# Stratigraphic Framework of the Wolfcamp – Spraberry of the Midland Basin

Abilene Geologic Society

May 20, 2021

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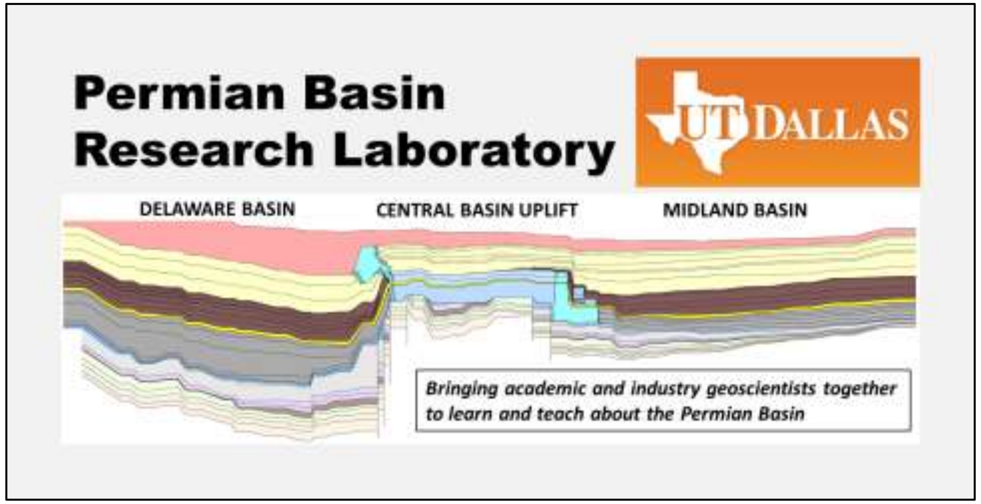
Permian Basin Research Lab
University of Texas at Dallas

# Permian Basin Research Lab at UT Dallas

Dr. Robert J. Stern and Mr. Lowell Waite, Co-Directors

-- established January, 2019 --




## Goals:

- Advance understanding of all geologic aspects of the Permian Basin through open applied research, **linking academia and industry**
- Educate and better prepare students for professional careers in the oil and gas industry
  - Graduate courses offered:
    - Geology of the Permian Basin
    - Petroleum Geoscience
    - Paleo Earth Systems: Global Themes
    - Carbonate Sedimentology

https://labs.utdallas.edu/permianbasinresearch/

# Stratigraphic framework of Wolfcamp – Spraberry: Objectives

- Review the tectono-stratigraphic framework of the Wolfcamp and Spraberry deep-water units of the Midland Basin, west Texas
- Briefly discuss the facies/characteristics of these rocks
- Highlight the differences between the Wolfcamp shale (A – D) and Spraberry depositional systems

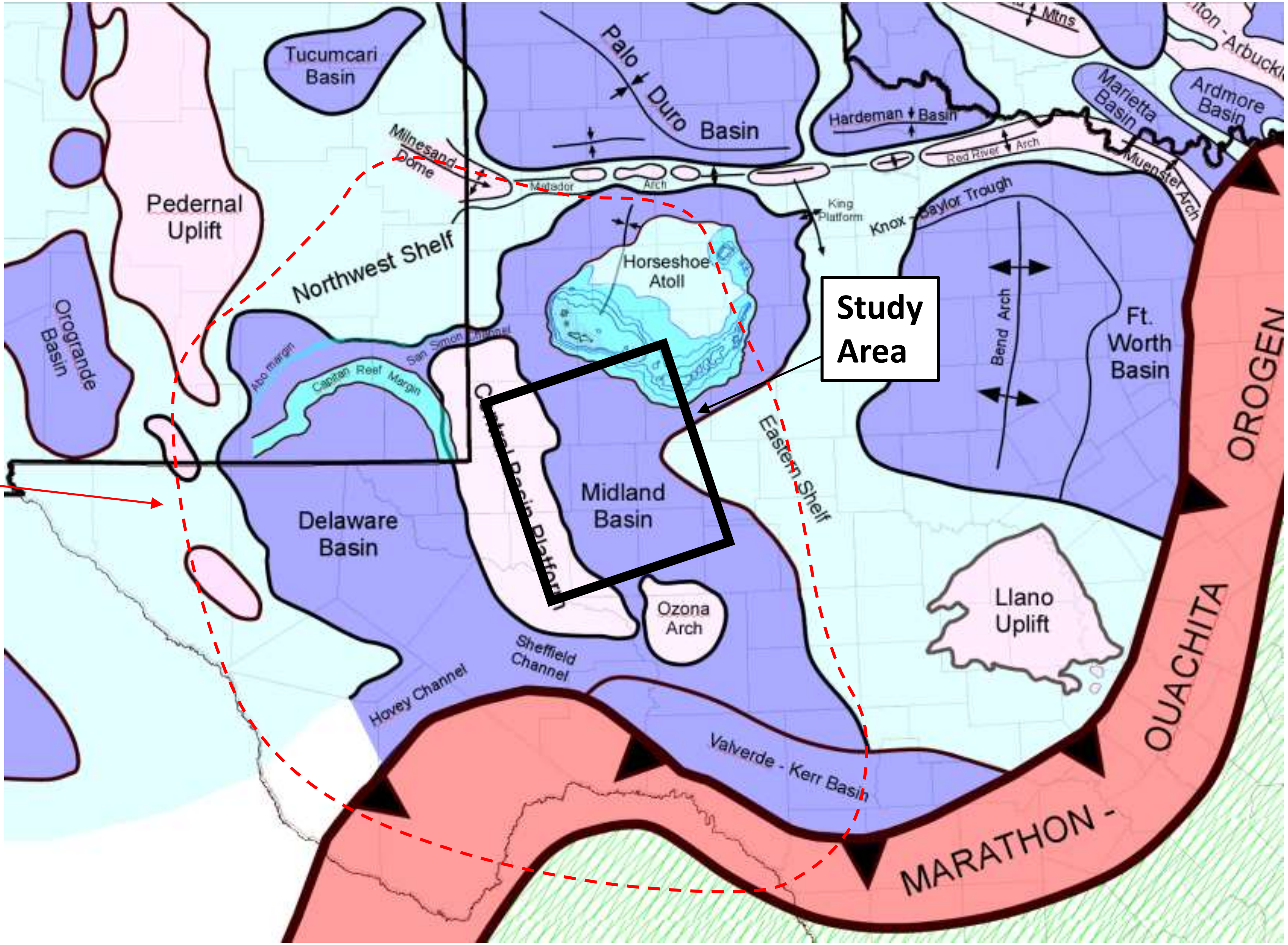
*Note: Although not specifically addressed, the framework outlined here is applicable to the Delaware Basin*

*This talk focuses on geology and does not discuss engineering/completion topics*

# Greater Permian Basin Region

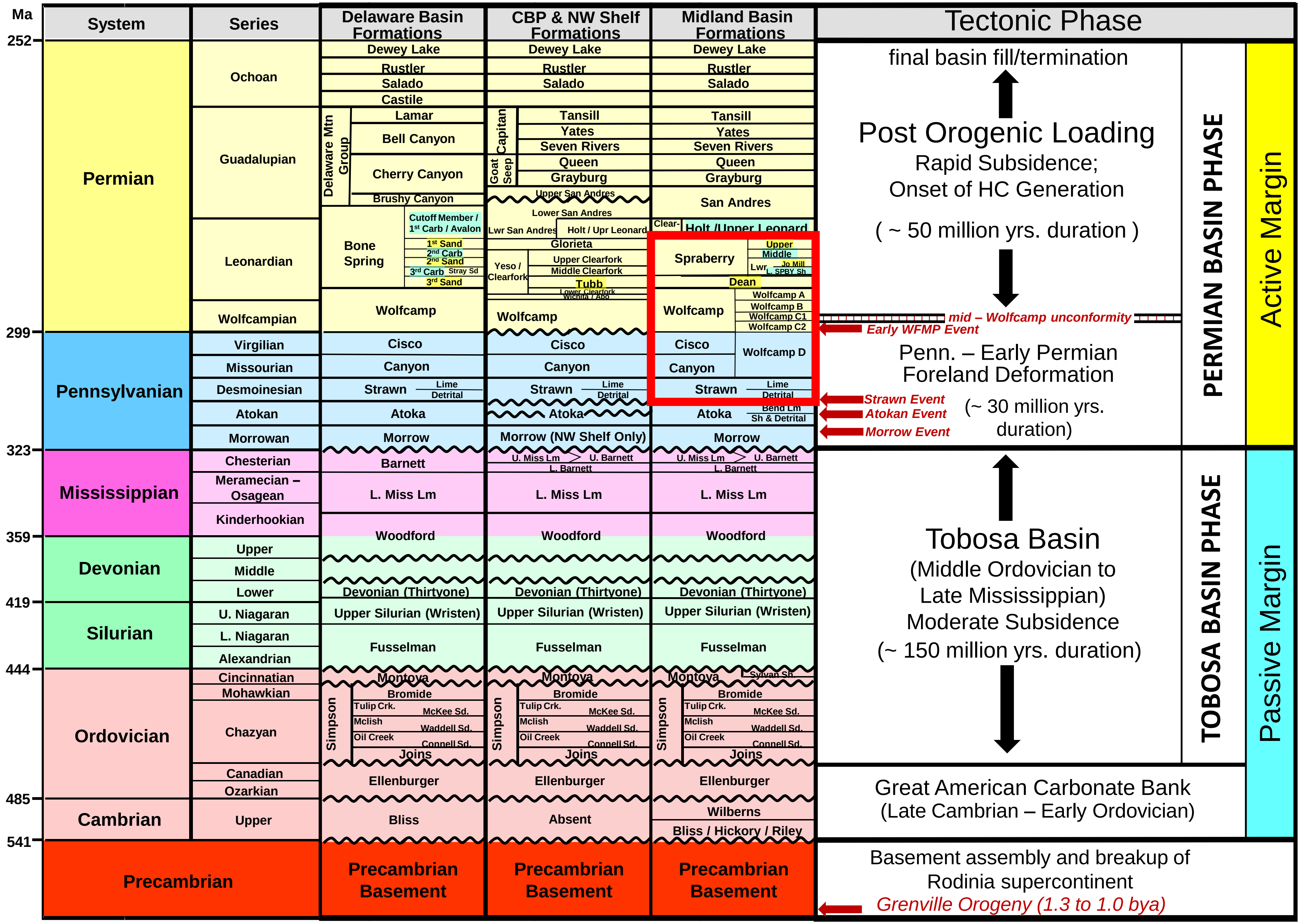
- Confluence of Marathon-Ouachita fold and thrust belt and Ancestral Rockies basement-involved uplifts
(Penn. – early Permian)

Precursor
Tobosa Basin
(Ord. to Miss.)




Fold and thrust belt
Basement uplift
Shallow marine shelf
Reef / shoal complex
Deep marine basin

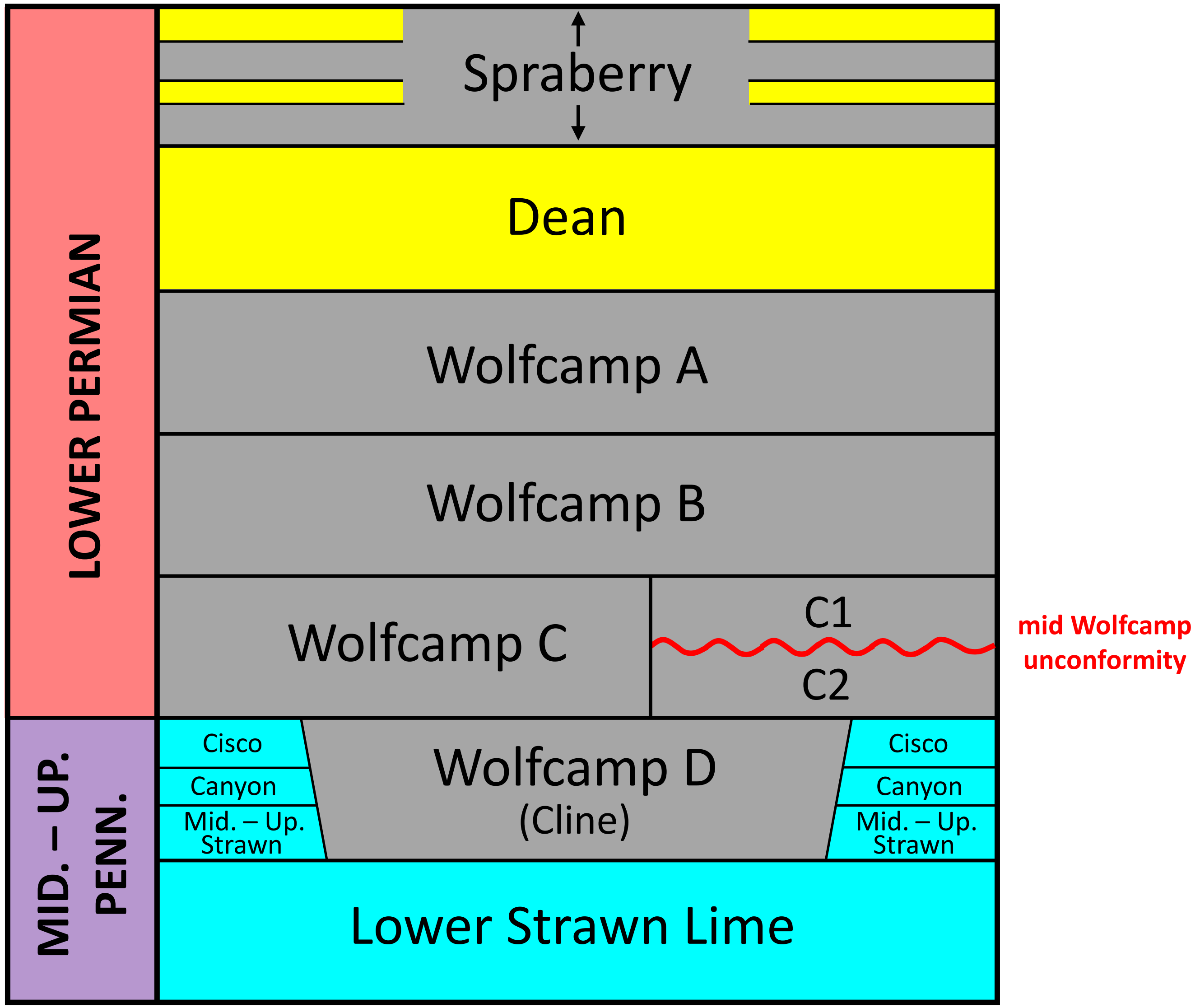
# Permian Basin Stratigraphy and Tectonic History

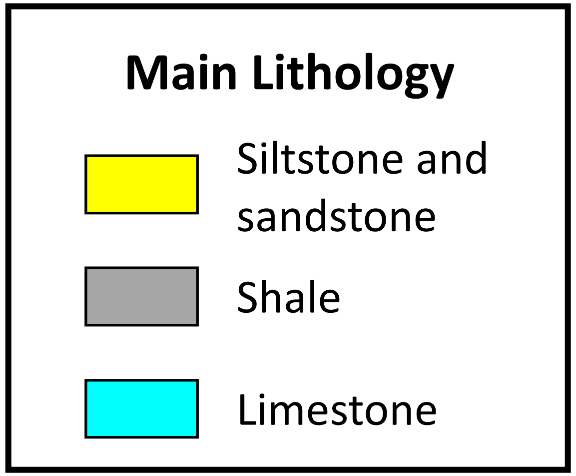



UTD PBRL

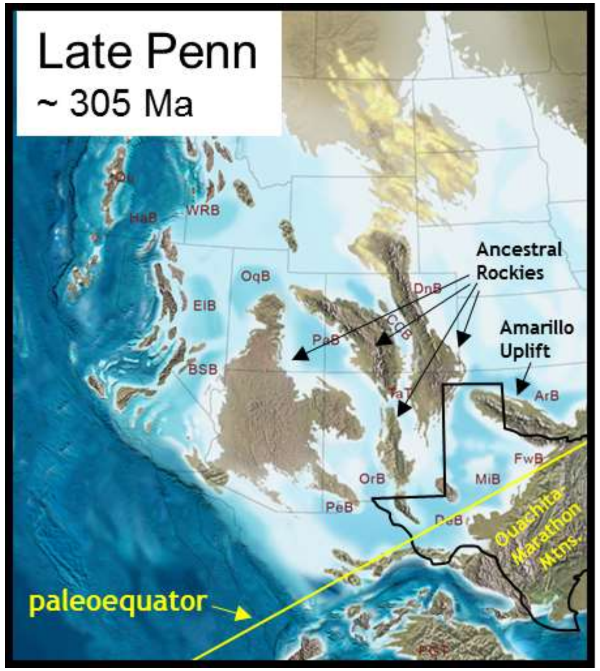
(modified from Reed, unpub., 2016)

