An Integrated Screening Approach to support Carbon Sequestration efforts in Kansas: 3D Faulted Framework Model of the Arbuckle Group & Precambrian Basement

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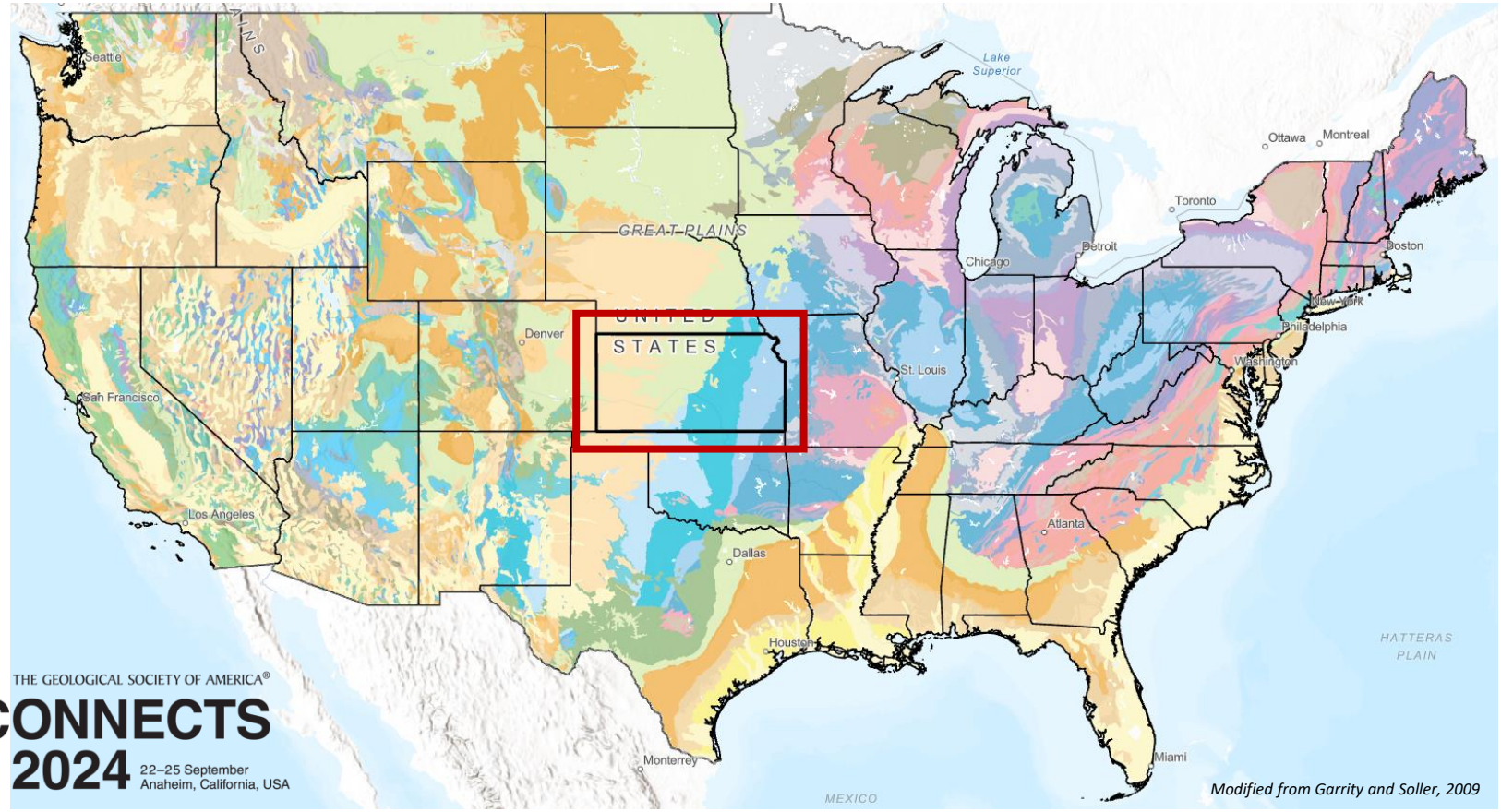
SDL
KGS Subsurface Dynamics Laboratory



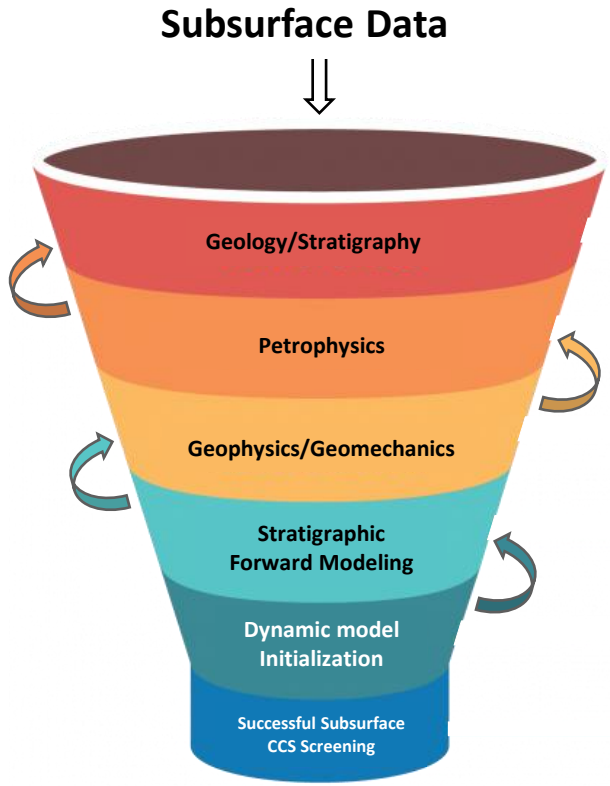
Agenda

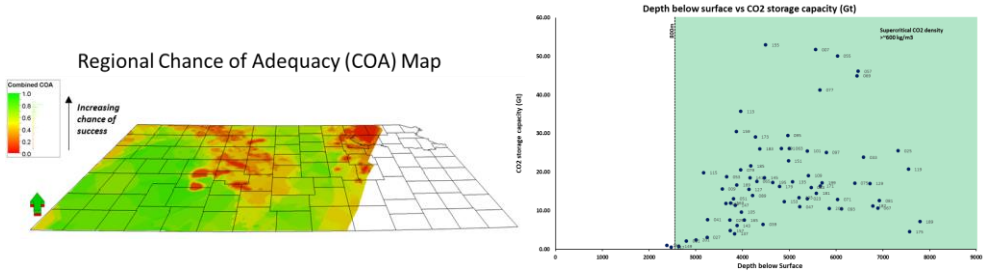
1. Introduction – Why Arbuckle?

2. Workflow-Why do it this way?
   Industry standard methodology – Time – Data - Resolution

3. Results / What have learned?

4. Looking into the future..



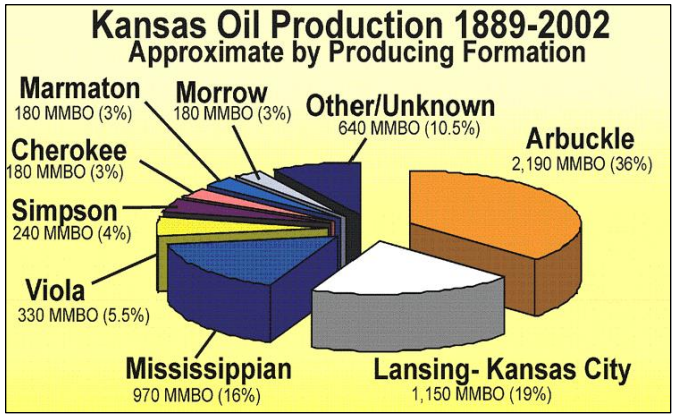


Regional/Basin Scale Subsurface CCS Screening Workflow

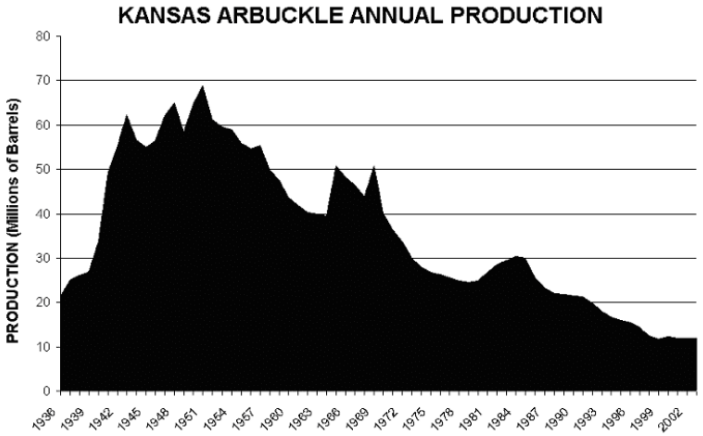
Why Arbuckle?

US DOE investigating 5 types of subsurface formations for geologic carbon storage

- Saline formation
- O&G reservoirs
- Unmineable coal seams
- Organic rich shales
- Basalt formations



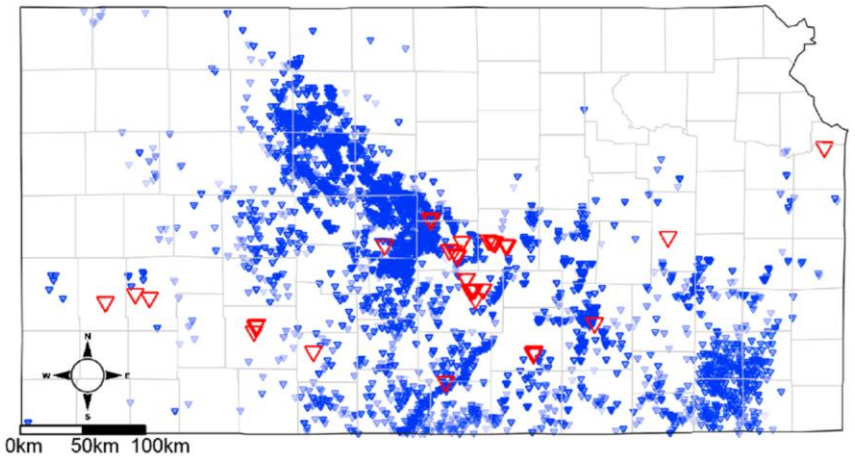
Arbuckle reservoir production data in million barrels, compared to total Kansas oil production. (Franseen et. al., 2004)



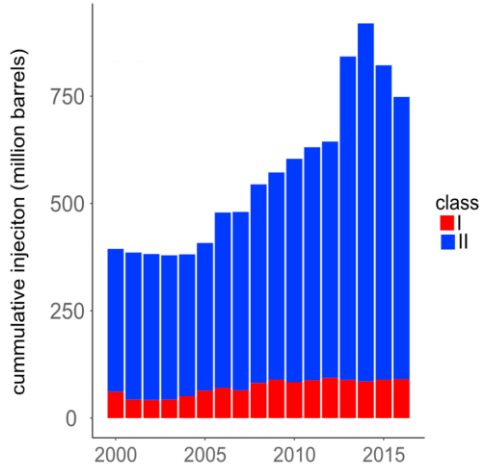
Annual Production from Kansas Arbuckle reservoirs. (Franseen et. al., 2004)

