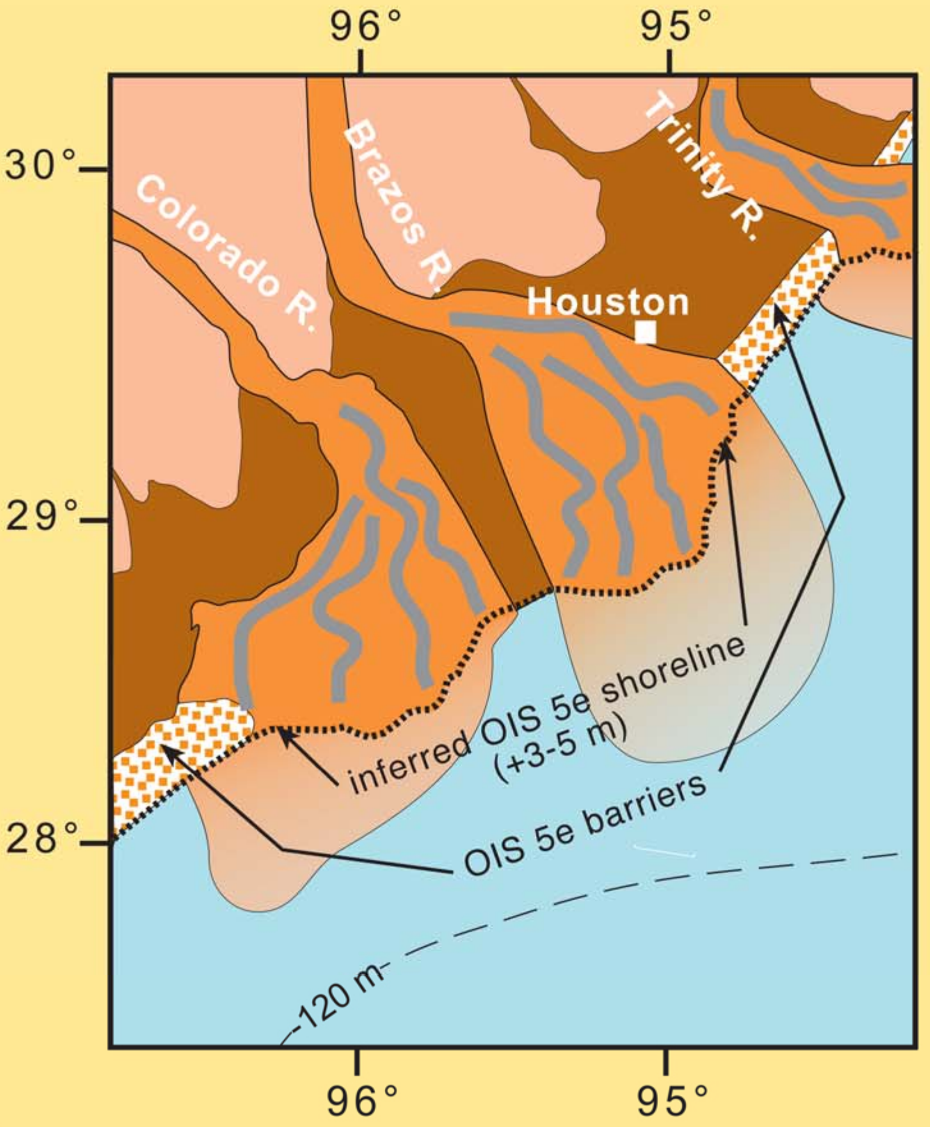
Incised Valleys as Conveyor Belts or Vacuum Cleaners



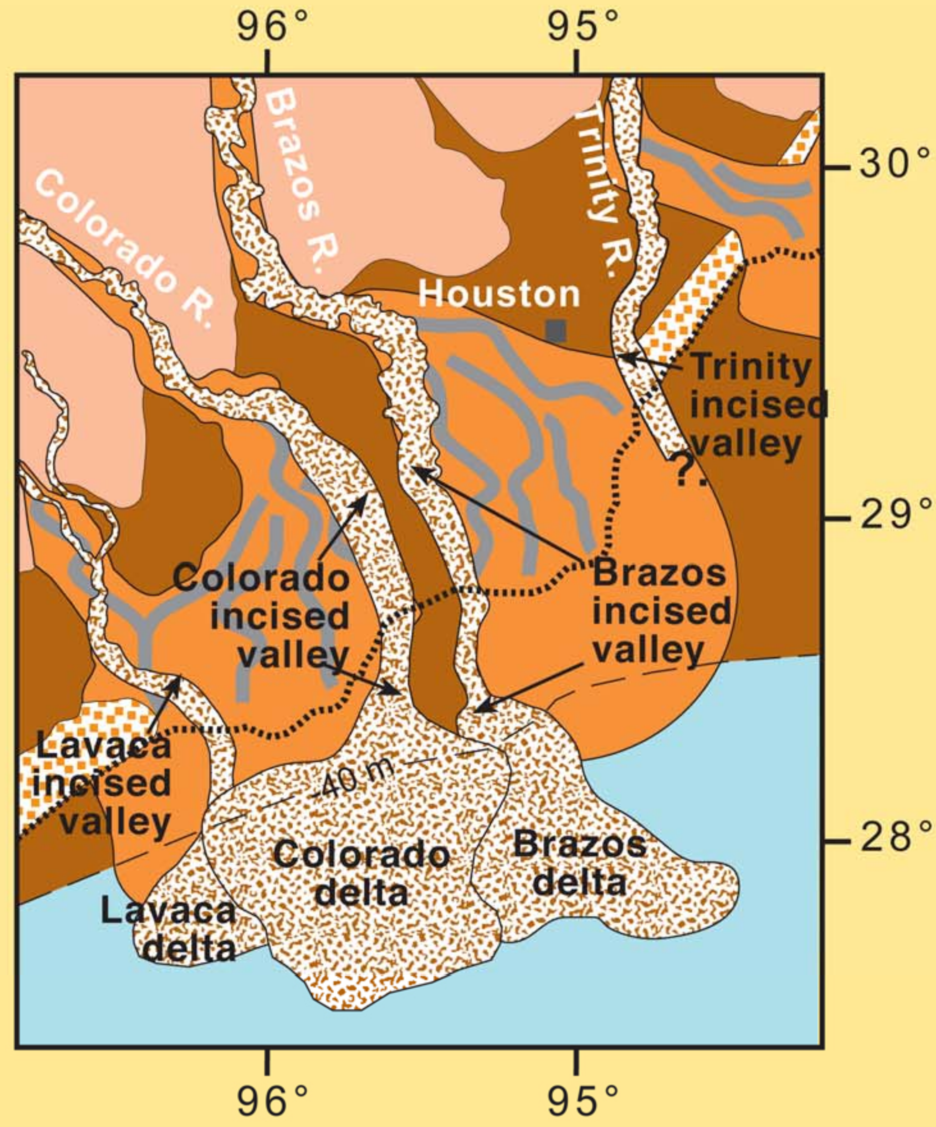
after Blum and Törnqvist (2000)

