Methodology for Capacity Estimation for Waste Disposal and Carbon Management*

Yevhen Holubnyak[1], Tiraz Birdie[2], Tandis S. Bidgoli[1], and Jennifer Hollenbach[1]

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[1]Kansas Geological Survey, Kansas Geological survey, Lawrence, KS (eugene@kgs.ku.edu)
[2]TBirdie Consulting, Lawrence, KS

Abstract

Recent development in unconventional plays put unprecedented pressure in several regions of continental USA and other parts of the world on geological formations used for disposal of saline flow-back water, especially in plays with high water cuts. Normally, volumetric approach is taken to quantify storage or waste disposal capacity; however, since mentioned geological formations are also used by other industries, such as chemical, agricultural, and others for waste disposal and because these geological formations are also targeted as a potential sinks for anthropogenic CO_2, it is important to quantify waste disposal and/or storage capacity resources more precisely, taking into account multiple risk factors associated with these activities.

This work is using case studies from Kansas and Oklahoma to illustrate alternative methodology for waste management and resource capacity estimations. Originally, a detailed geological characterization was performed for a DOE-funded project (DE-FE-0002056), where existing well-log and core data was analyzed, and new exploratory wells were drilled in central and western Kansas with extensive logging and coring programs. Based on this analysis several injection sites were selected, characterized, and geological models were produced. Calculation of storage capacity for south-central and southwestern Kansas was performed where researchers used several different approaches, including volumetric calculations, extrapolation-based, detailed regional model numerical simulation, and using statistical approach. However, after this study was performed, new variables that affect storage capacity were uncovered: seismicity, competing injection wells, and others that were not accounted for by original study.

To improve upon previous work and propose a different and more comprehensive approach, we decided to combine volumetric approach with other criteria that state and federal regulatory agencies use to regulate waste injection, such as knowledge of structural elements, seismicity, protected freshwater aquifers above injection zones, hydrostatic in-situ head and fracture gradient of target formation, and others. The resulting product is a detailed areal map where safe, intermediate, and risky for injection areas are highlighted. This map could be used by regulators and businesses to select future injection sites or to recognize and negotiate potential risks before acute developments.

Selected References

Aansari, E., and T.S. Bidgoli, 2018, Statistical analysis of the Arbuckle pressure and static fluid level (abstract): GSA Abstracts with Programs, v. 50/1, final paper number 20-4.

Carr, T.R., D.F. Merriam, and J.D. Bartley, 2005, Use of relational databases to evaluate regional petroleum accumulation, groundwater flow, and CO_2 sequestration in Kansas: AAPG Bulletin, v. 89/12, p. 1607-1627.

Deutsch, C.V. 2002. Geostatistical Reservoir Modeling: Oxford University Press, 448p.

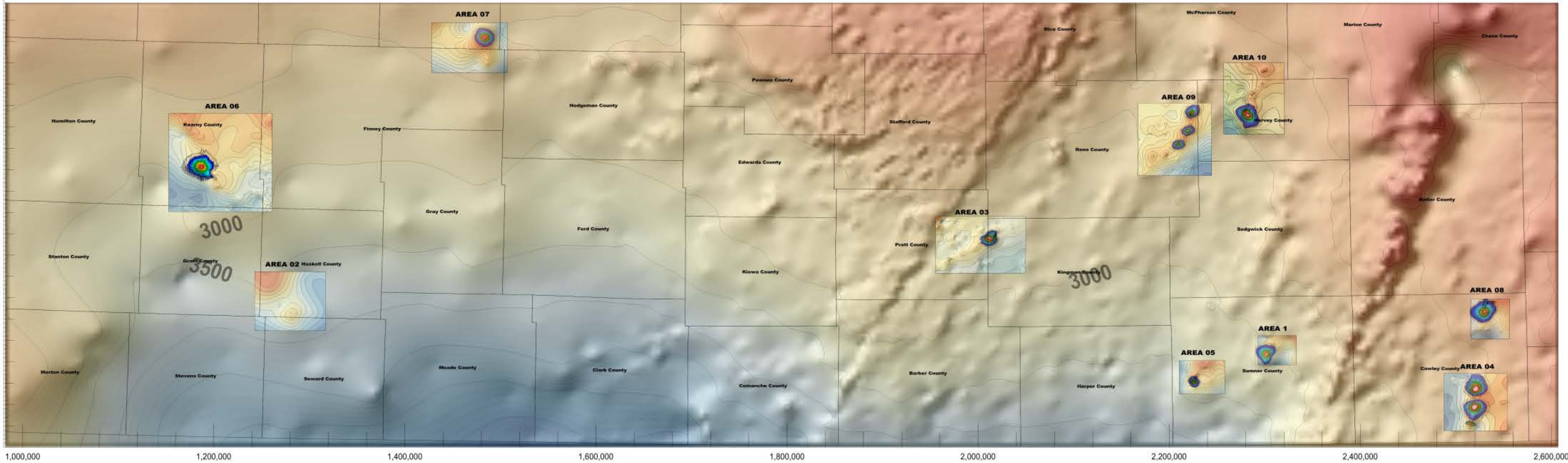
Duboise, M.K., 2018, History, Challenges, and Opportunity. Website accessed August 22, 2018, http://www.betterenergy.org/wp-content/uploads/2018/03/Marty-Dubois.pdf.

Jorgensen, D.G., J.O. Helgesen, and J.L. Imes, 1993, Regional aquifers in Kansas, Nebraska, and parts of Arkansas, Colorado, Missouri, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming—Geohydrologic framework: U.S. Geological Survey Professional Paper 1414-B, 72p.

Merriam, D.F., 1963, The geologic history of Kansas: Kansas: Geological Survey Bulletin, v. 162, 317p.

Website

http://blog.recursiveprocess.com, website accessed August 22,2018.



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AAPG Annual Convention and Exhibition 2018

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May 21, 2018

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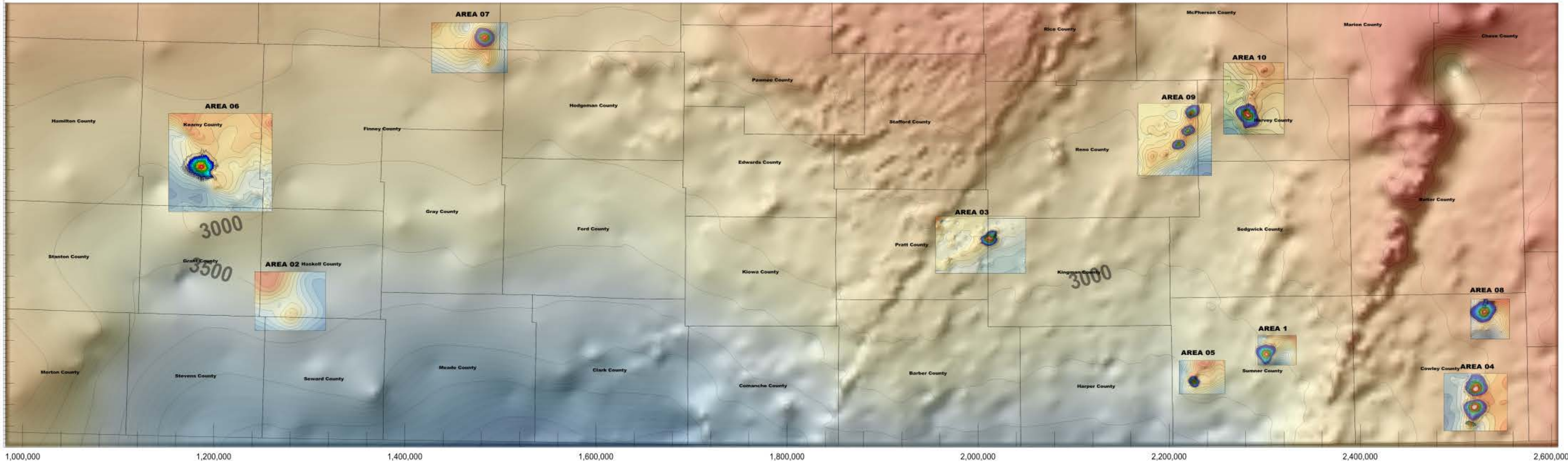


Outline

- Modeling CO_2 storage capacity for South-Central Kansas Arbuckle aquifer
- Current state of seismicity and waste water disposal in Sothern Kansas
- How risk of seismicity affects storage capacity

Highlights of past quarter: 45Q specifics

45Q specifics*

Enacted 2/9/2018 as part of a Federal budget bill

- Restricted to projects that begin construction before February 9, 2025 (seven years after enactment date).
- Can be claimed for a 12-year period beginning the day the equipment is placed in service
- Credits can be claimed by the capture facility but can be transferred to the storage facility, but not directly by the transporter
- 2017 tax credits are $12.83/tonne for EOR and $22.66/tonne for saline storage.
- Credit from 2018 through 2026 is a linear interpolation from 2017 credit values increasing to $35 for EOR and $50 for saline storage in 2026, plus an annual adjustment for inflation.
- Credit is $35 for EOR and $50 for saline storage from 2026 on.
- Adjusted annually for inflation after 2026.
- Injected into a qualified EOR project or in a secure geologic storage

