Dockum Group Revisited: Deposition and Tectonic Significance*

Alton Brown[1]

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[1]Consultant, Richardson, TX, USA (altonabrown@yahoo.com)

Abstract

The Late Triassic Dockum Group is not a petroleum-productive formation, but Dockum burial pushed more strata into the oil window and records structural evolution during a critical time of transition from Permian-aged foreland basin style to thermal subsidence in areas marginal to the Gulf of Mexico.

Deposition is fluvial and lacustrine, but there are significantly different interpretations on the volume and type of lake deposits. According to older work (e.g., McGowen et al. 1977), lakes were large, with delta, delta plain, and basin facies. Lake basin facies have evidence for subaerial exposure, indicating that lakes were dry for extended periods. Lake deposits were interpreted as the central part of a closed Dockum basin, which was depositionally poorly connected to age-equivalent Chinle Formation deposits in central New Mexico. Recent work interprets fewer and shallower lakes (i.e., Lehman and Chatterjee 2005). Many of the lake basin and delta facies were reinterpreted as flood plain mudstones and sheet flood deposits, respectively. Drainage was interpreted as a predominantly west-flowing system continuous with Chinle deposition in New Mexico.

In the area with best lateral outcrop continuity (the Palo Duro Canyon area) outcrops show unequivocal lacustrine delta clinoforms, the toes of which interfinger with lacustrine mudstones and the tops of which grade into delta-top sandstones, just as described by Seni (1978). Evidence supporting reinterpretation of Dockum lakes as flood plain deposits is equivocal, and many outcrops interpreted as flood plain mudstones and sheet flood sandstones are better interpreted as lacustrine basin facies and lake delta front sandstones. Many of the peculiar features of the Dockum mudstones are more consistent with lake deposits than with a predominantly subaerial floodplain deposit.

Dockum lakes do not indicate closed basin deposition as proposed by McGowen et al. (1977). Dockum lakes formed in flood basins marginal to rivers flowing to the west. Dockum lakes were selectively deposited over the Dockum basin along the Texas – New Mexico border due to its higher Late Triassic subsidence rate, in a manner similar to that seen on actively subsiding alluvial basins today. The Dockum basin was continuous with the New Mexico Chinle deposits until the late Cretaceous.

Detrital zircon age spectra from the Dockum Group document changing sediment source area, possibly in response to exhumation during initial opening of the Gulf of Mexico (Dickinson et al. 2010). Large-scale structural and erosion patterns over the Eastern Shelf and under the East Texas basin show that uplift was centered on the Ouachita Tectonic Front and that tilting marginal to the uplift predated Dockum deposition. Detrital zircon ages and mineralogical zonation show changing source area in response to this uplift.

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Alton Brown
Consultant; altonabrown@yahoo.com

Background

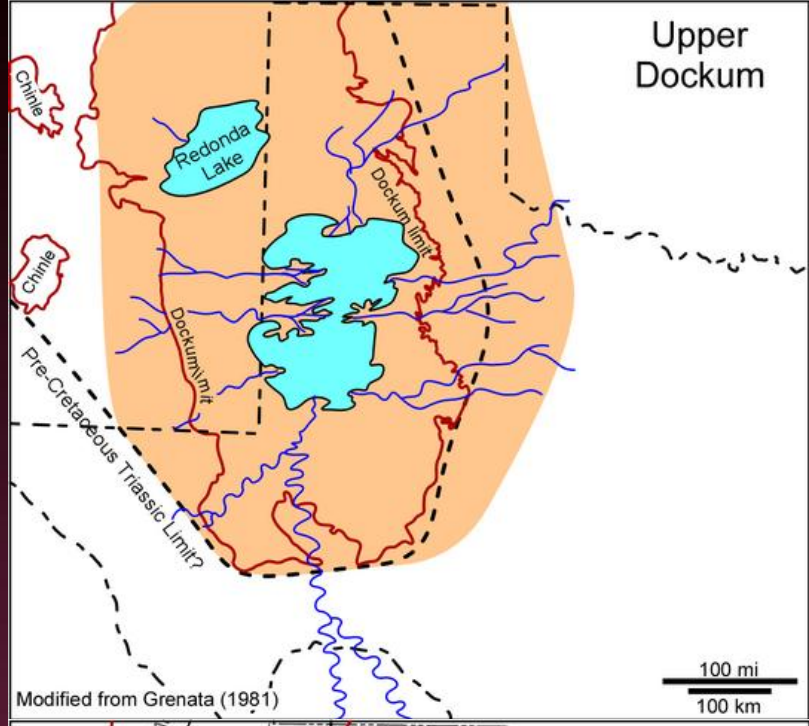
- Dockum Group: a thick, Late Triassic, non-marine fluvial – lacustrine redbed deposit capping the Permian basin.
- Controversial depositional environments. McGowen et al. (1977) interpret large lakes, whereas more recent studies (e.g., Lehman and Chaterjee 2005) interpret fewer, smaller lakes.
- Controversial tectonic significance. Was Dockum basin a continuation of Permian basin subsidence, a product of Pacific Margin tectonics, or related to initial opening of Gulf of Mexico?

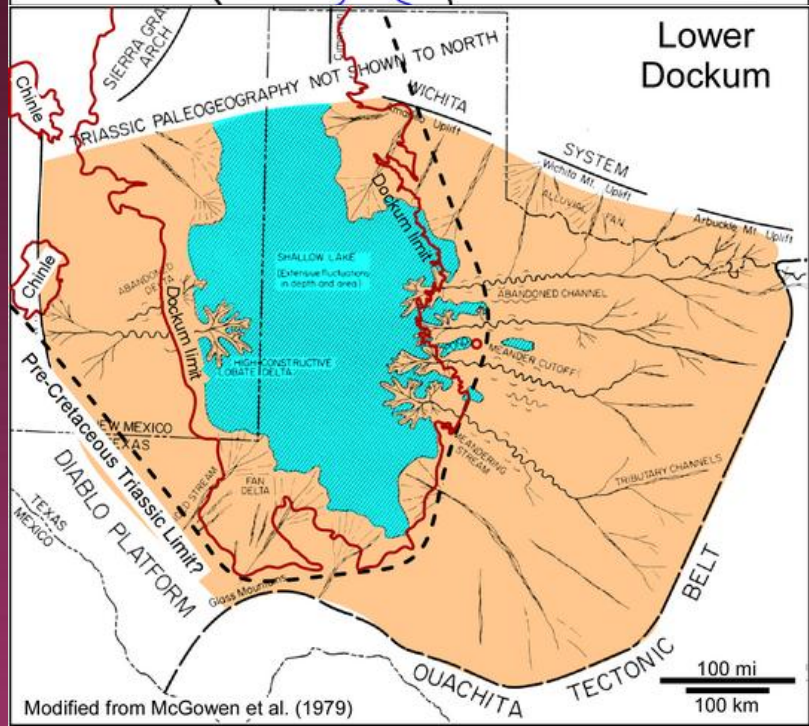
Objectives

- Clarify Dockum lacustrine facies distribution and its relation to regional sedimentation.
- Interpret tectonic setting from sediment supply and subcrop patterns.
- Integrate depositional systems with tectonic framework.

