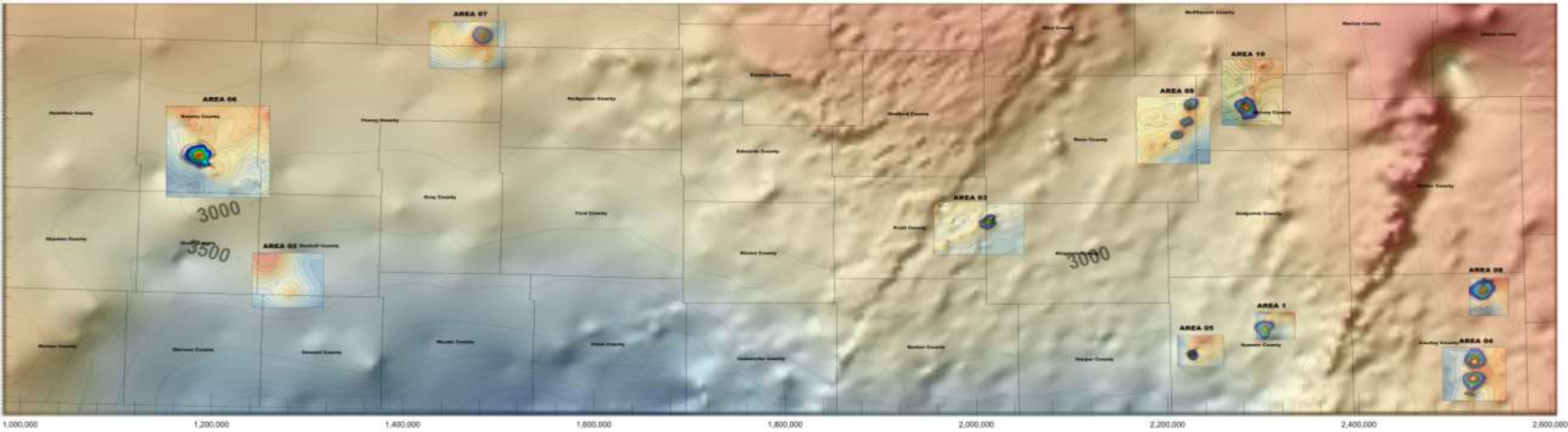


Lessons Learned from the UIC Program: Pore-space Issues

Eugene Holubnyak

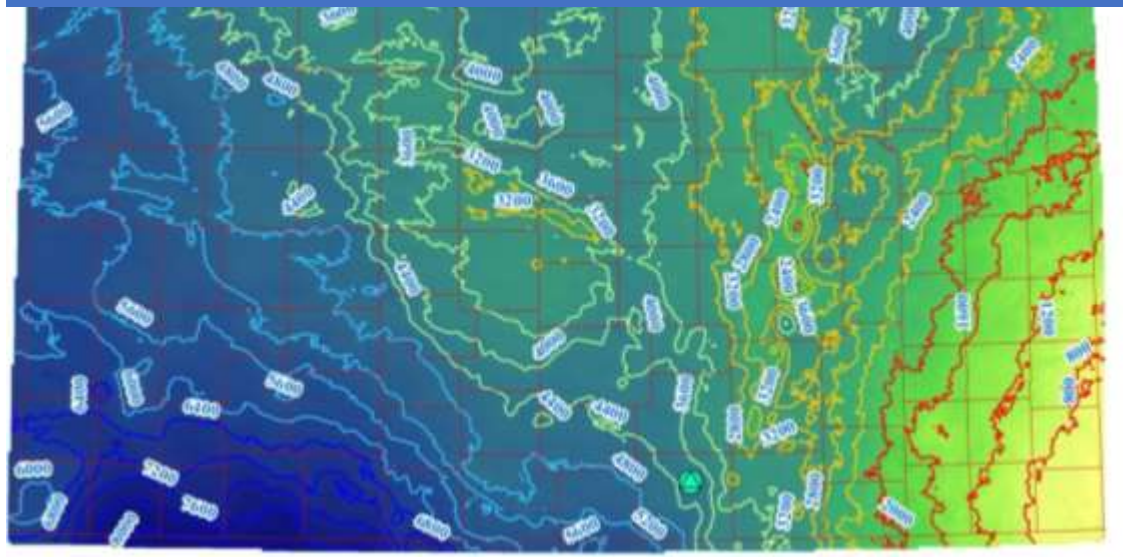
Baltic Carbon Forum

October 10, 2025

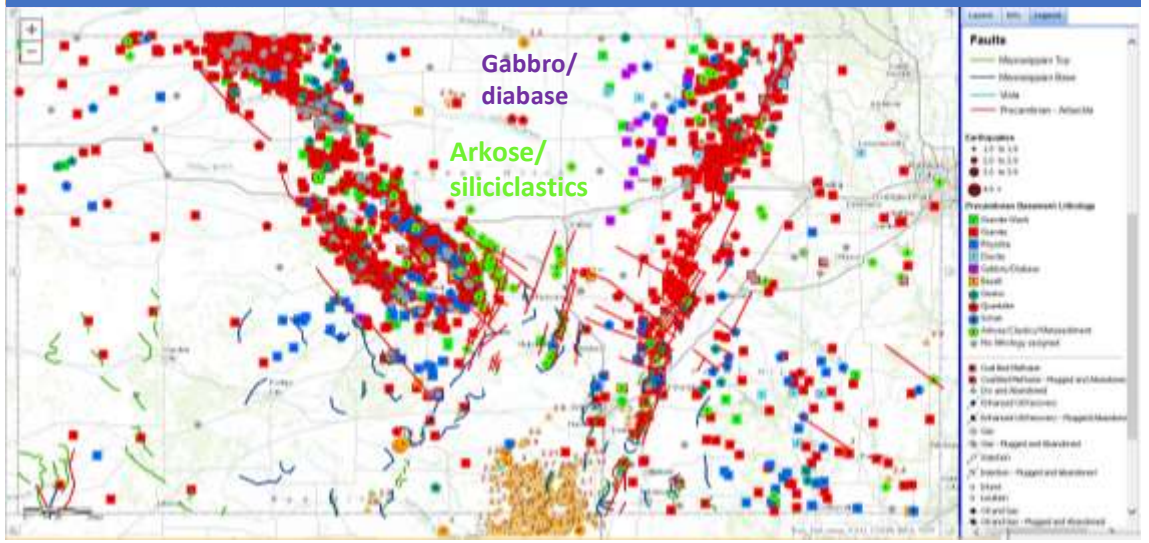
Competition for Pore-space in KS

- Wellington field CO_2 pilot and seismic array for background monitoring from IRIS Pascal
- Class II wells
  - Mississippian Lime, Woodford Shale, etc. – unconventional plays and high water cuts
- KS Induced Seismicity Task Force
- KGS, USGS seismic arrays
- Action from Kansas Corporate Commission – limited injection volumes in areas of interest
- Class I and Class II wells and saga continues
  - Arbuckle working group
- Lessons from ND: 2017 Mosser v. Denbury Case
- Implications for carbon management and other industries

