Fracture and Non-Matrix Pore Development Related to Evaporite Paleokarst Collapse, Lower Cretaceous Comanche Shelf, Texas*

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Abstract

Laterally continuous, intrastratal breccia zones and the resulting non-matrix pore structures and fractures are significant reservoir features that modify the permeability in subsurface reservoirs. The associated non-matrix pores occur within the brecciated zone and within suprastratal beds overlying the collapsed zones. Despite the chaotic appearance of the brecciated zones, the deformation styles and associated fracture intensity can be defined and characterized for improved reservoir characterization. Significant layer-bound faulting, folding and brecciation occur within regions that are devoid of tectonic activity, but preexisting structures may influence the overall geometry of the deformation zones.

Using outcrops that extend over 80 miles across the Comanche Shelf of central Texas, we have mapped evaporite paleokarst brecciation and associated deformation within the Lower Cretaceous Edwards Formation, specifically the Kirschberg Evaporite Member. Within this expansive outcrop we have analyzed three major intervals: (1)a substratal interval beneath the evaporite zone; (2) an intrastratal interval containing the evaporites or breccias in which the former evaporites were dissolved; and (3) a suprastratal interval overlying the evaporites that commonly shows deformation generated by collapse into the caverns created by evaporite dissolution. Deformation within the substratal interval is characterized by low-intensity opening-mode fractures with orientations that parallel preexisting Paleozoic structures that unconformably subcrop below the zone of interest. Intrastratal deformation is characterized by both extensional and compressional structures, including normal and reverse faults and folding. Faults and fold axes within this zone also parallel preexisting structural trends. In addition, zones of extensive chaotic brecciation occur in localized areas. Finally, suprastratal deformation includes extensional and compressional faulting and zones of high intensity opening-mode and shear fracture zones.

We use a model of coalesced, isolated collapse to explain deformation zones observed in outcrop which result in predictable belts of deformation styles. Many factors can influence the style of deformation within evaporite paleokarst, but comparison of this work to other

areas of evaporite paleokarst suggest that potentially reactivated preexisting structures and sediment input may be important factors in the style of deformation observed.

References

Ewing, T.E., 1995, What we don't know about the structural history of the West Texas Basin: The Bulletin of the Houston Geological Society, v. 38/4, 11 p.

Rose, P.R., 1972, Edwards Formation, surface and subsurface, central Texas: Ph.D. Dissertation, University of Texas, Austin, Austin, Texas, USA, 301 p.

Zahm, L.C., 1997, Depositional model and sequence stratigraphic framework for upper Albian/lower Cenomanian carbonate ramp, western Comanche Shelf, Texas: M.A thesis, University of Texas at Austin, Austin, Texas, USA, 134 p.

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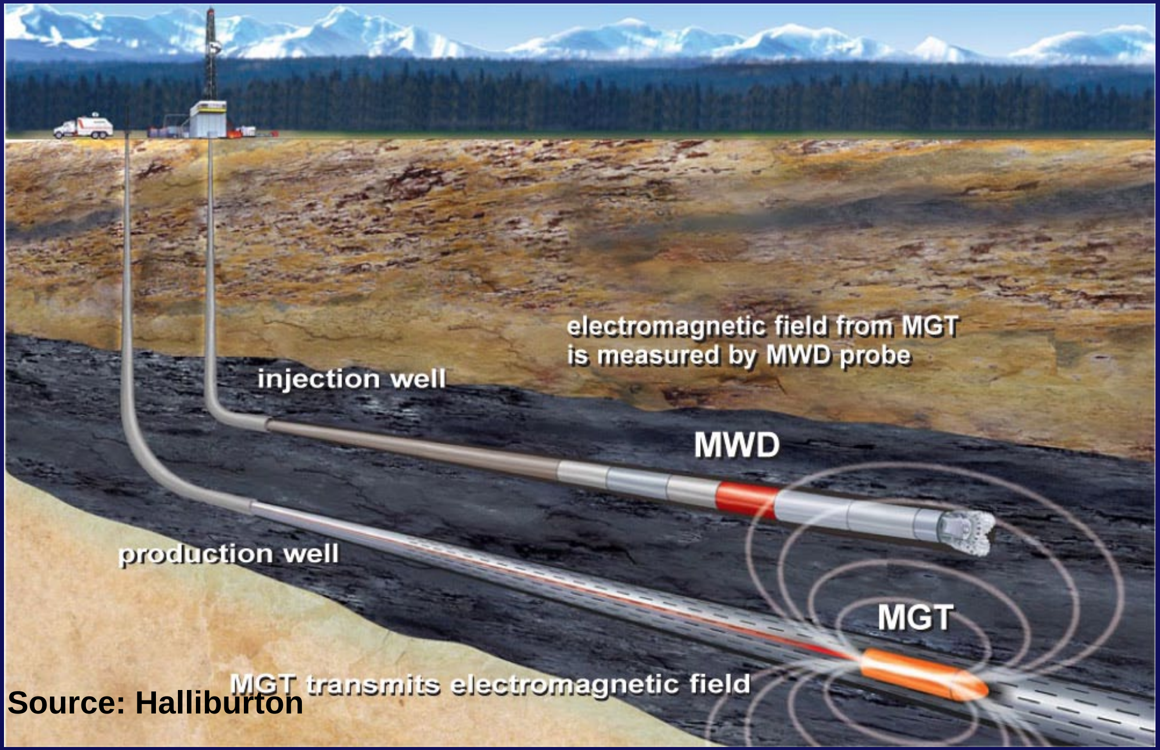
Reservoir Characterization Significance

- Dissolution and removal of evaporite-rich horizons creates significant brittle, atectonic deformation.
- Faults, fractures, and pores that develop are potential fast pathways for fluid movement, creating a challenging issue for enhanced oil recovery in the surrounding matrix strata.

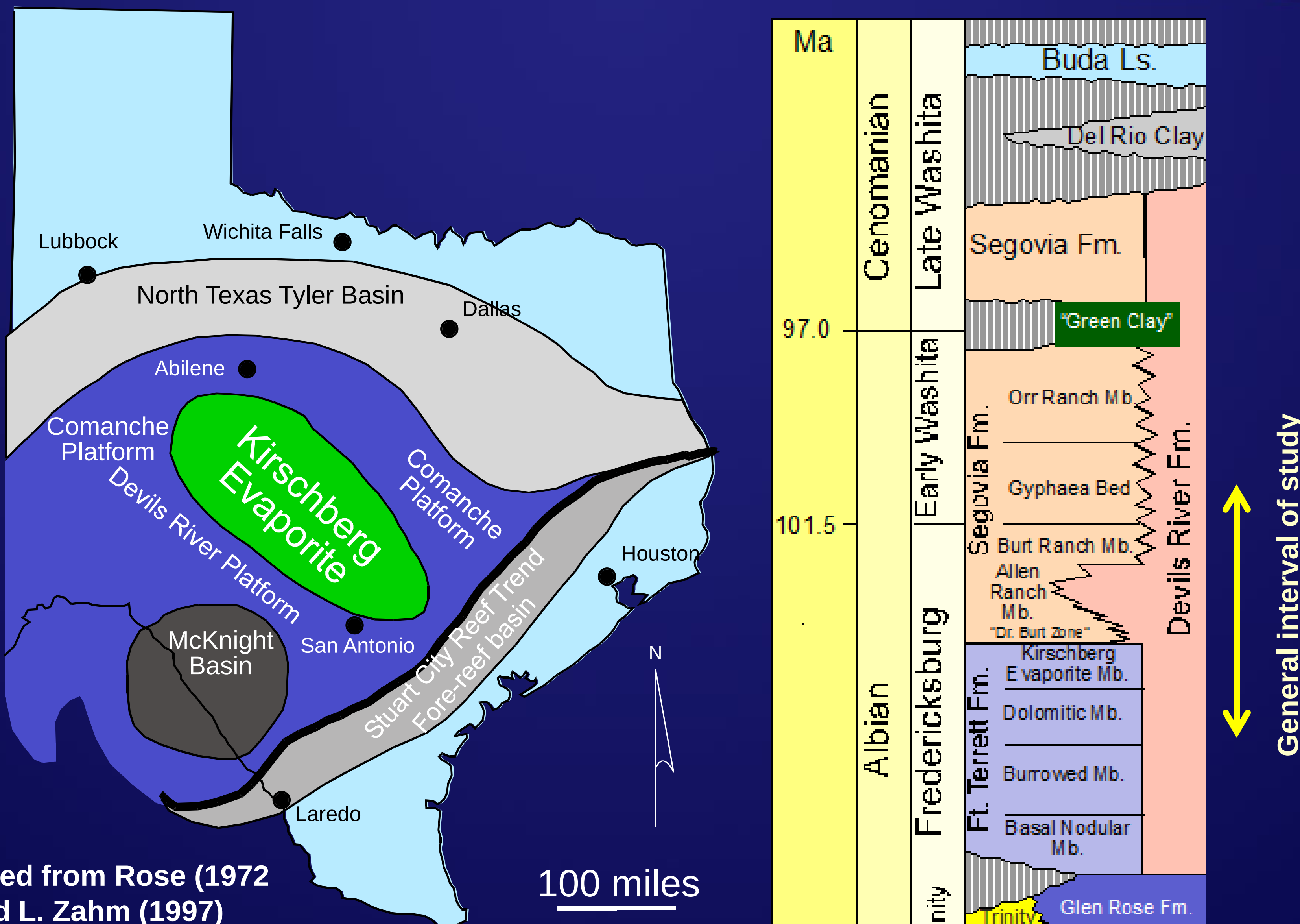


Source: Halliburton

Key Questions

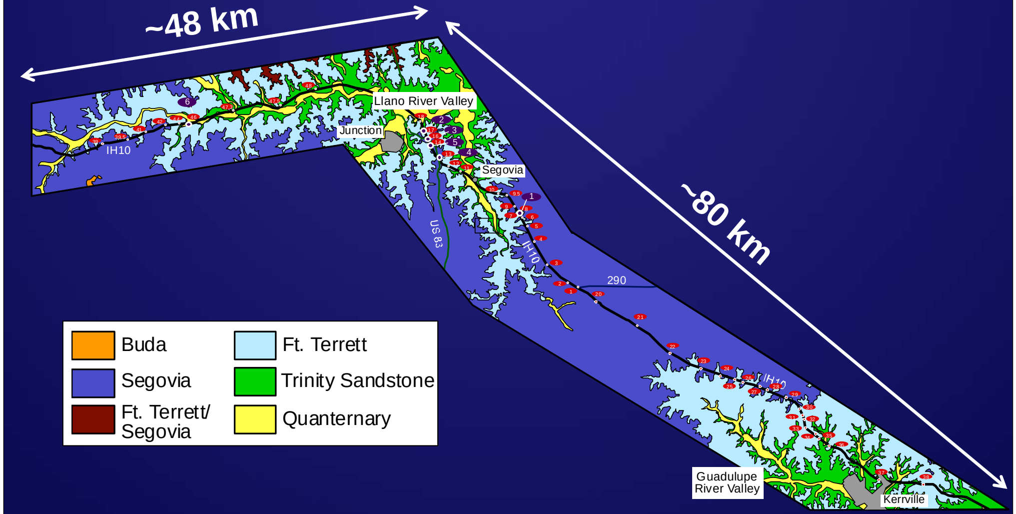
- What are important factors in deformation styles within evaporite paleokarst systems?
- What pore types do we see within evaporite paleokarst?
- How do we explain complex deformation styles?
- Do pre-existing Paleozoic faults effect the style and orientation of deformation during collapse?