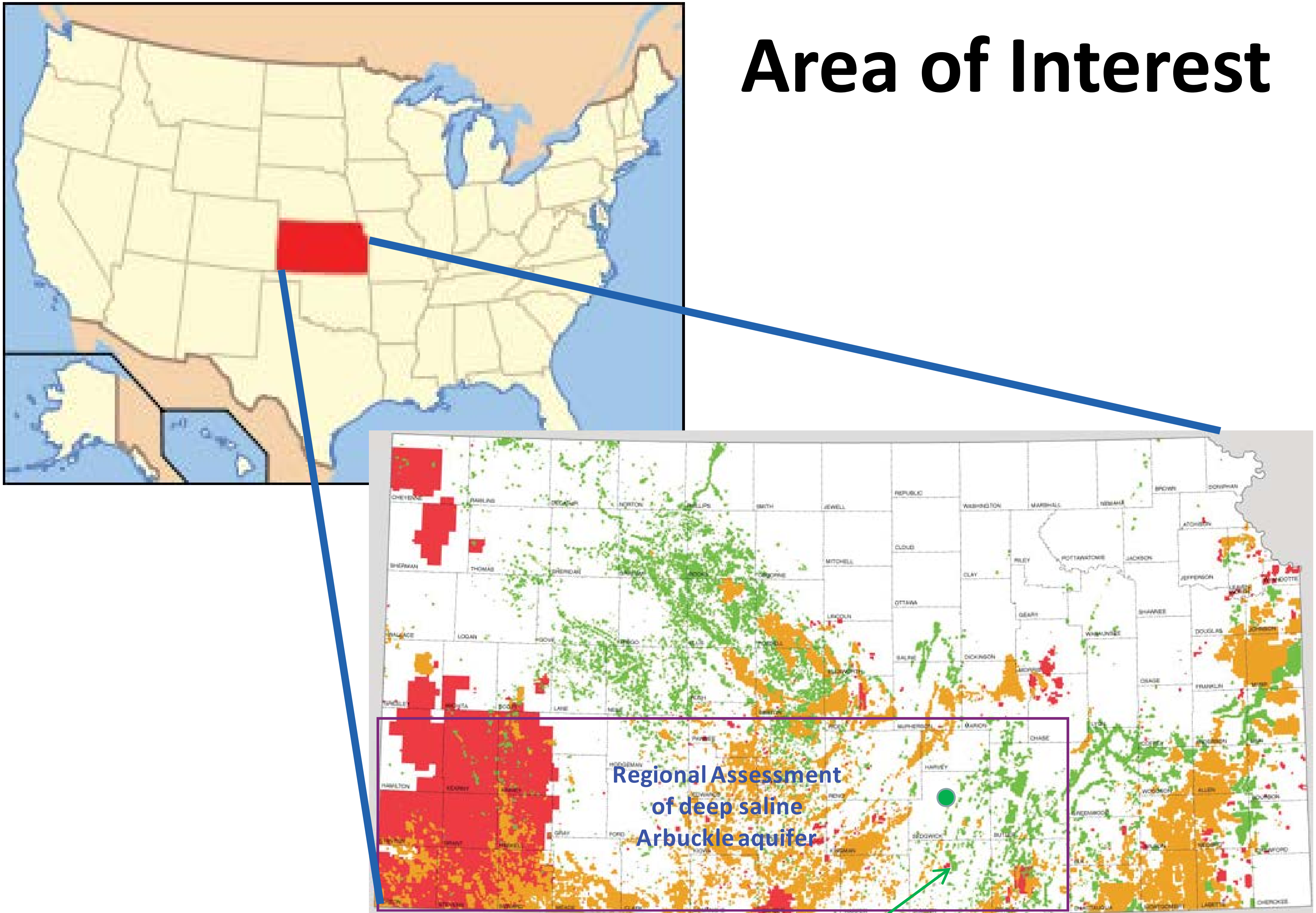
** Sources: NEORI (Kurt Walzer), CLATF, State CO2 EOR Workgroup (Brad Crabtree), and S. 1535 document*

Credits (no inflation)

	EOR	Saline
2017	$12.83	$22.66
2018	$15.29	$25.70
2019	$17.76	$28.74
2020	$20.22	$31.77
2021	$22.68	$34.81
2022	$25.15	$37.85
2023	$27.61	$40.89
2024	$30.07	$43.92
2025	$32.54	$46.96
2026 - 2035	$35.00	$50.00

Duboise, 2018

Area of Interest

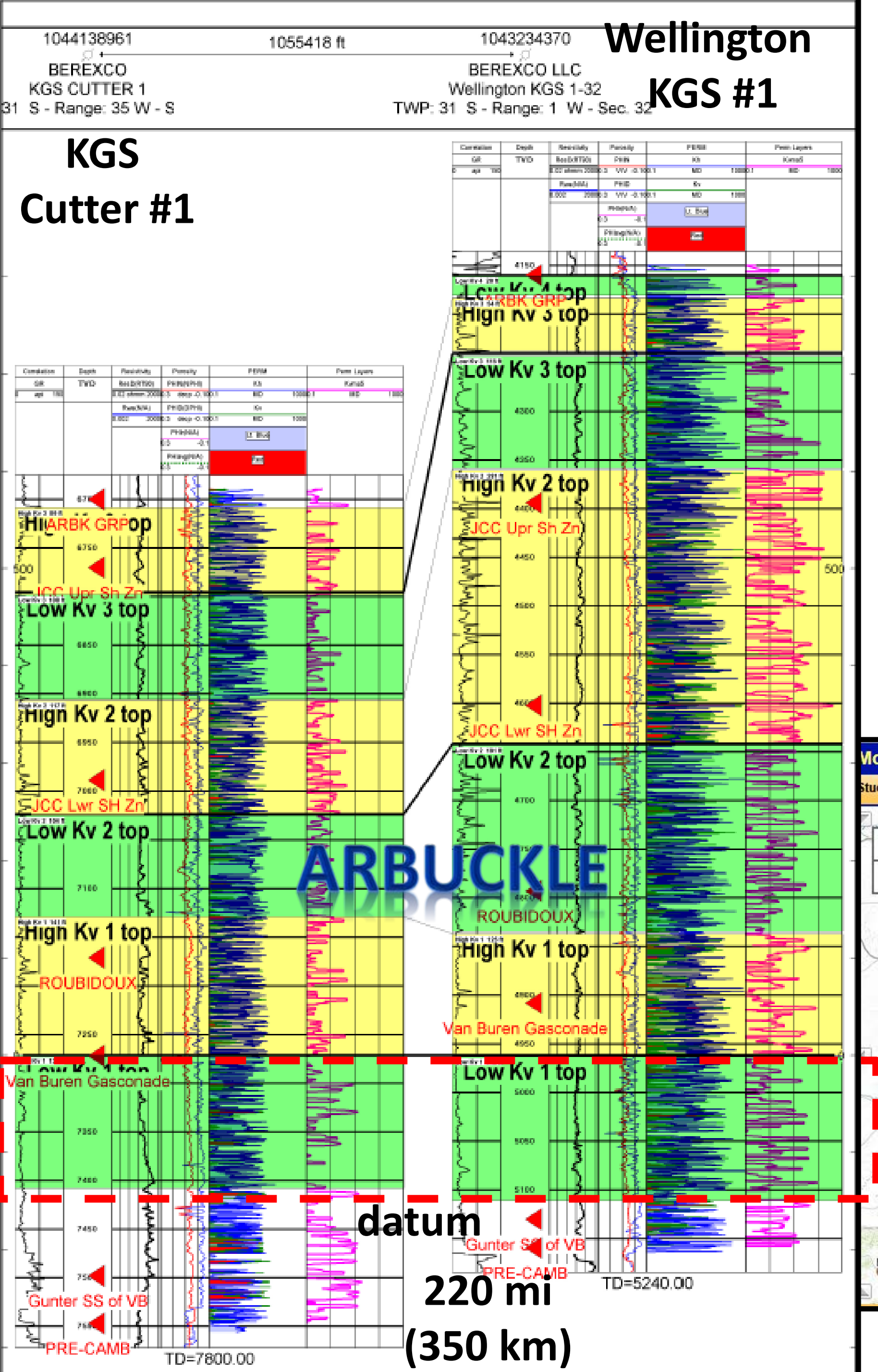


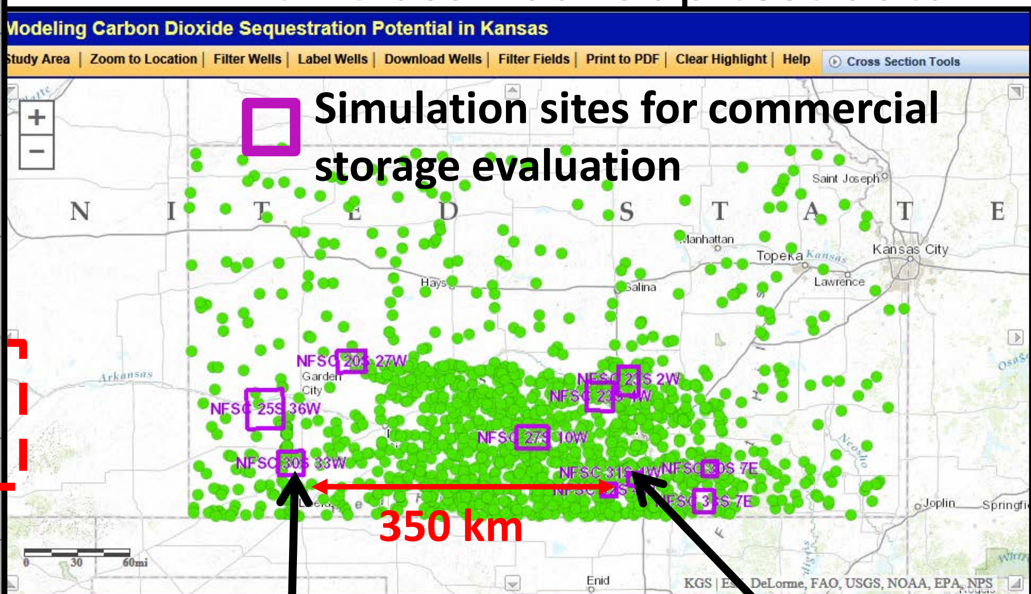
Plan for Capacity Estimations Study

- Determine formations of interest and outline the area of review
- Select promising sites of interest with known structure (total of 10)
- Gather data
  - Available through existing database at KGS and other sources
  - Drill and core wells, process 3D seismic, well test analysis, process logs, etc.
- Create geologic models for 10 sites and an entire region
- Perform dynamic simulations