Arbuckle:

- **Producing oil and gas for ~100 years**
- **A saline formation with huge waste-water injection history**
- **At the right depth for CO_2 storage!!**

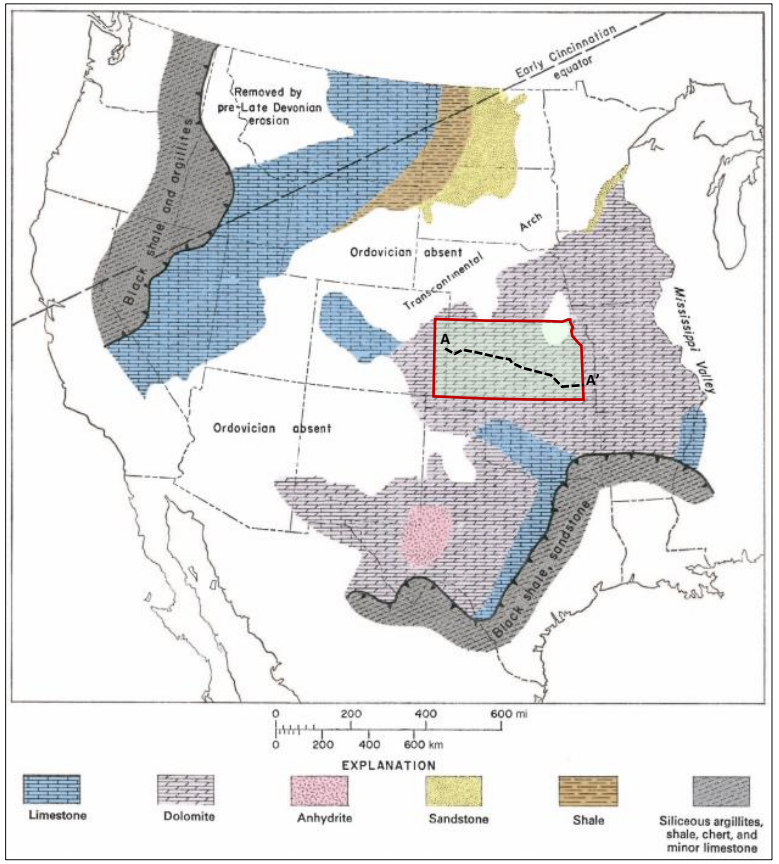


Locations of 49 Class I wells (red) and 2,381 Class II wells (blue) that dispose wastewater into the Arbuckle Group in Kansas. (Ansari et. al., 2019)

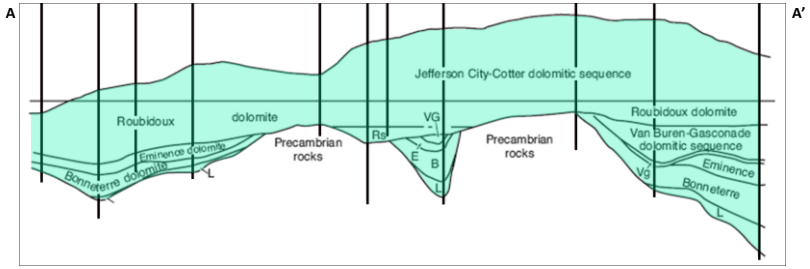


Yearly wastewater injection volumes from Class I (red) and Class II (blue) wells. (Ansari et. al., 2019)

Arbuckle: Regional Geology

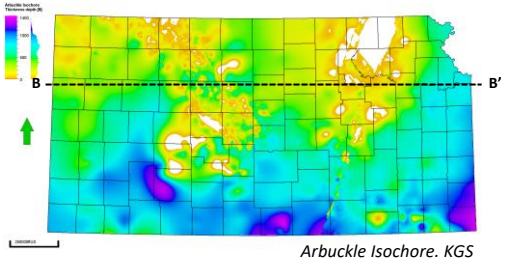


Distribution of Lower Ordovician lithofacies of western US (Arbuckle Fm in Kansas) (Fritz et. al., 2012)

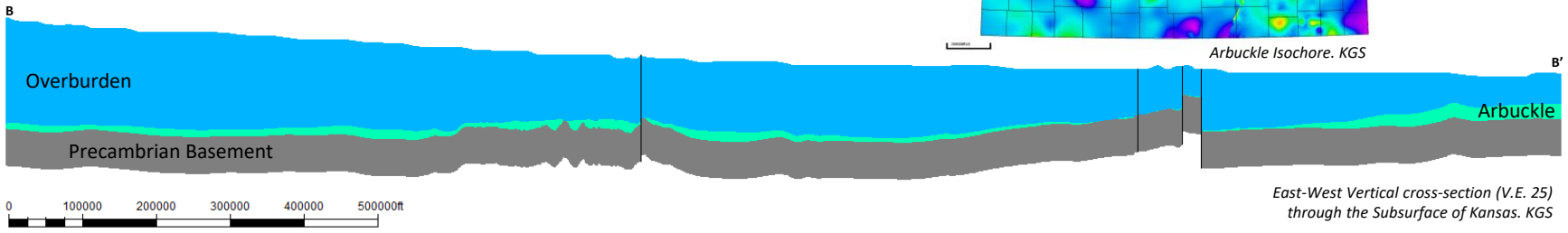


Diagrammatic cross-section of Arbuckle Group across Kansas. (Franseen et. al., 2004)

- **Arbuckle Group** – Cambro-Ordovician carbonate rocks (Reservoir, mostly dolomitized) resulting from Paleozoic transgressions as part of the Sauk Sequence
- Overlain regionally and locally by **Maquoketa**, **Chattanooga** and **Heebner** Shale (Seal: Ordovician, L. Miss-Dev, Pennsylvanian)
- Present in most of Kansas, except NW and NE Kansas due to post depositional uplift and erosion.



Arbuckle Isochore. KGS

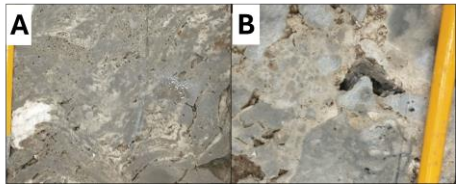


East-West Vertical cross-section (V.E. 25) through the Subsurface of Kansas. KGS

Chattanooga Shale

MGPI Processing #1, Atchison, KS

Maquoketa Shale

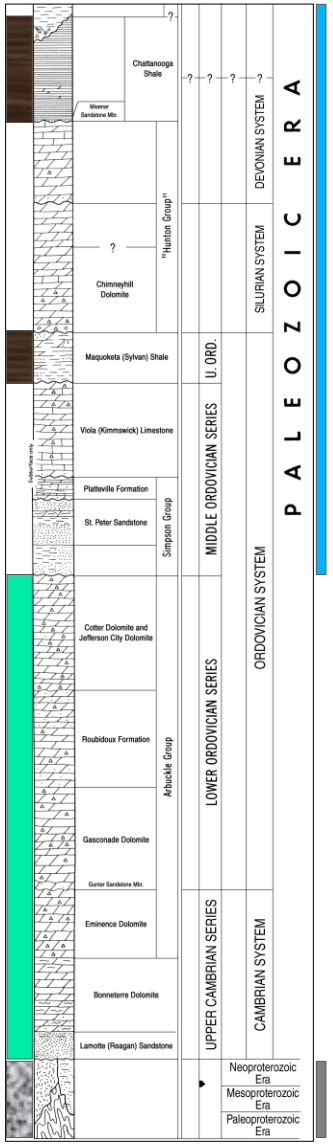


A,B- Core photographs of Microbial carbonates with vuggy porosity. MGPI Processing #1, Atchison, KS

Arbuckle

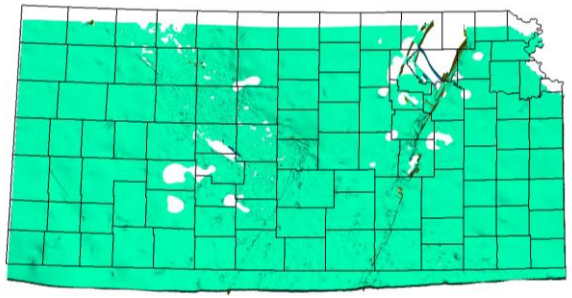
MGPI Processing #1, Atchison, KS

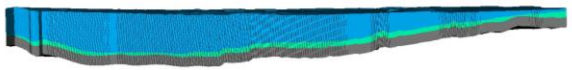
Precambrian Basement

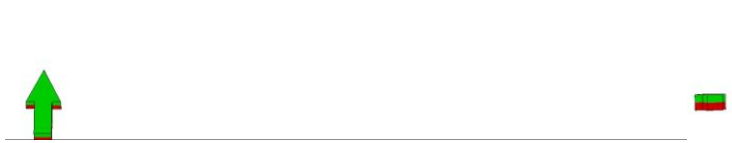


Strat section, KGS Bulletin, 189 Plate 1

Workflow







Products from ~6 months of work

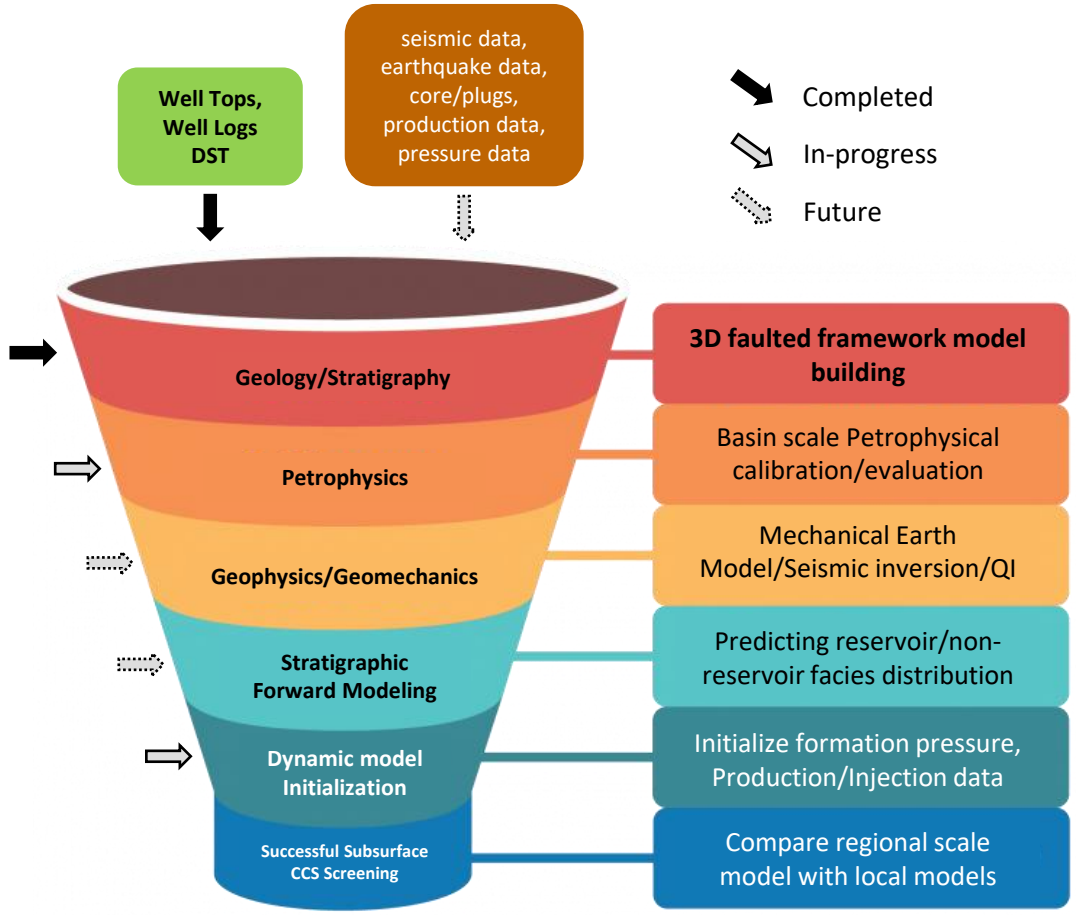
- Faulted framework model
- 2000*2000 ft cell size, 149 layers in Arbuckle with **~176 million cells**
- Regional CCS potential map and considerations

