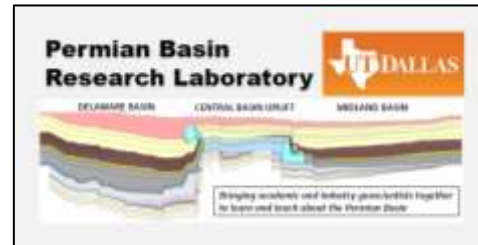


Re-exploring the Eastern Shelf of the Midland Basin

Dallas Geologic Society
November 15, 2023

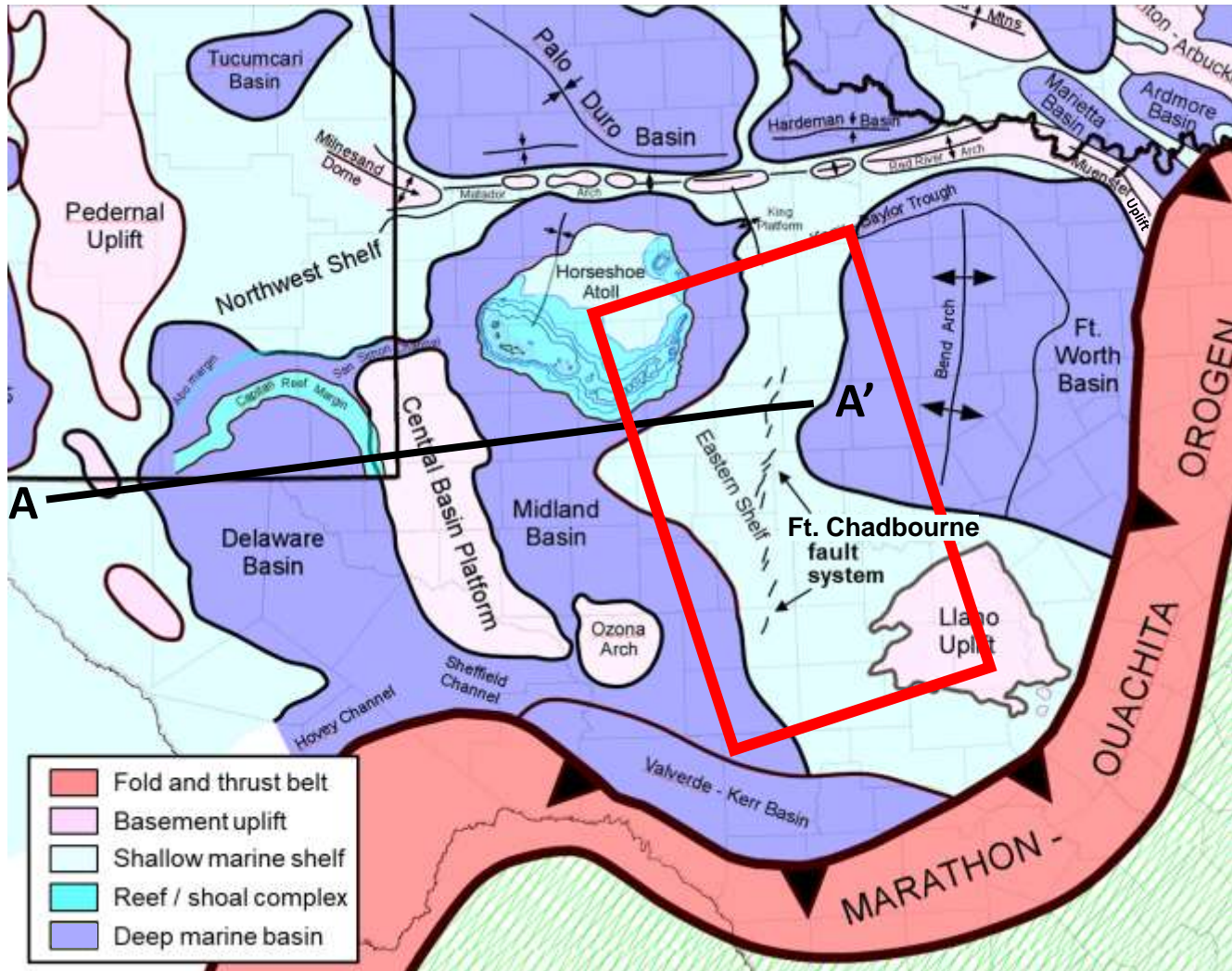
Lowell Waite
Department of Geosciences
Permian Basin Research Lab
University of Texas at Dallas



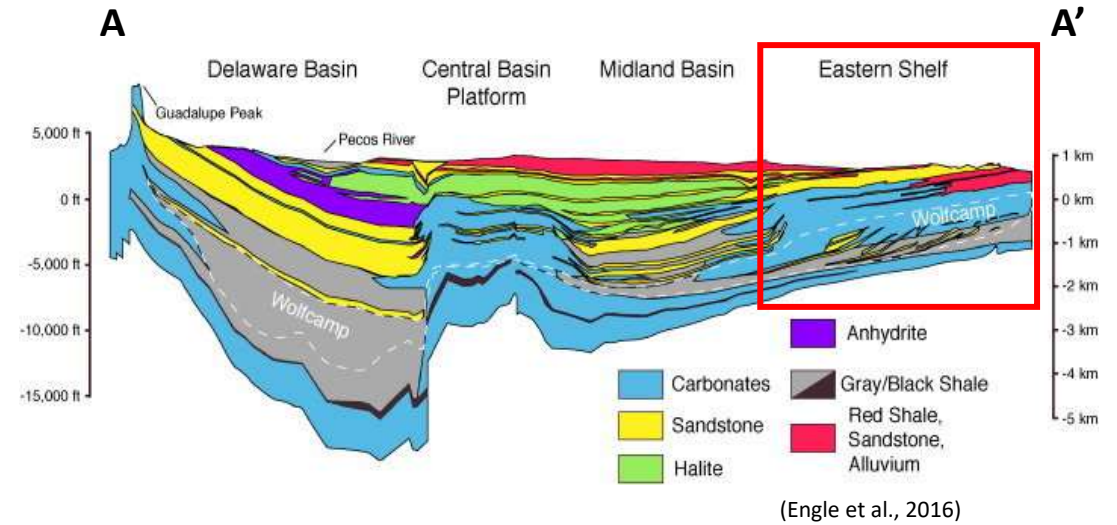
The Eastern Shelf Region: Introduction

- Over a century of exploration has proven the Eastern Shelf of the Midland Basin to be a prolific conventional hydrocarbon-producing region
- Main reservoirs include Lower Ordovician Ellenburger dolomite and a number of middle Pennsylvanian to early Permian sandstones and limestones at relatively shallow drill depths (~ 4000 – 8000 ft MD)
- The stratigraphic complexity of the region, coupled with large number of producing zones and the inherent incomplete state of the historical well data base, provides **opportunities for future exploration**, for both permeable and low-permeable (“tight”) conventional reservoirs

Greater Permian Basin of west TX and SE New Mexico: Paleogeographic elements

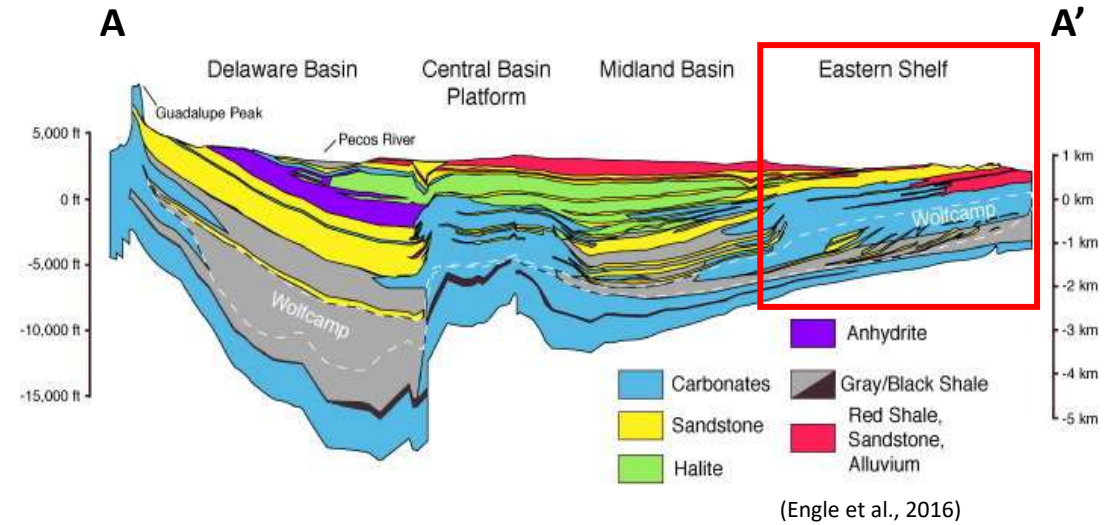
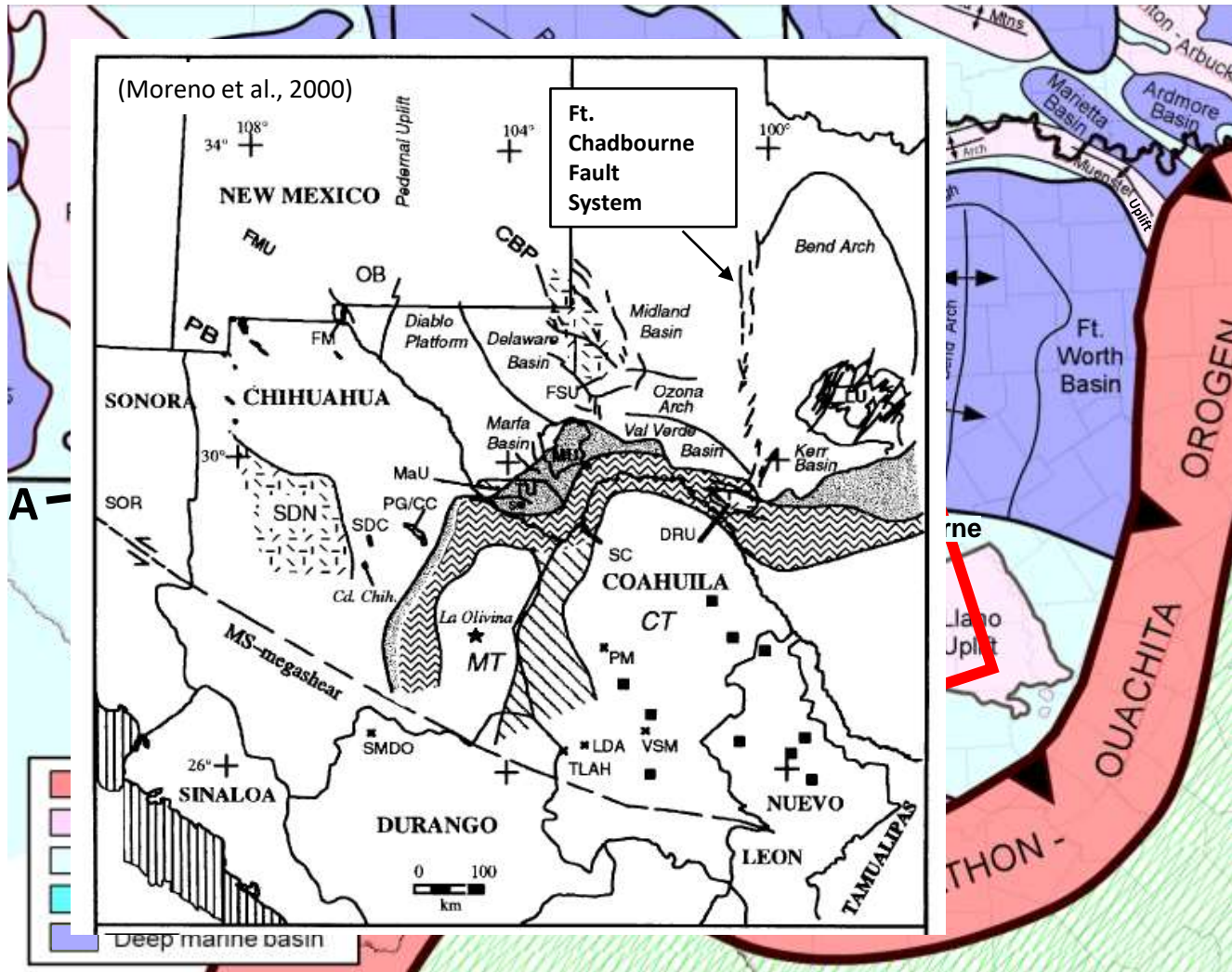


100 mi.



- Eastern Shelf one of several high-standing Permo-Pennsylvanian shelves surrounding deeper Delaware and Midland basins
- Eastern Shelf dips westward ~ 1.3 degrees
- General stratigraphy: thin Pre-Penn (mostly L. Ord. Ellenburger dolomite and U. Camb. Ss) unconformably overlain by thick Pennsylvanian to lower Permian carbonate and clastic units ($\sim 4000 - 8000$ ft. MD)
- Note location of Ft. Chadbourne fault system: chain of small basement-involved structural blocks; upthrown to east (part of Ancestral Rockies deformation)

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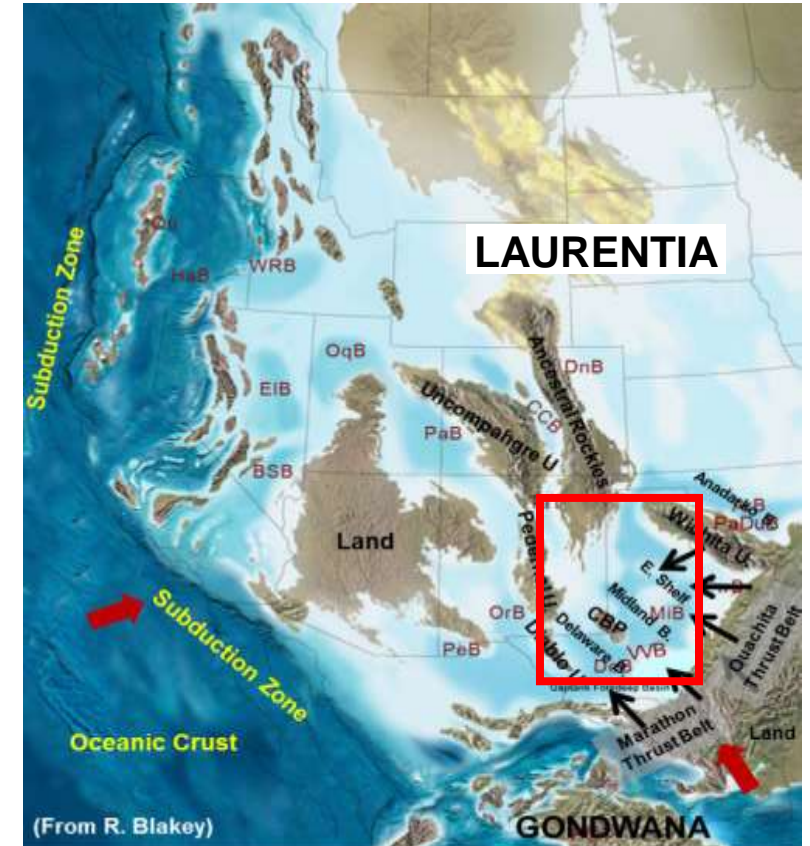
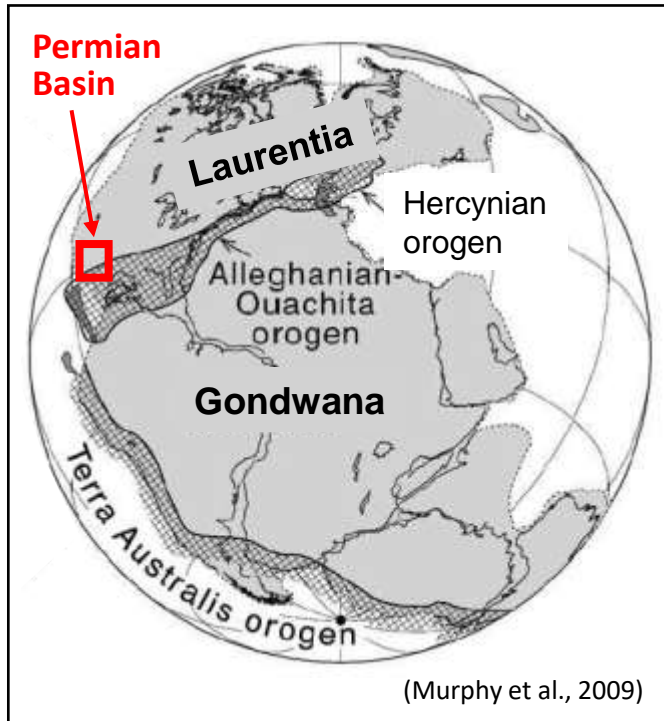
100 mi.

