Sequence Stratigraphic Control from Alluvial Architecture of Upper Cretaceous Fluvial System - Wahweap Formation, Southern Utah, U.S.A*

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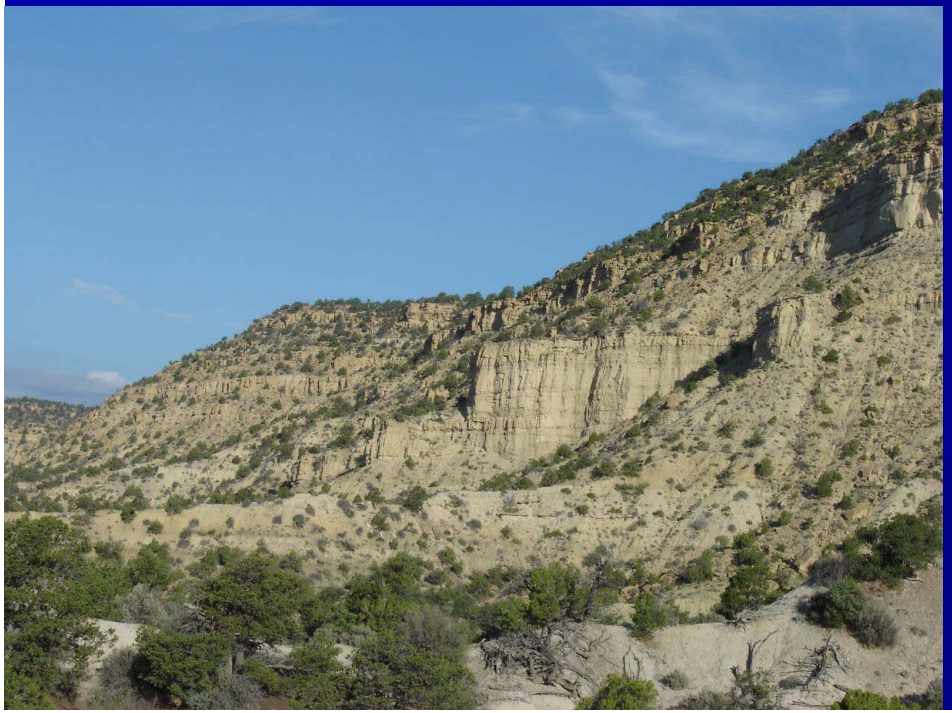
Abstract

The Wahweap Formation (Fm) is a ~400 m thick package of fluvial/estuarine channel sandstones and floodbasin mudstones deposited adjacent to the Western Interior Seaway (WIS) during the Late Cretaceous. It contains four informal members: the lower, middle, upper and capping sandstone members. This study aims to test existing tectono-eustatic basin models and reconstruct the sedimentary and tectonic history of the southern Cordilleran foreland basin during this important interval.

A radiometric date of 80.1 Ma has been obtained from the lower part of the middle member, indicating that the middle and upper members were deposited during the Claggett transgression, a eustatic rise in the WIS that occurred at ~79.6 Ma. Sedimentological analysis and sand:mud ratios suggest that the lower member, which contains two laterally extensive sandstone bodies with internal erosive surfaces and intraformational rip-up clasts, was deposited in a low accommodation space setting.

The middle member is dominated by grey mudrocks with minor carbonaceous shale and fine-grained sandstone. It represents the fastest sediment accumulation rate in the Wahweap Fm and records a shift to a high accommodation space setting at the same time as the initiation of the Claggett transgression in the WIS. The upper member consists of several thick sandstone bodies interbedded with mudrocks. Tidally influenced inclined heterolithic strata and the brakish water trace fossil Teredolities are present suggesting, along with its appropriate age, that the upper member corresponds to the sea level highstand in the WIS during the Claggett transgression. Sedimentological evidence and new age data therefore suggest that stratigraphic changes in the Wahweap Fm are eustatically rather than tectonically driven, and support previous placement of a sequence boundary at the upper/capping sandstone contact.

Sequence Stratigraphic Control on Alluvial Architecture in an Upper Cretaceous Fluvial System – Wahweap Formation, Southern Utah, U.S.A.