Data used

- Well tops: ~6000 Precambrian Basement & ~70,000 Arbuckle
- Well logs: ~220 wells (~3-4 per county)
- DST data ~ 100 wells

Other data available

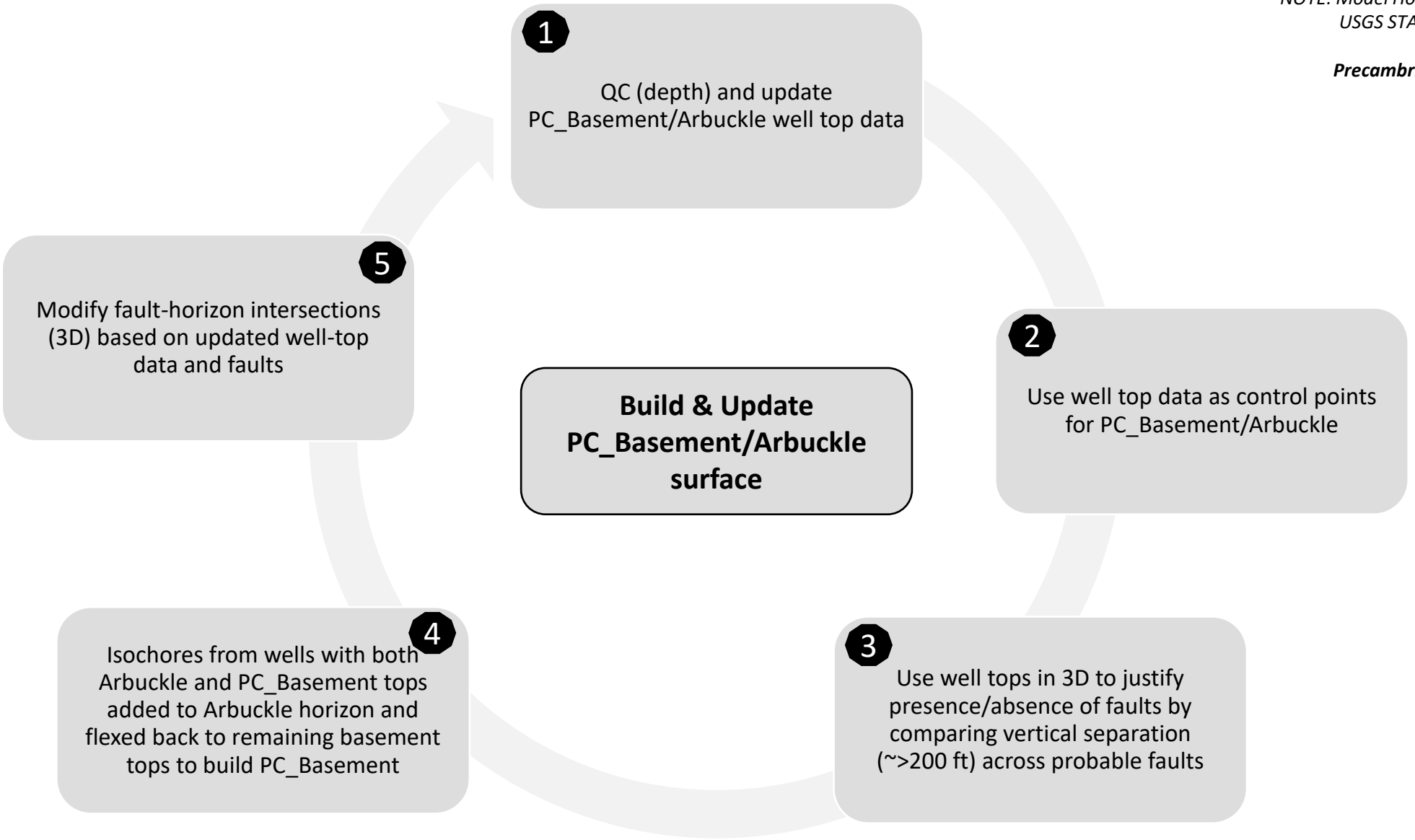
2D/3D seismic, Earthquake, Gravity, cores/cuttings, DST & production data



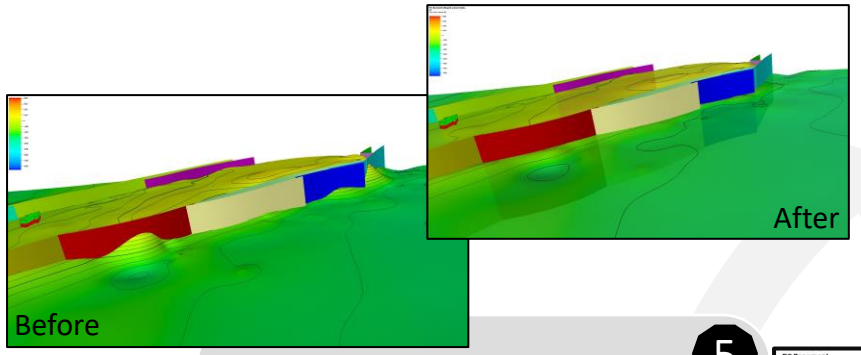
Regional/Basin Scale Subsurface CCS Screening Workflow

Faulted Framework modeling

*NOTE: Model Horizon outputs are used as USGS STATEMAP subsurface maps (See Kolbe's poster on **Precambrian Basement of Kansas**)*

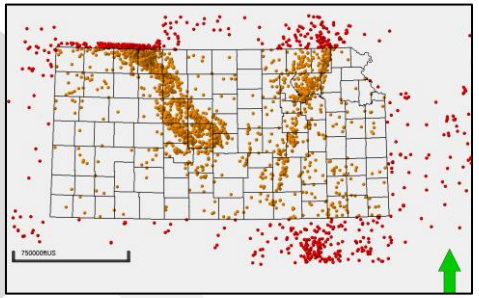


Faulted Framework modeling



1

QC (depth) and update PC_Basement/Arbuckle well top data



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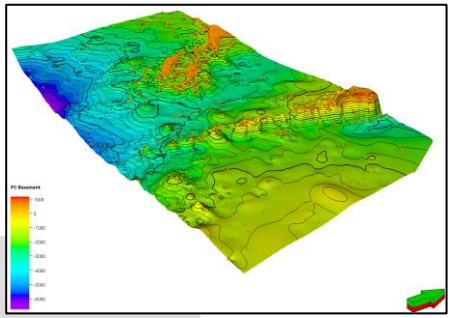
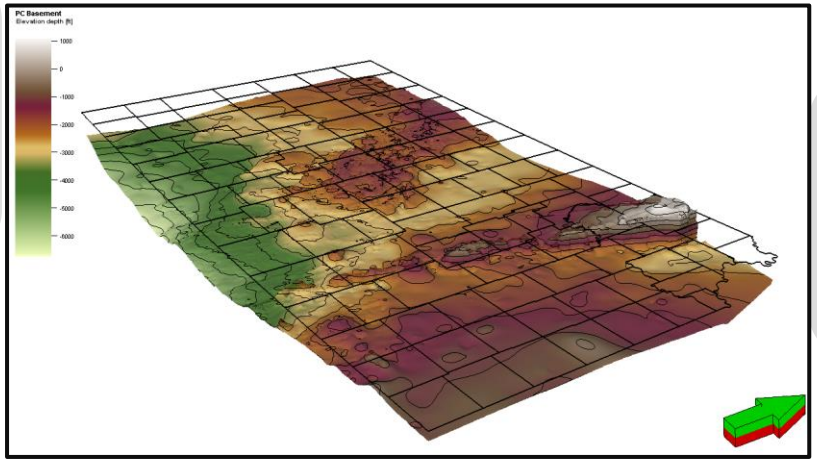


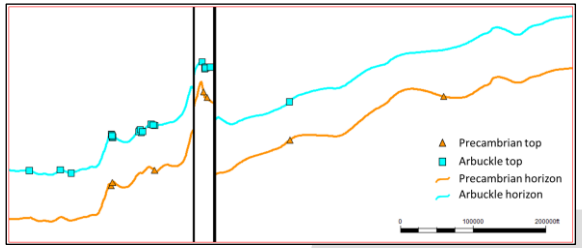
5

Modify fault-horizon intersections (3D) based on updated well-top data and faults



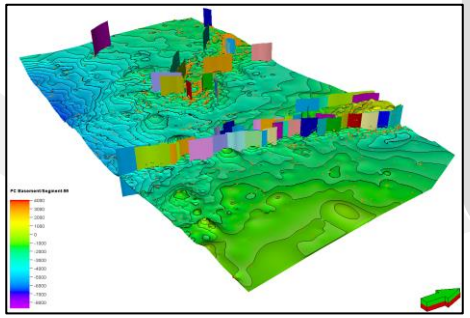
2

Use well top data as control points for PC_Basement/Arbuckle



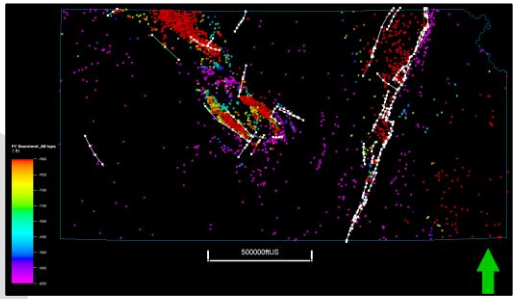
4

Isochores from wells with both Arbuckle and PC_Basement tops added to Arbuckle horizon and flexed back to remaining basement tops to build PC_Basement



3

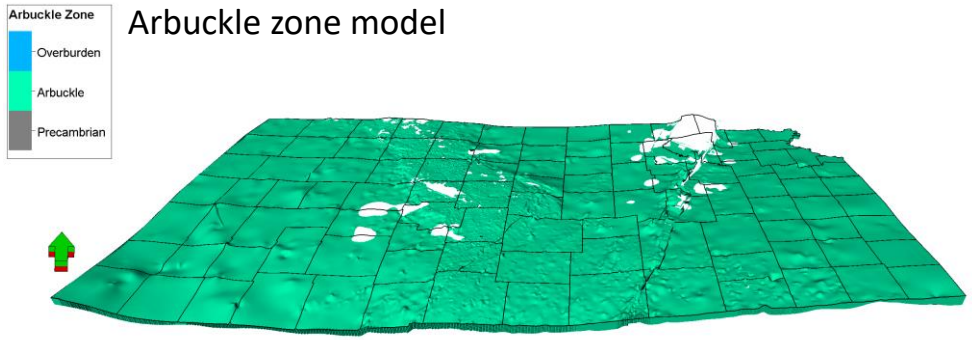
Use well tops in 3D to justify presence/absence of faults by comparing vertical separation (~>200 ft) across probable faults



