Sedimentologic and Stratigraphic Effects of Episodic Structural Activity During the Phanerozoic in the Hugoton Embayment, Kansas USA

W. Lynn Watney[1], John Youle[2], Dennis Hedke[3], Paul Gerlach[4], Raymond Sorenson[5], Martin Dubois[6], Larry Nicholson[7], Thomas Hansen[10], David Koger[8], and Ralph Baker[9]

[1]Kansas Geological Survey, The University of Kansas, Lawrence, KS.
[2]Sunflower LLC, Longmont, CO. [3]Hedke-Saenger Geoscience, Ltd., Wichita, KS.
[4]Charter Consulting, Miramar, FL. [5]Consultant, Tulsa, OK. [6]Improved Hydrocarbon Recovery, LLC, Lawrence, KS. [7]Western Frontier Inc., Hanover, KS. [8]Koger Remote Sensing, Ft. Worth, TX. [9]Consultant, Houston, TX. [10]Bittersweet Energy, Inc., Wichita, KS.

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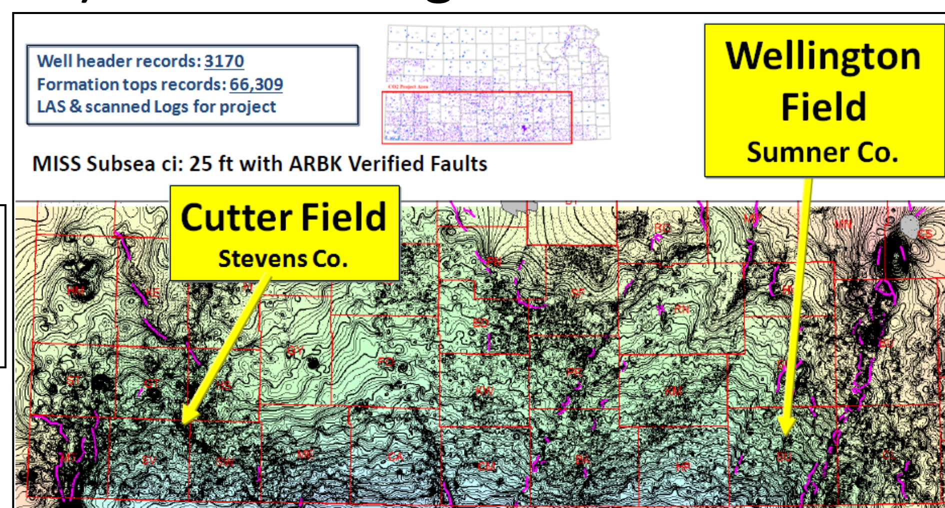
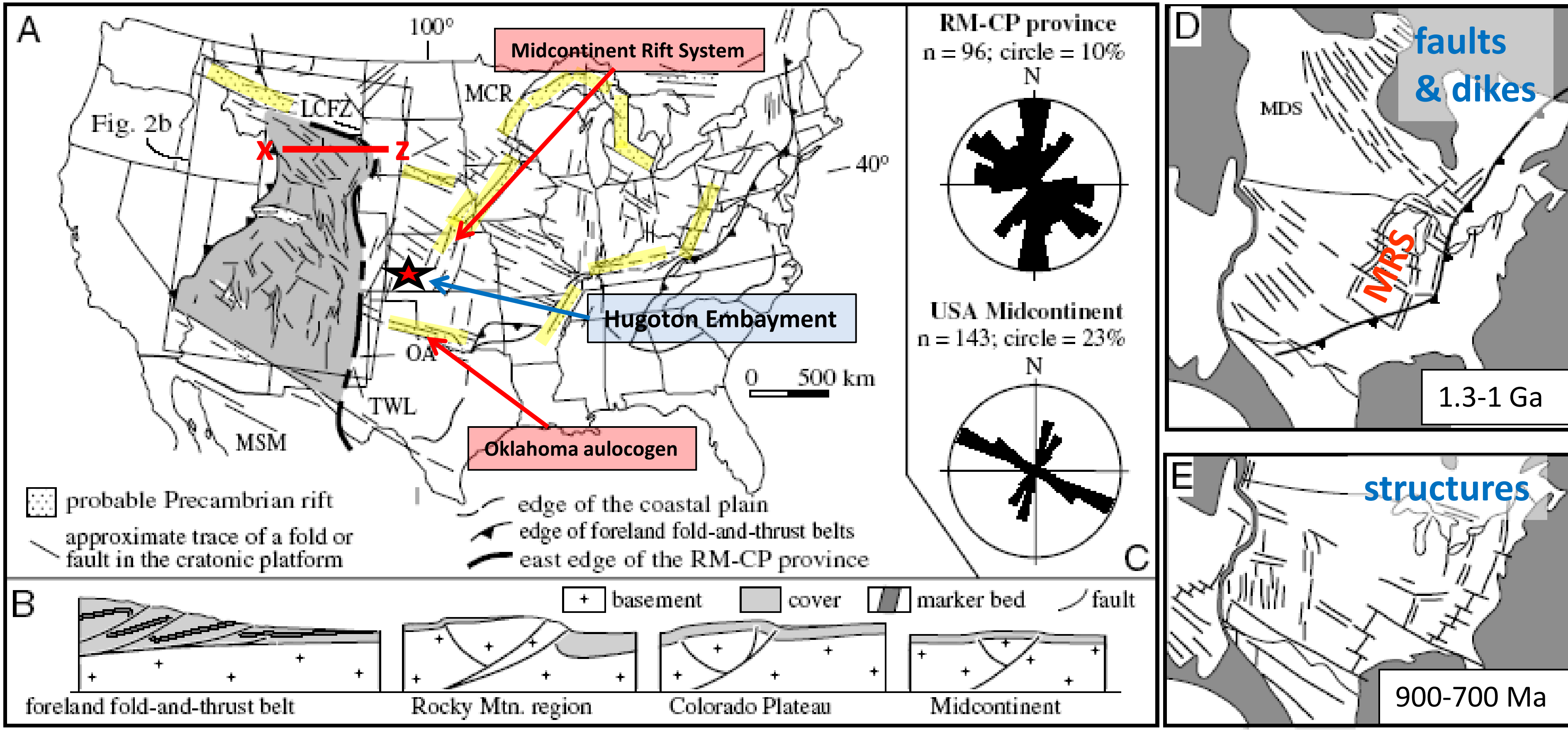
Outline

- **Anadarko Basin** – Proterozoic extension to Phanerozoic compression
- **Hugoton Embayment (HE)** – 10,000 km^2 northern extension of Anadarko Basin
- **Major structures in the HE –** prominent evidence of compressional reactivation along basement lineaments
- **Episodic structural movement** – post tectonic movement affecting sedimentation/stratigraphy throughout Phanerozoic
- **Pattern of deformation** – strongly influenced by basement weaknesses (the template) and evolving stress field
- **Summary**



Extensional faults and folds dominated the cratonic platform during the Proterozoic

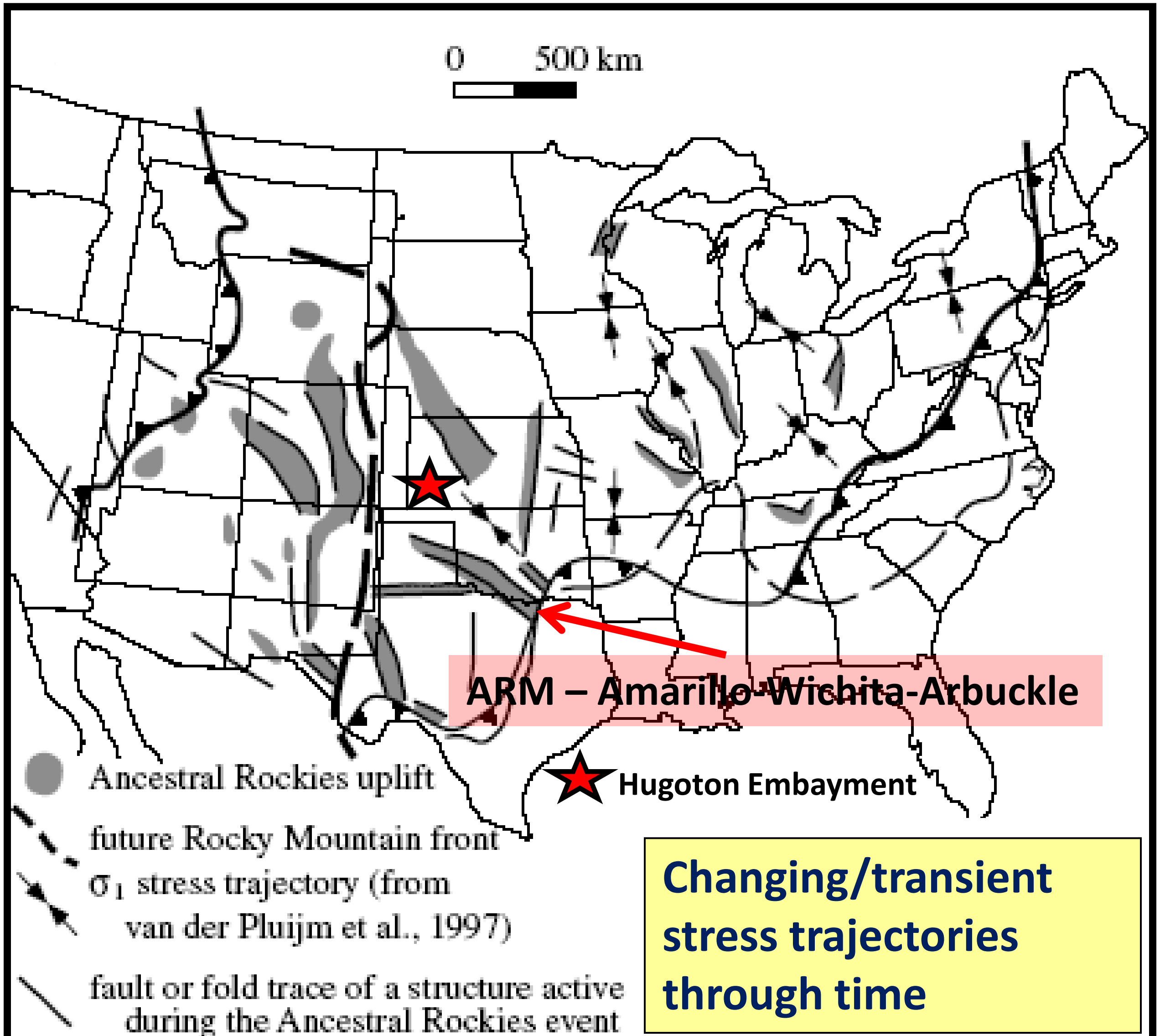


- **Two dominant directions of extensional structures in Proterozoic**
- **Faults reactivated during Phanerozoic compressional orogenies (Kluth and Coney, 1981)**
- **Inversion of once normal faults leading to *reverse & oblique-slip***

Marshak, Karlstrom, and Timmons (2000)

Ancestral Rockies Structures

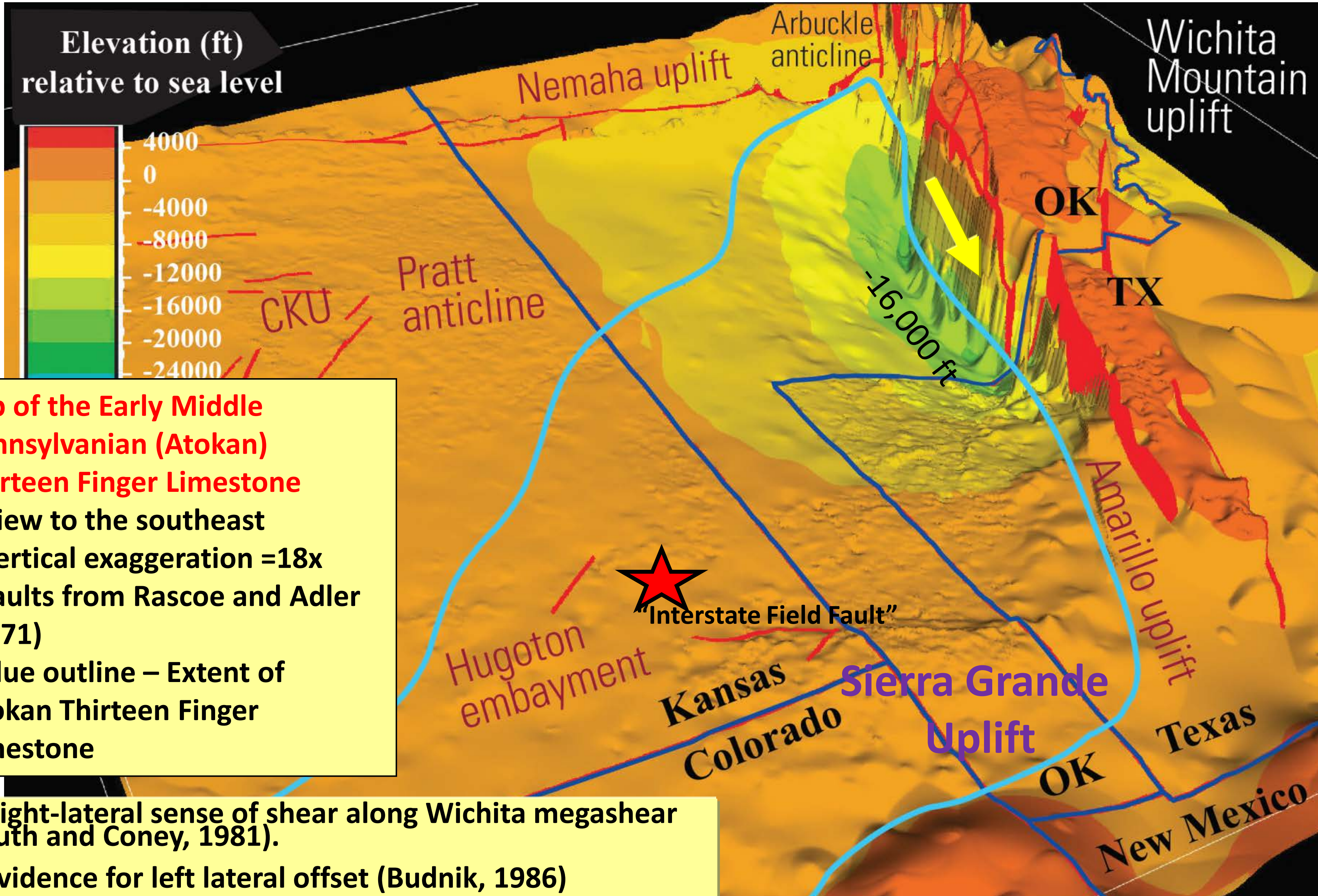
Early Chesterian - Late Leonardian deformation



