The Paradox Salt Basin, Utah and Colorado: Recognition of New Types of Salt Structures and Their Impact on Salt-Related Traps*

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Abstract

The Paradox Basin in southeastern Utah and southwestern Colorado has a long history of successful near-salt hydrocarbon production utilizing a relatively simple stratigraphic play strategy of Pennsylvanian and Permian siliciclastic reservoirs upturned against long, linear salt walls. With the continuously improving seismic imaging of salt systems and voluminous well-bore datasets acquired from salt basins worldwide, new types of near-salt features and associated traps have been identified and successfully tested recently, particularly in the Gulf of Mexico. However, these new features have not been previously recognized in the Paradox salt basin. Utilizing 2D seismic lines, well logs and new detailed outcrop studies of Gypsum Valley in the Paradox Basin, we highlight several of these newly recognized salt features that indicate that the Paradox Basin is a much more dynamic and complex salt system than previously thought. Identification of these new structures at other Paradox salt walls may provide new exploration concepts in this mature salt basin and lead to a reinterpretation of the basin evolution and salt tectonic history. Newly recognized salt features include: 1) megaflaps comprising steeply dipping panels of Pennsylvanian Honaker Trail and uppermost Paradox reservoir strata that extend 2.5 km up the side of the salt walls; 2) lateral carbonate caprock that formed during Permian and Triassic caprock events and have been misidentified in the past as Pennsylvanian Honaker Trail Fm..; 3) halokinetic radial faults, which extend short distances (<2 km) away from the salt wall and are concentrated at the arcuate ends of salt walls; 4) counter-regional faults merging into the proximal margins of the salt walls and detaching on autochthonous salt at depth; 5) shoulder anticlines, which are salt-margin dissolution anticlines that are present

where the steep edges of diapirs step abruptly inward. Megaflaps are commonly blown traps, or areas of poor pressure protection. Lateral caprock may form salt-flank reservoir facies or trap thief zones. Radial faults can provide reservoir seal or may compartmentalize salt flank traps. Counter-regional faults may form low angle 3-way closure against salt. Shoulder anticlines are newly identified traps with excellent charge scenarios.

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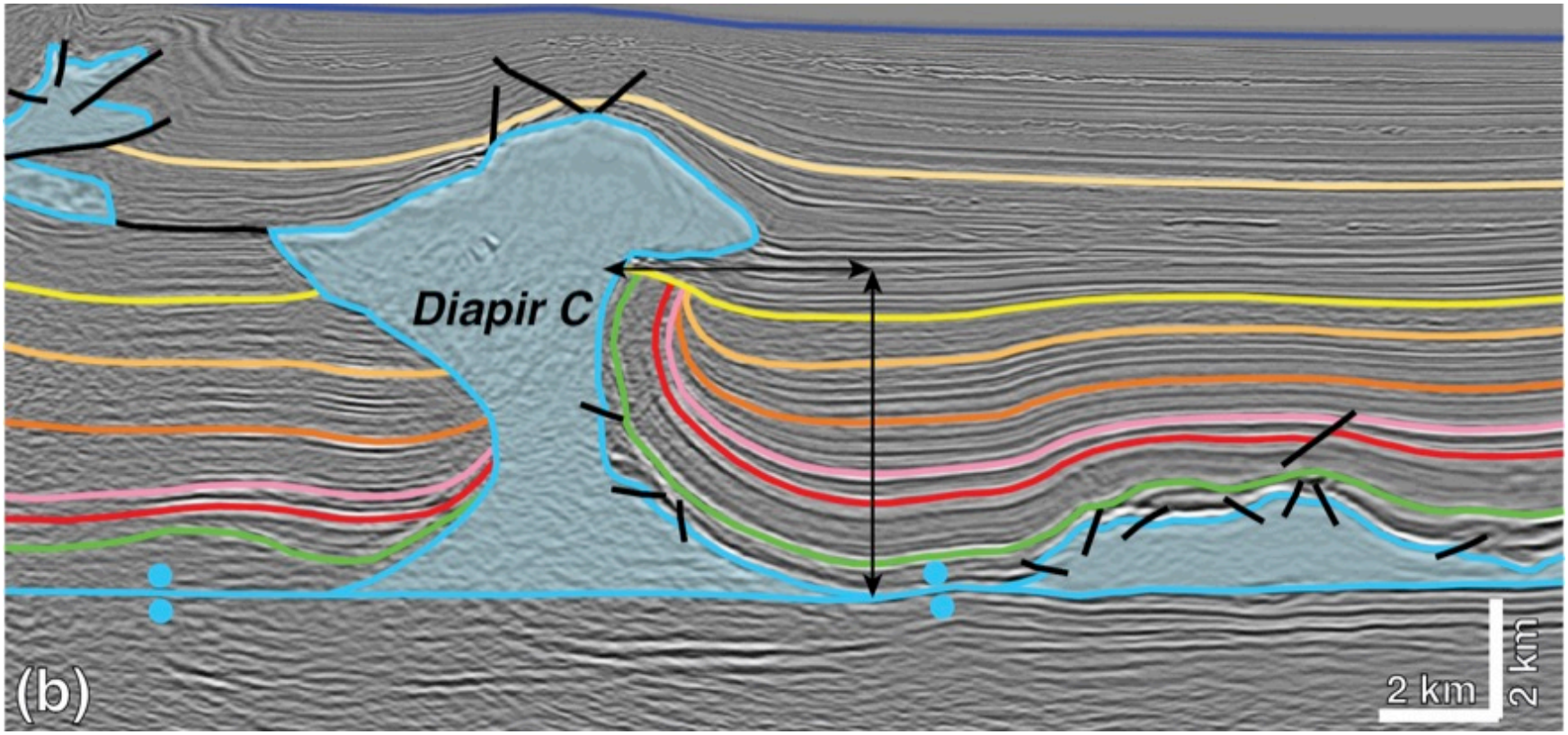
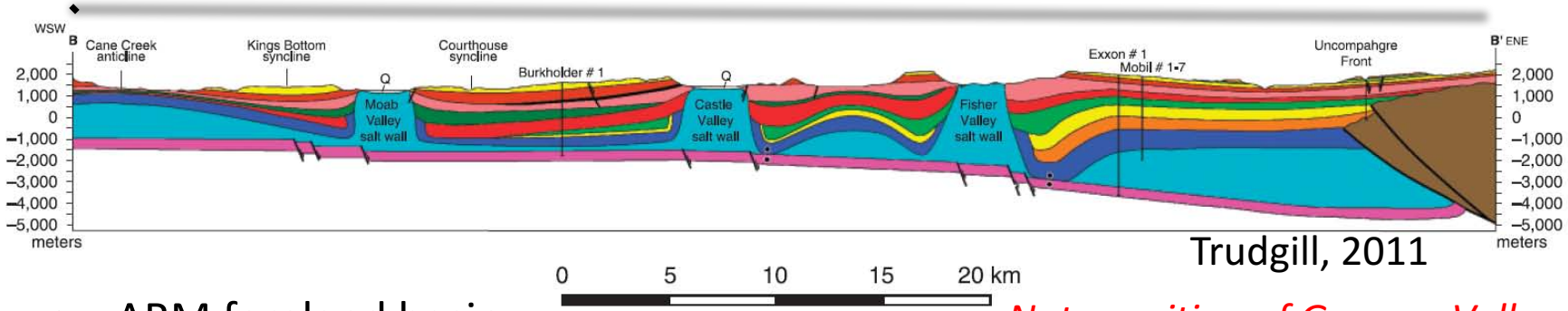
Recent Recognition of New Types of Salt Features using New Technology & Extensive Exploration in Major Producing Salt Basins

- GoM, North Sea, Pricaspian, South Atlantic basins, etc.