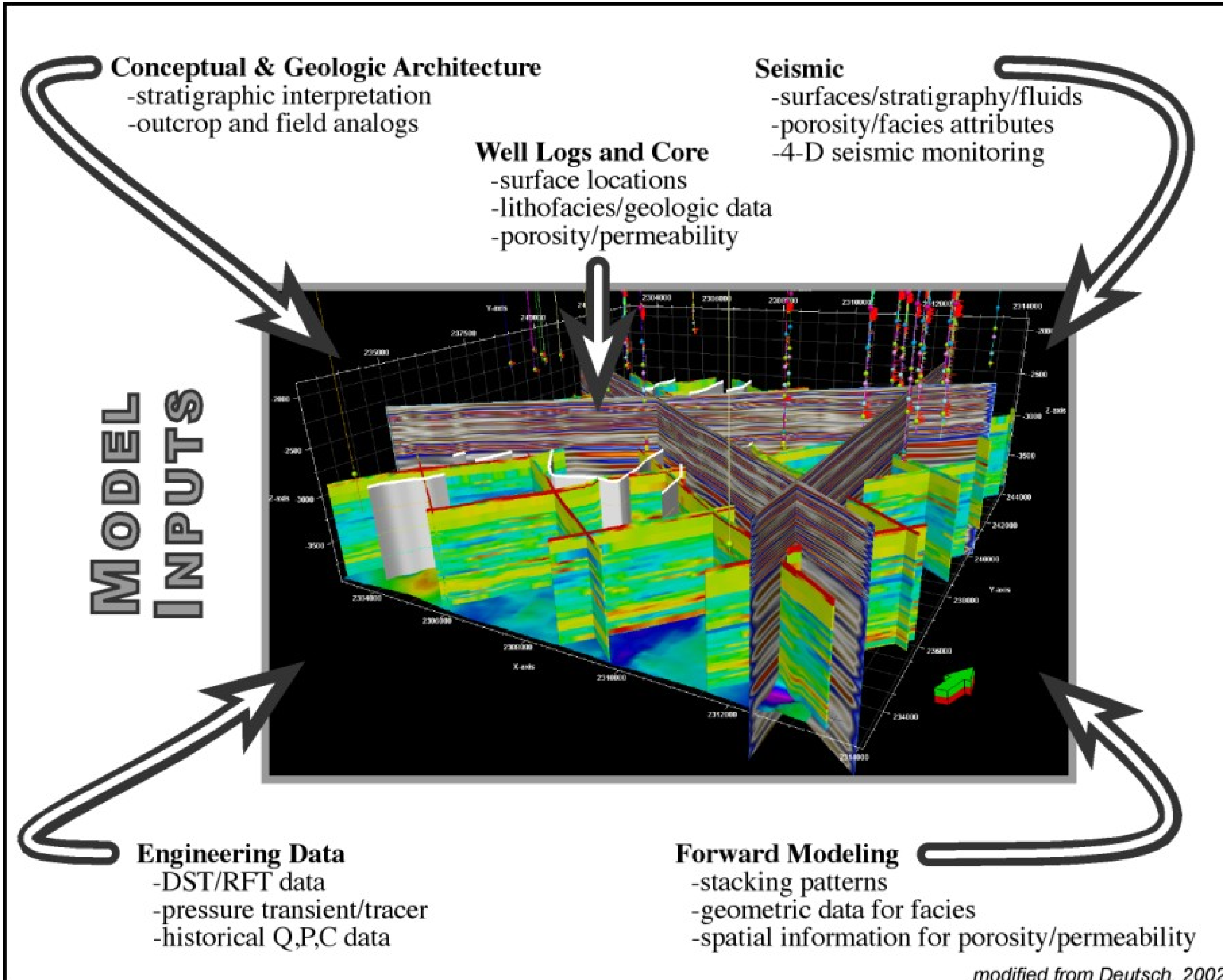
Computed Kh & Kv in Arbuckle Group for Digital Type Wells (●)

- Correlation of flow units based on K_h & K_v
- Between Cutter and Wellington Fields (350 km apart)
- Testing log-derived permeability with Class I buildup test data



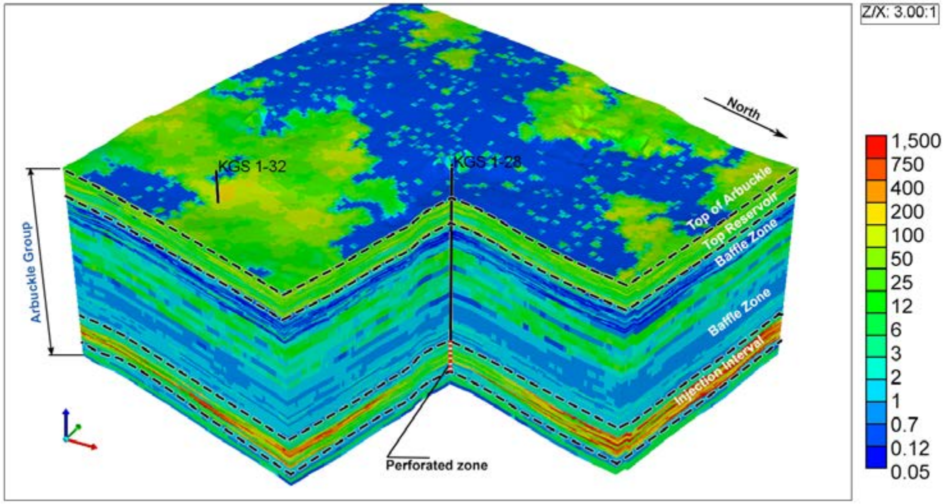


Cutter KGS #1 Wellington KGS #1-32

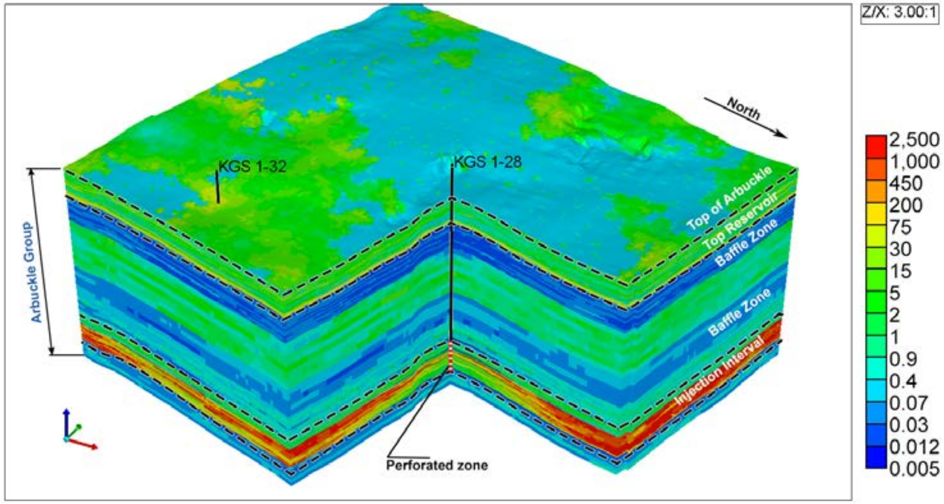


modified from Deutsch, 2002

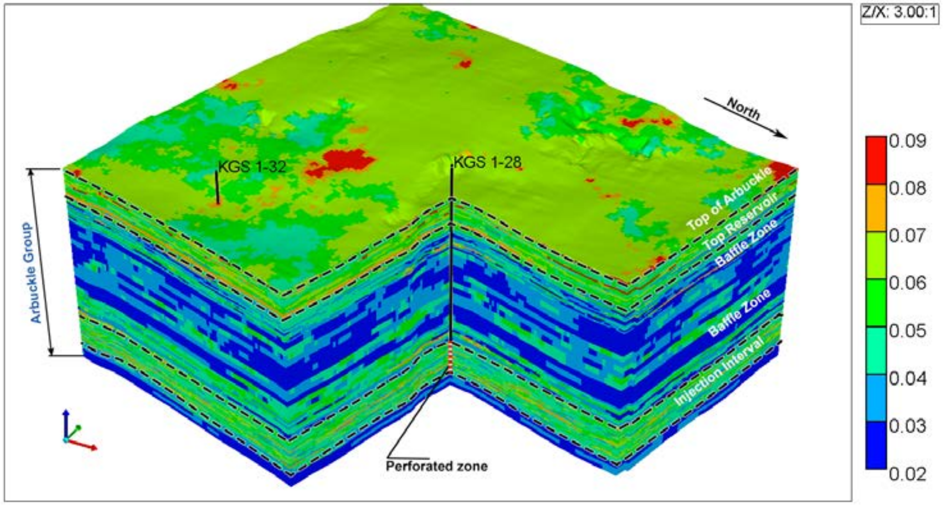
Permeability (K90)



Permeability (Vertical)