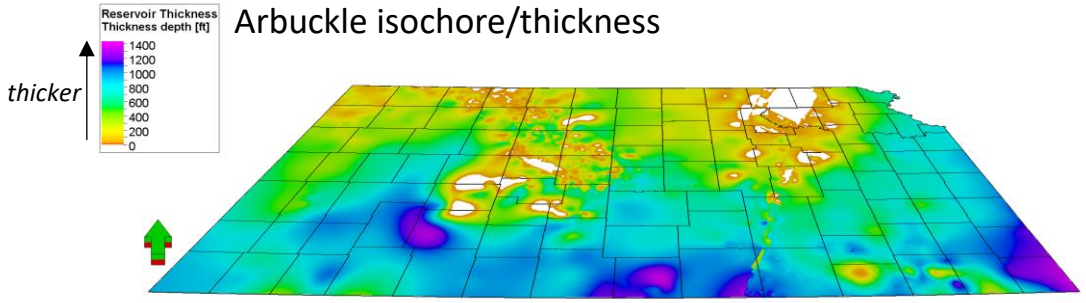
1. Reservoir Presence

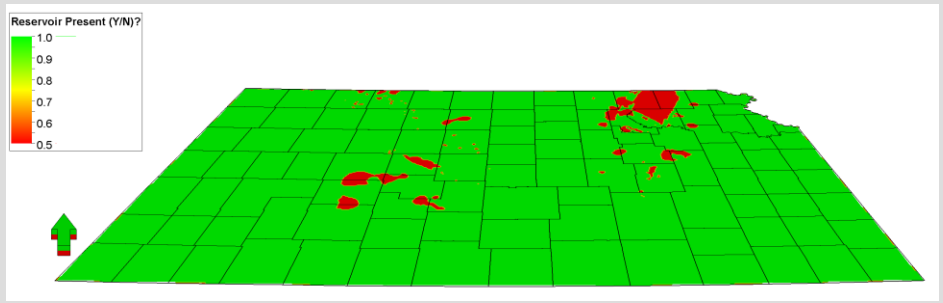
**COA – Chance of Adequacy*

Arbuckle zone model



Arbuckle isochore/thickness





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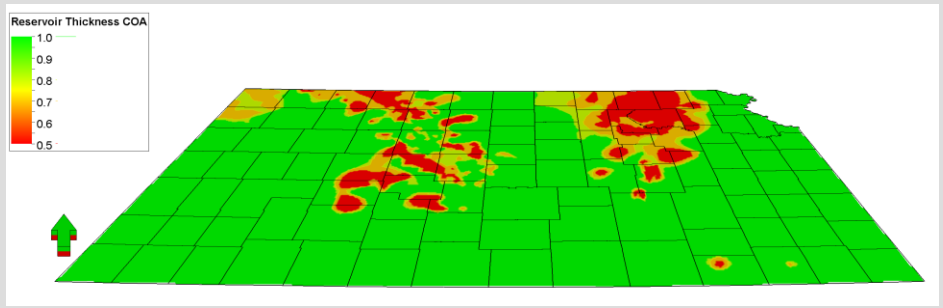

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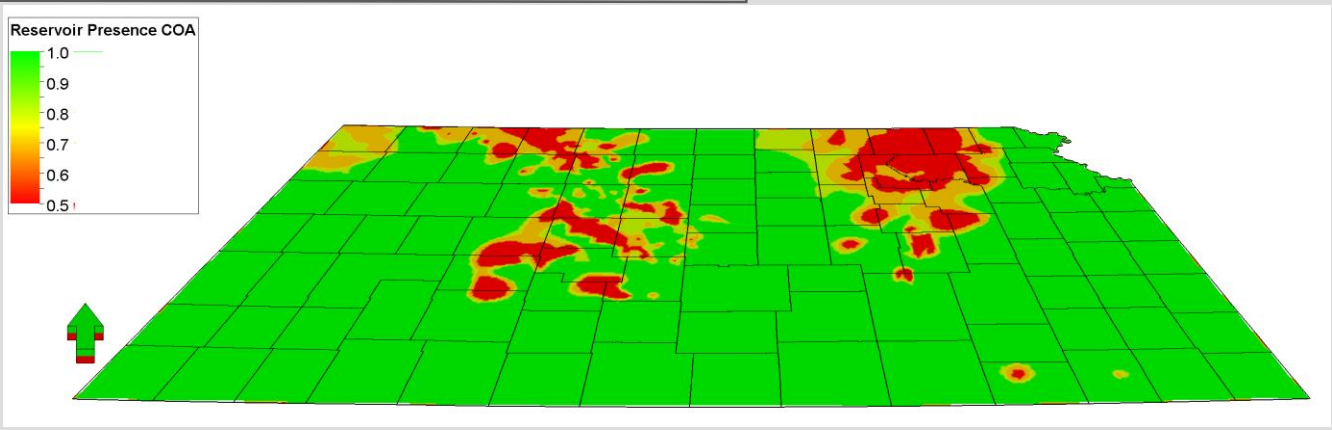
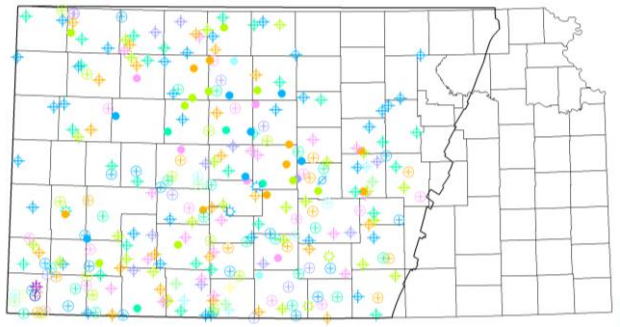
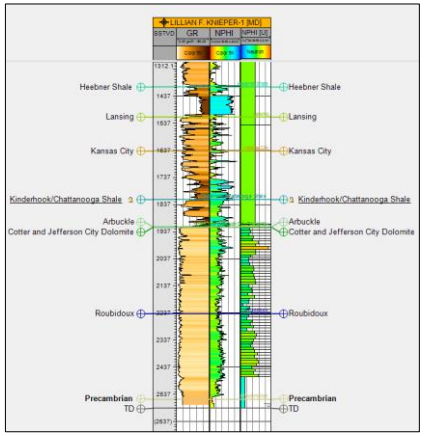