# MIDLAND BASIN: SIMPLIFIED STRATIGRAPHY AND FACIES



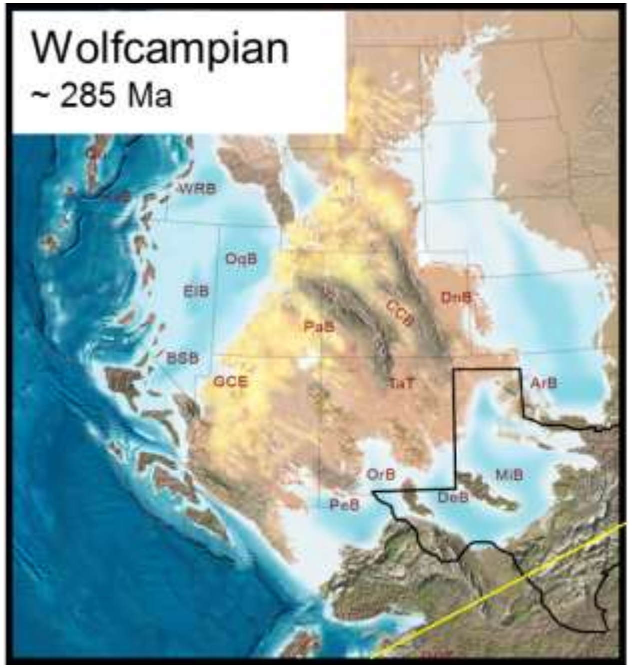
# LATE PENNSYLVANIAN – EARLY PERMIAN EVOLUTION OF WESTERN PANGEA

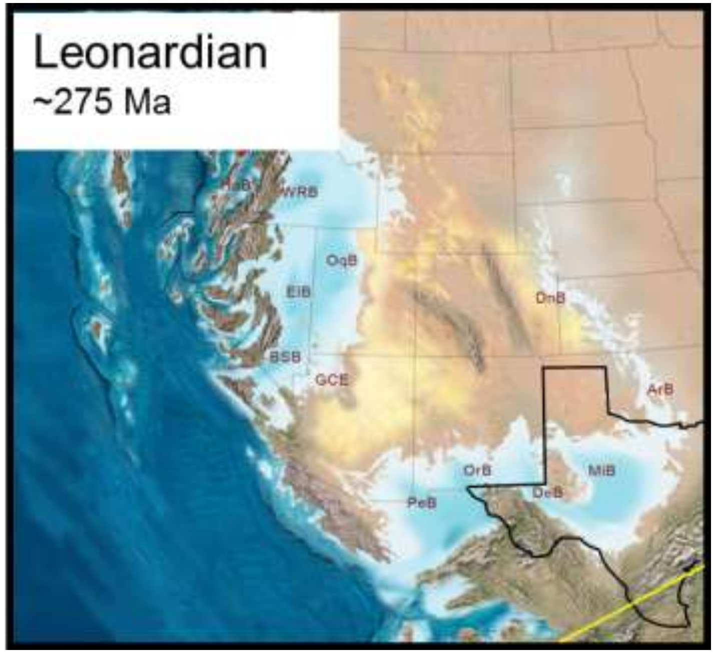



A very dynamic time in Earth history, especially in west Texas

## Late Pennsylvanian

- Icehouse climate; PB in humid-tropical setting (abundant rainfall)
- Numerous high-freq., high-amplitude sea-level changes
- Expansion of Penn seaway (long-term rise); stratified water columns
- Continued tectonism in west Texas (Marathon-Ouachita FTB, rise of ARM)




## Wolfcampian – Early Leonardian

- Waning icehouse, transition to greenhouse
- Northward drift of Pangea
- Increasing aridity & expansion of continental desert in western U.S.
- Cratonic emergence / contraction of seaway (onset of long-term SL fall)
- Culmination of tectonic pulses in W. TX (mid WC); Pacific arc volcanism (Late WC-Leon.); PB enters rapid subsidence phase (Dean - Spraberry)

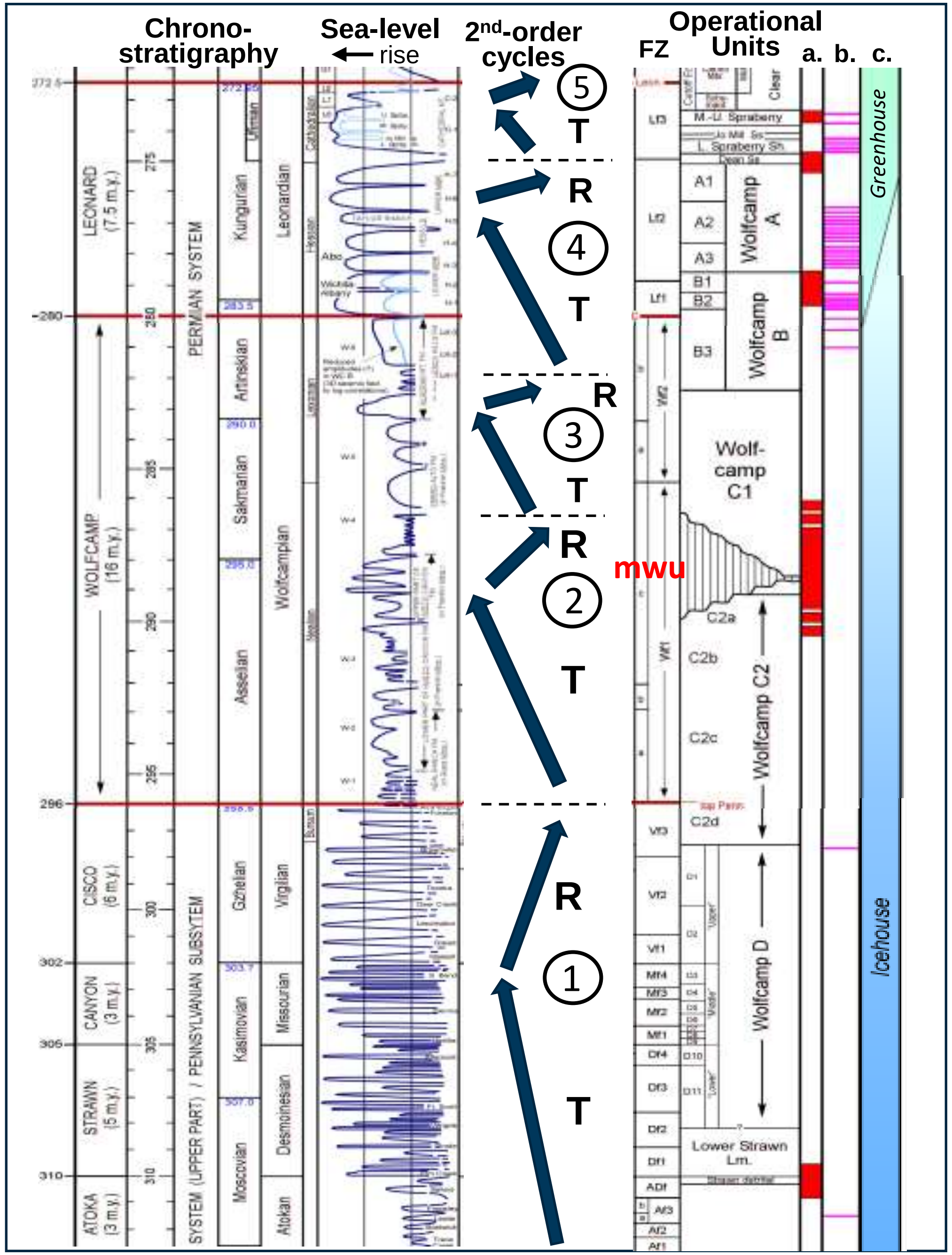
(maps: Ron Blakey, NAU/Colorado Plateau Geosystems)

# Stratigraphic framework, Wolfcamp - Spraberry

(Waite et al., 2019, AAPG SW Section mtg)

Numerous 3rd- and higher-order cycles of sea-level change organized into larger 2nd-order trends (5 – 10+ m.y. in duration); from oldest to youngest:

1. **Atoka - WC D - lowermost WC C2**
2. **WC C2**
3. **WC C1**
4. **WC A - B**
5. **Dean – Spraberry**




FZ. Fusulinid zonation

a. Tectonic pulses

b. Ash beds

c. Climate phase

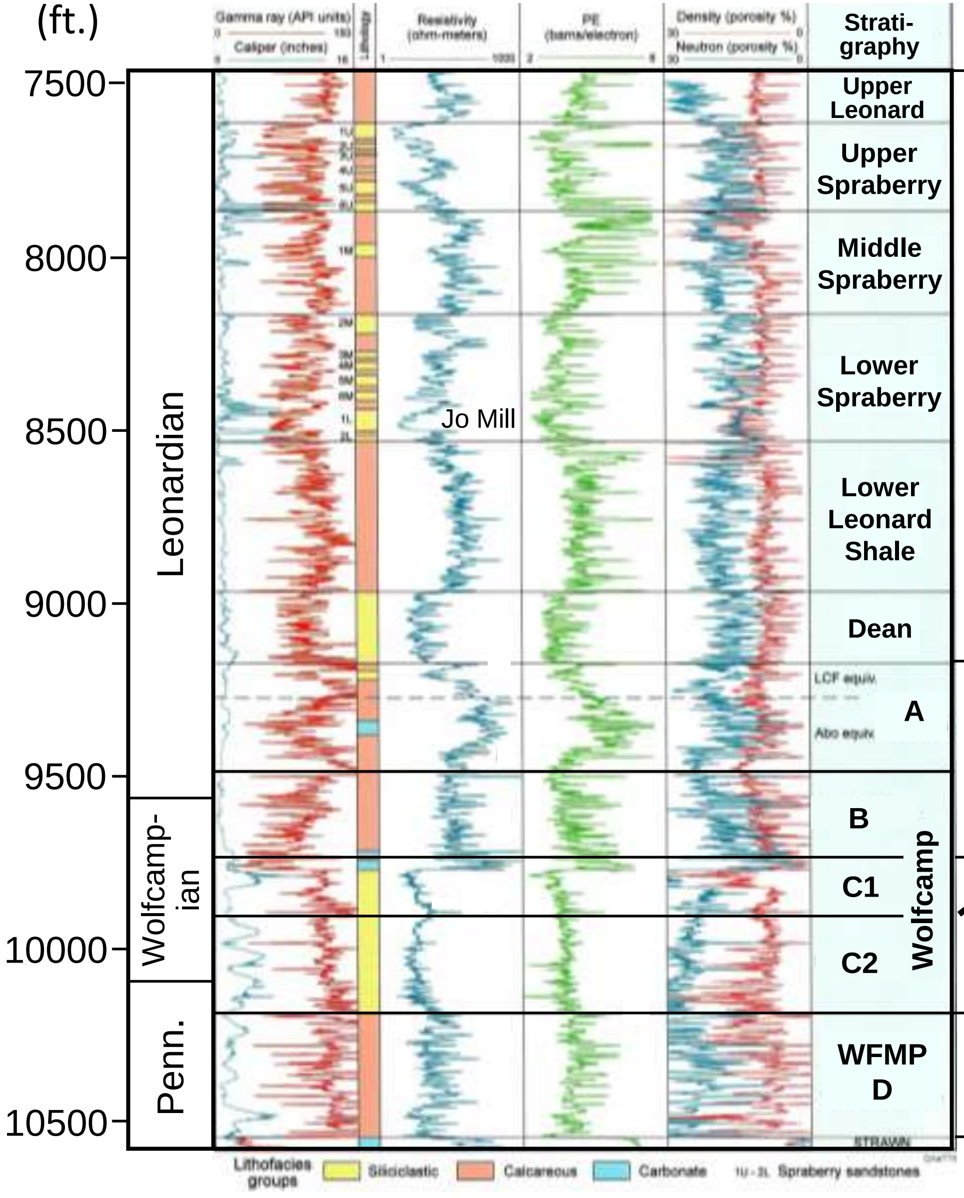
mwu: mid-Wolfcamp unconformity

R = Regression

T = Transgression

(Sea-level curve from Ross and Ross, 2009; Fusulinid zonation from Wahlman, 2019)

# Midland Basin Type Log




(modified from Hamlin and Baumgardner, 2012)

## *GENERAL DESCRIPTION / DEPOSITIONAL FACIES*

(Based on numerous core studies)

**Spraberry – Dean:**
silty mudstones and clay-rich siltstones punctuated by multiple deeper-water submarine fan complexes (incl. massive to laminated, fine-grained sandstones)

**Wolfcamp A – B:**
silty- and calcareous organic-rich mudstones; carbonate percentage increases upward

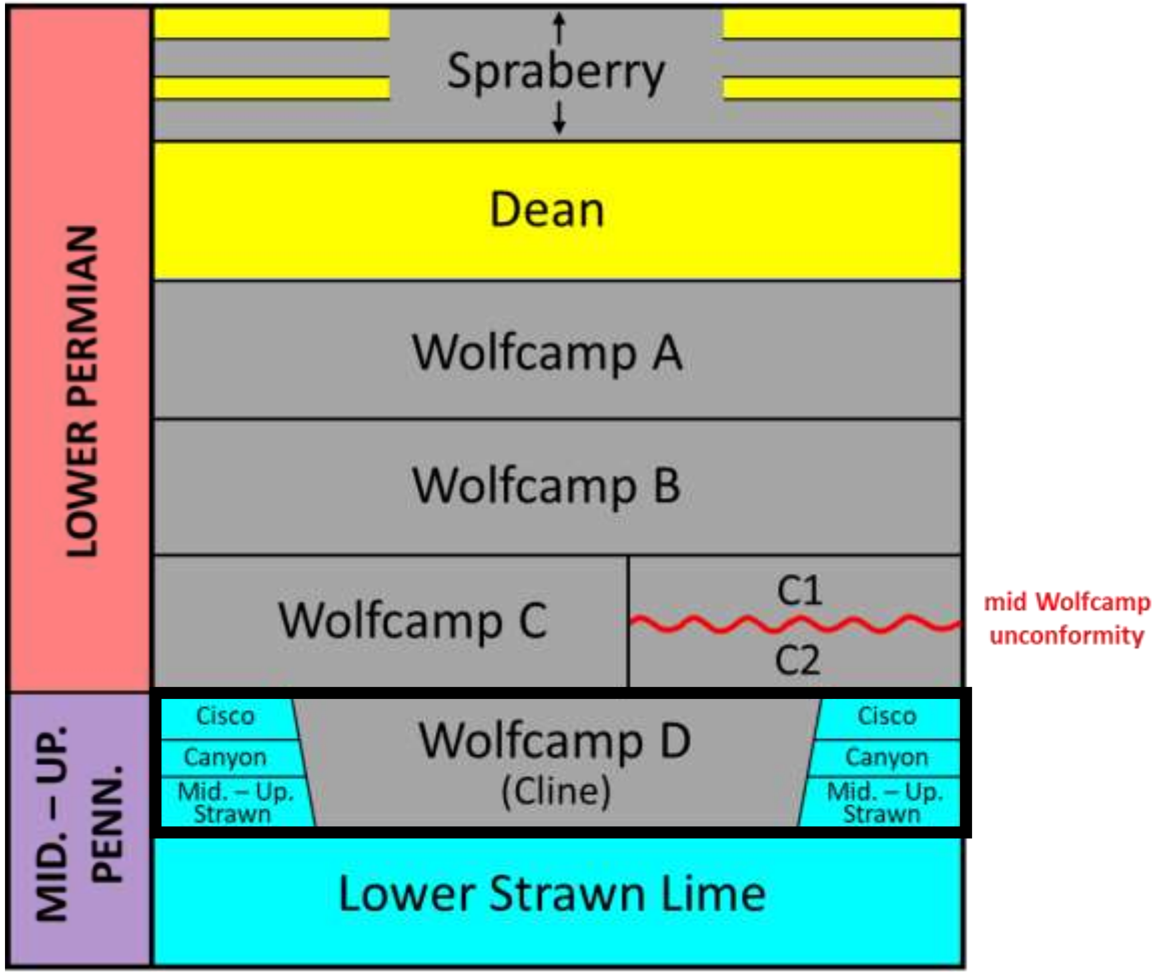
***mid-WC unconformity***

**Wolfcamp C**: Clay-rich shale (progradation of Eastern Shelf deltas & Glasscock Nose)

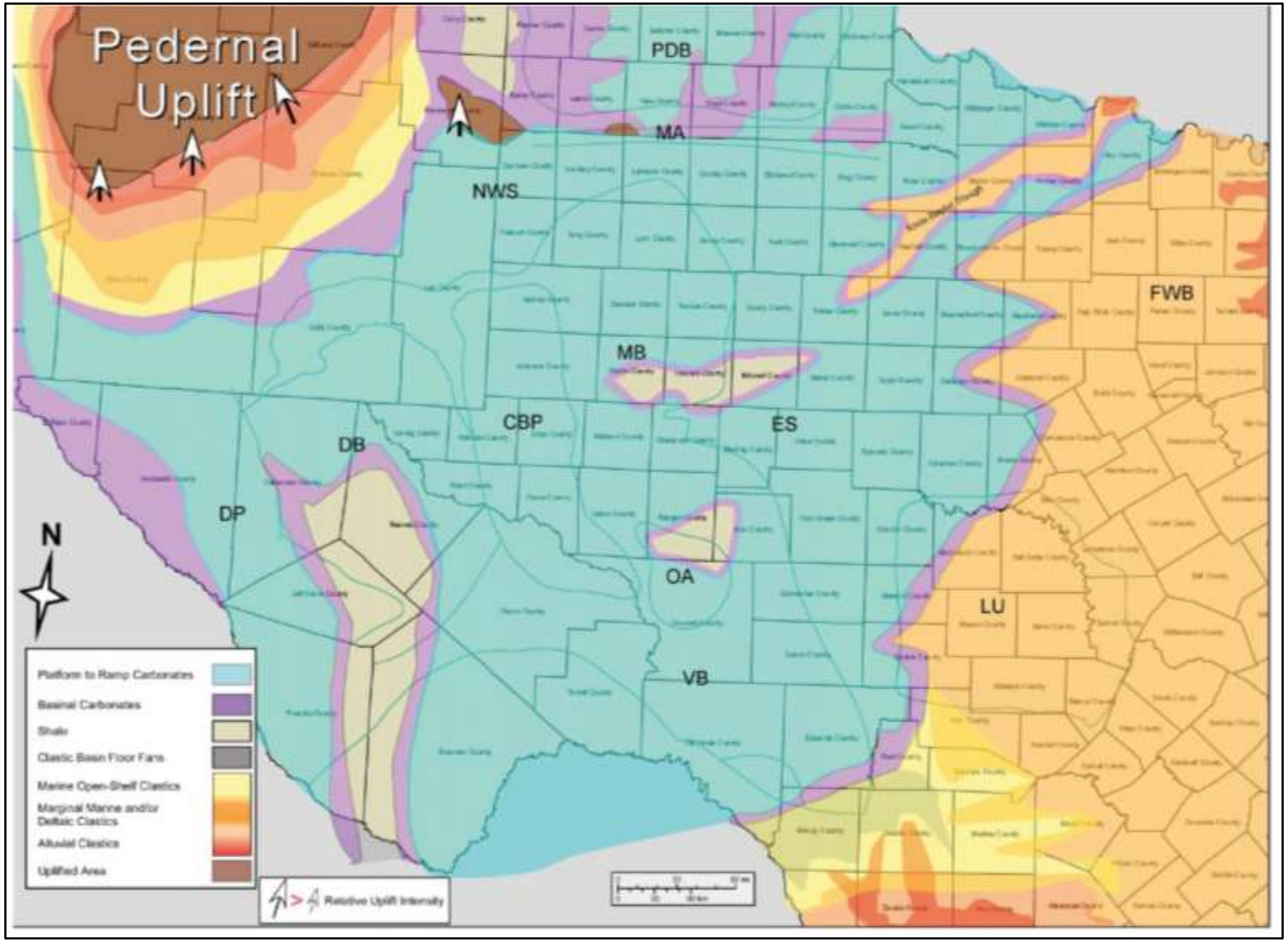
**Wolfcamp D**: Basinal cyclothems (starved basin)