Marshak, Karlstrom, and Timmons (2000)
Ages from Dickinson and Lawton (2003)

Intraplate fault reactivation is mainly dependent on orientation of (weak) fault zones relative to plate margin… deformation in interior can be represented by simple rheological models (van der Pluijm et al., 1997)

Prominent Tectonism during Morrowan and Atokan time



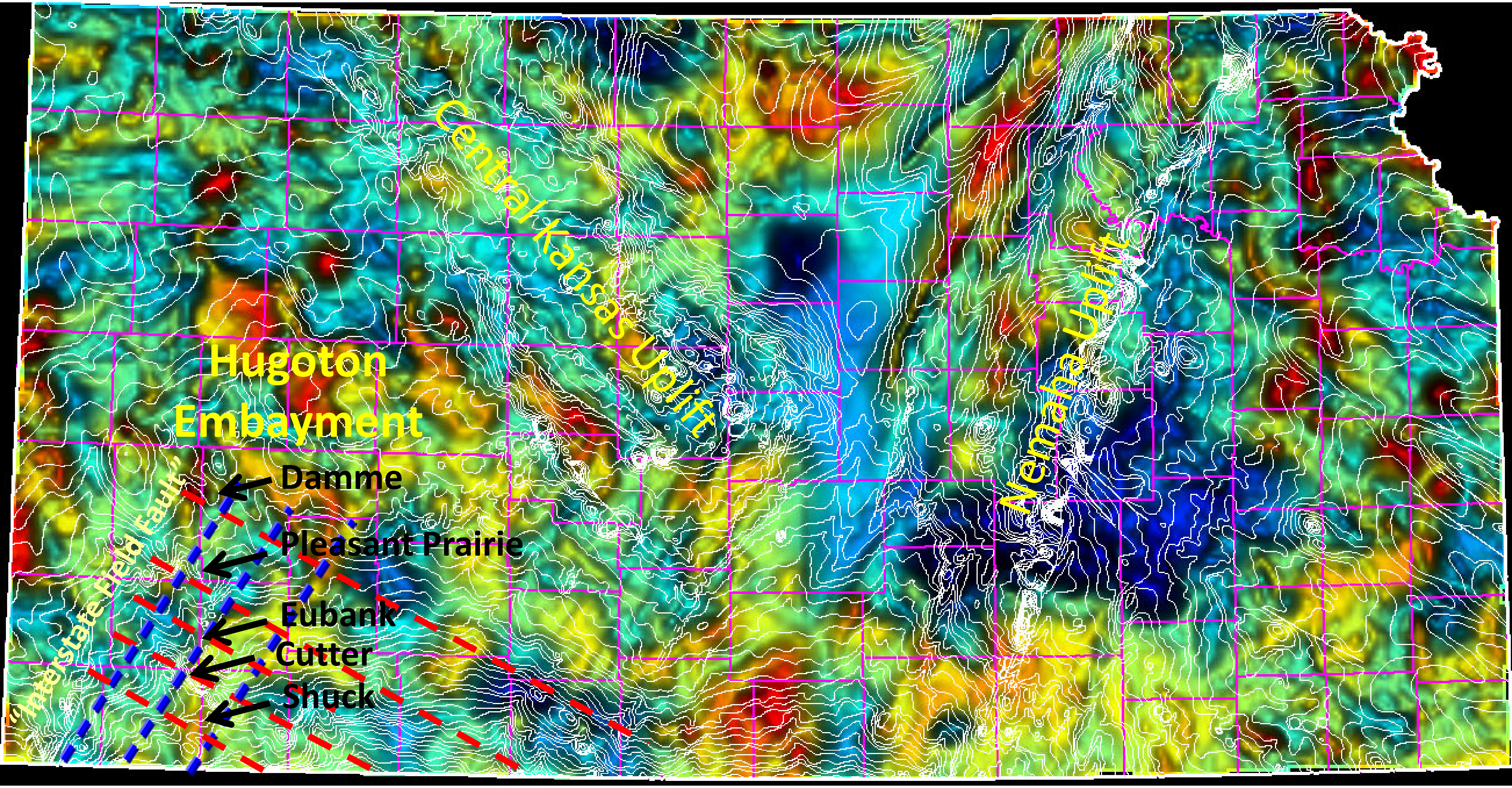
Top of the Early Middle Pennsylvanian (Atokan) Thirteen Finger Limestone

- **View to the southeast**
- **Vertical exaggeration =18x**
- **Faults from Rascoe and Adler (1971)**
- **Blue outline – Extent of Atokan Thirteen Finger Limestone**

- **Right-lateral sense of shear along Wichita megashear (Kluth and Coney, 1981).**
- **Evidence for left lateral offset (Budnik, 1986)**
- **Palinspastic restoration oblique slip (left reverse slip) on the uplift bounding faults (McConnell, 1989)**

(Higley, 2011)

Strong correlation between many Proterozoic structures exemplified by magnetic field and Phanerozoic structures



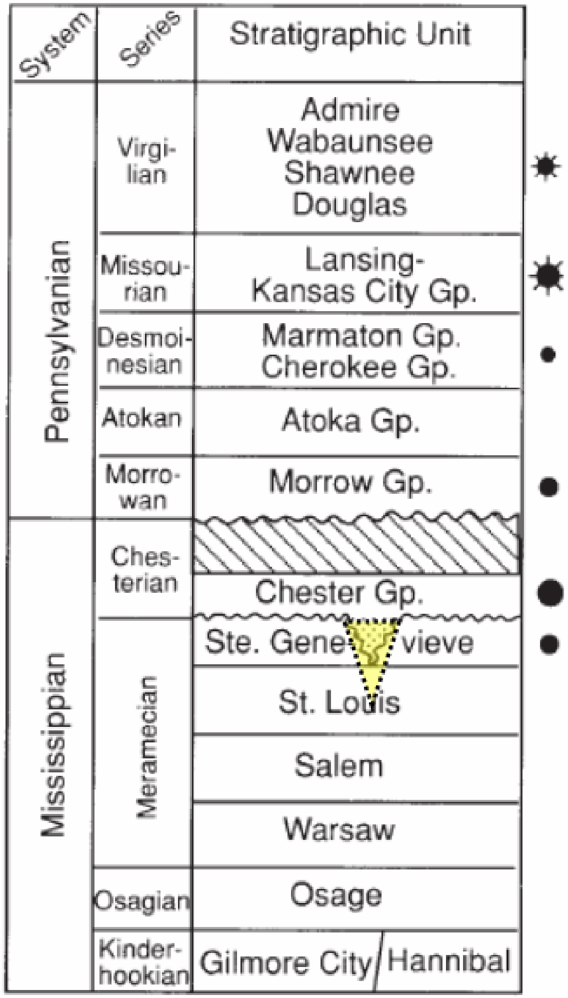
Total Intensity of Magnetic Field Reduced to Pole overlain with configuration of Precambrian surface

- **Very close correspondence of Phanerozoic structures to magnetic anomalies**
- **Local and subregional changes in strike and dip appear to closely correlate to magnetic map**
- **Major influence on lithofacies distribution and characteristics of sequences**

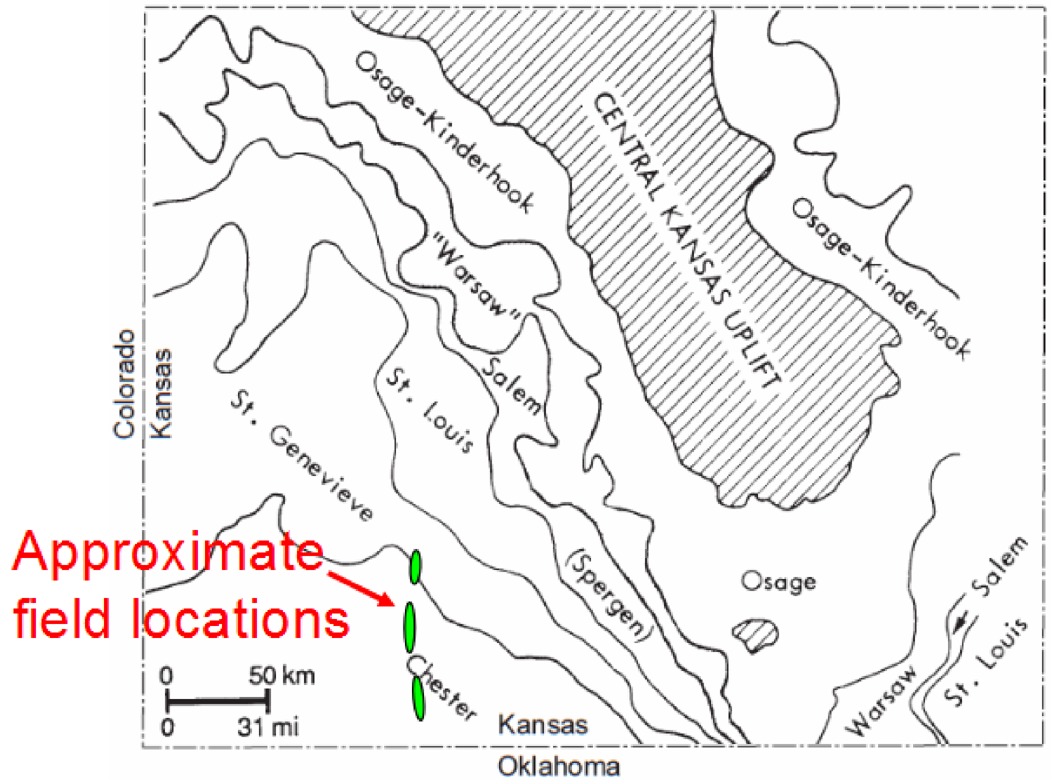
50 mi

(Cole, 1976; Kruger, 1999)

Stratigraphic setting



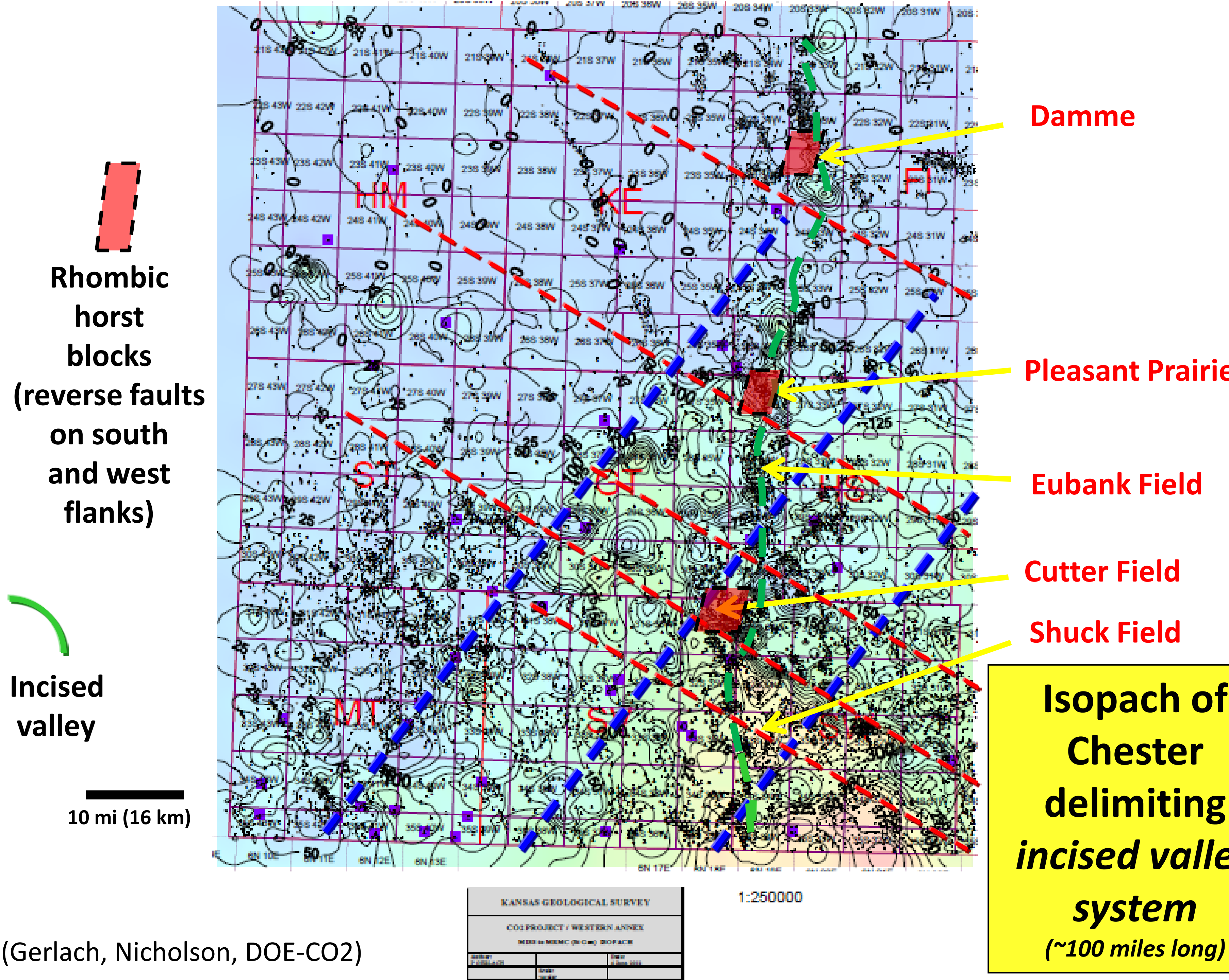
Generalized stratigraphic column (Montgomery and Morrison, 1999).