TEXAS COAST SYSTEMS TRACT EVOLUTION

Last Interglacial Highstand



Last Glacial Falling Stage

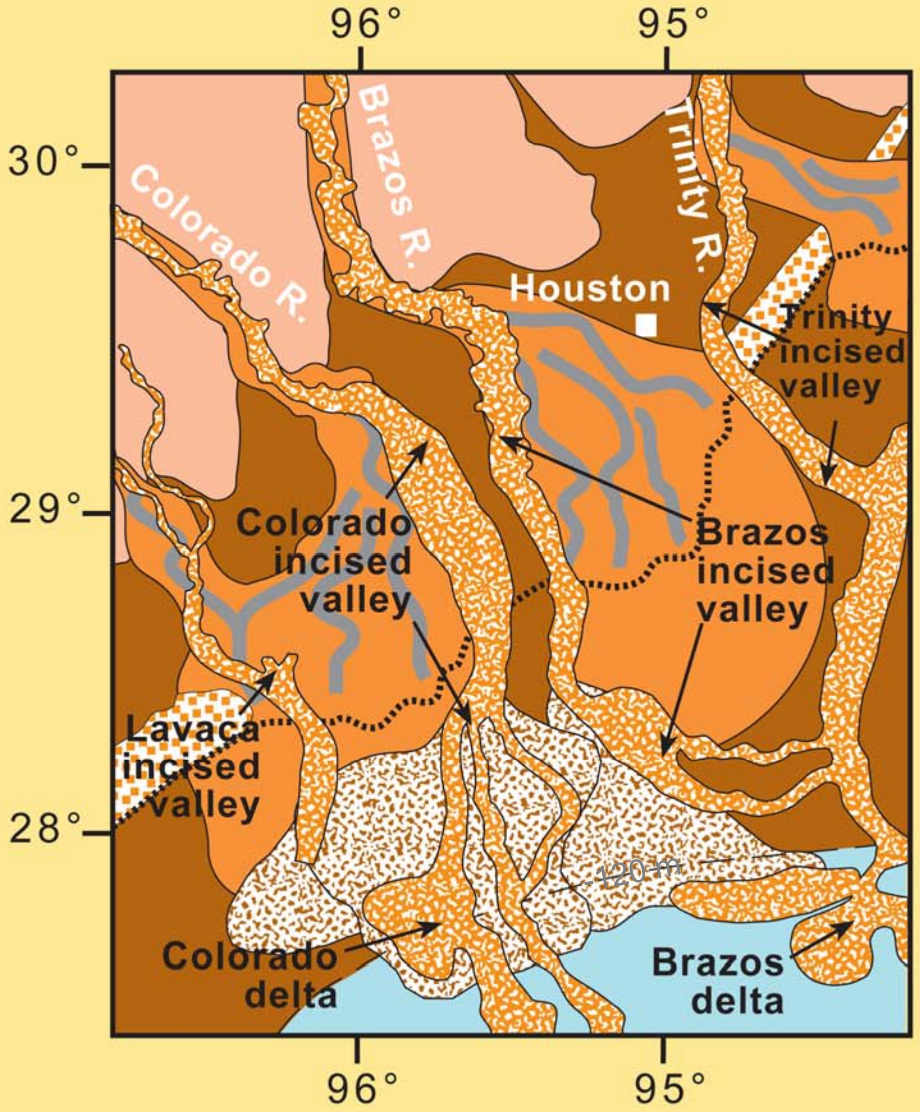


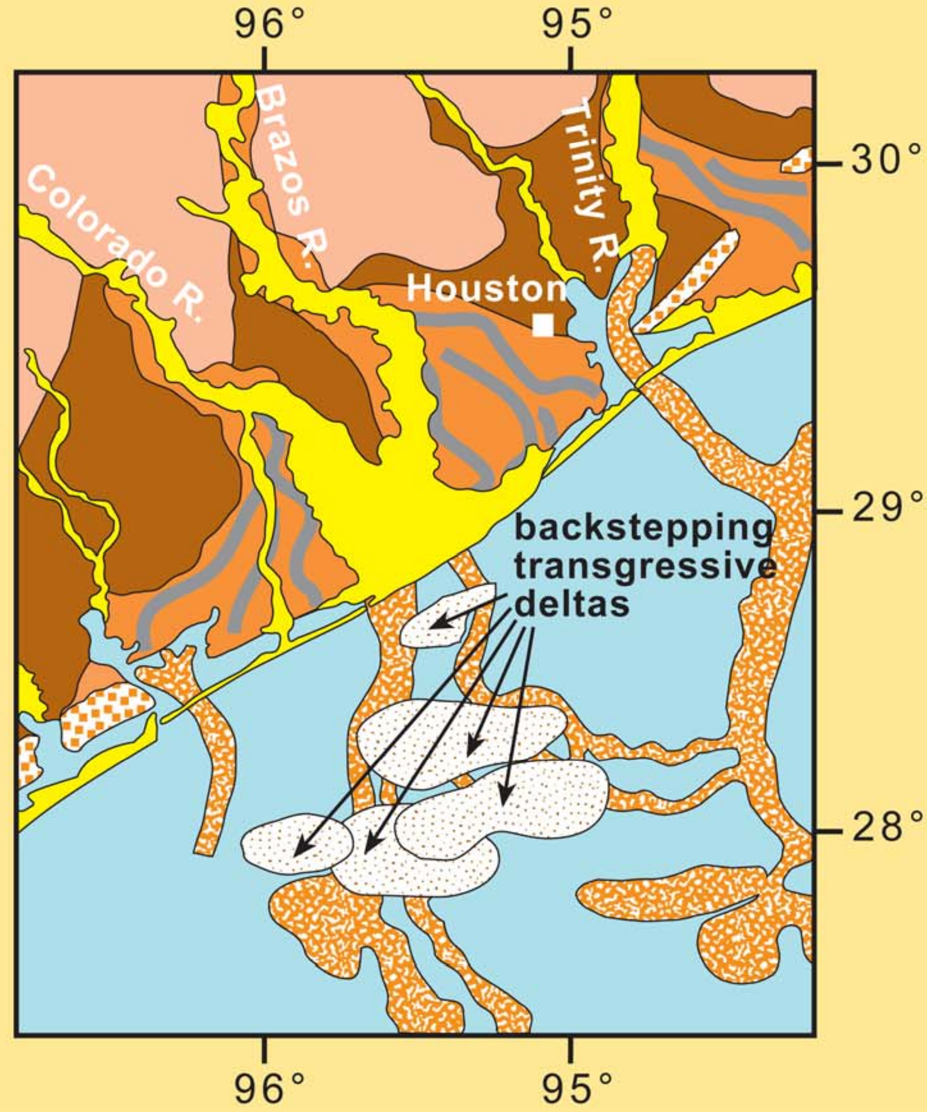
after Blum and Aslan (2006) and Anderson and Fillon (2004)

TEXAS COAST SYSTEMS TRACT EVOLUTION

Last Glacial Lowstand

Holocene Transgression and Highstand

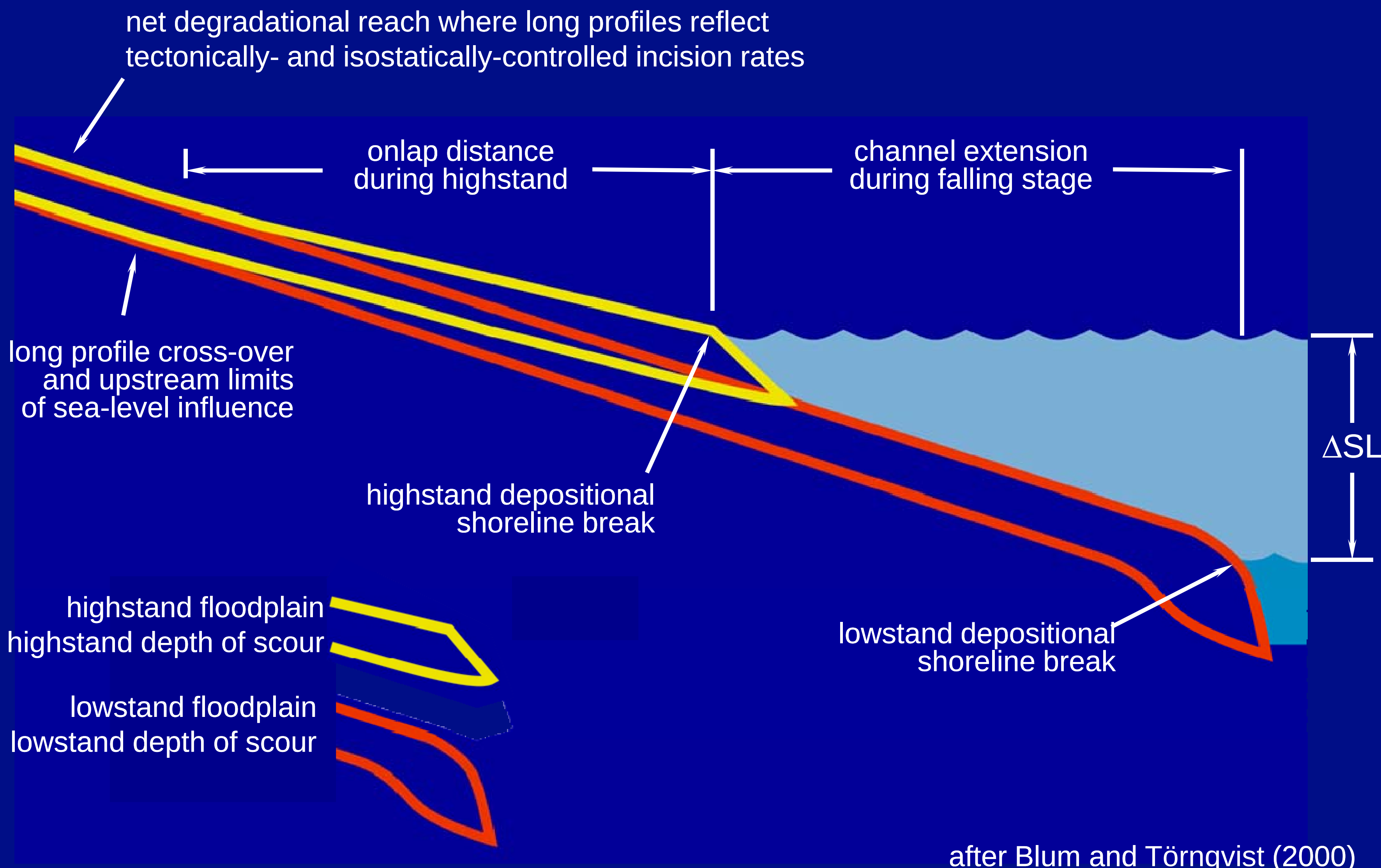




after Blum and Aslan (2006) and Anderson and Fillon (2004)

LONG PROFILE RESPONSE TO SEA-LEVEL CHANGE

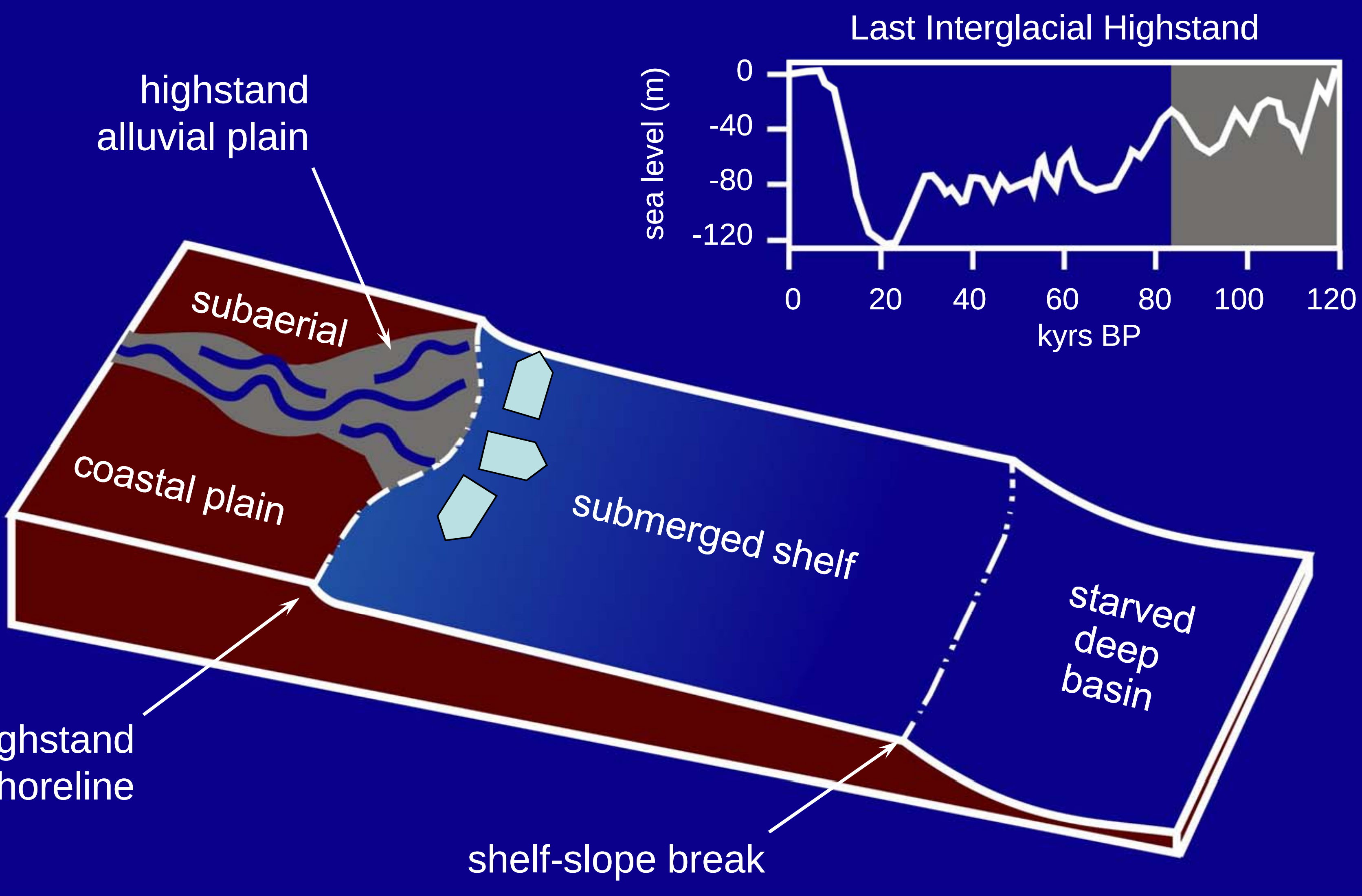
Geometric Forcing of Incised Valley Formation



after Blum and Törnqvist (2000)