**Lower Strawn:** shallow-water platform limestones

# Wolfcamp D (Cline)



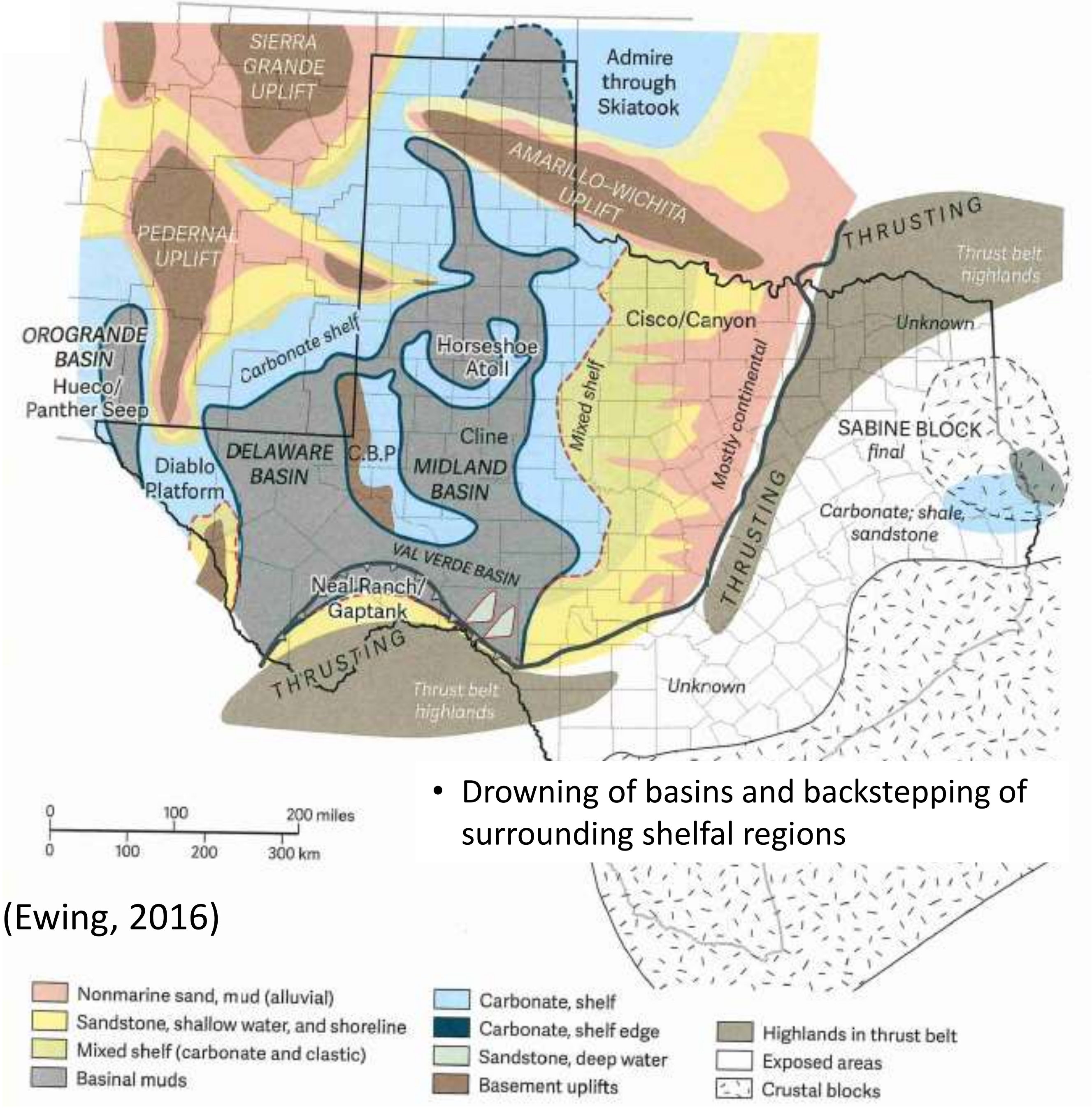
# Lower Desmoinesian Facies (Lower Strawn Limestone)




(Wright, 2011)

- Shallow water platform carbonate facies extend across entire Midland Basin and Eastern Shelf region
- Lower Strawn Limestone is generally < 200 ft. thick in Midland Basin
- Core analyses indicate typical Penn shelf cyclothem deposits: burrowed skeletal wackestones grading upward into phylloid algal packstones and skeletal grainstones, capped by exposure surfaces
- Pre-dates drowning of Midland, Delaware basins

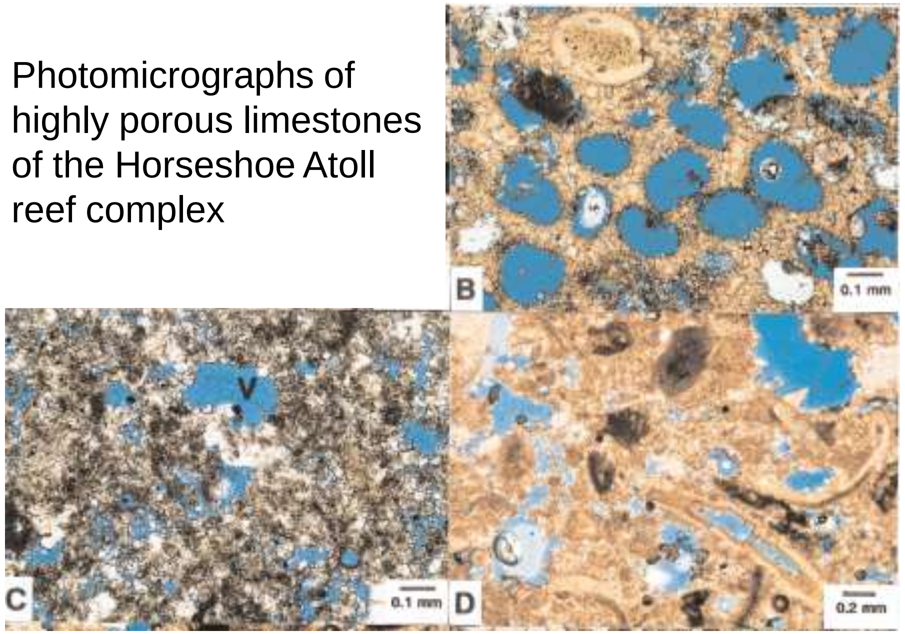
# Wolfcamp D (Canyon – Cisco) facies




- Drowning of basins and backstepping of surrounding shelfal regions

(Ewing, 2016)

Photomicrographs of highly porous limestones of the Horseshoe Atoll reef complex

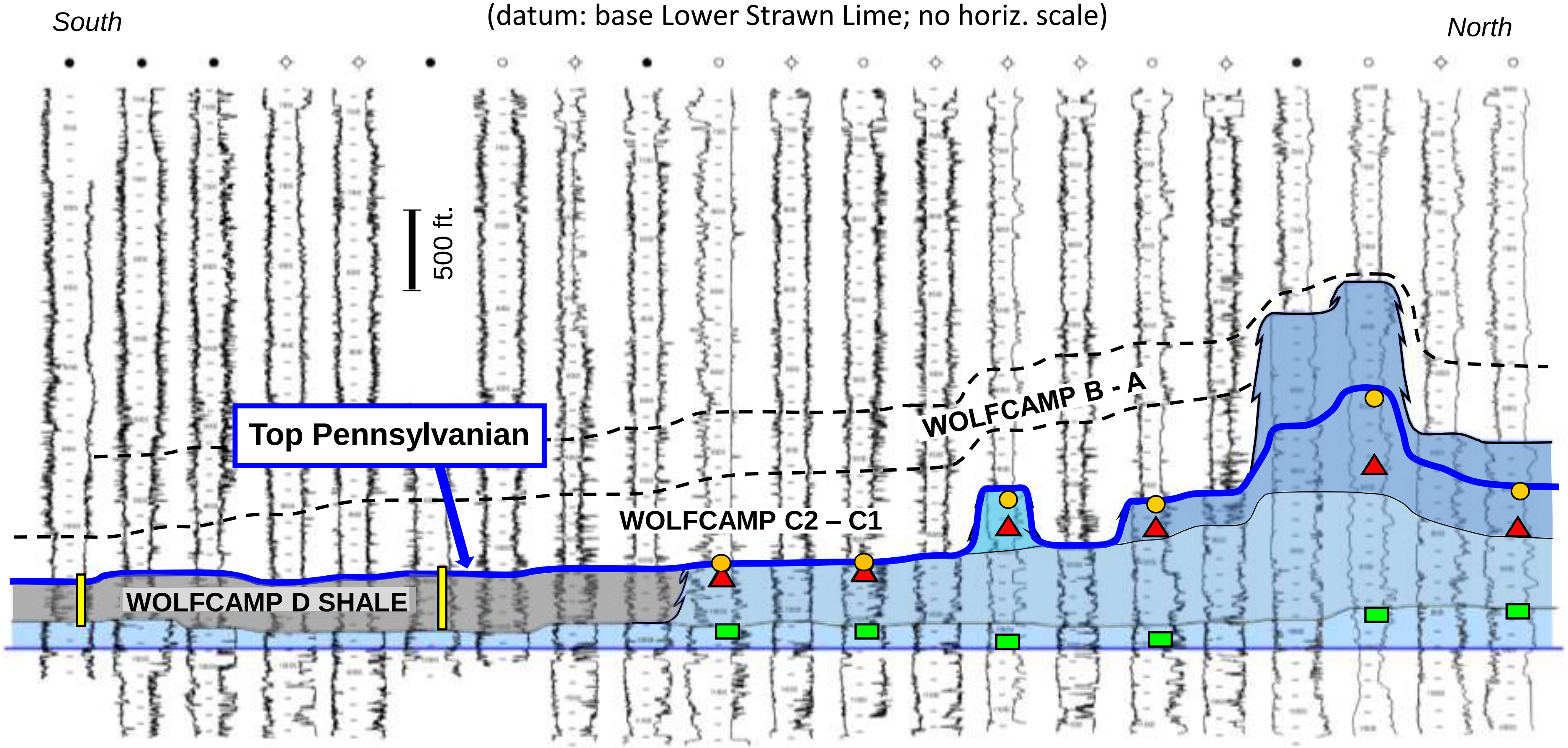


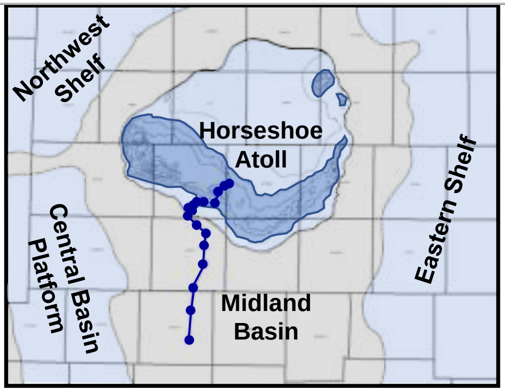

(Saller et al., 1999)

Organic-rich Wolfcamp D (Canyon – Cisco) black shales in core from the center of Midland Basin

# Wire-line log correlation from Midland Basin to Horseshoe Atoll

(datum: base Lower Strawn Lime; no horiz. scale)




**Paleo control**

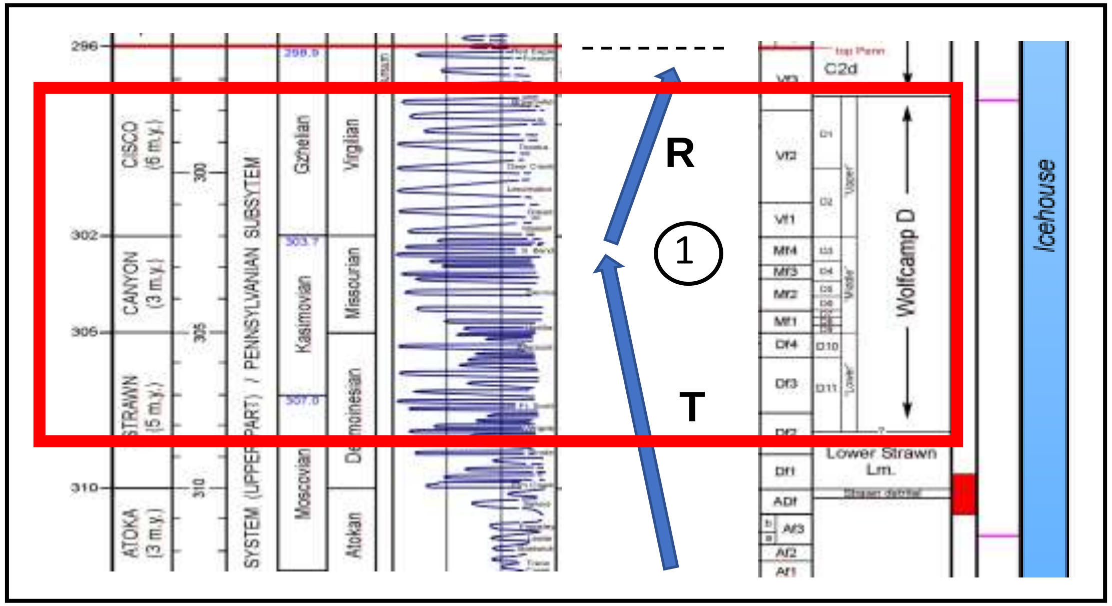
- Cisco fusulinids (yellow circle)
- Canyon fusulinids (red triangle)
- Lower Strawn fusulinids (green rectangle)
- **cored interval** (yellow bar)

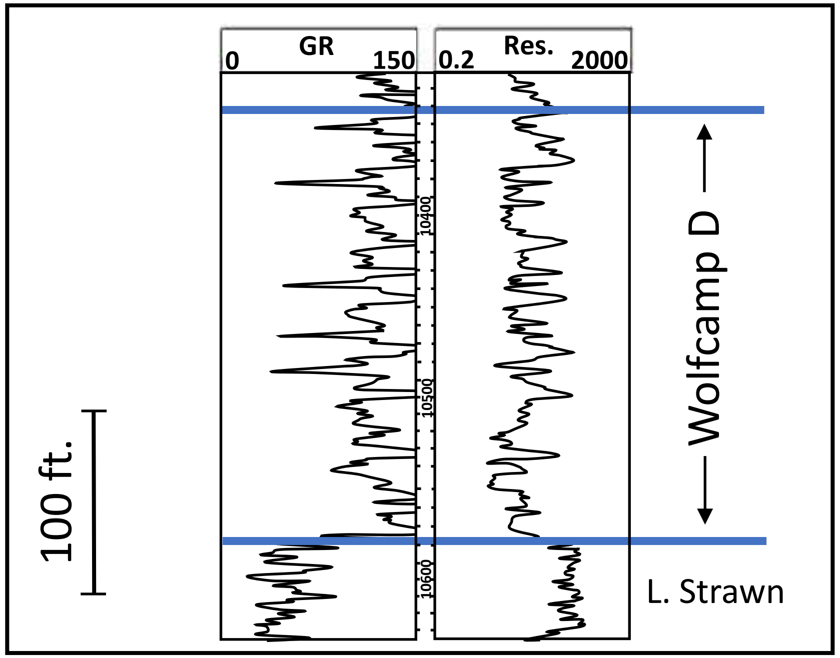
## Observations:

- Shale facies (basin) transition abruptly into carbonate reef facies (Atoll)
- Wolfcamp D shale is Penn. age (correlation to fusulinid-bearing LS)

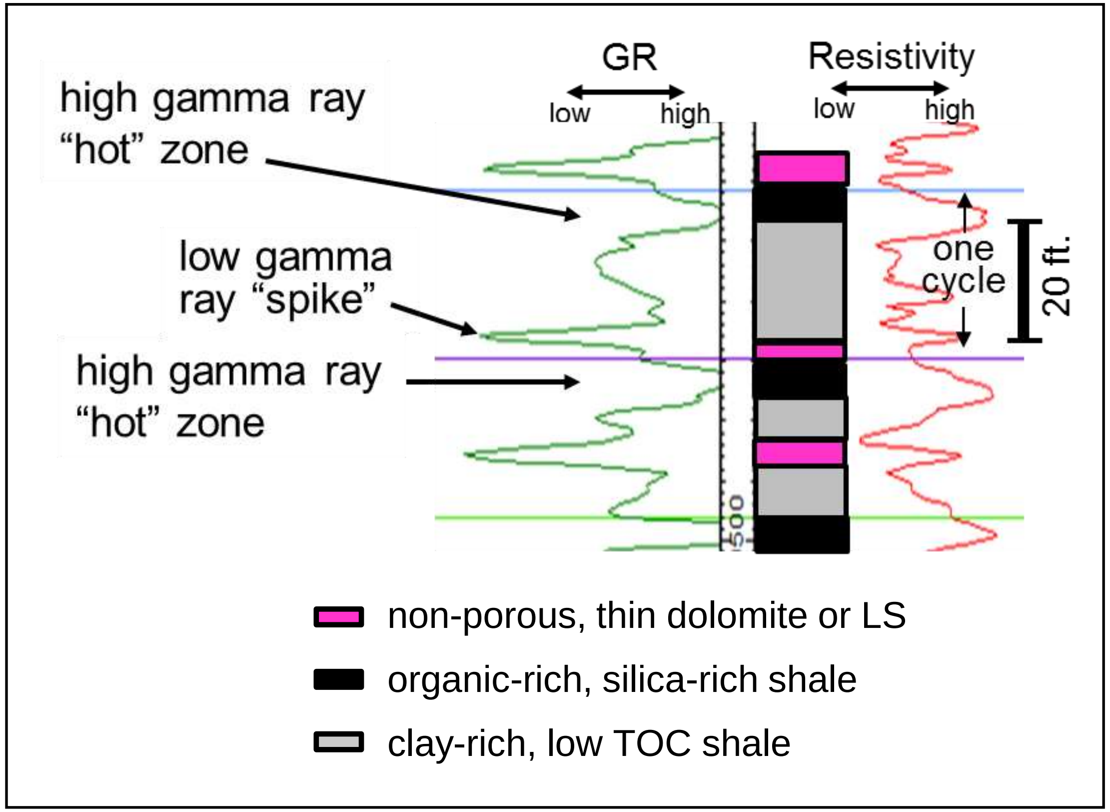
(L. Waite, unpublished, 2015)

