Pennsylvanian reef trend of the Eastern Shelf

Lowell Waite

Dept. of Sustainable Earth Systems Sciences
Permian Basin Research Lab
University of Texas at Dallas

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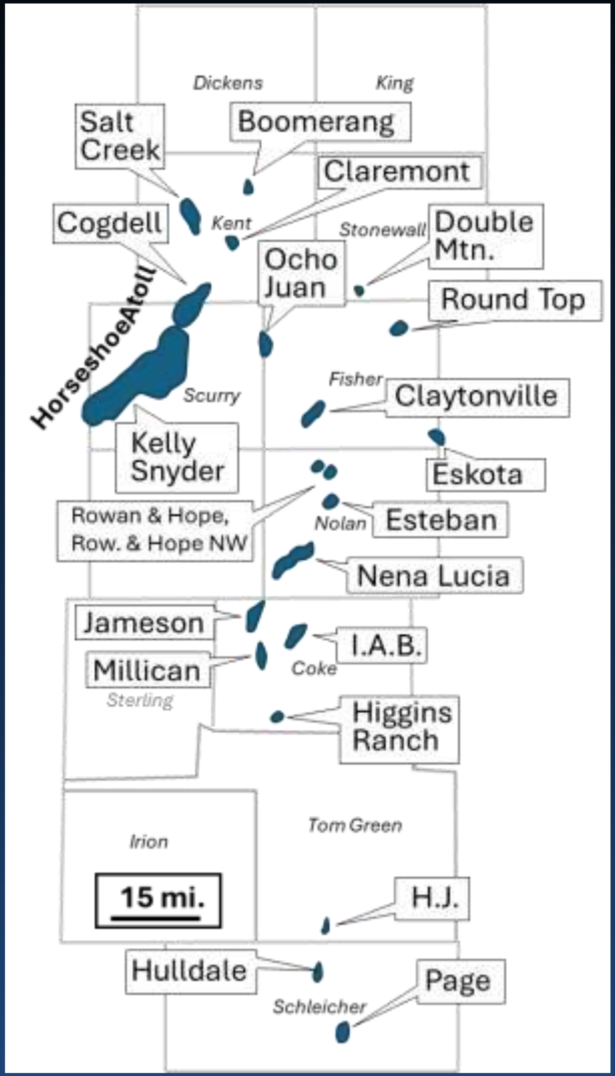


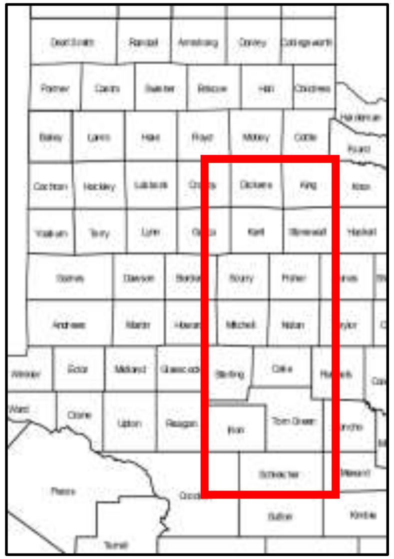
Outline

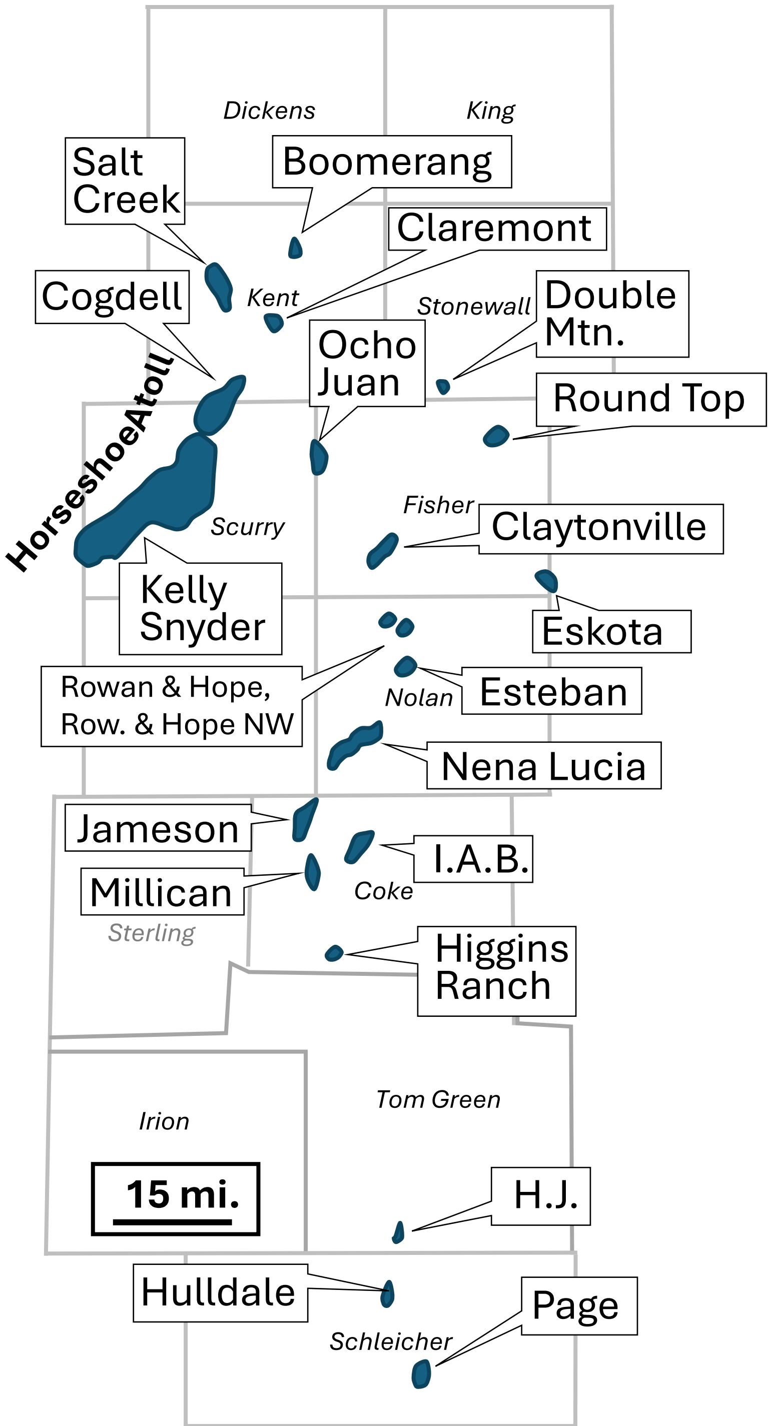
- Overview of Penn reefs of Eastern Shelf
  - Trend map
  - Reefs (?) or what ?
  - The data problem: lack of deep well control and 3D seismic coverage

- Comparison of reef sizes and orientations

- Reef topography: the role of sea-level change vs. erosion

Maximizing future reserves requires accurate geologic / reservoir models



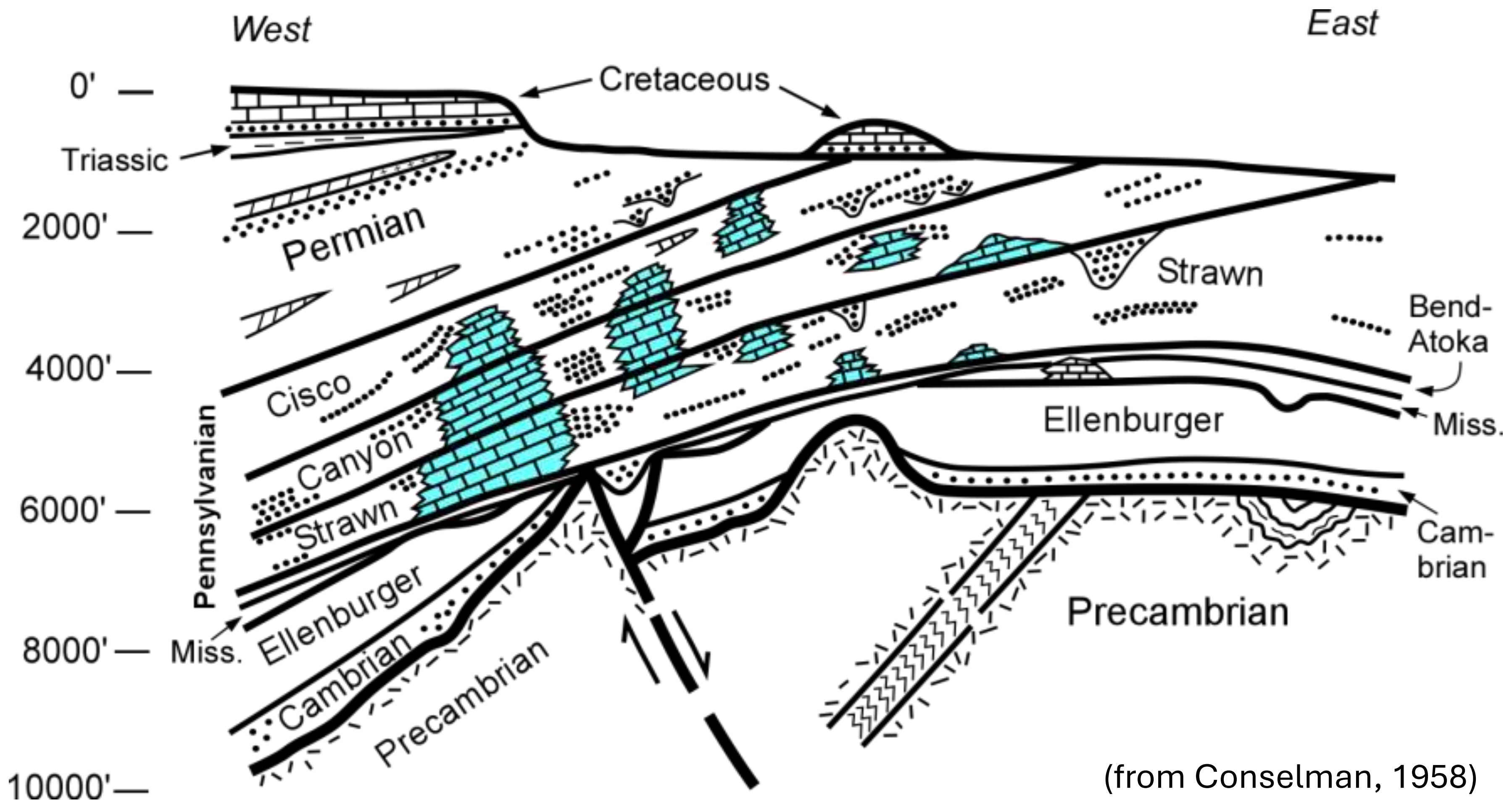


Pennsylvanian Reef Trend of the Eastern Shelf

(from Conselman, 1960)

- String of individual reefs stretching more than 300 miles long and 60 miles wide (480 x 100 km)
- Note that this map is incomplete, only showing most of the larger reef fields
- The Pennsylvanian age of the reefs (i.e., Strawn, Canyon, Cisco) varies along the trend
- “Reef” facies are only one component of these carbonate masses; multiple carbonate facies

