BASIN HISTORY AND TECTONICS OF THE PERMIAN BASIN:

KEYS TO THE SUPERBASIN

Thomas E. Ewing
Frontera Exploration Consultants
San Antonio TX 78259

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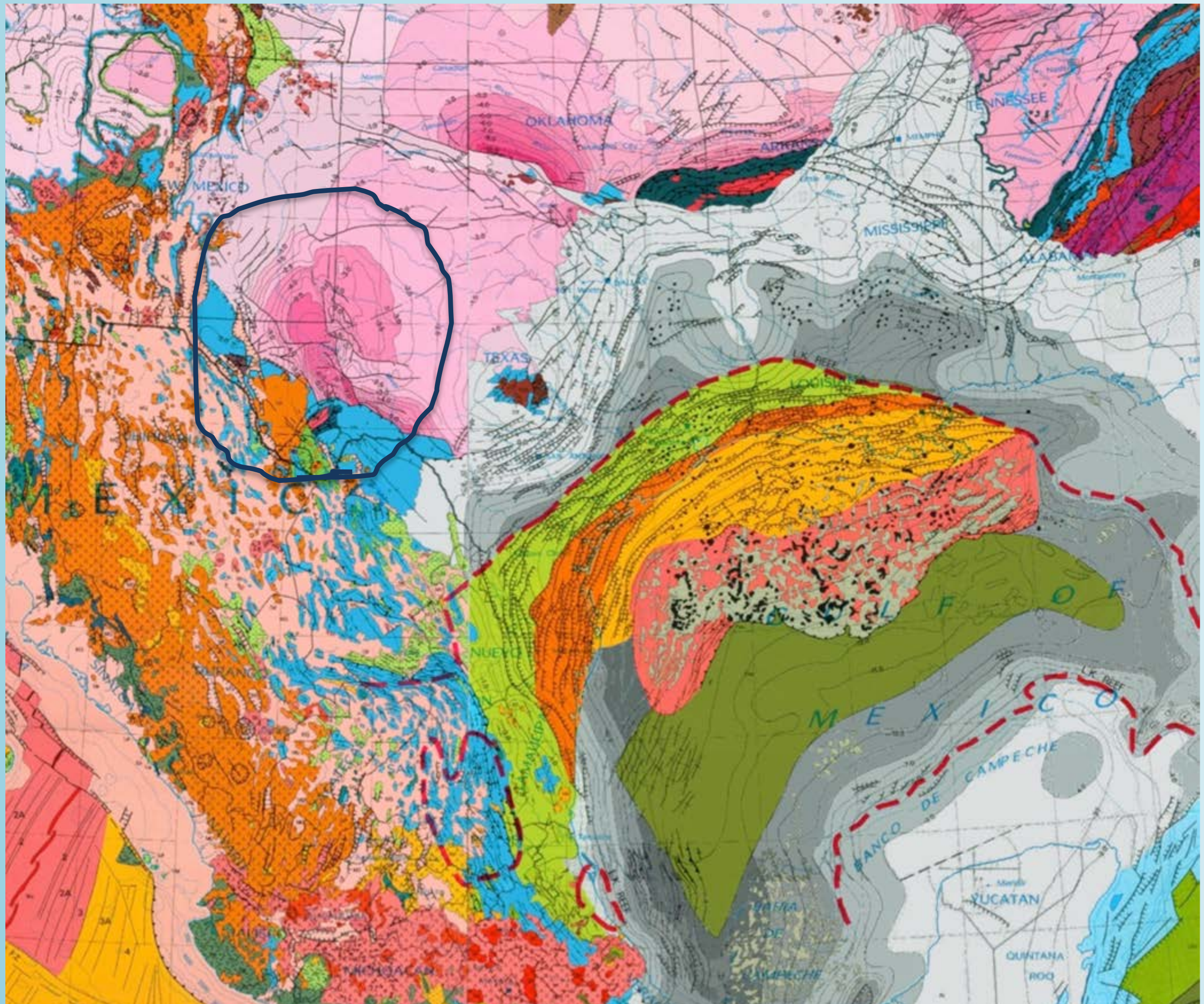
THE PERMIAN SUPERBASIN

- Thick Permian rocks identified in 1910s; major Permian oil fields found, 1920s on
- Deeper folded and faulted (ARM) structures were identified, and large Ellenburger-Devonian oil fields found, 1940s on
- Mixed bag of basinal sediments (carbonate – siltstone – mudstone) developed, 1950s on
- Modern technology applied 2000s on causing new highs in production and activity.

KEY QUESTIONS

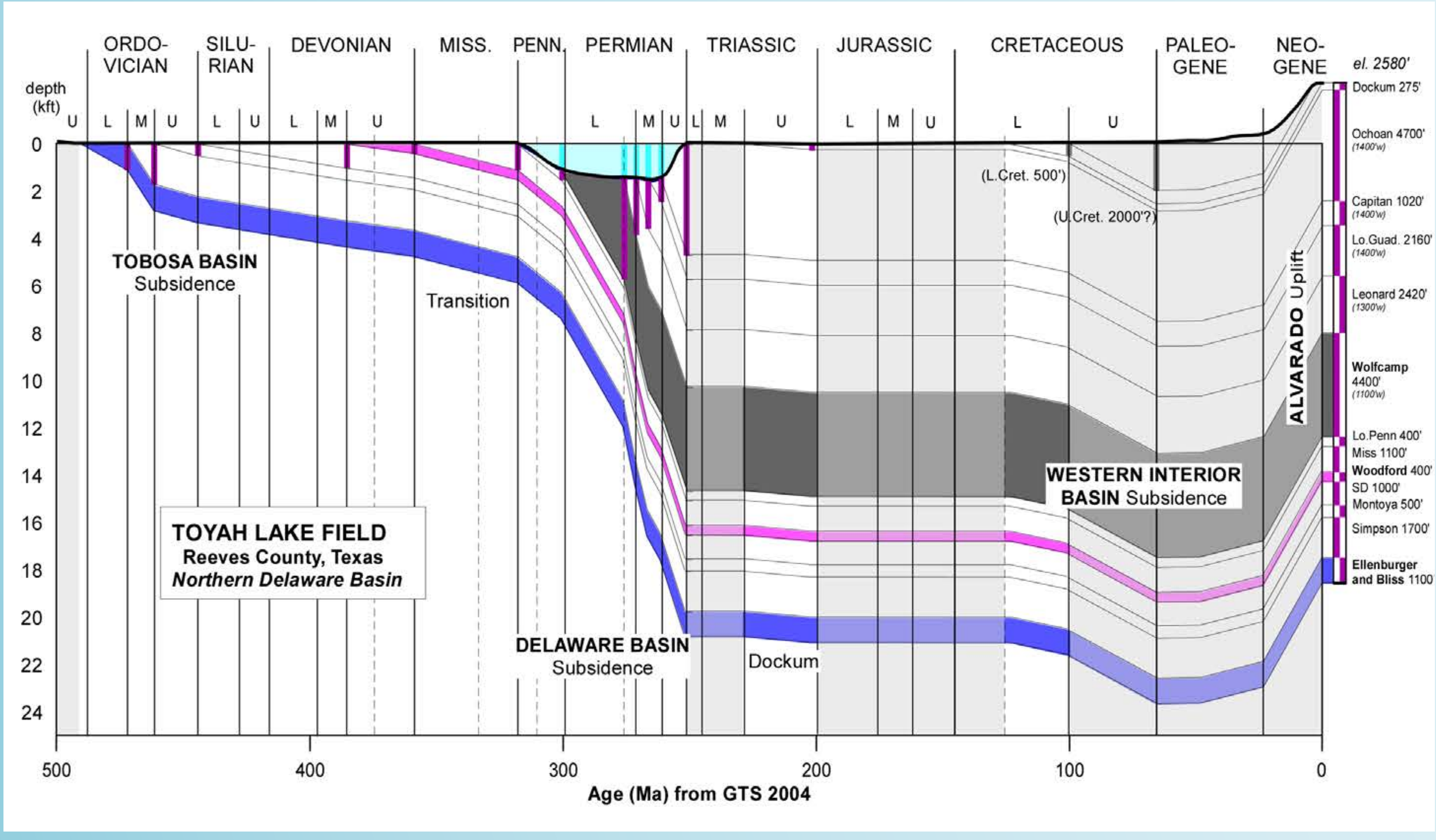
- WHY IS THIS A SUPERBASIN?
- Why so many / so much organic-rich source?
  - How are the pre-Penn sources preserved?
  - Why do we get persistent basin environments in Penn-Perm?
- How does Penn-Wolfcamp structuring affect oil generation and migration?
- Why do we get such widespread oil-window conditions?

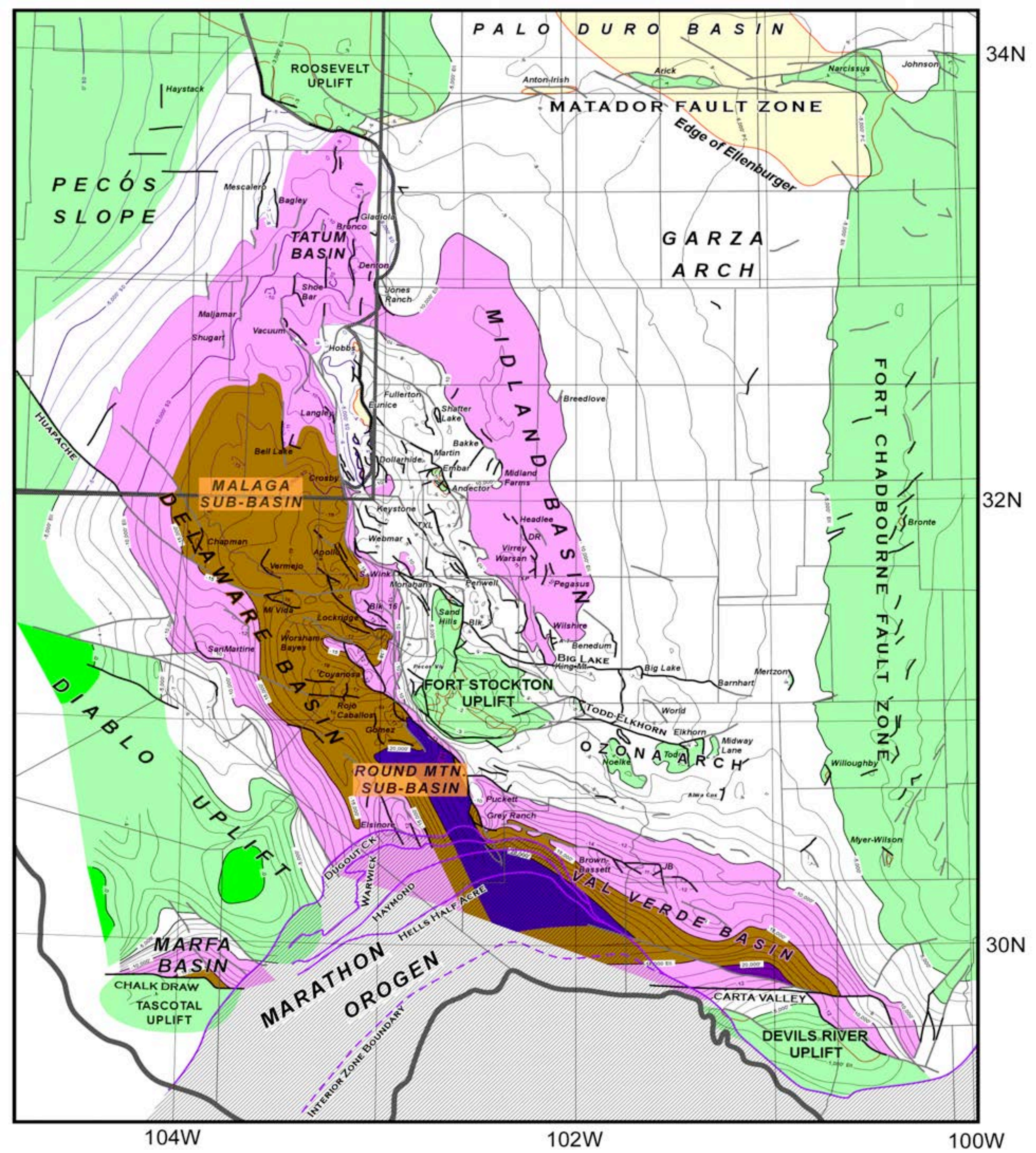
LOCATION OF
WEST TEXAS (PERMIAN) BASIN



Muehlberger, 1996, Tectonic Map of North America

BASIN SUBSIDENCE – PECOS, TX

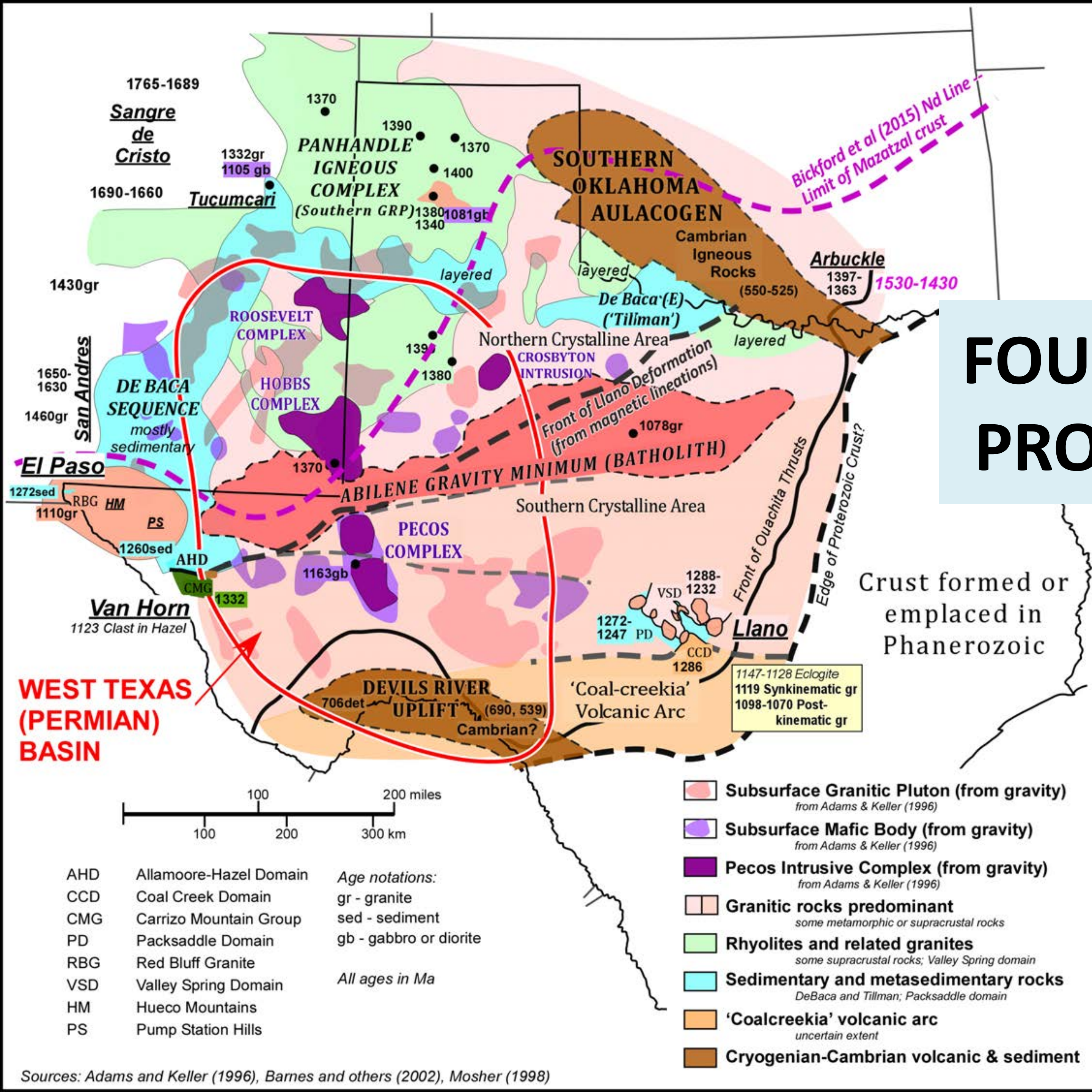




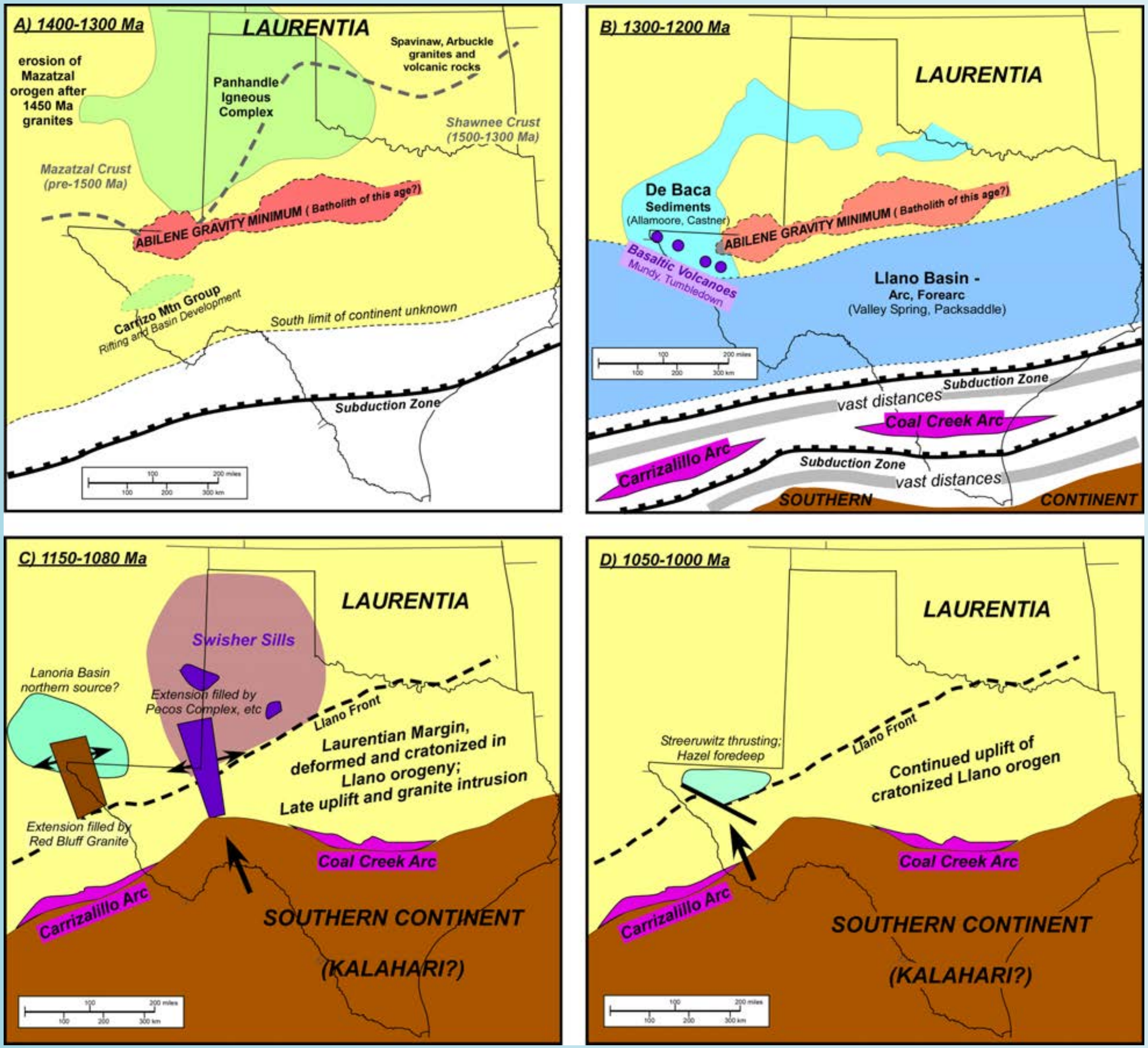
WEST TEXAS (PERMIAN) BASIN: *STRUCTURE, TOP ELLEN-BURGER* (Lower Ordovician)