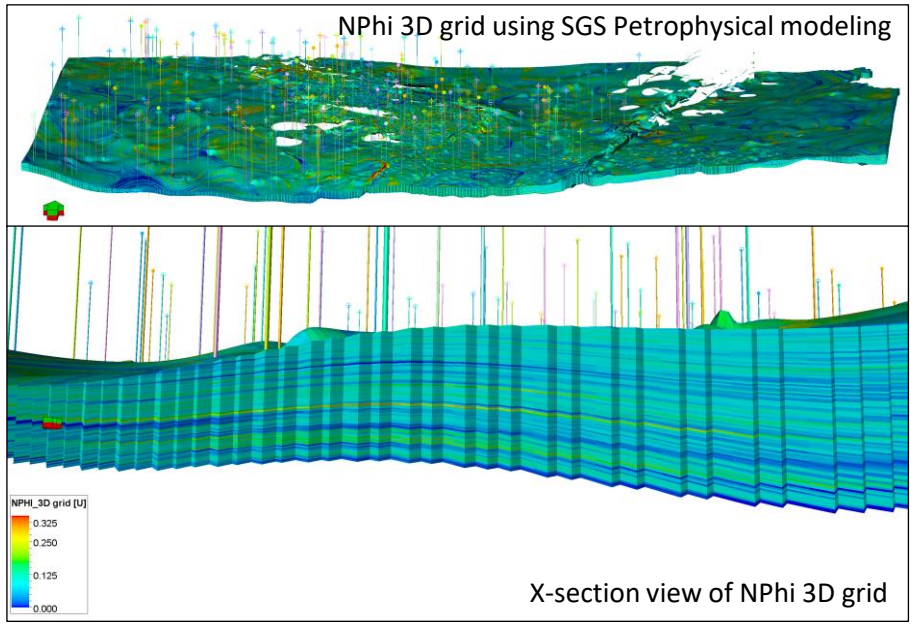
2. Reservoir Quality- Porosity



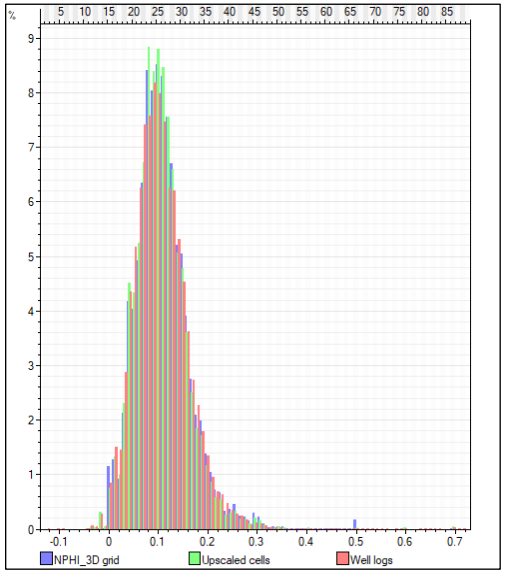
~300 wells



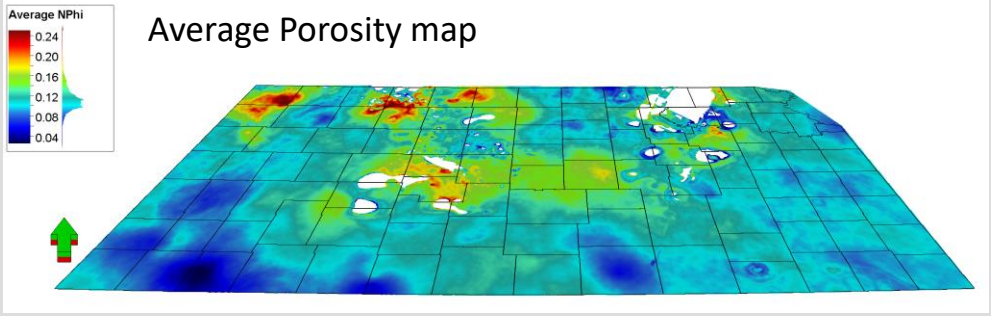
Well log vs Upscaled Porosity



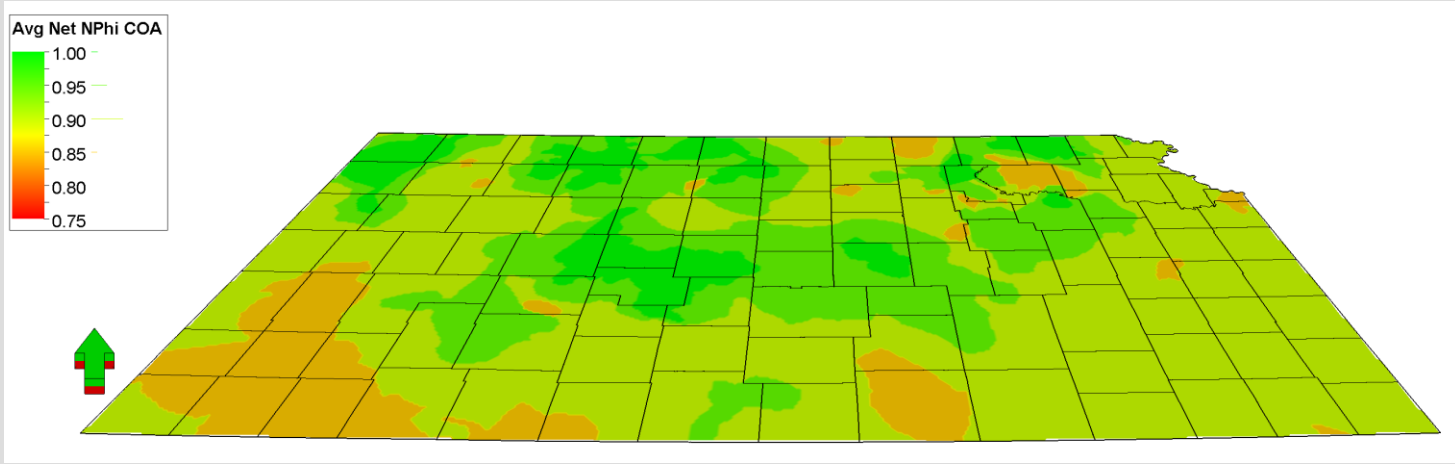
X-section view of NPhi 3D grid



Well log vs Upscaled vs 3D grid Por



Average Porosity map



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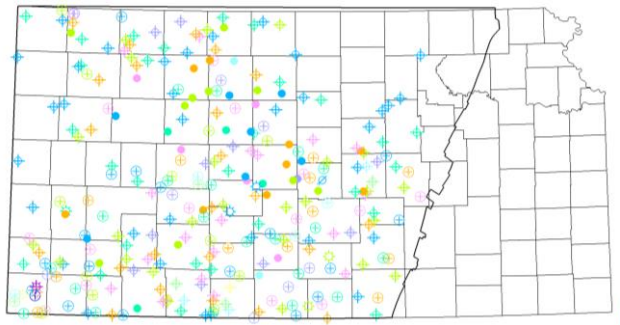
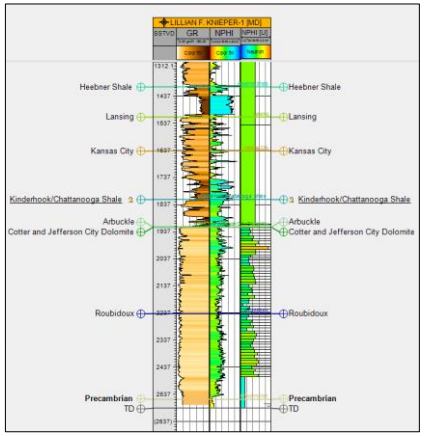
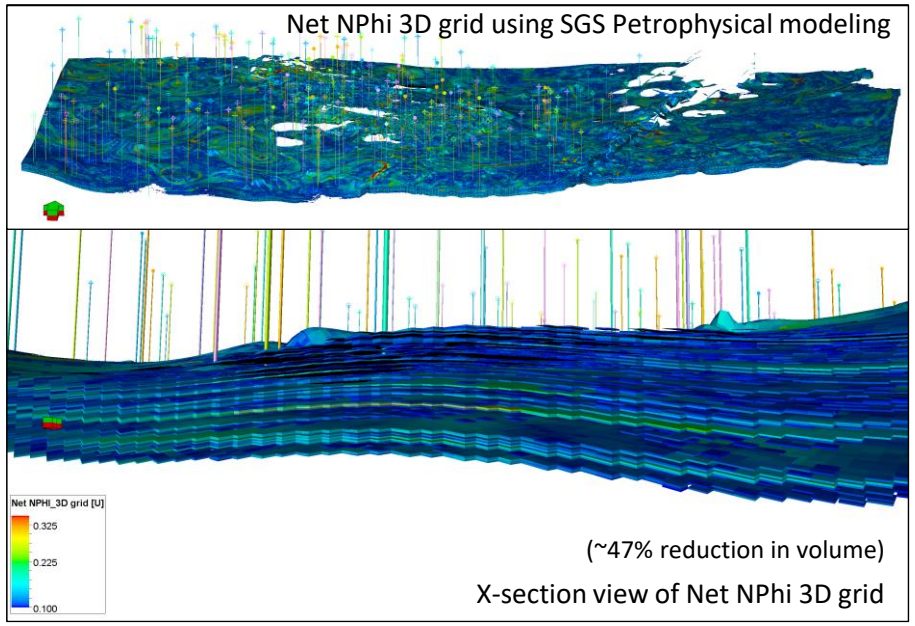


~300 wells

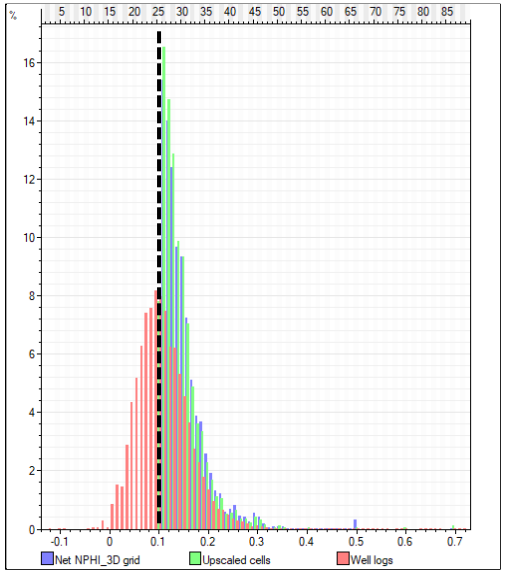


Well log vs Upscaled Porosity

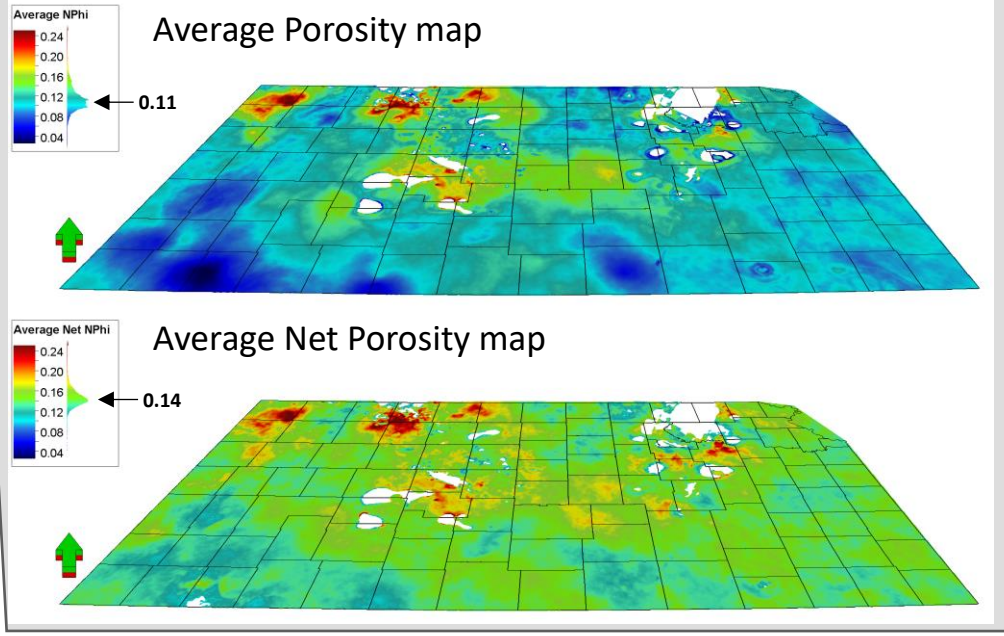


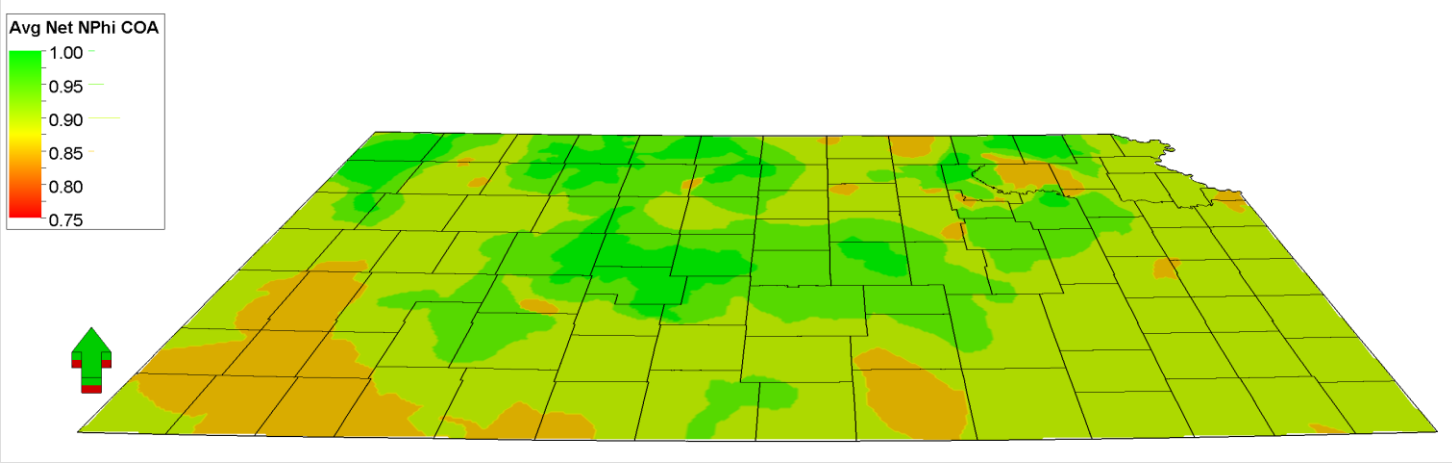
(~47% reduction in volume)

X-section view of Net NPhi 3D grid



Well log vs Upscaled vs 3D grid Por

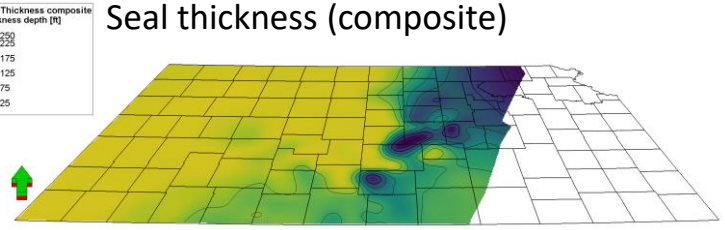




3. Seal (*leakage*)

Seal thickness (composite)

