DIGITAL MAPPING TECHNIQUES 2024

The following was presented at DMT '24
May 13 - 16, 2024

The contents of this document are provisional

See Presentations and Proceedings
from the DMT Meetings (1997-2024)
http://ngmdb.usgs.gov/info/dmt/

An Integrated Approach to Subsurface Mapping at the Kansas Geological Survey: The Precambrian Basement

By Souvik Bhattacharjee, Kolbe Andrzejewski, Alan Peterson (Kansas Geological Survey)

Surficial and bedrock geological mapping are critical methods to understanding resources like oil and gas, as well as critical minerals, hazards, structural geology, and the potential for CO2 sequestration. Geologic mapping is also fundamental to the work of a state geological survey. At the Kansas Geological Survey, we have built an integrated model for the Precambrian basement using a plethora of datasets and many state-of-the-art techniques with the help of StateMap funding. The Precambrian basement, aged ~1.0 Ga and older, is composed of crystalline rocks lying beneath the Paleozoic and younger sedimentary rocks.

The method involved use of Precambrian well top data from Kansas and its surrounding states as input, referring to legacy fault traces and hand drawn contours from previous studies, and using the 3D modeling software SLB Petrel, to build a 3D faulted framework model for the subsurface of Kansas, starting with the Precambrian basement.

The most recent update of the basement map to state of Kansas was in 1979 based on approximately 3,000 wells and hand drawn contours. The map is currently updated with more than 2,000 additional well tops and lithology from cores, and will be iteratively updated using additional data e.g., well logs, earthquake hypocenter data, seismic data, new wells/core/cuttings, and gravity data, as and when they are available. The output from Petrel, which is a 3D surface/horizon, is exported to ArcGIS Pro in zmap.grid format and converted to a DEM with additional metadata to be published on the Kansas Geological Survey website and the GeMS database.

This workflow will be applied to generate other shallower horizon/surface maps for the subsurface of the state of Kansas i.e., Arbuckle, regional Mississippian, Dakota, as a part of the USGS StateMap project.

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KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

Digital Mapping Techniques (DMT) 2024, Bloomington-Normal, IL

Study Area, Significance

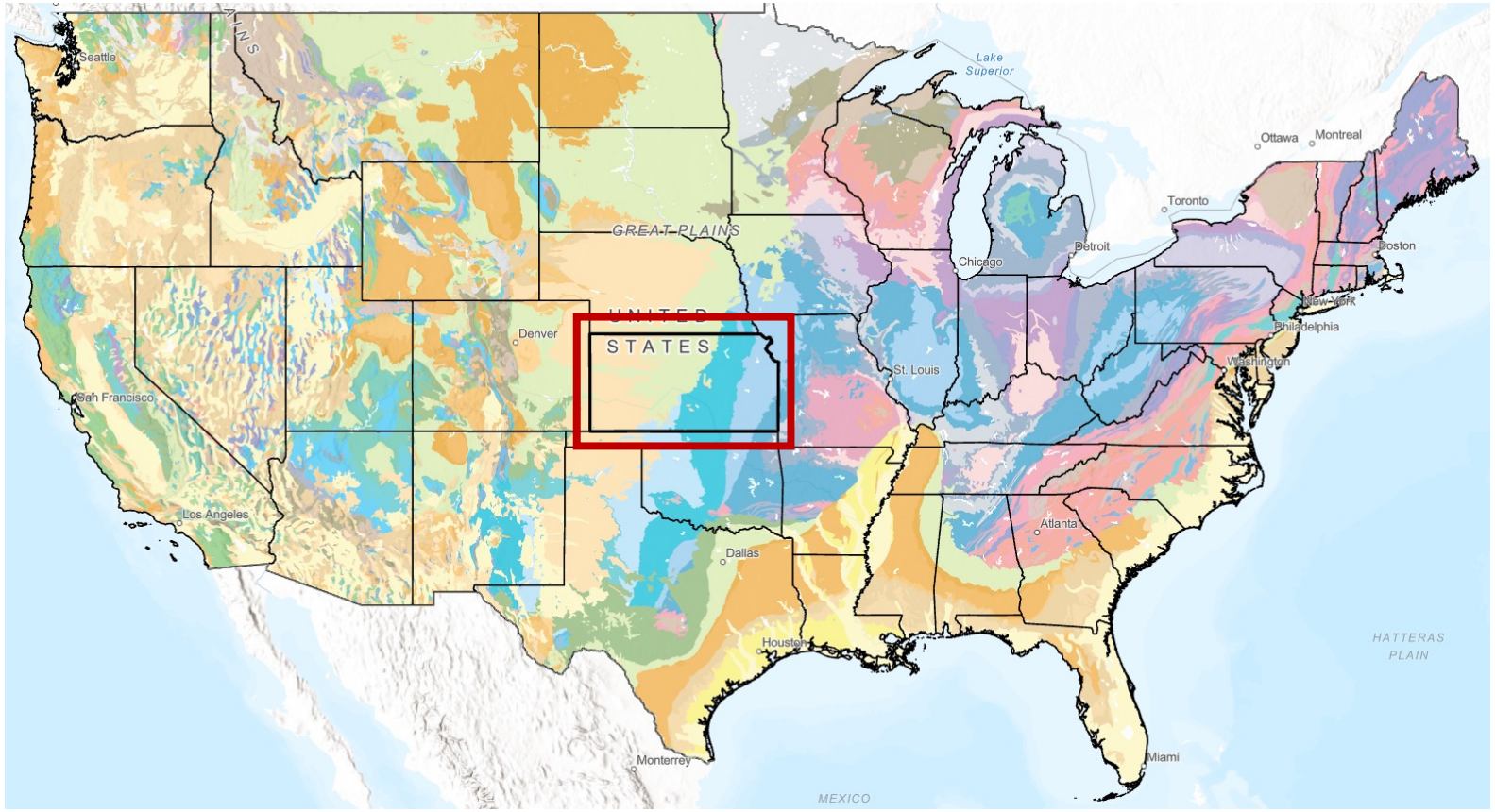
Study Area
- Kansas Midcontinent
- Central USA, good place to start