PERMIAN BASIN: FOUNDATIONS AND EARLY HISTORY

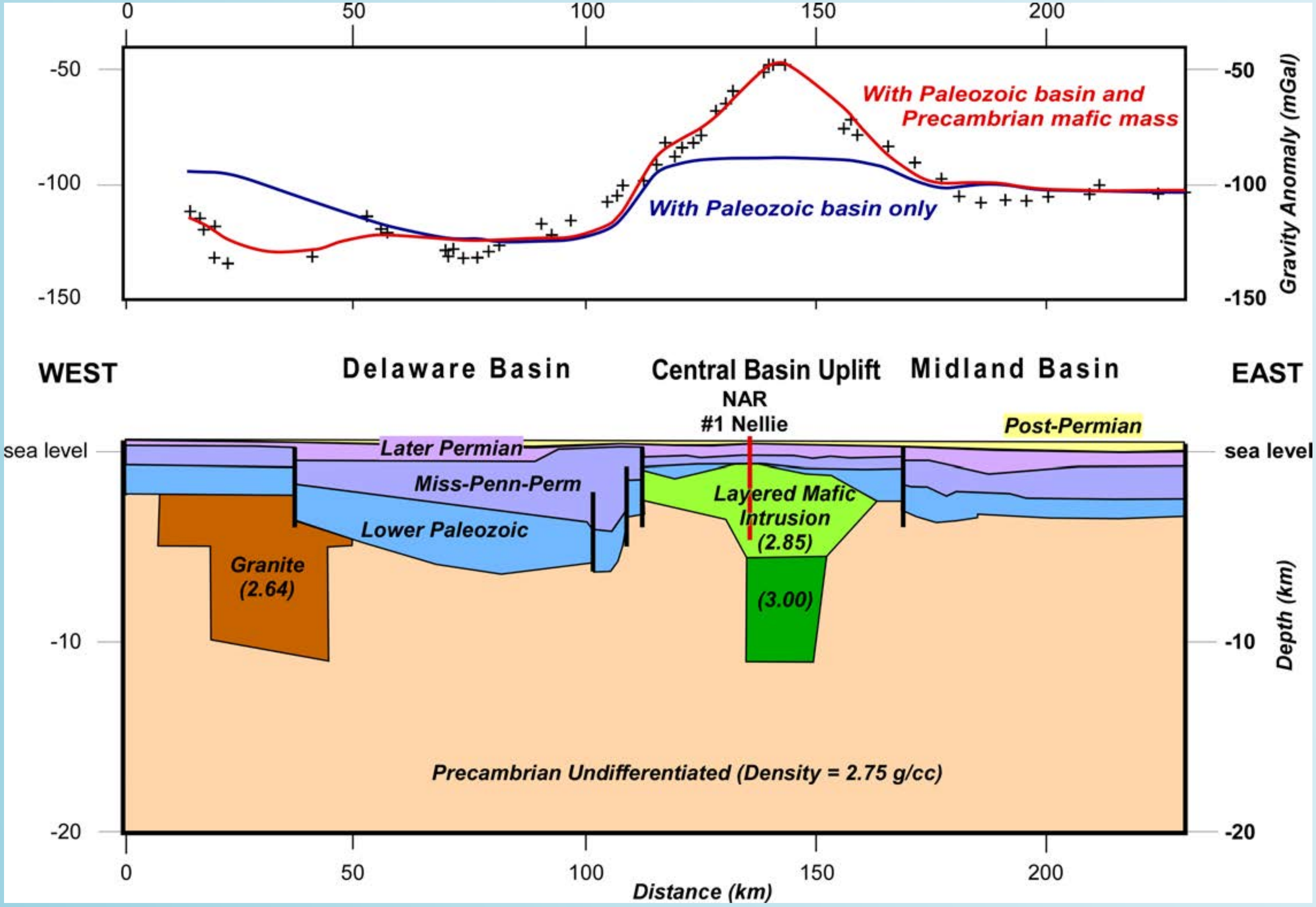
FOUNDATION - PROTEROZOIC



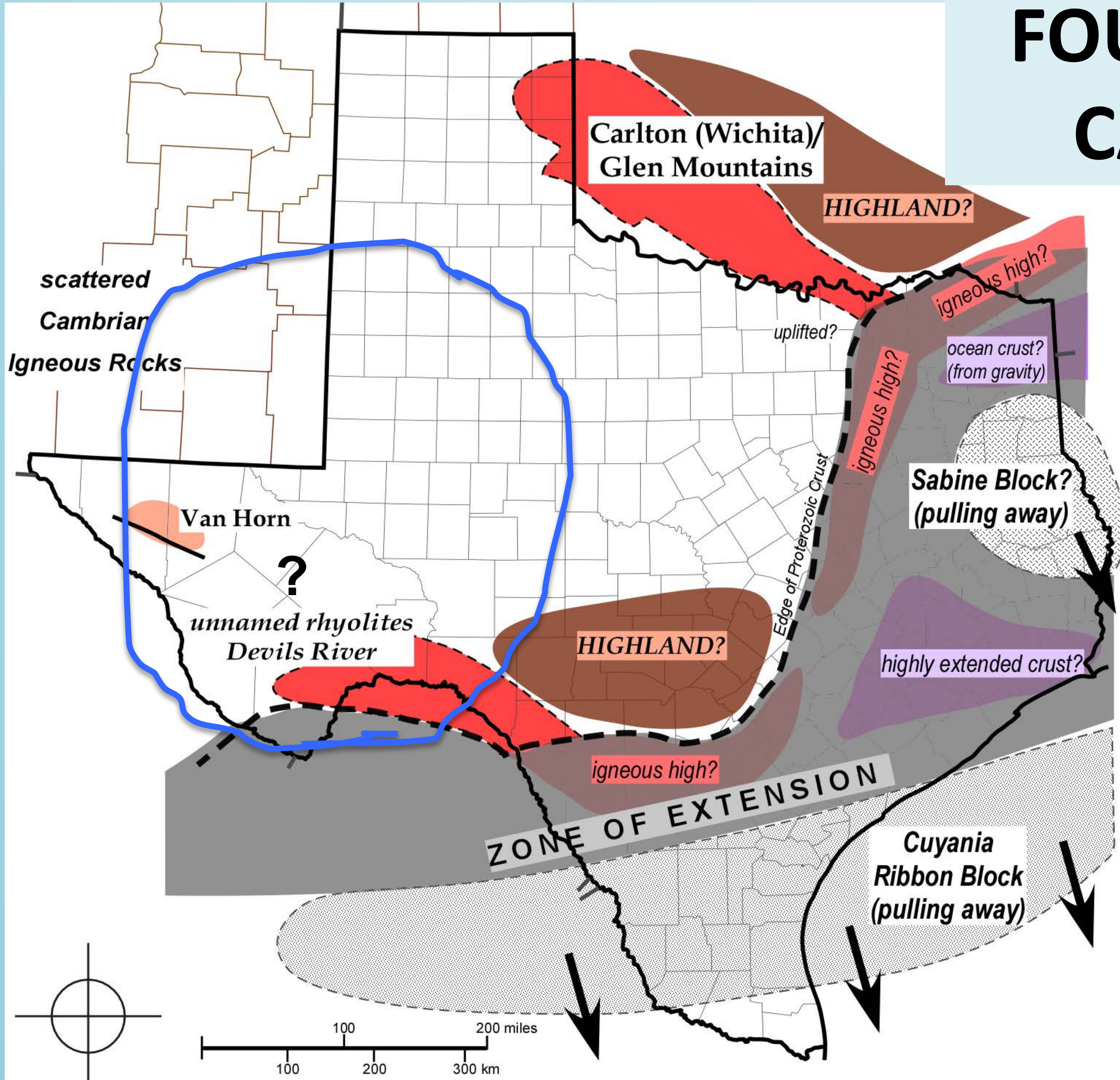
PROTEROZOIC HISTORY



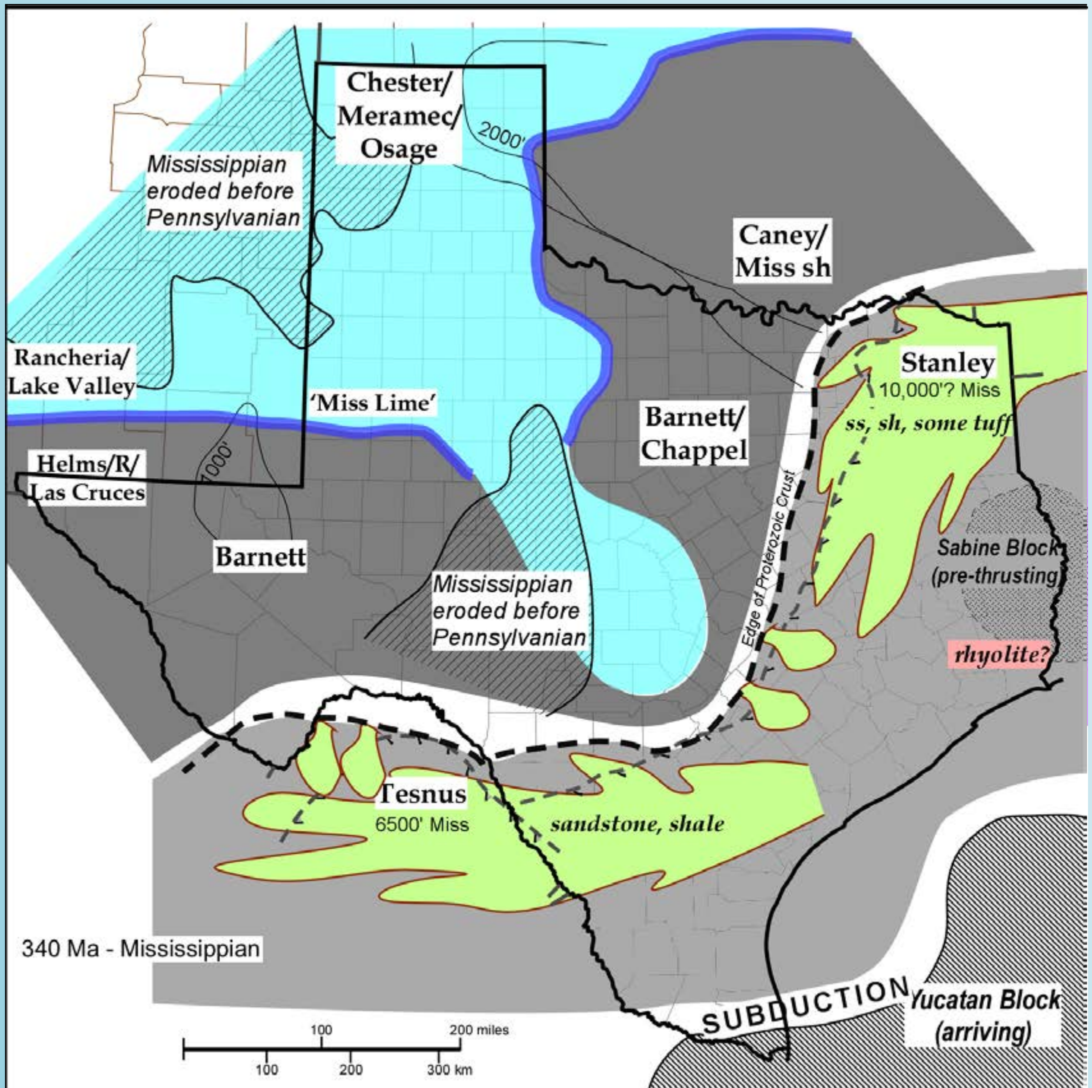
PECOS MAFIC COMPLEX
AT THE CORE OF THE PERMIAN BASIN



FOUNDATION - CAMBRIAN



TEXAS GEOHISTORY, TOBOSA PHASE



530 Ma – Middle Cambrian

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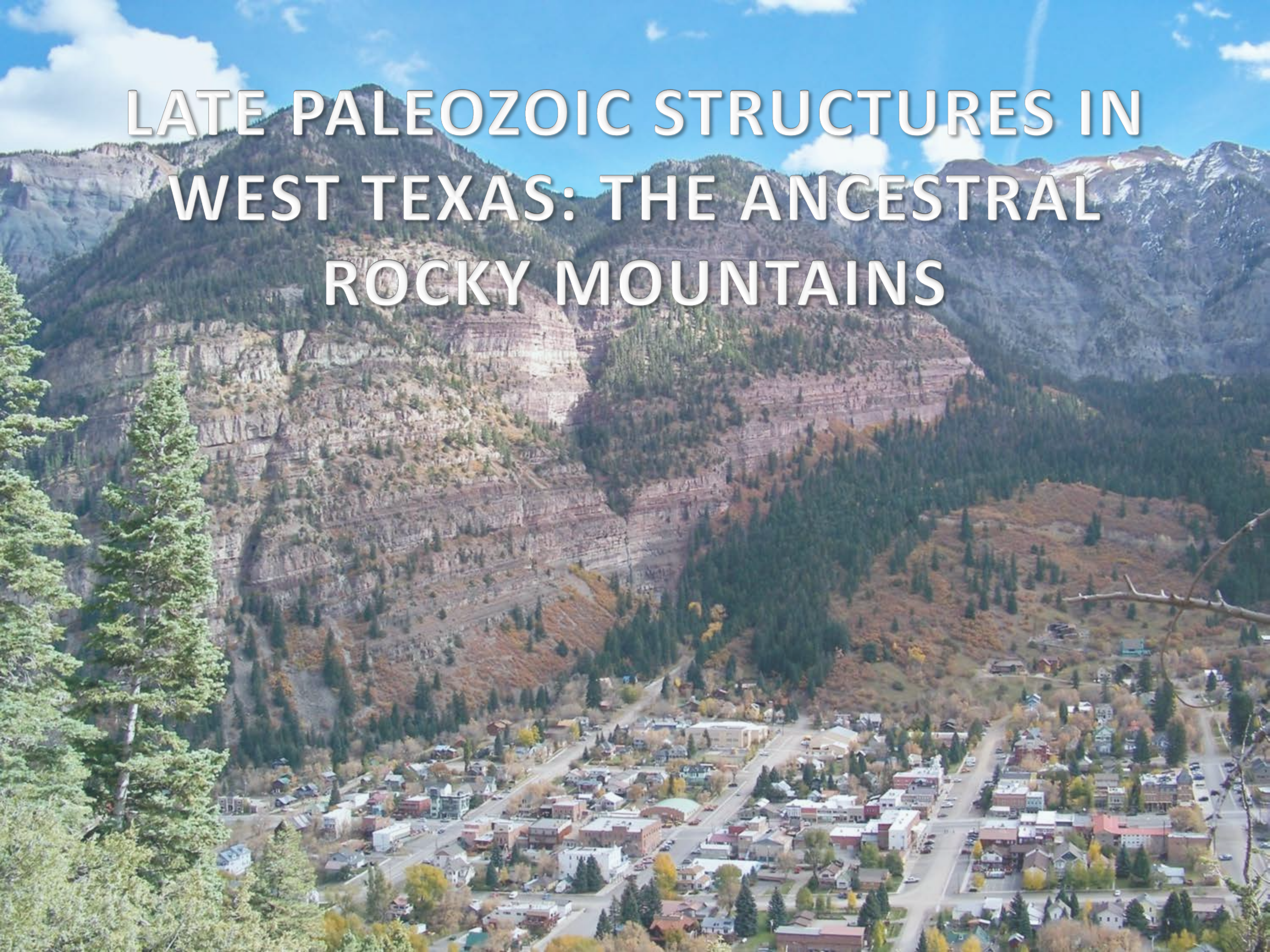
455 Ma – Middle Ordovician