Gulf of Mexico Megaflap

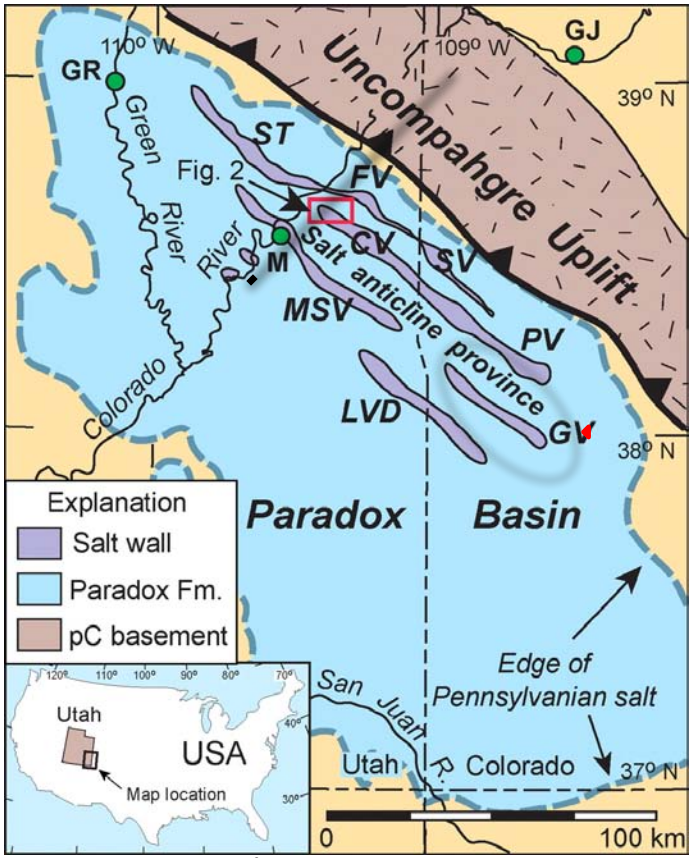
Paradox Basin Basics



Trudgill, 2011

- ARM foreland basin
- Pennsylvanian Paradox Fm. salt
- Permian progressive southwestward diapir initiation in response to Permian fluvial Cutler depositional loading
- Roughly symmetrical, linear salt walls
- Synchronous rise rate & equal standing salt walls
- Synchronous Jurassic cessation of passive diapirism across basin
- Cenozoic dissolution & faulted diapir roof collapse
- Oil generation in the Jurassic? Late Cretaceous?

Note position of Gypsum Valley (GV)

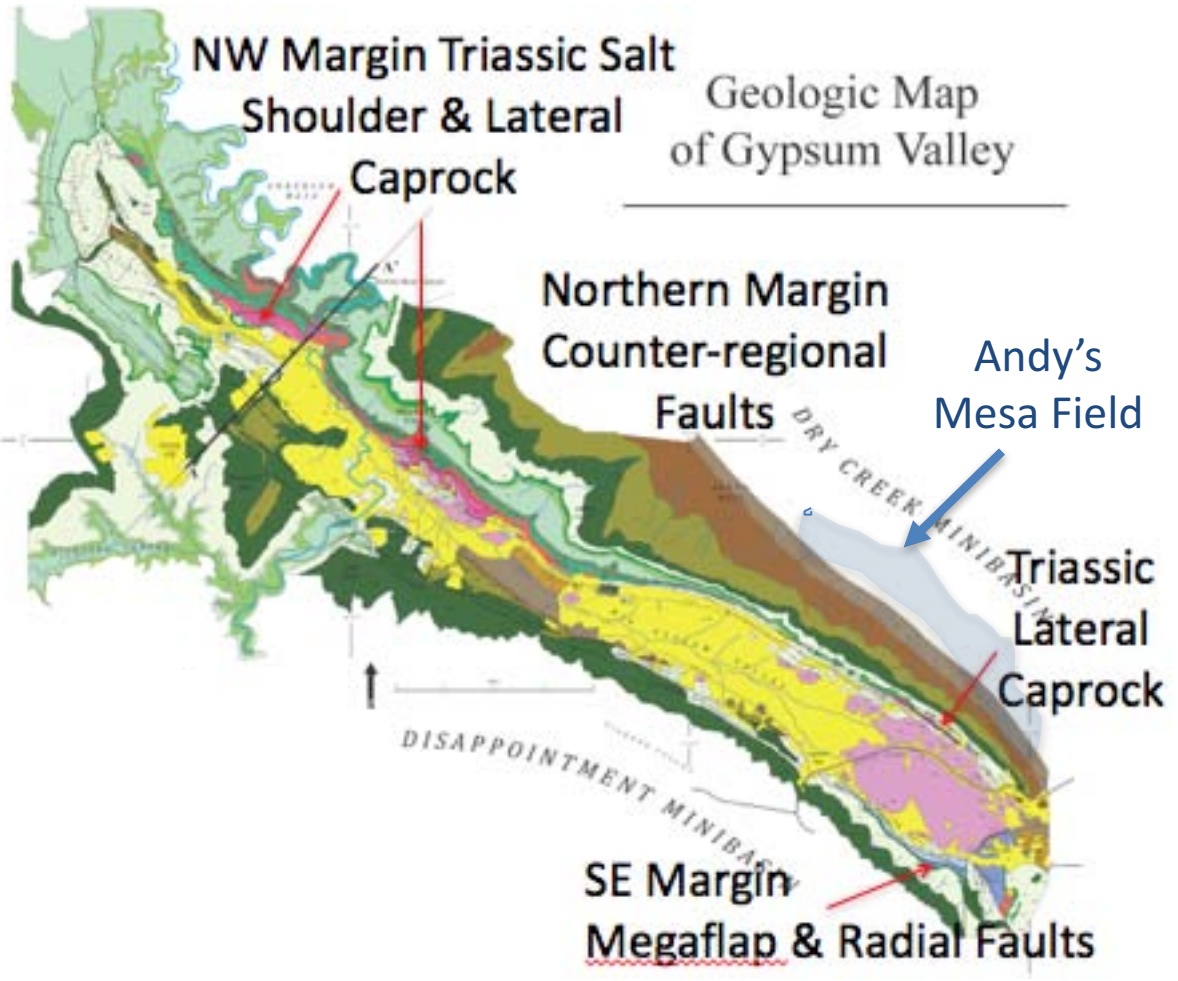


Lawton & Buck, 2006

Newly Recognized Salt-Related Features in the Paradox Basin

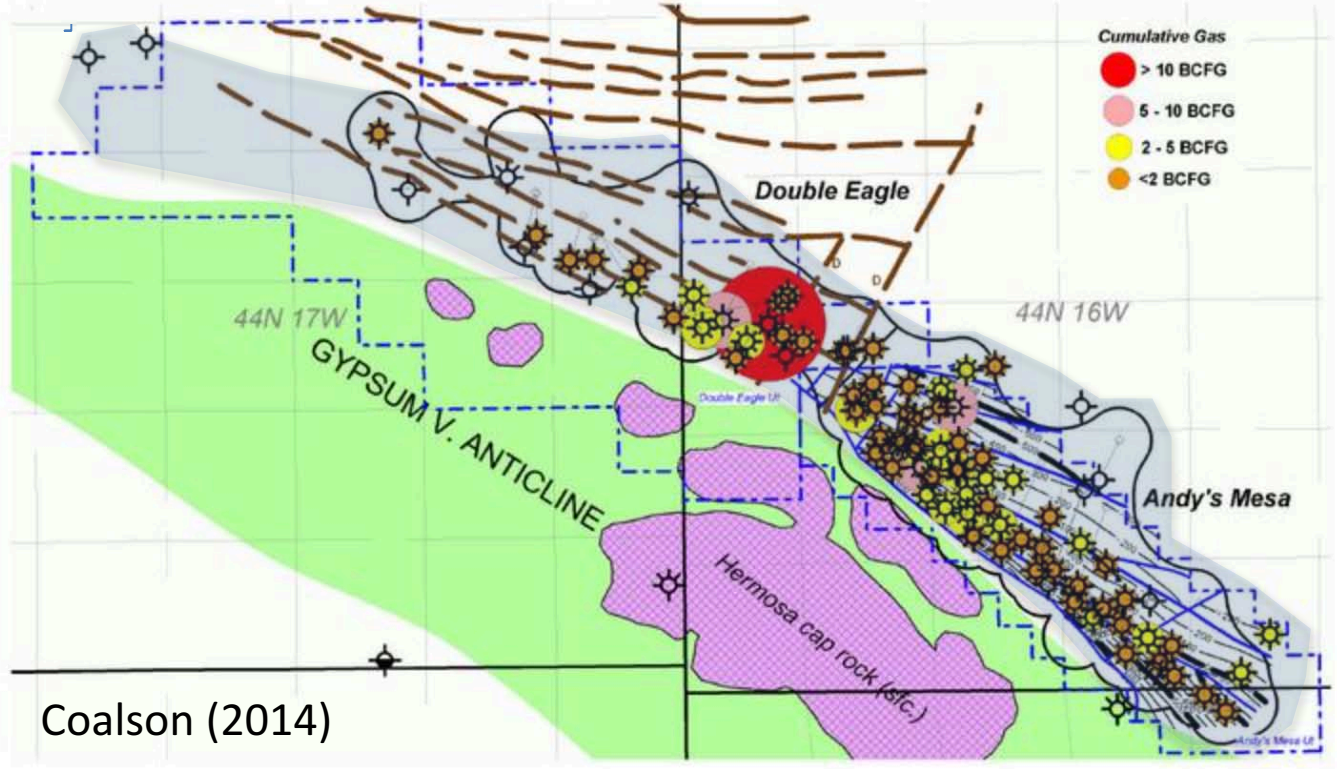
Using 2-d seismic, well logs, and outcrop analysis at Gypsum Valley & Castle Valley

