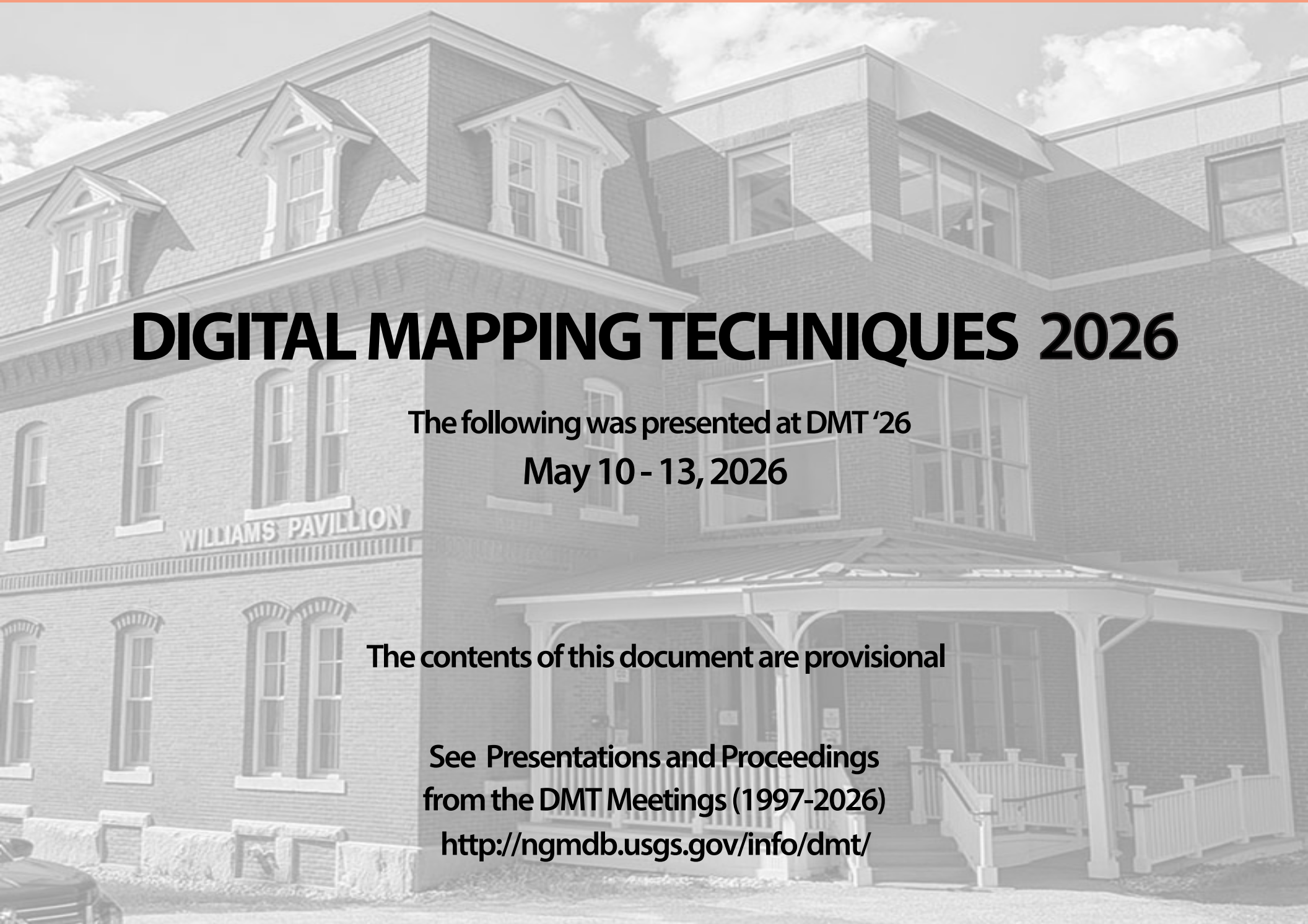


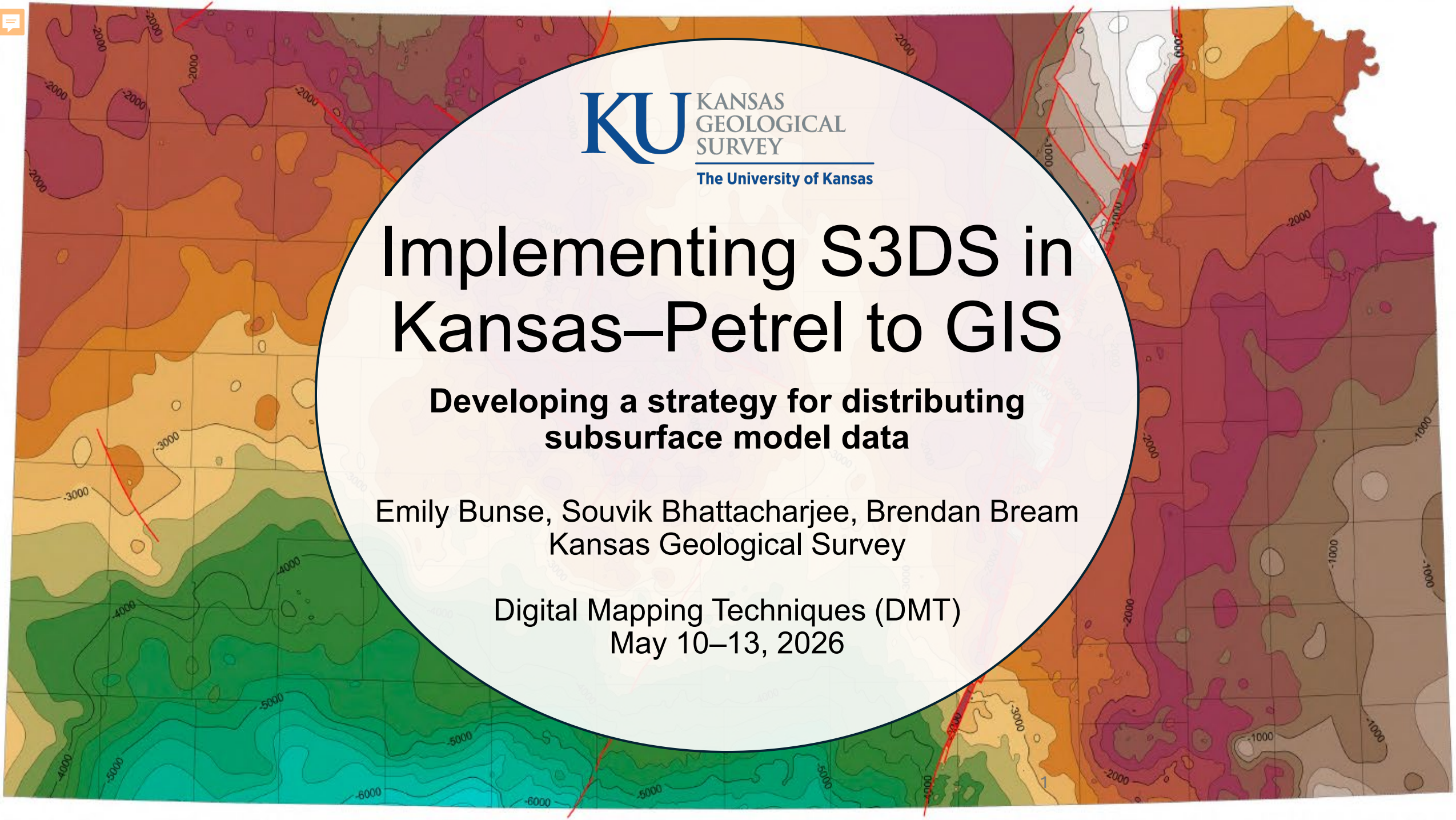
DIGITAL MAPPING TECHNIQUES 2026

The following was presented at DMT '26

May 10 - 13, 2026

The contents of this document are provisional

See Presentations and Proceedings
from the DMT Meetings (1997-2026)
http://ngmdb.usgs.gov/info/dmt/



KANSAS GEOLOGICAL SURVEY
The University of Kansas

Implementing S3DS in Kansas–Petrel to GIS

Developing a strategy for distributing subsurface model data

Emily Bunse, Souvik Bhattacharjee, Brendan Bream
Kansas Geological Survey

Digital Mapping Techniques (DMT)
May 10–13, 2026

Topics

Current subsurface research in Kansas

Getting familiar with **Petrel** for subsurface modeling

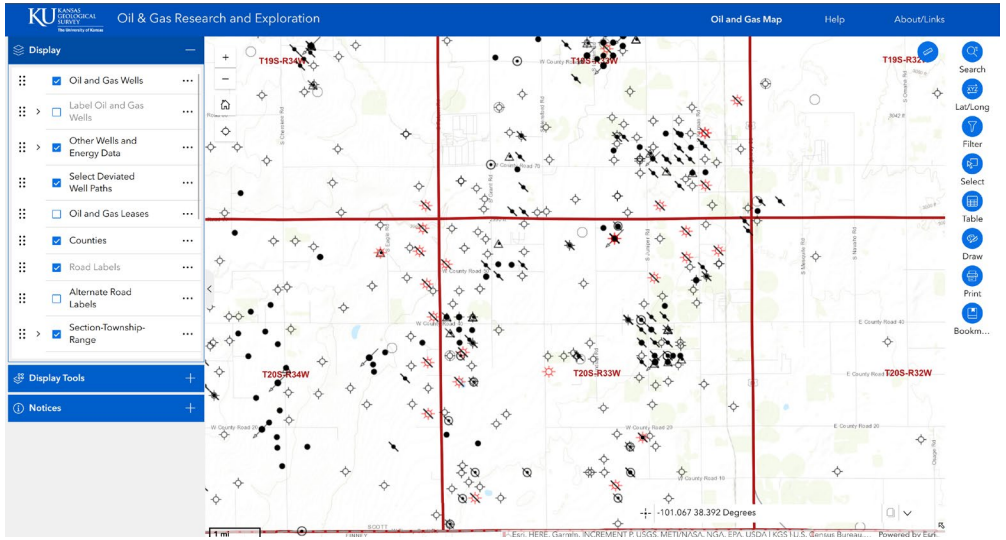
Subsurface data distribution goals and challenges

S3DS is crucial in a 3-part data distribution plan

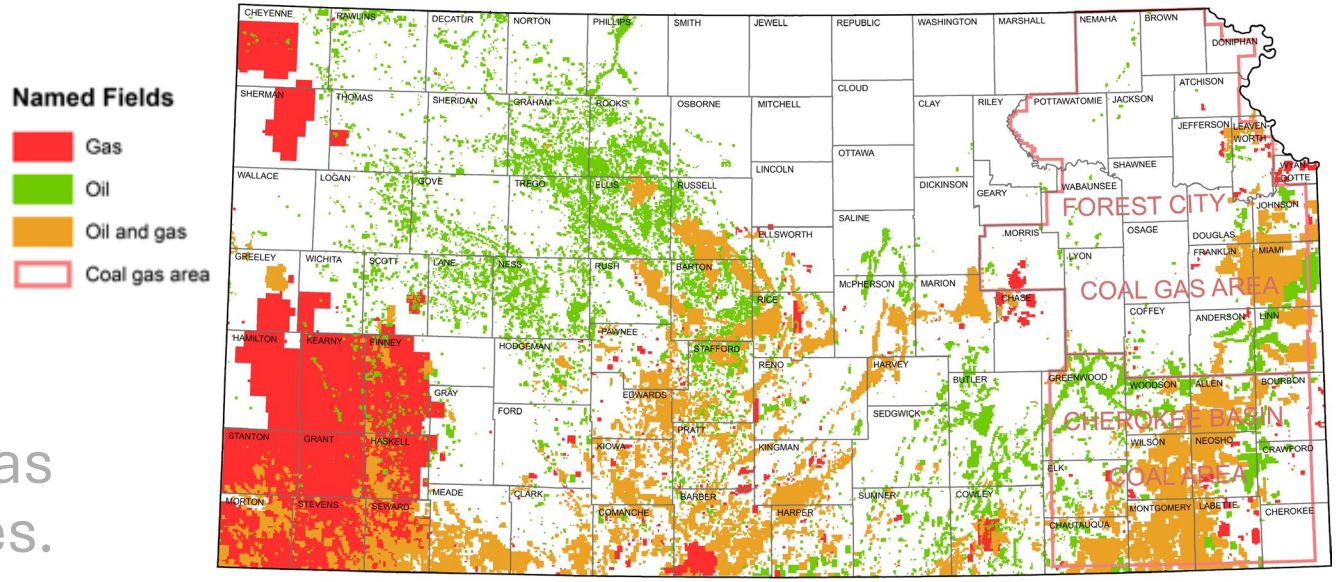
"All models are wrong, but some are useful."
George E.P. Box, statistician

Why model the subsurface in Kansas?

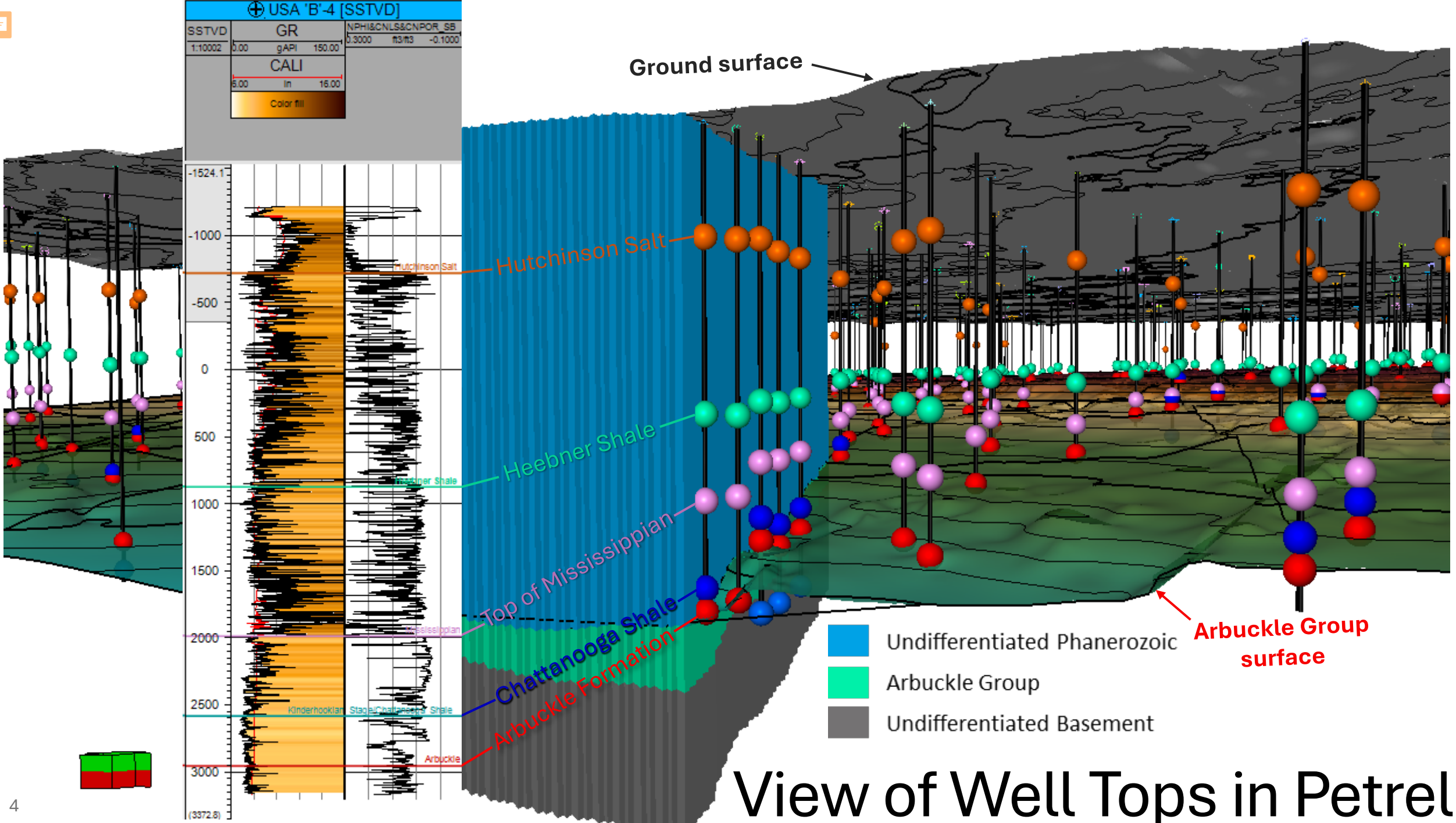
1. Kansas is data- and interpretation-rich
   - KGS serves data for over 825,000 wells
   - Over 500,000 oil and gas wells
   - 2+ million well tops
2. Kansas is resource-rich
   - Oil and gas production
   - Hydrogen/helium development
   - 7 aquifer systems
   - Aggregates
   - Critical minerals
3. Kansas has complex faults but is not as structurally challenging as other states.