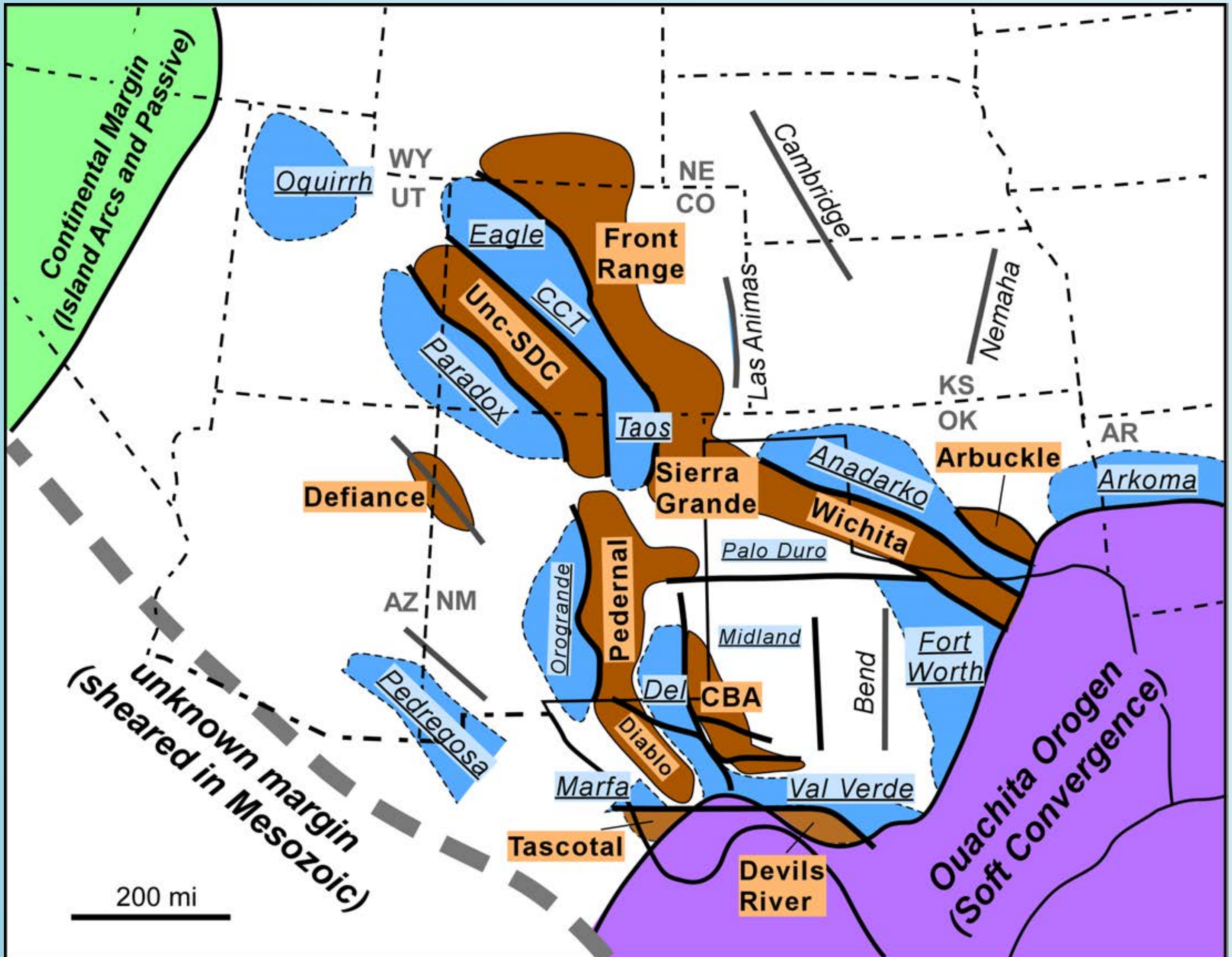
420 Ma – Silurian/Devonian

340 Ma – Mississippian

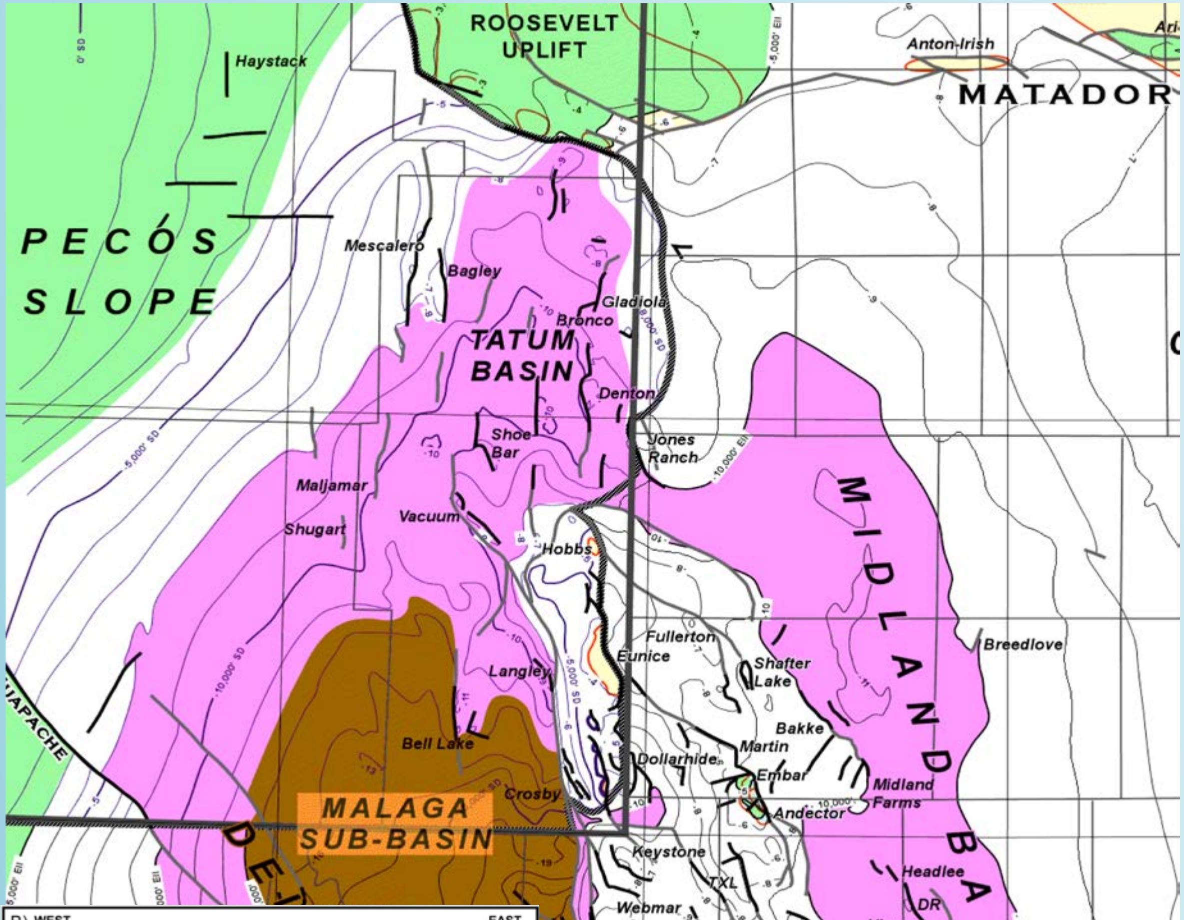
LATE PALEOZOIC STRUCTURES IN WEST TEXAS: THE ANCESTRAL ROCKY MOUNTAINS

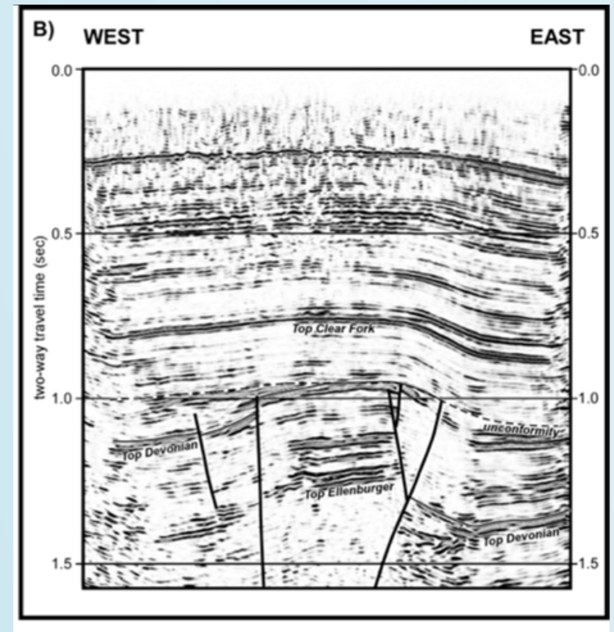


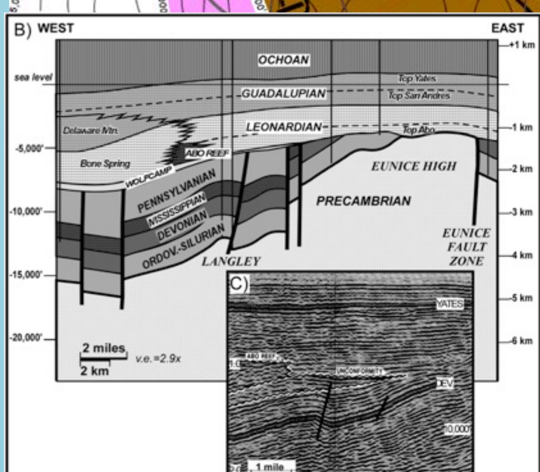
LATE PALEOZOIC: ANCESTRAL ROCKY MOUNTAINS (ARM) OROGEN



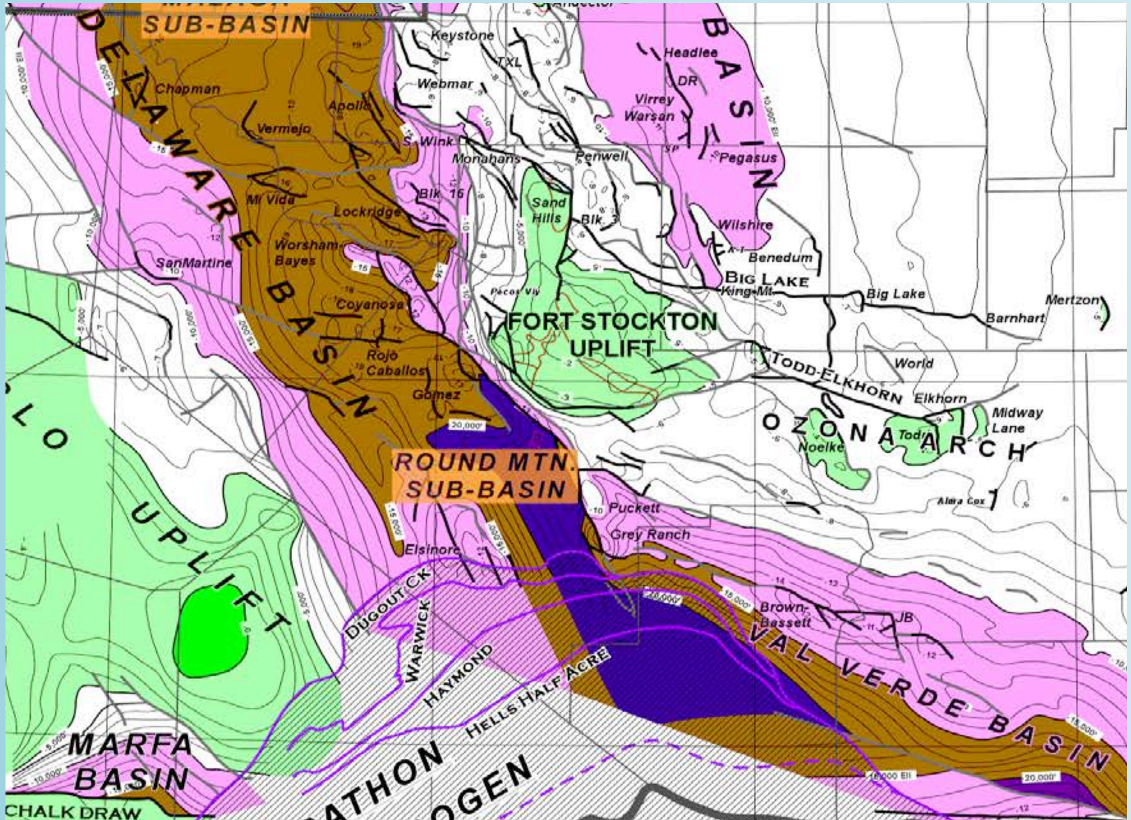
ARM STRUCTURES IN WTB (N)

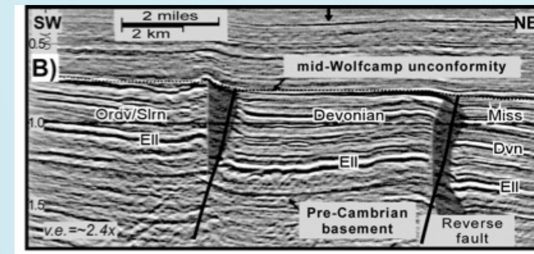


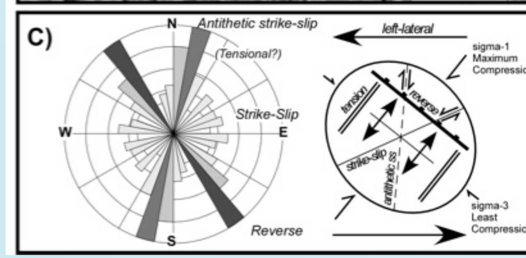


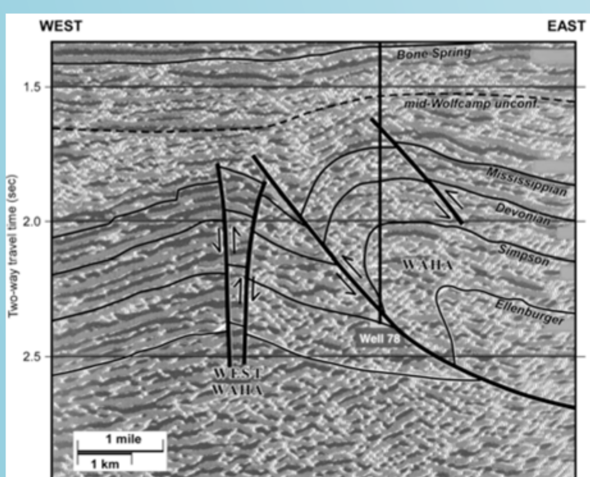


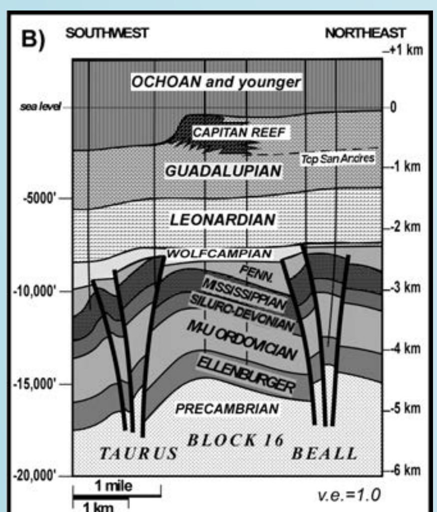
ARM STRUCTURES IN WTB (S)

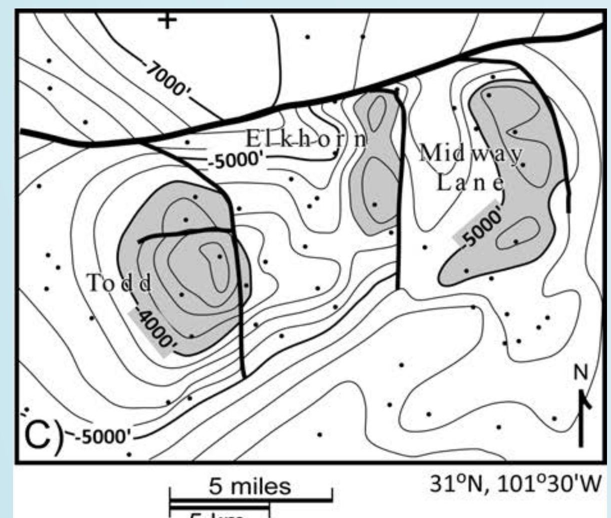




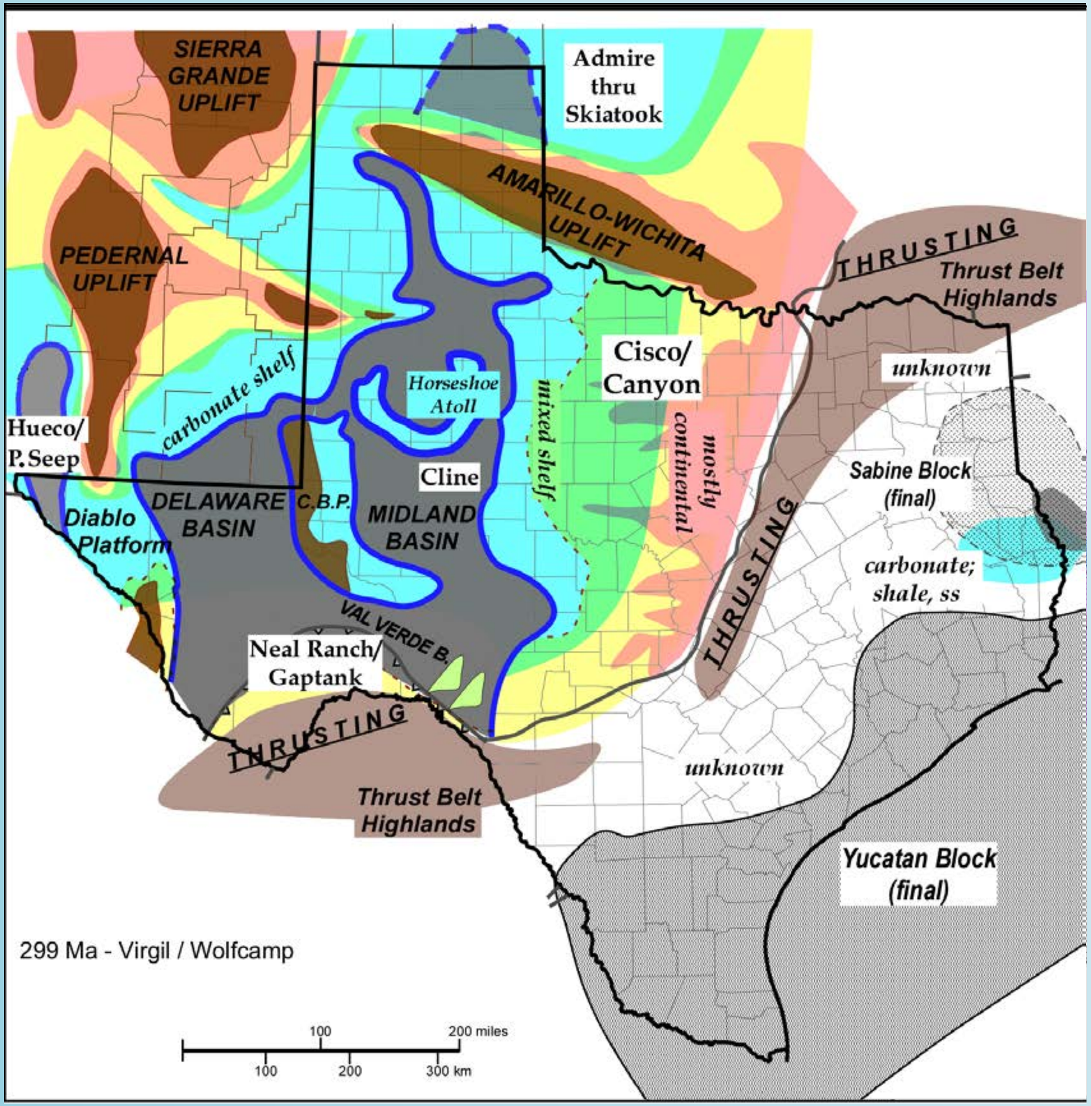








TEXAS GEOHISTORY, ARM PHASE



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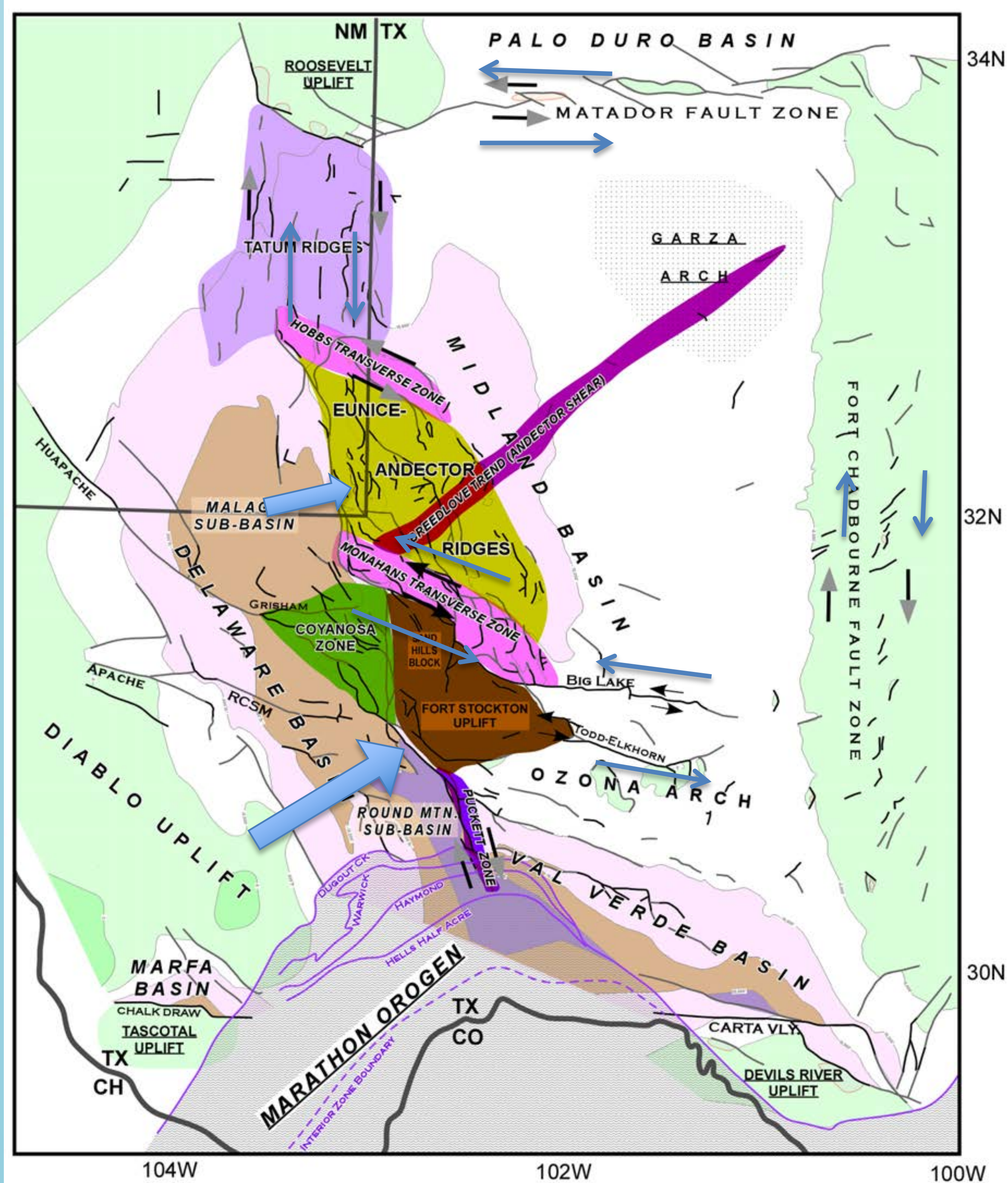
318 Ma – Early Pennsylvanian