Paleogeography



Modified from Rose (1972 and L. Zahm (1997)

40+ Outcrop Exposures Along Highway

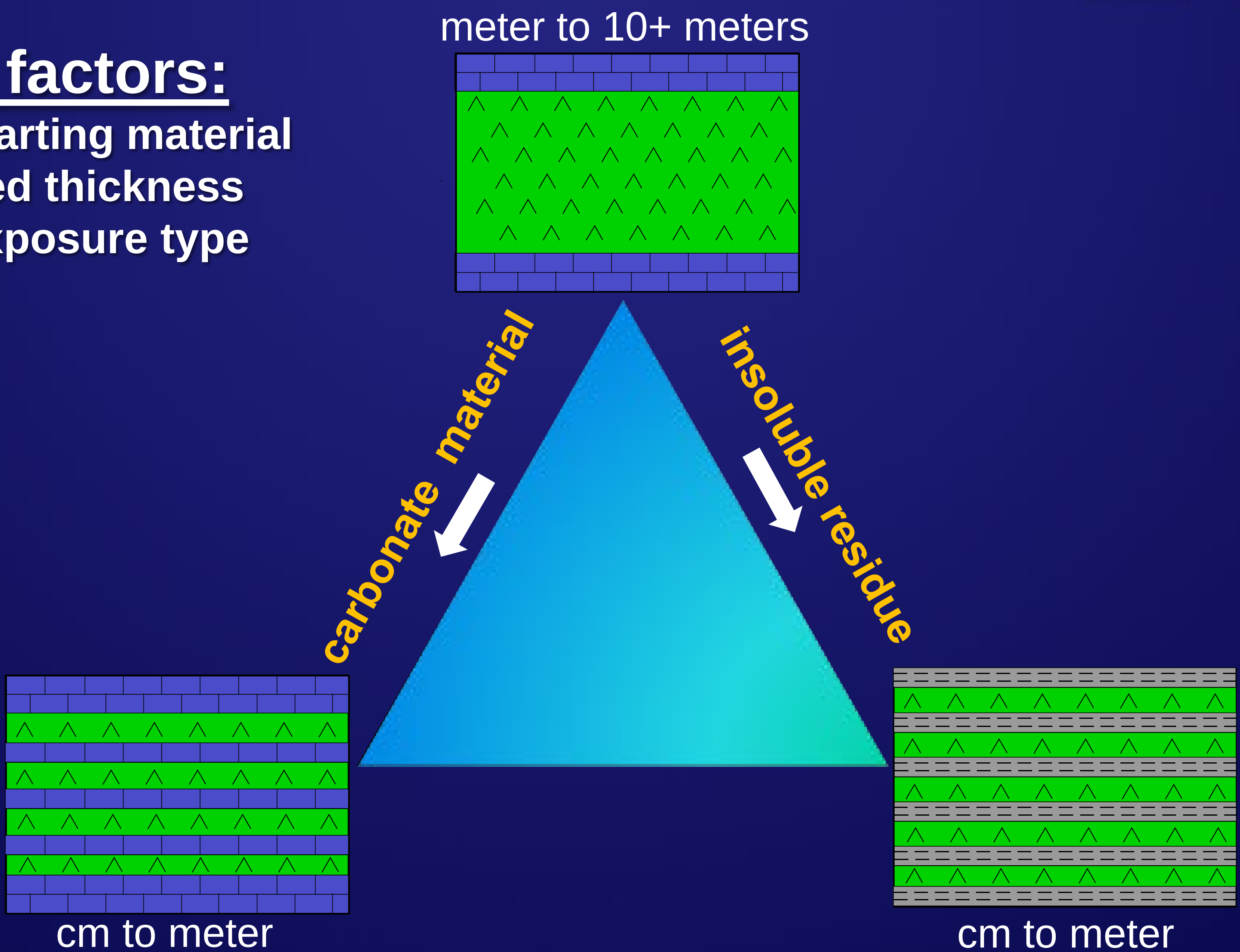


Reservoir Characterization Research Laboratory

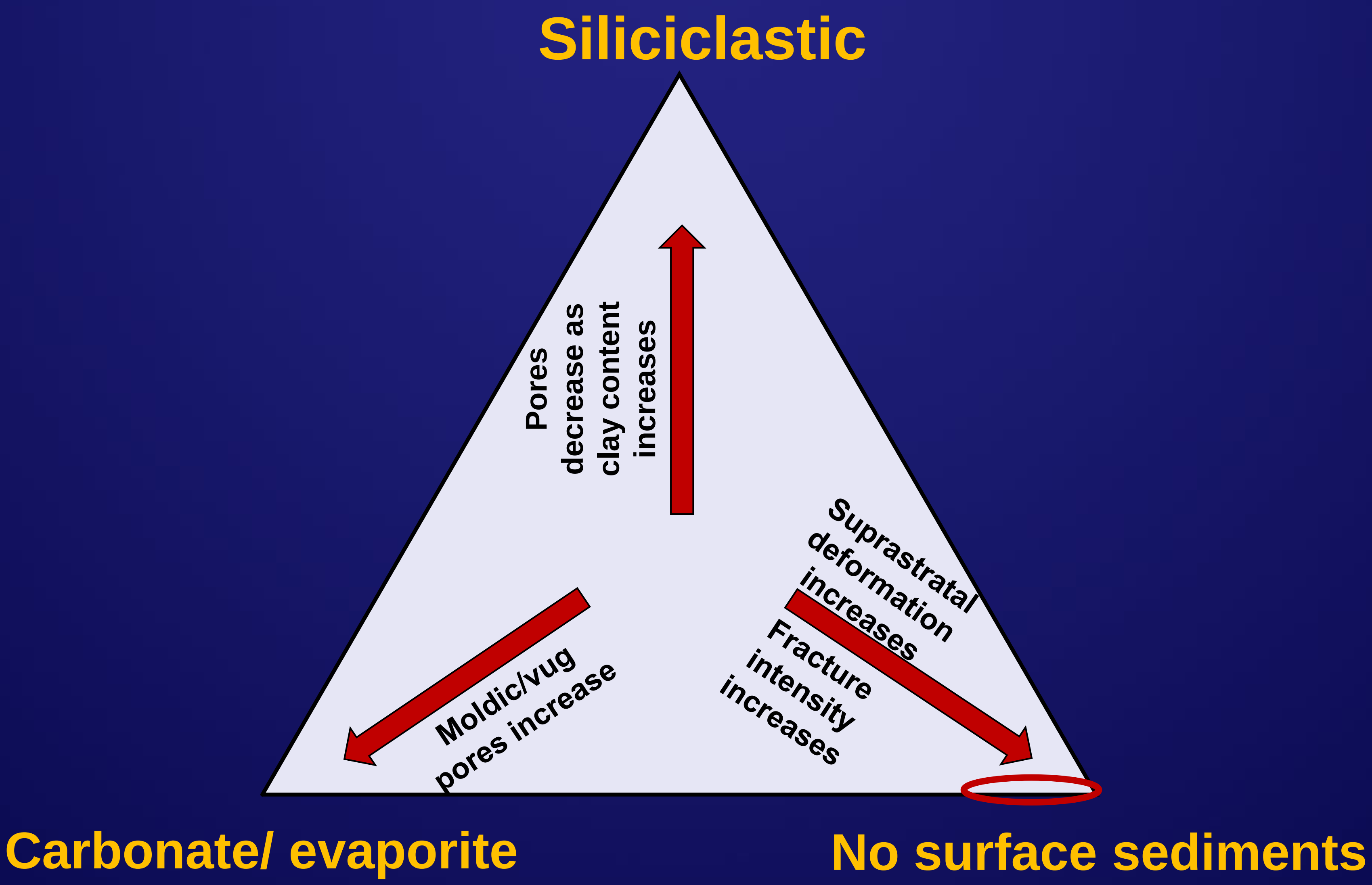
Presenter's notes: In general carbonate karst is discontinuous and evaporite karst is stratigraphically continuous.