- **Megaflaps**
- **Lateral Carbonate Caprock**
- **Halokinetic Radial Faults**
- **Counter-regional Faults**
- **Salt Shoulder Anticlines**

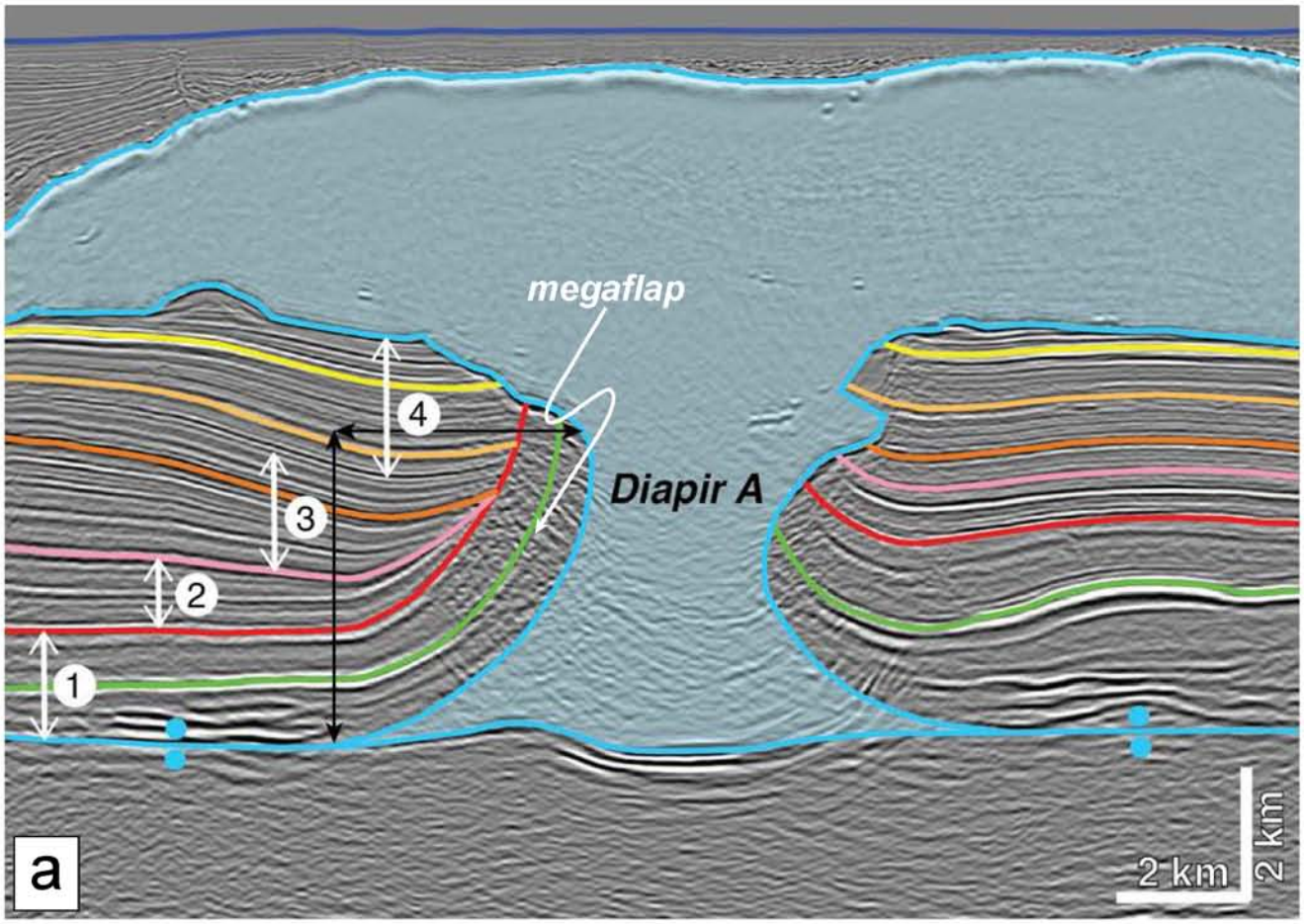


Andy's Mesa Field Summary

- Discovery 1967, oil & gas production to present
- Play type: Conventional gas
- Trap: fault & stratigraphic pinchout against Paradox salt
- Depths: 4,200-8,400 ft
- Reservoirs:
    - Permian Cutler fluvial channel ss. -59 wells
    - Pennsylvanian Honaker Trail fluvial channel ss -36 wells
- Source: Pennsylvanian Paradox Fm organic-rich carbonate mudstones



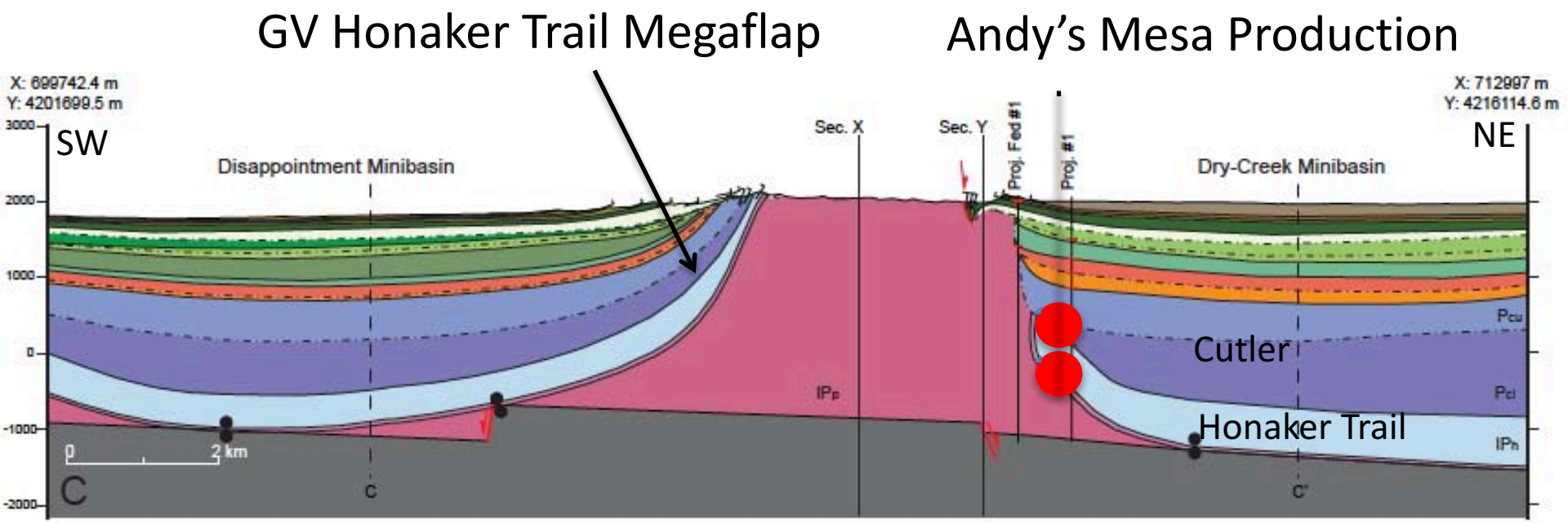
Megaflaps



Rowen et al., 2016

- Increasingly recognized in GoM
- Often discovered post-drill due to poor seismic imaging beneath salt
- Blown traps due to over-pressure
- Seals (?) to onlapping reservoirs