310 Ma – Middle Penn.

299 Ma – Beginning of Permian

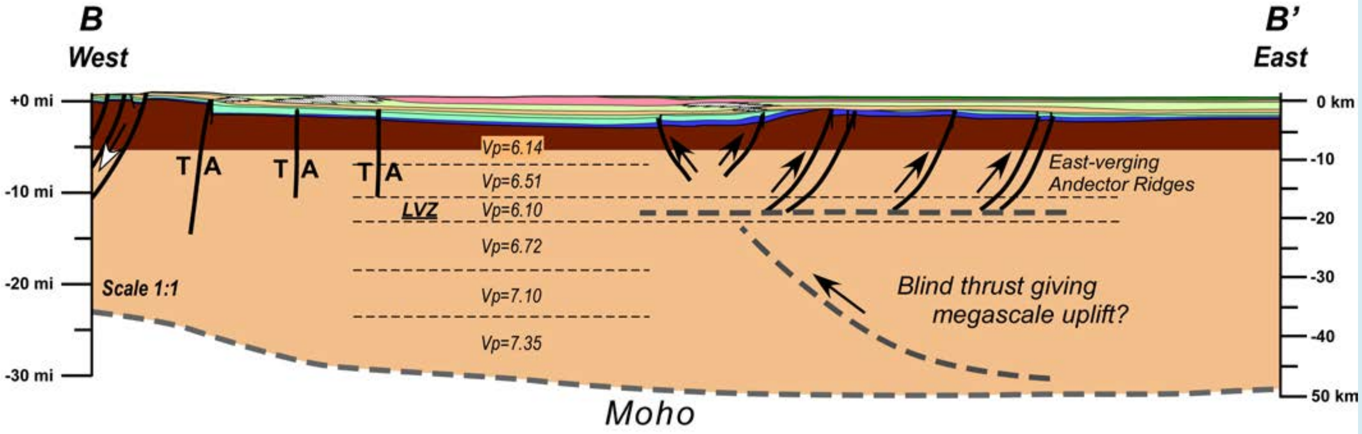


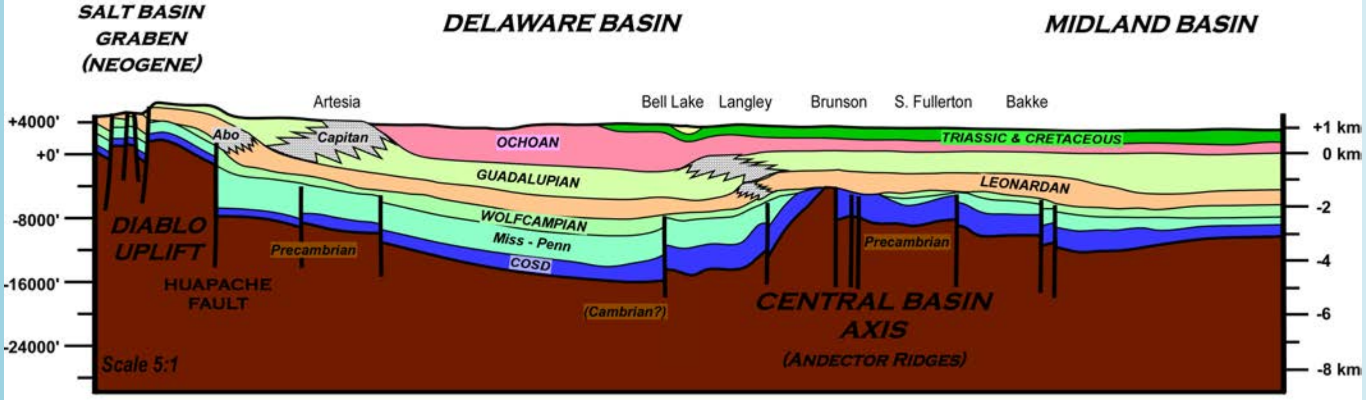
ARM IN WTB:

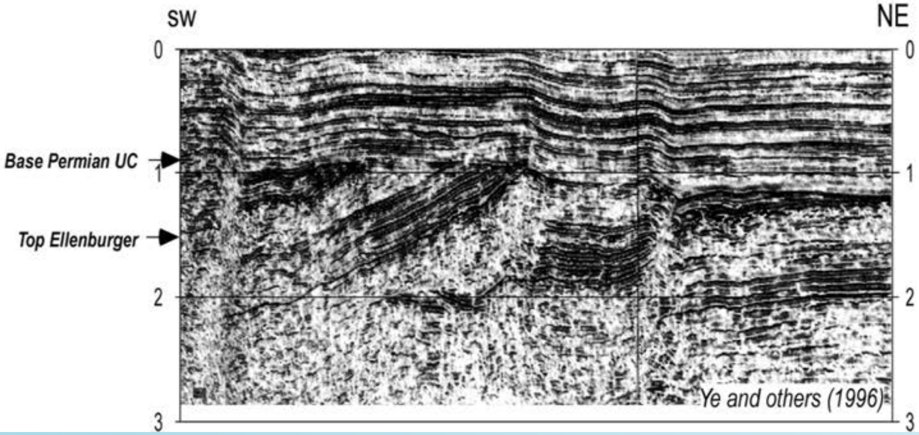
MACRO-SCALE DOMAINS AND KINEMATICS

NORTHERN SECTION

(Guadalupe Peak to Big Spring)

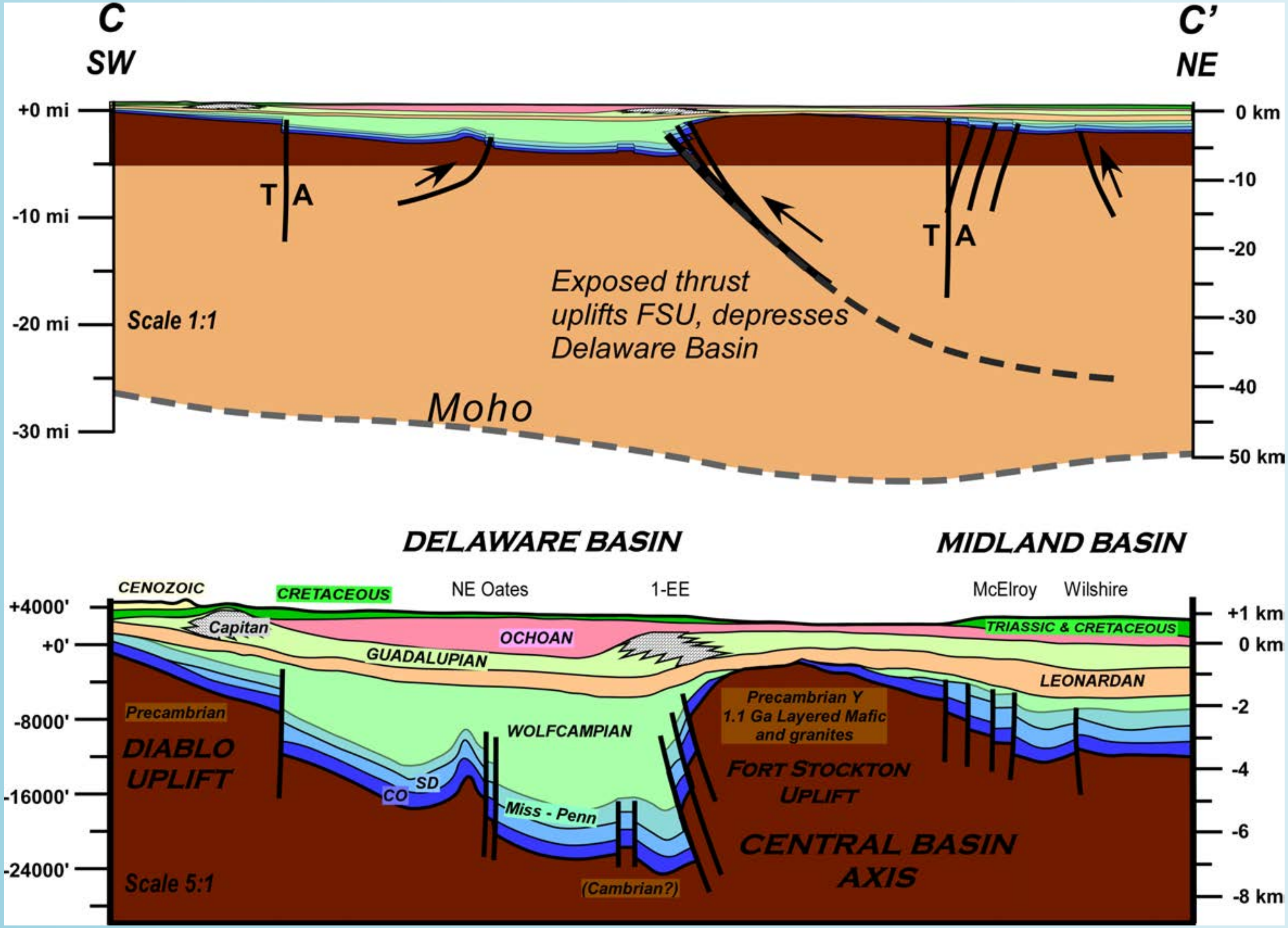






SOUTHERN SECTION

(Fort Stockton Uplift)

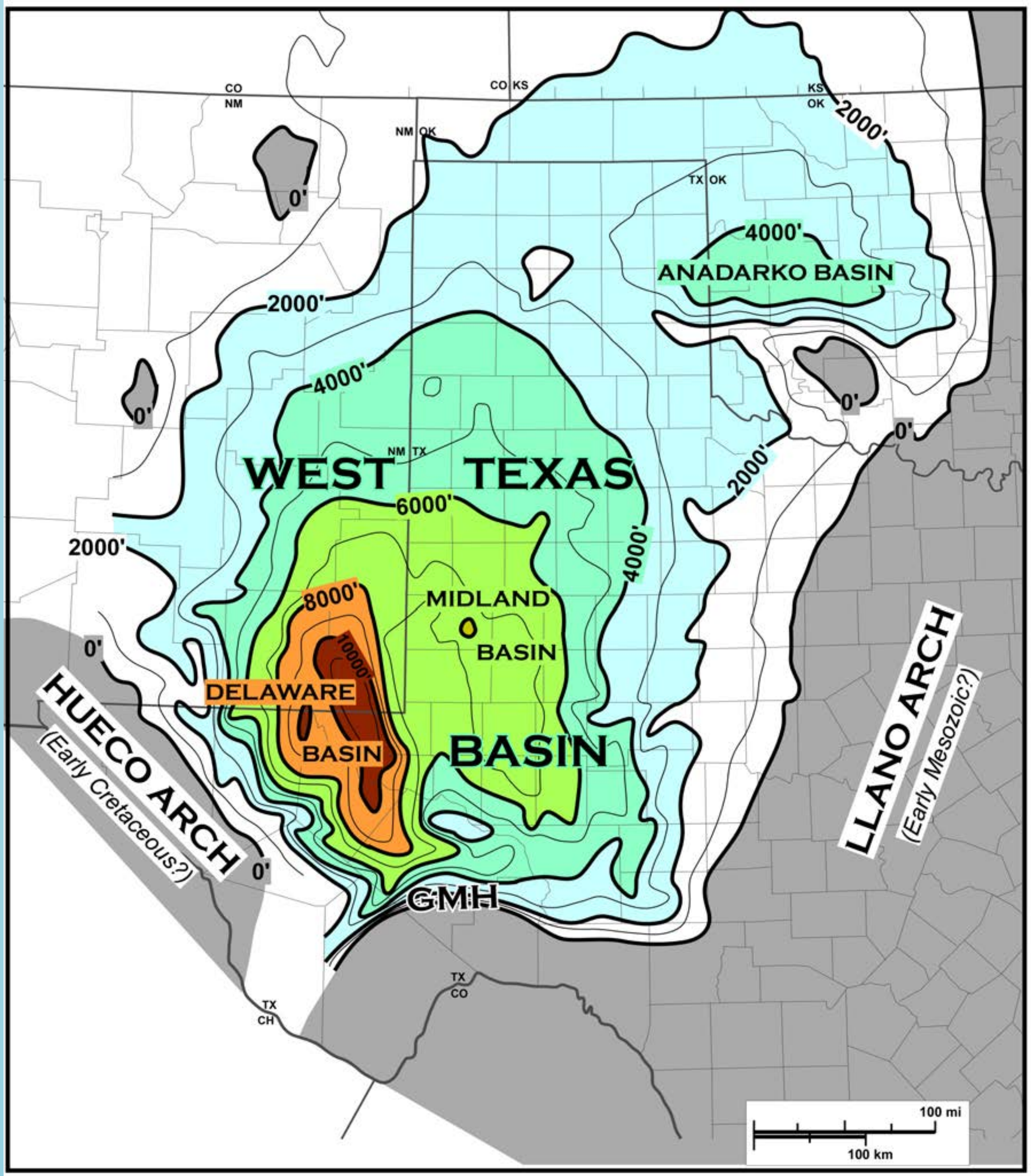


PERMIAN BASIN SUBSIDENCE

GIGASCALE SUBSIDENCE;

THE PERMIAN BASIN PROPER

- Basinwide subsidence begins in Pennsylvanian
  – Responsible for minor erosion of uplifts, lack of basement exposures
  – Drowns the Strawn platform, creates persistent basins
- Subsidence outlasts deformation into late Permian
  – Thick (2-3 km), complex sedimentary package
  – finally sealed by Late Permian salt
  – Causes maturation of Devonian-Penn shales and charging of reservoirs

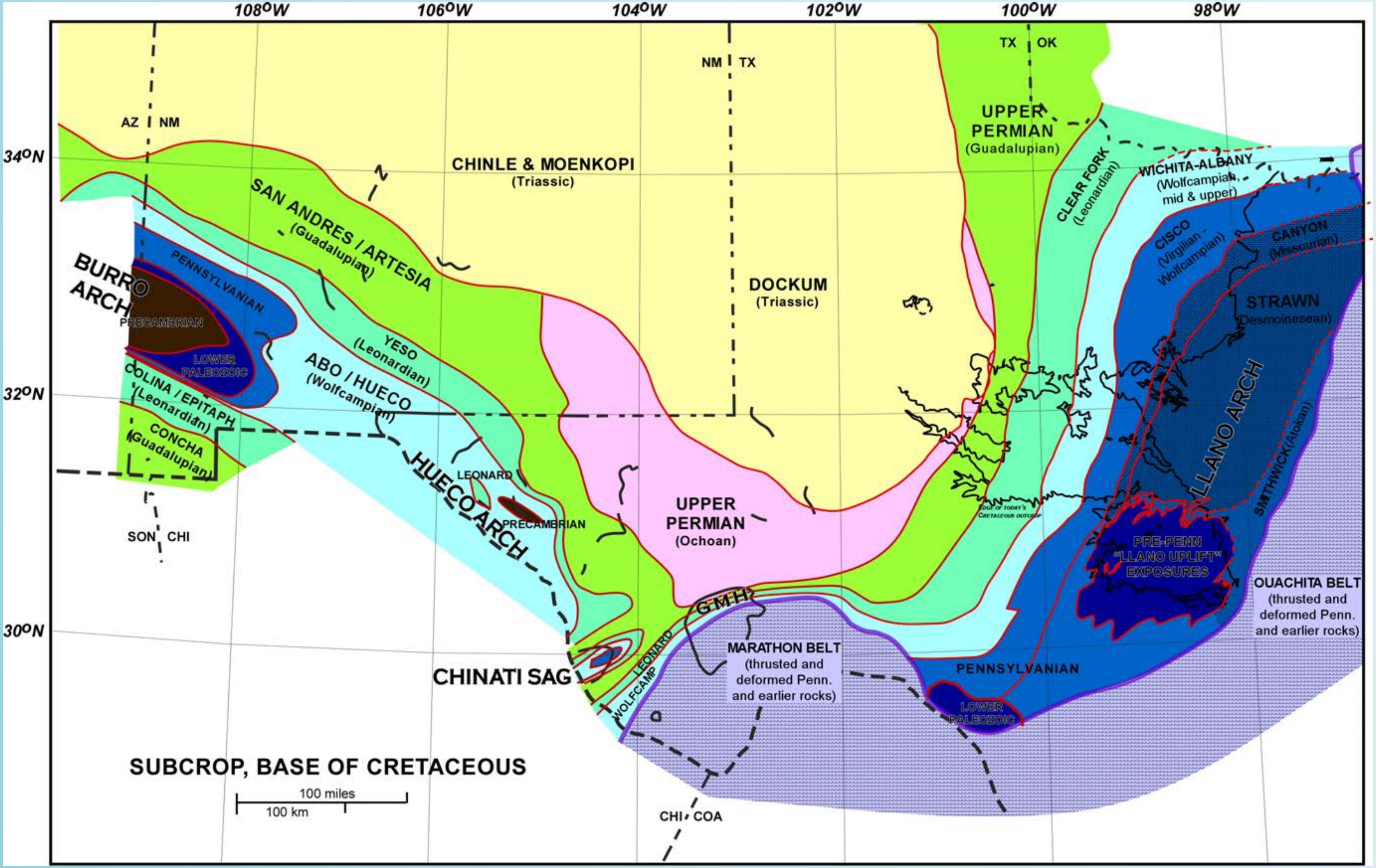


ISOPACH, POST-WOLFCAMP PERMIAN STRATA

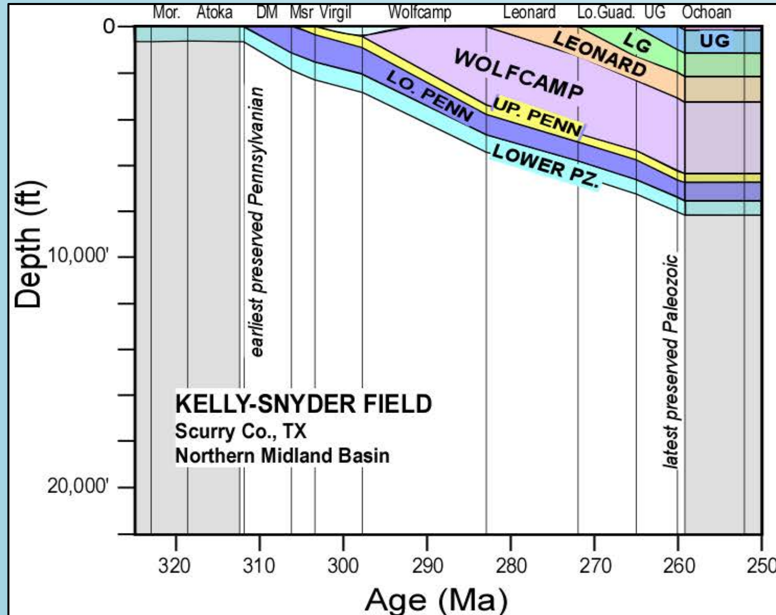
Note: W, S, E margins are
Modified post-Permian!