INCISED VALLEYS AND VALLEY FILLS

Form from Fluvial-Deltaic Transit of the Shelf



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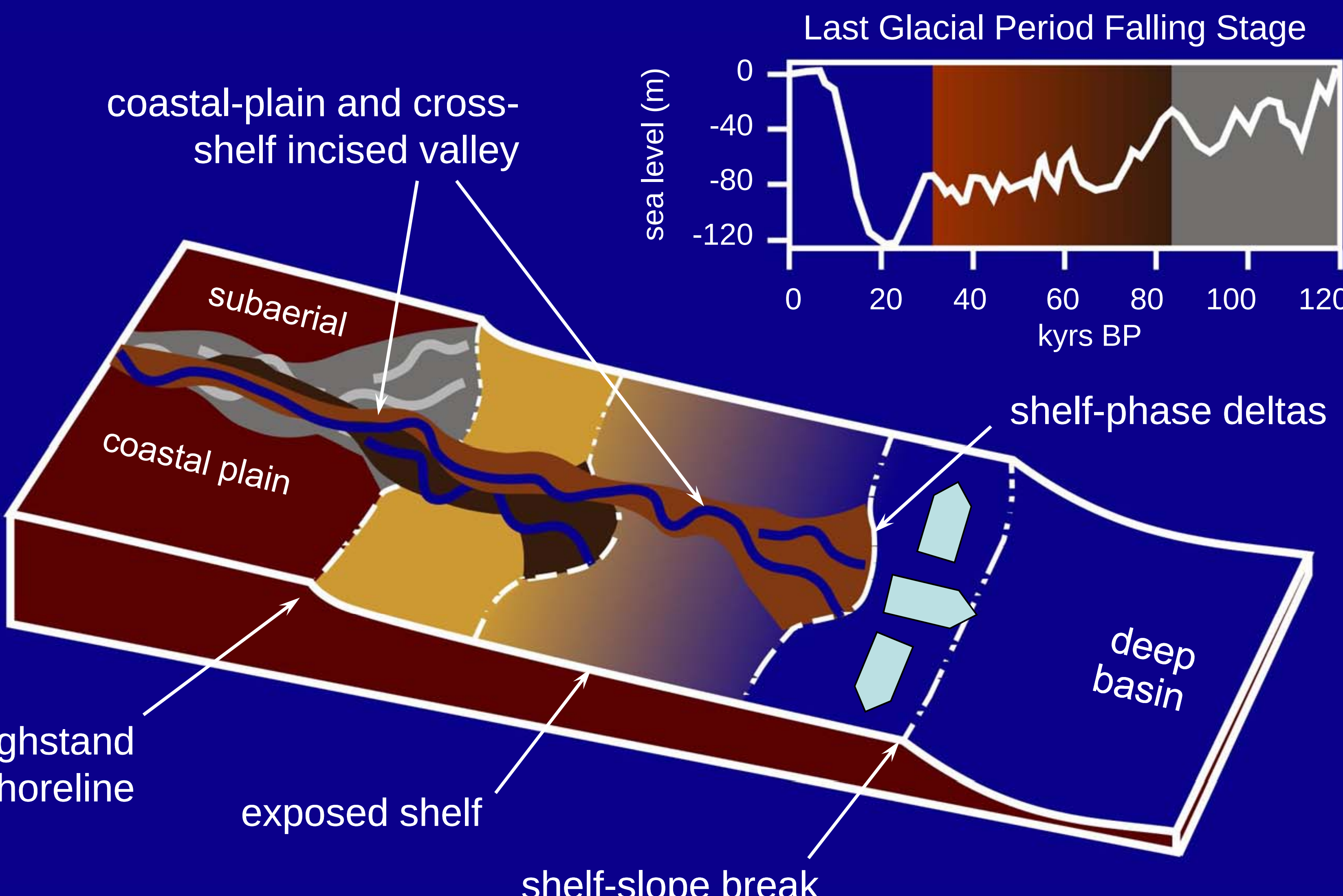

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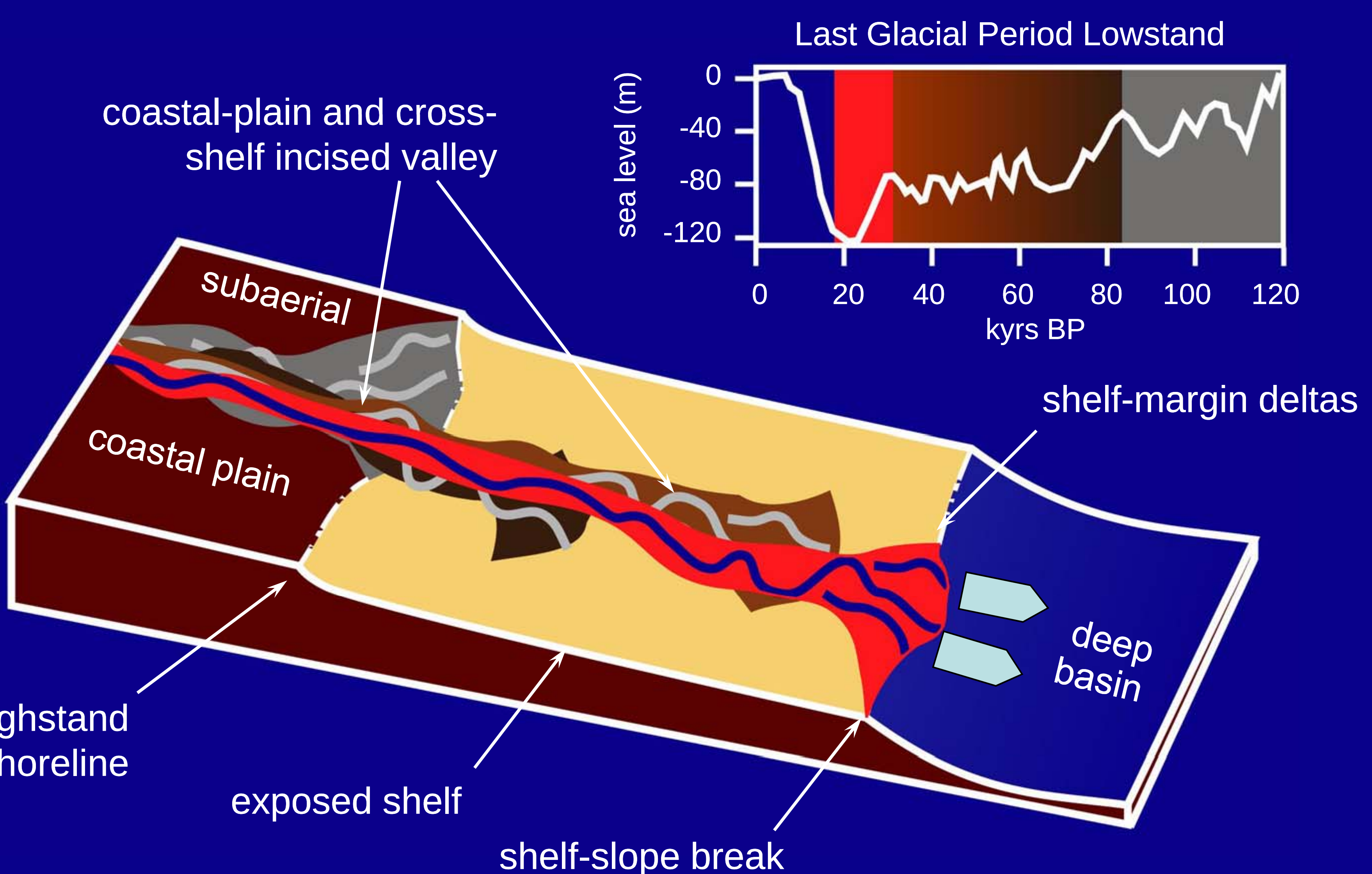

INCISED VALLEYS AND VALLEY FILLS

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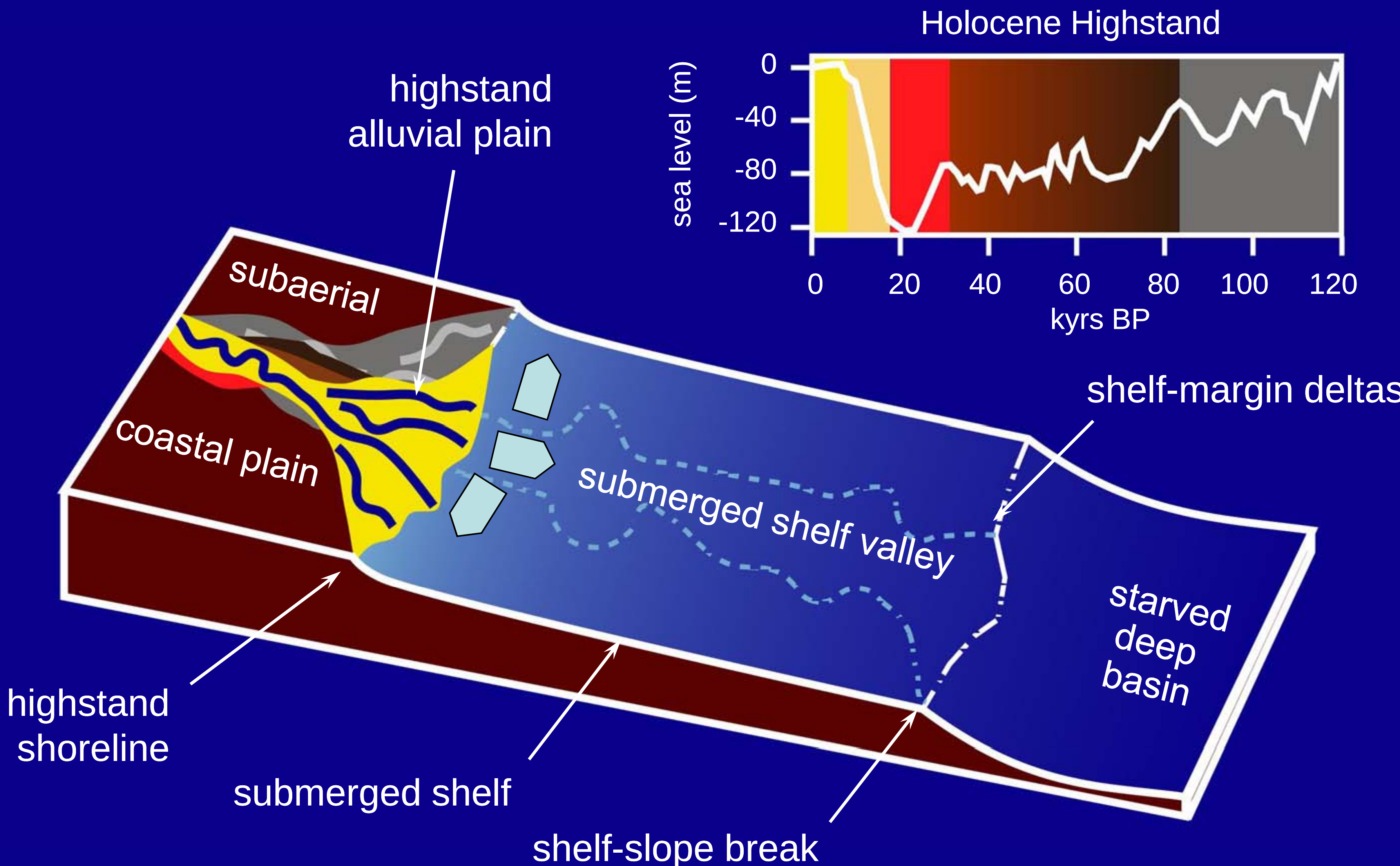

KEY TOPICS OF DISCUSSION

- Climate forcing of sediment supply…..maximum hinterland supply during highstand?
- Formation of valleys during sea-level fall and lowstand…..modulation of supply and significance of fluvial deposition for sediment export
- Merging of valley systems during transit of the shelf…..significance for sediment supply to the shelf margin and beyond

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THE BQART MODEL

(Syvitski and Milliman, 2007)

- This model can be applied to provide a snapshot “first draft” estimate for the last glacial maximum.
- Need B, Q, A, R, T

$$Q_s = 0.0006\ BQ^{0.31}A^{0.5}RT$$

Where: Q_s = Sediment Discharge or Load (MT/yr)

$B = IL(1-T_e)E_h$

- I = Glacier Factor (area covered by glaciers)
- L = Lithology Factor (values of 0.5-3)
- T_e = Trapping efficiency of lakes and reservoirs
- E_h = Human factor

Q = Mean Water Discharge (km^3/s)