Mapping
- Fundamental work of the Survey

The subsurface is critical for the state
- Oil production
- Mineral exploration
- Wastewater injection
- CO2 sequestration

USGS StateMap funded
- Started back in FY20

Foundation for future work of the 3D subsurface models for the state of Kansas
- Template going forward
- Start at the bottom



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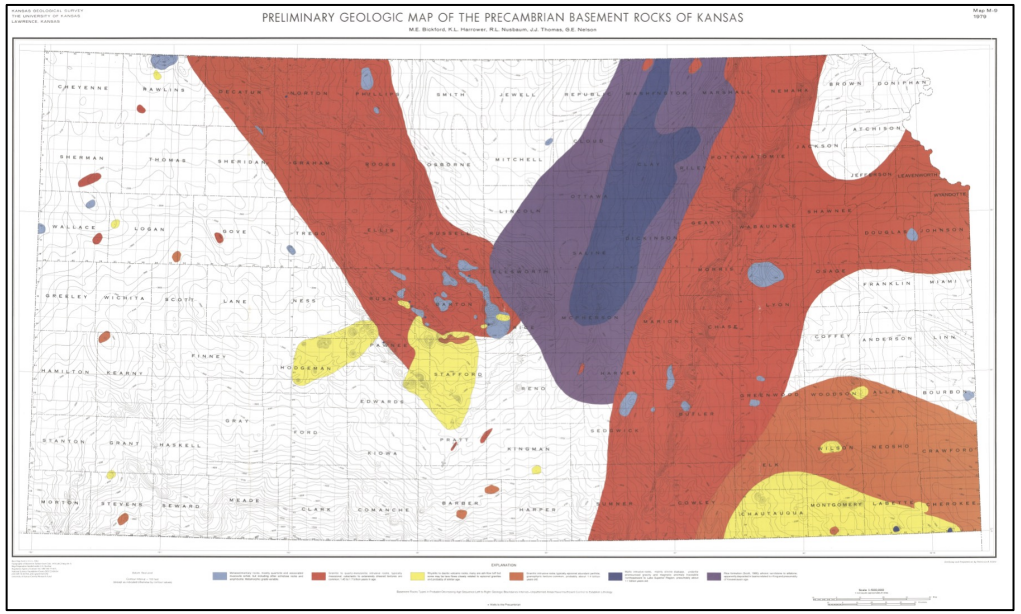
Previous Kansas Subsurface Efforts



Bickford et al., 1979

Previous map with lithologies debuted in 1979

Previous efforts:

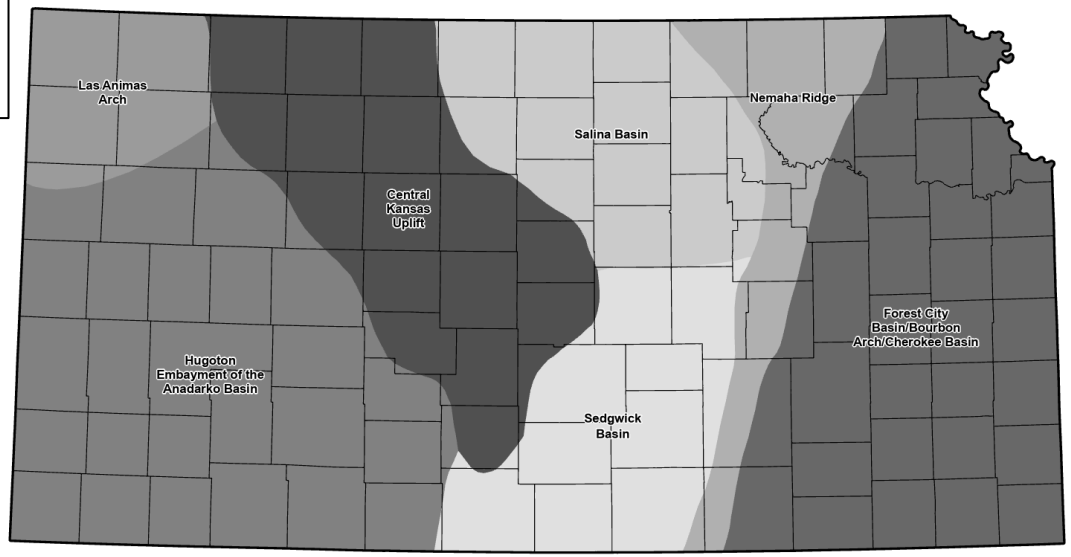
- Utilized 3,000 wells
- Structural hand contours from Cole (1976)