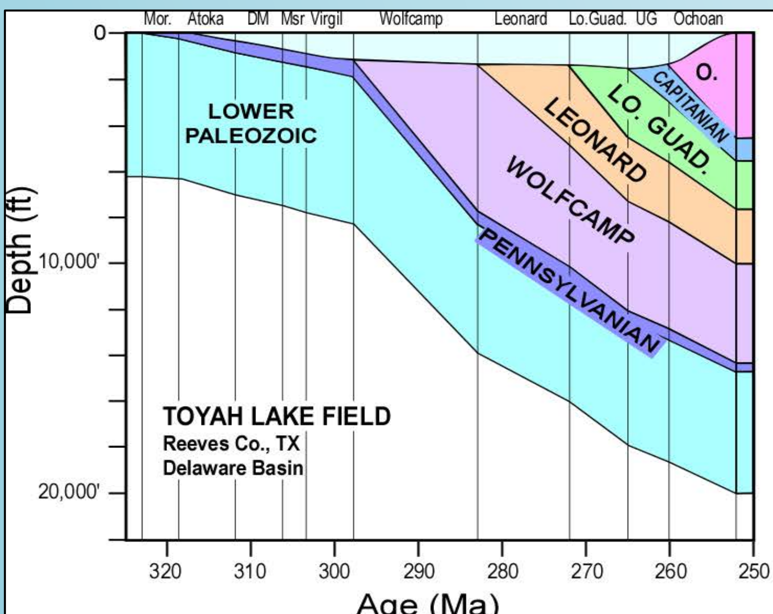
Ewing, 1991, after
McKee and Oriel (1967)

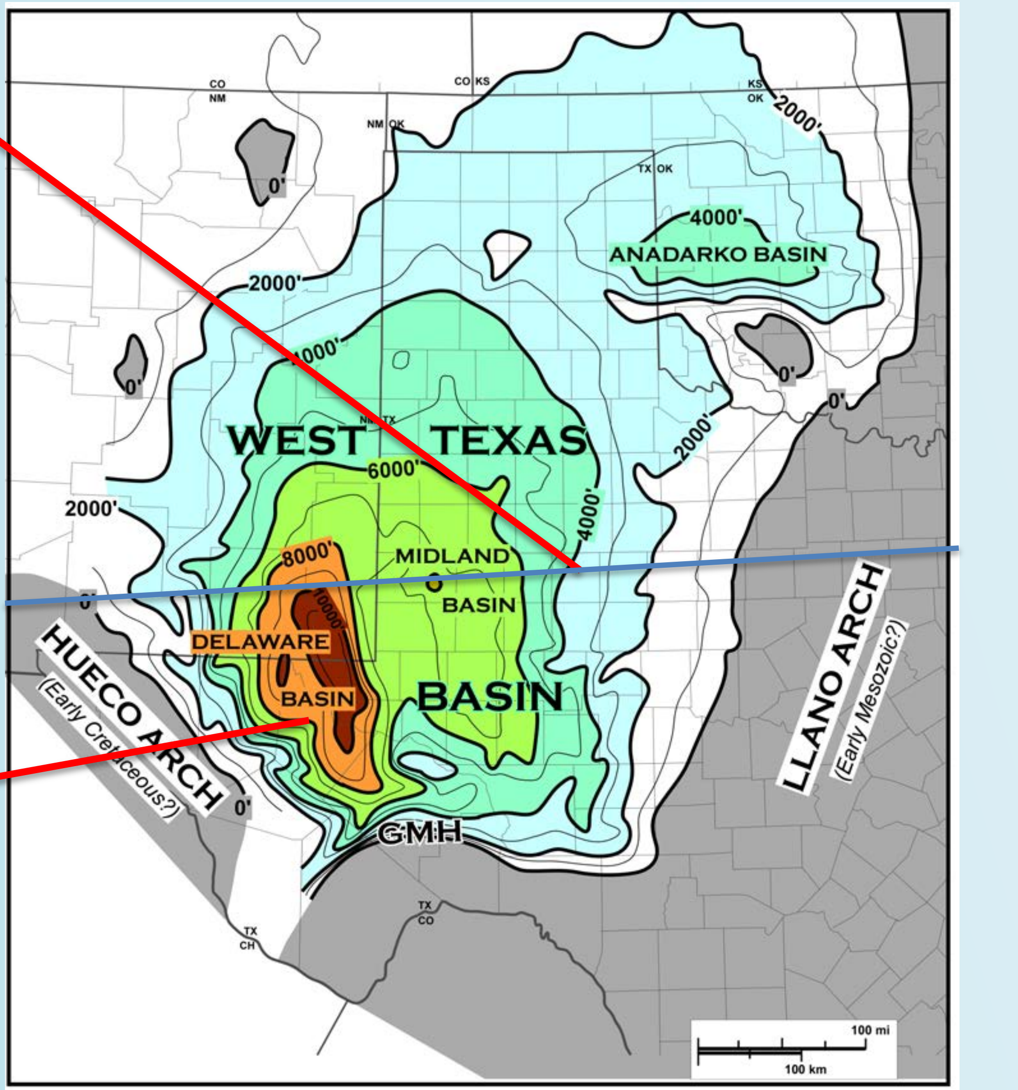
PRE-CRETACEOUS SUBCROP



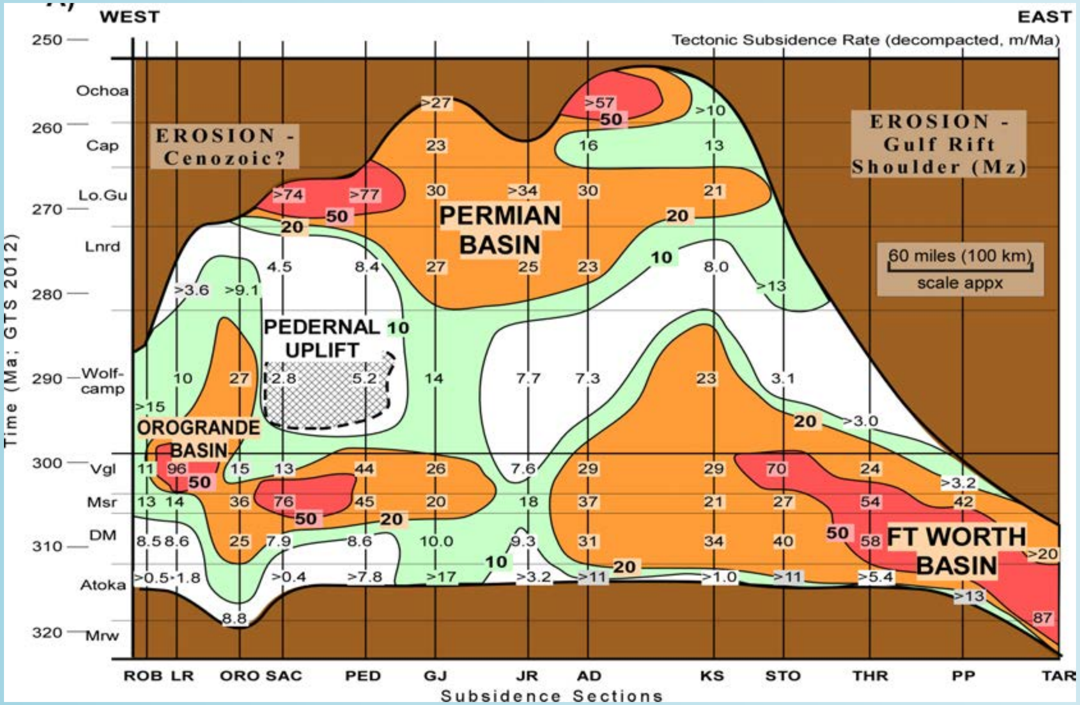
BASINWIDE SUBSIDENCE

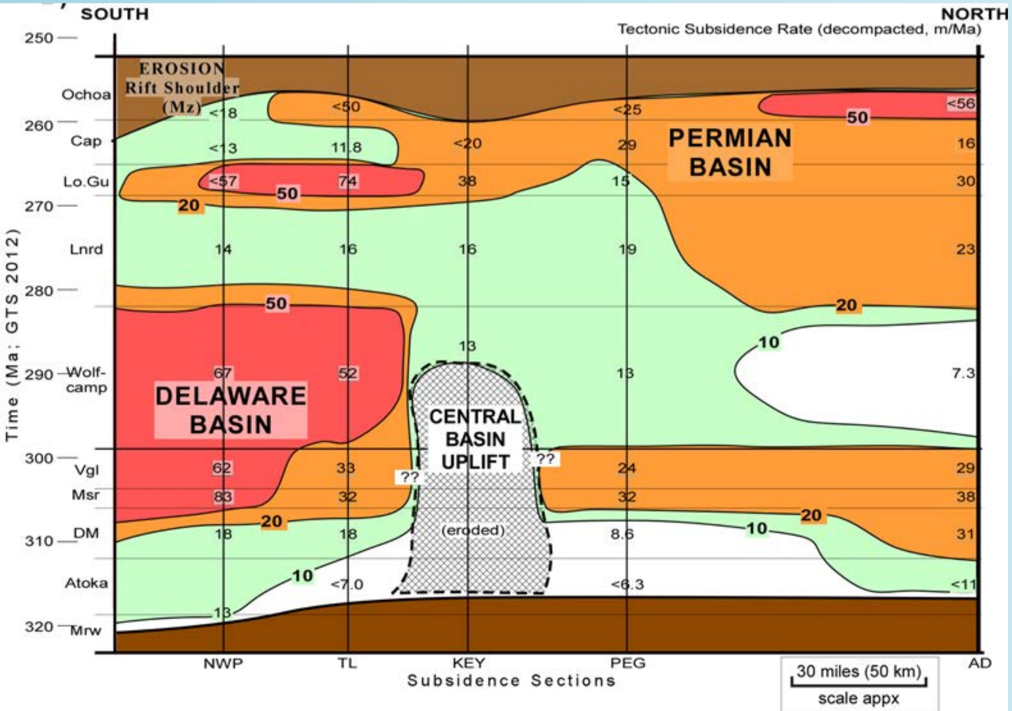






TECTONIC SUBSIDENCE THROUGH TIME

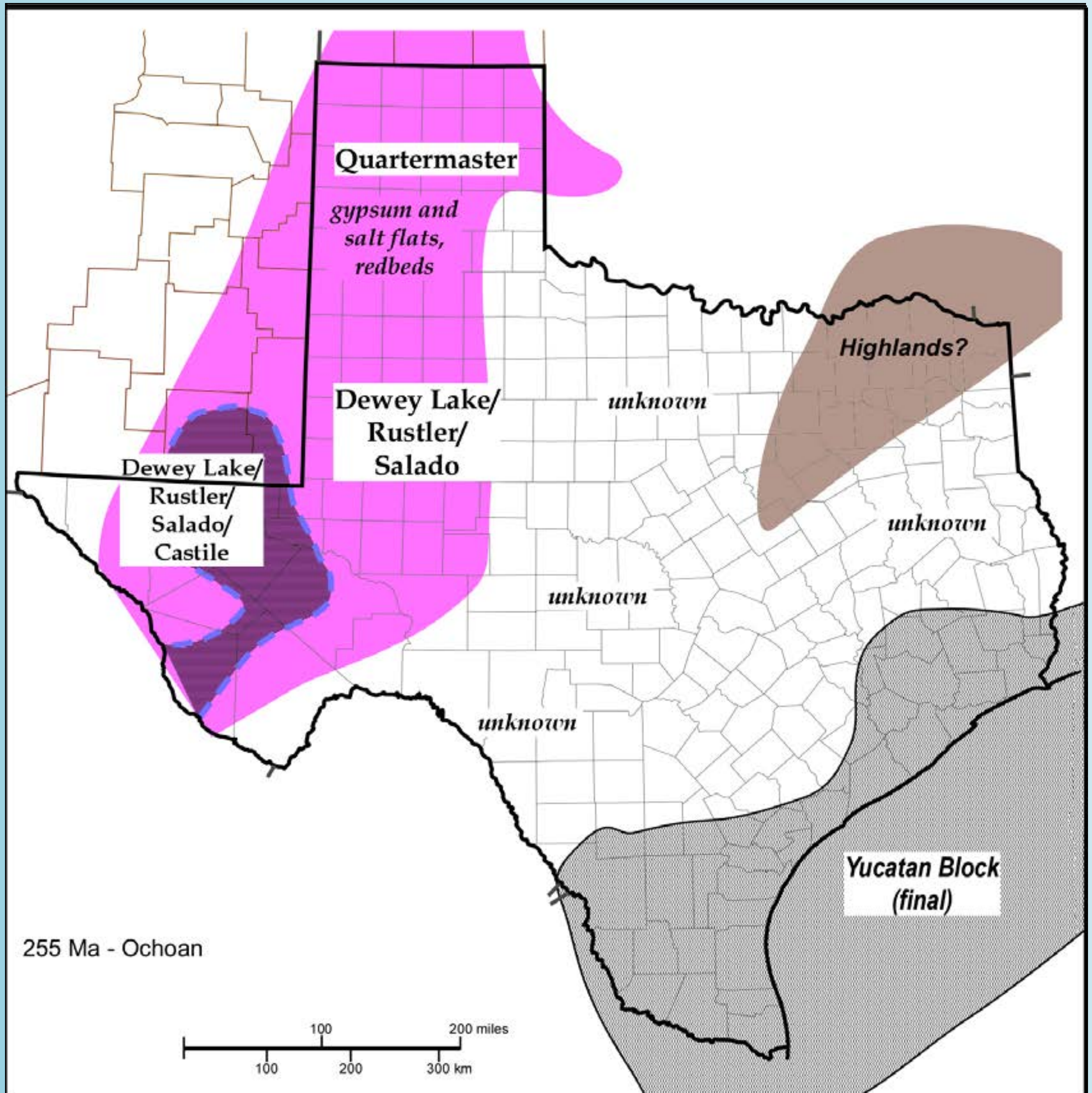




A) W-E section; note strong Fort Worth Basin subsidence due to Ouachita loading; ARM basins; later increase in Permian Basin subsidence.

B) S-N section; note strong Delaware Basin subsidence, later Permian Basin subsidence.