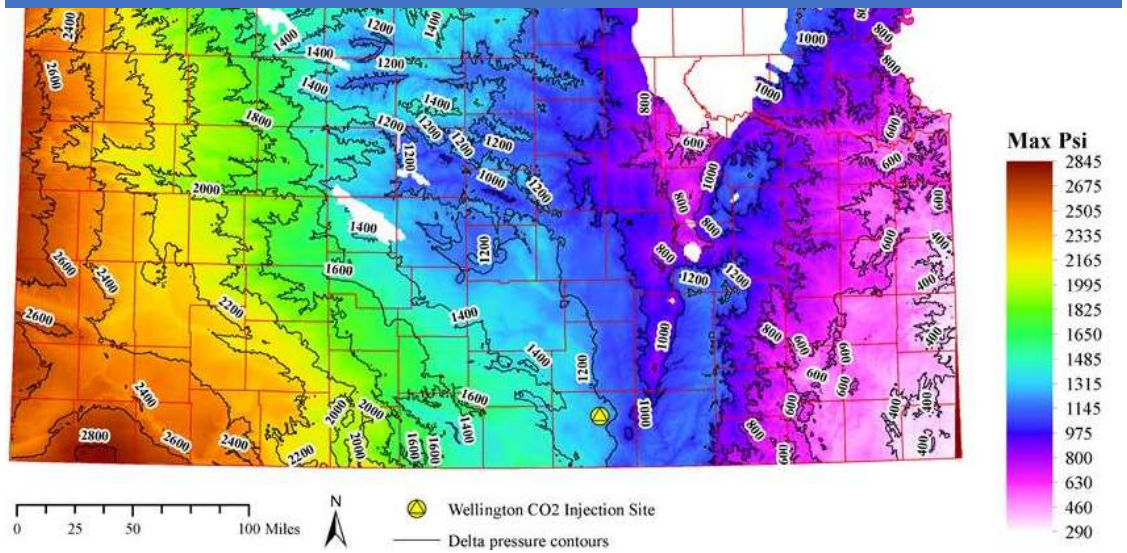
Depth (in feet) Below Ground Surface to Top of Arbuckle



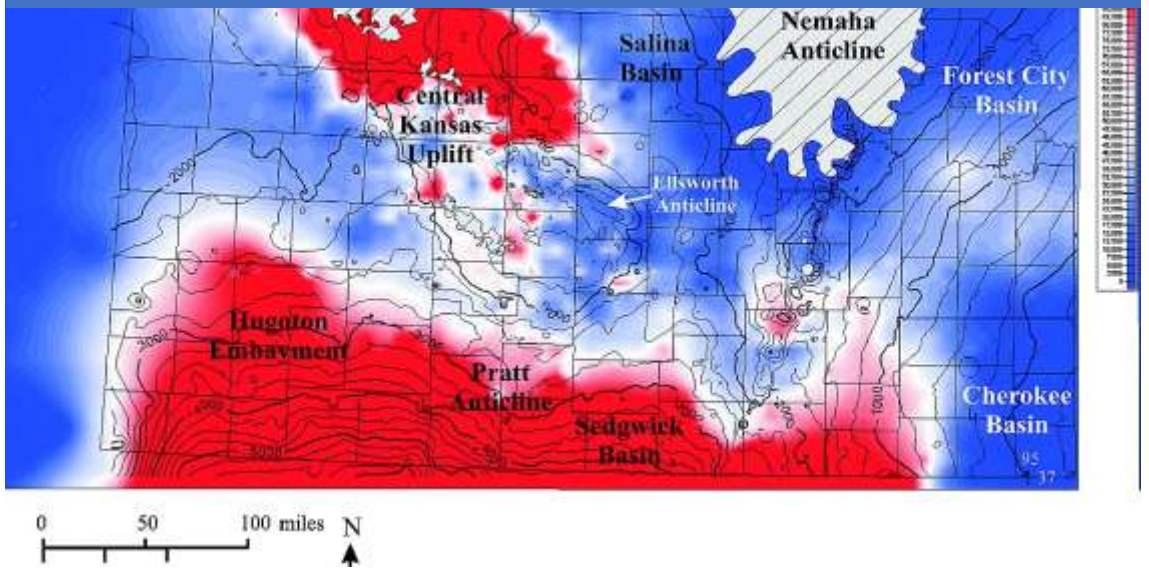
Basement geology and structure (Midcontinent Rift System)



