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Data Collection and Curation for Increasing the Efficiency of Multi-Resource Assessments

Sean T. Brennan, Matt Merrill, and Jenny Lagesse

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U.S. Department of the Interior
U.S. Geological Survey

PRI

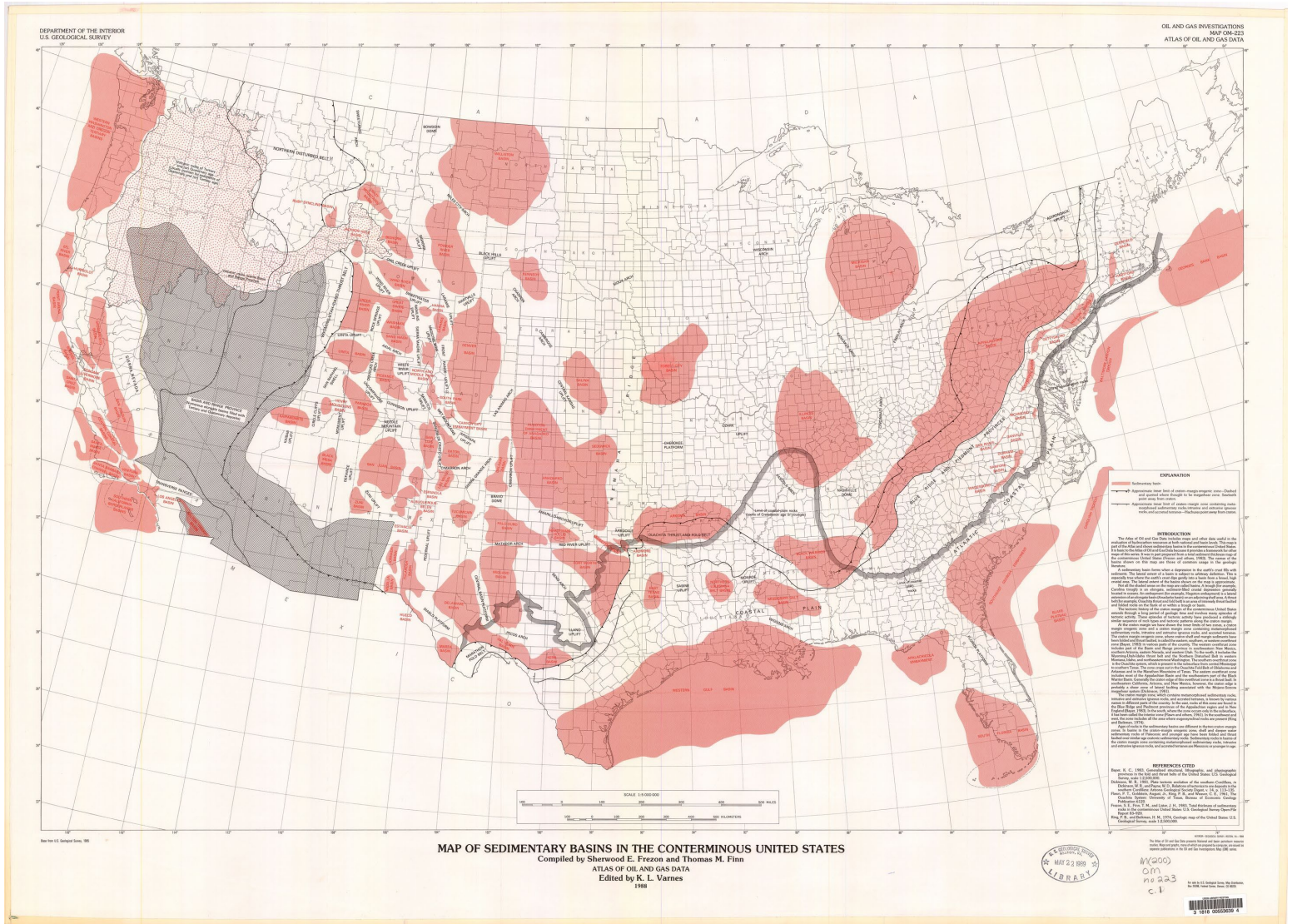
Overview

- In the Energy Resources Program of the U.S. Geological Survey, we do several kinds of resource assessments.
- By assessment I mean: a geology-based, statistical estimate of an energy resource.
- These assessments involve various types of geologic data:
  - descriptive, tabular, and geospatially-organized.
- And all those data are run through either:
  - statistical algorithms to determine probabilistic resources estimates, or
  - geospatial processes to determine broad feasibility of the presence of a resource.