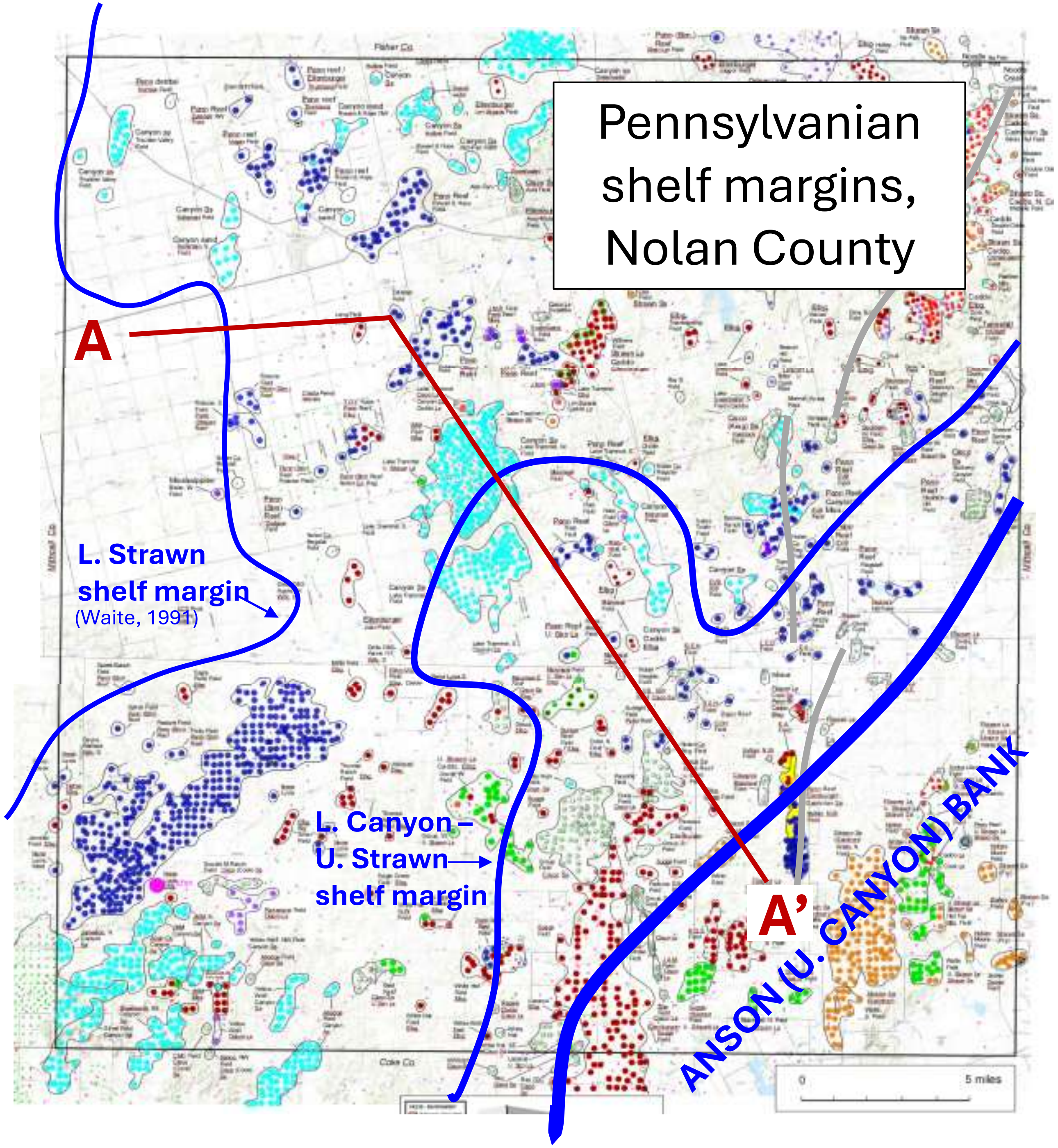
Pennsylvanian reefs of the Eastern Shelf



(from Conselman, 1958)

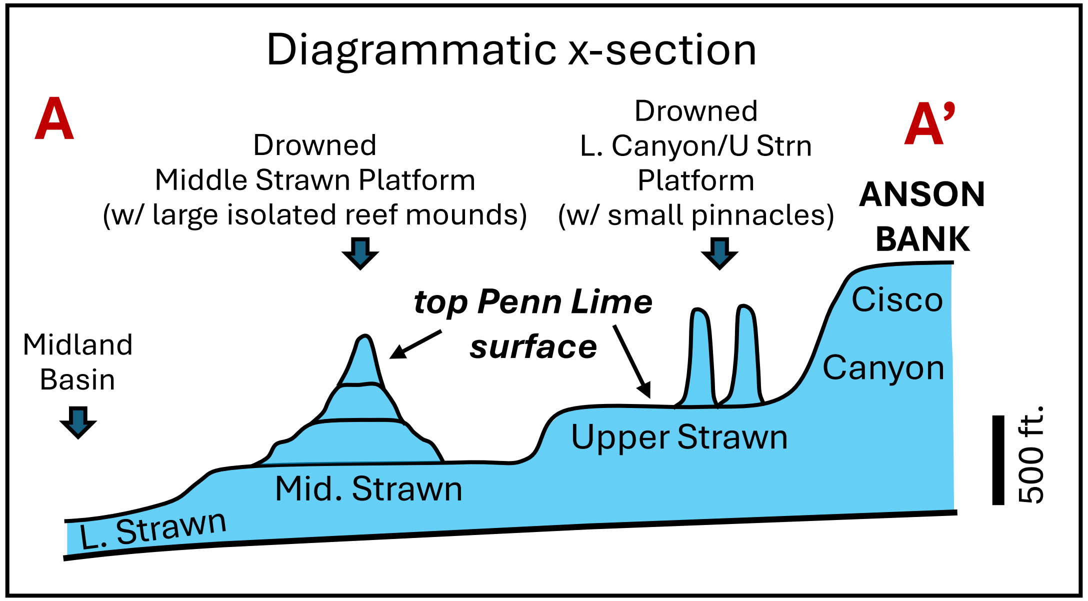
- Penn reefs vary in age
  - Cisco
  - Canyon
  - Strawn
- Some masses include all ages
- Reefs are encased by shale facies, but many are closely associated with time-equivalent and/or younger (Wolfcampian) sands
- There are also a number of individual skeletal and ooid bars on the ES (some of which are components of the "reefs"

Pennsylvanian shelf margins, Nolan County



INDEX

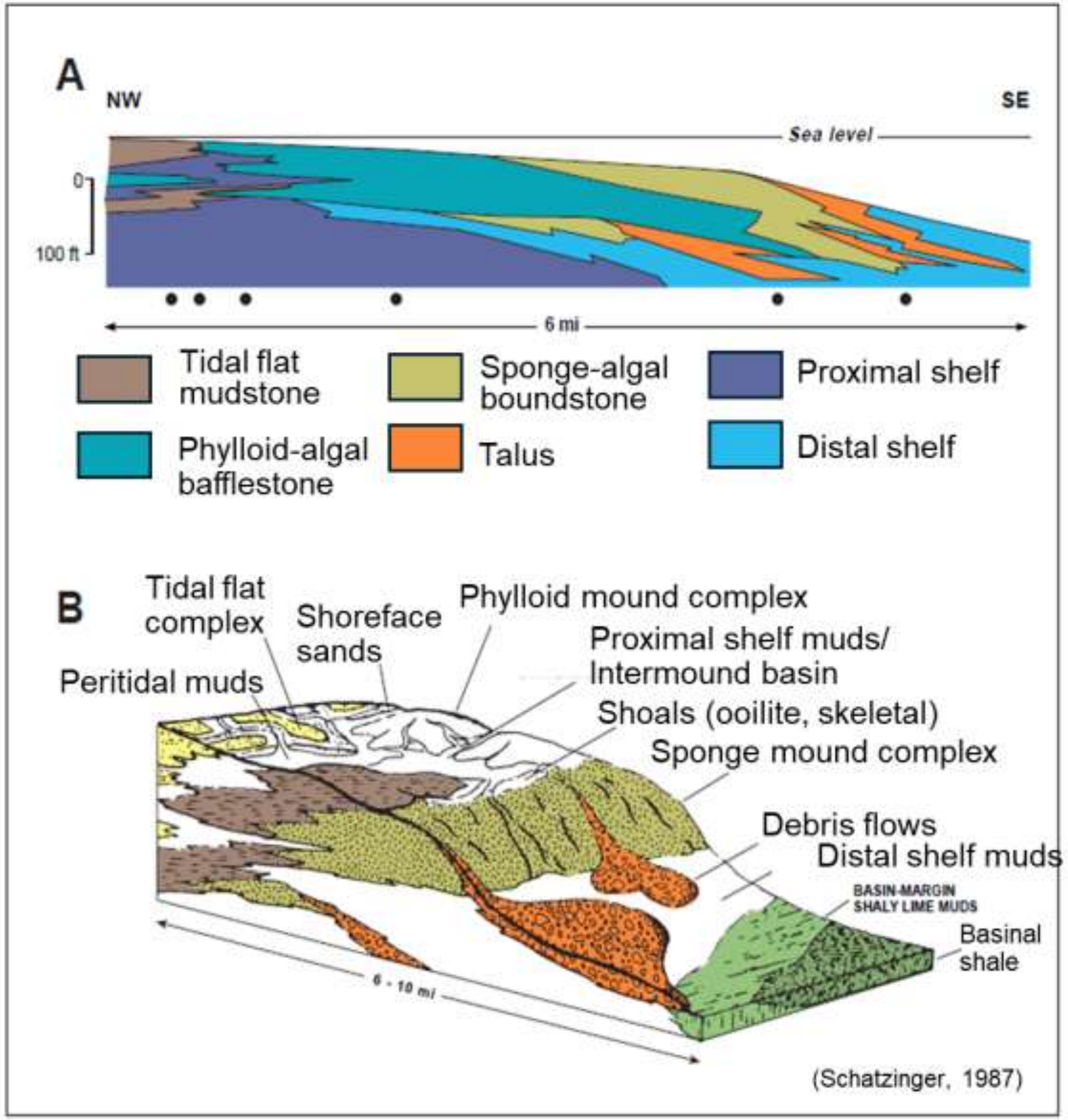
- Cisco (Lower Wolfcamp) Ls / Ss
- Odom Ls
- Canyon Ss
- Caddo Ls
- Penn Reef
- Mississippian
- U.Strawn Ls
- Ellenburger
- Strawn Ss
- Camb. Ss

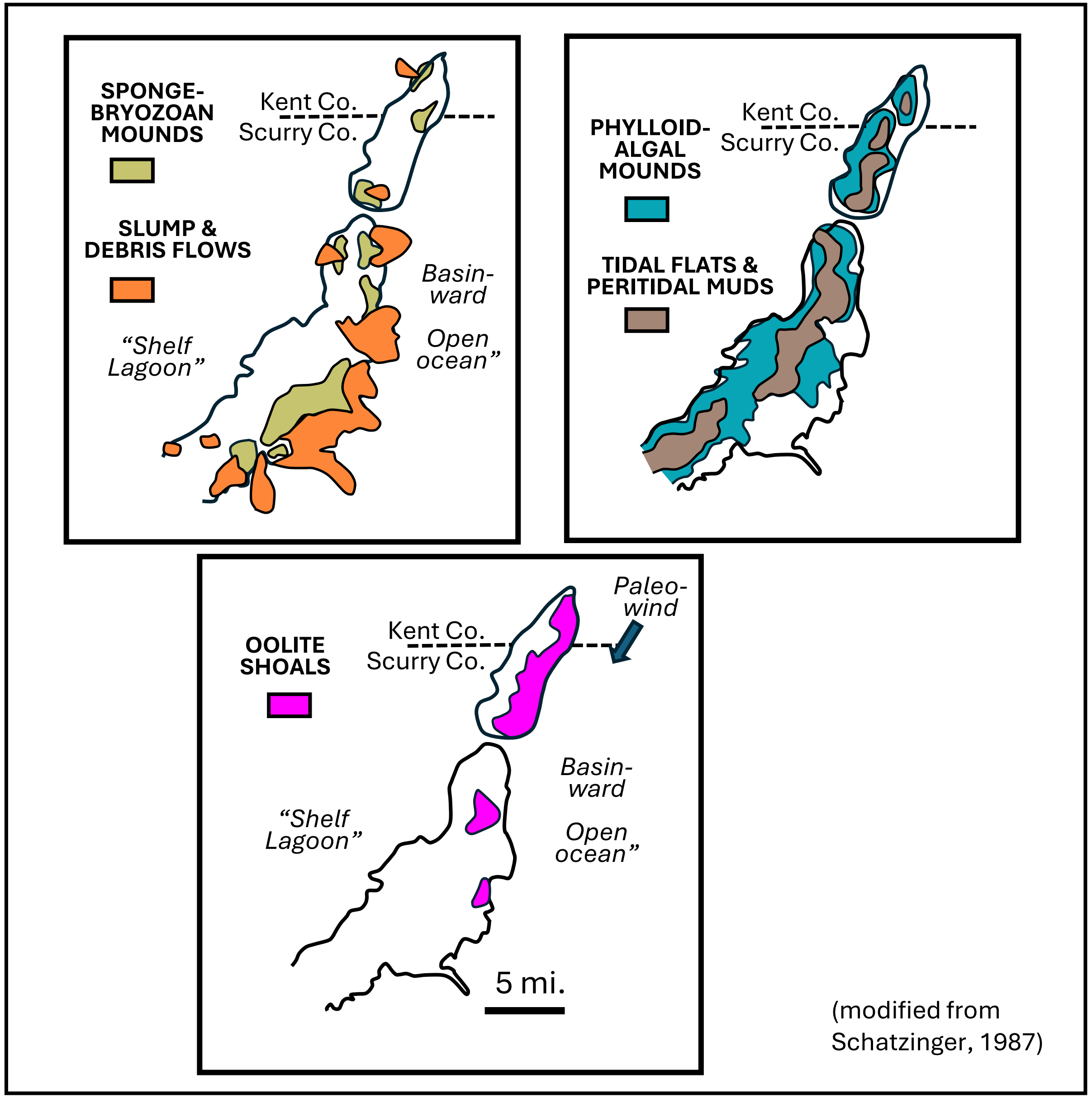


- Many reefs show a "haystack" or "pinnacle" geometry developed above a series of regional drowned platforms
- "Top Penn Lime" surface is therefore highly diachronous across the region (Early Strawn to Cisco)