Subcrop pattern for Mississippian strata, western Kansas (Ebanks, 1991).

Valley incision took place during exposure of the Meramecian. Subsequent Chesterian transgression, punctuated by still-stands filled the narrow, nearly linear valley with fine-grained reservoir sand.

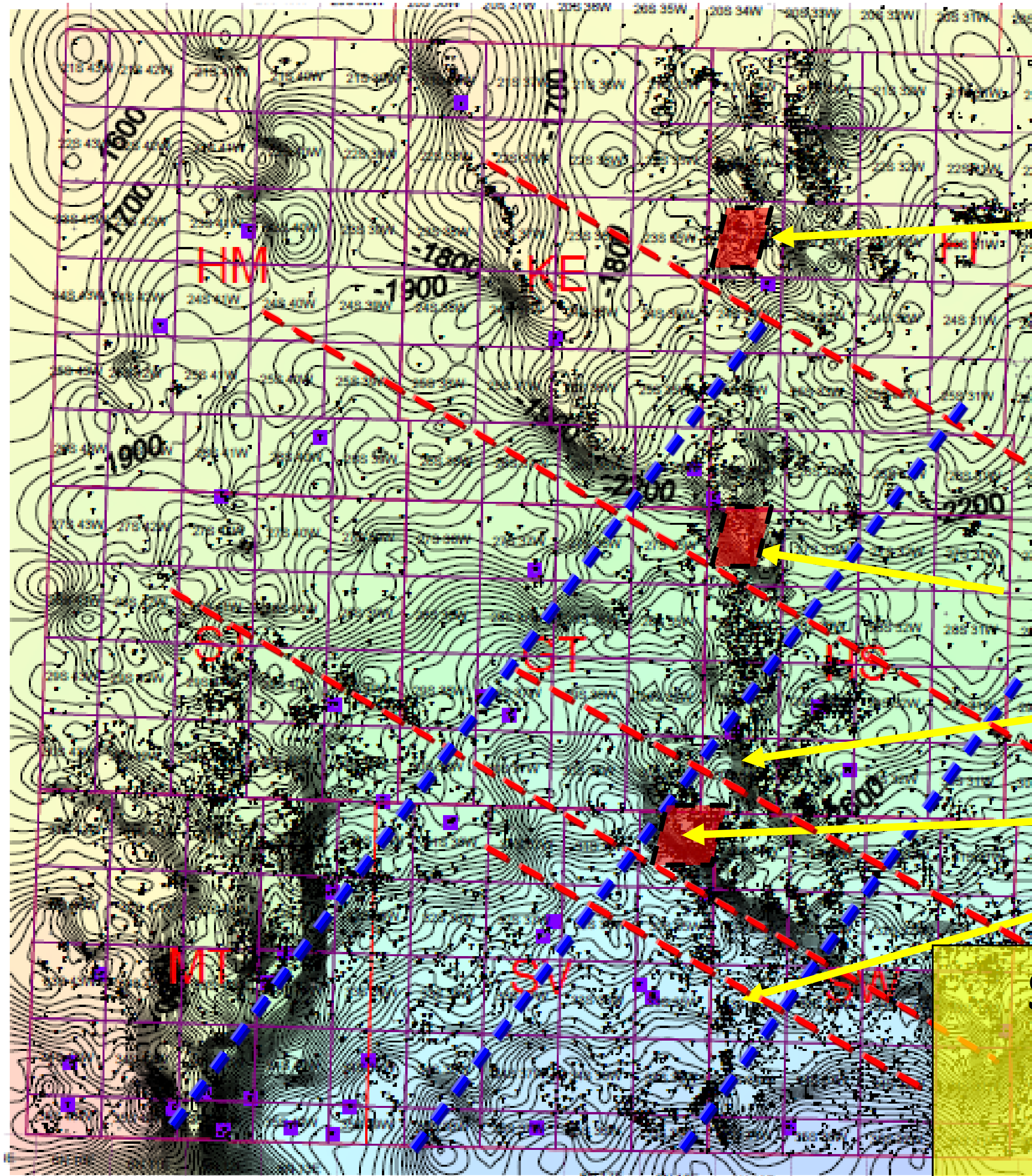
Dubois (2013)



Isopach of Chester delimiting *incised valley system*

(~100 miles long)

(Gerlach, Nicholson, DOE-CO2)



Structure Top Meramec Mississippian

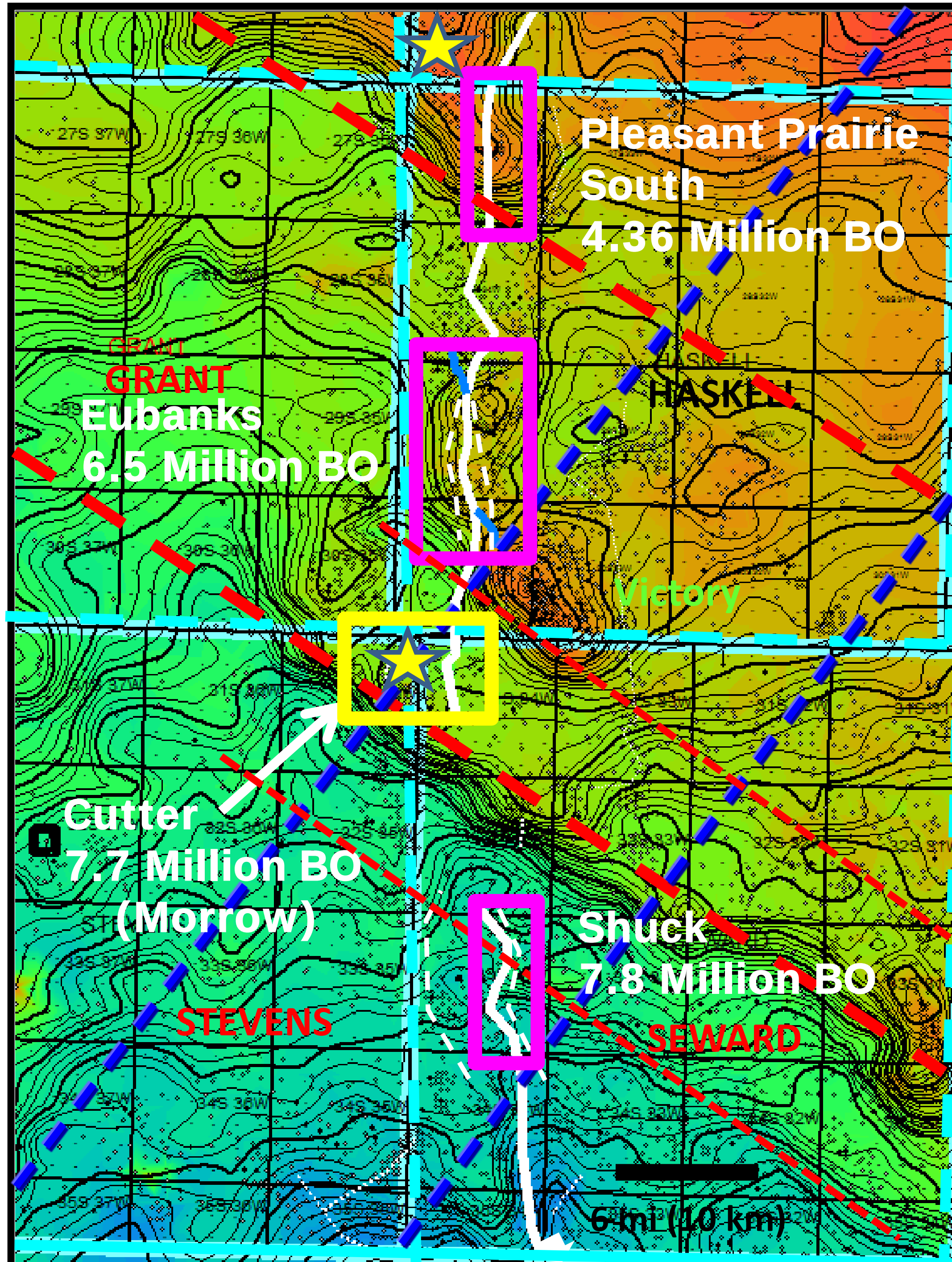
Horst with faulted southwest and west flanks

(Gerlach, Nicholson, DOE-CO2)

Chester valley incision and fill predated post-Mississippian – pre-Middle Pennsylvanian Ouachita related structural events

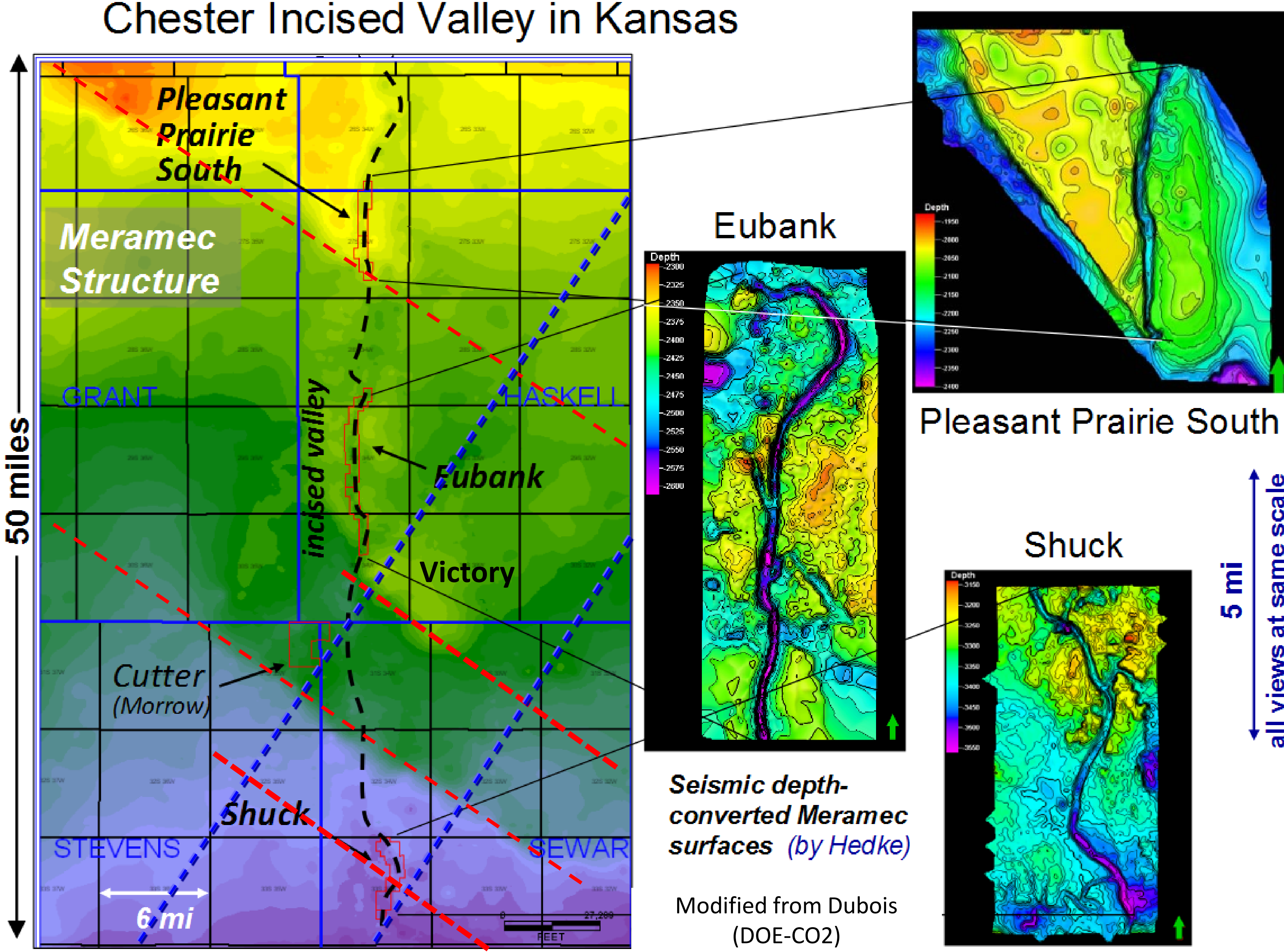
- However, traps in valley fill sand pools were sprung by Ouachita events.
- No channel deflection around features.
- Ubiquitous fractures in Chester IVF cores.
- Antecendent paleogeomorphology controlling valley location is discussed in context of more subtle structural deformation