Overview

Most USGS Energy Resources Program assessments are in sedimentary basins:

- Petroleum (conventional and continuous)
- CO_2 storage
- Energy Storage
- Oil and Gas Waters



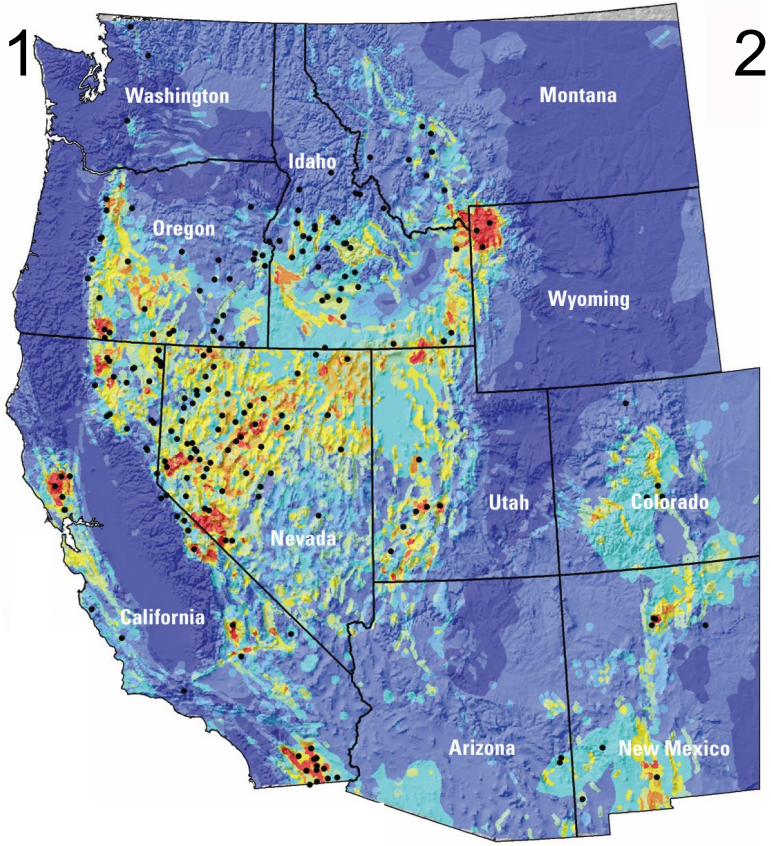
Frezon, S., and Finn, T.M., 1988

Overview

However, not all USGS Energy Resources Program assessments have been restricted to sedimentary basins:

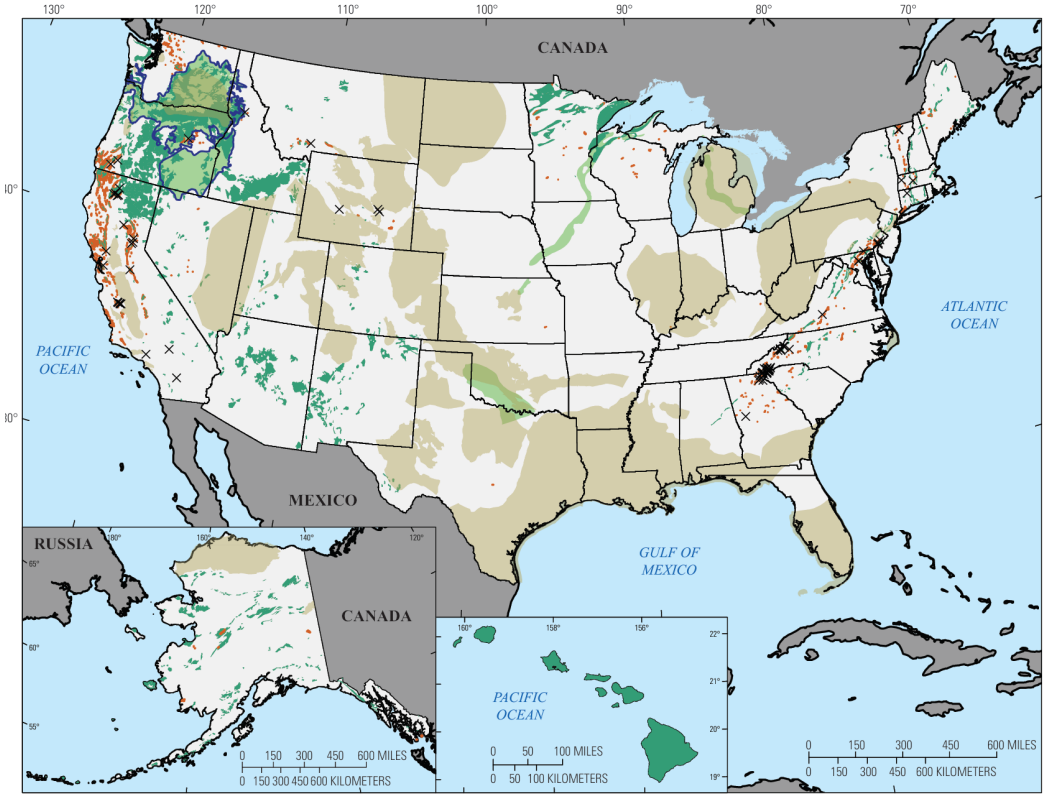
1. Geothermal
2. Carbon mineralization
3. Natural Hydrogen