# Wolfcamp D: Basinal cyclothems

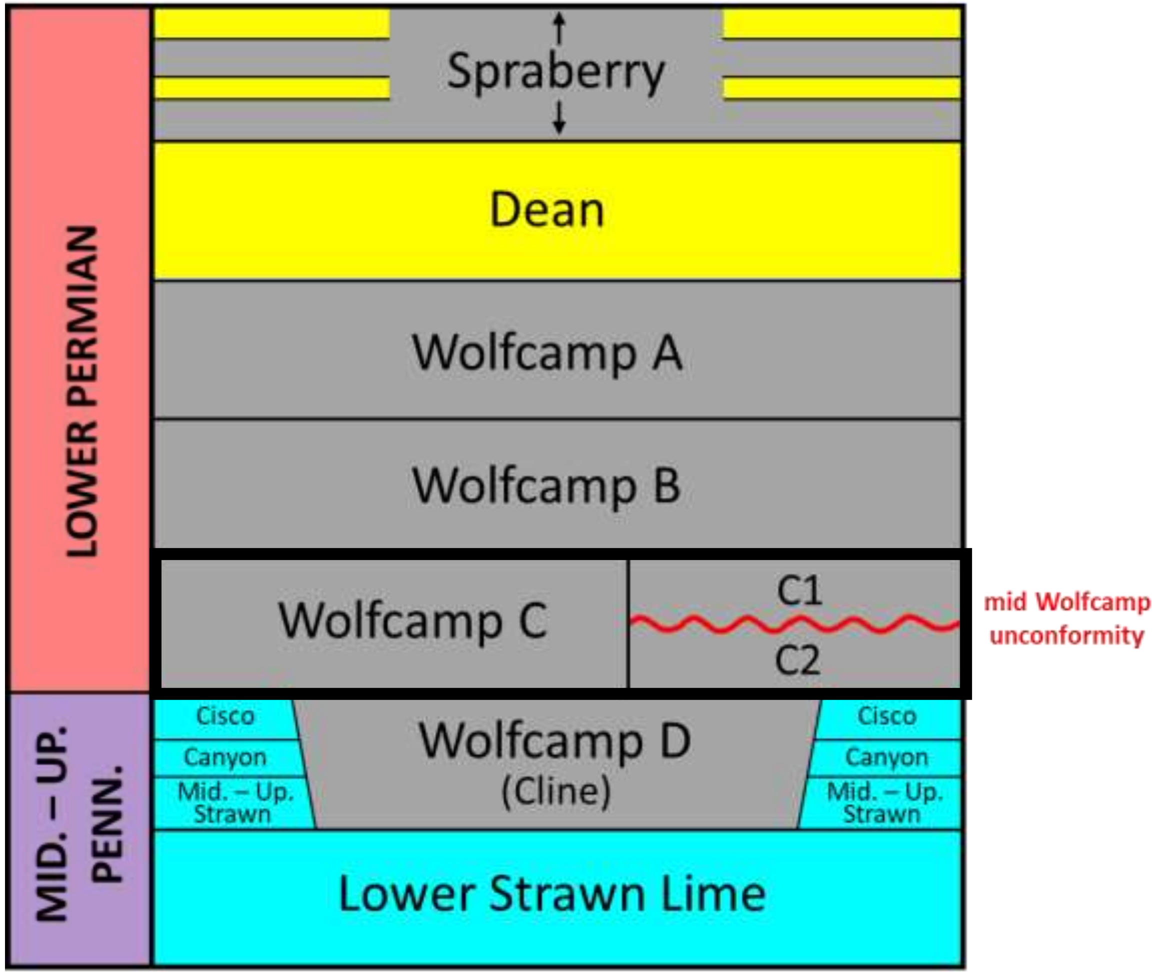


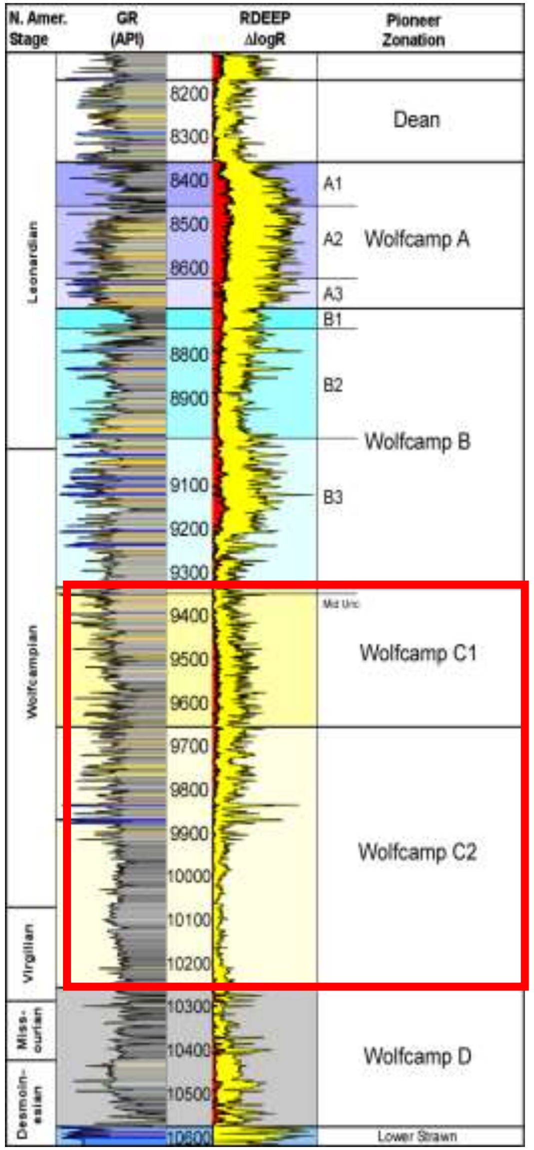

- Equivalent to classic "Penn. cyclothems" on shelves
- Silica – rich shales; relatively high clay content
- Each basinal cyclothem = 15 – 45 ft. thick; bounded by thin dolomite or LS; highly correlative basin-wide
- Organic content partitioned into multiple thin cycles
- High pore pressures due to depth, maturity



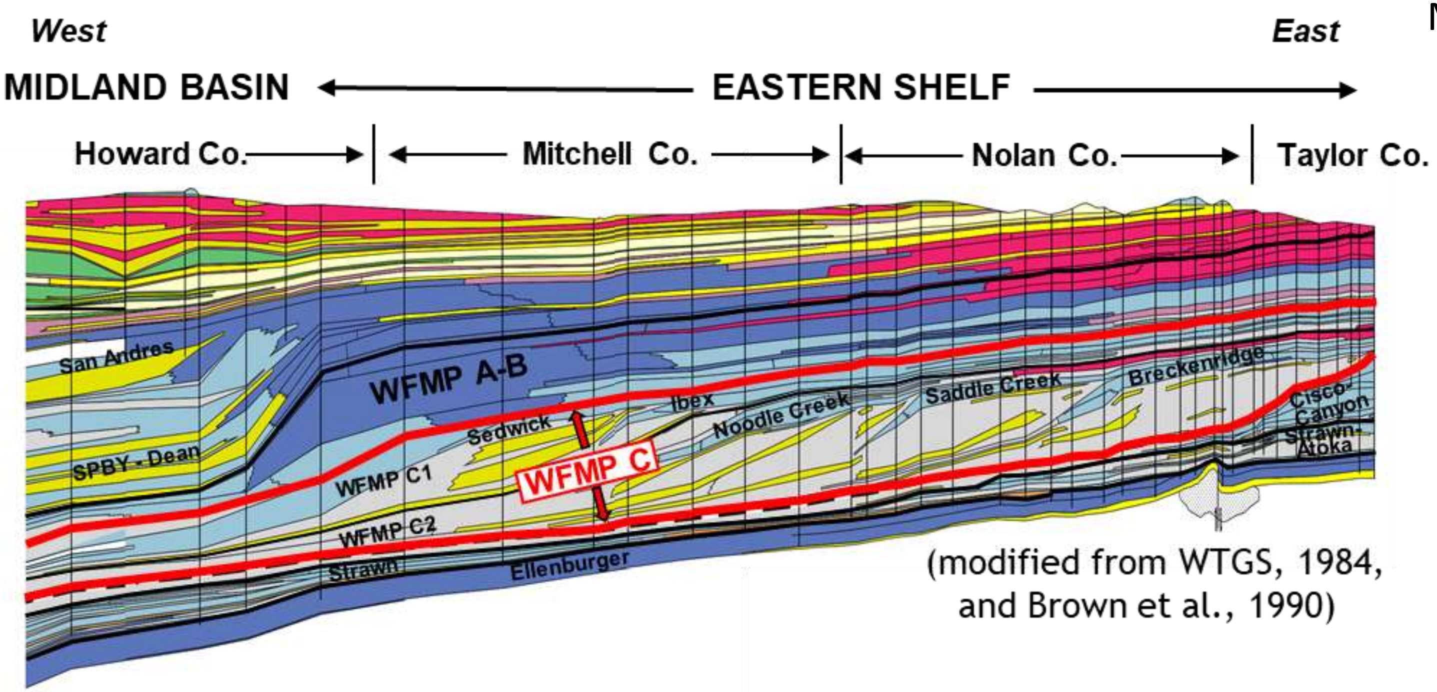
# Wolfcamp C


LOWER PERMIAN
MID. – UP. PENN.
Spraberry
Dean
Wolfcamp A
Wolfcamp B
Wolfcamp C
C1
C2
mid Wolfcamp unconformity
Cisco
Canyon
Mid. – Up. Strawn
Wolfcamp D
(Cline)
Cisco
Canyon
Mid. – Up. Strawn
Lower Strawn Lime

# Wolfcamp C




(Sinclair et al., 2018)



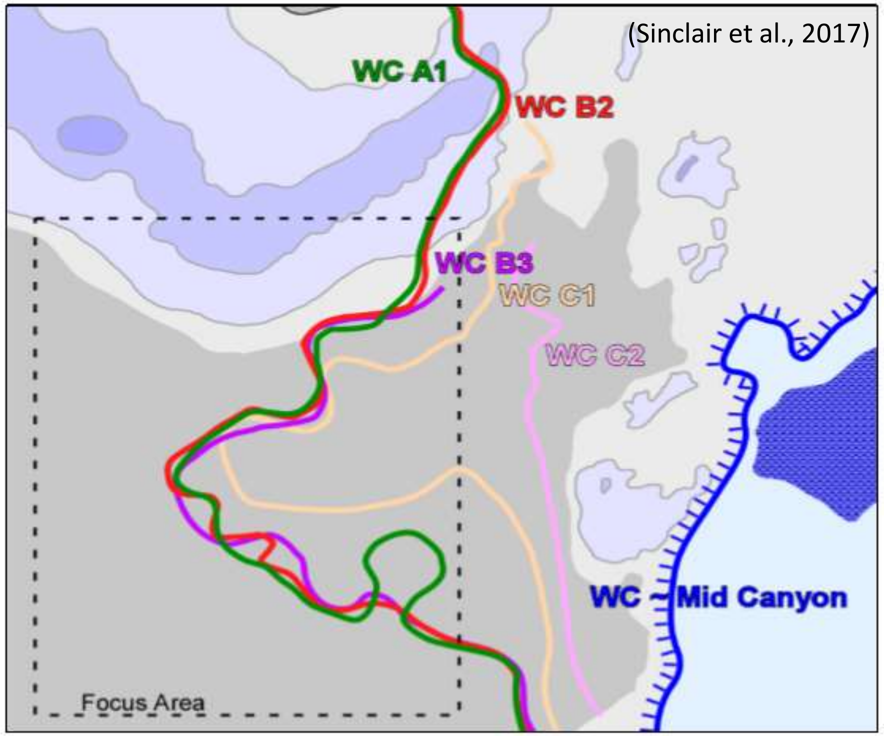

(modified from WTGS, 1984, and Brown et al., 1990)

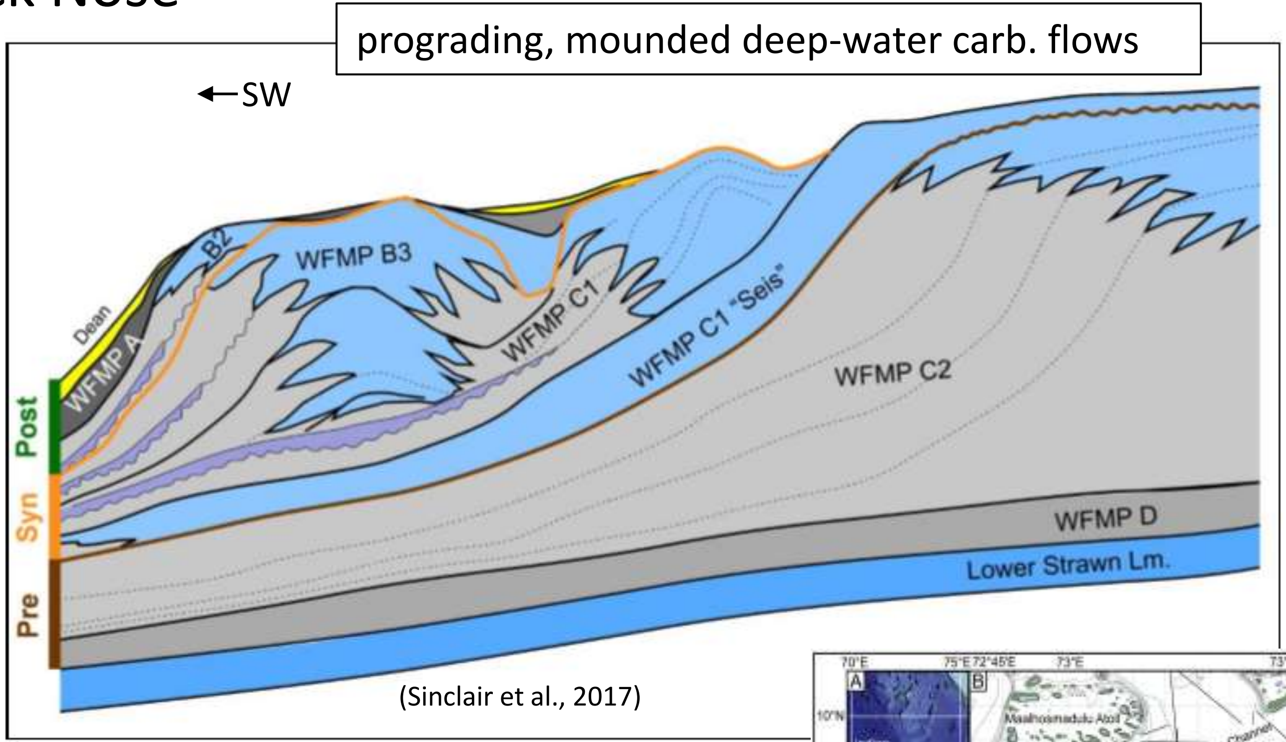
Preliminary correlation of MB tops to Eastern Shelf

| Eastern Shelf | | MB |
|---|---|---|
| Cisco Group | Elm Creek | A |
| Cisco Group | Admiral-Coleman Junc. | B |
| Cisco Group | Sedwick-Ibex | C1 |
| Cisco Group | Noodle Creek Camp Creek | C2 |
| Cisco Group | Saddle Creek-Crystal Falls | C2 |
| Cisco Group | Breckenridge-Finis Sh. | C2 |
| Canyon Gp. | | WFMP D |
| M. – U. Strawn | | WFMP D |
| Lower Strawn | | |

- Westward progradation of Eastern Shelf delta systems and platform margins (100 -150 km)
- C2 basinal shales are largely clay-rich
- Initial development of Glasscock Nose during WFMP C1 time
- Uplift of CBP structural blocks and development of mid-Wolfcamp unconformity

# Sequential development of the Glasscock Nose

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Carbonate delta drift: A new sediment drift type