KGS Oil and Gas Interactive Mapper, https://maps.kgs.ku.edu/oilgas/



Oil and Gas Fields in Kansas map, featured in KS GeoMaps, 2025



View of Well Tops in Petrel

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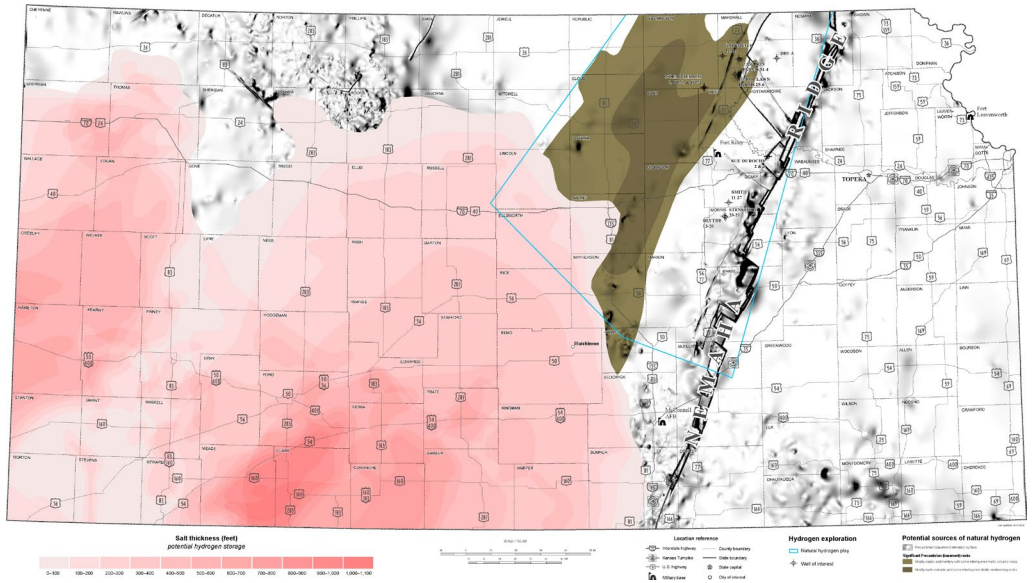
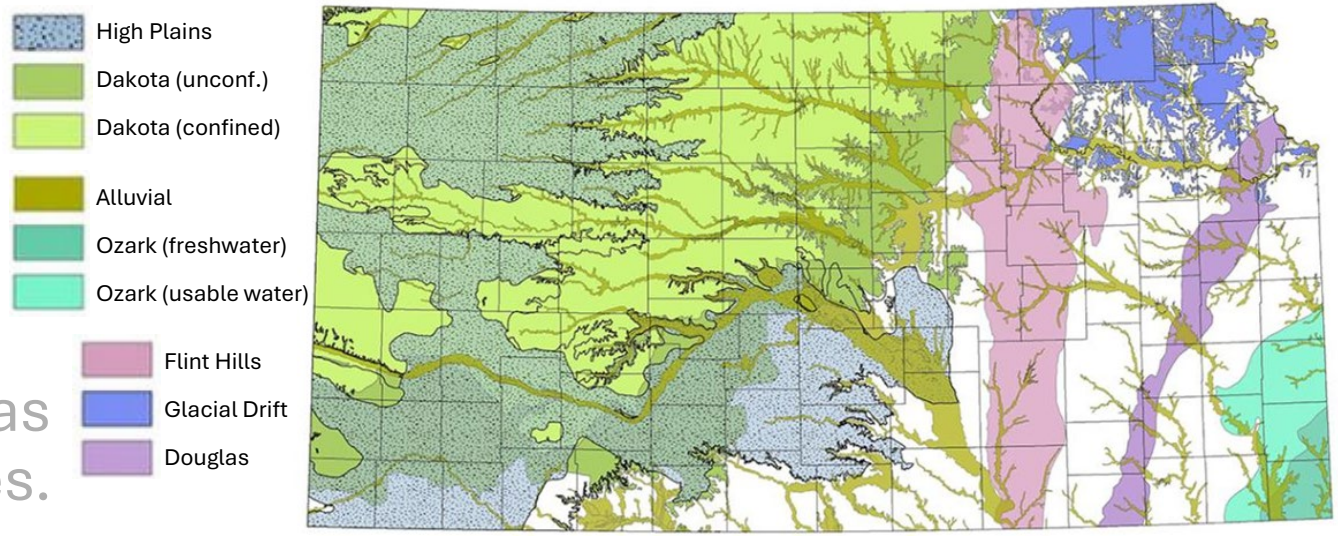


Hydrogen potential in KS. Pink polygons represent salt thickness which has hydrogen storage potential; brown polygons represent natural hydrogen potential. Unpublished map, 2025.



Aquifer systems in KS, https://geokansas.ku.edu/aquifers

Why model the subsurface in Kansas?

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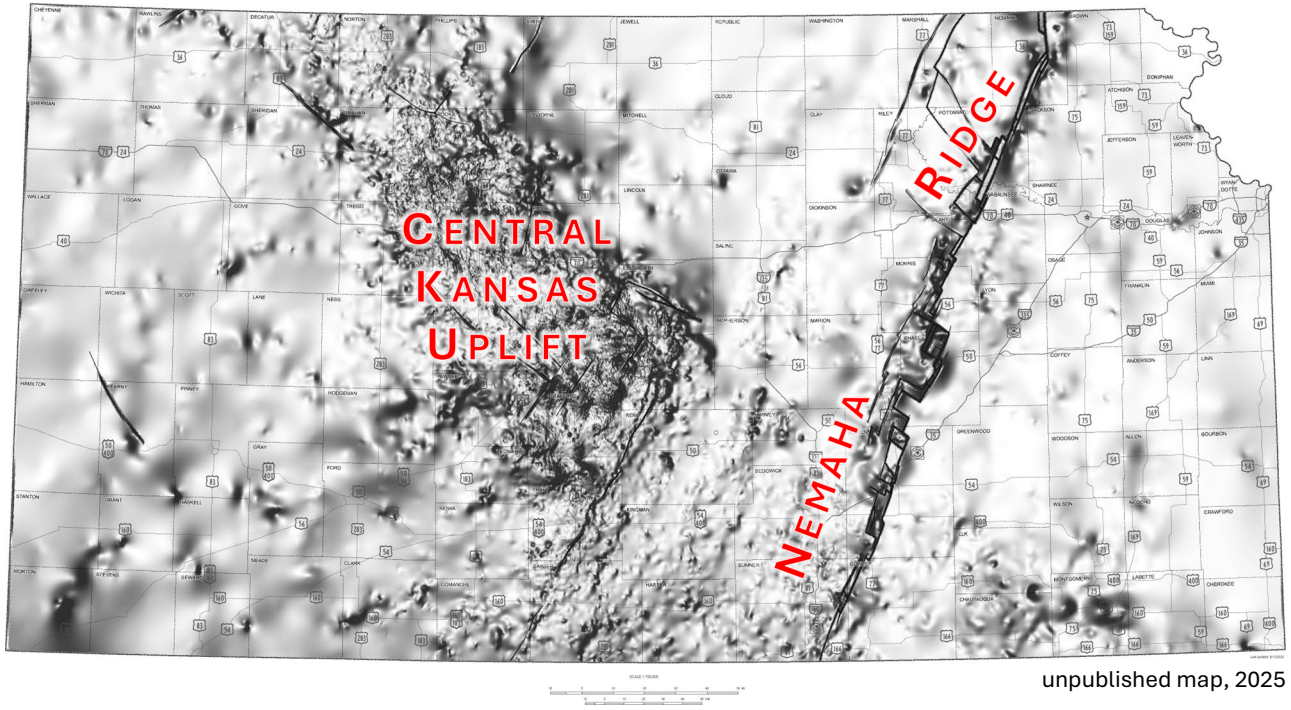
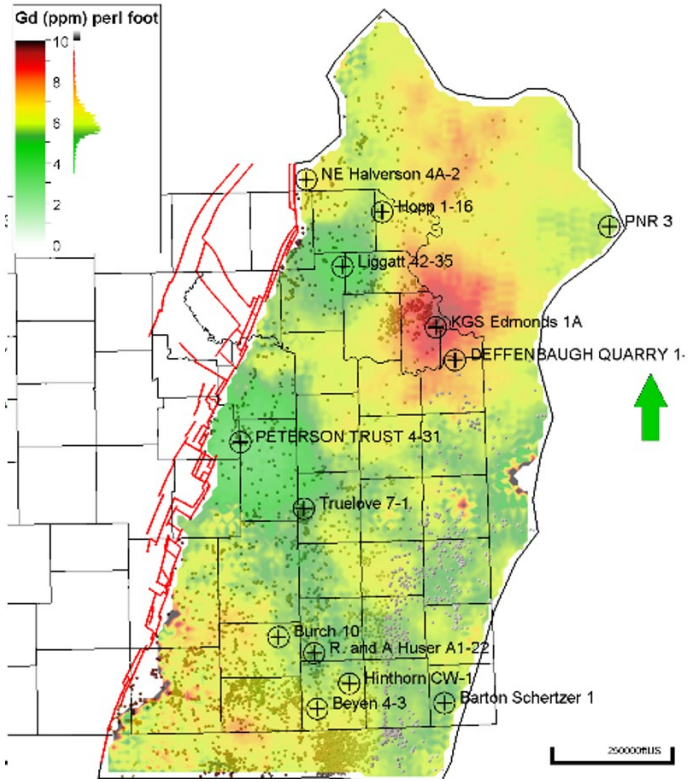


unpublished map, 2025

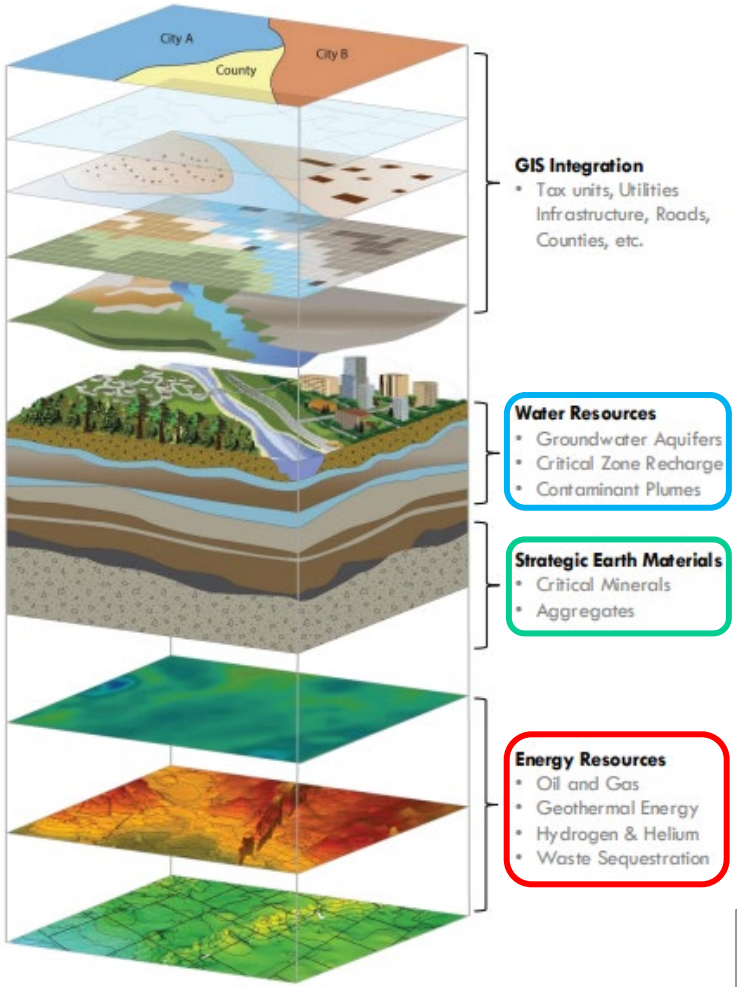
Precambrian basement and subsurface faults

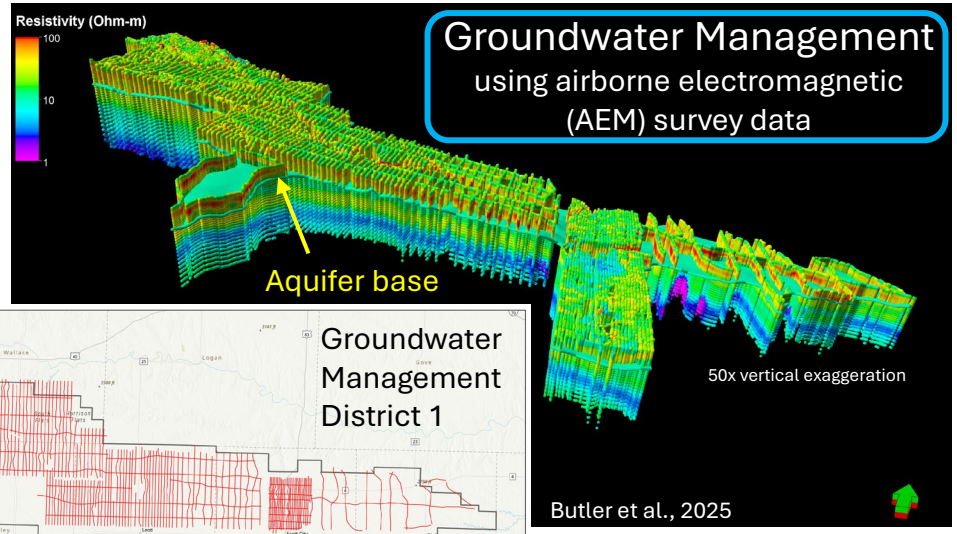
Why model using Petrel?

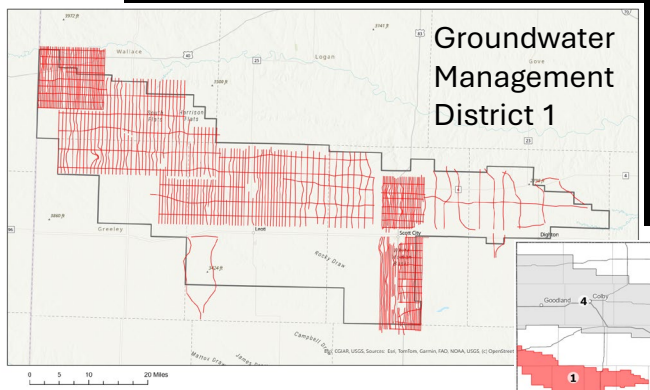
Assessment of Gadolinium (Gd)
(ppm) per vertical foot

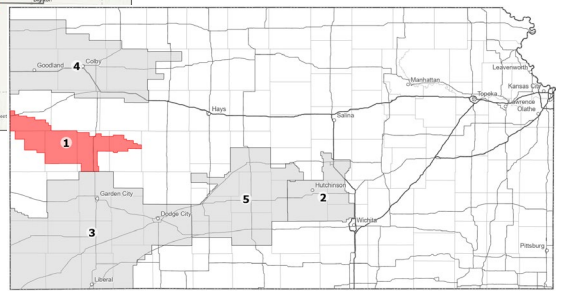


Oborny et al., 2025



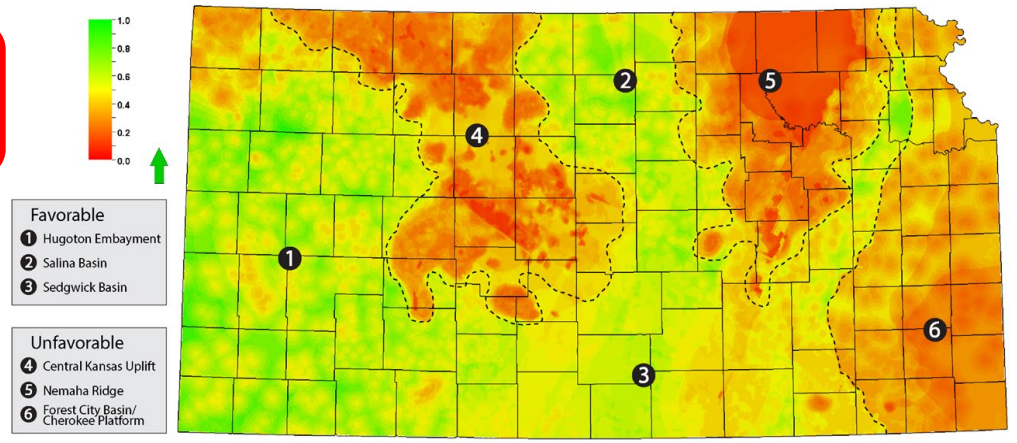






- 2,900 AEM line miles flown
- Average depth = 244m (800 ft)