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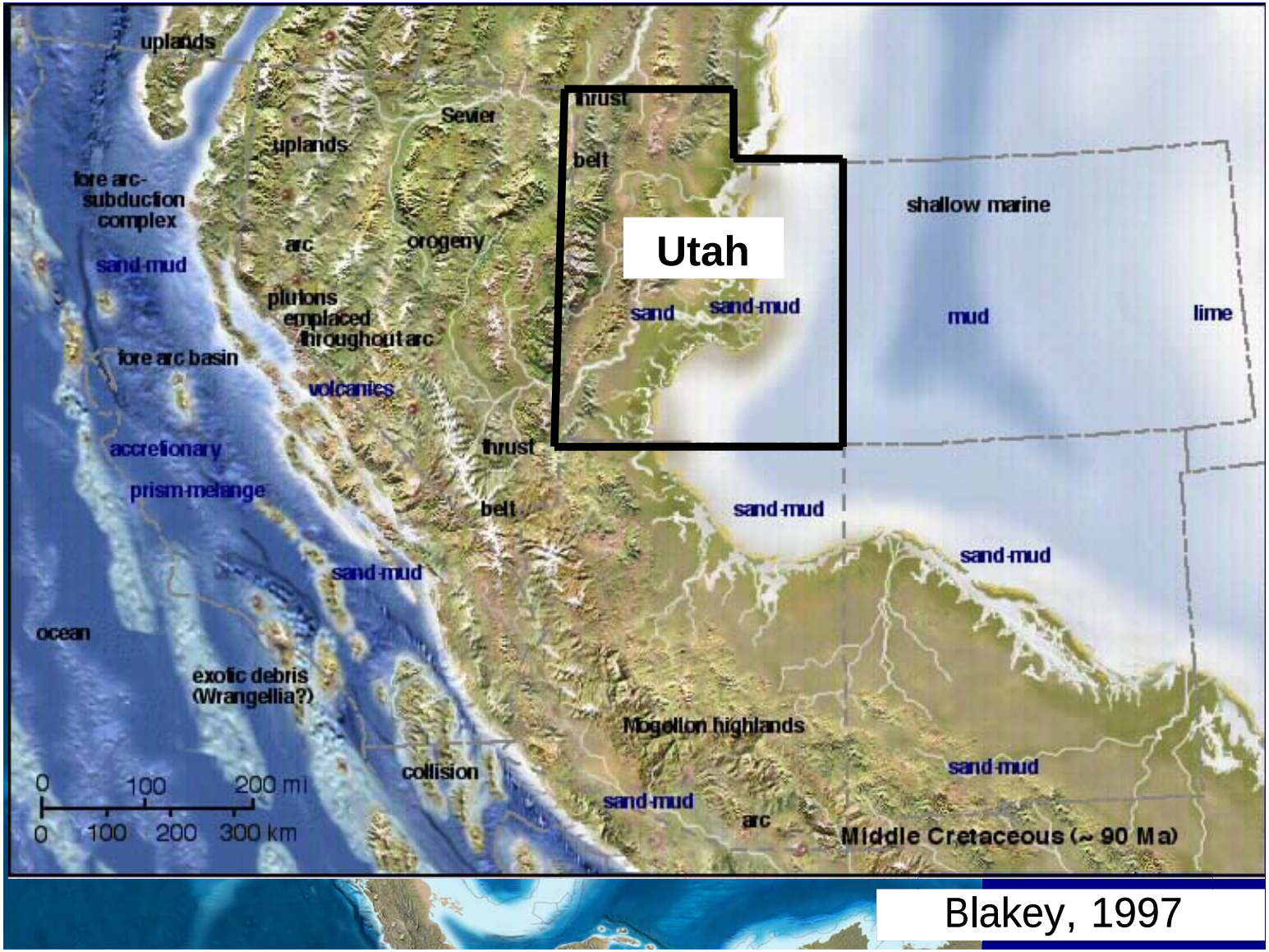
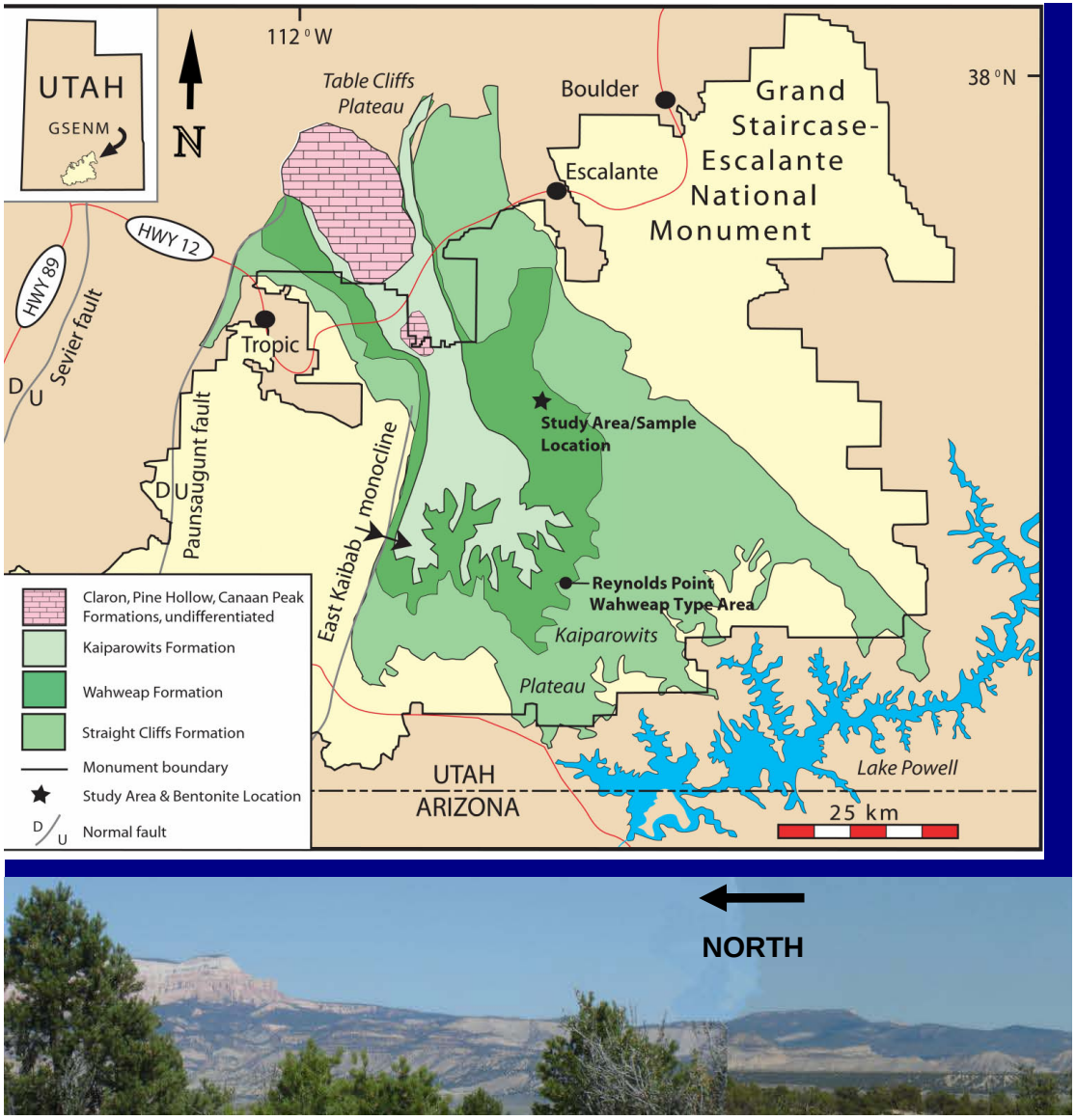
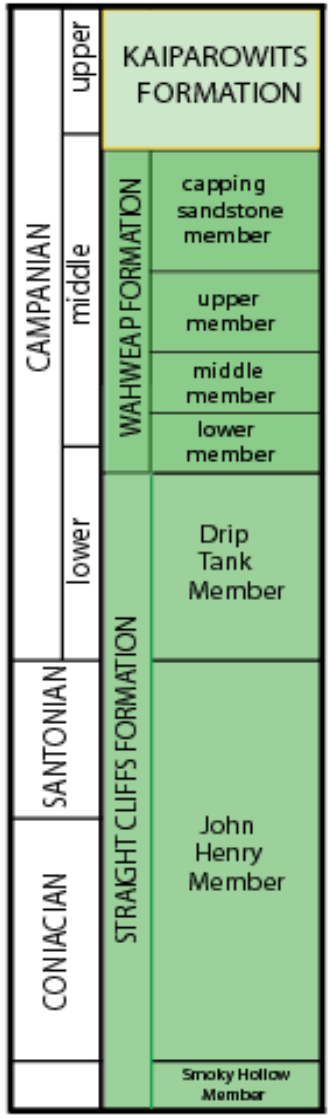
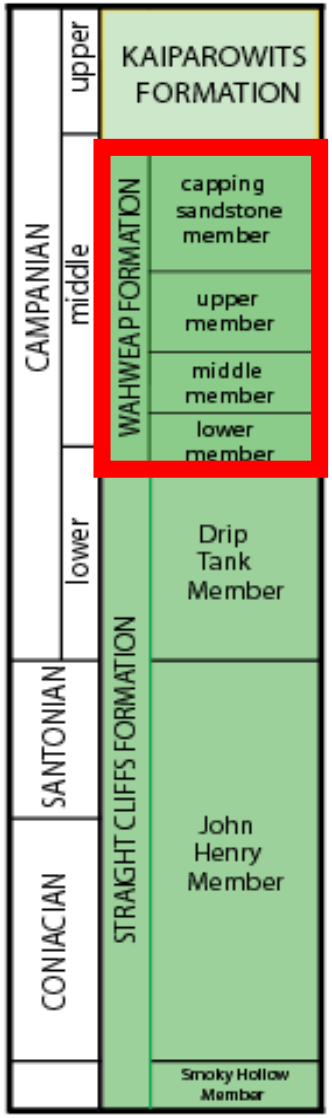
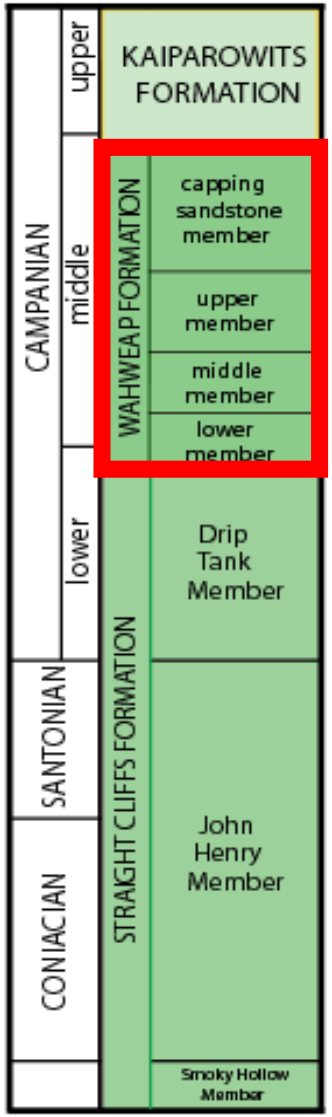

uplands
Sevier
thrust
belt
uplands
fore arc-
subduction
complex
sand-mud
arc
orogeny
Utah
shallow marine
plutons
emplaced
throughout arc
sand
sand-mud
mud
lime
fore arc basin
volcanics
accretionary
prism-melange
thrust
belt
sand-mud
sand-mud
sand-mud
ocean
exotic debris
(Wrangellia?)
Mogollon highlands
sand-mud
collision
sand-mud
arc
Middle Cretaceous (~ 90 Ma)
0 100 200 mi
0 100 200 300 km
Blakey, 1997

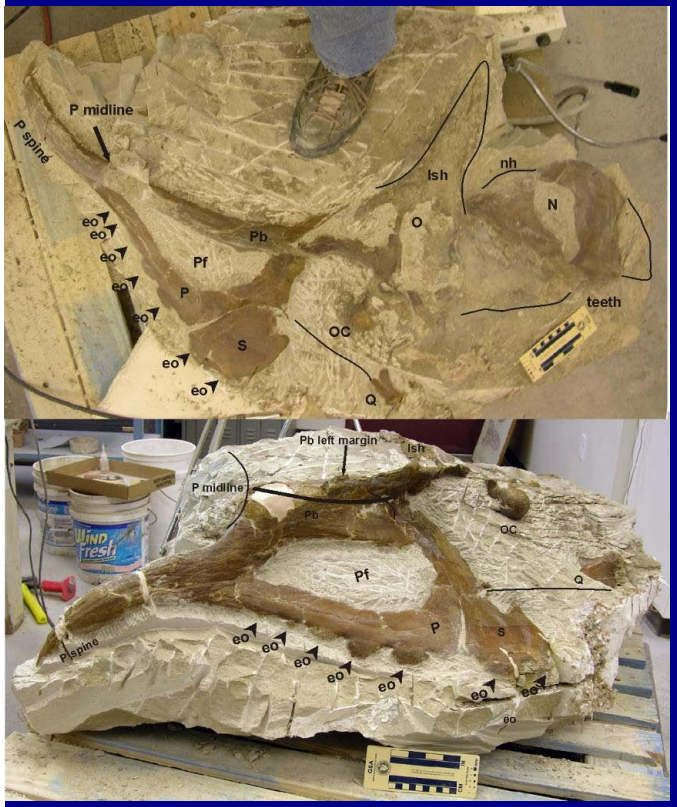

UTAH
GSENM
N
112 °W
38 °N
Table Cliffs Plateau
Boulder
Grand Staircase-Escalante National Monument
Escalante
HWY 12
HWY 89
Sevier fault
Tropic
D U
Paunsaugunt fault
Study Area/Sample Location
East Kaibab monocline
Reynolds Point
Wahweap Type Area
Kaiparowits Plateau
Lake Powell
UTAH
ARIZONA
25 km
Claron, Pine Hollow, Canaan Peak Formations, undifferentiated
Kaiparowits Formation
Wahweap Formation
Straight Cliffs Formation
Monument boundary
Study Area & Bentonite Location
Normal fault
NORTH


CAMPANIAN
upper
middle
lower
SANTONIAN
CONIACIAN
KAIPAROWITS FORMATION
WAHWEAP FORMATION
capping sandstone member
upper member
middle member
lower member
STRAIGHT CLIFFS FORMATION
Drip Tank Member
John Henry Member
Smoky Hollow Member


CAMPANIAN
upper
middle
lower
SANTONIAN
CONIACIAN
KAIPAROWITS FORMATION
WAHWEAP FORMATION
capping sandstone member
upper member
middle member
lower member
STRAIGHT CLIFFS FORMATION
Drip Tank Member
John Henry Member
Smoky Hollow Member


