

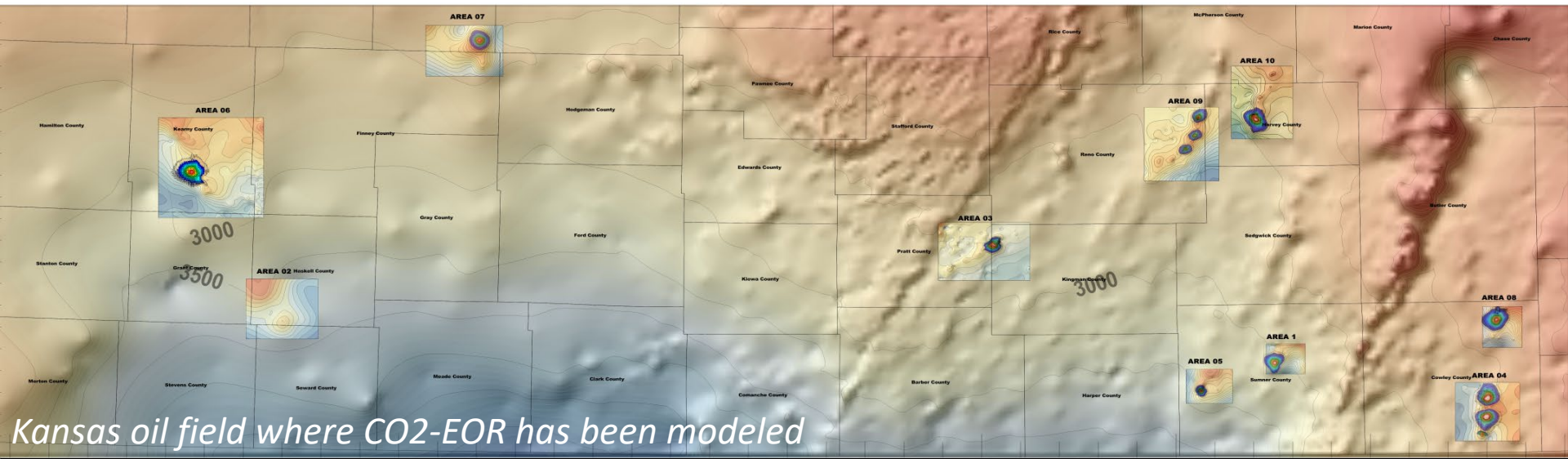
Industrial Waste-Fluid Disposal and Availability of Pore-space: Technical and Regulatory Challenges

Yevhen Holubnyak, , Jennifer Hollenbach, Tiraz Birdie, and Esmail Ansari

Underground Injection Control Conference

February 16-19, 2020

San Antonio, TX



Kansas oil field where CO₂-EOR has been modeled

An aerial photograph of a vast agricultural landscape. The foreground and middle ground are dominated by large, flat fields in various shades of green and brown, suggesting different crops or stages of growth. In the center-right, there is a farmstead with several buildings, including a large white structure and a smaller yellow one. To the right of the farmstead, a long, straight row of white hay bales stretches across the field. The background shows a flat horizon under a clear blue sky.

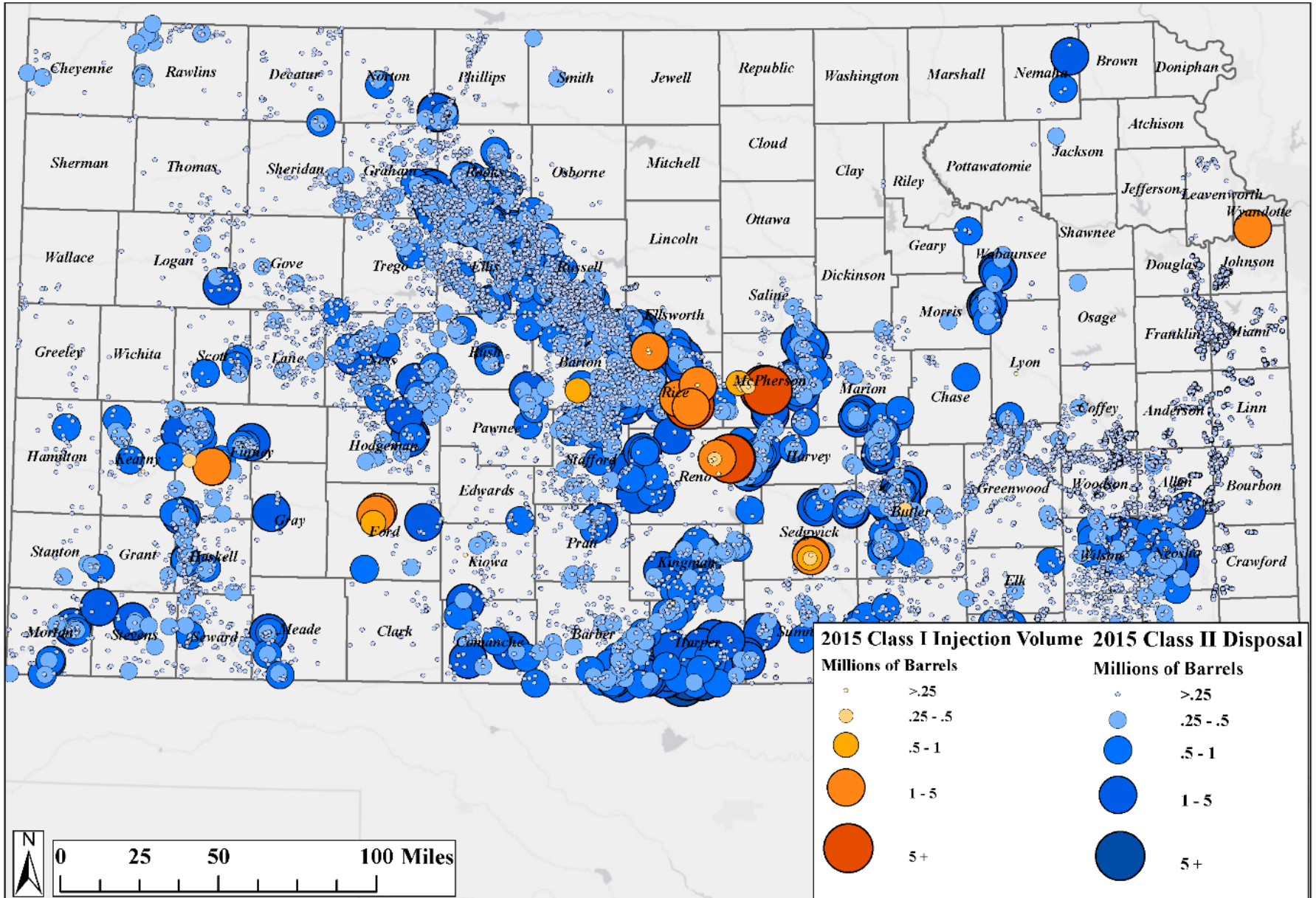
Outline

- Underground Injection Control (UIC) Class I, II, and VI in KS
- Induced seismicity in KS and OK and implications for CCUS:
 - Aquifer fill-up?
 - Competition for resources?
- Resource characterization
 - Capacity estimations for CO₂ geological storage/disposal
 - Alternatives, solutions, path forward?

Who is Injecting in Arbuckle?

- UIC Class I – Kansas Department of Health and Environment (KDHE)
 - Wells used to inject hazardous wastes or dispose of industrial and municipal fluids beneath the lowermost formation containing, within one quarter (1/4) mile of the well bore, a source of fresh or usable water
 - “On vacuum” – no WHP
- UIC Class II – Kansas Corporate Commission (KCC)
 - Class II wells are used only to inject fluids associated with oil and natural gas production. Class II fluids are primarily brines (salt water) that are brought to the surface while producing oil and gas
 - Some WHP is allowed (~500 psi)
- UIC Class VI - ???

Class I & Class II Disposal Volumes (2015)



2013

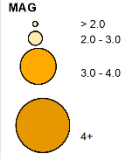
Earthquakes over time

2014

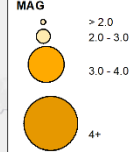
2015

2016

USGS Earthquakes 2013



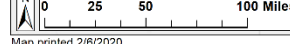
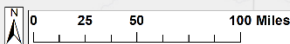
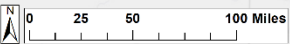
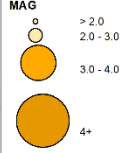
USGS Earthquakes 2014



USGS Earthquakes 2015



USGS Earthquakes 2016



Map printed 2/6/2020

Sources: Kansas Geological Survey, USGS, ESRI

Map printed 2/6/2020

Sources: Kansas Geological Survey, USGS, ESRI

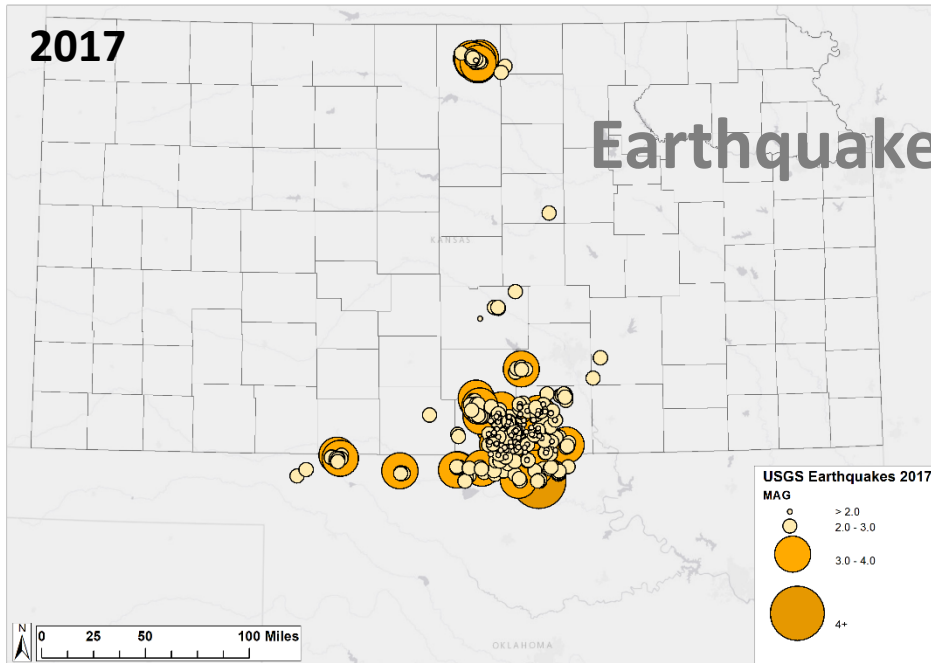
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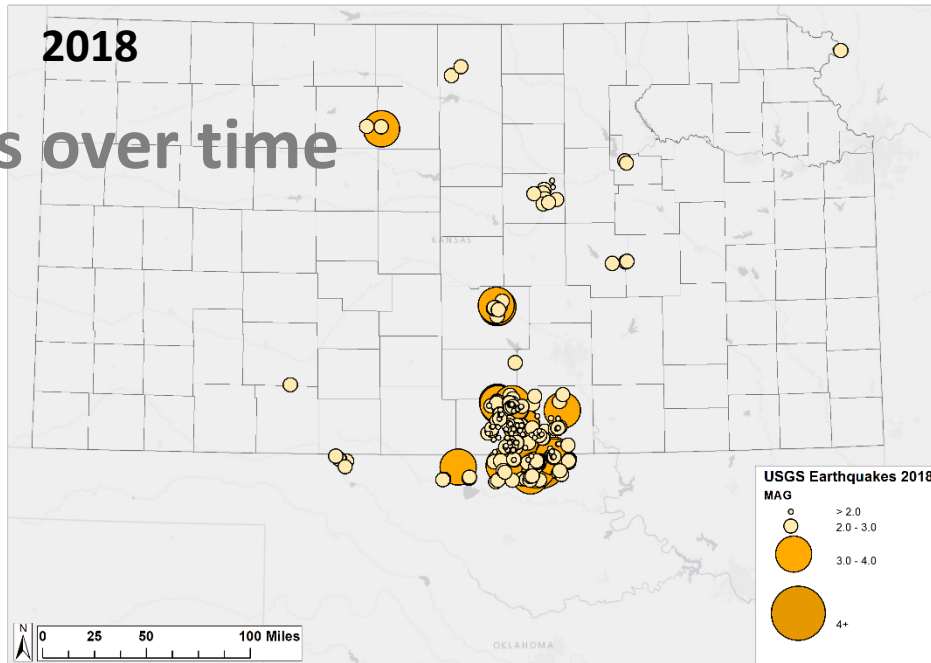
2017