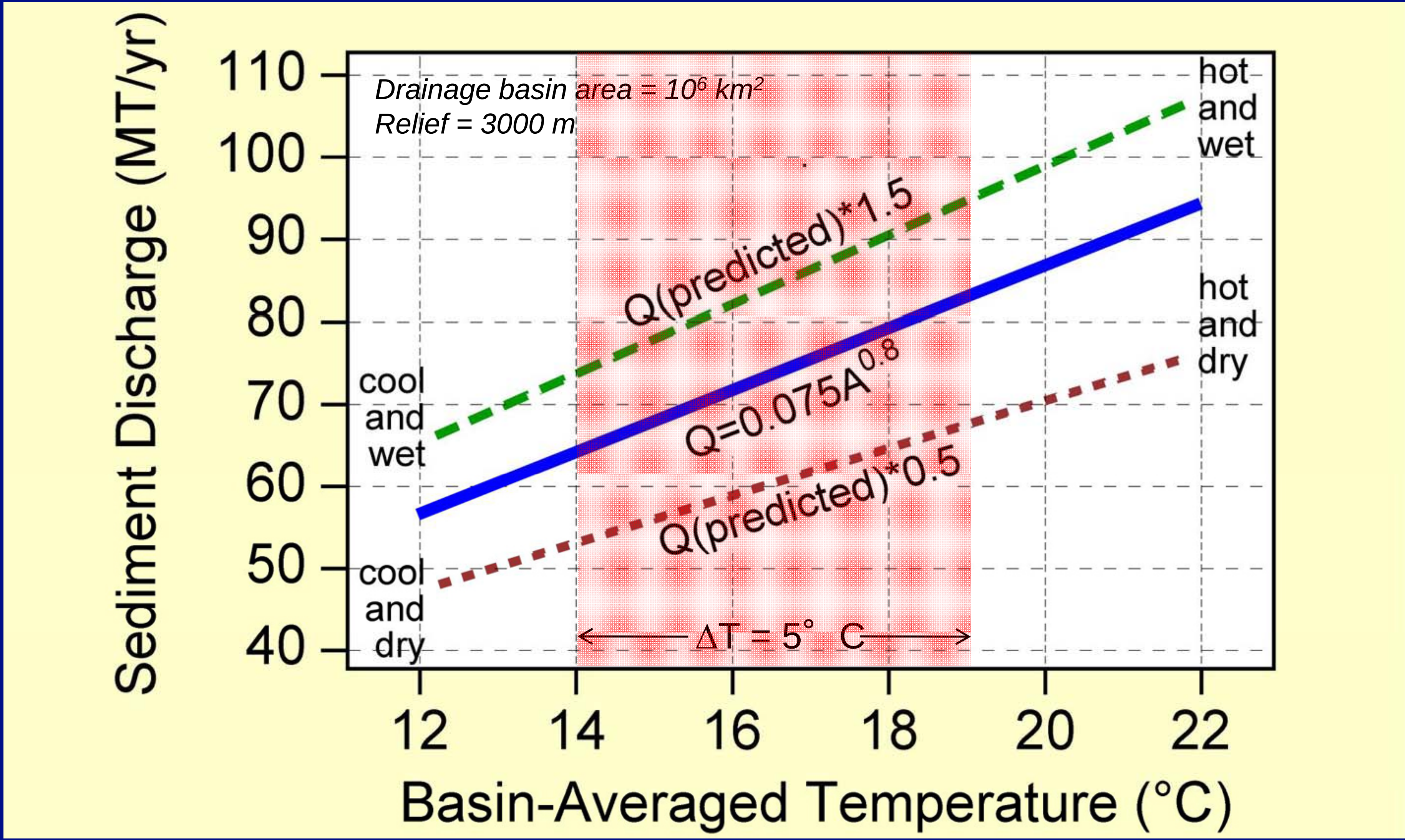
A = Drainage Area (km^2)

R = Maximum Relief (km)

T = Basin-averaged Temperature (° C)

PREDICTED CHANGES IN SEDIMENT YIELDS

Full Glacial to Full Interglacial Climate Change



- *BQART model predicts lower supply during cooler climates (10-40%)*
- *minimum supply during glacio-eustatic sea-level lowstand*

KEY TOPICS OF DISCUSSION

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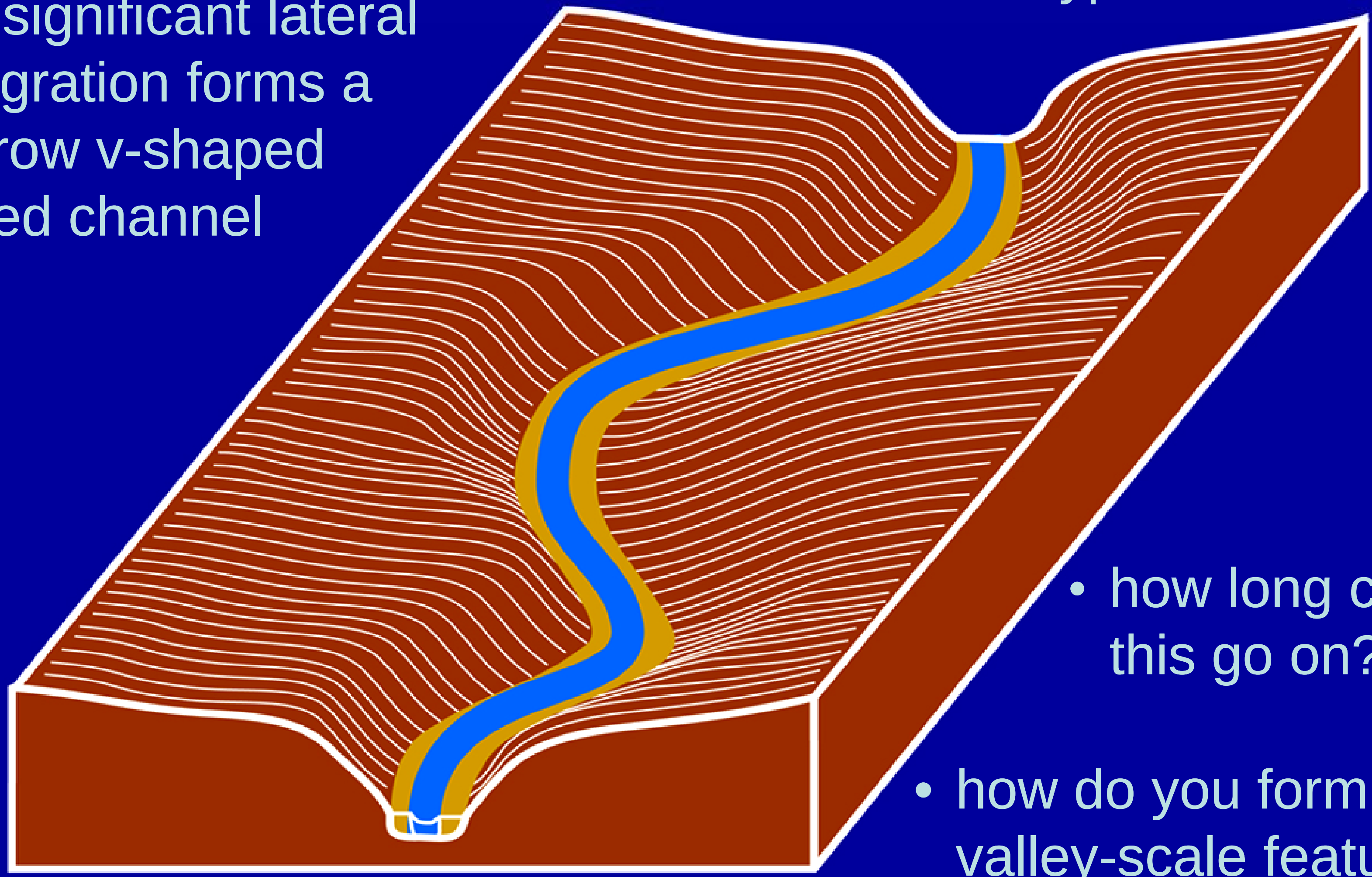
HOW DO YOU FORM AN INCISED VALLEY?

channel incision
and cross-shelf extension with
sediment bypass

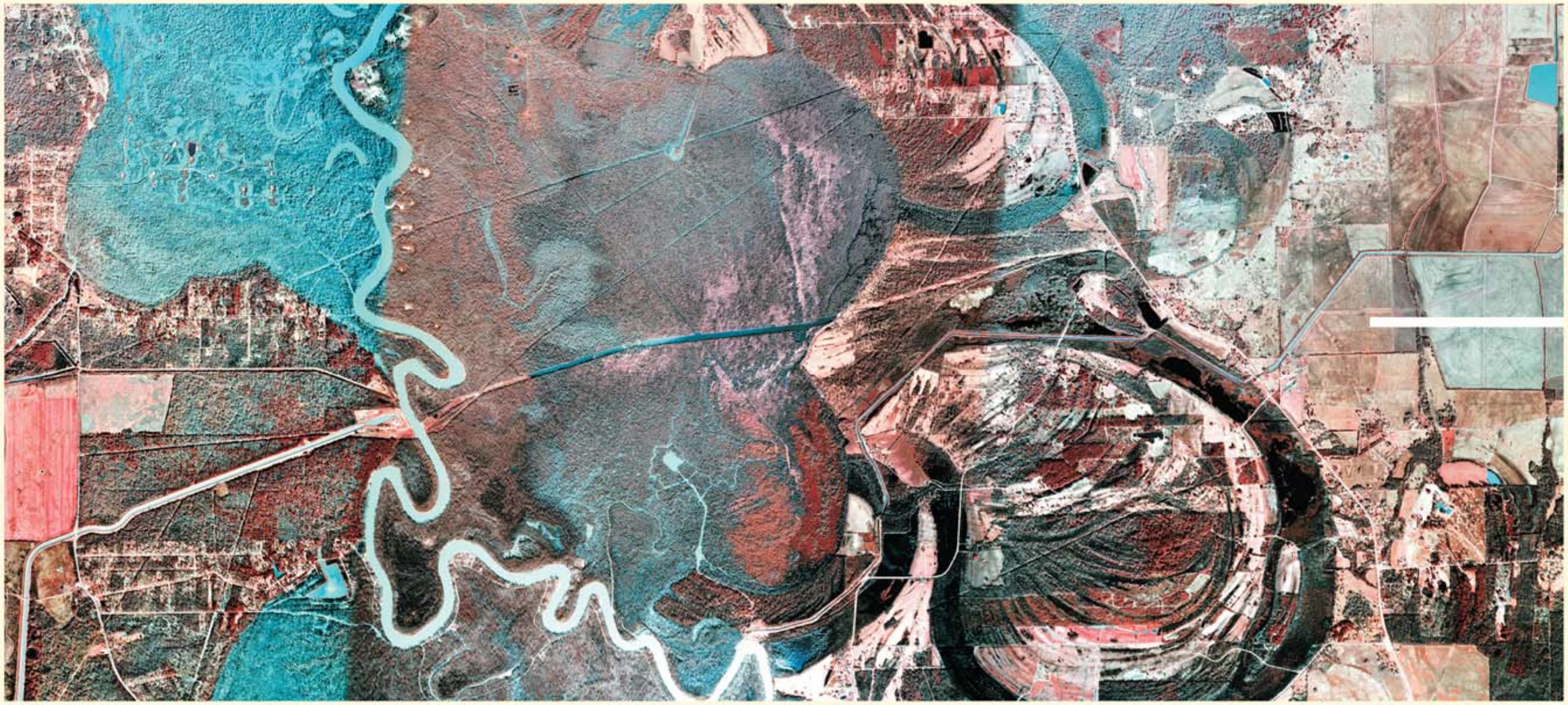
no significant lateral
migration forms a
narrow v-shaped
incised channel

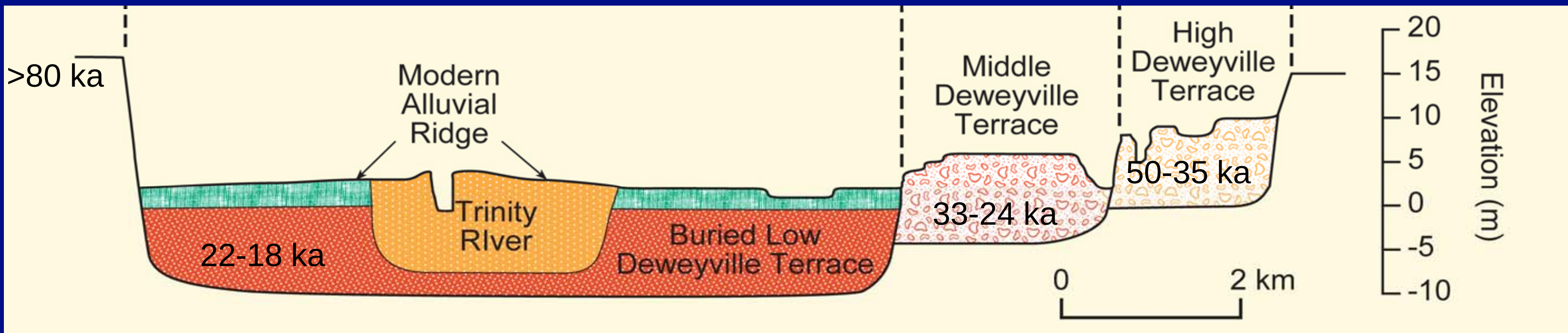


- how long can this go on?
- how do you form a valley-scale feature?