CAMPANIAN
upper
middle
lower
SANTONIAN
CONIACIAN
KAIPAROWITS FORMATION
WAHWEAP FORMATION
capping sandstone member
upper member
middle member
lower member
STRAIGHT CLIFFS FORMATION
Drip Tank Member
John Henry Member
Smoky Hollow Member

Wahweap fossils

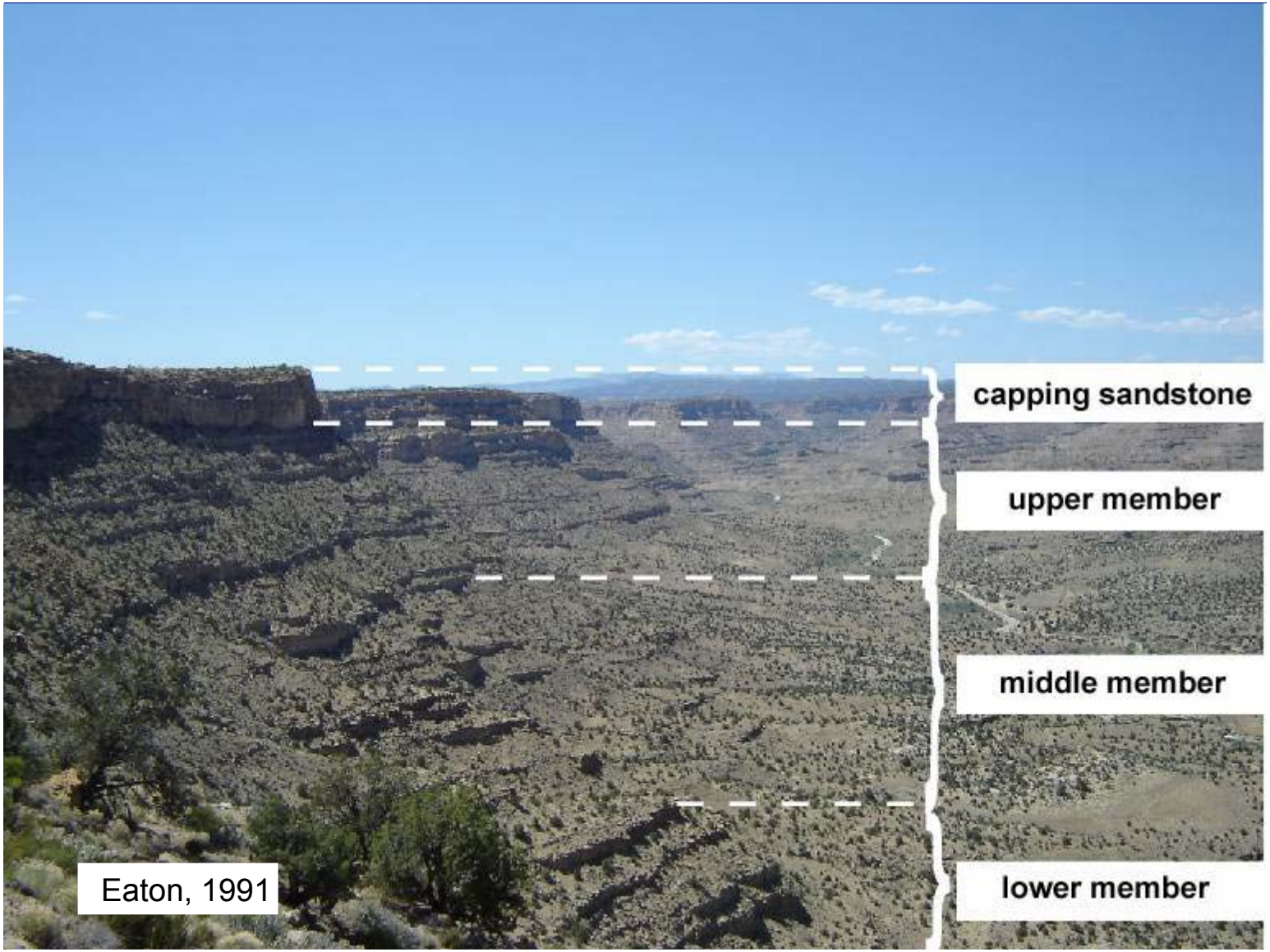


Cimolodon electus

Cimolodon similis

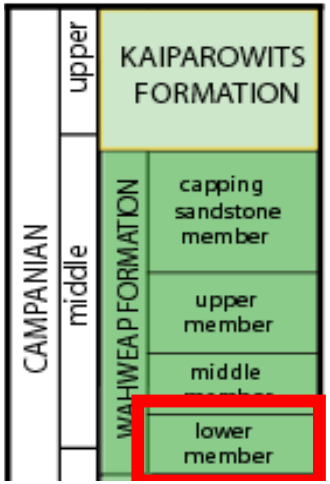
Cimexomys sp. cf. *C. antiquus*

Eaton, 2002

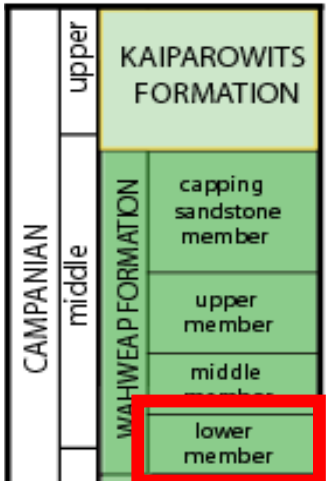

capping sandstone
upper member
middle member
lower member
Eaton, 1991


Henry Mountains
"beds on Tarantula Mesa"
Tarantula Mesa Formation
Masuk Formation
Muley Canyon Formation

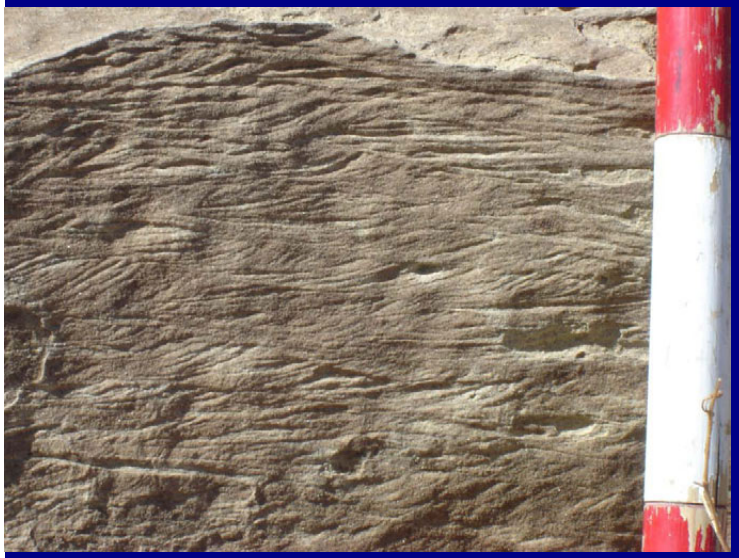
Facies (Kaiparowits Plateau)



Facies (Kaiparowits Plateau)



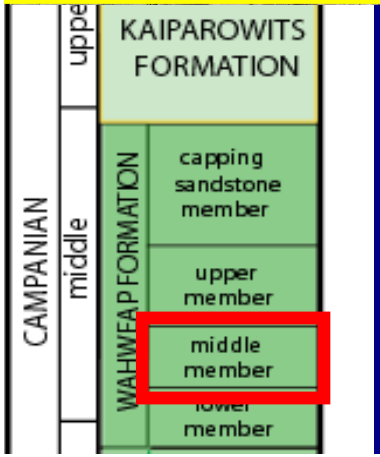
Lower Member



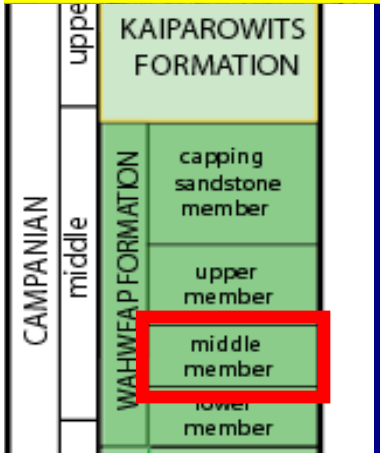
- Mud dominated with two extensive amalgamated sandstone bodies
- Carbonaceous shale (subaqueous floodplain), splay and levee deposits
- Pedogenic carbonate associated with amalgamated sandstone bodies

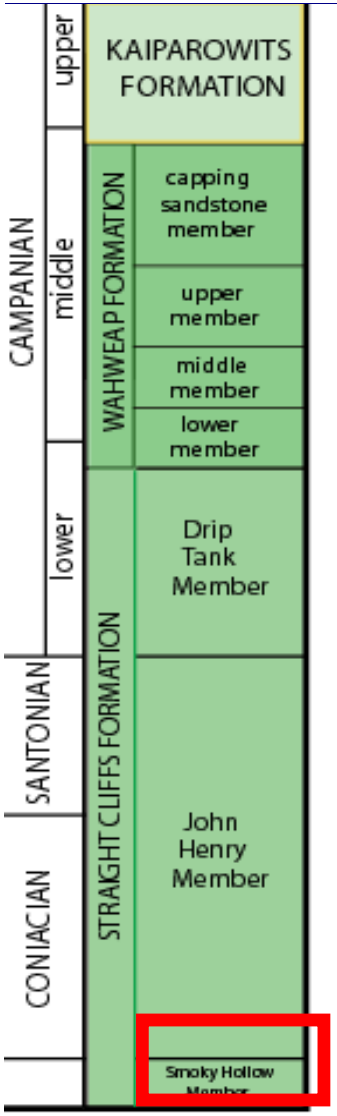
Rapid sedimentation in a seasonal environment