Arbuckle carbon capture and storage
potential chance of adequacy map

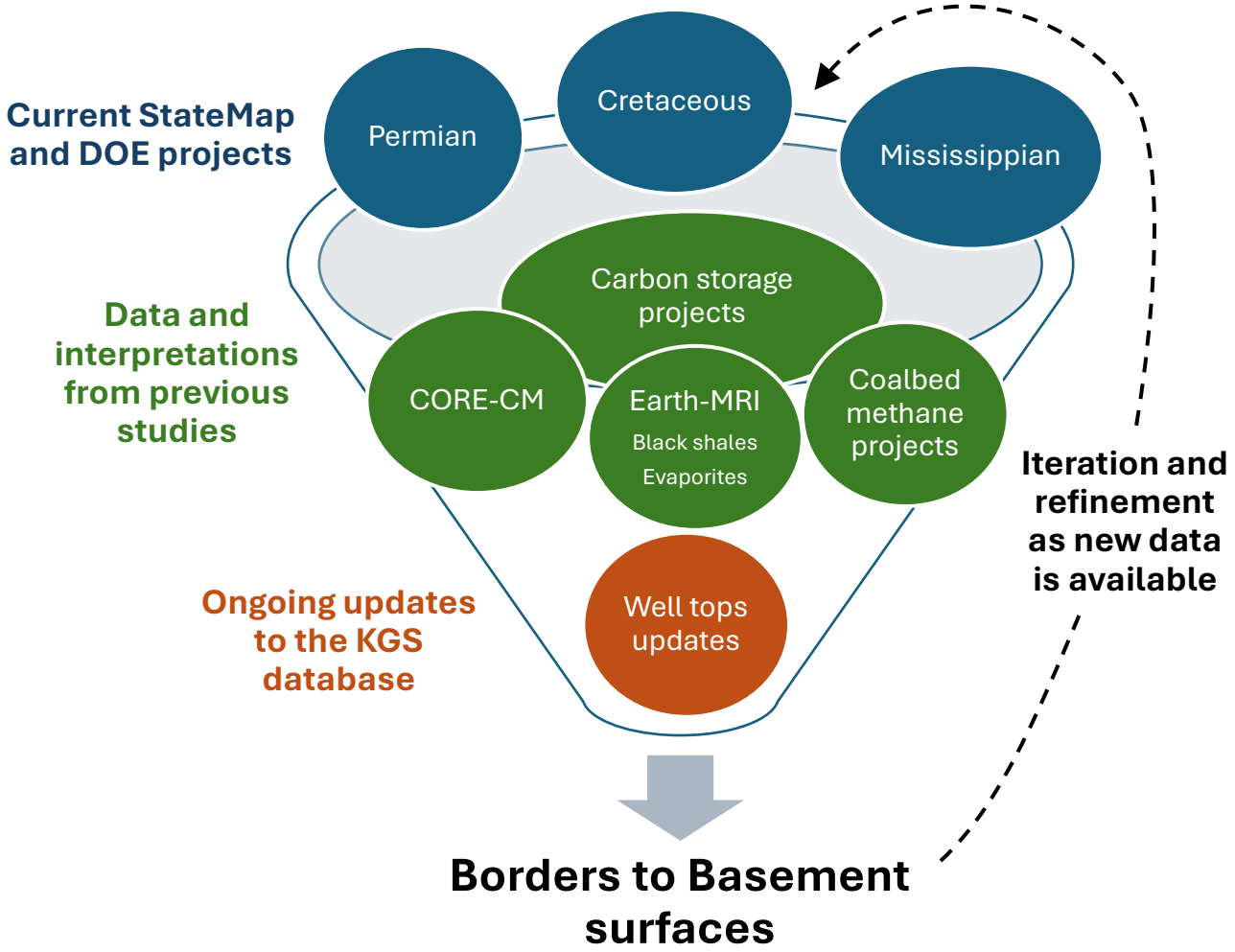


Bhattacharjee et al., *in review*

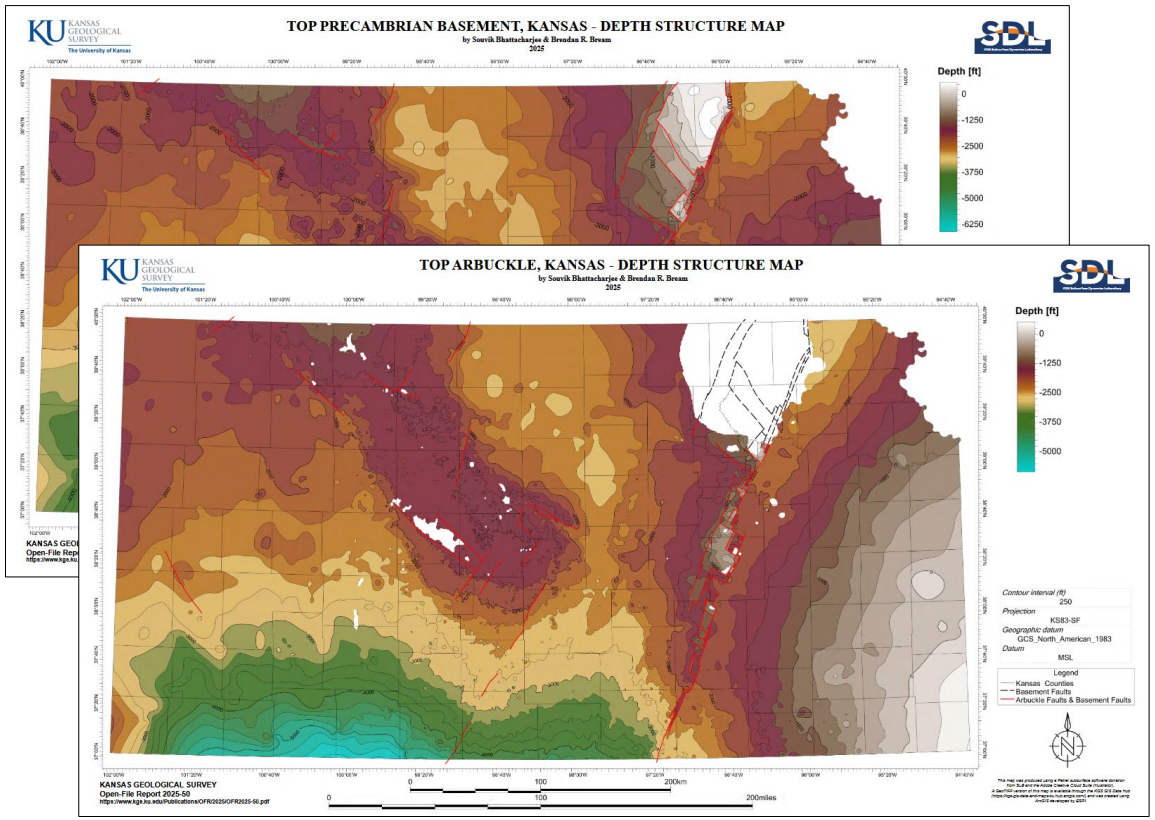
Static and dynamic resource evaluation

KS Borders to Basement Project

- **Phase 1** key *resource* surfaces planned between top of Precambrian basement and lower Pennsylvanian by 2028.
- **Phase 2** develop key surfaces that intersect with outcrops in the state (lower Pennsylvanian to present Quaternary).
- Statewide coverage of key stratigraphic surfaces
- Models will include rock properties like total porosity



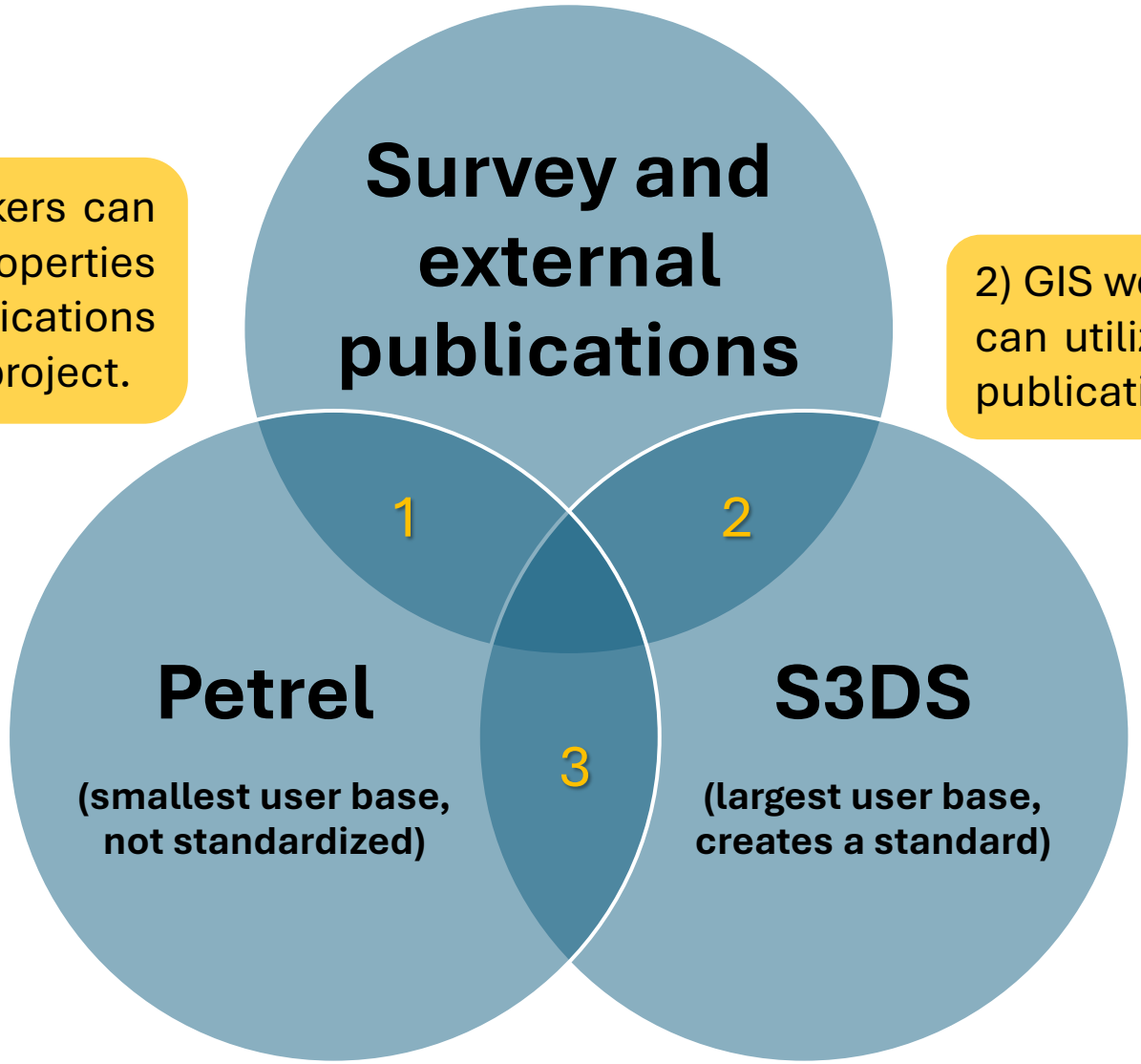
First surfaces: KGS OFRs 2025-49 and 2025-50



Bhattacharjee and Bream, 2025a&b

How should KGS distribute subsurface models?

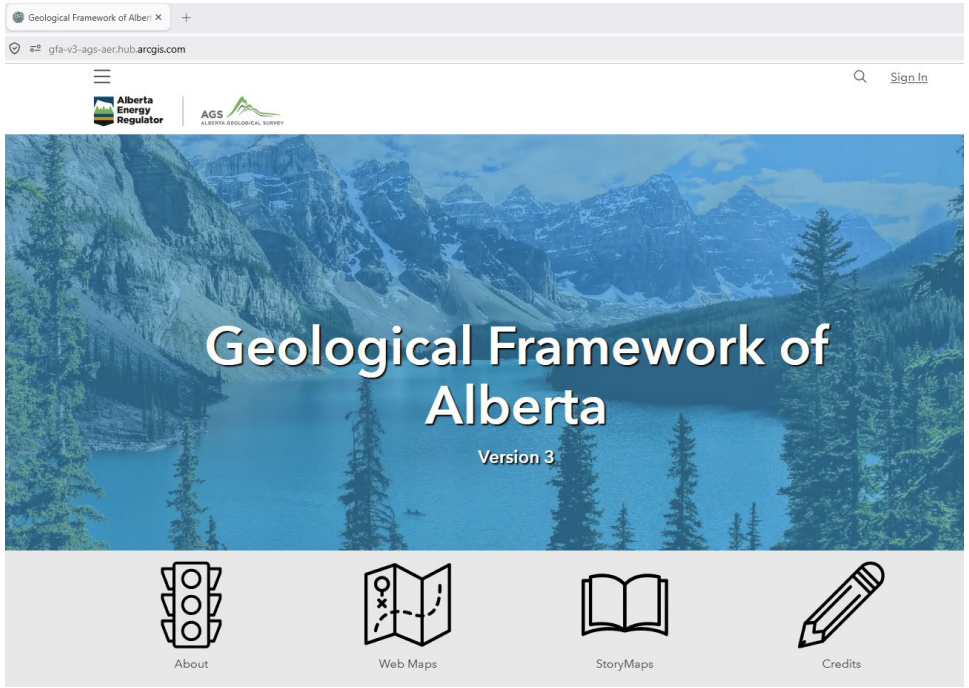
1) Industry workers can utilize rock properties reported in publications from the Petrel project.

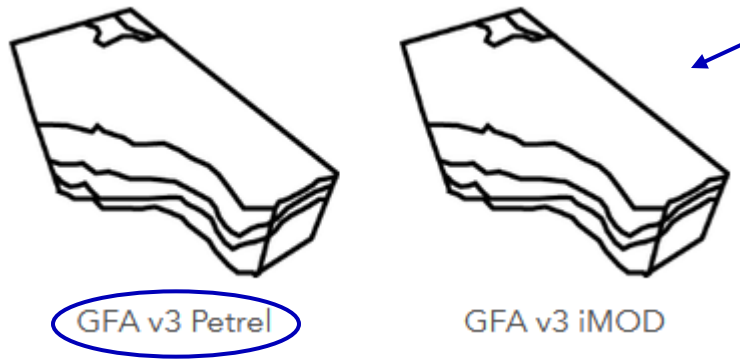


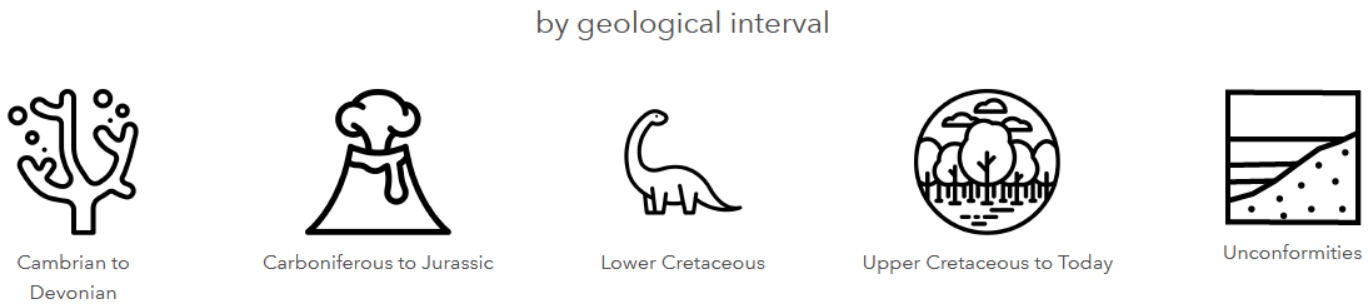
2) GIS workers and students can utilize digital data from publications via S3DS.

3) Petrel and S3DS must have shared metadata, naming conventions, and standards.

Building on Alberta's example…but with faults





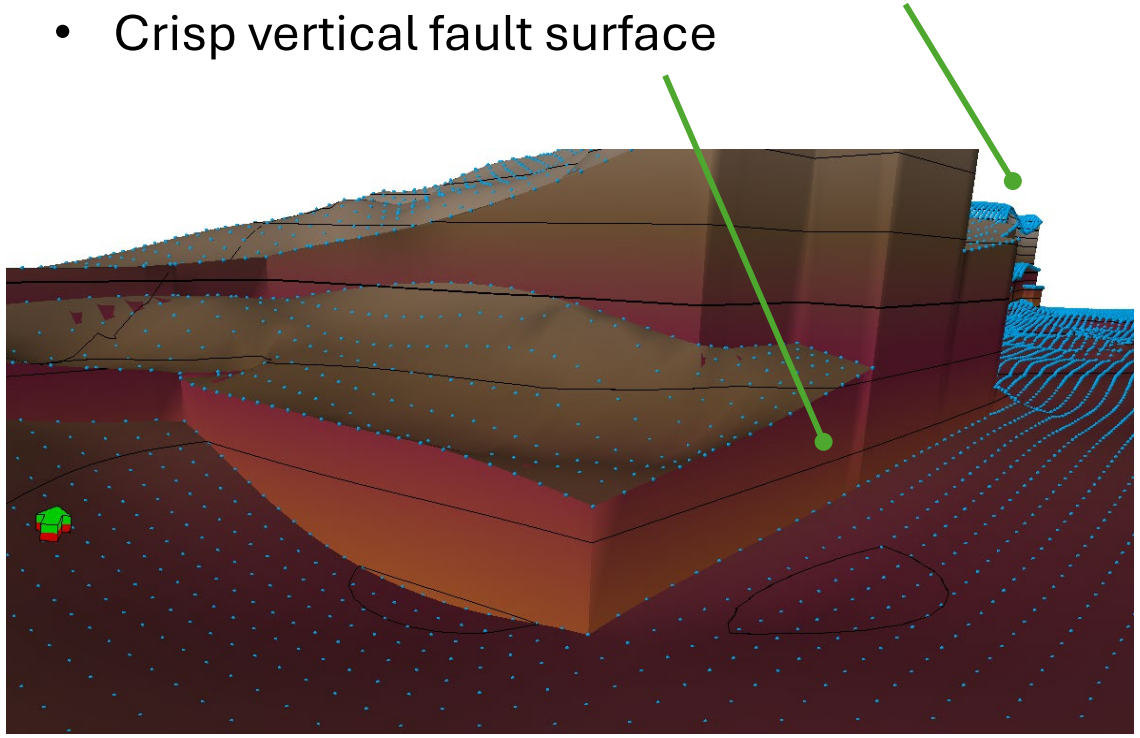


Alberta Geological Survey, 2025, 3D Geological Framework Project ArcGIS Hub

A complex faulted framework is best shown in multi-z

All points and volumetric modeling are honored in multi-z surfaces

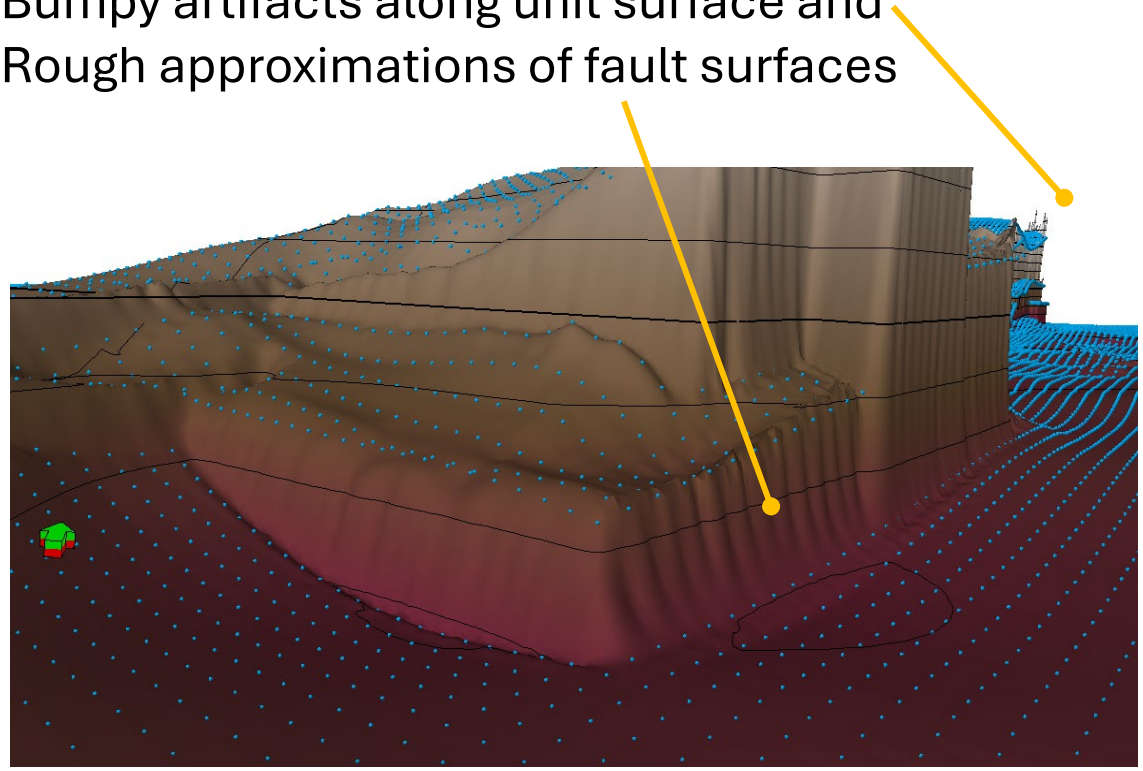
- Topographically smooth unit surface
- Crisp vertical fault surface