Pennsylvanian – Early Permian Themes

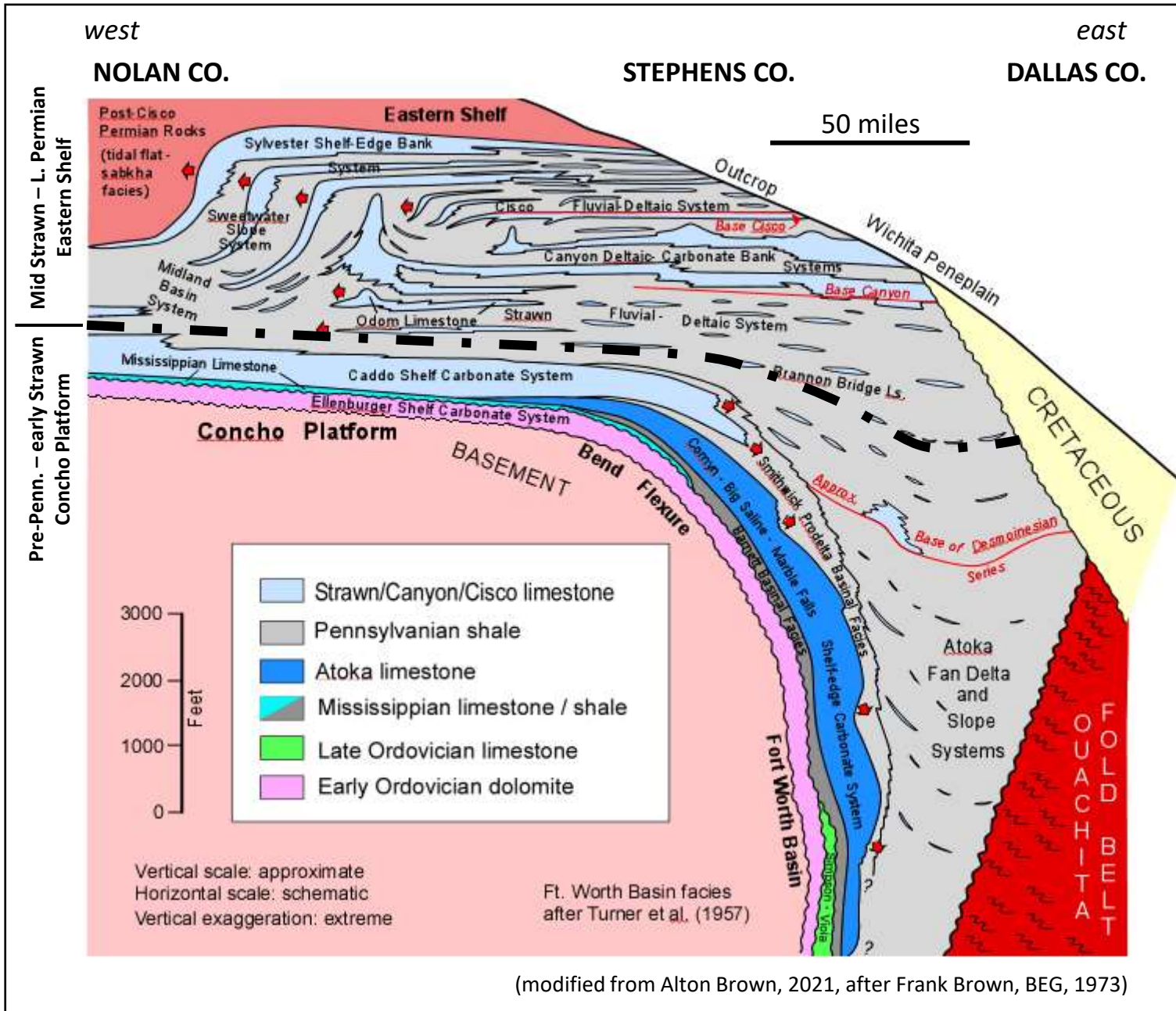
- SW Laurentian region during assembly of Pangea; active margin phase: Hercynian orogeny & rise of Ancestral Rockies (Tobosa Basin becomes Permian Basin)
- Climate: Icehouse phase throughout Penn. – Early Permian, transitioning to greenhouse; Permian Basin in low-latitudes (tropics); humid w/ monsoonal precipitation
- Sea level: long-term rise and expansion of Penn. seaway; short-term: **Penn cyclothems** (high frequency, high amplitude glacioeustatic cycles)
- Dominance of phylloid algae as main reef builders (aragonite skeletons; limestones susceptible to early leaching)

Early Penn. (Atokan)

Late Penn. (Missourian)



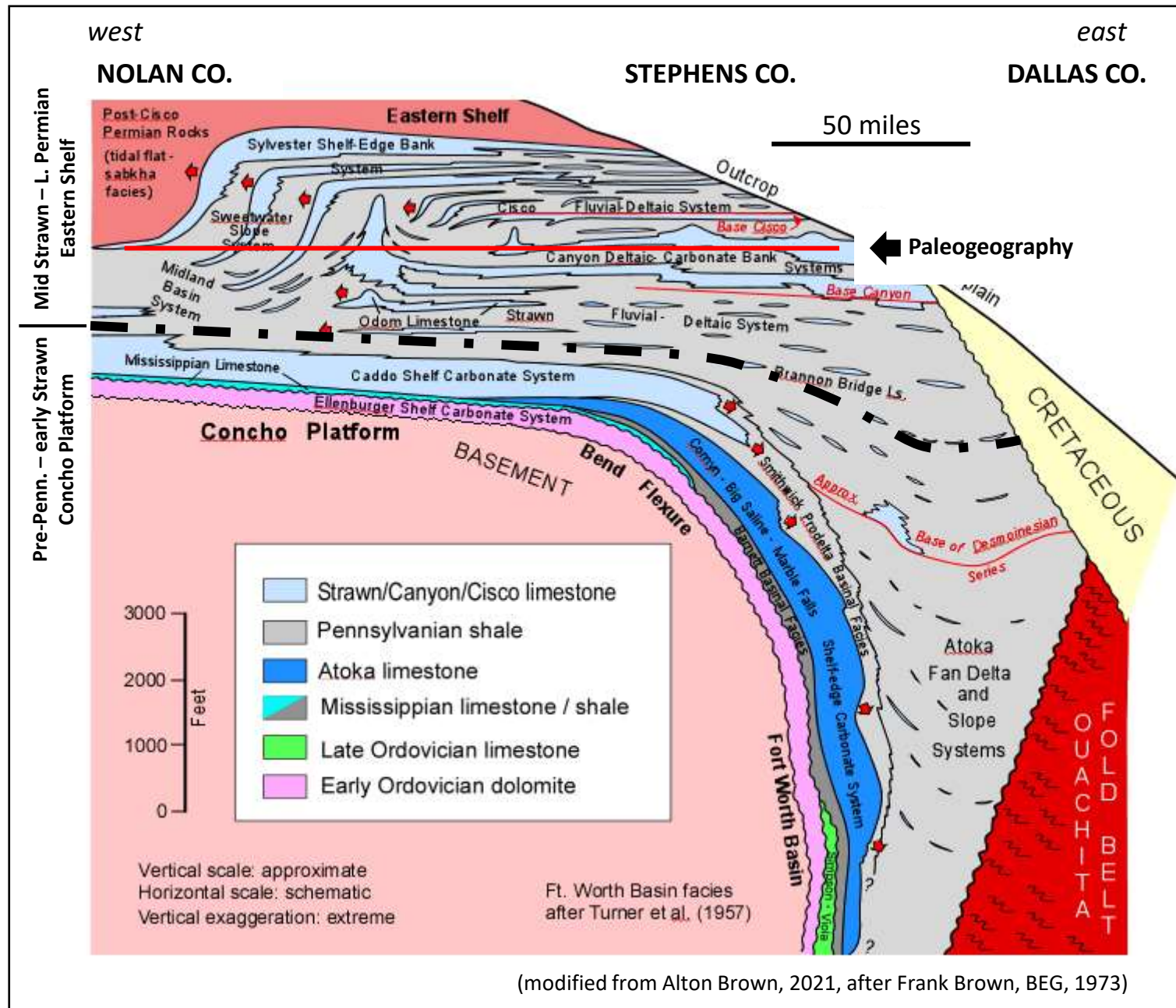
Eastern Shelf Depositional Systems



(modified from Alton Brown, 2021, after Frank Brown, BEG, 1973)

- Prior to middle Strawn time (pre-Odom; thick dashed line), the Eastern Shelf was a shallow-water carbonate platform (Concho Platform) constituting the eastward dipping, western margin of the actively subsiding Ft. Worth Basin
- Following the rapid filling of the Ft. Worth Basin by Early Penn. Atoka and early Strawn clastics, deposition shifted to westward-dipping sedimentary systems defining the Eastern Shelf of the subsiding Midland Basin
- Penn – L. Perm sediments represent a thick assemblage of numerous alternating cyclothem deposits (lowstand clastics, highstand carbonates)

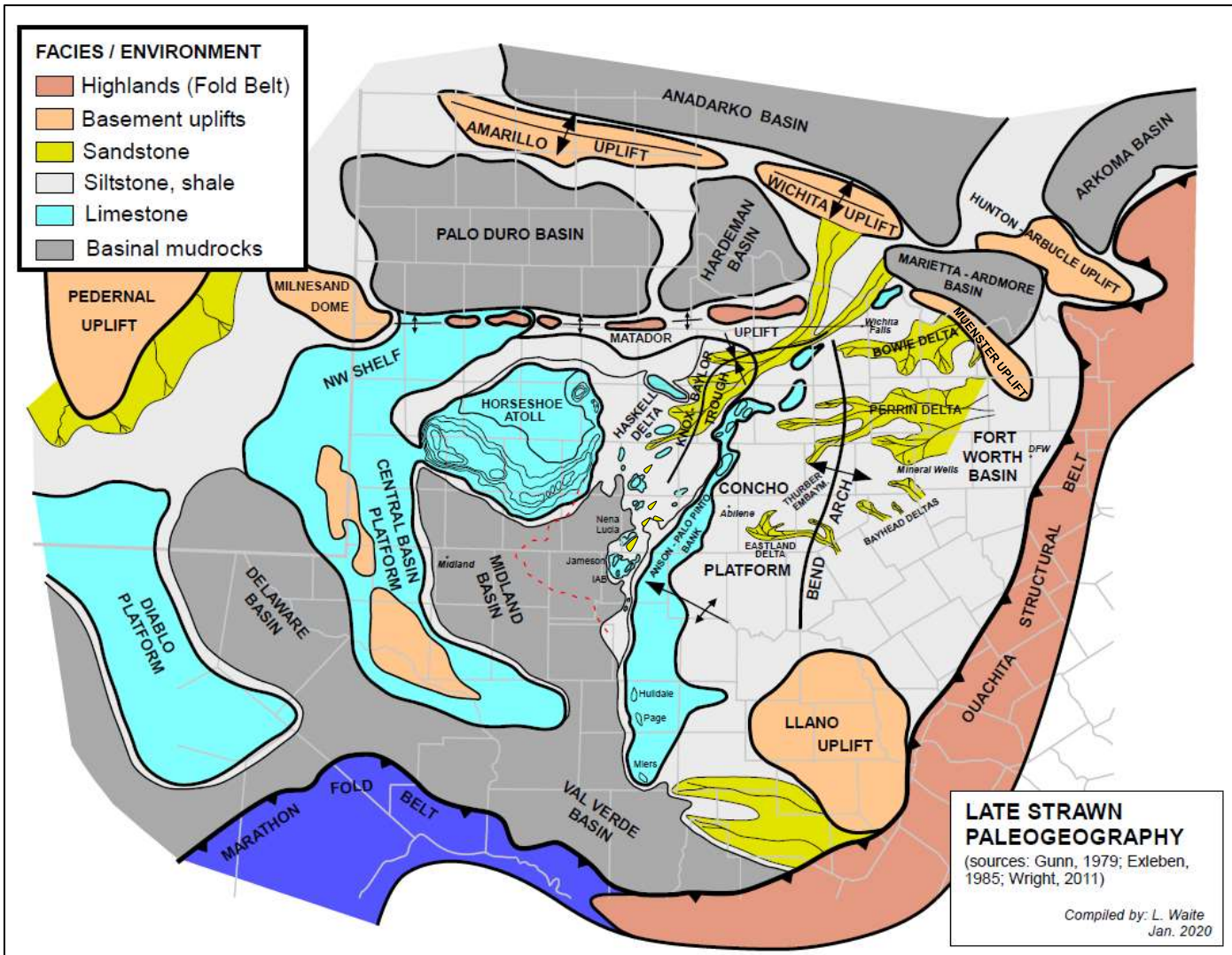
General Stratigraphy of the Eastern Shelf



(modified from Alton Brown, 2021, after Frank Brown, BEG, 1973)

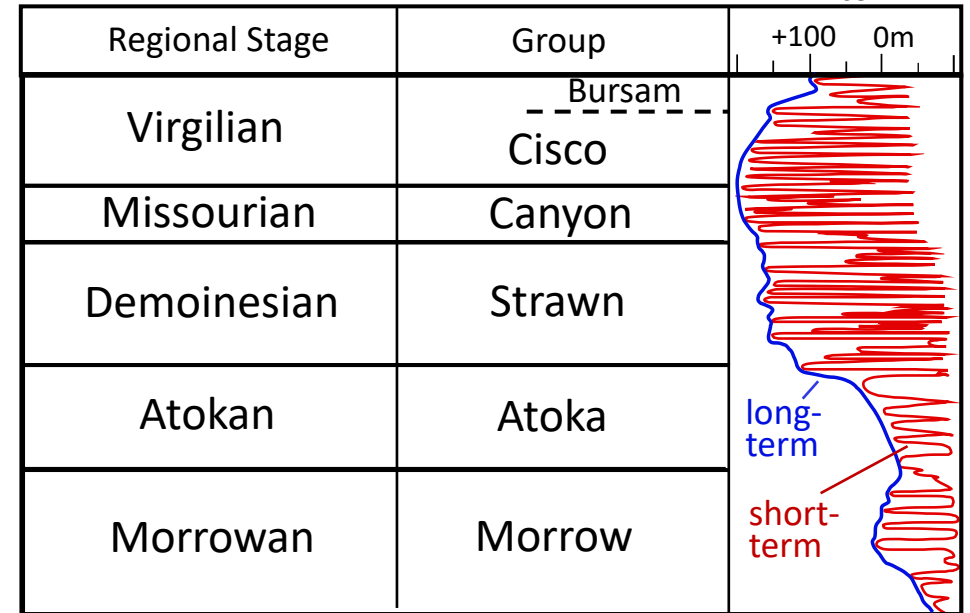
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Late Desmoinesian - Missourian (Upper Strawn - Canyon) Paleogeography



Pennsylvanian Eustasy (after Wright, 2020)

Sea Level
← rise



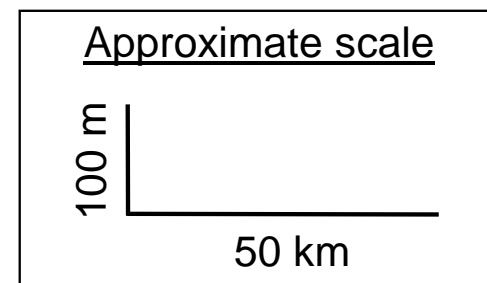
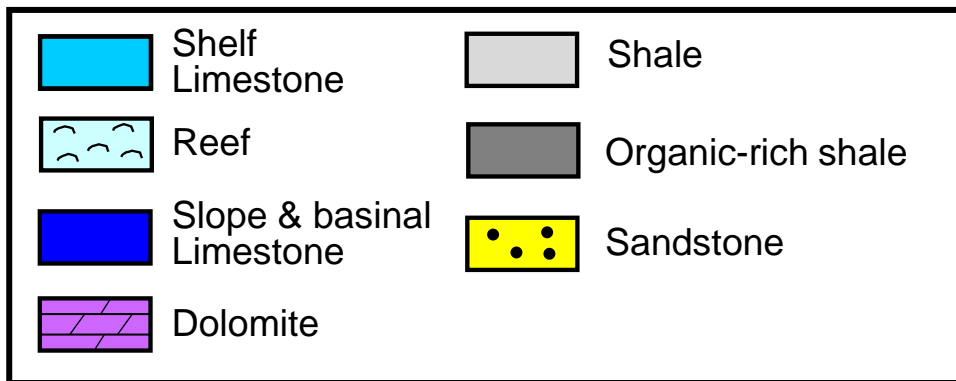
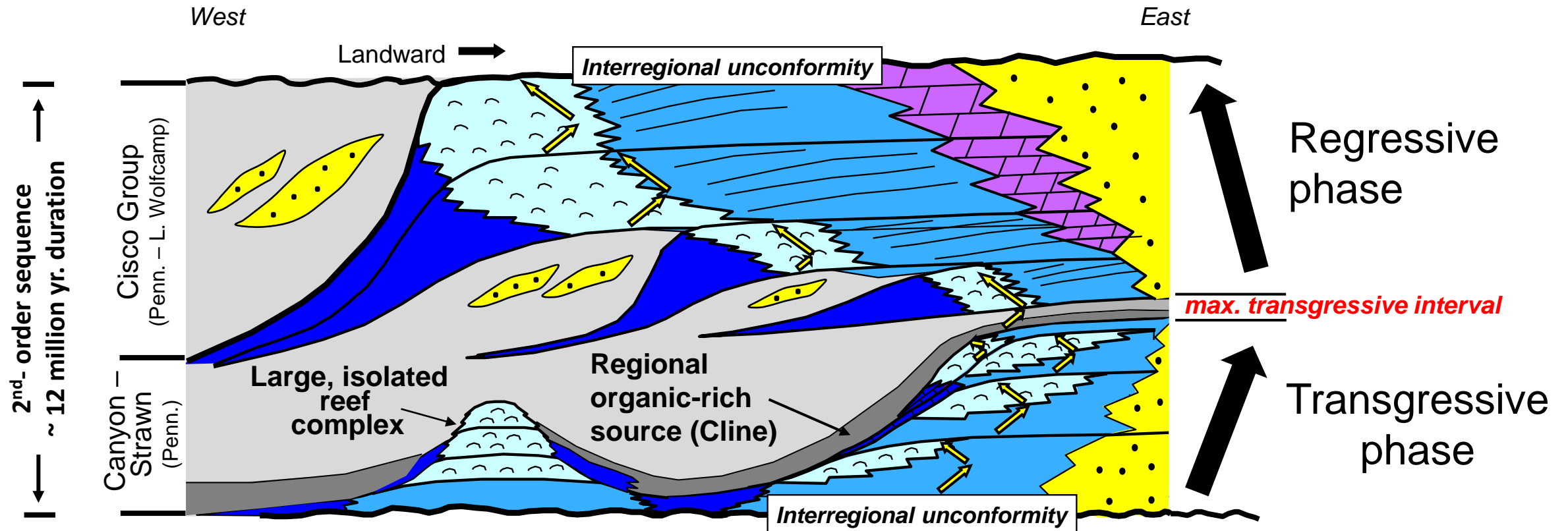
Long-term sea-level (tectonic control)