Dockum Paleogeography: Large Lake Model of McGowen and Coworkers

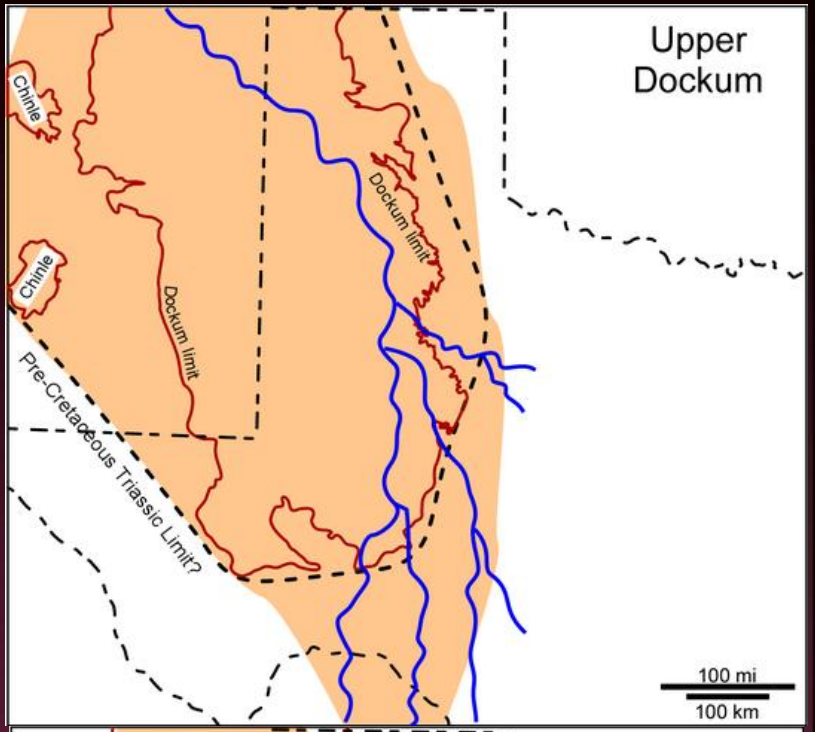
- Mudrocks interpreted as lake deposits.
- Large, relatively shallow (15 m = 16 ft) lakes with lacustrine deltas, and delta plains.
- Lakes located in central part of Dockum Basin.
- Sediment supplied from all directions. Dockum basin was a closed drainage basin.

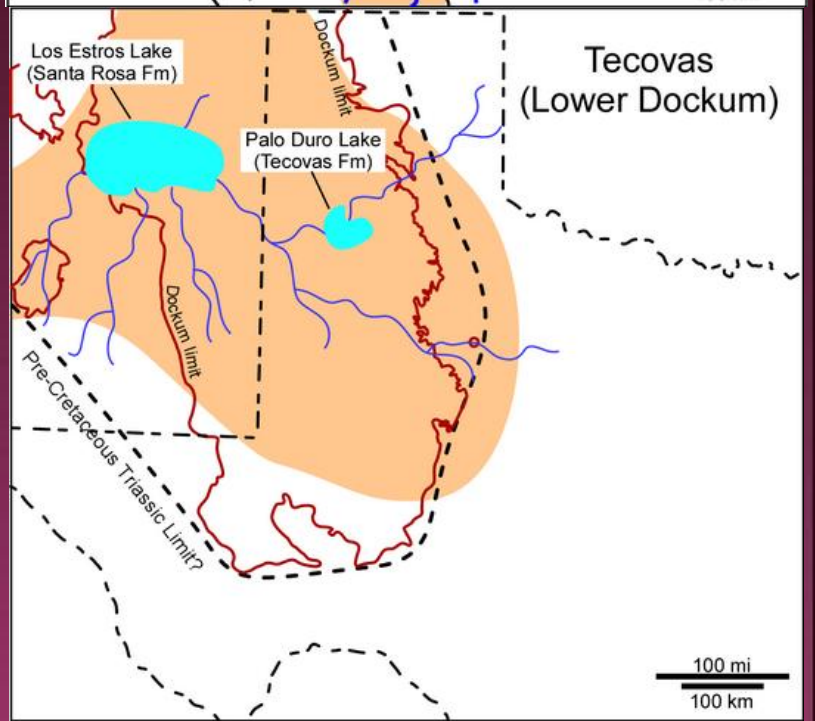




Dockum Paleogeography: Small Lake Model of Lehman and Coworkers

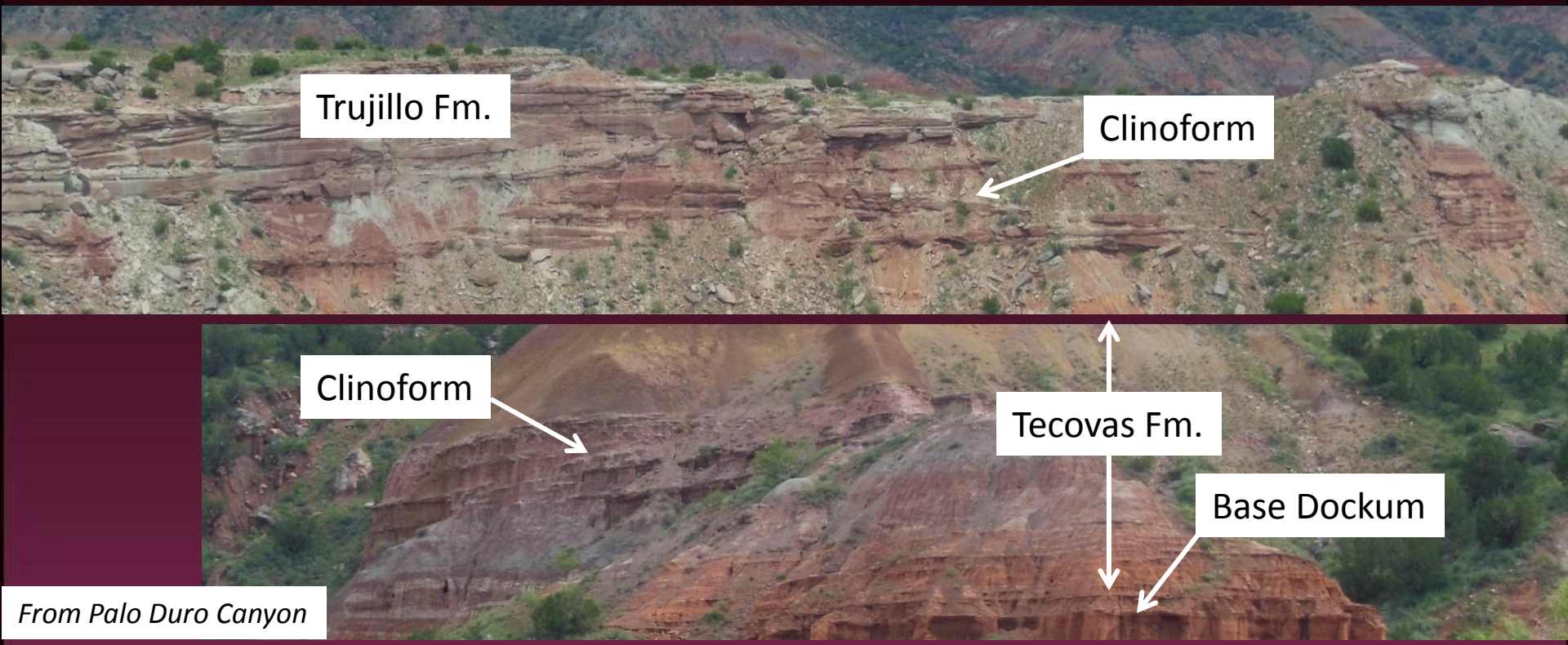
- Most mudrocks interpreted as floodplain deposits.
- Upper Dockum (Trujillo – Cooper Canyon): Fluvial floodplain with ponds and no large lakes.
- Lower Dockum (post Tecolotito): Dominantly fluvial with a few (smaller) large lakes. Closed basin.





Cooper Canyon-Trujillo (upper Dockum) and Tecovas (lower Dockum) paleogeography from Martz (2008) after Lehman (in prep.).