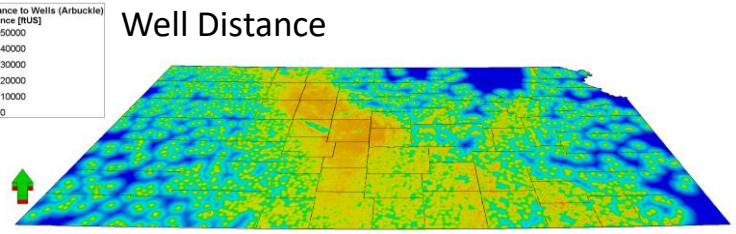
thicker



**combination of Chattanooga, Maquoketa & Heebner shales (regional distribution)*

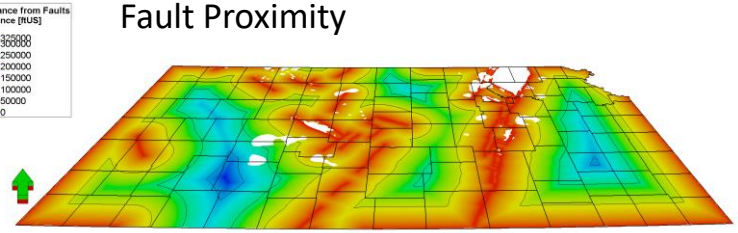
Well Distance

farther

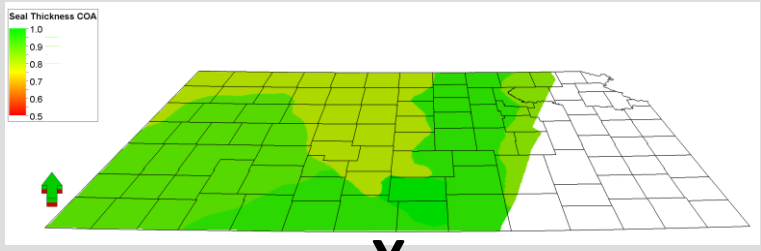


Fault Proximity

farther



**Pseudo Faults at the boundary/edge of the model not considered for the COA map*



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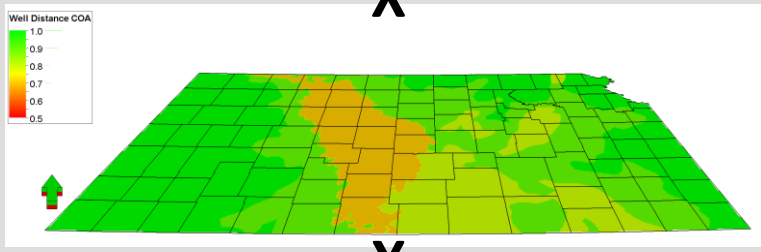

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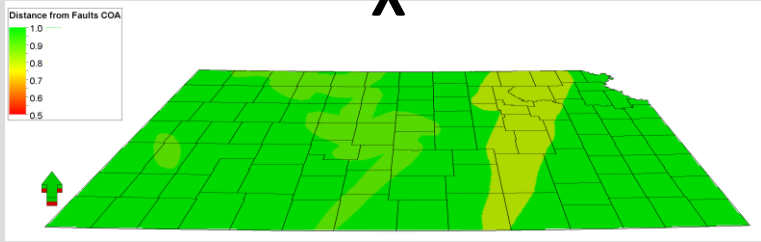

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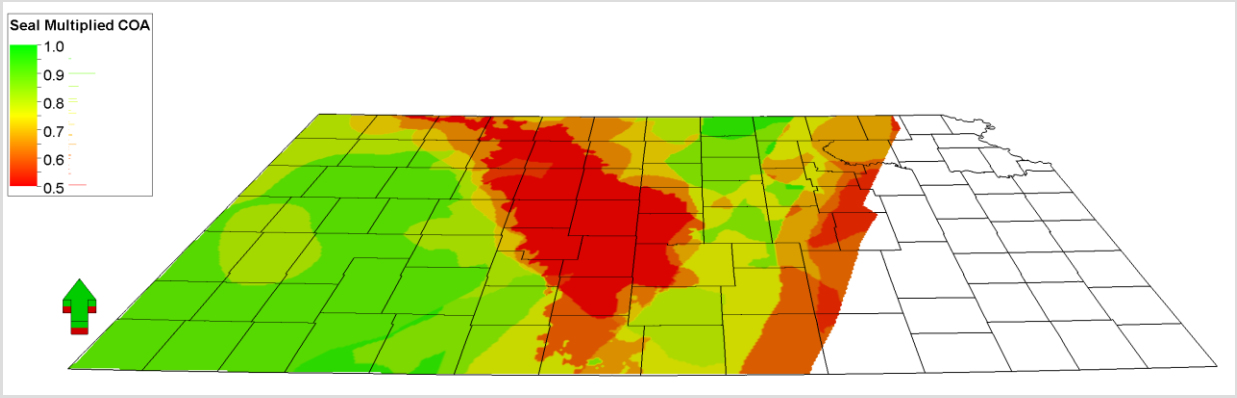
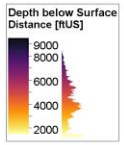
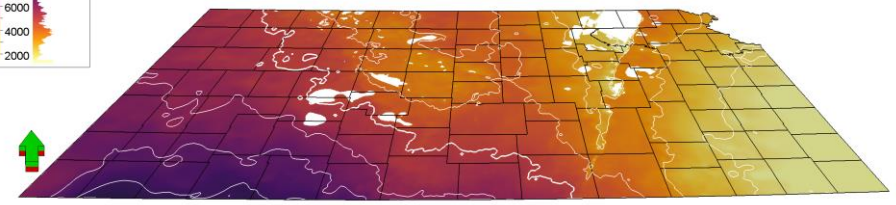
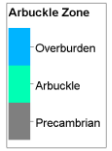


4. CO_2 phase state (supercritical vs subcritical)

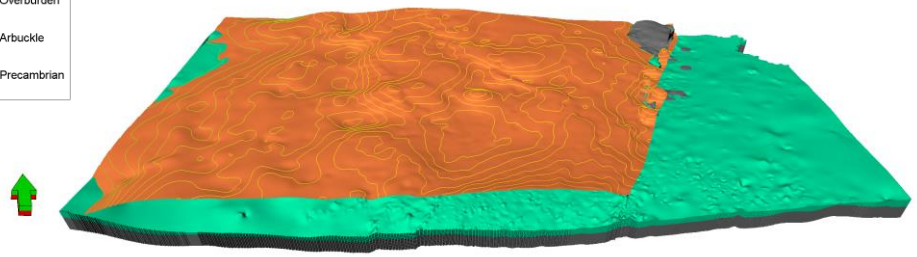


Arbuckle depth below surface

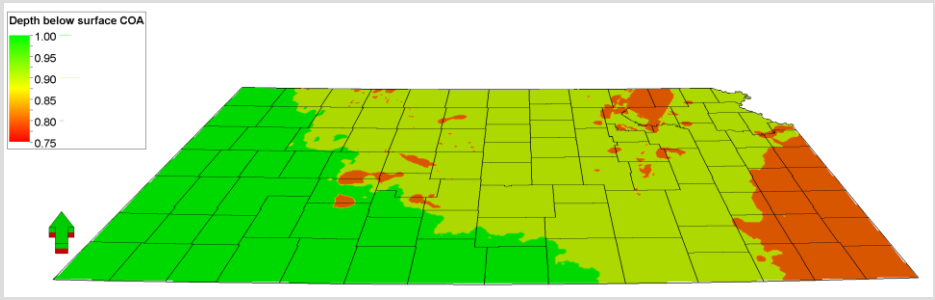




CO_2 Supercritical Surface



Special thanks to Mark White for DST interpretation using STOMP (n=~100 wells)



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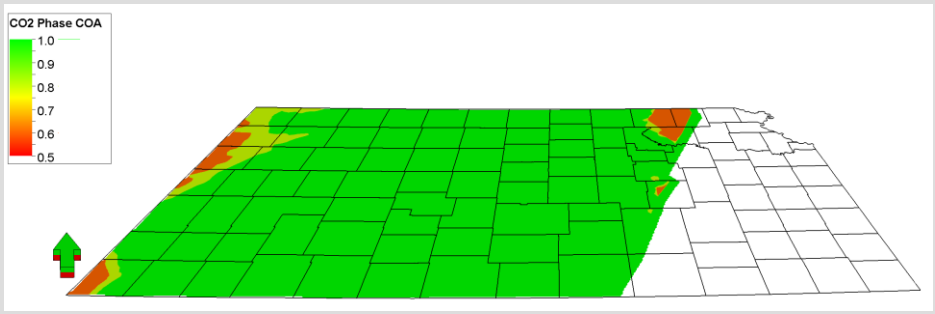