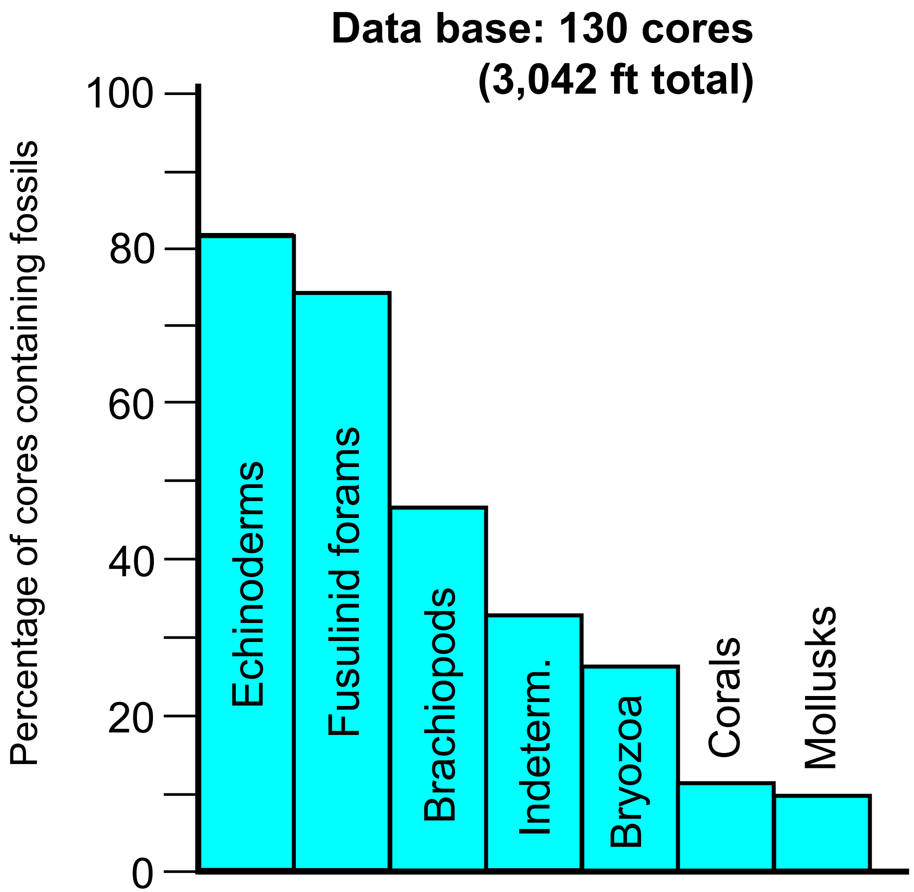
Reef of the eastern side of the Horseshoe Atoll (SACROC, Diamond M, Cogdell, Salt Creek) remain the best documented; proxy for Eastern Shelf reefs

- Schatzinger (1987) notes that buildups at SACROC are a stacked series of many carbonate facies, including tidal flat, ooid/skeletal grainstones, and phylloid algal and sponge reefs





Major non-algal / non-sponge fossil constituents of the Atoll



Note: ooids constitute a large % of grain types in places along outer margin of Atoll

<u>Carbonate fabrics</u>

- Grainstone: 46.3%
- Packstone/ Wackestone/ Mudstone 35.2%
- Rudstone (debris flows) 15.9%

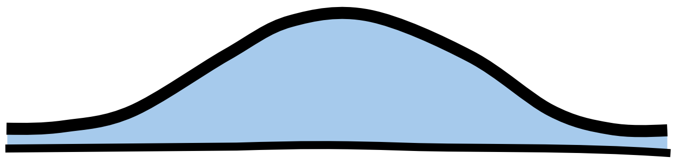
97.4% $CaCO_3$

- Shale 2.6%

(data from Myers et al., 1956; Bergenback and Terriere, 1953; Schatzinger, 1983)

Reefs ? or what ?

- Clearly, the term “reef” an oversimplification for these carbonate masses
- Better terms might include “reef complexes,” “carbonate buildups,” “reef-shoals,” or “reef-mounds”
  - Main characteristics:
    - isolated, positive topographic relief
    - myriad of carbonate facies



-- OK to call them reefs, but remember the complexities of these carbonate masses--

REEFING REVISITED, or
A Reef is A Reef is a Reef
By:
Frank B. Conselman
Consulting Geologist
Ransom Canyon, Texas

(Abilene Geol. Soc., 1983)

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  - Reefs ?
  - **The data problem: lack of well control and 3D seismic**
- Comparison of reef sizes and orientations
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Penn reefs of the Eastern Shelf: The data problem

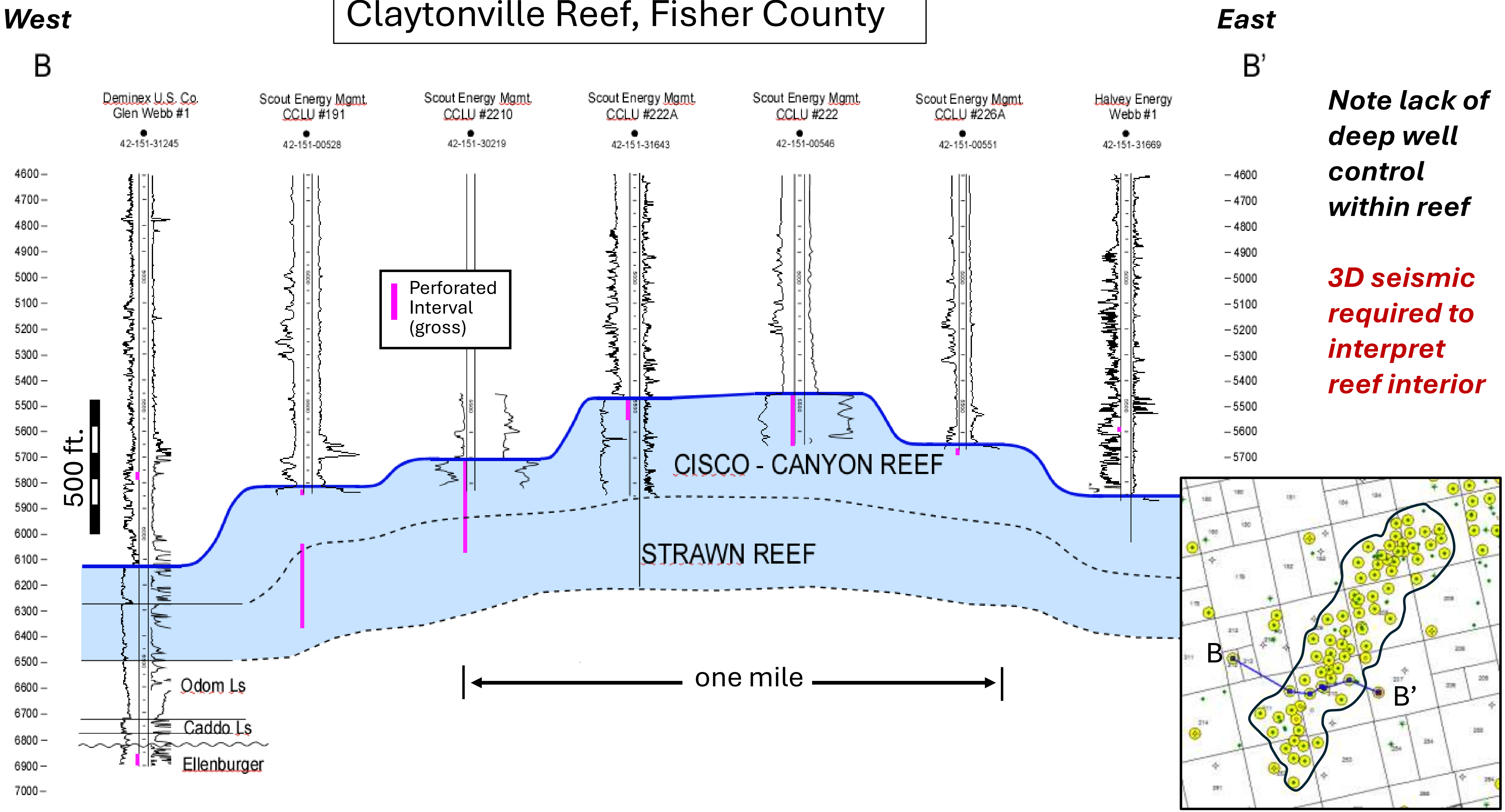
- Most, if not all reefs on the Eastern Shelf lack wells that completely penetrate the buildups in their highest (thickest) portions

- Consequently, defining the top the reef using well logs is not a problem; but accurately characterizing internal structure/correlation requires 3D seismic; not all are imaged

- Historically, deeper zones within these reefs are considered "wet" without the benefit of full suites of deep, modern logs

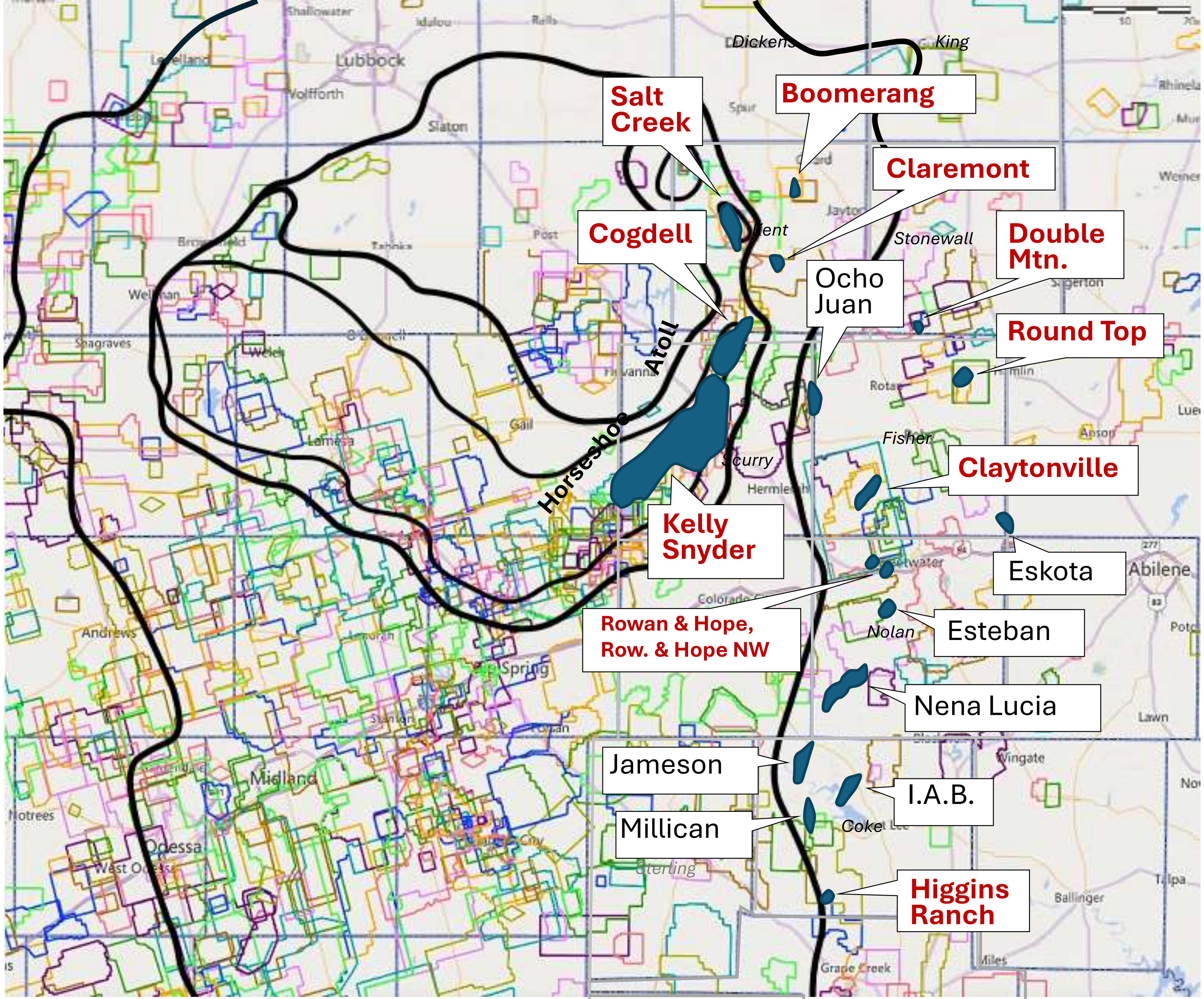
- Could deeper pay zones exist, particularly within the Strawn ?