- **Subsea structure on top of Mississippian Meramec** (Ste. Gen. in most of the area). 25' C.I. (smoothed)
- Chester incised valley axis shown as white line.
- Chester valley fill fields located within pink rectangles.
- **Horst blocks** at Cutter, Victory, Eubank, and Pleasant Prairie are faulted on south and west flanks
- **Horst blocks** on north sides of regional NW-trending lineaments



Youle (DOE-CO2)

Chester Incised Valley in Kansas



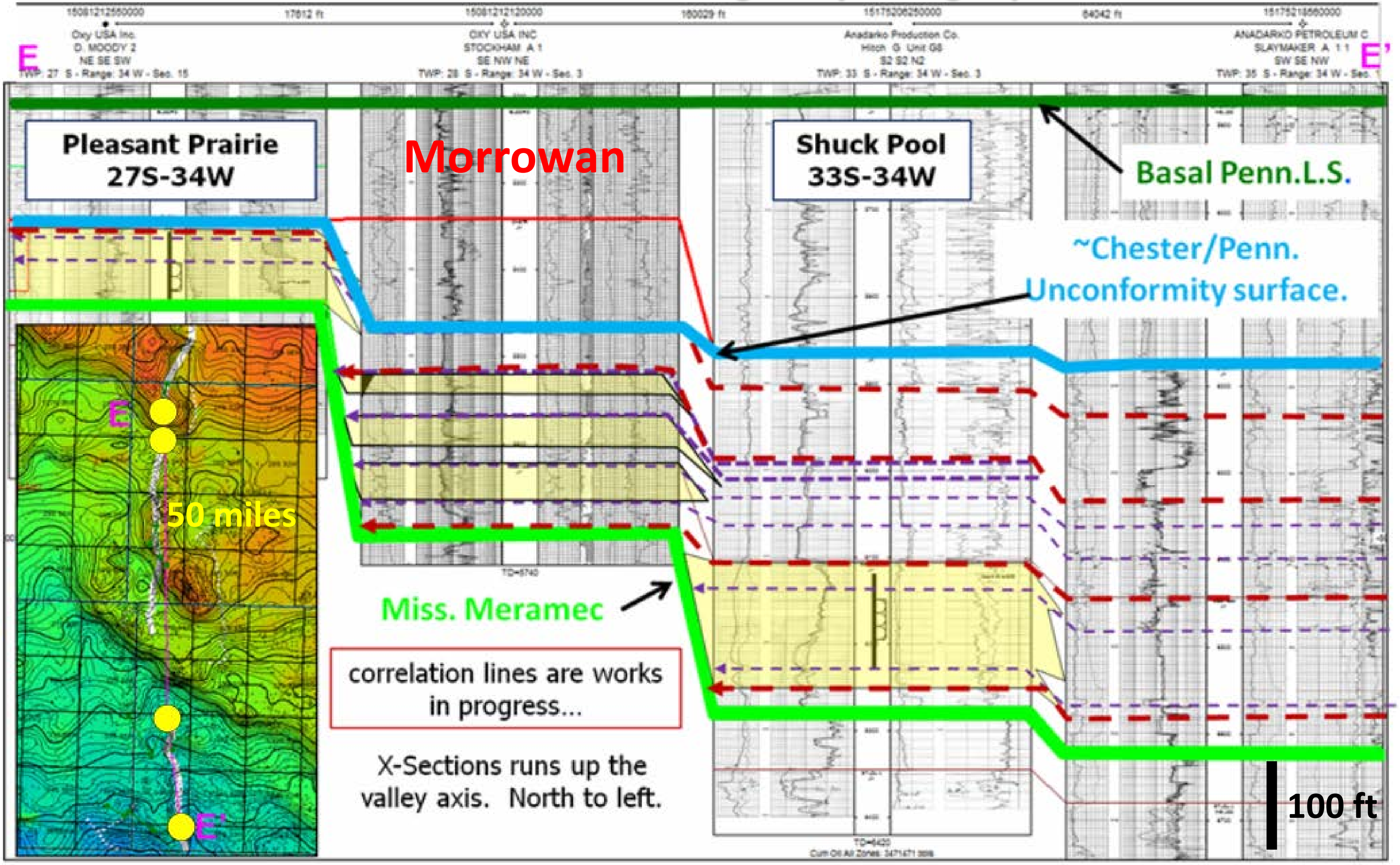
Seismic depth-converted Meramec surfaces (by Hedke)

Modified from Dubois (DOE-CO2)

Chester Sequence Stratigraphy

North

Stuctural influence of fall lines along valley during deposition?

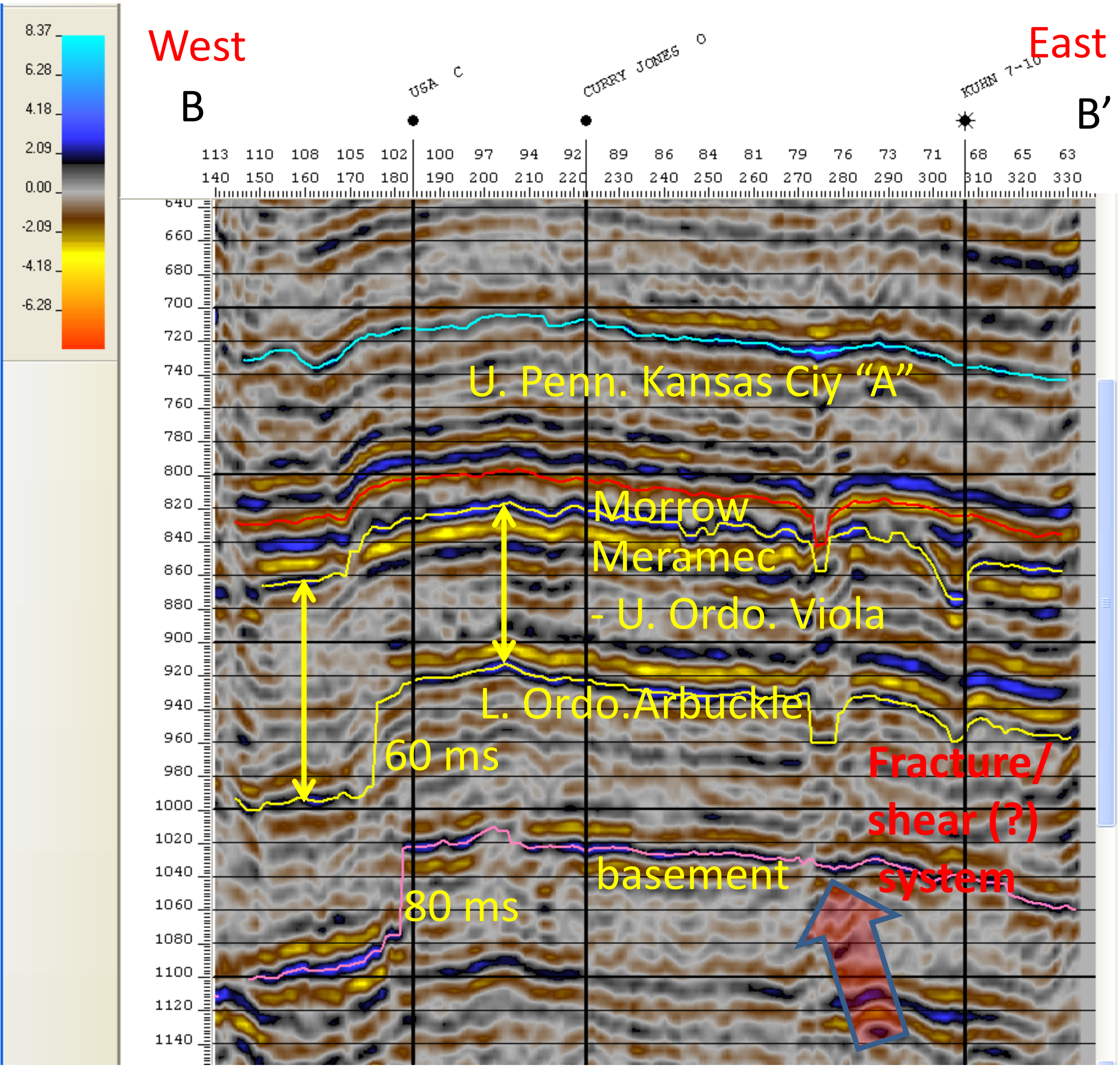


work by John Youle

The cyclic retrogradational nature of Chester shoreline advances into Kansas are interpreted to have filled incised valleys with a series of 'back-stepping' stacked estuarine sandstone reservoirs. Red dashed lines are postulated sequence boundaries, and purple lines are possible parasequences. *(Youle)*

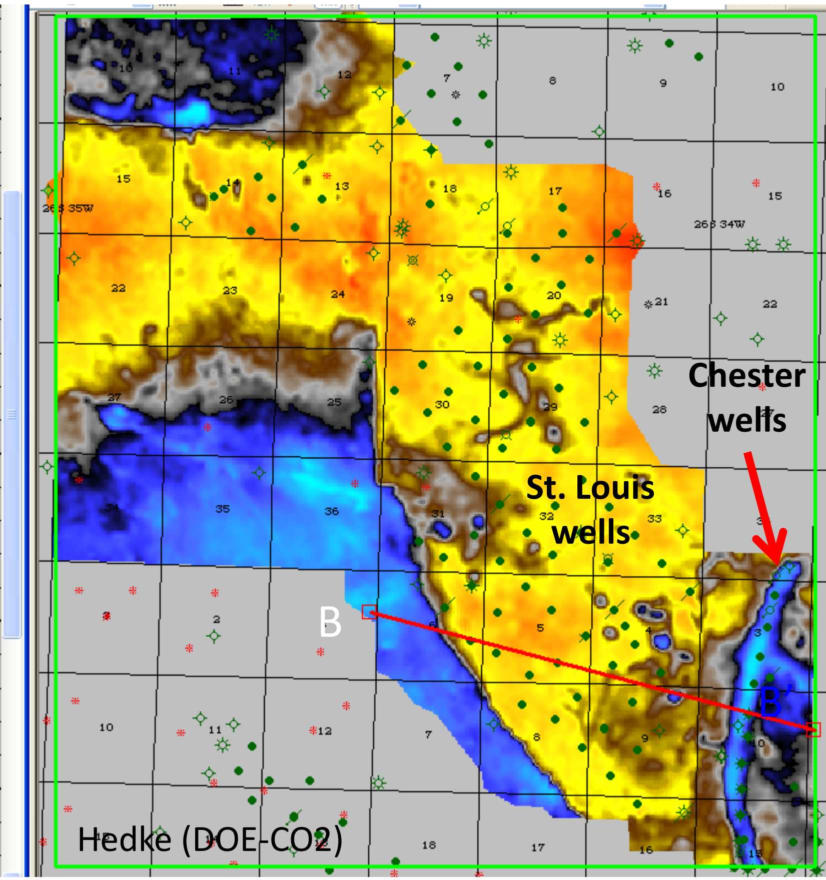
55% expansion of the Mississippian-to-Upper Ordovician Viola Limestone interval across major fault

-- Chester incised valley coincide with location of N-NE fracture set



Arbitrary Time Profile B-B', W – E

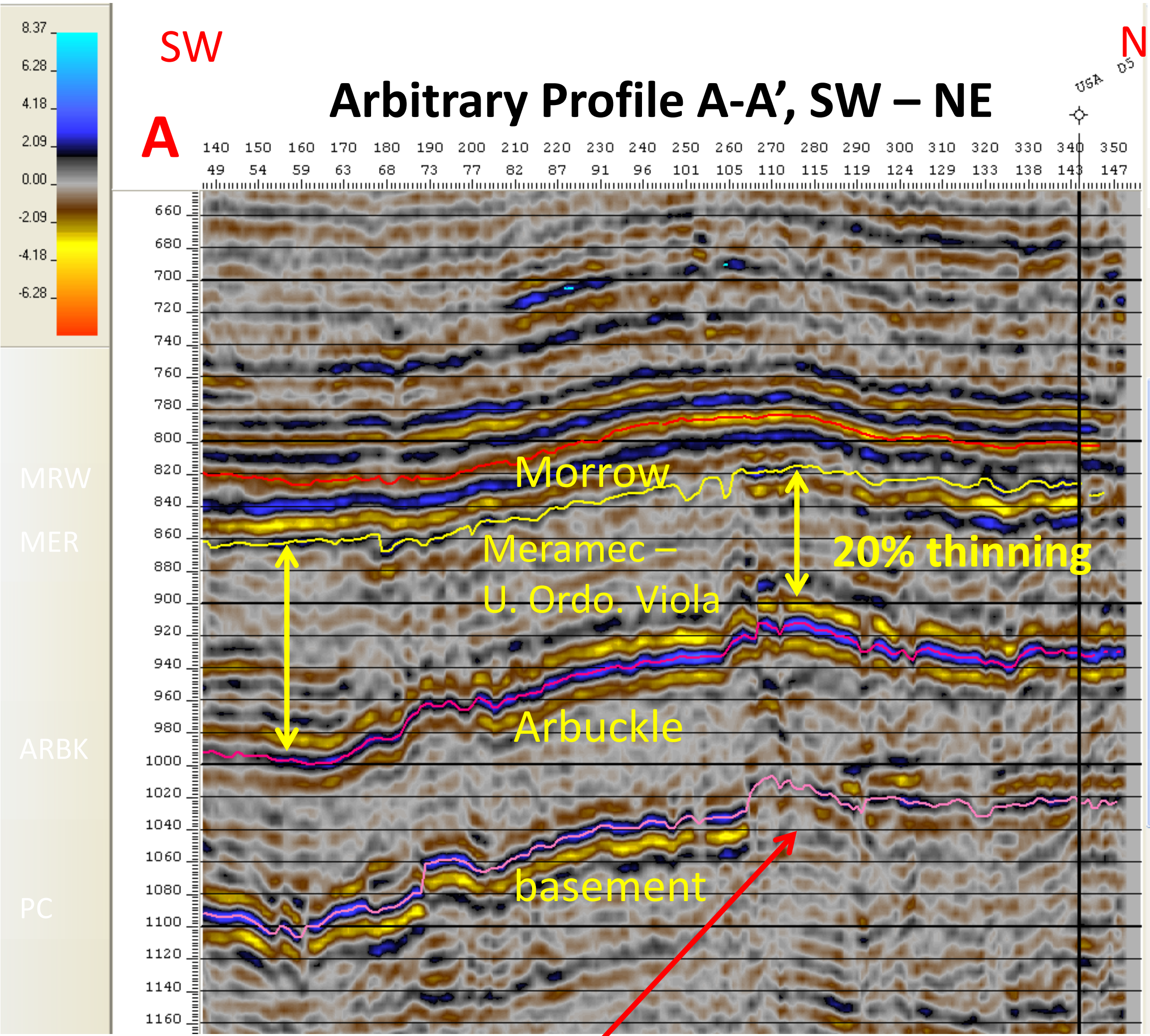
Disrupted beds within the St. Louis interval that are suggestive of karst collapse.