Maximum Allowable Increase in Pore Pressure

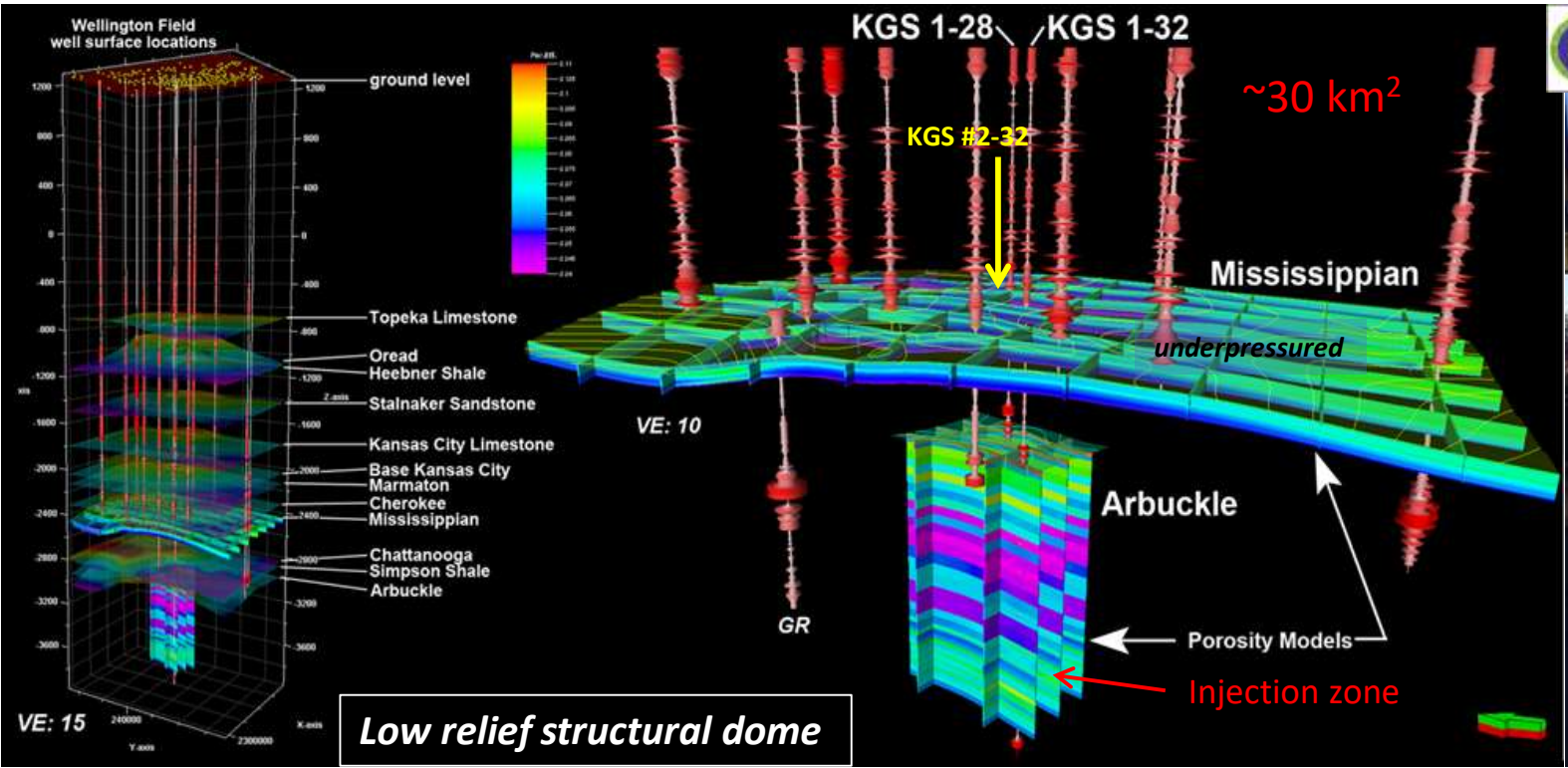


Salinity of Cambrian-Ordovician Arbuckle Group in Kansas



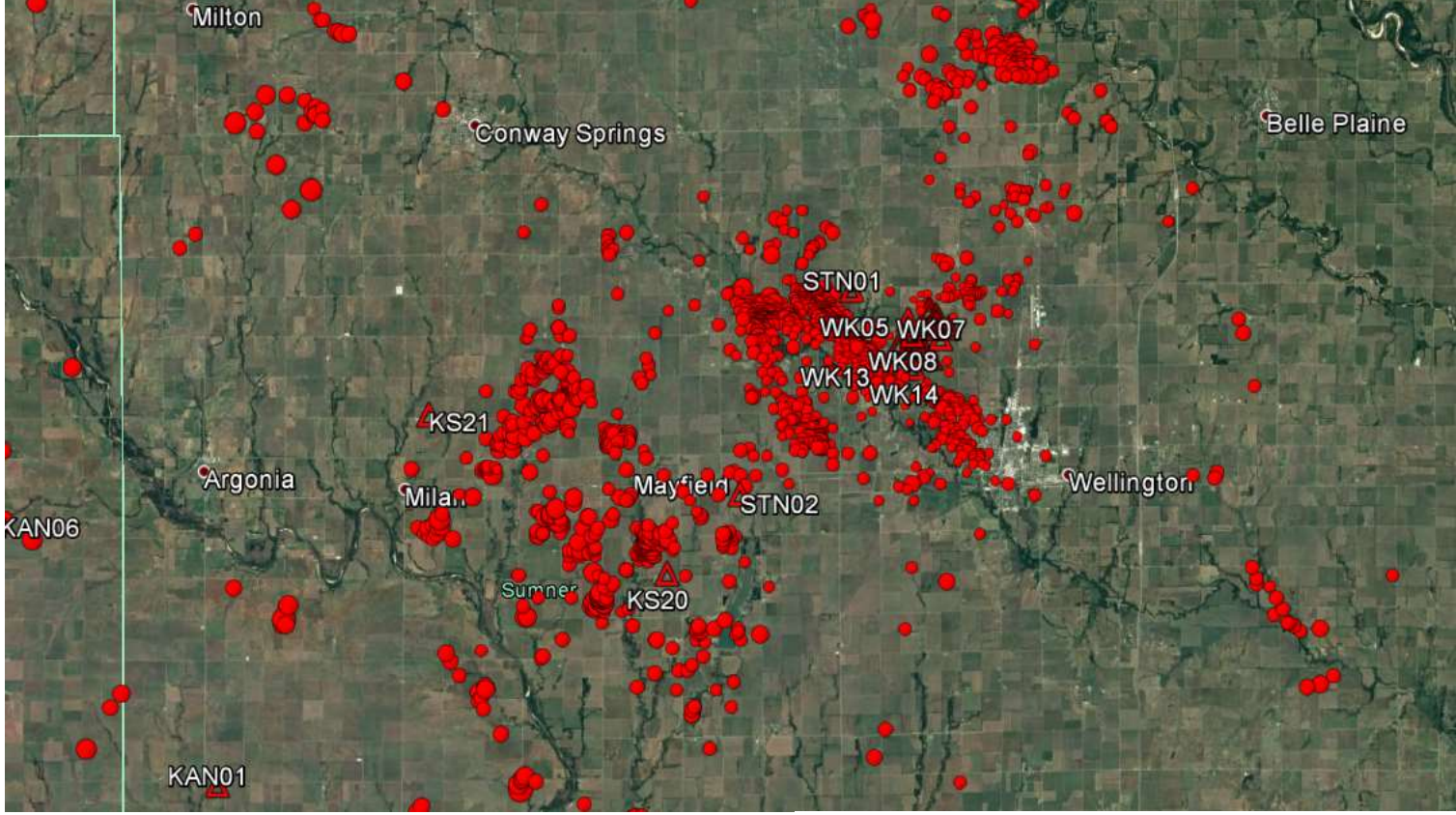
Wellington EOR and UIC Class VI Project

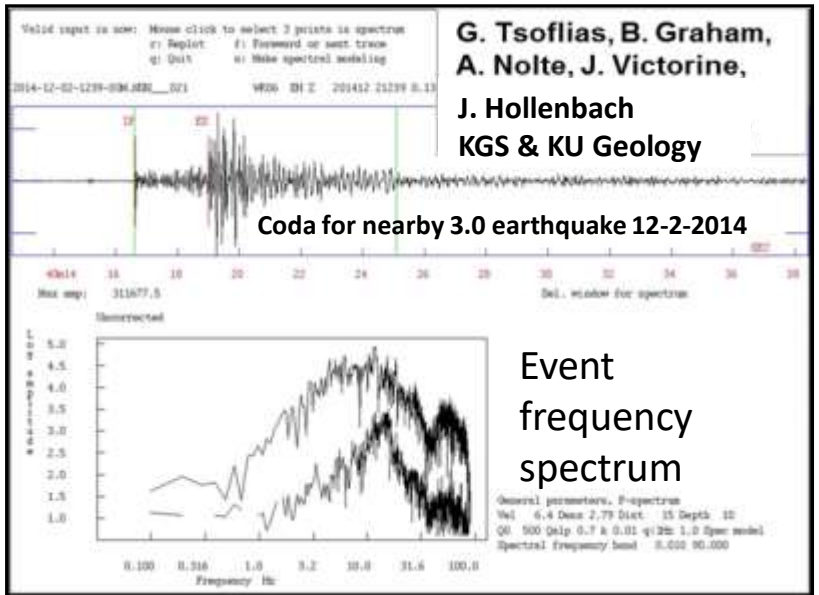
- **Demonstrated that 99% permanence of injected CO_2**
  - 20K metric tonnes injected into KGS #2-32 into *Mississippian siliceous dolomite reservoir between January-June 2016*
  - *CO_2 plume and EOR response as forecast by model* ***(Class II UIC permit)***
  - Up to 40K metric ton injection into underlying *Arbuckle Group dolomitic saline aquifer* ***(attempted Class VI UIC permit)***
- **Demonstrated reliable and cost effective MVA (monitoring, verification, and accounting) tools and techniques**
- **Developed best practices for effective and safe CO_2-EOR and CO_2 saline storage**

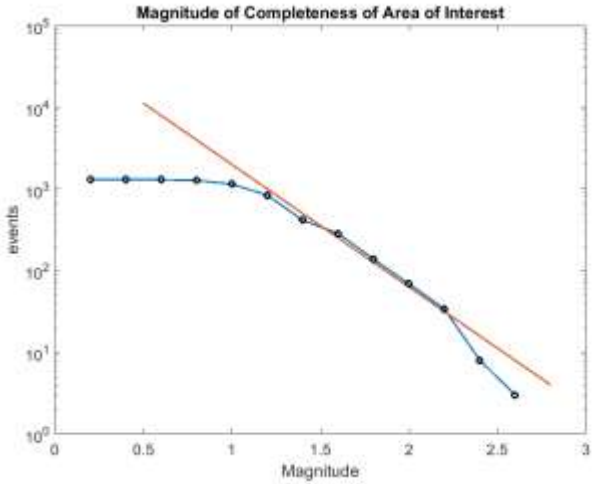


Seismicity Monitoring

- Seismic monitoring network at Wellington pilot injection site
- M_c ~1.2
- Smallest measured has been M_w 0.4
- **No earthquake has been detected** within Wellington field in association with the CO_2 pilot injection into KGS #2-32