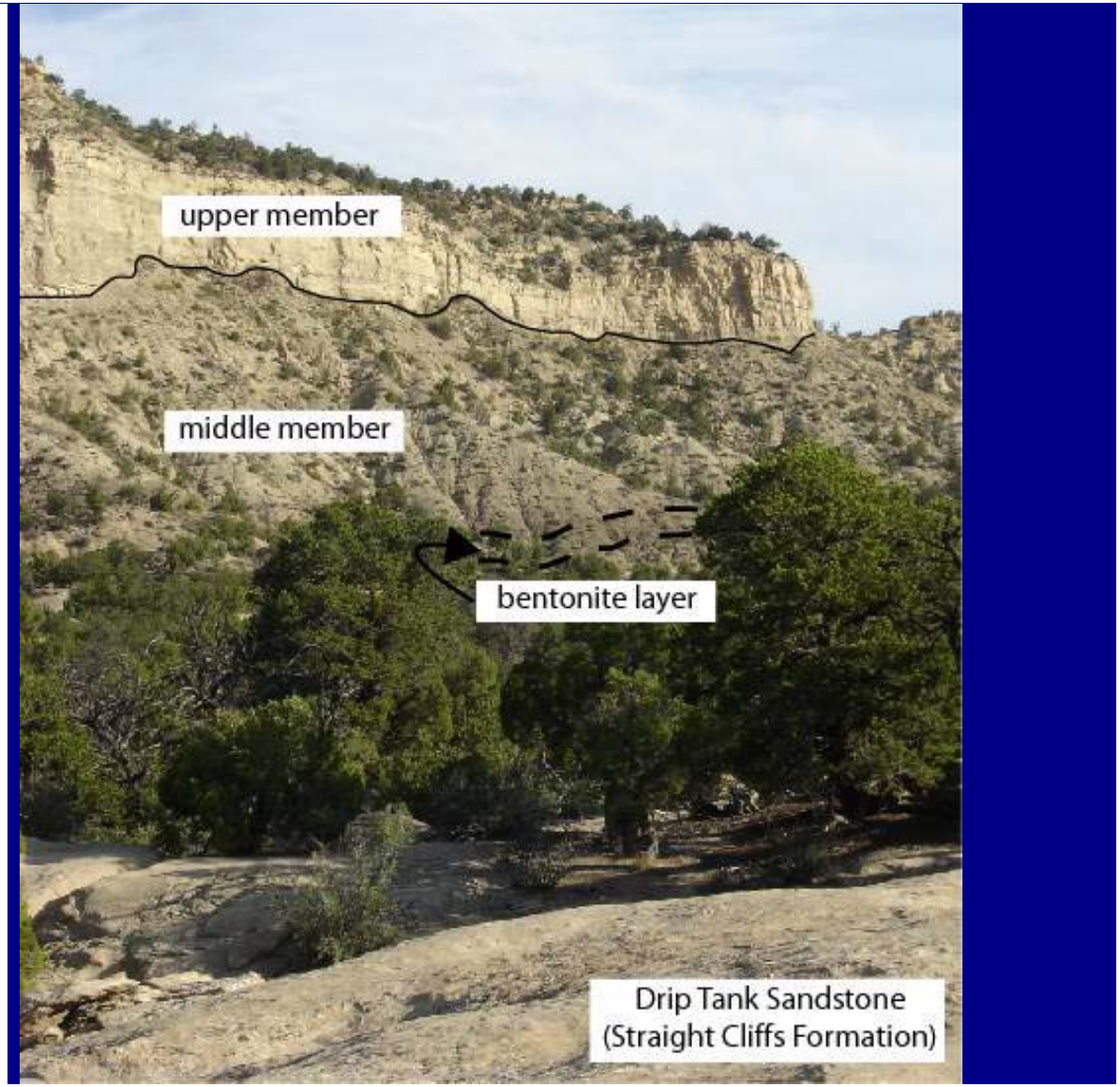
Facies (Kaiparowits Plateau)



Facies (Kaiparowits Plateau)

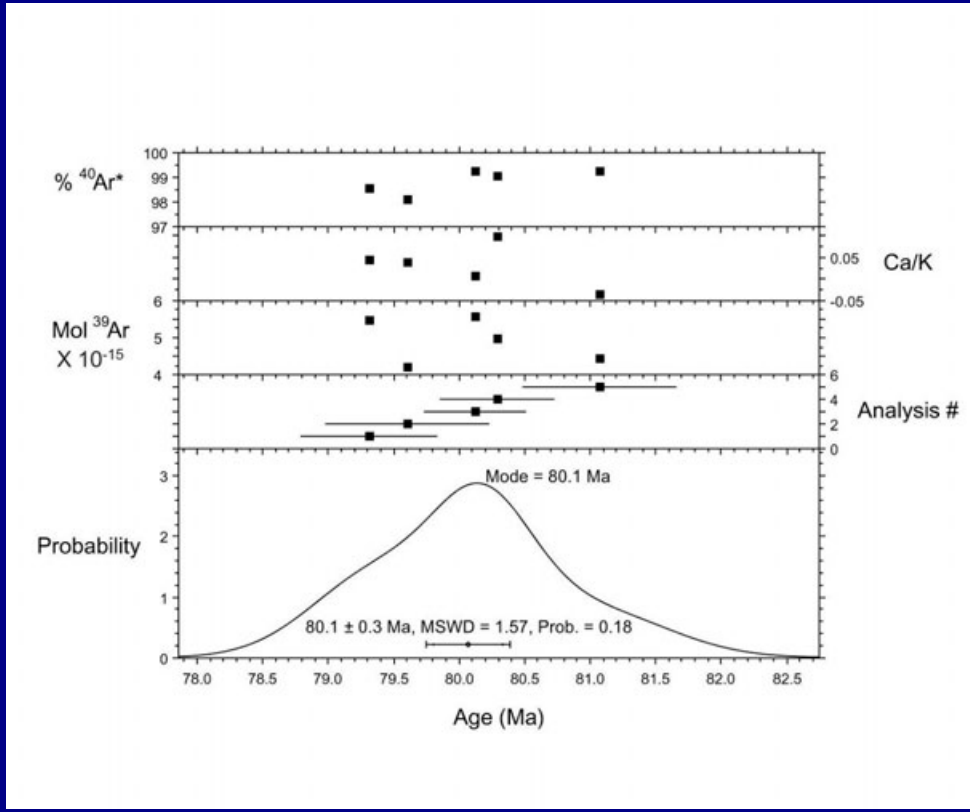



CAMPANIAN
upper
middle
lower
SANTONIAN
CONIACIAN
KAIPAROWITS FORMATION
WAHWEAP FORMATION
capping sandstone member
upper member
middle member
lower member
STRAIGHT CLIFFS FORMATION
Drip Tank Member
John Henry Member
Smoky Hollow Member


upper member
middle member
bentonite layer
Drip Tank Sandstone
(Straight Cliffs Formation)

Age information provided by $^{40}Ar/^{39}Ar$ dating of 5 sanidine crystals

- Radiometric dates from a volcanic ash
- Detrital zircon ages from the capping sandstone (Larsen, 2007)
- Previous radiometric dates from the overlying Kaiparowits Formation

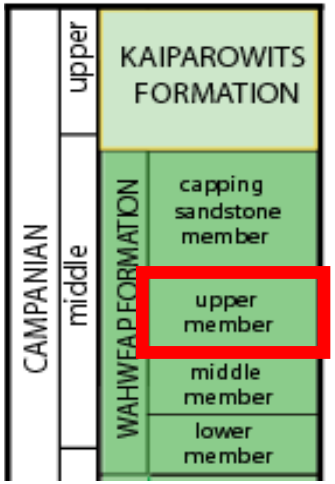


Middle Member

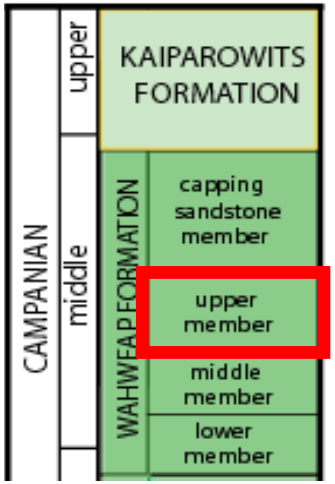
- Mud dominated
- Carbonaceous shale (subaqueous) with minor pedogenesis towards top of horizons
- Channel elements contain wackes or siltstones

High accommodation space, rapid sedimentation

Facies (Kaiparowits Plateau)



Facies (Kaiparowits Plateau)

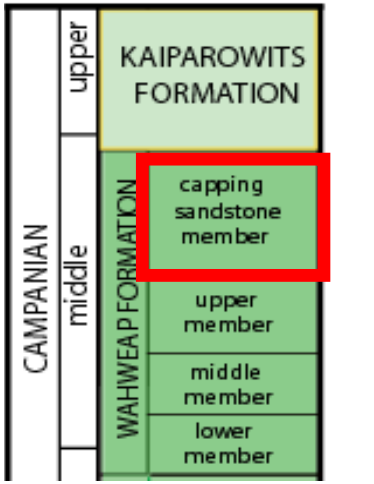


Upper Member

- Sandstone dominated
- IHS occurs in lower part
- Multistorey channel sandstones, numerous levee and splay deposits