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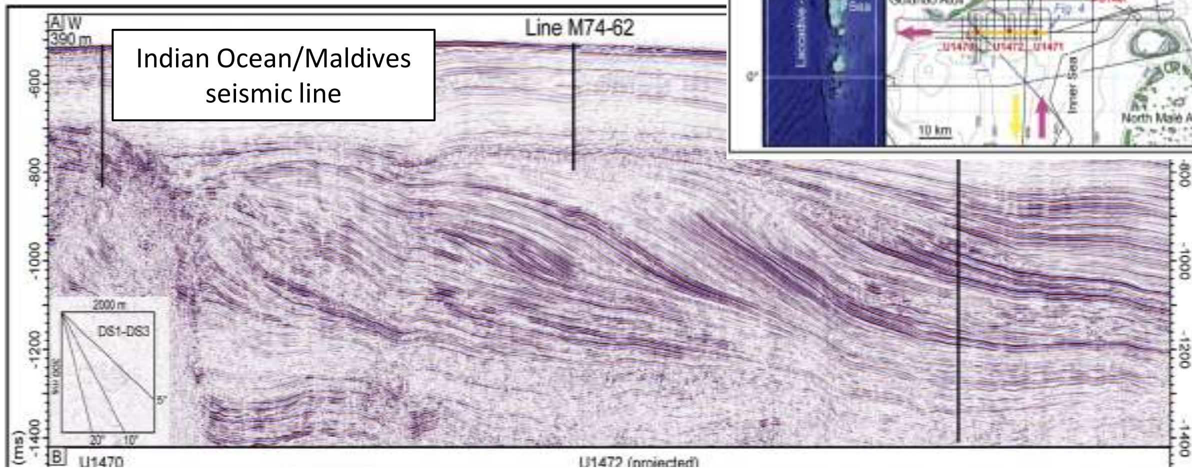
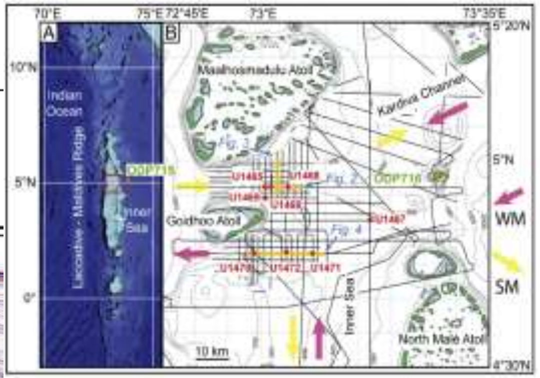
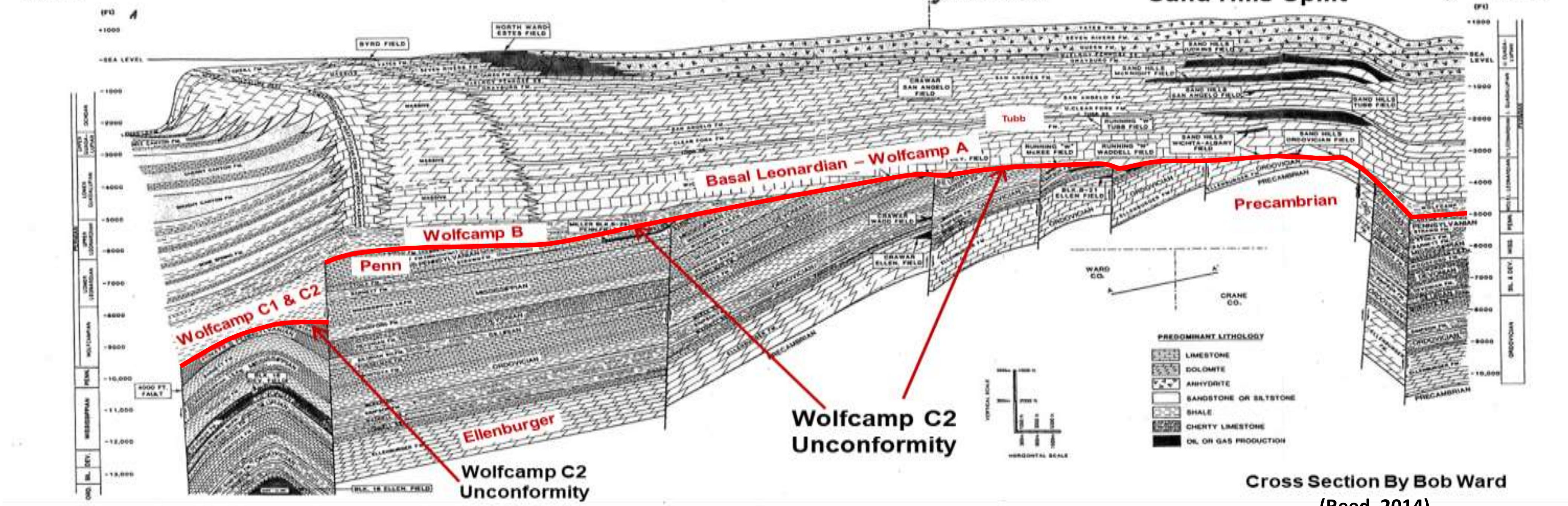
## Possible analog: carbonate delta drift

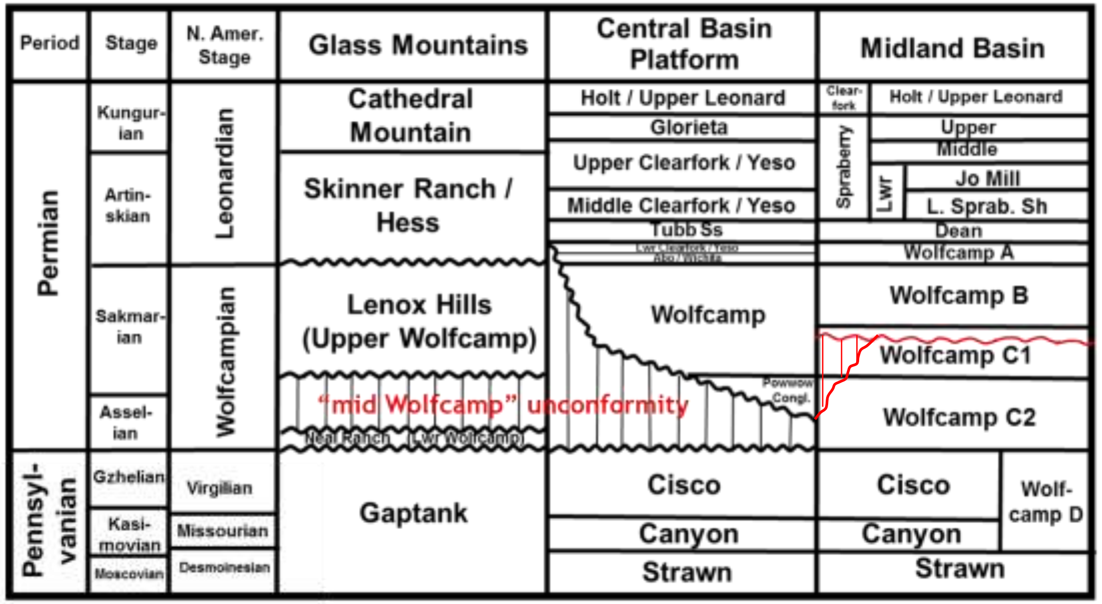


# mid-Wolfcamp unconformity on the CBP

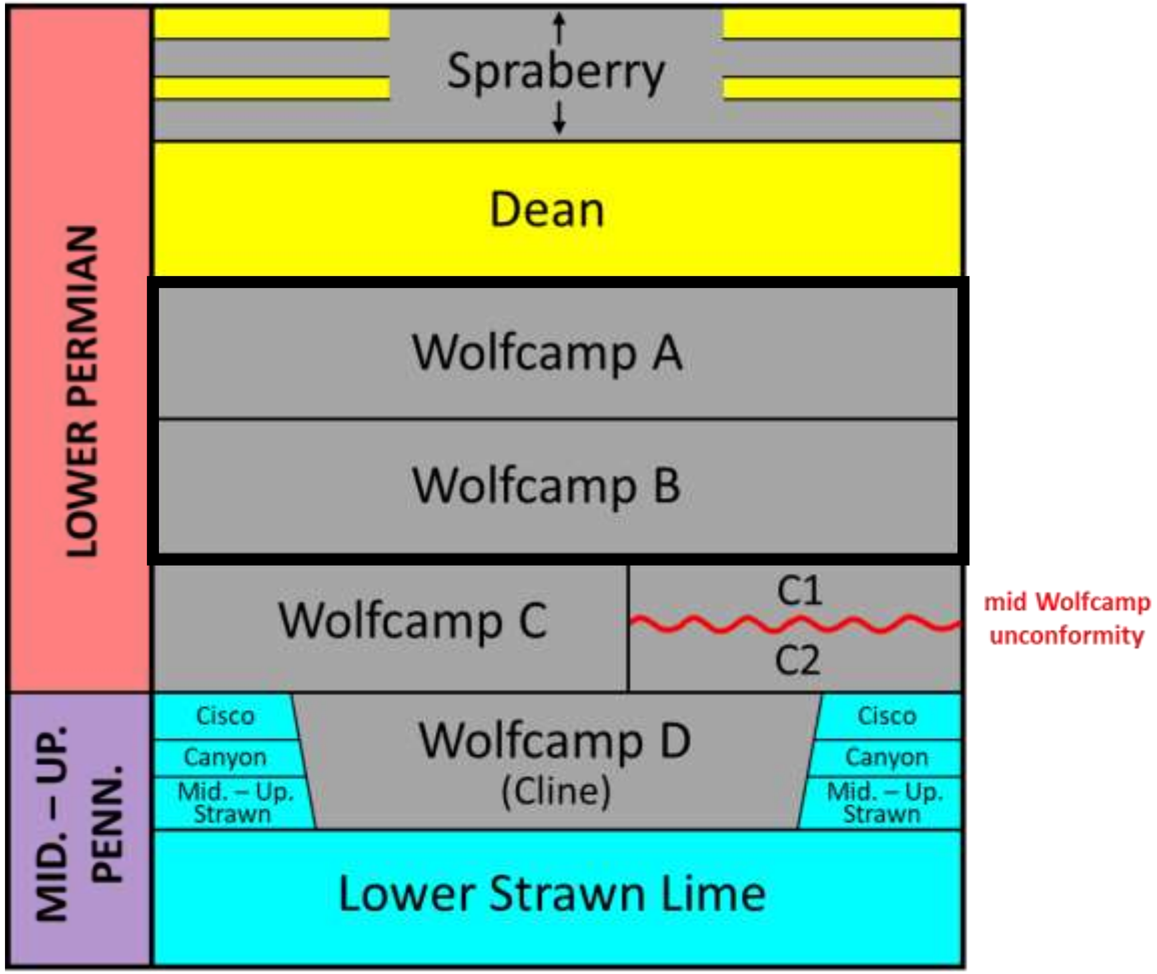



Cross Section By Bob Ward
(Reed, 2014)




- last major tectonic pulse prior to middle – late Permian subsidence phase
- note diachronous nature of unconformity across Permian Basin region
- Midland Basin: angular unconf. identified on regional seismic

# Wolfcamp A - B



LOWER PERMIAN
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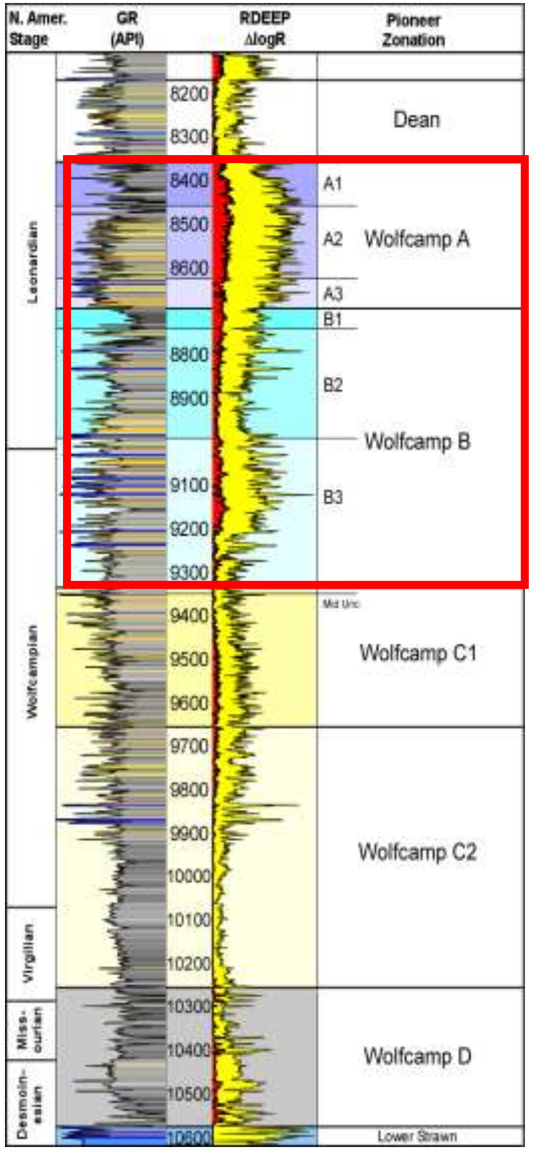
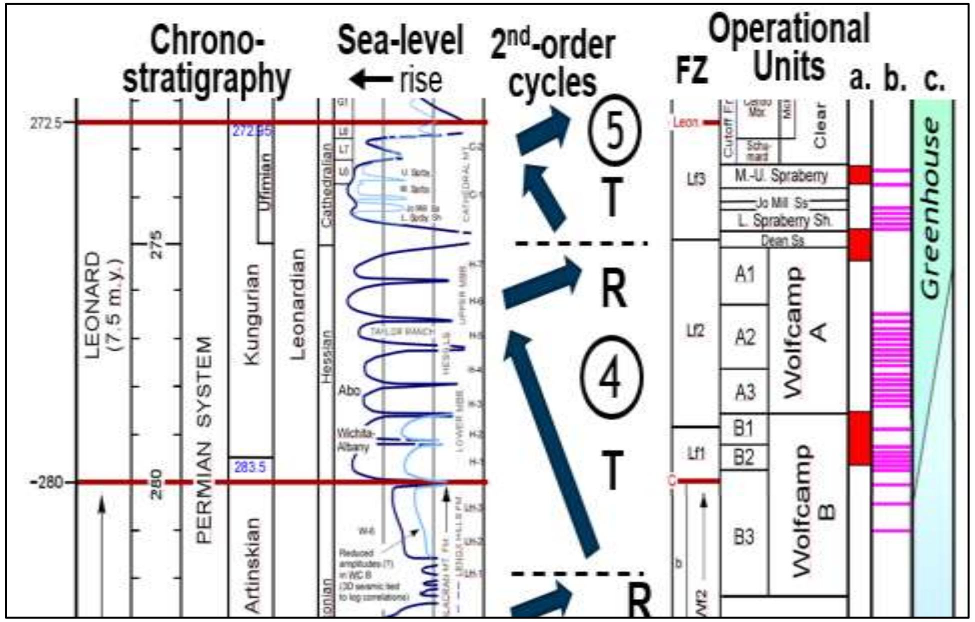
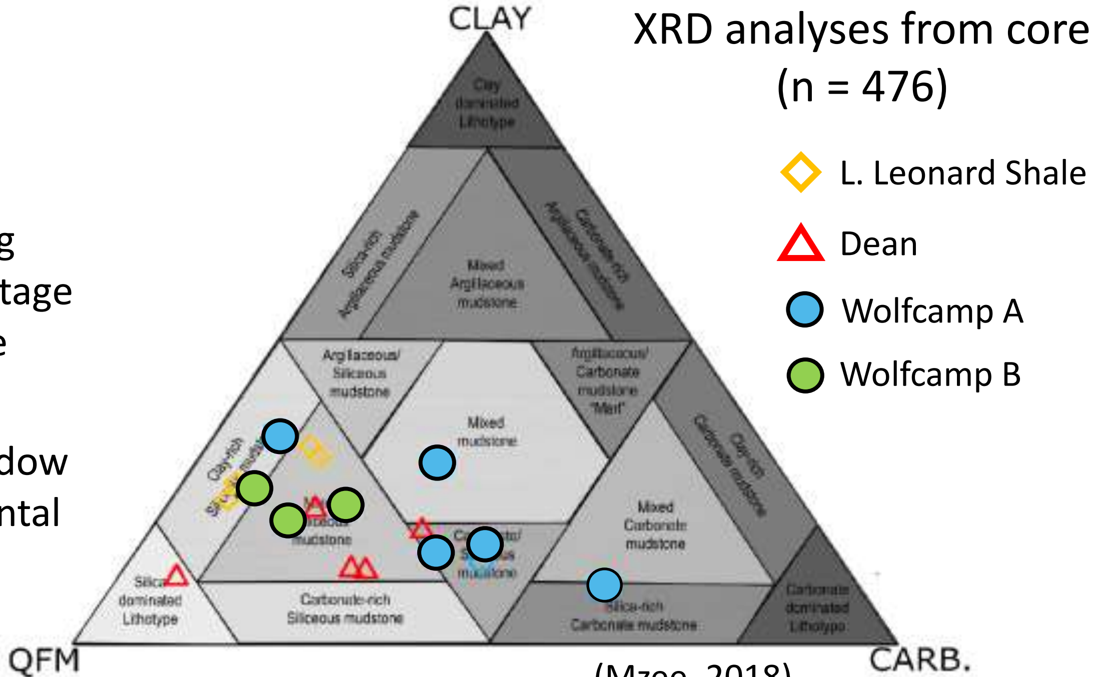
# Wolfcamp A - B



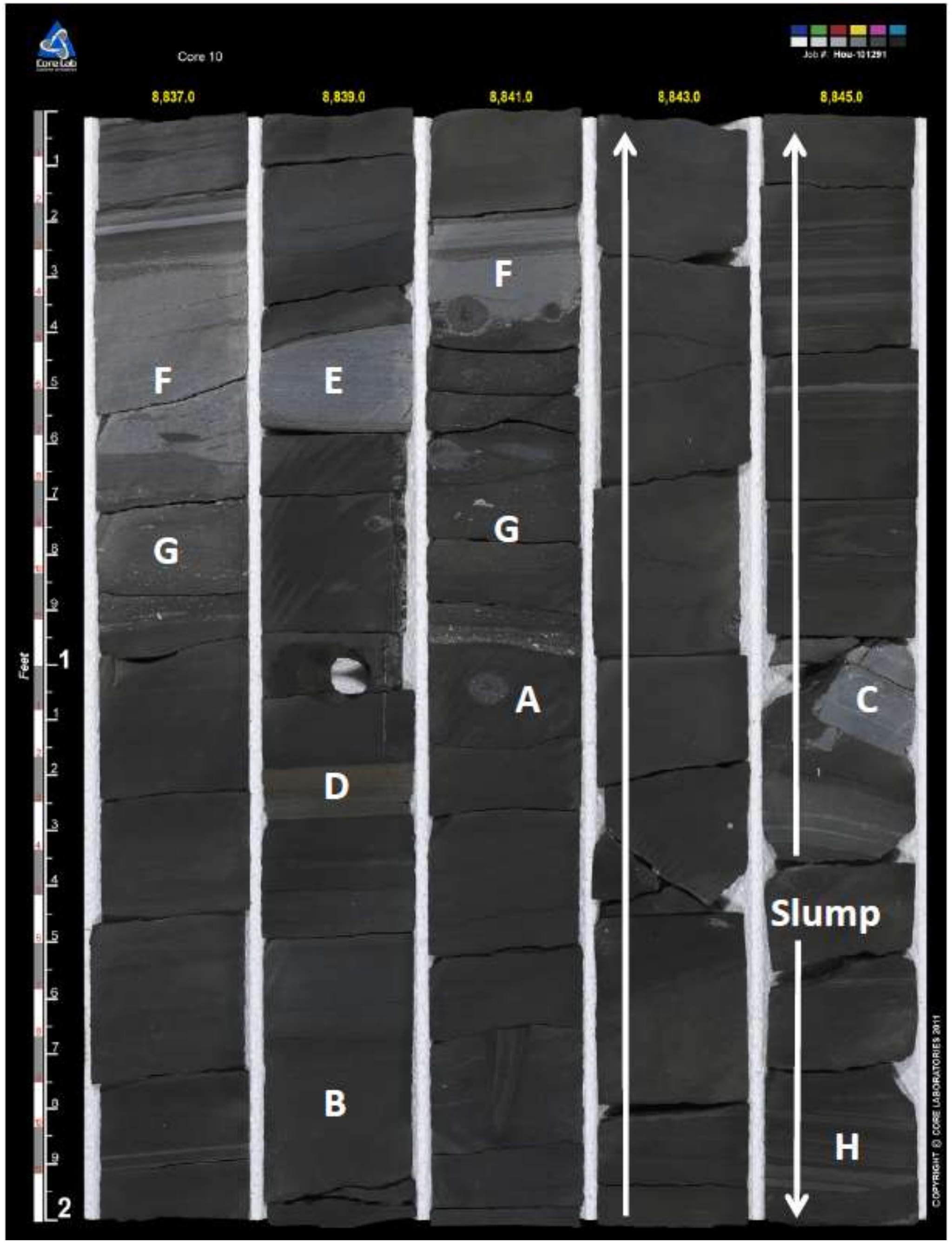

(Sinclair et al., 2018)