Map printed 2/6/2020

Sources: Kansas Geological Survey, USGS, ESRI

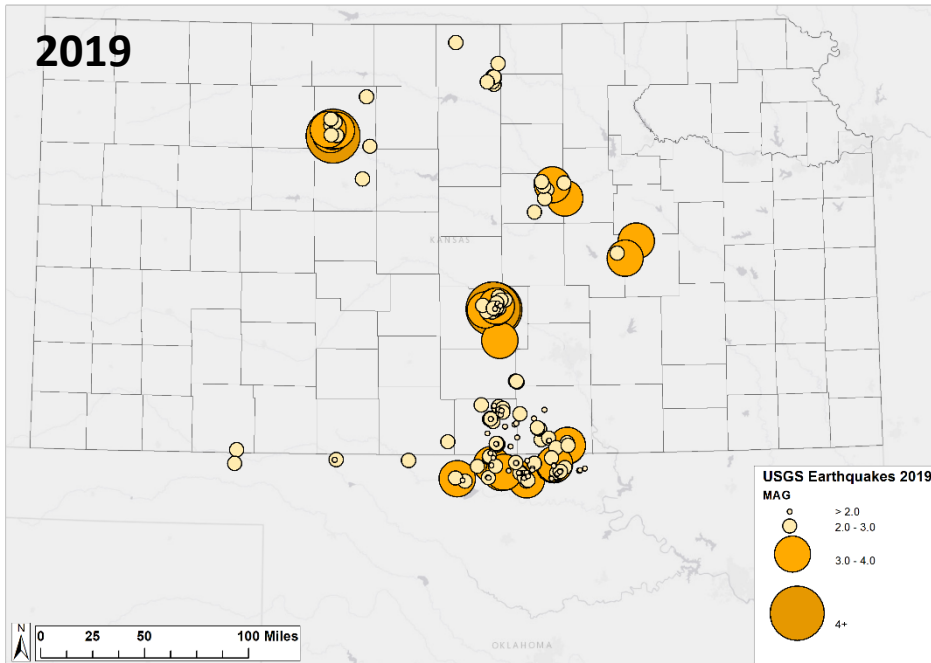
2018



Map printed 2/6/2020

Sources: Kansas Geological Survey, USGS, ESRI

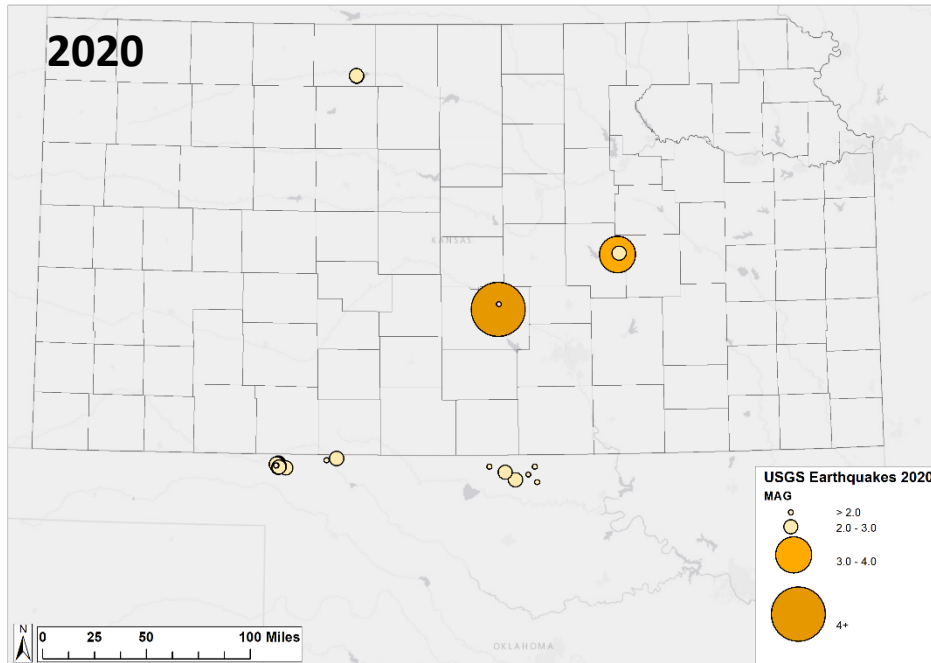
2019



Map printed 2/6/2020

Sources: Kansas Geological Survey, USGS, ESRI

2020



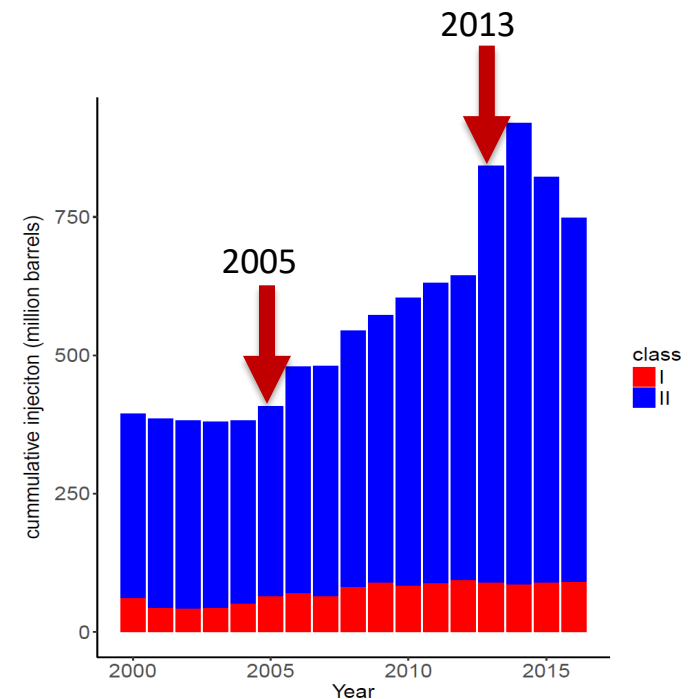
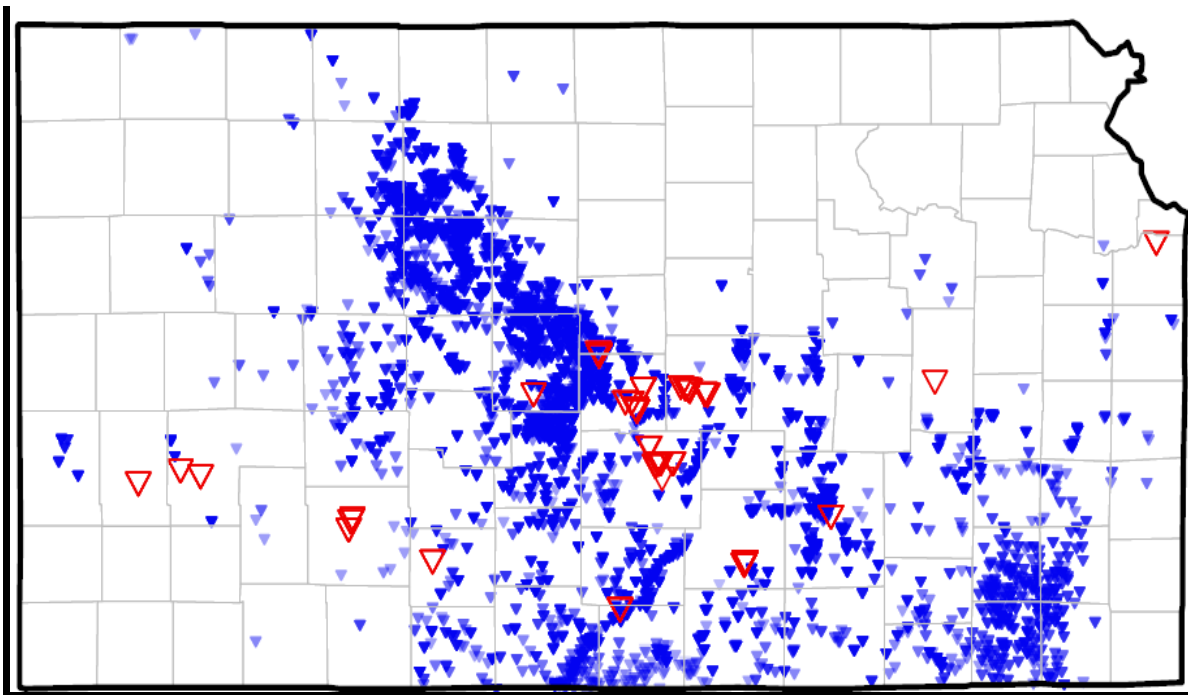
Map printed 2/6/2020