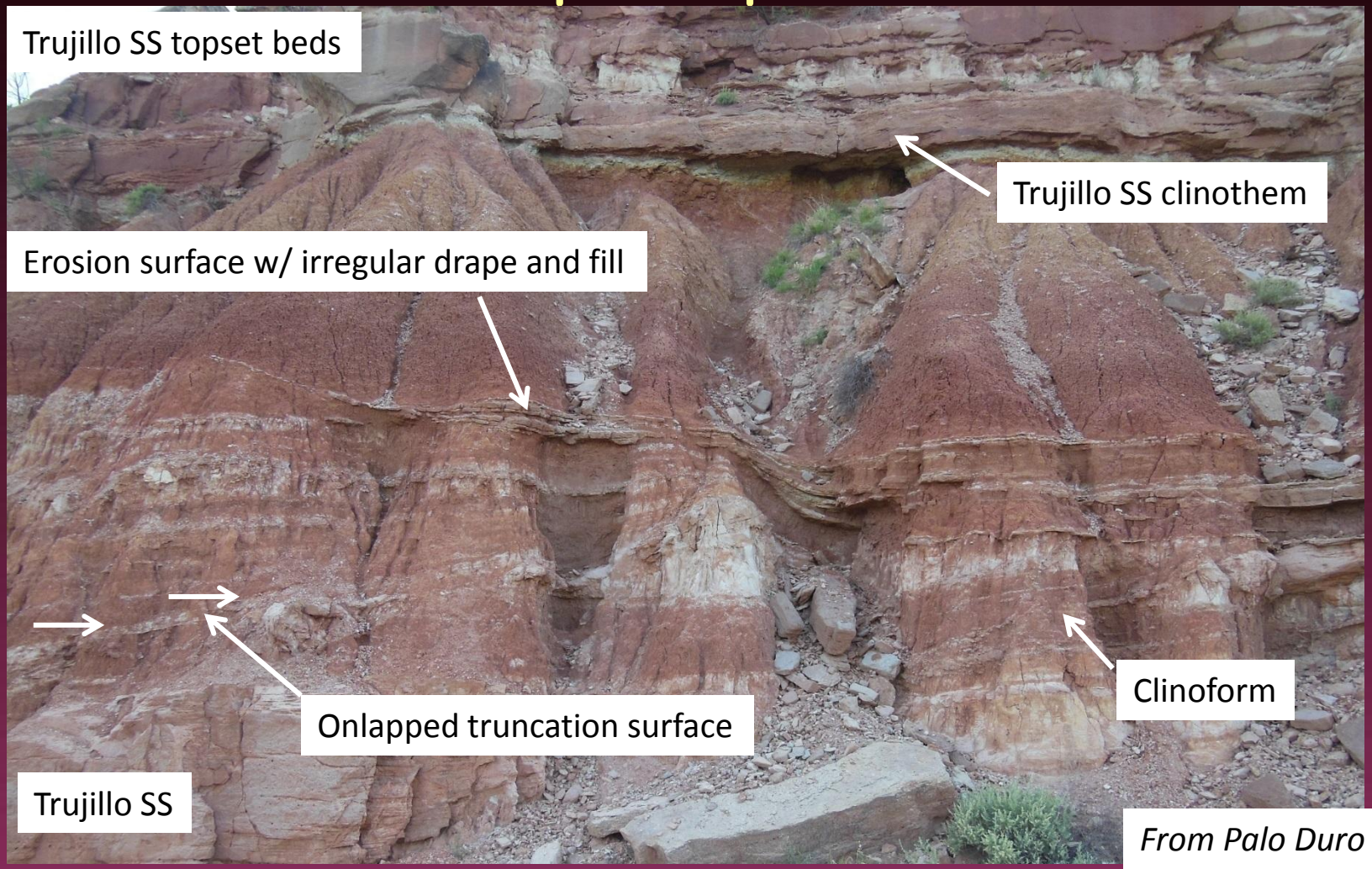
Lake Facies Identification from Clinoforms



From Palo Duro Canyon

- Clinoform stratal patterns overstepped by delta plain and fluvial sandstones.
- Bioturbated mudrocks and siltstones interfingering with sandstone clinothems.
- Implications: Mudstones are lake basin deposits. Lake depth during progradation is the clinoform height, up to ~5 m (16 ft).

Peculiar Dockum Stratal Patterns are Toe-of-Slope Deposits



- Depositional strike section; delta sediment transport towards camera.
- Bedding patterns indicate intermittent deltaic deposition and toe-of slope erosion.

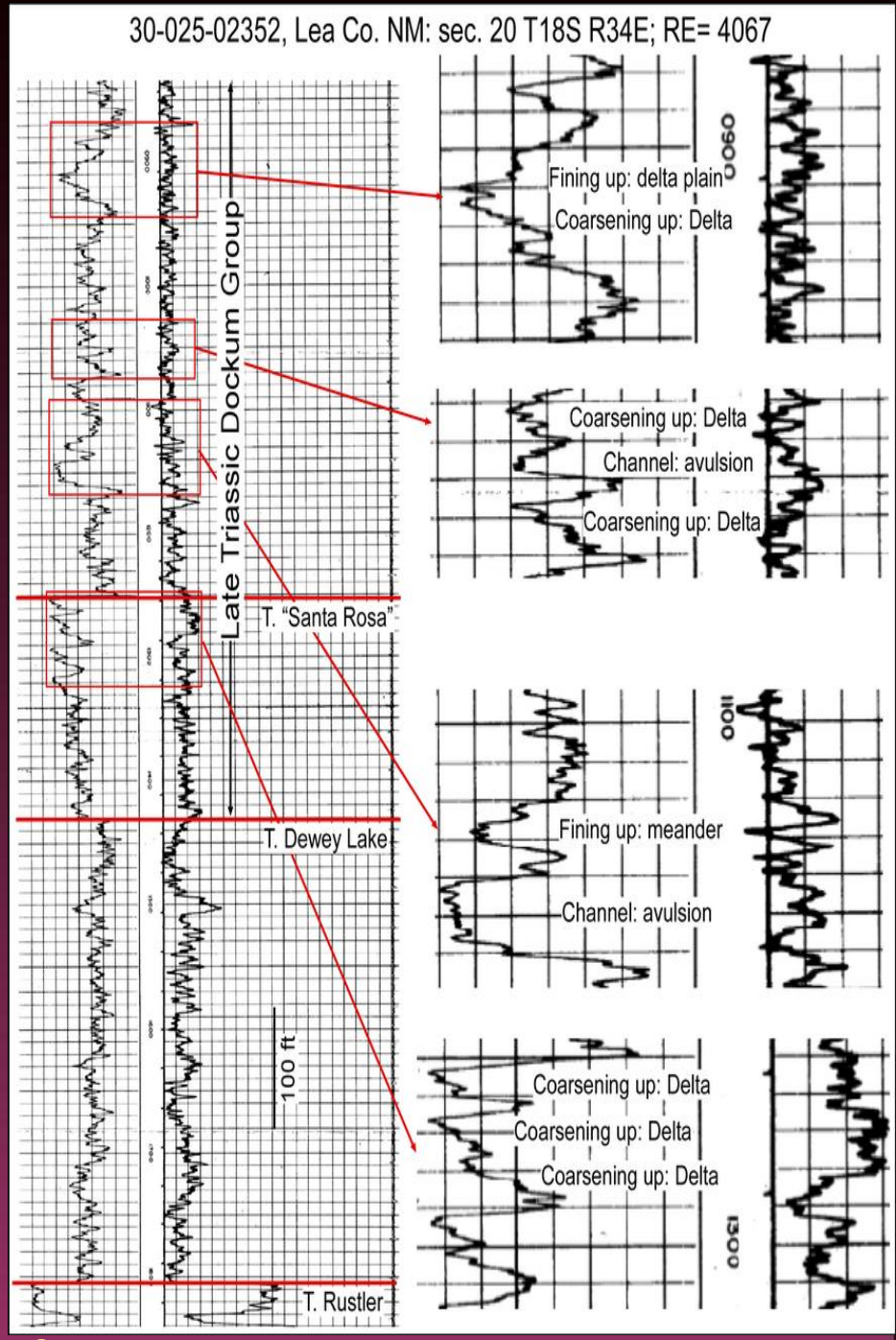
Possible Lacustrine Deltas in Other Areas

Cooper Canyon Fm. (Upper Dockum), southern Garza County, TX. Figures from Martz (2008); © Jeffrey Martz.

- Many outcropping Dockum "fluvial" sandstones have clinothems interfingering downdip with mudstones, a pattern more consistent with prograding deltas.
- If deltas, a significant fraction of Dockum mudrocks are lacustrine basin facies in southern areas as well as at Palo Duro.