- 700+ ft. of organic-rich, silica- and calcareous-rich mudstone punctuated by numerous density flows (carb. turbidites and debris flows)
- Six operational sub-units:
  - A1
  - A2
  - A3
  - B1
  - B2
  - B3
- WC B are predominantly siliceous mudstones
- WC A are mixed carb-silica mudstones
- Aggradation of carbonate margins during second-order highstand increase percentage of $CaCO_3$ into basin during WFMP A time
- Interval currently resides in peak oil window in Midland Basin; remains a main horizontal drilling target

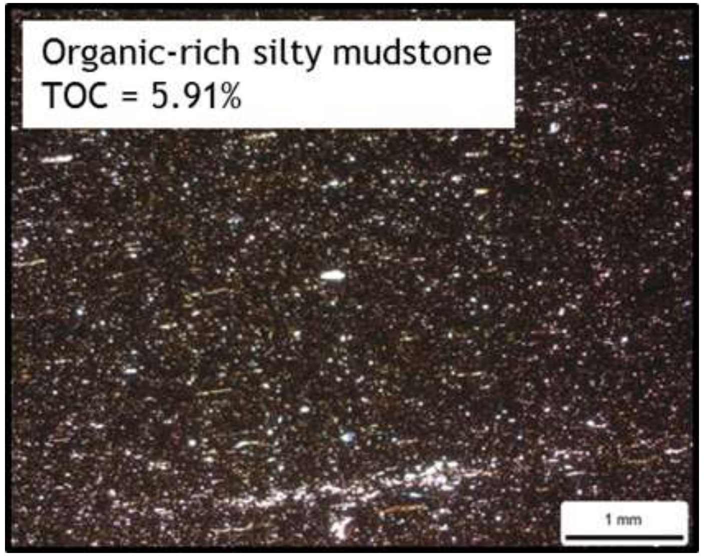


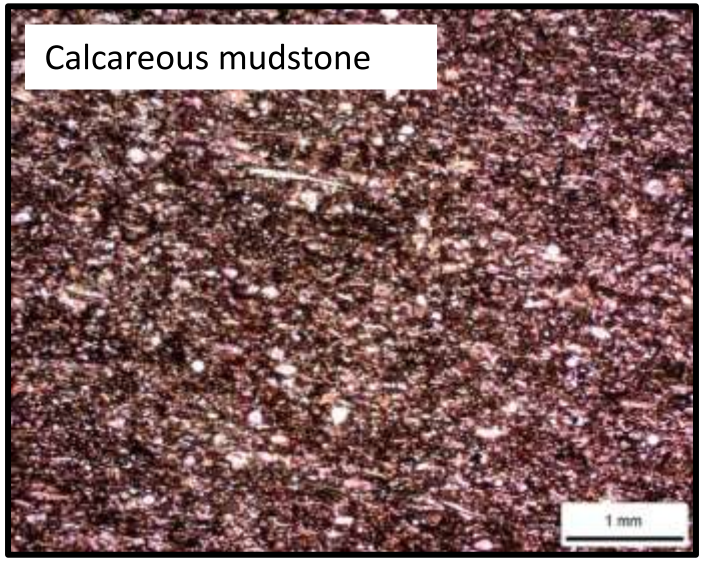

(Mzee, 2018)




## Wolfcamp B2



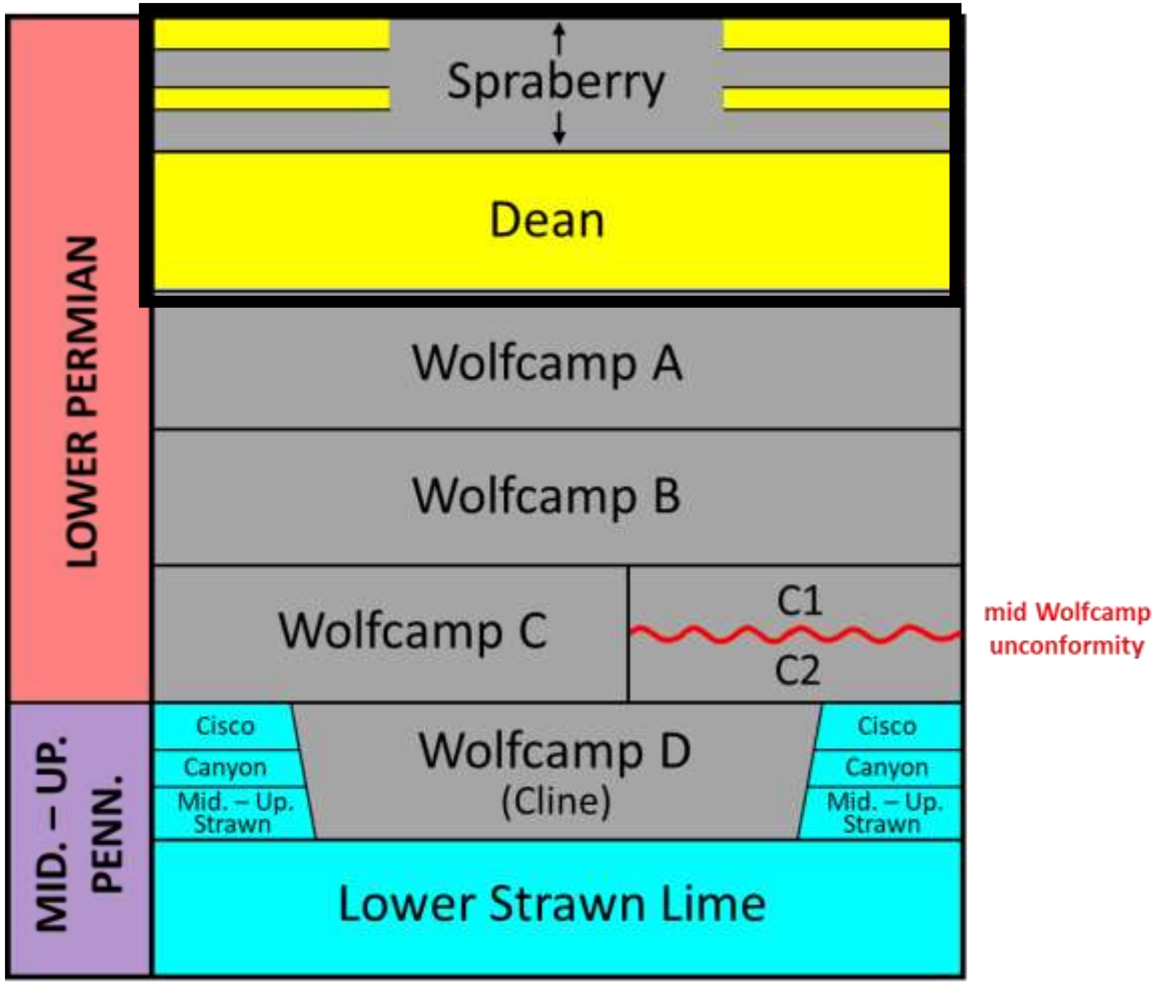

## Wolfcamp A3



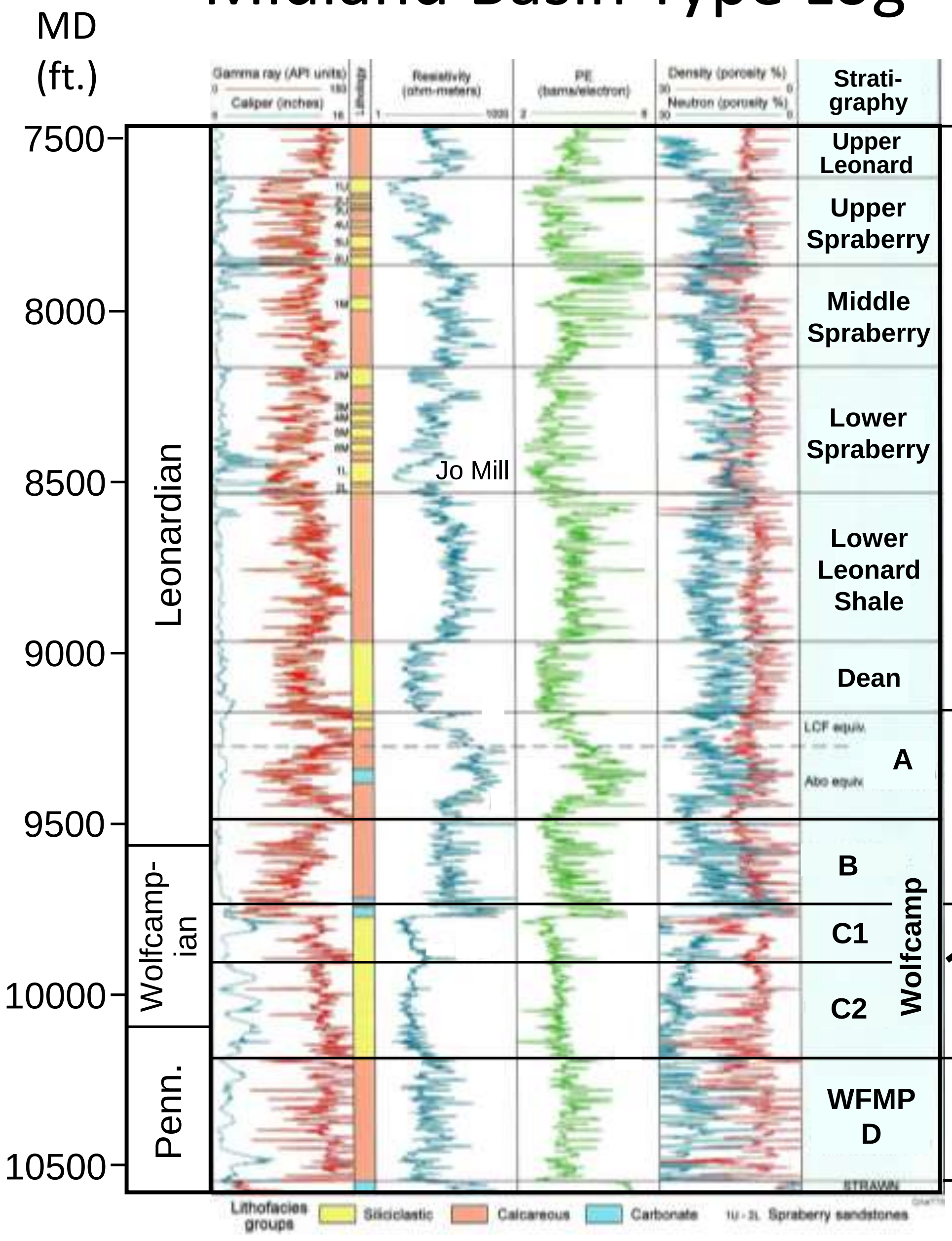

Photograph of core, **Wolfcamp B2**, depth 8837-8847 feet. (A) Structureless silty mudstone with phosphatic concretion. (B) Calcareous silty mudstone. (C) Carbonate lithoclast. (D) Ash bed. (E) Carbonate concretion. (F) Skeletal grainstone with erosive base and reworked concretions. (G) Thin, muddy debrite with deformed mudclast. (H) Sheared and rotated package of thin beds at the bottom of a slumped interval, 8847-8843 ft.

(Murphy, 2105)

# Spraberry - Dean



# Midland Basin Type Log




## *GENERAL DESCRIPTION / DEPOSITIONAL FACIES*

**Spraberry – Dean:**
silty mudstones and clay-rich siltstones punctuated by multiple deeper-water submarine fan complexes (incl. massive to laminated, fine-grained sandstones)

**Wolfcamp A – B:**
silty- and calcareous organic-rich mudstones; carbonate percentage increases upward

***mid-WC unconformity***

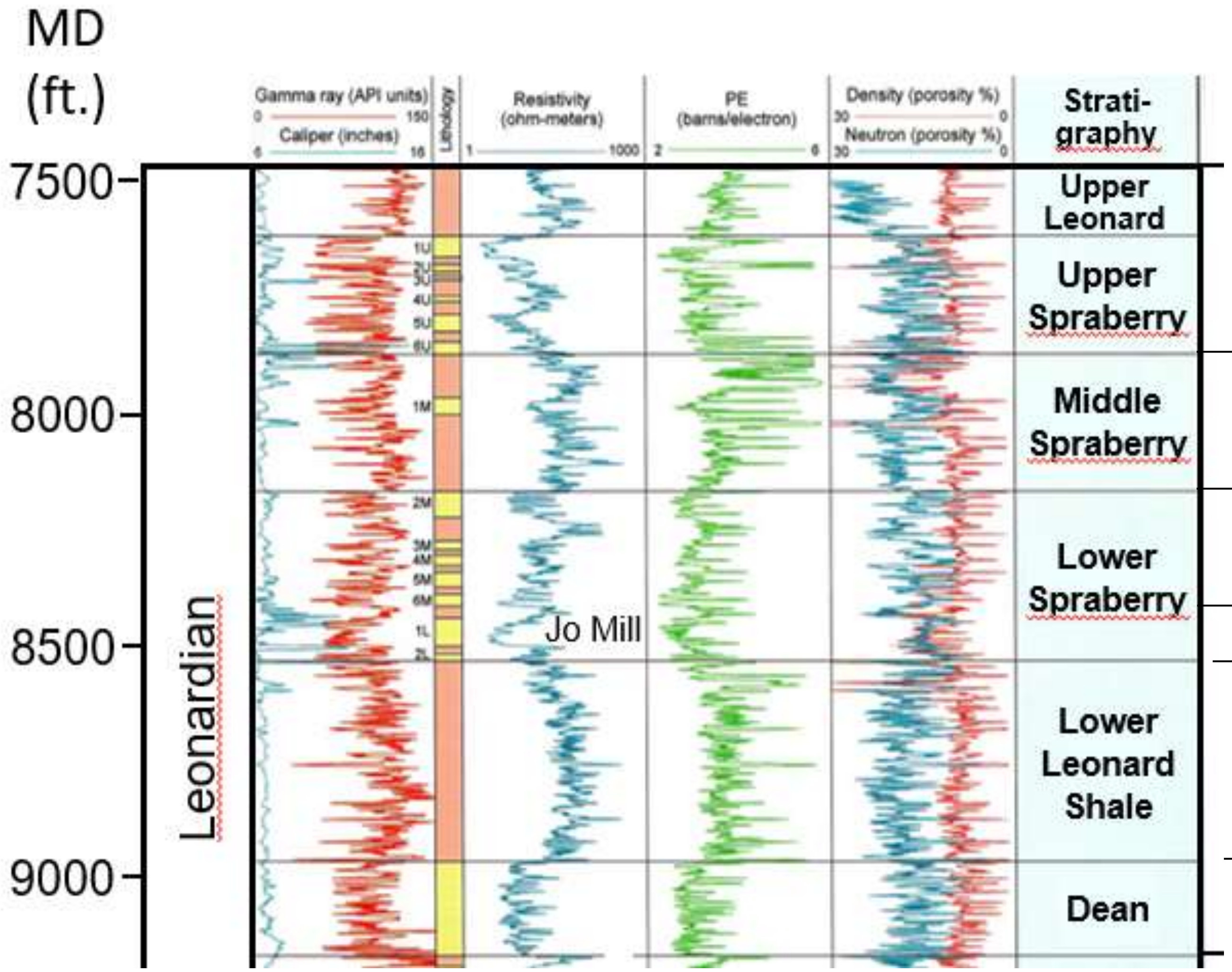
**Wolfcamp C**: Clay-rich shale
(progradation of Eastern Shelf deltas & Glasscock Nose)

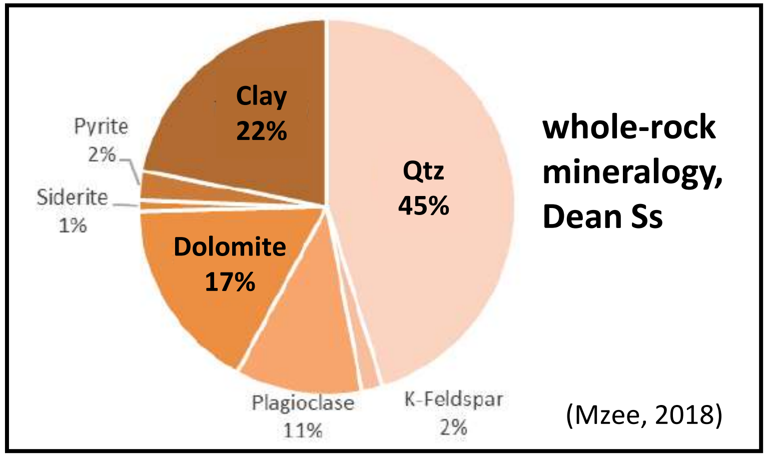
**Wolfcamp D**: Basinal cyclothems (starved basin)

**Lower Strawn:** shallow-water platform limestones

(modified from Hamlin and Baumgardner, 2012)