Sources: Kansas Geological Survey, USGS, ESRI

Earthquakes over time

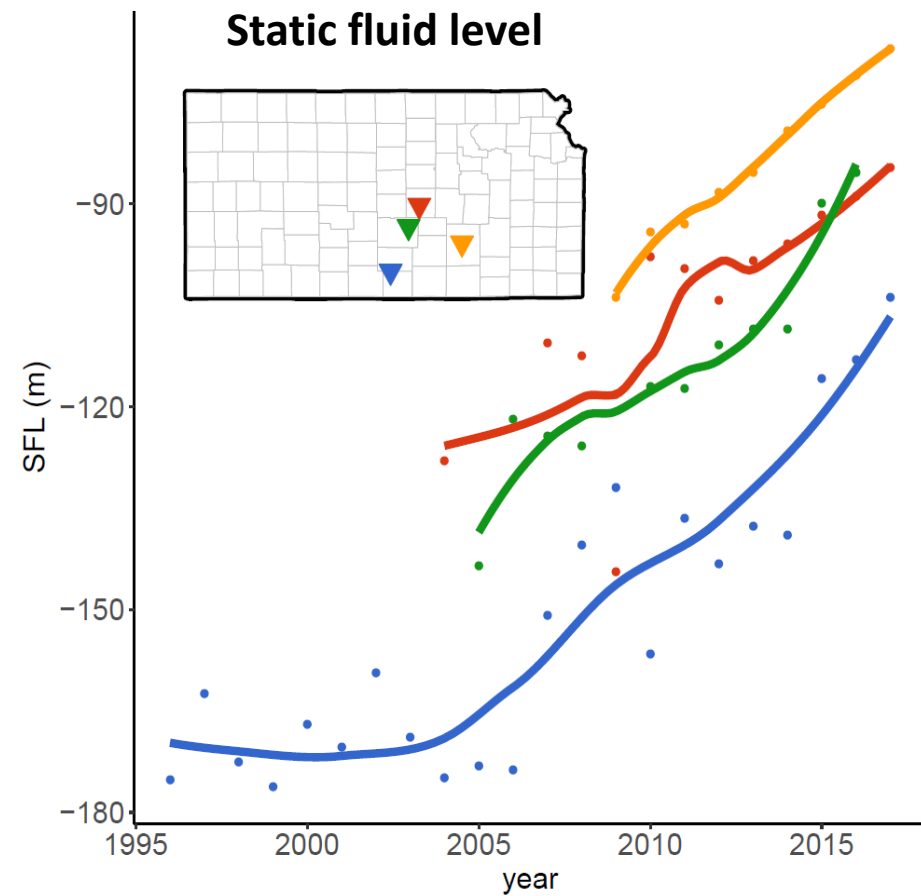
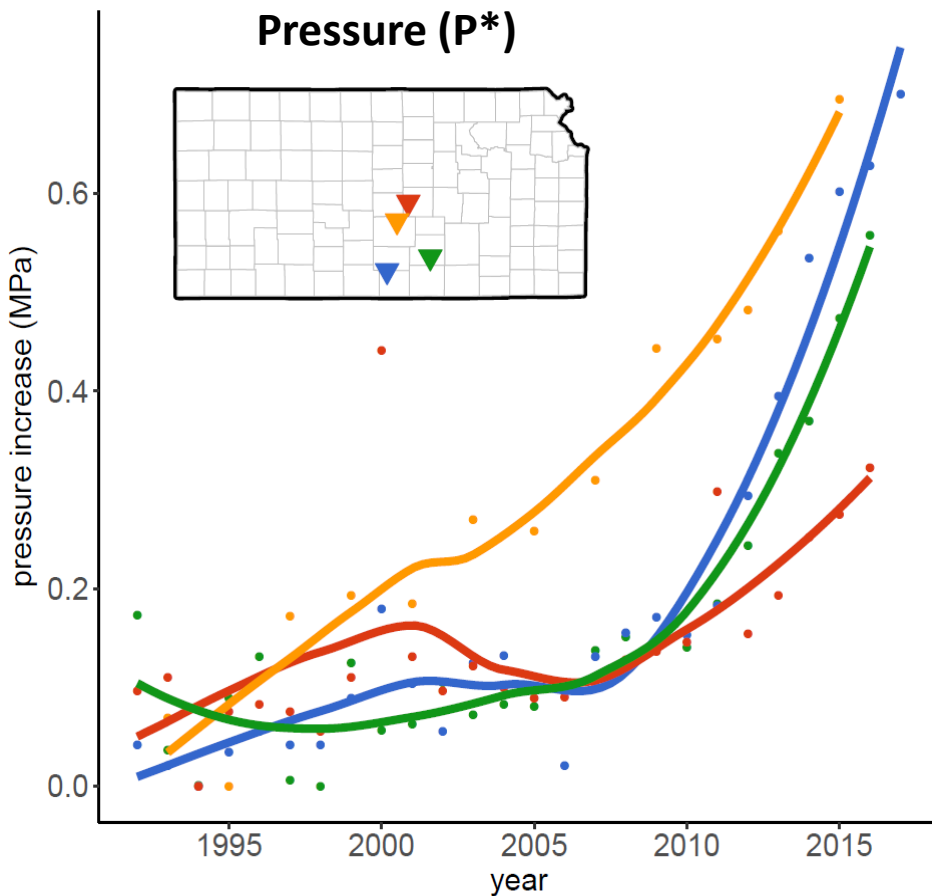
Kansas Arbuckle disposal wells

- 49 Class I and 2381 Class II Arbuckle wells across Kansas
- Volumes increase in 2005, peak in 2013-2014 to >750 million barrels, and drop to 500 million barrel in 2015

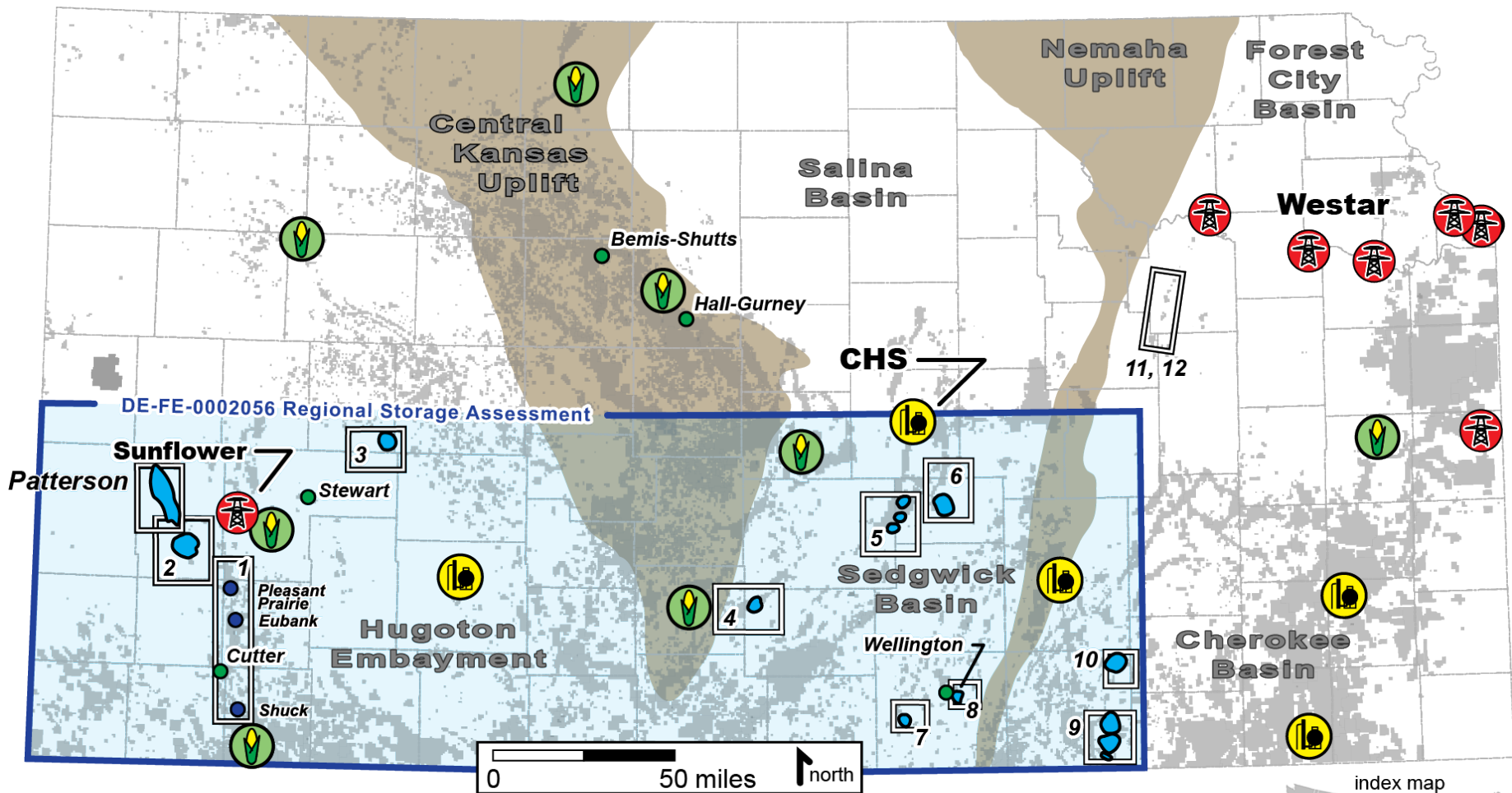



Increases in pressure and static fluid level


- Class I wells show increase in pressure and SFL
- Class II would show similar tendencies if data is available
- Pressure increase more pronounced near Harper and Sumner counties
- Reno County well(orange) shut-in for two decades





CCUS in Kansas






 coal-fired power plant

 ethanol plant

 oil and gas fields

 petroleum refinery or manufacturing plant (cement & fertilizer)

 geologic storage complex study area and closure

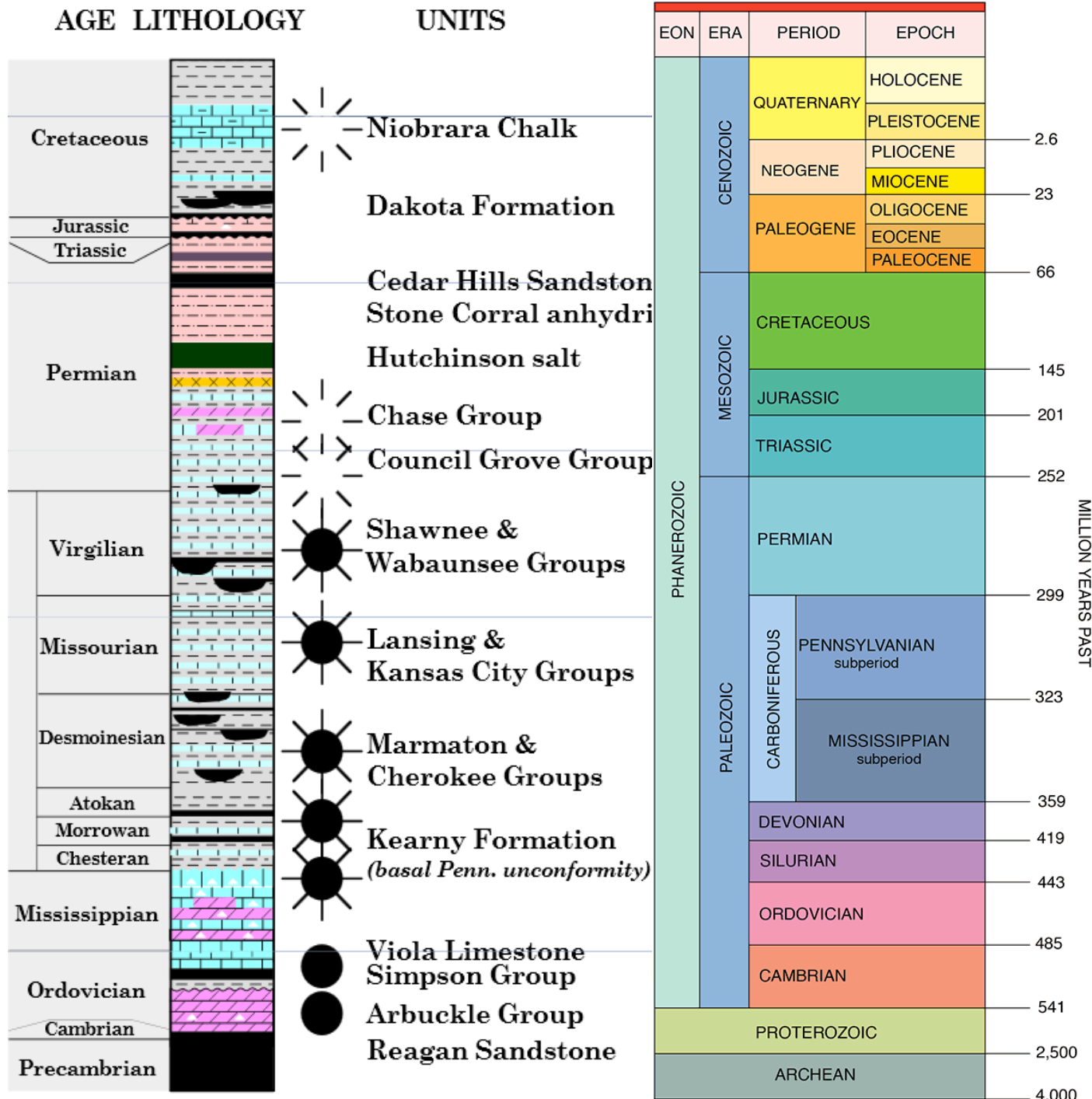
 DOE site characterization study
 DOE EOR study