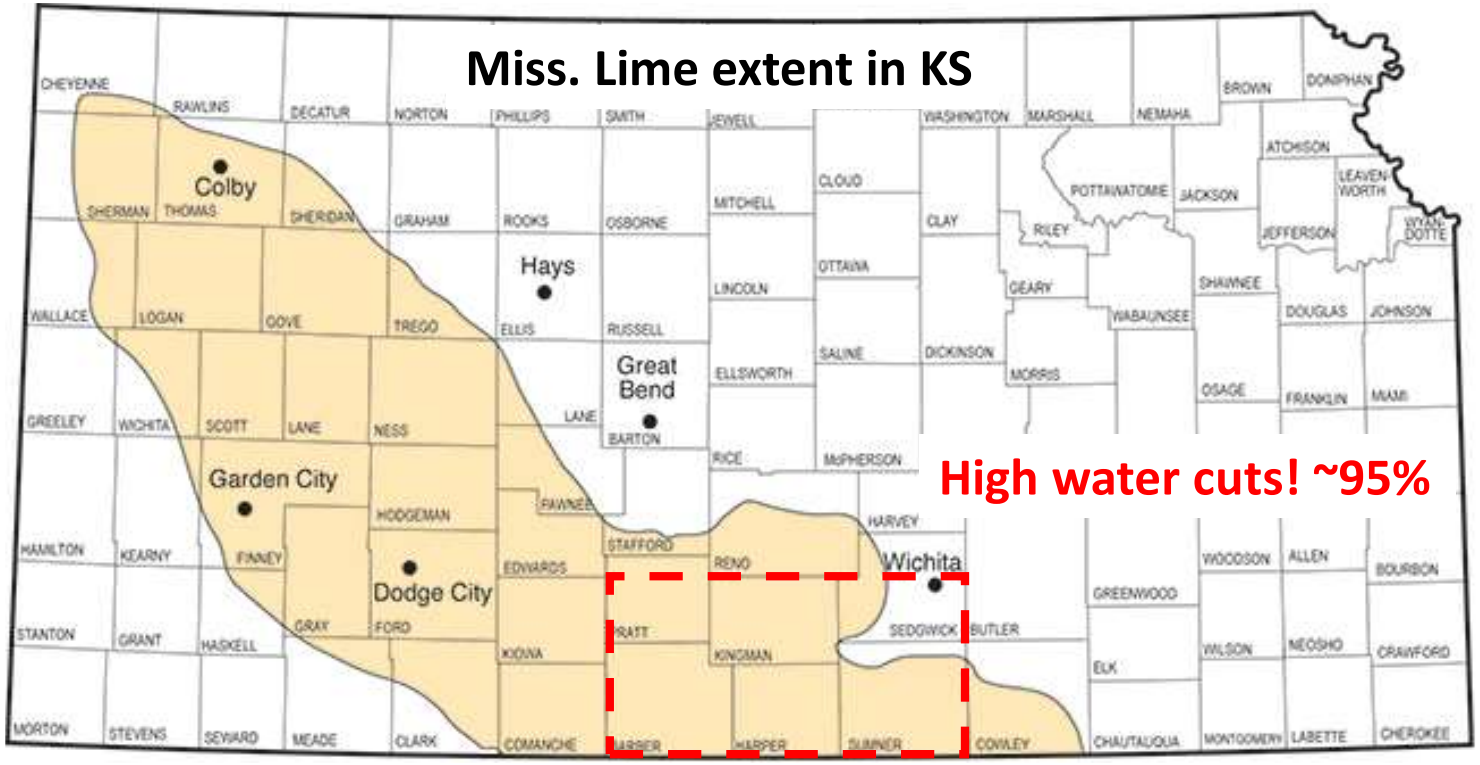


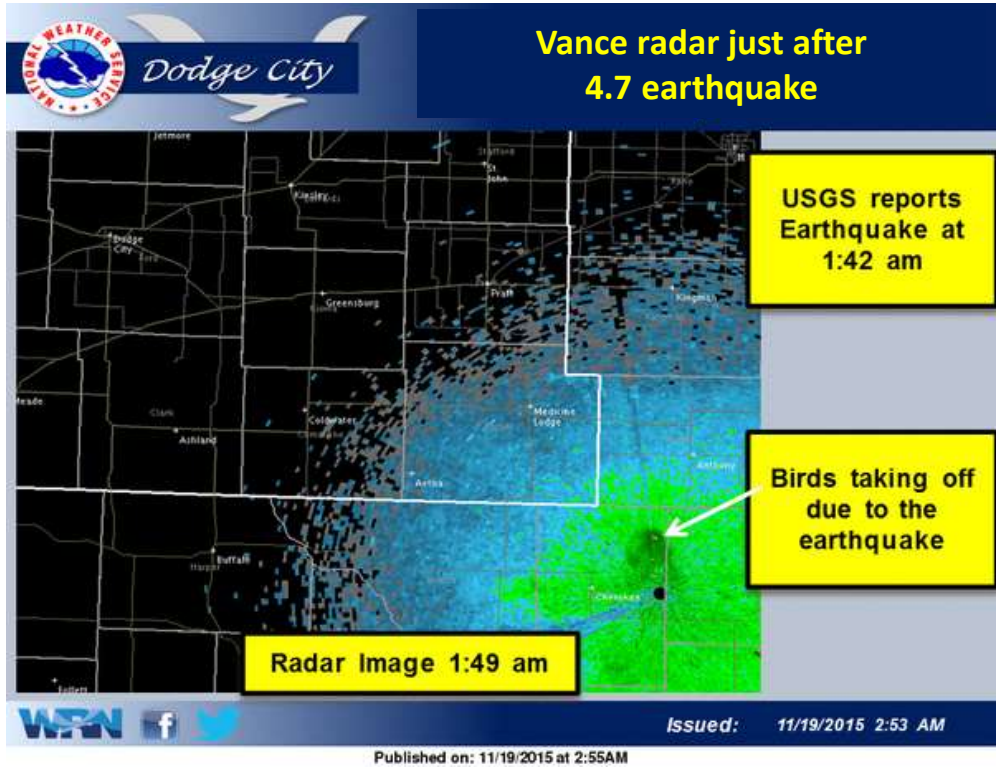




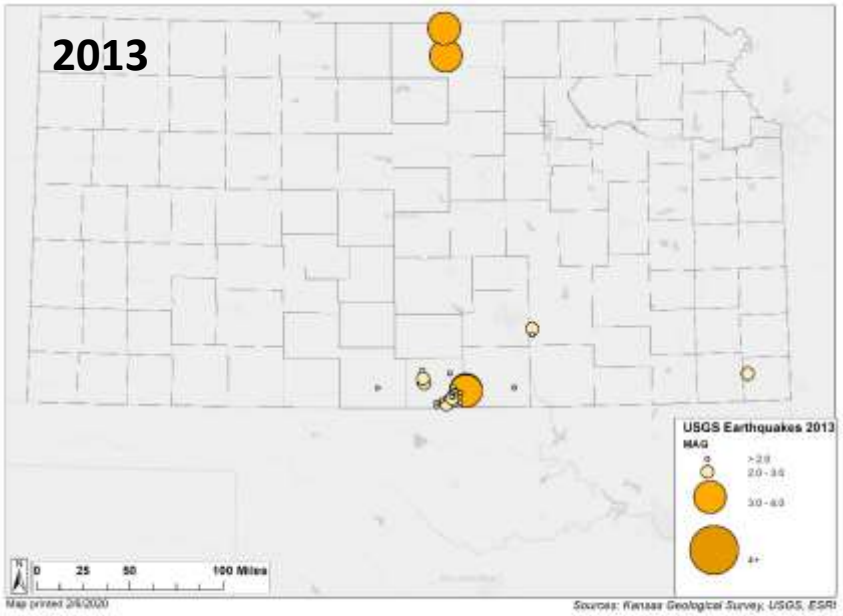
History of Seismicity in Kansas

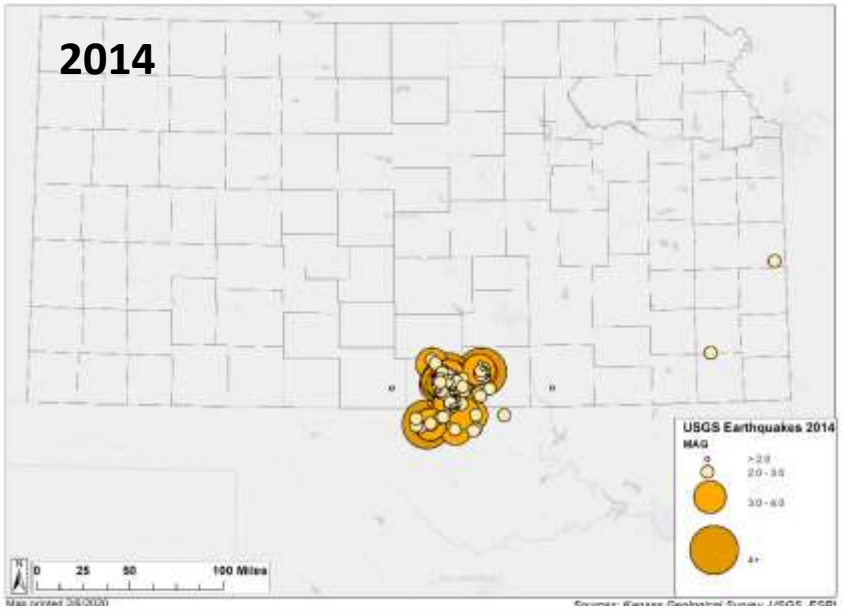
- From 1981 through 2010, Kansas experienced 30 recorded earthquakes.
- In 2013, there were 4 recorded earthquakes in Kansas.