Wireline Log Patterns

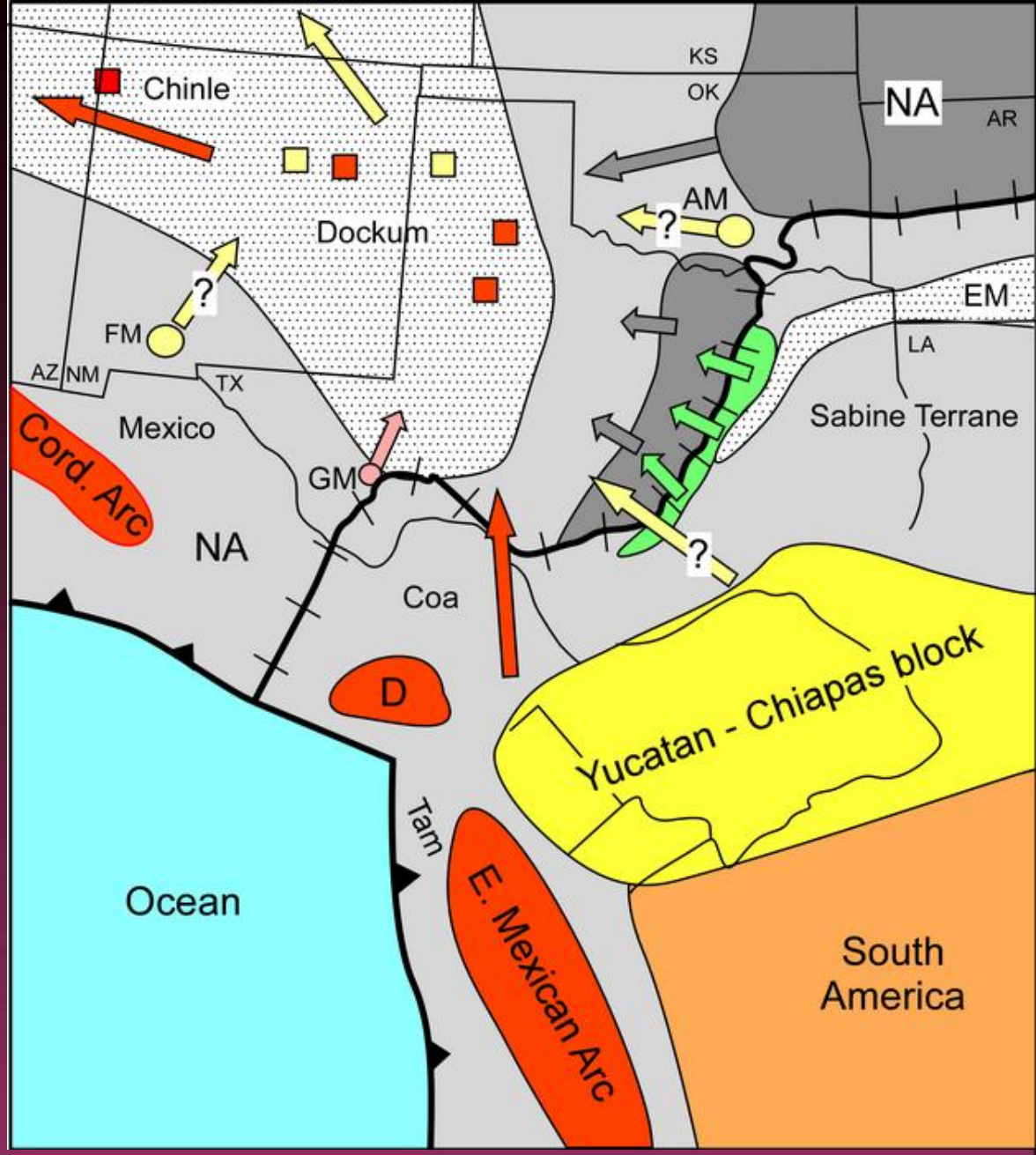
- Coarsening-upwards: Lacustrine delta.
- Fining-upwards: Meander point bar and delta plain.
- Blocky sandstones: Avulsion channels.
- All depositional units are thin (<~20 ft).
- Thicker sandstones are composite bodies: meander belts, incised systems, stacked deltas, etc.
- Thicker mudrocks are probably composite lacustrine - marsh deposits.



Gamma ray - neutron

Dockum Basin Was NOT Closed!

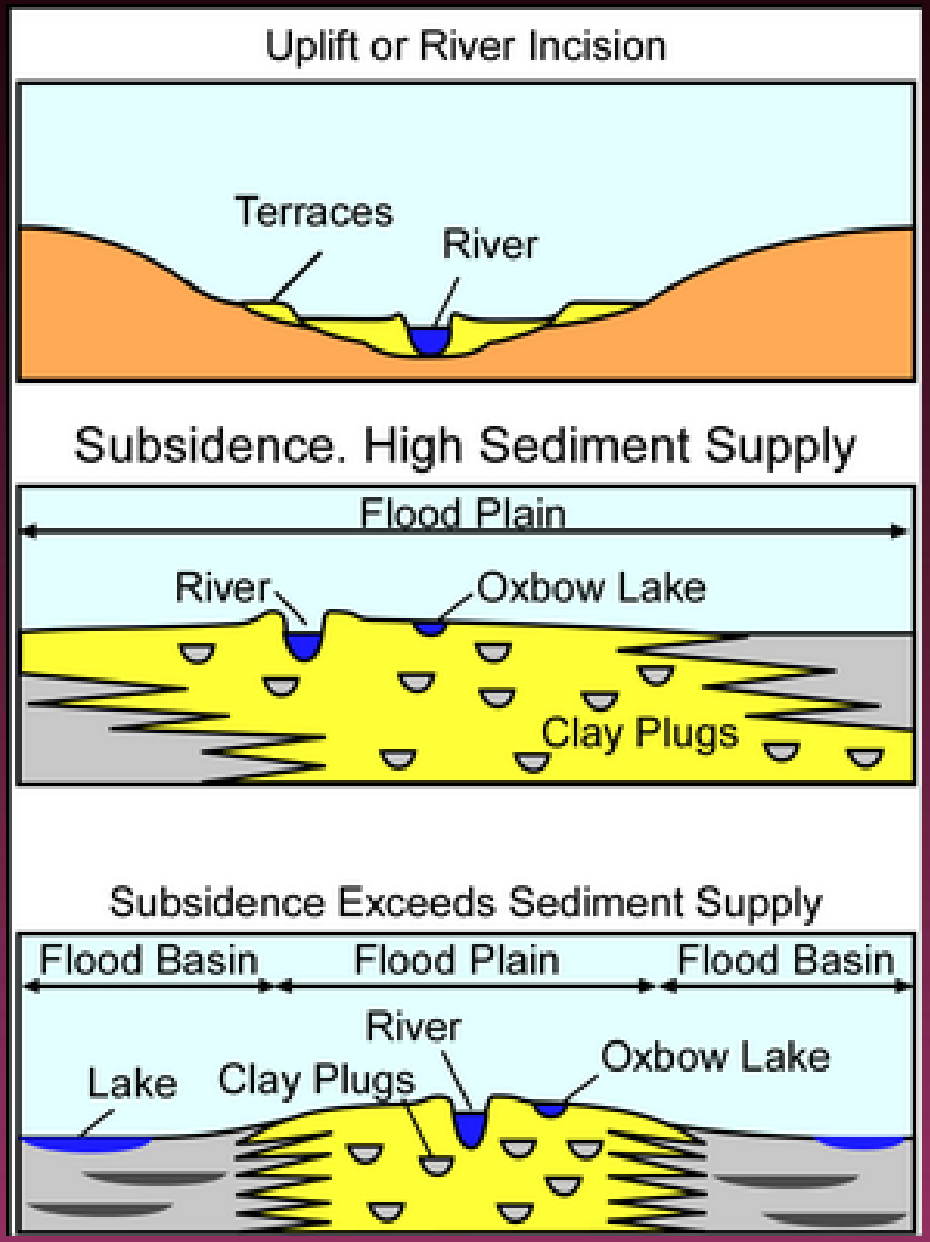
- Detrital zircons and other tracers: Dockum sediment derived from south, east and northeast.
- Drainage from Dockum:
  - To northwest during Tecolotito (lowest Dockum) deposition.
  - To Chinle Group (west) during most Dockum deposition.