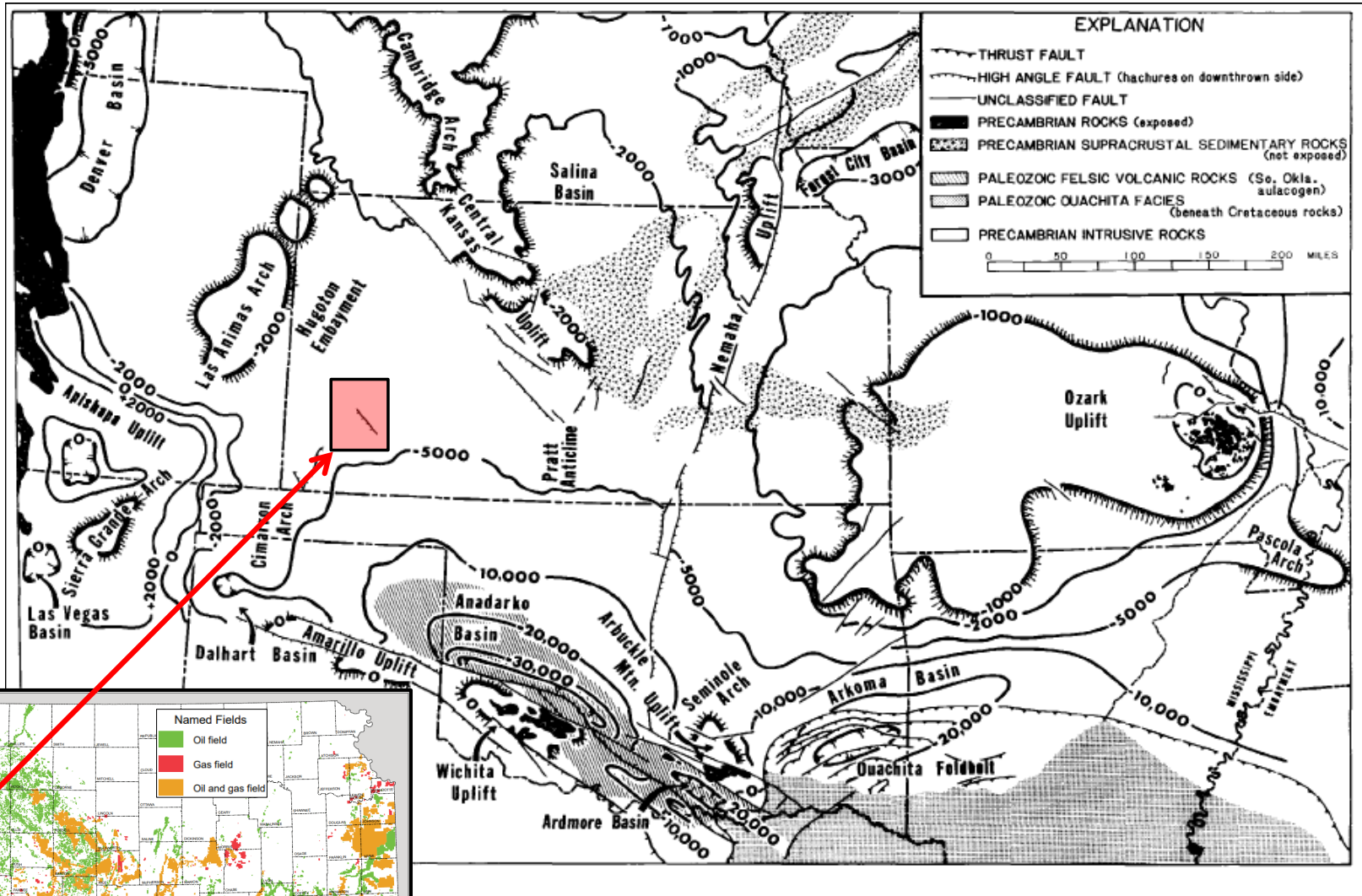
Why Arbuckle?

Although some shallower formations are used for disposal or could be used as disposal targets, Arbuckle Group tops all other formations in the MidCon region:

- Continues extent through the region
- Thickness
- Under-pressured, or pressure potential
- Reservoir properties
- Alternatives?

