Separating Allogenic and Autogenic Controls in a Super-Greenhouse Fluvial System*

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Abstract

The early Eocene fluvial succession in the Uinta basin displays distinct stratigraphic changes in channel-fill and lateral/vertical channel amalgamation character. The channel fills alternate between "normal," with dominantly trough-cross-stratified sandstones organized into thalweg deposits and barforms with lateral, downcurrent and upcurrent accretion directions. Such "normal" channels alternate at different scales with channel fills that are dominantly plane-parallel and climbing-ripple laminated, organized into erosionally based, thick, downstream accreting packages, in many places bioturbated at their tops. Such channel fills indicate rapid local infilling and consequent high avulsion rates. Avulsions are commonly linked to autogenic controls like local gradient or topographic variations. We link the avulsion-rate variations to episodic changes into highly seasonal, ephemeral discharge and deposition with an initial erosional stage, followed by high rates of deposition, and then by nondeposition, bioturbation, and paleosol formation. The great thickness of individual accretion packages suggests that such channels were locally filled and forced to avulse during a single season. In some stratigraphic intervals the degree of lateral and vertical channel amalgamation suggests development of megafans. Based on stable carbon isotope and paleosol analyses, we link these high-frequency stratigraphic changes in fluvial deposition style to the PETM and the successive early Eocene hyperthermals. We interpret the changing fluvial style to be controlled by intensification of the hydrological cycle during the hyperthermals. Nevertheless, the specific distribution of channel fill styles and avulsion rates is controlled by local erosion and deposition rates, and laterally the channel style changes due to these autogenic controls.

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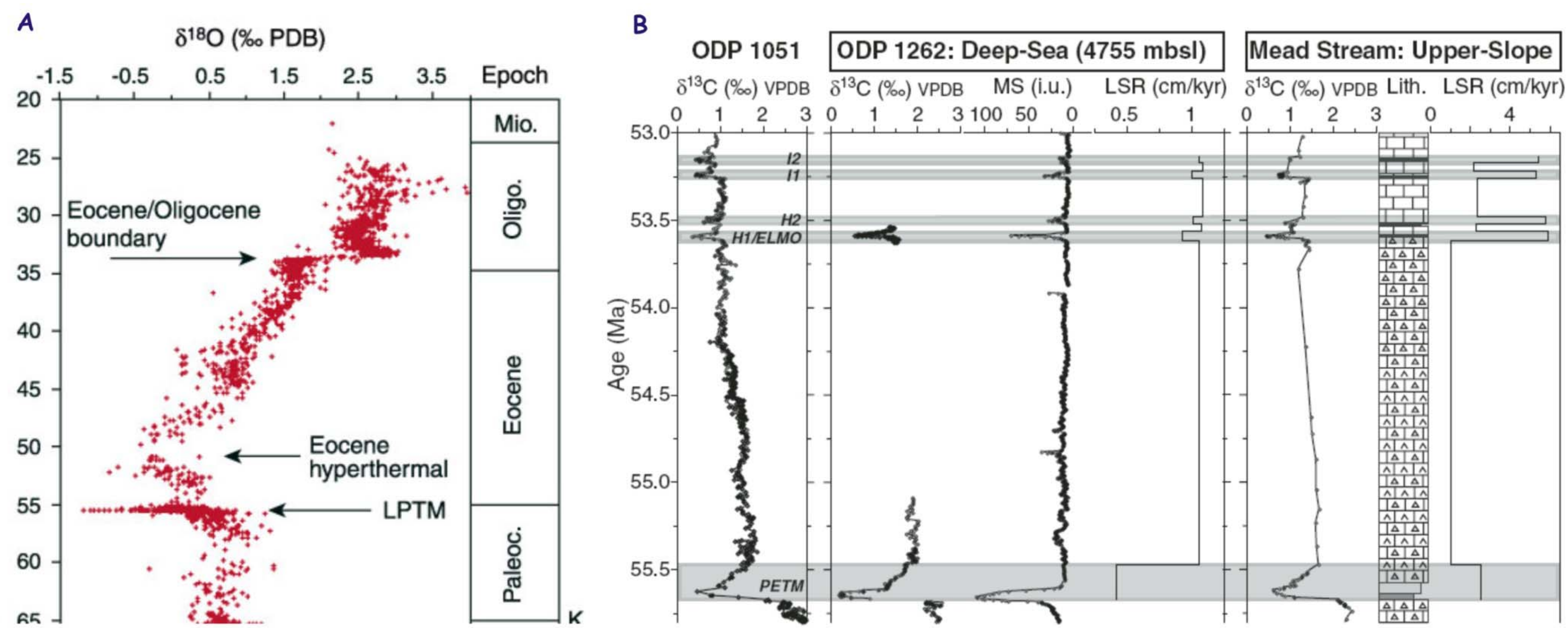
"SUPER-GREENHOUSE" EARLY EOCENE CLIMATE:

Paleocene/Eocene Thermal Maximum (PETM) - ca 55.3-55.7 Ma

(Lourens et al., 2005)

Hyperthermals H1, H2, I1, I2 - ca 53.6, 53.5 & 53.3-53.2 Ma

(Cramer et al., 2003; Lourens et al., 2005)



(A) modified from Bralower, et al., 2002, after Zachos et al., 1993, 2001, (B) from Nicolo et al., 2007

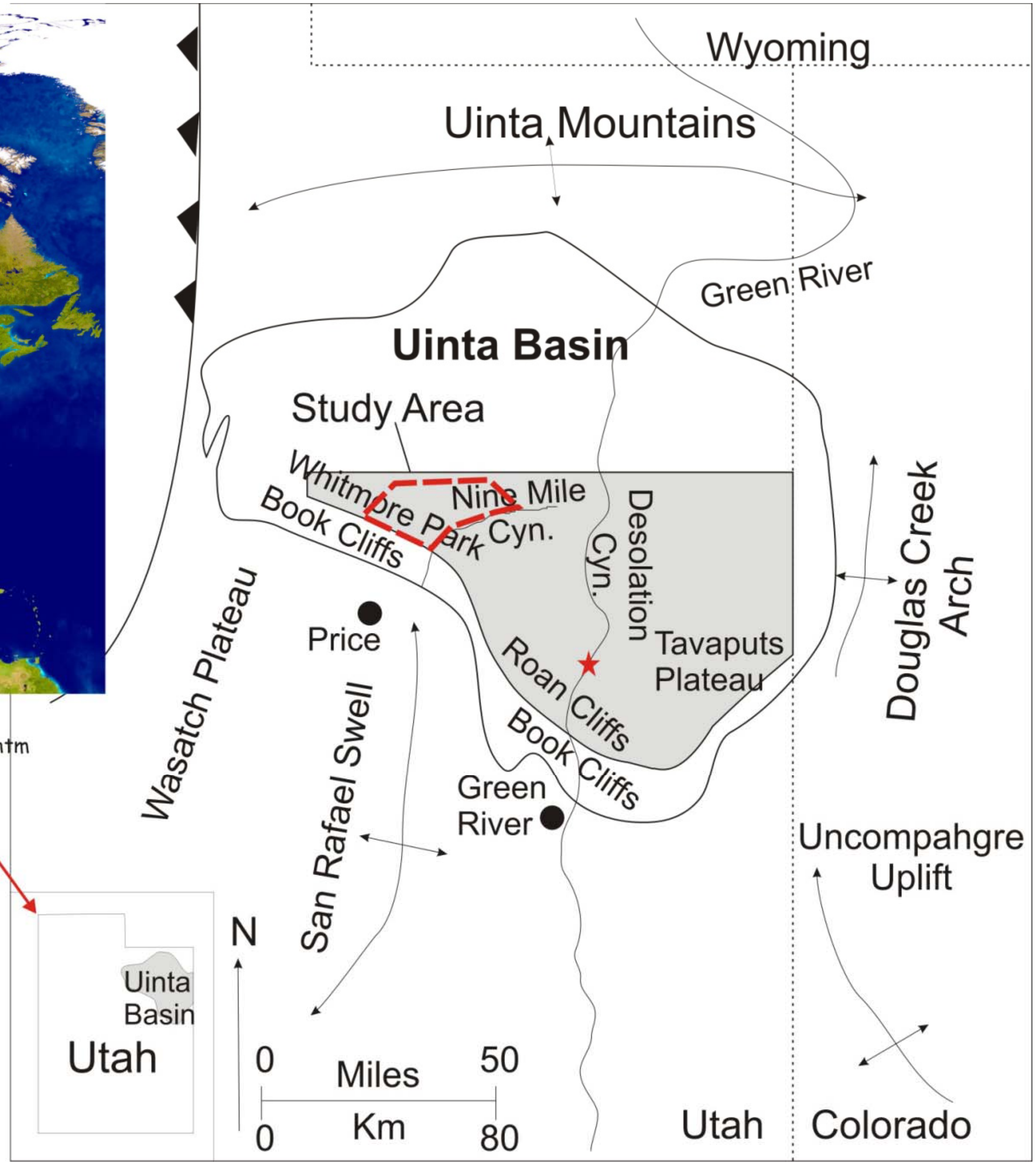
QUESTIONS

- What are the effects of climate change on river systems?

- What are the controls on water discharge?
- Deposition rates?
- Channel type changes?
- Channel avulsions?

UINTA BASIN, UTAH

Satellite image of North America from
http://www.geographicguide.com/north-america-image.htm



Map based on
Castle (1990) and Taylor (2002).