Many new wells, methods since then

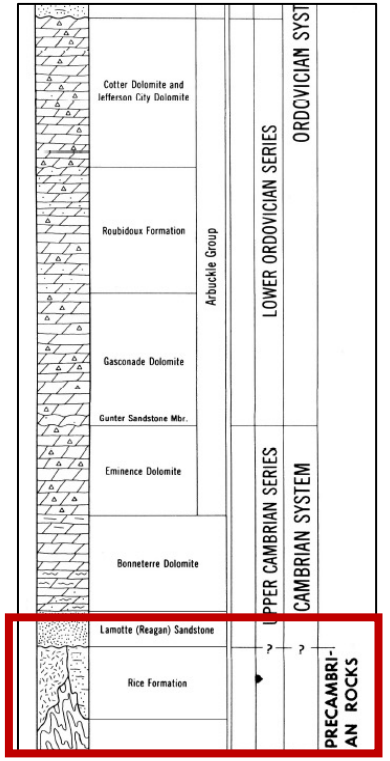
What is the basement?

- Crystalline rocks lying beneath the Paleozoic and younger sedimentary rocks
- Sometimes exposed at the surface, not in Kansas

Kansas basement is Precambrian > 540 Ma



Modified from Xia et al., 1996



Kansas Strat. Column

Updated Map

An Update 45 years later!

More than 5,000 wells
- Point density/color

Model/surface built in Petrel

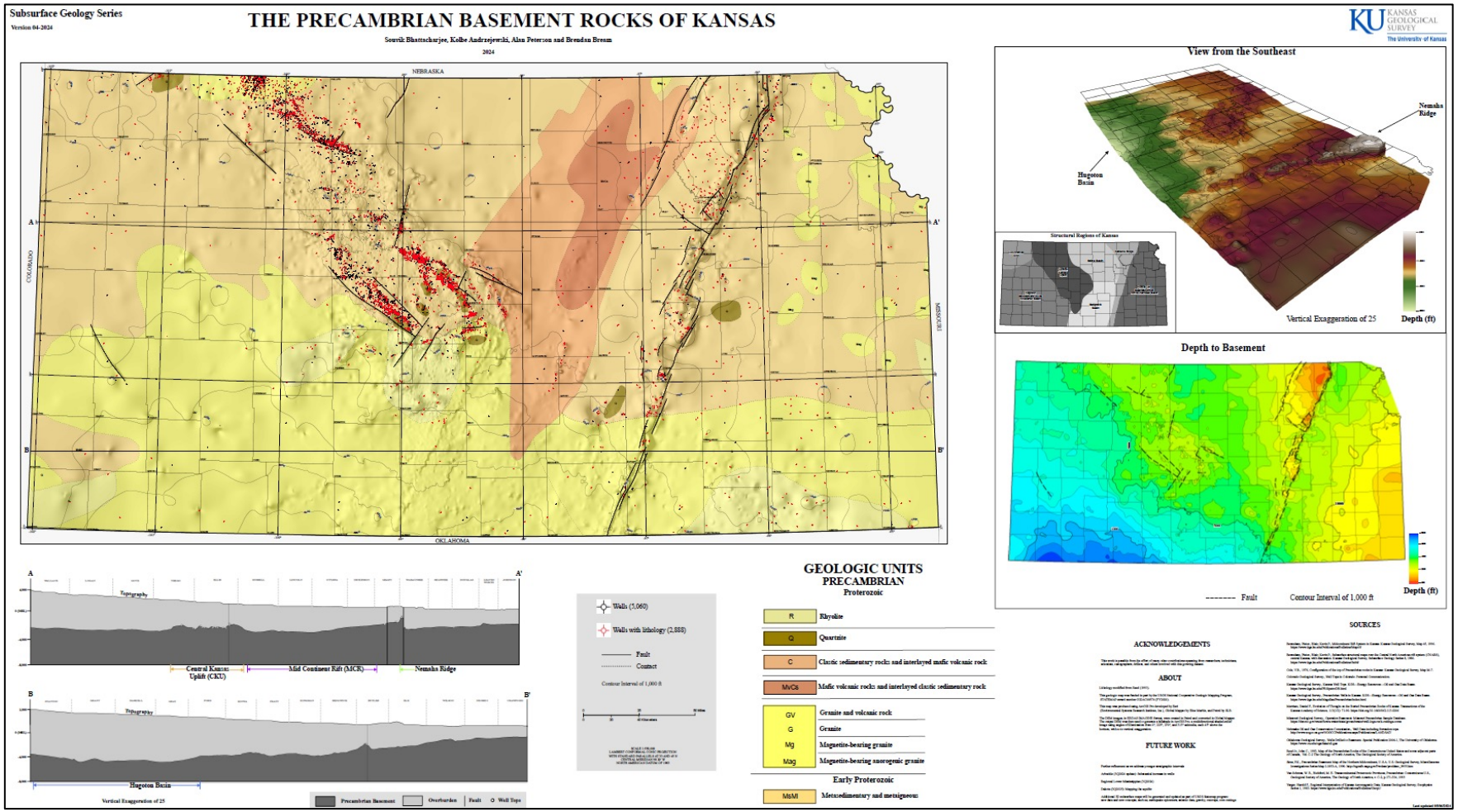
Publish in KGS's Subsurface Geology Series