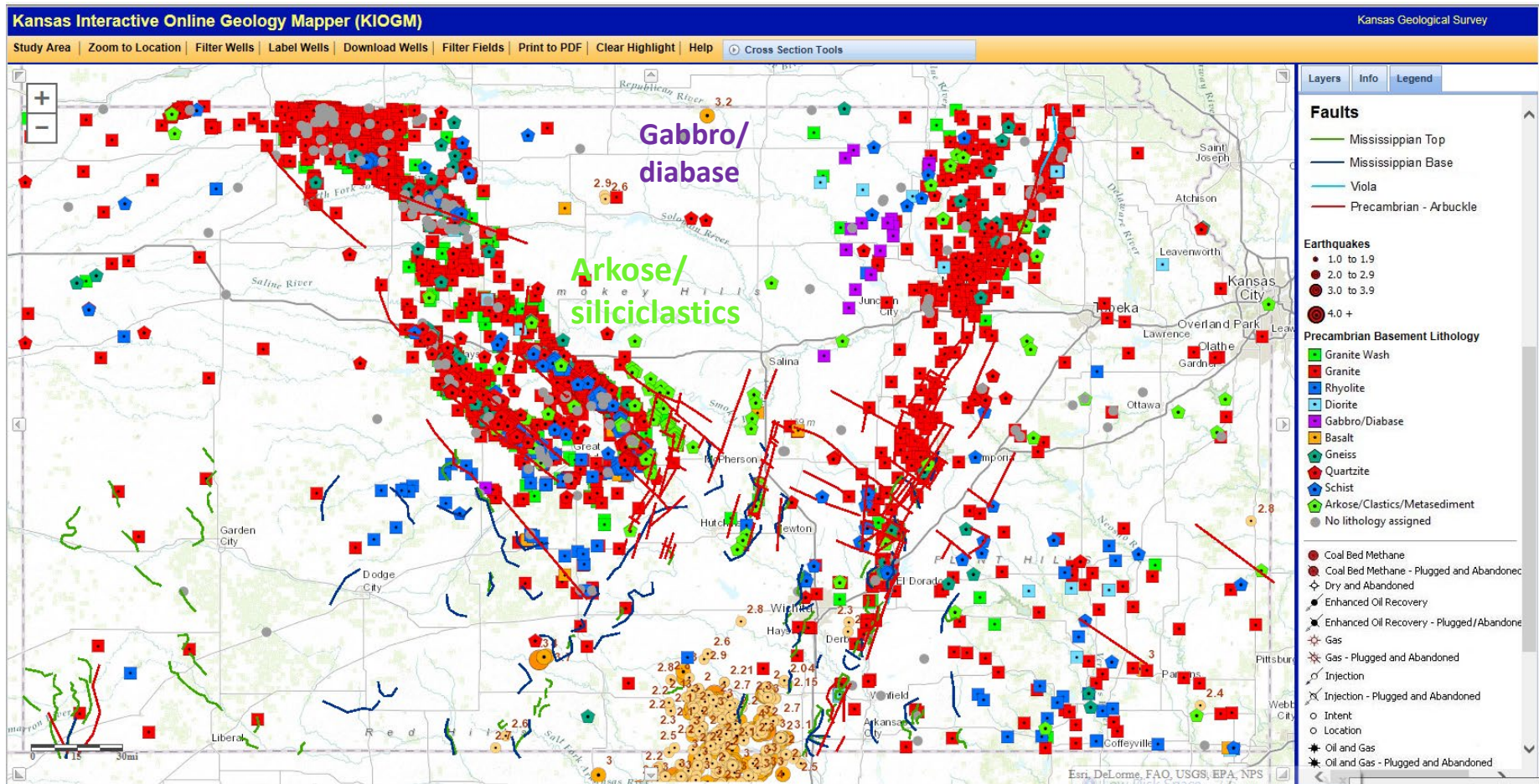


Geologic Setting

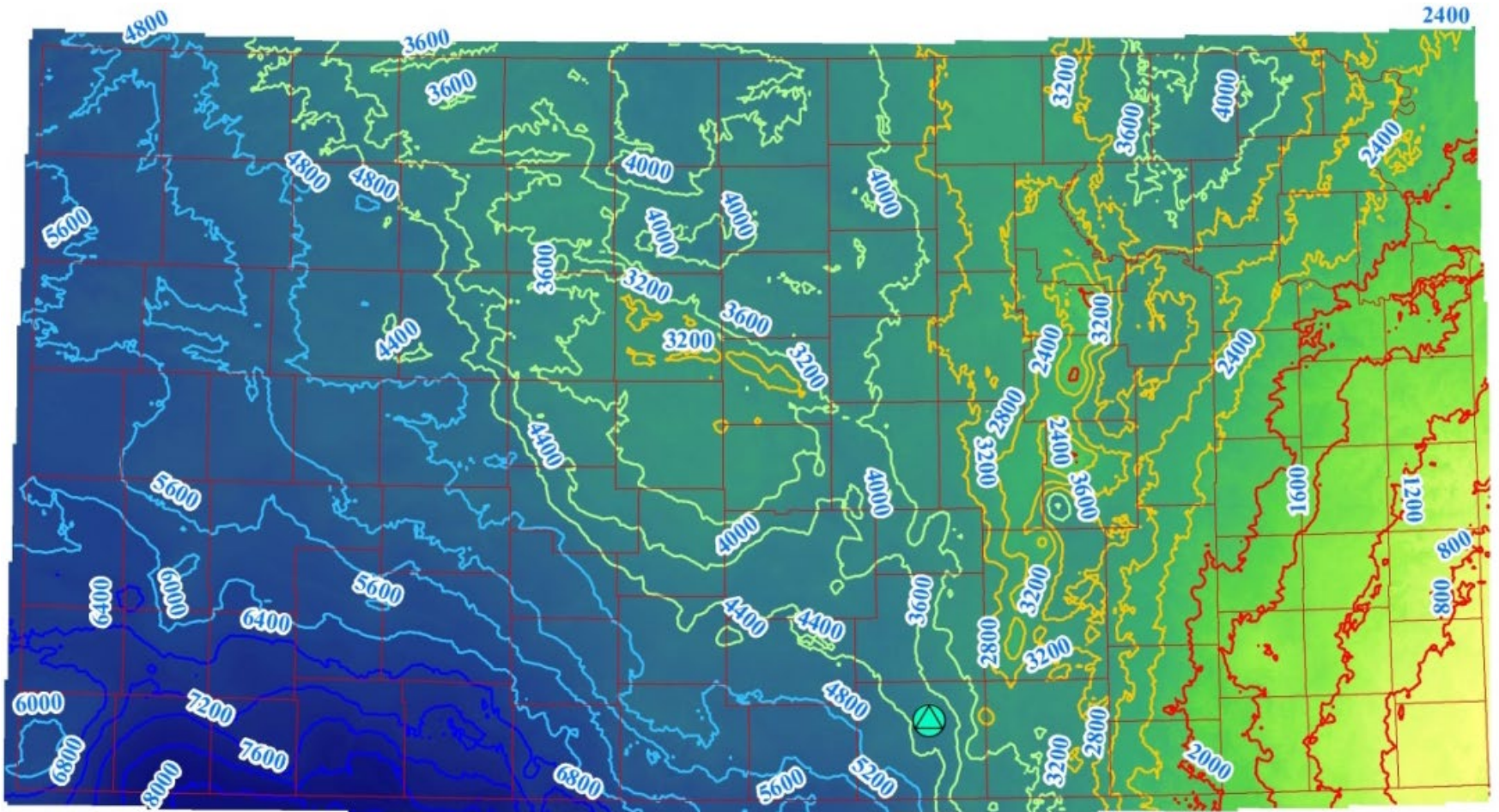


Basement geology from sample rock types in the area of the induced seismicity

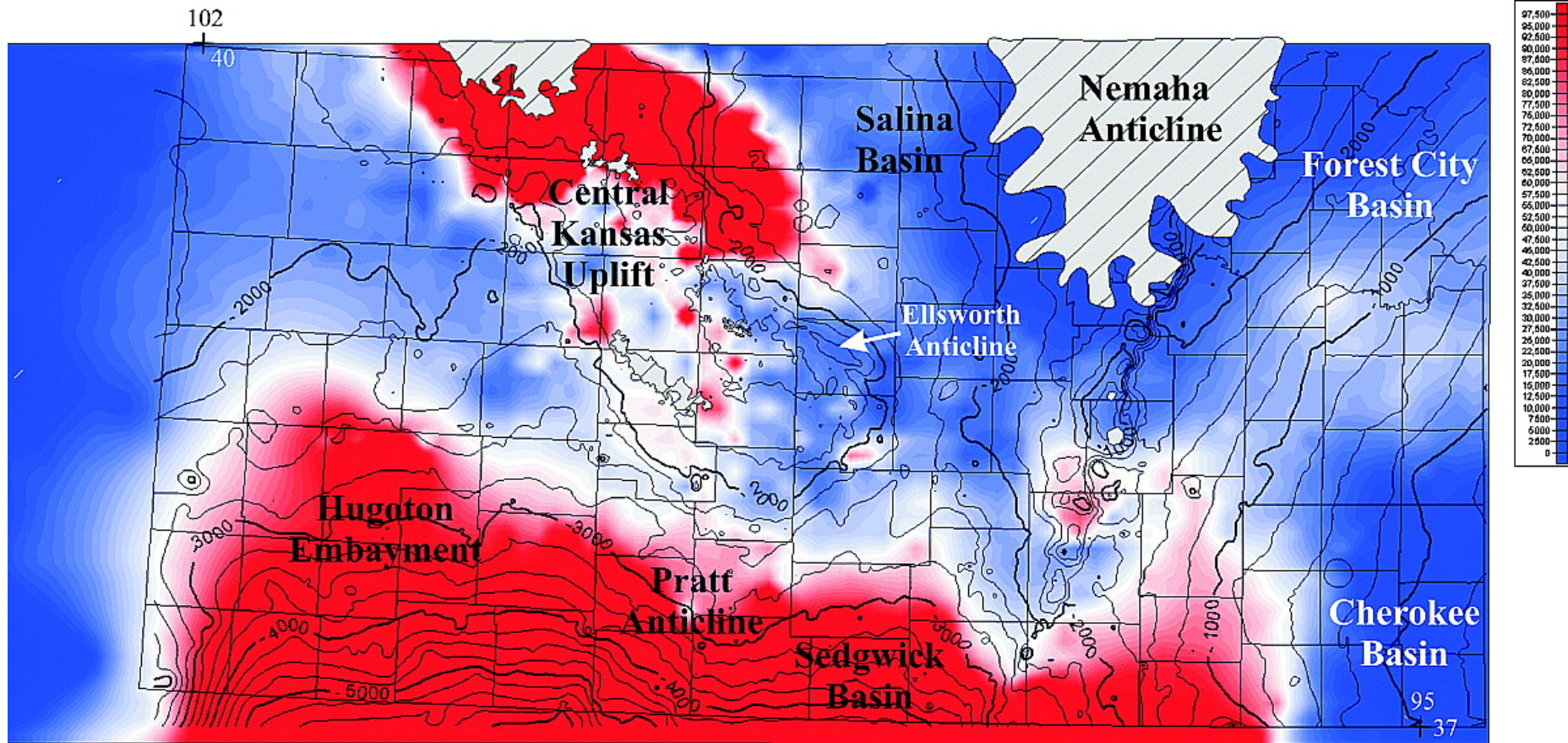
→ *thick arkosic sediment fill indicative of the Midcontinent Rift System (MRS)*