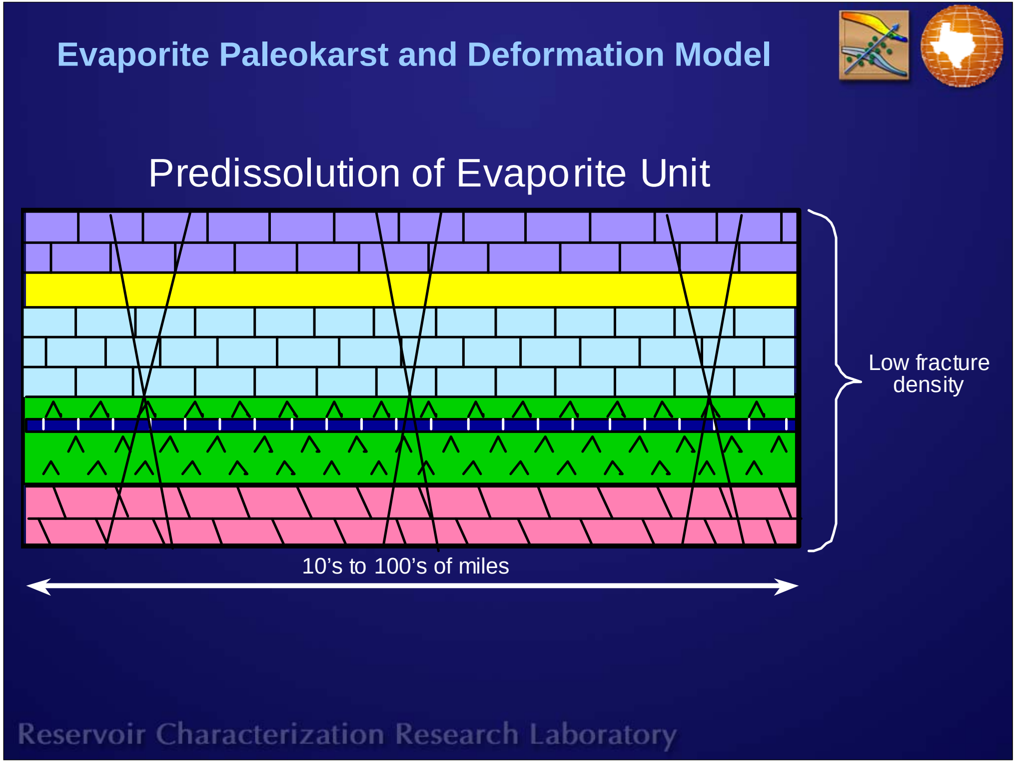
Initial Strata Types

Key factors:
- starting material
- bed thickness
- exposure type



Post-Dissolution Fill Deposits

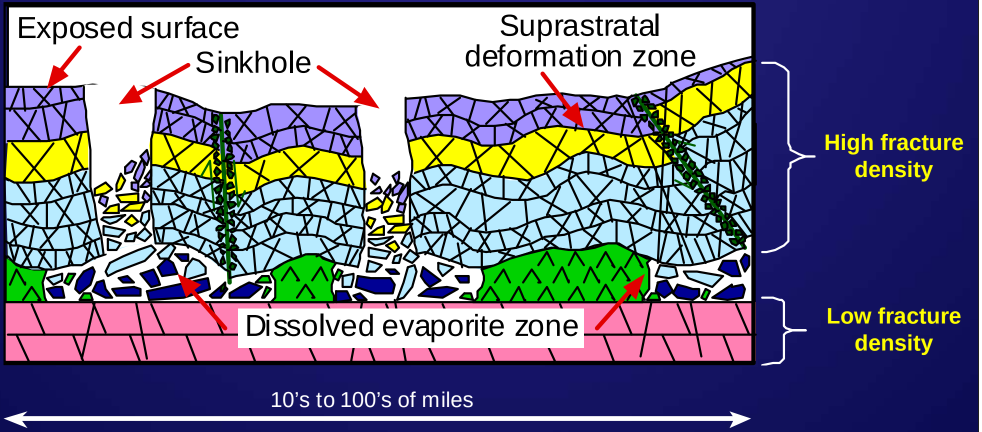




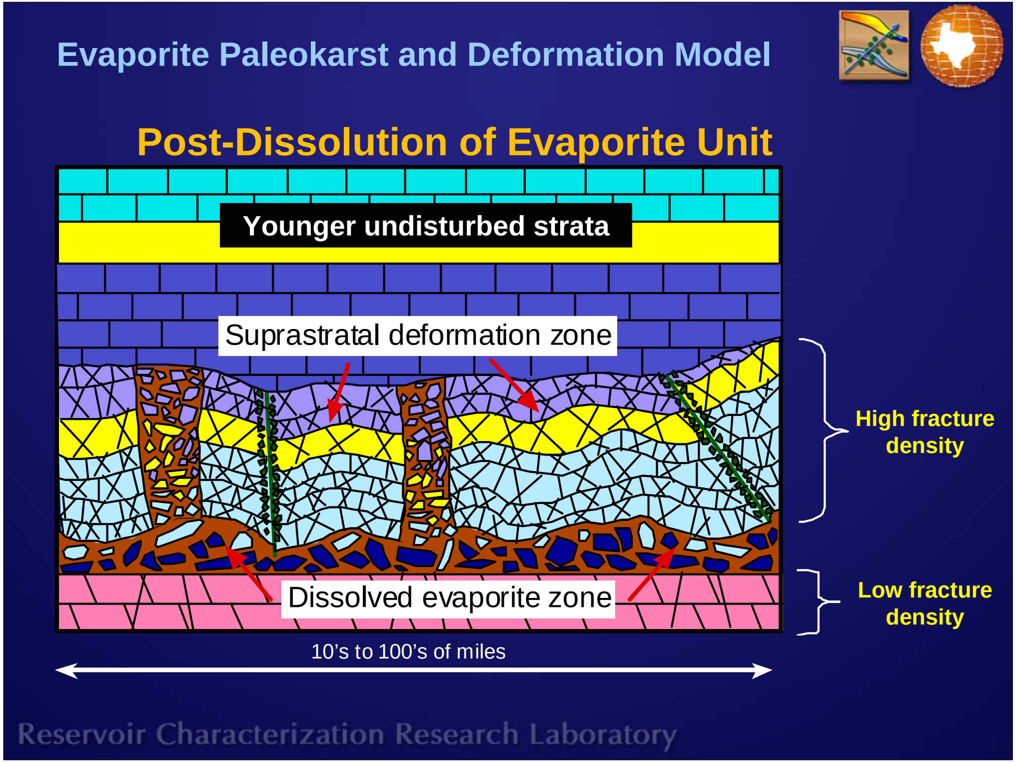
Presenter's notes: In general carbonate karst is discontinuous and evaporite karst is stratigraphically continuous.

Evaporite Paleokarst and Deformation Model

Dissolution of Evaporite Unit



Presenter’s notes: In general carbonate karst is discontinuous and evaporite karst is stratigraphically continuous.



Presenter's notes: In general carbonate karst is discontinuous and evaporite karst is stratigraphically continuous.