Update planned with new datasets

Layout in ArcGIS Pro

Display in Map Gallery

Features:
- Multiple cross sections
- Depth to Basement
- Oblique view



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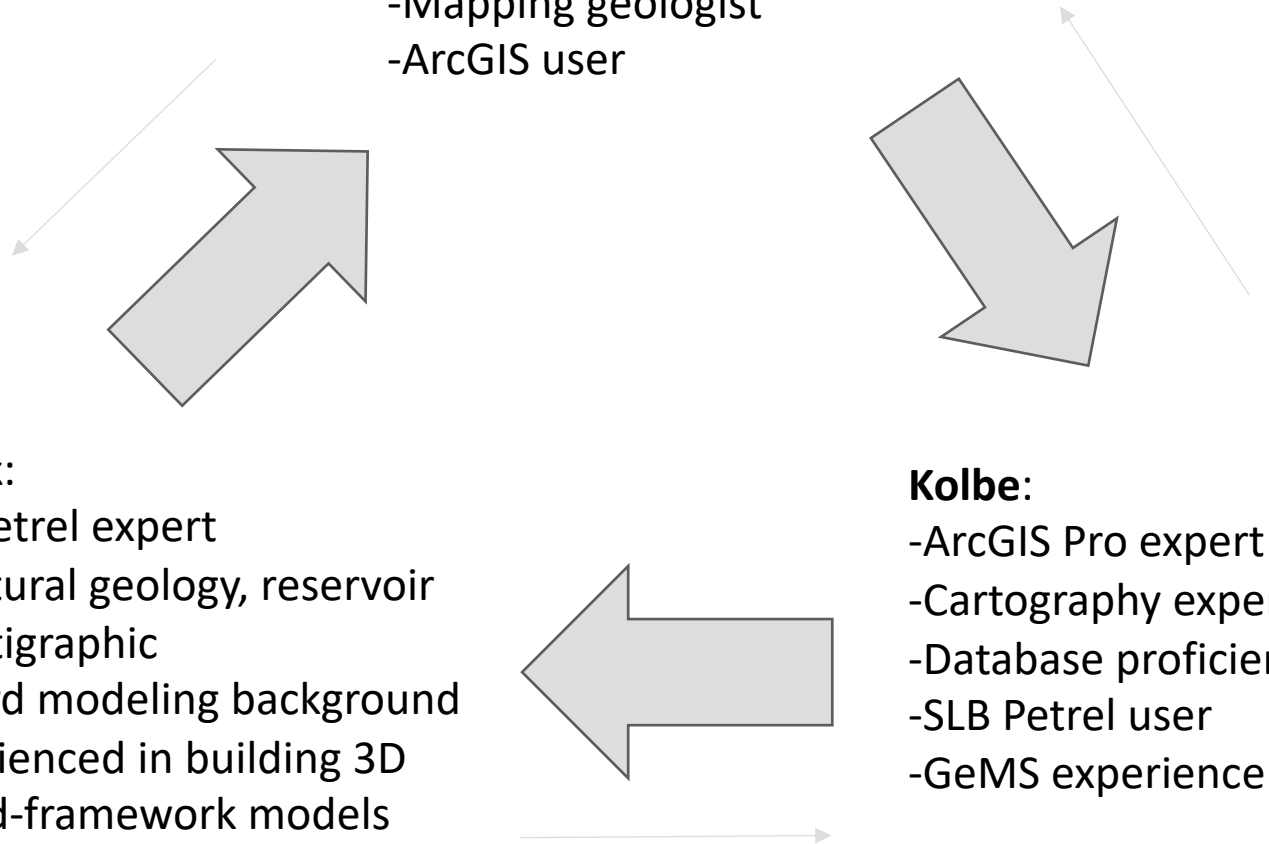
3 Phases of Project

Phases:
- Inputs
- Iteration
- Outputs

We each have our own expertise/backgrounds
- Complement each other
- Map not possible without everyone's input
- Workflow isn't oneway, multiple loops

Alan:
-Kansas Structural expert
-Well database power user
-Mapping geologist
-ArcGIS user



Souvik:
-SLB Petrel expert
-Structural geology, reservoir & stratigraphic forward modeling background
-Experienced in building 3D faulted-framework models

Kolbe:
-ArcGIS Pro expert
-Cartography experience
-Database proficient
-SLB Petrel user
-GeMS experience