- Prolonged transgression drowns the underlying L. Strawn Concho Platform; organic-rich black shales (Wolfcamp D / Cline) deposited in rapidly subsiding “starved” basins

Short-term sea-level (glacioeustasy)

- During glacial maxima (S.L. lowstands), tectonically-active Ancestral Rockies uplifts and Ouachita Fold Belt shed voluminous amounts of clastics (channel/delta/slope systems) across Eastern Shelf
- During glacial minima (highstands), massive shallow-water carbonate deposition occurs along outboard shelf margins, including a series of large, isolated carbonate mounds/reefs

Schematic stratigraphic architecture, Penn. – lower Permian, Eastern Shelf

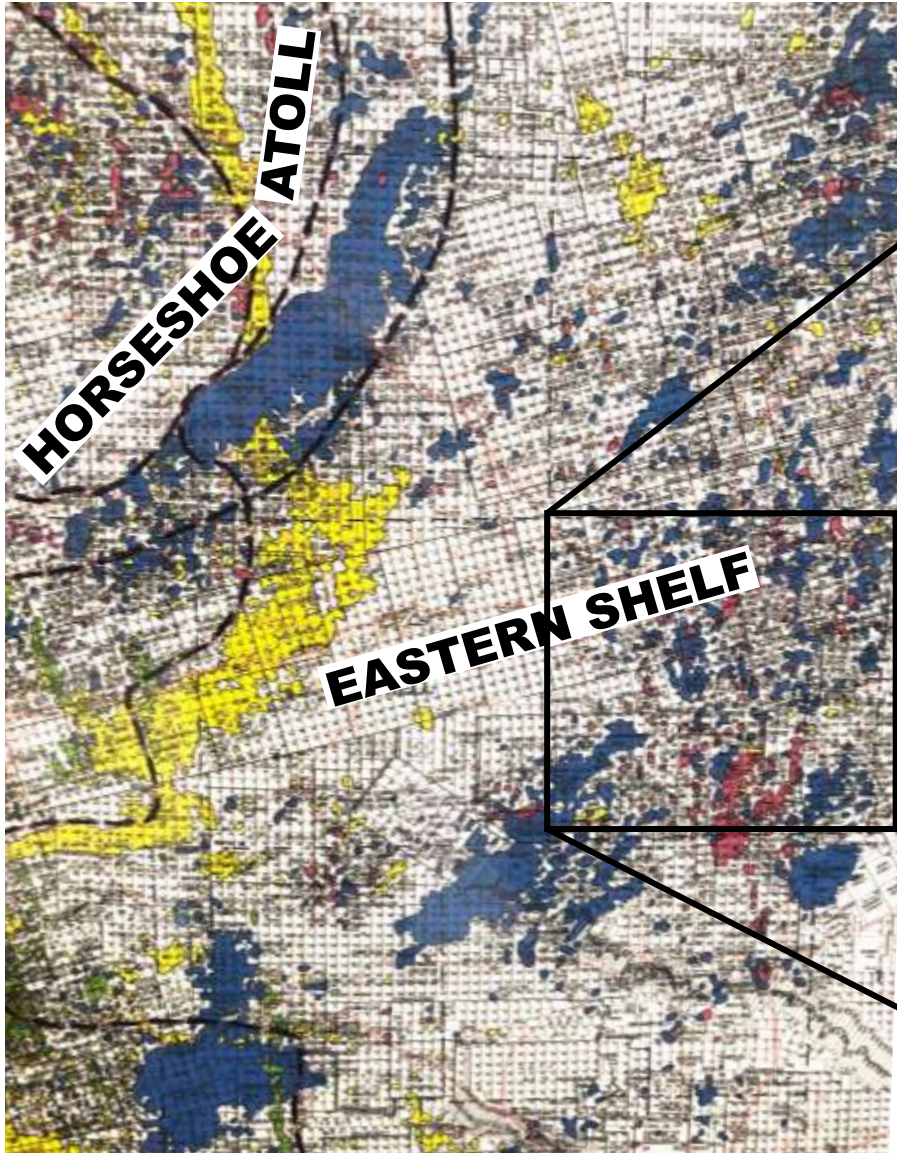


(L Waite, 1988, unpublished)

- Goal of study: better understanding of producing trends along western margin of Eastern Shelf

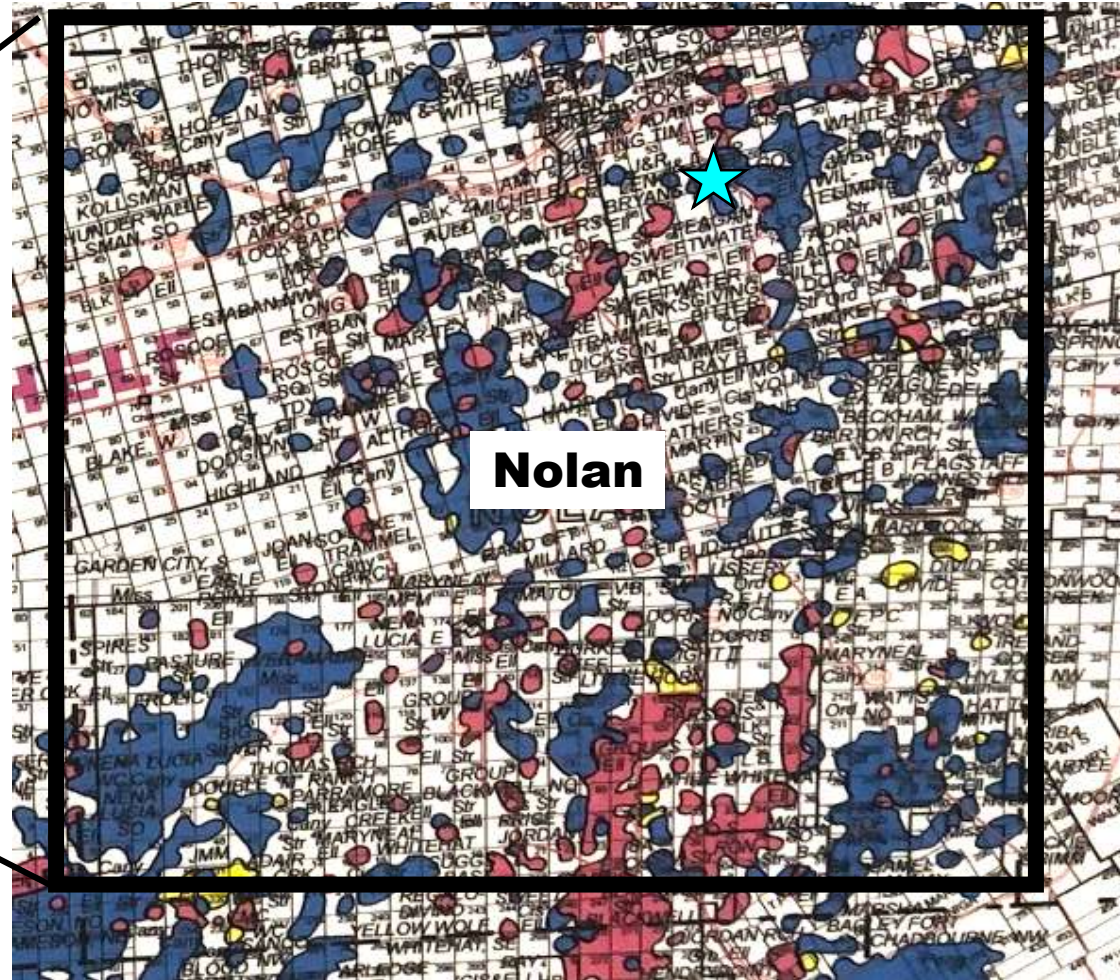
- Question: what is remaining potential ? (via field growth, exploration, horizontal drilling, etc.)

- Starting point: Nolan County
 - Centrally-located; previously worked (late 1980s)
 - Two small Caddo core samples provided by UTD alum Jerry Bergthold ★

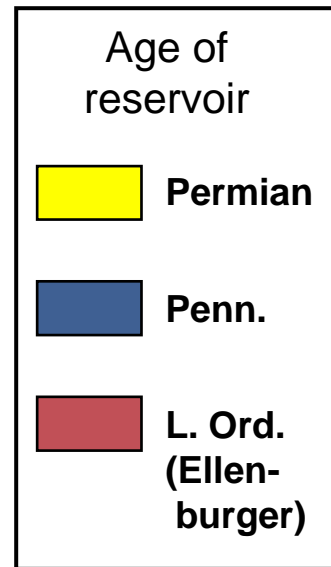


30 miles

(Midland Map Co.)



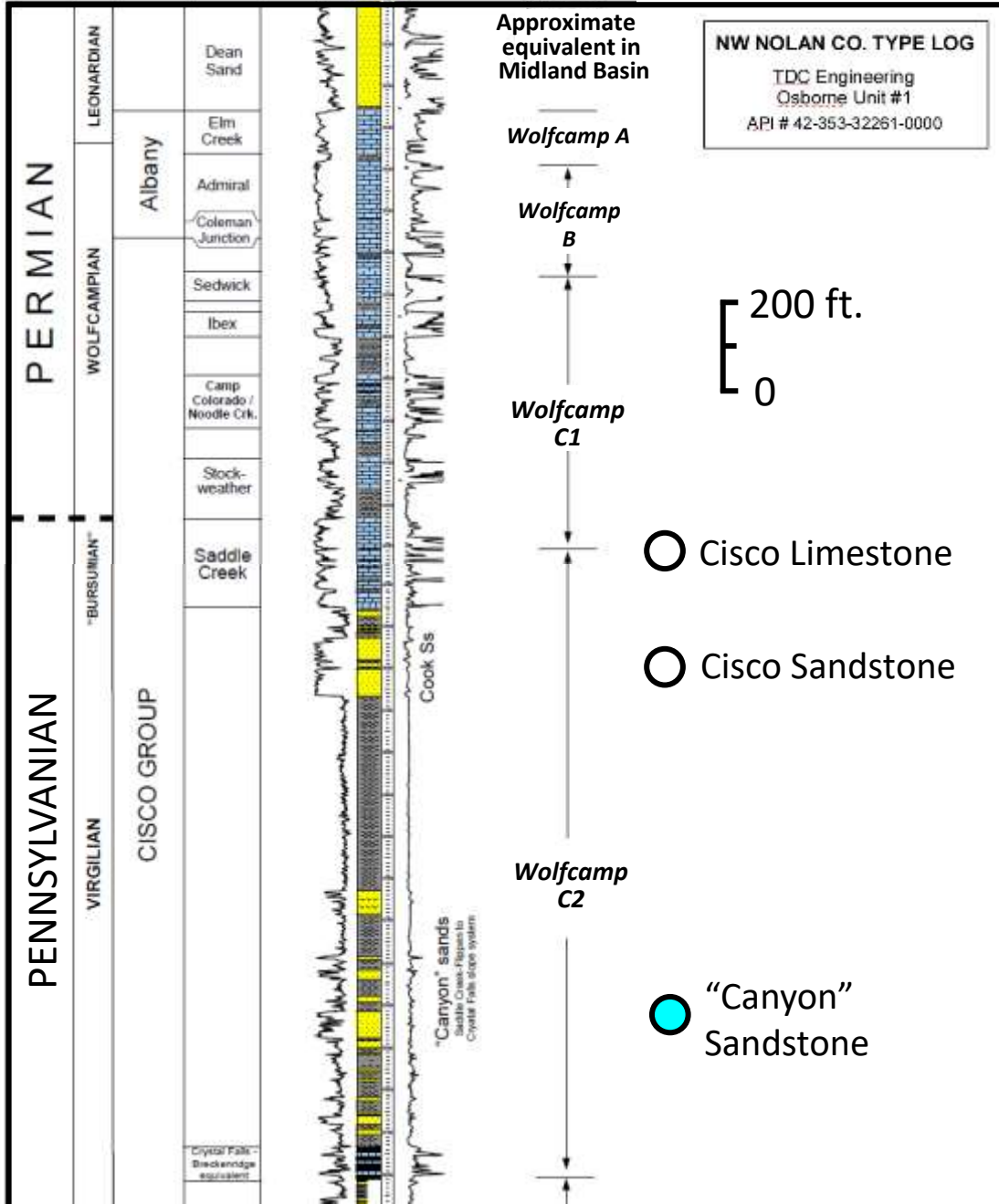
10 miles



Analysis of Nolan Co. producing trends: Method

- Export Nolan County wells from Enverus database including producing zone (n = 5123)
- Utilizing Petra, check perforated zones for each well; amend Enverus producing zones ($n_{\text{ammended}} = 4926$)
 - 3.8 % of wells in eliminated mainly due to non-reported perfs
 - Some wells eliminated due to missing API#
- Identify & map a number of high-resolution producing zones (11 total; color-coded by zone)
- Analyze drilling and producing statistics (ongoing; not discussed here)

Note: Individual checking of perf zone(s) in all wells is a very time-consuming, but critical step in the identification and assignment of correct, high-resolution producing zones

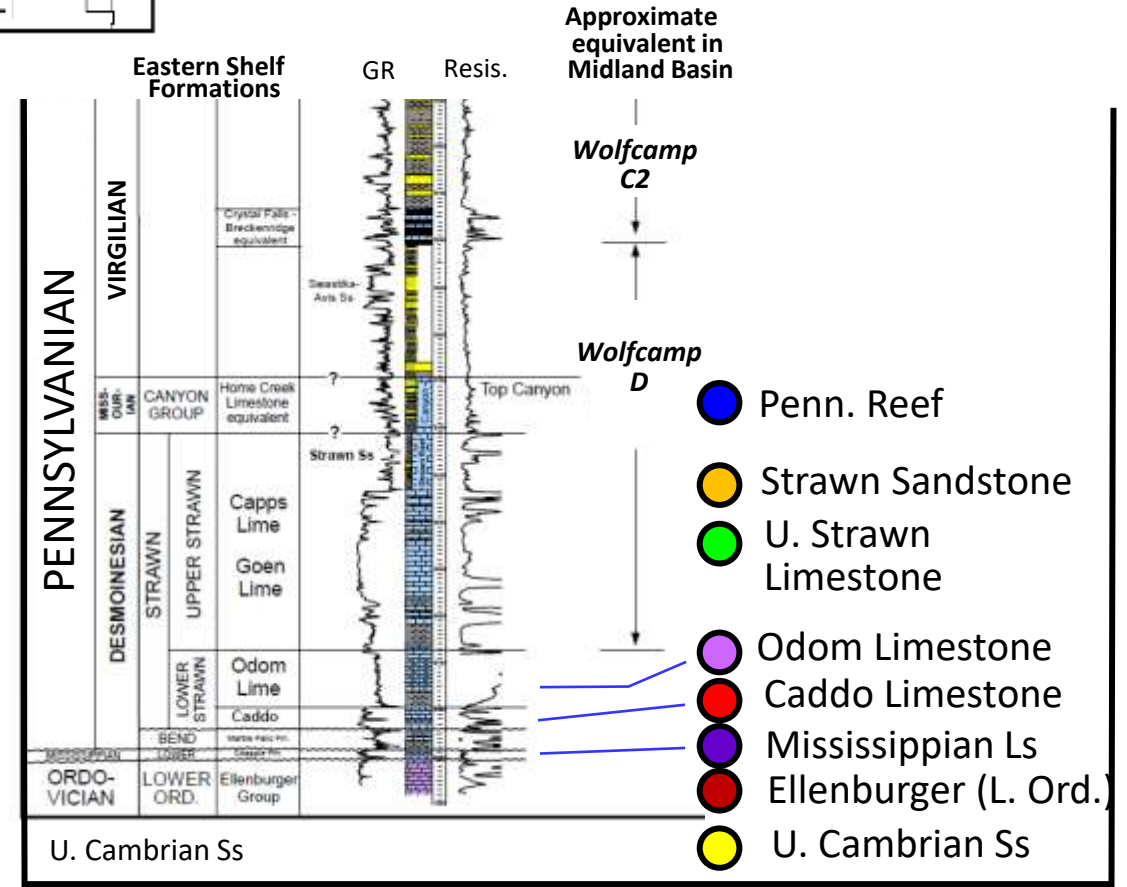


NW Nolan Co. type log with stratal position of high-resolution producing zones (11)