Depth (in feet) Below Ground Surface to Top of Arbuckle

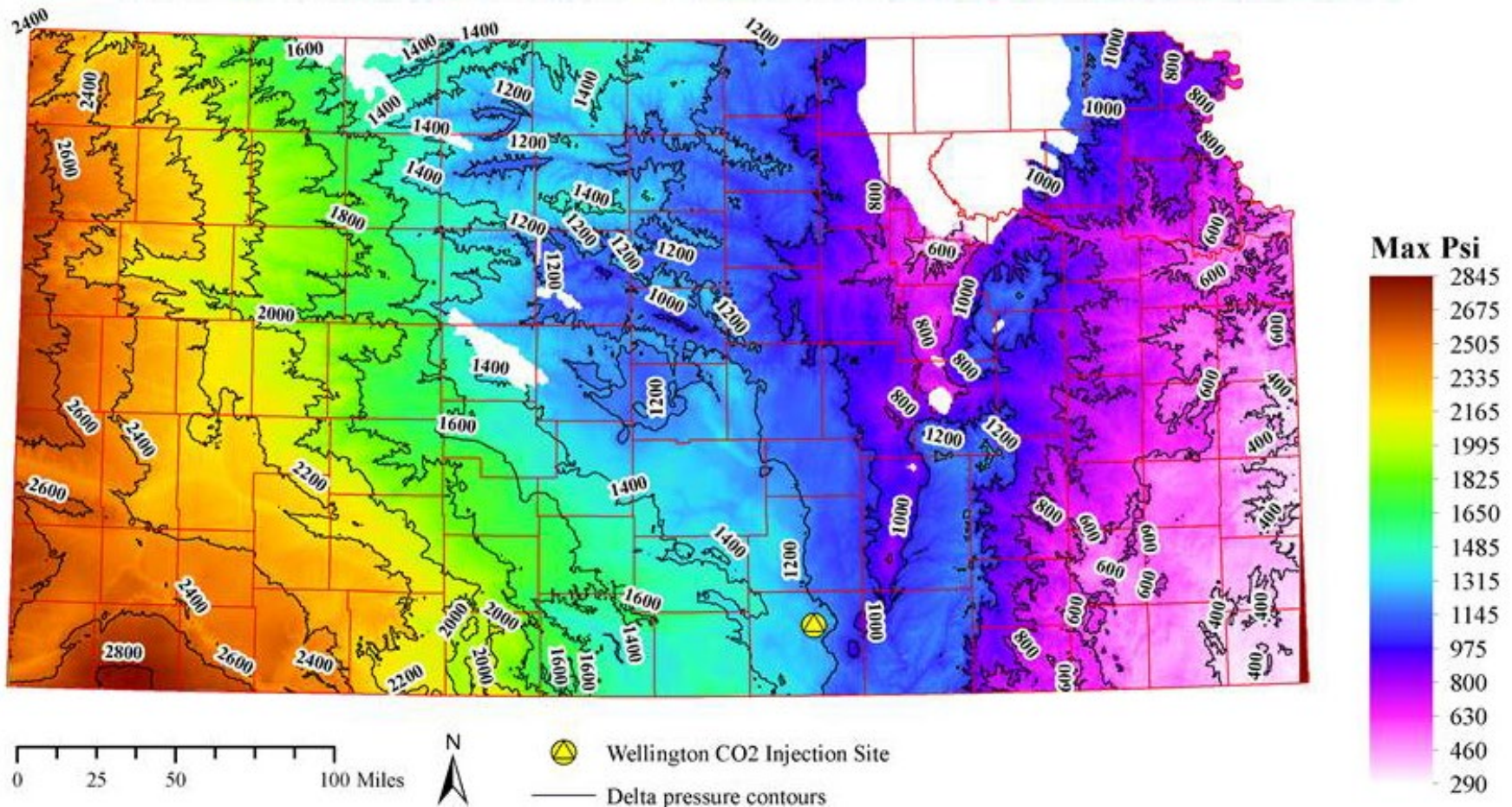


Salinity of Cambrian-Ordovician Arbuckle Group in Kansas

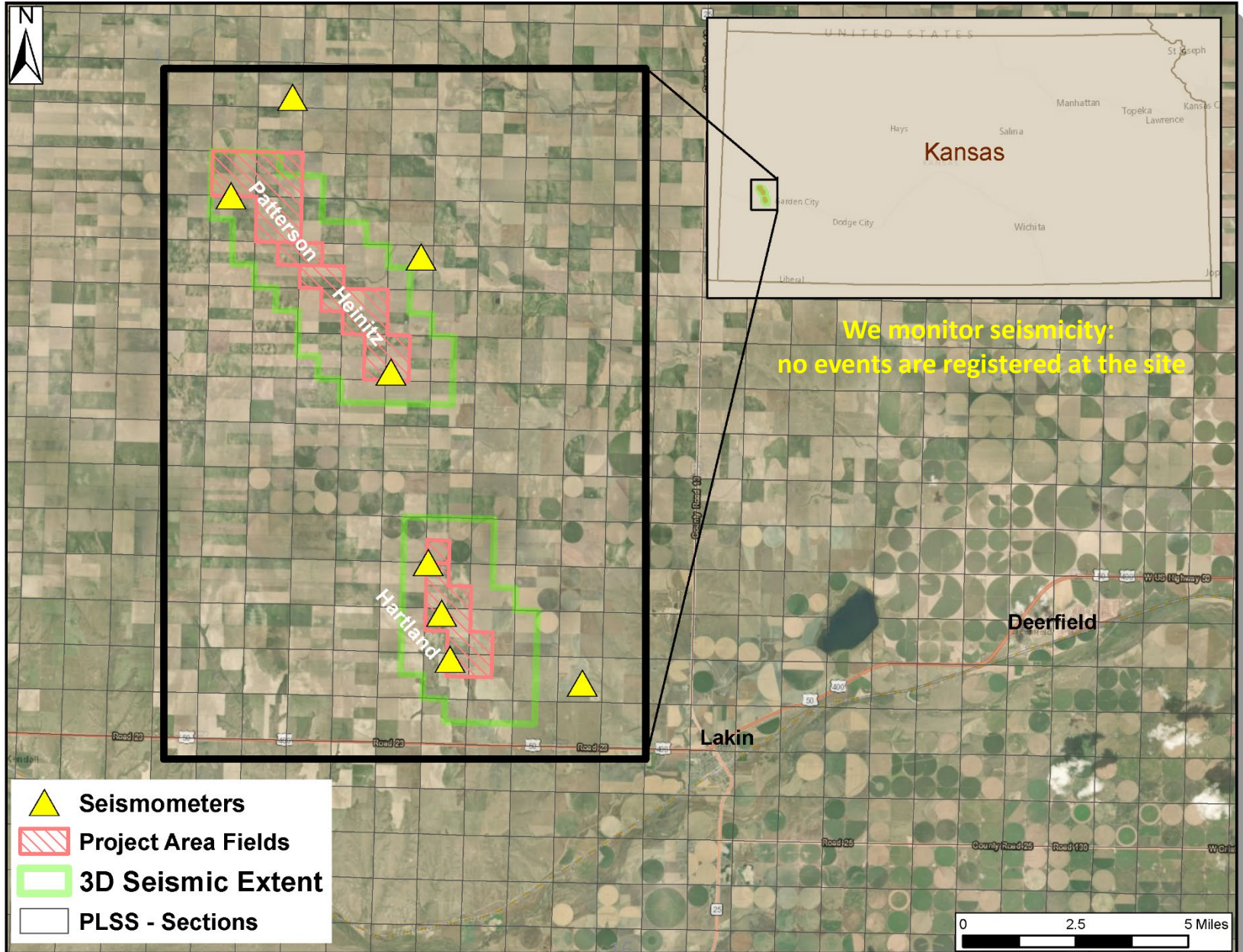


Maximum Allowable Increase in Pore Pressure from Ambient Conditions

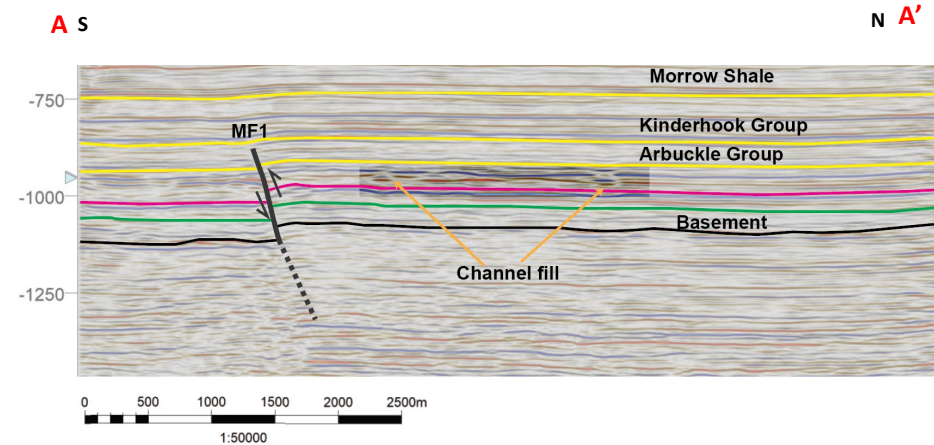
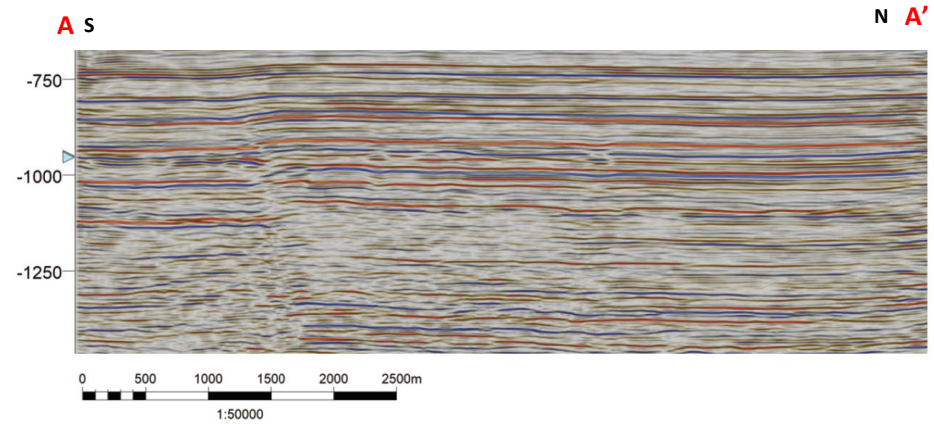
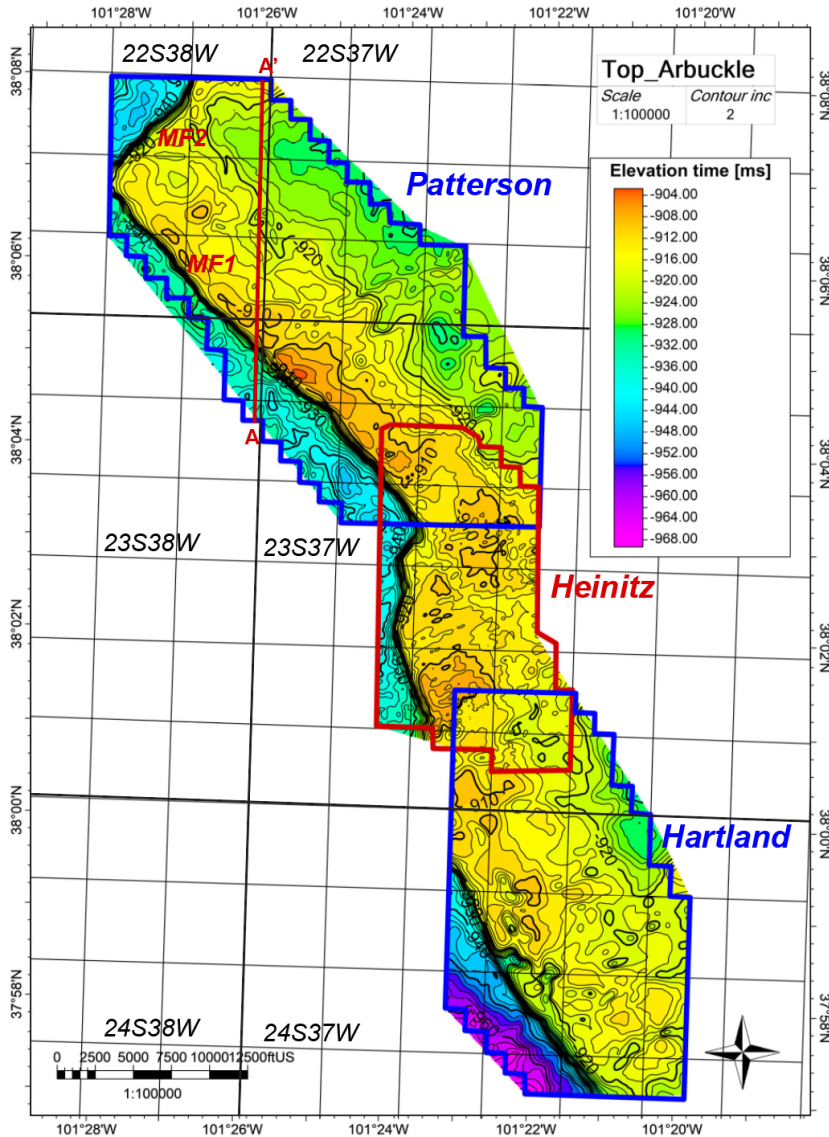
Based on UIC Class VI rule limitation of pore pressure to not exceed 90% of fracture gradient



Patterson Site Location and Infrastructure

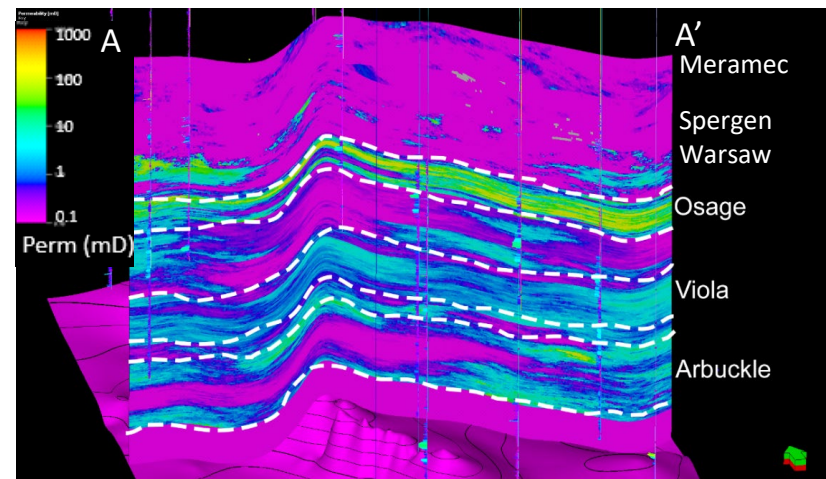
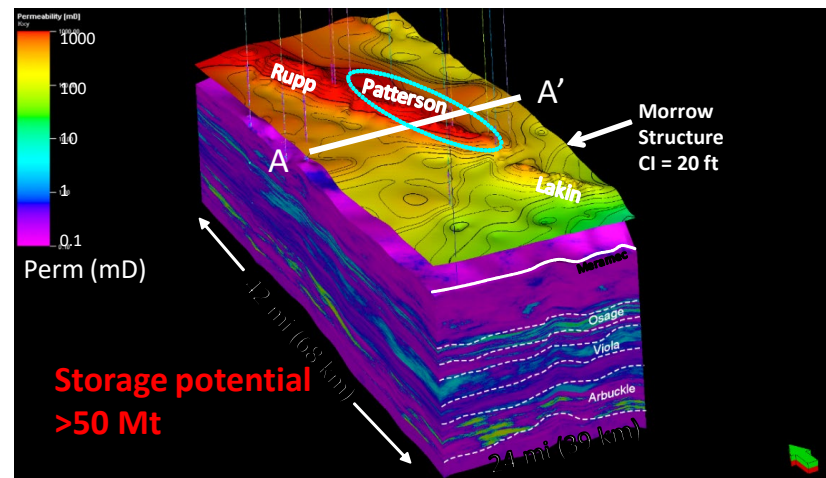
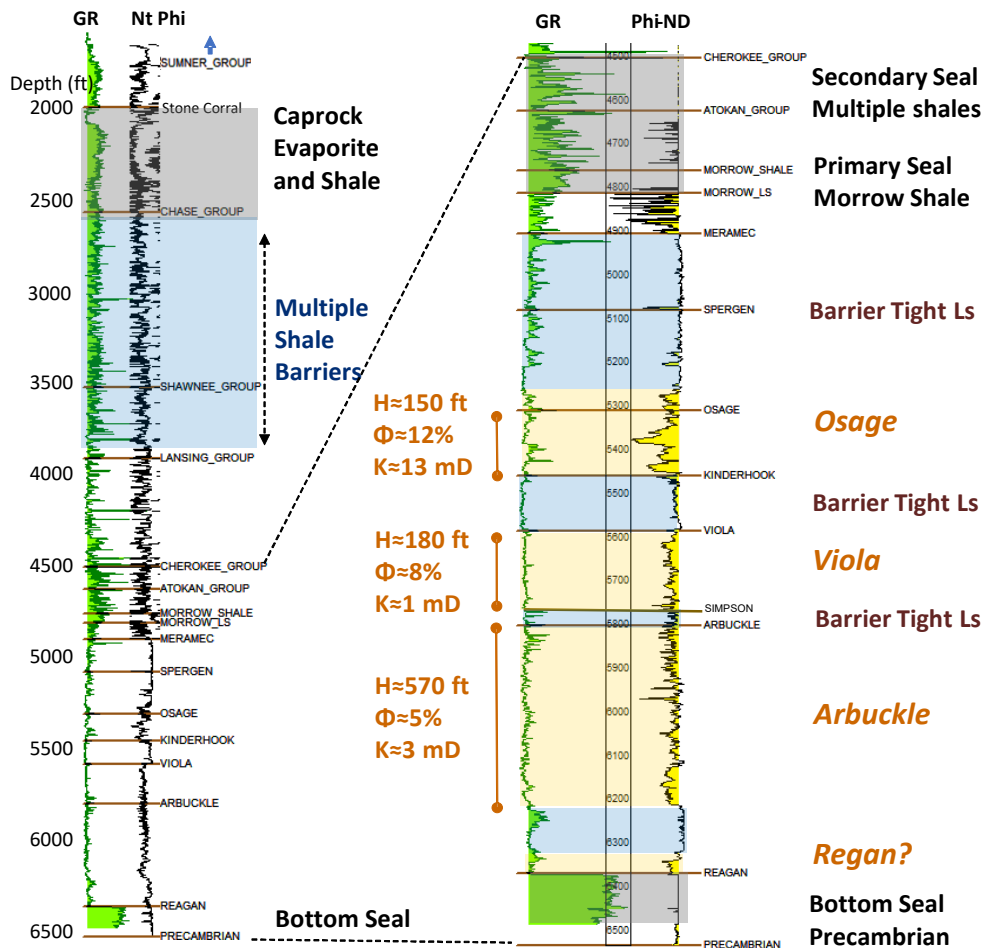


Structural Framework



- Reverse faults identified in the Patterson area offset the reservoir intervals, but not interrupt the Morrow Formation primary seal.