A) Multi-z model surface

Surfaces resampled to single-z nodes create

- Bumpy artifacts along unit surface and
- Rough approximations of fault surfaces



B) Single-z model surface

KGS Subsurface Data Layers

Inputs + Reference = Model outputs

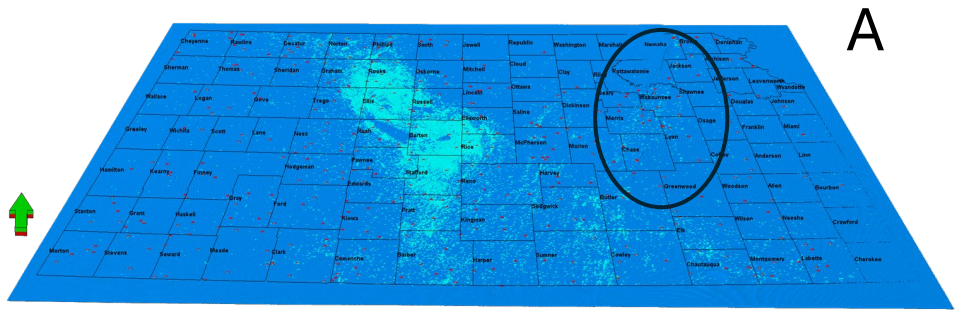
KGS Oil and Gas Database
Well Top Interpretations

Filtered unit well tops

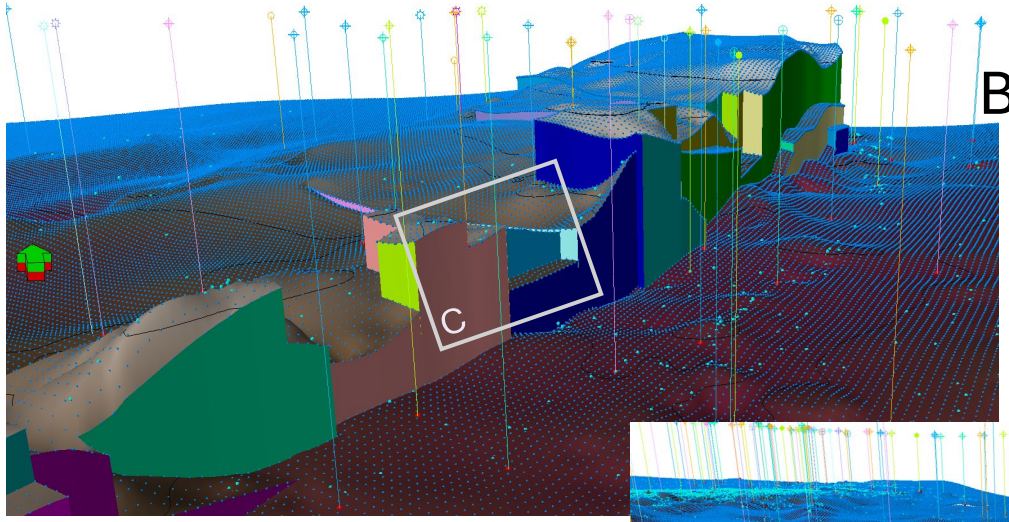
Well log analysis

Model control tops

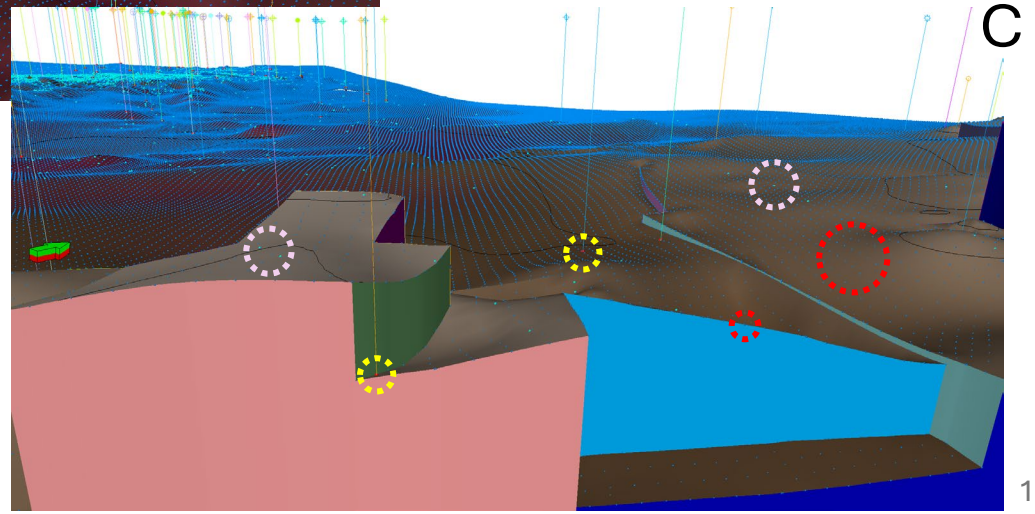
Isochore points



All three point data sets for Arbuckle, together.



B and C are views of the inputs with the final Arbuckle top surface model. Both views include vertical faults, Arbuckle wells extending from the ground surface to the unit top elevation, and the points marking the top unit elevations.

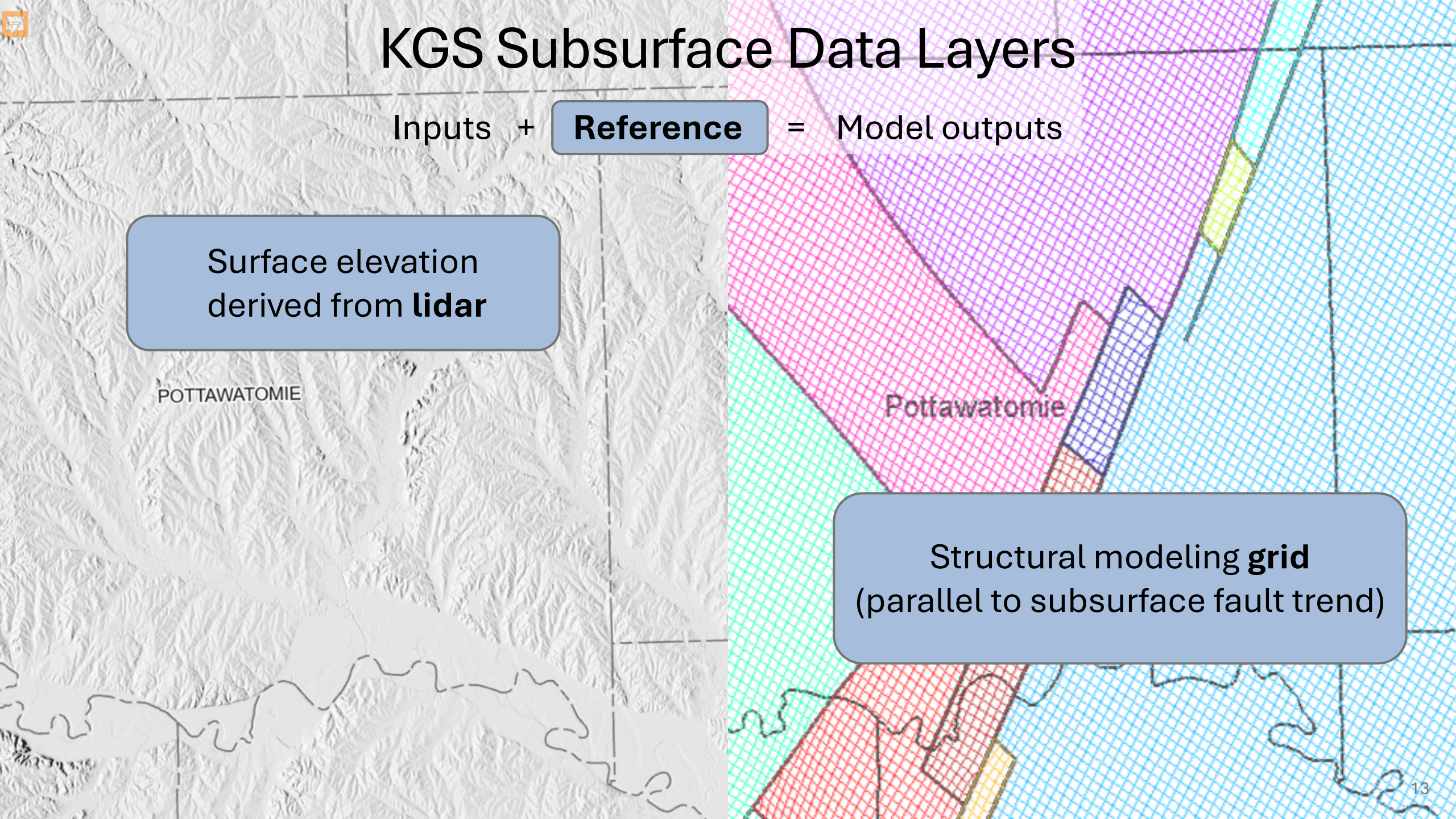


Red circle – grid nodes
Yellow circle – well tops backed by well logs
Pink circle – well tops from KGS database

KGS Subsurface Data Layers

Inputs + **Reference** = Model outputs

Surface elevation derived from **lidar**



Structural modeling **grid** (parallel to subsurface fault trend)

KGS Subsurface Data Layers

Inputs + Reference = **Model outputs**

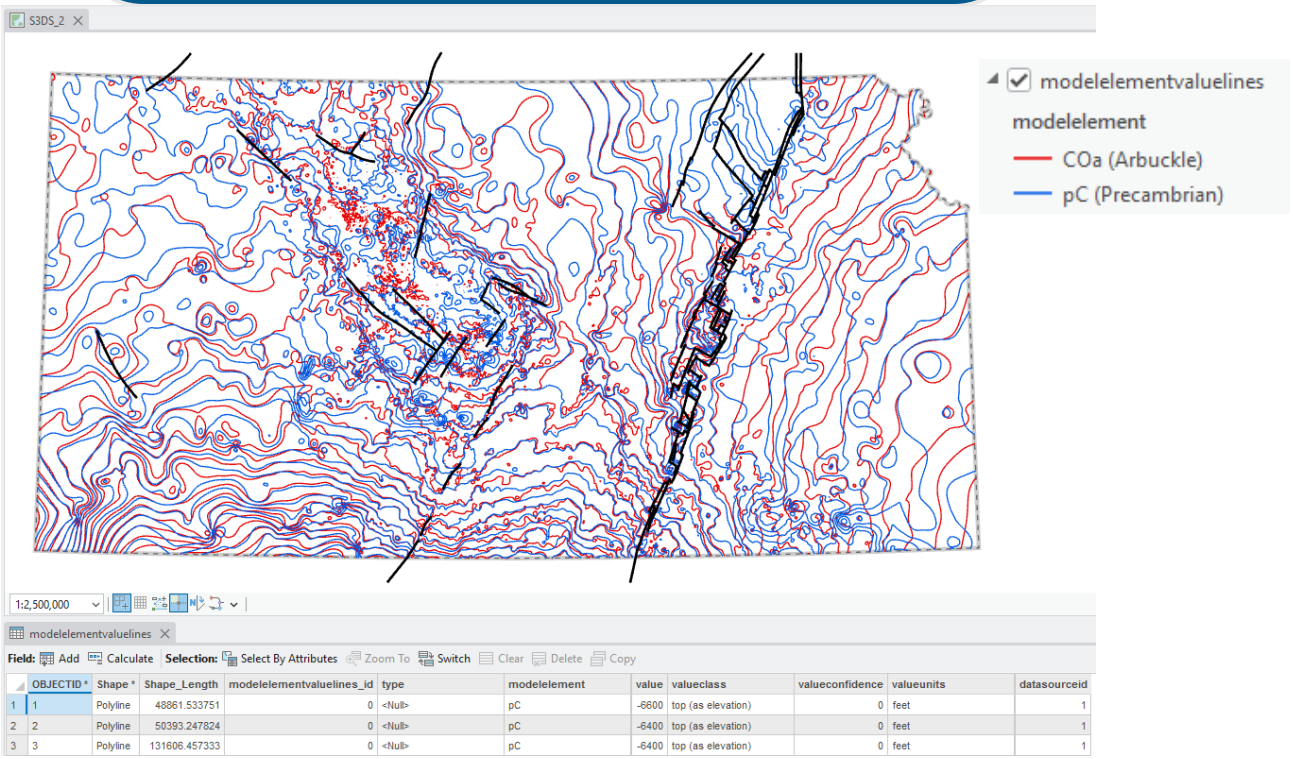
✓ Standard

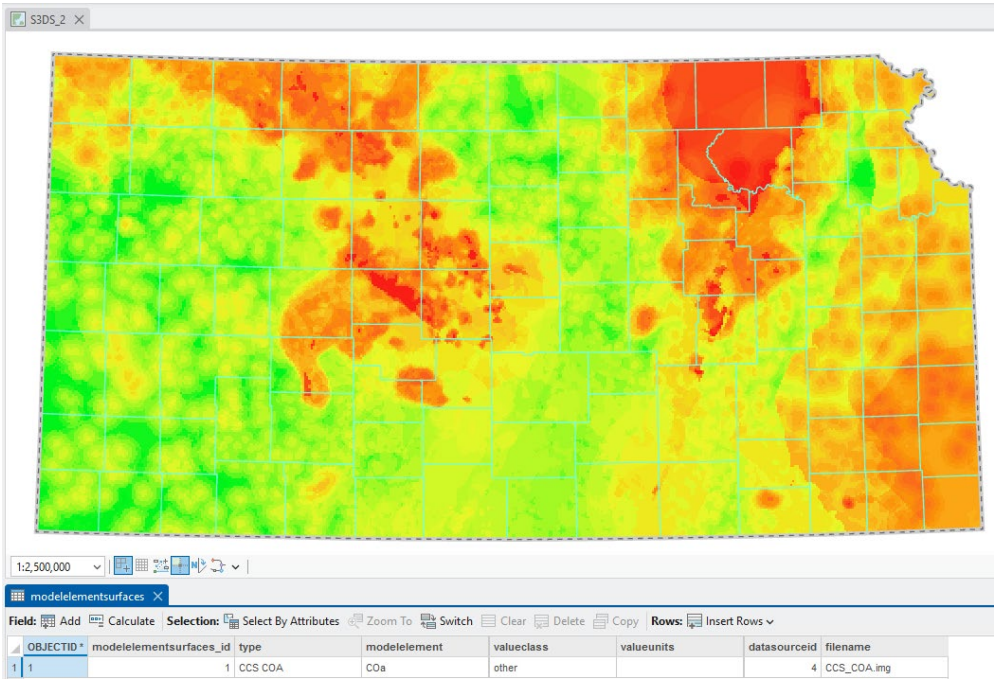
❑ Optional/derivatives

✓ Vector surfaces

(depth wrt MSL)

- Top/Base faulted framework grid points
- Top/Base 200-ft contour lines
- Isochore contour lines or grid points
- Fault horizon lines
- Polygons where unit is absent