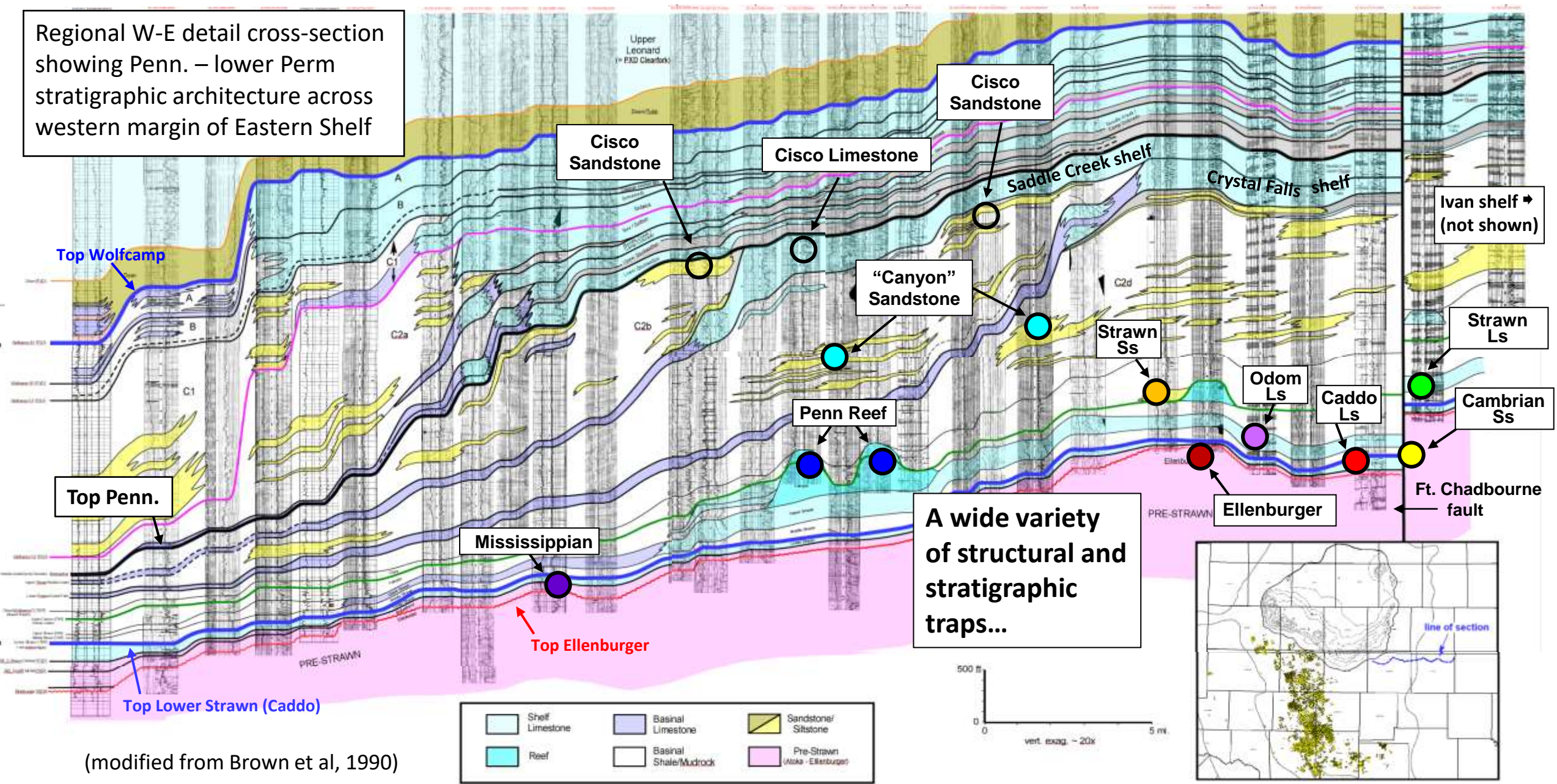


Main Lithology

- Limestone
- Dolomite
- Sandstone
- Grey shale
- Black shale



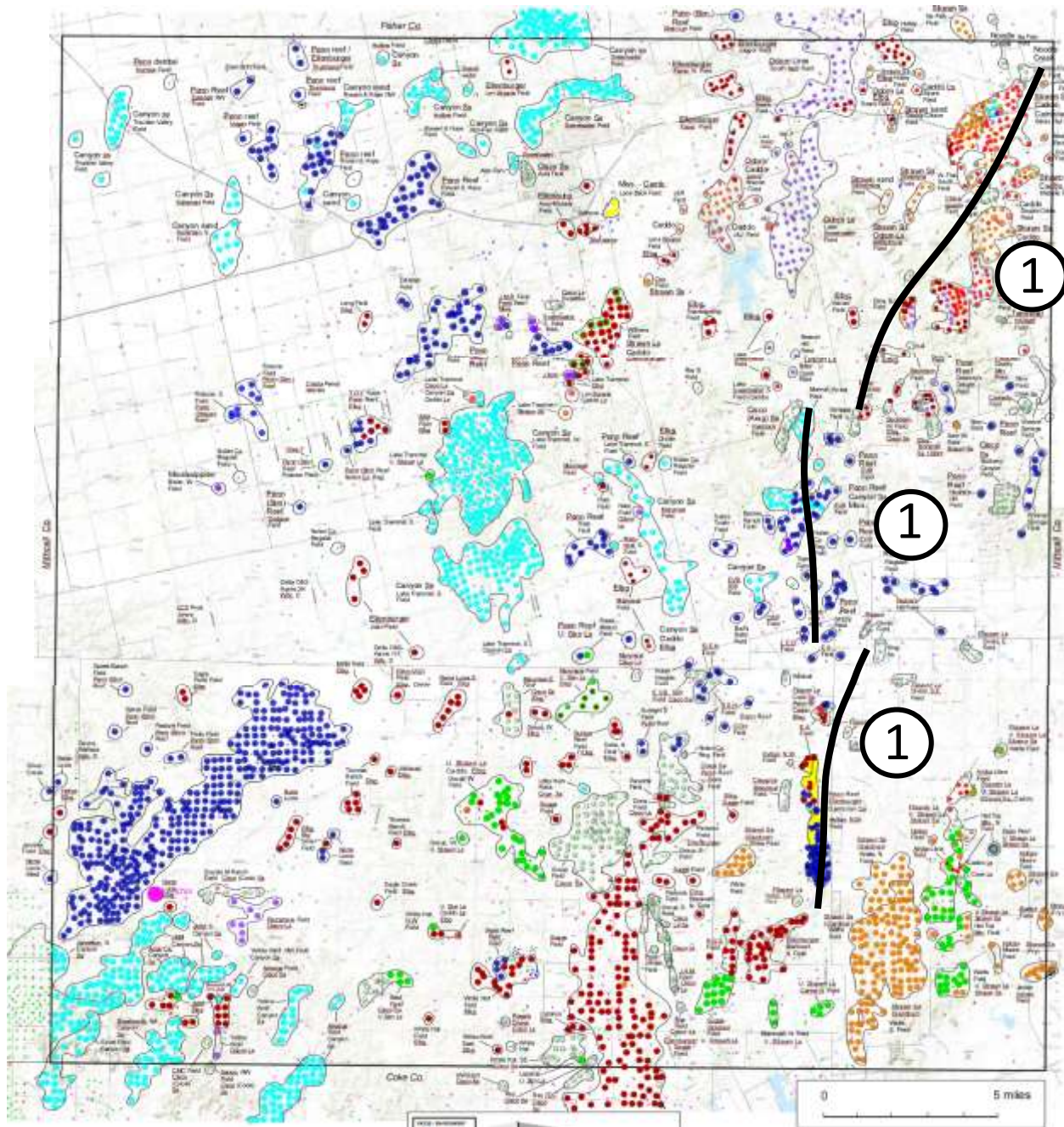
Regional W-E detail cross-section showing Penn. – lower Perm stratigraphic architecture across western margin of Eastern Shelf



A wide variety of structural and stratigraphic traps...

(modified from Brown et al, 1990)

NOLAN COUNTY
PRODUCING TRENDS
MAP



INDEX

- Cisco (Lower Wolfcamp) Ls / Ss
- Canyon Ss
- Penn Reef
- U. Strawn Ls
- Strawn Ss
- Odom Ls
- Caddo Ls
- Mississippian
- Ellenburger
- Camb. Ss

Nolan County Producing Trends

- ① Ft. Chadbourne structural and combination traps; multiple zones (Cambrian Ss, Elbg., Caddo Ls, Strawn Ss., U. Strawn Ls, Penn Reef. Canyon Ss) (faults from Ewing, Tectonic Map of TX)

Nolan County Producing Trends

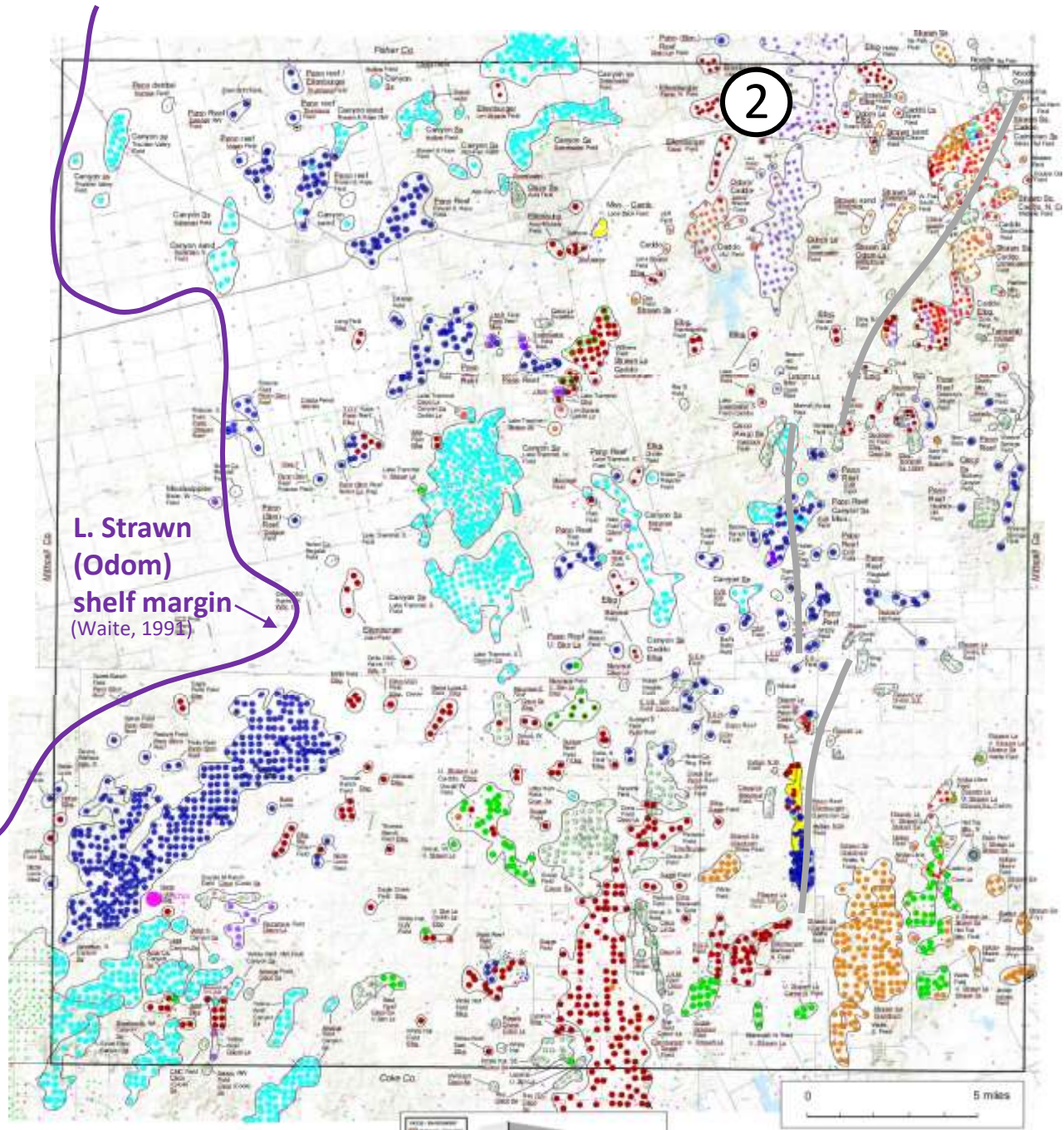
INDEX

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- Strawn Ss
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2

L. Strawn
(Odom)
shelf margin
(Waite, 1991)

- ① Ft. Chadbourne structural and combination traps; multiple zones (Cambrian Ss, Elbg., Caddo Ls, Strawn Ss., U. Strawn Ls, Penn Reef. Canyon Ss) (faults from Ewing, Tectonic Map of TX)
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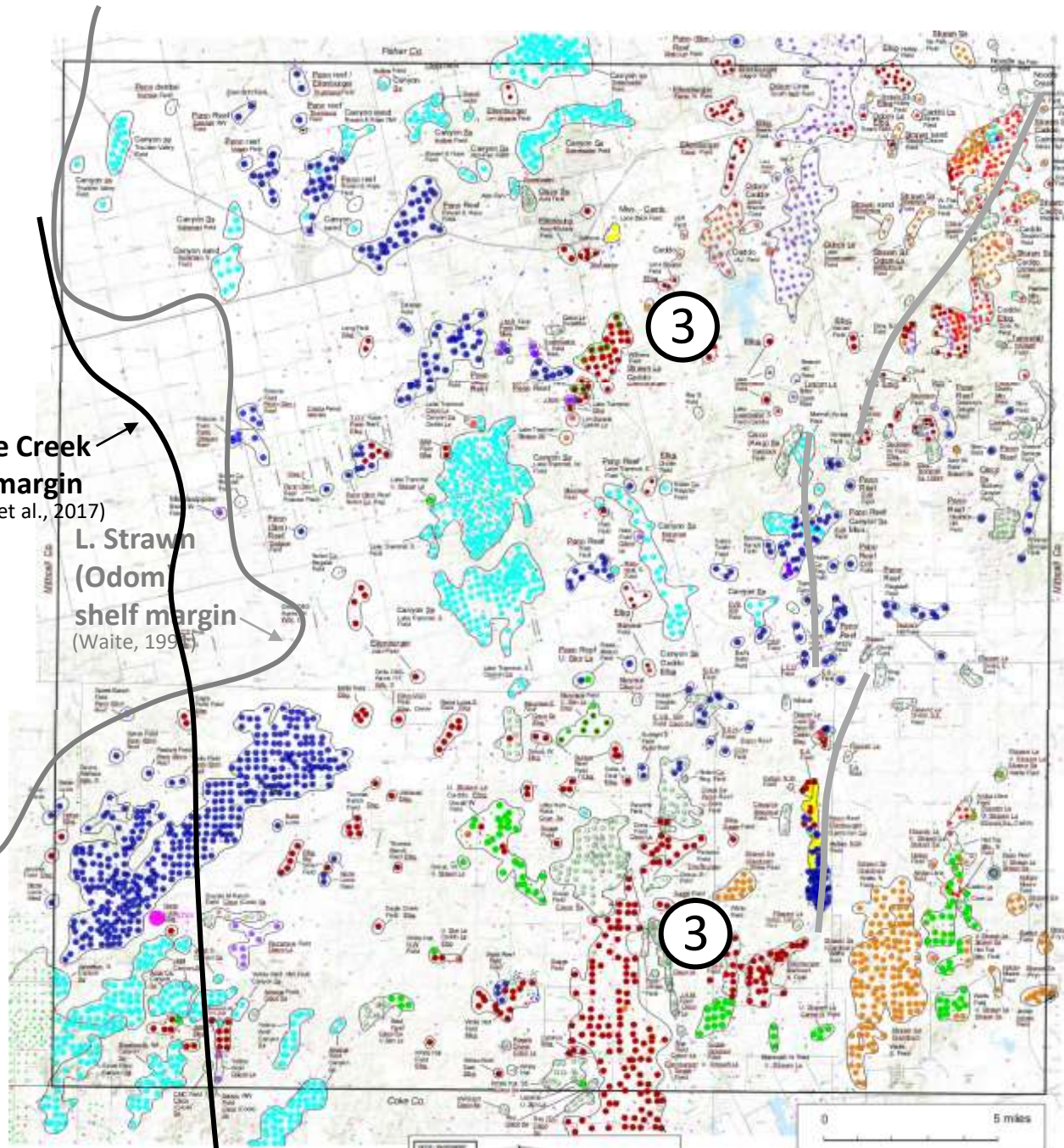
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Saddle Creek shelf margin
(Heintz et al., 2017)