Storage Units



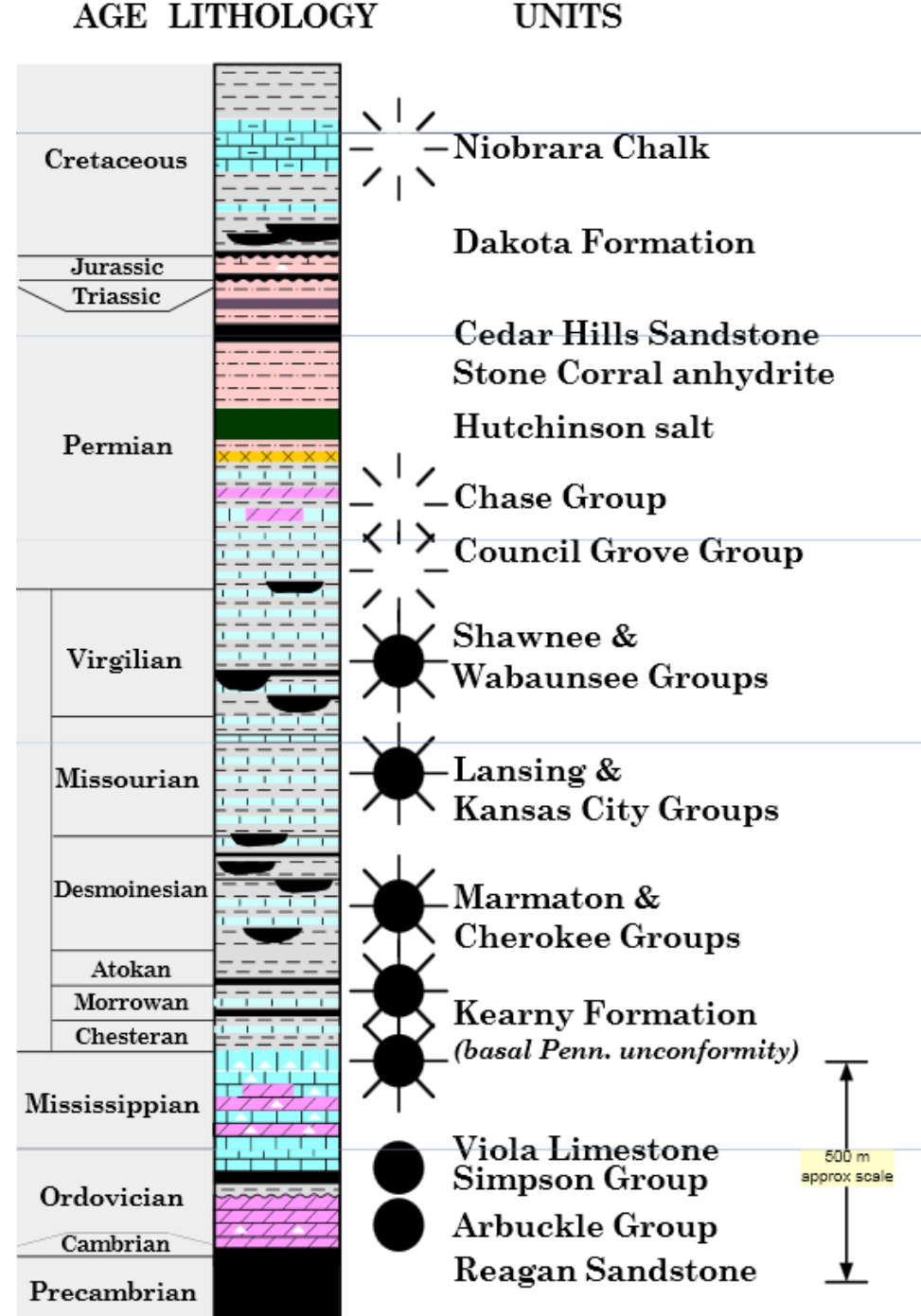
3-D volume of permeability from the top of the basement to Meramec; map above the is the top of the Morrow; map at the base of the cross section is the top of the basement.

Modified from ICKan Project Final Report (DEFE0029474)

Stratigraphy illustrated by wireline log from a key well in the Patterson Site (Longwood Gas Unit #2 well).

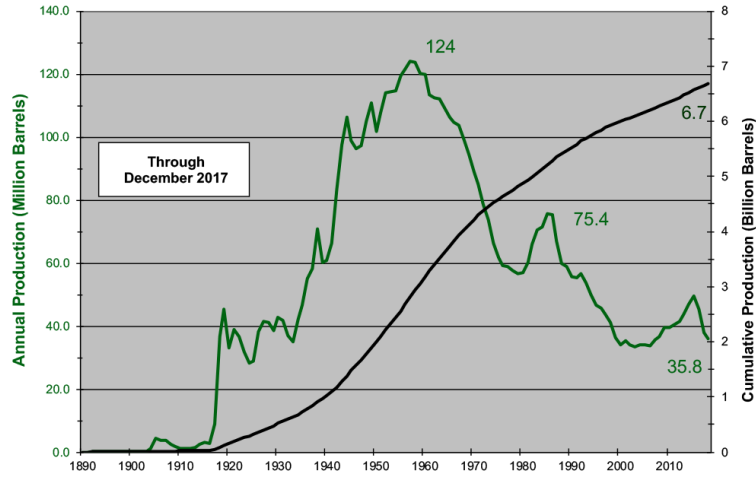
Additional SWDW Resources

- Cedar Hills – 820 SWDW
- Lansing-KC – 326 SWDW
- Mississippian – 264 SWDW
- Glorietta – 101 SWDW
- Stalnaker – 86 SWDW
- Topeka – 54 SWDW
- Hunton – 51 SWDW
- Maybe it is time to update inventory?

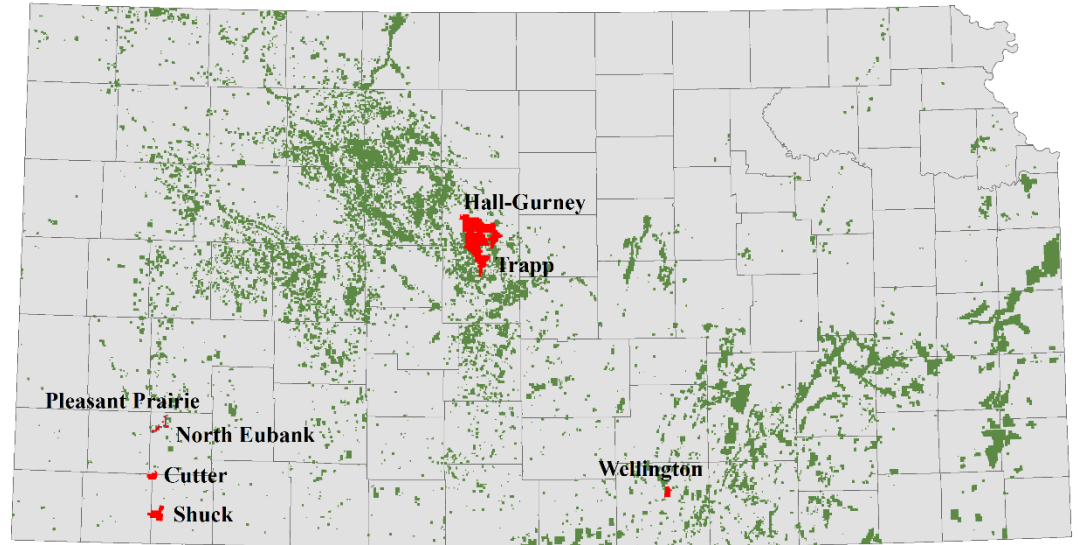


CO₂ EOR in Kansas

Kansas Oil Production is Falling



Numerous Potential Sites for EOR



■ Potential EOR Sites
■ Oil Fields

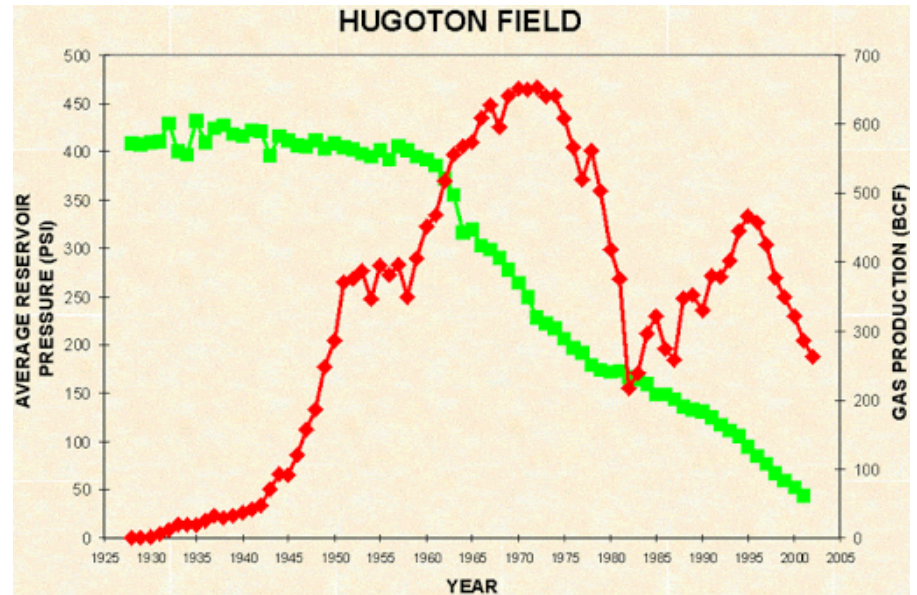
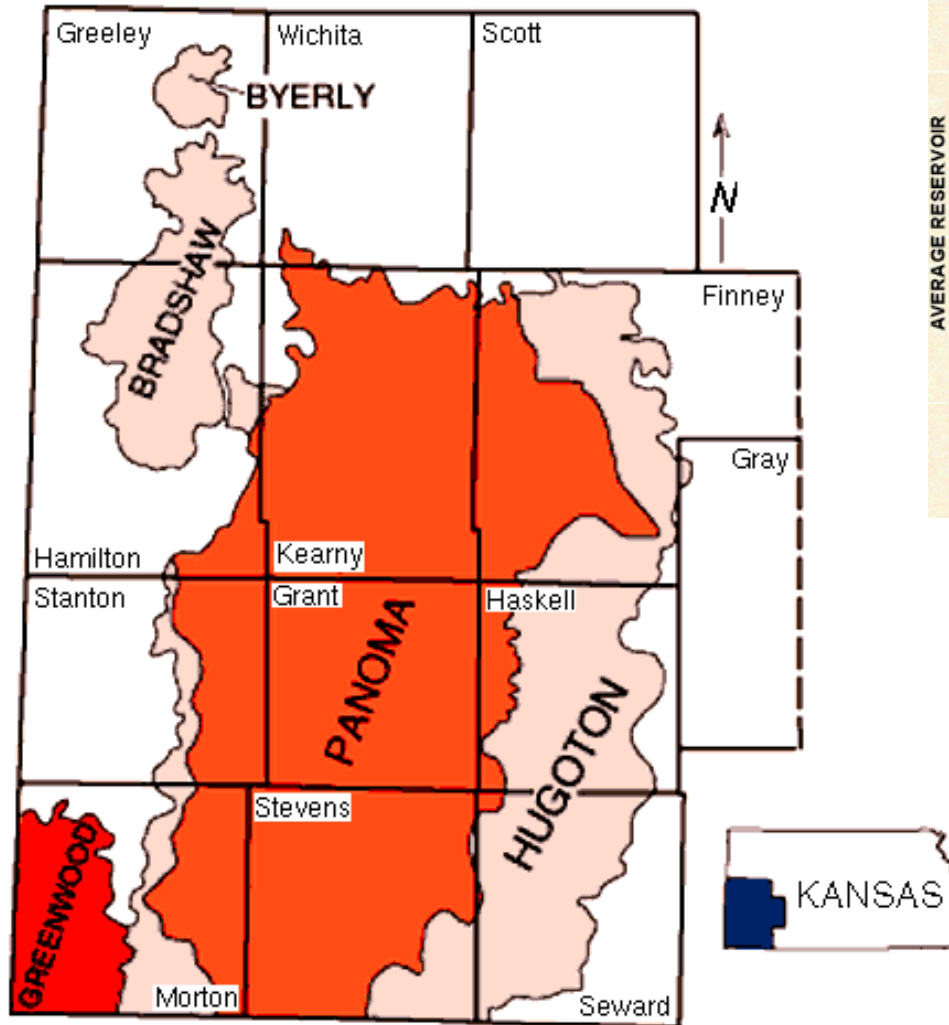
Sources: ESRI, USGS, Kansas Corporation Commission, Kansas Geological Survey, DASC

