Alternative Views for Common Assumptions: Reassessing the Origin and Significance of Sequence Boundaries Using Field and Flume*

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Abstract

Field data and recent experimental studies independently question long-held paradigms regarding the origin and time significance of fluvially carved sequence boundaries as well as genetic relationships between these surfaces and the strata they bind. These field data derive from an updip to downdip transect through the Cretaceous Dakota Group of the U.S. southern High Plains. The experimental data derive from repeated basin-scale runs of sequence development during relative sea-level change simulated in the Jurassic Tank at the University of Minnesota, St Anthony Falls. Both experimental and field data show that fluvial sand above sequence boundaries are deposited coexistent with the carving of the underlying sequence boundary. The field data do this by inference from mapped cross-cutting relationships within observed stratigraphy and the experimental data through scaled reproduction of the processes inferred and products observed from the field. Both sources converge to reinforce assertions regarding sequence boundaries that require readjustment of some commonly held views. Namely, surfaces commonly mapped as sequence-bounding unconformities were not necessarily synchronously exposed, record no common age, and may not consistently separate older from younger strata. Also, fluvial strata above sequence boundaries do not necessarily reflect passive burial of these surfaces during subsequent transgression. Instead these strata may record co-generation of fluvial reservoir architecture and the underlying sequence-boundary over the full duration of the transgressive/regressive cycle because of close genetic links between the two. Furthermore, valley incision and sequence-boundary erosion need not reflect updip knickpoint migration from the shore;thus valleys and sequence-boundary continuity may commonly be lost down depositional dip.

Alternative Views for Common Assumptions: Reassessing the Origin and Significance of Sequence Boundaries using Field and Flume

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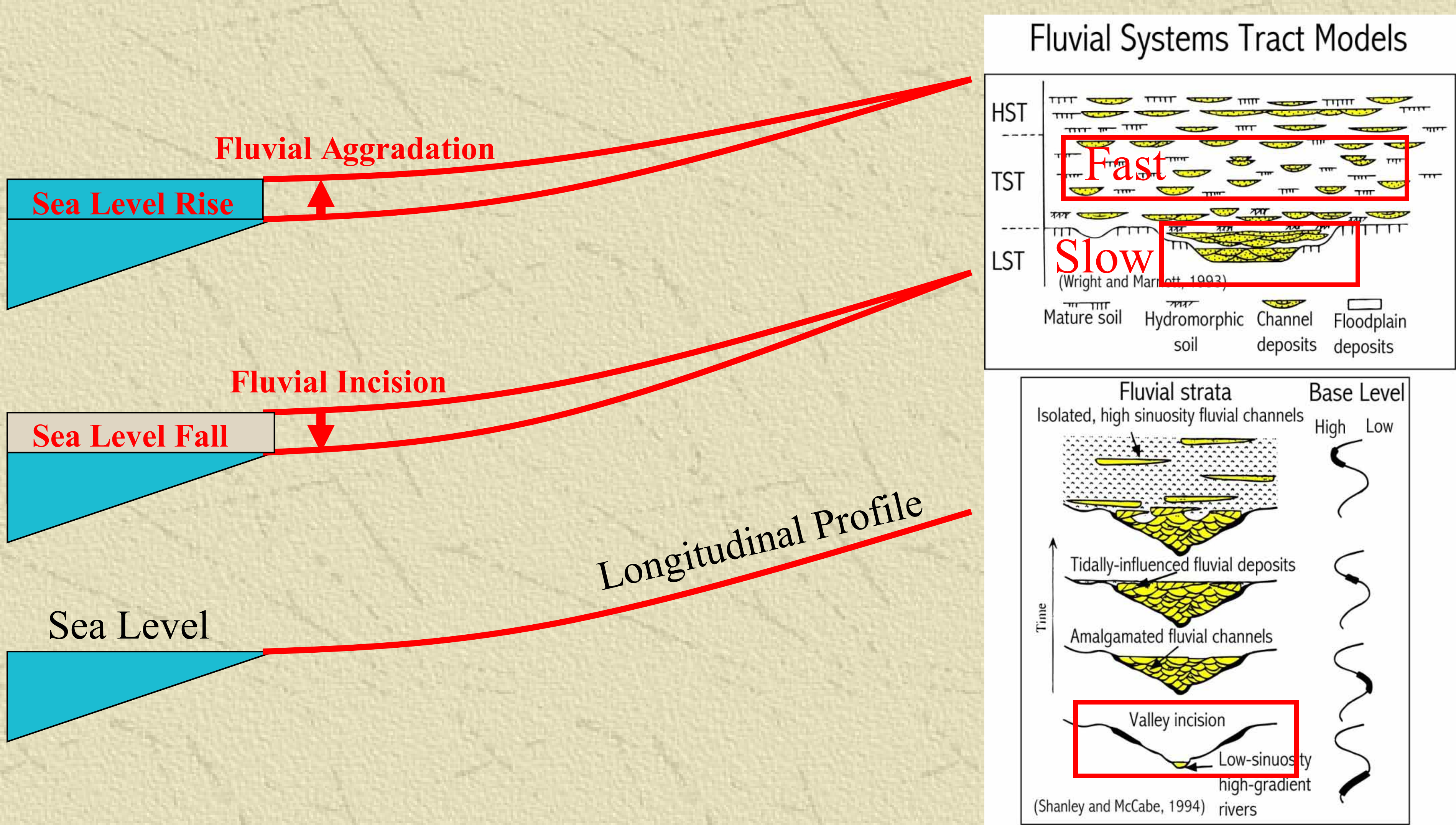
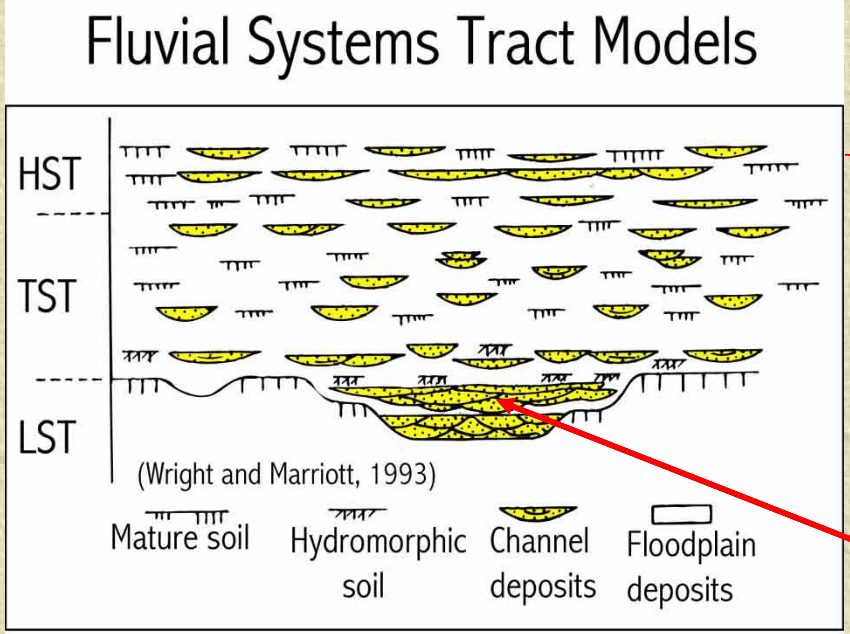
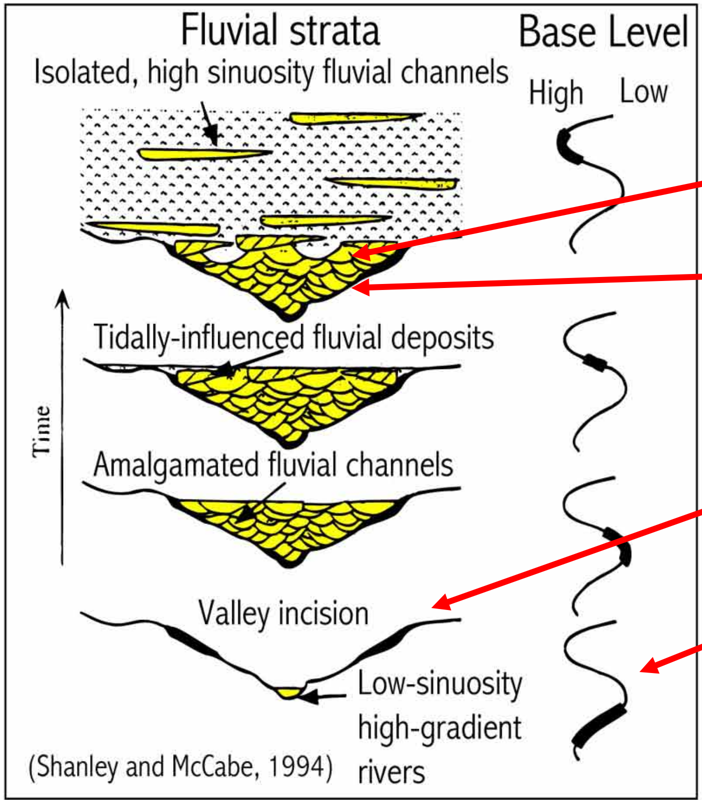
Fluvial Response to Base Level Change and Generation of Sequences



Upstream and Lateral?





Some Common Assumptions

Progressive Stacking in Sheets during Filling with little Valley Modification

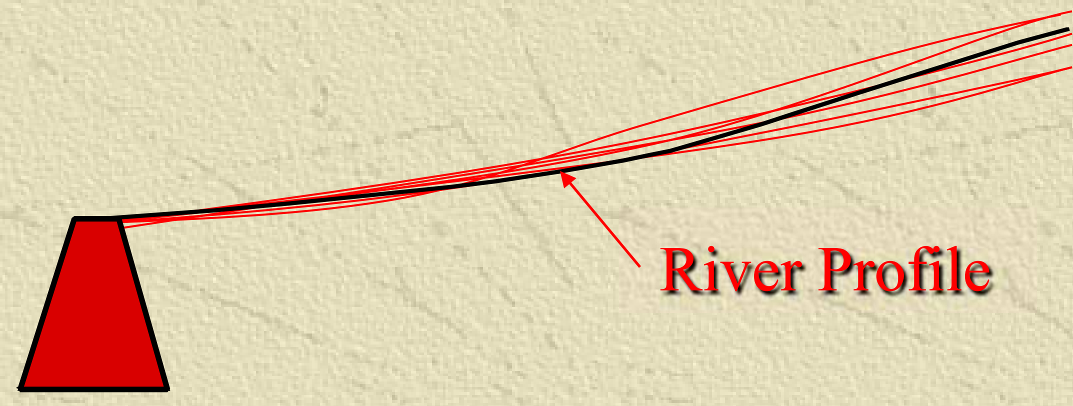
Stratigraphic Valley = Topographic Valley

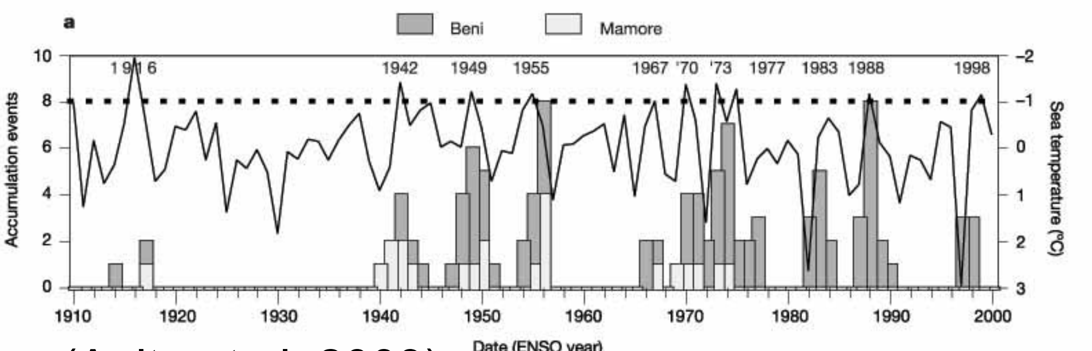
Somewhat Synchronous Sequence Boundaries

Subaerial Lowstand Surface of Erosion

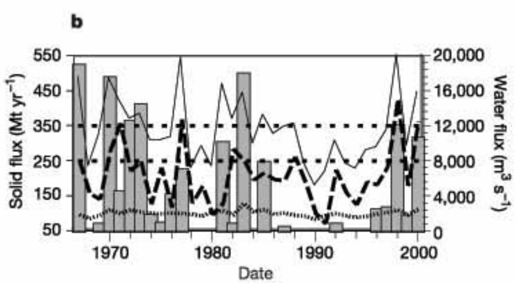
Incision during Falling Stage and Lowstand