DATASET

- Measured sections, mapping, walk-out of stratigraphic intervals
- Paleosol & continental trace fossil analyses
- Bulk organic carbon isotope ($\delta^{13}C_{org}$) & C_{org}/N_{tot}

Dominant channel-fill type

Sedimentary structures:

- dominantly plane-parallel-laminated sandstones
- +convex-up low-angle bedforms
- +climbing ripples
- +structureless sandstones
- +soft-clast conglomerates
- +minor cross-stratification (5-10% of observed volume)

Geometry:

- multiple internal erosion surfaces
- convex-up low-angle barforms with, dominantly downstream accretion sets
- in places bioturbation & paleosols at accretion set boundaries

Plane-parallel lamination gradational

Sedimentary structures:

- dominantly gradational plane-parallel-laminated sandstones
- +convex-up low-angle bedforms
- +climbing ripples
- +structureless sandstones
- +soft-clast conglomerates
- +minor cross-stratification (5-10% of observed volume)

Geometry:

- multiple internal erosion surfaces
- convex-up low-angle barforms with, dominantly downstream accretion sets
- in places bioturbation & paleosols at accretion set boundaries

= HIGH DEPOSITION RATES & EPISODIC DEPOSITION

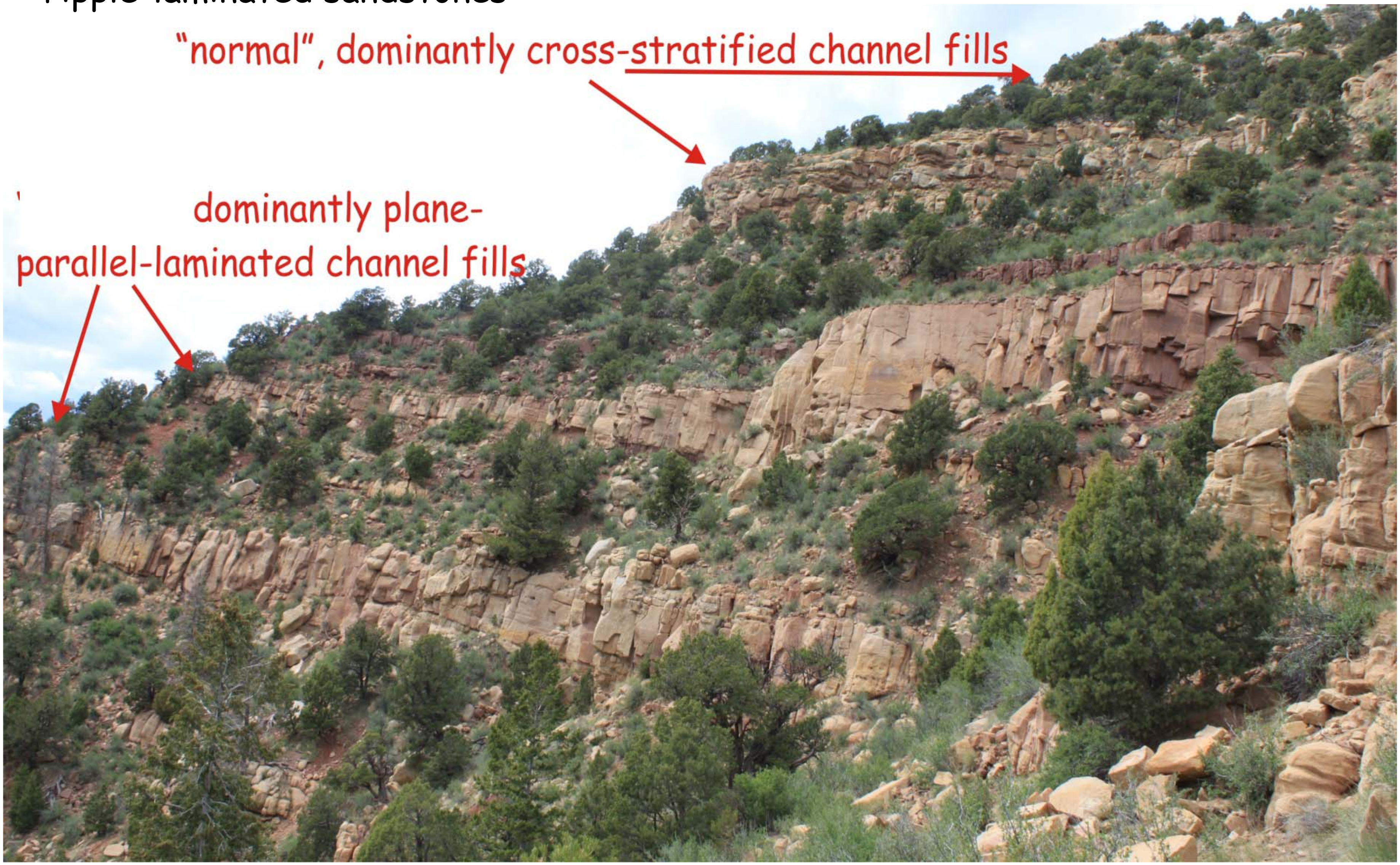
"NORMAL" CHANNEL FILLS

Sedimentary structures:

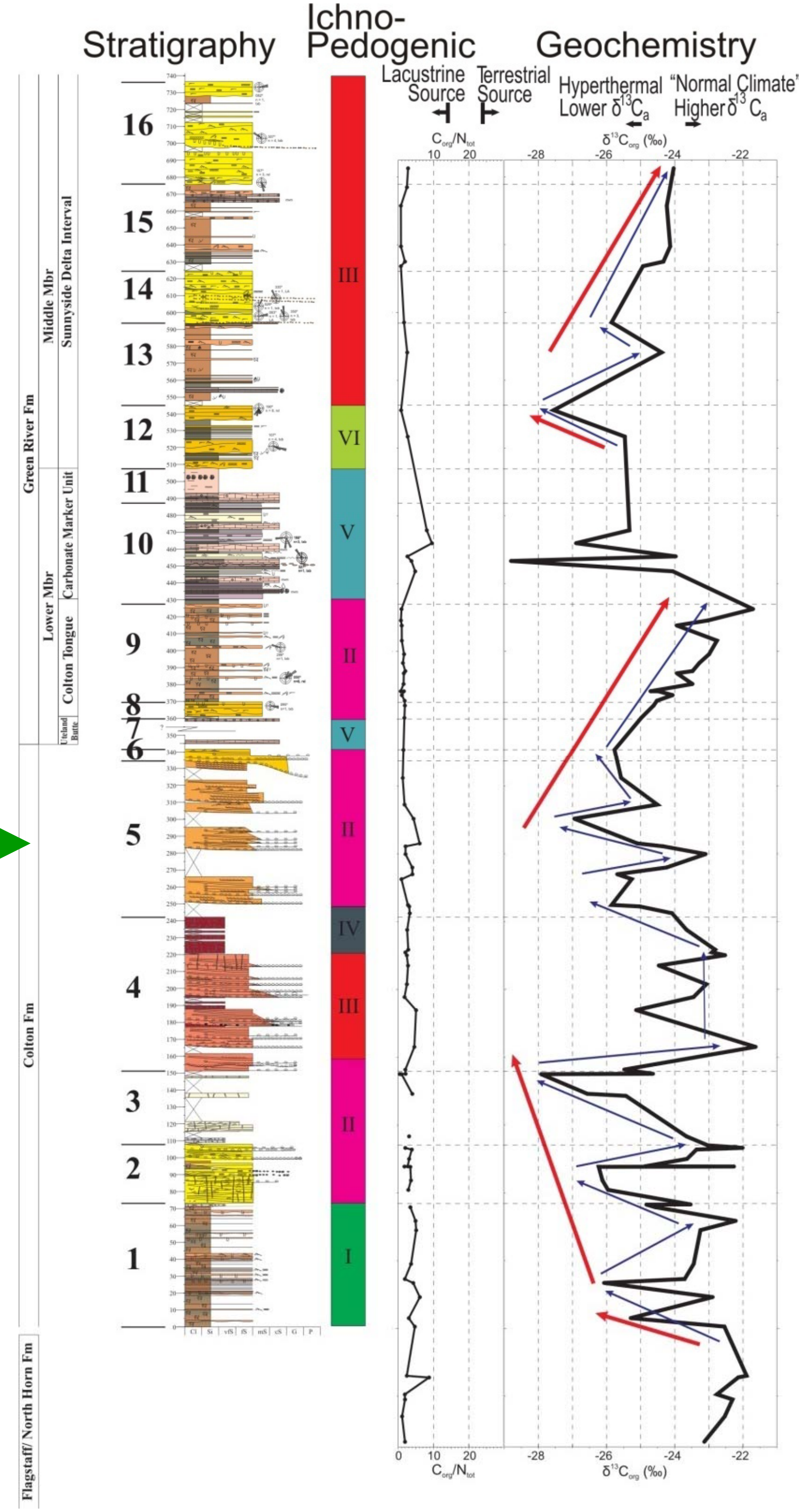
- dominantly cross-stratified sandstones
- +plane-parallel-laminated sandstone
- +ripple-laminated sandstones

Geometry:

multiple internal erosion surfaces
complex, thin, lateral, downstream and upstream accretion sets



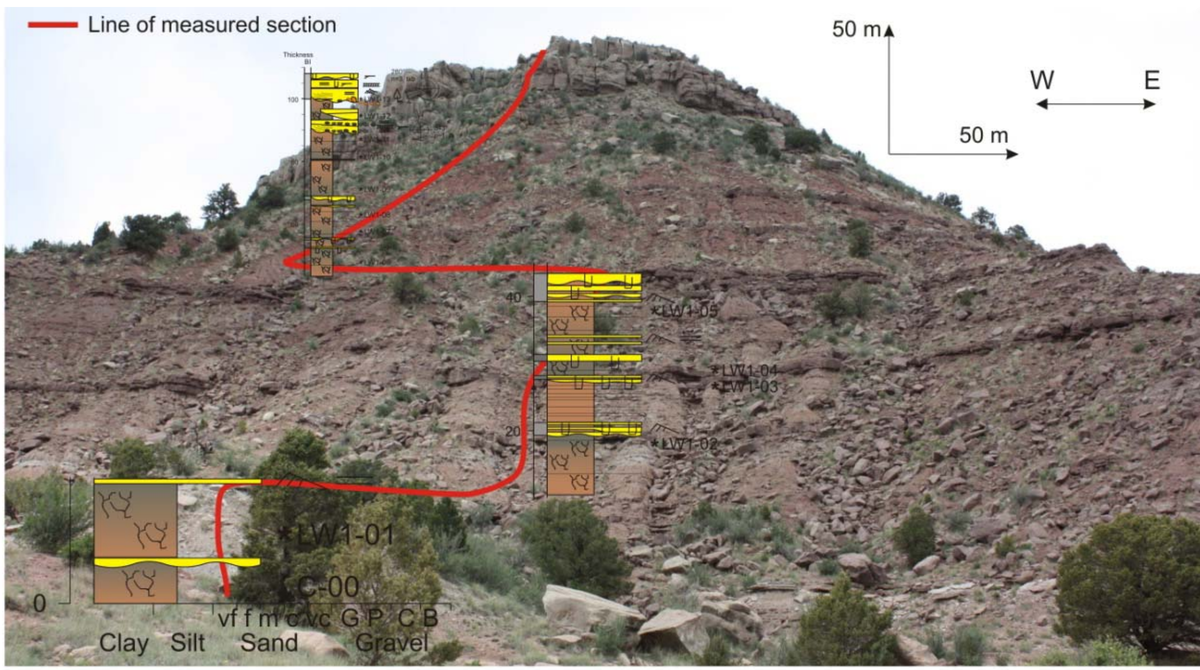
"NORMAL" CHANNEL FILLS: more continuous deposition & stable water & sediment discharge - stable climate vs intensely monsoonal?