TEXAS GEOHISTORY, PERMIAN PHASE



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299 Ma – Beginning of Permian

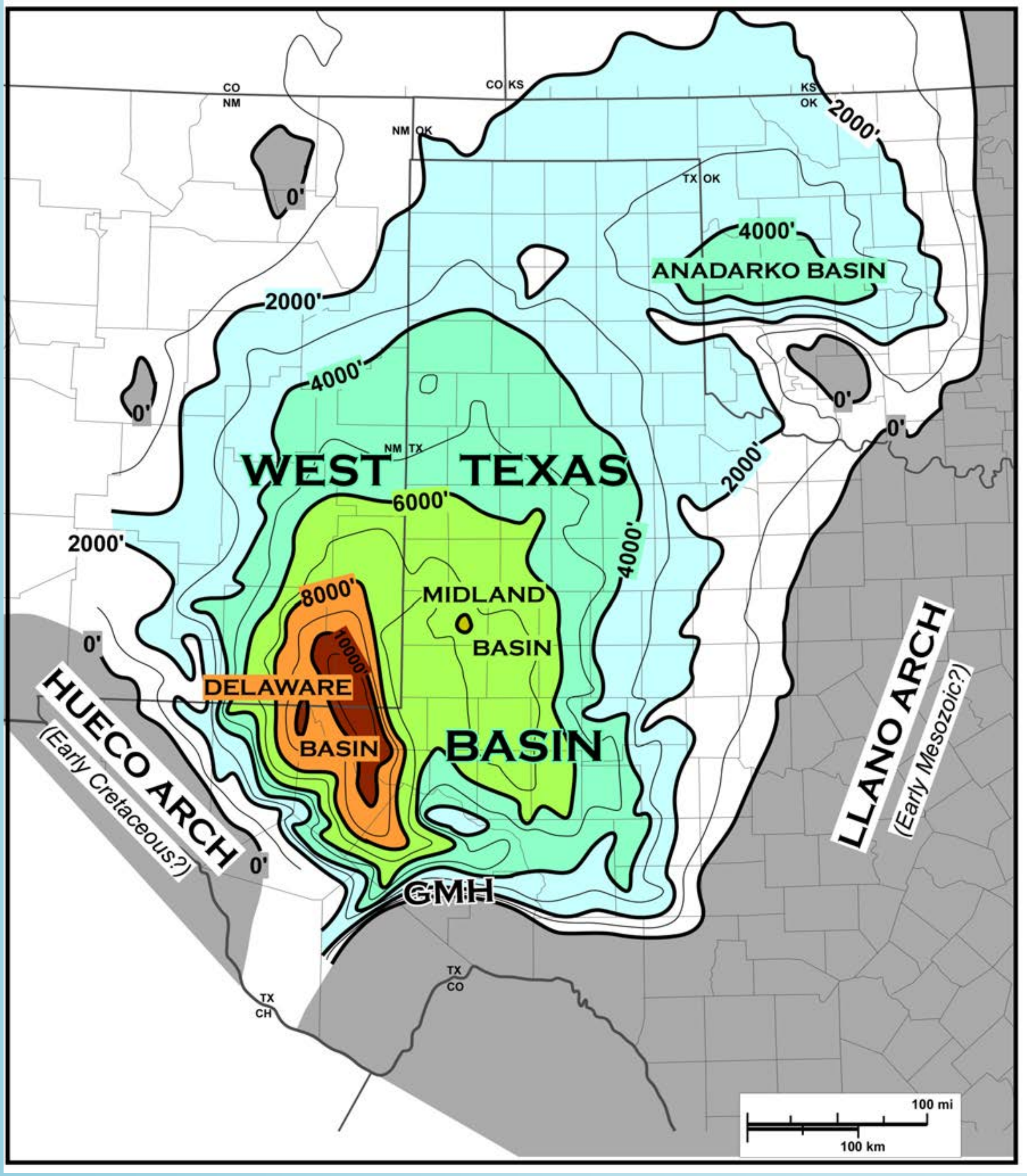
290 Ma – Wolfcampian (Early Permian)

278 Ma – Leonardian (Middle Permian)

265 Ma – Guadalupian (Middle Permian)

255 Ma – Ochoan (Late Permian)

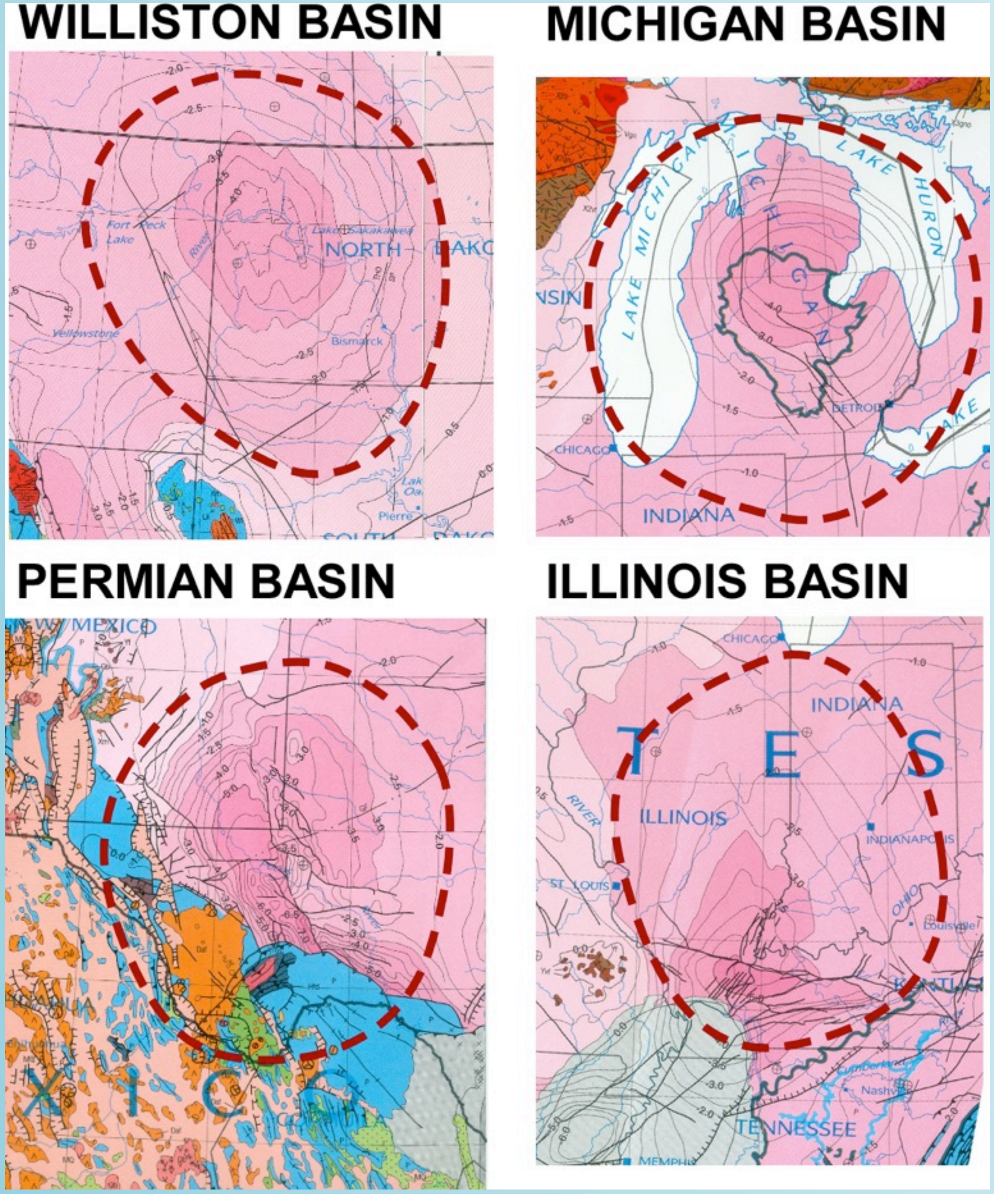
WHAT IS THE PERMIAN BASIN?



Bowl of subsidence centered on Kermit area

INTRACRATONIC BASIN centered on Ft Stockton Uplift (cf Michigan, Williston, Illinois Basins)

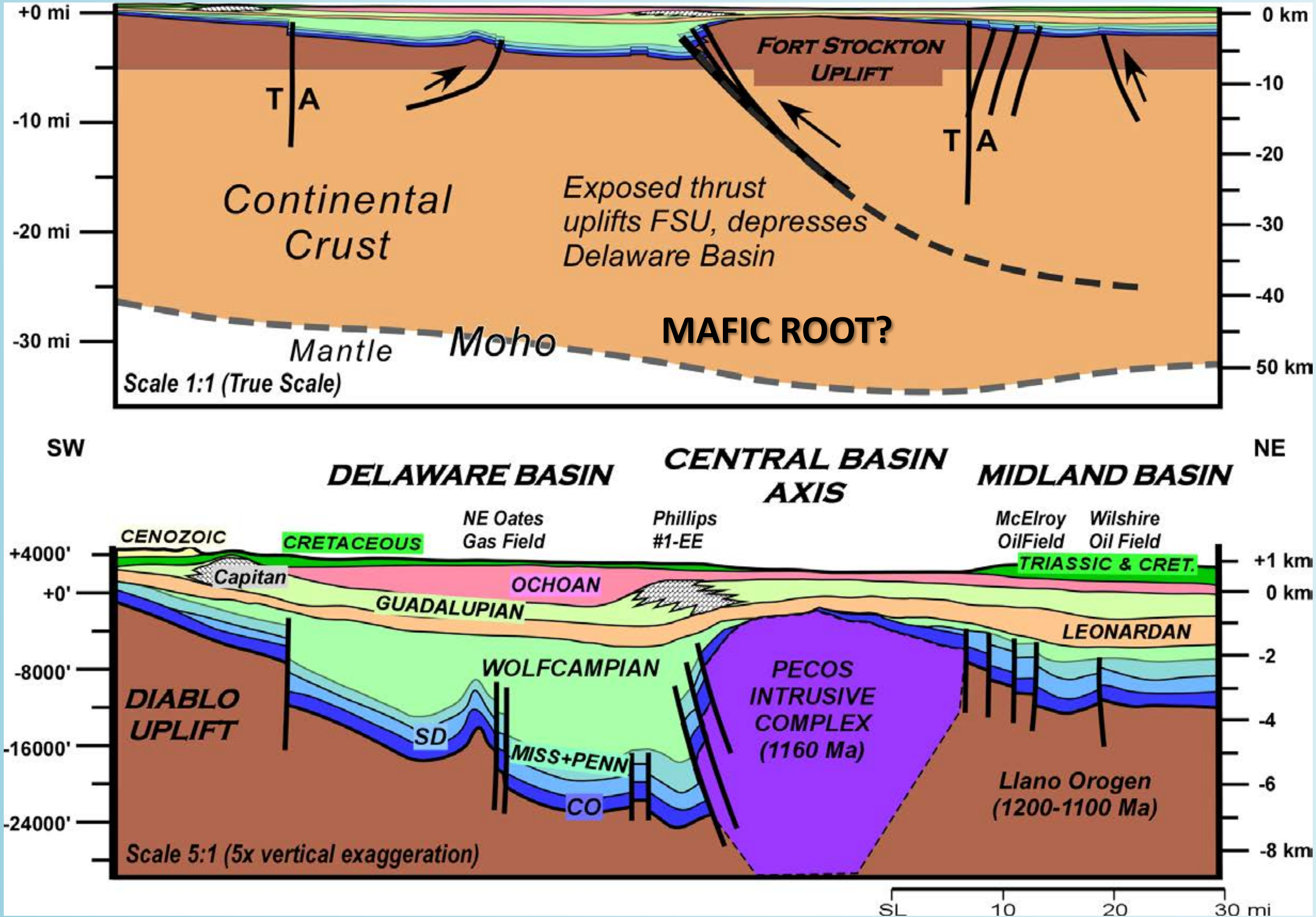
SW, S, E margins modified by Mesozoic, Cenozoic uplift



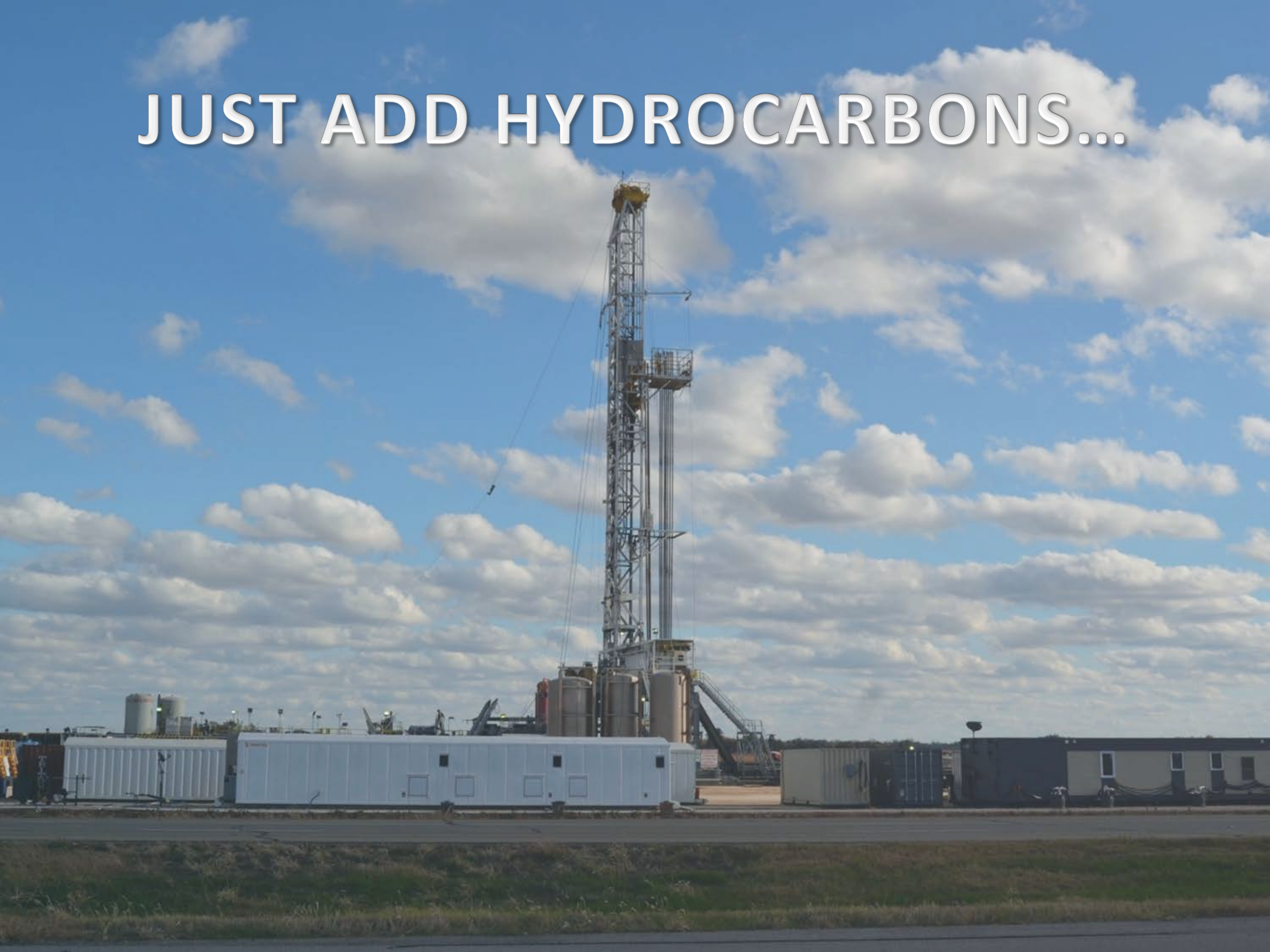
COMPARISON OF BASINS

Muehlberger, 1996, Tectonic Map of North America

FT. STOCKTON UPLIFT AND PECOS INTRUSIVE COMPLEX

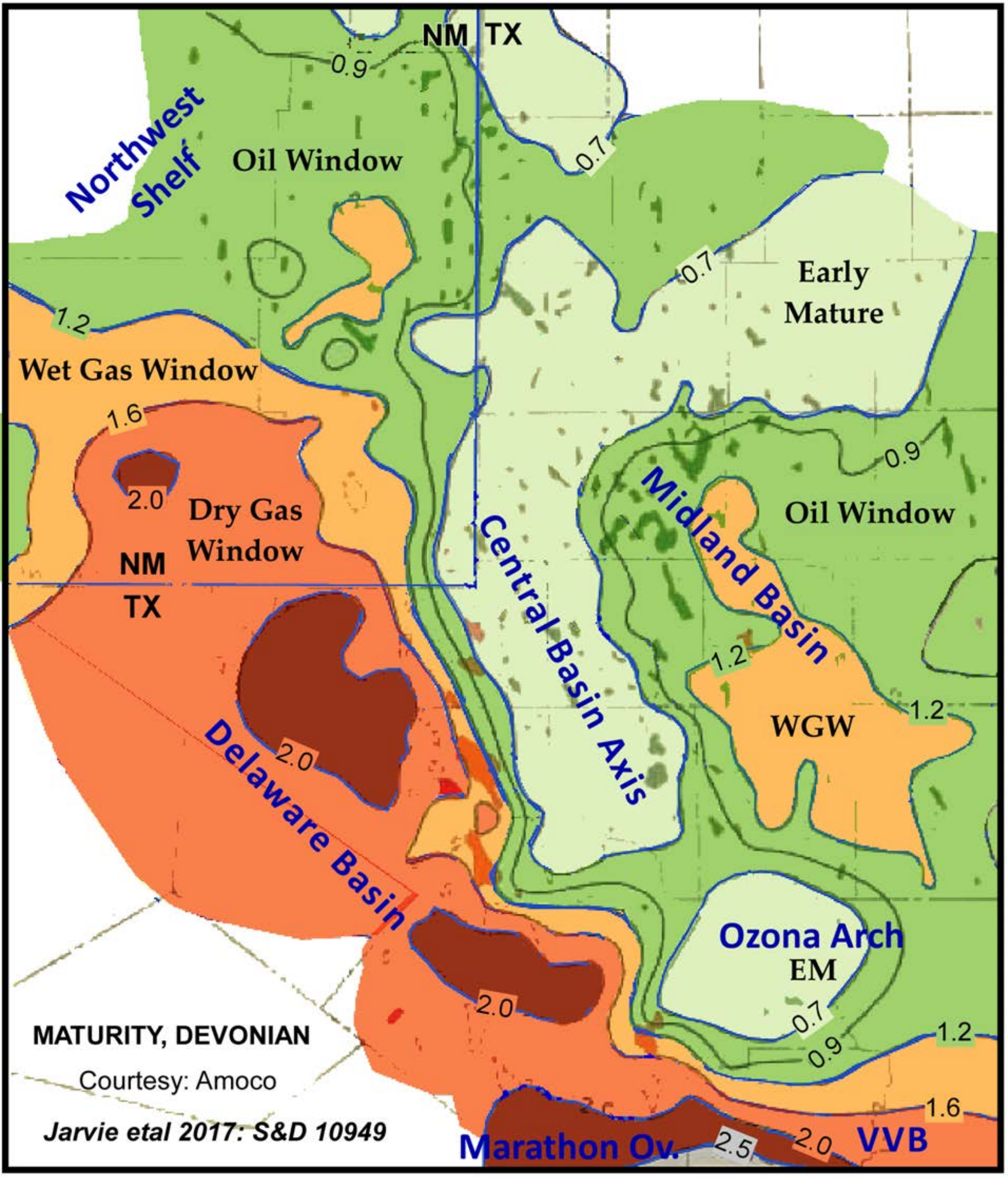


JUST ADD HYDROCARBONS…



OIL AND GAS WINDOWS

- Today, most all of Midland Basin and shallower Delaware Basin are in the oil window in major source rocks; deep and western Delaware Basin are in the gas window.
- Without Permian subsidence, probably only the deep Delaware Basin would be in oil window!
- Permian Basin subsidence also enhanced the deep, silled marine basins that let organic matter accumulate to form Penn-Perm source rocks.