Claytonville Reef, Fisher County



Note lack of deep well control within reef

3D seismic required to interpret reef interior



3D seismic surveys

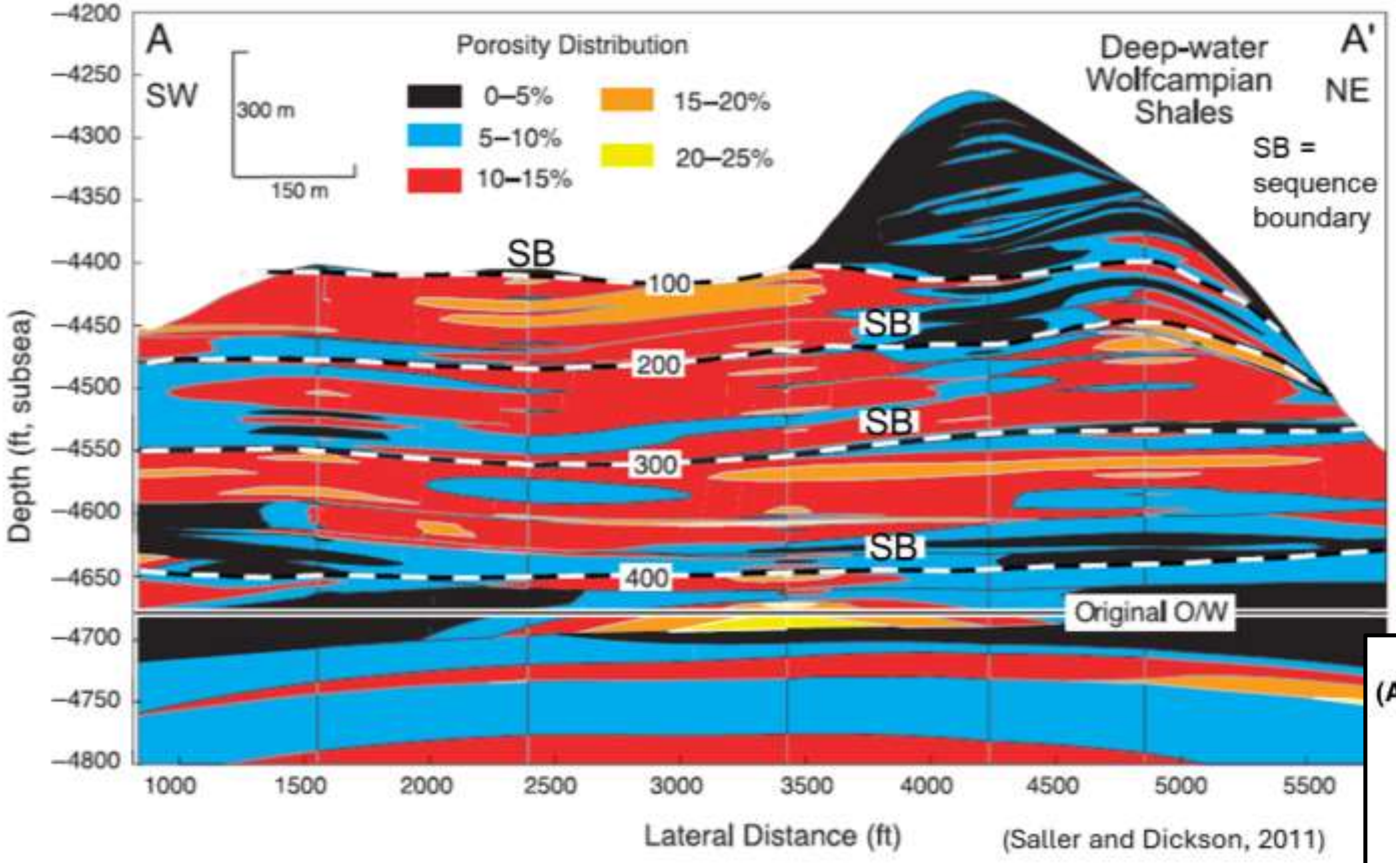
Midland Basin – Eastern Shelf

Seismic base map from SEI
https://www.seismicexchange.com

Note lack of data on Eastern Shelf vs. Midland Basin

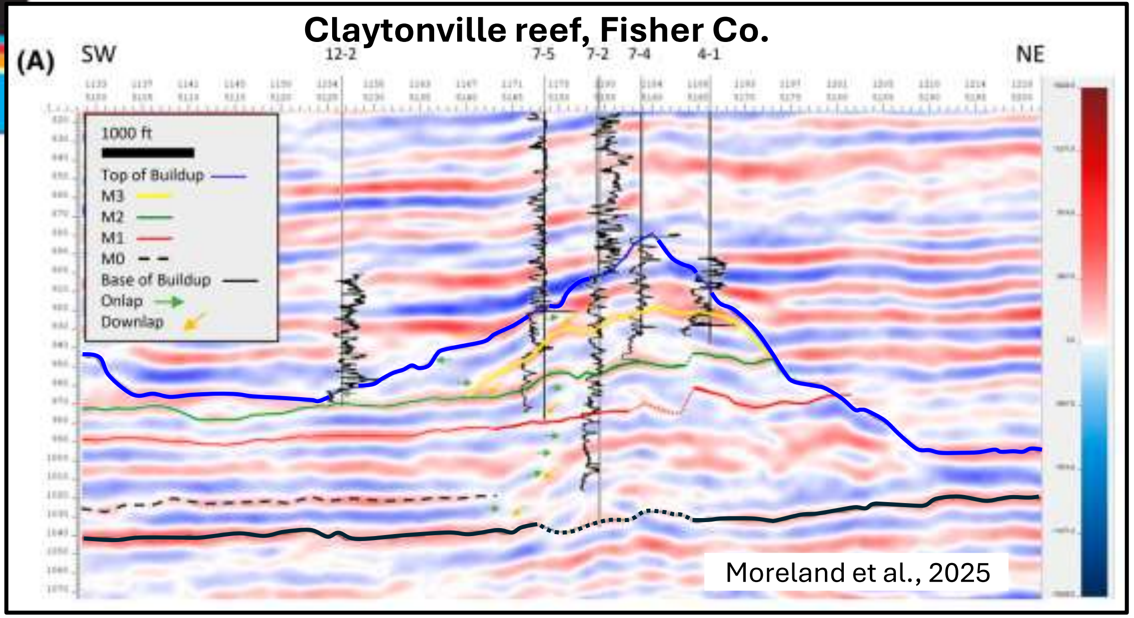
60% of reefs on Eastern Shelf covered by 3D seismic (highlighted in red font)

Internal complexity of Penn Reefs: Porosity distribution model, Reinecke Field (Borden Co., Horseshoe Atoll)



- Nature of Penn. cyclic carbonate deposition provides opportunities for stranded porosity and isolated, unproduced pay
- Note deep porosity below mapped O/W contact (100% wet ?)
- Application of horizontal drilling

3D seismic shows internal stratigraphic architecture and complexities of these buildups



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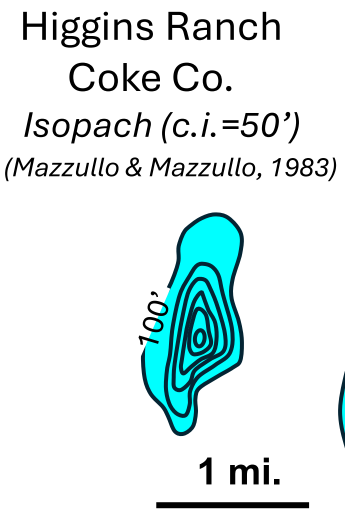
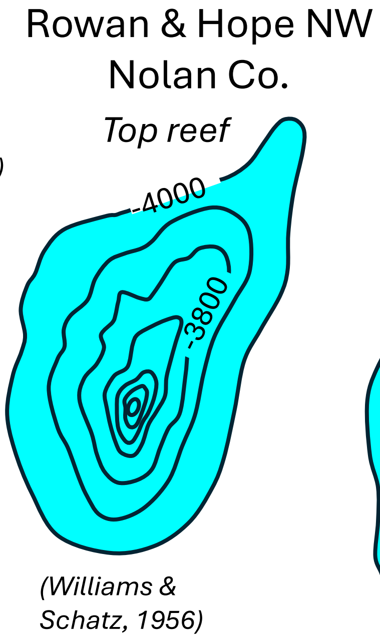
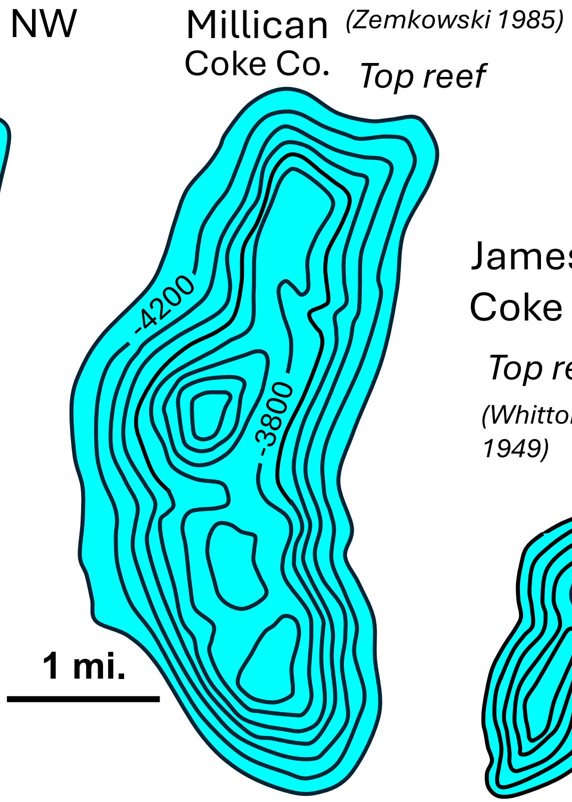
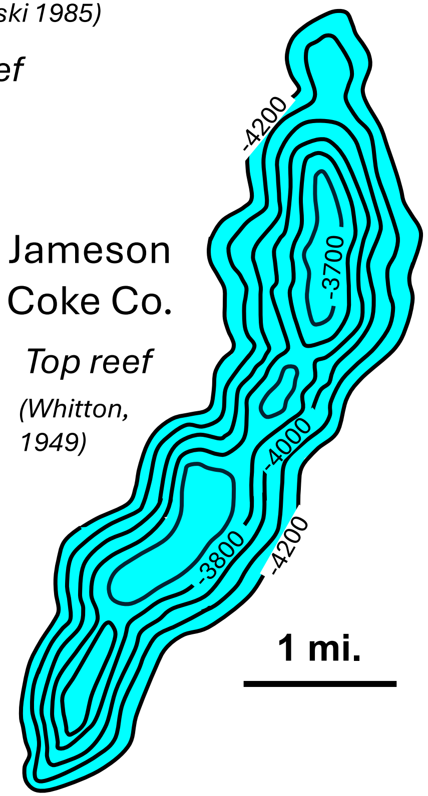
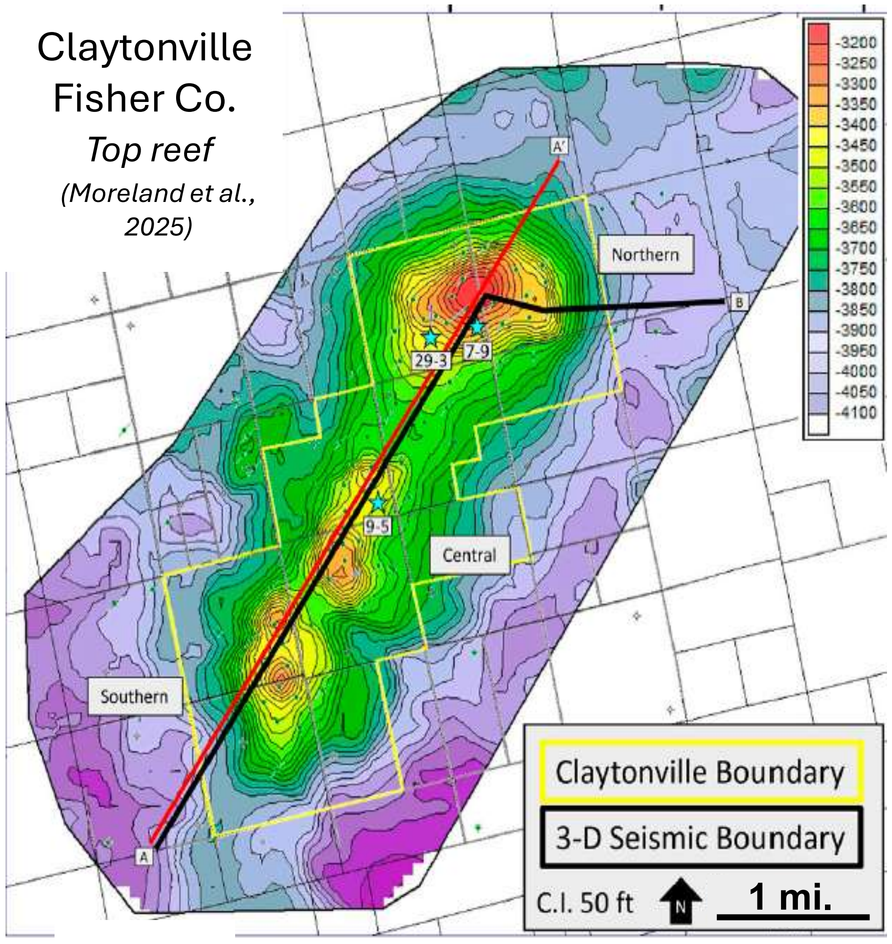
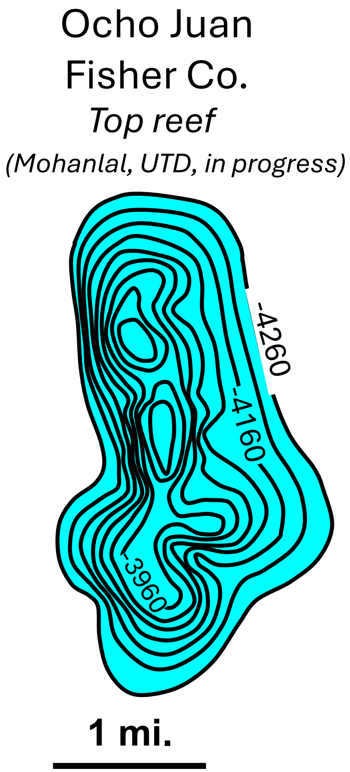