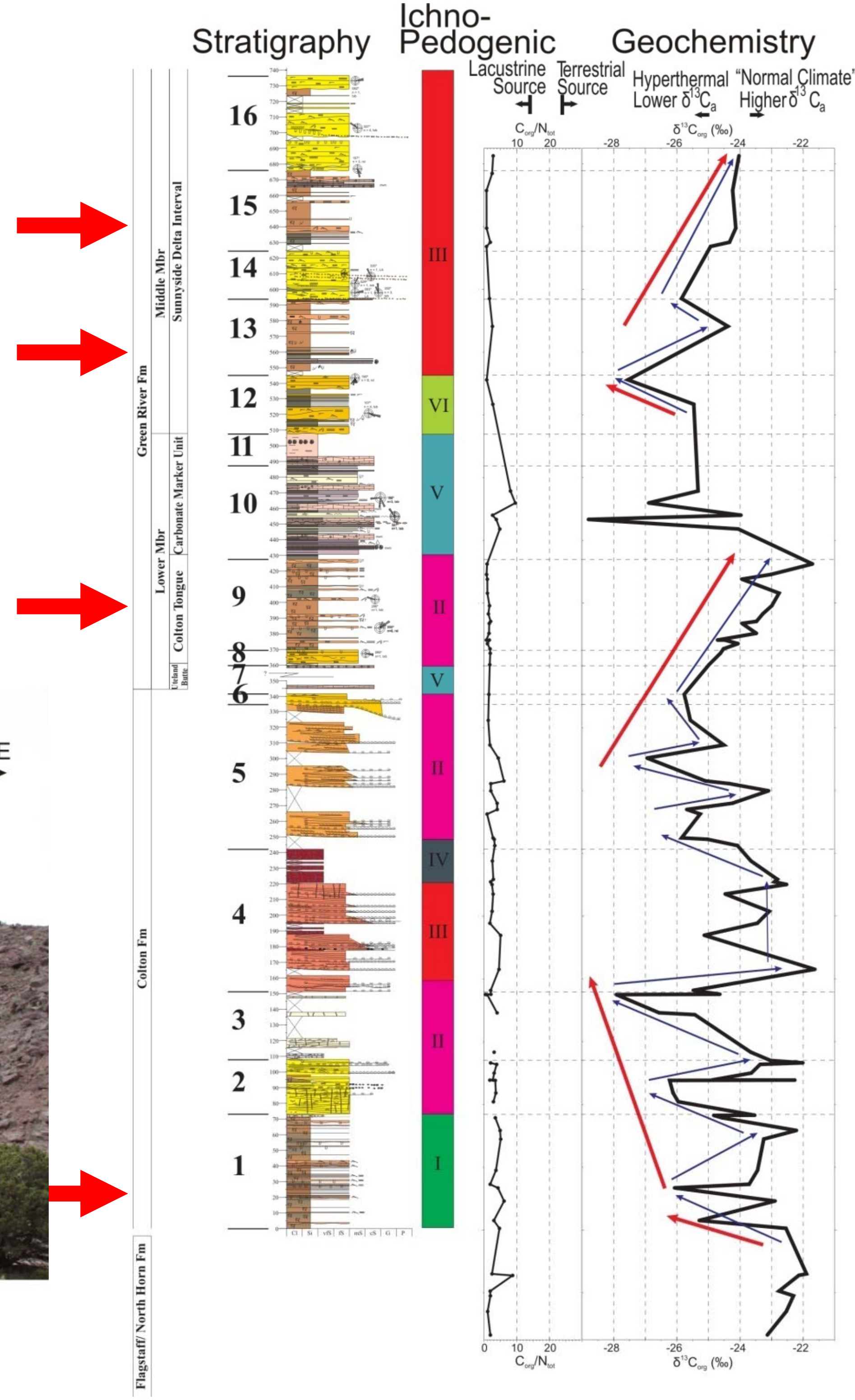


HIGH-DEPOSITION-RATE CHANNEL FILLS 1

Units 1, 9, 13, 15:

- Small channels = low water discharge
- Encased in thick floodplain fines = high fine-grained sediment supply
- Paleosols: monsoonal climate

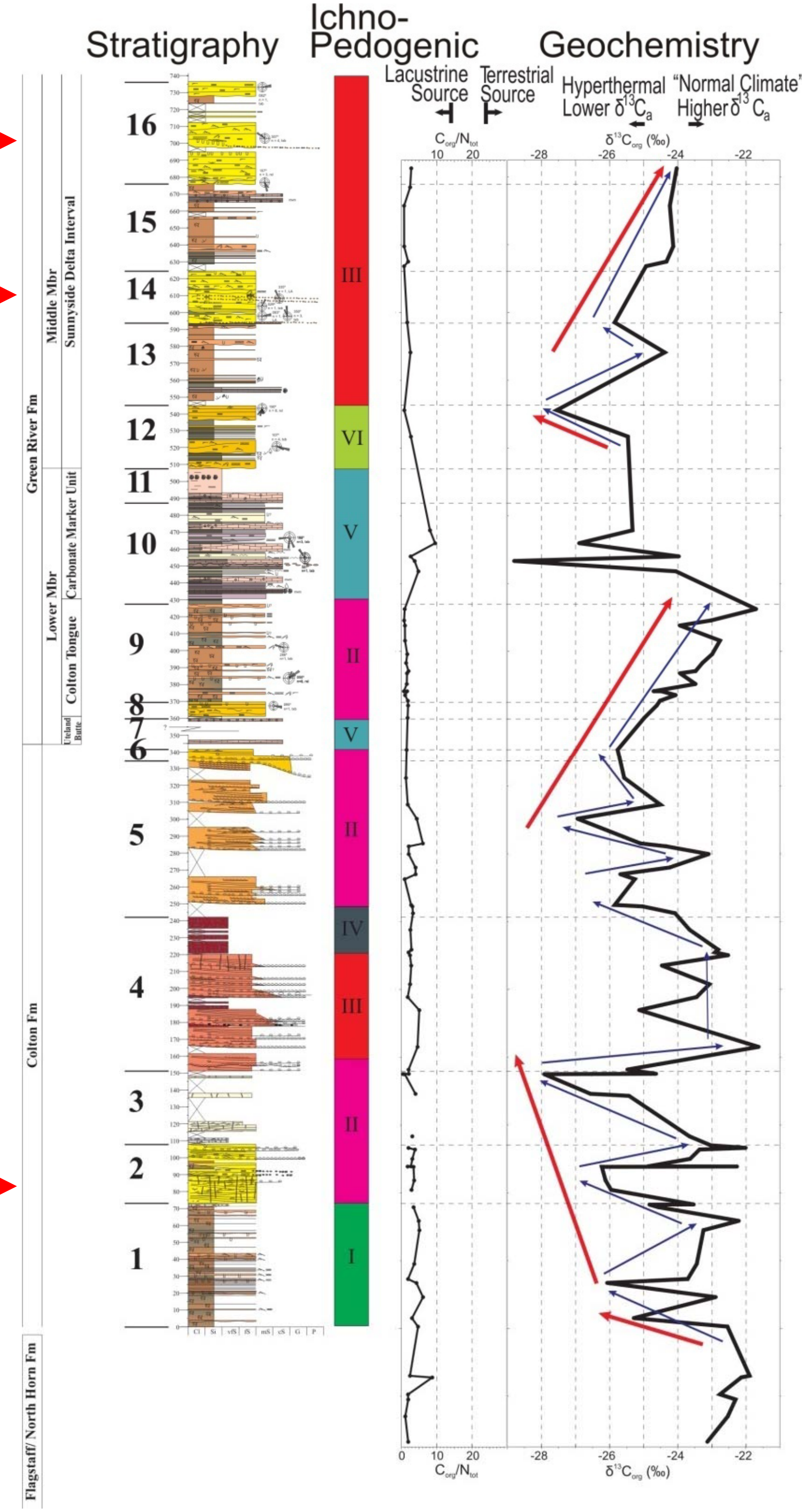




HIGH-DEPOSITION-RATE CHANNEL FILLS 2

Units 2, 14, 16:

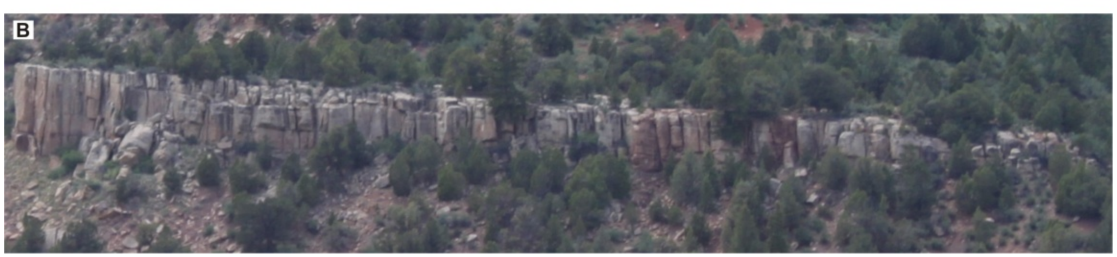
- Large channels, erosional bases = high water discharge
- Thick accretion sets = high sand supply
- Bioturbation on accretion set boundaries = episodic
- Channels laterally amalgamated = higher avulsion rates
- Paleosols: oxisols, but bioturbation indicates wet conditions - more intense monsoonal climate with distinct dry & wet periods;

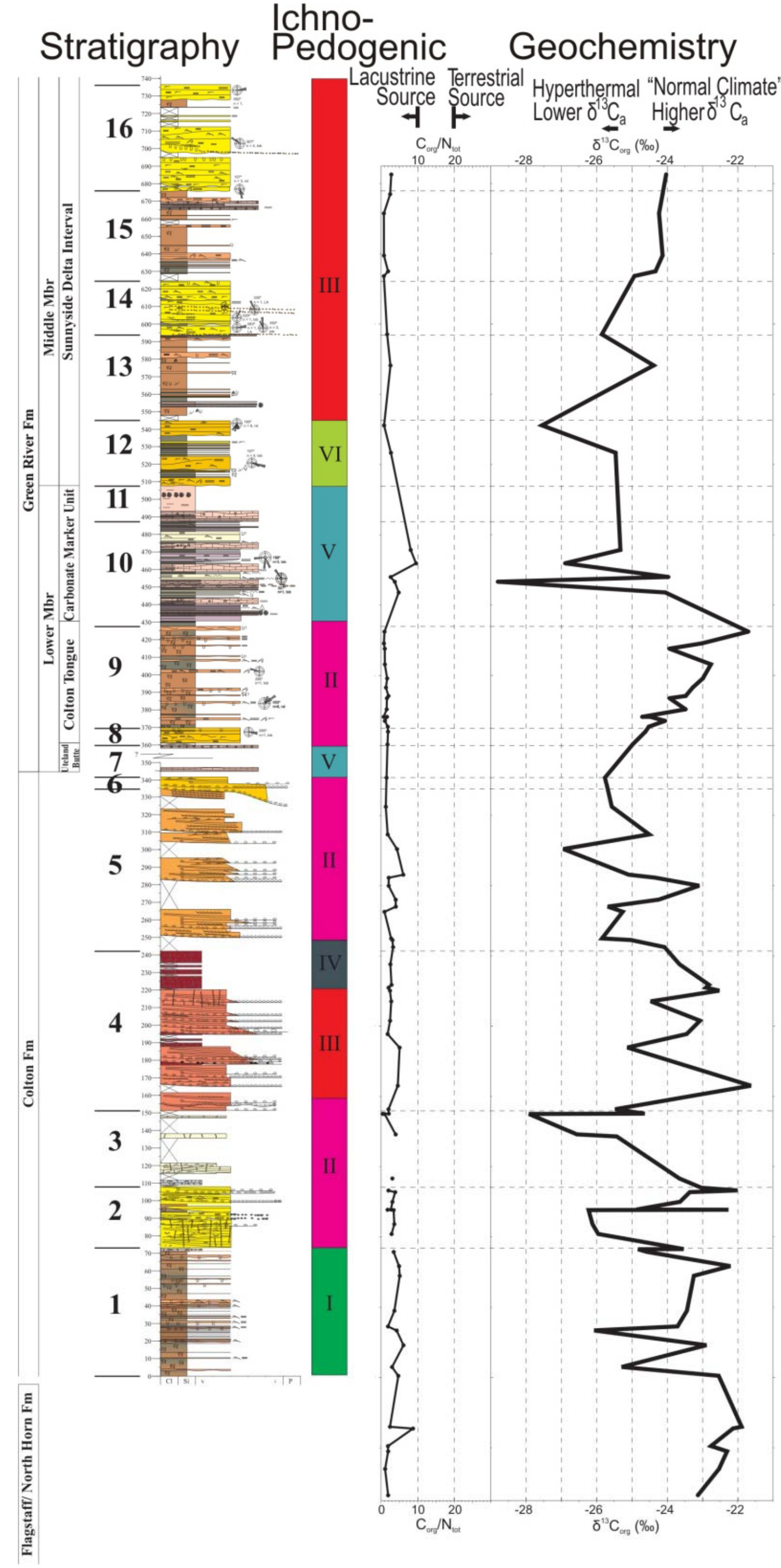


HIGH-DEPOSITION-RATE CHANNEL FILLS 3

Units 6, 8, 12:

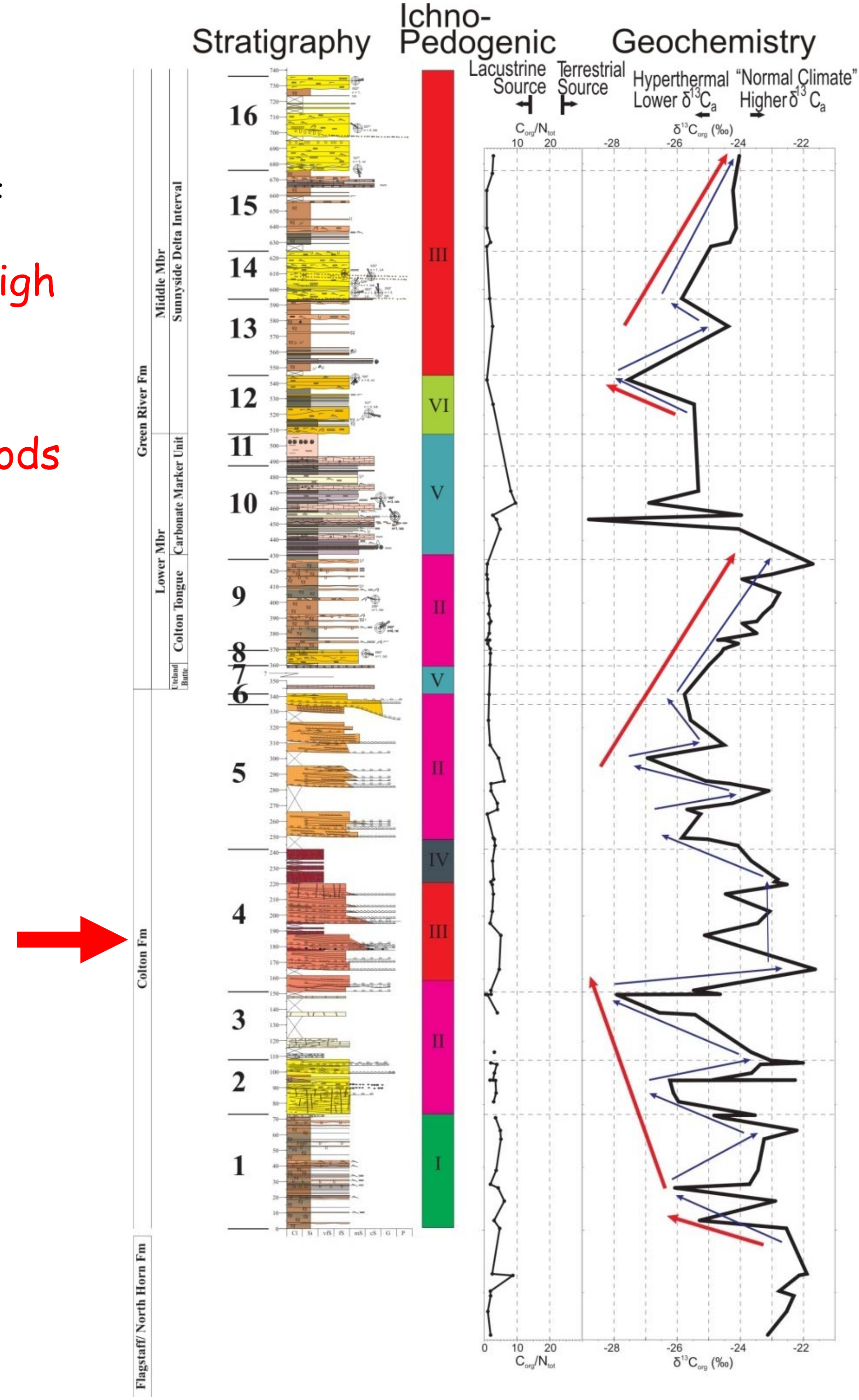
- Same as HIGH-DEPOSITION RATE CHANNEL FILLS 3, but vertically isolated = "pulses" of this style of deposition





HIGH-DEPOSITION-RATE CHANNEL FILLS 4

- Largest channels, 10's of m erosion at bases = very high water discharge
- Thickest accretion sets (up to 20 m) = very high sand supply, very high deposition rates
- Bioturbation & paleosol formation common on accretion set boundaries = very episodic with long periods of non-deposition = long dry periods with intense wet periods
- Channels laterally & vertically extremely amalgamated = very high avulsion rates
- This package has deepest erosion surfaces & highest aggradation rates
- Fluvial megafan