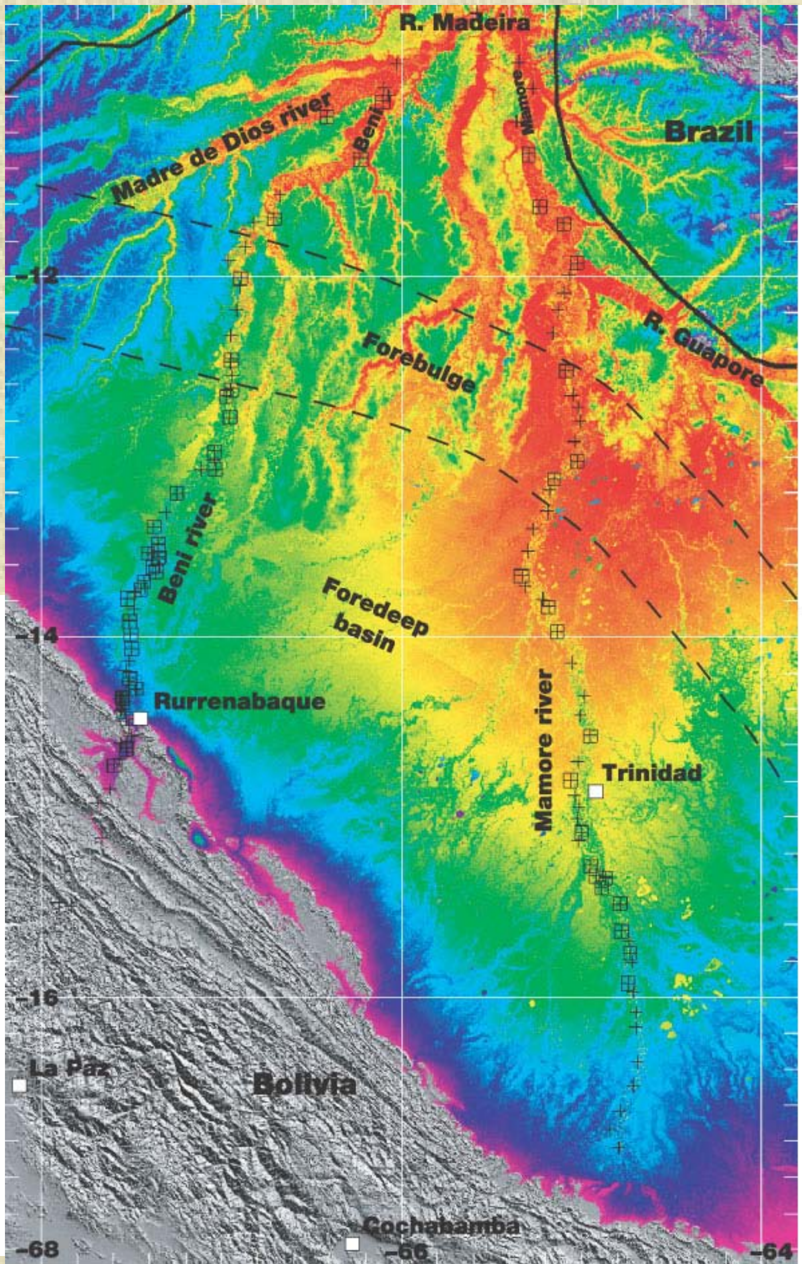
Climate and Sediment Storage



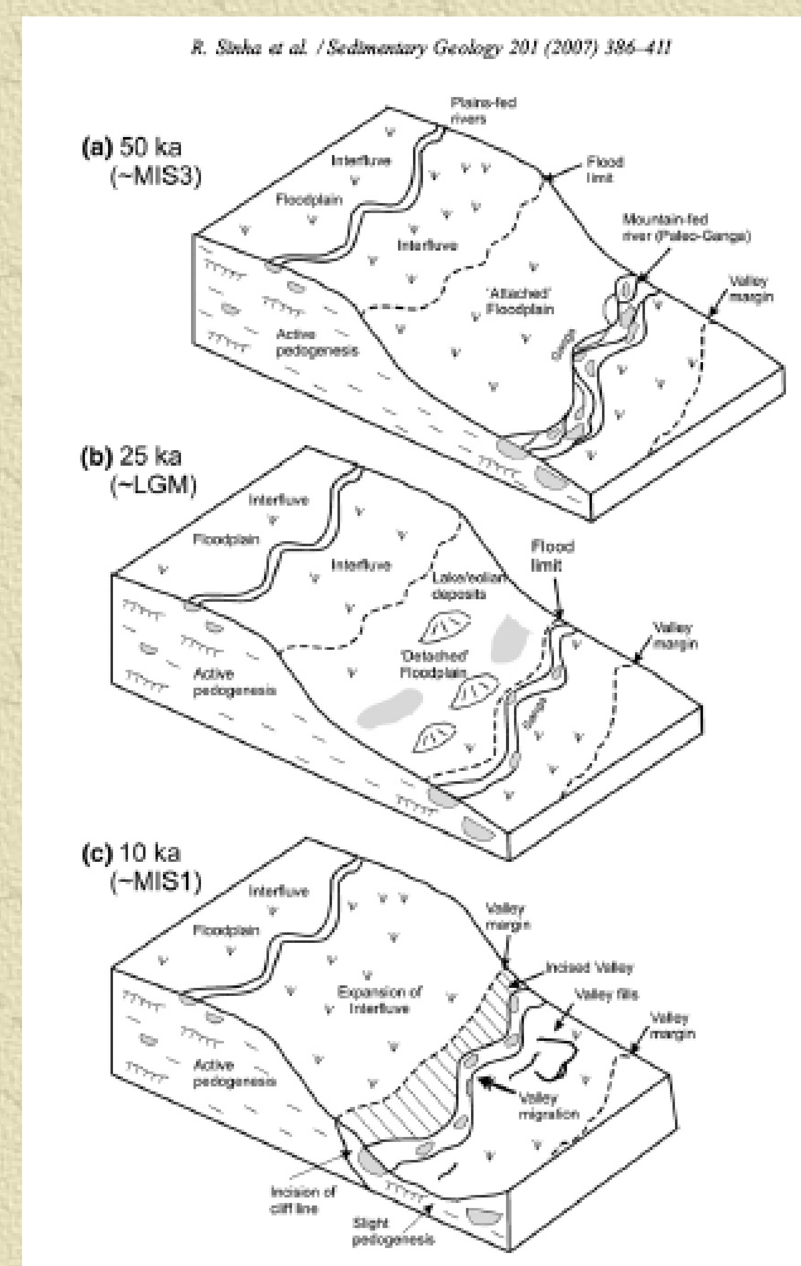


(Aalto et al. 2003)

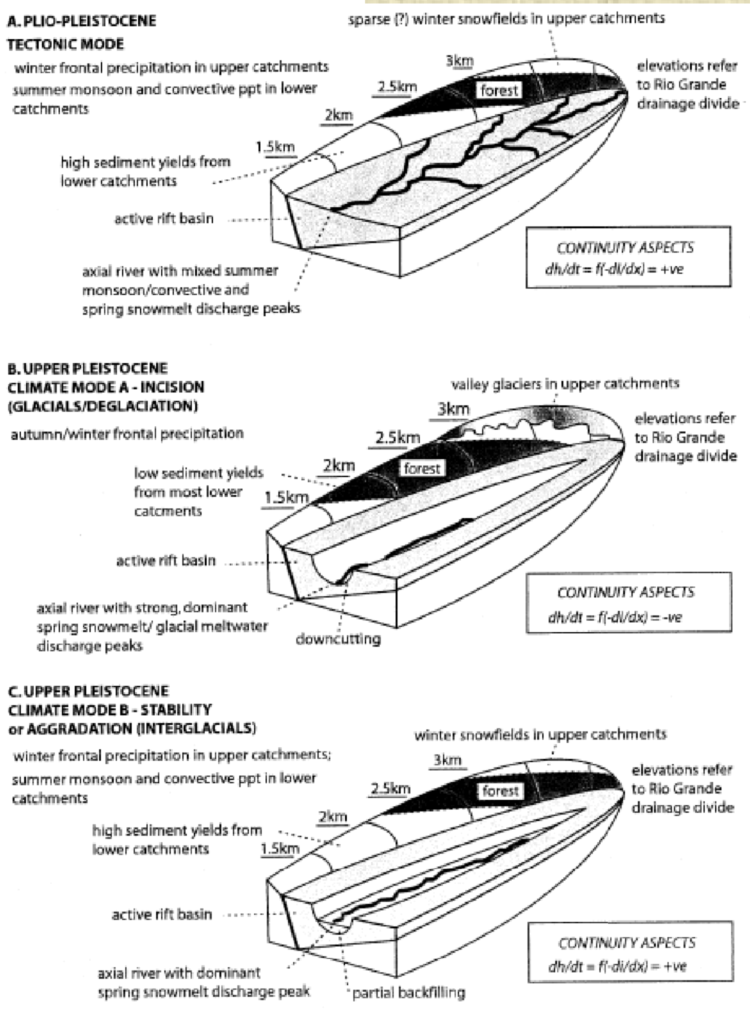




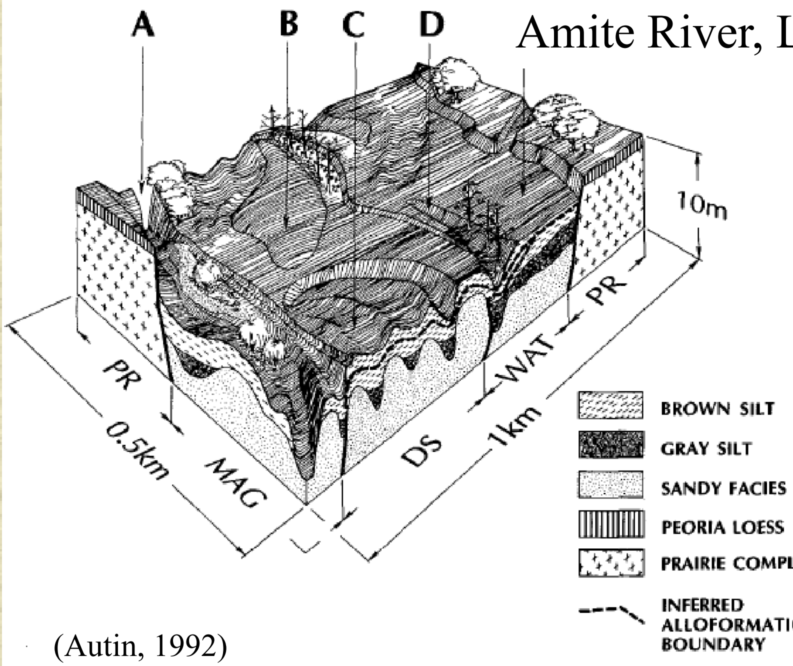
Ganges Incision from Climate Change



Rio Grande, NM
(Leeder and Mack, 2007)

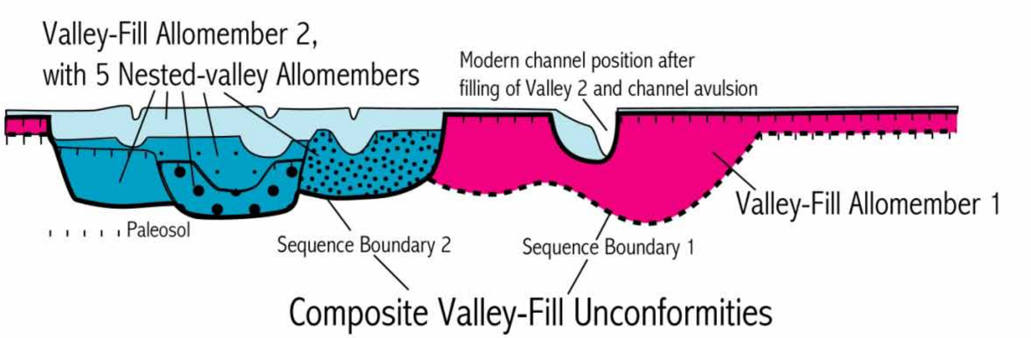


Amite River, La



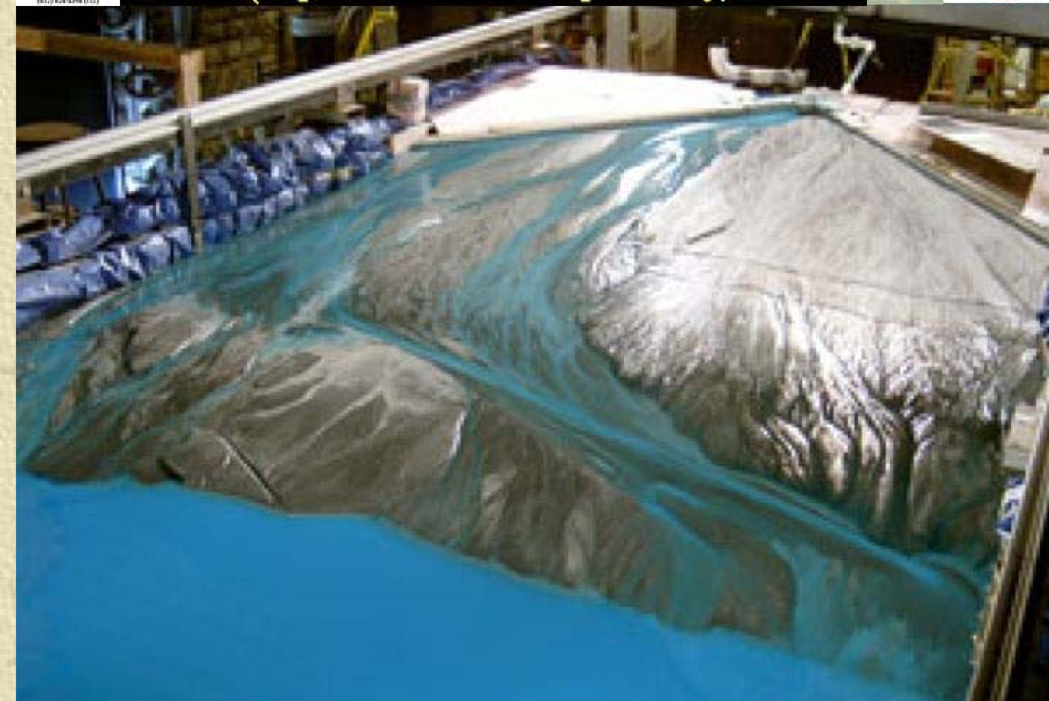
(Autin, 1992)

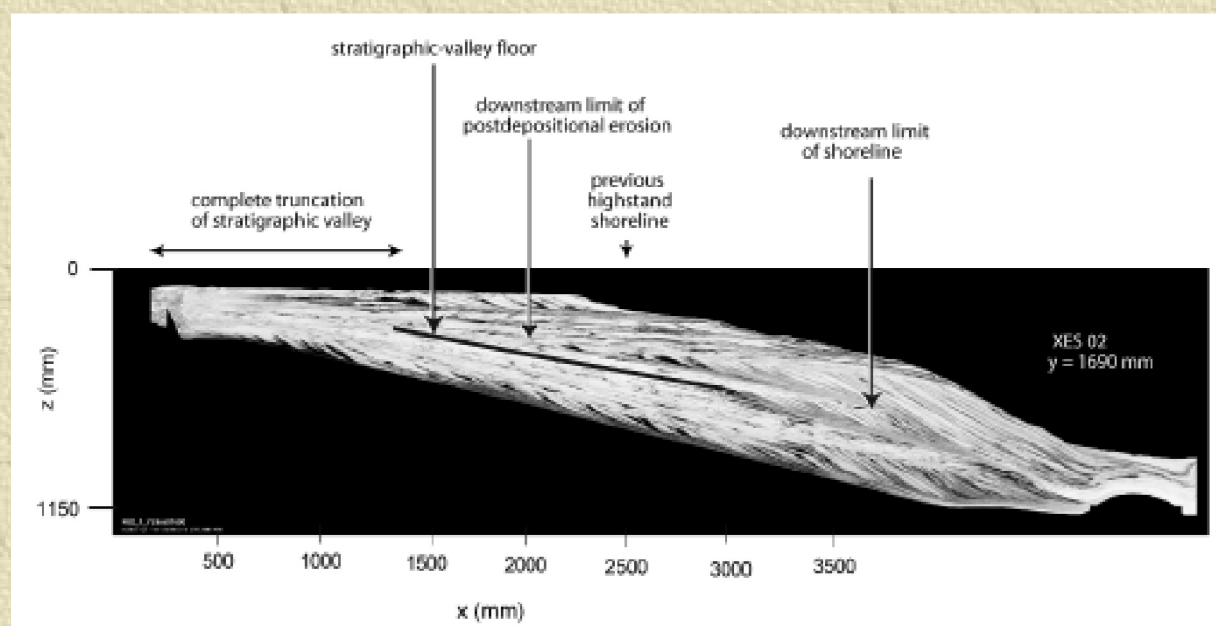
Nested-Valley Allomembers and Sequence Boundaries of the Colorado River, TX