Inputs

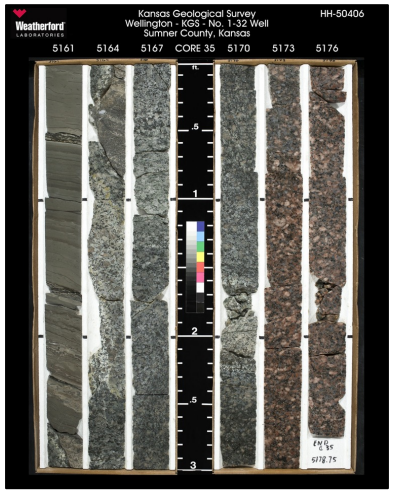
Started with millions of wells & then queried out for basement tops

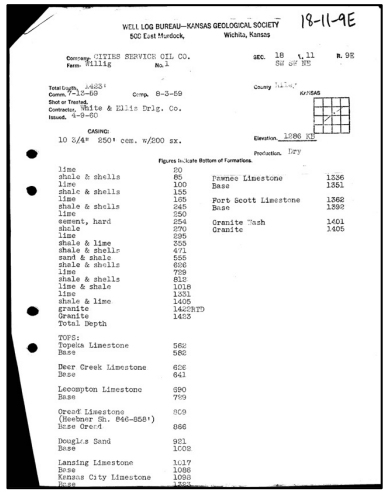
Datasets

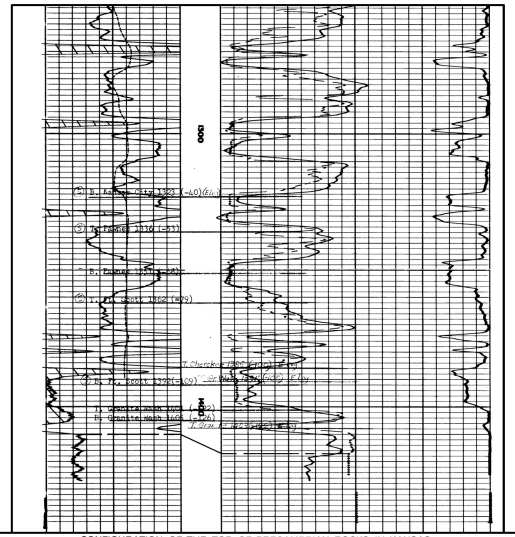
- Current: Well tops, contours, some core
- Future: well logs, seismic, gravity, Earthquakes, all core, cuttings