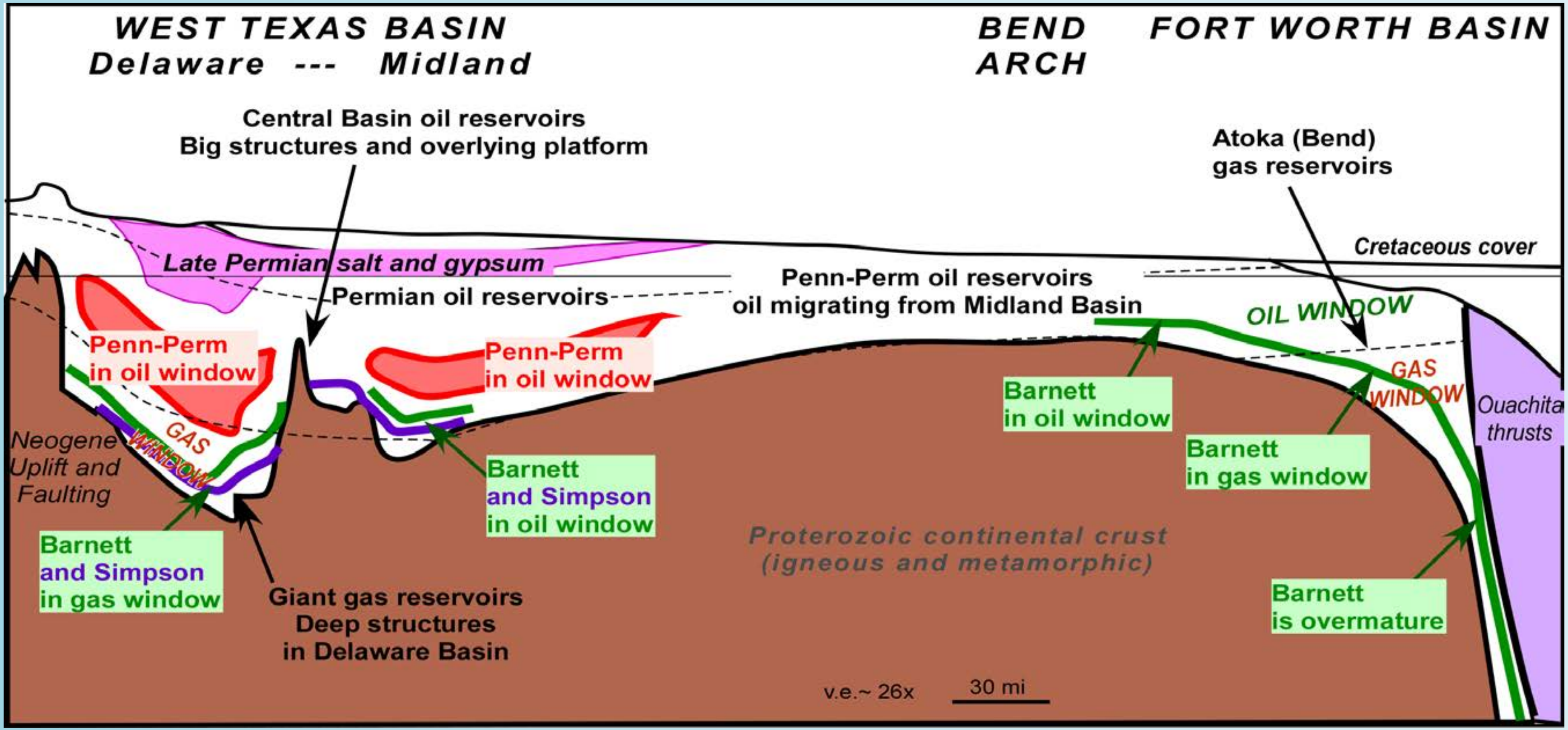
MATURITY AND PRODUCTION IN WEST TEXAS BASINS

Devonian is in the oil or wet gas window over most of the Permian Basin, with dry gas in the deeper Delaware Basin

This maturity over a broad area is due to the broad Permian Basin subsidence after ARM tectonics.

(Jarvie et al., 2017)

PETROLEUM SYSTEMS, WEST TEXAS BASINS



1) Four source zones; three low in pile (Simpson, Woodford, Barnett)
2) Maturation due to Permian subsidence for most of basin
3) Late salt seal reduces leakage; Permo-Triassic generation products preserved

Ewing, 2016

QUESTIONS?


reef
slope
reef
reef
slope
toe of slope
Cherry Canyon Fm (older basin deposits)

ABSTRACT

- The West Texas (Permian) Basin is a complexly structured intracratonic basin with prolific oil and natural gas production from conventional reservoirs and from thick, prolific organic mudrocks.
- The basin has two phases of subsidence; a lesser phase in Ordovician-Devonian time ('Tobosa basin'), and the main phase in Pennsylvanian and Permian time (the 'Permian basin' proper).
- It is built on diverse Proterozoic crustal units, including a ca. 1120 Ma layered mafic complex that may be related to basin origins. The crust was fractured during Cambrian rifting of the southern margin of North America; the pattern of this fracturing in the deep Delaware Basin is obscure but may have governed late Paleozoic fault patterns.
- Faulting and folding occurred in the Pennsylvanian to early Permian, as part of the Ancestral Rocky Mountains (ARM) orogen.
  - In the Basin, the ARM contains a variety of small to medium basement-cored uplifts, folds, thrust faults and two trends of strike-slip faults
  - The overall pattern of folds and faults is consistent with SW-NE compression.
  - This SW-NE compressive stress could not have originated from the northwestward convergence of the Ouachita-Marathon thrust belt southeast of the ARM, but may have originated either from the Pacific (by flat subduction) or from strong continental collision in the Appalachian Orogen.
  - Lines of weakness generated during the Proterozoic and/or Cambrian concentrated stress and created the complex structures.
- The West Texas branch of the ARM is buried by over 2.5 km of post-deformational Permian strata -- the Permian Basin.
  - Subsidence began during ARM deformation, then increased in rate and continued to the end of the Permian.
  - Permian subsidence resulted in the maintenance of the deep marine Midland and Delaware basins that were not filled in until Late Permian time.
  - These basins were only connected to the world ocean by narrow and relatively shallow straits. The subsiding basins were poorly oxygenated, and thus were able to accumulate great thicknesses of organic mudstone and other basinal sediment.
  - Despite Mesozoic basin-margin modifications to the east, south and southwest, the Permian subsidence shows a bowl-shaped pattern centered on the Central Basin axis of uplift.
  - This axis is the site of the Pecos mafic complex, which was subjected to compression in Pennsylvanian time. Sinking of a mafic crust or its subjacent lithosphere, begun during compression, may have been a driving force for Permian subsidence.
- The Permian subsidence was responsible for putting source rocks into the oil window in the Midland and northern Delaware basins. Further maturation to gas occurred within the deep basins generated by ARM deformation and Marathon thrust loading.

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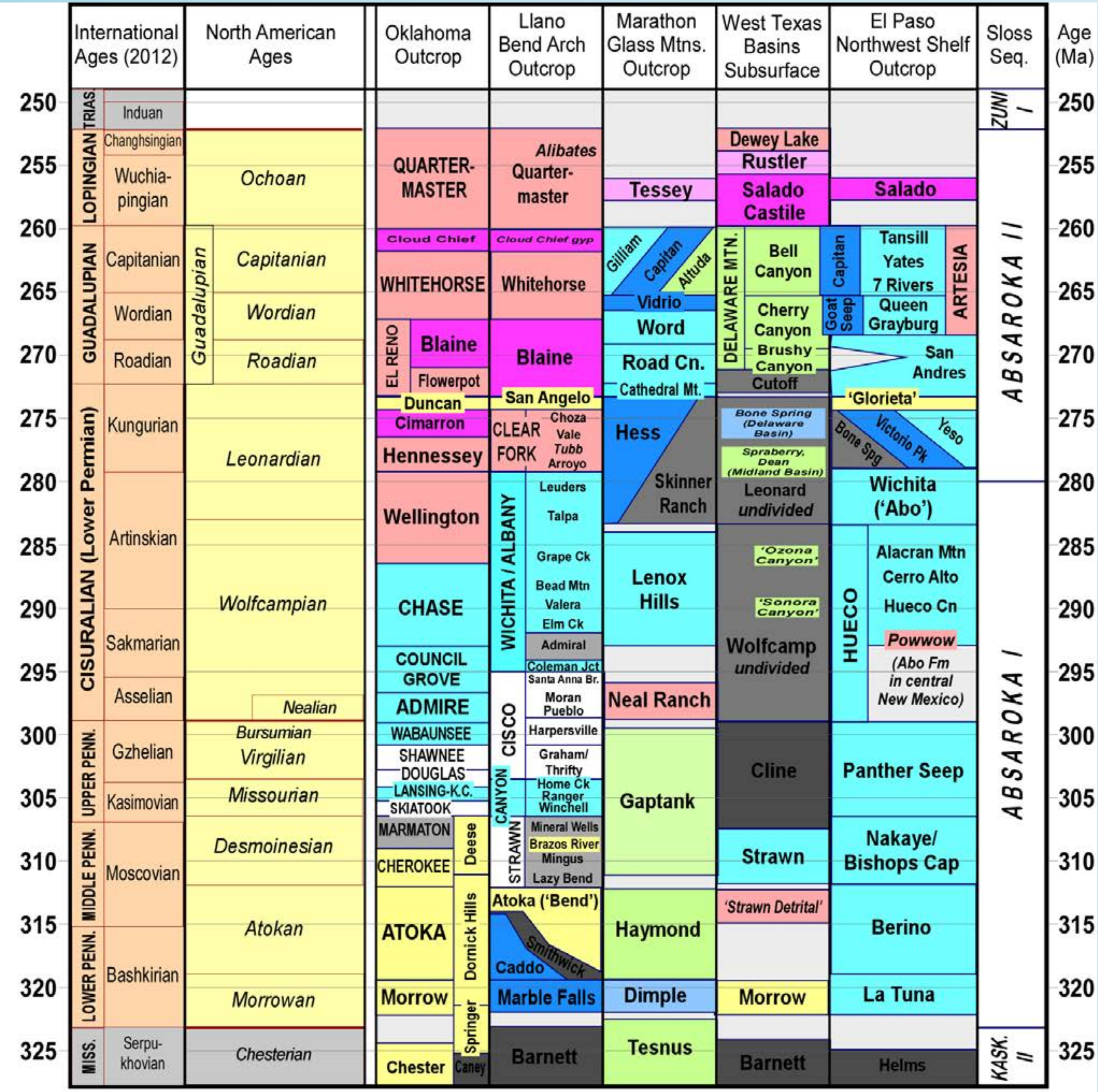
POSSIBLE CAMBRIAN FAULT TRENDS

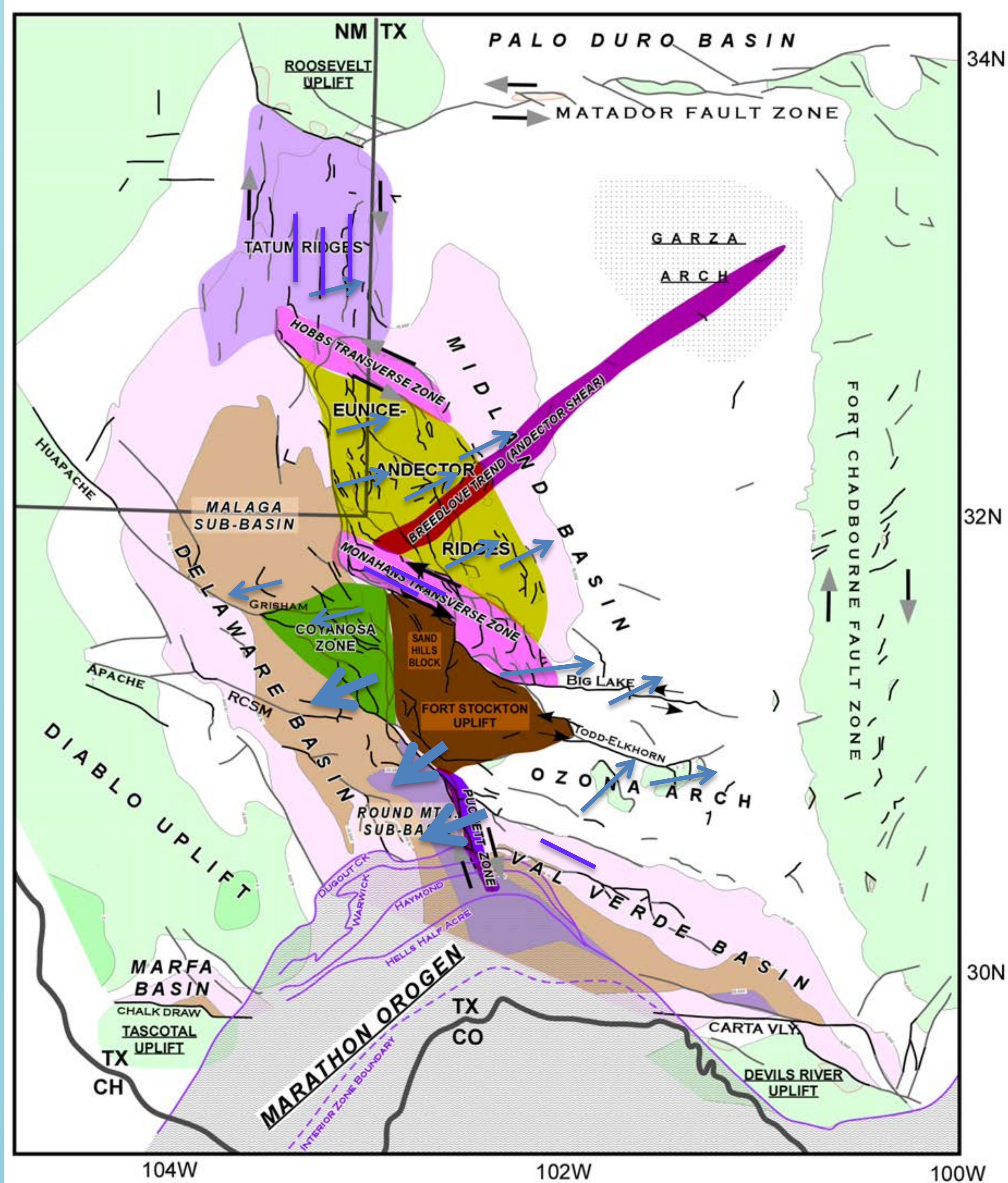


ROCKS AND TIME, LATE PALEOZOIC

Ewing, 2016

SCALE OF FEATURES AND DEPTH TO CRUSTAL DETACHMENT

- IF scale of basement-cored features related to depth to detachment (i.e., sled-runner)…
- Macroscale features imply upper-crust detachments (<20 km)
- Megascale uplifts imply whole-crust involvement
- Presence of BOTH scales implies a deep thrust of the CBA over Delaware, blind except at FSU



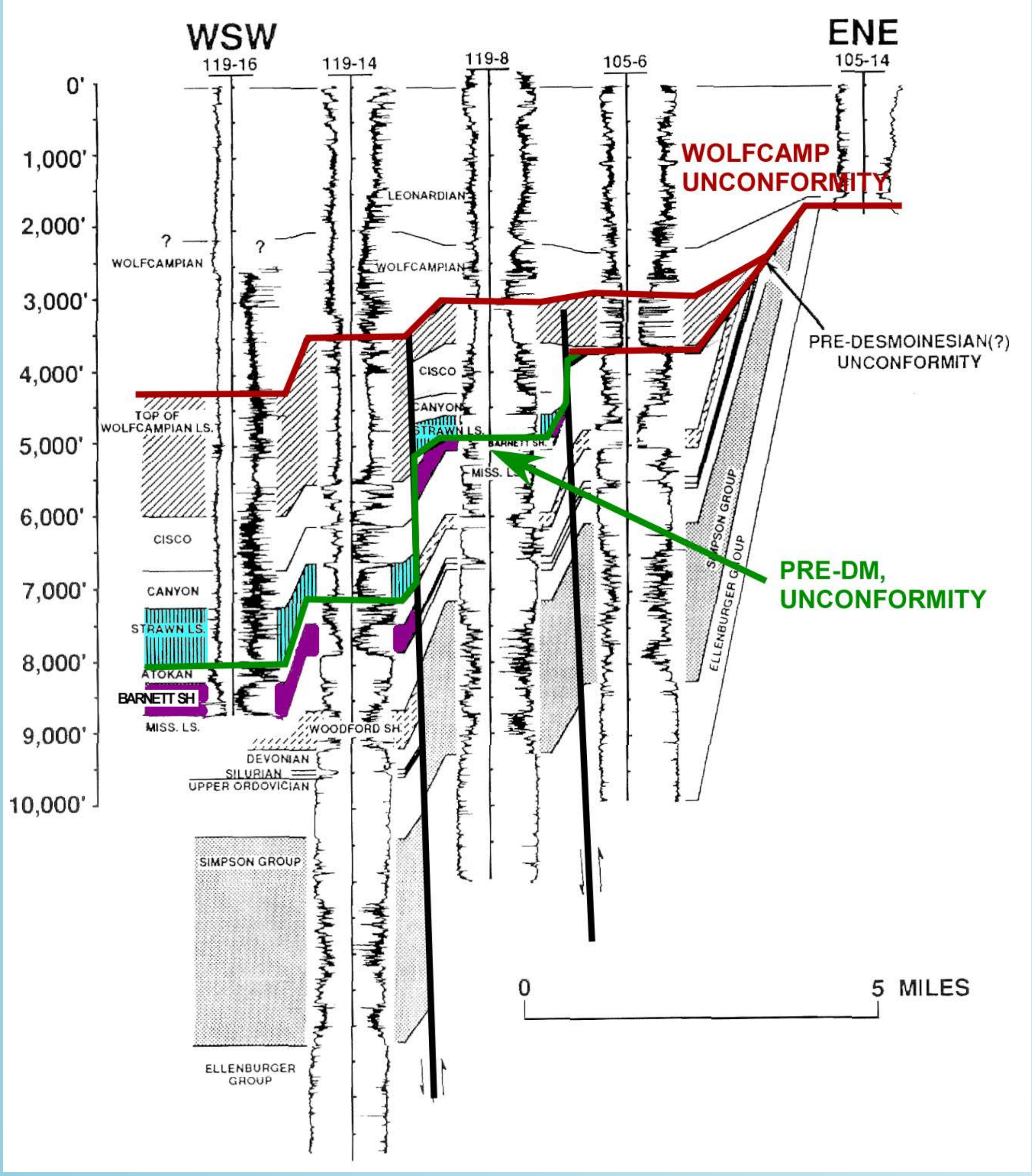
ARM IN WTB:

MACRO-SCALE DOMAINS:

Indicated sigma-1 for macroscale structures

TIMING OF DEFORMATION

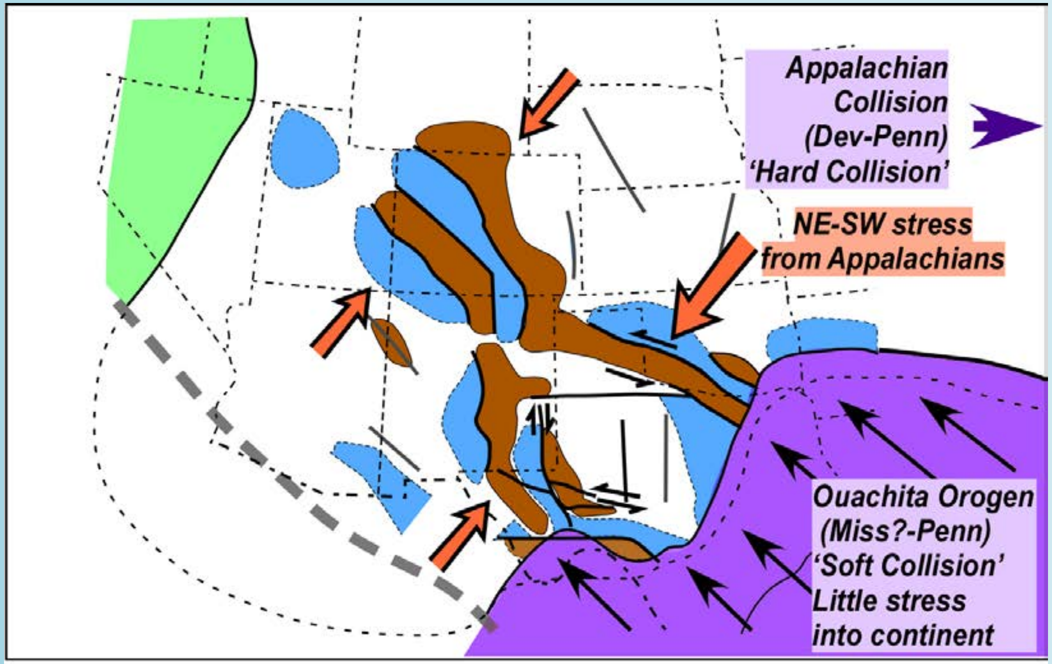
- Major unconformities pre-Strawn (Early Penn), mid-Wolfcamp (Early Permian)
- Most structures in central basin seem to be Wolfcamp, with prior activity likely
- Structures to NE, E, SE show earlier activity and are not reactivated in Wolfcamp
- No useful evidence for varying sigma-1