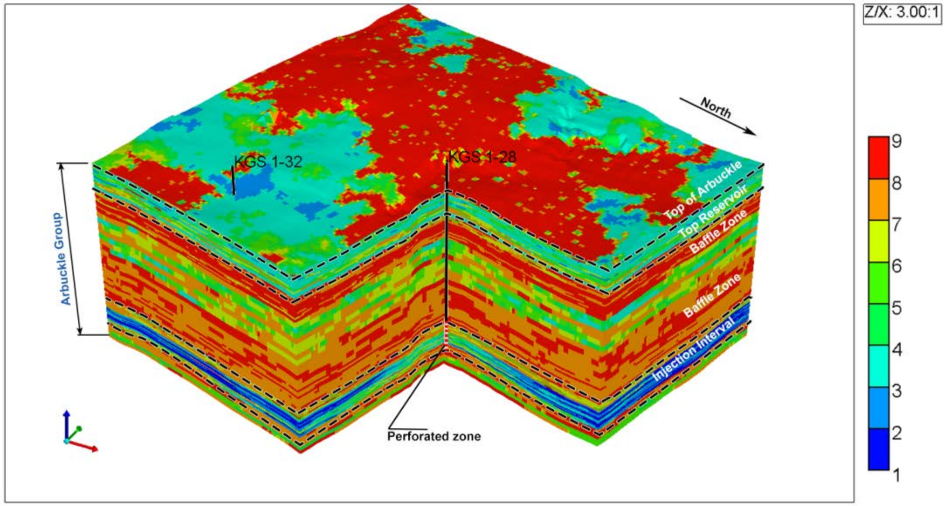


Rock Type Based on RQI

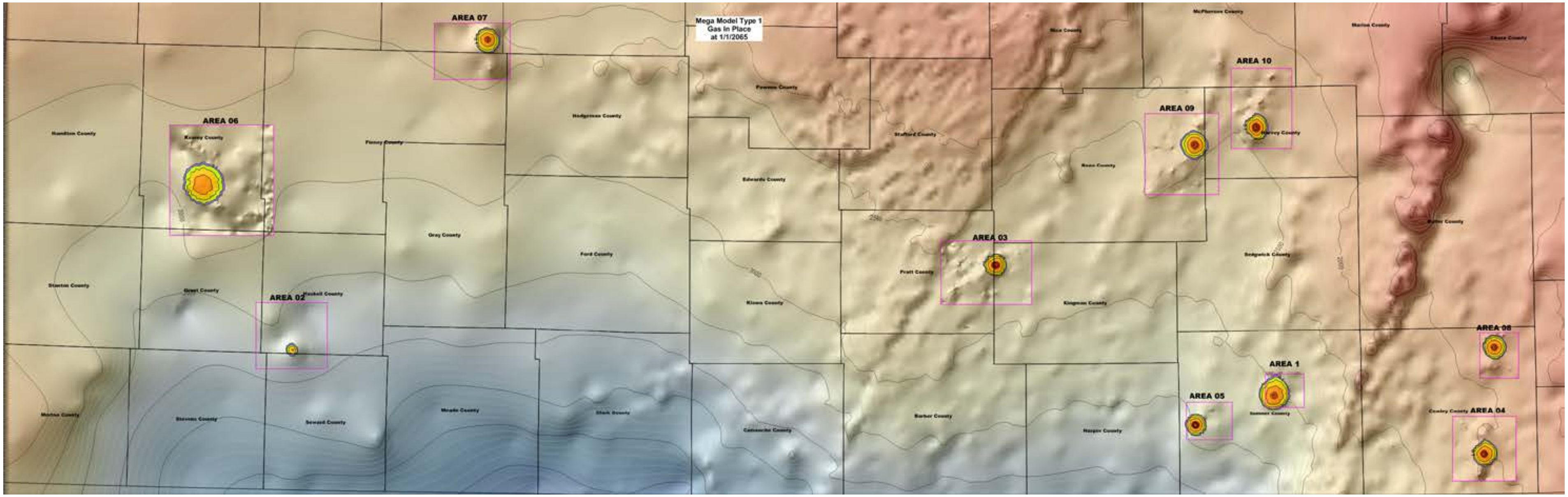


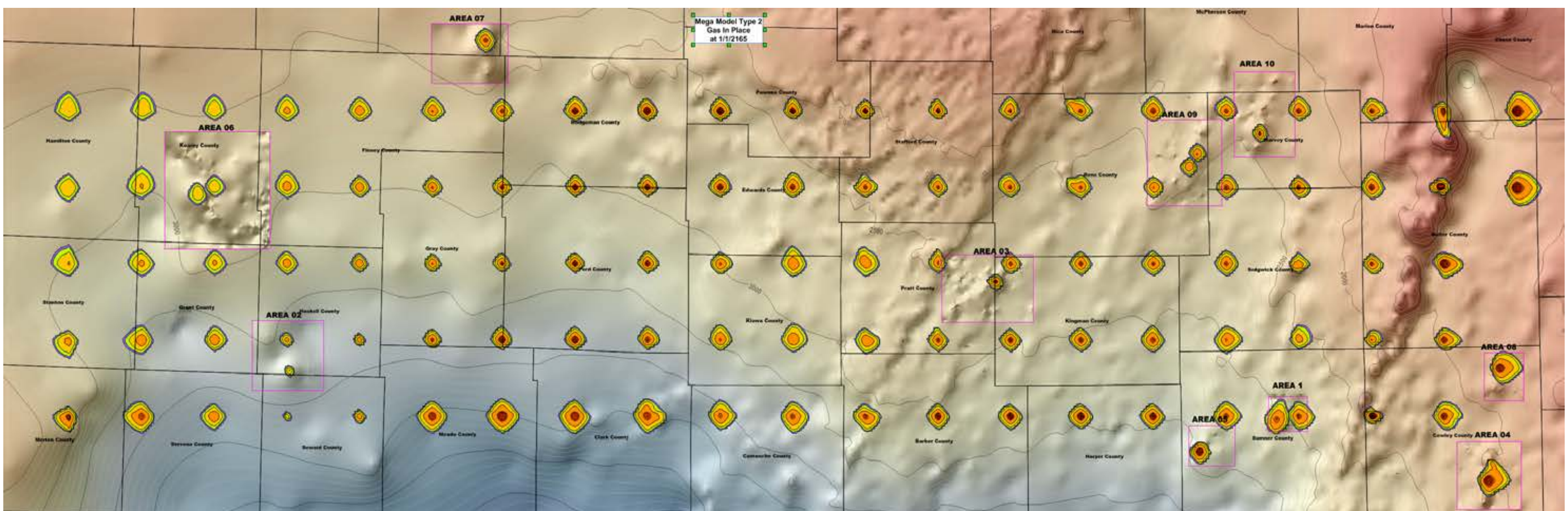
Rock Type Based on RQI

$$RQI = 0.0314\sqrt{Perm/_{Porosity}}$$



CO_2 Spatial Distributions: 10 sites vs Max Capacity





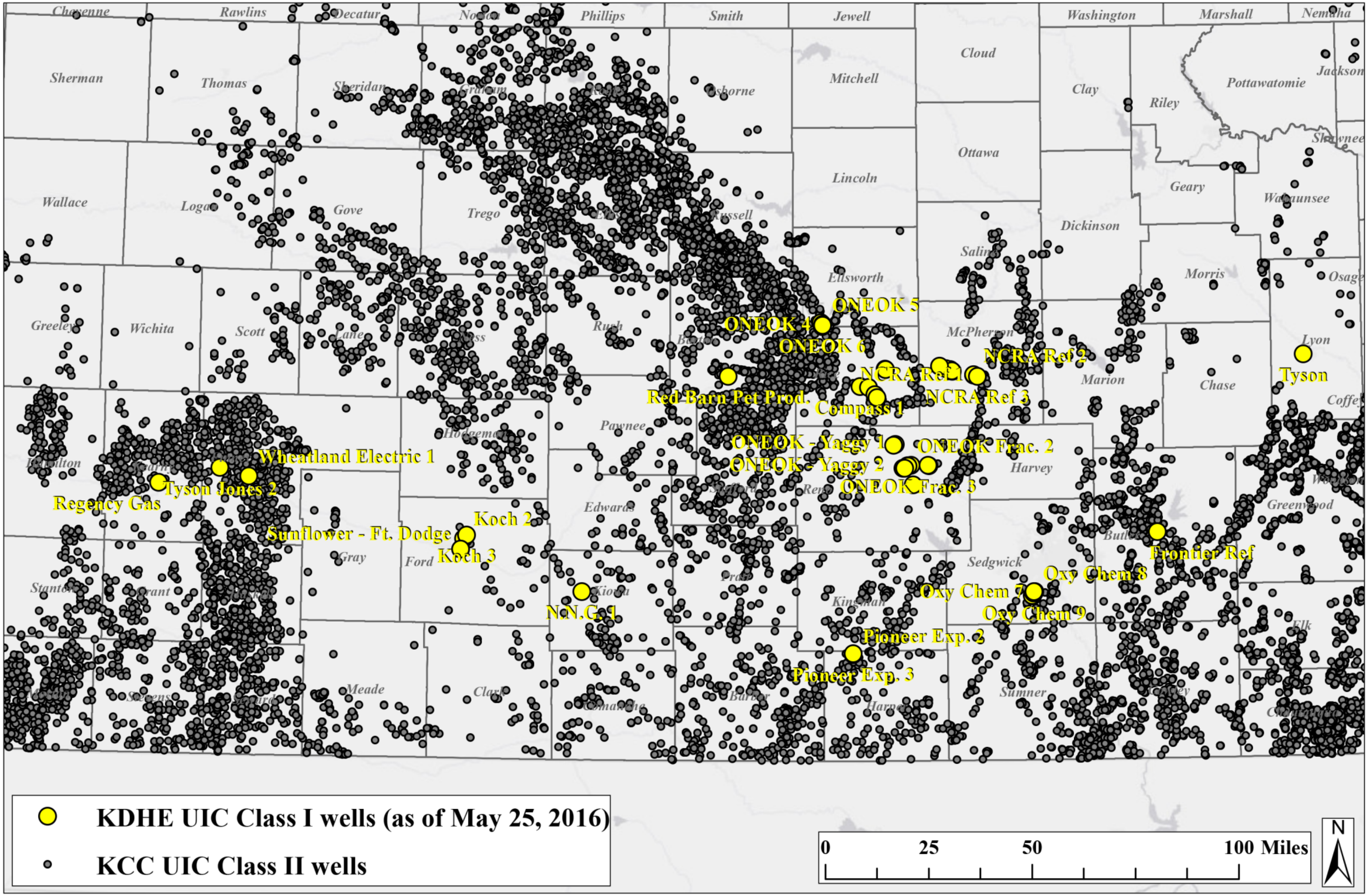
Simulated commercial storage capacity in the Arbuckle saline aquifer for 10 sites

Area	Estimated Storage Capacity (P50), million tonnes	Area, km^2	Gross Thickness, m	Net Reservoir Thickness, m	Porosity, %	Average Permeability, md	Depth, m	Limiting Injection Pressure, bar	Reservoir Pressure, bar
1	79	1.4	300	66	5	25	1184	187	144
2	1	5.2	223	49	4	15	1508	223	175
3	49	6.1	258	57	6	15	1388	210	162
4	121	6.6	240	53	6	15	1170	179	138
5	55	1.4	300	66	5	19	1581	240	185
6	98	2.4	205	45	6	23	1310	194	150
7	71	1.2	209	46	3	31	1266	189	145
8	104	2.6	240	53	6	20	1089	169	130
9	98	5.8	230	51	6	18	1377	206	158
10	104	5.4	208	46	6	25	1224	183	141
Regional Model	4000	821	243	54	5	21	1288	195	150

Is there a competition for resources?