HIGH-DEPOSITION-RATE CHANNEL FILLS 4

- Largest channels, 10's of m erosion at bases = very high water discharge
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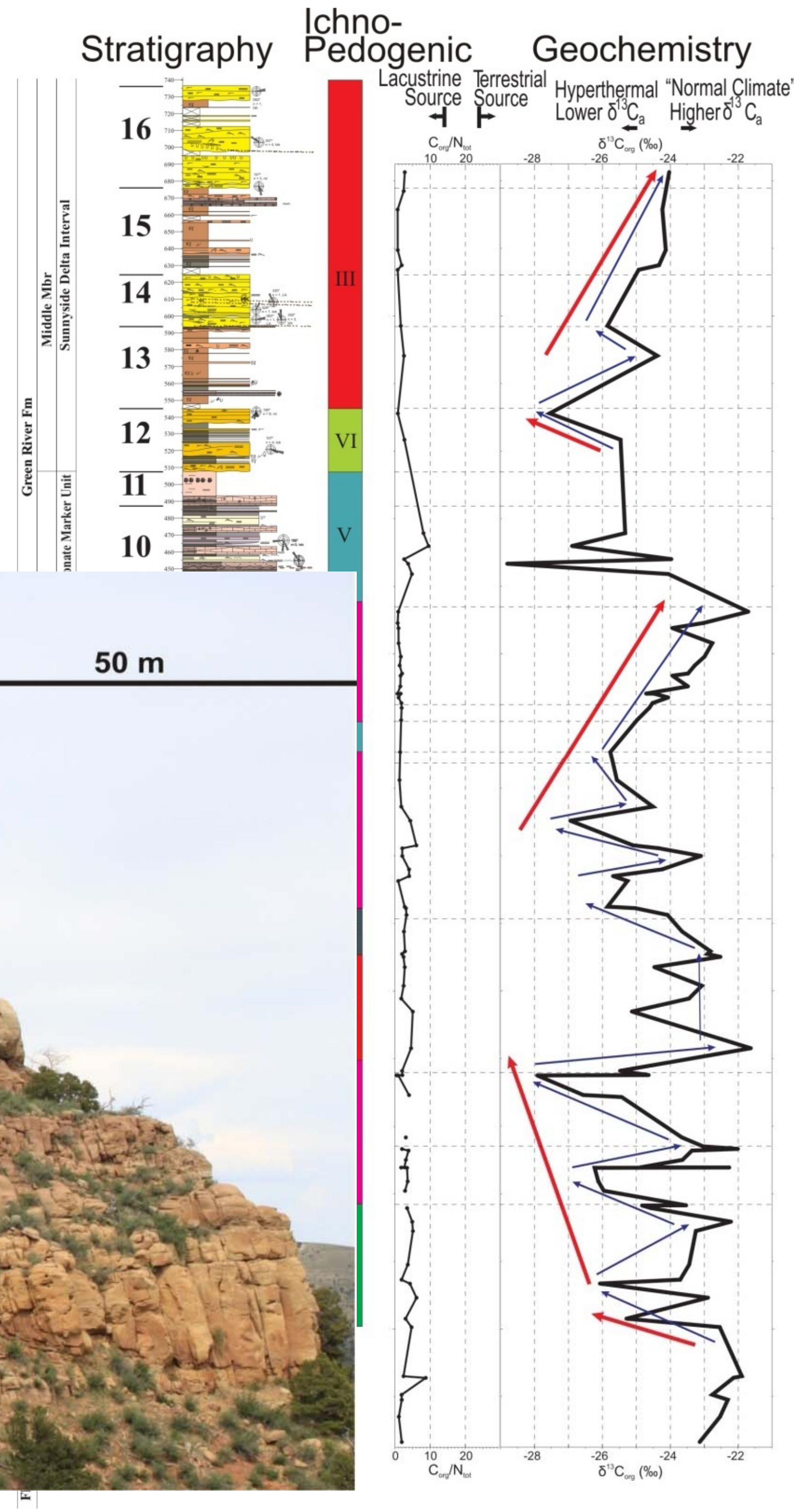
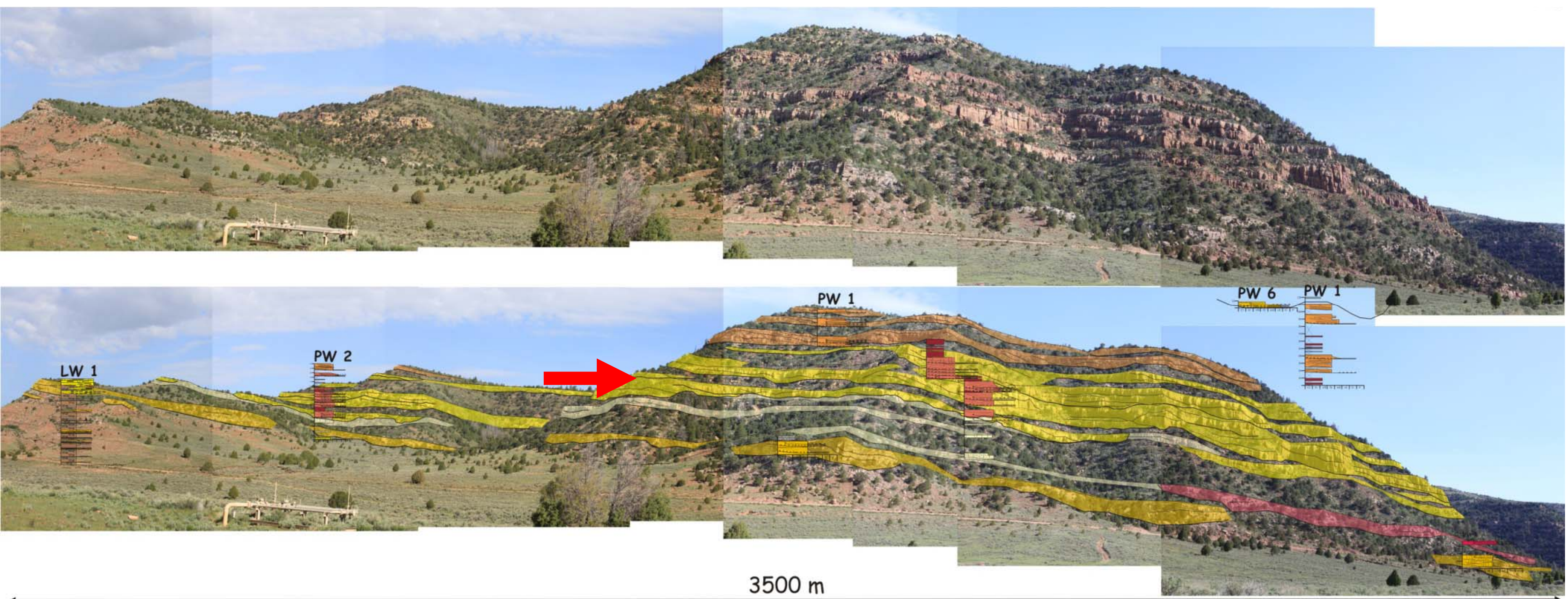
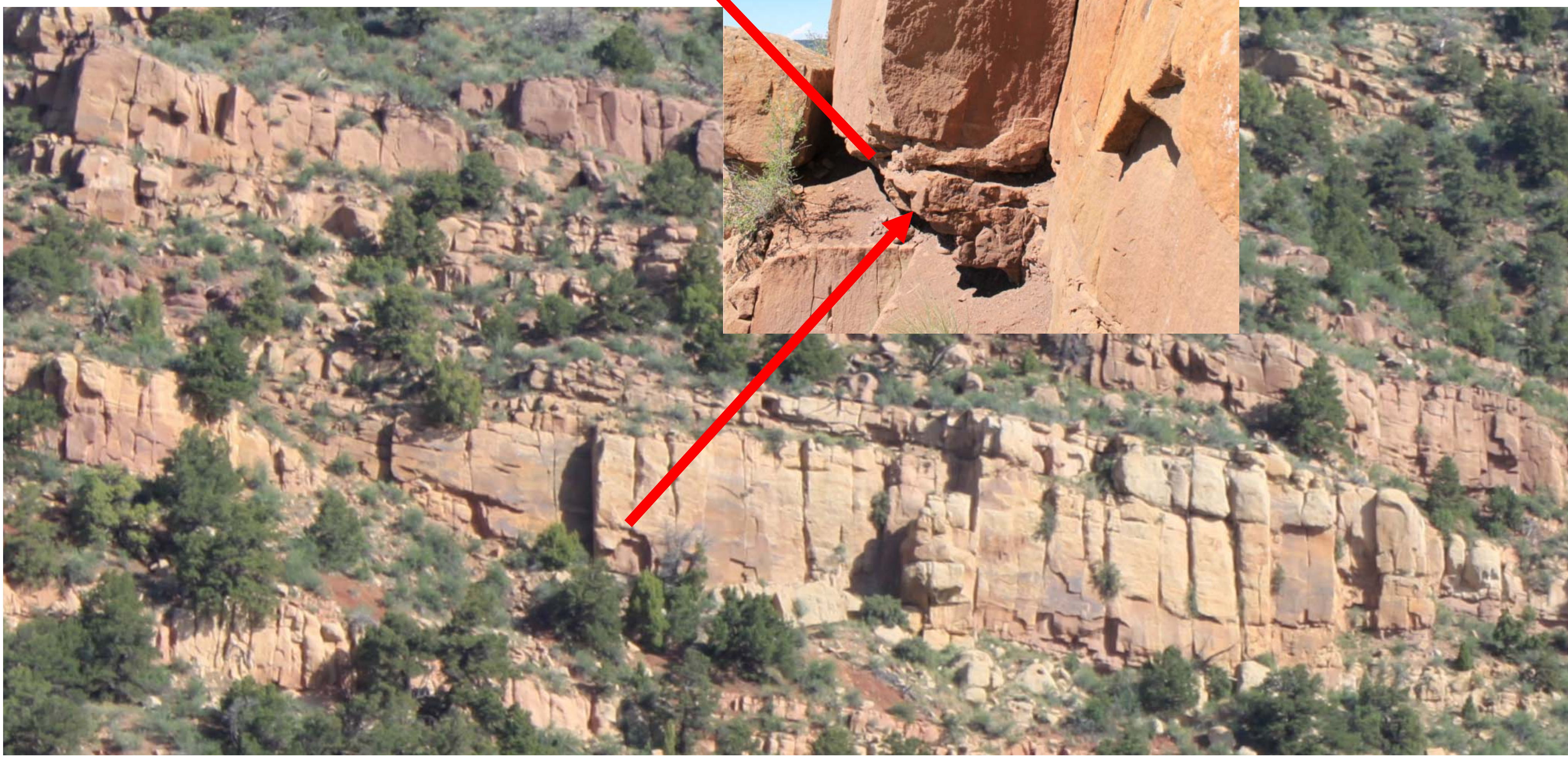