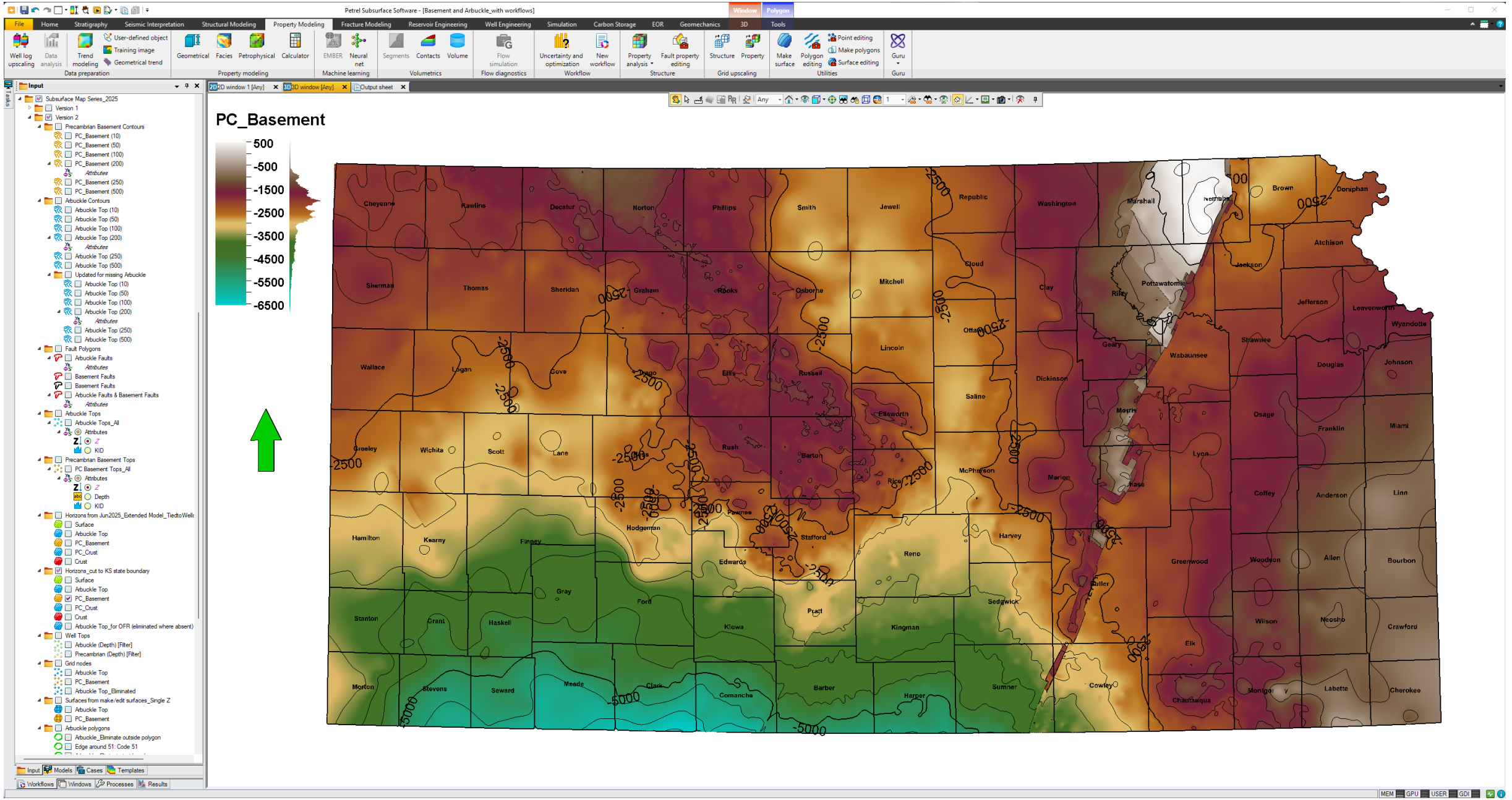
❑ Raster surfaces

- Depth below topo surface
- Dip angle/azimuth
- Gamma ray thickness
- Thickness between unit surfaces
- Rock properties (porosity, etc.)
- Resource potential

Software comparison

	Data	Geologic applications	Training	Customization
SLB Petrel	Resides within the project.	Serves the subsurface energy industry Natively 3D for subsurface work Geologic resource simulation built in Can rotate the model grid parallel to most of the faults (w/ structural grain)	Steep learning curve; difficult to obtain product support. Can get a costly consultation for org.	Can create no-code workflows. Must coordinate with SLB to create plug-ins.
Esri ArcGIS	Accessed from files outside of the project file.	Geology is one of many industries. Data display, interpolation, and volumetric processing is possible but requires more user problem solving for complex geology.	Resources for learning are readily available and are often free.	Processes can be scripted in no-code, low-code, and application programming methods.

A peek inside a Petrel project...



Moving data from Petrel to the S3DS database

Top/base of unit

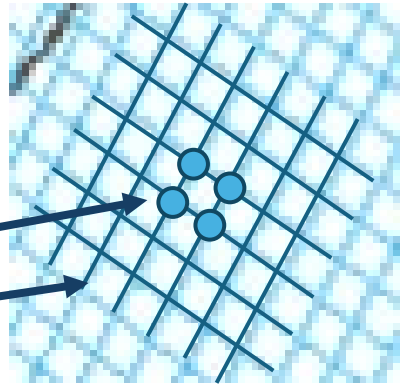
- Subsurface Map Series_2025
  - Version 1
  - Version 2
    - Precambrian Basement Contours
    - Arbuckle Contours
    - Fault Polygons
    - Arbuckle Tops
    - Precambrian Basement Tops
    - Horizons from Jun2025_Extended Model_TiedtoWells
    - Horizons_cut to KS state boundary
    - Well Tops
    - Grid nodes
    - Surfaces from make/edit surfaces_Single Z
    - Arbuckle polygons

Contour interval = 200 feet

- PrecambrianArbuckle_s3ds2.gdb
  - datasources
  - descriptionofmodelelements
  - deviatedboreholepicks
  - deviatedboreholetracks
  - glossary
  - kgswelltopconfidencedict
  - measurementunits
  - modelelementsurfaces
  - modelelementvaluelines
  - modelelementvaluepoints
  - novaluelines
  - novaluepolys
  - valueclassdict
  - verticalboreholepicks
  - verticalboreholepoints

Top of unit elevation points (2,000 x 2,000 feet)

Along the model grid "skeleton"



Moving data from Petrel to the S3DS database

Top/base of unit

descriptionofmodelelements

Field: Add Calculate | Selection: Select By Attributes Zoom To Switch Clear Delete Copy | Rows: Insert Rows

		modelelement	name	age	description	hierarchykey	datasourceid	descriptionofmodelelements_id
1	2	pC	Precambrian basement	Precambrian	The Precambrian basement in Kansas includes the following lithologies: metasedimentary rocks, mostly quartzite and associated muscovite schist, but including other schistose rocks and amphibolite, metamorphic grade vairable; granitic to quartz-monzonitic intrusive rocks, typically mesozonal, cataclastic to extensively sheared textures are common, 1.45 to 1.7 billion years in age; ryholitic to dacitic volcanic rocks, many are ash--flow tuff b…	1-0	7	1
2	3	faults	Basement faults	Precambrian-Ordovician	The faults in the model are built based on a minimum vertical separation of greater than 200 ft between top Arbuckle and/or Precambrian basement well tops from the KGS database. The horizontal distance between well tops that define a fault varies depending on the magnitude of the fault offset but is generally less than 10,000 feet laterally.	2-0	2	2
3	4	COa	Arbuckle Group	Cambrian-Ordovician	The Arbuckle Group consists of Upper Cambrian and Lower Ordovician deposits. The lithology mostly consists of white, buff, light-gray, cream, and brown crystalline dolomite; chert is common in the upper part.	3-0	8	3

0 of 3 selected

datasources

Field: Add Calculate | Selection: Select By Attributes Zoom To Switch Clear Delete Copy | Rows: Insert Rows

		source	url	methoddescription	notes	datasources_id
1	2	Bhattacharjee and Bream, 2025a	https://www.kgs.ku.edu/	Precambrian basement well tops from the KGS Oil and Gas Wells database imported in Petrel as point data with X, Y, and Z coordinates (n= about 5,000). Precambrian basement well tops (a subset of the KGS database) associated with about 400 wells with wireline logs were selected. The geocellular mo…	Suggested citation: Bhattacharjee, S., and Bream, B. R., 2025, Top Precambrian Basement, Kansas – Depth Structure Map: Kansas Geological Survey OFR 2025-49, 3 p.	1
2	3	Bhattacharjee and Bream, 2025b	https://www.kgs.ku.edu/	Arbuckle well tops from the KGS Oil and Gas Wells database imported in Petrel as point data with X, Y, and Z coordinates (n= about 62,000). Arbuckle well tops (a subset of the KGS database) associated with about 400 wells with wireline logs were selected. The geocellular model horizons are tied to thes…	Suggested citation: Bhattacharjee, S., and Bream, B. R., 2025, Top Arbuckle, Kansas – Depth Structure Map: Kansas Geological Survey OFR 2025-50, 3 p.	2
3	4	KGS, 2025	https://www.kgs.ku.edu/	Kansas oil and gas well repository database.	<Null>	3
4	5	Bhattacharjee et al., in review	<Null>	The carbon capture and storage potential chance of adequacy map (CCS_COA.img raster) methodology is described in this paper.	Bhattacharjee, S., Bream, B. R., White, M., and Gumble, J., in review, Importance of regional evaluations in support of Class VI well applications: An example from the Arbuckle Group of Kansas.	4
5	6	Baars, 1995	https://www.kgs.ku.edu/	Previous study of the Kansas Precambrian basement. Referenced in construction of faults for this report.	Baars, D. L., 1995, Basement tectonic configuration in Kansas: Kansas Geological Survey Bulletin, v. 237, p. 7-9.	5
6	7	Cole, 1976	https://www.kgs.ku.edu/	Previous study of wells and construction of the top of the Kansas Precambrian basement.	Cole, V. B., 1976, Configuration of the top of the Precambrian rocks in Kansas: Kansas Geological Survey, Map M-7, scale 1:500,000.	6
7	8	Bickford et al., 1979	https://www.kgs.ku.edu/	Previous study of the Kansas Precambrian basement. Used in DescriptionOfModelElements for lithologic description of pC unit.	Bickford, M.E., Harrower, K.L., Nusbaum, R.L., Thomas, J.J., and Nelson, G.E., 1979, Preliminary geologic map of the Precambrian basement rocks of Kansas: Kansas Geological Survey, Map Series, no. M-9, 1 sheet, scale 1:500,000.	7
8	9	Zeller (ed.), 1968	https://www.kgs.ku.edu/	Accepted handbook of Kansas stratigraphic nomenclature. Used in DescriptionOfModelElements for lithologic description of COa unit.	Ordovician System, in, Zeller, D.E., (ed.), The stratigraphic succession in Kansas: Kansas Geological Survey, Bulletin, no. 189, pp. 14-15. and Cambrian System, in, Zeller, D.E., (ed.), The stratigraphic succession in Kansas: Kansas Geological Survey, Bulletin, no. 189, pp. 11-13.	8

Moving data from Petrel to the S3DS database

Multi-z poses a challenge when distributing to other software

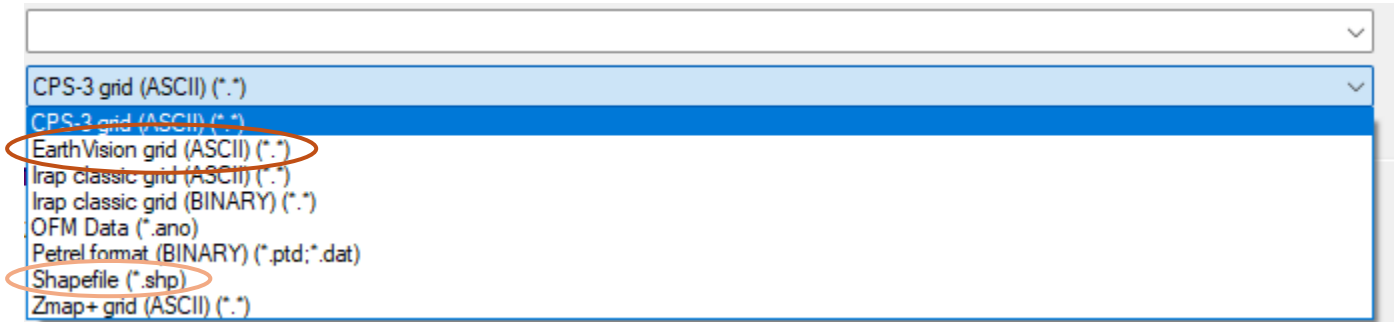
Can modify in text editor to import to ArcGIS Pro via **ASCII 3D To Feature Class** tool

Hello, old friend…

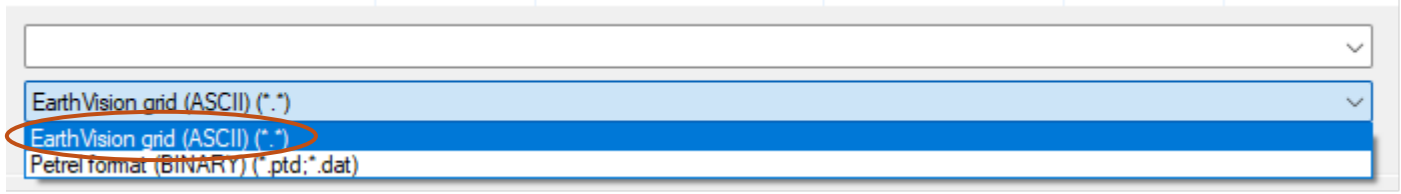
Can import Zmap to ArcGIS with Exprodat Data Assistant

Needs further testing…

Petrel output file formats for *single-z*

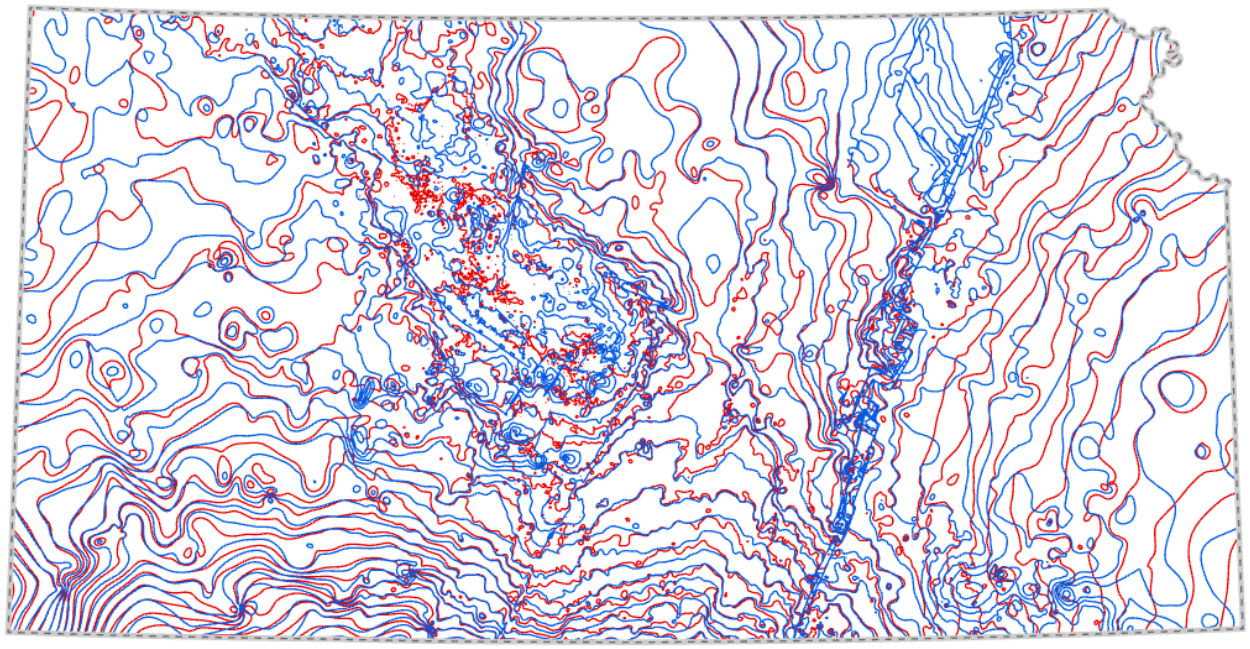


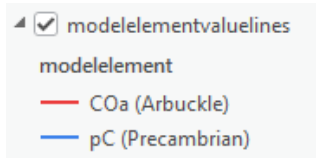
Petrel output file formats for *multi-z*



Moving data from Petrel to the S3DS database

Top/base of unit





1:2,500,000 2,319,878.47 1,419,270.83 ftUS

modelelementvaluelines

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2	2	Polyline	4	<Null>	pC	-6400	top (as elevation)	<Null>	feet	1	2
3	3	Polyline	3	<Null>	pC	-6400	top (as elevation)	<Null>	feet	1	3
4	4	Polyline	8	<Null>	pC	-6200	top (as elevation)	<Null>	feet	1	4
5	5	Polyline	4	<Null>	pC	-6000	top (as elevation)	<Null>	feet	1	5
6	6	Polyline	9	<Null>	pC	-6000	top (as elevation)	<Null>	feet	1	6
7	7	Polyline	6	<Null>	pC	-5800	top (as elevation)	<Null>	feet	1	7
8	8	Polyline	8	<Null>	pC	-5800	top (as elevation)	<Null>	feet	1	8
9	9	Polyline	5	<Null>	pC	-5600	top (as elevation)	<Null>	feet	1	9