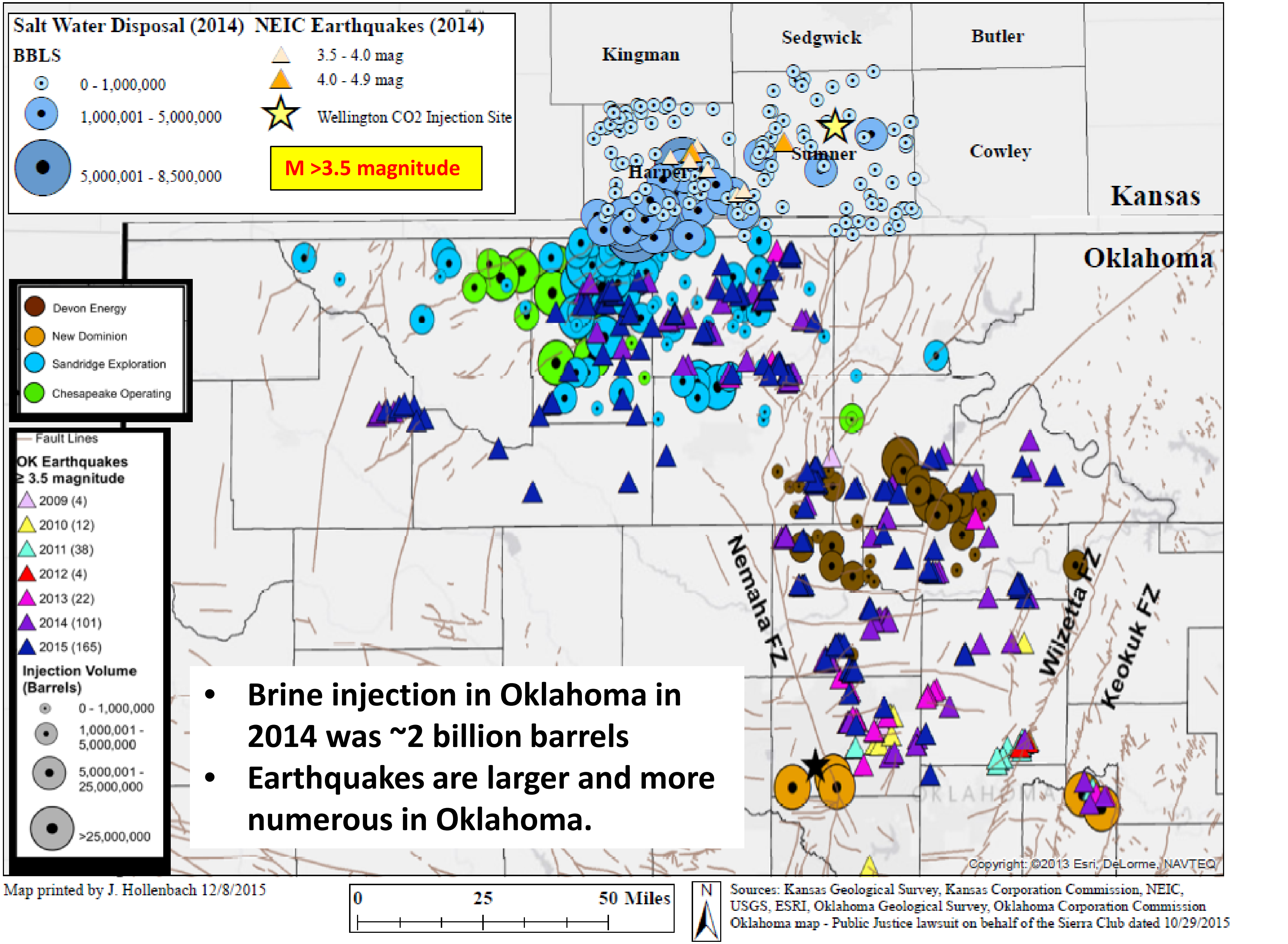
- UIC Class I – Kansas Department of Health and Environment (KDHE)
  - Wells used to inject hazardous wastes or dispose of industrial and municipal fluids beneath the lowermost formation containing, within one quarter (1/4) mile of the well bore, a source of fresh or usable water
  - <u>“On vacuum” – no WHP</u>
- 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
  - <u>Some WHP is allowed (~500 psi)</u>
- UIC Class VI - ???

Kansas Disposal Wells



Sources: Kansas Department of Health and Environment, ESRI, USGS, Kansas Corporation Commission, Kansas Geological Survey

Earthquakes and geology in central KS and OK



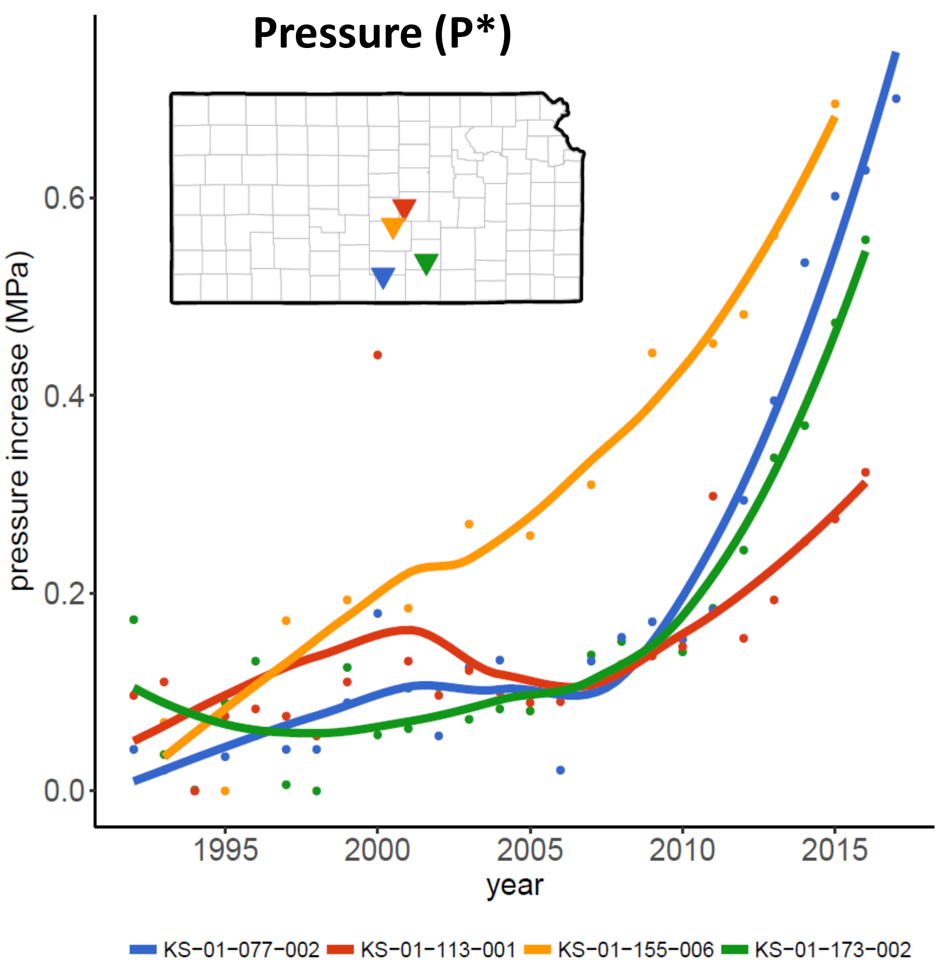
- Brine injection in Oklahoma in 2014 was ~2 billion barrels
- Earthquakes are larger and more numerous in Oklahoma.