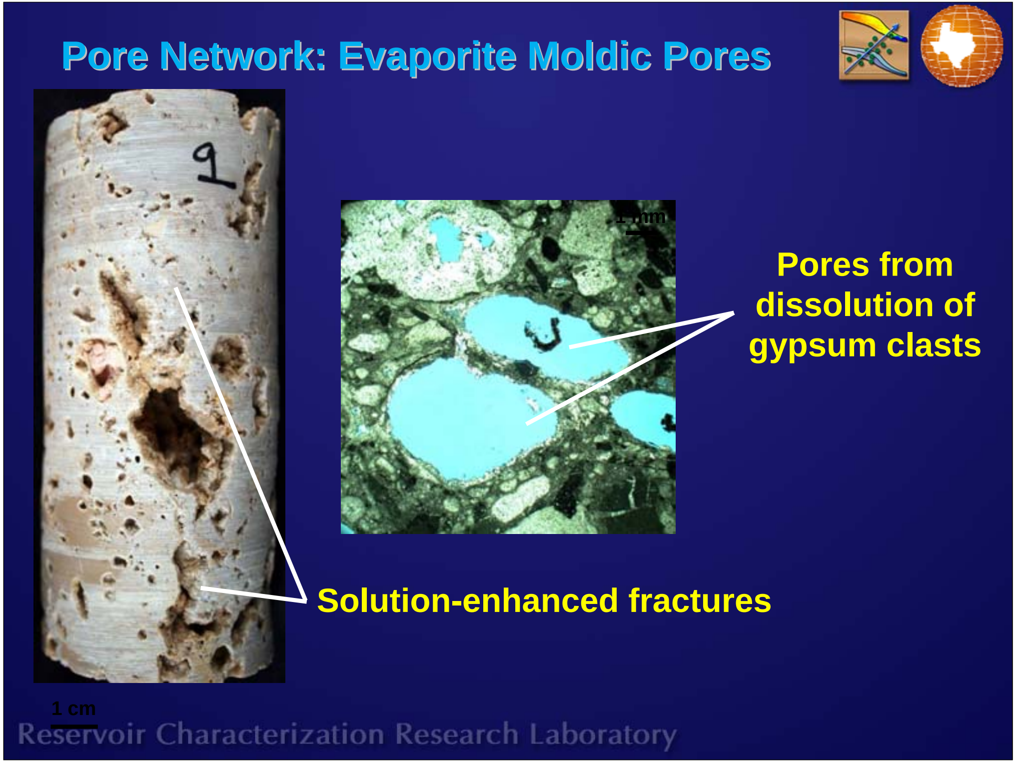
Pore Network: Interclasts Pores

Presenter's notes: Was at a conference on paleokarst

Pore Network: Evaporite Moldic Pores

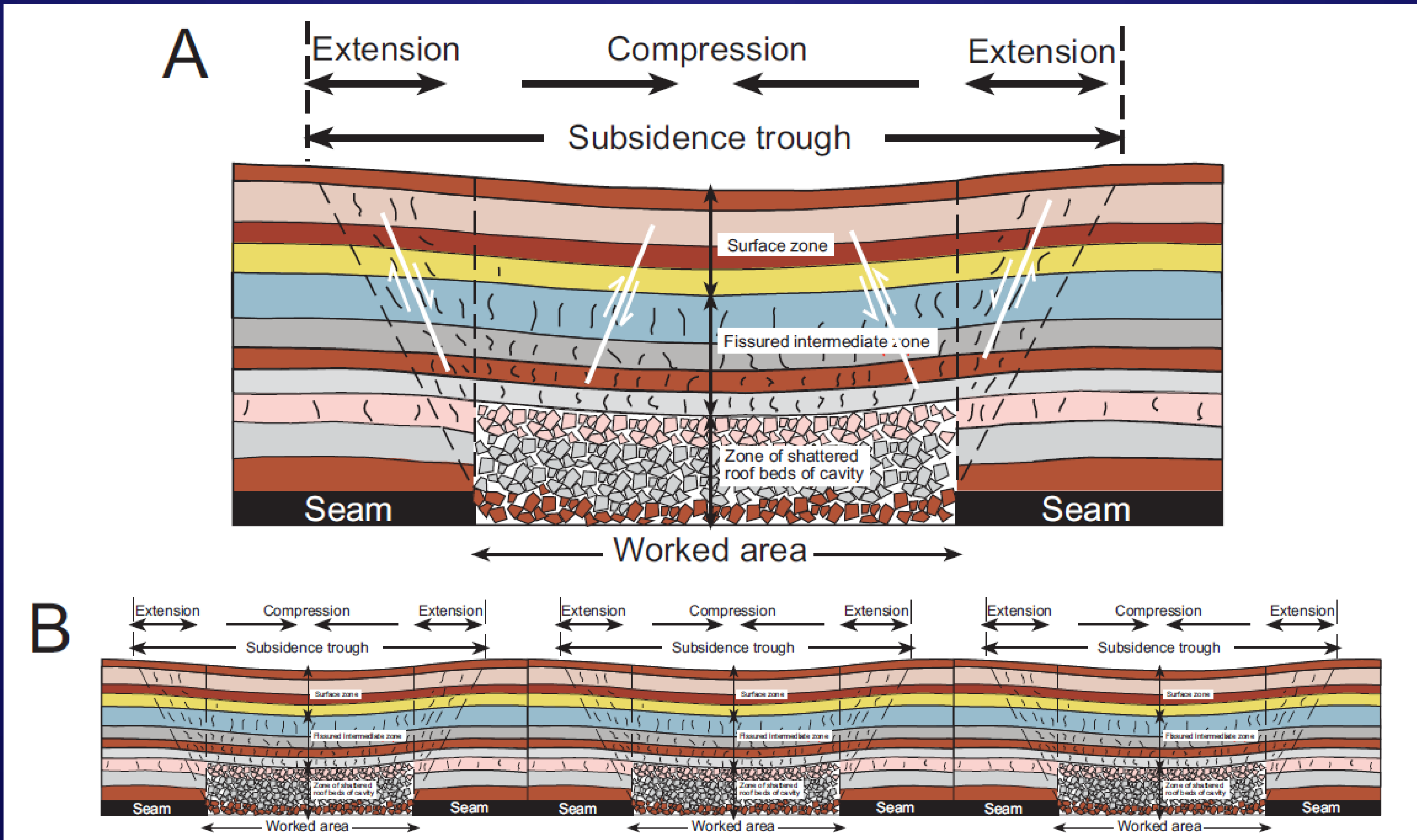
Evaporite moldic pores

Presenter's notes: Was at a conference on paleokarst

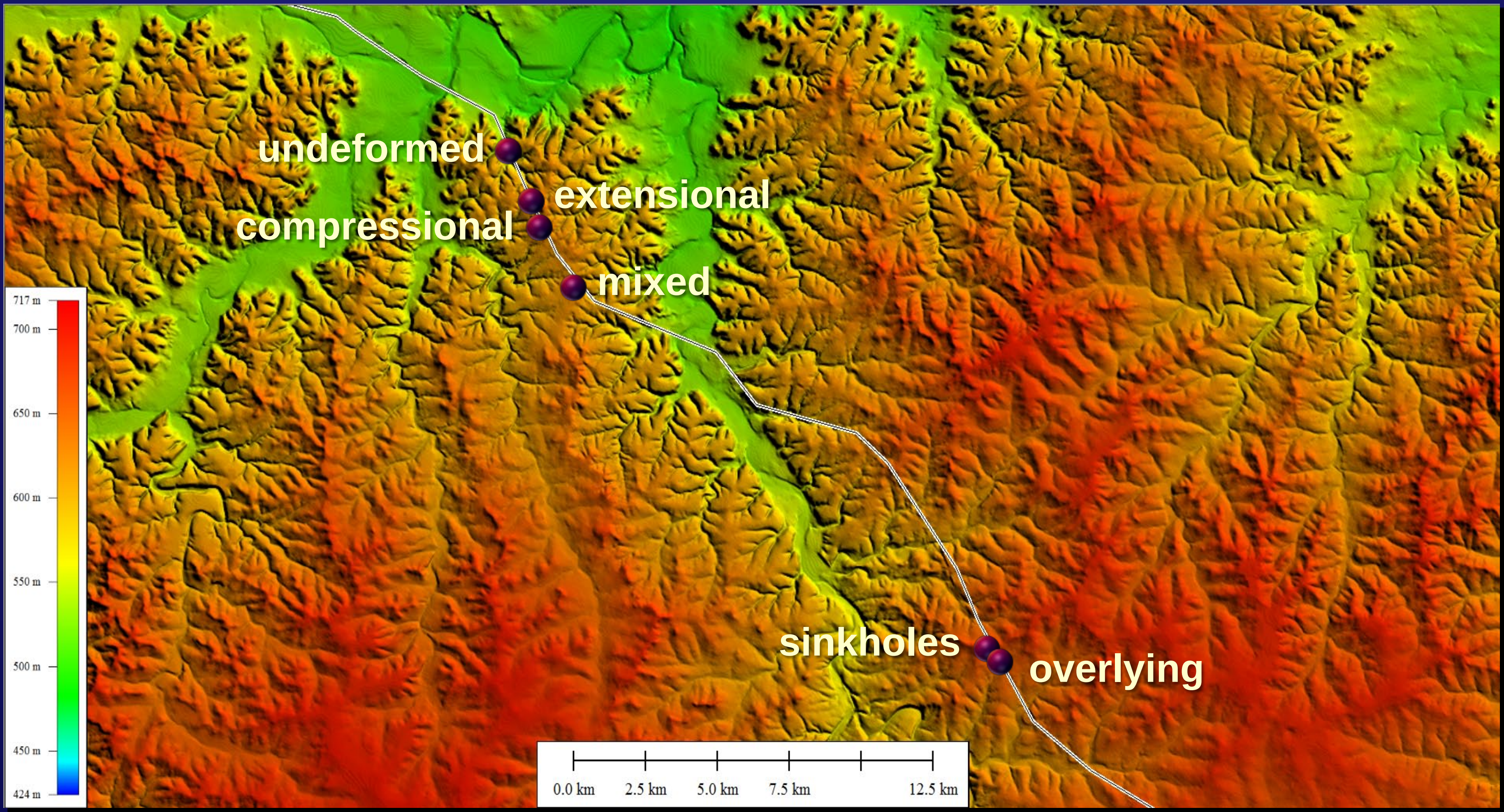


Presenter's notes: Was at a conference on paleokarst

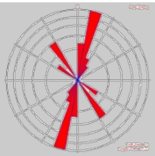
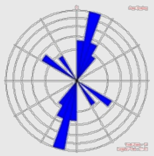
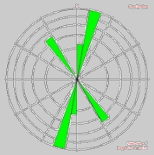
Model for Extension, Compression and Mixed



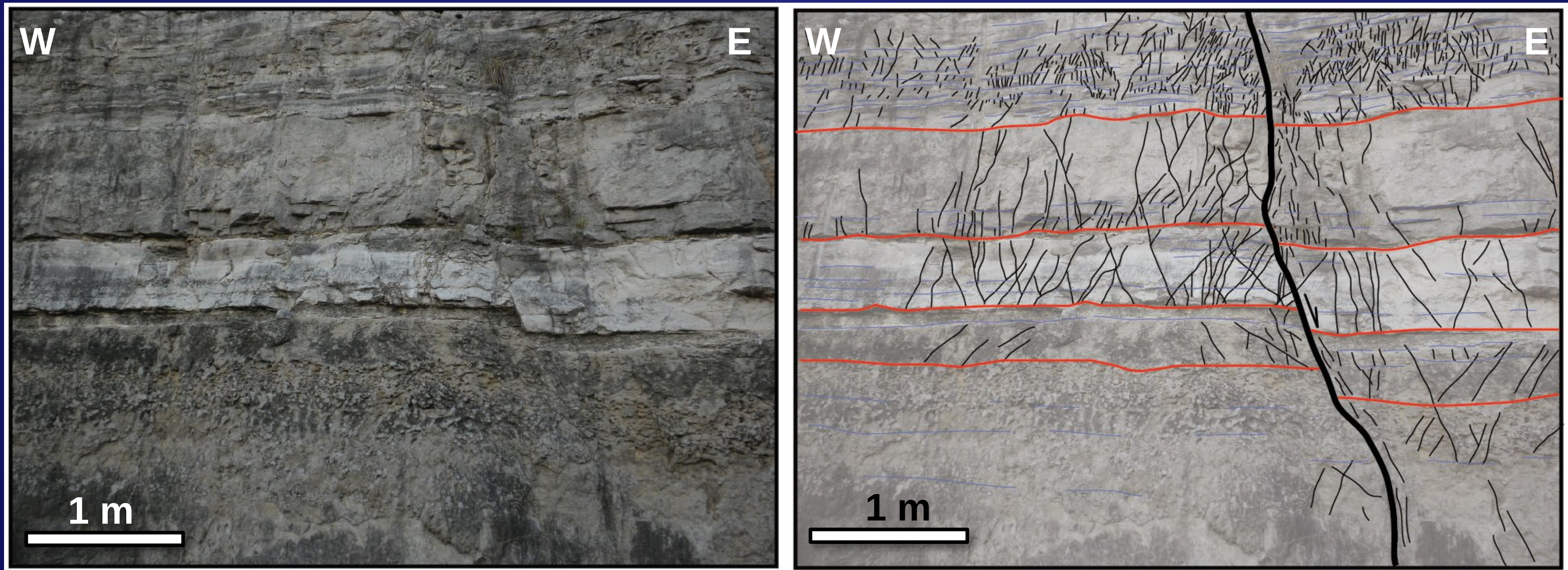
Key Localities with Model

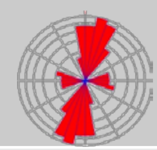
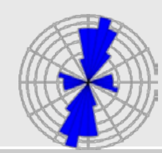
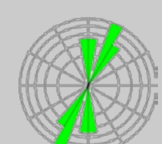


Prekinematic – Opening-Mode Joints

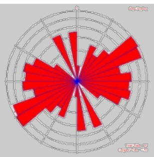
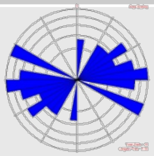
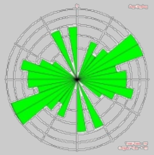
Lithofacies	Bed thickness (m)	Fracture Style	Average Spacing (m)	Normalized FSI	Orientation
Grainstone	0.65	All	1.1	0.6	N15E N30W 
Grainstone	0.65	Bed-bound	1.7	0.4	N15E N55W 
Grainstone	0.65	Throughgoing	3.4	0.2	N15E N35W 