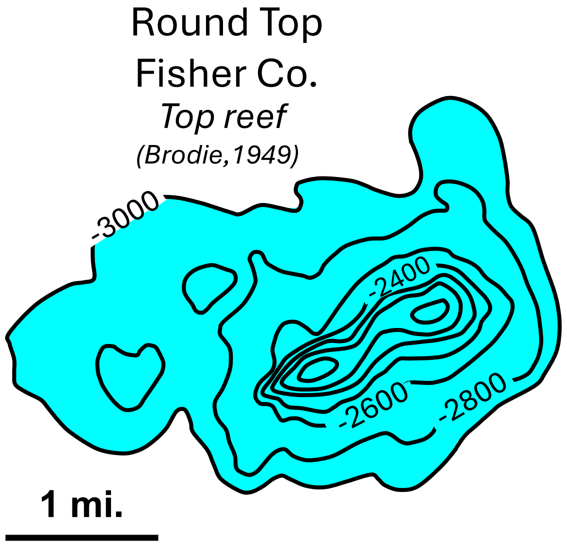






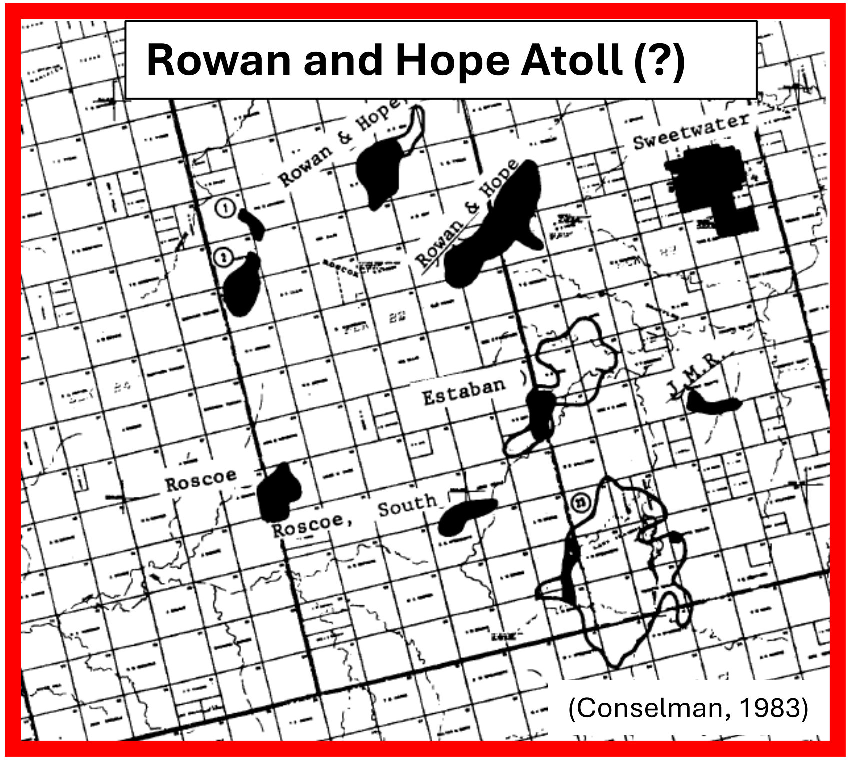


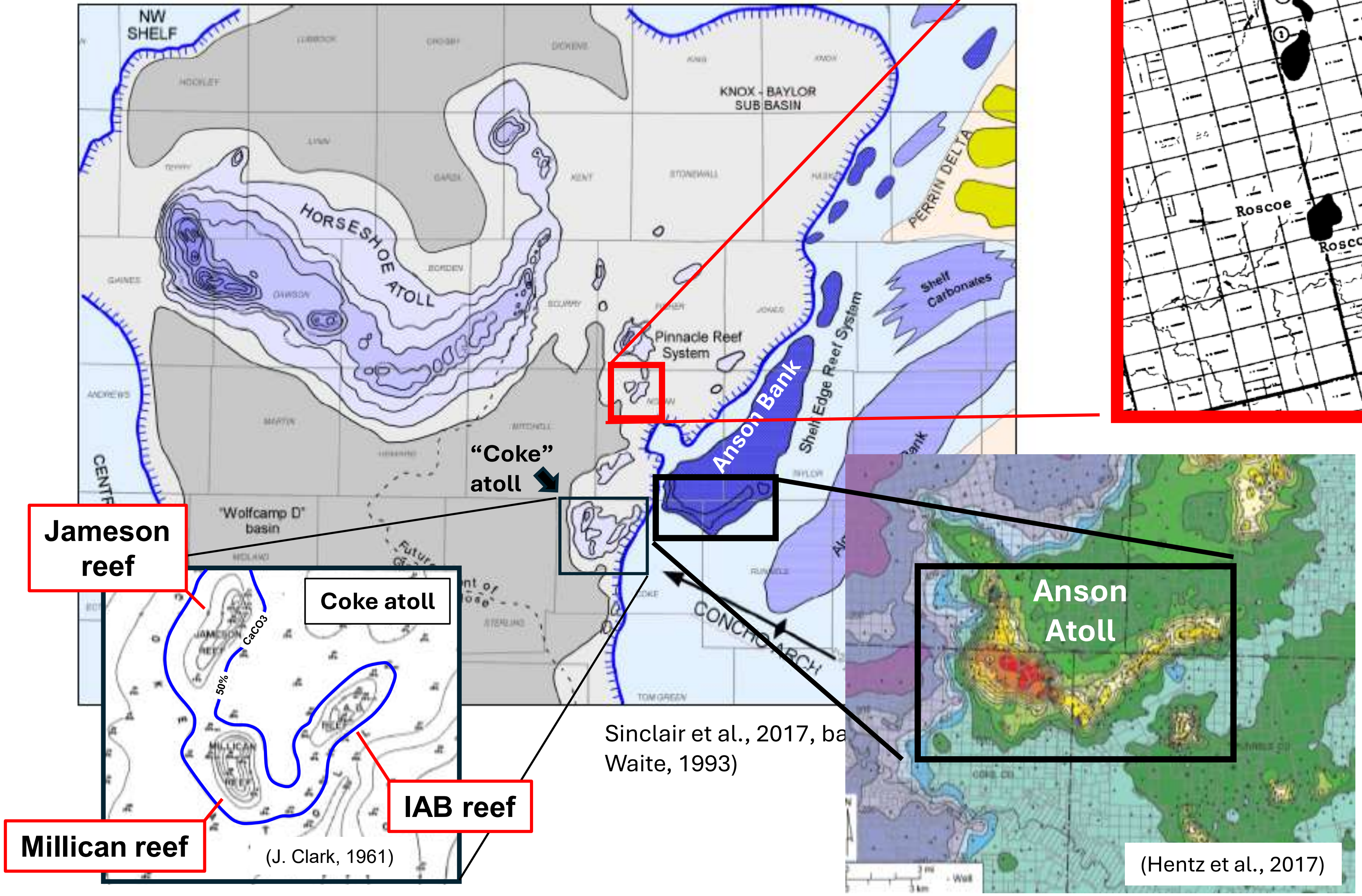




- Most ES reefs are elongate with a broad base and one or more high-standing pinnacles
- Dimensions: 1 – 2 miles wide, varying lengths (1- 7 miles)
- Dominant orientation: N – NE (facing into paleo trade winds); some, like Ocho Juan and Kelly Snyder, are oriented N-S