Late Triassic Paleogeography modified from Dickinson and Lawton (2001)

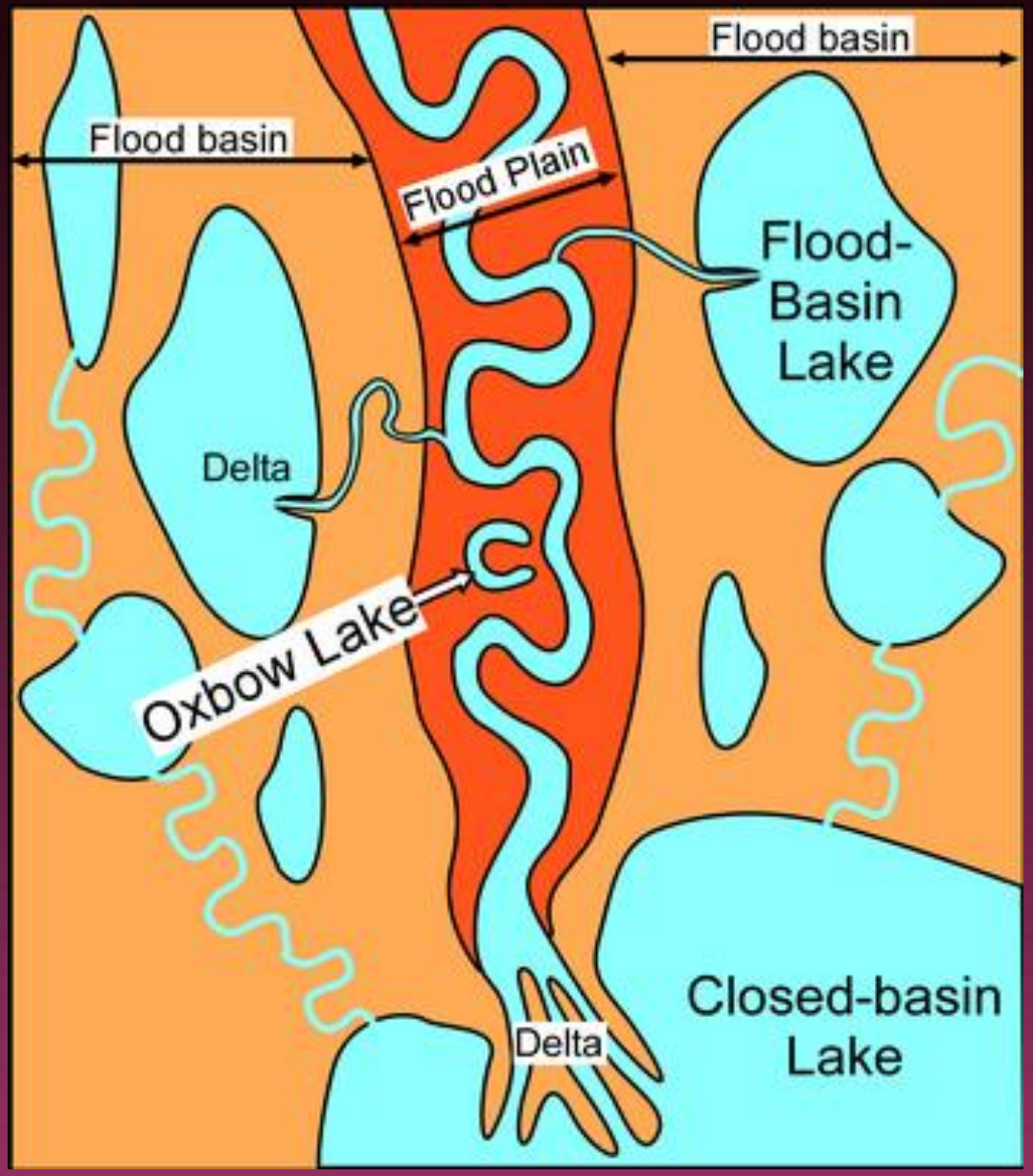
Fluvial Facies and Accommodation Space

- Uplift or fluvial incision:
  - No permanent sediment preservation.
- Subsidence, high sediment supply:
  - Low topographic relief. No or limited flood basin.
  - Fraction of fine-grained facies depends on subsidence vs. meandering rates.
- Subsidence exceeds sediment supply
  - Flood plain: Infrequently flooded. Forested crevasse and levee deposits.
  - Flood basin: Frequently flooded; Lakes and marsh deposits.
  - More frequent avulsion.



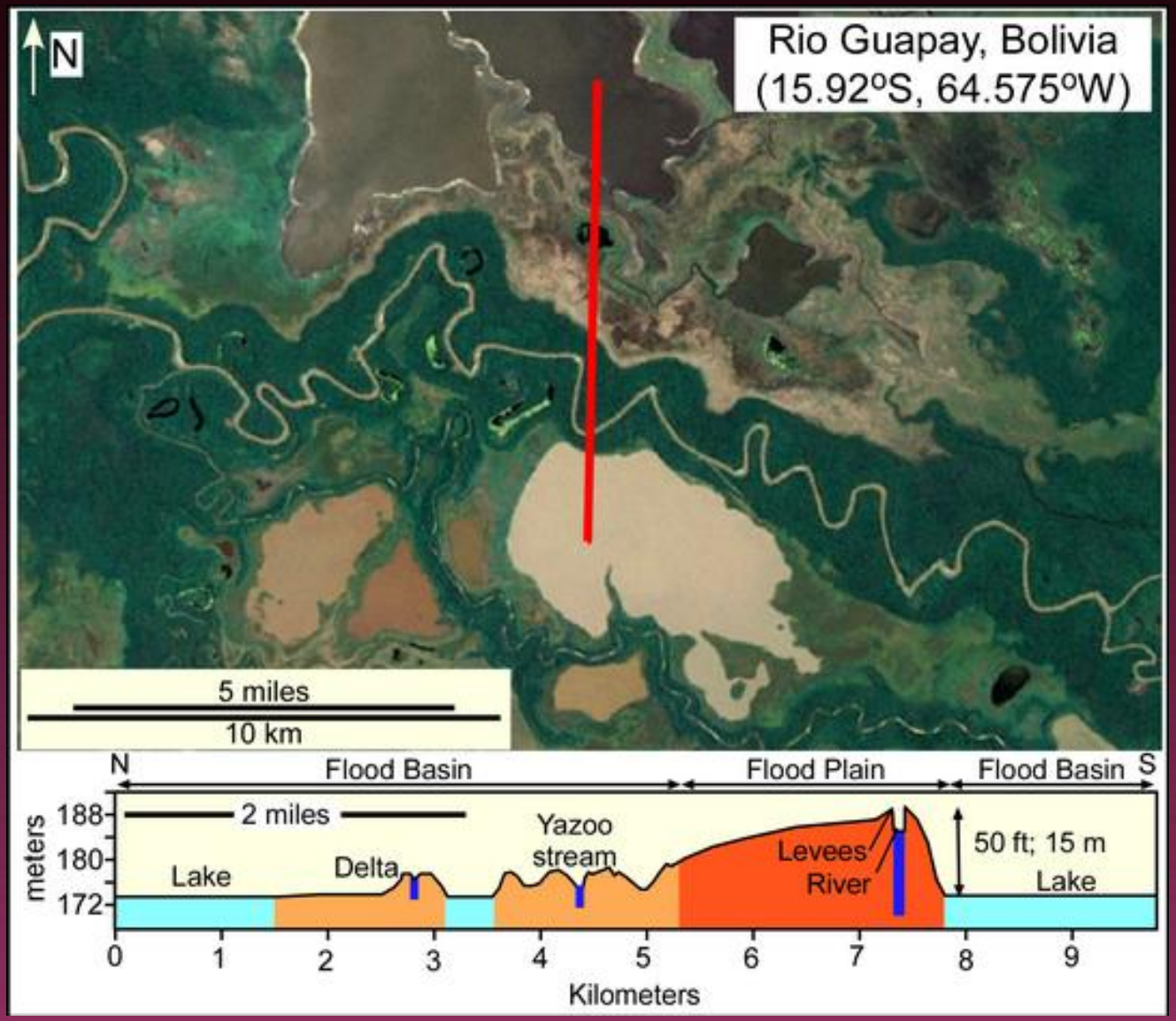
Fluvial-Associated Lakes

- Oxbow lakes: small, on flood plain.
  - Meander and avulsion systems.
- Flood-basin lakes: small to large; on flood basin.
  - Only in areas of subsidence exceeding sediment supply.
- Closed basin lakes: end of drainage basin.