0 of 1,649 selected

descriptionofmodelelements

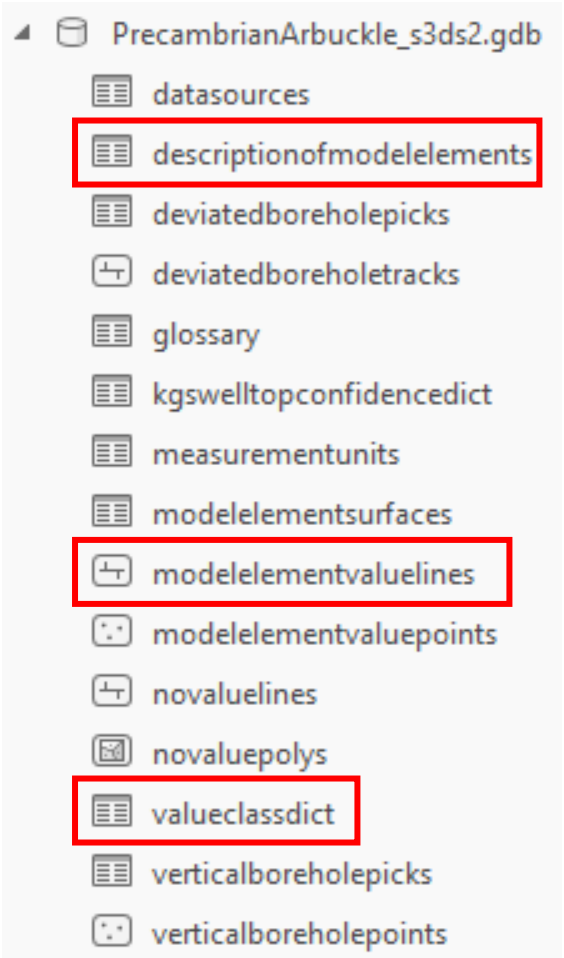
Field: Selection: Rows: Insert Rows

	..	modelelement	name	age	description	hierarchykey
1	2	pC	Precambrian basement	Precambrian	The Precambrian...	1-0
2	3	faults	Basement faults	Precambrian-Ordovician	The faults in the...	2-0
3	4	COa	Arbuckle Group	Cambrian-Ordovician	The Arbuckle Gro...	3-0
		Click to add new row.				

valueclassdict

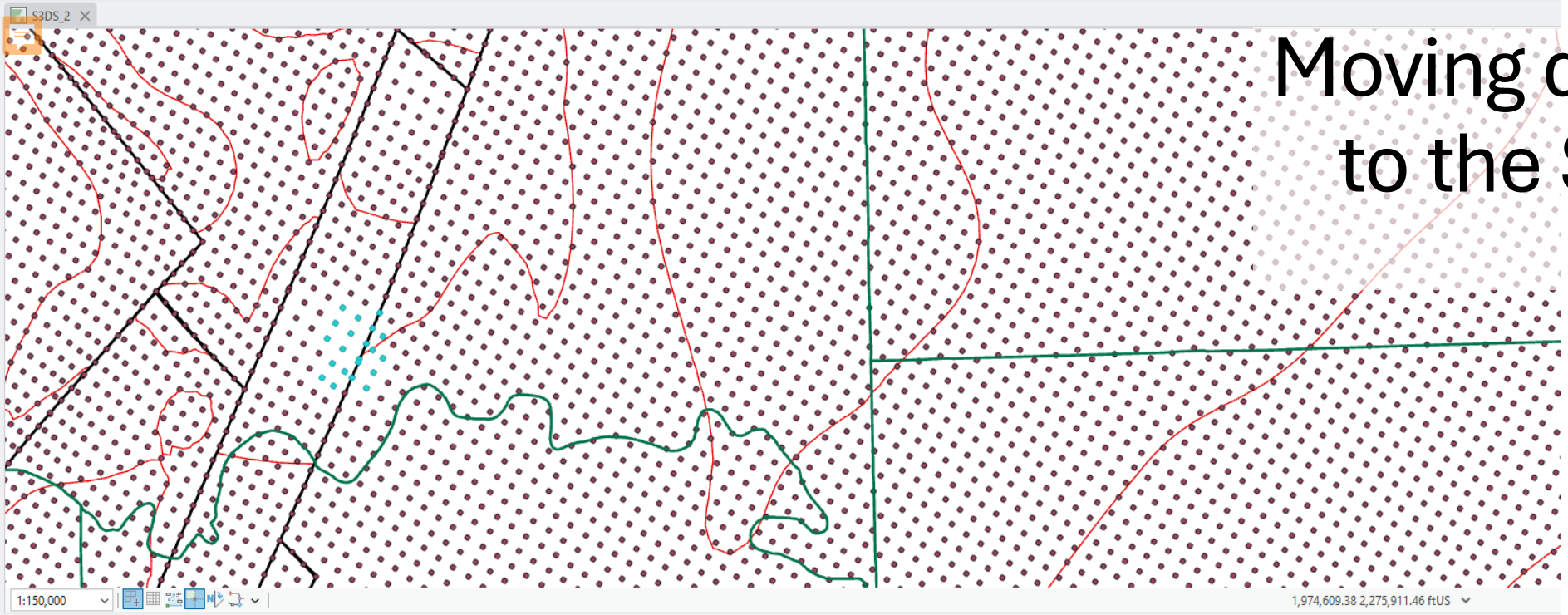
Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy Rows: Insert Rows

	O..	valueclassdict_id	valueclass	hierarchykey	definition
1	1	1	<Null>	01	Measurements of geologic bodies.
2	2	2	<Null>	01.01	Top: the uppermost bounding surface of a geologic entity.
3	3	3	top (as elevation)	01.01.01	The top of a geologic entity measured as elevation above sea level.
4	4	4	top (as depth)	01.01.02	The top of a geologic entity measured as distance below land surface.



Moving data from Petrel to the S3DS database

Top/base of unit



modelelementvaluelines | modelelementvaluepoints

Field: Add Calculate | Selection: Select By Attributes Zoom To Switch Clear Delete Copy | Highlighted: Unselect Reselect Zoom To Switch Clear Delete Copy

	..	Shape *	type	modelelement	value	valueclass	valueconfidence	valueunits	datasourceid	modelelementvaluepoints_id
1	5	Point	<Null>	pC	-880	top (as elevation)	<Null>	feet	1	575823
2	5	Point	<Null>	pC	-873	top (as elevation)	<Null>	feet	1	575824
3	5	Point	<Null>	pC	-892	top (as elevation)	<Null>	feet	1	576457
4	5	Point	<Null>	pC	-886	top (as elevation)	<Null>	feet	1	576458
5	5	Point	<Null>	pC	-880	top (as elevation)	<Null>	feet	1	576459
6	5	Point	<Null>	pC	-2021	top (as elevation)	<Null>	feet	1	576460
7	5	Point	<Null>	pC	-2053	top (as elevation)	<Null>	feet	1	576461
8	5	Point	<Null>	pC	-911	top (as elevation)	<Null>	feet	1	577088
9	5	Point	<Null>	pC	-904	top (as elevation)	<Null>	feet	1	577089

27 of 662,712 selected | 0 of 27 highlighted

modelelementvaluepoints
County
Faults
modelelementvaluelines
modelelement
COa (Arbuckle)
pC (Precambrian)

descriptionofmodelelements

Field: Selection: Rows: Insert Rows

	..	modelelement	name	age	description	hierarchykey
1	2	pC	Precambrian basement	Precambrian	The Precambrian...	1-0
2	3	faults	Basement faults	Precambrian-Ordovician	The faults in the...	2-0
3	4	COa	Arbuckle Group	Cambrian-Ordovician	The Arbuckle Gro...	3-0

Click to add new row.

valueclassdict

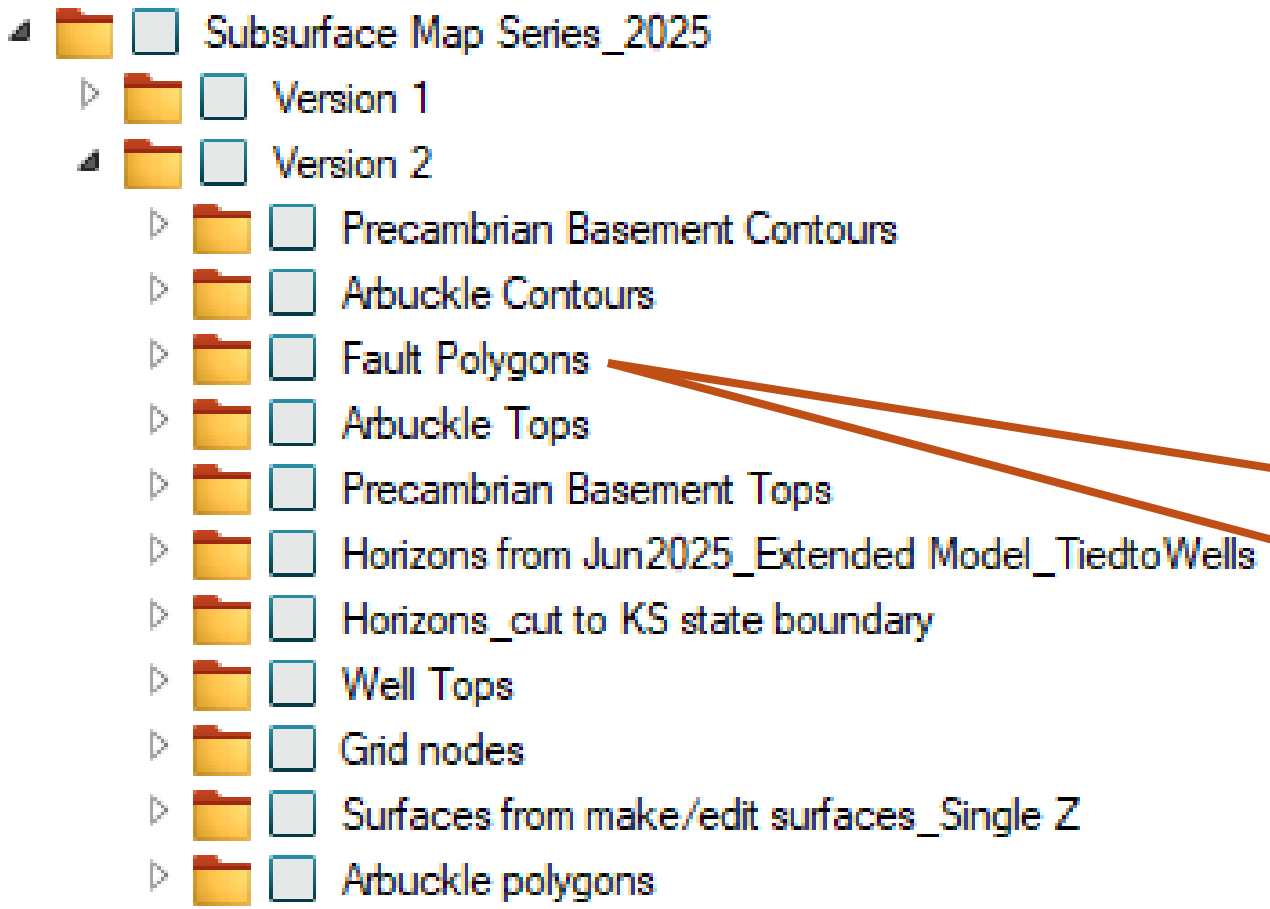
Field: Add Calculate | Selection: Select By Attributes Zoom To Switch Clear Delete Copy | Rows: Insert Rows

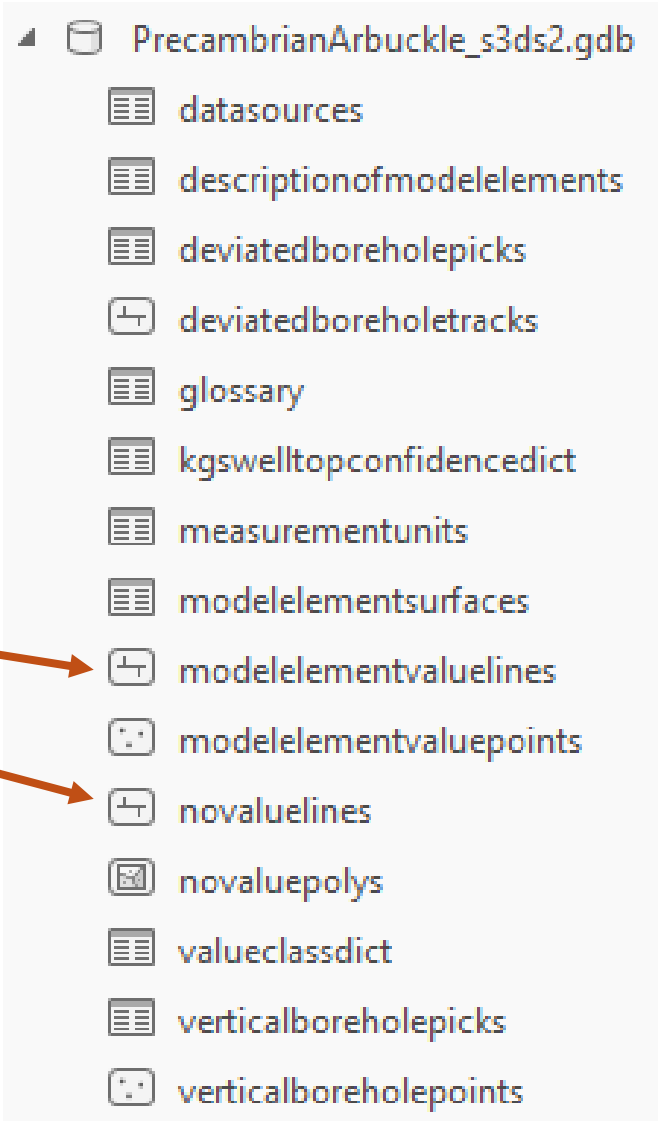
	O..	valueclassdict_id	valueclass	hierarchykey	definition
1	1	1	<Null>	01	Measurements of geologic bodies.
2	2	2	<Null>	01.01	Top: the uppermost bounding surface of a geologic entity.
3	3	3	top (as elevation)	01.01.01	The top of a geologic entity measured as elevation above sea level.
4	4	4	top (as depth)	01.01.02	The top of a geologic entity measured as distance below land surface.

PrecambrianArbuckle_s3ds2.gdb
- datasources
- descriptionofmodelelements
- deviatedboreholepicks
- deviatedboreholetracks
- glossary
- kgswelltopconfidencedict
- measurementunits
- modelelementsurfaces
- modelelementvaluelines
- modelelementvaluepoints
- novaluelines
- novaluepolys
- valueclassdict
- verticalboreholepicks
- verticalboreholepoints