- In 2014, there were 127 recorded earthquakes in Kansas.
- In the first three months of 2015, there were 51 recorded earthquakes in Kansas.
- The majority of those earthquakes occurred in Harper and Sumner Counties.

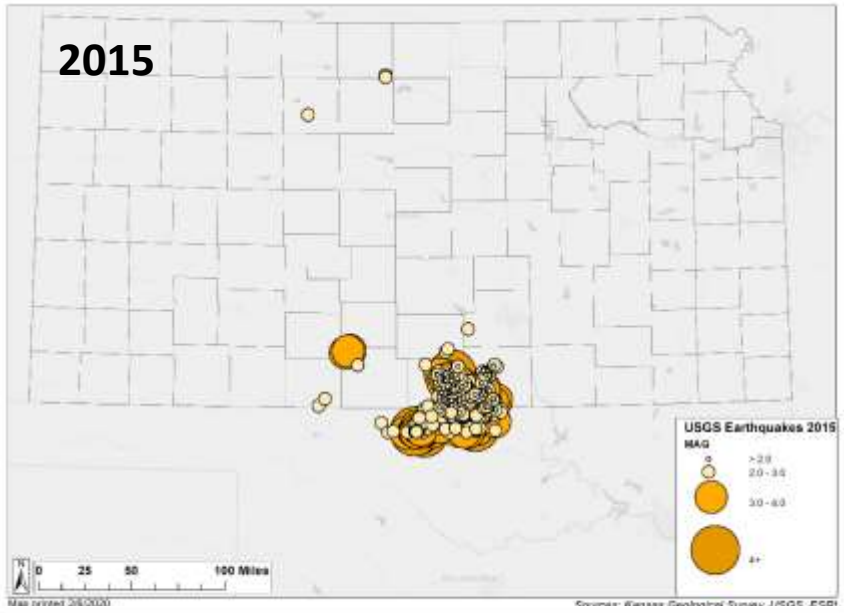


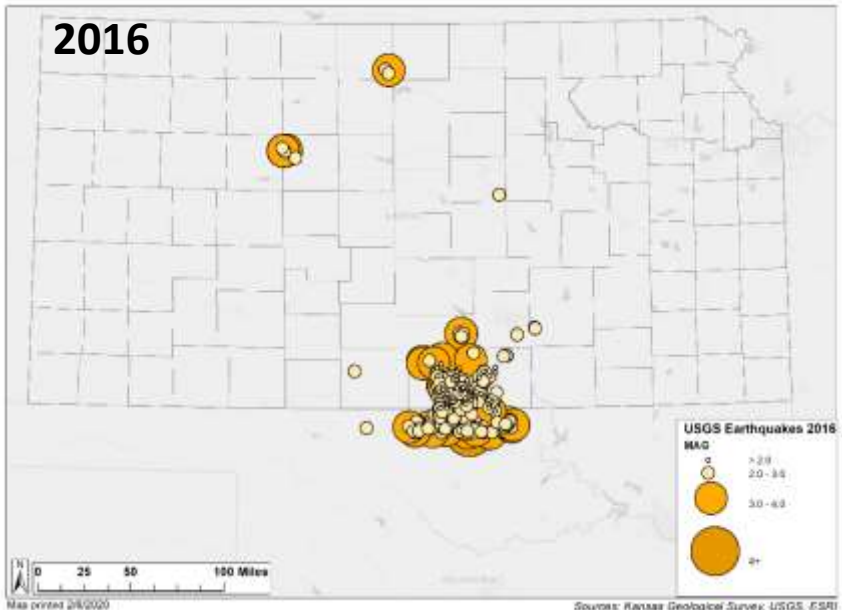


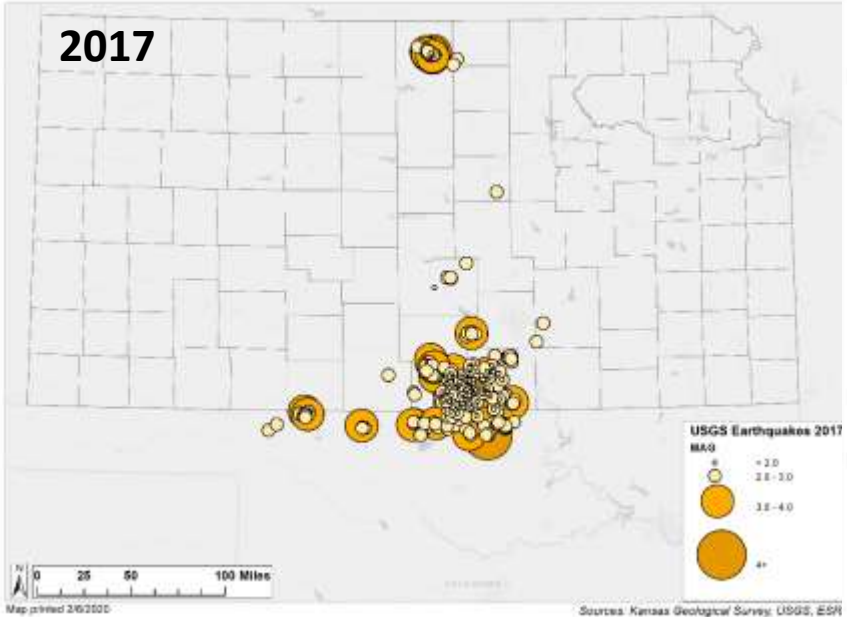
Earthquakes over time: KGS & USGS arrays