Flood Basin Lakes

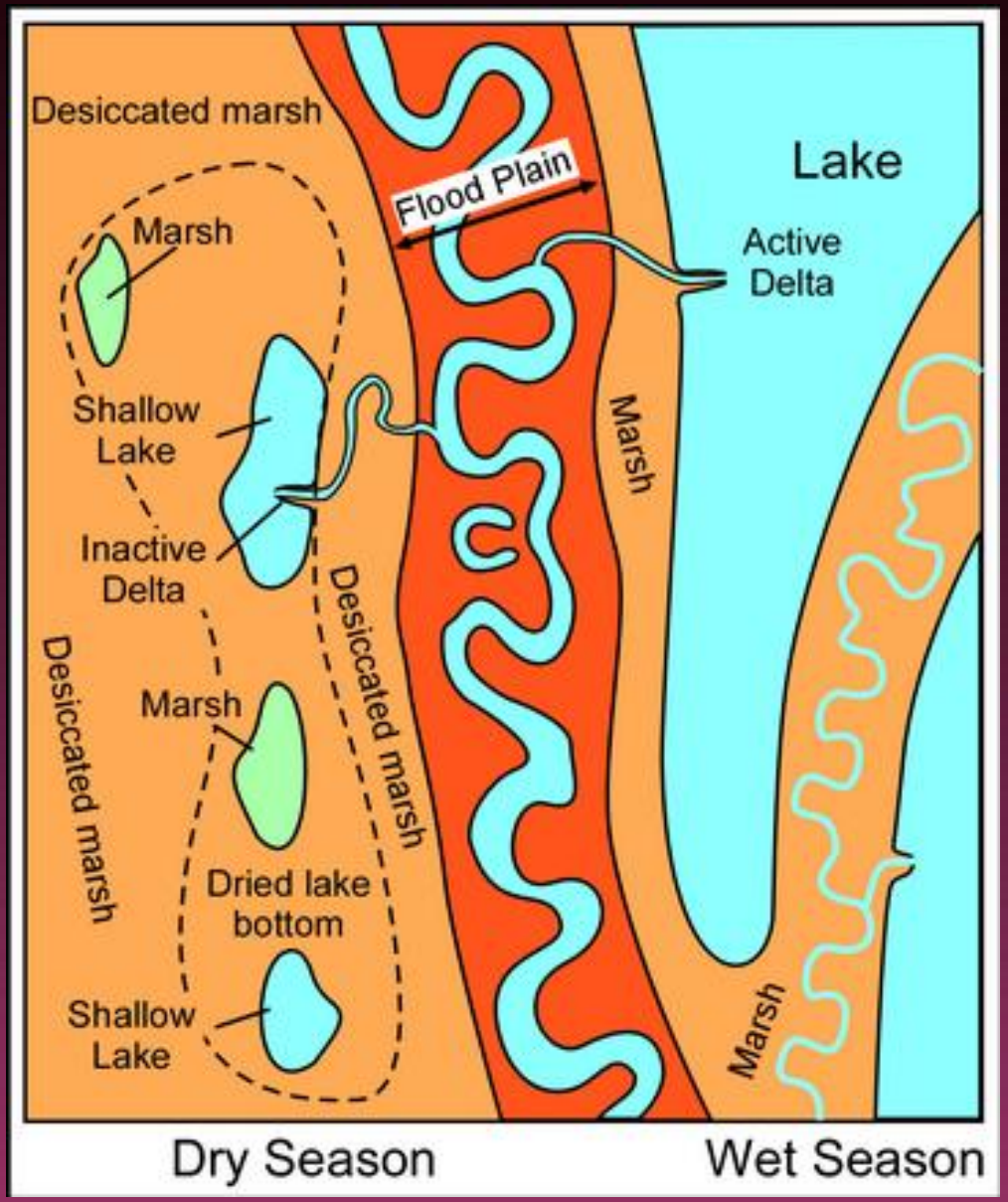
- Modern analog: sub-Andean Beni Basin, South America:
  - Seasonal floods.
  - Rapid subsidence.
- Flood plain:
  - Relatively narrow topographic high; mostly dry.
  - Forested.
  - Small oxbow lakes.
- Flood basin:
  - Marsh
  - Large lakes with deltas
  - Yazoo streams



USGS image provided by Google Earth. Copyright Google Earth.
Google Earth elevation data is approximately corrected for trees.