“Mini” atoll configurations





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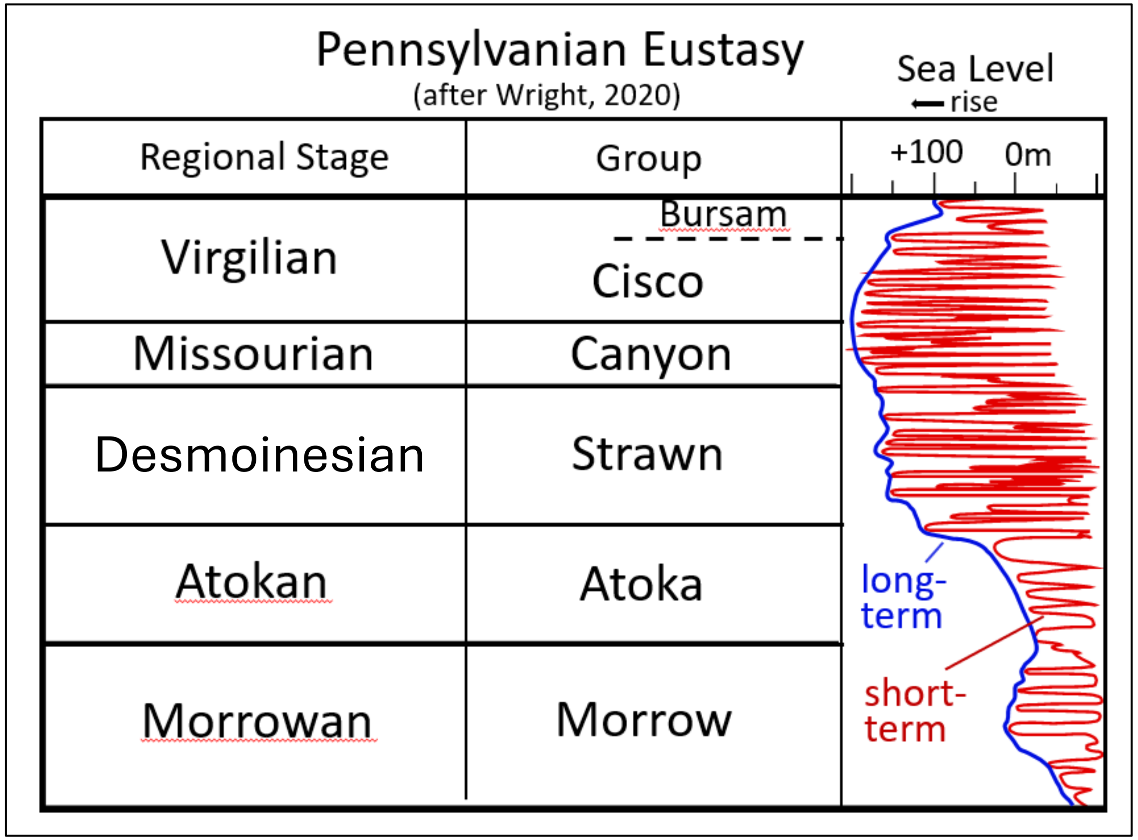
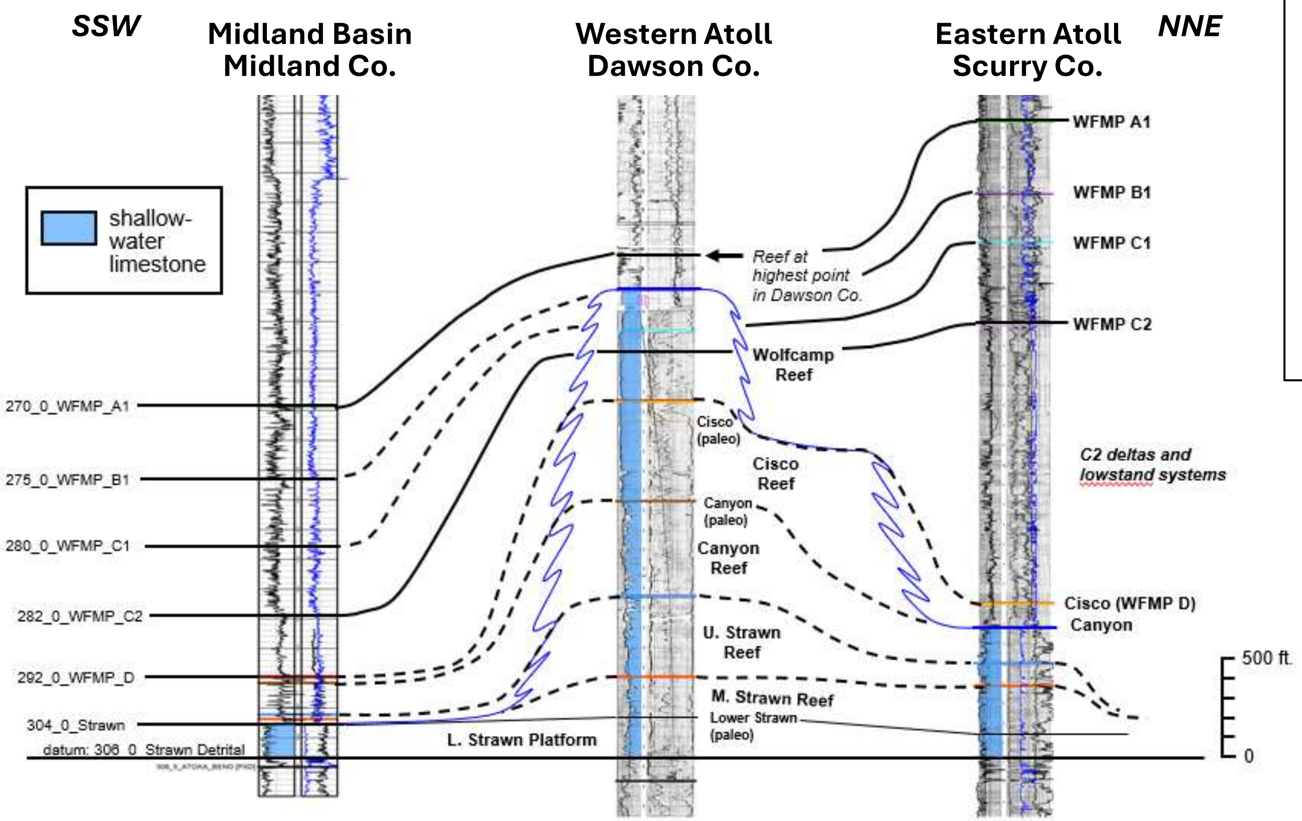
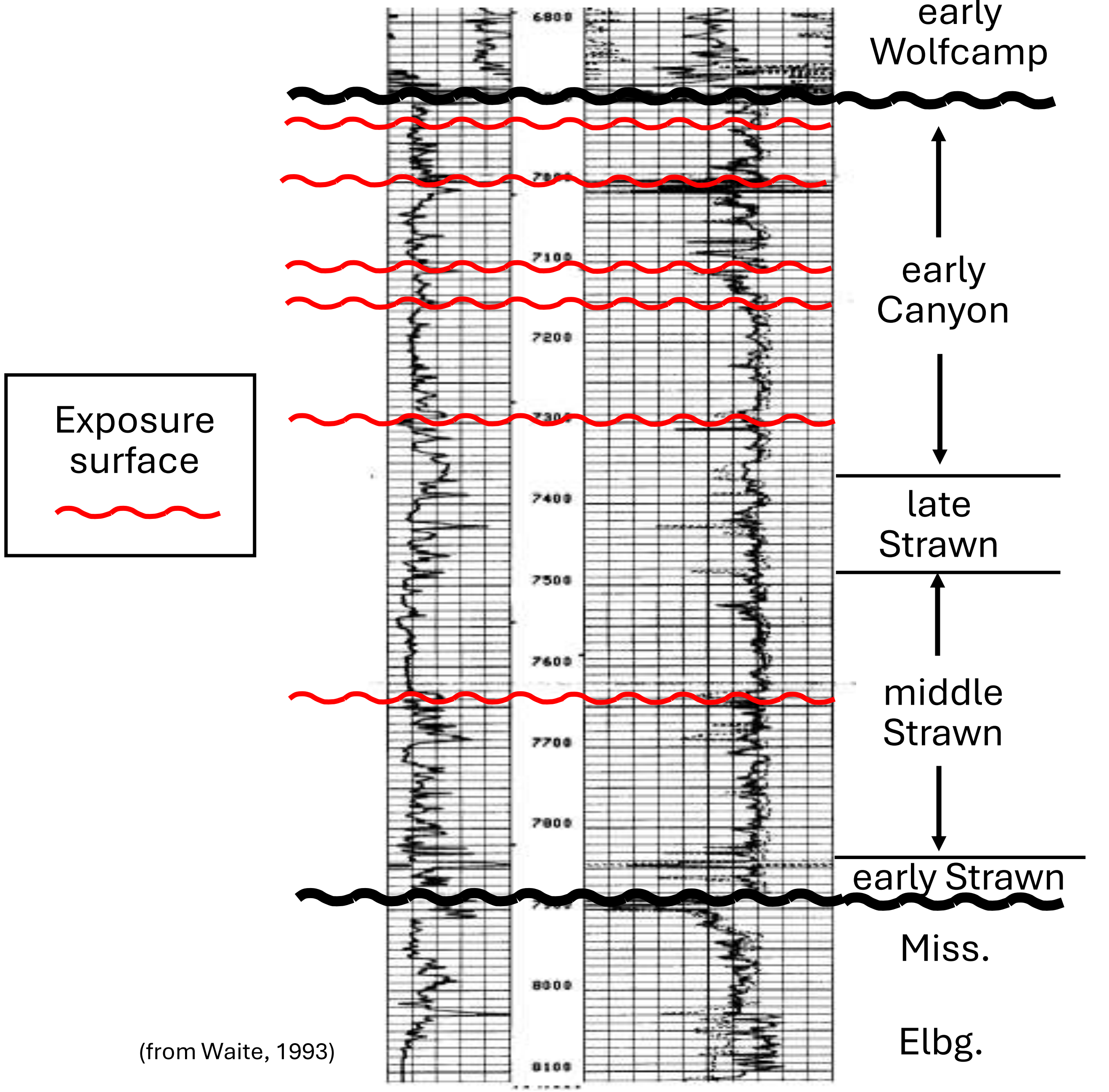
Haystack / pinnacle shape of Penn reefs is partially the result of subsidence and partial drowning during a long period of sea-level rise throughout Desmoinesian (Strawn) time

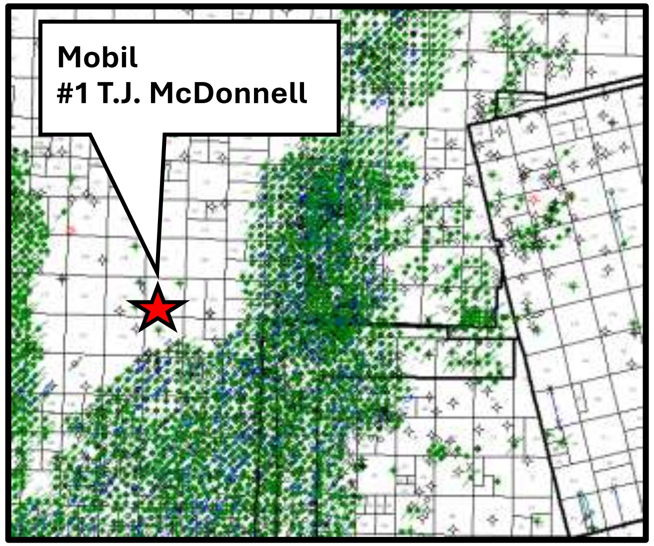




Reef geometry was also highly modified by multiple periods of erosion / karsting during multiple, glacially-driven lowerings of sea-level

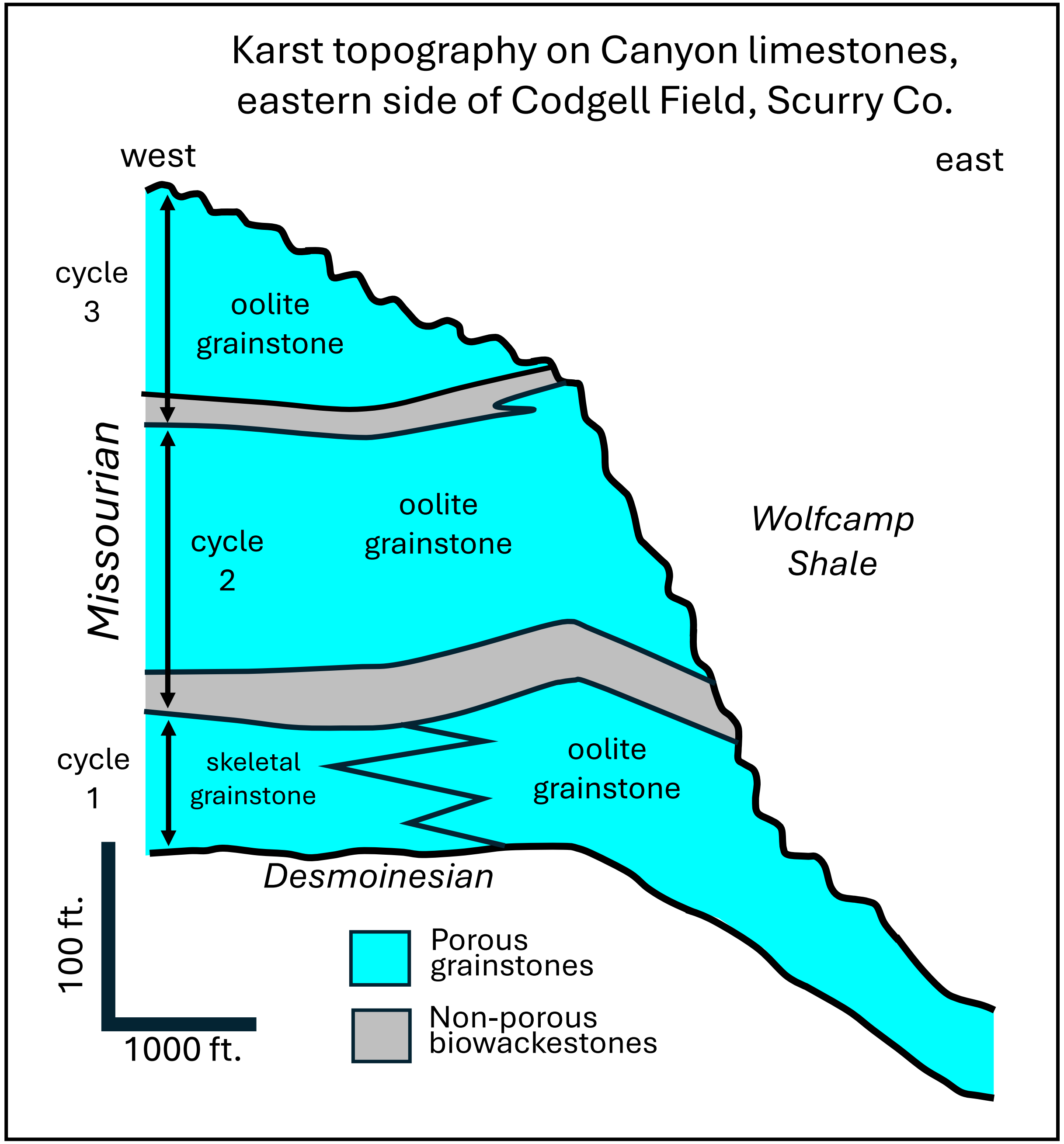
Mobil #1 T.J. McDonnell
Scurry Co., Texas