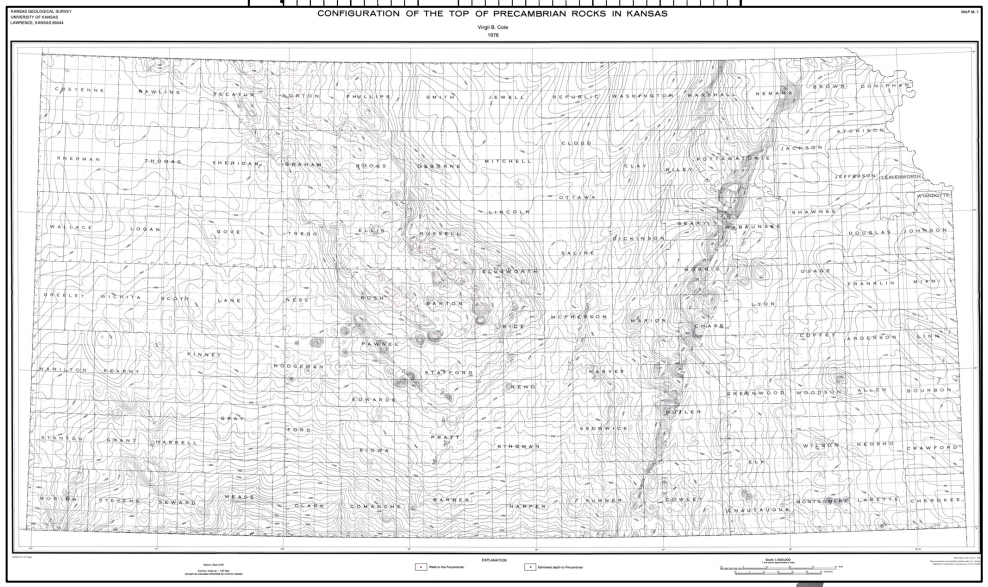
Multiple sources

- Principally KGS well database
- Gathered wells from surrounding states



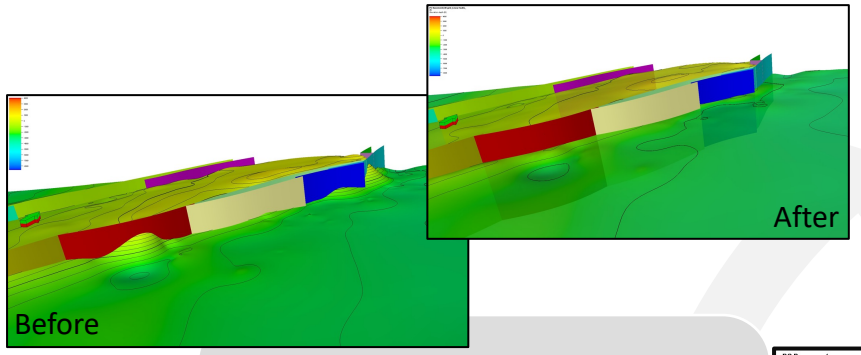




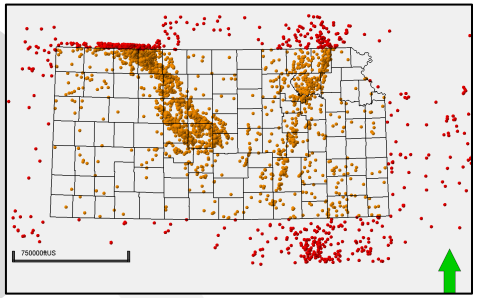


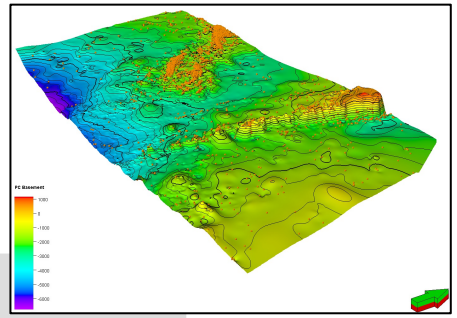
Cole, 1976

Iteration

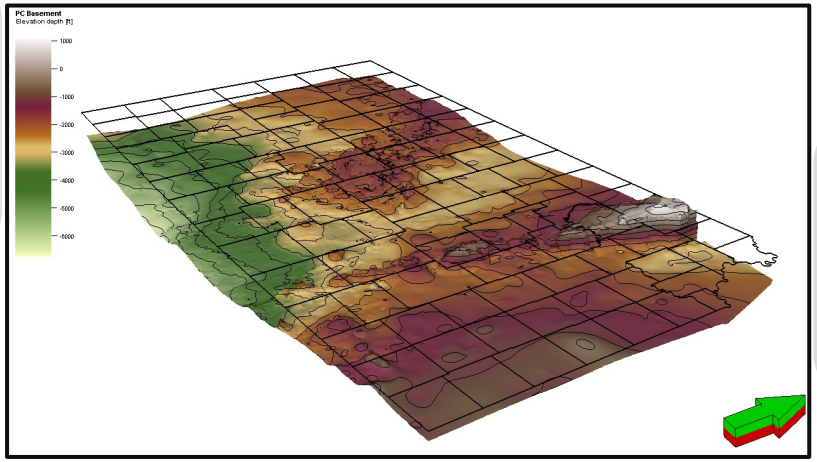


QC (depth) and update PC_Basement/Arbuckle well top data

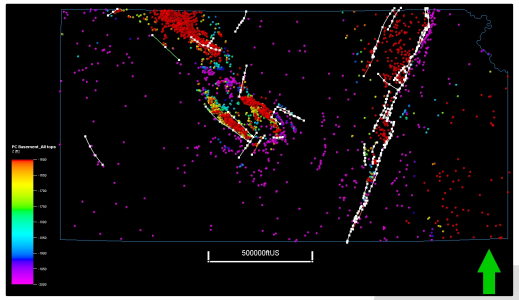




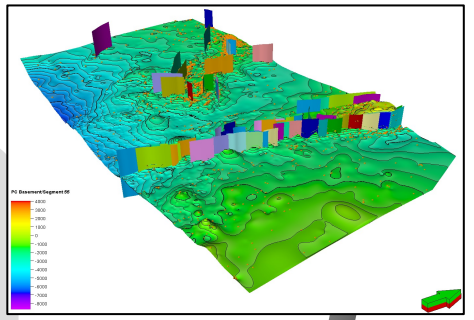
Use well top data as control points for PC_Basement/Arbuckle



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



Use well tops in 3D to justify presence/absence of faults by comparing vertical separation across probable faults



Refer legacy fault traces to build 3D faulted framework model

Outputs

Data exchange between SLB Petrel and Esri ArcGIS

Deliverables need to be in GeMS

- “Fitting square peg into round hole”
- GeMS wasn’t designed for subsurface data

Dataset is provisional

- Continue to update

Ideally share DEM from model

- Contours are not sufficient
- Submit DEM as supplemental file

GeMS predicament will continue

- Arbuckle, Mississippian, Dakota
- No lithology for Arbuckle or Mississippian
- Geologic Names check and MapUnitPolys will be troublesome

Appendix 4. Frequently Asked Questions (FAQs)

How do I encode a three-dimensional (3D) geologic map?

ArcGIS, along with most other GIS software, is not designed to handle 3D (volume) data. See the preceding question for approximations that may be useful. In the future, consideration will be given to more fully adapting GeMS for 3D information.