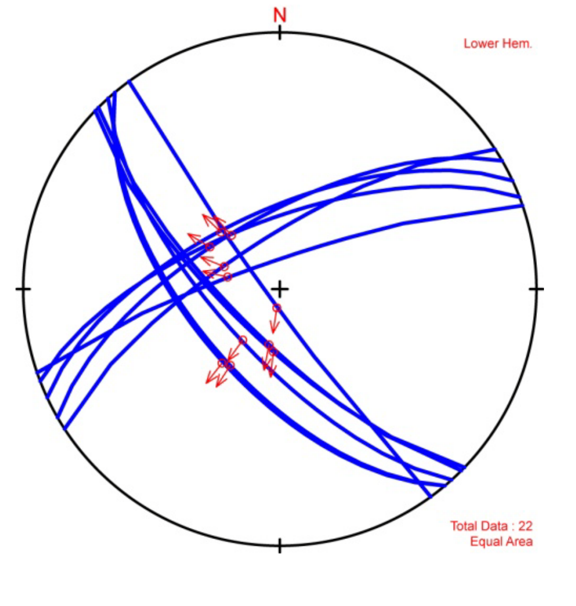
Synkinematic – Extensional Faulting



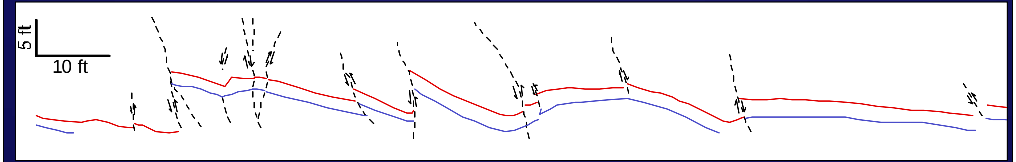
Lithofacies	Bed thickness (m)	Fracture Style	Average Spacing (m)	Normalized FSI	Orientation
Grain-Dominated Packstone	0.7	All	0.4	1.8	N28E N81W 
Grain-Dominated Packstone	0.7	Bed-bound	0.4	1.7	N31E N83E 
Grain-Dominated Packstone	0.7	Throughgoing	5.1	0.1	N38E N02W 

Synkinematic – Extensional Faulting

Lithofacies	Bed thickness (m)	Fracture Style	Average Spacing (m)	Normalized FSI	Orientation
Grain-Dominated Packstone	0.55	All	0.4	1.8	N60E N75W 
Grain-Dominated Packstone	0.55	Bed-bound	0.95	0.6	N85E N60E 
Grain-Dominated Packstone	0.55	Throughgoing	0.45	1.3	N60E N75W 



Compressional Faults



Reservoir Characterization Research Laboratory

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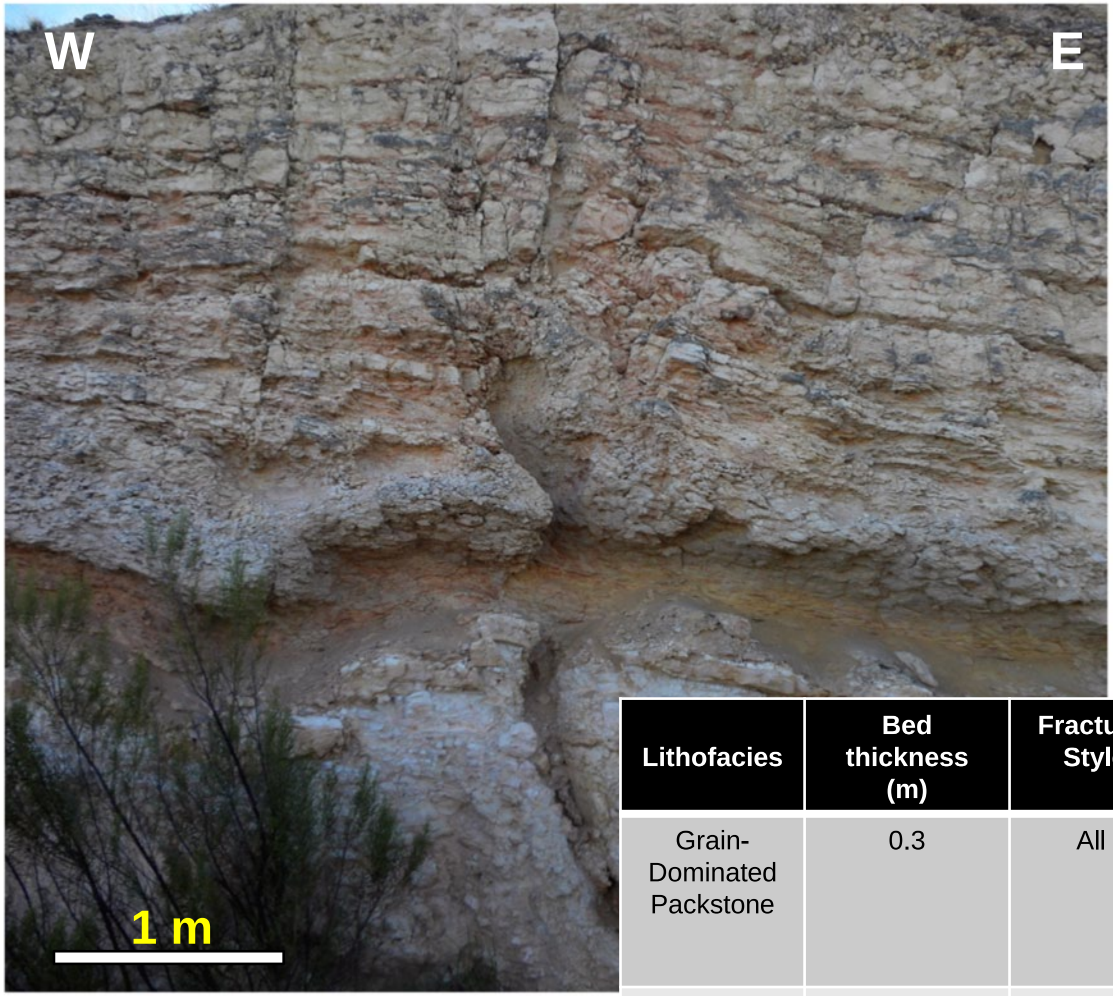
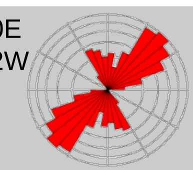
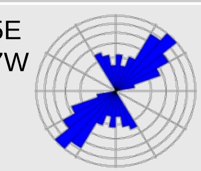
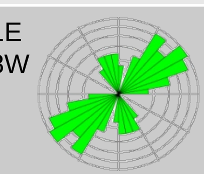
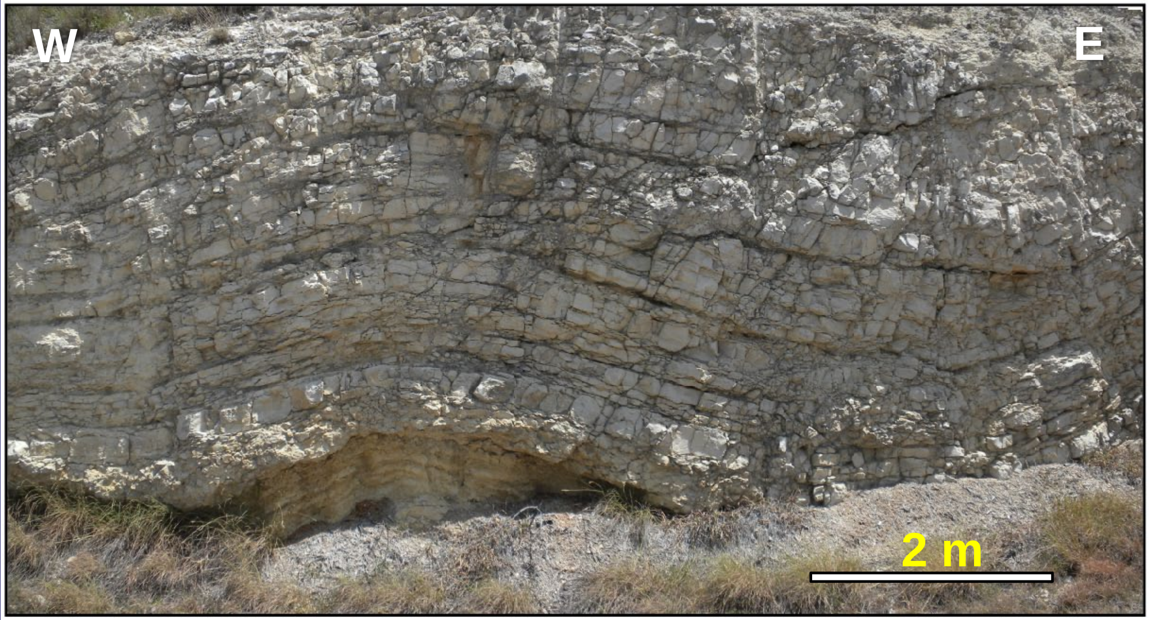
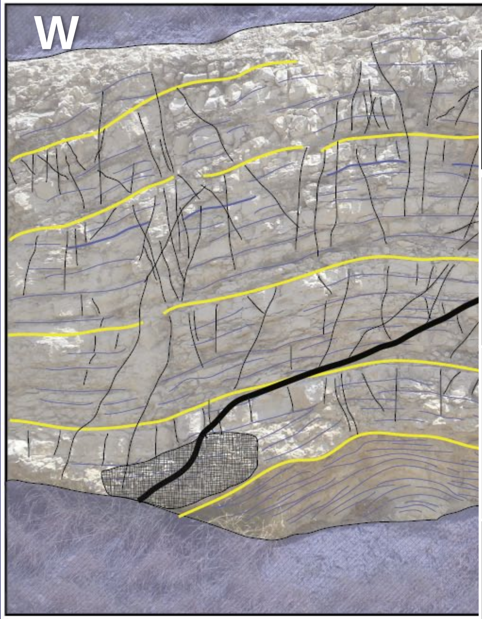
Compressional Faults

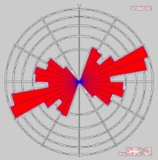
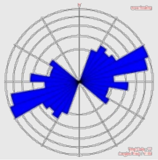
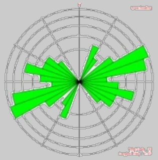