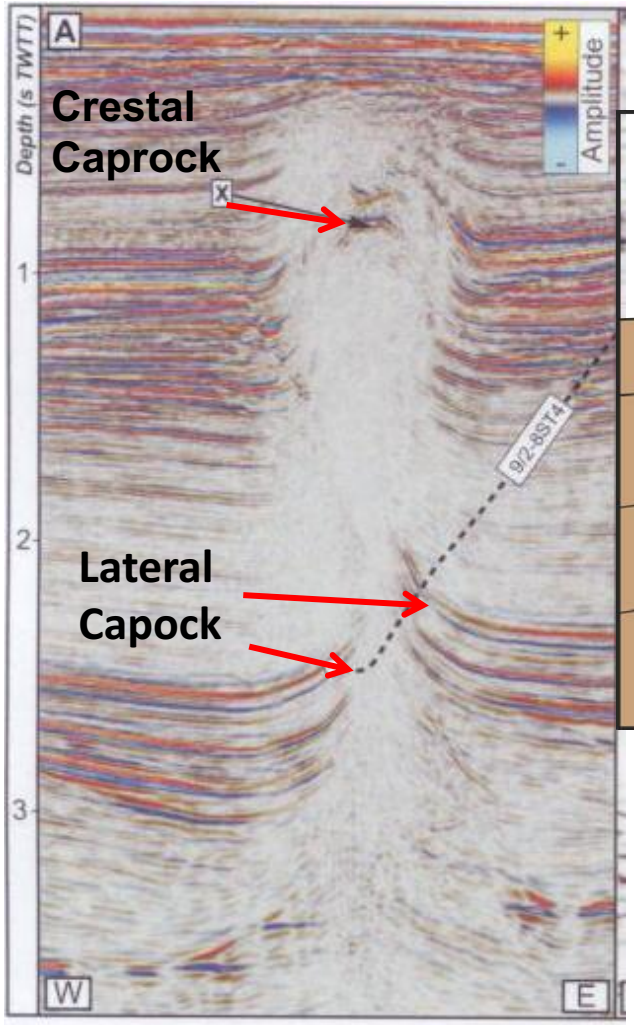
Gypsum Valley Megaflap



- Megaflap Pennsylvanian Honaker Trail and Permian Cutler traps are blown
- Megaflap facies are reservoirs, so won't seal
- Megaflap onlapping potential reservoirs face charge issues

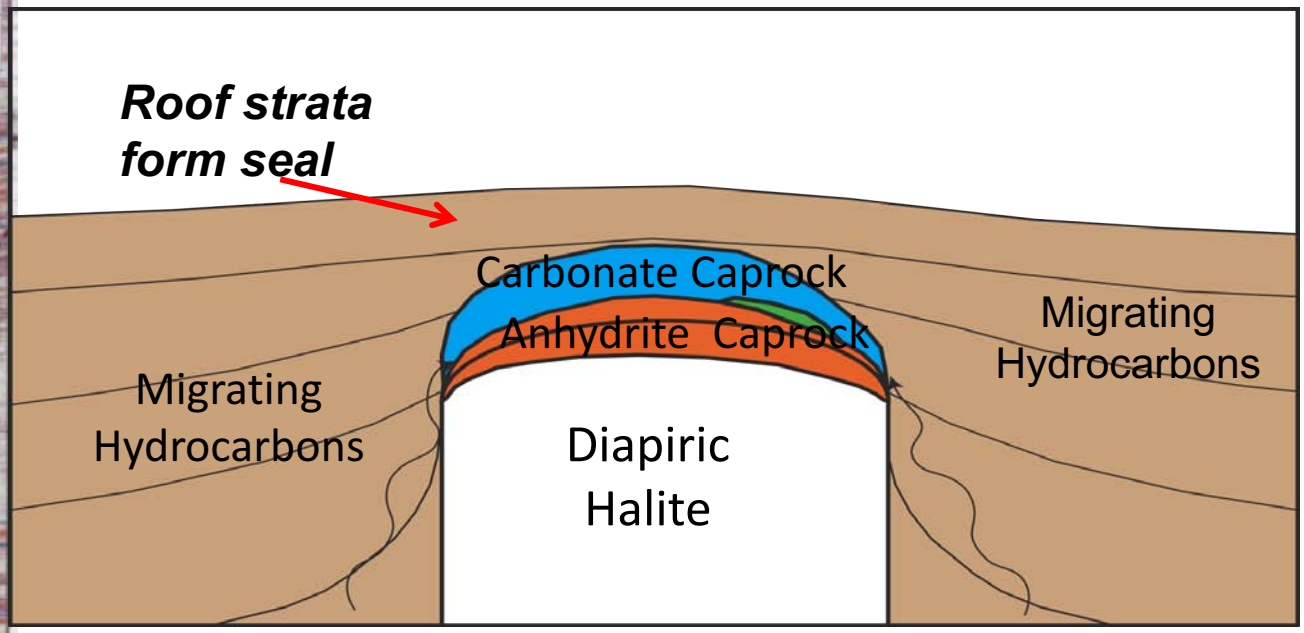
Carbonate Lateral Caprock

Epsilon Diapir, North Sea



Jackson, C. A. & Lewis, M.M., 2012

Carbonate caprock from anhydrite by sulfate reducing bacteria carried in hydrocarbons



- Miss-identified as carbonate stratigraphic units
- May provide exceptional salt flank reservoir
- May act as salt flank thief zone

Gypsum Valley Carbonate Lateral Caprock

- Mapped as Pennsylvanian Honaker Trail marine carbonates
- 2 ages: Triassic Chinle & Permian Lower Cutler
- Permian caprock possibly miss-interpreted as Honaker Trail at depth in Andy's Mesa wells