HOW DO YOU FORM AN INCISED VALLEY?

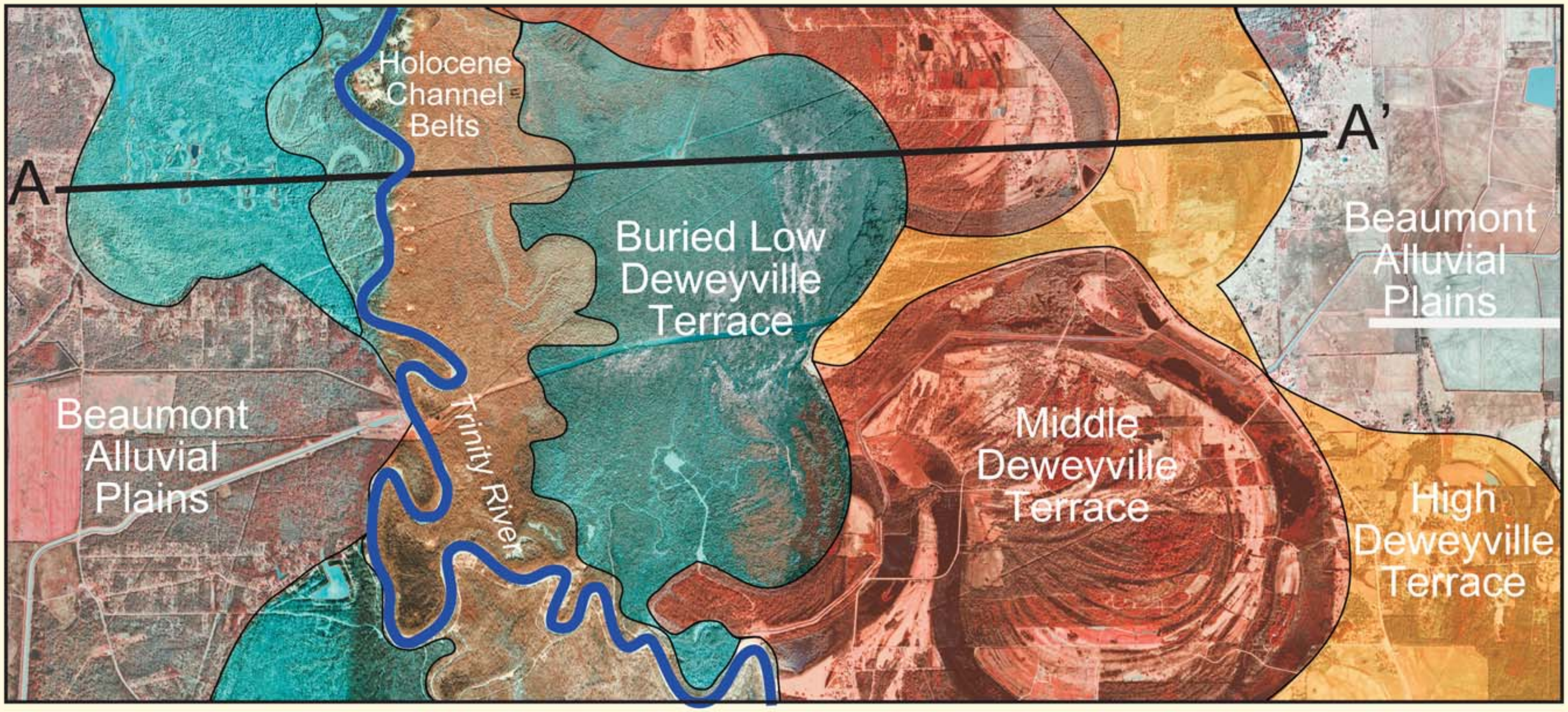
Deposition During Falling Stage: Lessons from the Trinity River, Texas

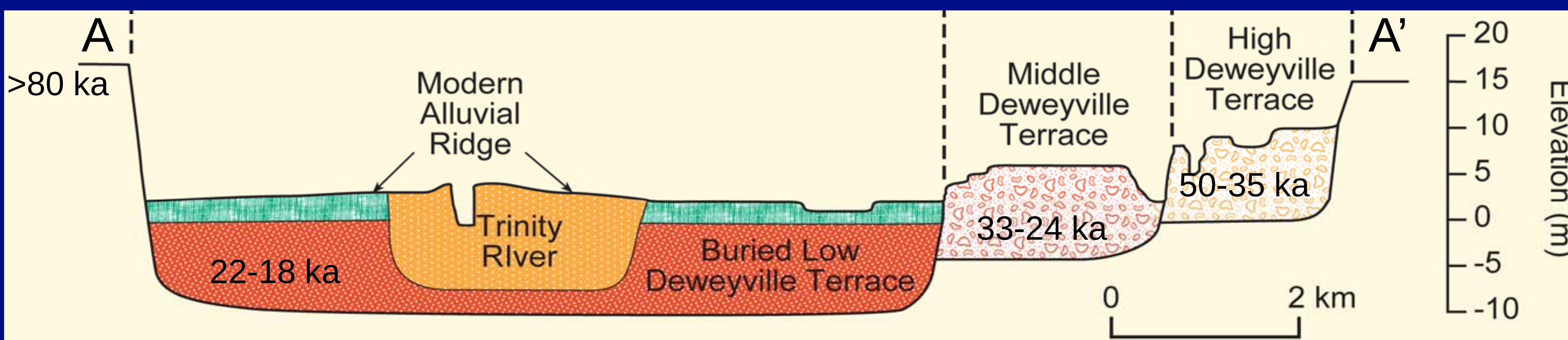




HOW DO YOU FORM AN INCISED VALLEY?

Deposition During Falling Stage: Lessons from the Trinity River, Texas

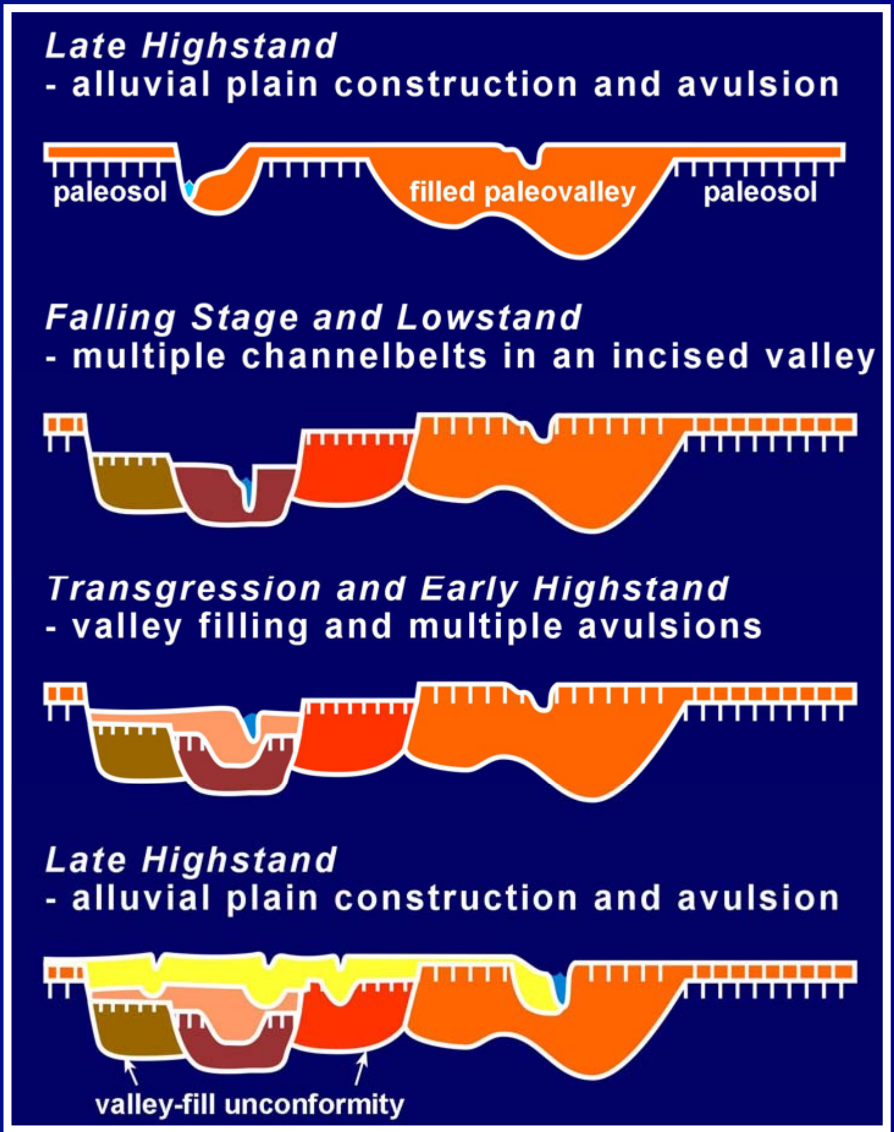




HOW DO YOU FORM AN INCISED VALLEY?