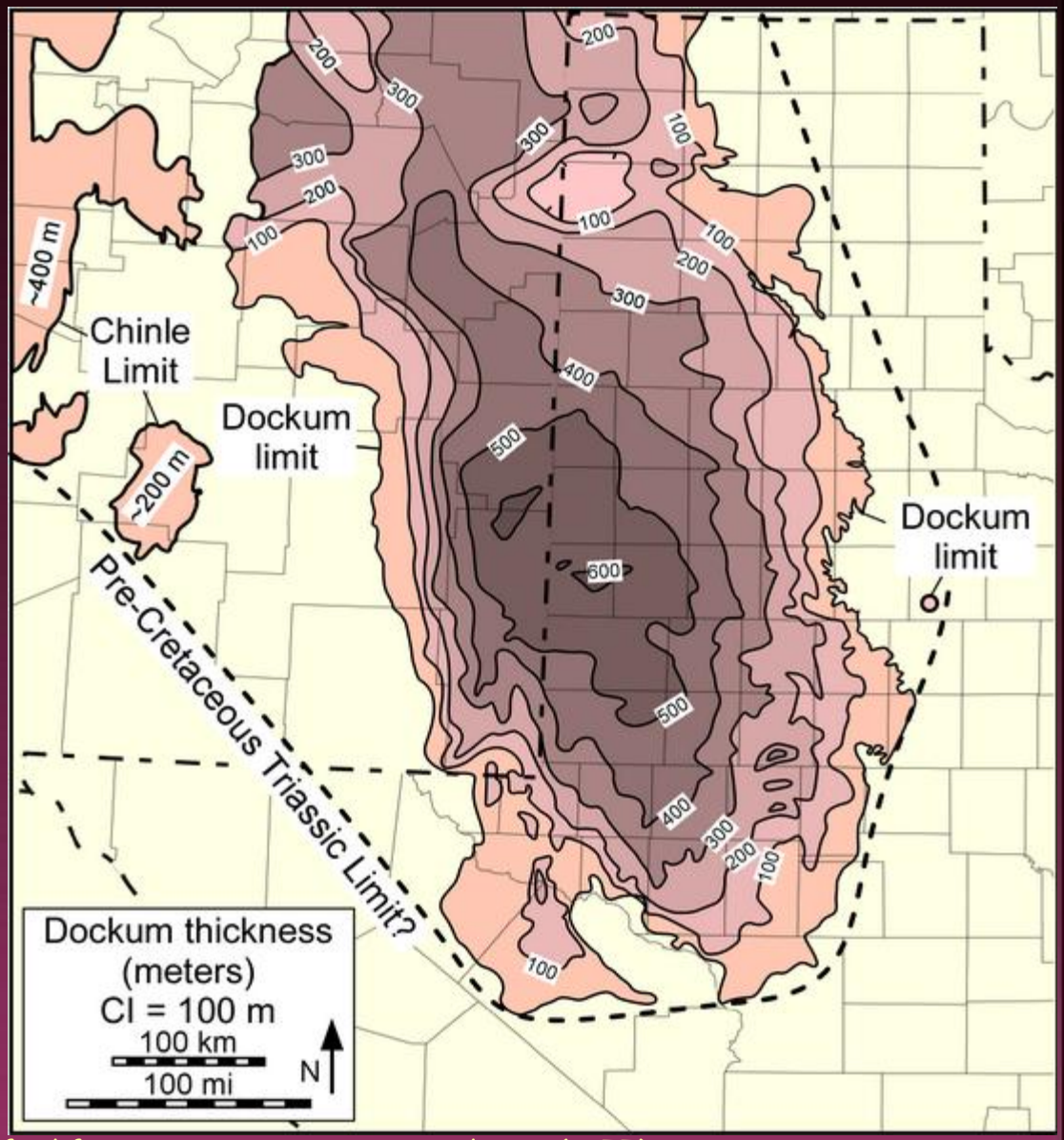
Dockum Depositional Model

- Smaller rivers; mud-dominated sediment load. Monsoonal climate: seasonal flooding.
- Relatively narrow, forested flood plain.
- Wide flood basins with marshes and lakes.
- Flood basin lakes:
  - Wet season: Large and relatively deep (> 2 m, 6 ft).
  - Dry season: small, shallow or completely desiccated.
- Lacustrine deltas grow during wet season from semi-permanent levee breaches.



Dockum Tectonic Setting

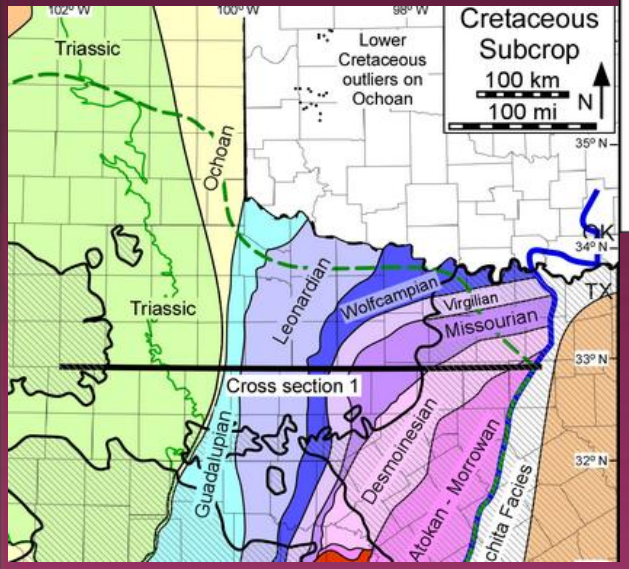
- Dockum basin subsidence is syndepositional.
  - Basal Dockum sandstones approximately concordant with base of unit.
  - Dips of shallower units decrease up section.
  - Thick axis does not correspond to Paleozoic basins.
  - Depositional thinning west of Dockum Basin
- Modern Dockum basin limits are erosional.
  - SW erosion associated with Late Jurassic uplift on margins of Chihuahua basin (Burro uplift; Diablo Platform).
  - Dockum continuous with Chinle before Early Cenozoic erosion.
  - East limit less eroded; pre-Cretaceous.

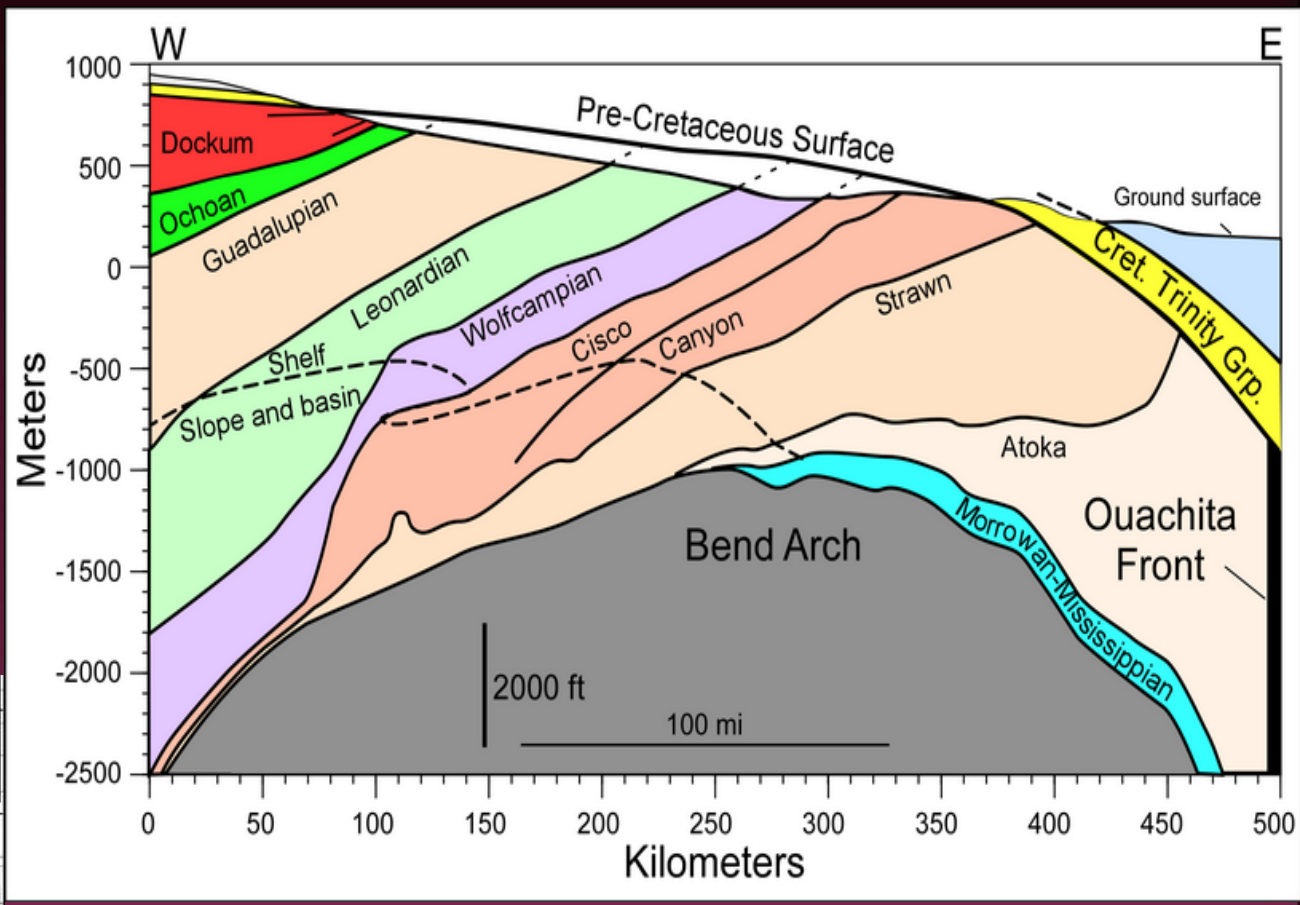


Modified from McGowen, Granata, and Seni (1977)