1



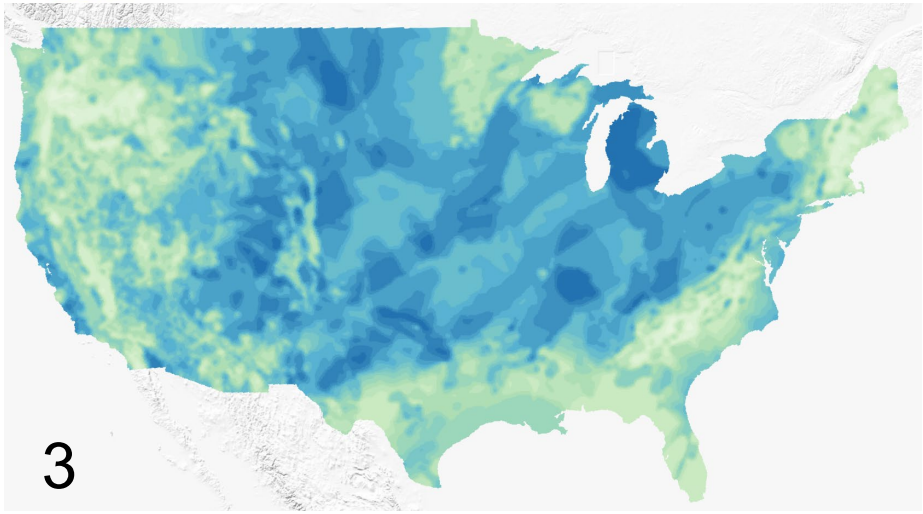
U.S. Geological Survey
Fact Sheet 2008-3082

2



Blondes and others, 2019

3



https://energy.usgs.gov/hydrogen/

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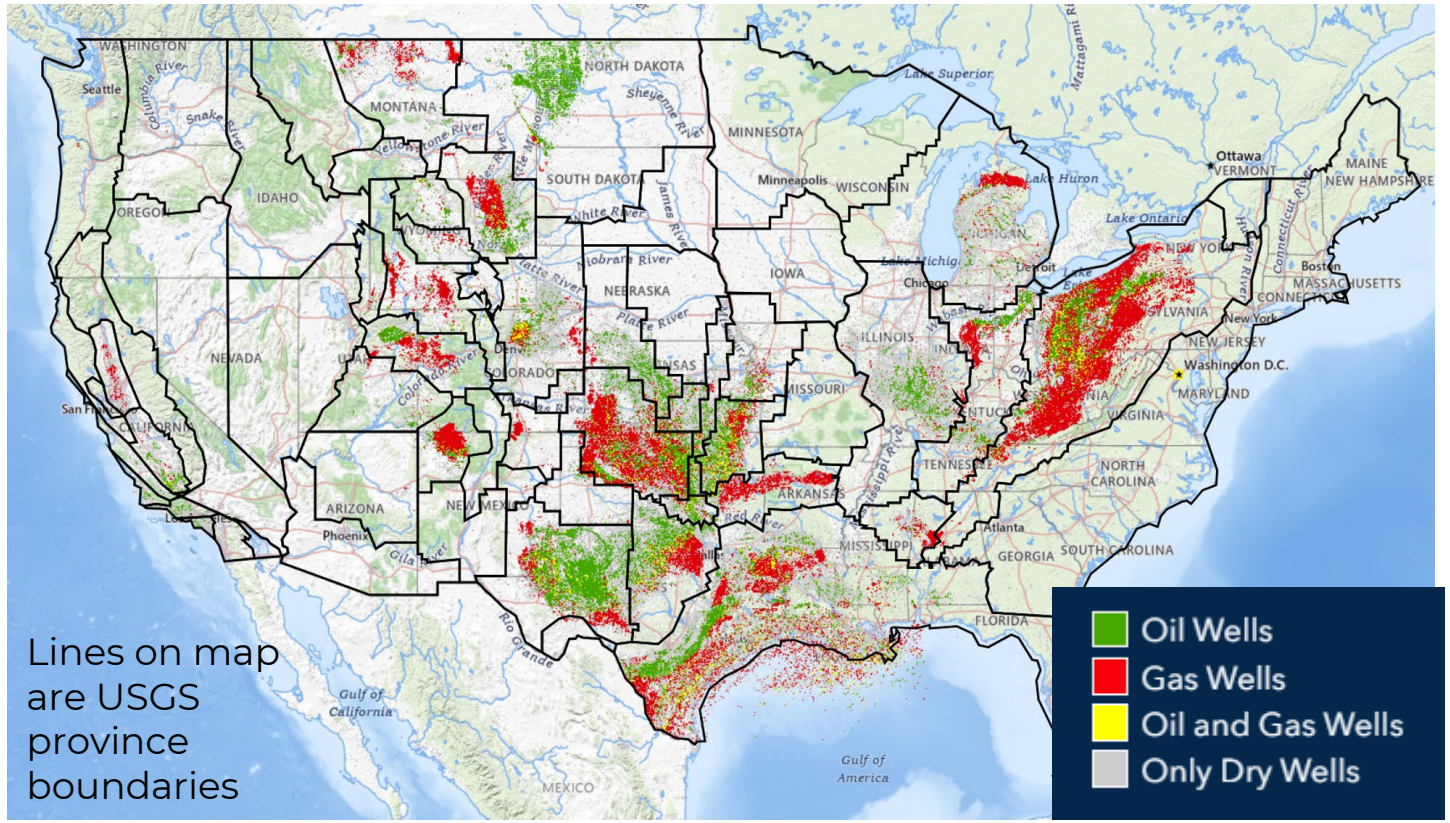
PRI