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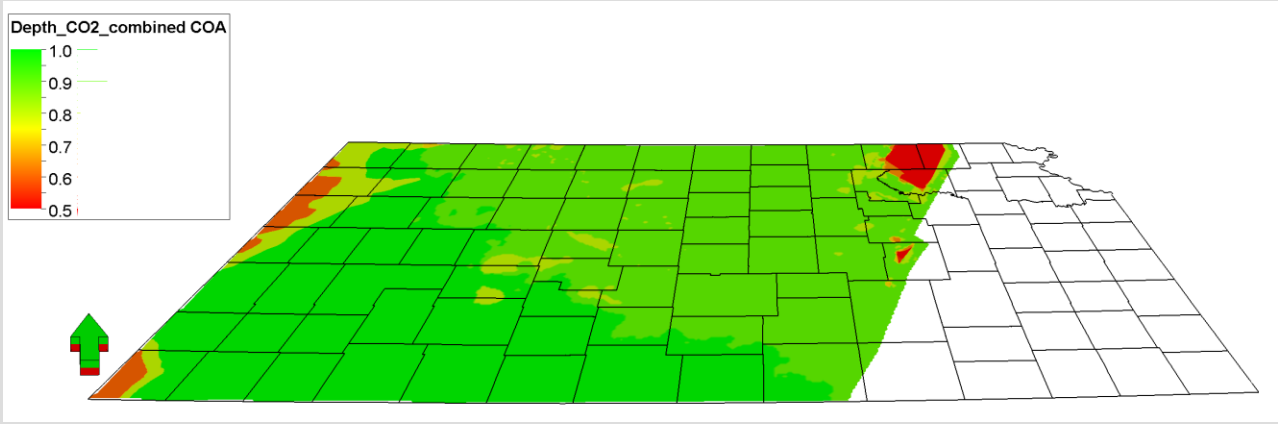
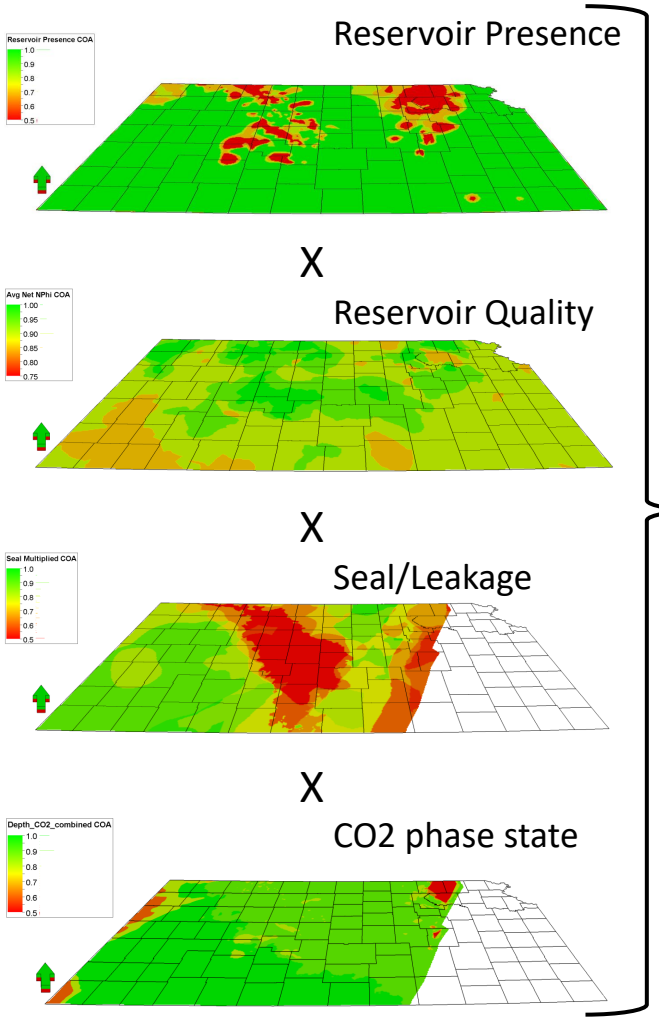
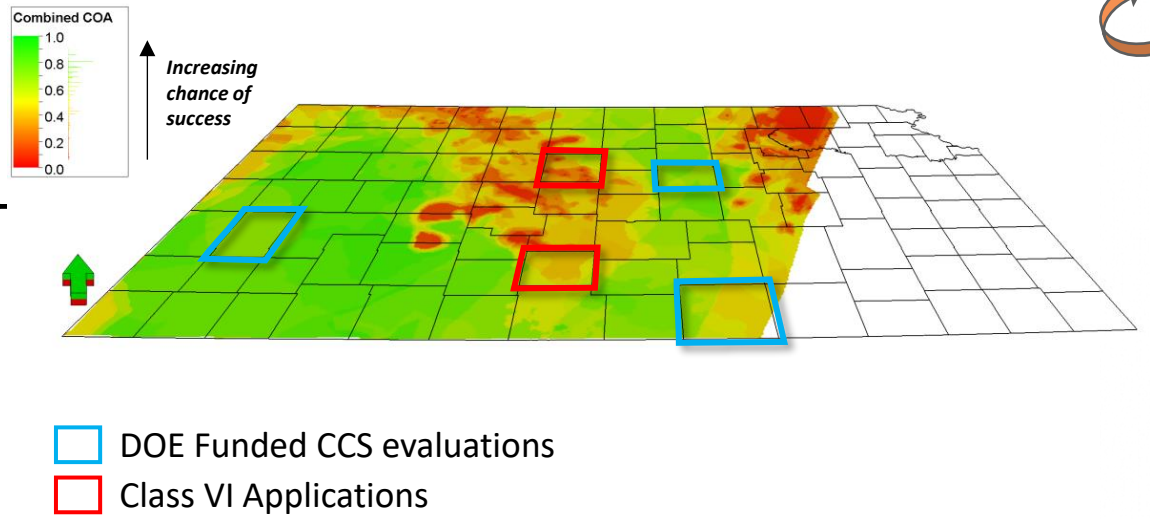


Regional COA

NOTE: Challenged play elements don't preclude a successful CCS project/prospect



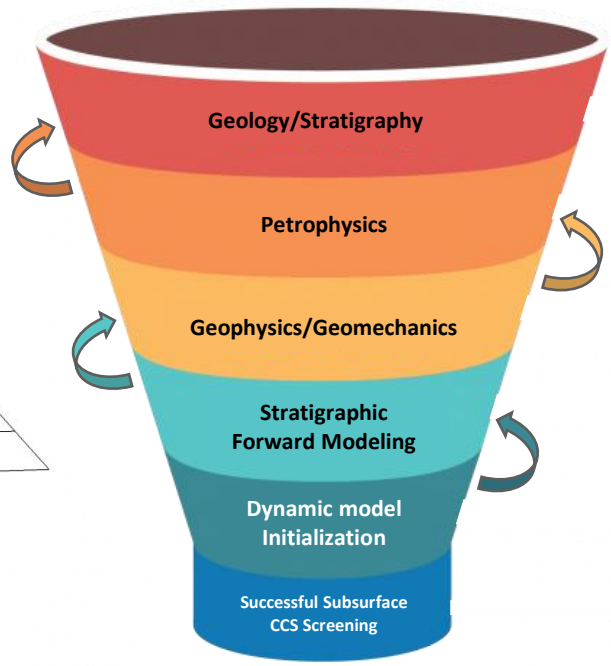
Aggregate CCS COA Map



DOE Funded CCS evaluations

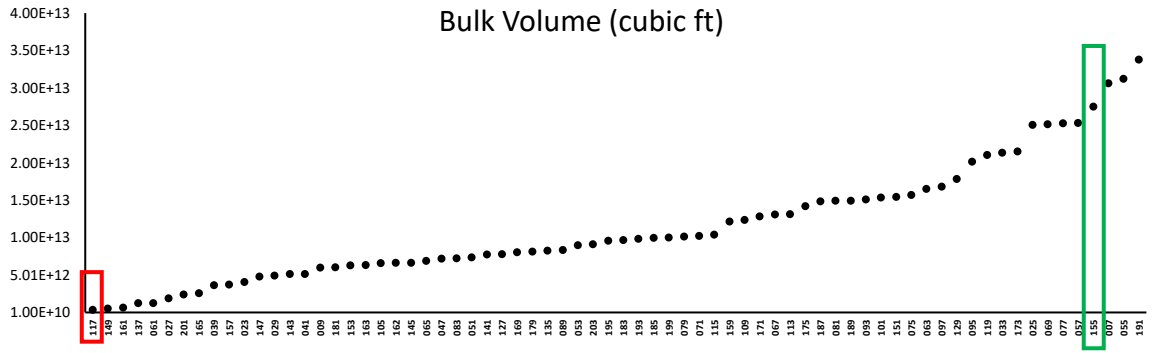
Class VI Applications

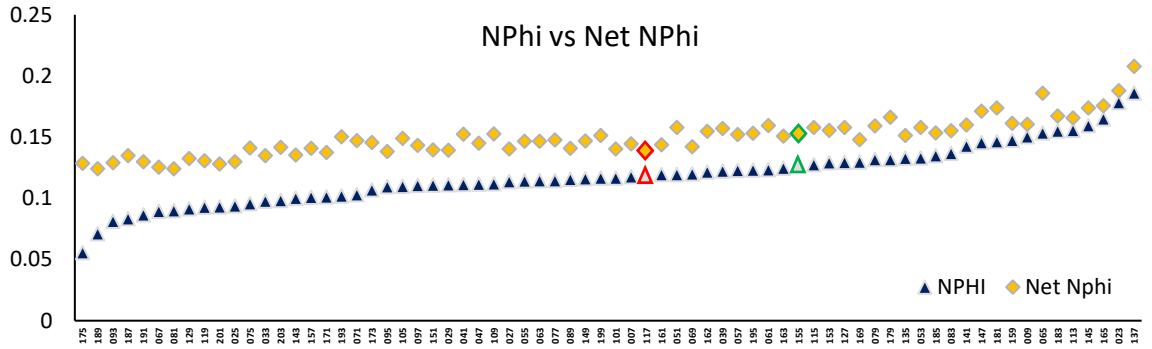
Subsurface Data

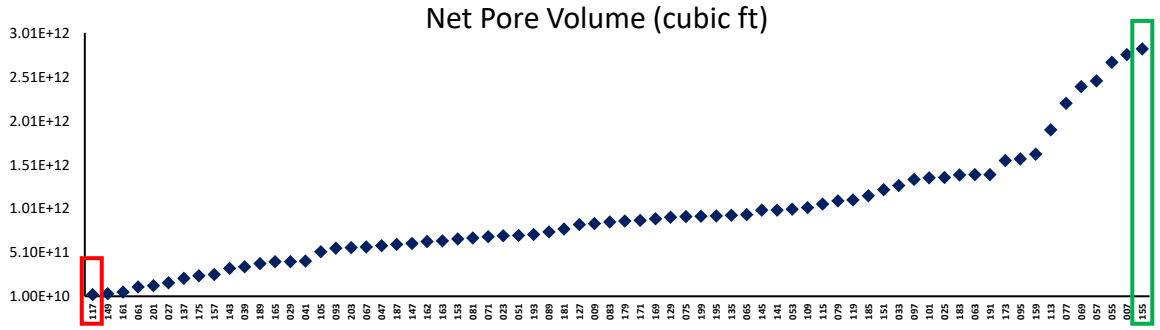


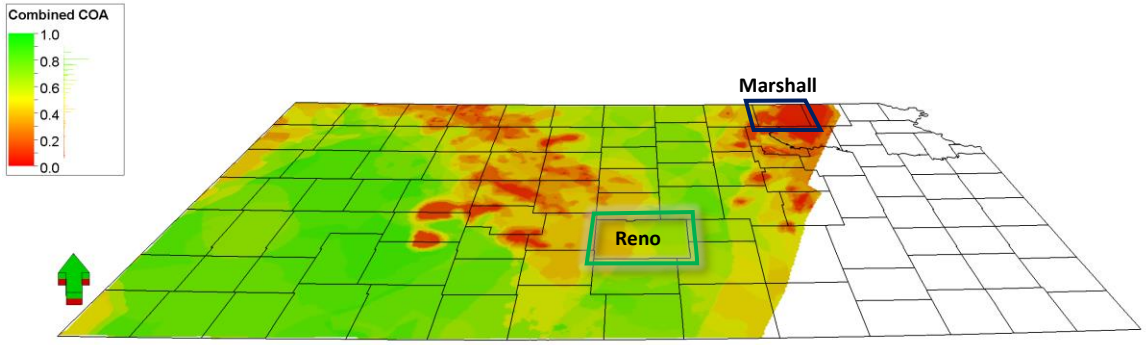
Regional/Basin Scale Subsurface CCS Screening Workflow