Moving data from Petrel to the S3DS database

Faults



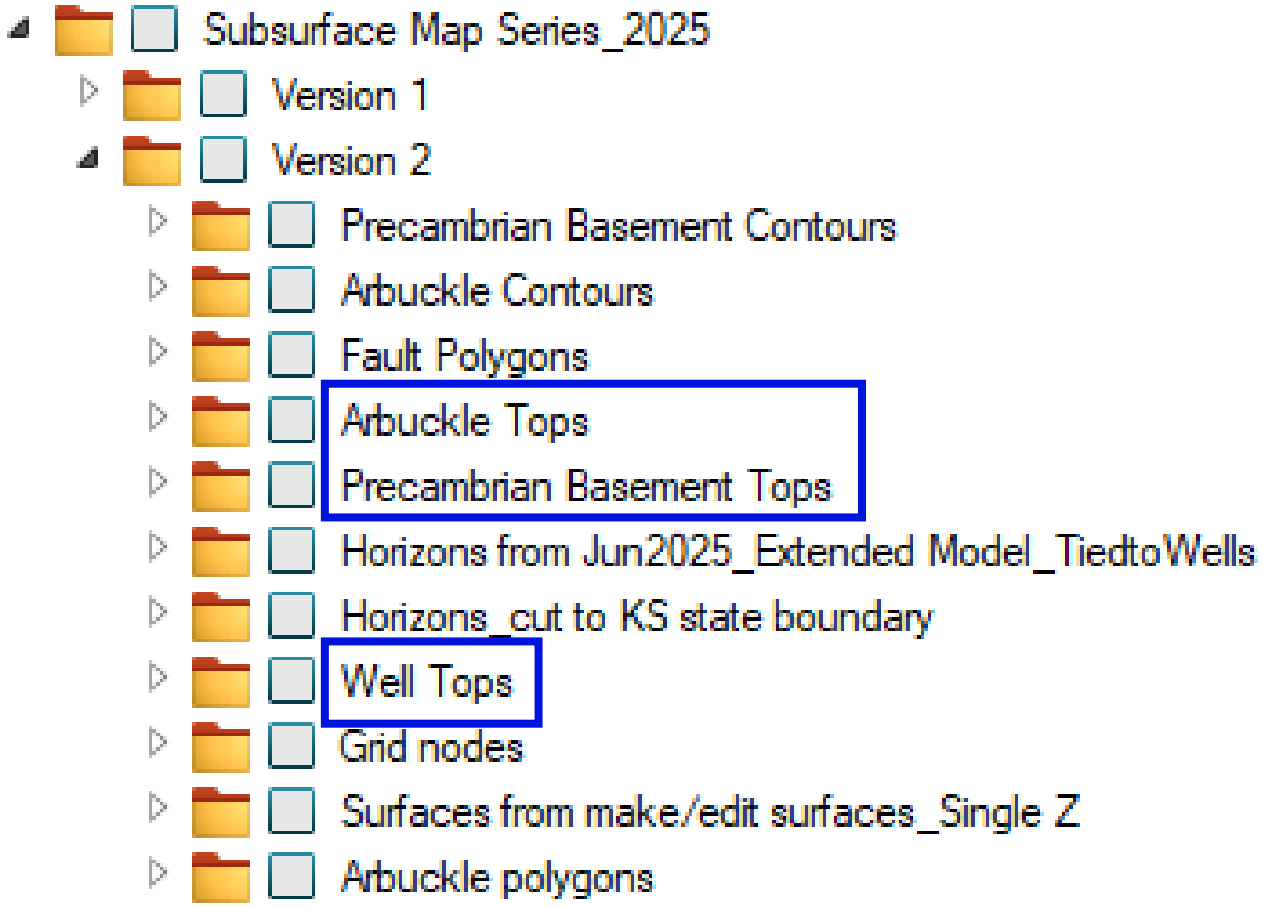


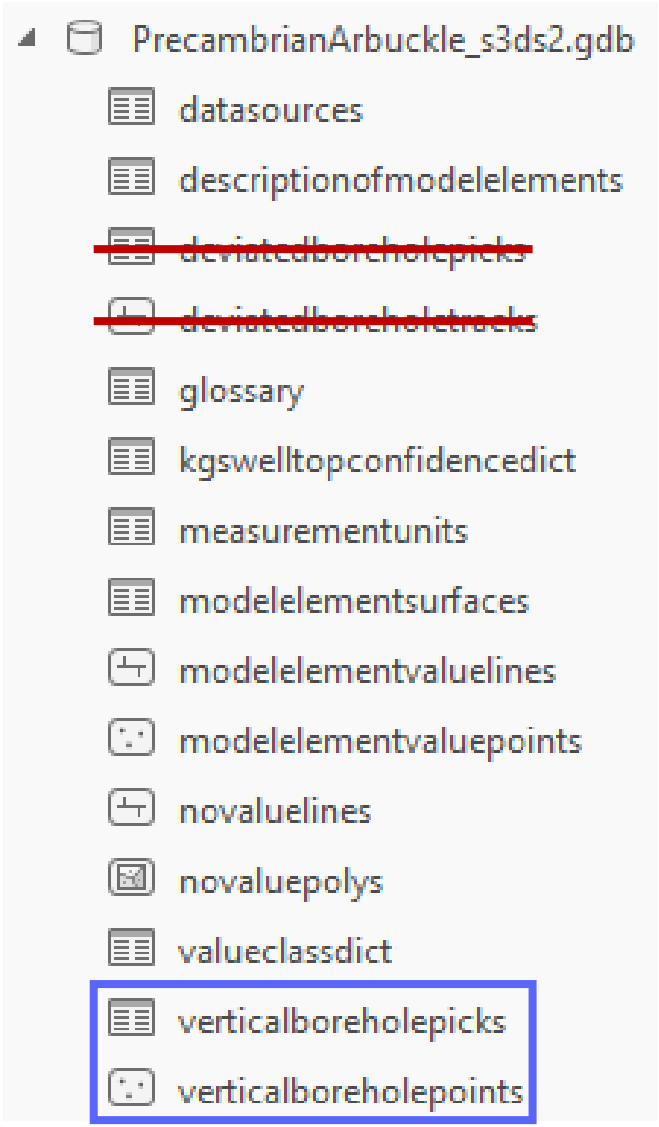
Still considering...

Value = z (elevation), but faults are lens shaped
novaluelines would tie fault lens to model element (unit)

Moving data from Petrel to the S3DS database

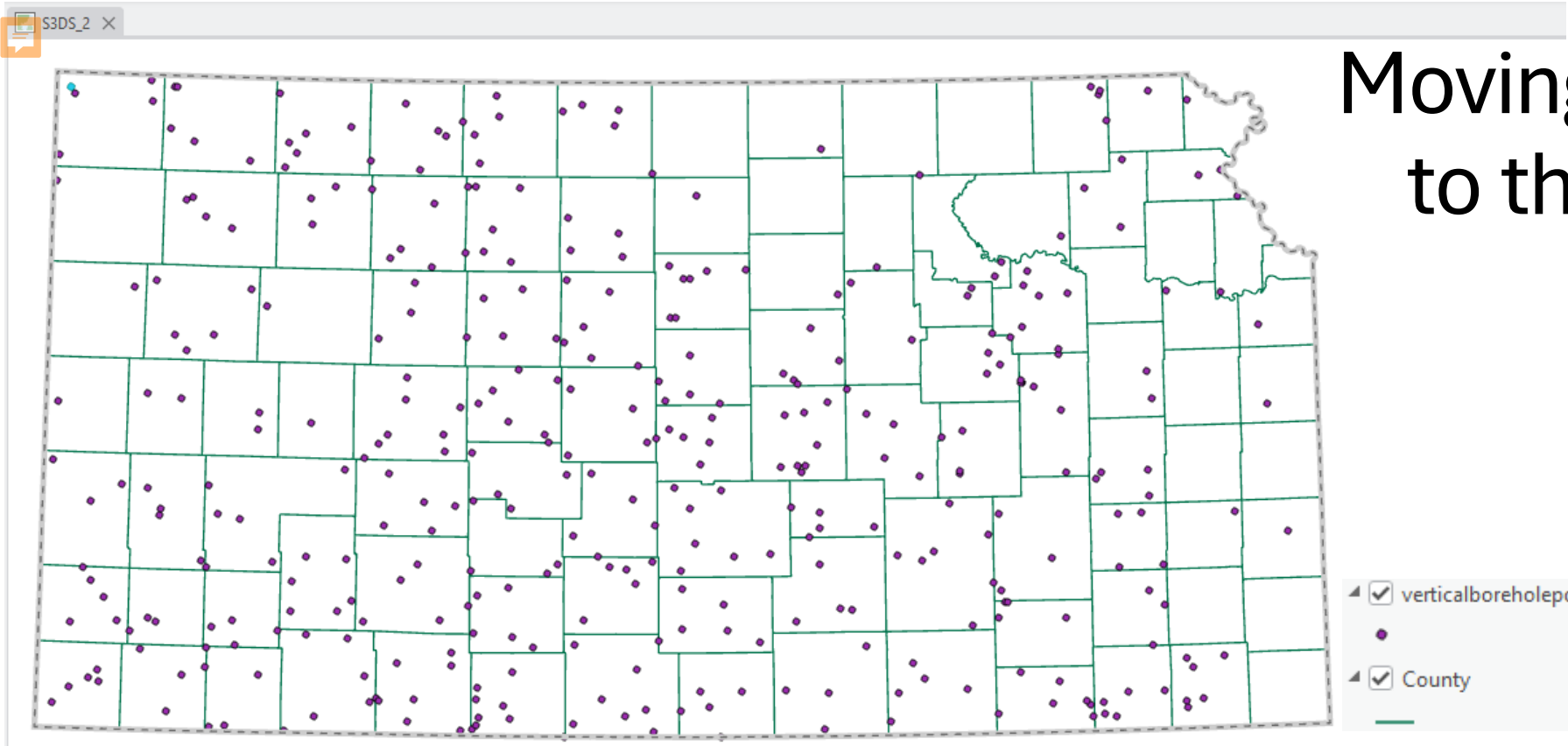
Inputs: well tops





Moving data from Petrel to the S3DS database

Inputs: well tops



verticalboreholepoints

Field: Add | Calculate | Selection: Select By Attributes | Zoom To | Switch | Clear | Delete | Copy

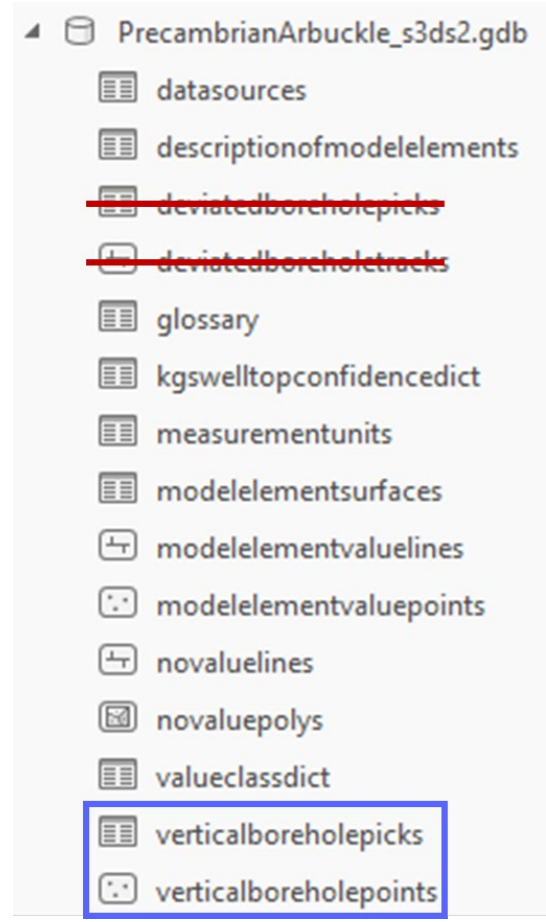
	..	Shape	verticalboreholepoints_id	type	borehole_identifier	datasourceid	totaldepth	totaldepthunits	Lease	API	SurfaceElevation
15	1	Point	1002954610	Model control well	1002954610	3	11300	feet	NOEL POERSCH	15-201-20003	1389.3483
16	1	Point	1006030846	Model control well	1006030846	3	5665	feet	A. M. PALMER	15-023-30009	3594.0009
17	1	Point	1006037795	Model control well	1006037795	3	5467	feet	SCHULTZ 'G'	15-047-20712	2067.2734
18	1	Point	1006051872	Model control well	1006051872	3	5778	feet	SCHLEGEL	15-055-20389	2682.1738
19	1	Point	1006052147	Model control well	1006052147	3	7044	feet	USA 'A'	15-055-20536	3035.5647

1 of 377 selected

verticalboreholepicks

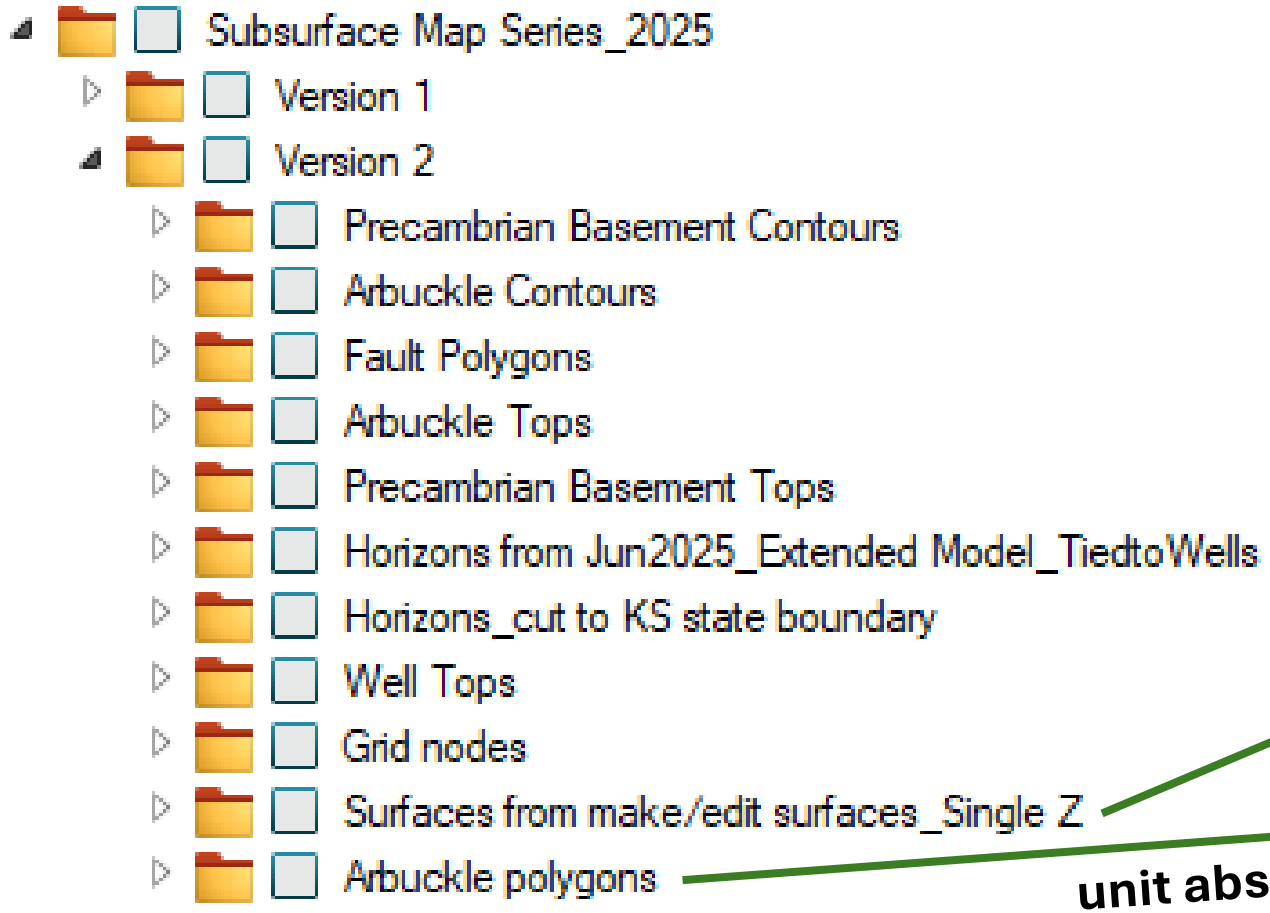
Field: Add | Calculate | Selection: Select By Attributes | Zoom To | Switch | Clear | Delete | Copy | Highlighted: Unselect | Reselect | Zoom To | Switch | Clear | Delete | Cop

	O...	verticalboreholepointsid	type	value	modelelement	valueclass	valueconfidence	valueunits	kgswelltopconfidence	datasourceid	MesuredDepth	verticalboreholepicks_id
1	15	1006030846	Model control well top	-2062	pC	top (as elevation)	<Null>	feet	4	1	5660	15
2	85	1006030846	Model control well top	-1928	COa	top (as elevation)	<Null>	feet	4	2	5526	85



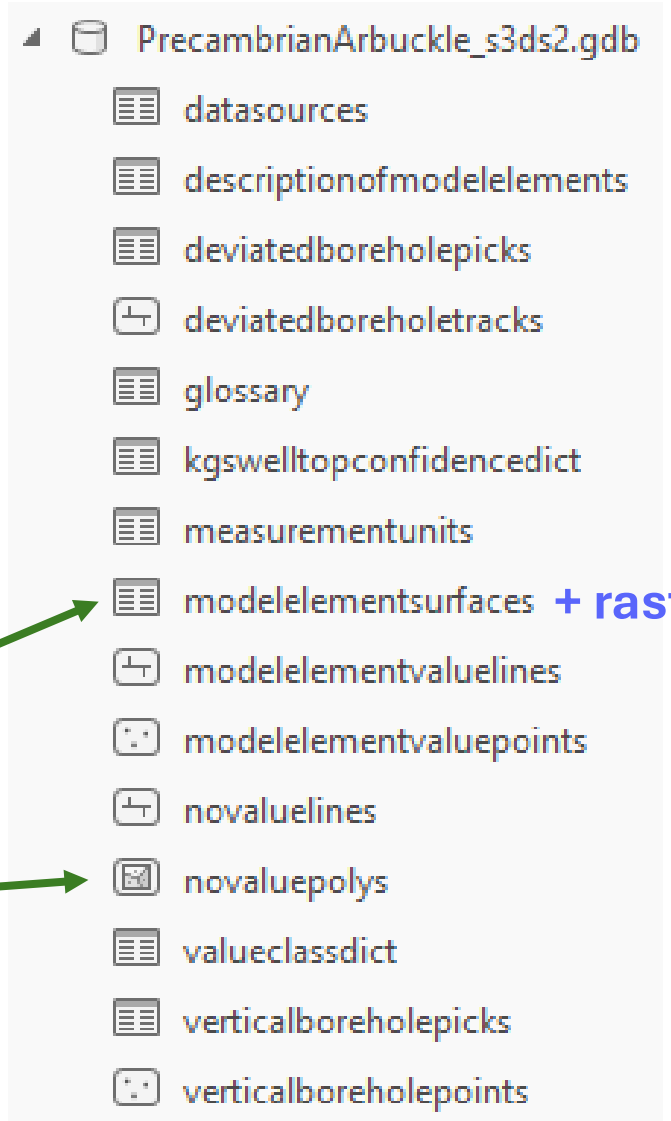
Moving data from Petrel to the S3DS database