# Dean – Spraberry units of the Midland Basin




**U. Spraberry**
- 2 major submarine fan complexes (Floyd and Driver fans)
- Equivalent to 1st Bone Spring Ss

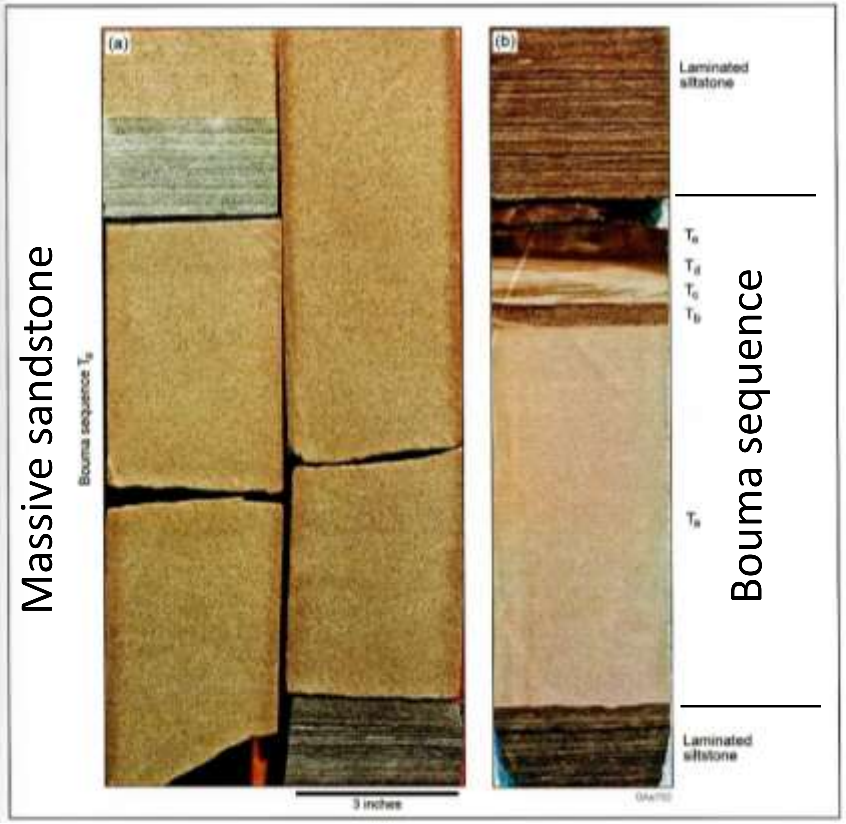
**M. Spraberry**
- silty, shales; minor fan complex

**L. Spraberry**
- siliceous shales, minor fans

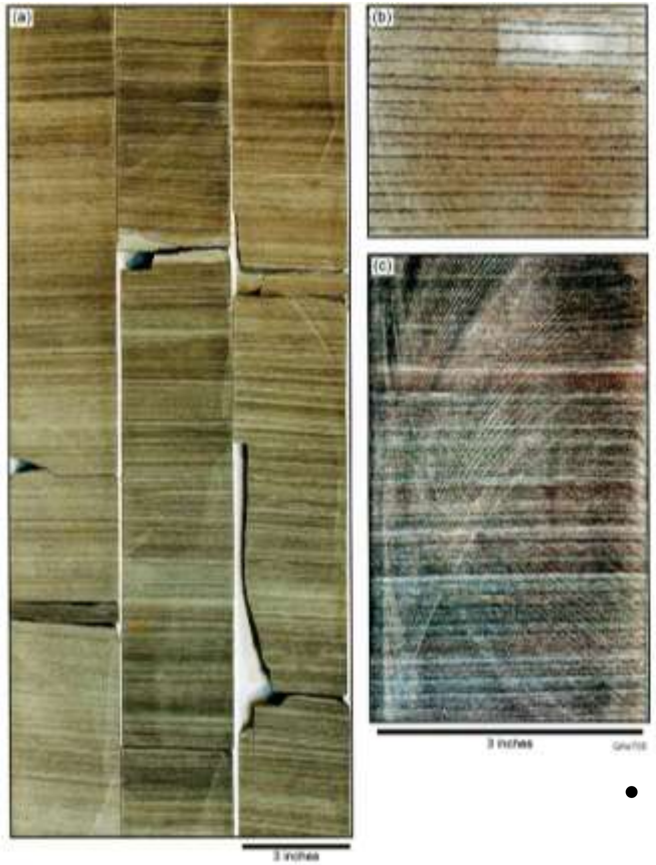
**Jo Mill**
- 2nd major incursion of submarine fans
- Equivalent to 2nd Bone Spring Ss

**Lower Leonard Sh.**
- organic-rich siliceous shales

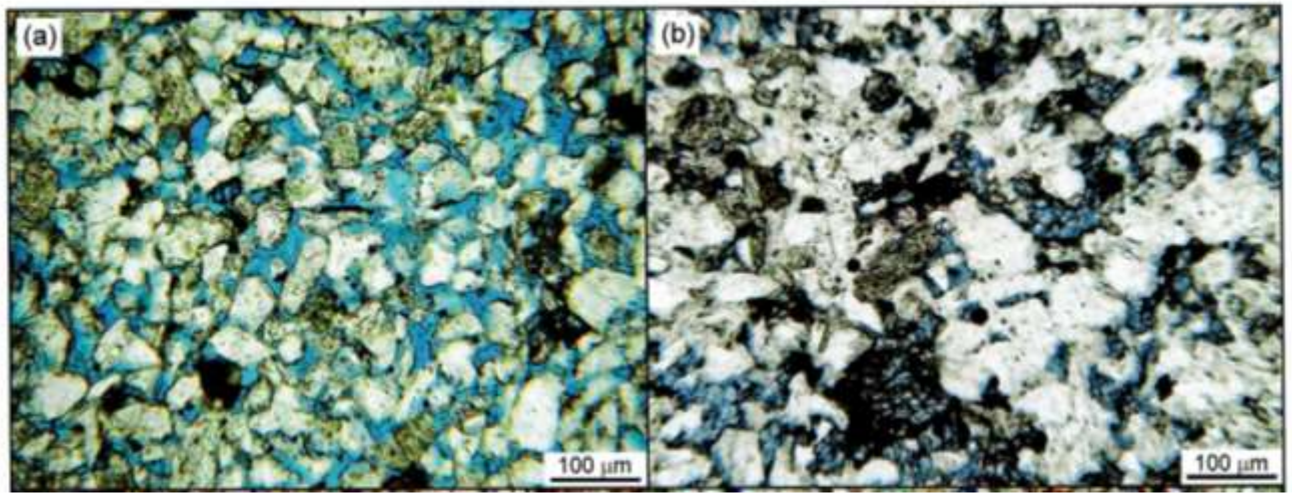
**Dean**
- 1st major incursion of submarine fans
- Equivalent to 3rd Bone Spring Ss




(Hamlin and Baumgardner, 2012)




Laminated siltstones



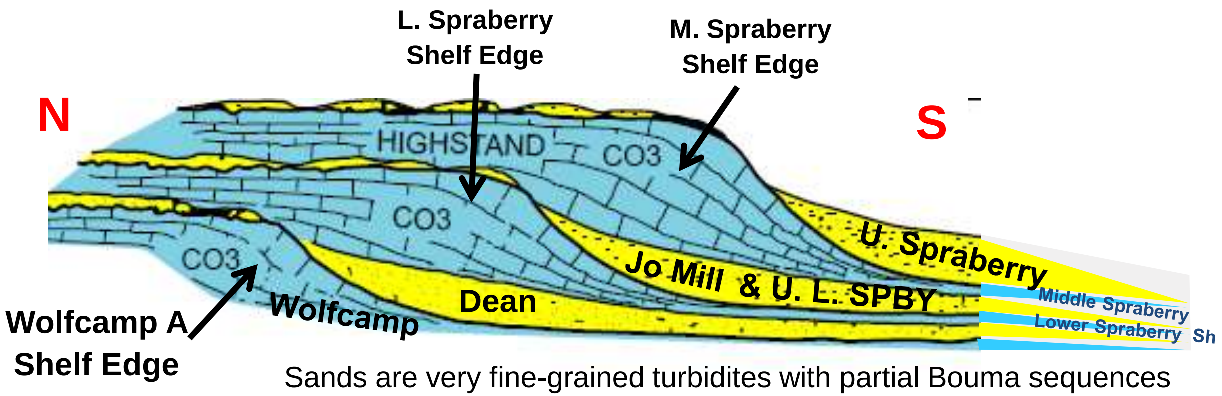

(a) Porous sandstone

(b) Sandstone cemented w/ ferroan dolomite

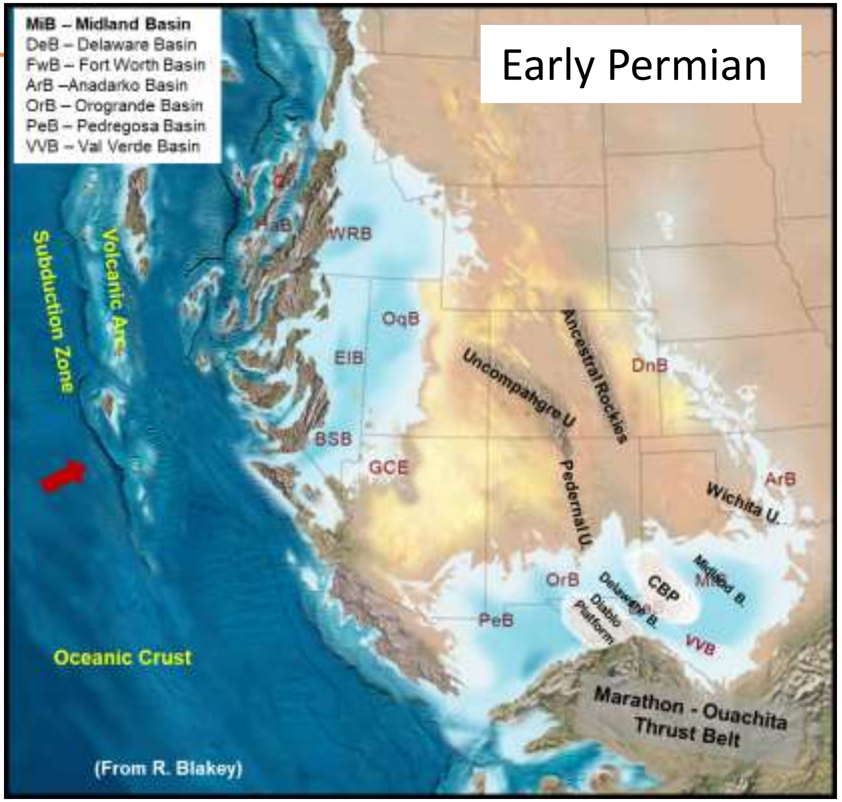
- All fans (Dean, Jo Mill, Middle & Upper Spraberry) are similar in appearance
- Main facies:
  - Massive f.g. sandstones (“Bouma A”)
  - Laminated siltstones / shales
  - Burrowed siltstones / shales ($O_2$)
  - Black shale (thin caps)
- Depositional model ?
- Provenance? (north vs. south)

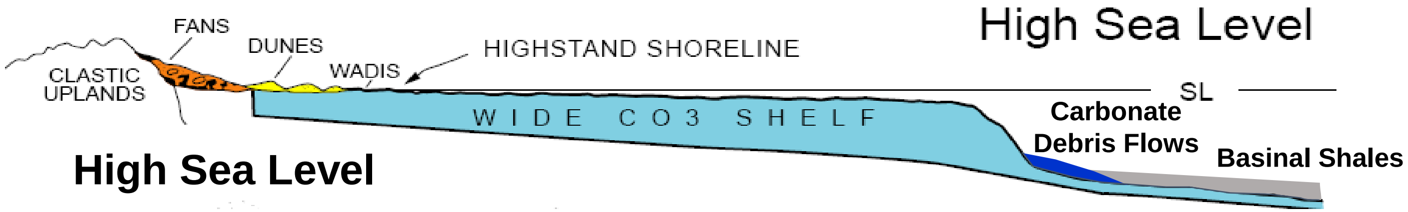
# Spraberry & Dean (Bone Spring) Depositional Model (based on Hanford, 1981)

Spraberry and shelf equivalents are alternating sand-rich and organic shale/carbonate-rich packages deposited during alternating high and low sea levels.

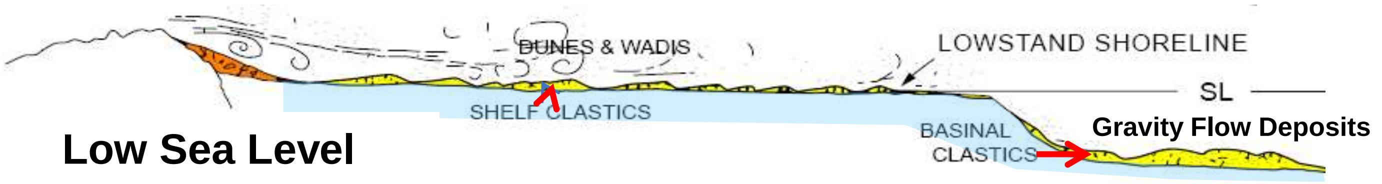



Sands are very fine-grained turbidites with partial Bouma sequences
Organic-rich shales highly laminated and not bioturbated; Organic-poor shales bioturbated
Thin dolomitic hard grounds observed in sands and shales



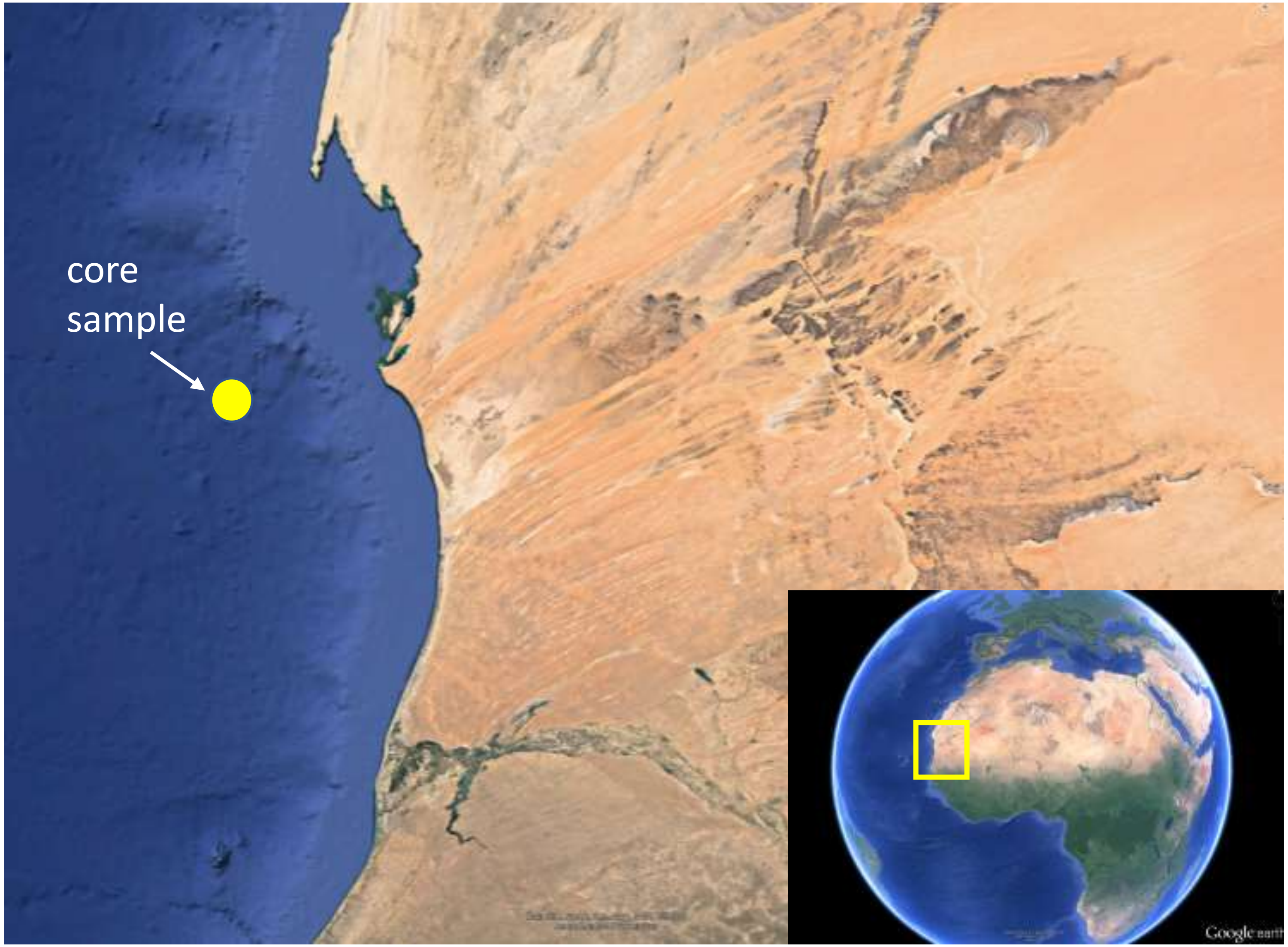




**Highstand –**
- Shelf submerged
- Carbonates on shelf
- Carbonate gravity flow deposits and organic-rich shales in basin