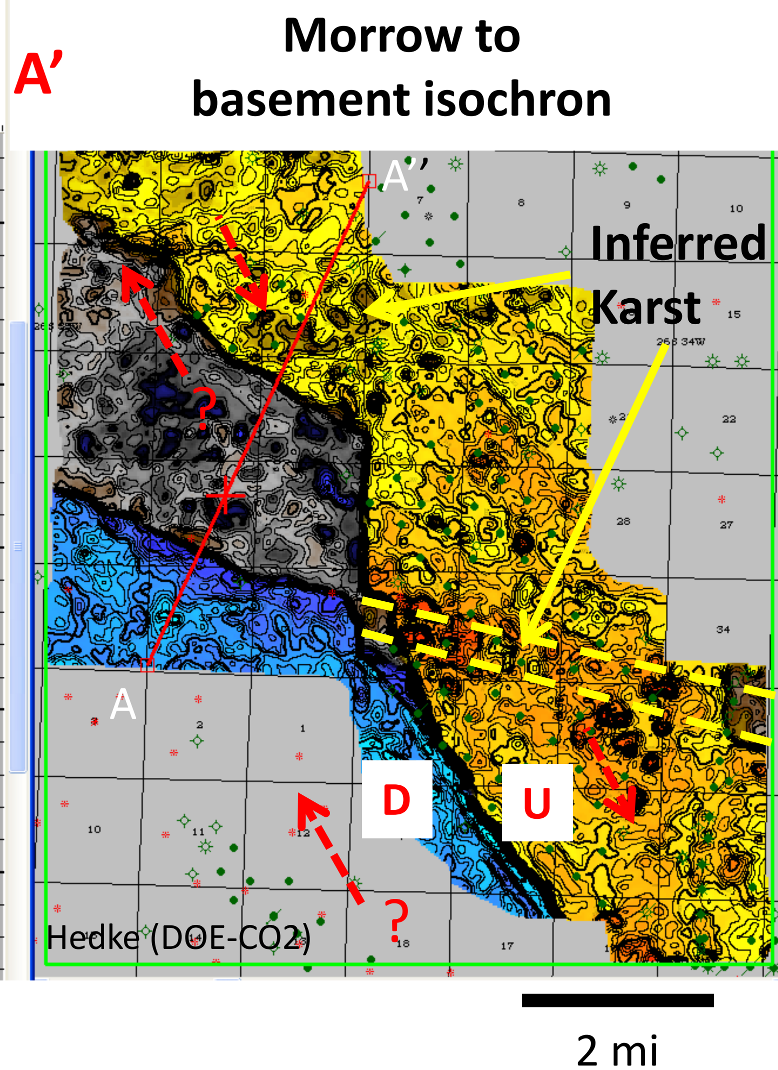


Meramec Time Structure Pleasant Prairie Field

Pleasant Prairie structural block

orientation of faults suggest right lateral component of faulting along a restraining bend



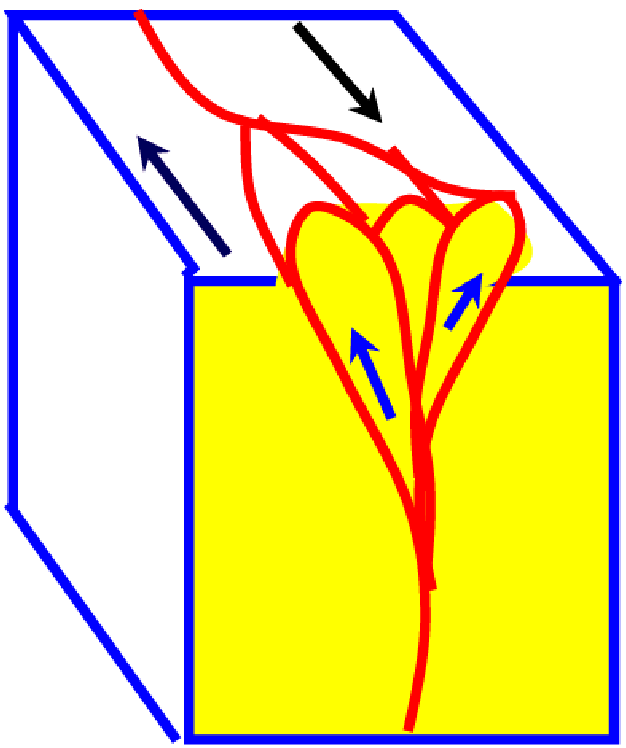


Flower structure
Right lateral fault?

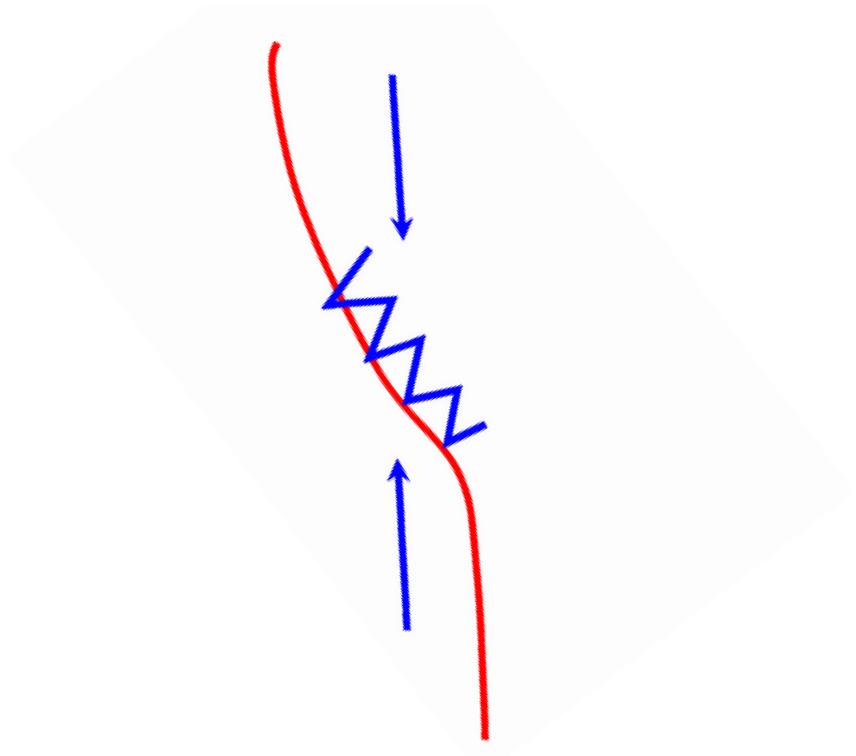
(left)
&

Strike-Slip Faults – flower structures & restraining bends

Flower Structures
Positive (Palm Tree) → Transpression
Right lateral



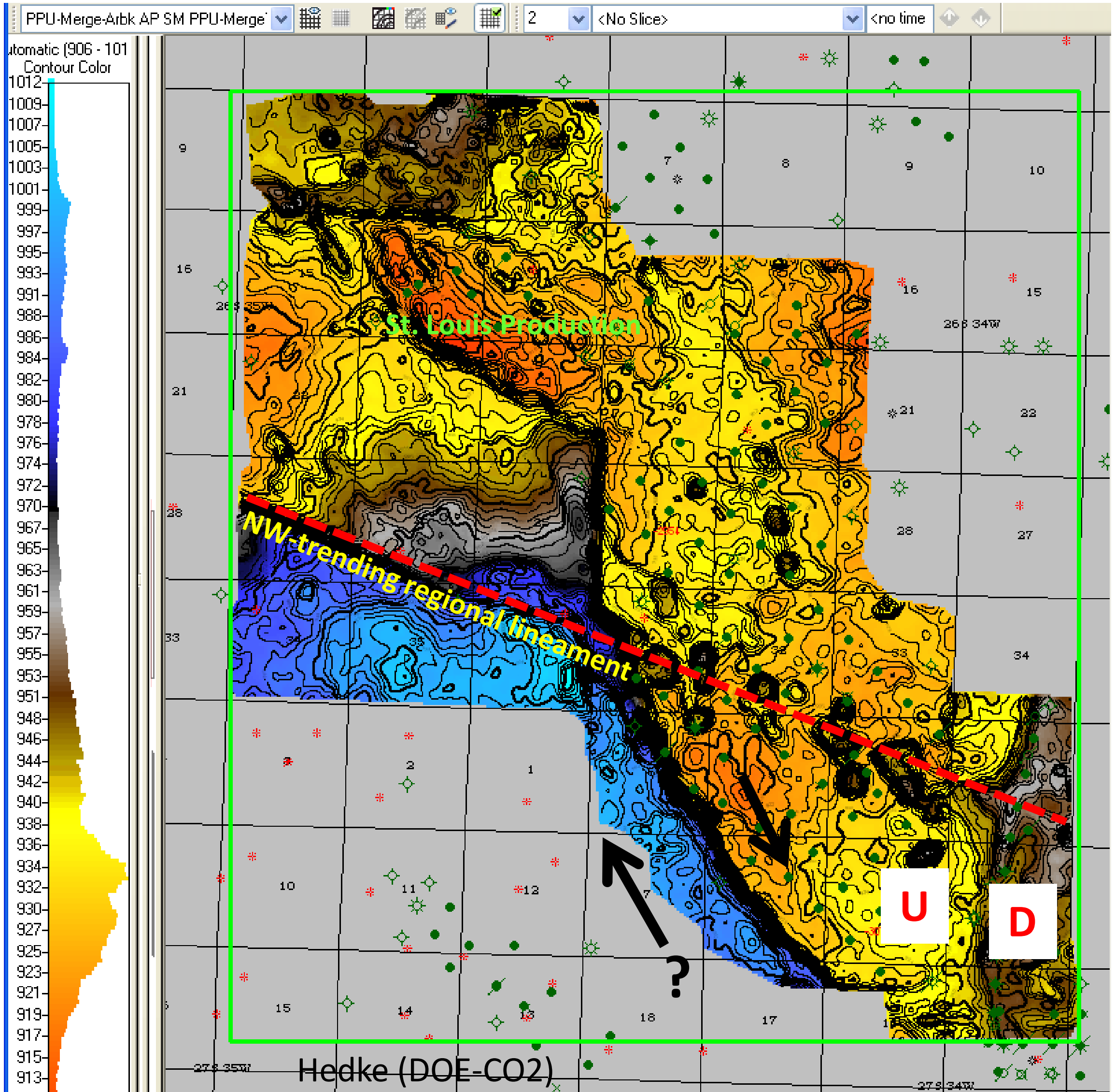
Restraining Bends-
transpressional zones
occurring at fault bends
Push Up Ridges



Modified from http://www4.uwsp.edu/geo/faculty/hefferan/geol320/strikeslip.html

Fault bounded orthogonal structural block

paleo Arbuckle karst (Ordovician in age) and Meramec karst developed along regional NW-trending lineament



Arbuckle Time Structure (Pleasant Prairie Field)

- Meramec age karst define partly define location of Chester incised valley
- Intersecting with NW-trending Arbuckle karst trend with north-trending fault corresponding with location of Chester IVF