L. Strawn (Odom) shelf margin
(Waite, 1995)

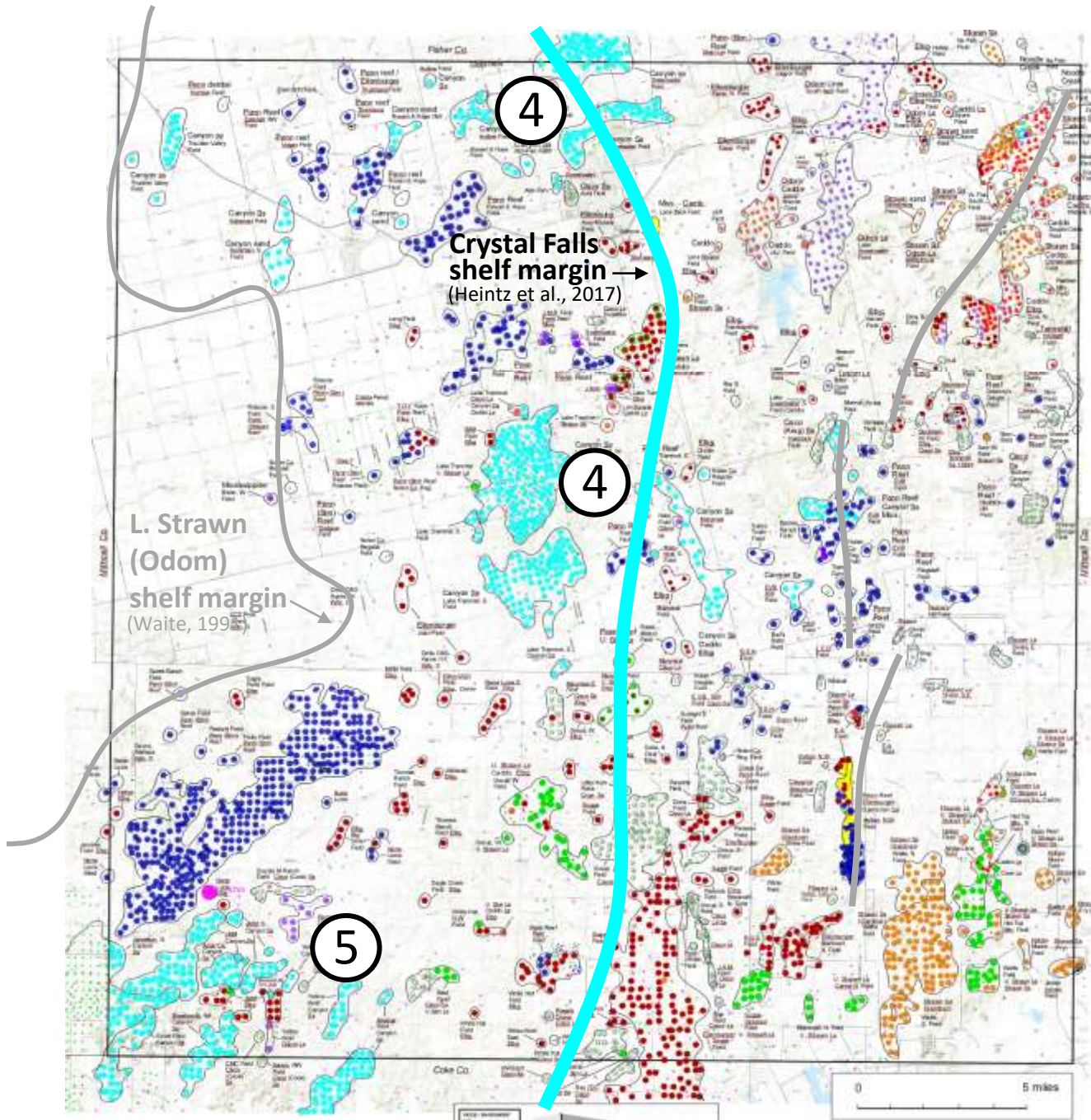


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Nolan County Producing Trends

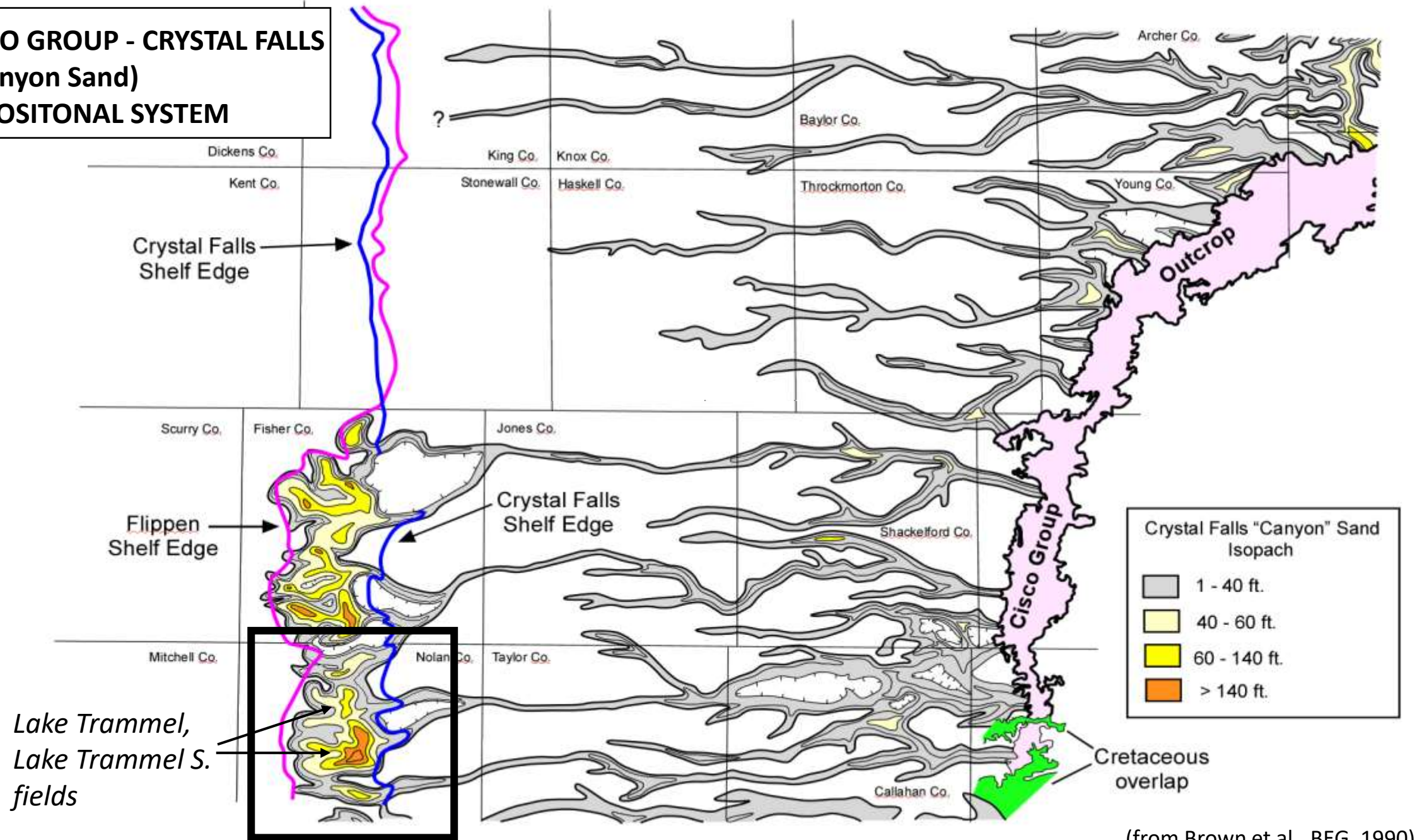
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**CISCO GROUP - CRYSTAL FALLS
("Canyon Sand")
DEPOSITONAL SYSTEM**

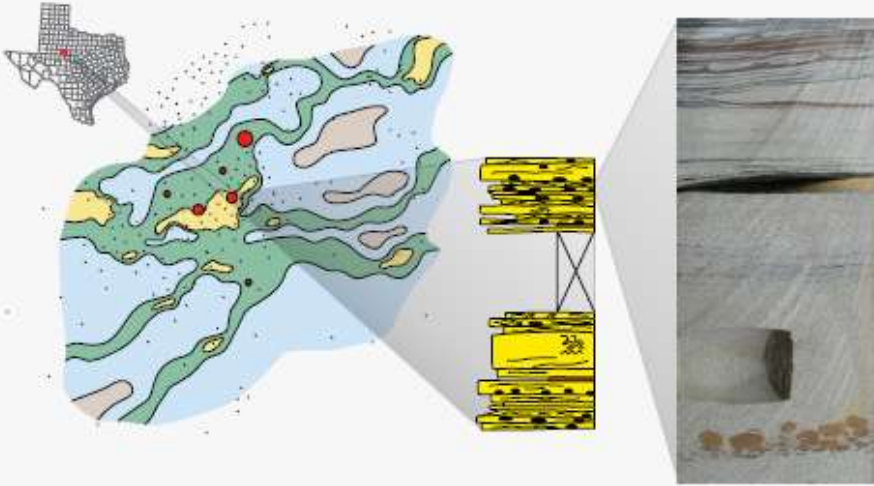


(from Brown et al., BEG, 1990)

Report of Investigations No. 288

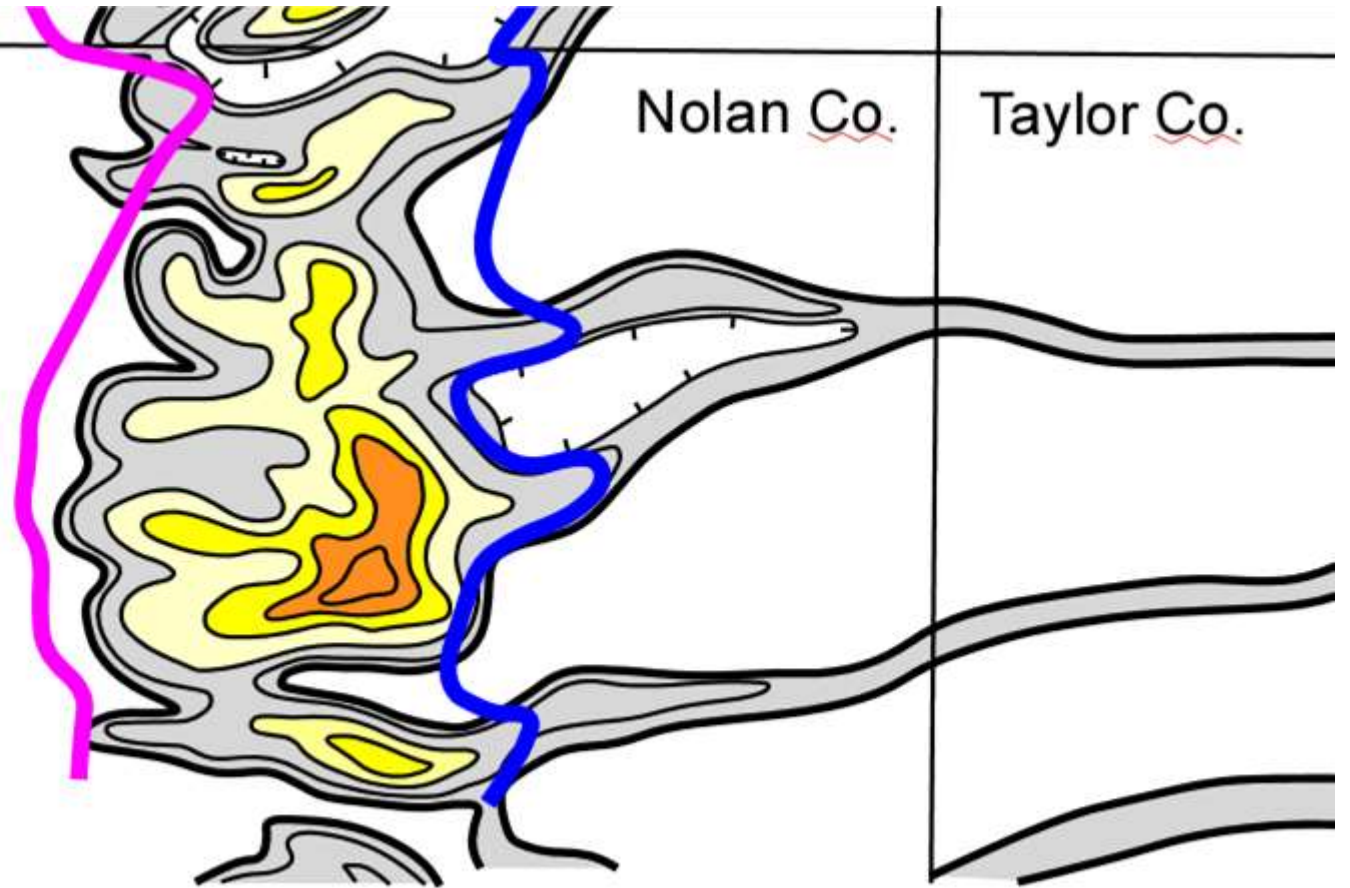
**Facies Variability and Geologic Controls on
Reservoir Heterogeneity in
Deepwater Slope Reservoirs in the
Pennsylvanian Cisco Group,
Lake Trammel South Field, Nolan County, Texas**

William A. Ambrose, Tucker F. Hentz, and David C. Smith



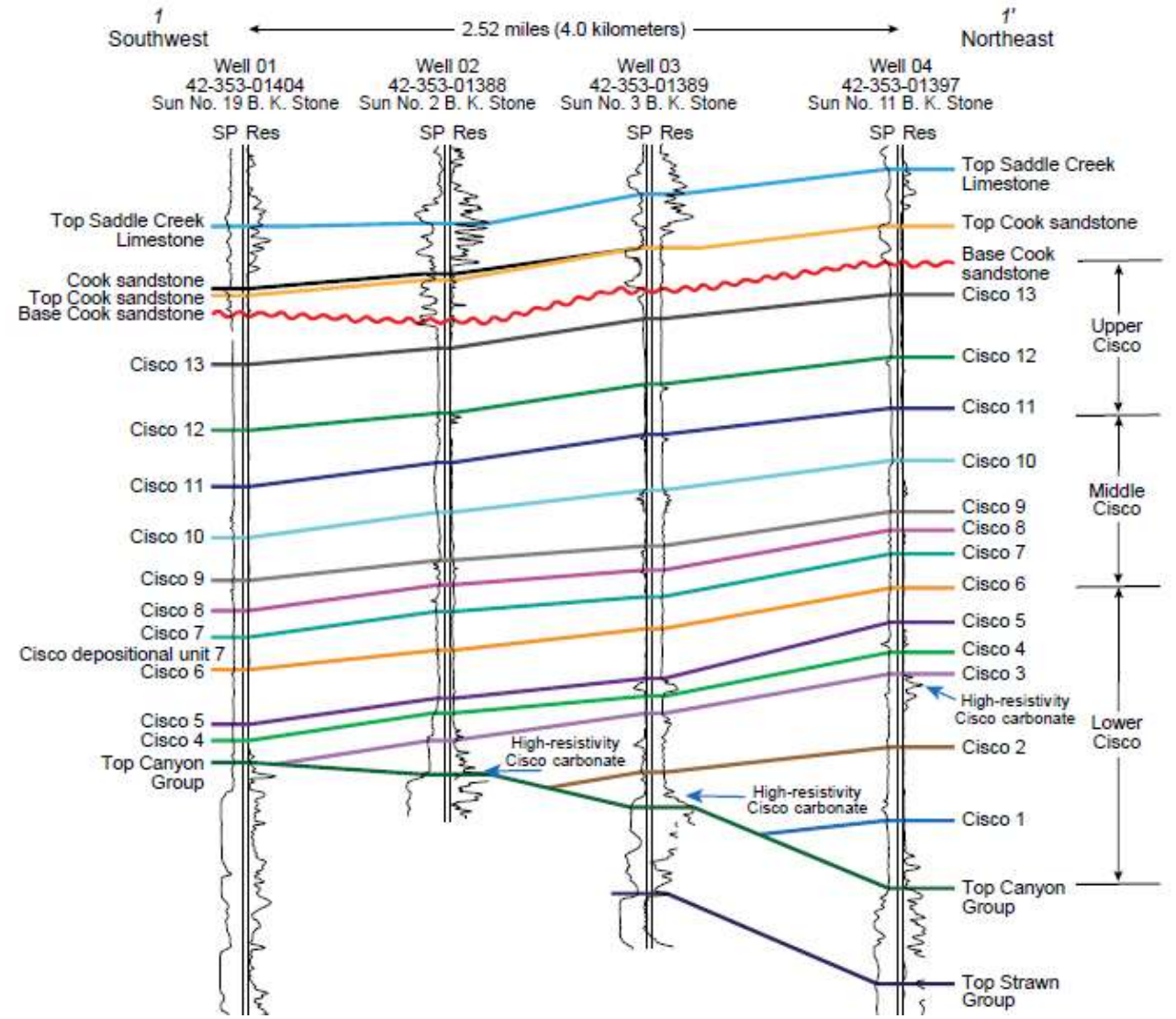
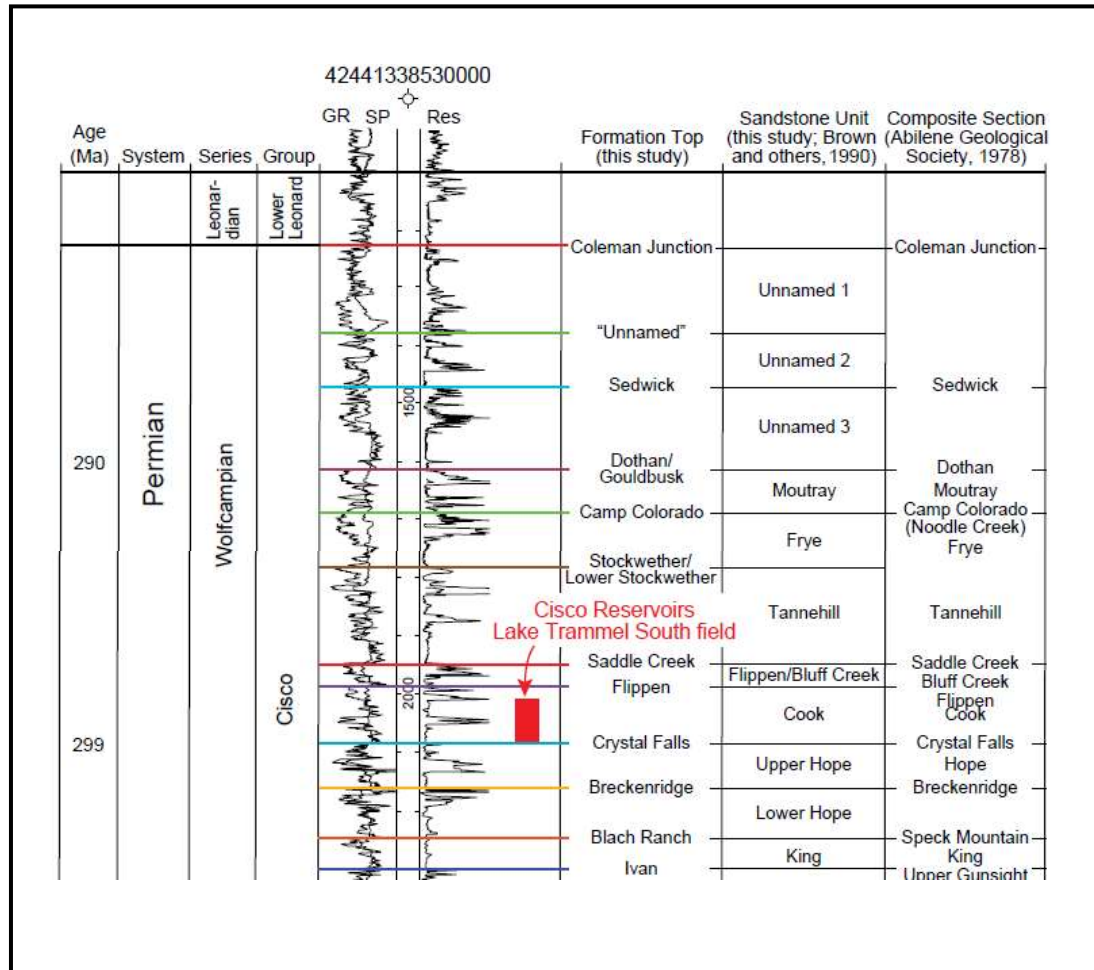
**BUREAU OF
ECONOMIC
GEOLOGY**