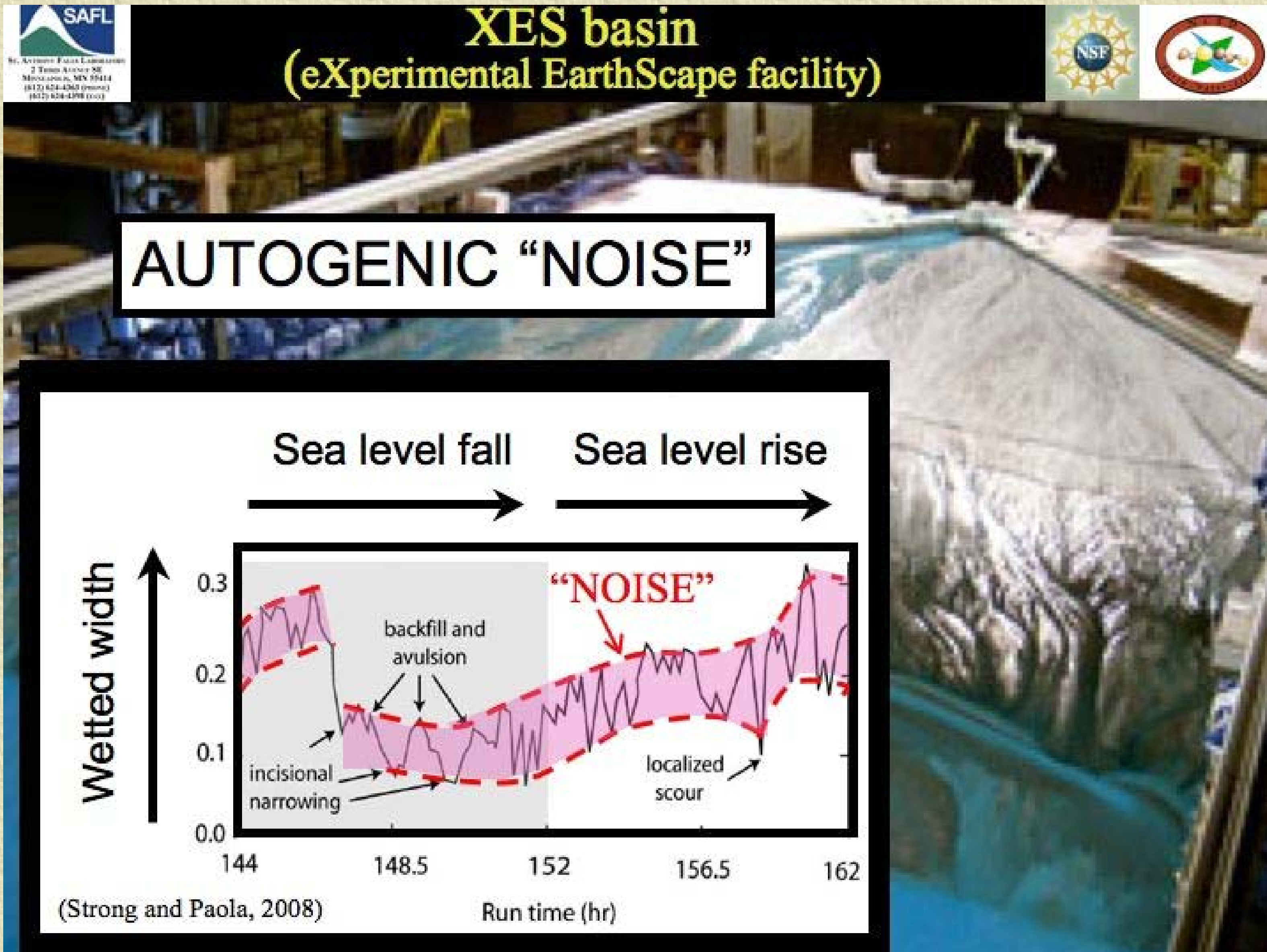
(Blum and Price, 1998)

XES basin
(eXperimental EarthScape facility)

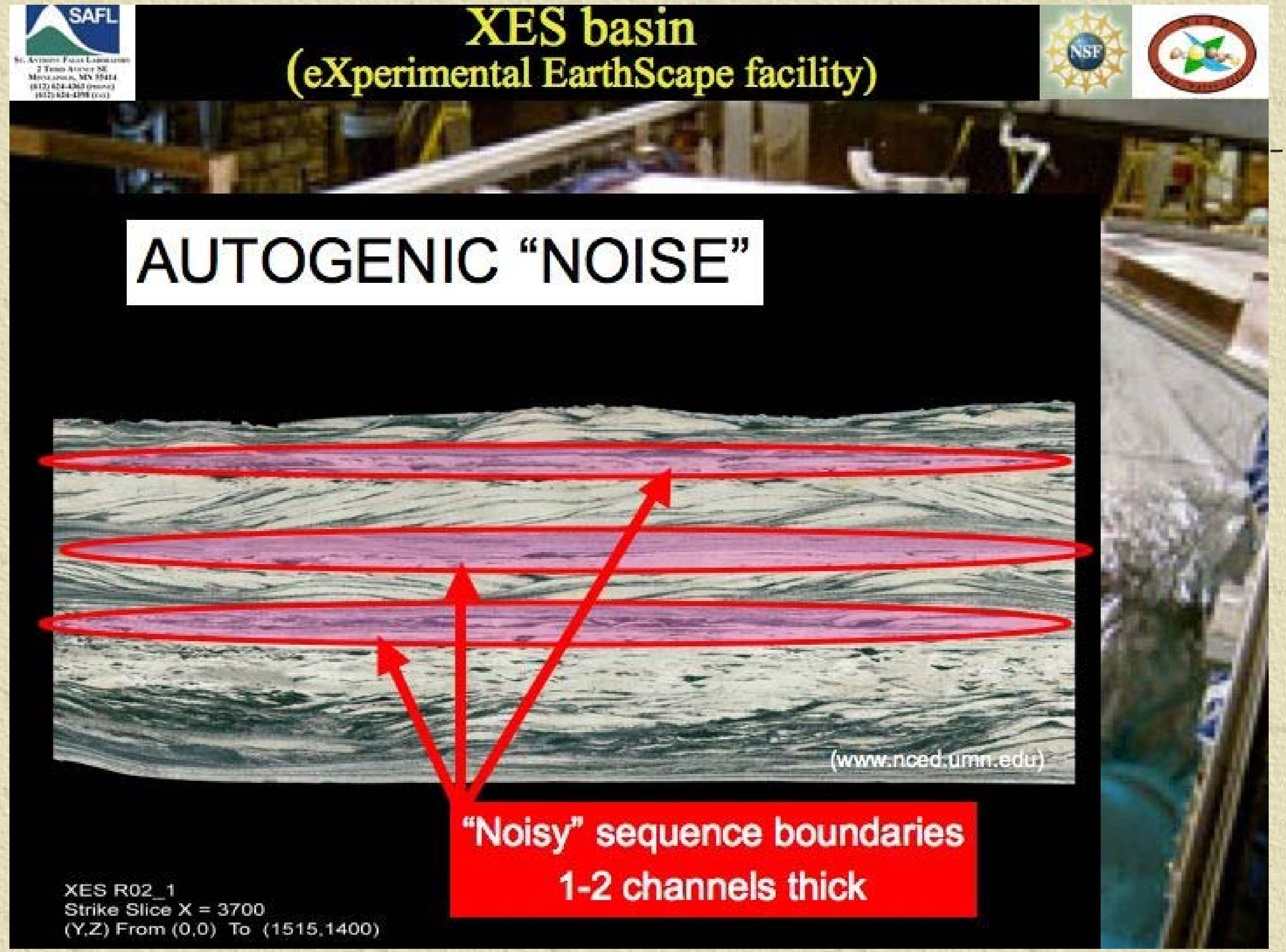




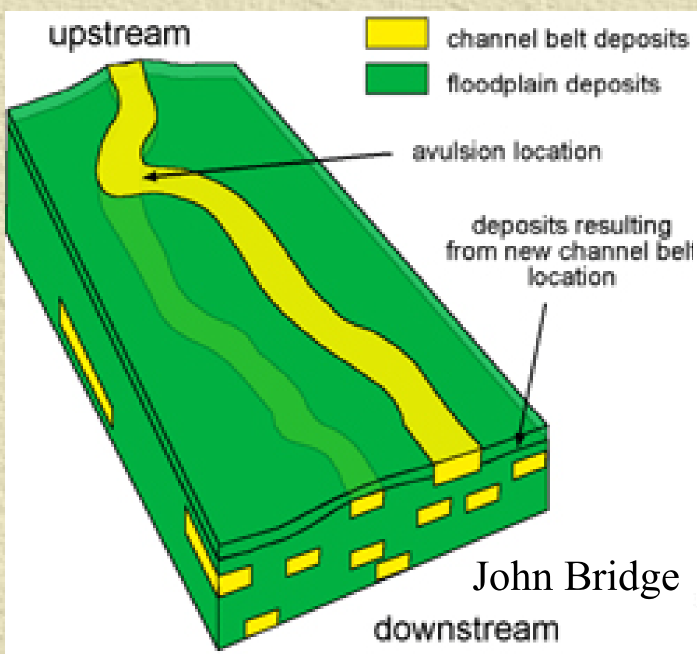
(Strong and Paola, 2008)



SAFL
XES basin
(eXperimental EarthScape facility)
AUTOGENIC "NOISE"
Sea level fall
Sea level rise
Wetted width
"NOISE"
backfill and avulsion
incisional narrowing
localized scour
0.3
0.2
0.1
0.0
144
148.5
152
156.5
162
Run time (hr)
(Strong and Paola, 2008)

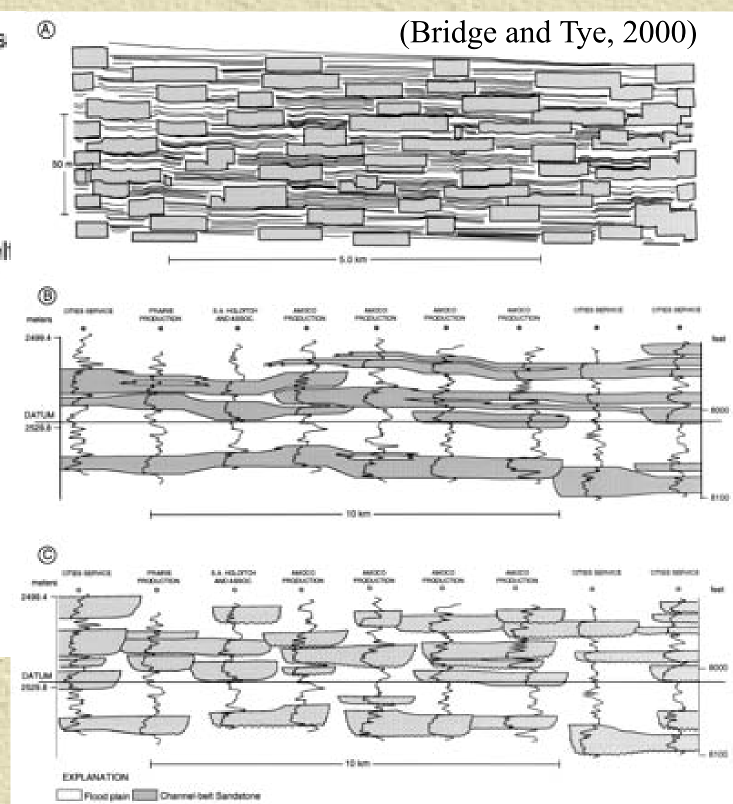


(Strong and Paola, 2008)



John Bridge

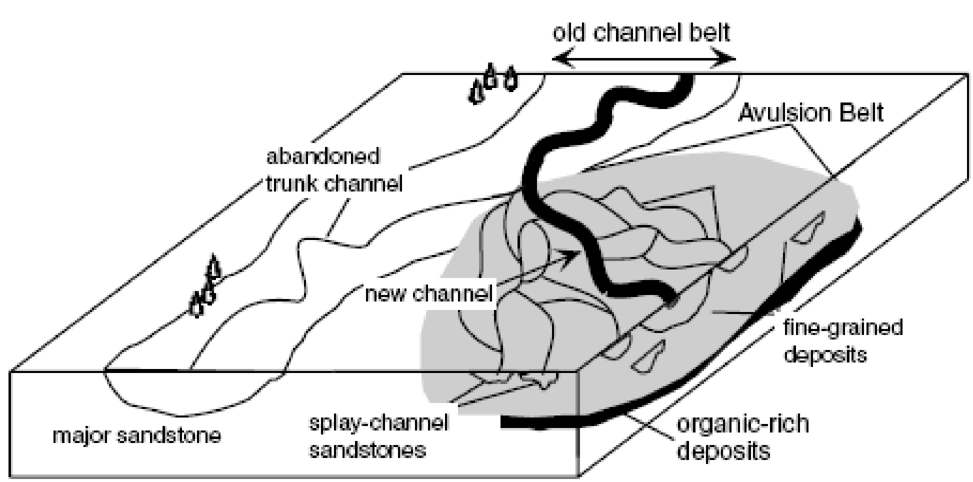
http://www.geol.binghamton.edu/faculty/bridge/R&Pcomputersim.htm

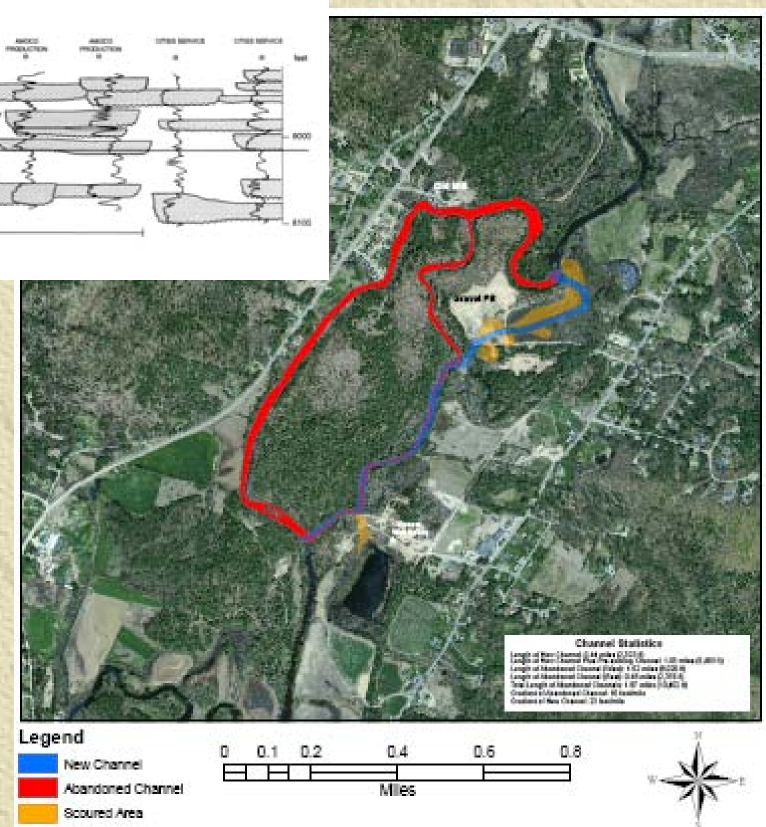


(Bridge and Tye, 2000)