Petrel
Shared earth—critical insight

ArcGIS Pro

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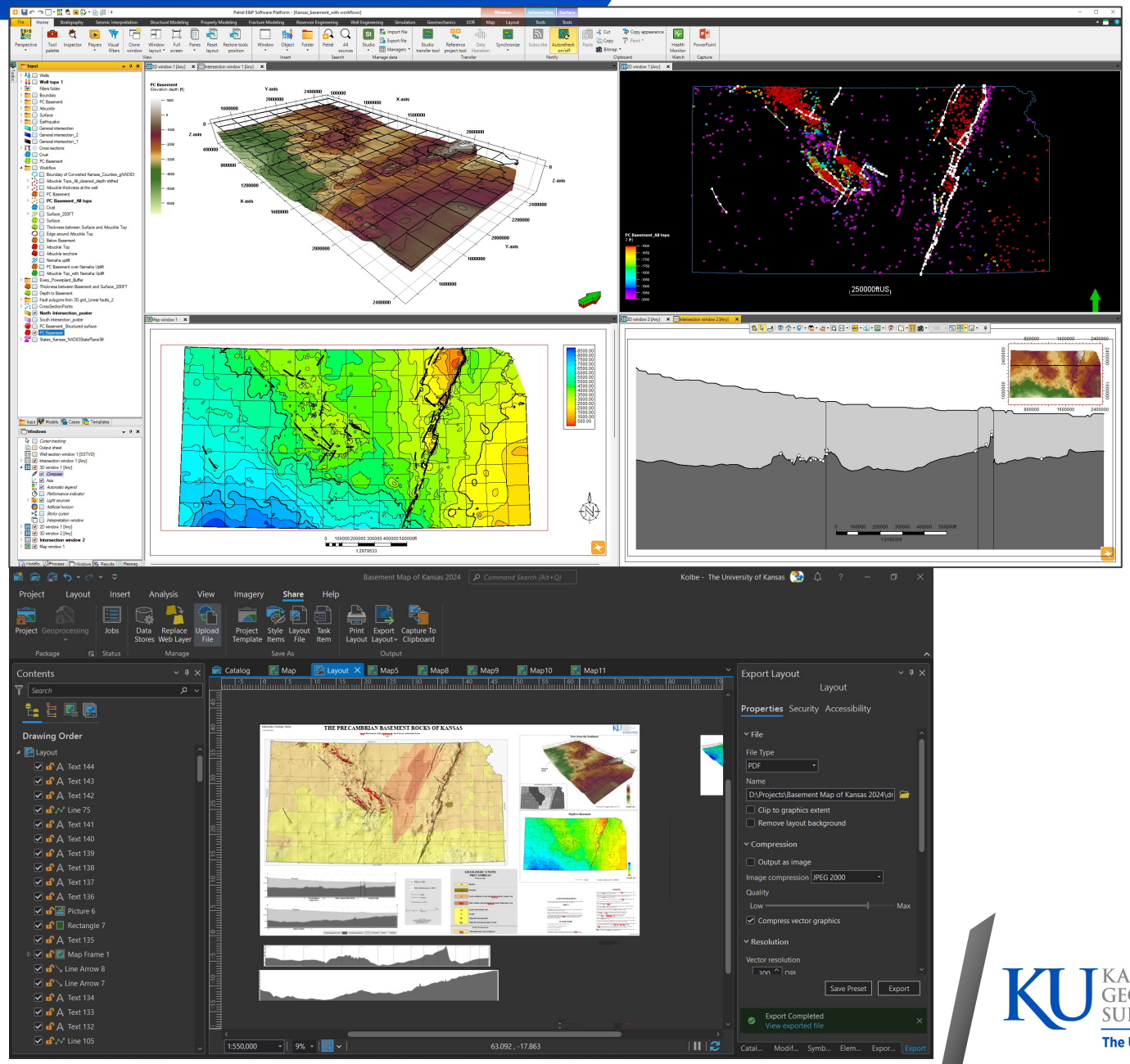
Challenges/Successes

Successes

- Large Dataset
- Collaborative
- Short time frame
- ArcGIS/Petrel effort
- Future subsurface maps
- Incorporating surrounding states well-top data

Challenges

- Large dataset (2.5 million records)
- Data QA/QC
- Subsurface data into GeMS
- Appropriate level of detail



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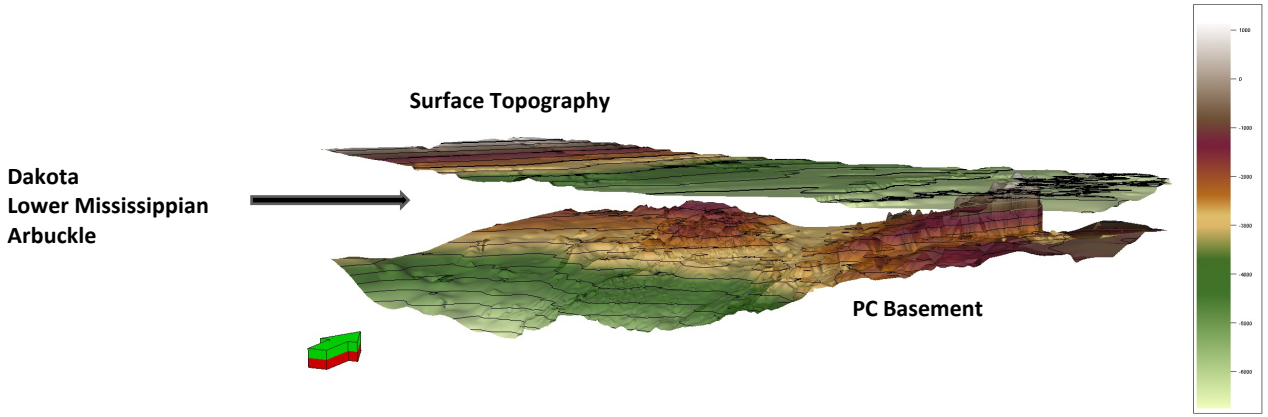
Future Work