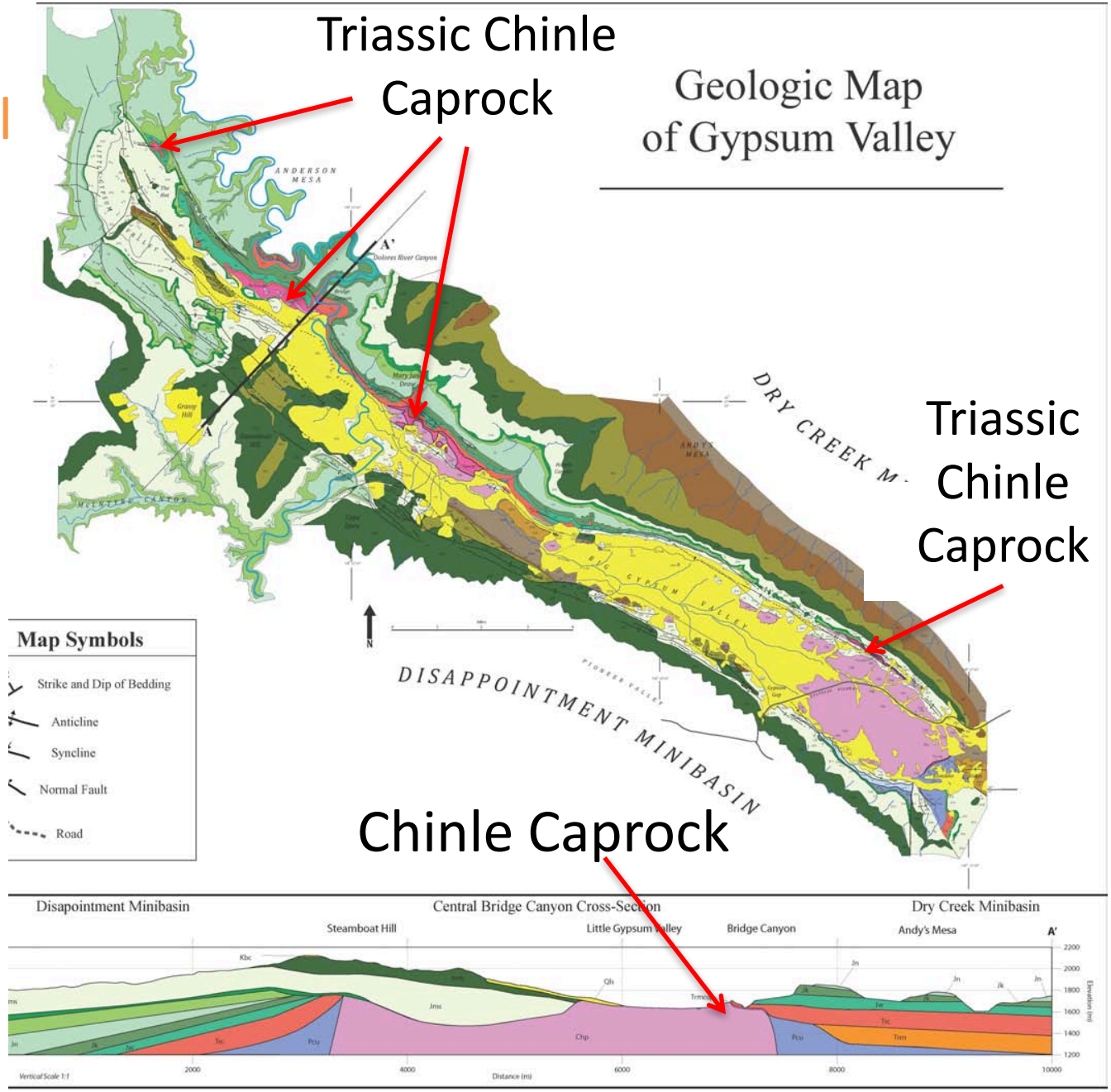


Figure 4. Geologic map of Gypsum Valley, Colorado based on Stokes and Phoenix (1948). Units and colors match those on the stratigraphic column (Figure 3). The study area (Figure 5) is outlined in red in both map and cross section view.

Triassic Chinle Lateral Caprock

Triassic Chinle – CO_3 Caprock Contact

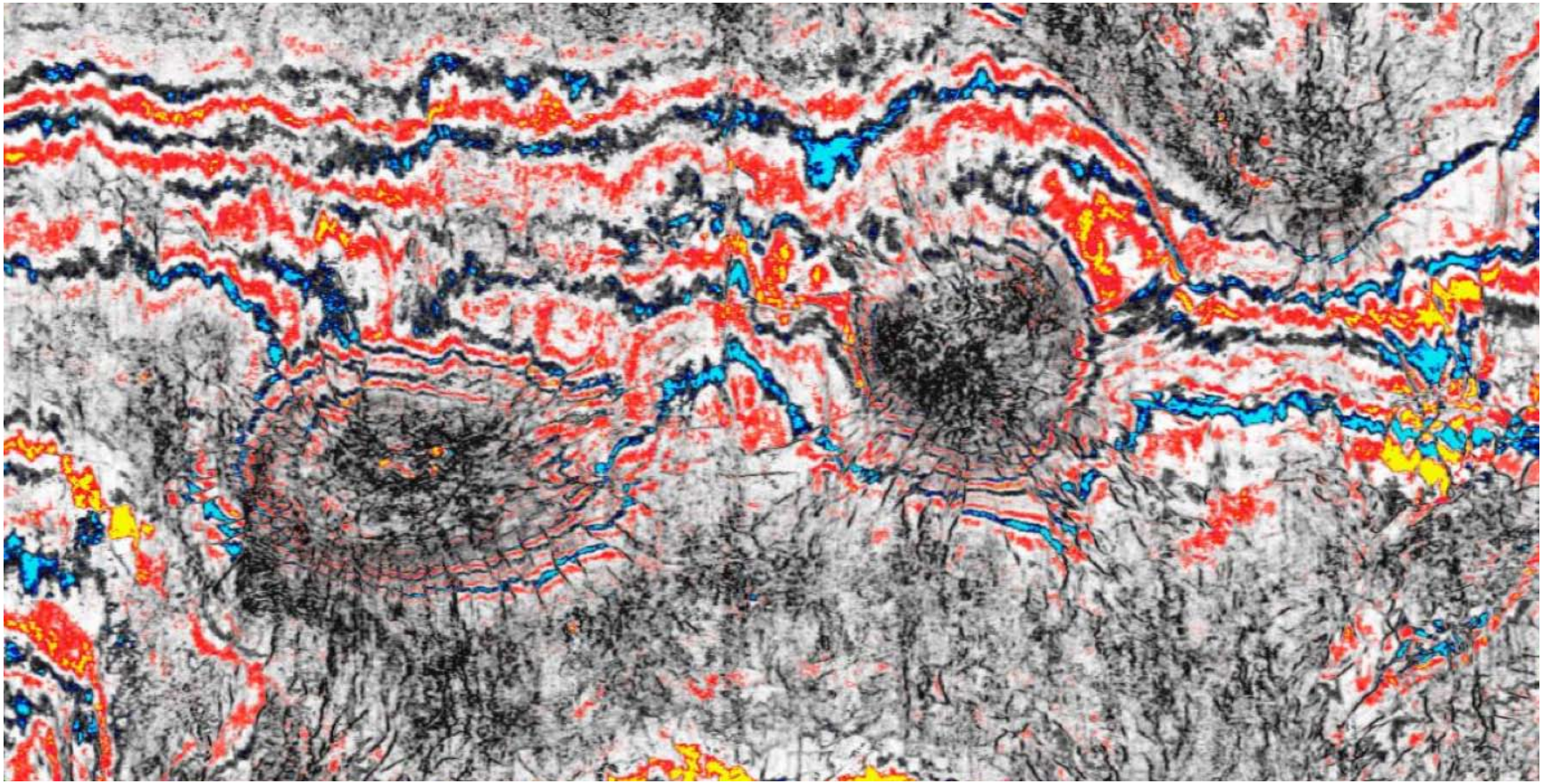
Carbonate Caprock

Gypsum Caprock

CO_3 Caprock mapped as Pennsylvanian Honaker Trail Formation

Radial Faults

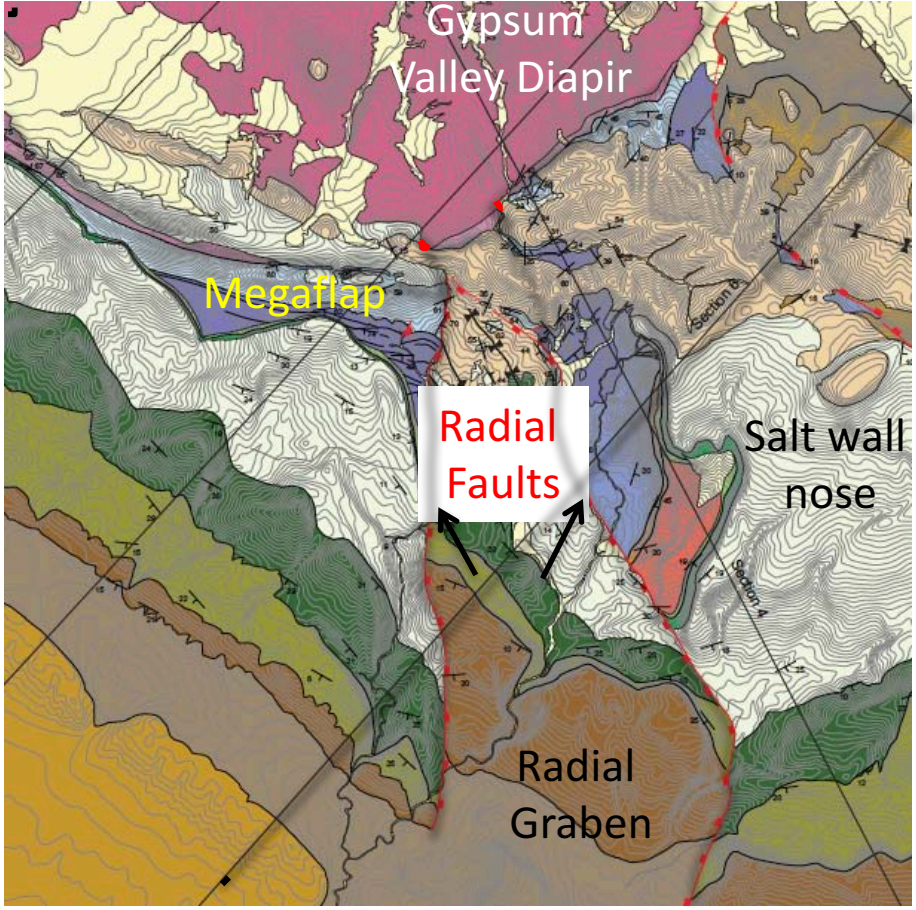
Time slice offshore Nova Scotia courtesy of WesternGeco and KerrMcGee