Avulsion

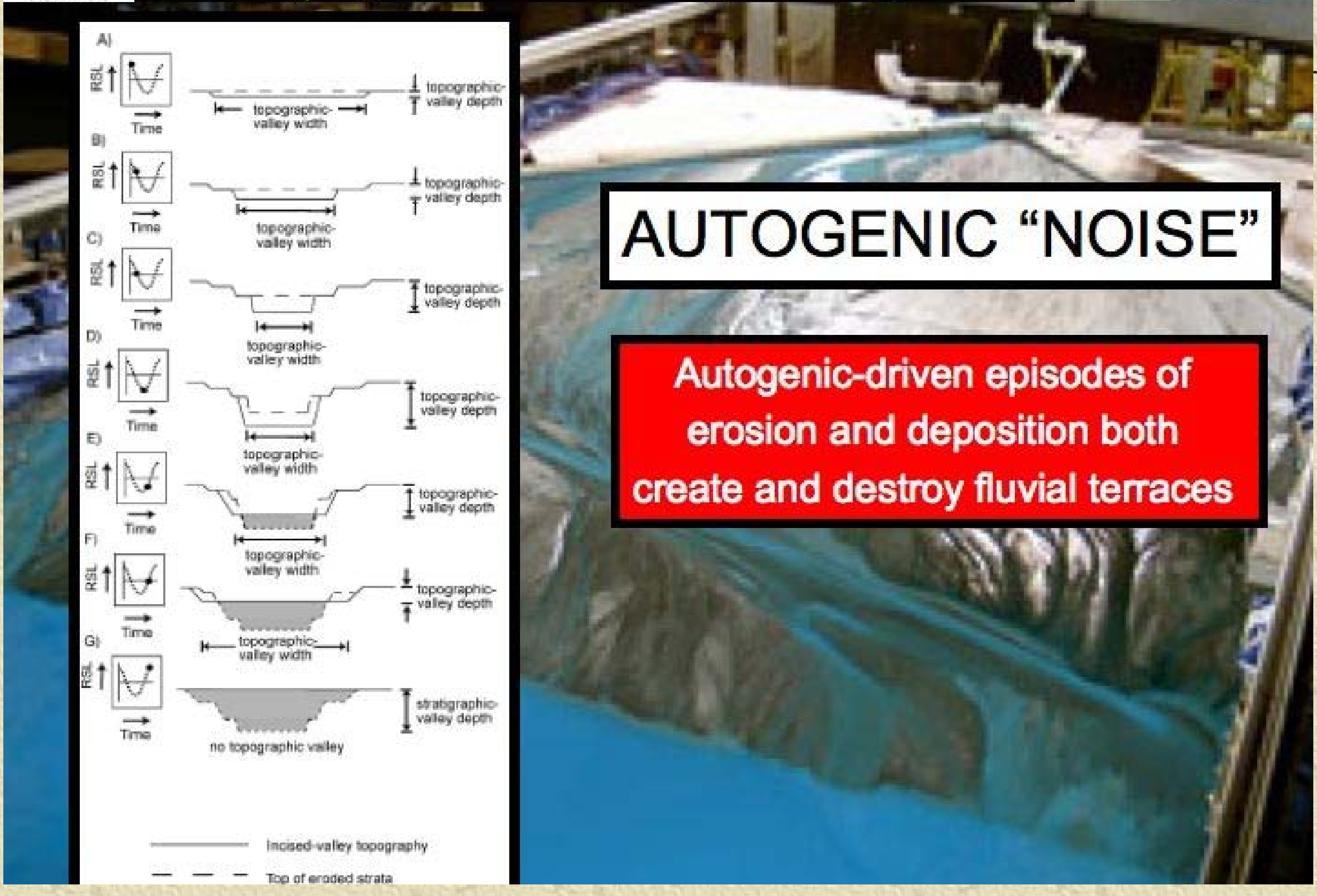
K.S. Davies-Vollum, M.J. Kraus / Sedimentary Geology 140 (2001) 235–249





http://www.friendsofsuncookriver.org/suncook_poster.pdf

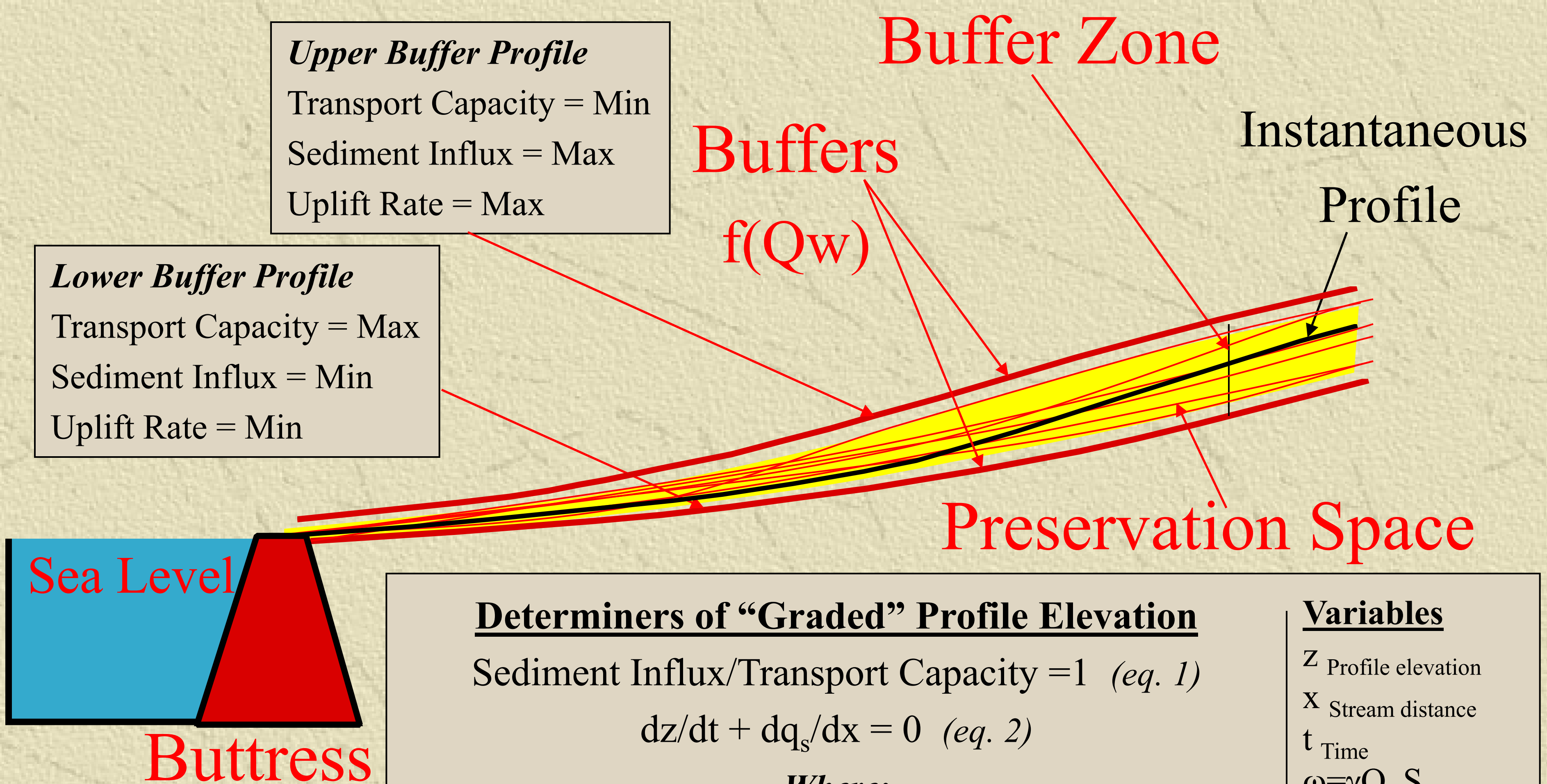
XES basin
(eXperimental EarthScape facility)



AUTOGENIC "NOISE"

Autogenic-driven episodes of erosion and deposition both create and destroy fluvial terraces

Base Level Buffers and Buttresses



Determiners of "Graded" Profile Elevation

Sediment Influx/Transport Capacity =1 *(eq. 1)*

$dz/dt + dq_s/dx = 0$ *(eq. 2)*

Where:

q_s = Sediment Discharge= f(ω, substrate erodability)

Sediment Influx = q_s delivered at x_i = f (drainage basin)

Transport Capacity = q_s that can be transported at x_i

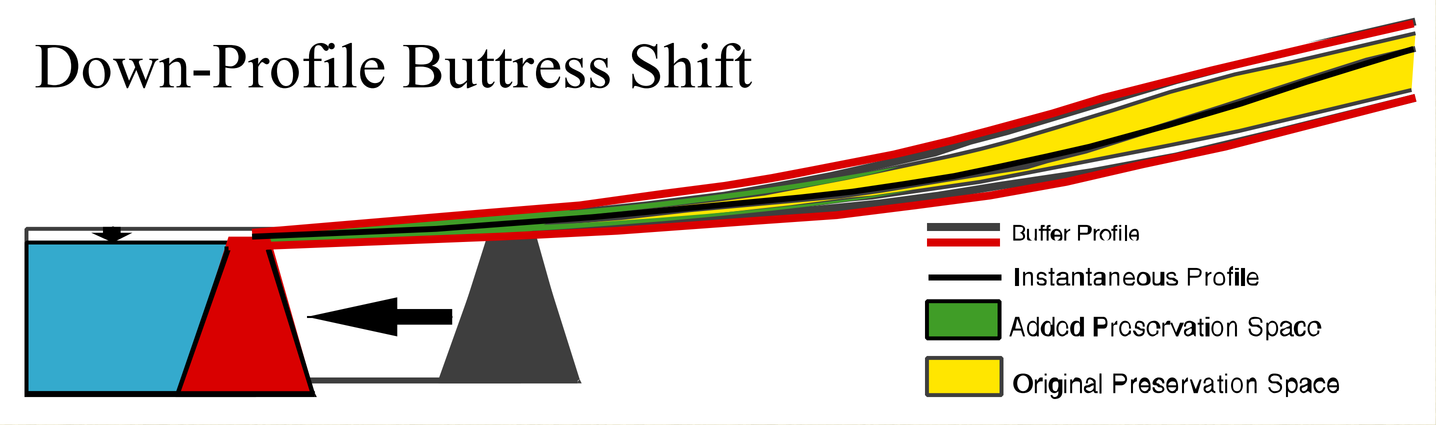
$dz/dt = 0$

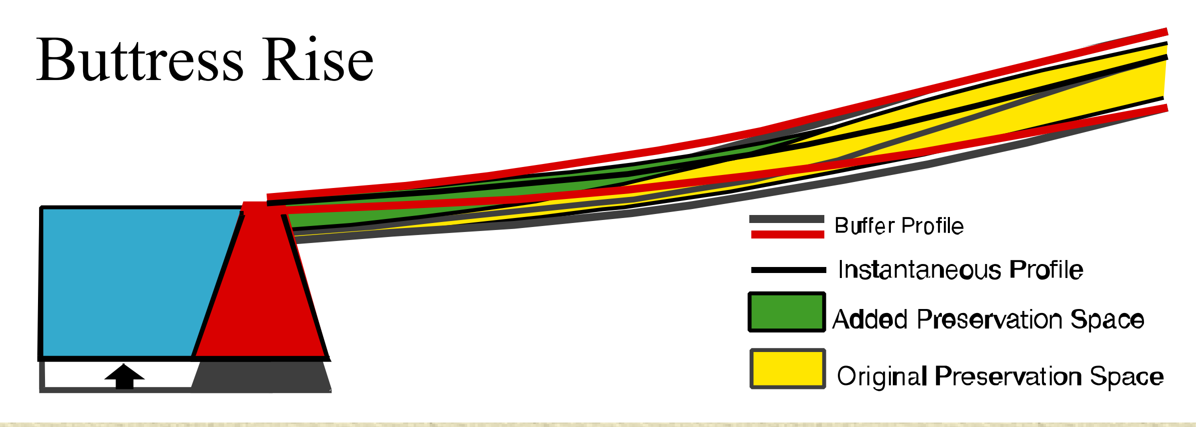
Variables

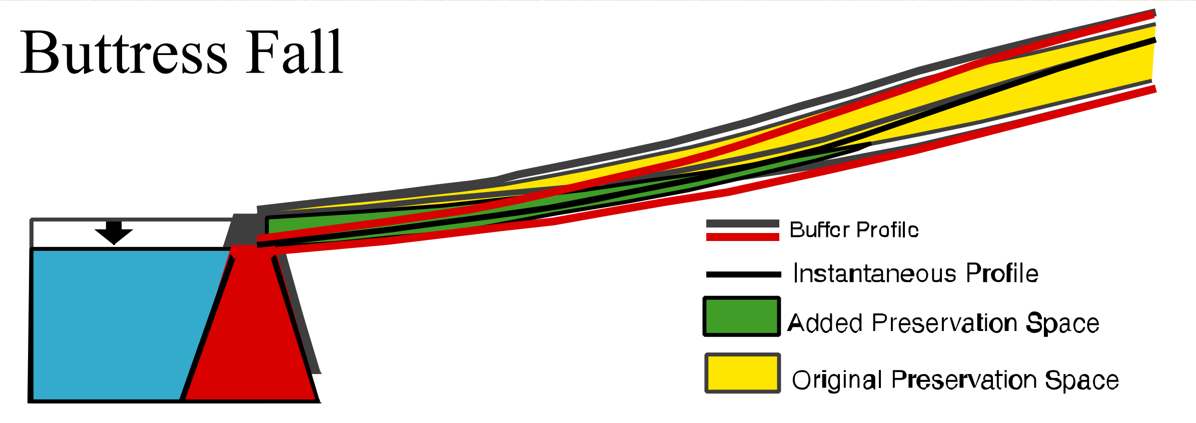
- z Profile elevation
- x Stream distance
- t Time
- $\omega=\gamma Q_w S$
- ω Stream Power
- γ Specific Weight
- Q_w Water Discharge
- S Slope

(Holbrook et al., 2006)