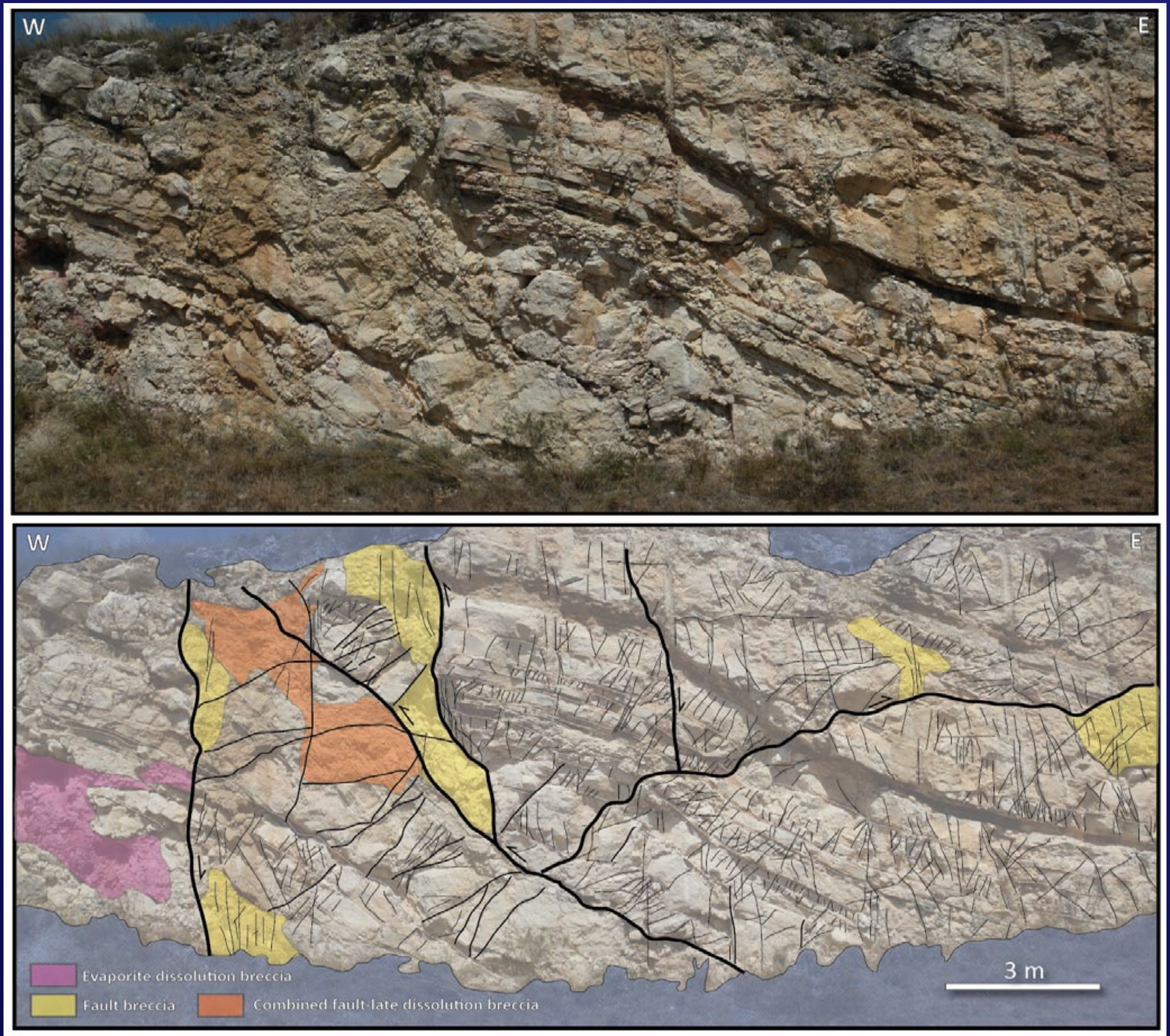
Lithofacies	Bed thickness (m)	Fracture Style	Average Spacing (m)	Normalized FSI	Orientation
Grain-Dominated Packstone	0.3	All	0.11	2.6	N50E N22W 
Grain-Dominated Packstone	0.3	Bed-bound	0.2	1.5	N55E N17W 
Grain-Dominated Packstone	0.3	Through-going	0.27	1.1	N61E N08W 

Compressional Buckling





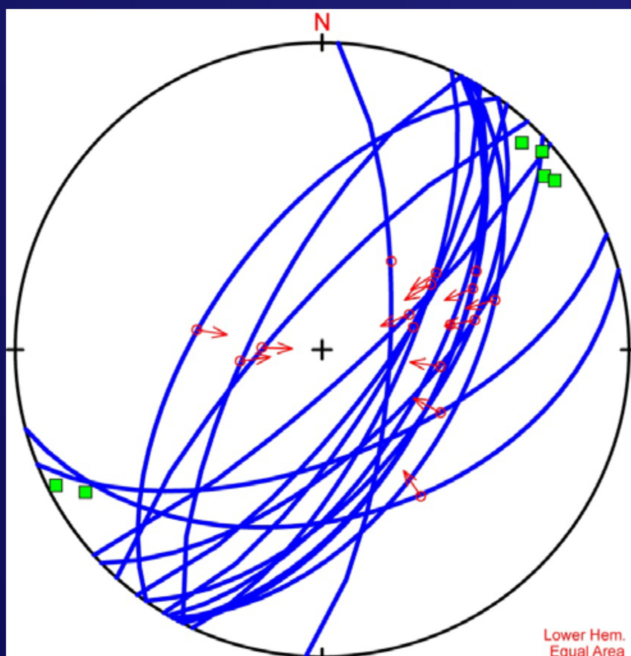
Lithofacies	Bed thickness (m)	Fracture Style	Average Spacing (m)	Normalized FSI	Orientation
Grain-Dominated Packstone	0.28	All	0.13	2.2	N69E N80W 
Grain-Dominated Packstone	0.28	Bed-bound	0.18	1.6	N71E N58W 
Grain-Dominated Packstone	0.28	Throughgoin g	0.5	0.6	N73E N79W 