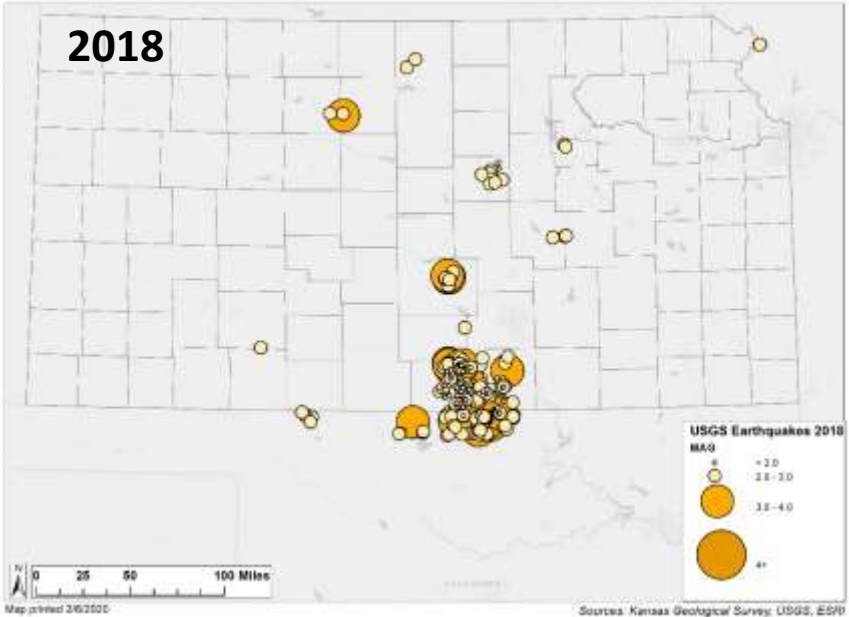










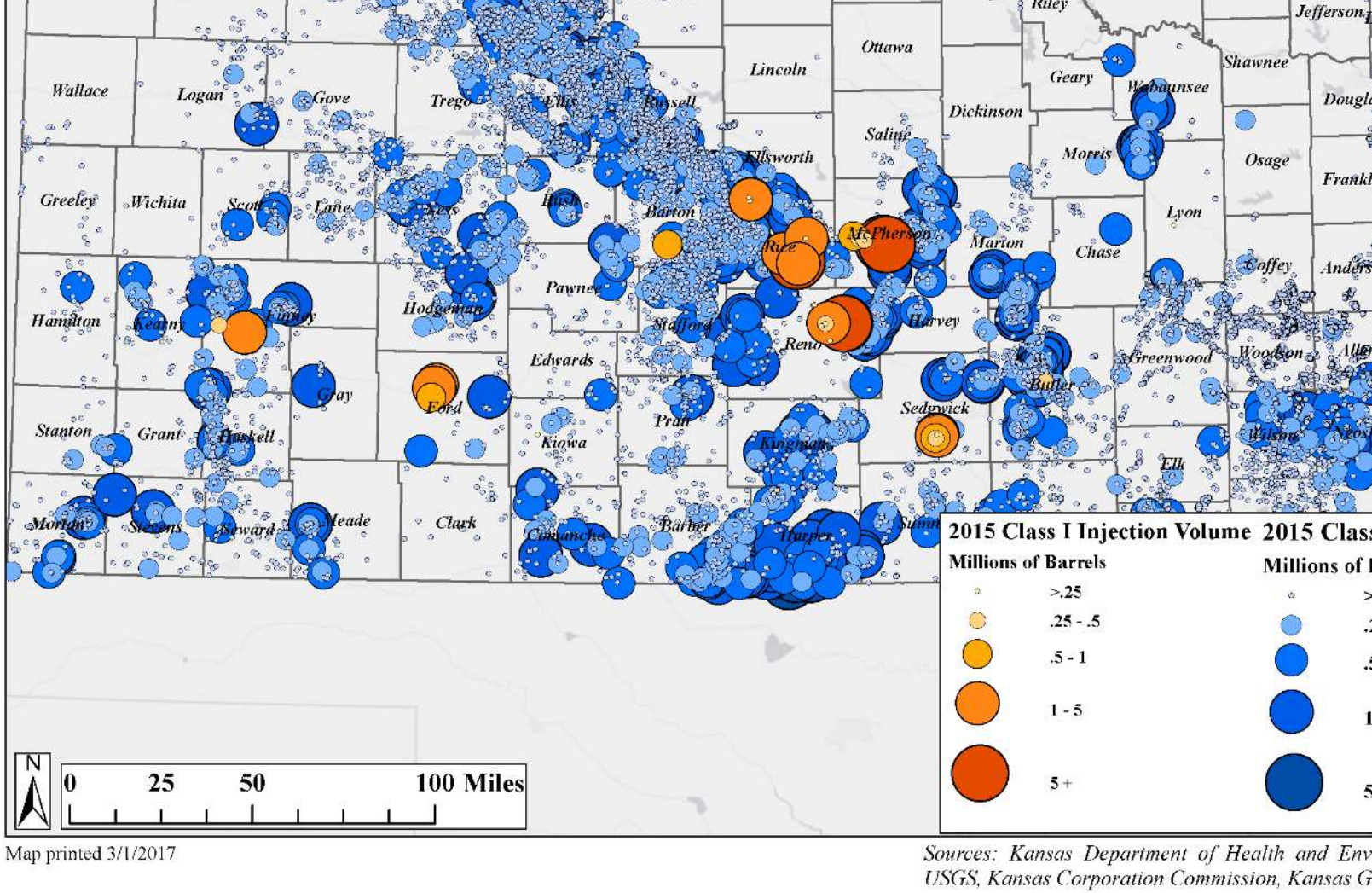


Who is Injecting in Arbuckle?

- Underground injection is the only disposal method which isolates waste
- UIC Class I, V – 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 only inject oil and natural gas production fluids: waterflood and waste
  - 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 – US EPA in Kansas

Fluid Disposal History in Kansas

- 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
- Equivalent of 9M CO_2 tones/year for one county
- Class I wells show increase in pressure and SFL
- Class II would show similar tendencies if data is available