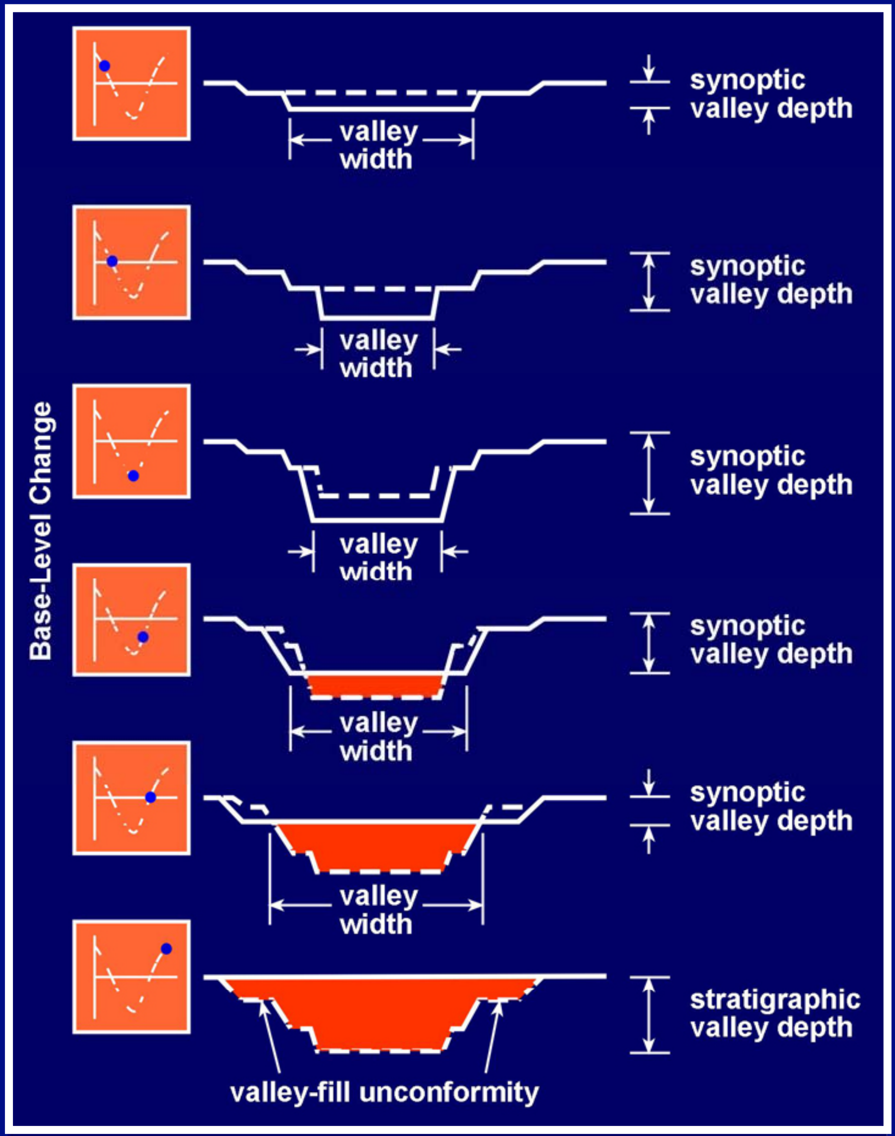
Composite Valley Fills: Lessons from Data and Experiments

Colorado River, Texas



after Blum (1991, 1994), Blum and Price (1998)

St. Anthony Falls Lab



after Strong and Paola (2006; 2008)

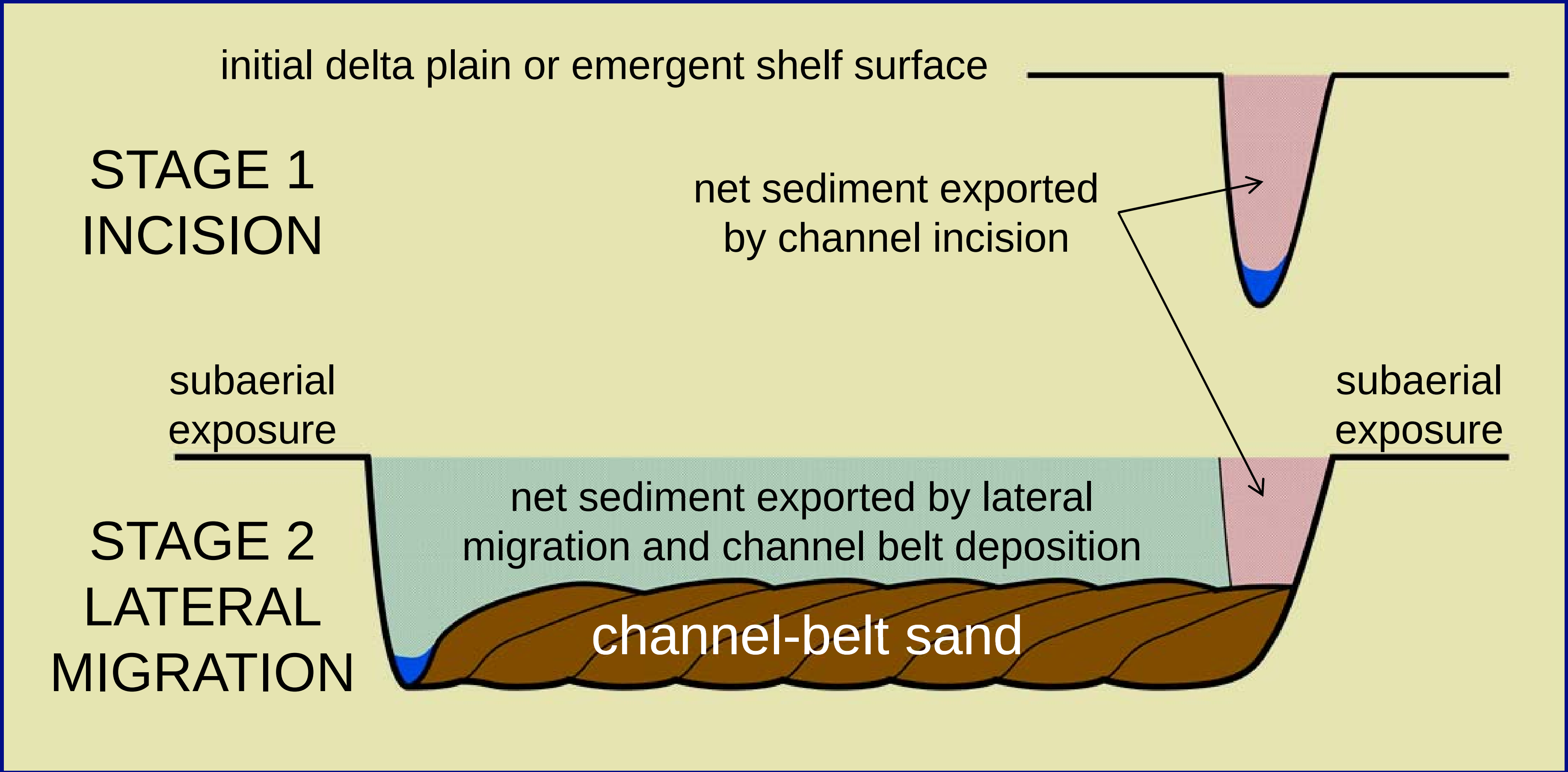
HOW DO YOU FORM AN INCISED VALLEY?

channel incision and cross-shelf extension with sediment bypass → valley widening by channel migration and channel-belt formation

- *step-wise incision, lateral migration, and channel-belt formation widen the incised channel into a valley-scale feature*
- *valley widening and channel-belt deposition are simultaneous*
- *basal valley-fill surface is a composite surface that is strongly time-transgressive, but it is the same age as the deposits that overlie it*

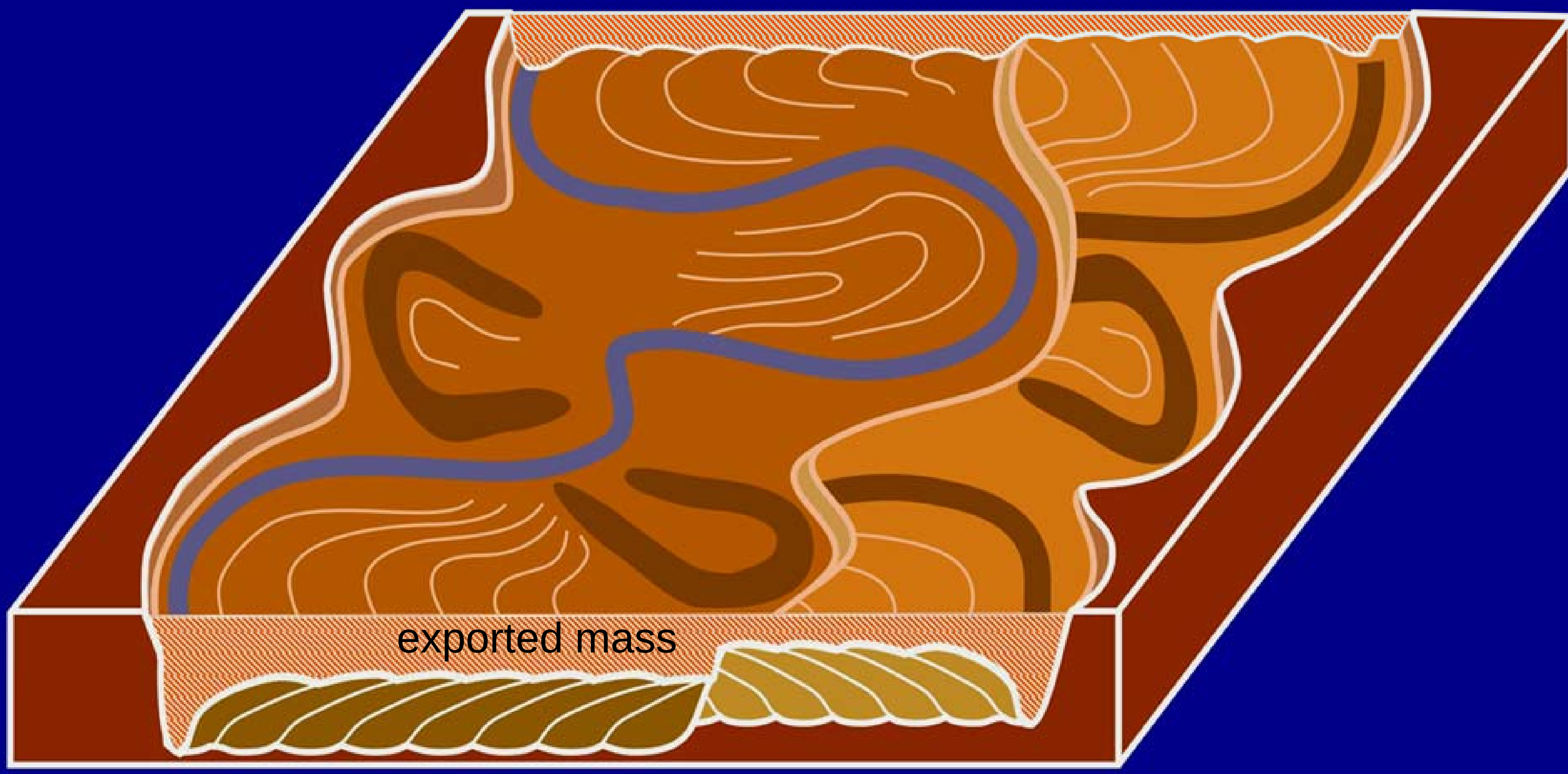
VALLEY EVOLUTION AND SEDIMENT SUPPLY

Importance of Incision vs. Lateral Migration and Contemporaneous Channel-Belt Deposition



- *periods of incision produce little extra sediment to be exported*
- *periods of lateral migration and channel-belt construction produce significant sediment to be exported*