PW 2
LW 1
3500 m


LW 1
PW 2
PW 1
PW 6
PW 1
3500 m

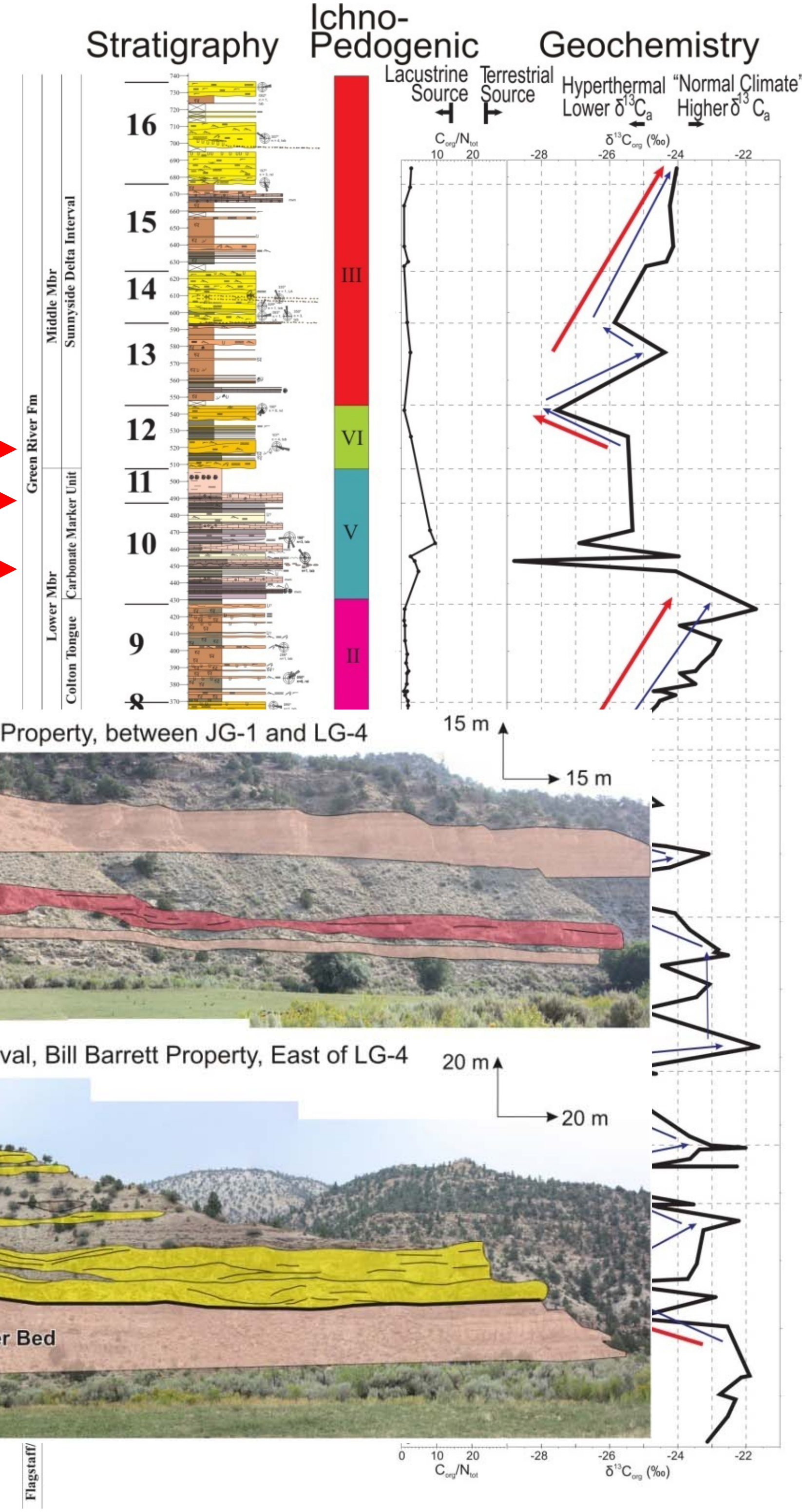
Paleosols on accretion sets

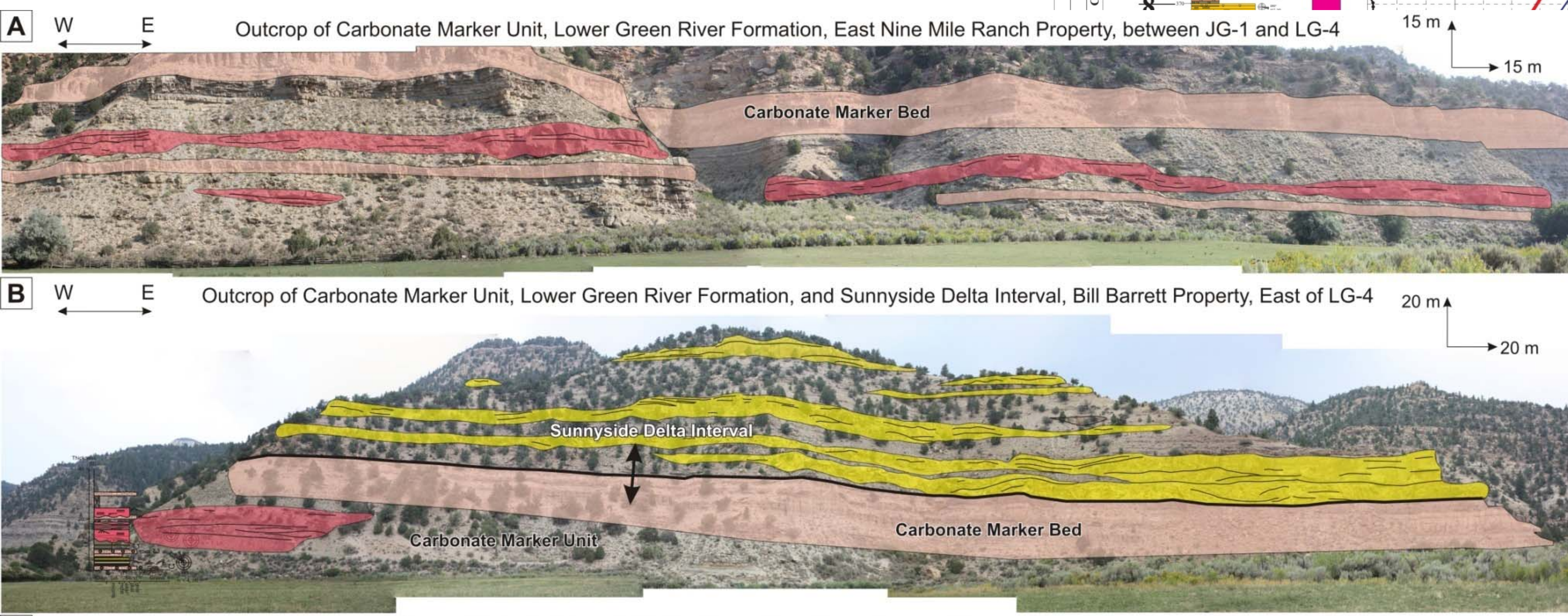


LAKE BEDS

Units (3), 7, 10, 12:

- dominantly carbonate lake sediments
- +siliciclastic mouth bars
- +some fine siliciclastic lake deposits
- = low siliciclastic sediment supply





PALEOSOLS & TRACE FOSSILS

Poorly developed soils, dry soils, wet trace assemblages; long dry periods with short wet - intense monsoon, high deposition rates

Supralittoral, wet

Lake

Better developed soils, dry soils, wet horizontal & shallow trace assemblages; higher water table, less distinct wet and dry, less intense monsoon