Slow reduction in accommodation space, tidal influence

Facies (Kaiparowits Plateau)

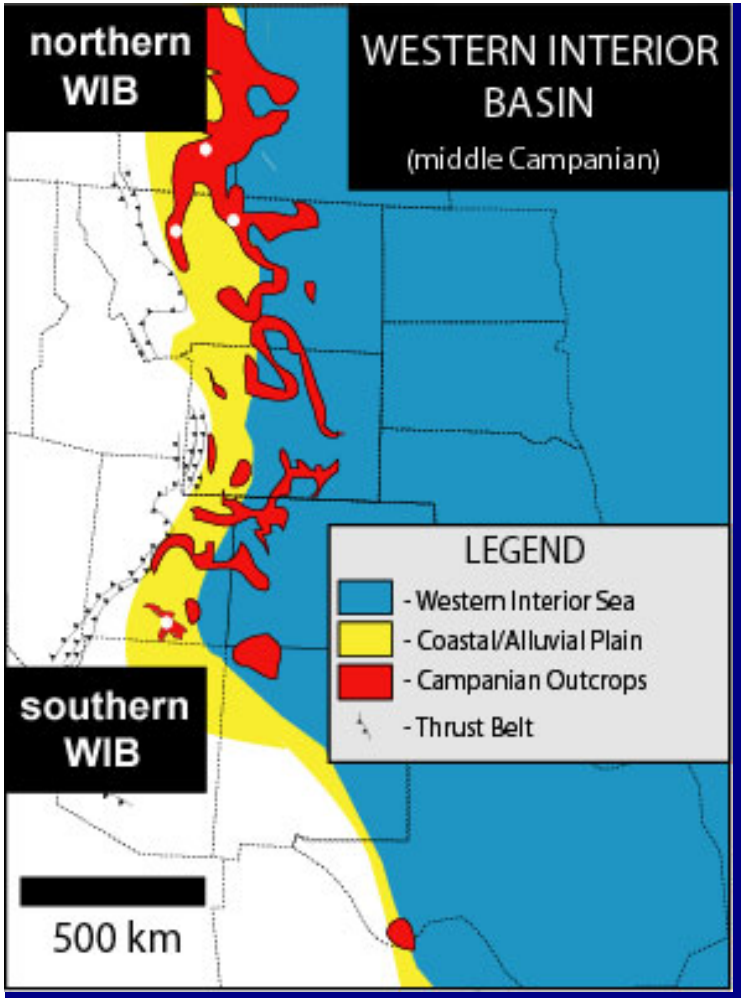


Capping Sandstone

- Major shift in depositional environment:

  meandering to braided
- Large bars, numerous internal erosive surfaces, incision up to 2 m
- Sandstone dominated; minor palaeosol horizons with pedogenic carbonate

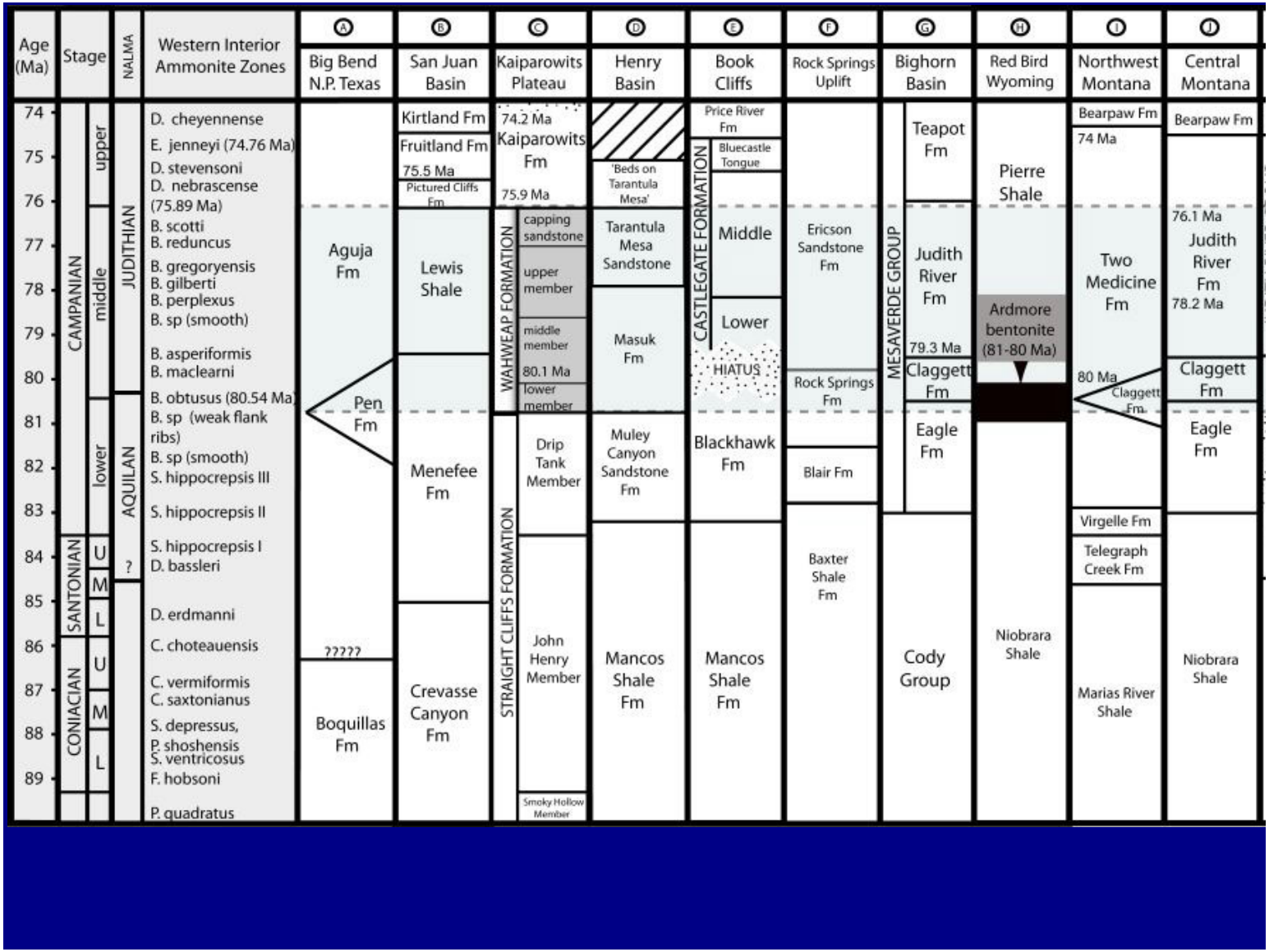
Low accommodation space, extensive reworking of deposits



Western Interior Seaway: Late Cretaceous cyclothems

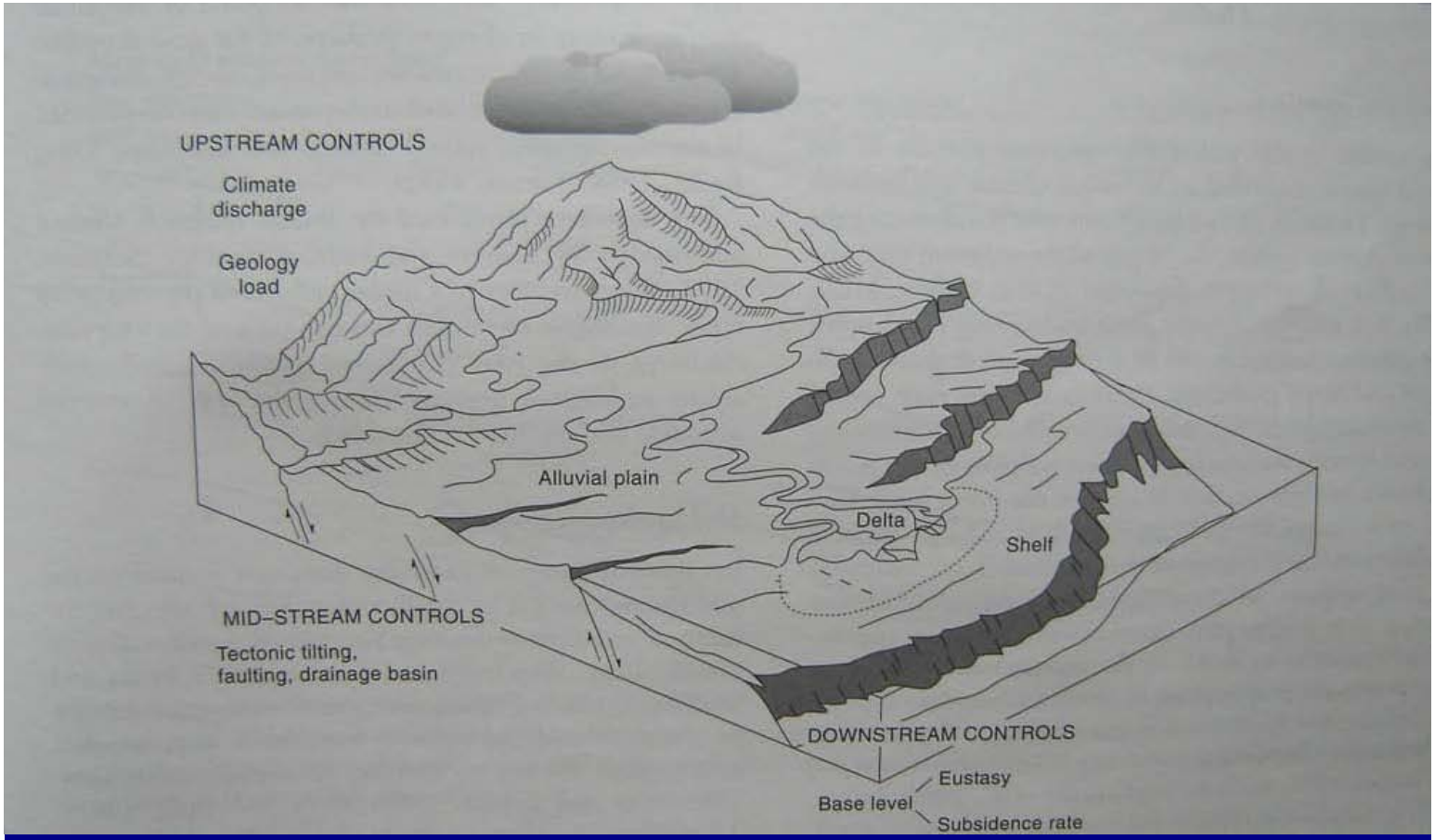
- Bearpaw (~74.0 Ma)
- Claggett (79.6 Ma)
- Niobrara
- Greenhorn