East Shelf Erosion

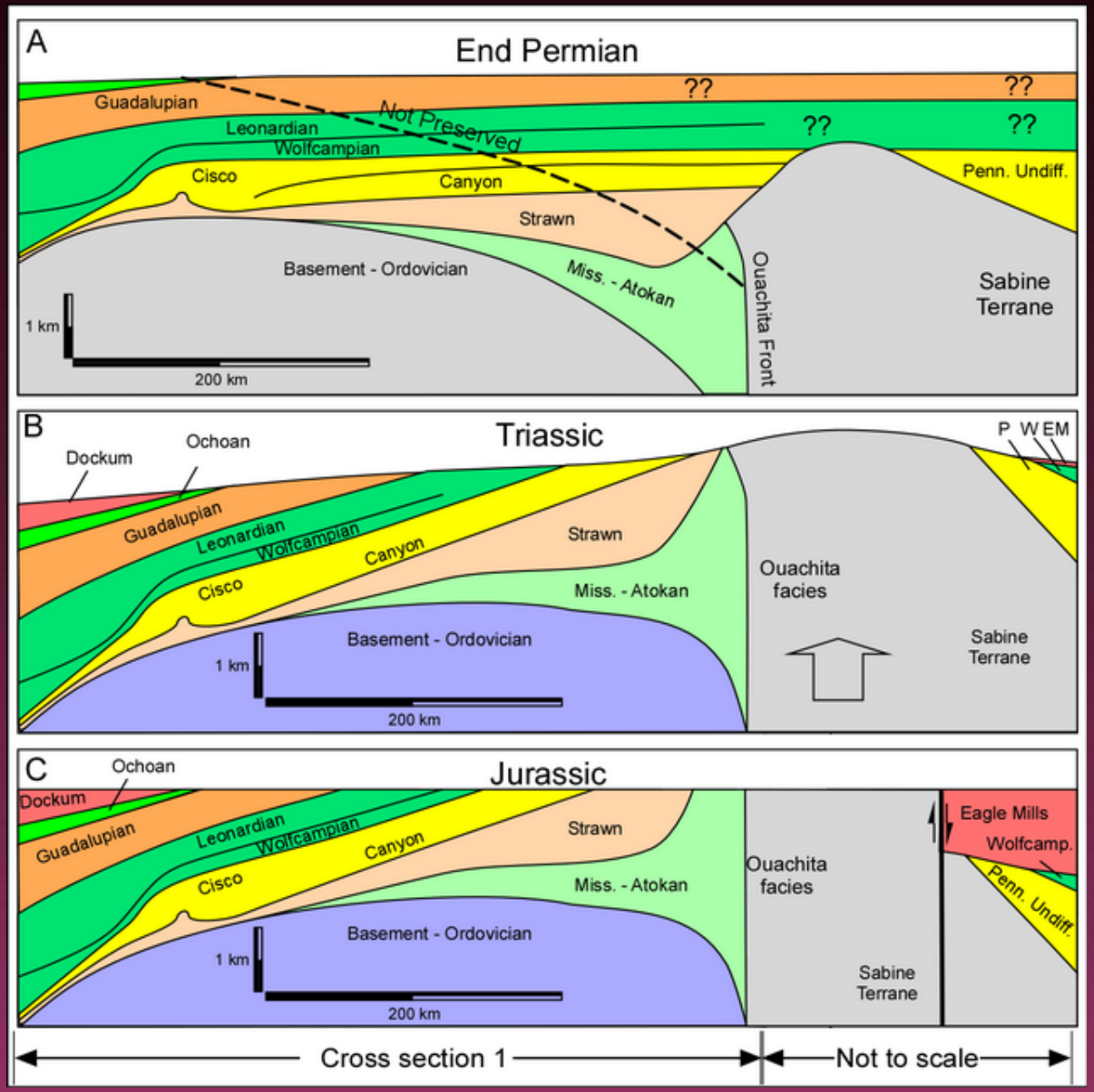
- Tilting and erosion was before or contemporaneous with Dockum deposition.
- Erosion greatest over Ouachita Tectonic Front





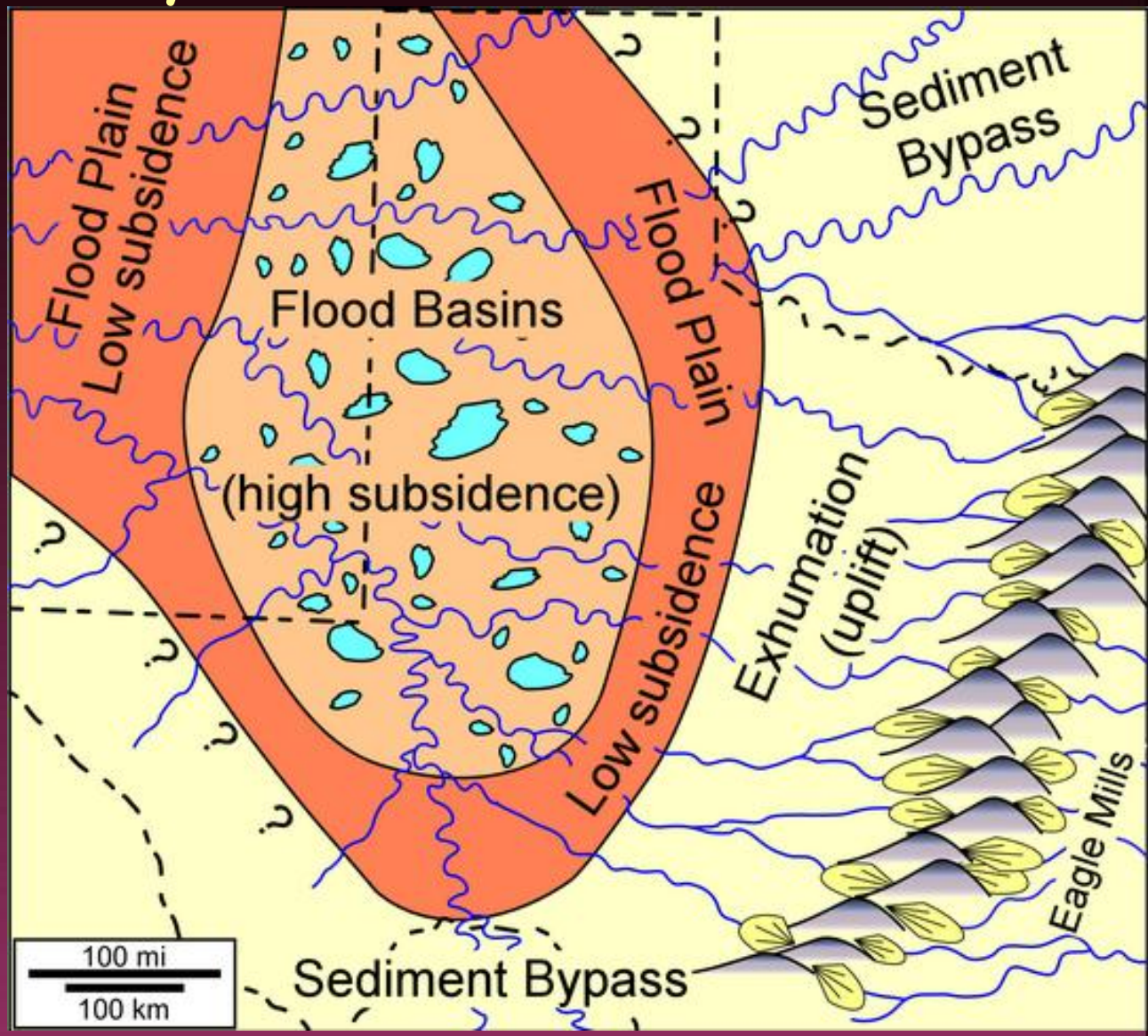
Ouachita Front Exhumation

- Post-tectonic Pennsylvanian and Permian strata were deposited east of the Ouachita trend.
- Erosion patterns mirror erosion west of the Ouachita Front.
- Erosion pre-dates Late Triassic Eagle Mills deposition and faulting.



Synthesis

- Drainage constrained by Cordilleran Arc high to SW.
- Active exhumation near Ouachita Front: initial stages of GOM opening.
- Predominantly flood plain deposition near basin margins.
- Predominantly flood basin deposition in central basin due to higher subsidence rate.
- Decreasing net sand towards center of Dockum basin.



Conclusions

- Dockum basin was not a closed sedimentary basin; it is part of a large predominantly west-flowing fluvial system.
  - Sediment source from northeast, east, and south with drainage to west constrained by arc systems.
  - East Shelf and Ouachita Tectonic Front exhumation controlled Dockum basin subsidence.
- Dockum mudrocks are predominantly fluvial flood-basin deposits:
  - Large lakes during wet season that partially or completely desiccated during dry seasons.
  - Wet season marshes desiccated to dryland soils during dry seasons.
  - Local arid soil formation in dry lakes during extended dry periods.
- Dockum sandstones are fluvial and deltaic deposits:
  - West-flowing trunk steams with narrow flood plains and wide flood basins.
  - Smaller Yazoo streams on flood basin.
  - Intermittent lacustrine deltas sourced from wet-season levee breaching.

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