Overview

- Systems-based models for many of our methodologies.
- How was a resource emplaced?
- How will a resource behave as it is being exploited?
- Similar data gathered for different needs.
- Data gathered in inconsistent ways.
- Decentralized storage, no way to know who had what.
- Subsequent assessments started with asking who had what data.
- Examples of our assessment processes.

Undiscovered petroleum resource assessments (conventional)

- Most well known ongoing USGS energy resource assessment series.
- After the 1995 national assessment we updated our methodology to the Petroleum Systems Model.
- Main parts of model are characterizing hydrocarbon 1. Generation, 2. Migration and, 3, Trapping.
- Model components require the depositional, burial/tectonic, fluid, and thermodynamic history for each system.

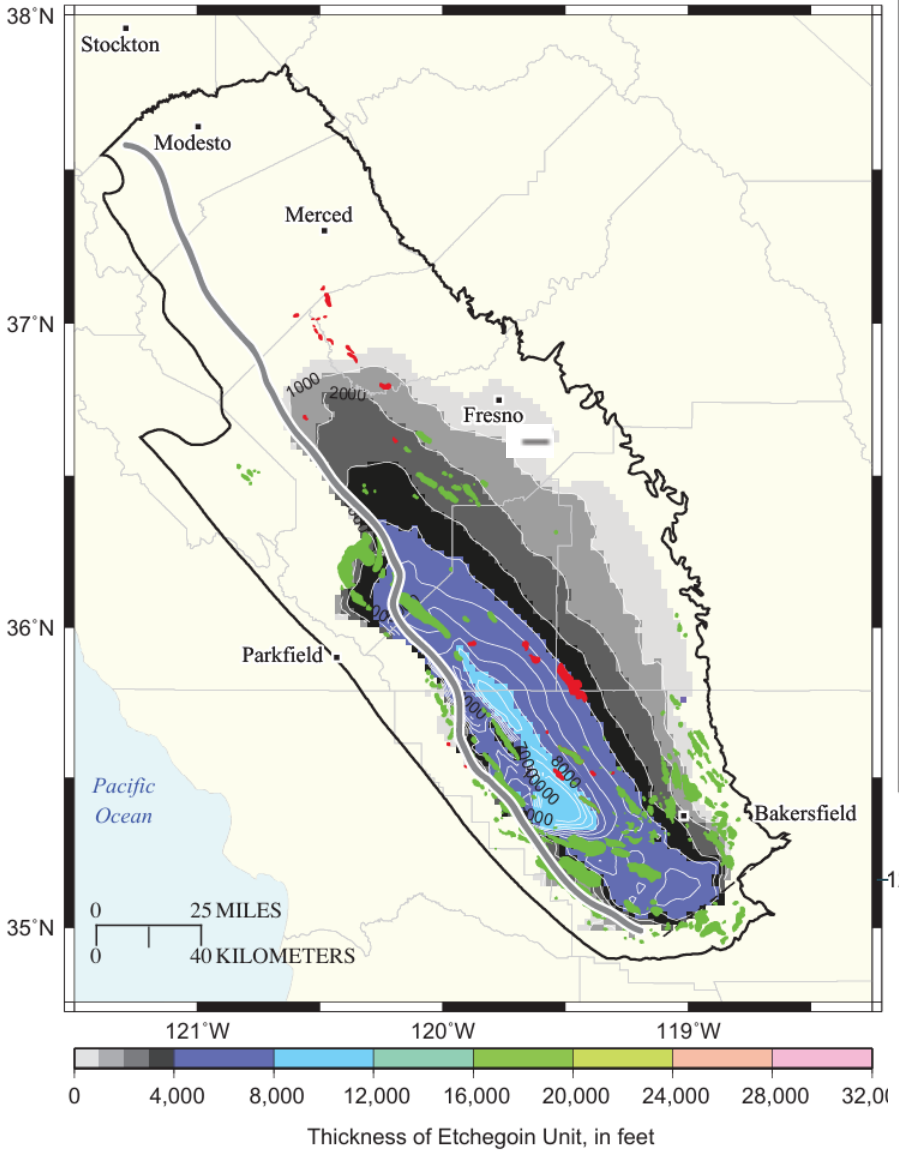


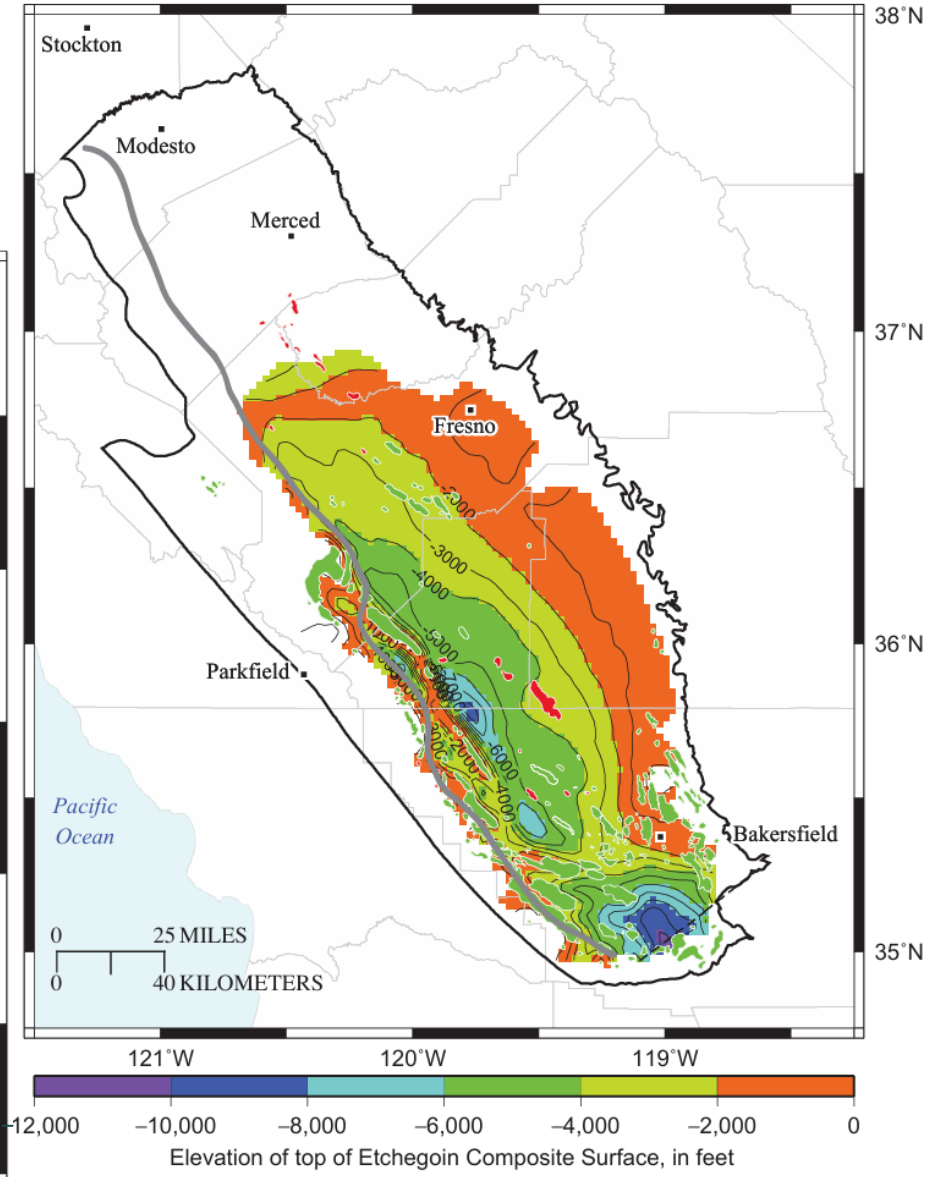
https://energy.usgs.gov/naga-map/

Petroleum assessments (conventional)

What data do we need?