Some Effects of Buttress Shift

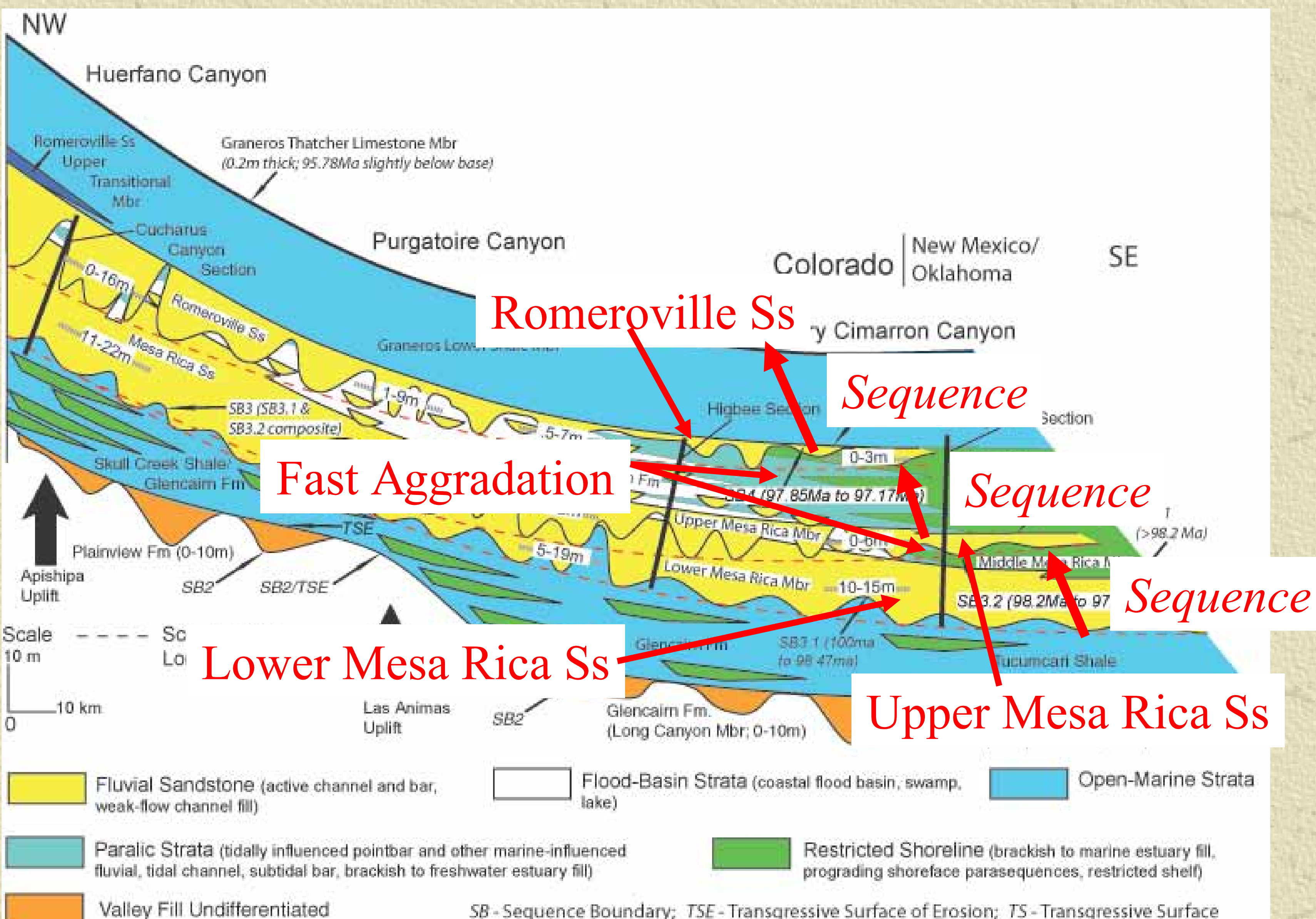






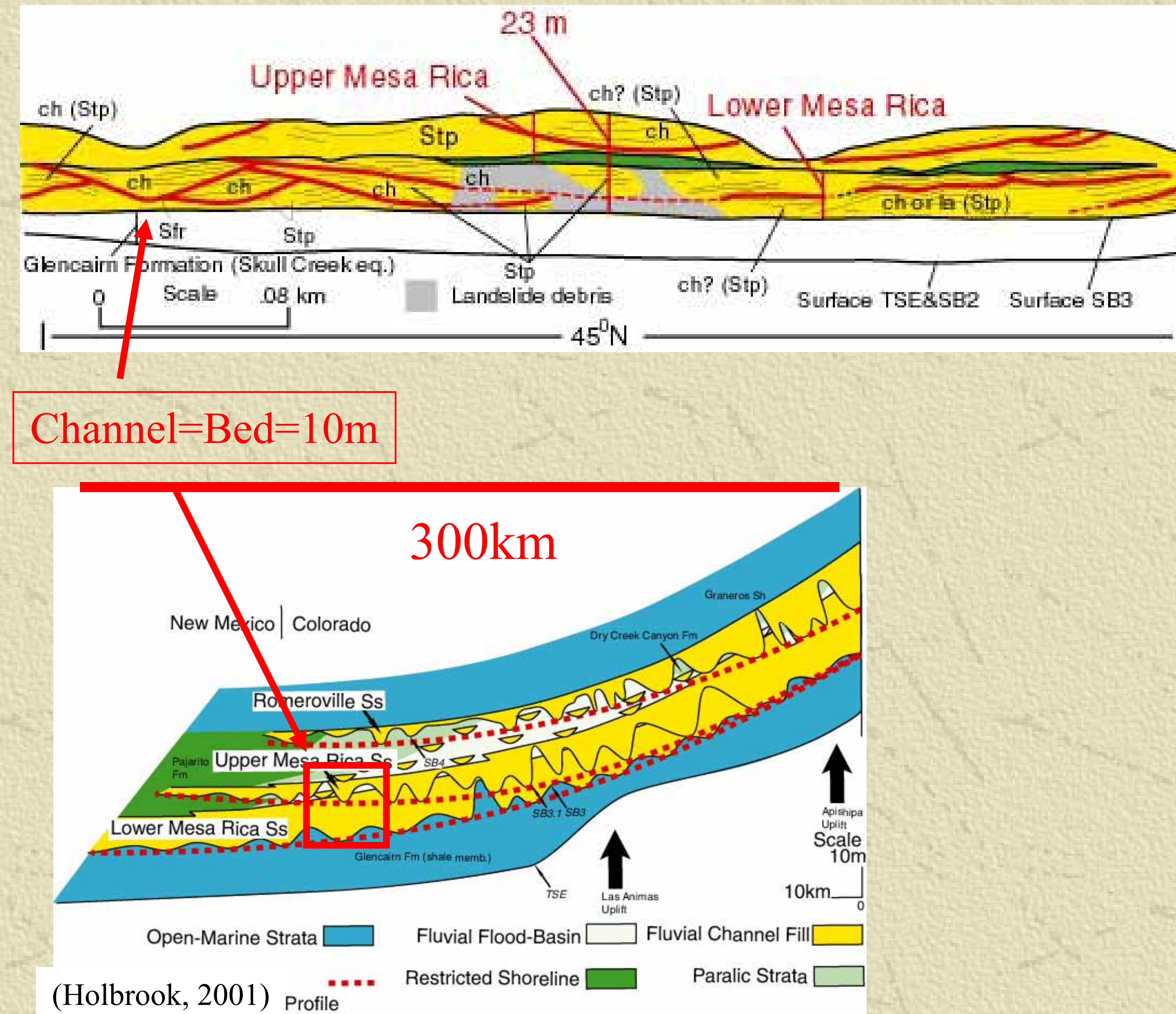
(Holbrook et al., 2006)

Cretaceous Dakota Group, US Western Interior

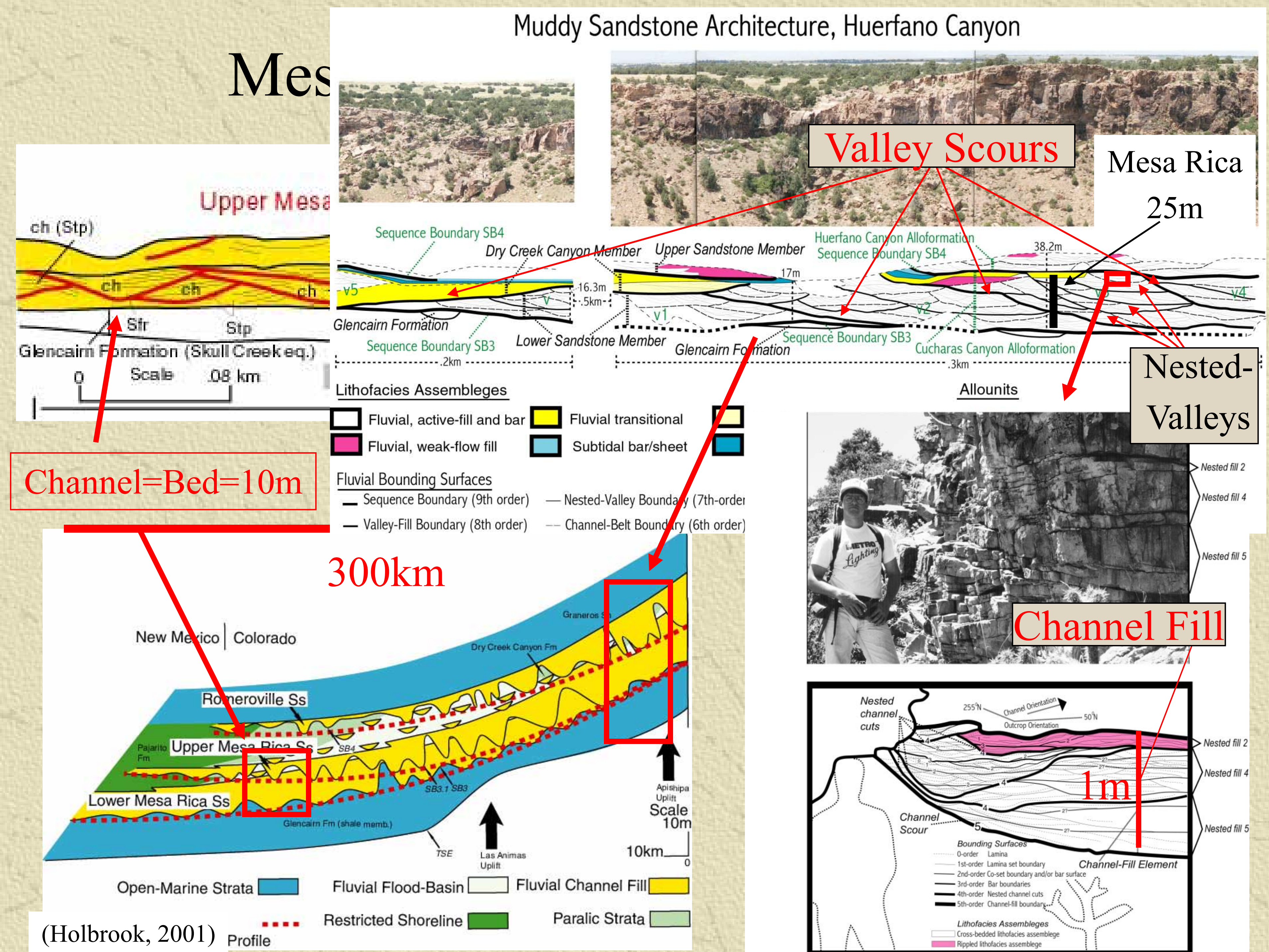


(Holbrook et al., 2006)

Mesa Rica Sandstone Architecture

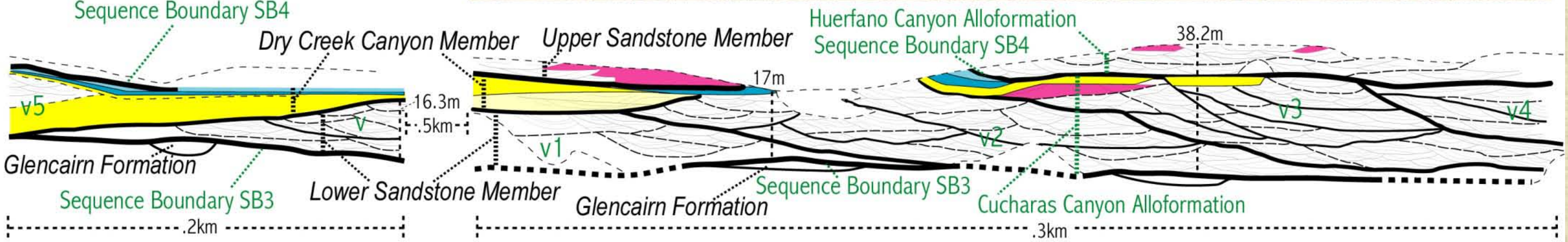


(Holbrook, 2001)



Mes
Muddy Sandstone Architecture, Huerfano Canyon
Valley Scours
Mesa Rica
25m
Upper Mesa
ch (Stp)
ch
ch
ch
Sfr
Stp
Glencairn Formation (Skull Creek eq.)
0 Scale .08 km
Channel=Bed=10m
Sequence Boundary SB4
Dry Creek Canyon Member
Upper Sandstone Member
Huerfano Canyon Alloformation
Sequence Boundary SB4
38.2m
17m
16.3m
.5km
v5
v
v1
v2
v4
v3
Glencairn Formation
Sequence Boundary SB3
.2km
Lower Sandstone Member
Glencairn Formation
Sequence Boundary SB3
Cucharas Canyon Alloformation
.3km
Nested-Valleys
Lithofacies Assembleges
Fluvial, active-fill and bar
Fluvial transitional
Fluvial, weak-flow fill
Subtidal bar/sheet
Fluvial Bounding Surfaces
Sequence Boundary (9th order)
Nested-Valley Boundary (7th-order
Valley-Fill Boundary (8th order)
Channel-Belt Boundary (6th order)
Allounits
300km
Nested fill 2
Nested fill 4
Nested fill 5
Channel Fill
New Mexico
Colorado
Graneros S
Dry Creek Canyon Fm
Romeroville Ss
Pajarito Fm
Upper Mesa Rica Ss
SB4
SB3.1 SB3
Lower Mesa Rica Ss
Glencairn Fm (shale memb.)
Apishipa Uplift
Scale 10m
10km
0
TSE
Las Animas Uplift
Open-Marine Strata
Fluvial Flood-Basin
Fluvial Channel Fill
Restricted Shoreline
Paralic Strata
Profile
(Holbrook, 2001)
Nested channel cuts
255°N
Channel Orientation
50°N
Outcrop Orientation
Nested fill 2
Nested fill 4
Nested fill 5
1m
Channel Scour
Bounding Surfaces
0-order Lamina
1st-order Lamina set boundary
2nd-order Co-set boundary and/or bar surface
3rd-order Bar boundaries
4th-order Nested channel cuts
5th-order Channel-fill boundary
Channel-Fill Element
Lithofacies Assembleges
Cross-bedded lithofacies assemblege
Rippled lithofacies assemblege

Muddy Sandstone Architecture, Huerfano Canyon



Lithofacies Assembleges

- Fluvial, active-fill and bar
- Fluvial transitional
- Tidally influenced point bar
- Fluvial, weak-flow fill
- Subtidal bar/sheet
- Open estuary/restricted marine

Allounits

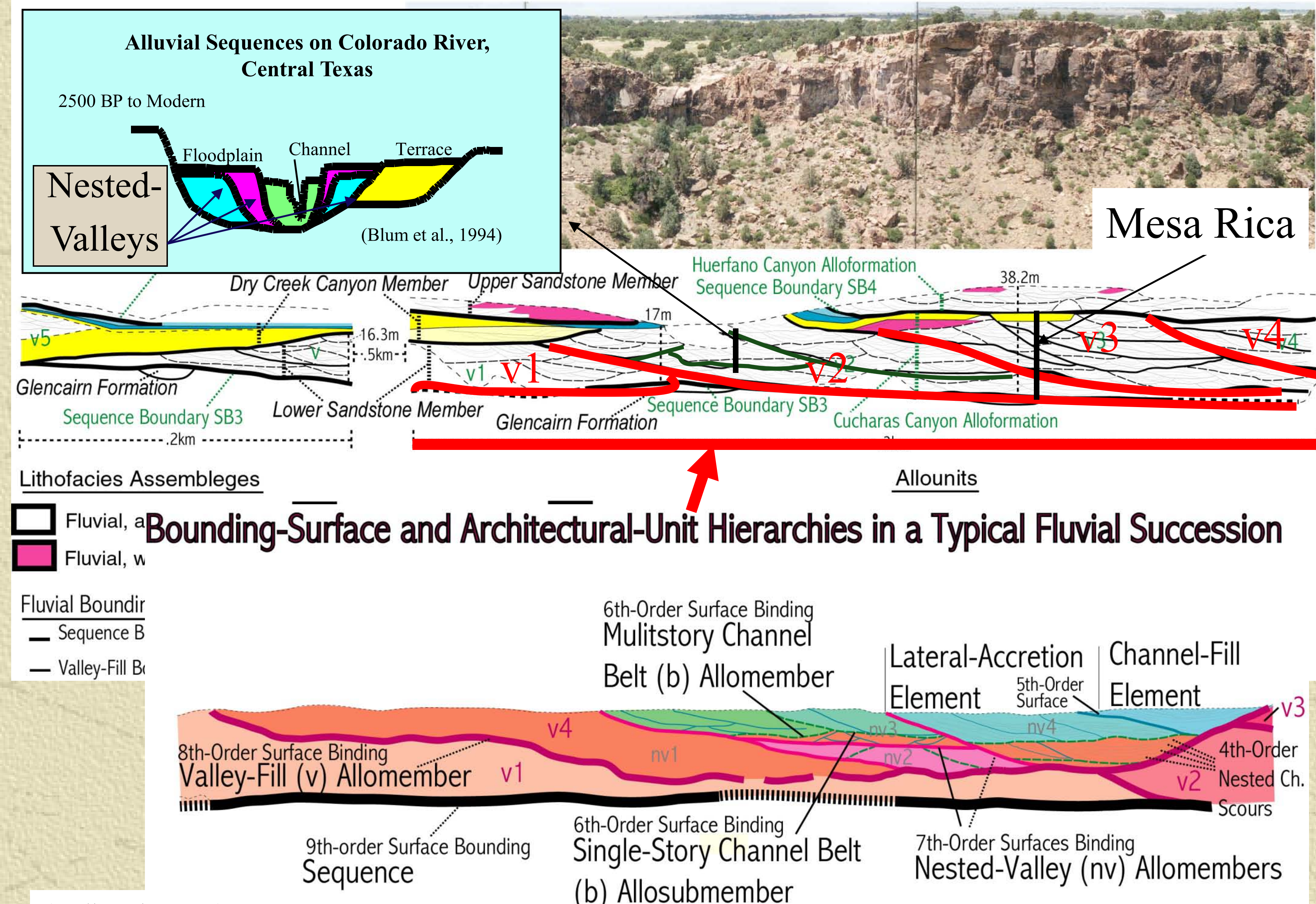
- nv(1,2,3,4) Nested-Valley Allosubmembers
- v(1,2) Valley-Fill Allomembers