2 mi

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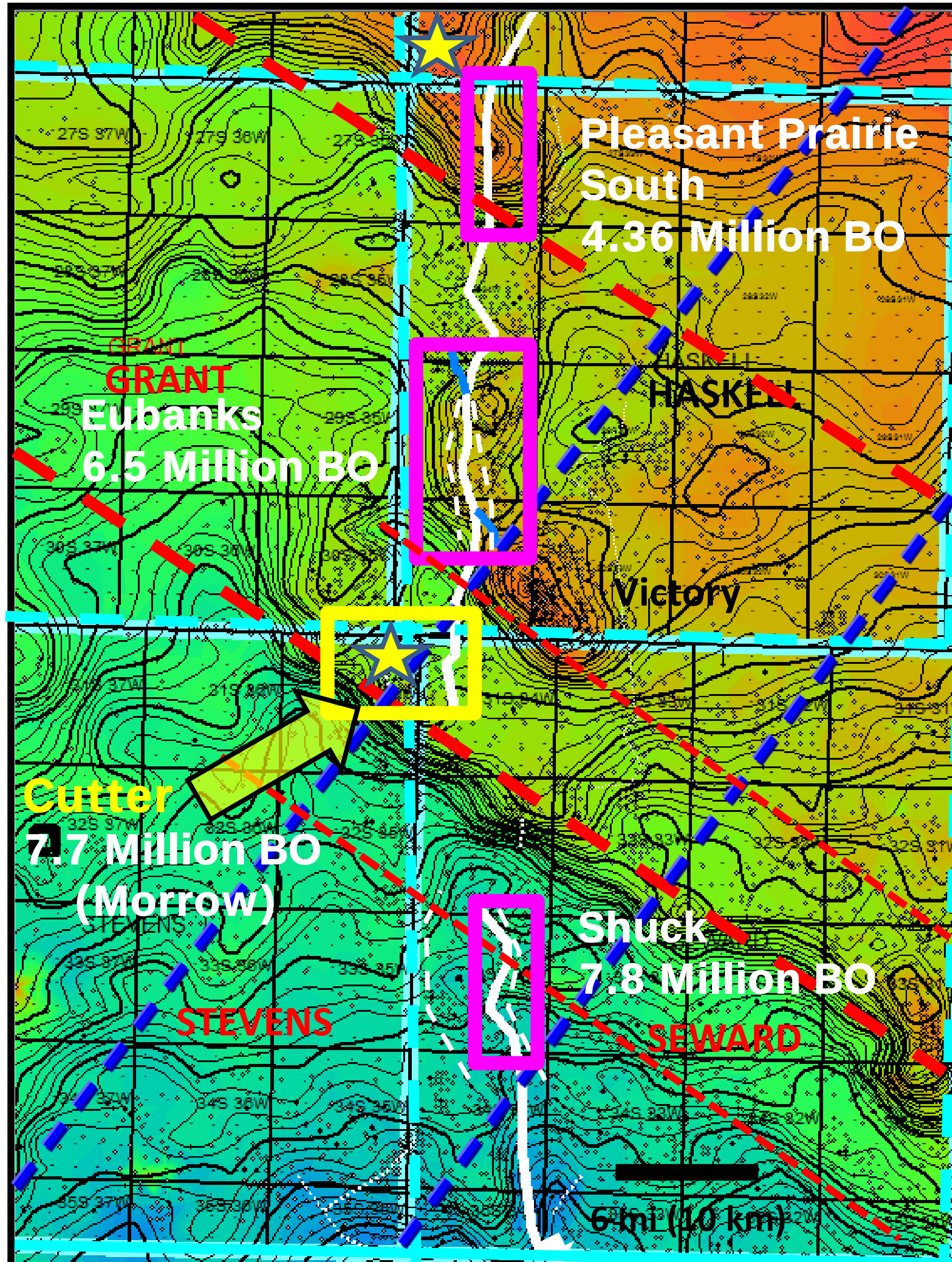
Youle (DOE-CO2)

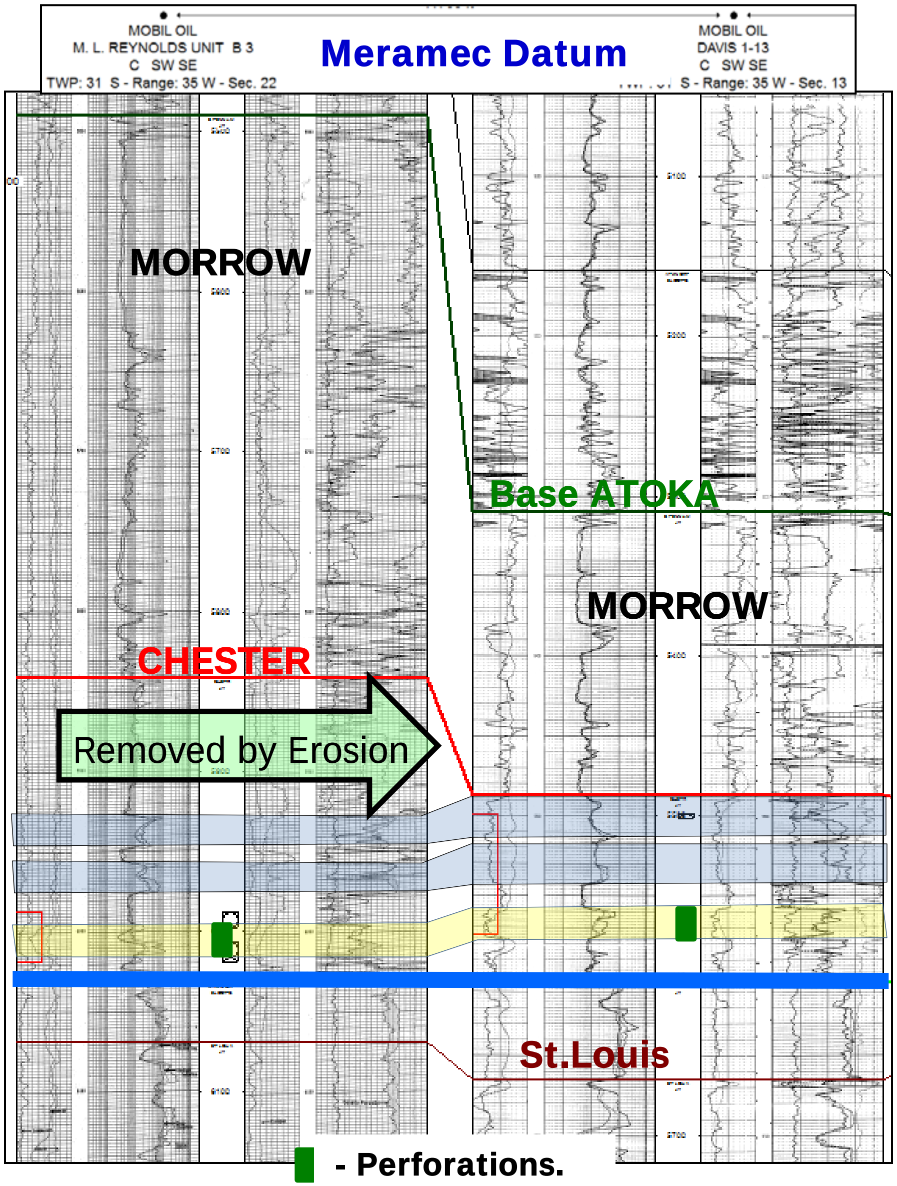


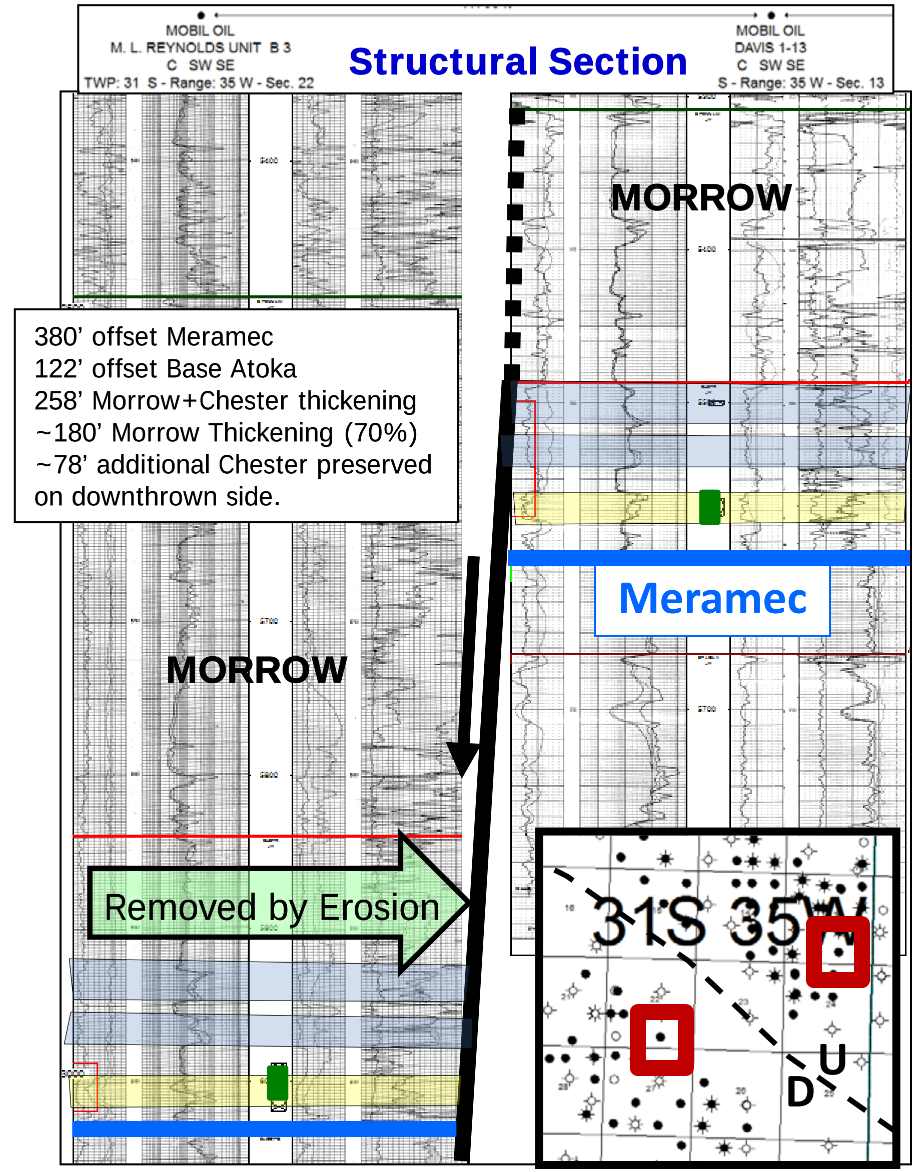
COMPARTMENTALIZATION:

Structural Compartments: Post Chester Fault Seals?

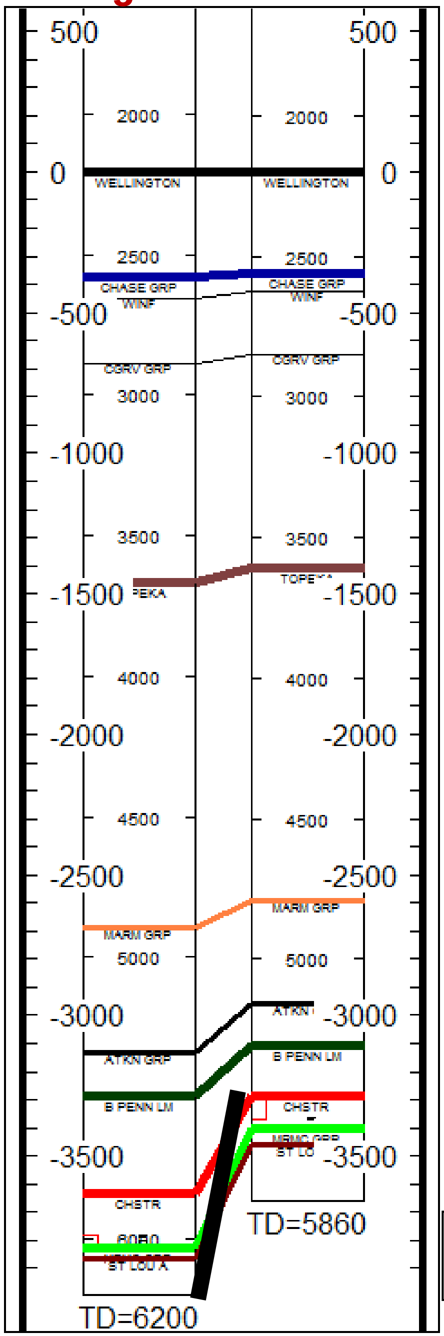
Cutter & Cutter South Field Areas

Current max. horizontal stress regime in midcontinent is NE-SW. Could Chester sands be locally sealed on the downthrown side of NW-SE trending faults?....if juxtaposed against tight Meramec Limestones?





Datum: Lower Permian Wellington



Cutter & Cutter South Field Areas

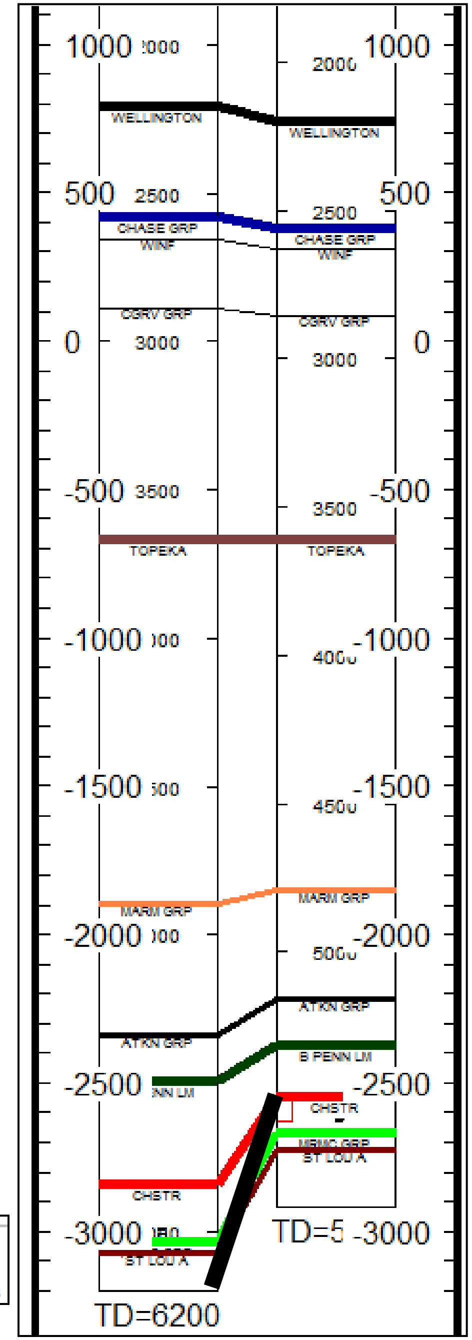
Up to at least Wellington time, subsidence continued on downthrown side of fault. However, amount of downthrown subsidence appears to have decreased over time at close to a constant rate.