- Current architecture of the rocks:
  - Thickness and structure



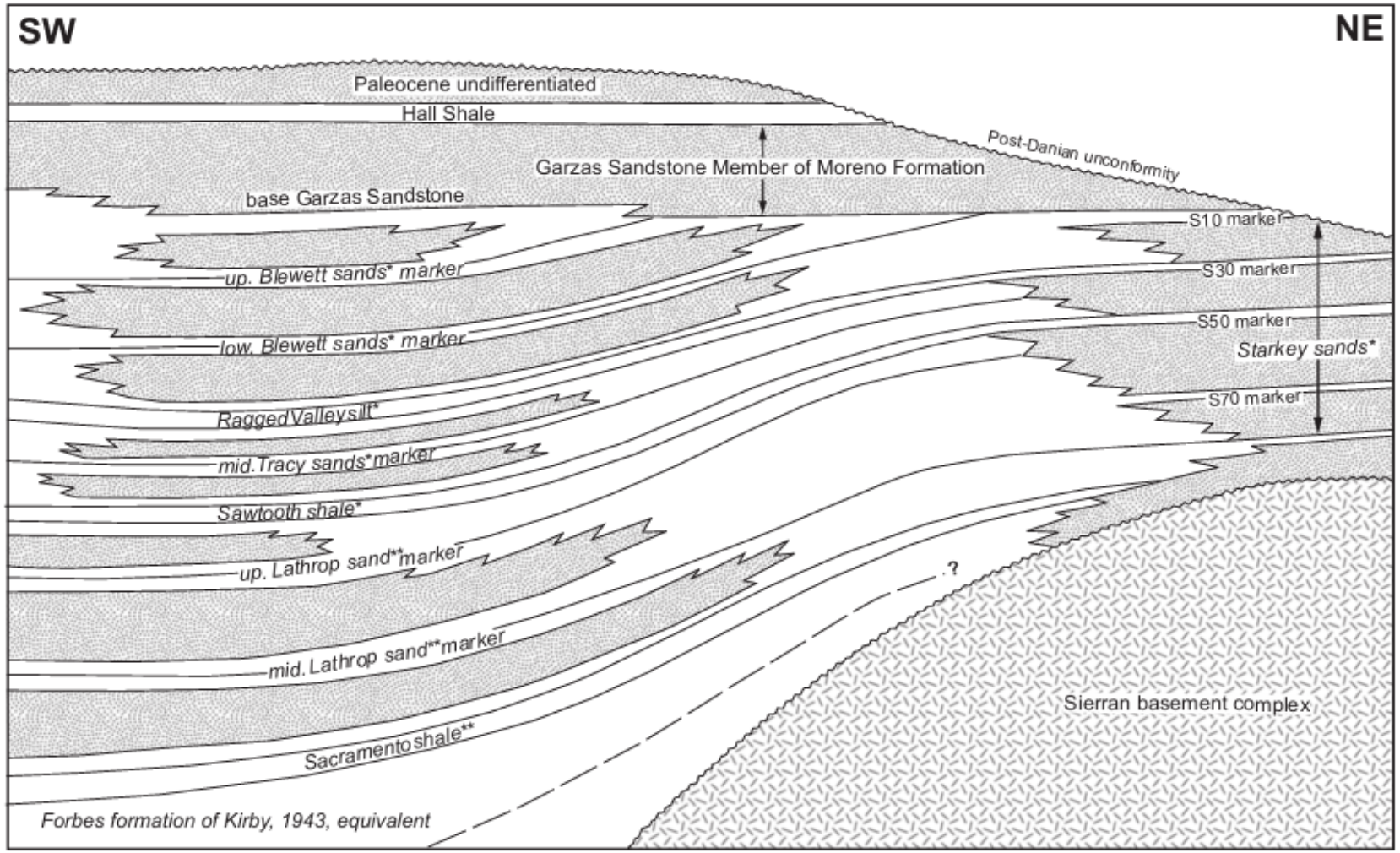


Hosford Scheirer, 2013

Petroleum assessments (conventional)

What data do we need?

- Current architecture of the rocks:
  - Thickness and structure,
  - Faulting/fracturing,
  - Stratigraphic and sequence stratigraphic models.



Hosford Scheirer, 2013

Petroleum assessments (conventional)

What data do we need?