Bureau of Economic Geology
Scott W. Tinker, Director
Jackson School of Geosciences
The University of Texas at Austin
2022



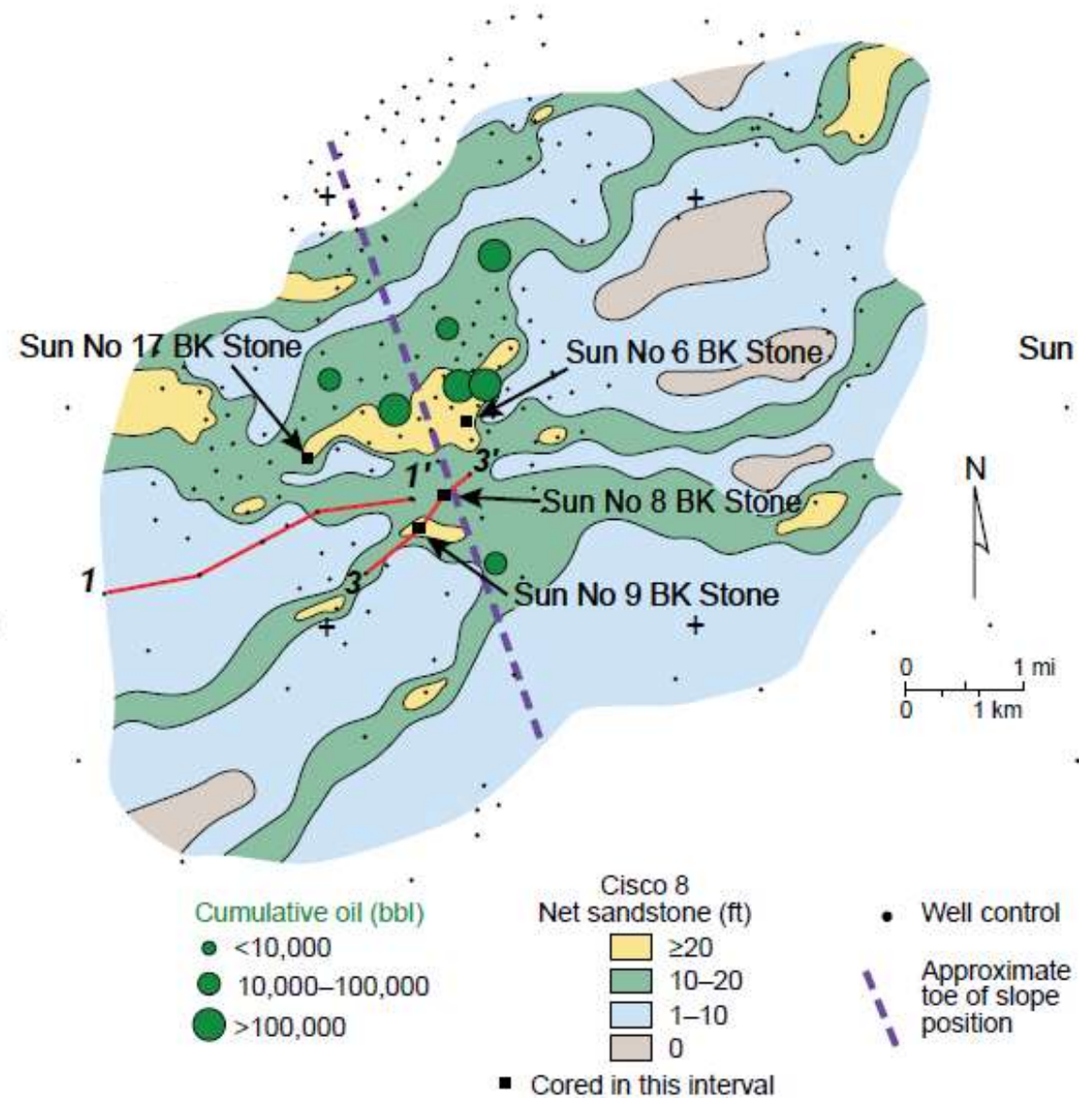
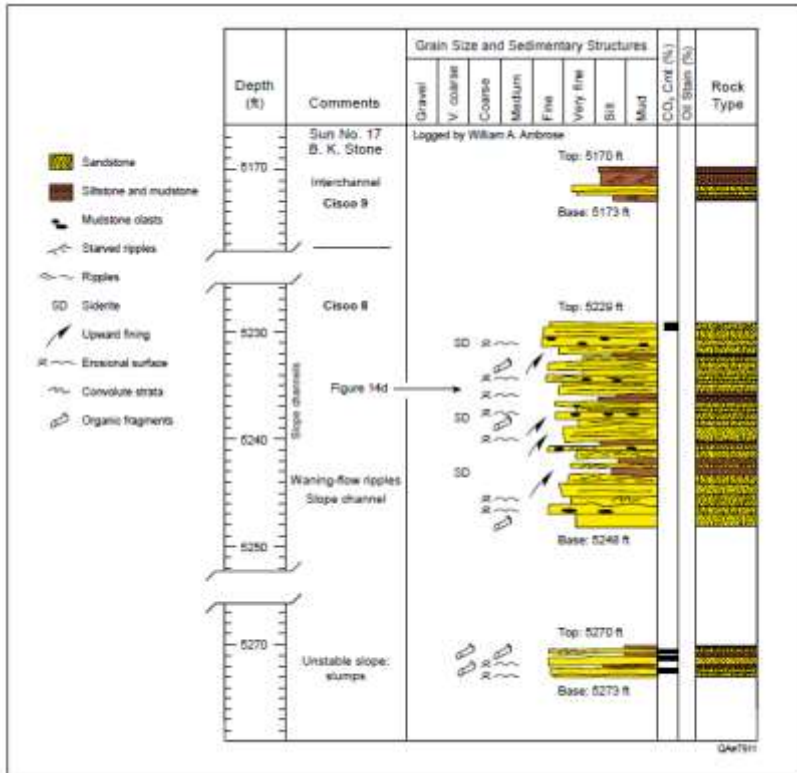
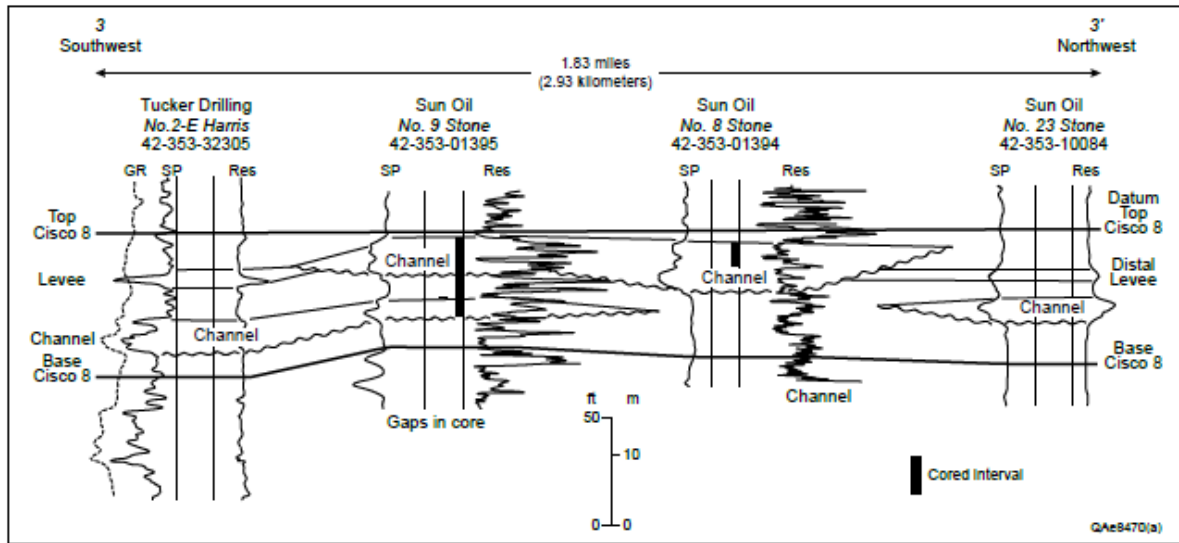
**Crystal Falls "Canyon" Sand
Isopach**

- 1 - 40 ft.
- 40 - 60 ft.
- 60 - 140 ft.
- > 140 ft.



Correlations: low-angle clinoform interpretation

Tidally-influenced slope channel systems

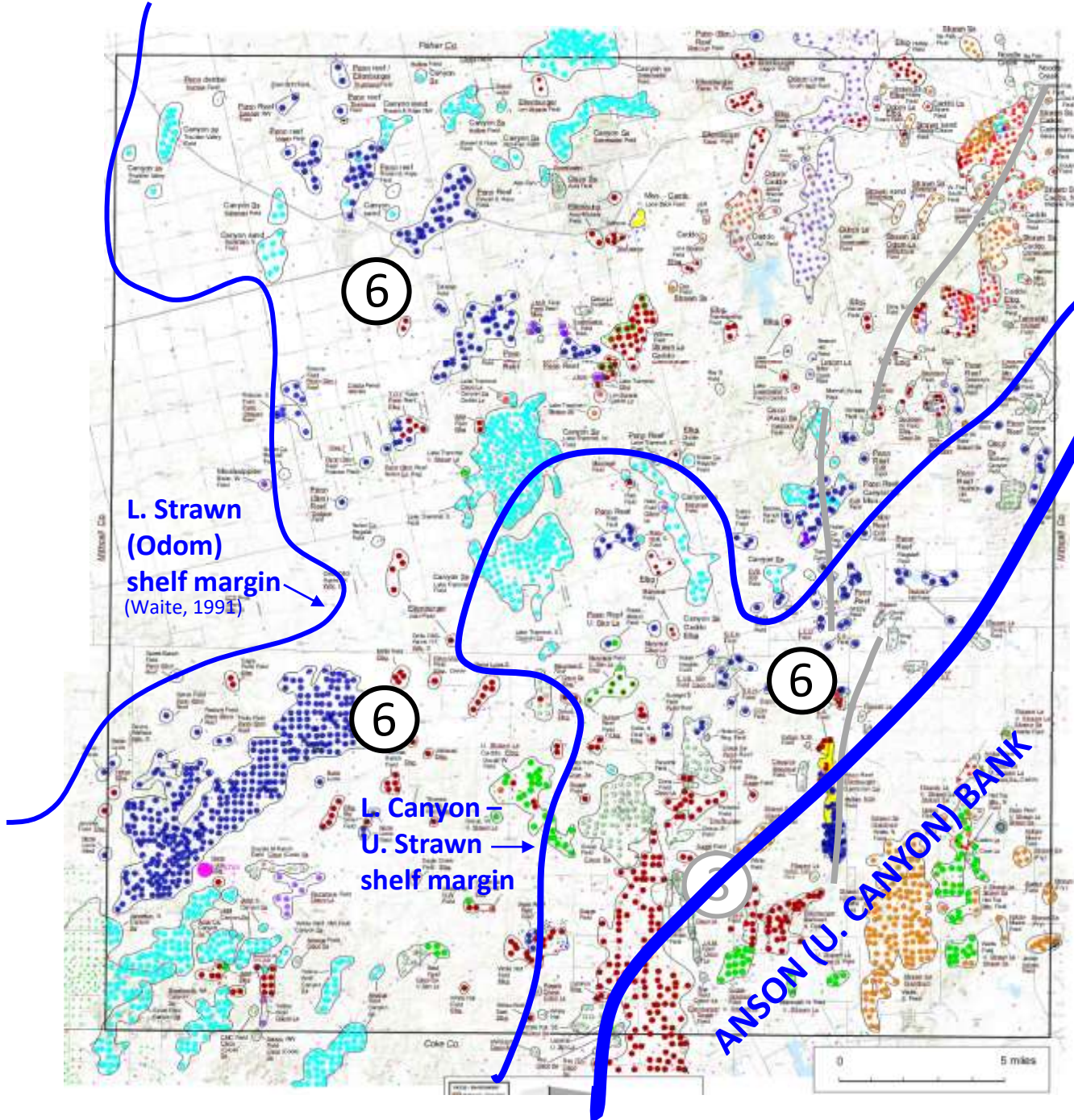


(Ambrose et al., 2022)