Kauffman, 1977

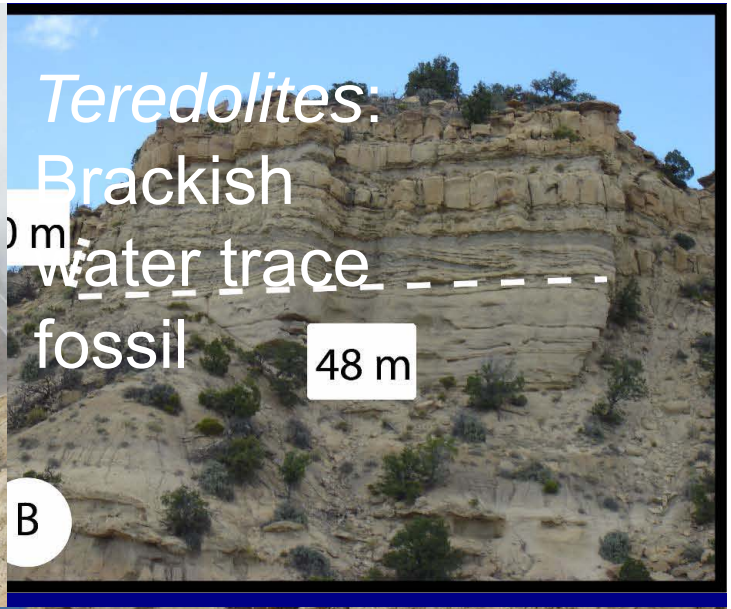

Age (Ma)
Stage
NALMA
Western Interior Ammonite Zones
A Big Bend N.P. Texas
B San Juan Basin
C Kaiparowits Plateau
D Henry Basin
E Book Cliffs
F Rock Springs Uplift
G Bighorn Basin
H Red Bird Wyoming
I Northwest Montana
J Central Montana
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
CAMPANIAN
SANTONIAN
CONIACIAN
upper
middle
lower
U
M
L
JUDITHIAN
AQUILAN
?
D. cheyennense
E. jenneyi (74.76 Ma)
D. stevensoni
D. nebrascense
(75.89 Ma)
B. scotti
B. reduncus
B. gregoryensis
B. gilberti
B. perplexus
B. sp (smooth)
B. asperiformis
B. maclearni
B. obtusus (80.54 Ma)
B. sp (weak flank ribs)
B. sp (smooth)
S. hippocrepsis III
S. hippocrepsis II
S. hippocrepsis I
D. bassleri
D. erdmanni
C. choteauensis
C. vermiformis
C. saxtonianus
S. depressus,
P. shoshensis
S. ventricosus
F. hobsoni
P. quadratus
Aguja Fm
Pen Fm
?????
Boquillas Fm
Kirtland Fm
Fruitland Fm
75.5 Ma
Pictured Cliffs Fm
Lewis Shale
Menefee Fm
Crevasse Canyon Fm
74.2 Ma
Kaiparowits Fm
75.9 Ma
WAHWEAP FORMATION
capping sandstone
upper member
middle member
80.1 Ma
lower member
STRAIGHT CLIFFS FORMATION
Drip Tank Member
John Henry Member
Smoky Hollow Member
'Beds on Tarantula Mesa'
Tarantula Mesa Sandstone
Masuk Fm
Muley Canyon Sandstone Fm
Mancos Shale Fm
Price River Fm
Bluecastle Tongue
CASTLEGATE FORMATION
Middle
Lower
HIATUS
Blackhawk Fm
Mancos Shale Fm
Ericson Sandstone Fm
Rock Springs Fm
Blair Fm
Baxter Shale Fm
MESAVERDE GROUP
Teapot Fm
Judith River Fm
79.3 Ma
Claggett Fm
Eagle Fm
Cody Group
Pierre Shale
Ardmore bentonite (81-80 Ma)
Niobrara Shale
Bearpaw Fm
74 Ma
Two Medicine Fm
80 Ma
Claggett Fm.
Virgelle Fm
Telegraph Creek Fm
Marias River Shale
Bearpaw Fm
76.1 Ma
Judith River Fm
78.2 Ma
Claggett Fm
Eagle Fm
Niobrara Shale

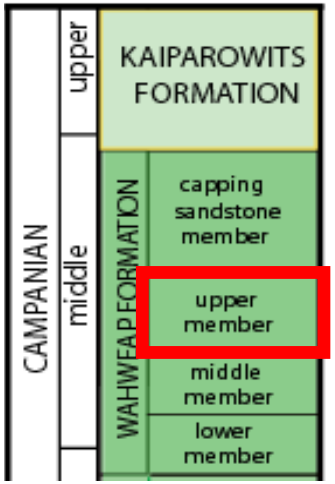
Non-marine sequence stratigraphy

- Changes in base level affect deposition in continental environments:
  - Stream type
  - Accommodation space (aggradation vs. amalgamation)
- Transgressions can be eustatic (global) or localised (due to tectonic subsidence).
- Were changes in base level during Wahweap deposition eustatic or tectonic?