- Current architecture of the rocks:
  - Thickness and structure,
  - Faulting/fracturing,
  - Stratigraphic and sequence stratigraphic models, 3-D models
- Source rock data,
- Porosity/permeability,
- Fluids present,
- Current thermodynamic conditions,
- Geologic model of the trapping mechanisms,
- And how all of these changed through time.

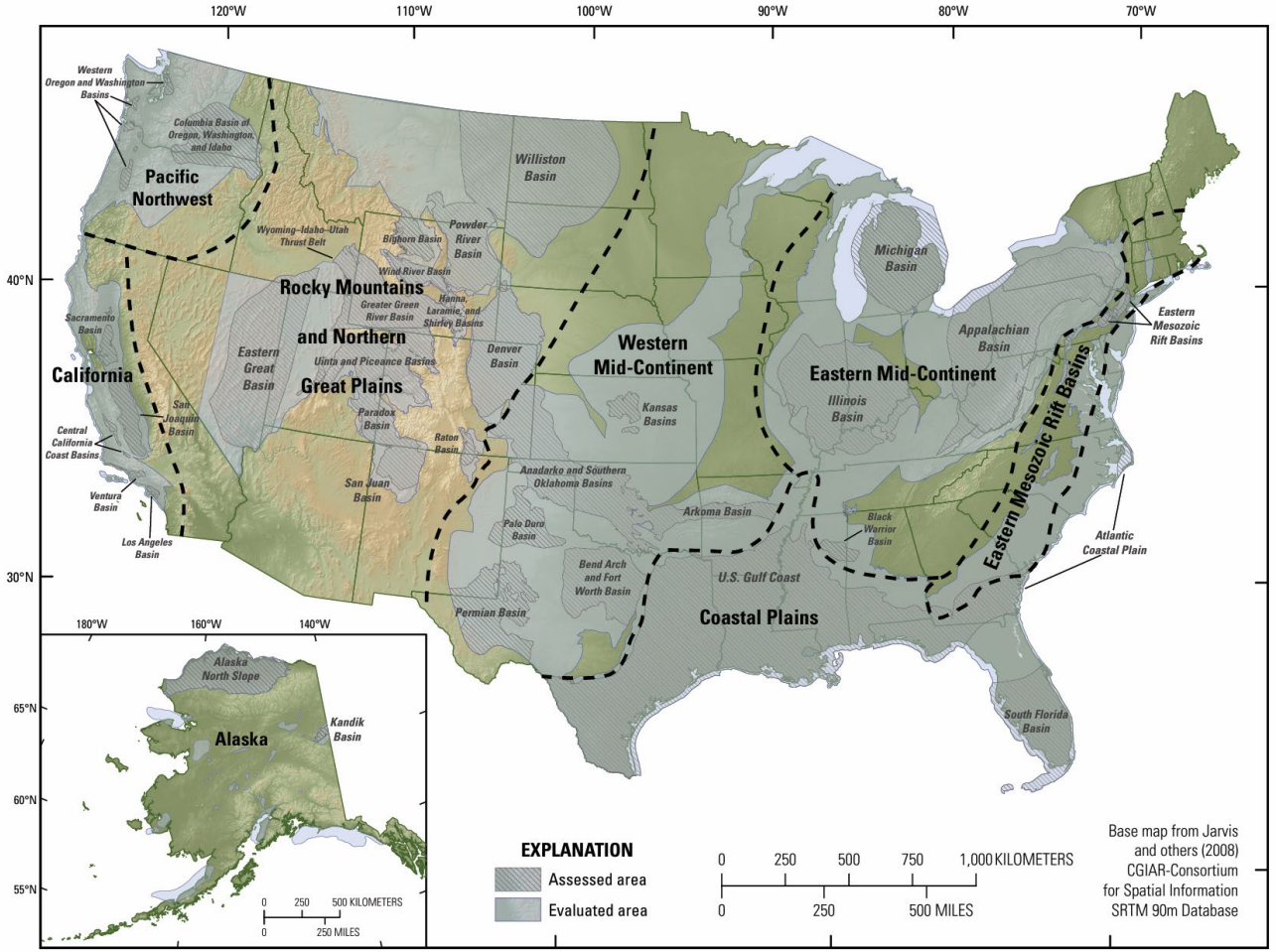
CO_2 storage

Very similar data needs.

Focus is on the migration part of the petroleum system but sped up by orders of magnitude.

Need:

- Stratigraphic and structural data:
  - Storage units,
  - Seal units,
- porosity/permeability,
- thermodynamic conditions,
- fluids present,
- faults and their potential for reactivation,
- what other resources could be impacted?