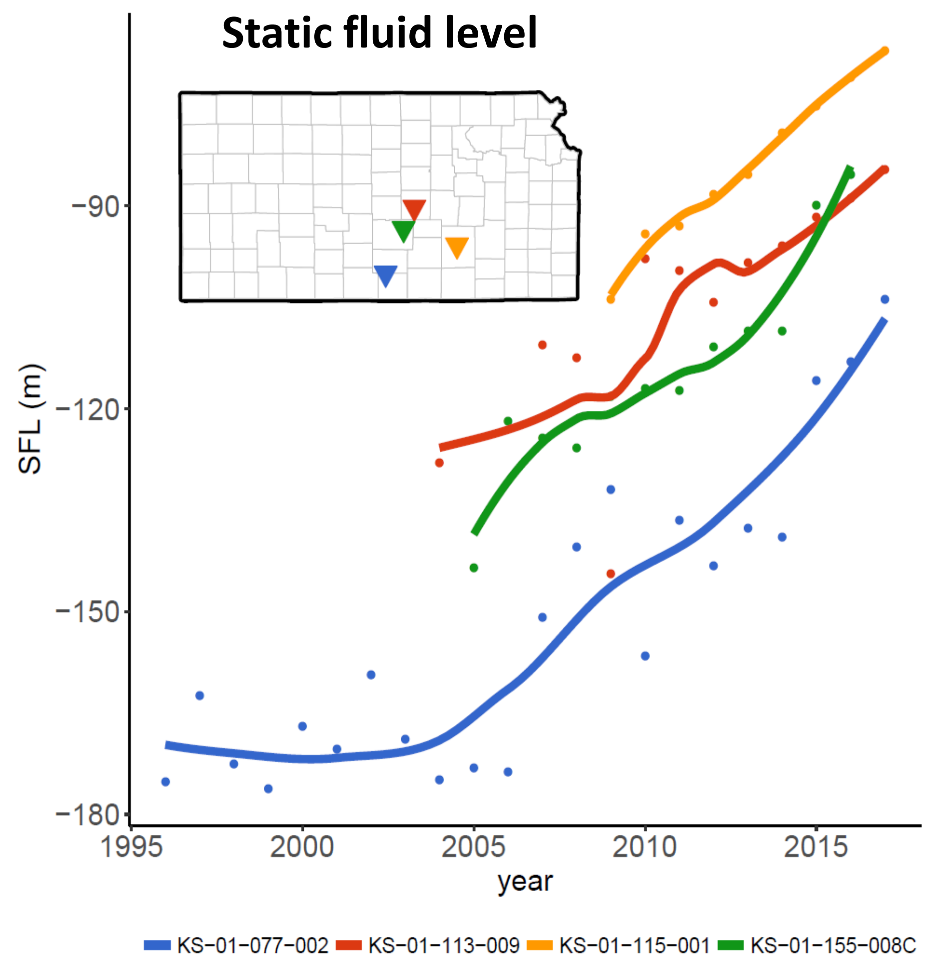
Map printed by J. Hollenbach 12/8/2015

Sources: Kansas Geological Survey, Kansas Corporation Commission, NEIC, USGS, ESRI, Oklahoma Geological Survey, Oklahoma Corporation Commission
Oklahoma map - Public Justice lawsuit on behalf of the Sierra Club dated 10/29/2015

Increases in pressure and static fluid level

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

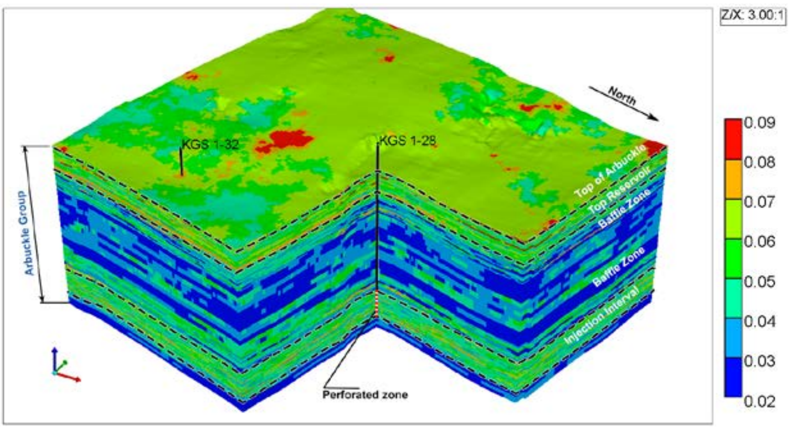




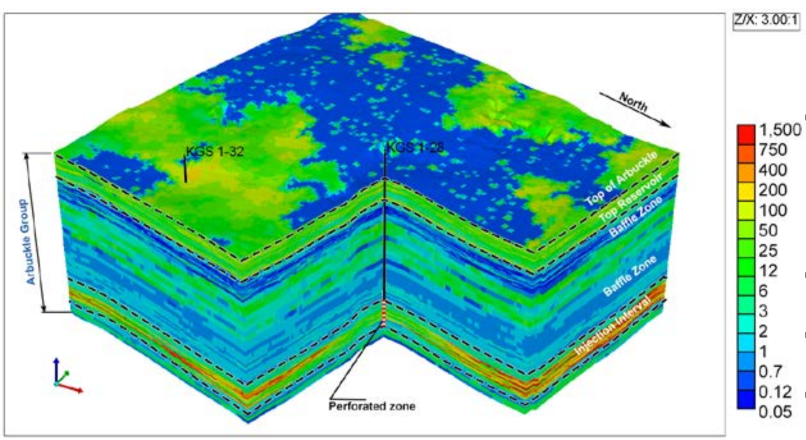
Bidgoli & Ansari, 2018

Common Analogs?

Arbuckle Porosity Model



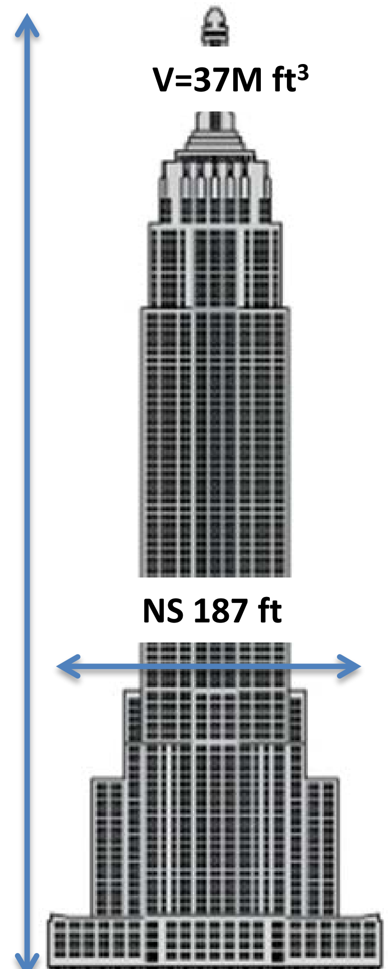
Arbuckle Permeability Model



- What is the capacity?
- Empty Volume = 37M ft^3 = 6.6M bbls
- If Ø = 5-7 %
- $Volume_Ø$ = ~450K bbls
- If efficiency = 50 %
- $Volume_e$ = ~ 225K bbls
- High volume wells used to deliver up to 30K bbls/day
- Therefore

  It would take up to 7-15 days to fill up this volume (<u>without considering existing water</u>)
- It would take 111-222 "ES units" to accommodate 50M bbls injected in 2014
- Translates into 3.9-7.8M ft^2
- Harper Co. Area = 22.4B ft^2
- "Plunging" system?