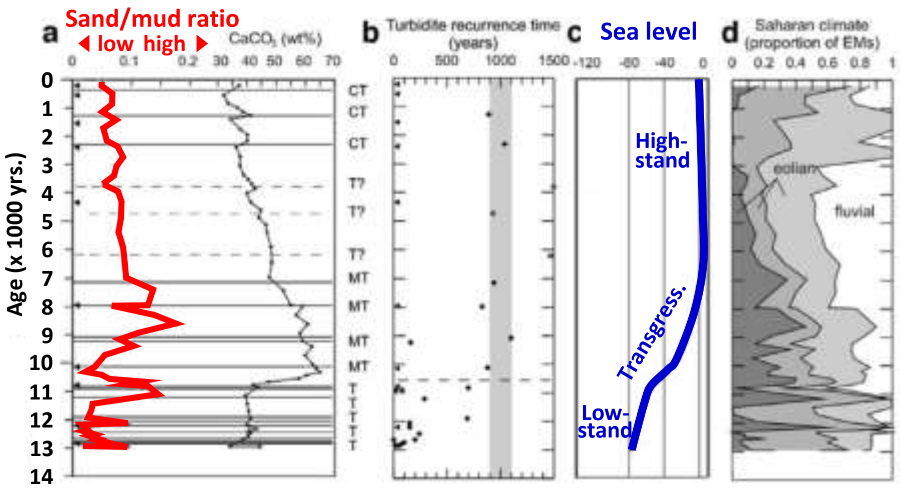


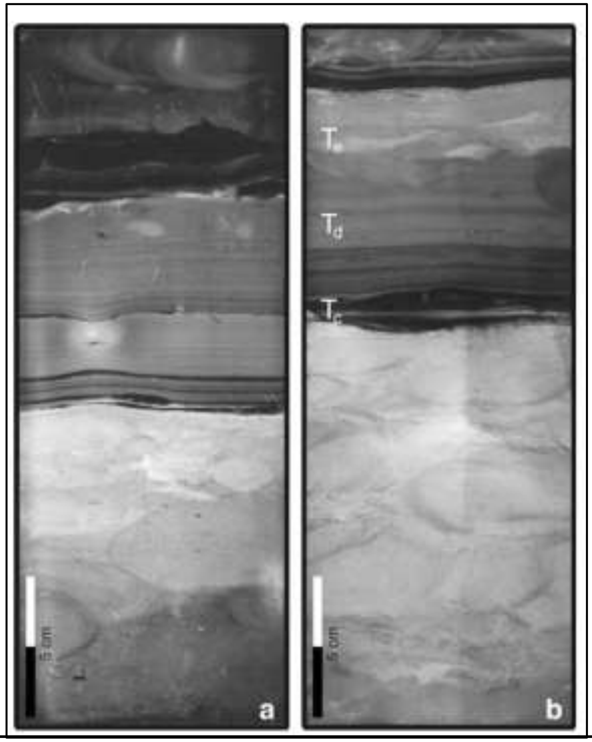

**Lowstand and ensuing transgression–**
- Shelf exposed
- Clastics move across shelf via wind and in wadis
- Clastic gravity flow deposits bypass shelf during lowstand and are cannabalized during early transgression

# Possible modern analog for Dean - Spraberry: Offshore Mauritania, African Sahara



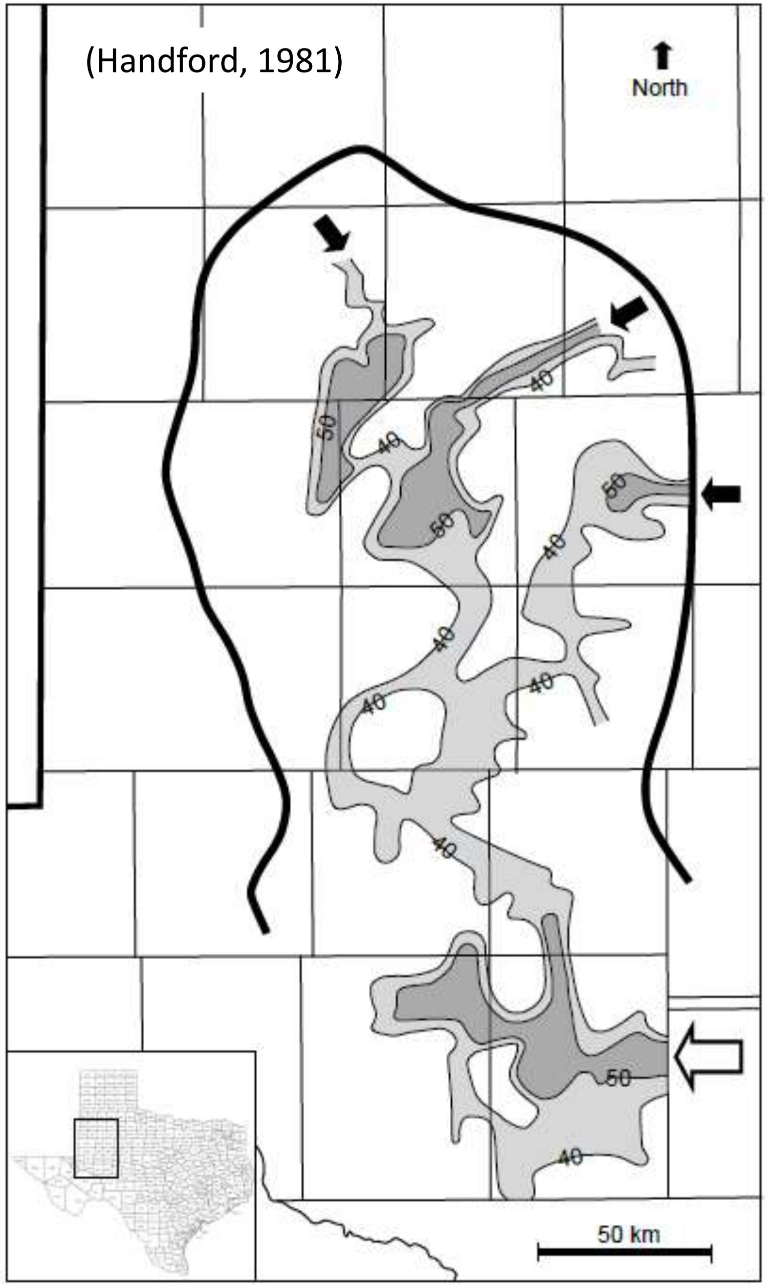

## Core data (Zuhlsdorff et al., 2008)



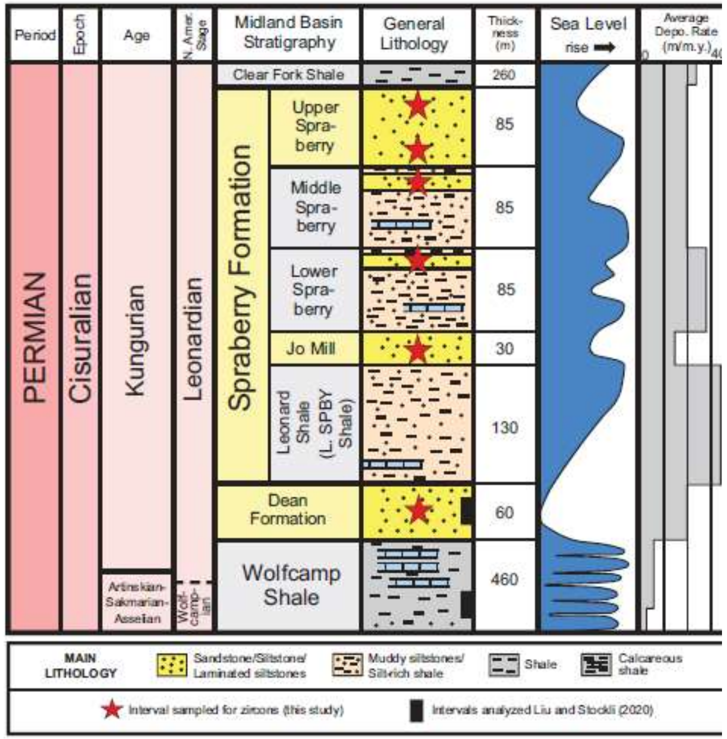



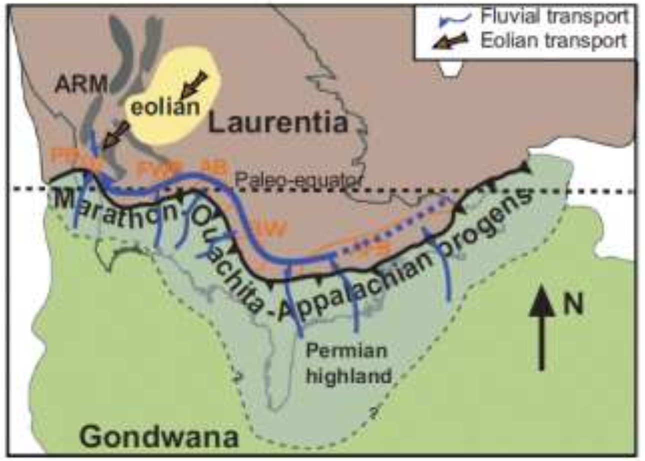
# Sediment provenance of the Dean - Spraberry

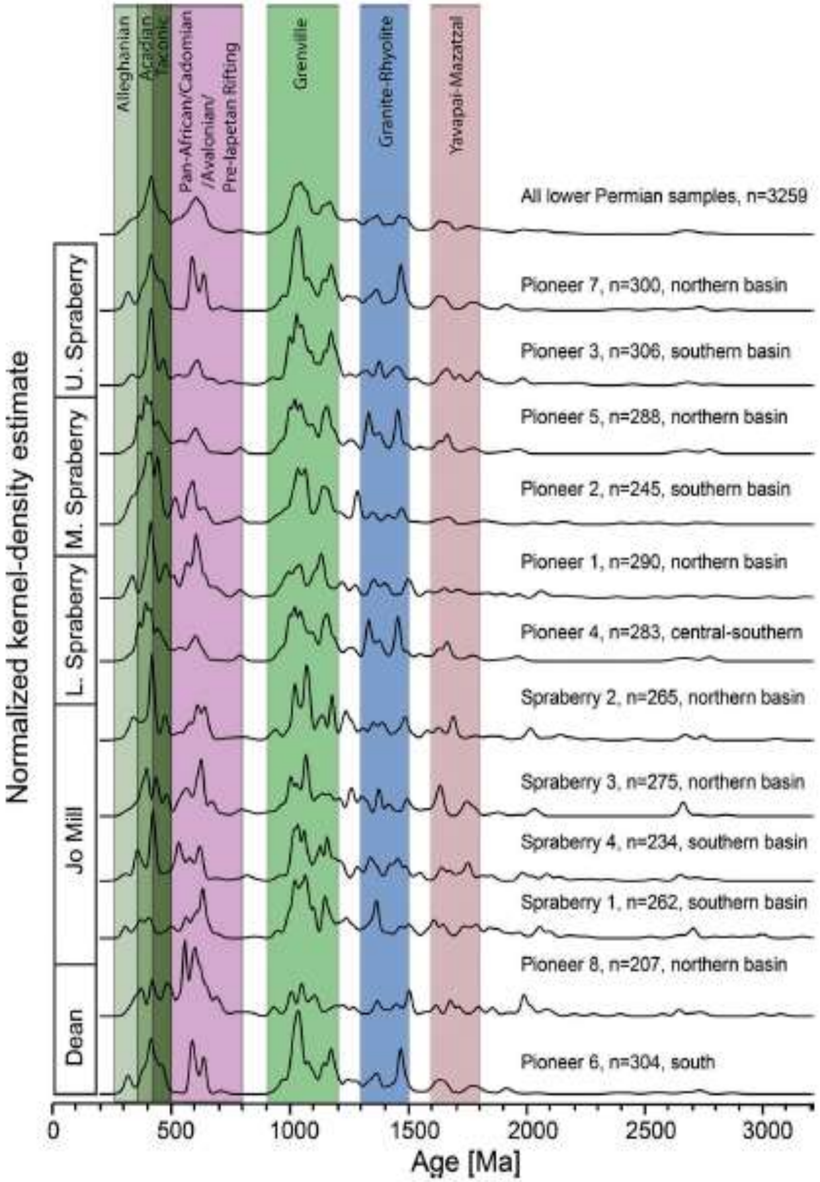
(Handford, 1981)

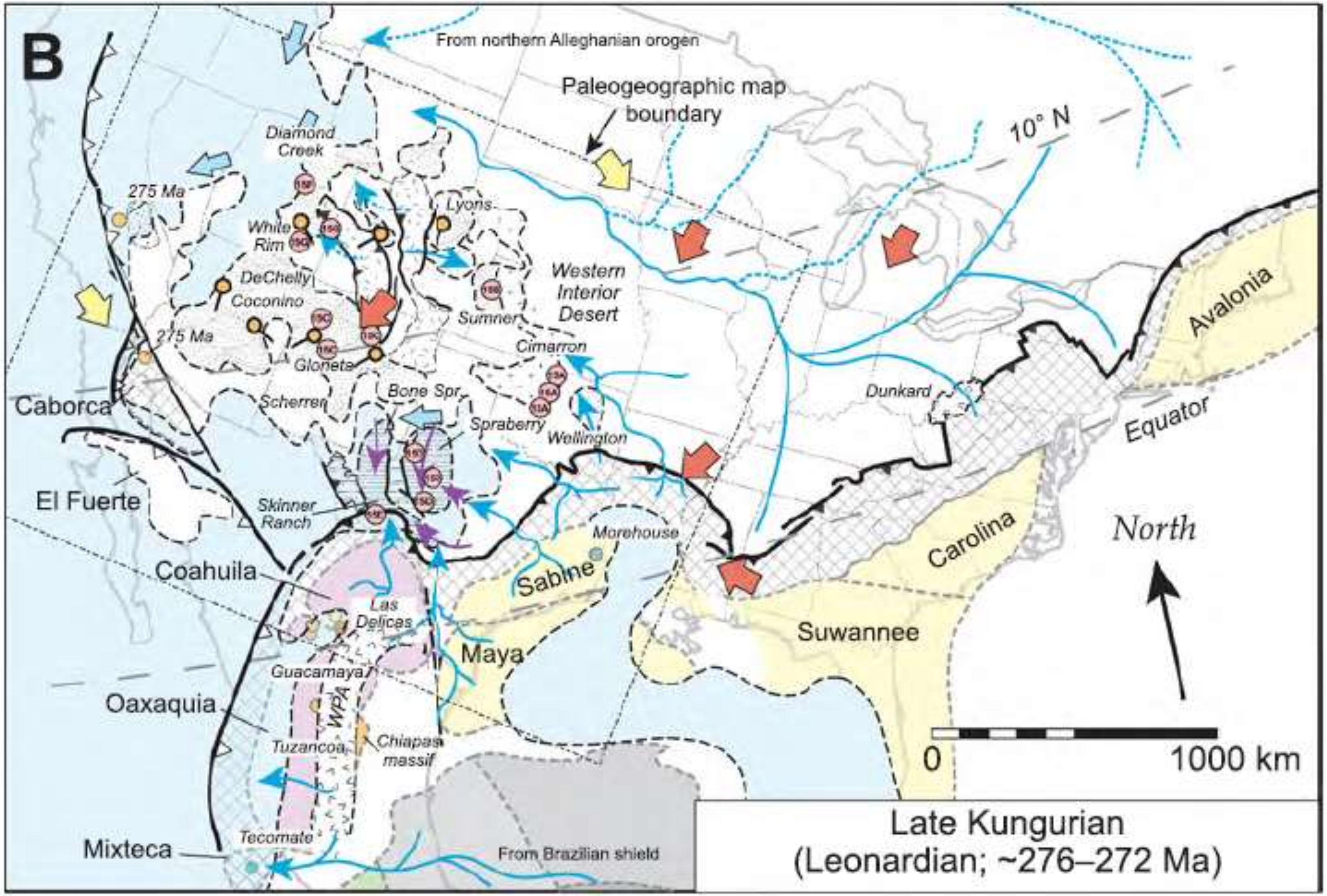



(Waite et al., 2020)



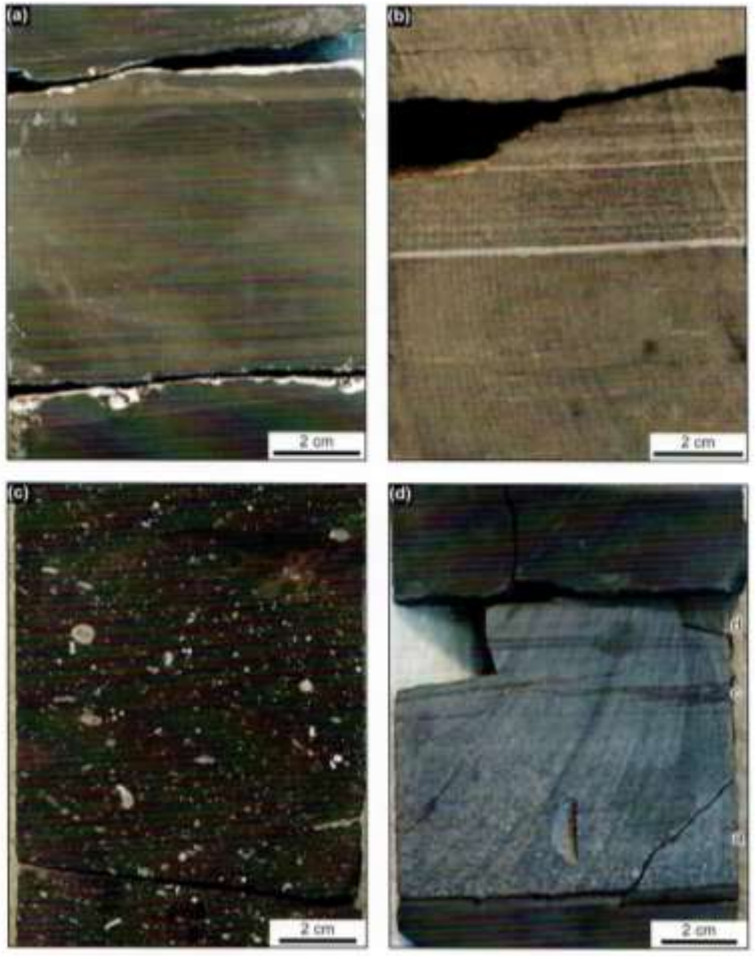






(Lawton et al., 2021)

# Summary and Conclusions

- The Wolfcamp – Spraberry interval of the Midland Basin consists of a series of lithologically- and mineralogically-complex facies; each interval is unique
  - Wolfcamp D: basinal cyclothems
  - Wolfcamp C: lower portion (C2) consists of clay-rich shales; mid-WC unconformity
  - Wolfcamp A - B: Silty, organic-rich, calcareous silty shales; carbonate % increases upward; zone currently resides in peak oil window
  - Dean - Spraberry: Argillaceous siltstones, punctuated by numerous submarine-fan complexes (massive & laminated sandstones)
- Complexity of these rocks reflects changing/evolving geologic conditions (eustasy, climate, tectonics, sediment supply, biota, etc.) along the SW margin of western Pangea during Late Pennsylvanian – early Permian time
- Geologists must work closely with drilling, completion, and reservoir engineers to fully communicate the complexity and uniqueness of each unit / horizontal target zone



(Hamlin and Baumgardner, 2012)

***"Not all shales are created equal"***