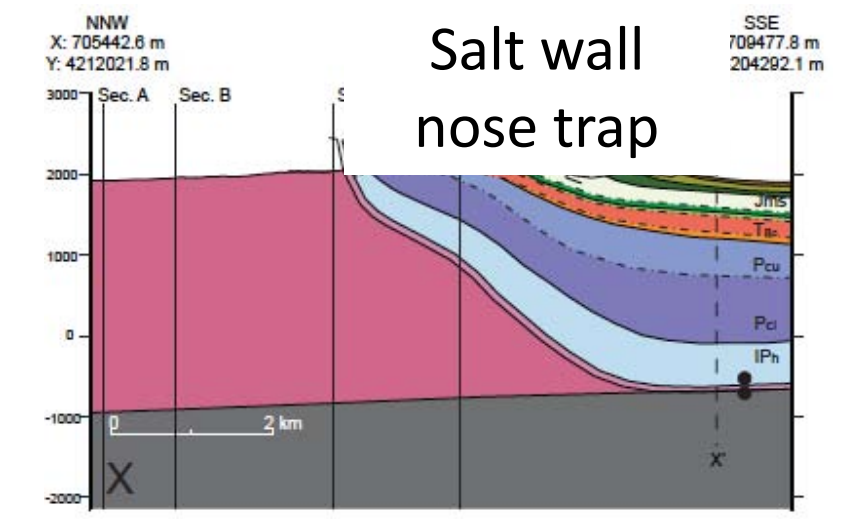


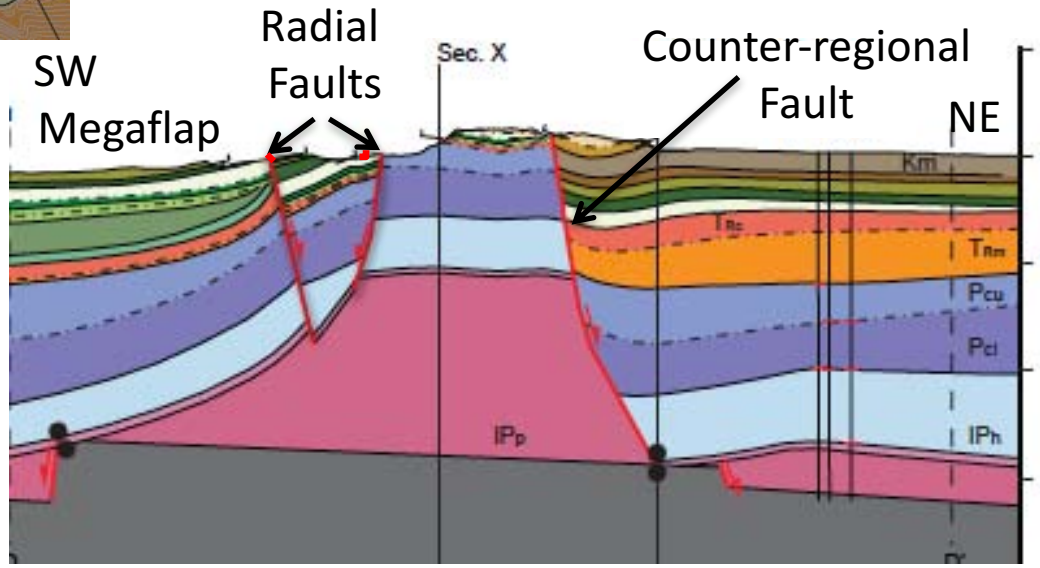
- Generated during passive rise of diapirs as roof strata drape – fold off the top
- Provide reservoir seal
- Or may compartmentalize salt flank traps

Gypsum Valley Radial Faults

- Formed at curved SE margin
- Truncates megaflap
- Extend <2km from salt wall edge
- Indicates passive rise of SE end of GV salt into the Cretaceous
- Bounds former salt wall nose trap

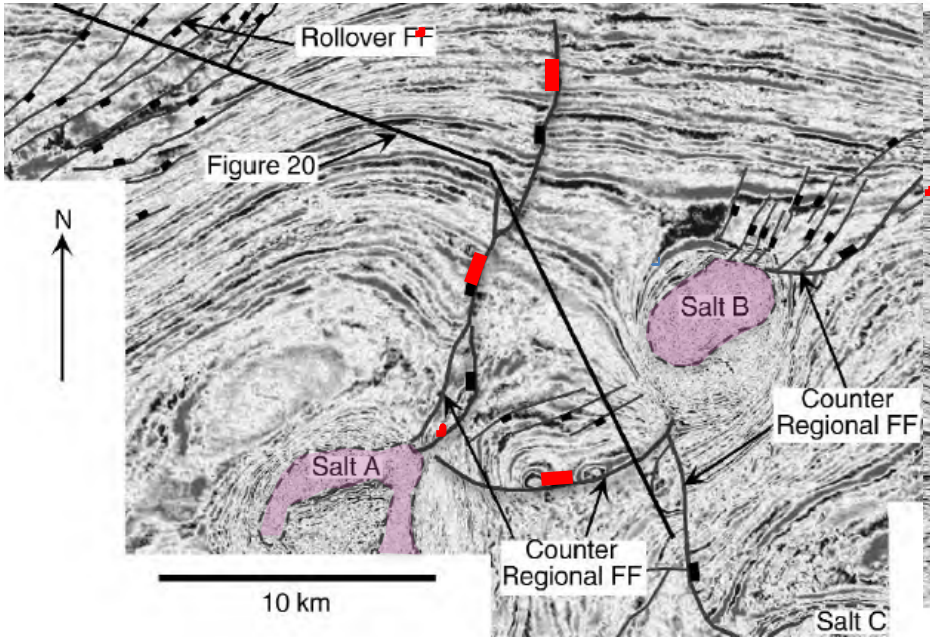




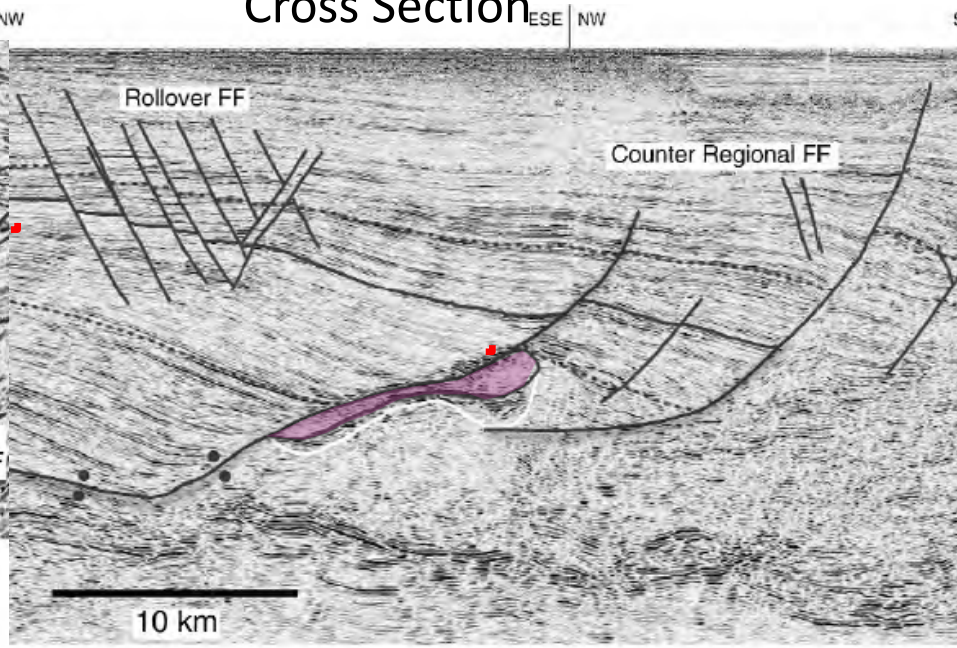


GoM Counter-Regional Faults

Time Slice



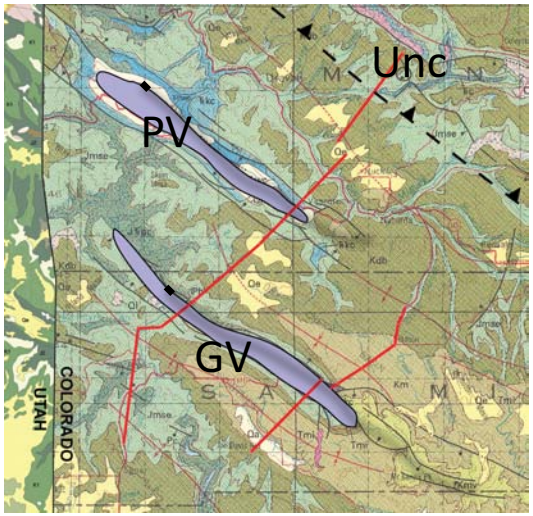
Cross Section



Rowan et. al. (1999)