Fluvial Bounding Surfaces

- Sequence Boundary (9th order)
- Valley-Fill Boundary (8th order)
- Nested-Valley Boundary (7th-order)
- Channel-Belt Boundary (6th order)
- Channel-Fill and Lateral-Accretion Element Boundary (5th order)
- Intrachannel/Bar Surface, Including Nested Channel Cuts (<4th order)

(Holbrook, 2001)

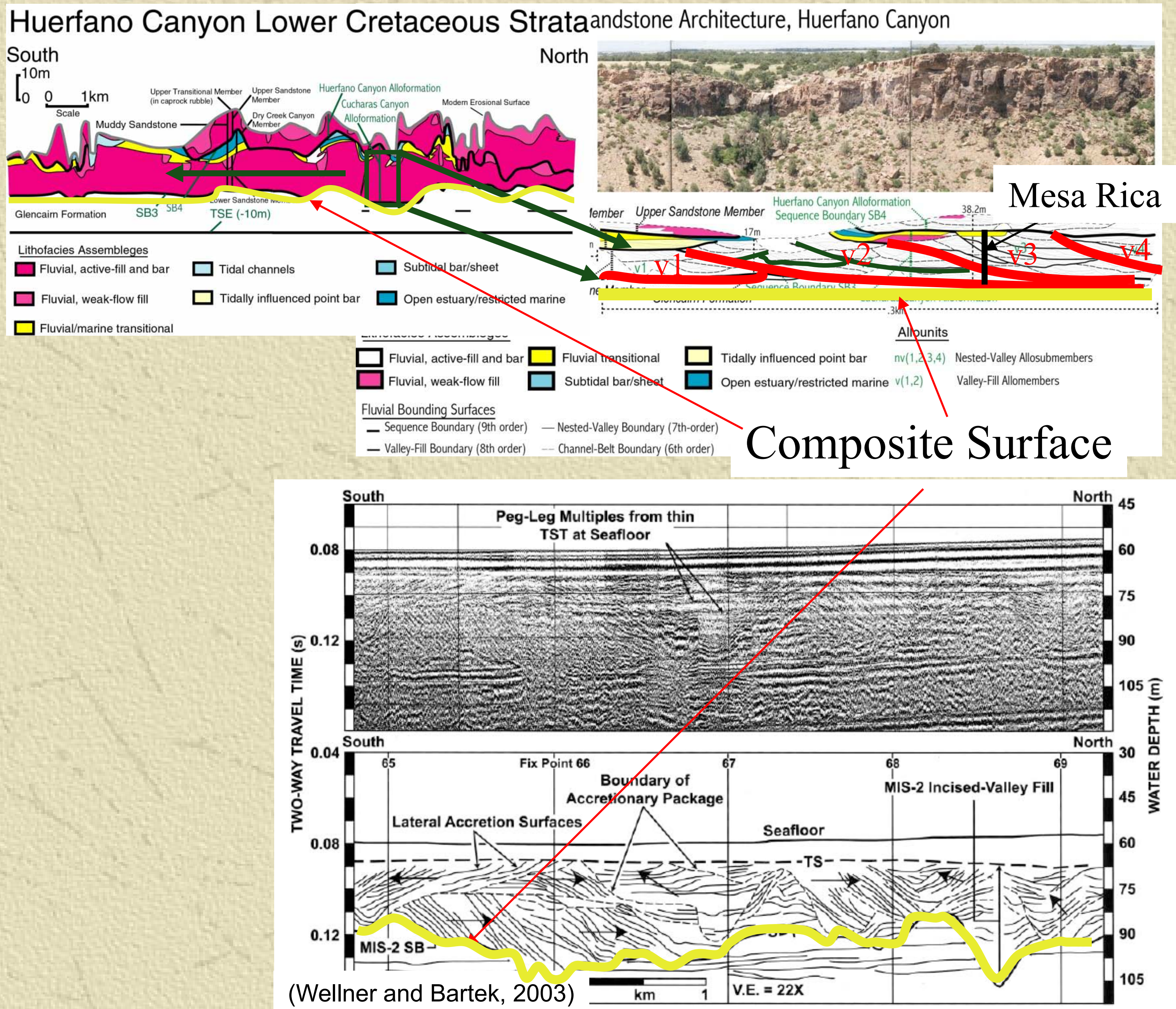
Muddy Sandstone Architecture, Huerfano Canyon



(Holbrook, 2001)

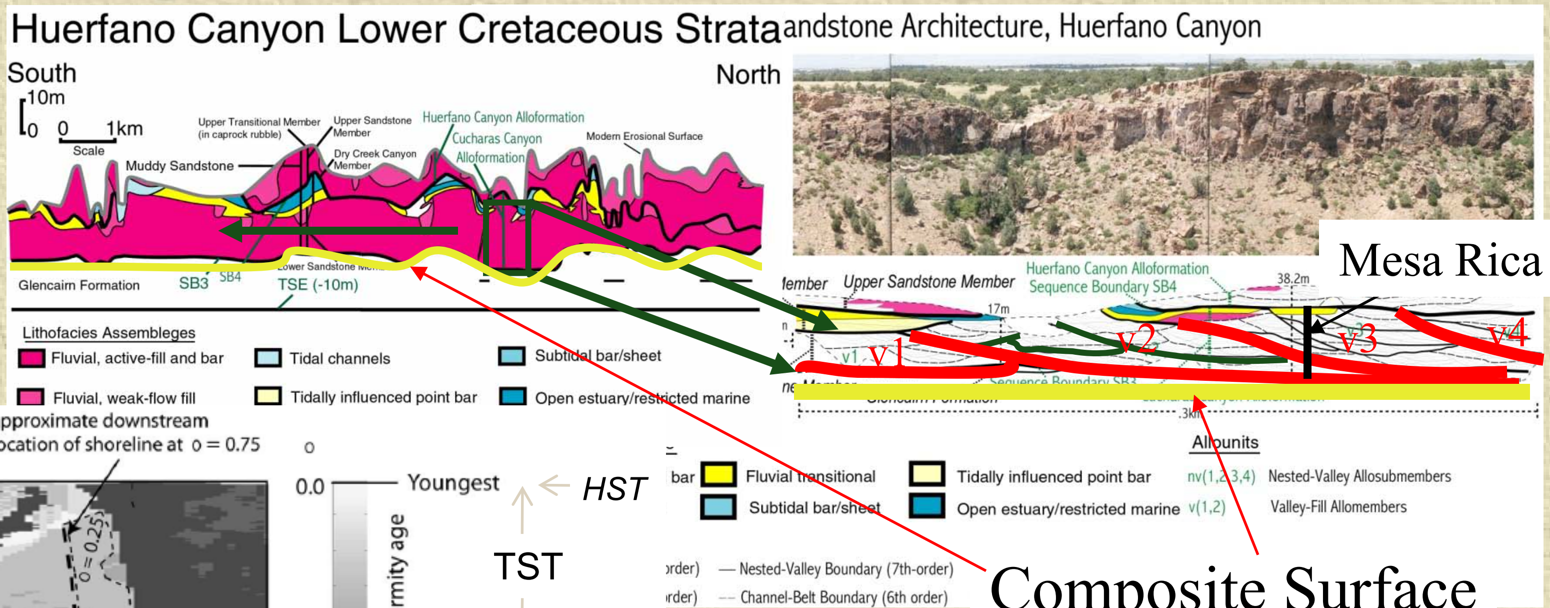
Implications for Sequence Boundaries, Sequence Architecture, and Sequence Construction

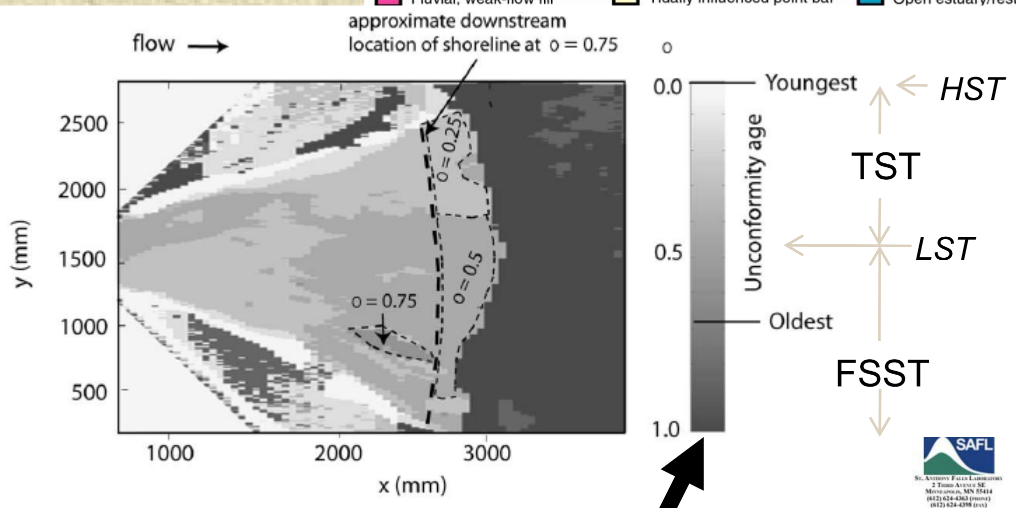
Sequence boundaries as time surfaces?



(Wellner and Bartek, 2003)

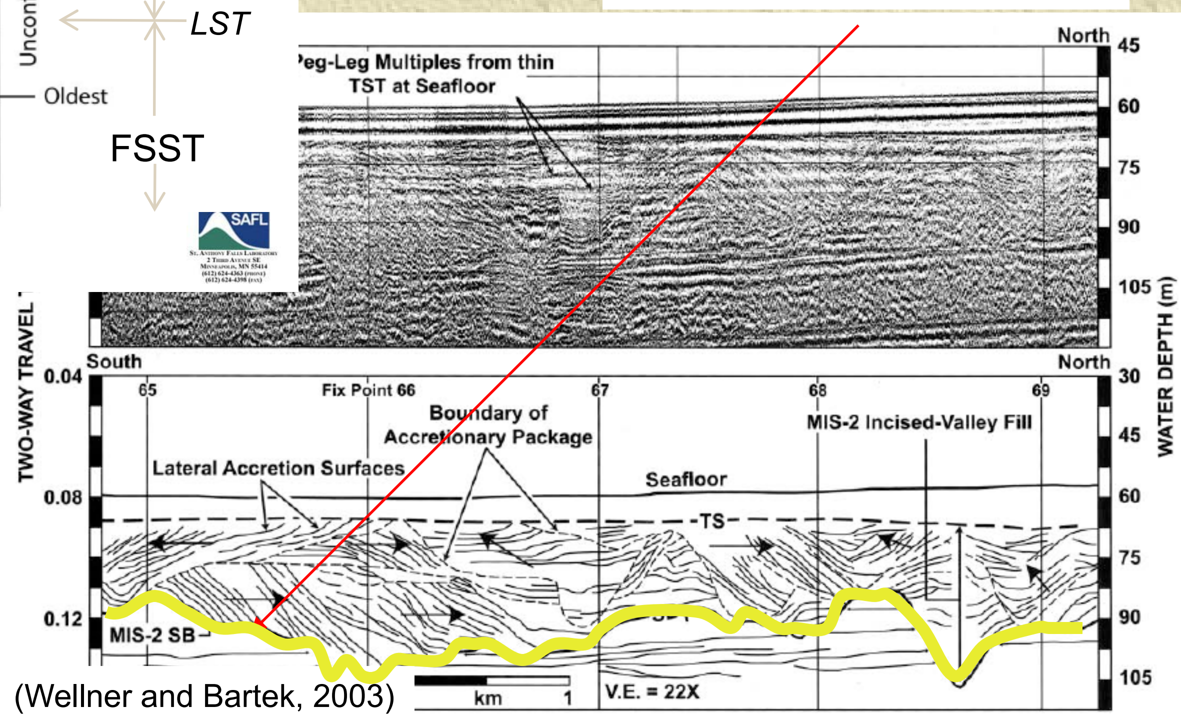
Sequence boundaries as time surfaces?





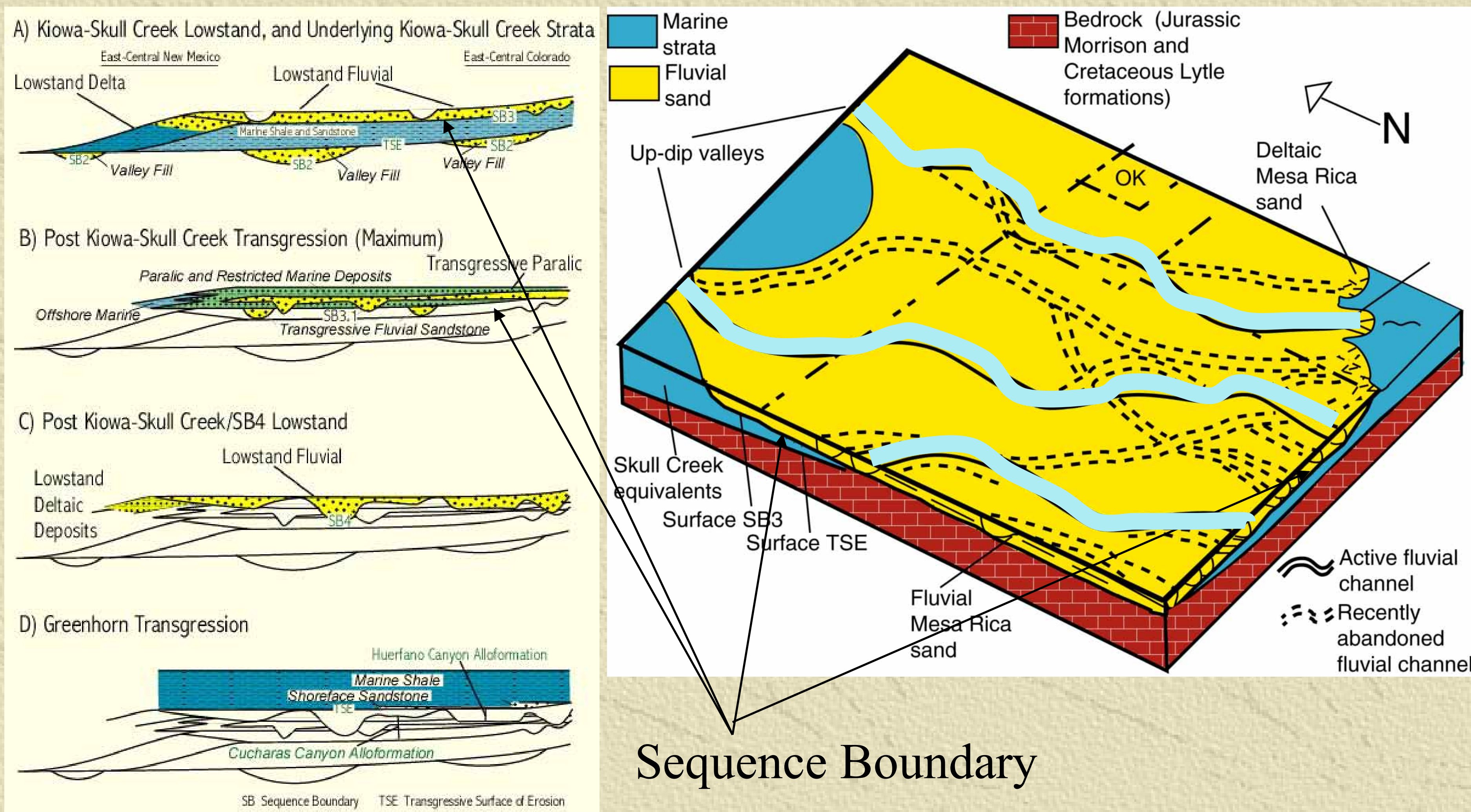
(Strong and Paola, 2008)

Sequence boundary formed over 75% of the entire sea level cycle!!!