Further refinement as we address younger stratigraphic intervals

- Arbuckle (3Q2024 update)
  - Substantial increase in wells
- Regional Lower Mississippian (3Q2024)
- Dakota (3Q2025)
  - Mapping the aquifer

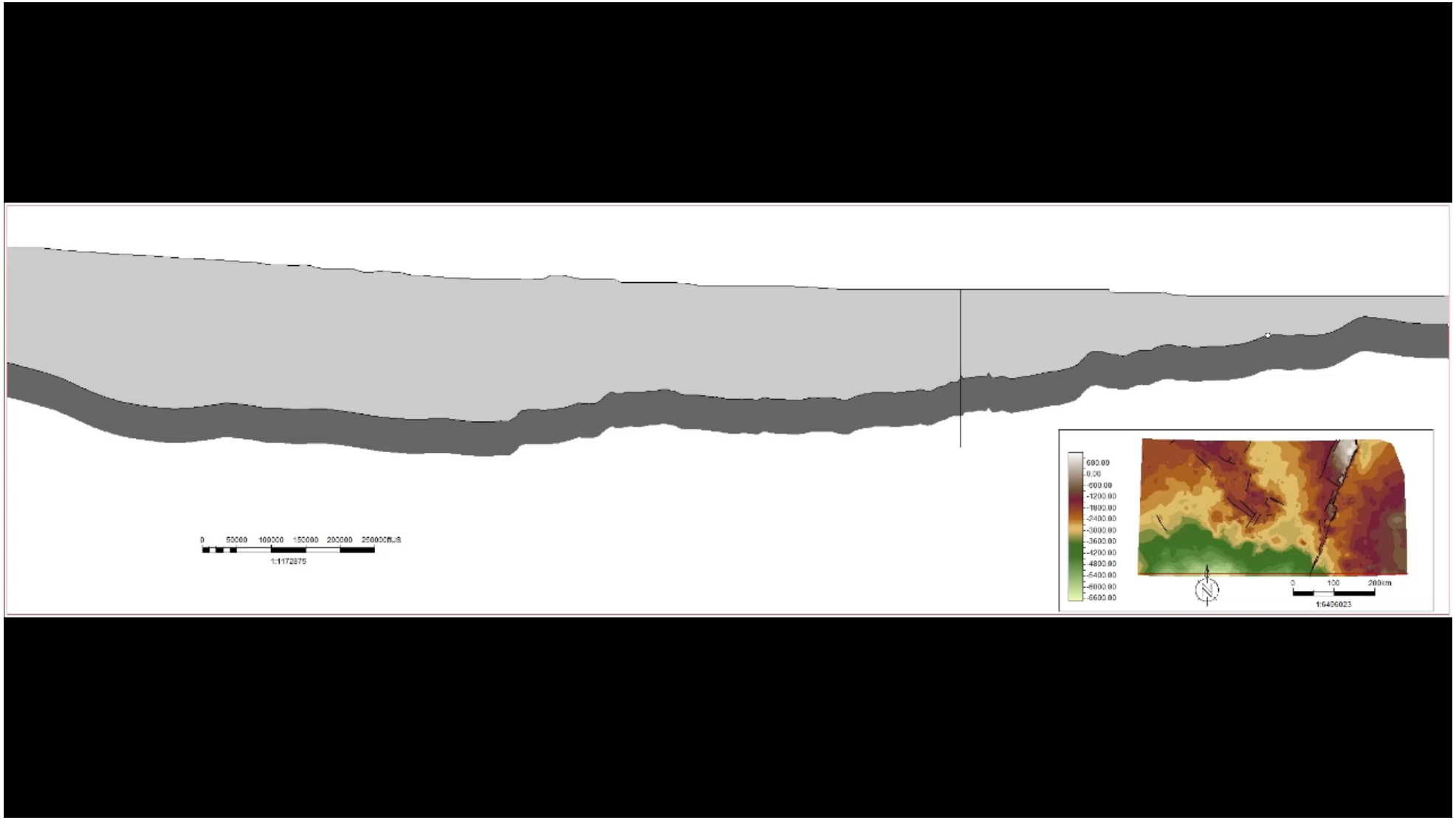


Additional 3D subsurface maps will be generated and updated as part of USGS Statemap program

- New data
- New concepts

Incorporate corrected data back into KGS well library

Animation: Cross Section



Animation: 3D fly