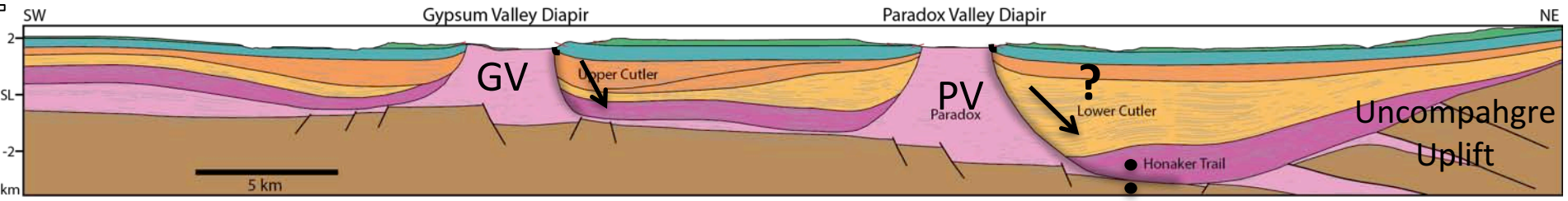
- Merge into the proximal margins of salt
- Detach on salt at depth
- Bound foot wall 3-way closures against salt where reservoir is against salt

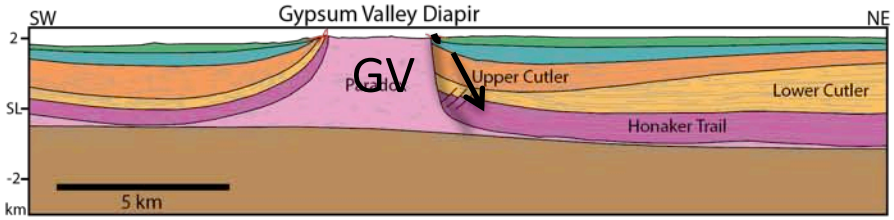
Gypsum Valley Counterregional Faults



- Form on north side of salt walls
- Gypsum Valley CR fault not active until Upper Cutler time
- Paradox Valley CR fault active Pennsylvanian Honaker Trail time
- Hanging wall traps against salt

Annotated 2D seismic lines

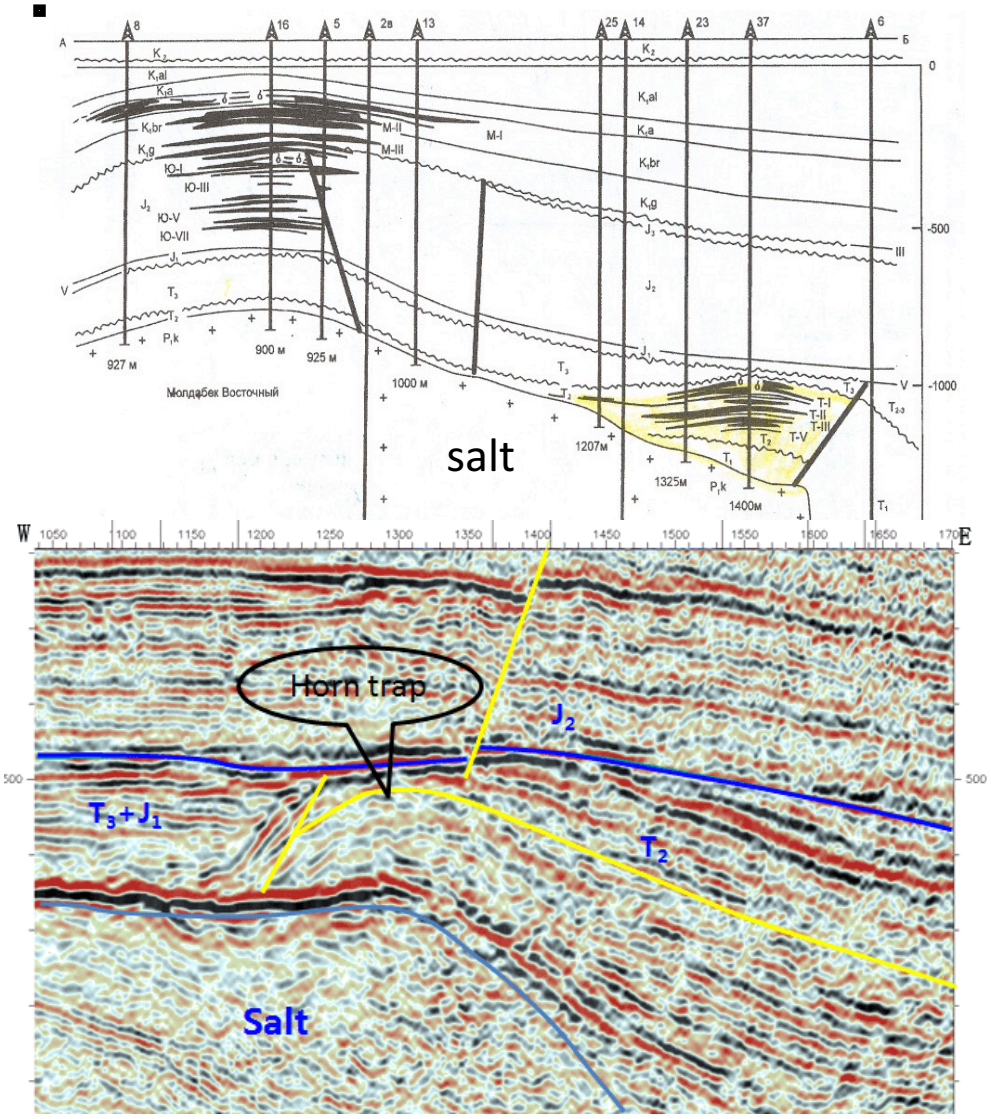




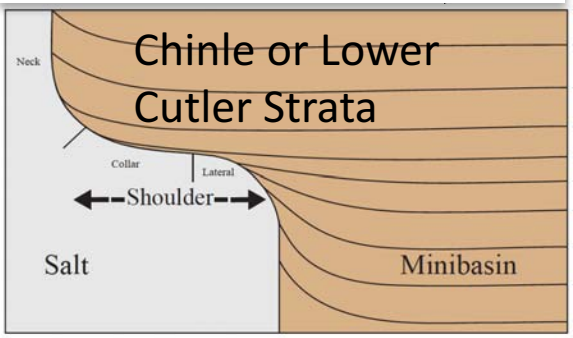
Salt Shoulder Role/Horn Traps

- Zone where diapir margin steps abruptly inward
- Onlapping supra-shoulder strata may host hydrocarbons
- Especially if associated with salt-dissolution-related anticlinal folds & normal faults
- In subaerial settings commonly associated with caprock