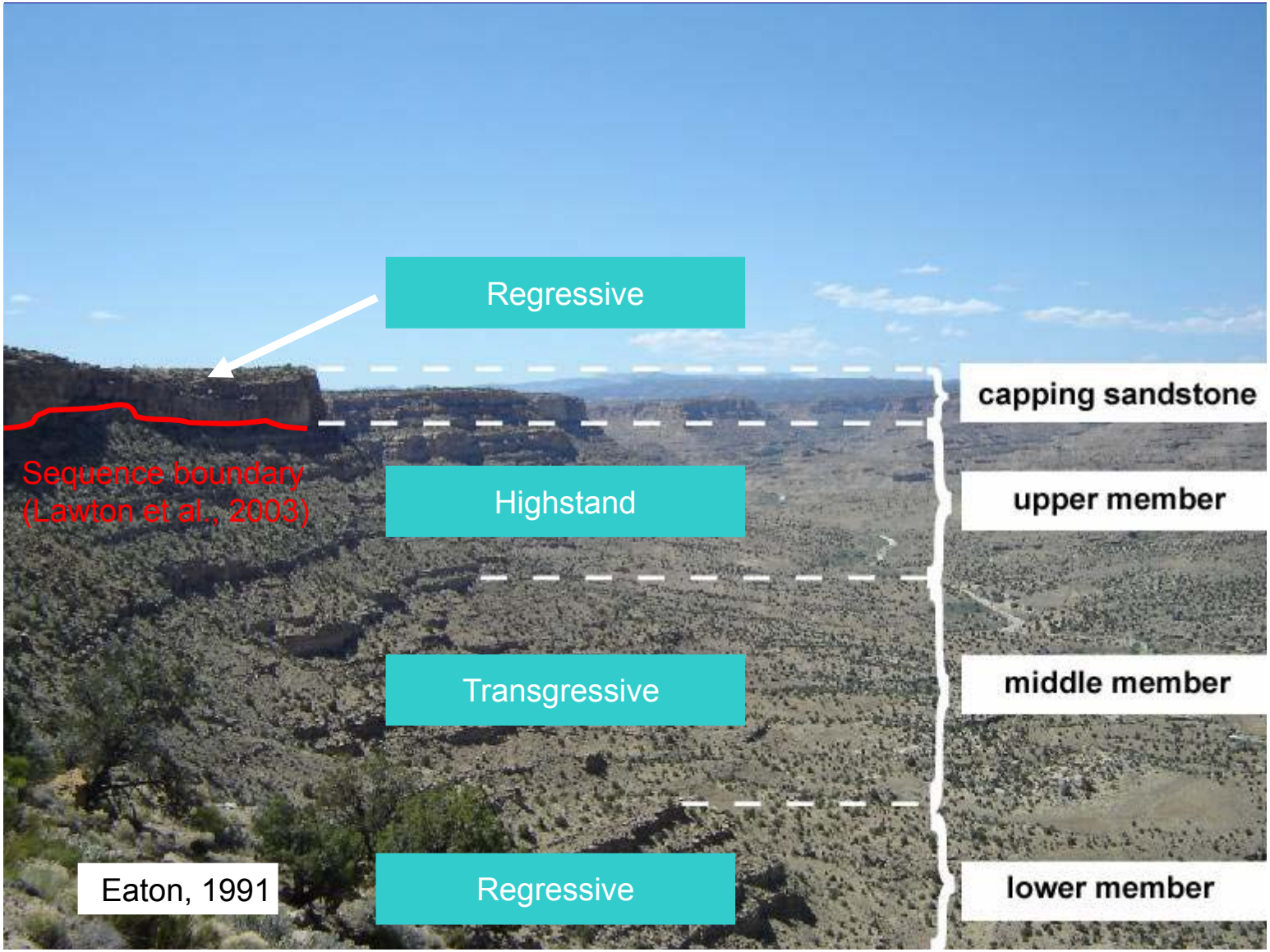


From Emery and Myers, 1996





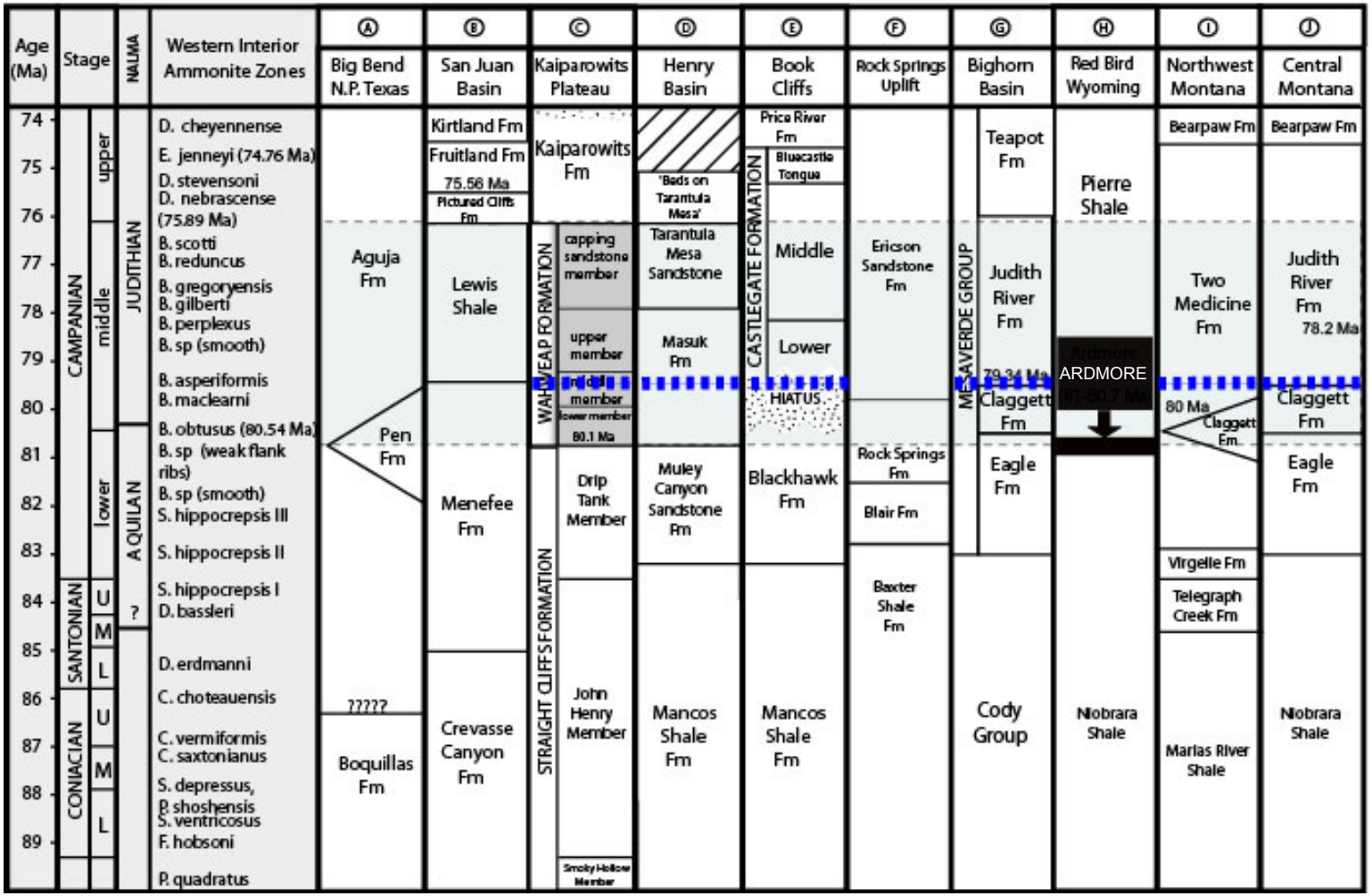
Heterolithic strata: Tidal couplets


Regressive
capping sandstone
Sequence boundary
(Lawton et al., 2003)
Highstand
upper member
Transgressive
middle member
Eaton, 1991
Regressive
lower member

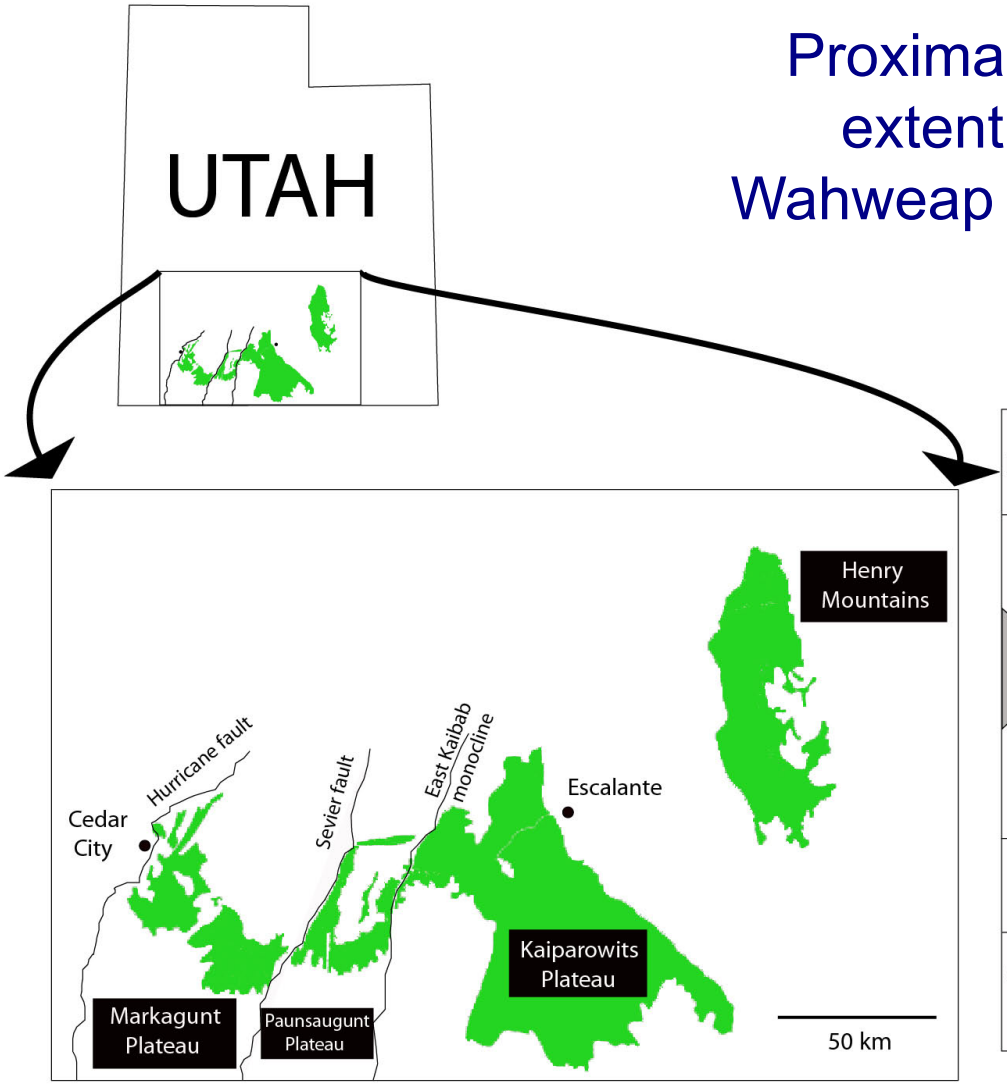
Are stratigraphic changes in the Wahweap Formation controlled by eustasy or tectonic events?

- Tectonic events generate changes that are localised and vary proximally/distally.
- Eustatic events generate changes that are extensive and noticeable in proximal and distal parts of a basin.