Extras



derivatives

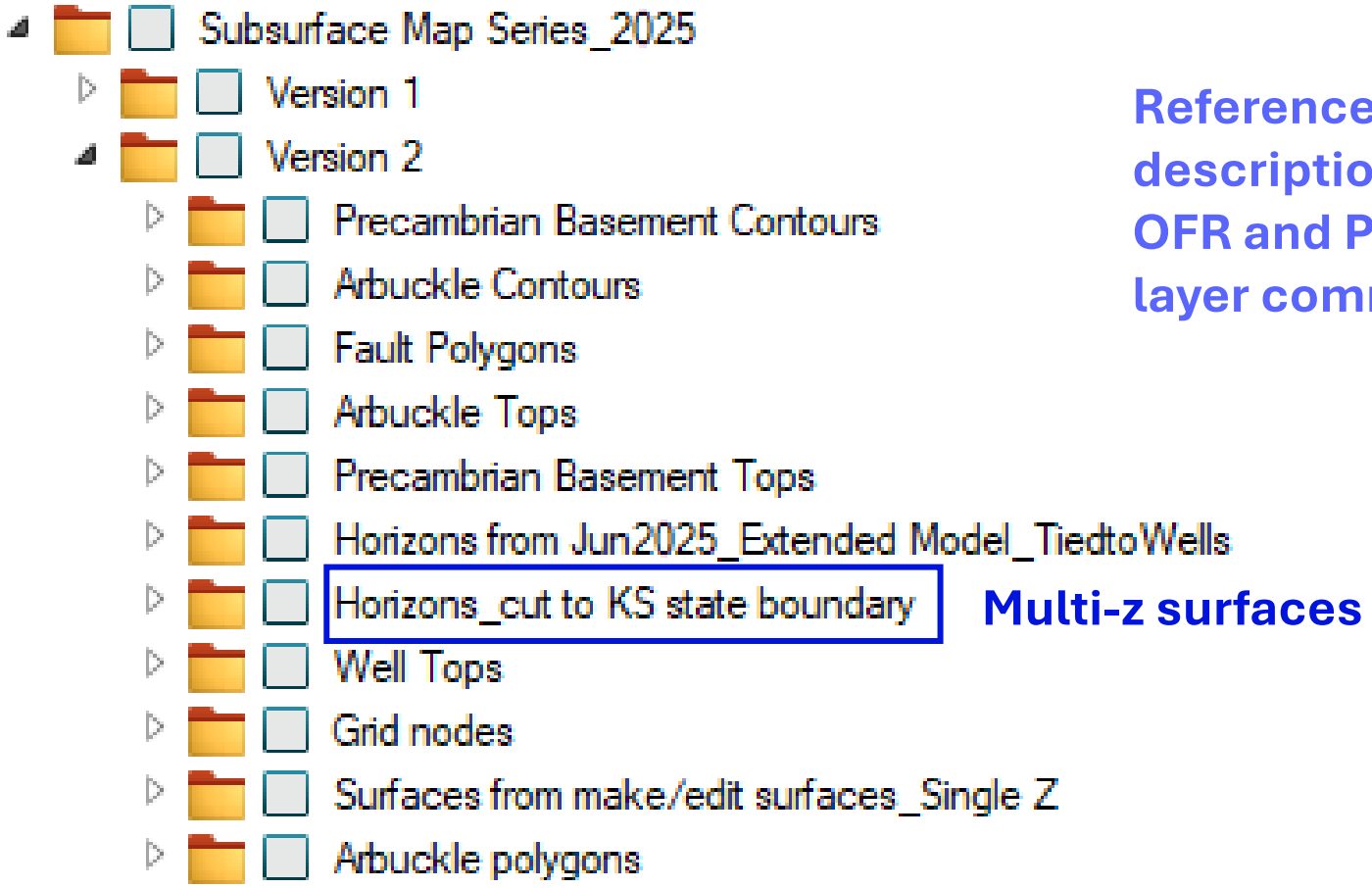
unit absent



+ rasters

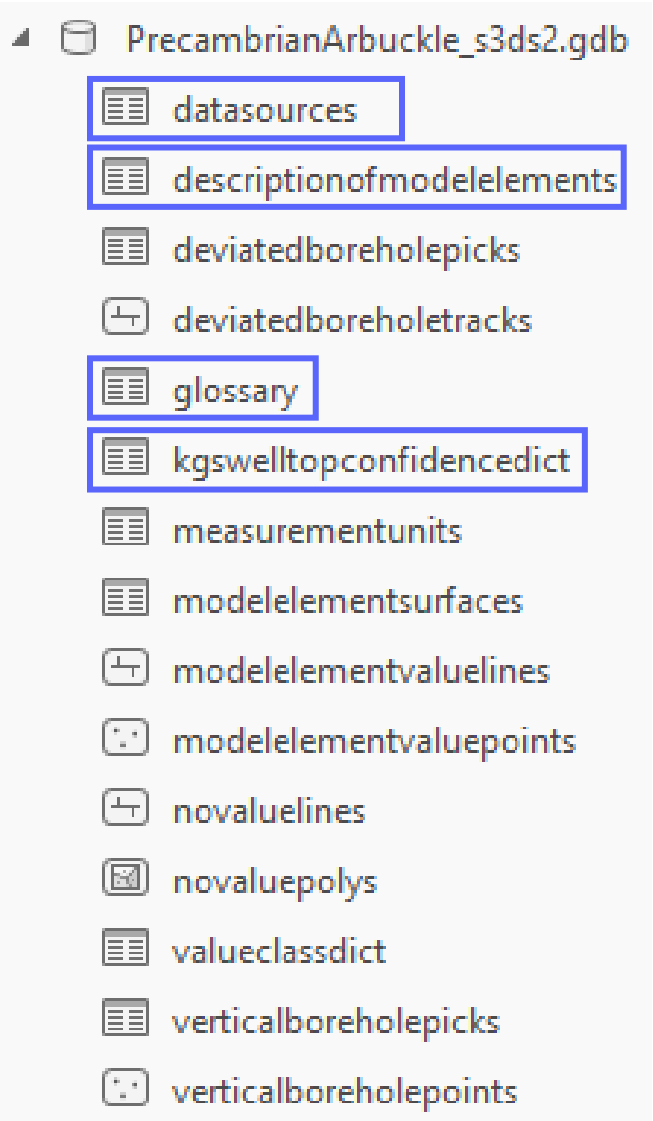
Moving data from Petrel to the S3DS database

Notable standalone differences

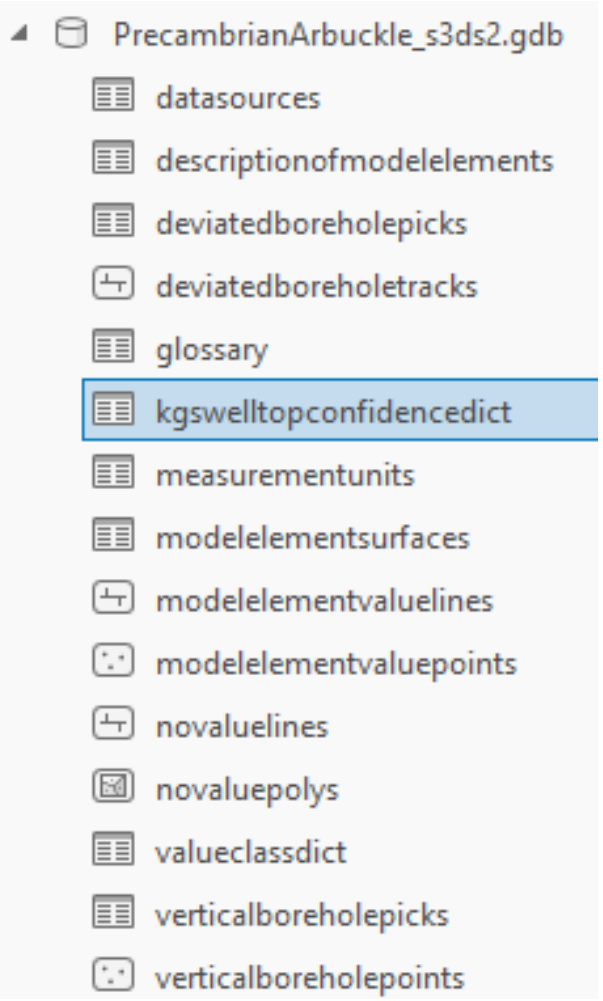


Multi-z surfaces

References and descriptions from OFR and Petrel layer comments



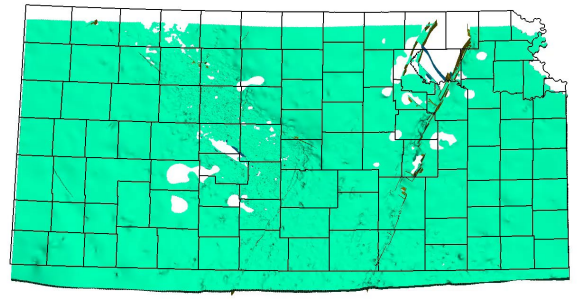
Moving data to the S3DS database – KS additions

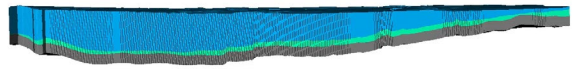


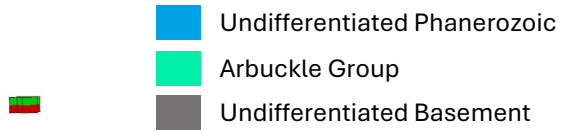
Score	Description
1	Tops sourced from paper/historical reference documents. This data source is accepted as entered and involves very little scientific interpretation.
2	Tops sourced from either manual or batch upload to Oracle but the data source is unknown to current KGS personnel. This data source is assumed to be verified by someone who took the time to upload the tops data but we can't pinpoint the actual source responsible for the data.
3	Tops source is science based but data creator varies so process of interpretation may vary (elog, geological report). This includes qualified internal source with oversight such as MS candidate research. Post-2025 this value may have been assigned by a KGS scientist to their own picked tops due to fewer resources available for evaluating the well.
4	Tops source is from a "highly respected" outside source or from a KGS source with known data loader but unknown data creator. Post-2025 this value may have been assigned by a KGS scientist to their own picked tops due to fewer resources available for evaluating the well.
5	Tops source is from a KGS scientist or project that we feel is/was solid in their technical approach to picking tops. Post-2025 this value may have been assigned by a KGS scientist to their own picked tops where they have high confidence.

What we'll continue to explore…

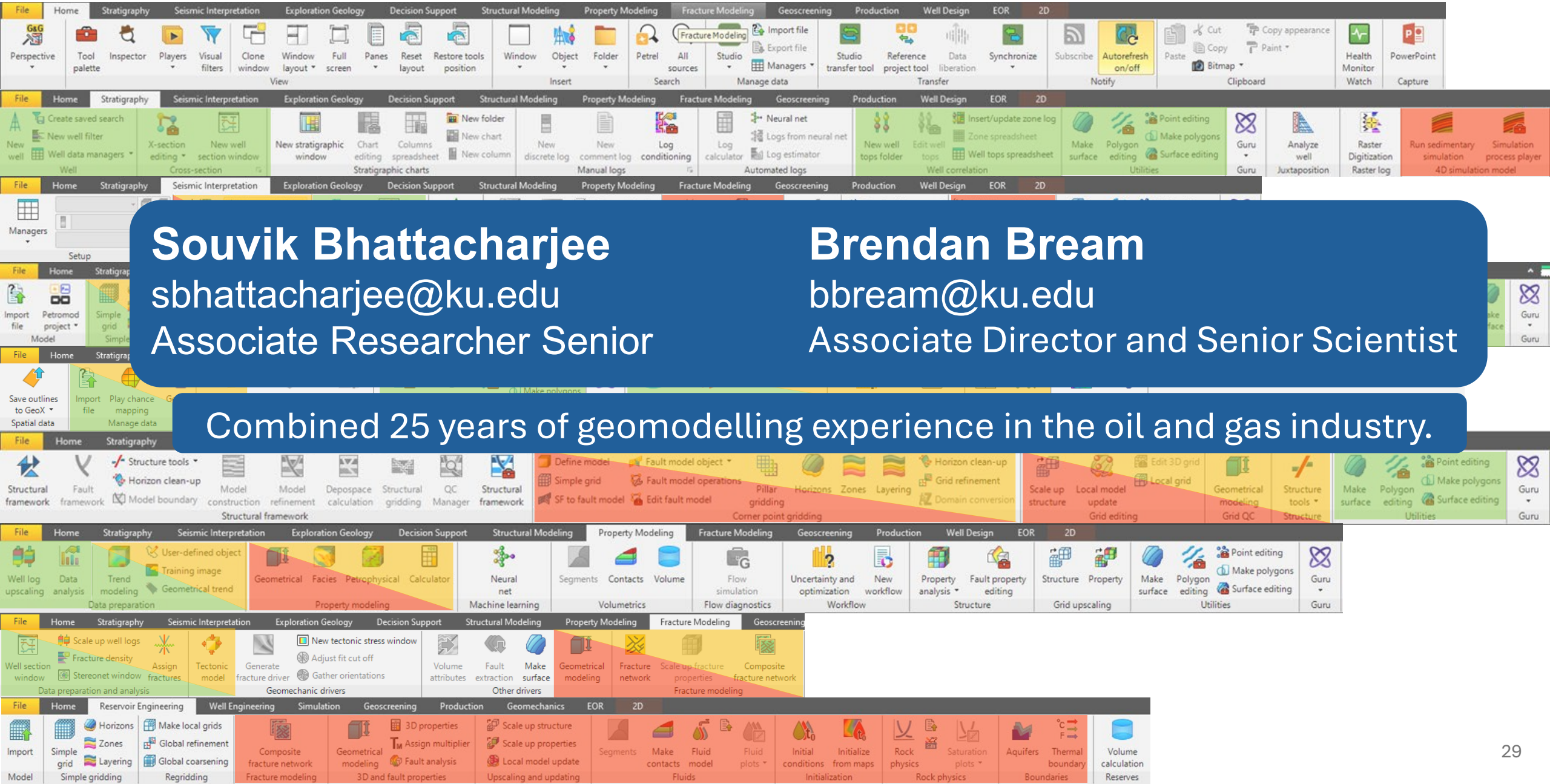
- Export options between Petrel and ArcGIS
  - Want to minimize the amount of re-interpolation we do in ArcGIS
  - Looking at an ArcGIS Pro add-in (Exprodat) that helps port between Petrel and ArcGIS
  - Not giving up completely on GIS and single-z representation of the model.
- Discussions about what derivative outputs we want to provide in S3DS and Petrel
- How we'll distribute data layers in ArcGIS Online
  - Can we build voxels with faulted framework points?
- Format of peer-reviewed survey publications for subsurface layers







For more information on… **modeling in Petrel and complex faulted frameworks**



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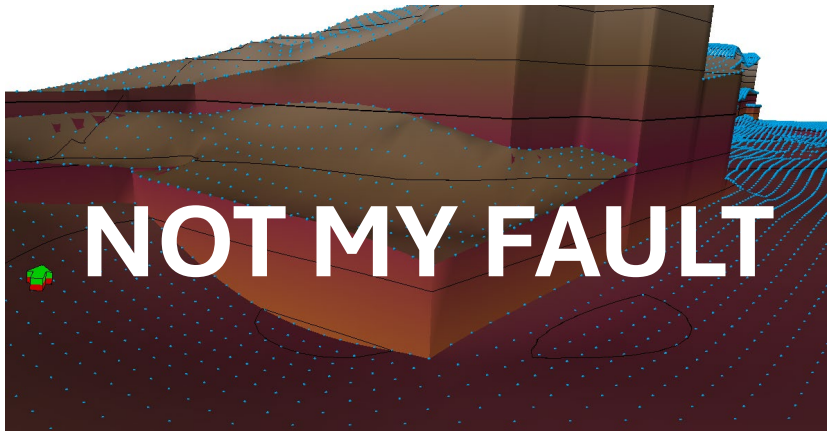
Associate Researcher Senior

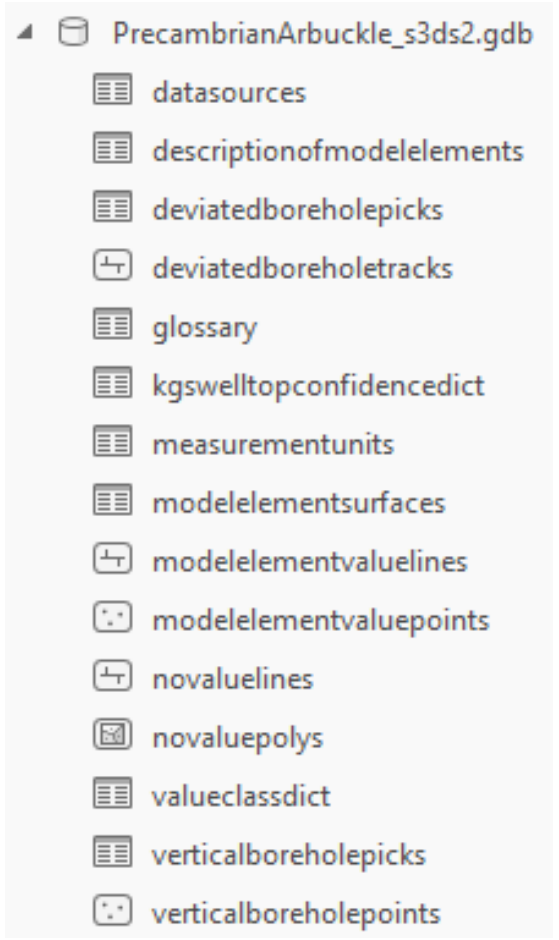
Brendan Bream
bbream@ku.edu
Associate Director and Senior Scientist

Combined 25 years of geomodelling experience in the oil and gas industry.

For more information on… **using S3DS and organizing subsurface datasets**

Emily Bunse
ebunse@ku.edu
Senior Cartographic Services Specialist





Previous KGS subsurface presentation

DMT 2024

https://ngmdb.usgs.gov/Info/dmt/docs/DMT24_Bhattacharjee.pdf

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

Souvik Bhattacharjee, Alan Peterson, Kolbe Andrzejewski

KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

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

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- Bhattacharjee, S. and Bream, B., 2025a, Top Precambrian Basement, Kansas – Depth Structure Map: Kansas Geological Survey, Open File Report 2025-49, 3p. https://www.kgs.ku.edu/Publications/OFR/2025/OFR2025-49.pdf
- Bhattacharjee, S. and Bream, B., 2025b, Top Arbuckle, Kansas — Depth Structure Map: Kansas Geological Survey, Open File Report 2025-50, 3p. https://www.kgs.ku.edu/Publications/OFR/2025/OFR2025-50.pdf.
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- Oborny, S., Andrzejewski, K., Bream, B.R., et al., 2025, CMCSCFCB—Critical Minerals in Coaly Strata of the Cherokee-Forest City Basin, https://doi.org/10.2172/3009807.
- Steeples, D.W., Buchanan, R., and Tollefson, J., 2025, Kansas GeoMaps: Kansas Geological Survey, Educational Series 4 (revised).