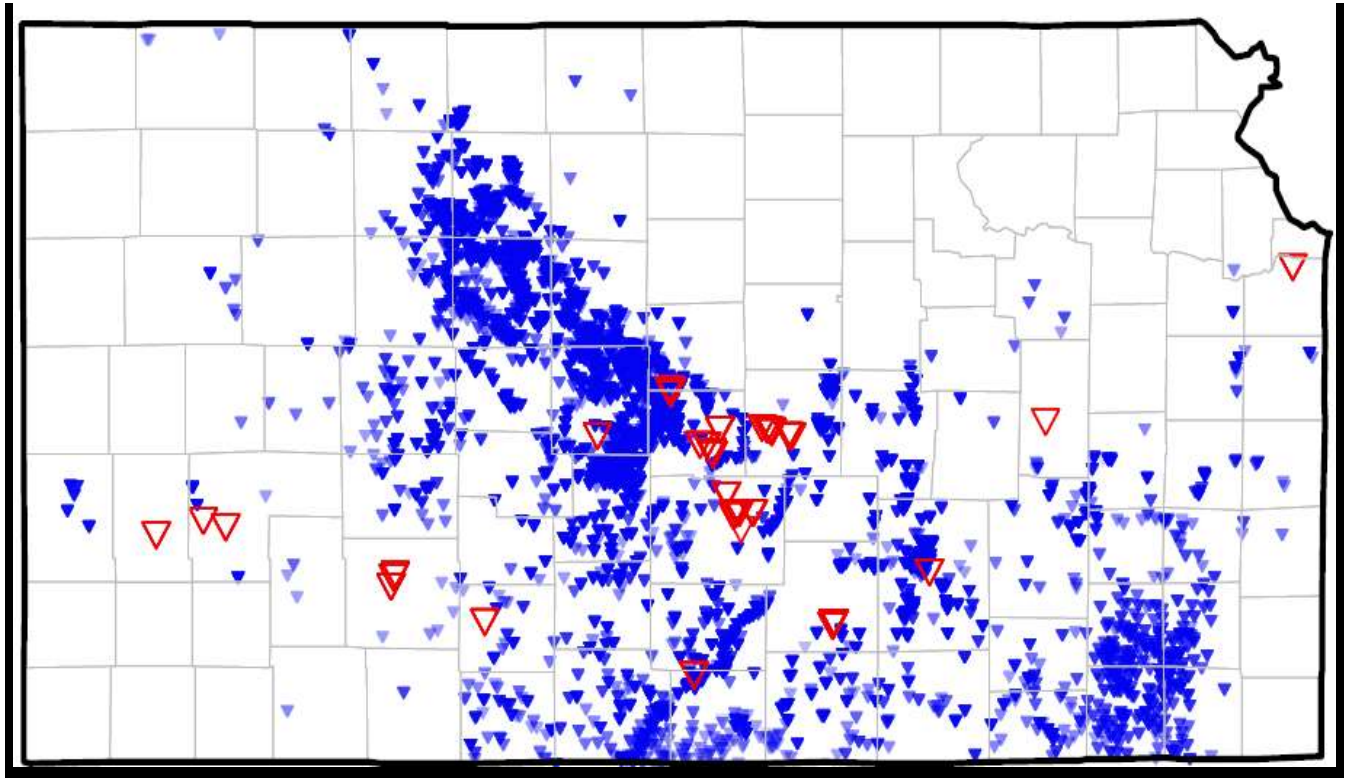


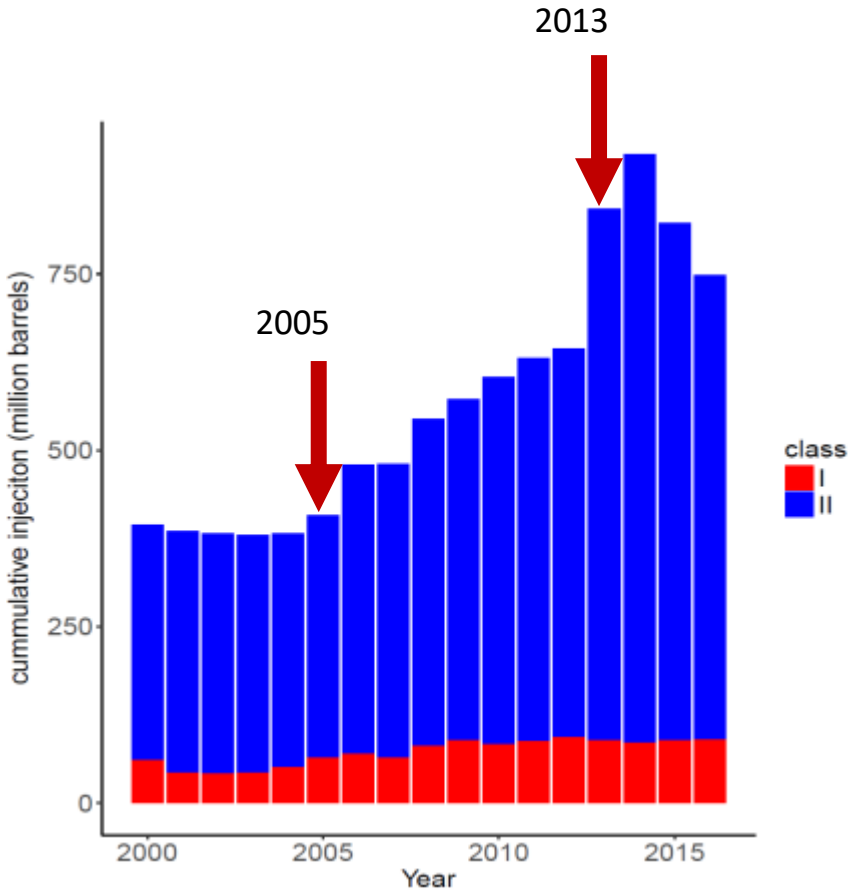
Map printed 3/1/2017

Sources: Kansas Department of Health and Env
USGS, Kansas Corporation Commission, Kansas G

Kansas Arbuckle disposal wells

- 49 Class I and 2381 Class II Arbuckle wells across Kansas
- Volumes increased in 2005, peaked in 2013-2014 to >750 million barrels, and dropped to 500M bbls in 2015
- Equivalent to ~9M tonnes of CO_2 per one county