Empire State Building



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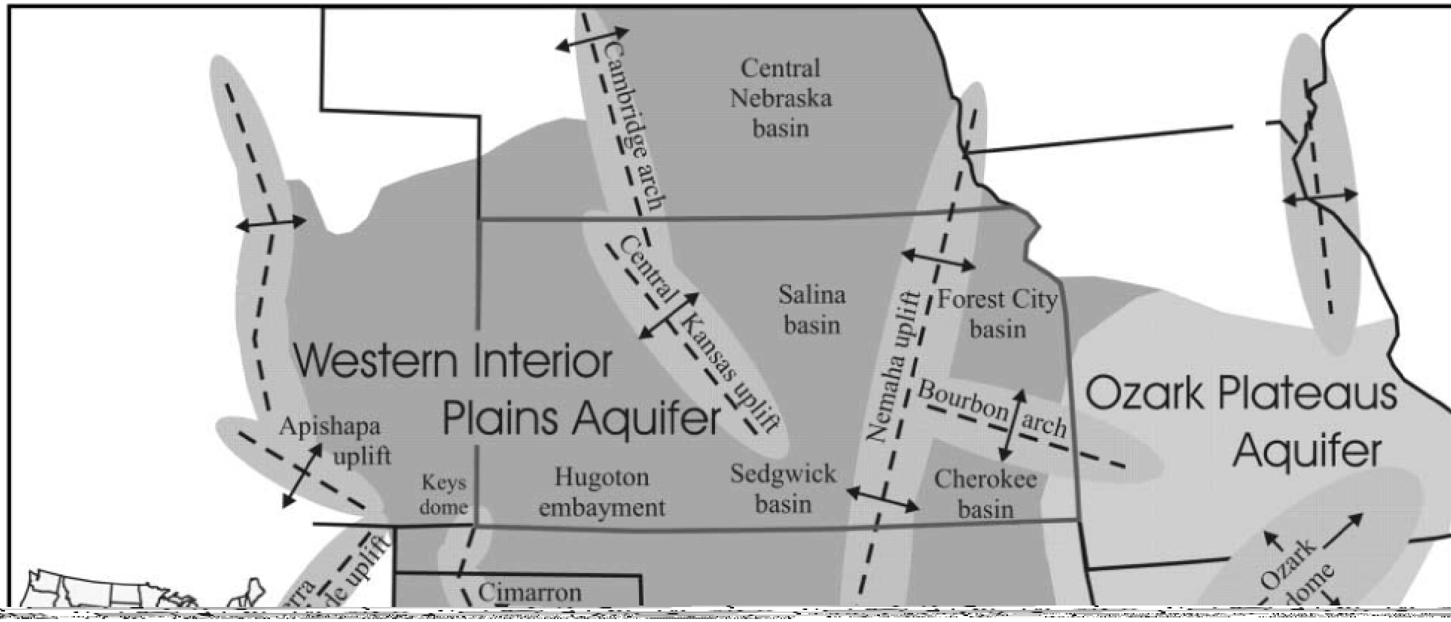
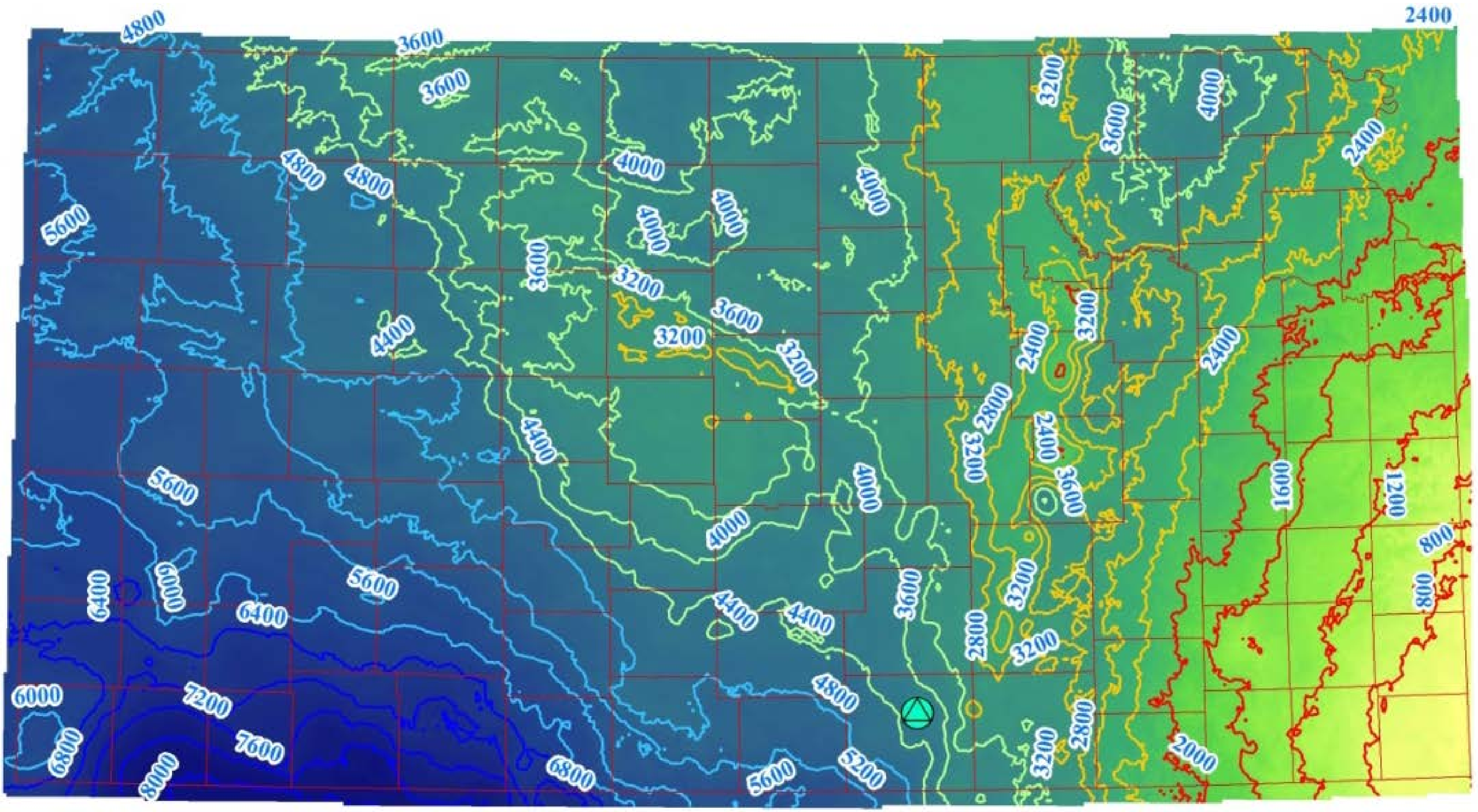
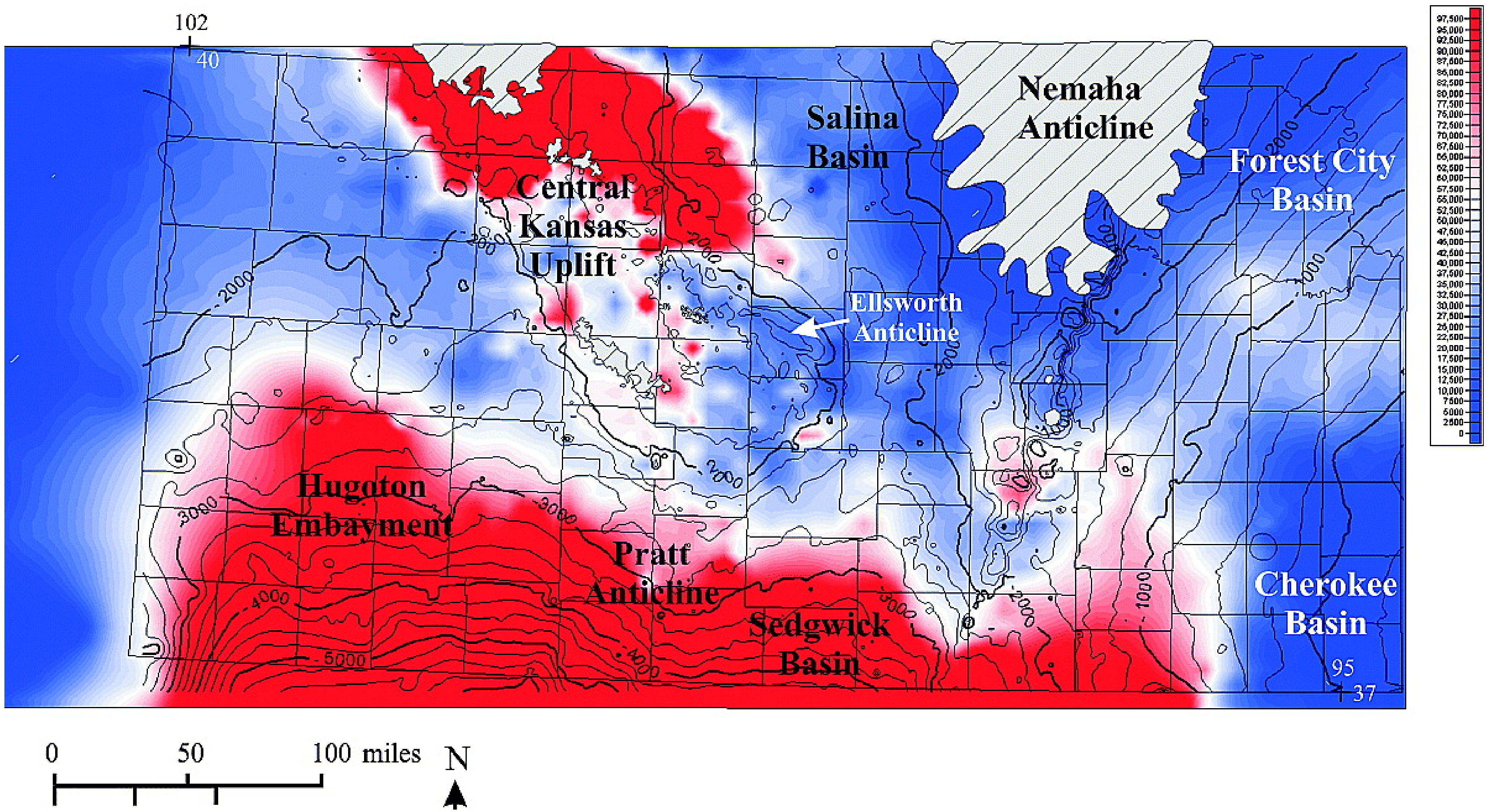
Structural features and aquifer systems of the mid-continent