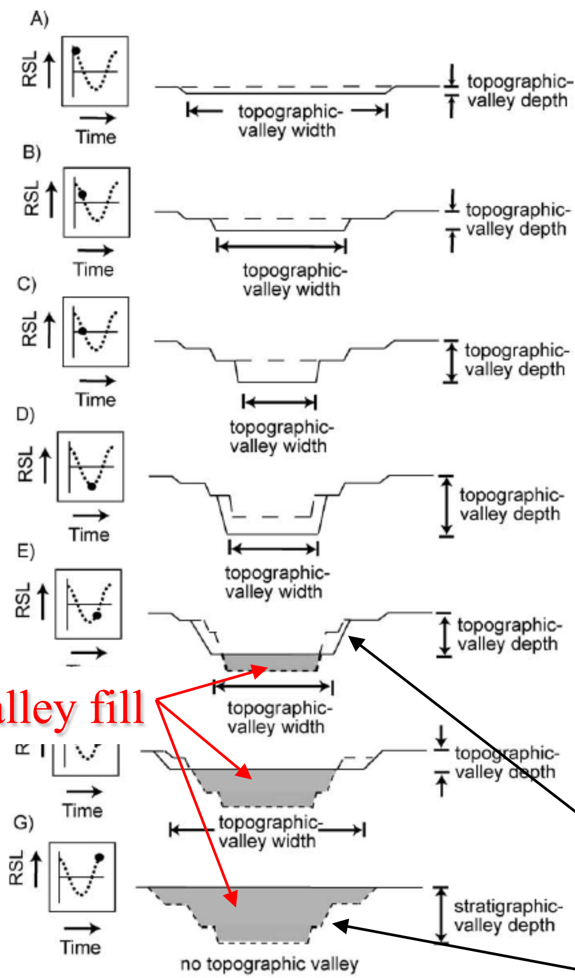
(Wellner and Bartek, 2003)

Sequence Boundaries as Topographic Surfaces?

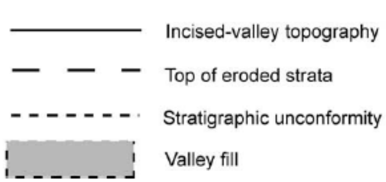


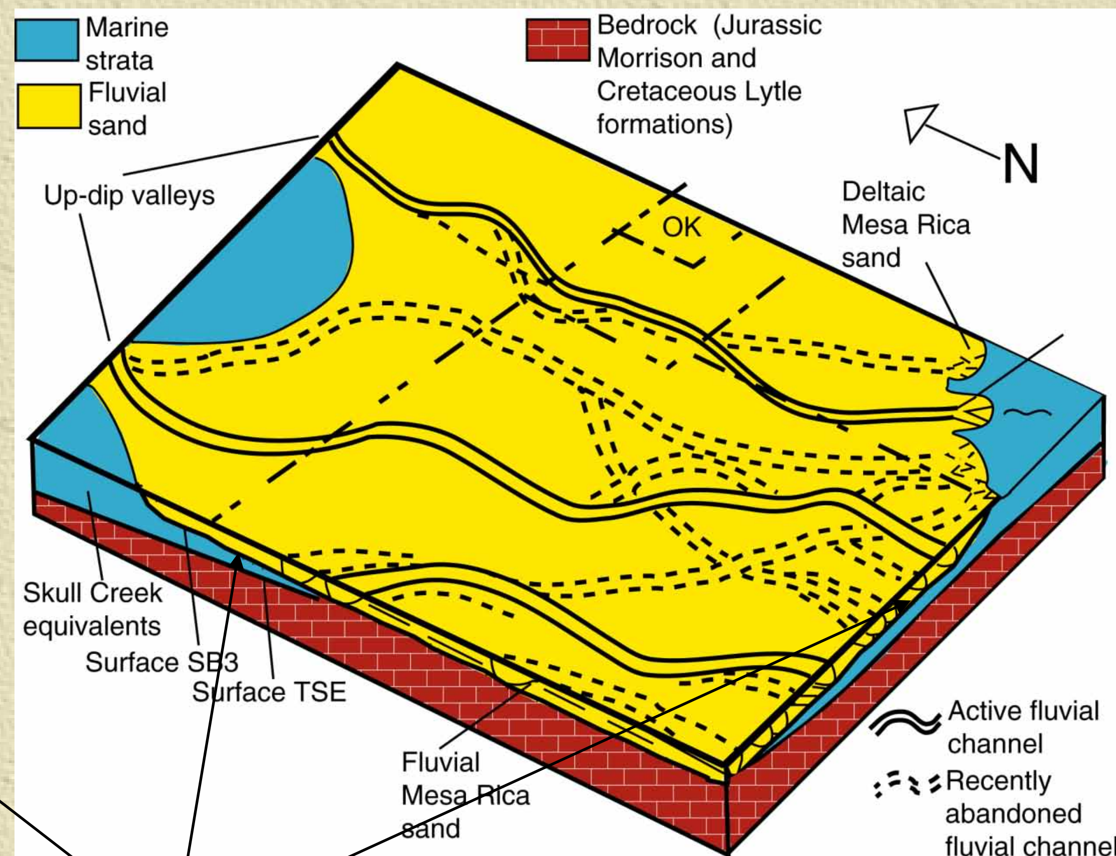
(Holbrook, 1996)

Sequence Boundaries as Topographic Surfaces?



(Strong and Paola, 2008)



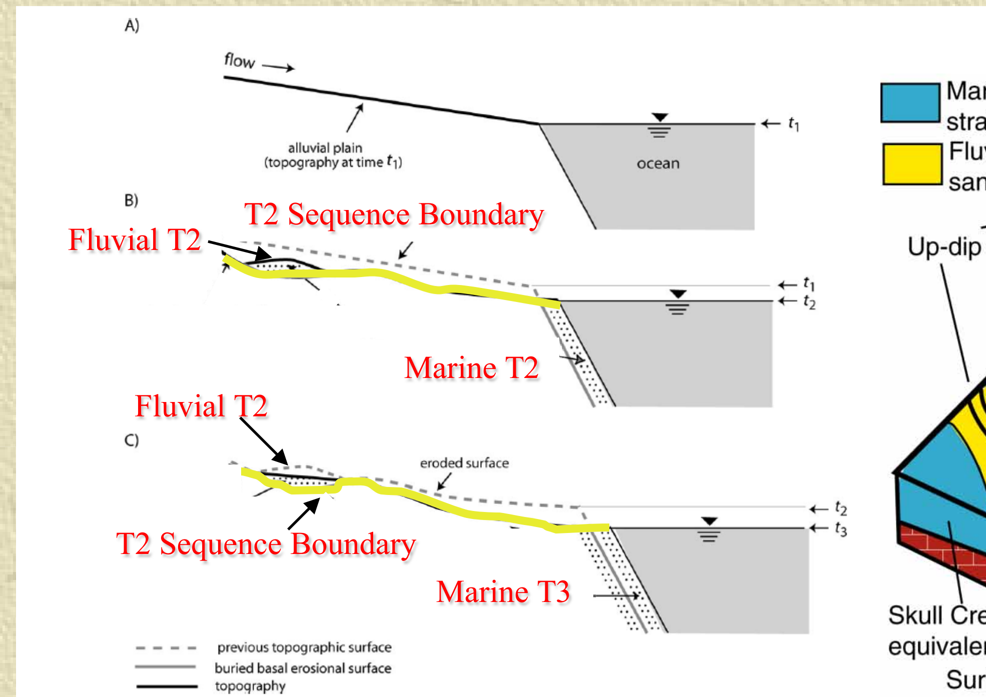


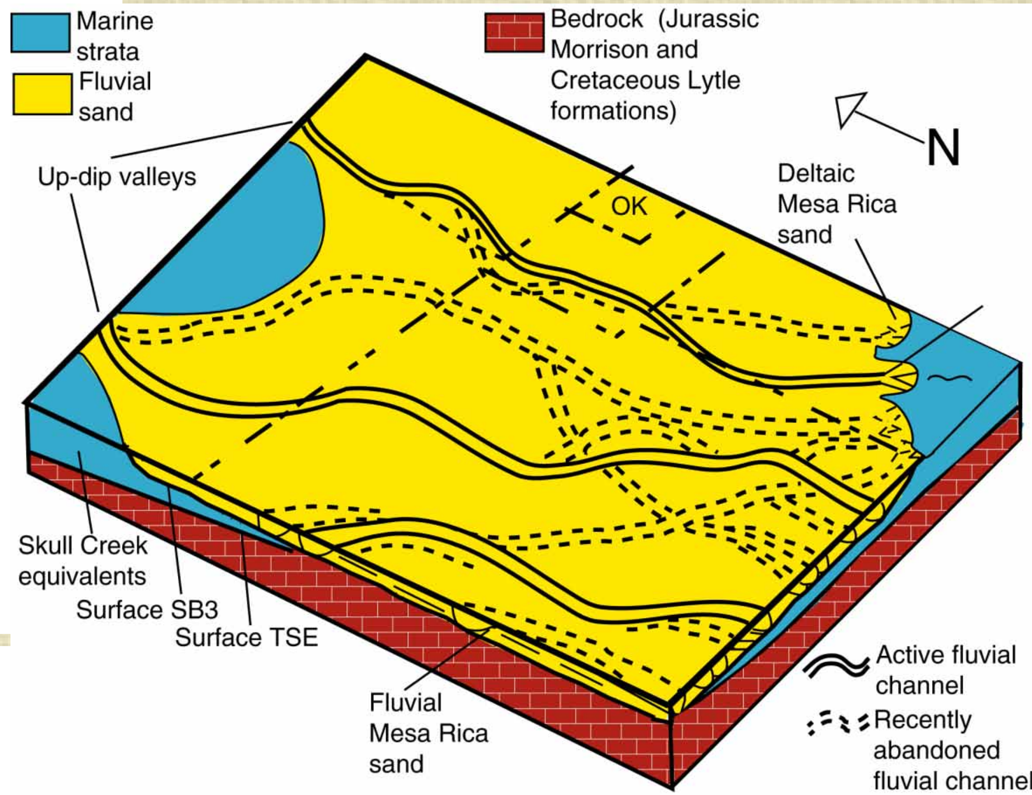
Valley fill

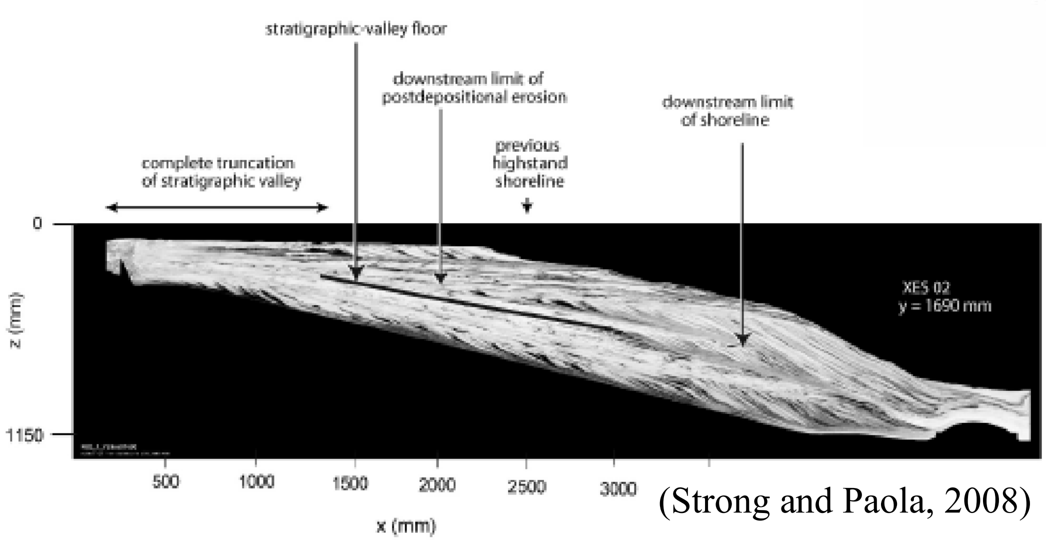
Sequence Boundary

Sequence boundary shaped throughout the T/R cycle

Sequence Boundaries as Unconformities?