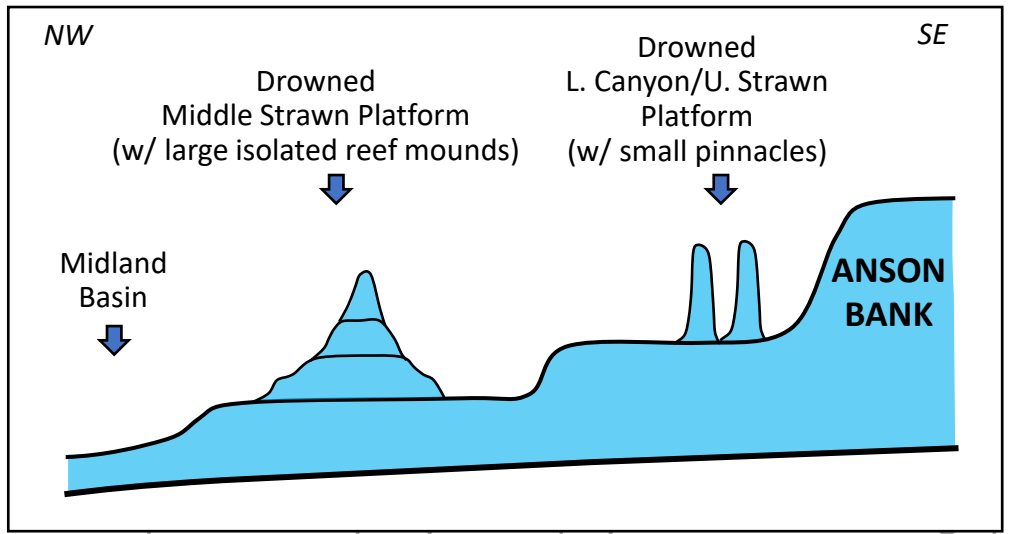
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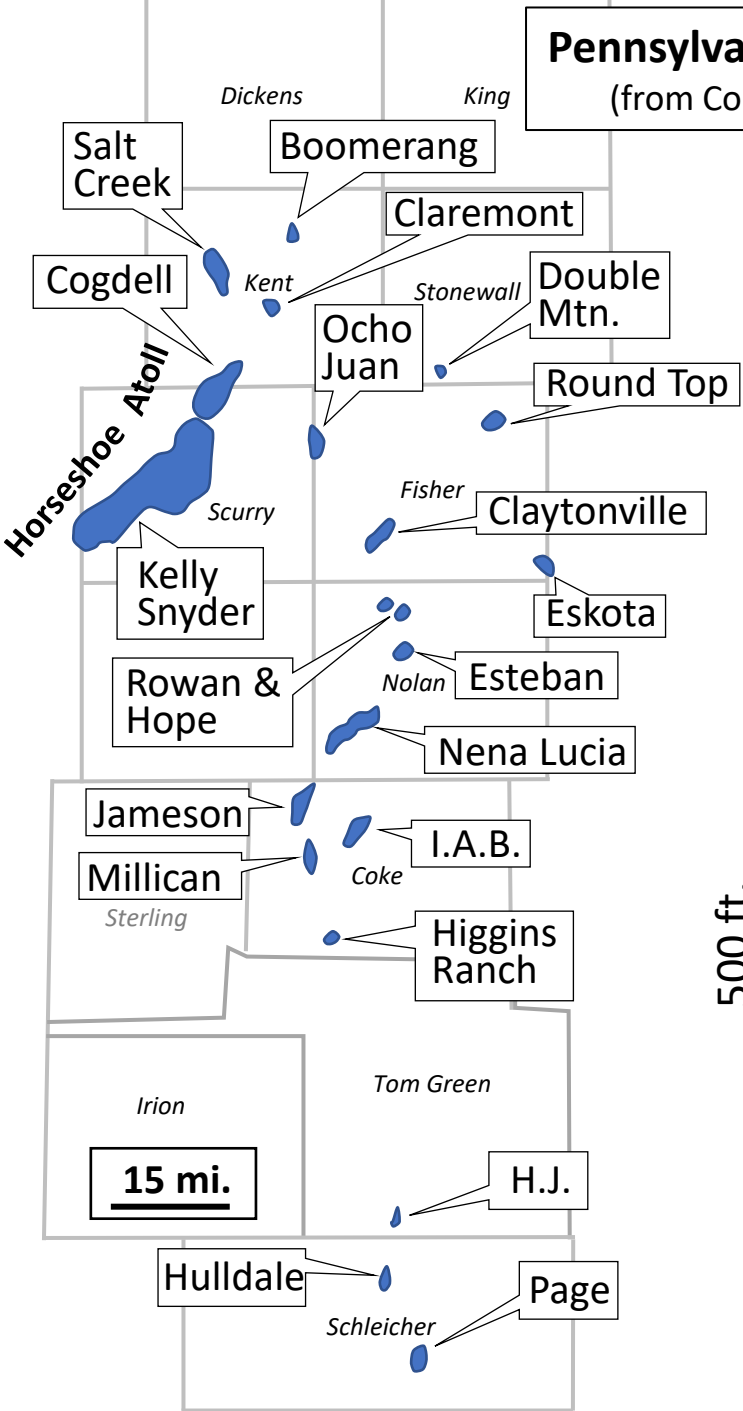
① Ft. Chadbourne structural and combination traps; multiple zones (Cambrian Ss, Elbg.,



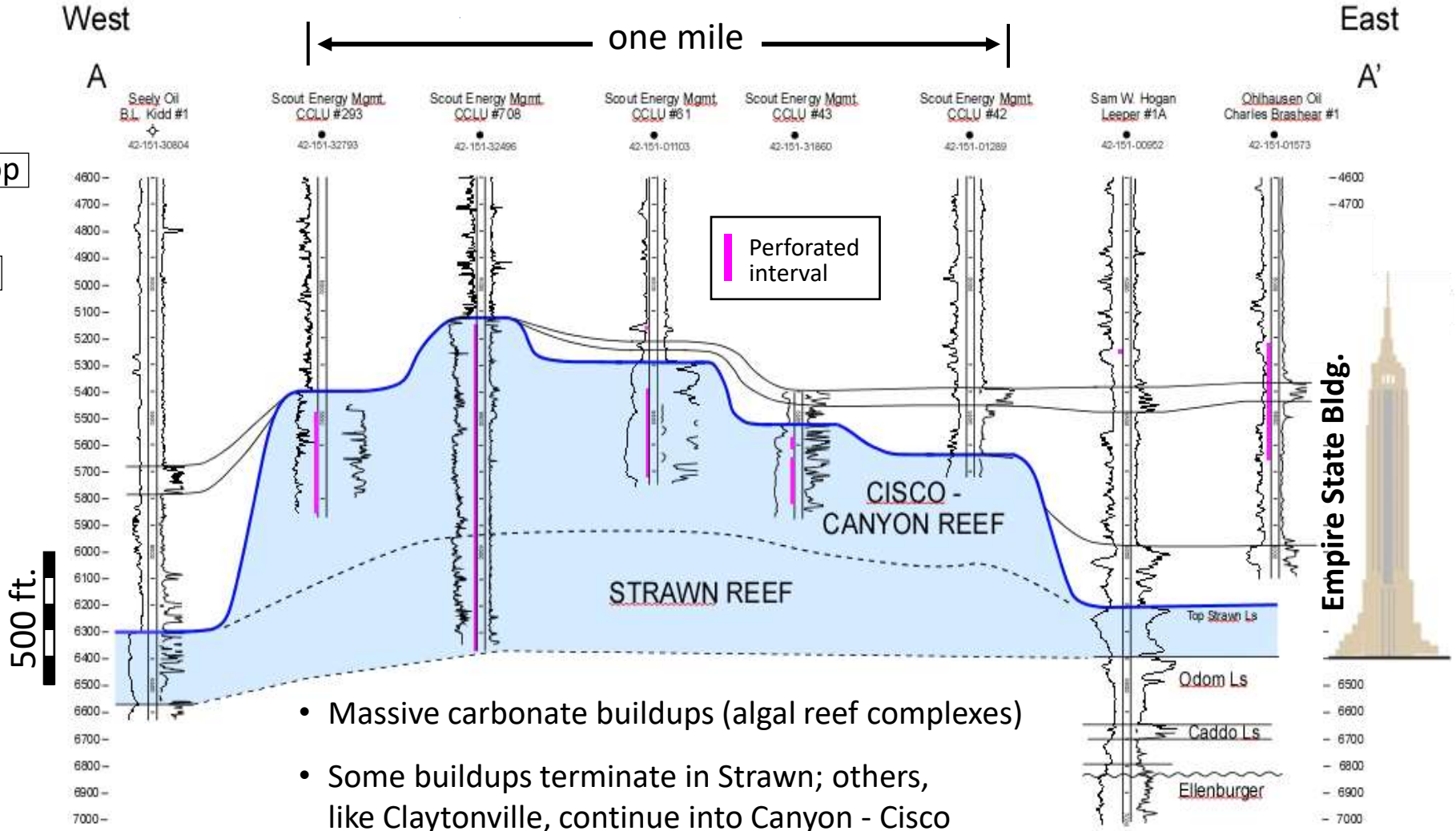
⑤ Canyon Ss (L. Wolfcamp) distal slope system

⑥ Small pinnacle reefs on L. Canyon drowned platform; large isolated reefs on L. Strawn drowned platform (bank margins from Waite, 1991)

Pennsylvanian Reef Trend
(from Counselman, 1960)



Claytonville Reef, Fisher County

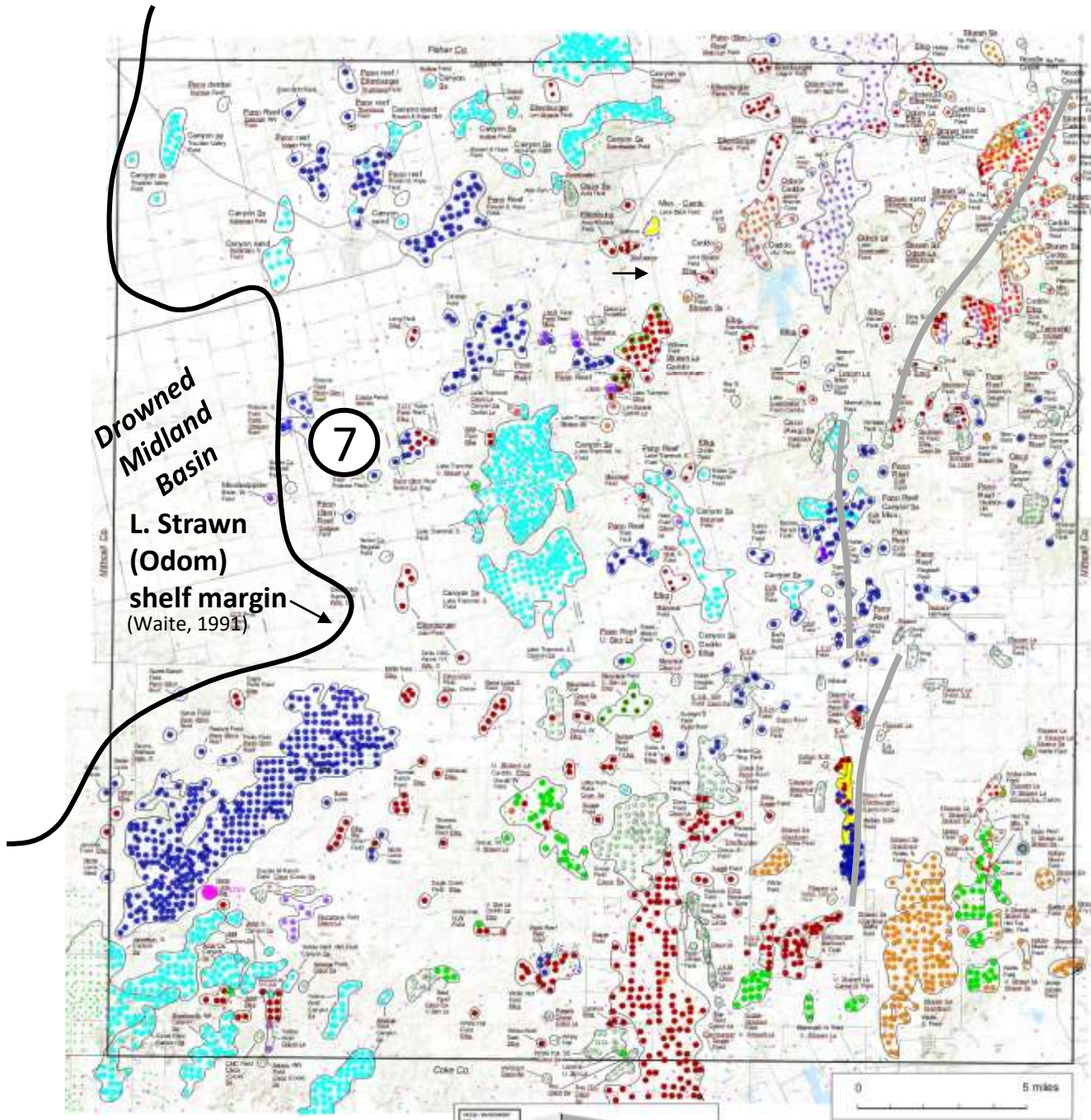


- Massive carbonate buildups (algal reef complexes)
- Some buildups terminate in Strawn; others, like Claytonville, continue into Canyon - Cisco
- Important conventional oil reservoirs
 Claytonville: ~ 67 MMBO
 Kelly Snyder: 1300 MMBO

Nolan County Producing Trends

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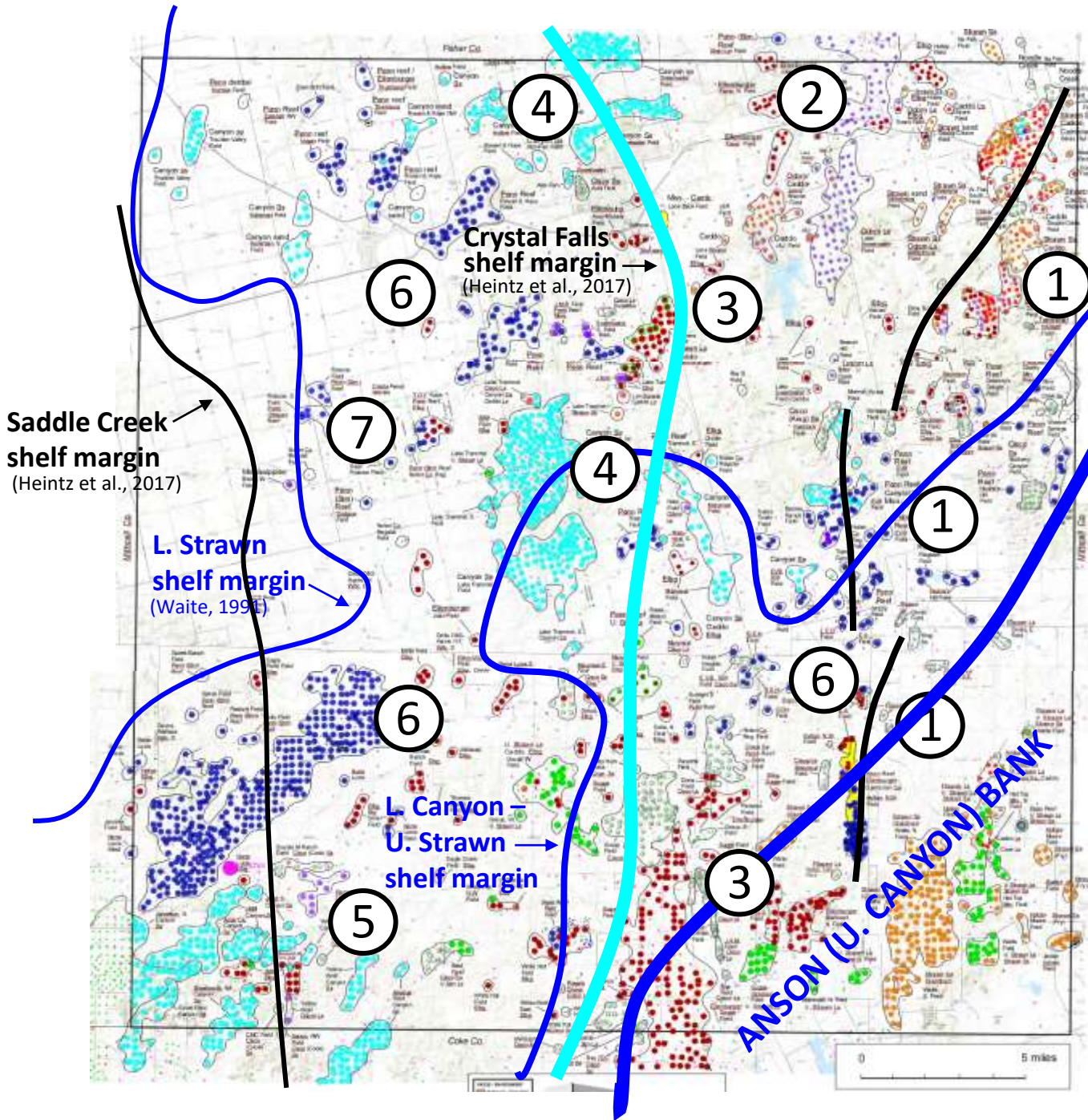
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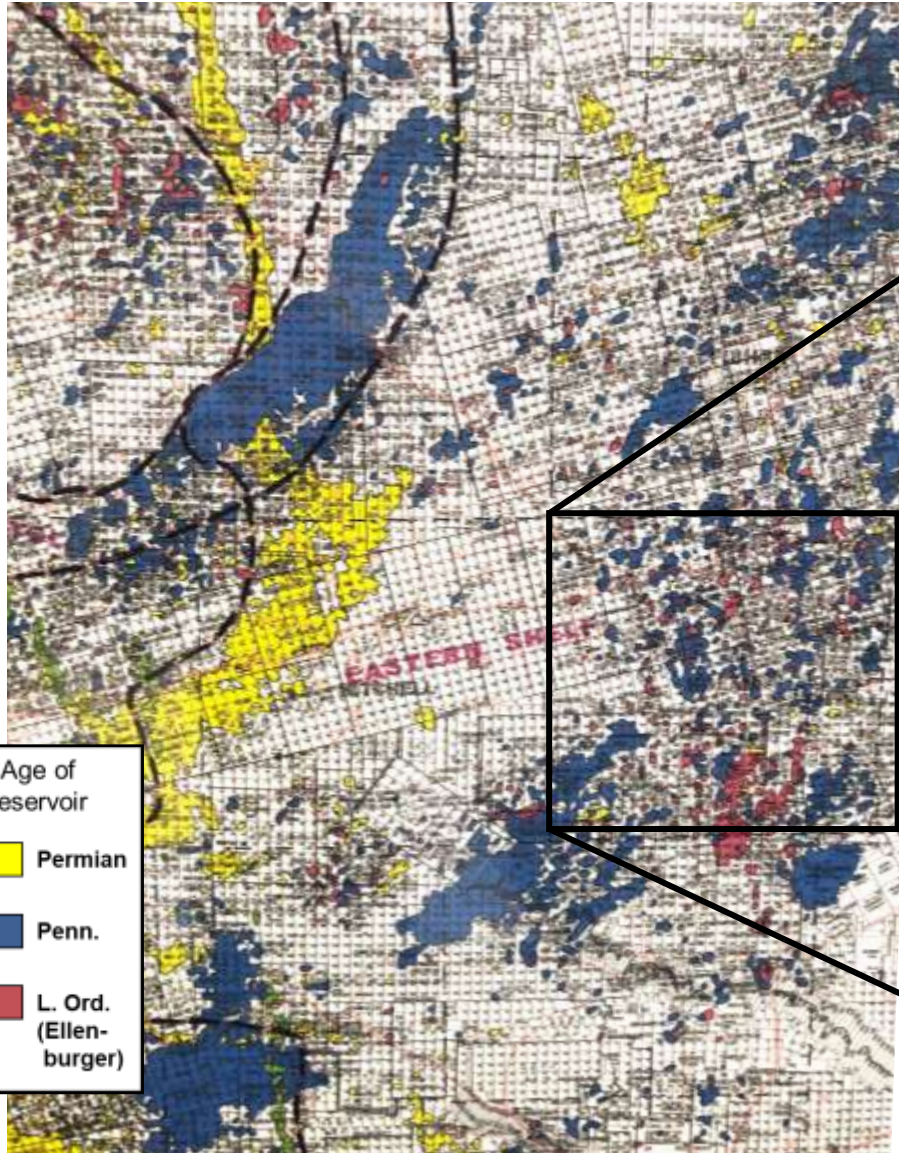
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- Goal of study: better understanding of producing trends along western margin of Eastern Shelf (Nolan County)