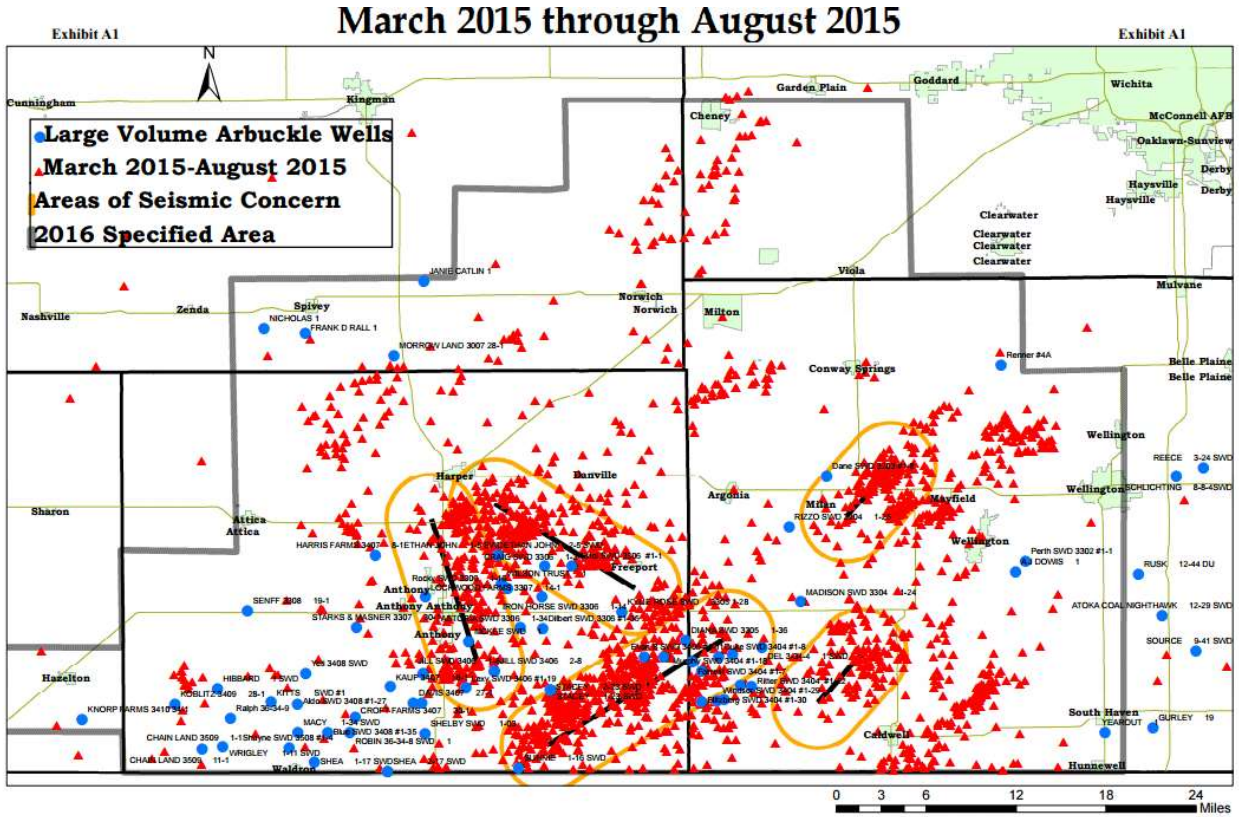
Bidgoli et al., 2019

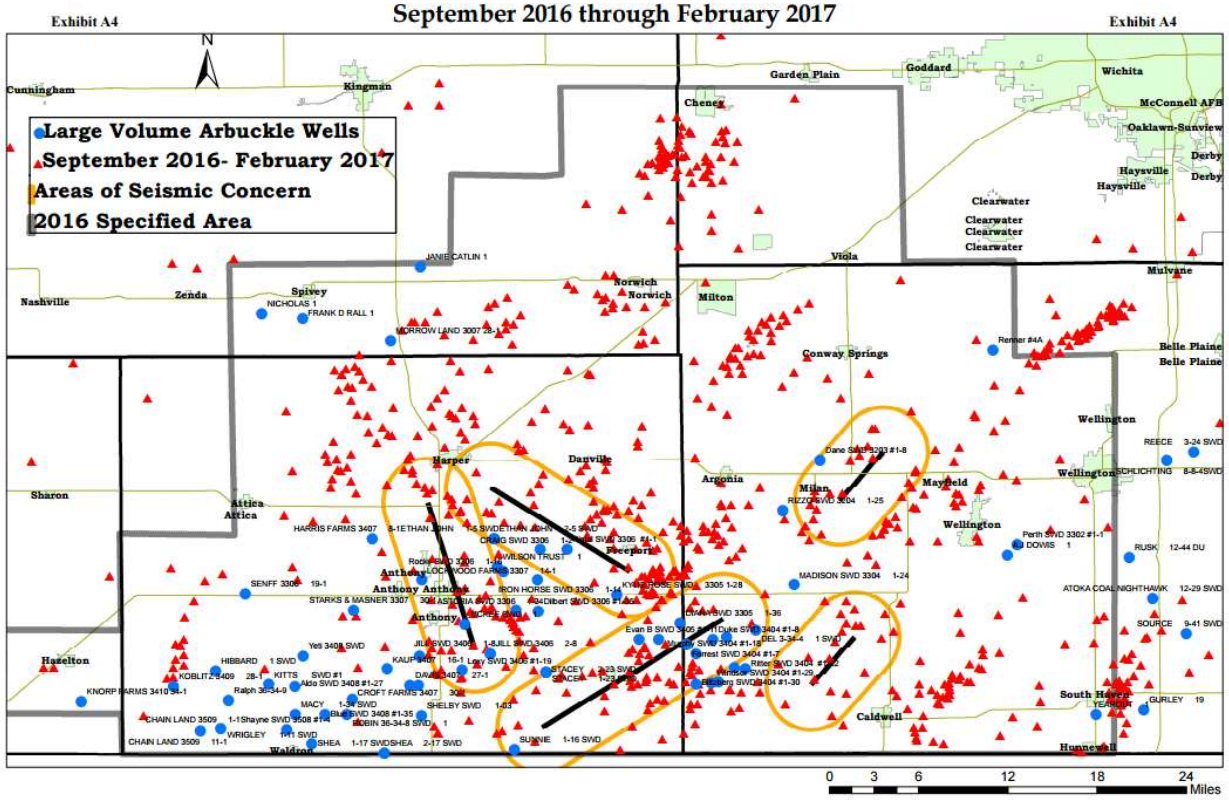
Regulatory Actions

- KCC orders 1
  - https://estar.kcc.ks.gov/estar/ViewFile.aspx/15-770%20Order.pdf?Id=ea831b2c-f398-4a05-9986-97f4cb45fe46
  - made operators verify the true vertical depths of the wells located inside the Areas of Concern
  - instituted a daily injection report to be filed monthly for all large volume Arbuckle wells,
  - defined **large volume** as more than **5,000 barrels of water per day**,
  - set a **daily maximum injection level of 25,000 barrels per day** for wells outside of the areas of concern within Harper and Sumner County
- KCC order 2
  - https://estar.kcc.ks.gov/estar/ViewFile.aspx/20160809115614.pdf?Id=aeae22e8-feb8-4a69-9a0b-b8d65044963c
  - While monitoring the effects of reduced saltwater injections after the initial Commission order, KCC staff noted a decrease in earthquakes that were 2.5 magnitude or larger in the “areas of concern”, but also noted an increase in smaller earthquakes outside of those areas.
  - In response, the Commission issued a second order in August 2016.
  - This second order extended limits beyond the five areas of concern to include parts of Harper, Sumner, Kingman, Sedgwick, and Barber counties.
  - However, the volume limits within the 5 original areas from the first Commission order remained in place.
  - The areas subject to the Second Order had a daily **maximum injection limit of 16,000 barrels** per day rather than the 25,000

Regulatory Actions

- KCC induced seismicity information
  - https://kcc.ks.gov/oil-gas/induced-seismicity





Kansas Legal and Regulatory Framework

Challenge		CO_2 EOR	Storage/ Sequestration	Possible Remedies
Statutory framework		Adequate	Not developed	Statutes for Sequestration
Pore Space	**Ownership**	Minerals owner	Surface owner	Statute to make definitive
	Aggregation (pooling / unitization)	Covered (KSA 1301-1303), but is rather weak	Needs to be addressed	Make less difficult to unitize (EOR). Expand for Sequestration. Eminent domain under a utility model (Sequestration).
Regulatory	**Well permitting**	Class II; State primacy	Class VI; EPA primacy	States may file for Class VI primacy
CO_2 ownership	**During operations**	Determined by contracts	Determined by contracts	Sequestration - utility model would simplify
	Post-closure, long-term liability	No issue?	Long-term liability	Sequestration - utility model could pass liability to State

Source: Mostly condensed from results from ICKan legal and regulatory studies (Steincamp, Schremmer, et.al.)

Pore Space Definition and Statutes

- 2017 Mosser v. Denbury Case - pore space use is a damage
- Surface owners are entitled to compensation for a mineral developer's use of subsurface pore space
- Compensation is due regardless of the surface owner's ability to use or any plans to access the pore space
- The court refused to speculate on how a surface owner could demonstrate or quantify damage
- SB 2344 was introduced in the 2019 legislative session to clarify the legislative intent of the subsurface pore space policy

Arkansas	Undecided, proposed surface owner in 2011 failed Senate
Colorado	Undecided, proposed surface owner, no action taken
Kansas	Undecided, proposed mineral owner in 2011 failed Proposed surface owner in 2012 failed
Kentucky	Undecided, case law suggests mineral owner
Louisiana	Undecided, case law suggests surface owner
Michigan	Undecided, case law suggests surface owner
Montana	Surface owner per 2009 Senate bill
New Mexico	Undecided, proposed surface owner in 2009 failed Surface owner entitled to damages per case law
New York	Undecided, case law suggests surface owner
North Dakota	Surface owner, use and migration not a damage per SB 2344
Oklahoma	Surface owner per case law and statute
Pennsylvania	Undecided, case law suggests surface owner
Texas	Undecided, conflicting case law
West Virginia	Undecided, case law suggests surface owner
Wyoming	Surface owner per 2008 House bill

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North Dakota Office of the Governor

Acknowledgements & Disclaimer

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Questions?

http://www.kgs.ku.edu/PRS/petroProj.html

Jeffrey Energy Center, KS, 2.16 gigawatts, ~12Mt CO_2