Since Wellington time Laramide tectonic events impacting the Keyes Dome, Sierra Grande Uplift, and Las Animas Arch resulted in 55’ of uplift and <u>dip reversal</u> on the Wellington in the downthrown well.

MOBIL OIL
M. L. REYNOLDS UNIT B 3
C SW SE
TWP: 31 S - Range: 35 W - Sec. 22

MOBIL OIL
DAVIS 1-13
C SW SE
TWP: 31 S - Range: 35 W - Sec. 13

Structural Section



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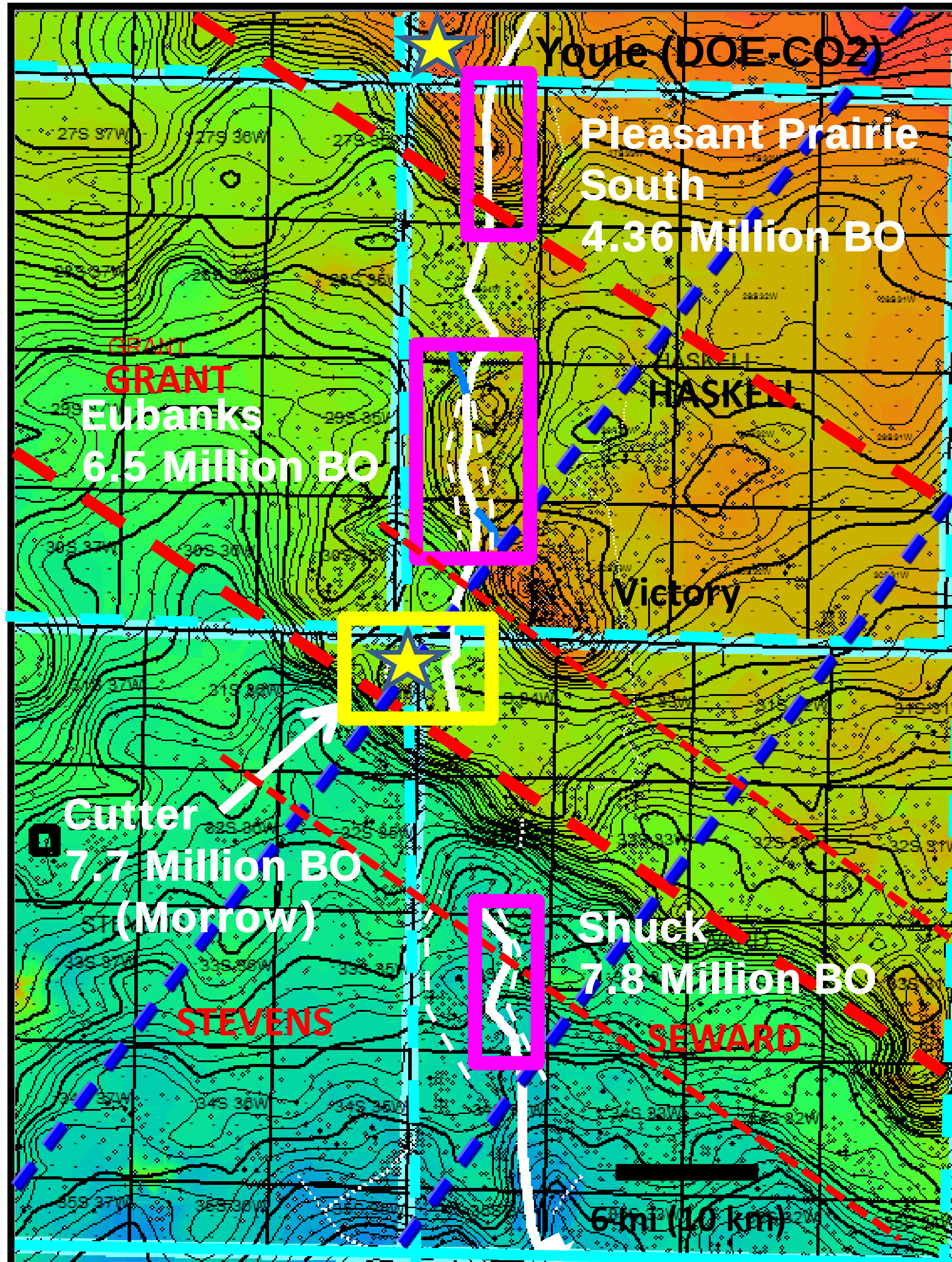
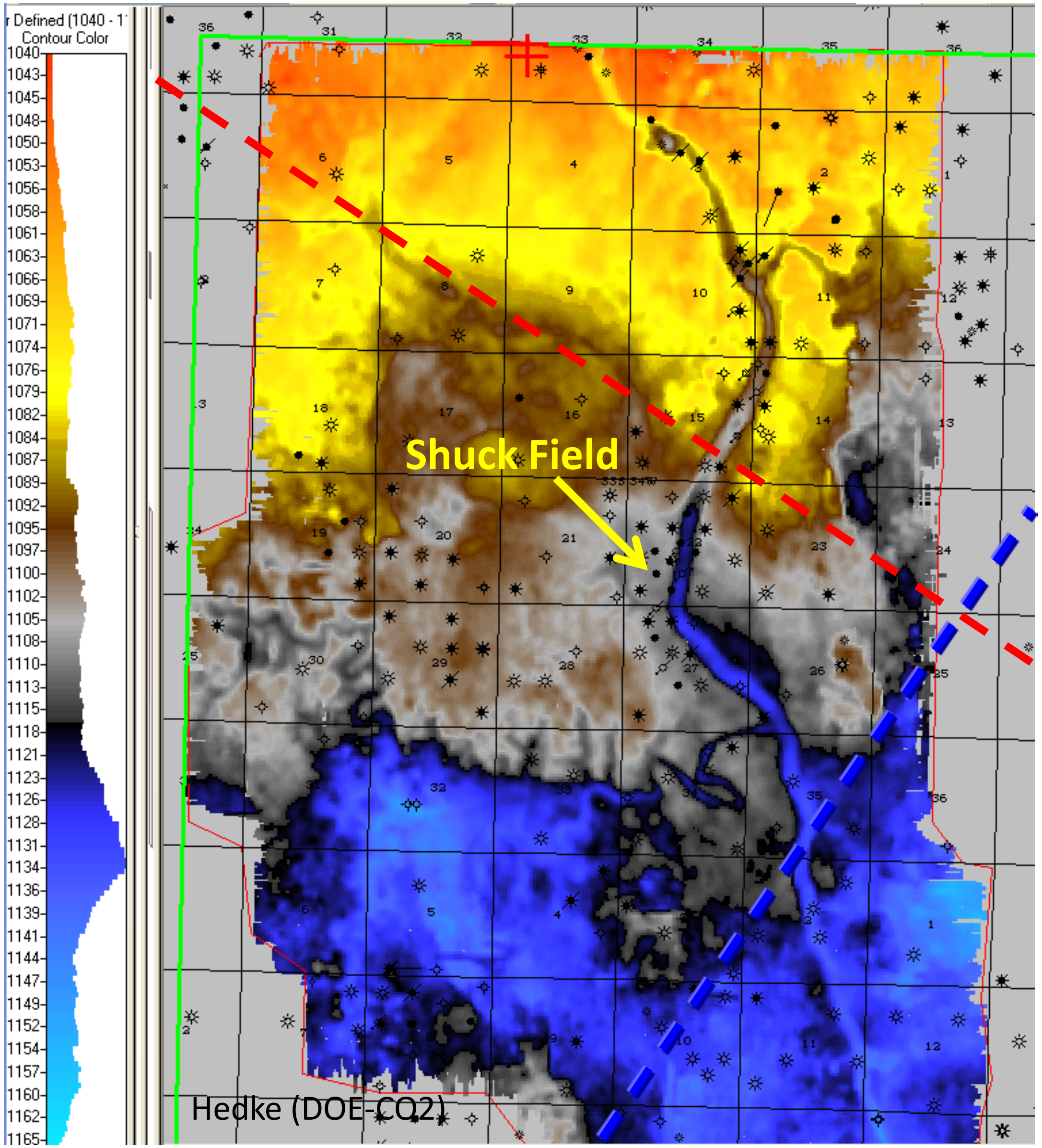


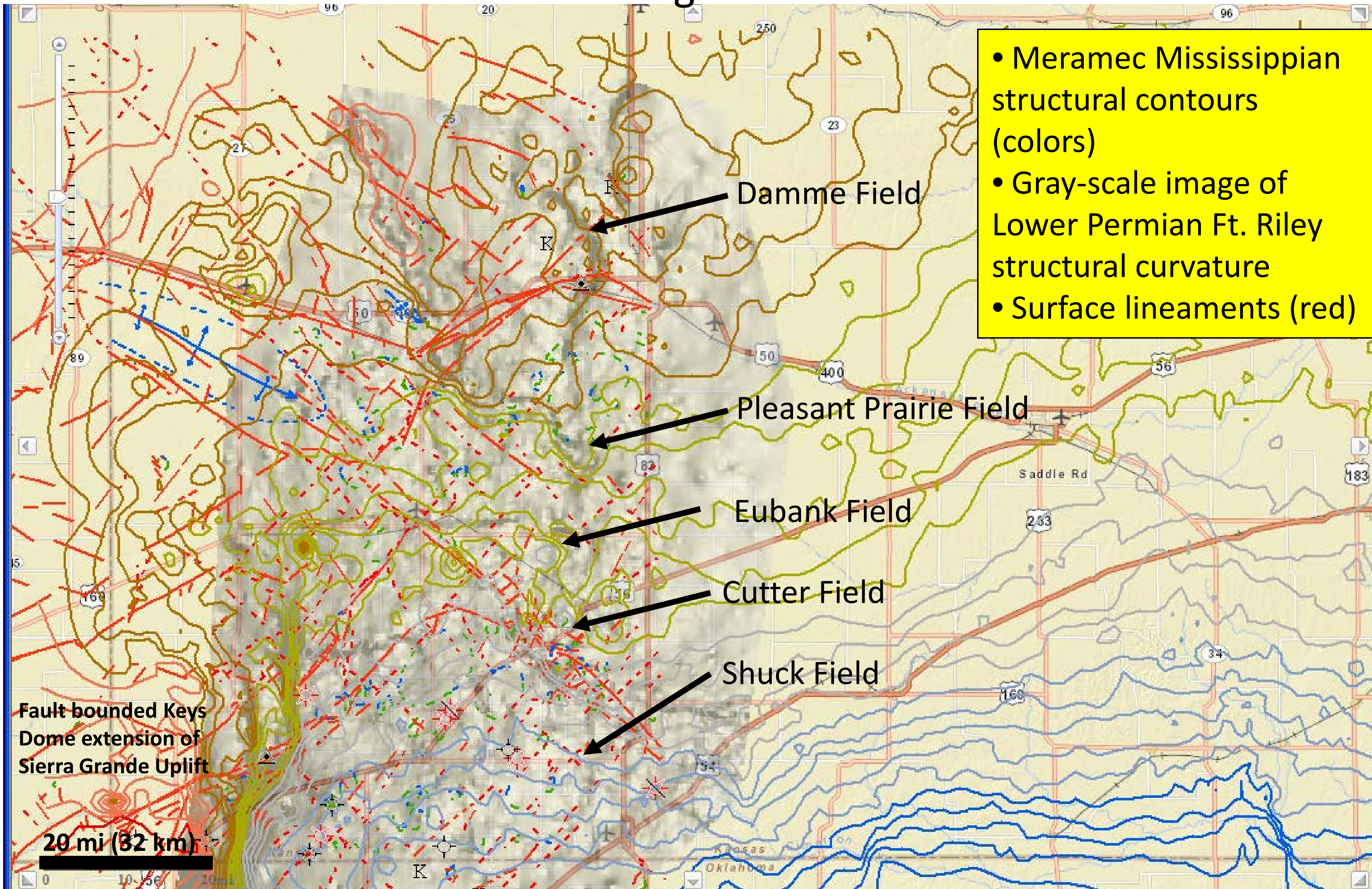
Shuck Field - Chester incised valley broadening into estuarine embayment to south near Oklahoma-Kansas line