Preliminary County Properties

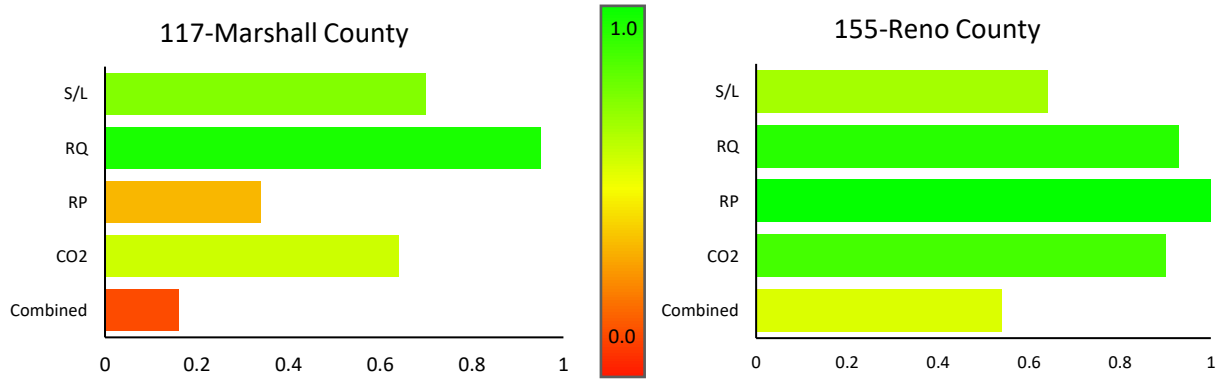




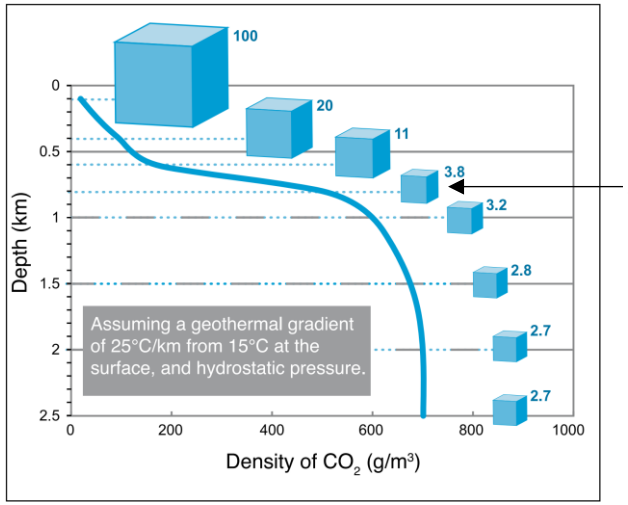




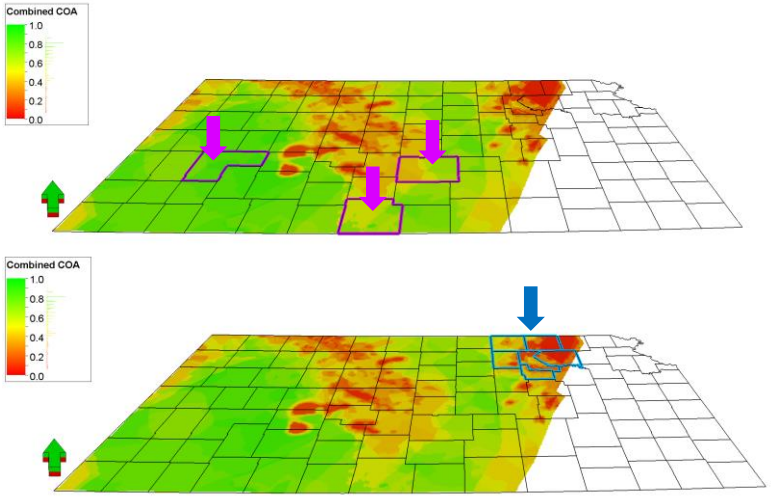
Comparing play elements of counties with the highest and lowest (Pore Volume) storage capacities

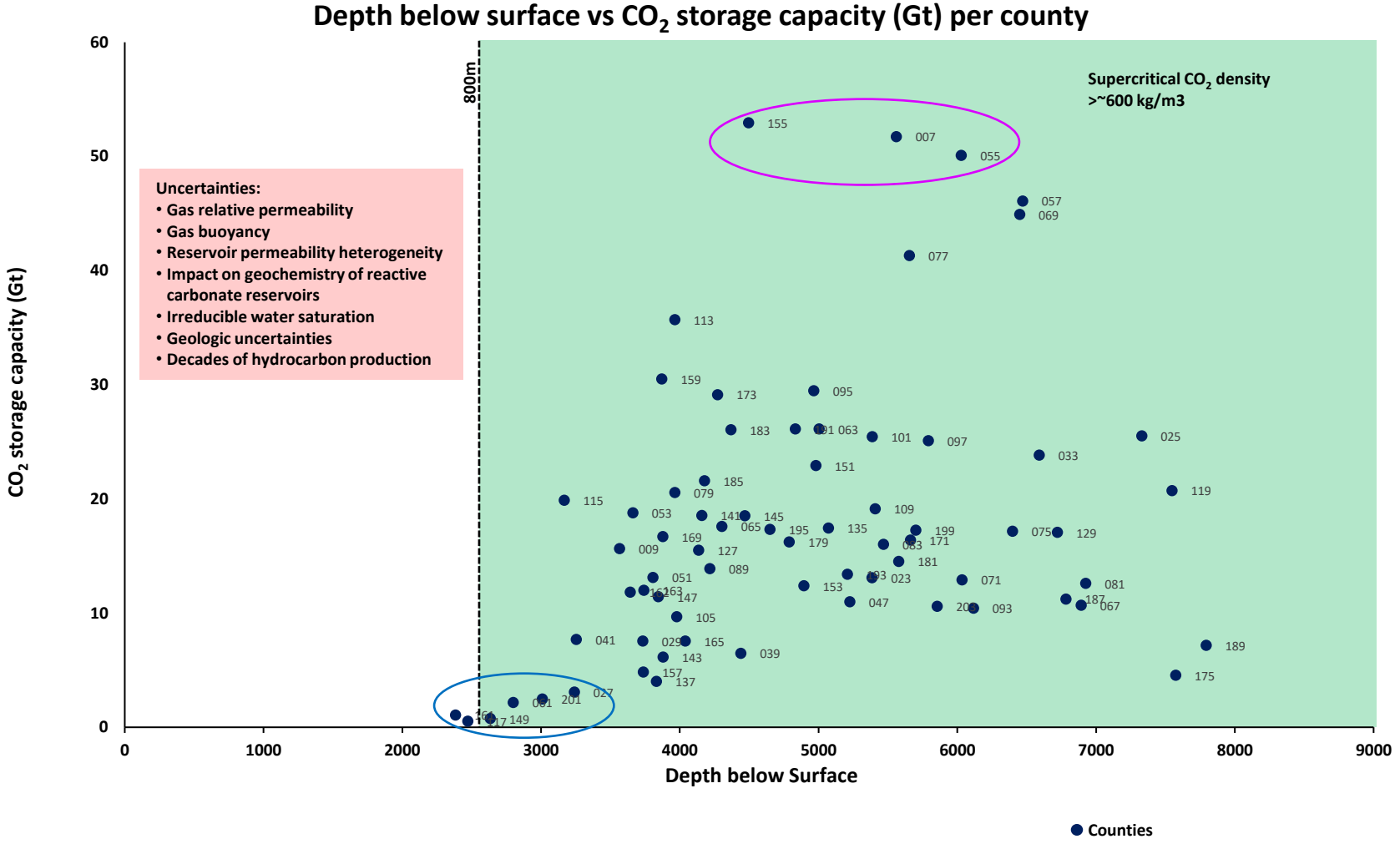


Preliminary CO_2 storage estimates (max)



Variation of CO2 density with depth. CO2 density increases rapidly at approximately 800 m depth, when the CO2 reaches a supercritical state. Cubes represent the relative volume occupied by the CO2 and down to 800 m, this volume can be seen to dramatically decrease with depth (IPCC Special Report on Carbon Dioxide Capture and Storage, 2005)





Conclusions

Takeaways:

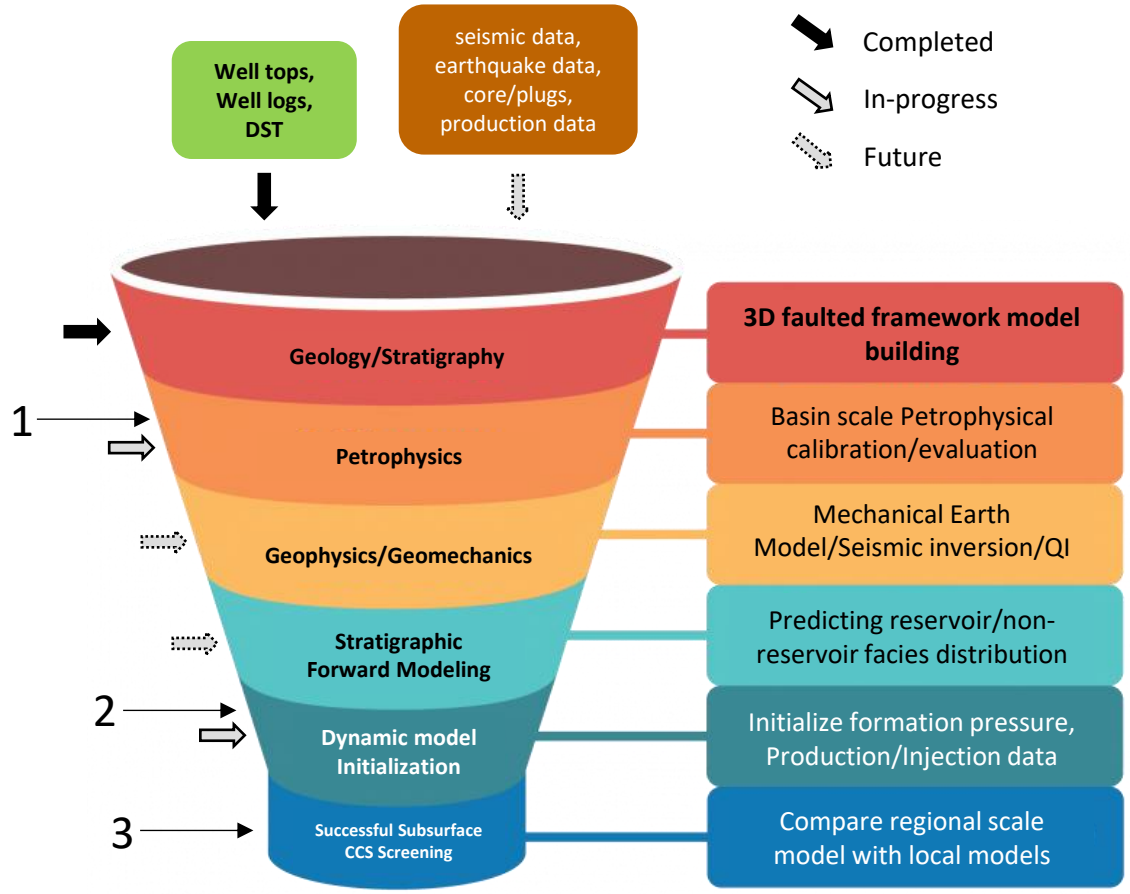
- Valuable regional screening effort, utilizing the Arbuckle-Basement faulted framework model
- Identify “favorable” vs potentially “challenged” areas

Scope for future work (near term):

1. Normalize all petrophysical data and build robust property models
2. Revise CO_2 phase study with additional DST data
3. Compare regional study with focus studies

Big Picture:

A basis for basin-scale modeling of Carbon Sequestration study in Kansas



Regional/Basin Scale Subsurface CCS Screening Workflow


Seattle
Lake Superior
Ottawa
Montreal
Toronto
GREAT PLAINS
Detroit
Chicago
Boston
Denver
St. Louis
San Francisco
Los Angeles
Atlanta
Dallas
Houston
Monterrey
Miami
MEXICO

THANK YOU