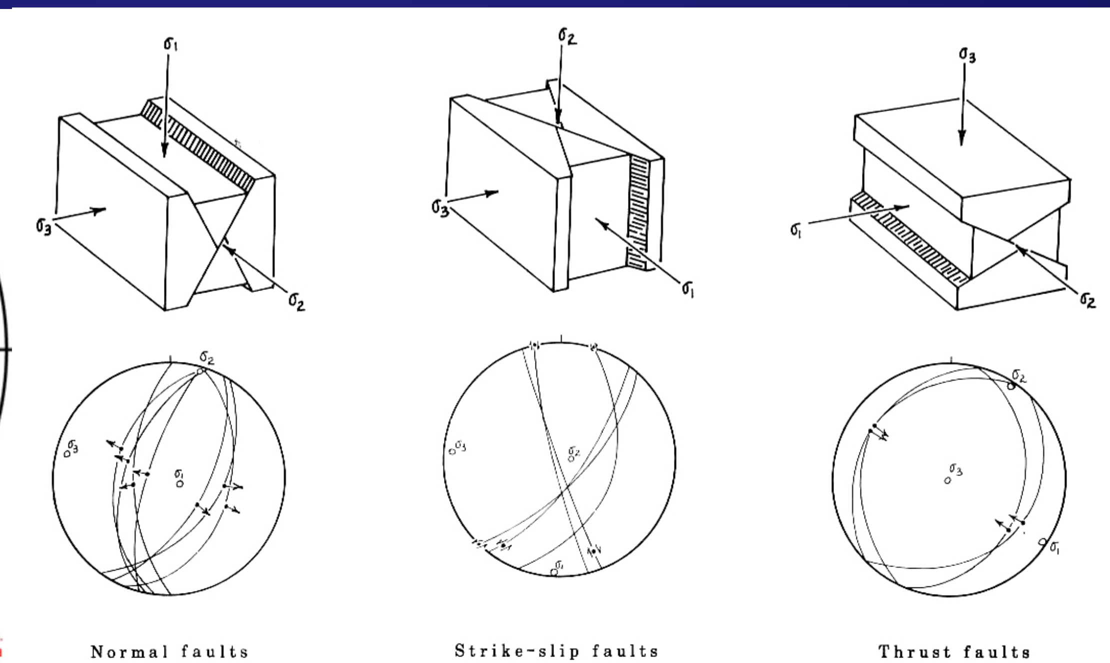


Mixed Deformation Style

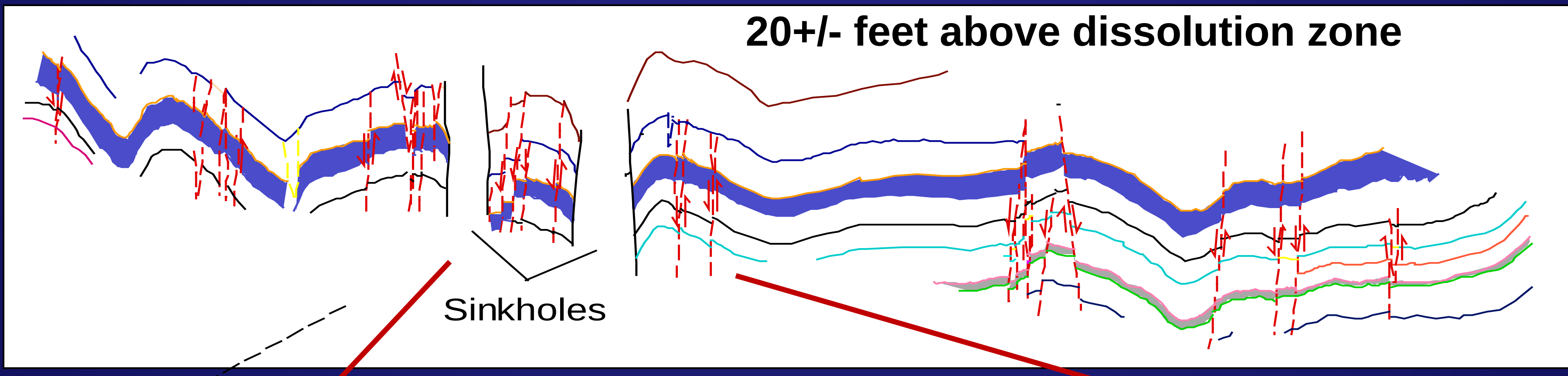
Extensional & Compressional Faulting

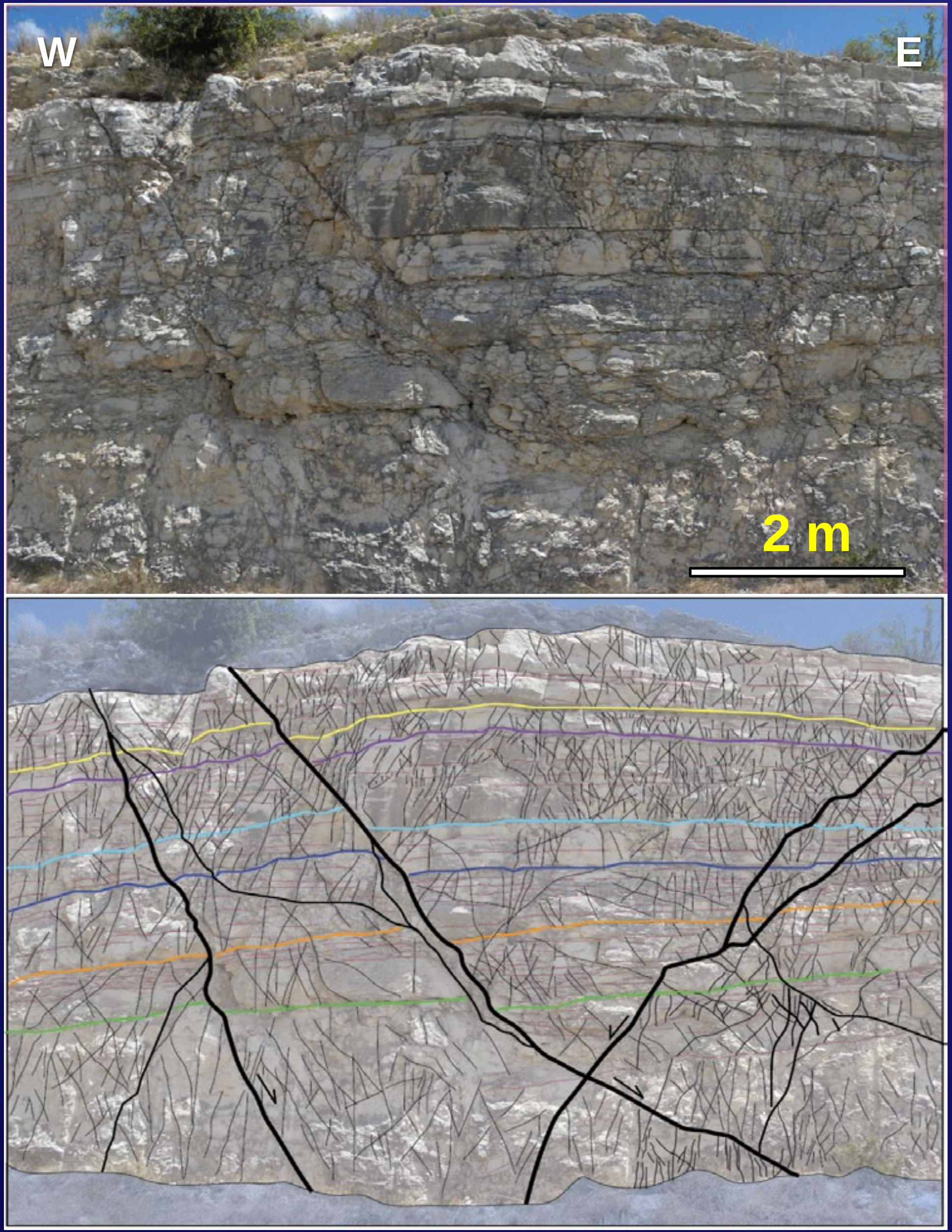
Reverse Faults – Reactivated Extensional Faults





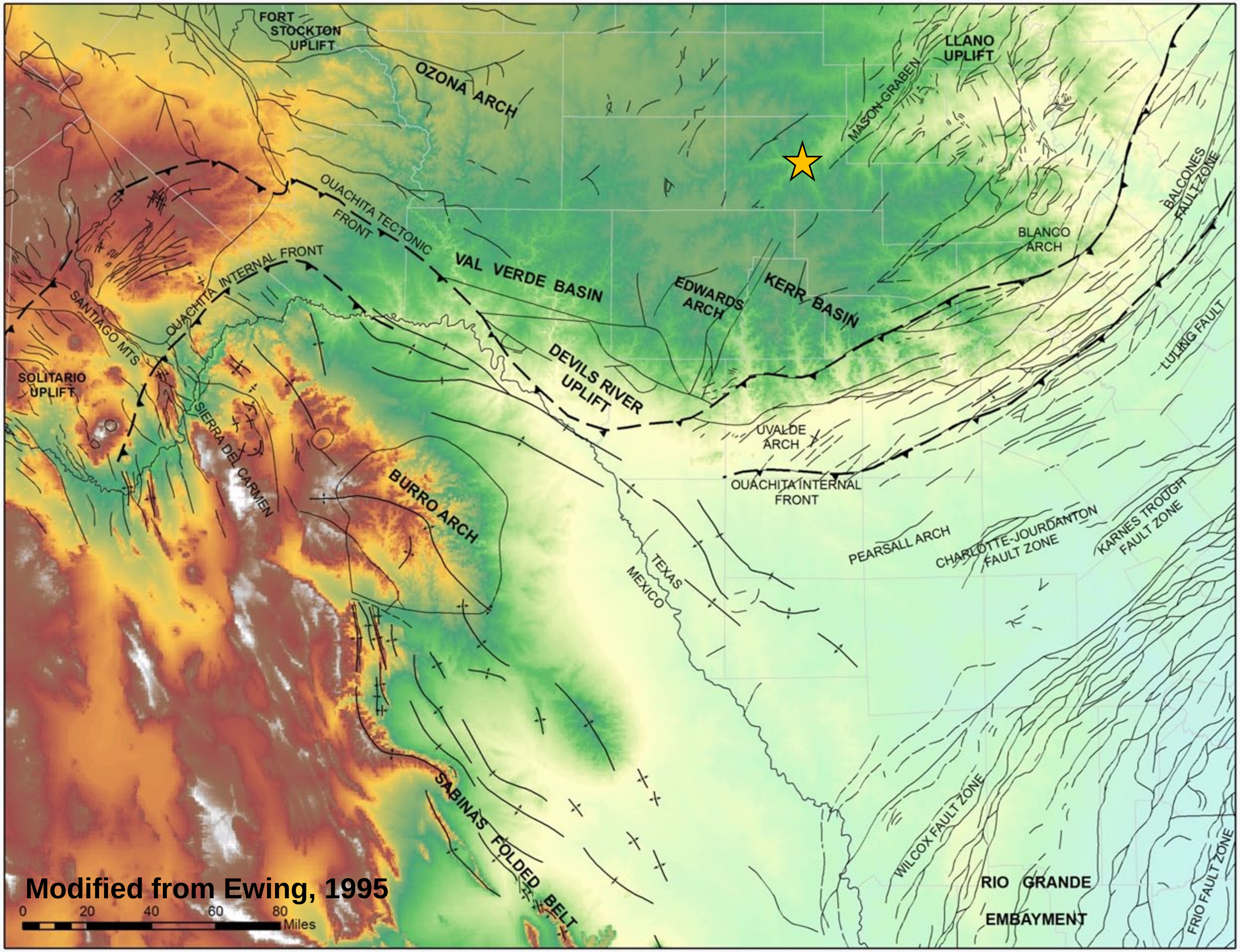
Disturbed Bedding Above Evaporite Dissolution Zone