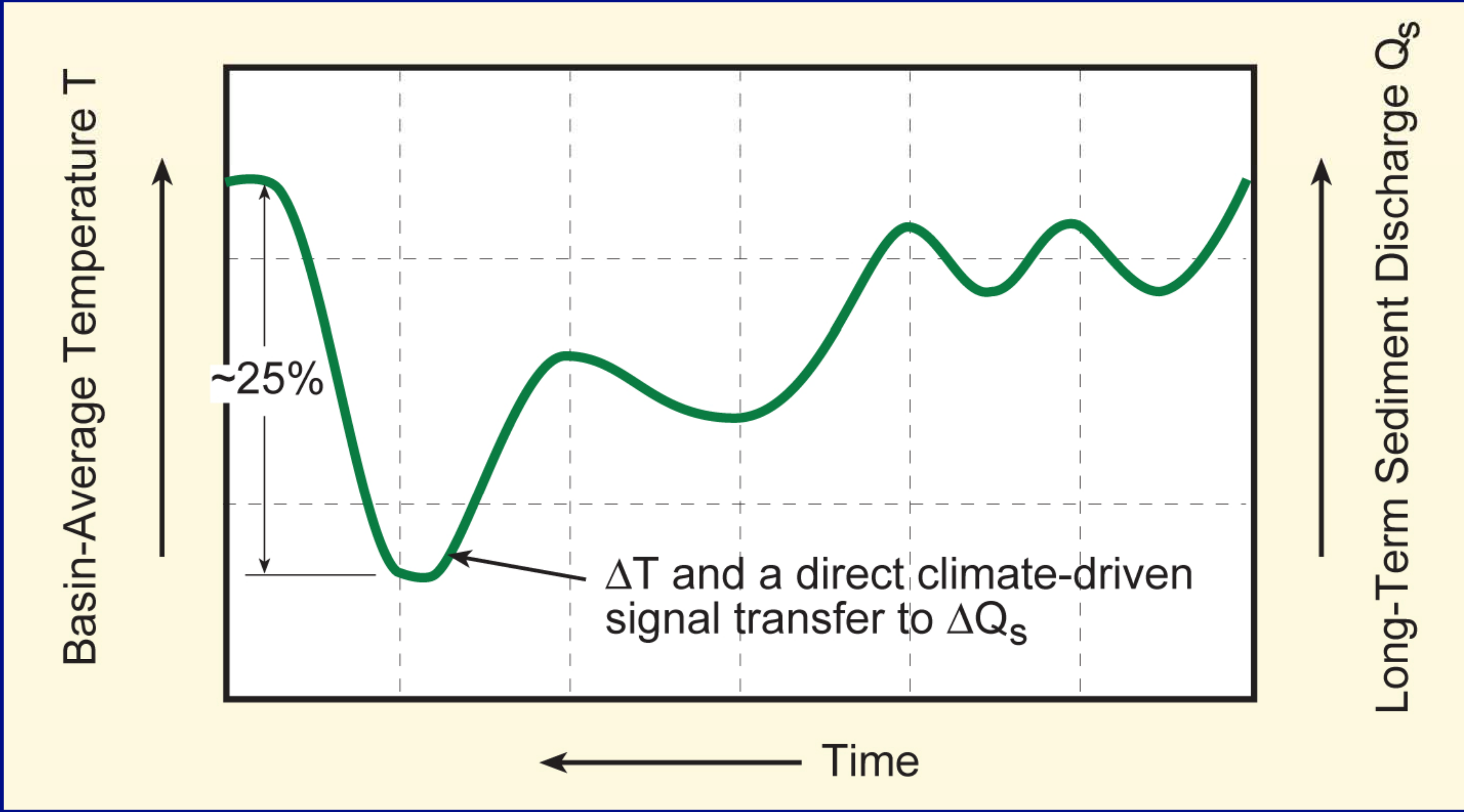
VALLEY EVOLUTION AND SEDIMENT SUPPLY



- *total sediment export is a small number, but it occurs stepwise*
- *periods of lateral migration and channel-belt deposition actually produce significant sediment to be exported (10-20% increase over background flux)*
- *mass balance basis to couple falling stage fluvial and deltaic deposition*

VALLEY EVOLUTION AND SEDIMENT SUPPLY

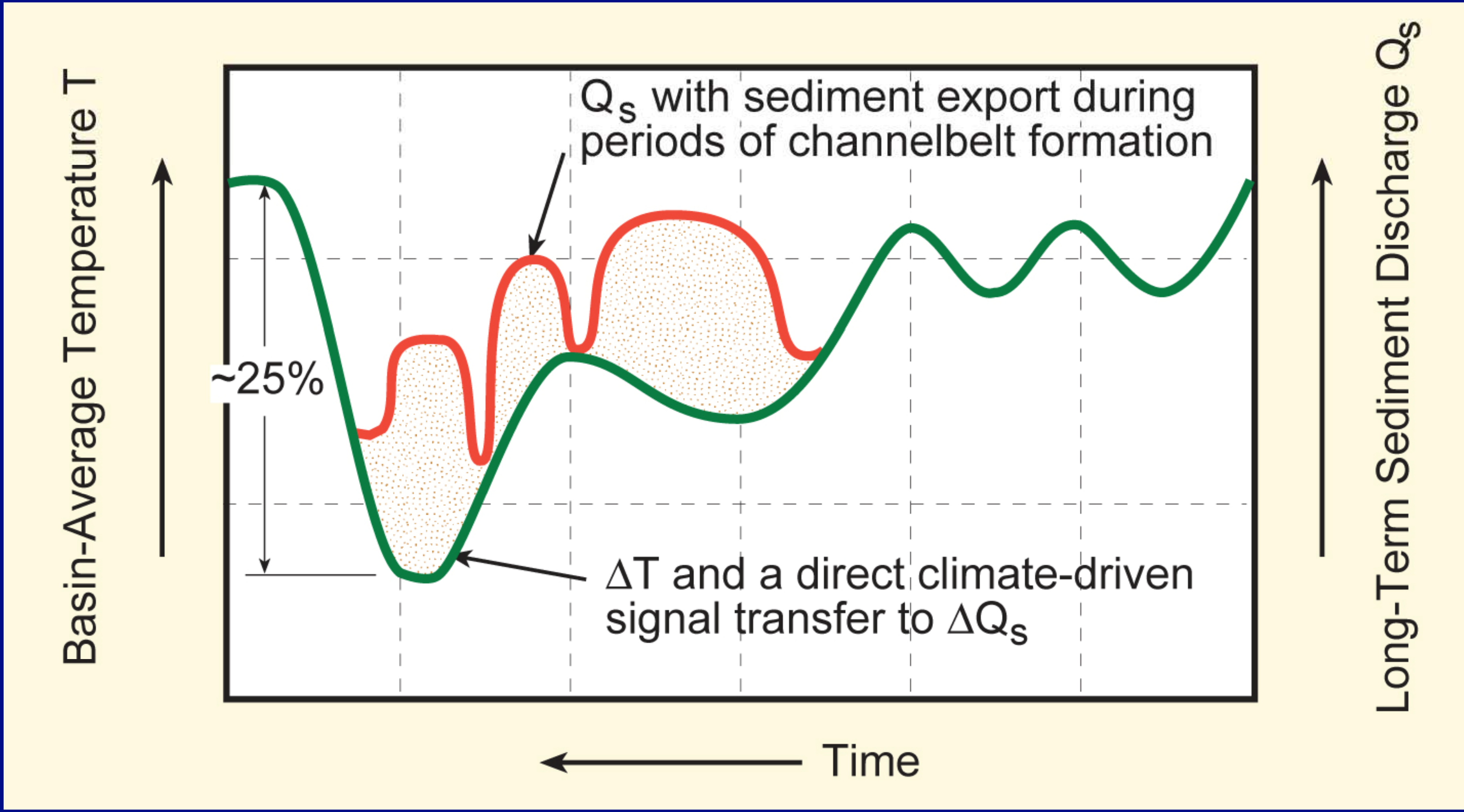
Sediment Export from Incised Valley



- *BQART model predicts lower supply during cooler climates*

VALLEY EVOLUTION AND SEDIMENT SUPPLY

Sediment Export from Incised Valley



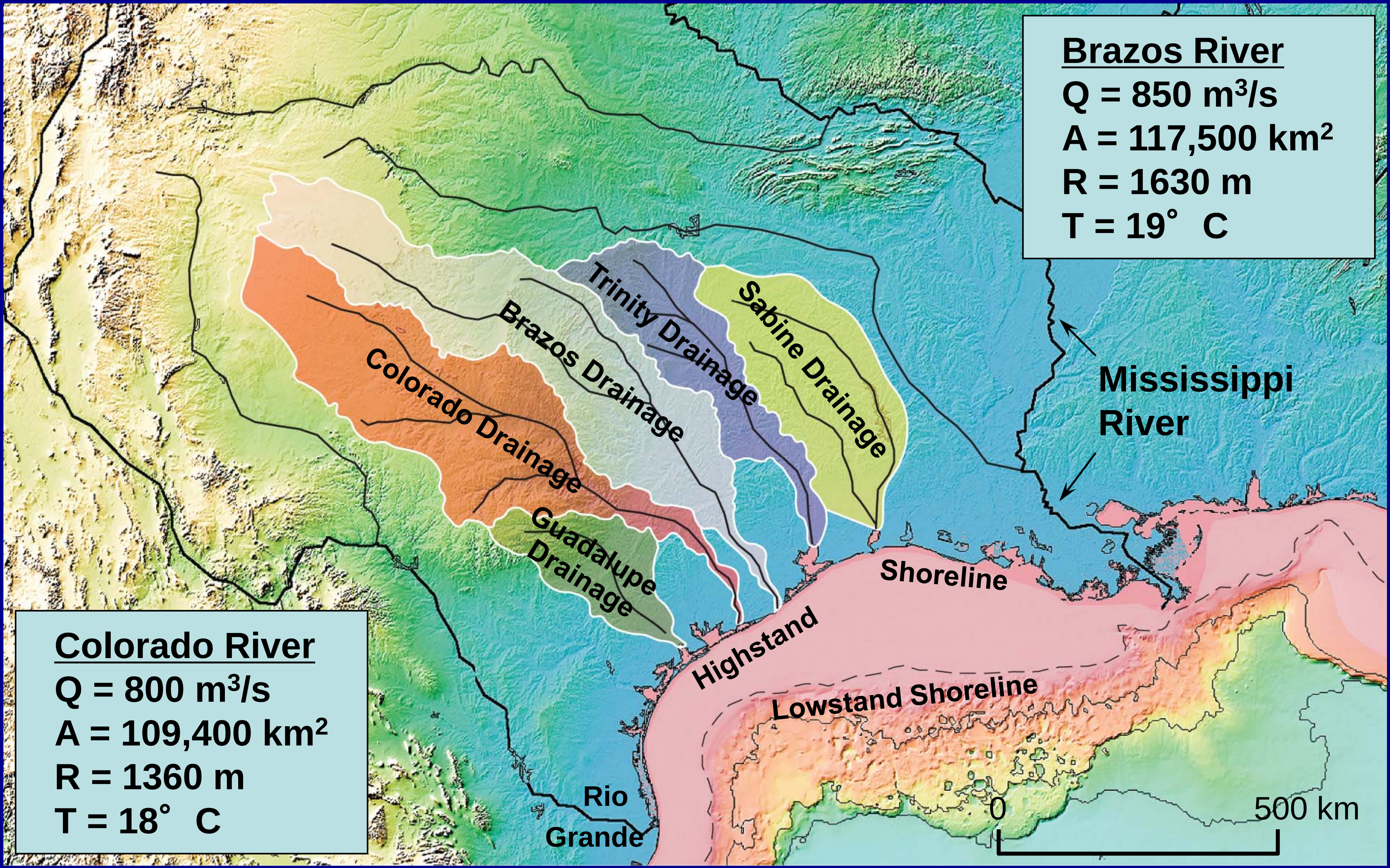
- *BQART model predicts lower supply during cooler climates*
- *Periods of incision add little additional sediment*
- *Periods of valley widening can augment lower supplies by 10-20%*

KEY TOPICS OF DISCUSSION

- Climate forcing of sediment supply…..maximum hinterland supply during highstand?
- Formation of valleys during sea-level fall and lowstand…..modulation of supply and significance of fluvial deposition for sediment export
- Merging of valley systems during transit of the shelf…..significance for sediment supply to the shelf margin and beyond