Basin	EOR Potential (mill bbl)	Net CO ₂ Demand (MMT)	Direct Jobs Created
Illinois-Indiana	500	160-250	1550-3100
Ohio	500	190-300	1550-3100
Michigan	250	80-130	800-1800
Kansas	750	240-370	2300-4600
	2000	670-1050	3200-12400

	Injection Rate (Mt/yr)	CO ₂ Storage (Mt)	Primary and Secondary (MMBO)	CO ₂ EOR (MMBO)	Basis for Estimate
Shuck	0.4	1.5	7.9	3.6	DE-FE000256
Cutter	0.5	1.3	5.4	2.8	DE-FE000256
N Eubank	0.6	1.5	7.4	4.6	DE-FE000256
Pleasant Prairie	0.3	0.5	4.7	2.2	DE-FE000256
Hall-Gurney	1	11.3	62.5	26.8	DE-AC26-00BC15124 and Pilot C12 Energy
Trapp	0.5	4.3	31.3	10.3	KGS reports
Wellington	0.6	2.2	16.2	5.3	DE-FE0002056 and Pilot
	3.9	22.8	135.4	55.7	

Alternatives and Underutilized Resources

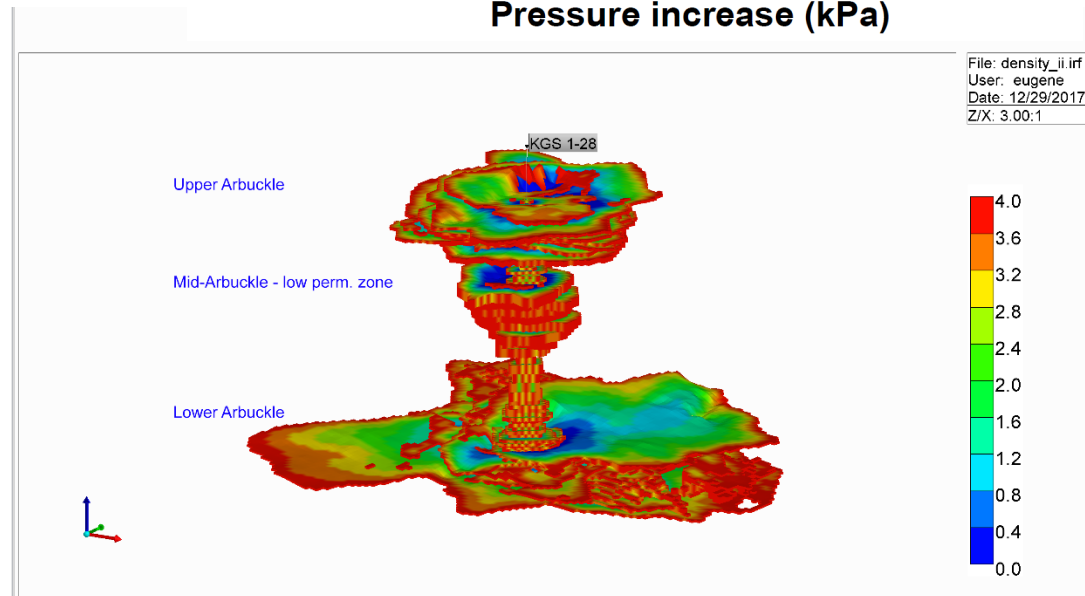
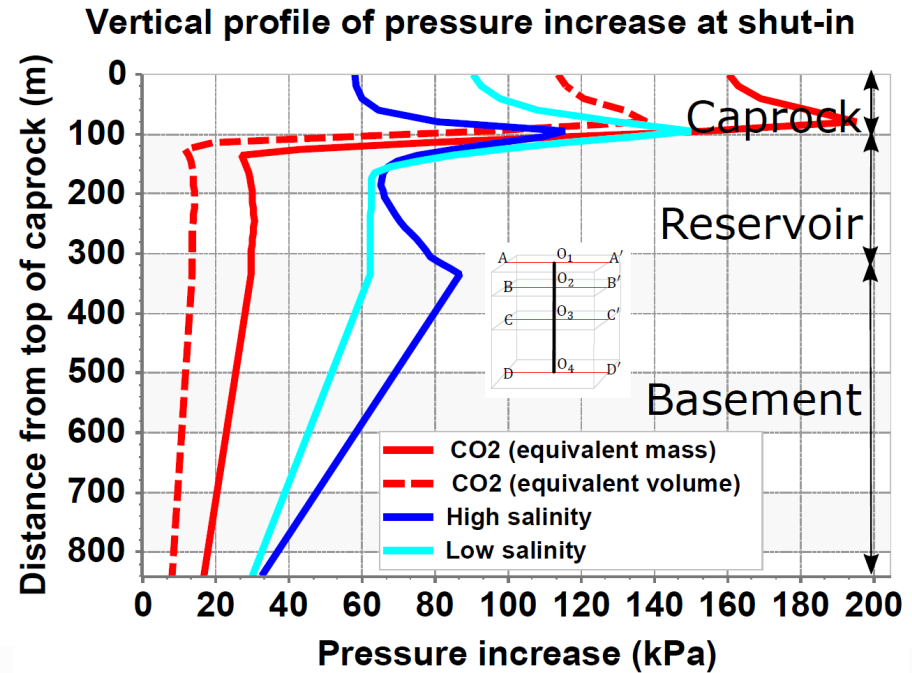
Hugoton Gas Field for SWD?



- Pressure depletion
- Gas production is falling
- What is the capacity?
- What are the risks?

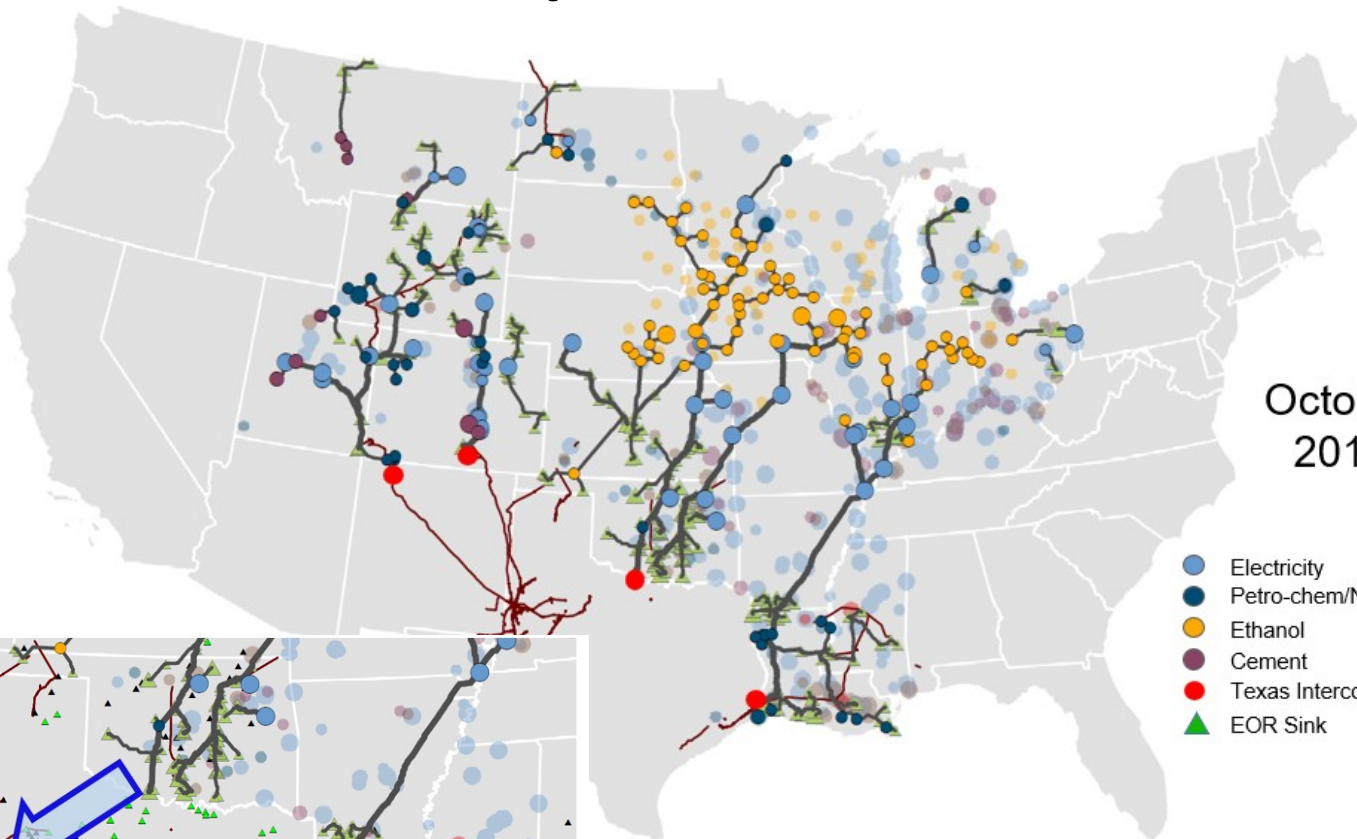
Resource Management

- What do we know about injection of fluids with different properties?
- What is optimal design of injection site?
 - How many wells?
 - Well density?
 - Completions?



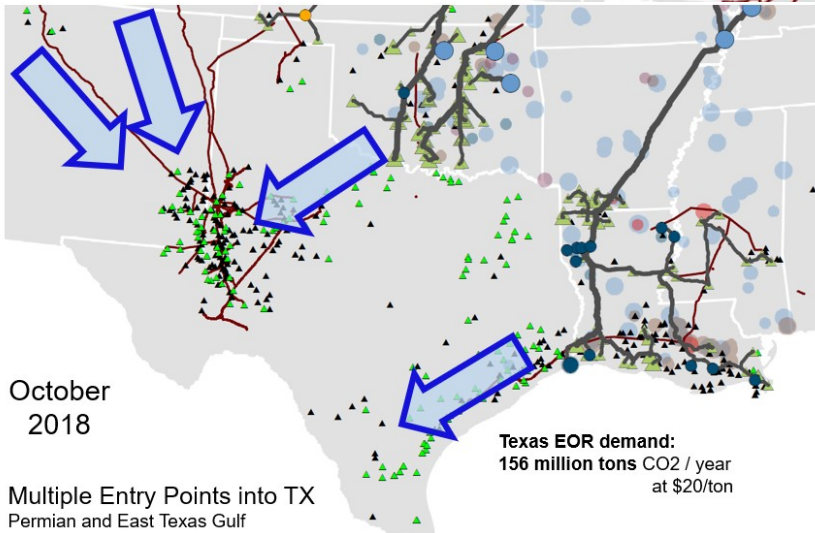
Many Potential Pipeline Routes Cross

REGIONAL
CARBON
CAPTURE
DEPLOYMENT
INITIATIVE



October
2018

- Electricity
- Petro-chem/NG Refining
- Ethanol
- Cement
- Texas Interconnection
- ▲ EOR Sink



October
2018

Multiple Entry Points into TX
Permian and East Texas Gulf

Texas EOR demand:
156 million tons CO₂ / year
at \$20/ton

Crabtree (2018)
Midwest Region Meeting

Summary

- Competition for resources means that careful site selection is essential
- Alternative resources for disposal/storage are likely available but reevaluation and research is needed
- CO₂-EOR option is important for CCUS success in the Mid-Continent
- Better design of disposal well sites and management strategies are needed
- Nation-wide infrastructure could help to solve the logistics

Acknowledgements

- Bittersweet Energy – Tom Hansen with Paul Gerlach and Larry Nicholson; Dennis Hedke, Martin Dubois and SW Kansas CO₂-EOR industry consortium, John Youle, George Tsoflias and students at KU, Gene Williams, and KGS staff supporting the acquisition of data, stratigraphic correlation, regional mapping
- Dana Wreath, Berexco, LLC for access and participation in drilling and testing at Wellington and Cutter fields and small scale field test at Wellington

Questions?

\$35

\$35

\$50

\$50

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