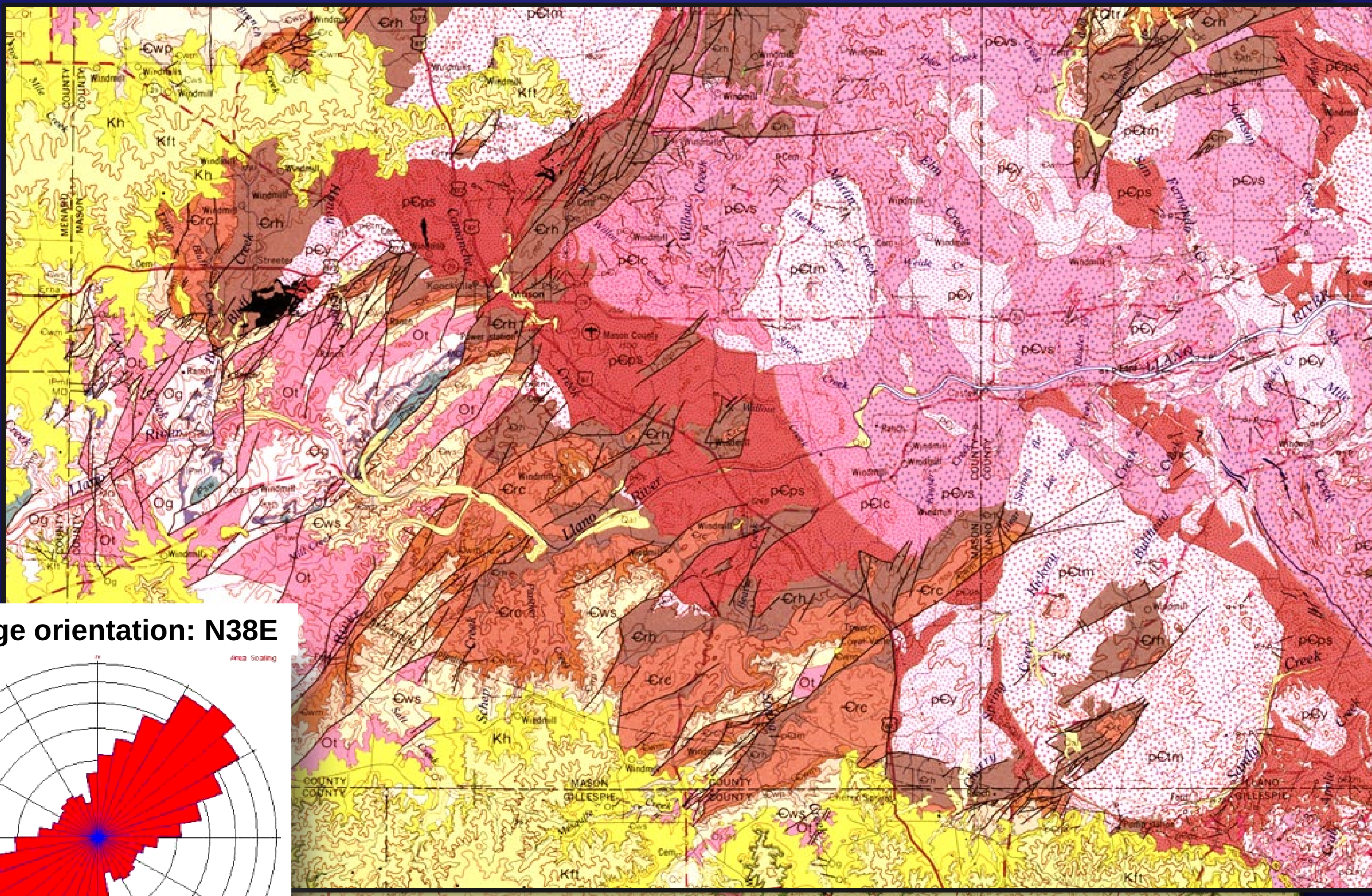


Overlying Extensional Faulting

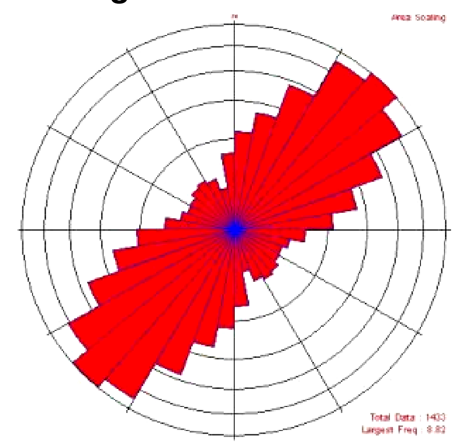
Tectonic Framework



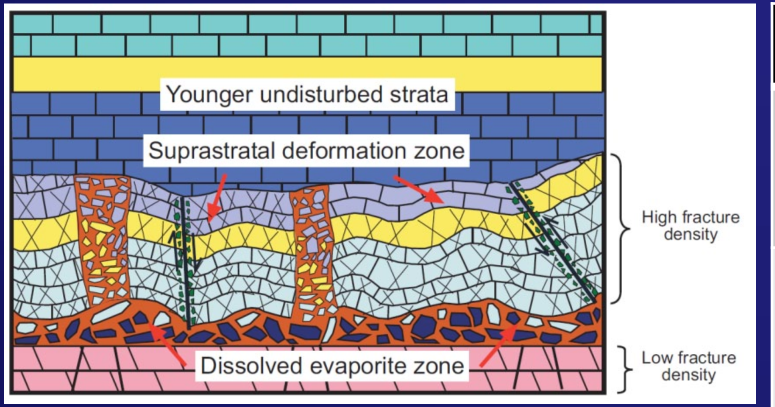
Paleozoic Fault Pattern



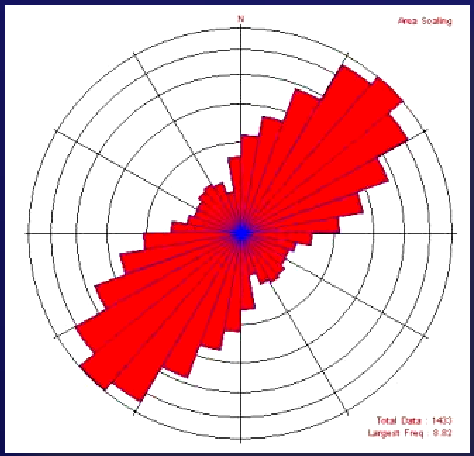
average orientation: N38E



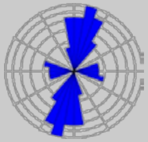
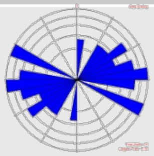
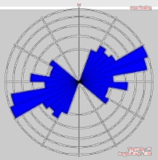
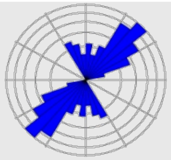
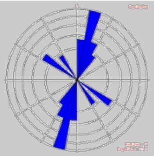
Evaporite Karst and Deformation Model



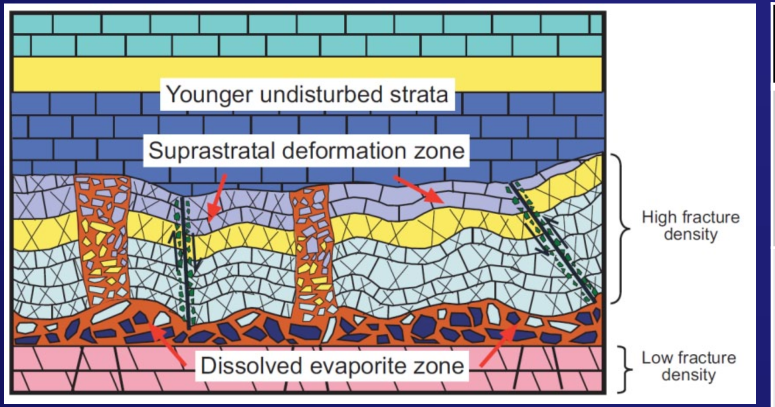
Bed-Bound Fractures



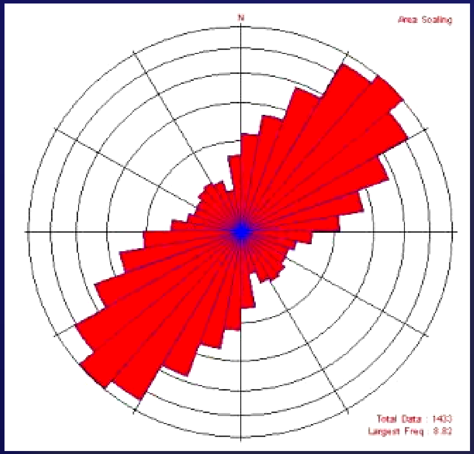
Paleozoic faults

Position	Average Spacing (m)	Normalized FSI	Orientation
Synkinematic: Overlying	0.4	1.7	N31E N83E 
Synkinematic: Extensional	0.95	0.6	N85E N60E 
Synkinematic: Compressional	0.18	1.6	N71E N58W 
Synkinematic: Compressional	0.2	1.5	N55E N17W 
Prekinematic: Opening-Mode	1.7	0.4	N15E N55W 

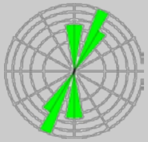
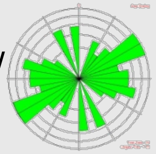
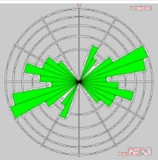
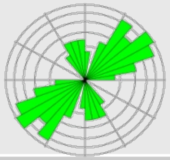
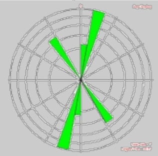
Evaporite Karst and Deformation Model



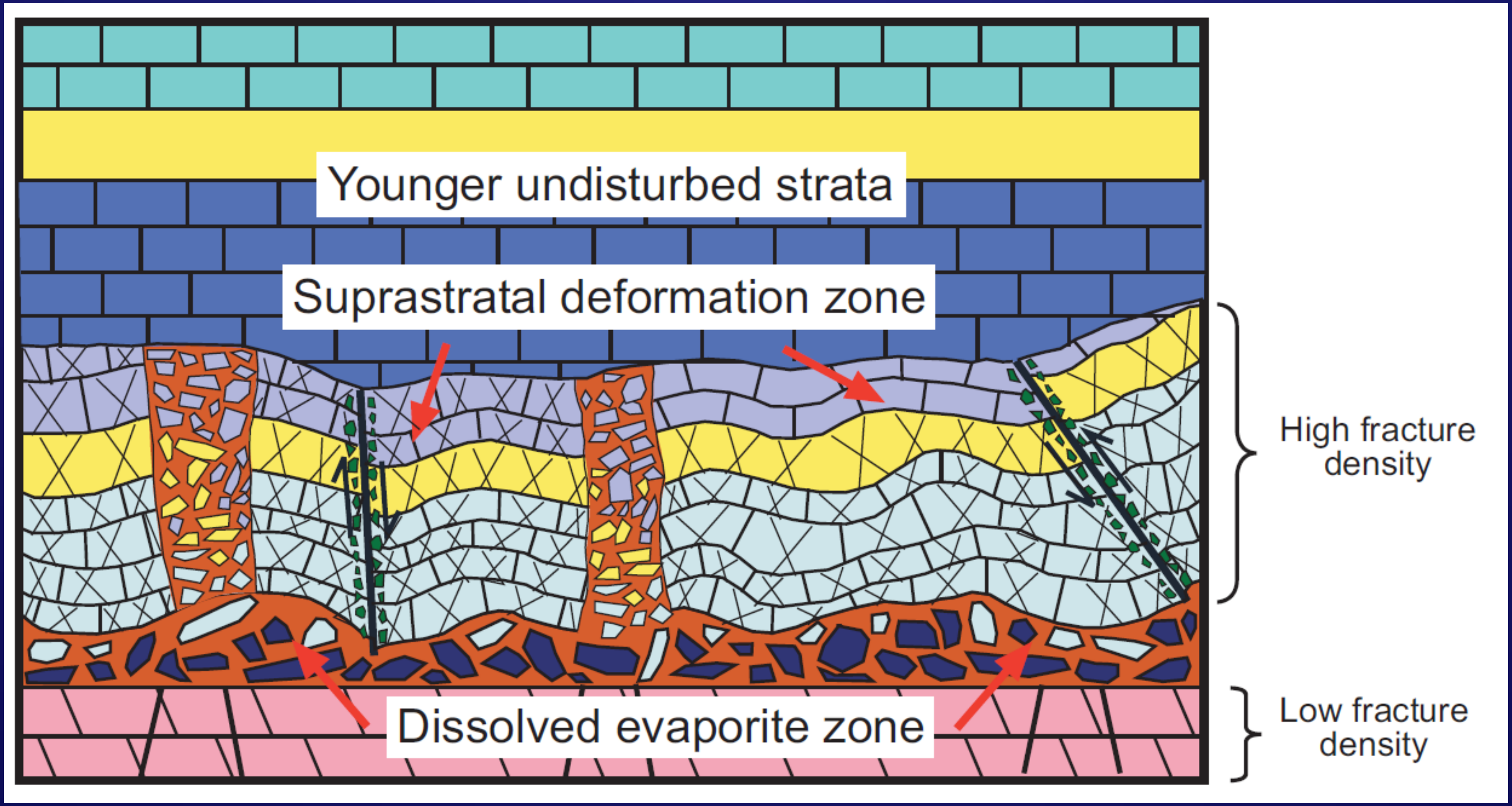
Throughgoing Fractures



Paleozoic faults

Position	Average Spacing (m)	Normalized FSI	Orientation
Synkinematic: Overlying	5.1	0.1	N38E N02W 
Synkinematic: Extensional	0.45	1.3	N60E N75W 
Synkinematic: Compressional	0.5	0.6	N73E N79W 
Synkinematic: Compressional	0.27	1.1	N61E N08W 
Prekinematic: Opening-Mode	3.4	0.2	N15E N35W 

Evaporite Paleokarst and Deformation Model



Conclusions

- **Important factors in deformation style include:**
  - **Beginning strata composition and thickness**
  - **Exposure type (e.g., burial vs. surface)**
  - **Sediment fill type following dissolution.**

- **Pore networks within paleokarst include interclast, evaporite molds, and solution-enhanced fractures.**

Conclusions

- Mapped faults in the prekinematic, Paleozoic strata are parallel to faults and fractures in the synkinematic deformed strata despite lack of throughgoing faults from Paleozoic to Cretaceous strata.
- Deformation of evaporite collapse is an atectonic process as the volume loss by dissolution is accommodated by local extensional faulting and compressional folding and reverse faulting.
- Intense fracture development occurs within the paleokarst and within overlying strata.