"Karsted hill" concept

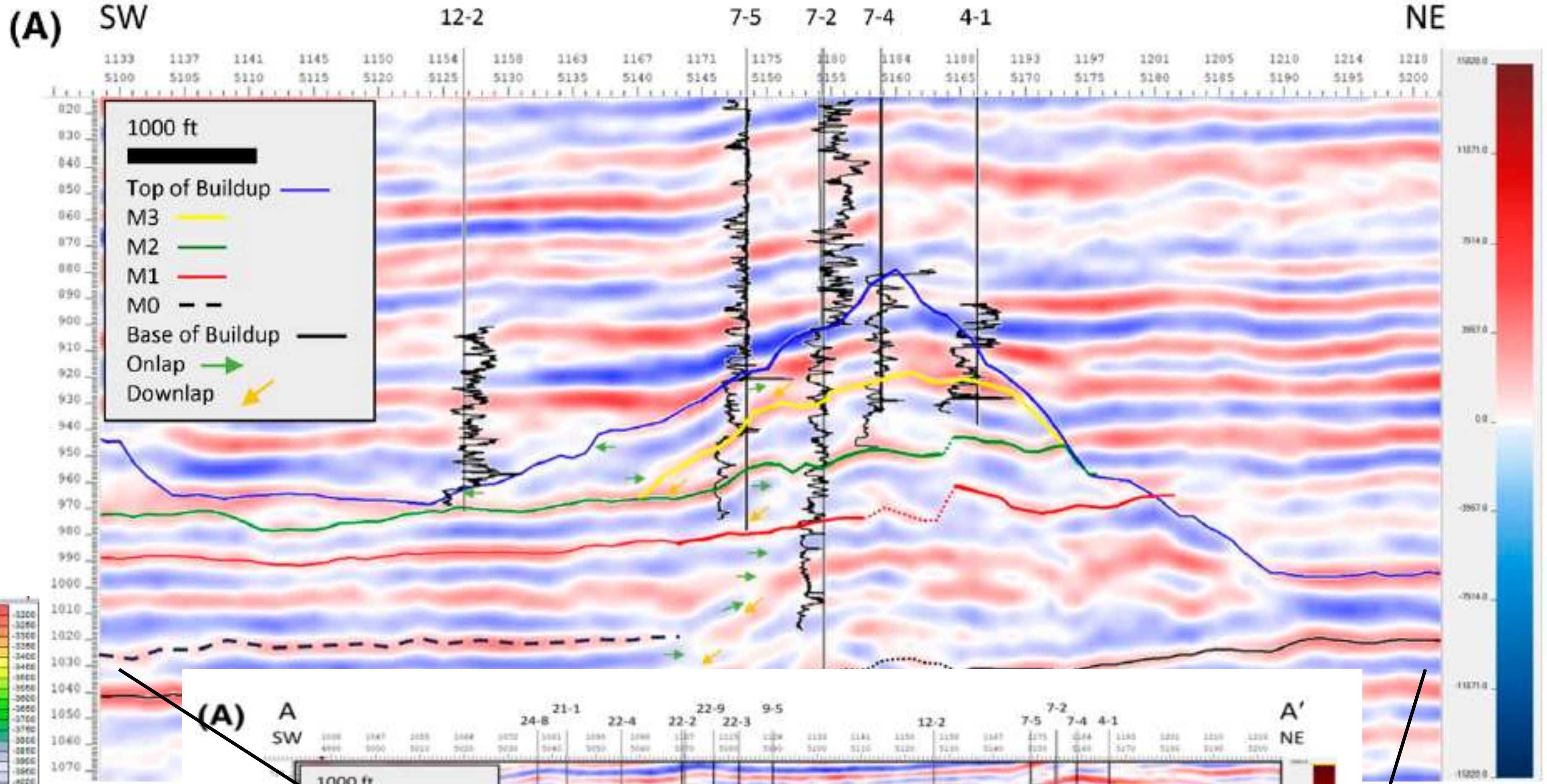
(Mazzullo, 1997, after Reid and Reid, 1991)

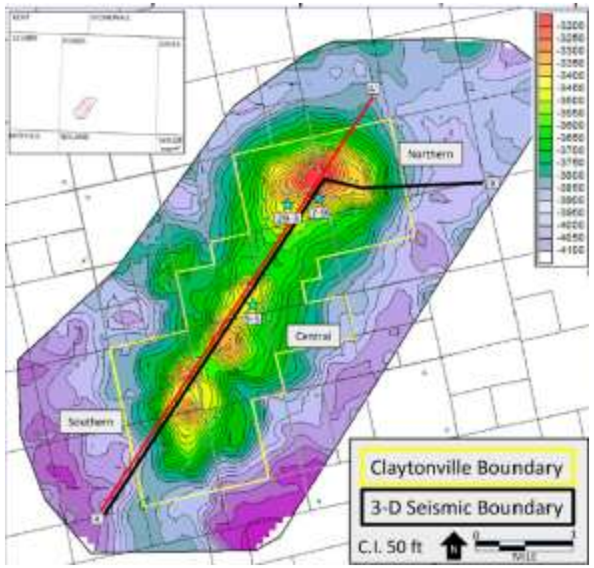


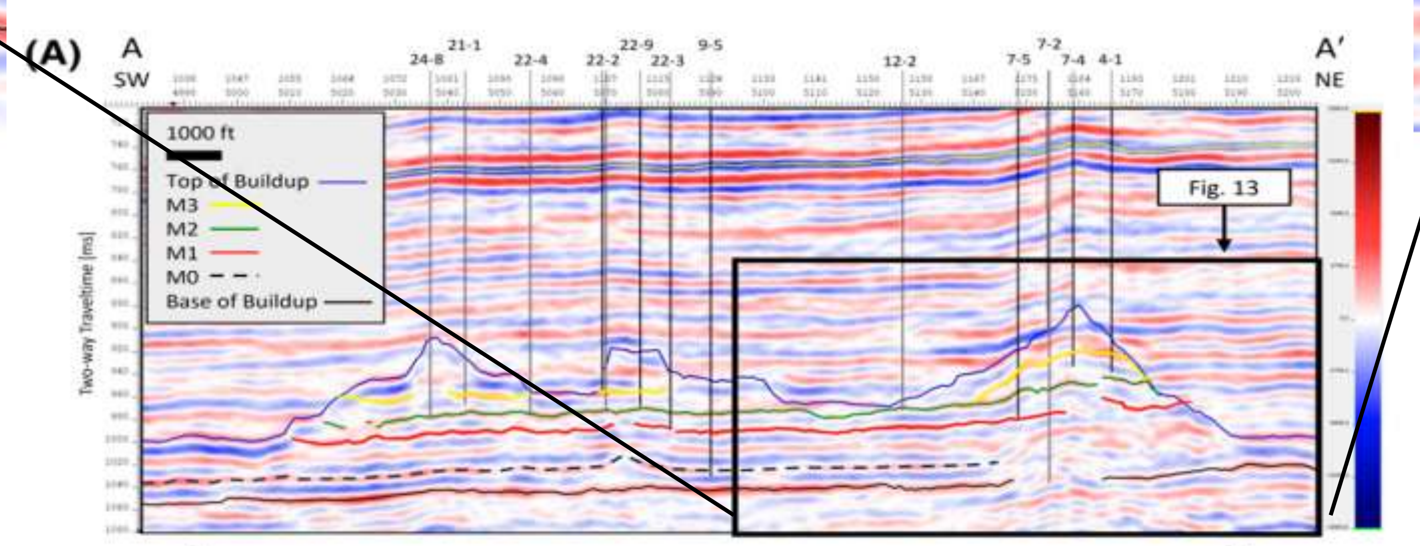
- Distinct upward-shoaling depositional cycles, each capped by an exposure surface

- Top limestone represents a diachronous surface, highly modified by erosion

A "karsted hill" on the Claytonville buildup



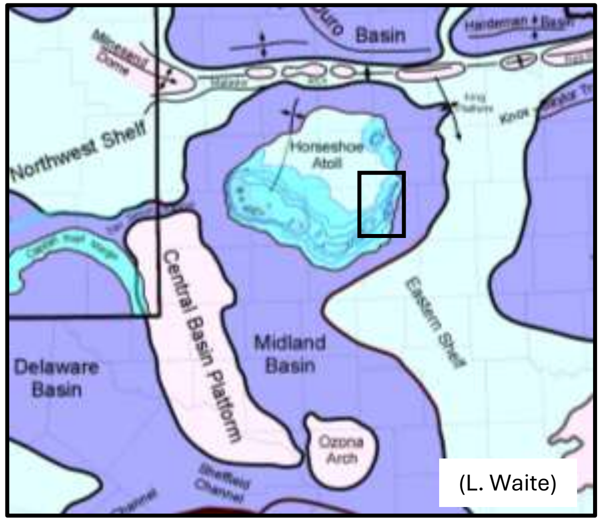


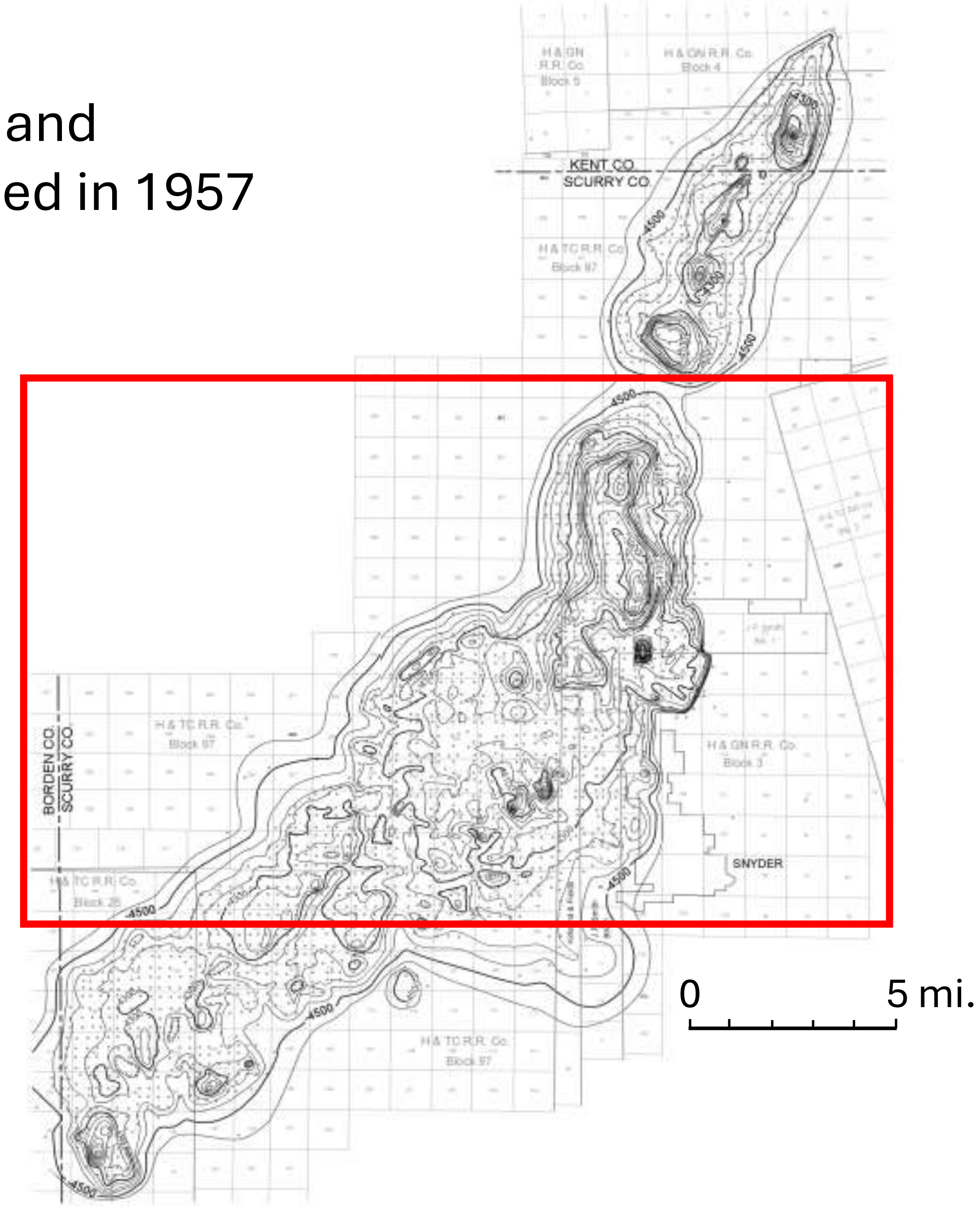


(Moreland et al., 2025)

Structure map of Kelly-Snyder (Scurry) and Cogdell reefs published in 1957

(Stafford, “Scurry Field” in Occurrence of Oil and Gas in West Texas, Univ. of Texas – BEG Publication No. 5716, August, 1957)



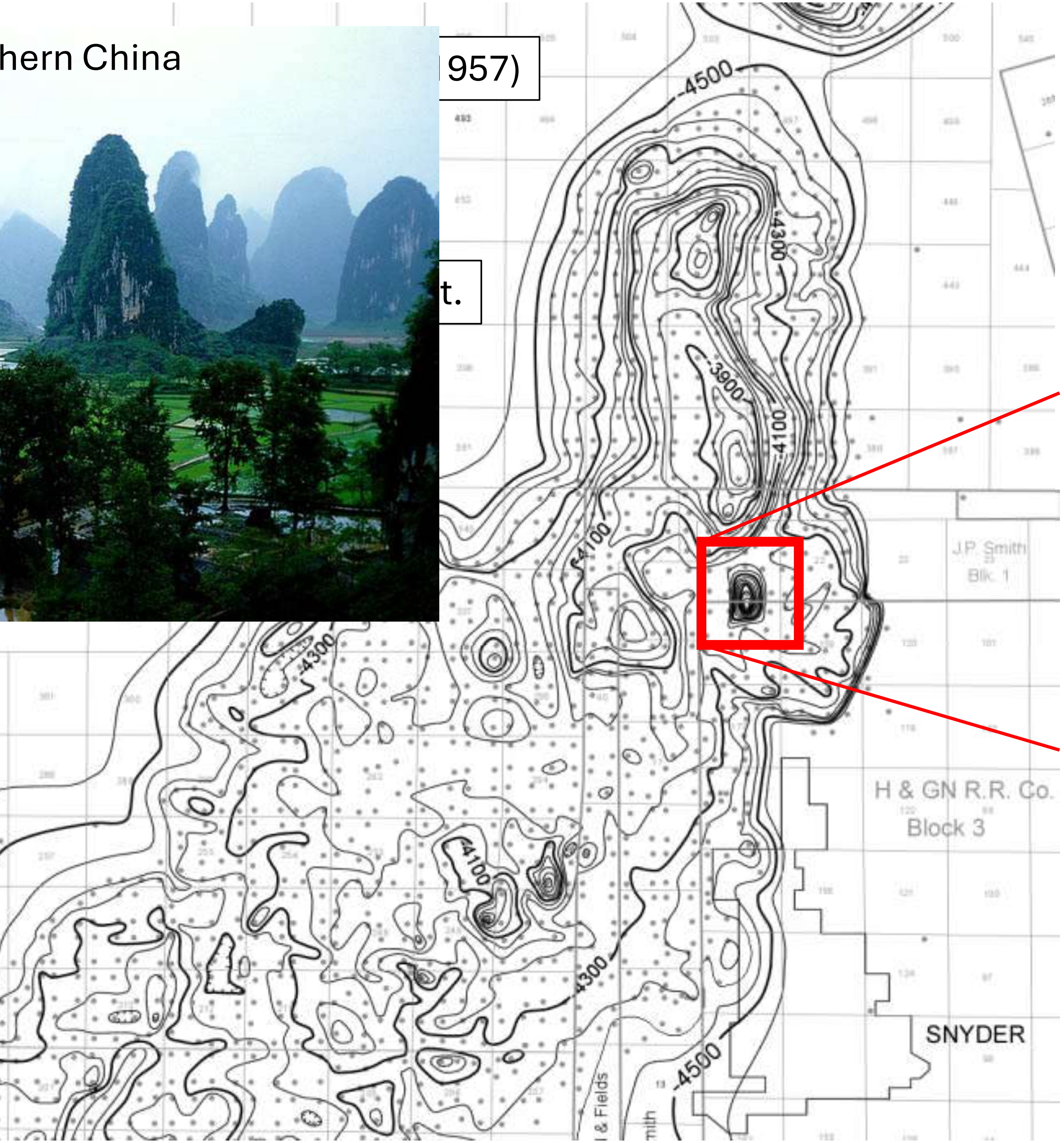


Contour interval = 50 ft.