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

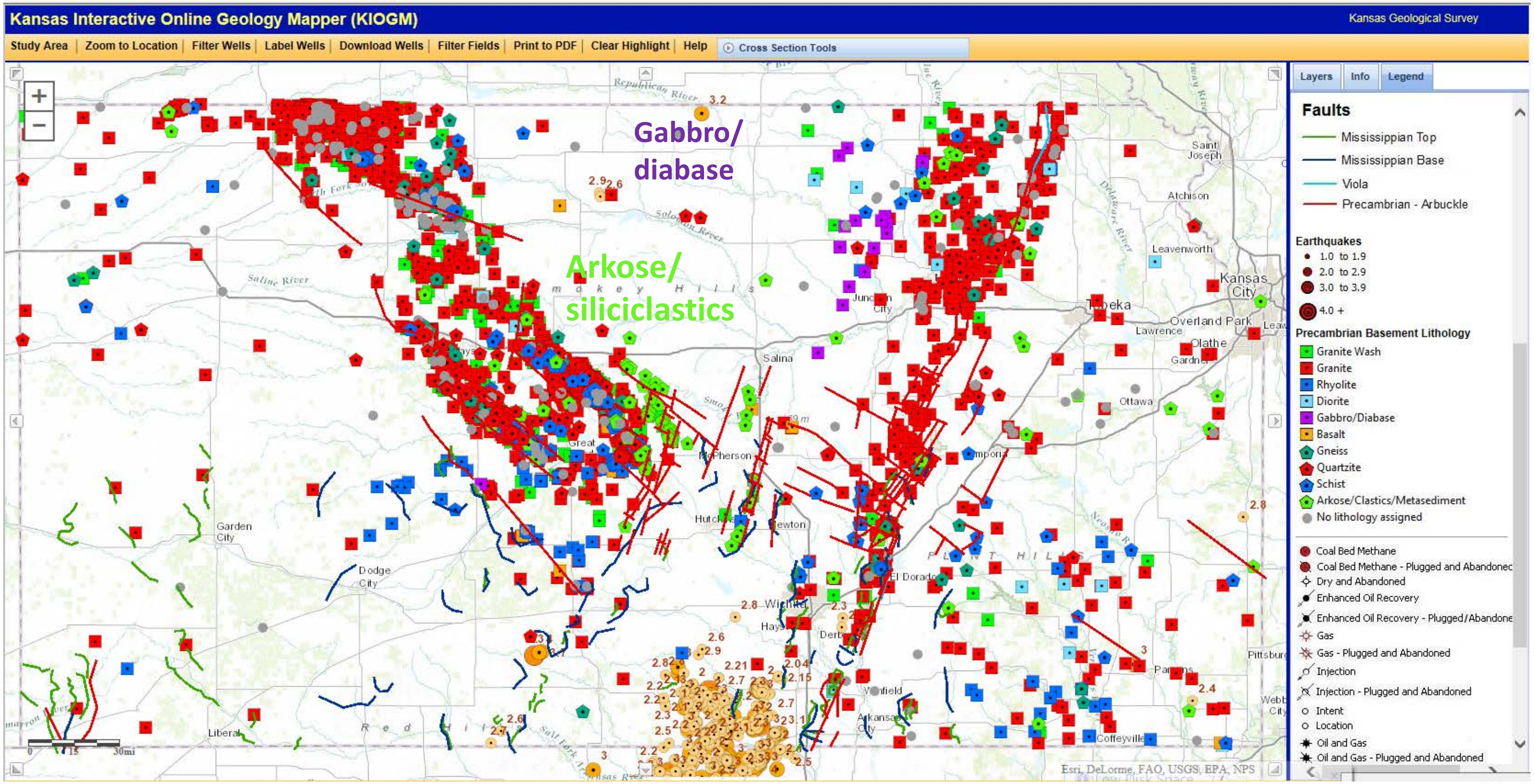


Salinity of Cambrian-Ordovician Arbuckle Group in Kansas



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

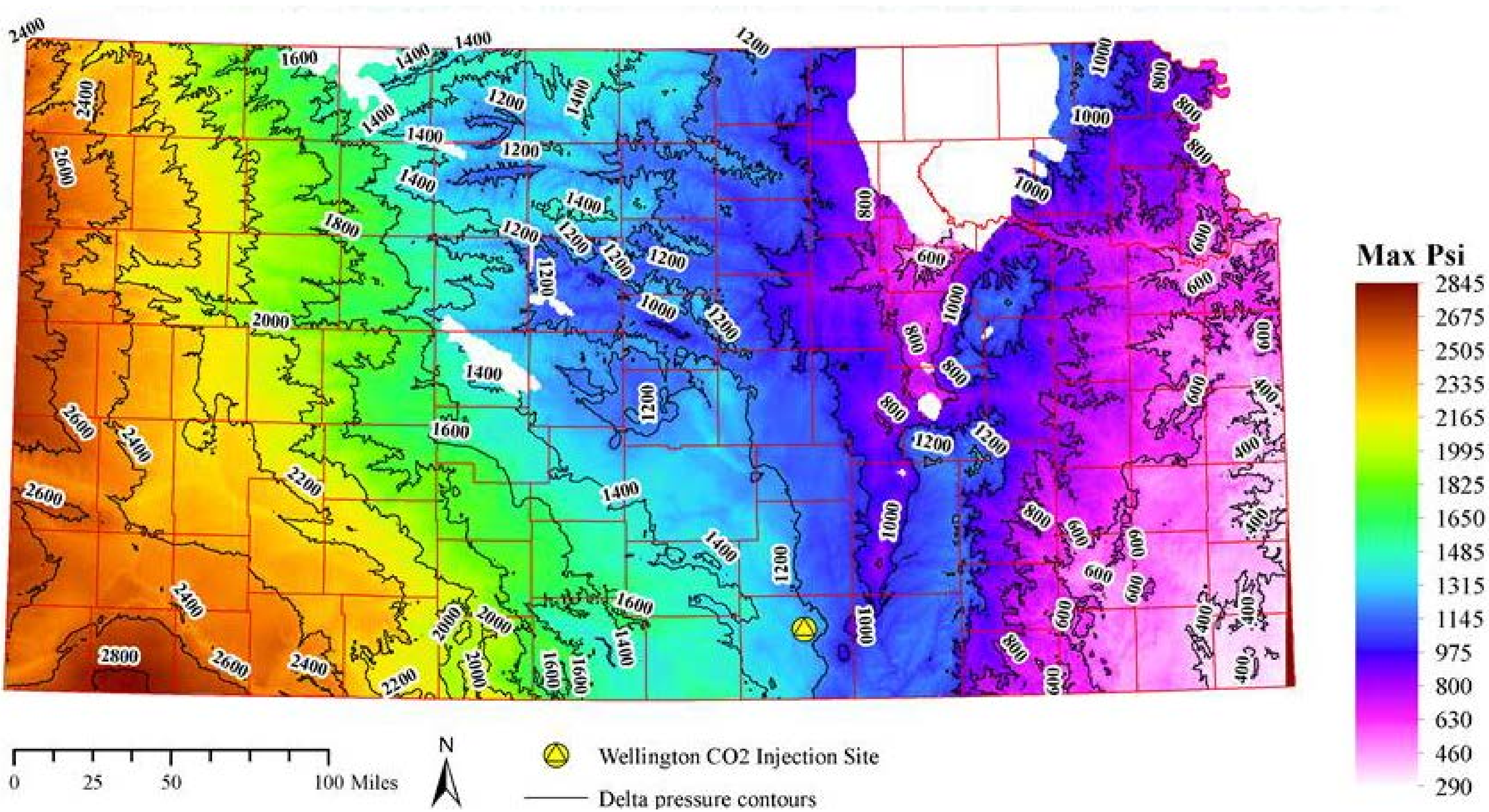
→ thick arkosic sediment fill indicative of the Mid-continent Rift System (MRS)



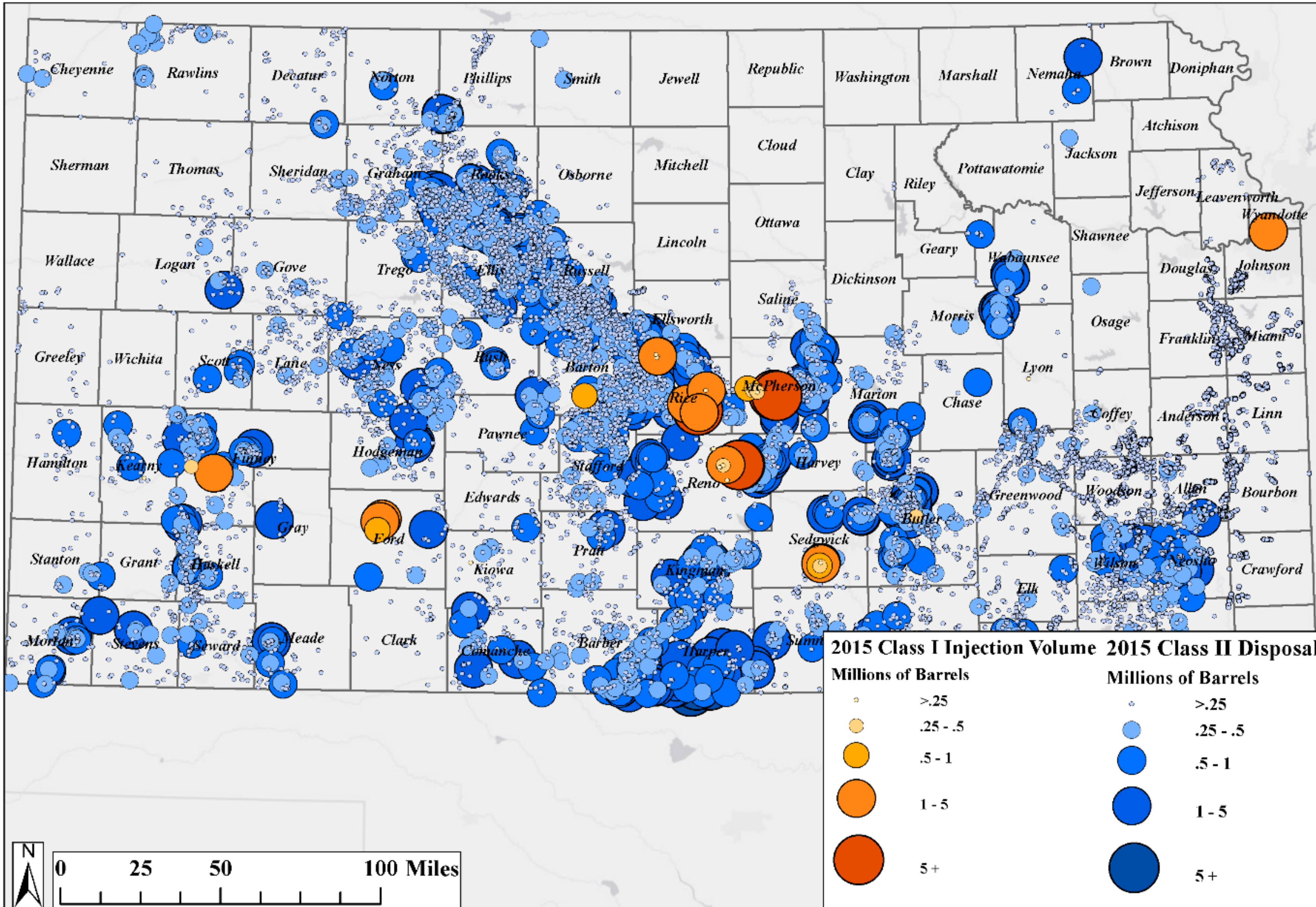
M. Killian, KGS

Maximum Allowable Increase in Pore Pressure from Ambient Conditions

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



Class I & Class II Disposal Volumes (2015)



Map printed 3/1/2017

Sources: Kansas Department of Health and Environment, ESRI, USGS, Kansas Corporation Commission, Kansas Geological Survey

Additional Factors

- Location and extent of freshwater aquifers
- The vertical separation between the top of the Arbuckle and the base freshwater aquifers
- Required increase in pore pressures (psi) to cause migration of brines from Arbuckle aquifer into the shallower freshwater aquifers.
- In-situ water levels
- Potentiometric surface of the Equivalent Freshwater Heads

Summary

- Does the risk of induced seismicity affect storage capacity?
  - Yes, absolutely, and indicates competition for resources
- Is the risk of induced seismicity a CCS killer?
  - No; however…
- In order to help regulators, improve strategic planning, and decrease competition, new resource map has to be created

Acknowledgements & Disclaimer

Acknowledgements

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- Justin Rubinstein, USGS
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