Age of the Claggett

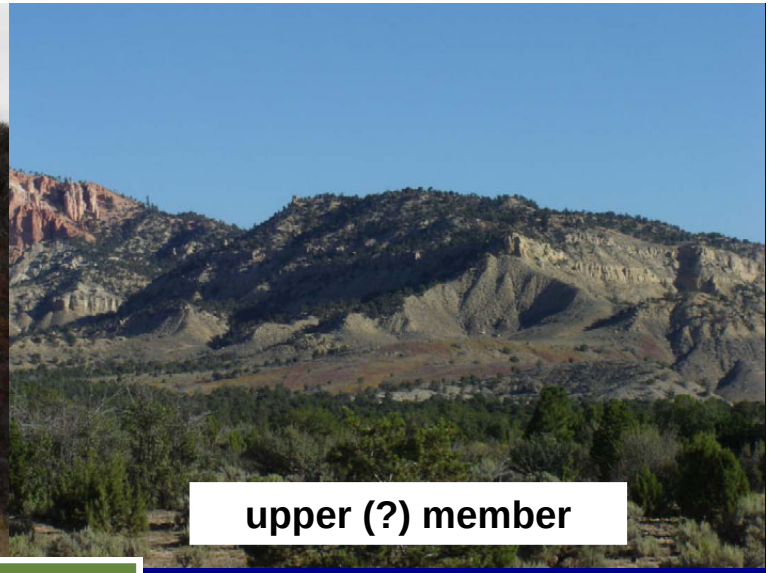


Proximal – distal extent of the Wahweap Formation

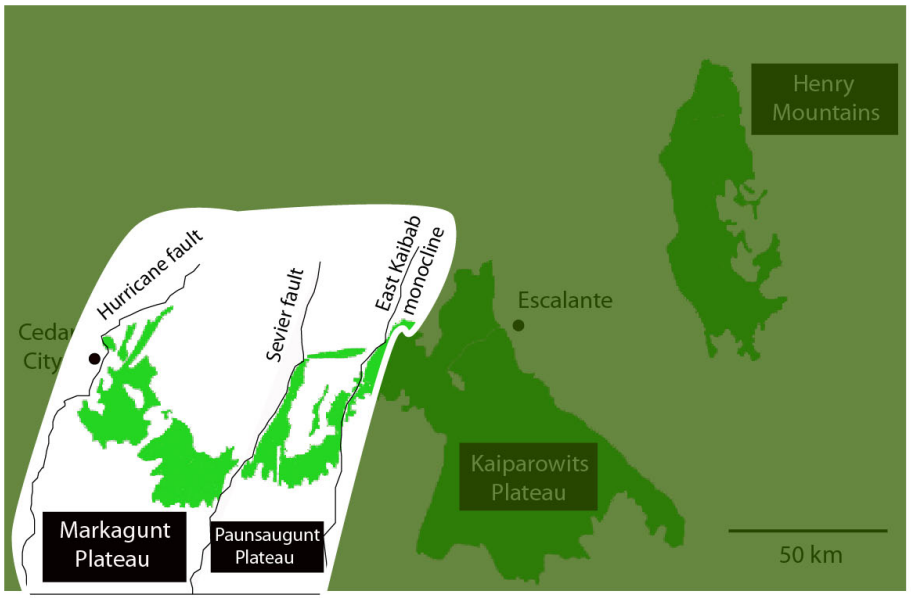


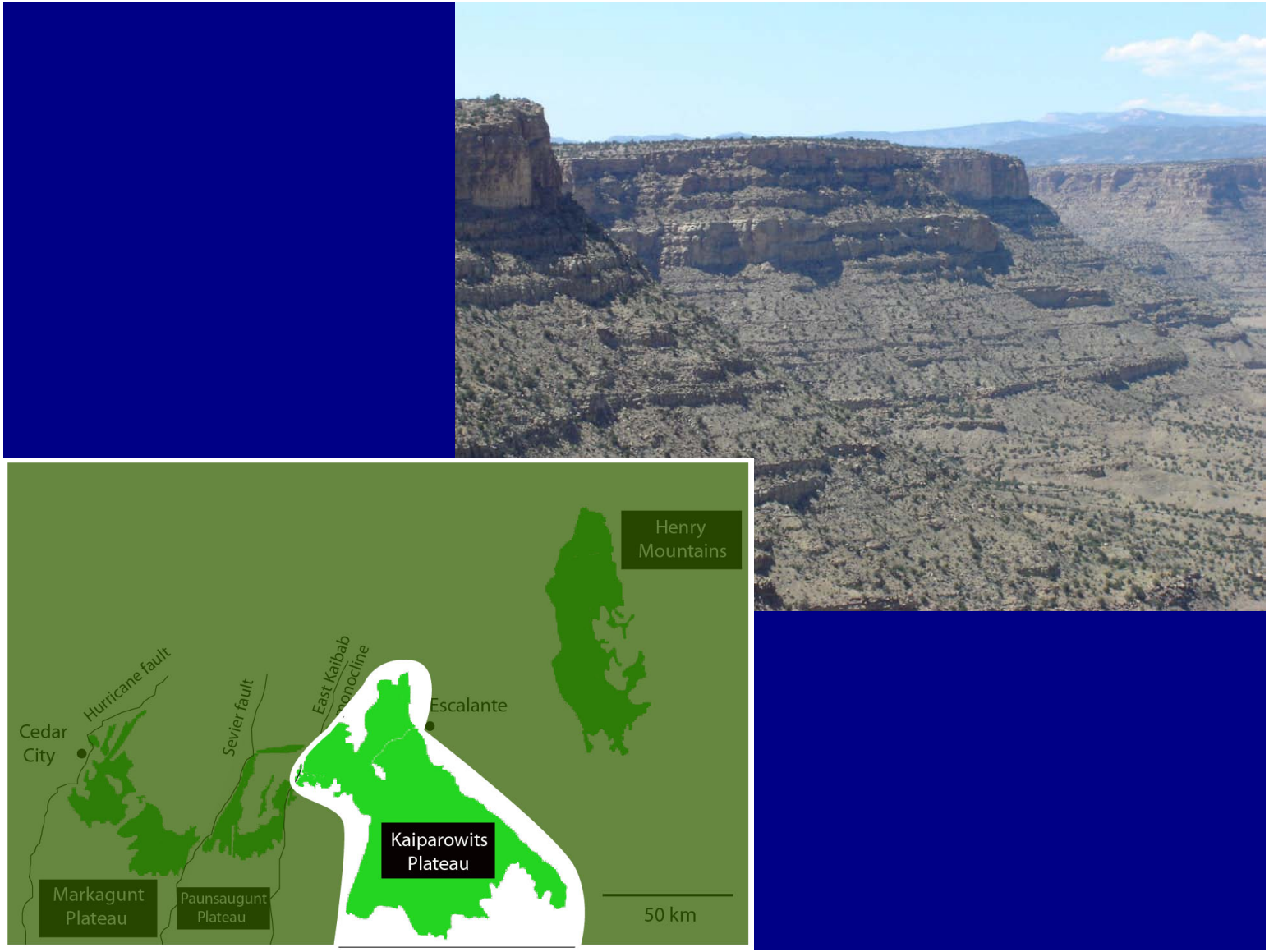
Markagunt/ Paunsaugunt plateaus	Kaiparowits Plateau	Henry Mountains
Claron Formation		
Uncon-formity	Kaiparowits Formation	"beds on Tarantula Mesa"
Kaiparowits (?) Formation	Wahweap Formation	Tarantula Mesa Formation
Wahweap Formation		Masuk Formation
Straight Cliffs Formation	Straight Cliffs Formation	Muley Canyon Formation

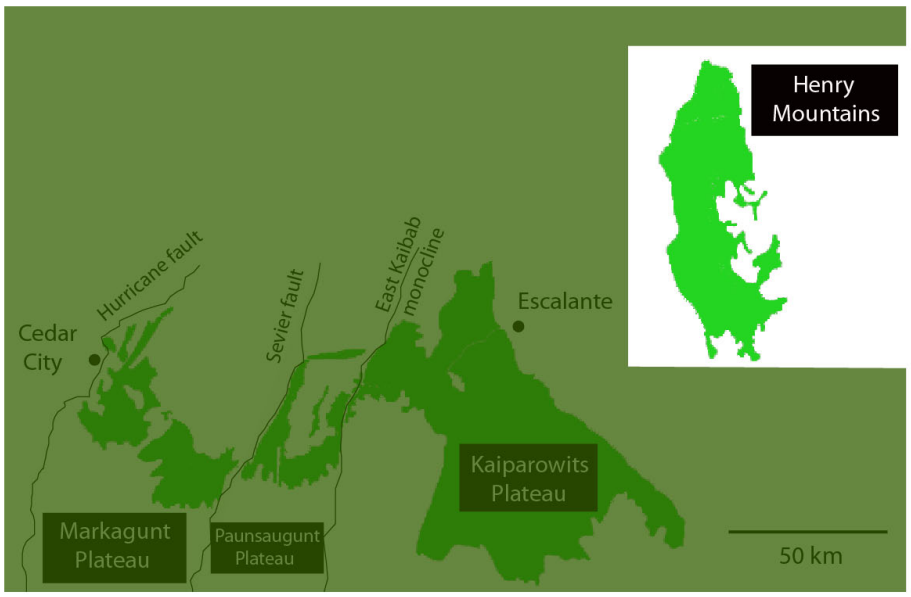
capping sandstone



upper (?) member




Henry Mountains
Hurricane fault
Sevier fault
East Kaibab
Escalante
Cedar City
Kaiparowits Plateau
Markagunt Plateau
Paunsaugunt Plateau
50 km


Henry Mountains
Hurricane fault
Sevier fault
East Kaibab monocline
Escalante
Cedar City
Kaiparowits Plateau
Markagunt Plateau
Paunsaugunt Plateau
50 km

Conclusions – Alluvial Architecture

- Wahweap deposition occurred in a wet, seasonal climate.
- Sand:mud ratios and alluvial architecture suggest high accommodation space in the lower and middle members, with low accommodation space in the top of the upper and capping sandstone.
- Alluvial architecture and correlation with other sequences support the placement of a sequence boundary at the upper-capping sandstone contact.

Conclusions – Tectonic and Eustatic Influences

- Eustasy (the Claggett transgression) controls major changes in stacking patterns, depositional environment and the position of sequence boundaries.

- Smaller-scale changes in alluvial architecture and sand:mud ratios may be tectonically or climatically driven.

Acknowledgements

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- Eric Roberts
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- Dr. Alan Titus, Doug Powell & Marietta Eaton
- L. Tapanila, T. Hieronymus, P. O'Connor
- Escalante Outfitters
- Mike Getty and the UMNH Field Crew

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