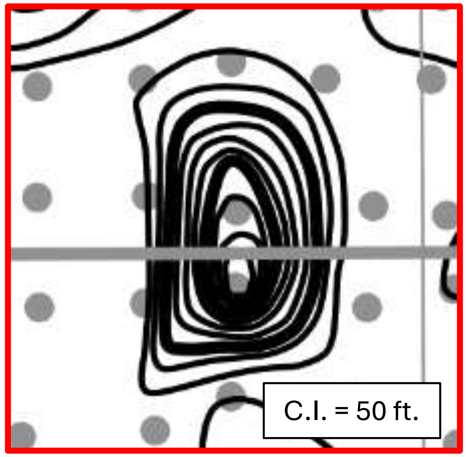
- Detailed structural configuration of reefs was defined less than a decade after initial oil discovery
- Well control (~ 40 ac. spacing) shows complex topographical pattern along the margins and interior of the reef complex, with numerous indentations, closed highs, and lows

Tower karst, southern China

https://science-junkie.tumblr.com/



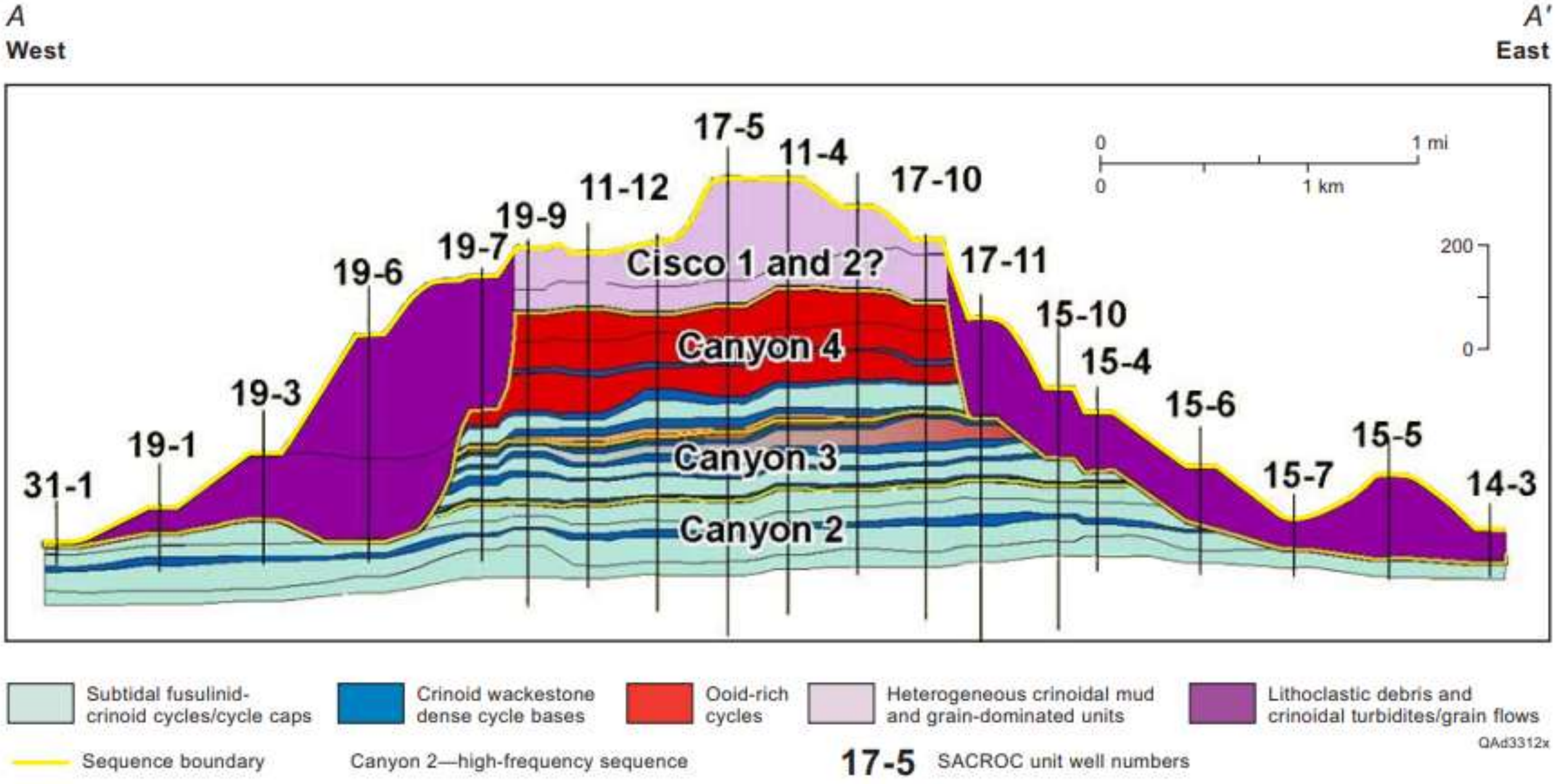
450 ft of relief in an area of 0.5 mi^2



0 3 mi.

East – West cross section, SACROC reef, Scurry County (Dutton et al., 2004)

- Multiple periods of growth & erosion results in amalgamation of eroded debris on flanks of buildups
- Flow units in reef interior do not extend to flanks



Pennsylvanian reefs of the Eastern Shelf: Summary

- Size and orientation of Penn reefs is somewhat variable
  - Most are elongate in NE-SW or N-S direction
  - Range from 1 – 7 mi long, 1 – 3 mi in width
- Wide range of facies, mostly skeletal / ooid pack- and grainstones; many crinoids (yes, there are “reefs,” but very little of the masses are framework reefs)
- Competing roles of long-term sea-level rise vs. short-term exposure with multiple periods of erosion define their final haystack/pinnacle shape
- Upon further review: We have much to learn
  - Many lack 3D seismic coverage required to assess internal reef geometry
  - Absence of deep, modern log suites hinders accurate detailed characterization
  - Efficiently draining these beasts and locating new reserves requires rigorous, geologic / reservoir models integrating log, 3D seismic, core, and production data

Many other topics to consider and discuss…

- Microfacies
- Fusulinid biostratigraphy
- Porosity types and distribution
- Permeability: lowstand vs. highstand units
- Production trends by facies (decline curves, cumulative oil-gas-water, etc.)
- Relationship of reefs to younger "Canyon" sands
- Relationship of reefs to independent grainstone shoals

- Role of stylolites and fractures
- Cement types
- Recognition of eroded debris in core
- Data mining of old publications

…just to name a few

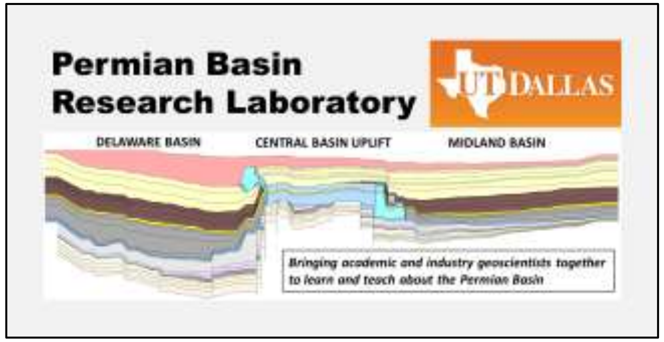
Eastern Shelf Penn reef operators:

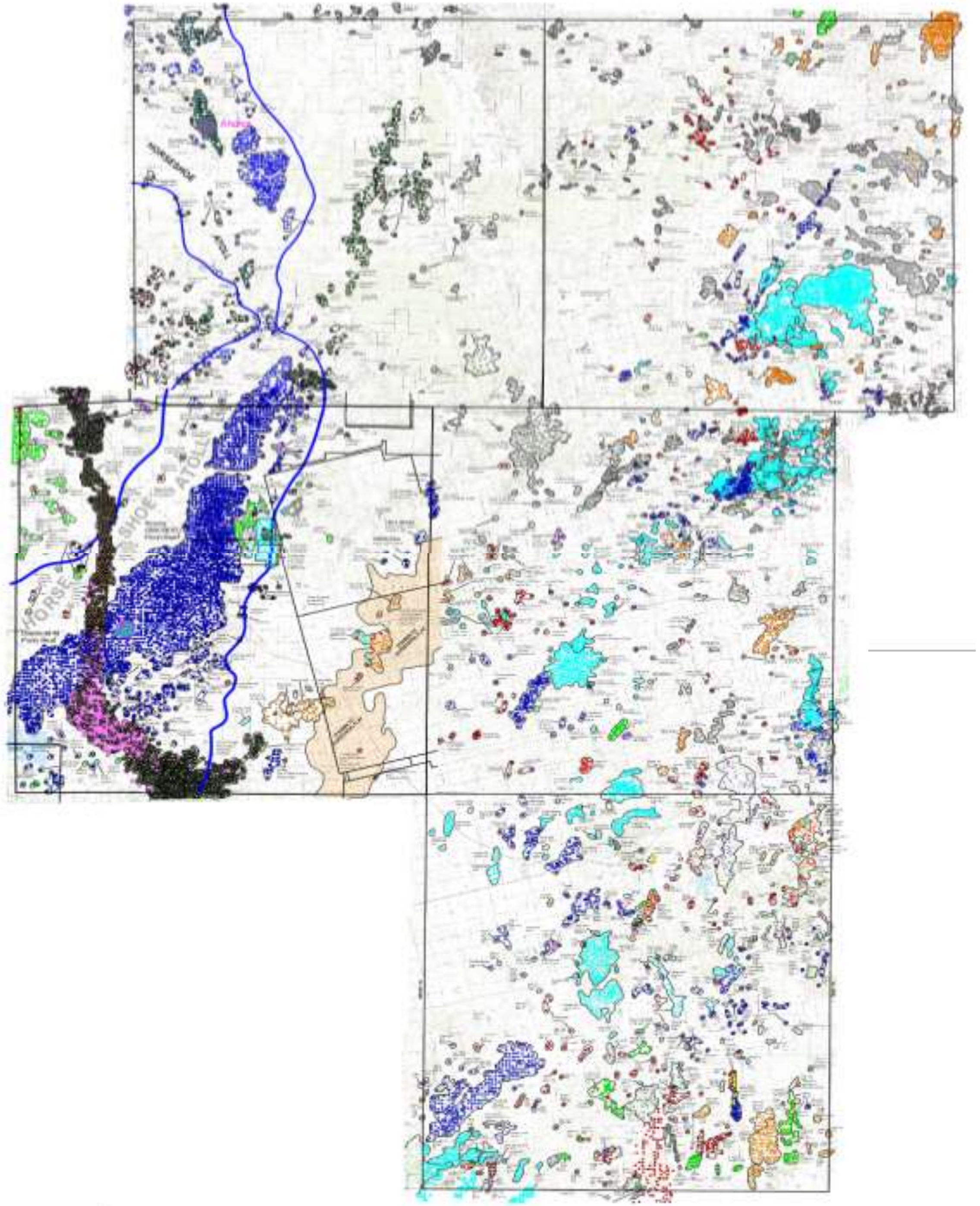
I'd love to hear from you

Email Lowell.waite@utdallas.edu

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

search: "Permian Basin Research Lab"





HORSE SHOE ATOLL