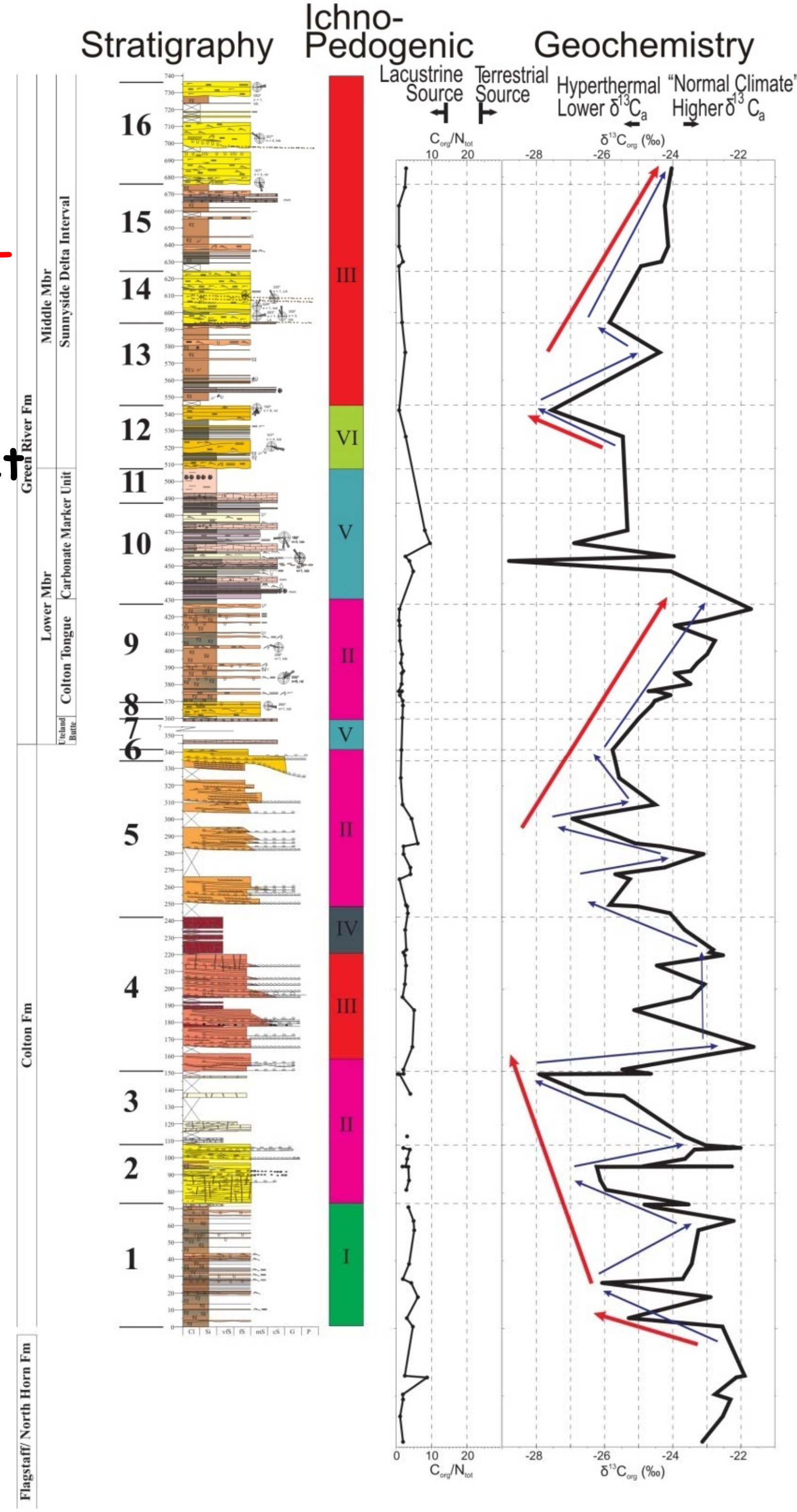
Lake

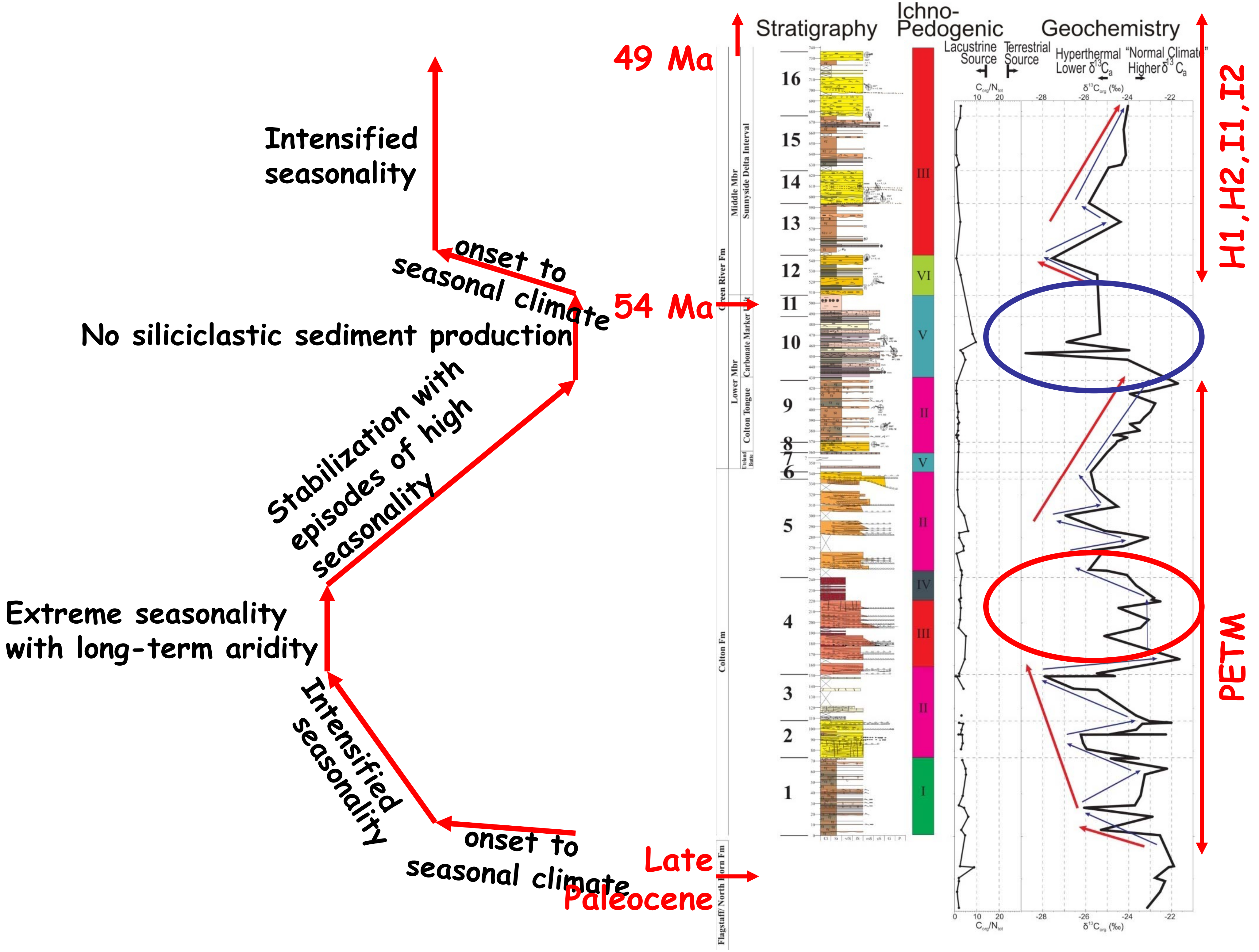
Better developed soils, dry soils, wet trace assemblages; distinct wet and dry monsoon, lower deposition rates

Poorly developed soils, dry soils, wet trace assemblages; long dry periods with short wet - intense monsoon, high deposition rates

Well developed soils, dry soils, wet trace assemblages; distinct wet and dry monsoon

Wet monsoon, well developed soils

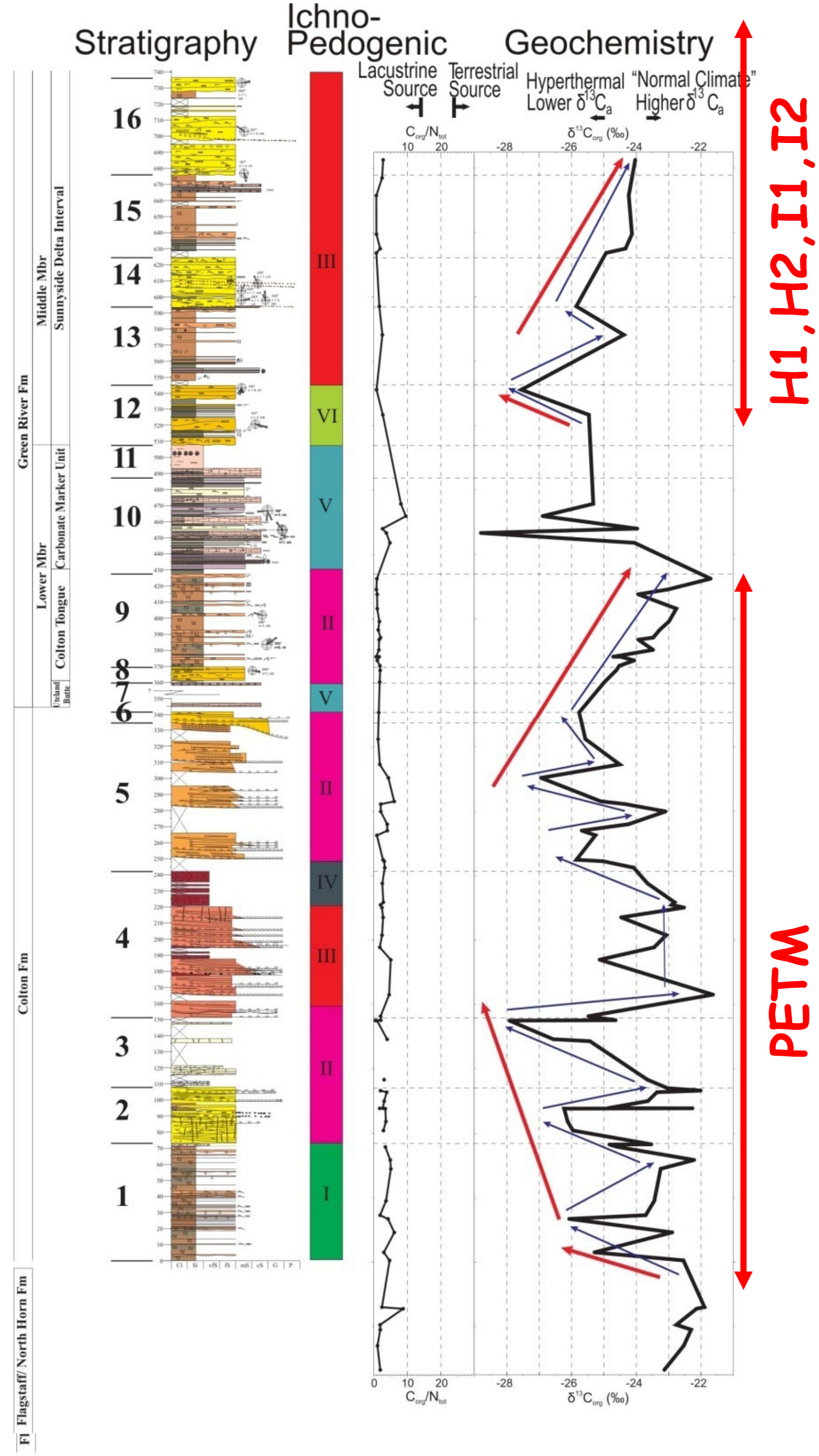



Intensified seasonality
onset to seasonal climate
No siliciclastic sediment production
Stabilization with episodes of high seasonality
Extreme seasonality with long-term aridity
Intensified seasonality
onset to seasonal climate
49 Ma
54 Ma
Late Paleocene
Stratigraphy
Ichno-Pedogenic
Geochemistry
Lacustrine Source
Terrestrial Source
Hyperthermal Lower δ13Ca
"Normal Climate" Higher δ13Ca
H1,H2,I1,I2
PETM
Green River Fm
Middle Mbr
Sunnyside Delta Interval
Lower Mbr
Carbonate Marker
Colton Tongue
Colton Fm
Flagstaff/ North Horn Fm
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
III
VI
V
II
V
II
IV
III
II
I

+ tectonic pulses?