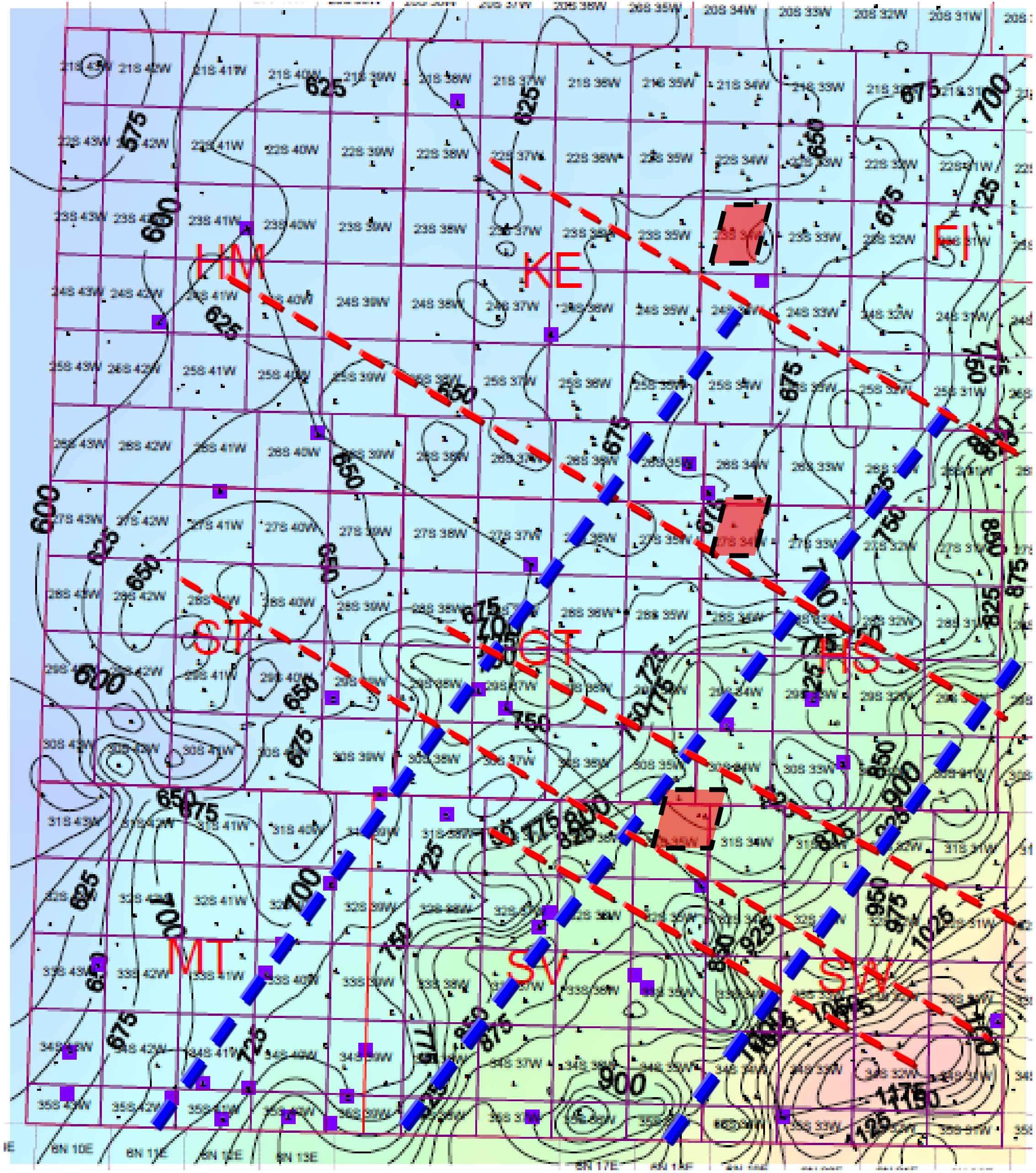


- Time Meramec surface (unconformity)
- Prominent Chester IVF with rectilinear NW- and NE-trend
- Multiple drainage features on edge of topographic break bordering estuarine embaymenet
- Channel widths ~ 300 ft
- NW-trending and NE-trending regional structural lineaments appear to depositional system

2 mi (3.2 km)

Shallower structures and surface lineaments suggest episodic movement of NW- and NE-trending deep-seated structures along N-S Chester IVF





Dominance of the NE-trending regional lineaments controlling lower Permian deposition in SW Kansas (more northerly paleo σ_1?)

25 mi (40 km)

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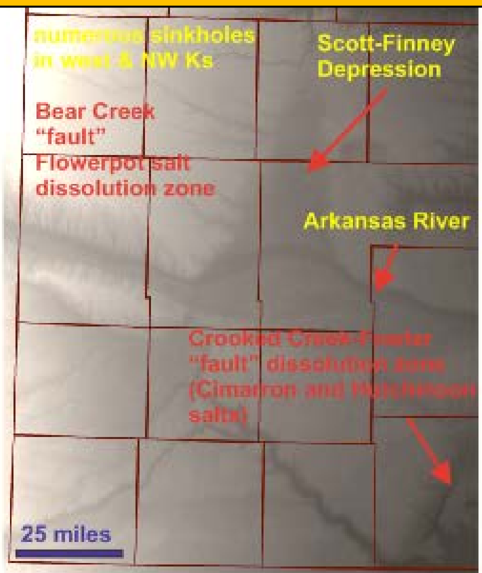
CO2 PROJECT / WESTERN ANNEX

1:250000

Isopach Lower Permian Hutchinson Salt to Neva Ls. (top Pennsylvanian)

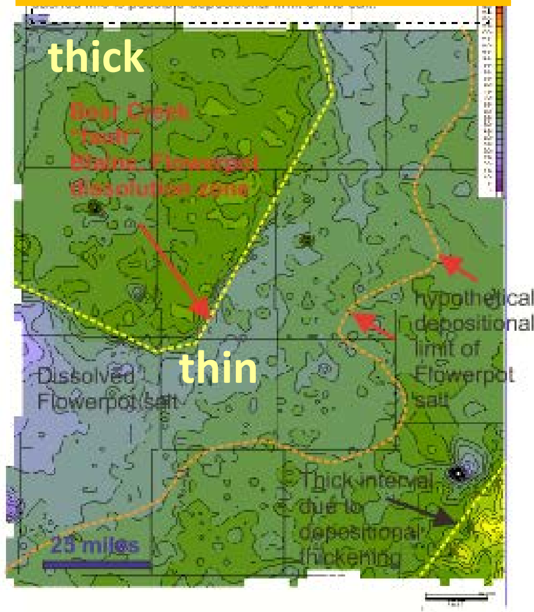
(Gerlach, Nicholson, DOE-CO2)

Gray scale DEM of SW KS
Postive above thicker Blaine halite



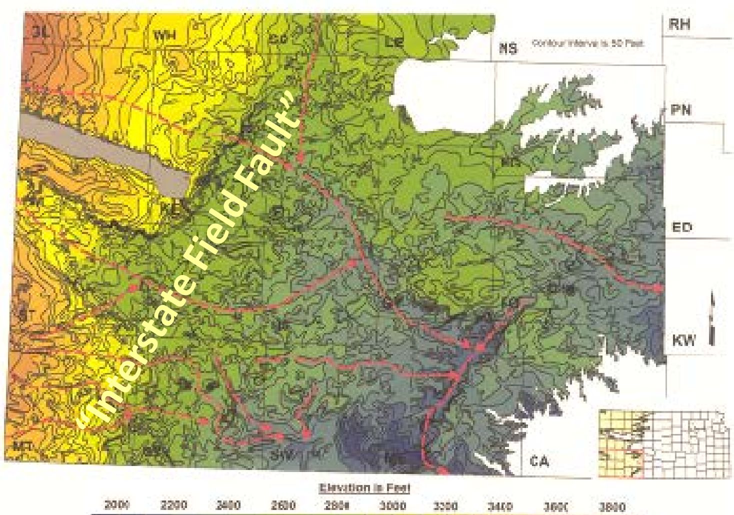
Surface elevation, gray scale (light = higher). Central portion of mapped area is topographically low.

Isopach of halite-bearing Lower Permian Blaine Fm.

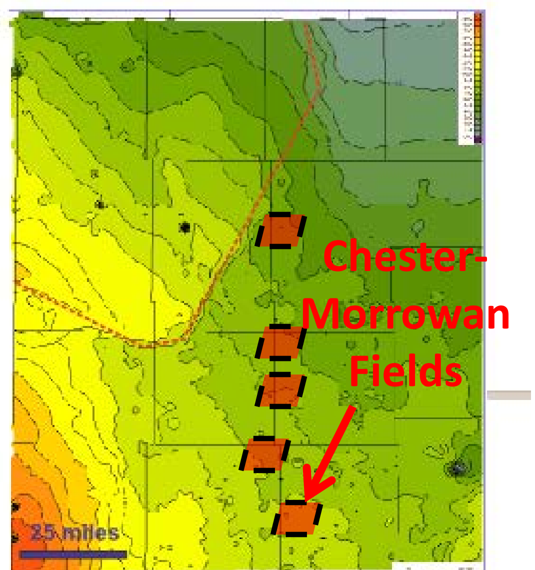


Proposed dissolution of lower Permian evaporites (~1000 ft below surface) during Late Tertiary & Neogene providing accomodation space for High Plains aquifer

- Inferred influence of NW- & NE-trending basement structures
- Timing of dissolution corresponds to regional uplift and tilting of Rocky Mountains and Great Plains during mid Miocene (McMillian et al., 2006; Goes and van der Lee, 2002)
- Timing similar to emplacement of gas into Hugoton Field (Sorenson, 2005)

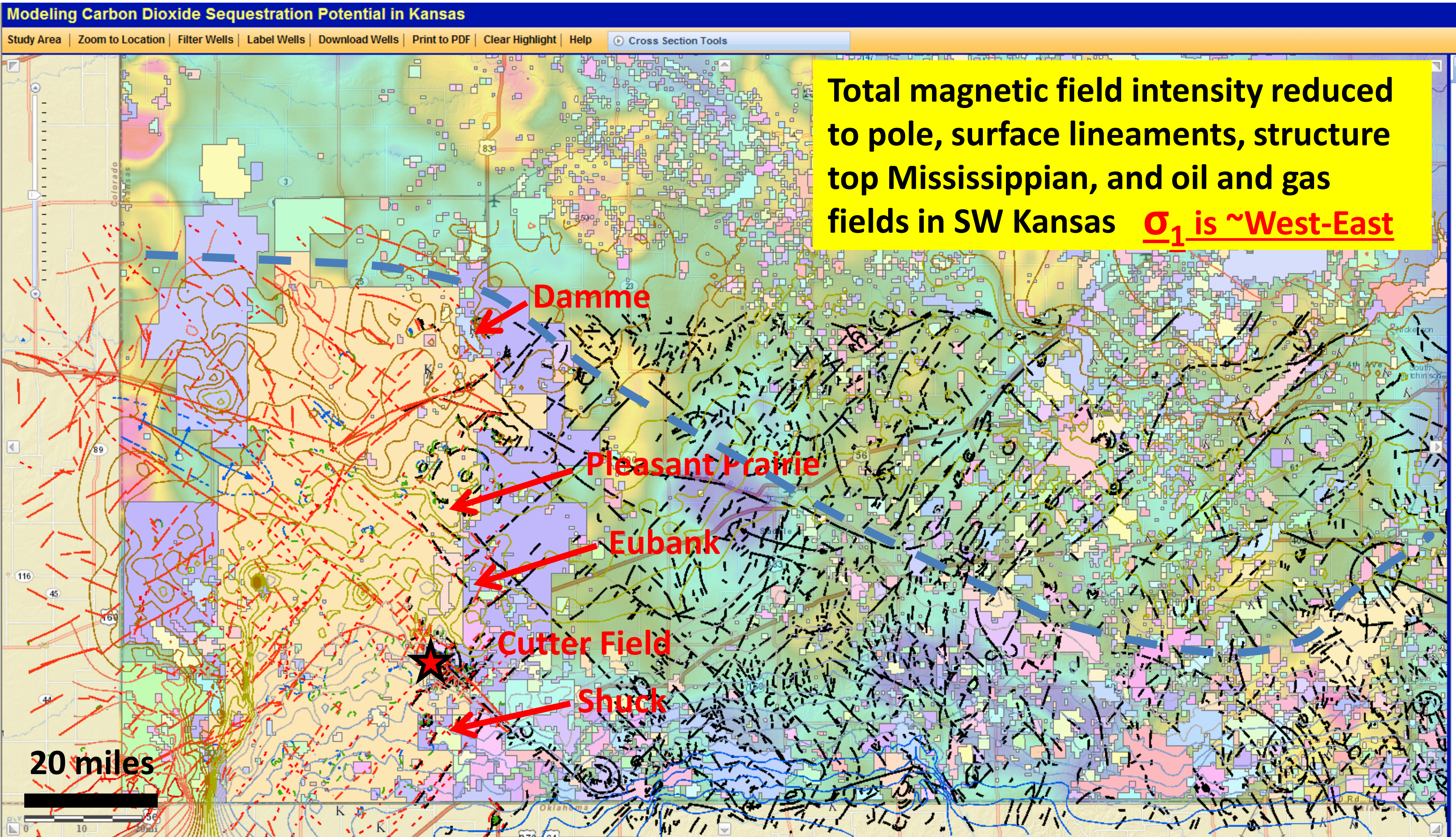


Bedrock elevation at base Pliocene Ogallala formation
Macfarlane and Wilson (2006)



Structure top of Blaine Formation

Regional surface lineaments maintain northwest and northeast dominant trends



Summary & Conclusions

- **Anadarko Basin** –Proterozoic extension to Phanerozoic compression from rift basins to horst & graben system
- **Hugoton Embayment (HE)** – 10,000 km^2 northern extension of Anadarko Basin and structurally integrated
- **Major structures in the HE –** prominent evidence of coupled and complex compressional events from far field stresses including diagnostic features such as flower structures and restraining bends developed along reactivated basement lineaments
- **Episodic structural movement** – post tectonic movement affecting sedimentation/stratigraphy throughout Phanerozoic including High Plains Aquifer and surface lineaments and topography
- **Pattern of deformation** – strongly influenced by prominent basement weaknesses (the template) revealed by potential fields and lineament analysis interacting with an evolving stress field

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