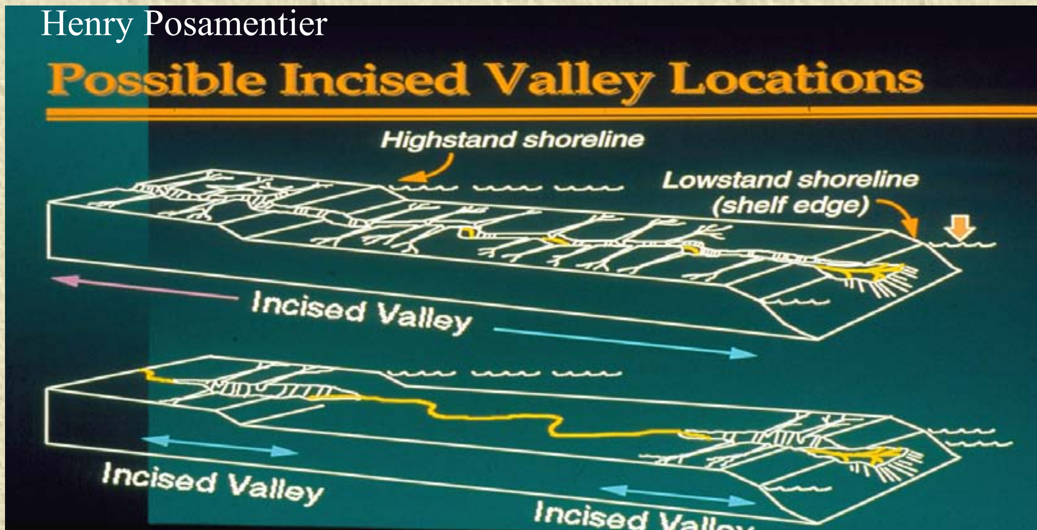




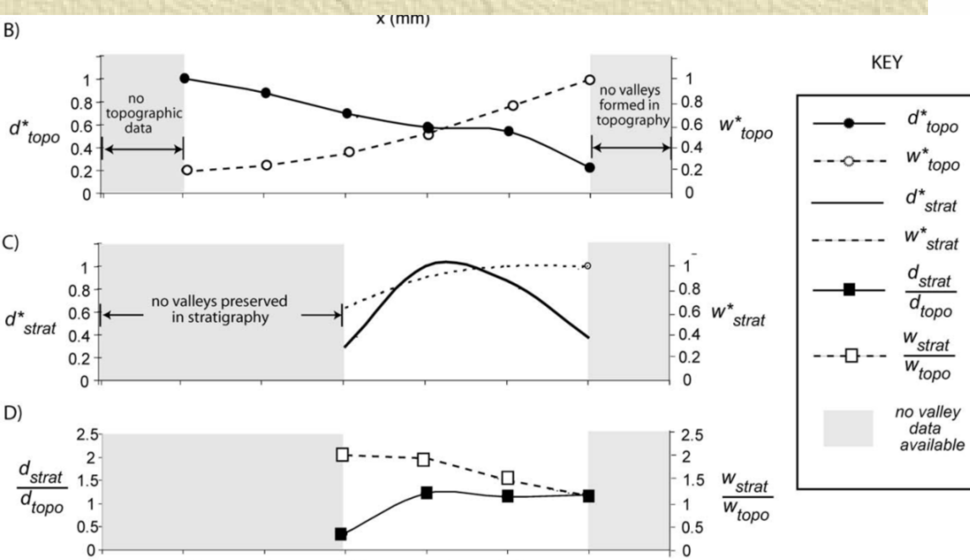


(Strong and Paola, 2008)

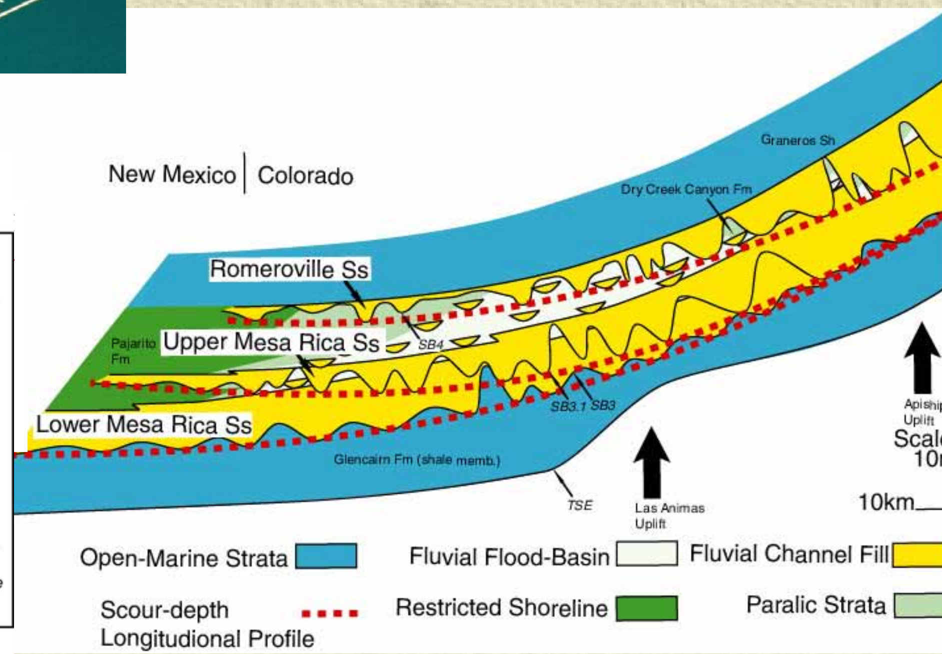
Valley Incision by Knickpoint or Buffer?



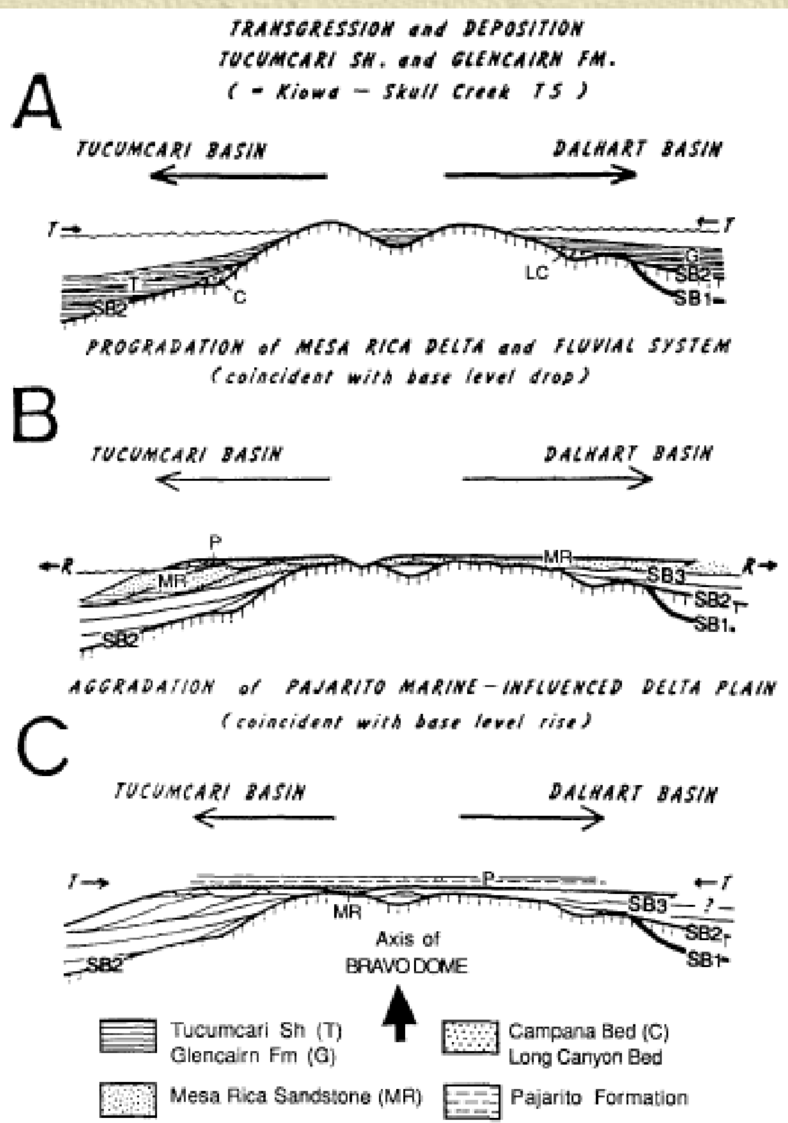
Knickpoint Valleys



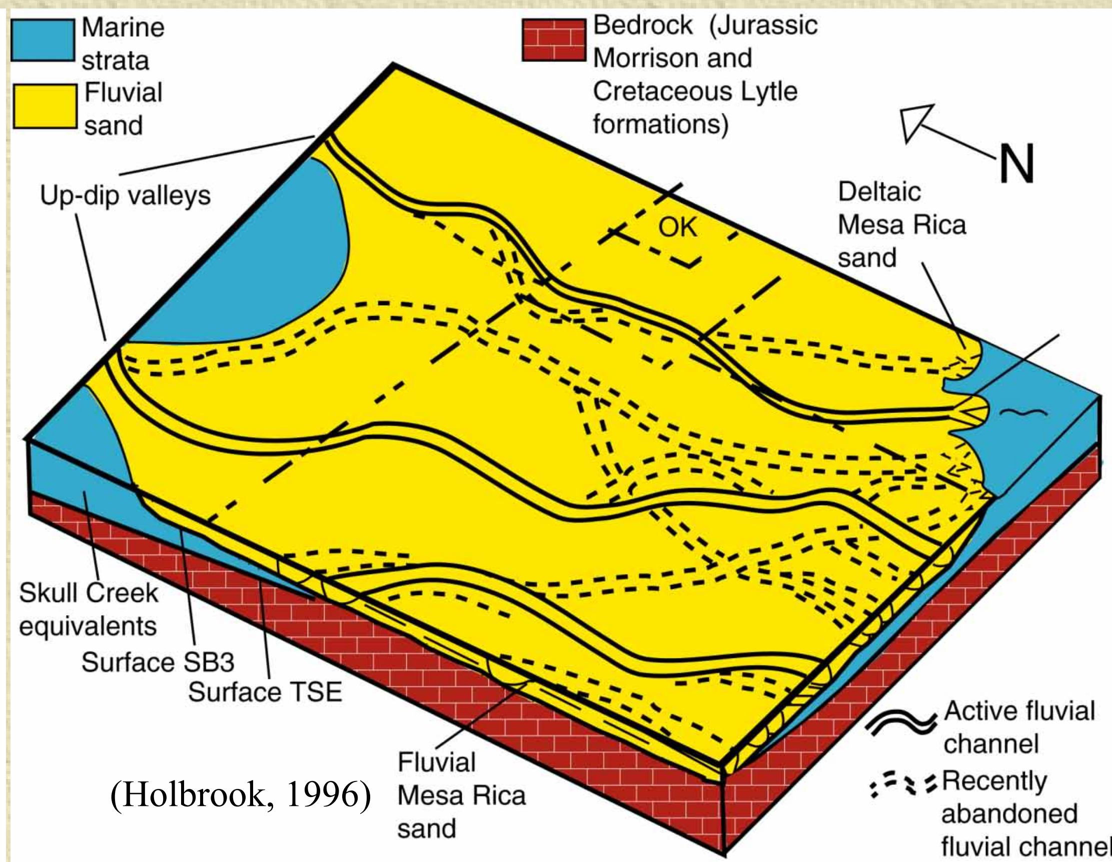
(Strong and Paola, 2008)



Implications for Rapid Flooding

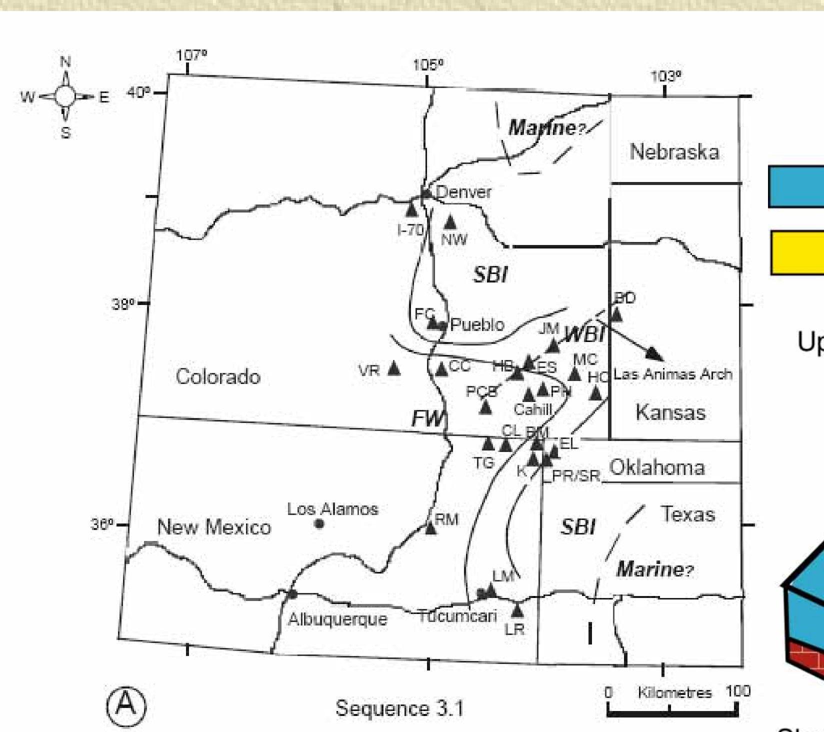


(Holbrook and Wright Dunbar, 1992)

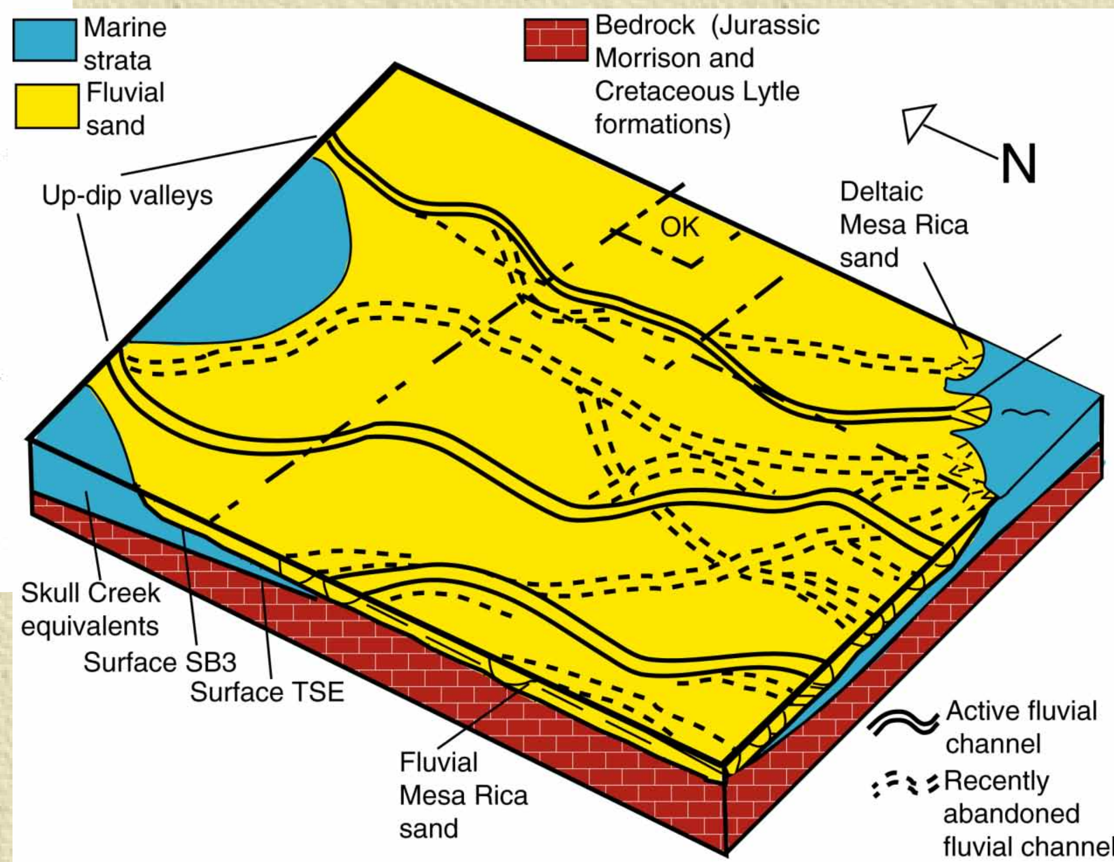


(Holbrook, 1996)

Implications for Rapid Flooding



(Oboh Ikuenobe et al., 2008)



(Holbrook and Wright Dunbar, 1992)

Conclusions

1) “Sequence boundaries” are time-transgressive composite surfaces formed over the duration of the T/R cycle…therefore…
2) “Sequence boundaries” rarely equate to topographic surfaces

3) “Sequence Boundaries” are not always unconformities

4) Valley erosion can initiate either in the proximal or distal region of the basin …Buffer vs. Knickpoint valleys

5) Sand sheets above “sequence boundaries” are prone to rapid transgression

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