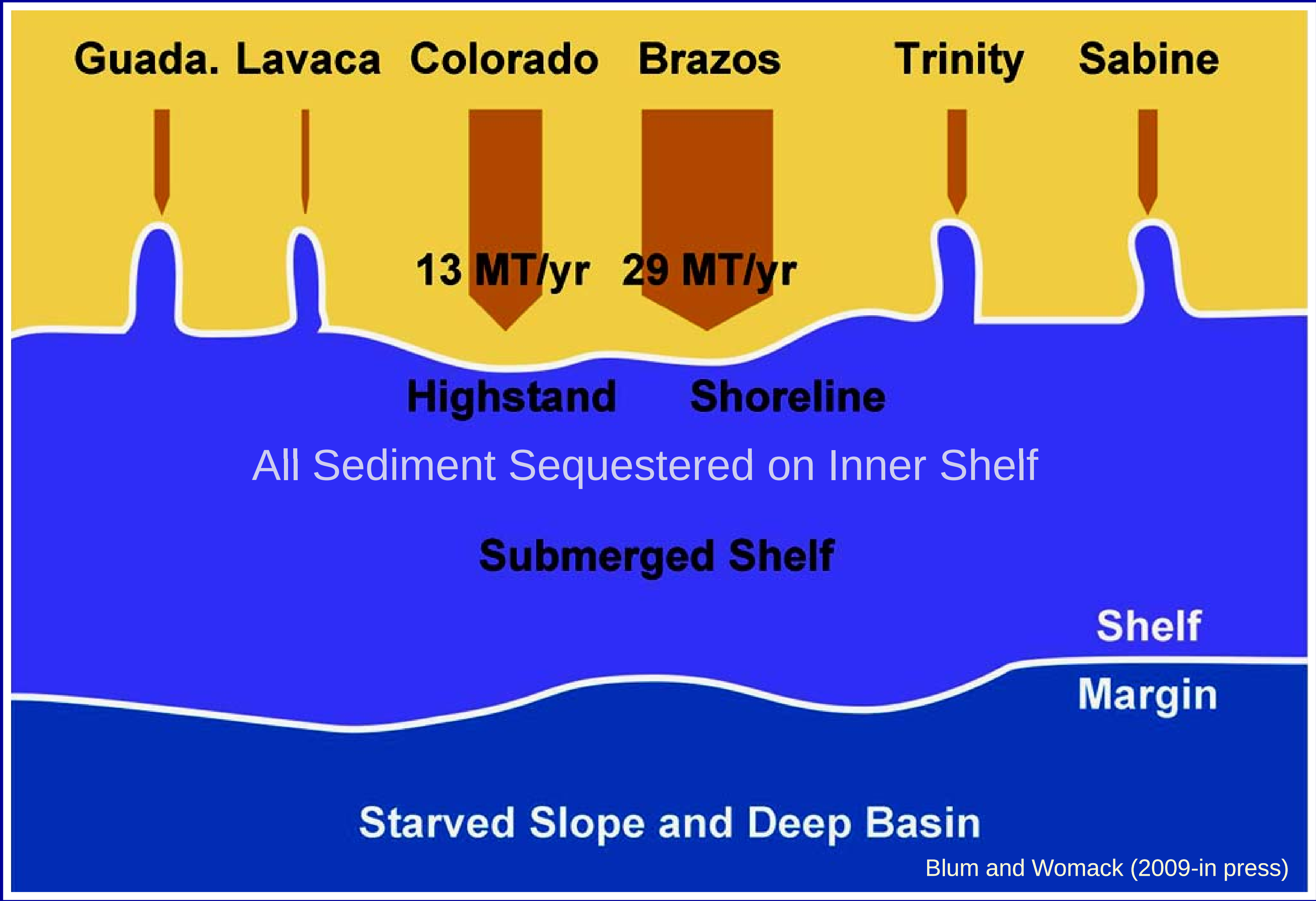
DRAINAGE BASINS OF THE TEXAS COAST

Highstand Configurations



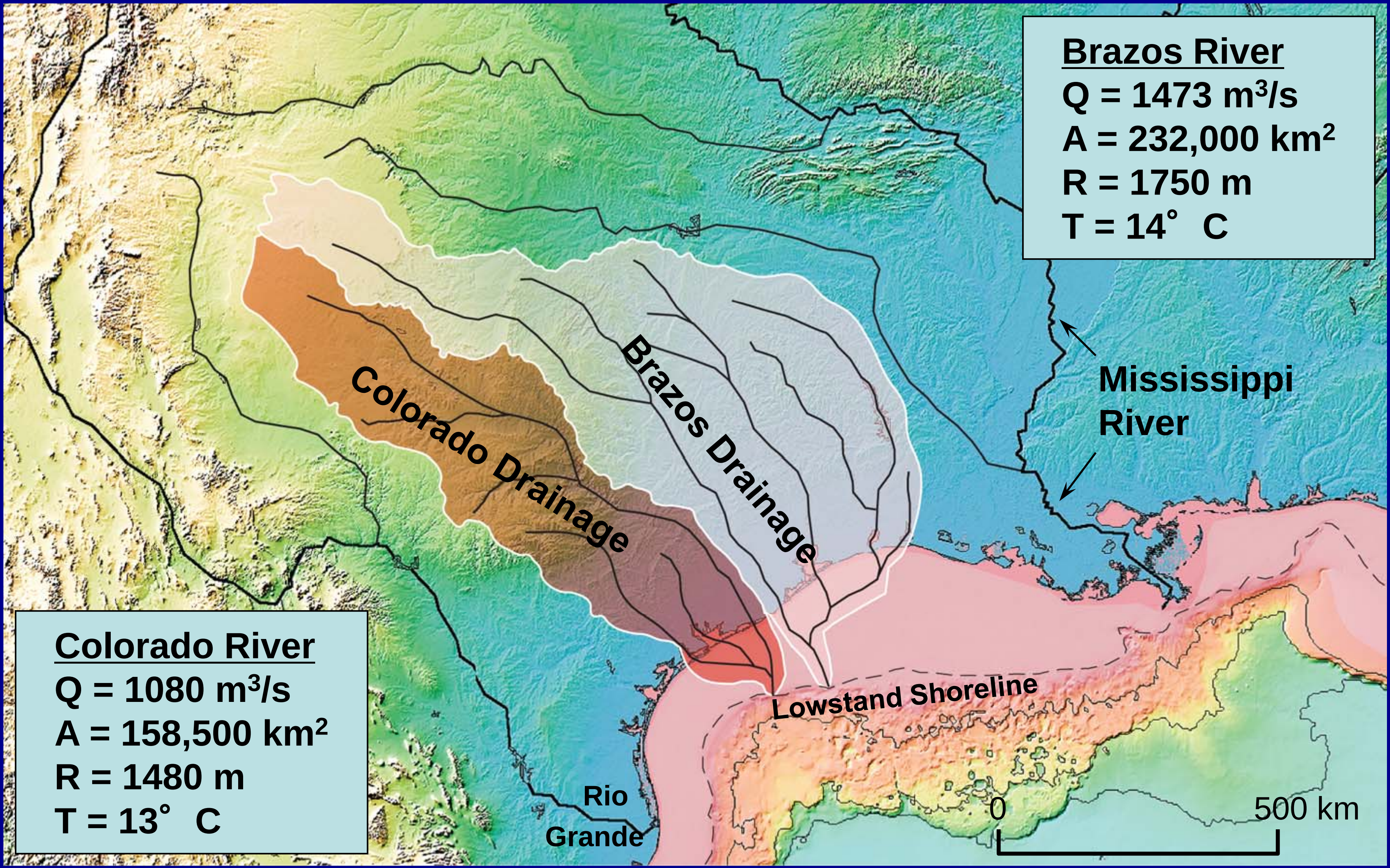
Blum and Womack (2009-in press)

FIRST DRAFT HIGHSTAND SEDIMENT BUDGET:
Colorado and Brazos Rivers, Texas



DRAINAGE BASINS OF THE TEXAS COAST

Lowstand Configurations



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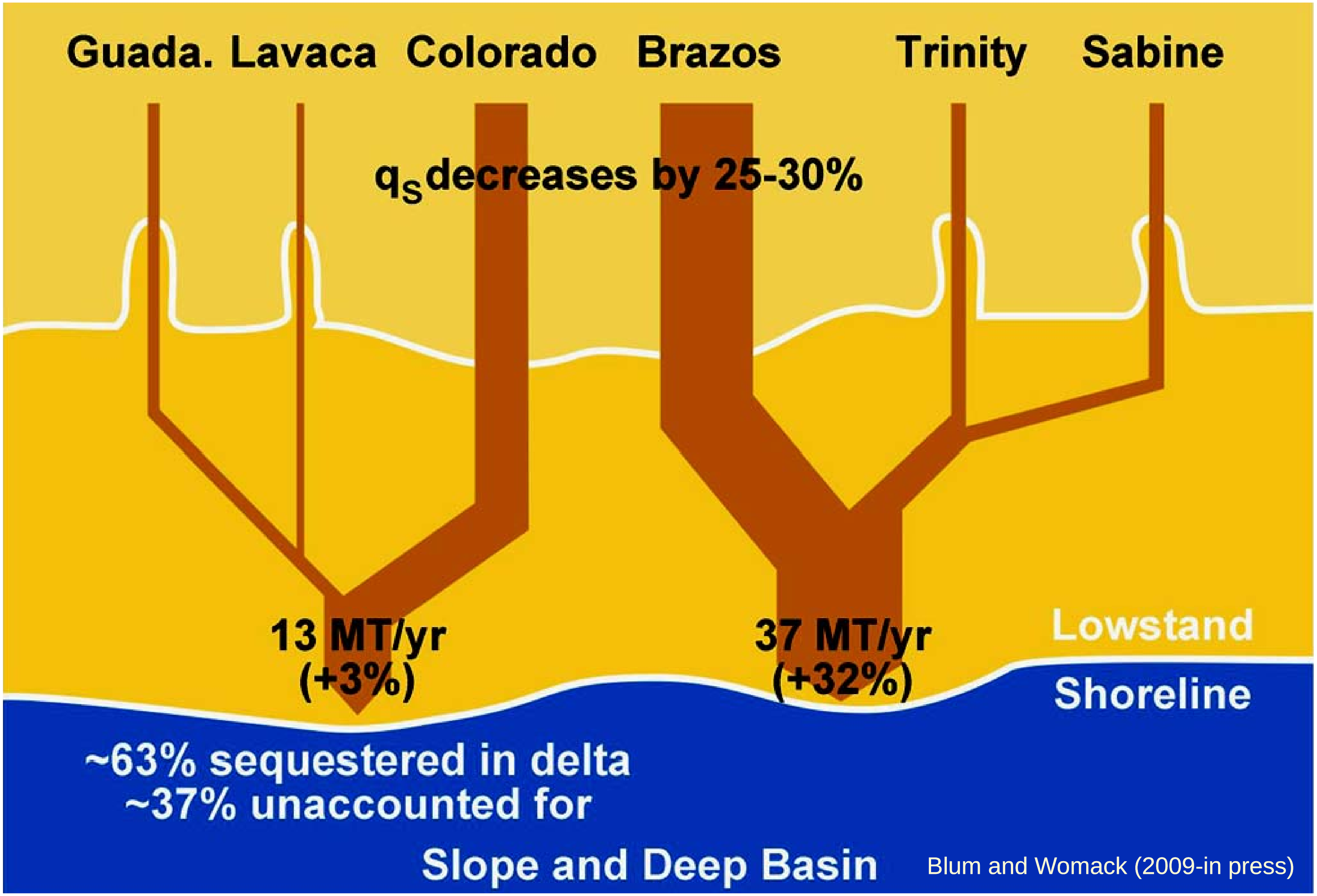

Blum and Womack (2009-in press)

CONCLUSIONS

- Total sediment supply from the hinterlands should decrease during sea-level fall and lowstand due to temperature depression.
  - supply from the hinterland may be at a maximum when river mouths reside in highstand positions, and storage takes place on the coastal plain and inner shelf
  - supply from the hinterland may be at a minimum when river mouths are extended to the shelf margin and directly feeding the slope and basin floor.

- Incised-valley evolution plays a role in sediment routing to the shelf margin and beyond in at least 2 distinct ways:
  - periods of incision DO NOT increase sediment supply
  - however, periods of valley widening AND fluvial deposition DO increase sediment supply by 10-30%
  - merging of channels on wide shelves will increase drainage area, which will increase sediment supply to point sources at the shelf margin