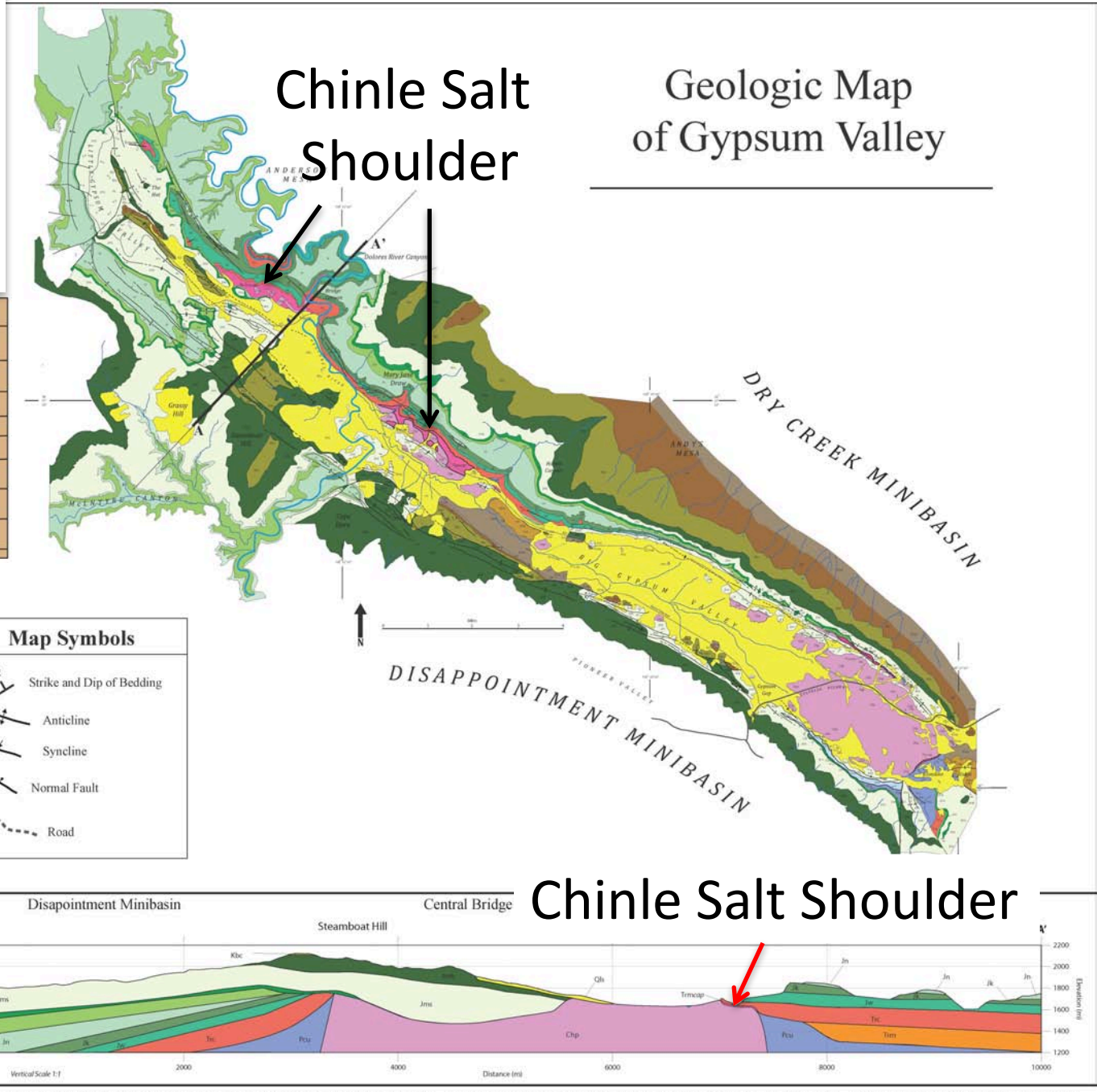
Pricaspian salt basin shoulder traps



Gypsum Valley Salt Shoulders



- <1km wide zone
- Extends 11km along northern edge of GV salt wall
- Onlapped by Triassic Chinle HS
- Progressive narrowing NW end of diapir



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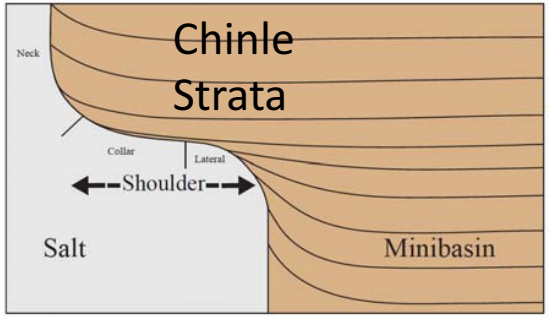
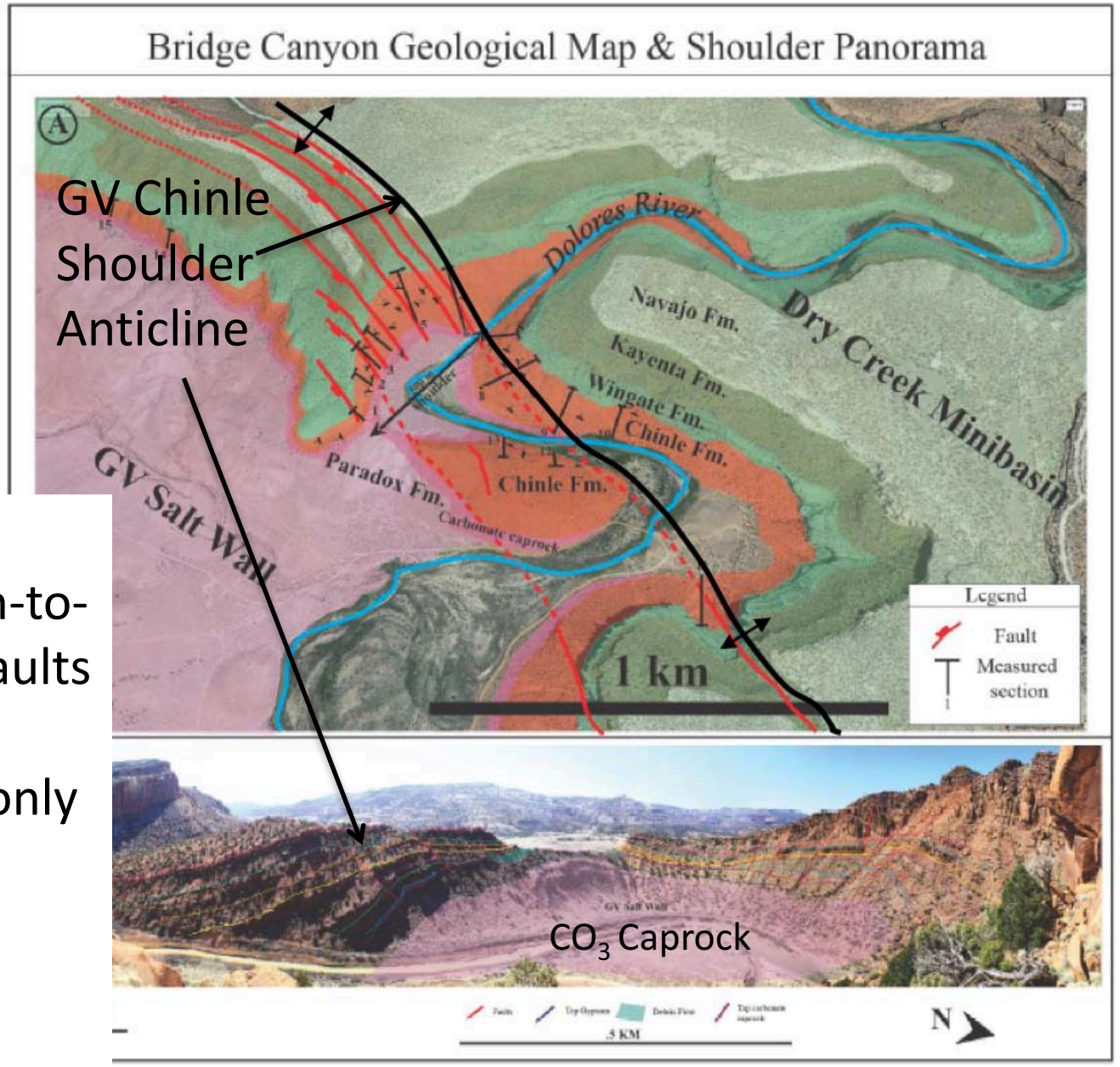
GV Chinle Salt Shoulder



- GV Chinle shoulder anticline with down-to-the diapir normal faults
- Chinle is bleached only at anticline
- Dead oil in Chinle channel sands on shoulder



Revisiting the Paradox Basin Salt-Related Traps

- Paradox Basin has many of the same complex salt structures found in other important hydrocarbon bearing salt basins
- Salt walls commonly asymmetric with trap potential varying from side to side
- Salt wall features and timing vary along the length of the salt wall & from side to side, but are predictable (?)
- Lateral carbonate caprock suggests hydrocarbons were generated earlier than previously thought (Permian pulse to get Cutler CO_3 Caprock & Triassic pulse to get Chinle CO_3 caprock)


Thanks for your attention!