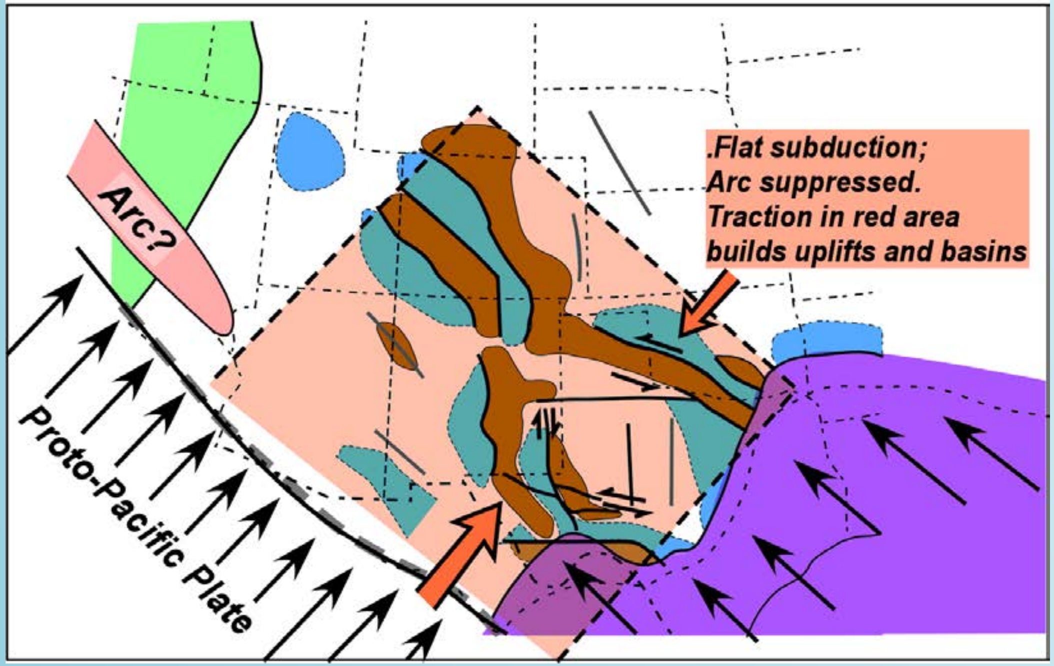


TWO UNCON-FORMITIES

Yang and Dorobek, 1995

MODELS FOR ARM DEFORMATION

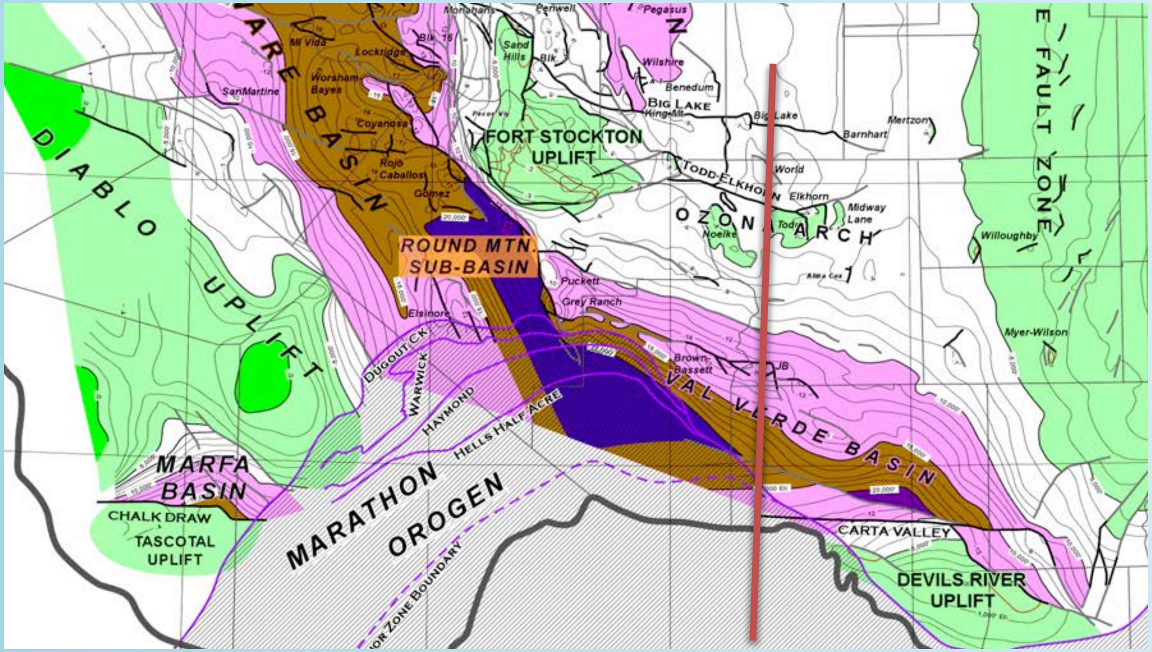




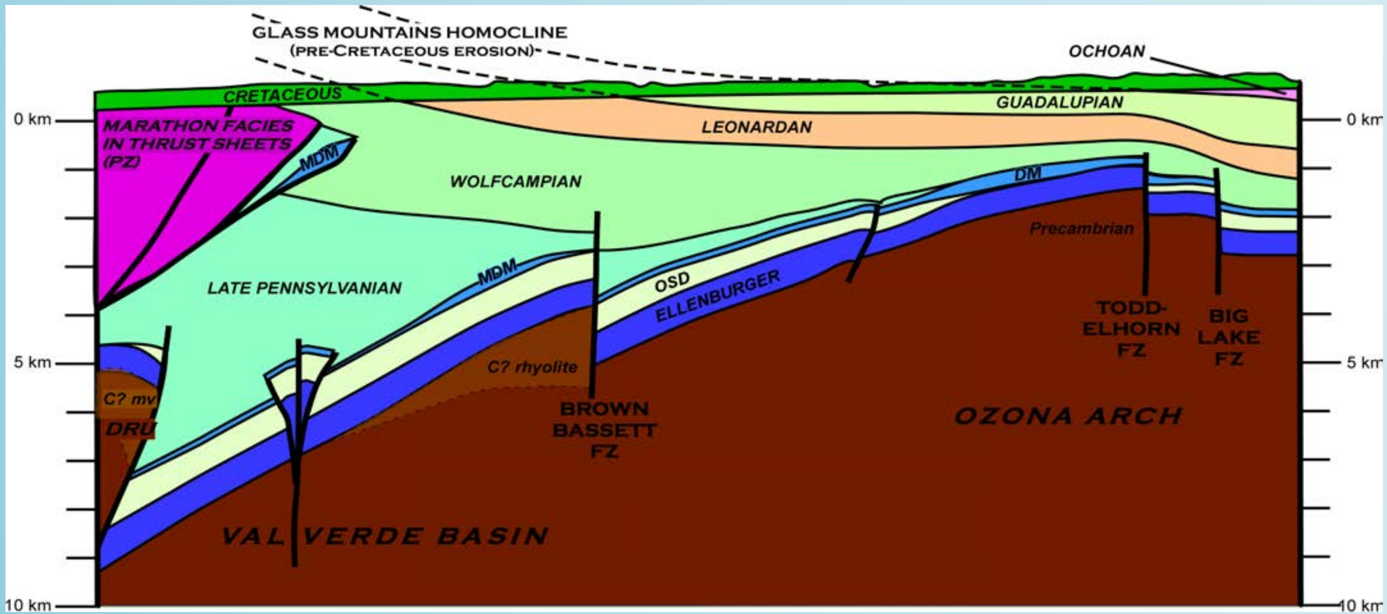
A) Far-field stress from Alpinotype collision in Appalachians; rotated to SW

B) Flat subduction of proto-Pacific plate to SW, analogous to Laramide basement-cored uplifts and basins

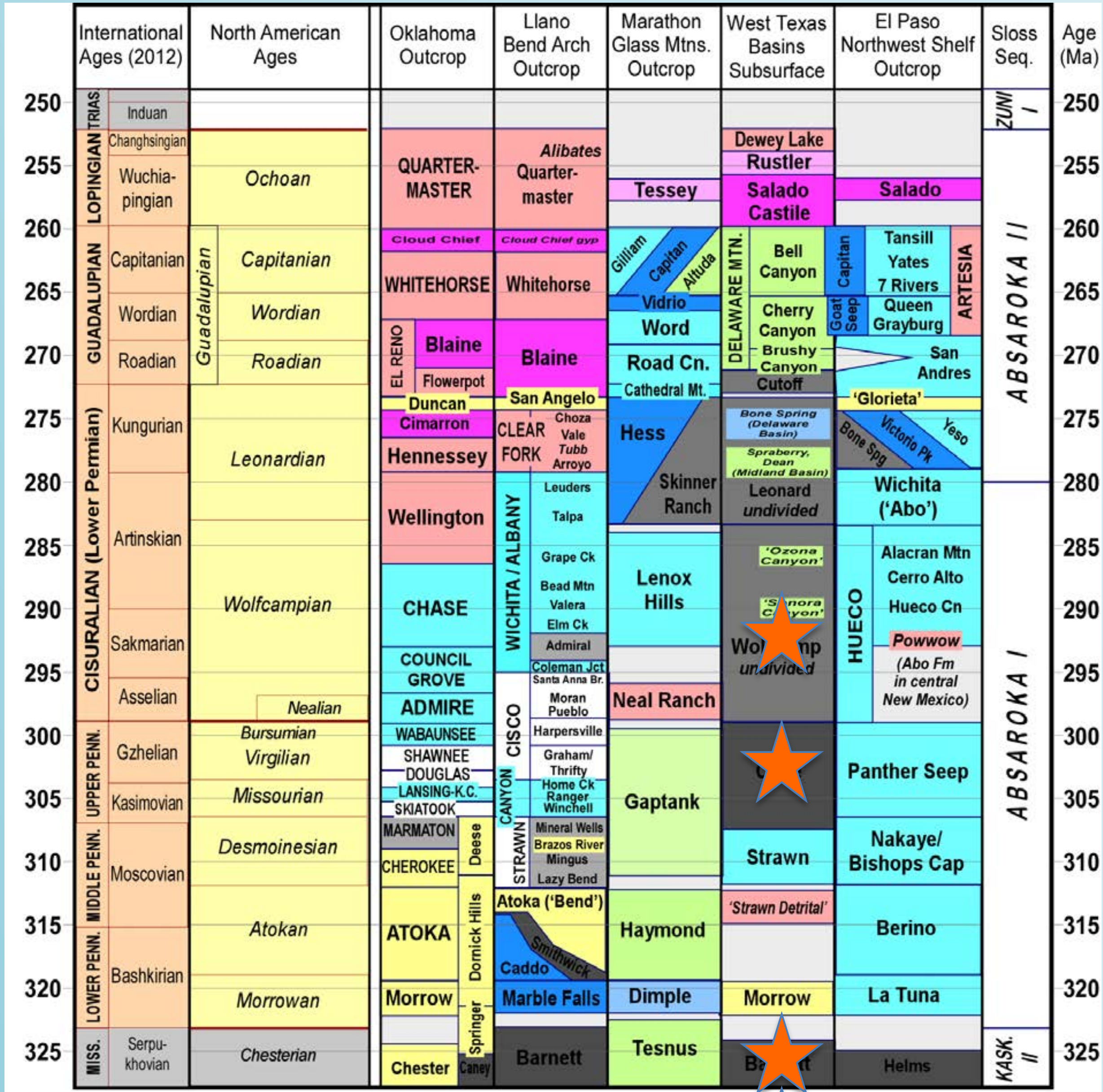
C) Recently proposed: transpression on SW margin leading to intraplate deformation



GLASS MTNS HOMOCLINE



SOURCE ROCKS IN TIME, WEST TEXAS BASIN



Ewing, 2016

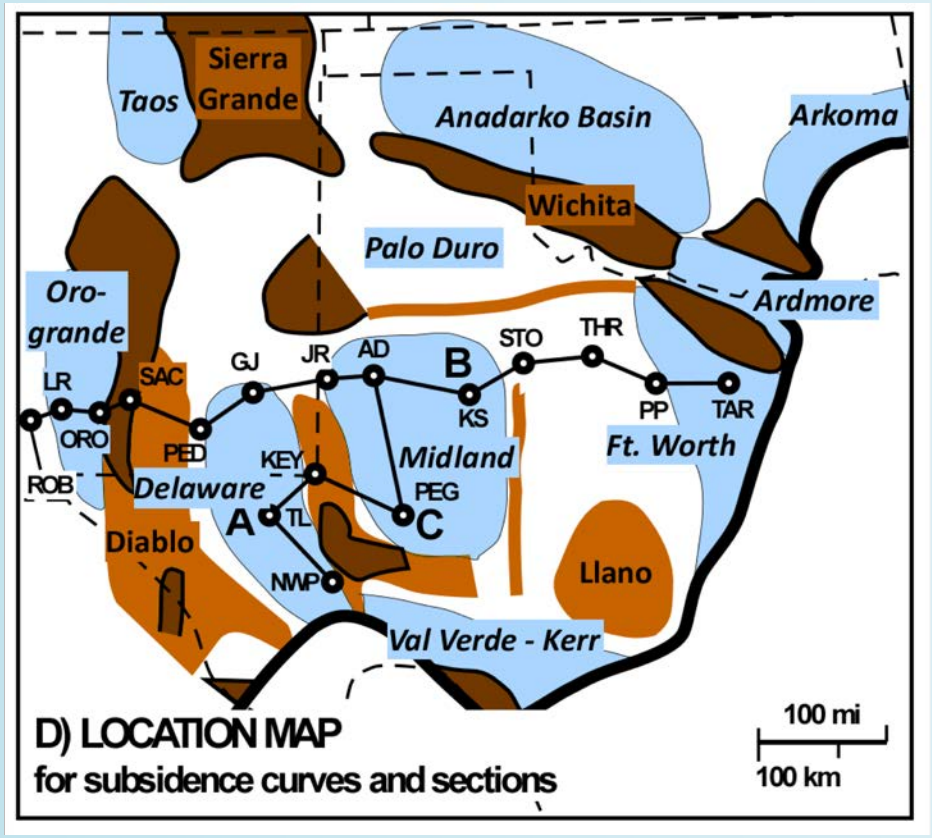
+Woodford (Dev), Simpson (Ord)

2D VIEW: CALCULATE TECTONIC SUBSIDENCE

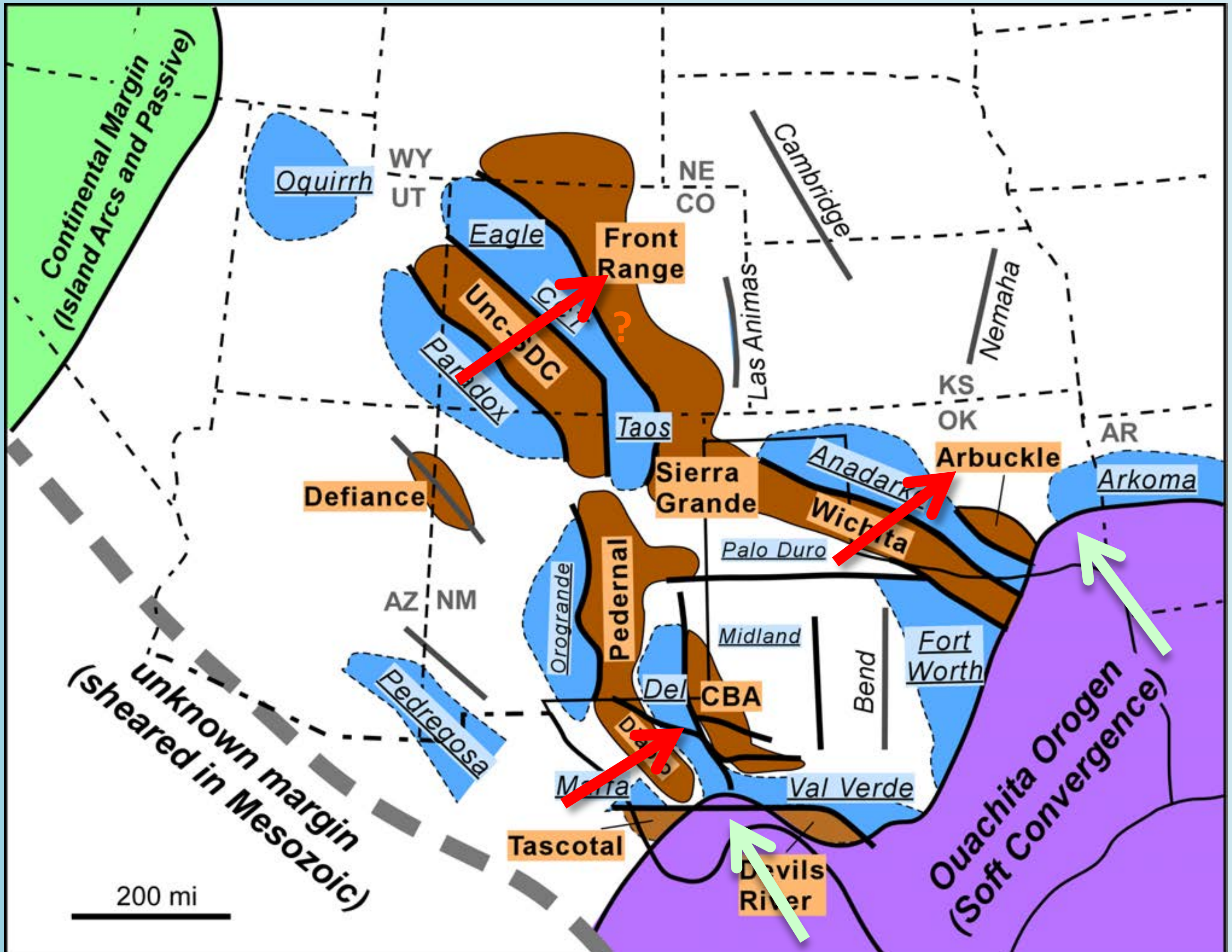
TECTONIC SUBSIDENCE –

Subsidence from 1D chart, corrected for the isostatic response to sediment loading;

attempts to show times and places where active tectonic processes are causing subsidence.



ARM VS OUACHITA OROGEN



Ouachita convergence to NW-NNW

Generates narrow foredeep basins (Arkoma, Ft Worth, Val Verde?)

Incompatible with ARM compression