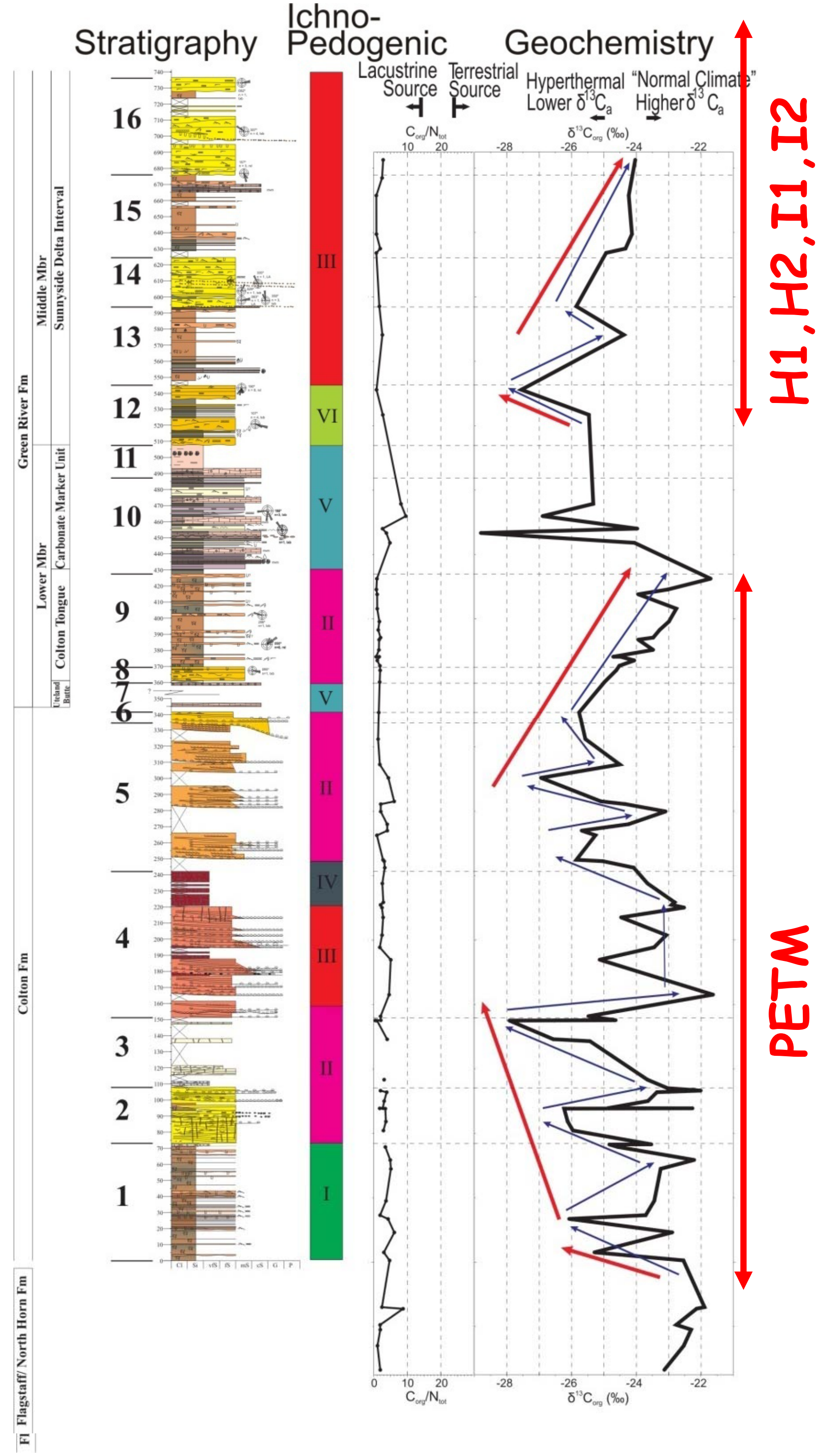
NO! no unconformities,
no syn-tectonic conglomerates, in contrast to North Horn Fm below or Uinta Fm above

Early Eocene tectonics provided a steady, long-term subsidence and source area uplift



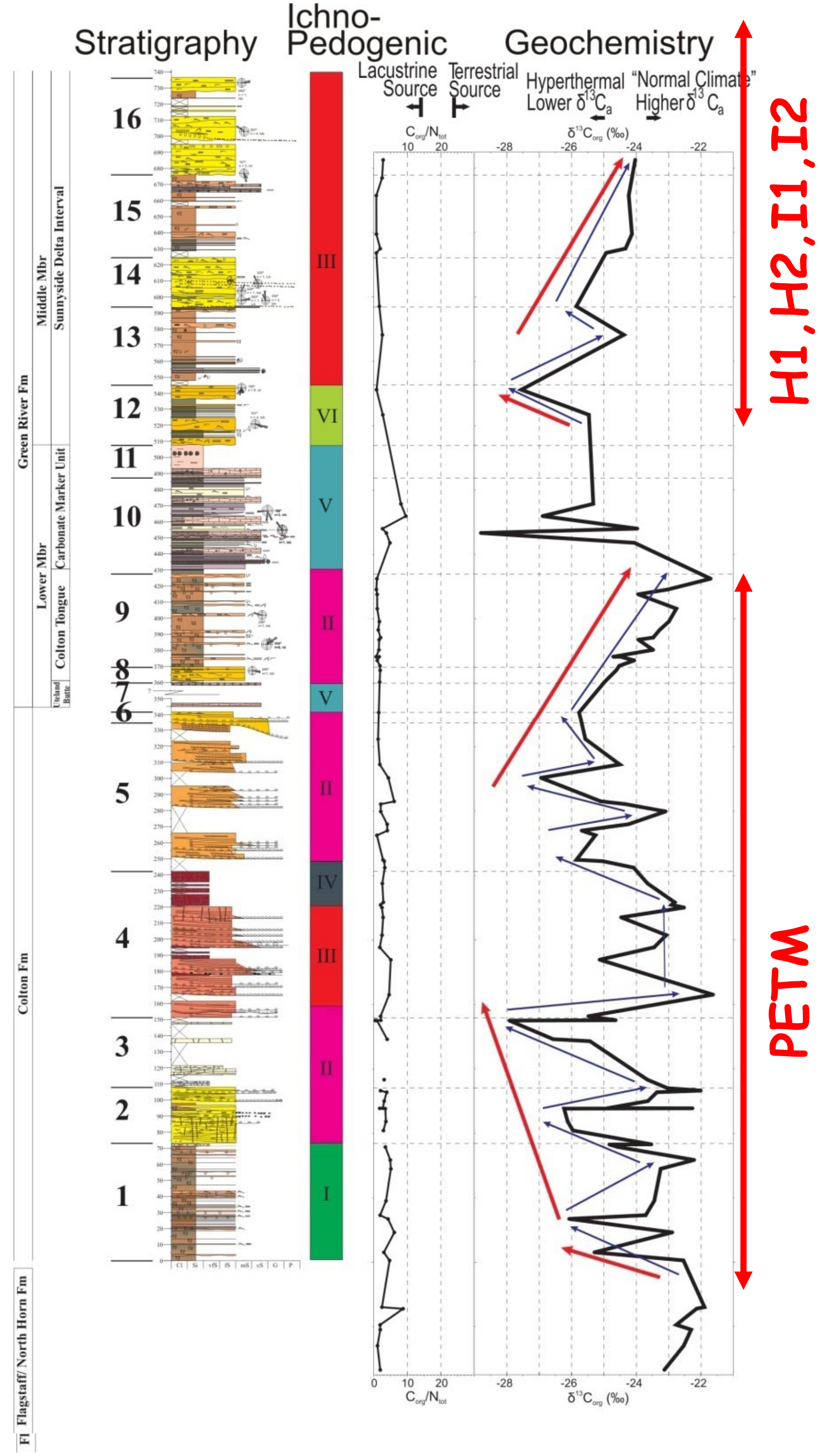
+ autocyclic changes?

? Lateral changes,
system's buffering capacity, e.g.,
delay between warming and
monsoon intensity or hydrologic
cycle intensity increase;
delay in sediment production ?



+ intra-PETM climate changes?

? Hyperthermals are more complex ?



CONCLUSIONS

Allogenic controls

-monsoon intensity, sediment production rate, water discharge, erosion rate, deposition rate & avulsion rate increased during PETM & younger early Eocene hyperthermals

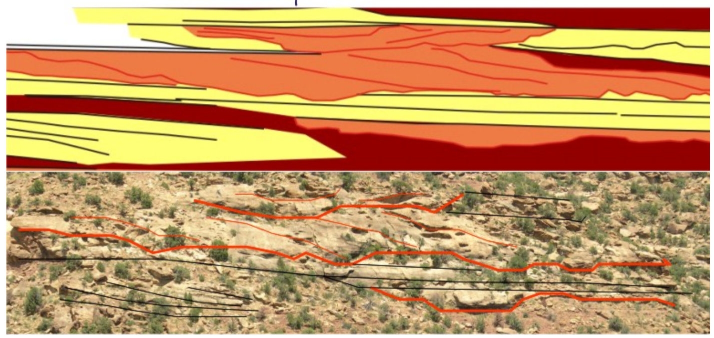
- lake expansion allowed by lower siliciclastic sediment supply, and perhaps more steady precipitation patterns during weaker monsoon between hyperthermals
- long-term steady basin subsidence & source area uplift caused by Laramide tectonics

Autogenic controls

-lateral variability in channel-fill characteristics, lateral variability in the degree of amalgamation

- specific location & frequency of avulsions

Alluvial Depositional Models



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