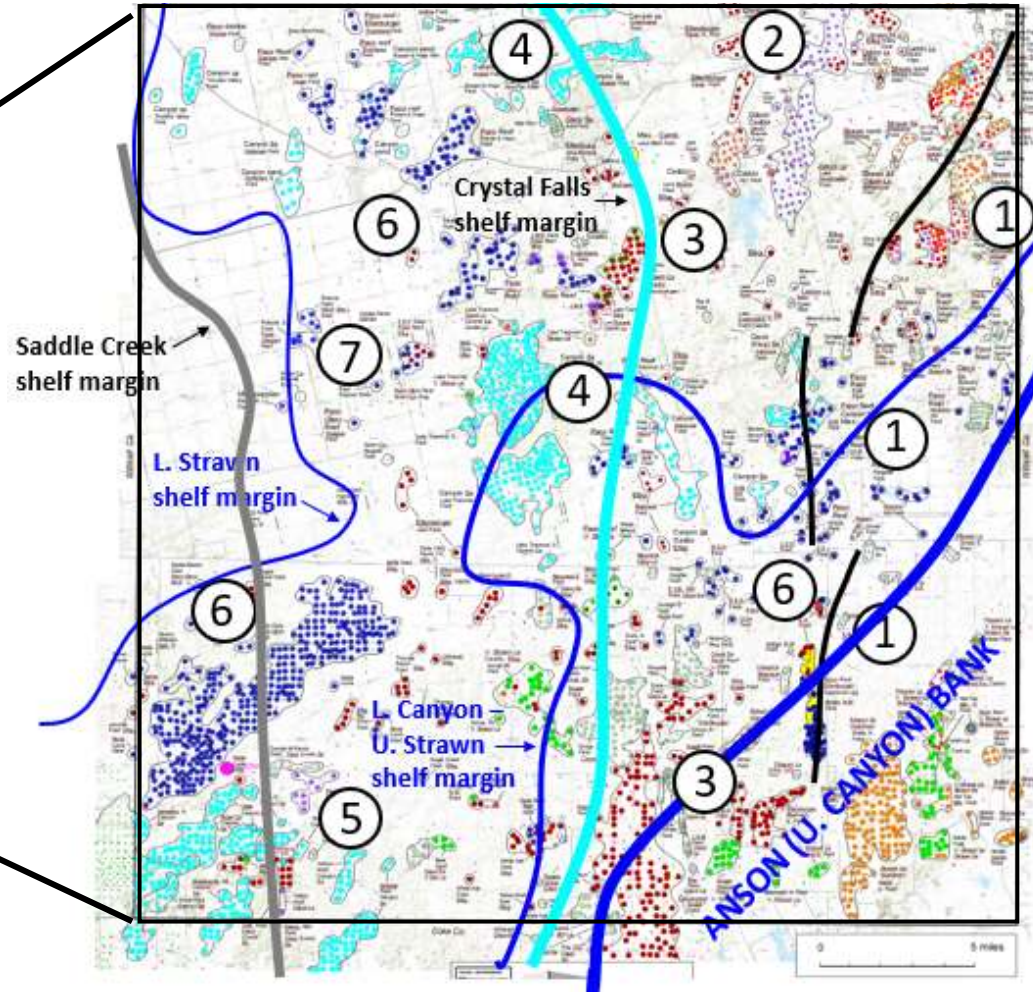


Age of reservoir

 Permian
 Penn.
 L. Ord. (Ellenburger)

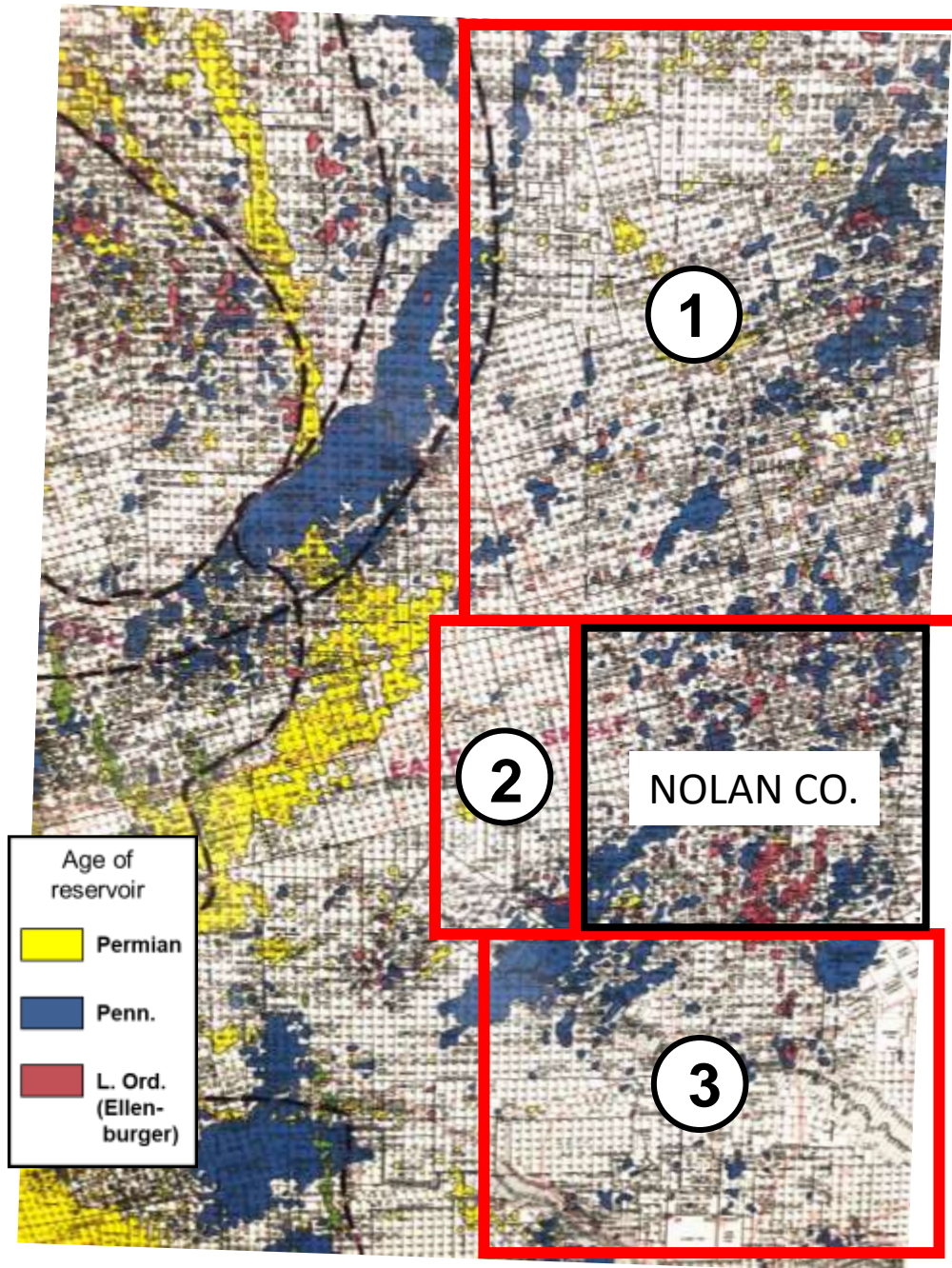
30 miles

(Midland Map Co.)



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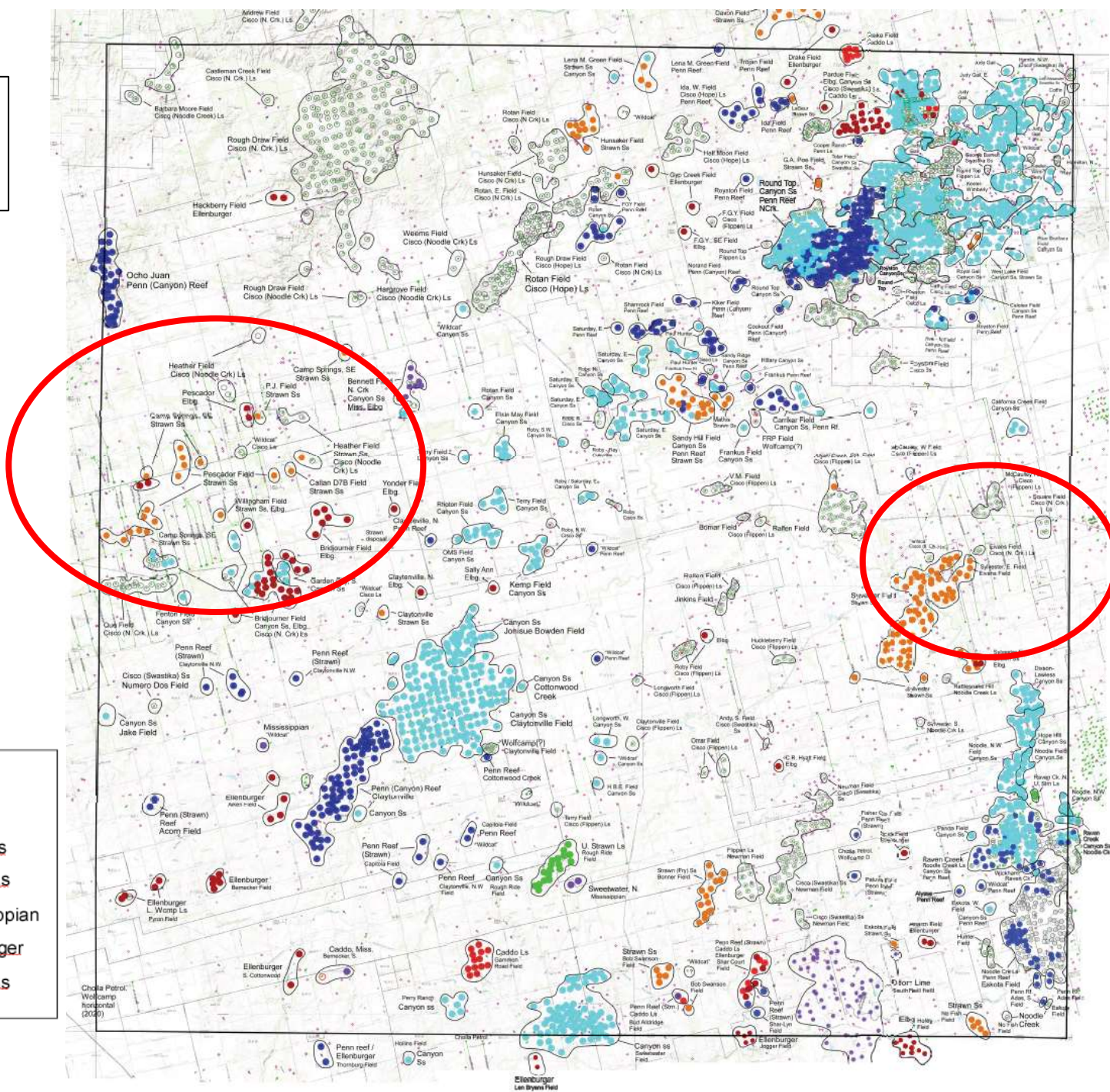


Current work

Producing zone identification for:

- Fisher Co.
 - Stonewall Co.
 - Kent Co. (eastern half)
 - Scurry Co. (eastern half)
- 1
- Mitchell Co. (eastern half)
- 2
- Coke Co.
- 3

Fisher Co. production



First impressions:

- Fewer producing wells compared to Nolan Co.
- Loss of Ft. Chadbourne fault trend
- Fewer Penn reefs (but larger complexes)
- Fewer Ellenburger fields
- Large Canyon Ss fields; more Strawn sandstone production
- Areally-large Cisco Group Ss & Ls fields
- More dry holes between existing fields; less deep well control
- Recent horizontal drilling targeting Strawn Ss

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Operators: Moriah Energy Investments (Midland)
King Operating Corp. (Dallas)
Verado Energy (Allen)
Carr Resources (Tyler)

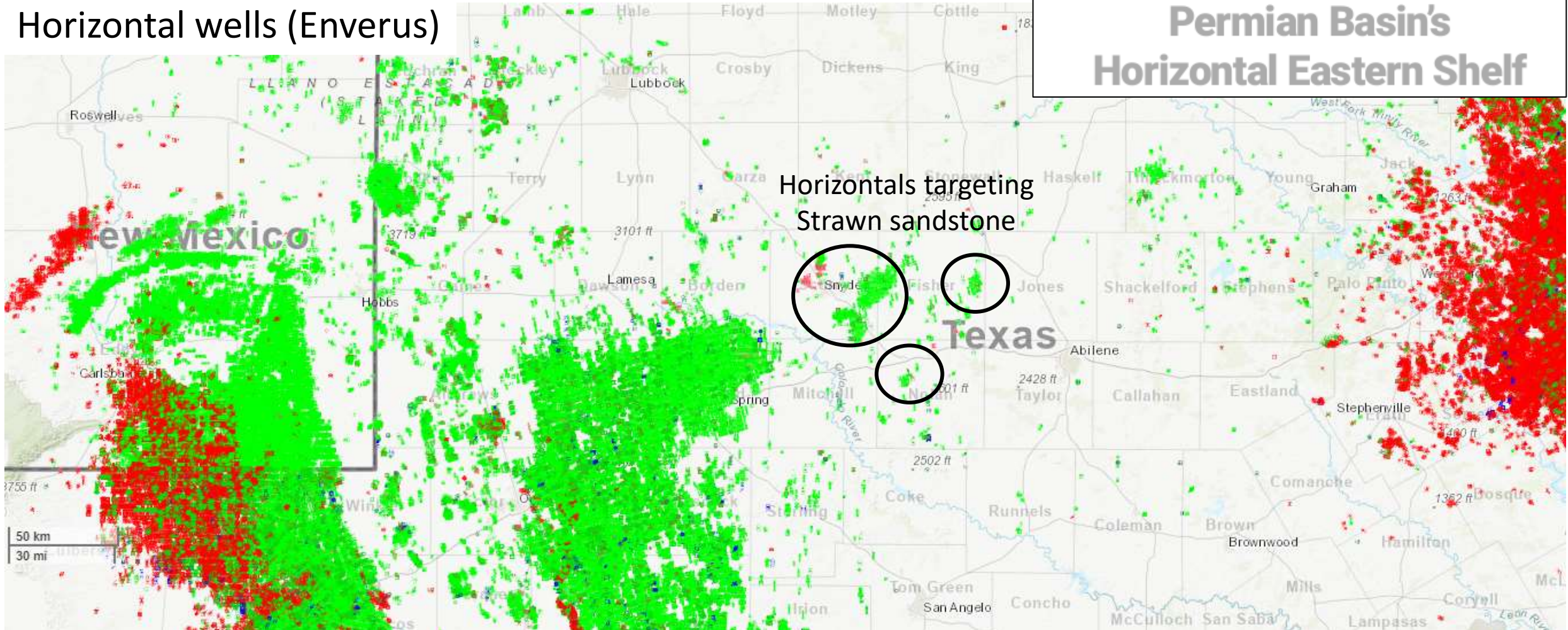
- D & C: ~ \$ 5 MM
- 400 – 500 MBO/well (5000' lateral)
- Water cut: 70%

HART ENERGY

Nissa Darbonne Oil and Gas Investor
09/28/2020

Small Play, Big Wells: Permian Basin's Horizontal Eastern Shelf

Horizontal wells (Enverus)



Re-exploring the Eastern Shelf of the Midland Basin

Summary

- The Eastern Shelf is a complex geologic region with multiple producing horizons
- Stratigraphic complexity, coupled with poorly-constrained data reporting, provide opportunity for further exploration
 - Vertical infill drilling of existing conventional zones
 - Application of horizontal drilling & completion technologies to tight sands and limestones
- Relatively low cost of drilling and completing should continue to provide favorable economics for smaller independents

Future work

- “Next-level” analysis of producing fields and trends (e.g., recent BEG report)
- Application of data mining and machine learning to production analysis
- Stretch goal: documentation of source rocks and migration pathways

website (Permian Basin Research Lab) -- <https://labs.utdallas.edu/permianbasinresearch/>