U.S. Geological Survey Fact Sheet 2013–3020

Hydrogen

Whole other set of issues.

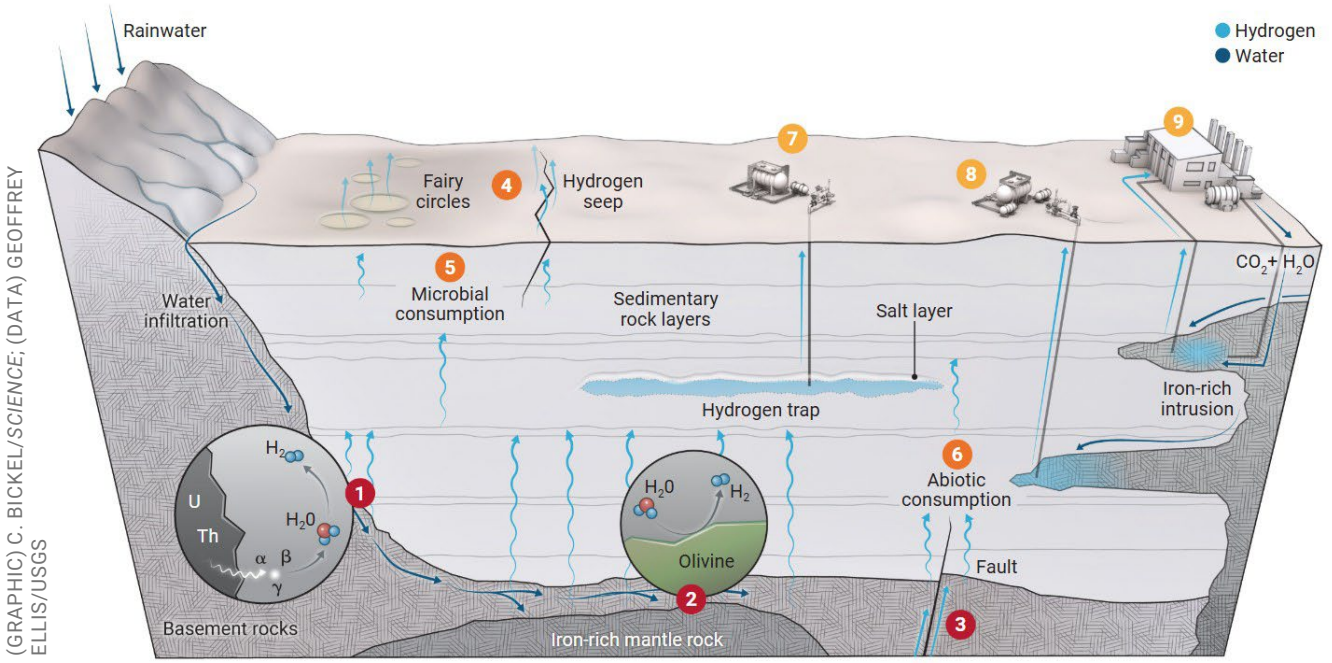
Source?

How is the H_2 liberated from the source?

How does it migrate?

Loss mechanisms?

The molecule is so small, what makes for an effective trap?



Generation

1 Radiolysis
Trace radioactive elements in rocks emit radiation that can split water. The process is slow, so ancient rocks are most likely to generate hydrogen.

2 Serpentinization
At high temperatures, water reacts with iron-rich rocks to make hydrogen. The fast and renewable reactions, called serpentinization, may drive most production.

3 Deep-seated
Streams of hydrogen from Earth's core or mantle may rise along tectonic plate boundaries and faults. But the theory of these vast, deep stores is controversial.

Loss mechanisms

4 Seeps
Hydrogen travels quickly through faults and fractures. It can also diffuse through rocks. Weak seeps might explain shallow depressions sometimes called fairy circles.

5 Microbes
In shallower layers of soil and rock, microbes consume hydrogen for energy, often producing methane.

6 Abiotic reactions
At deeper levels, hydrogen reacts withrocks and gases to form water, methane, and mineral compounds.

Extraction

7 Traps
Hydrogen might be tapped like oil and gas—by drilling into reservoirs trapped in porous rocks below salt deposits or other impermeable rock layers.

8 Direct
It might also be possible to tap the iron-rich source rocks directly, if they're shallow and fractured enough to allow hydrogen to be collected.

9 Enhanced
Hydrogen production might be stimulated by pumping water into iron-rich rocks. Adding carbon dioxide would sequester it from the atmosphere, slowing climate change.

"Hidden hydrogen: Does Earth hold vast stores of a renewable, carbon-free fuel?" Science, 2023

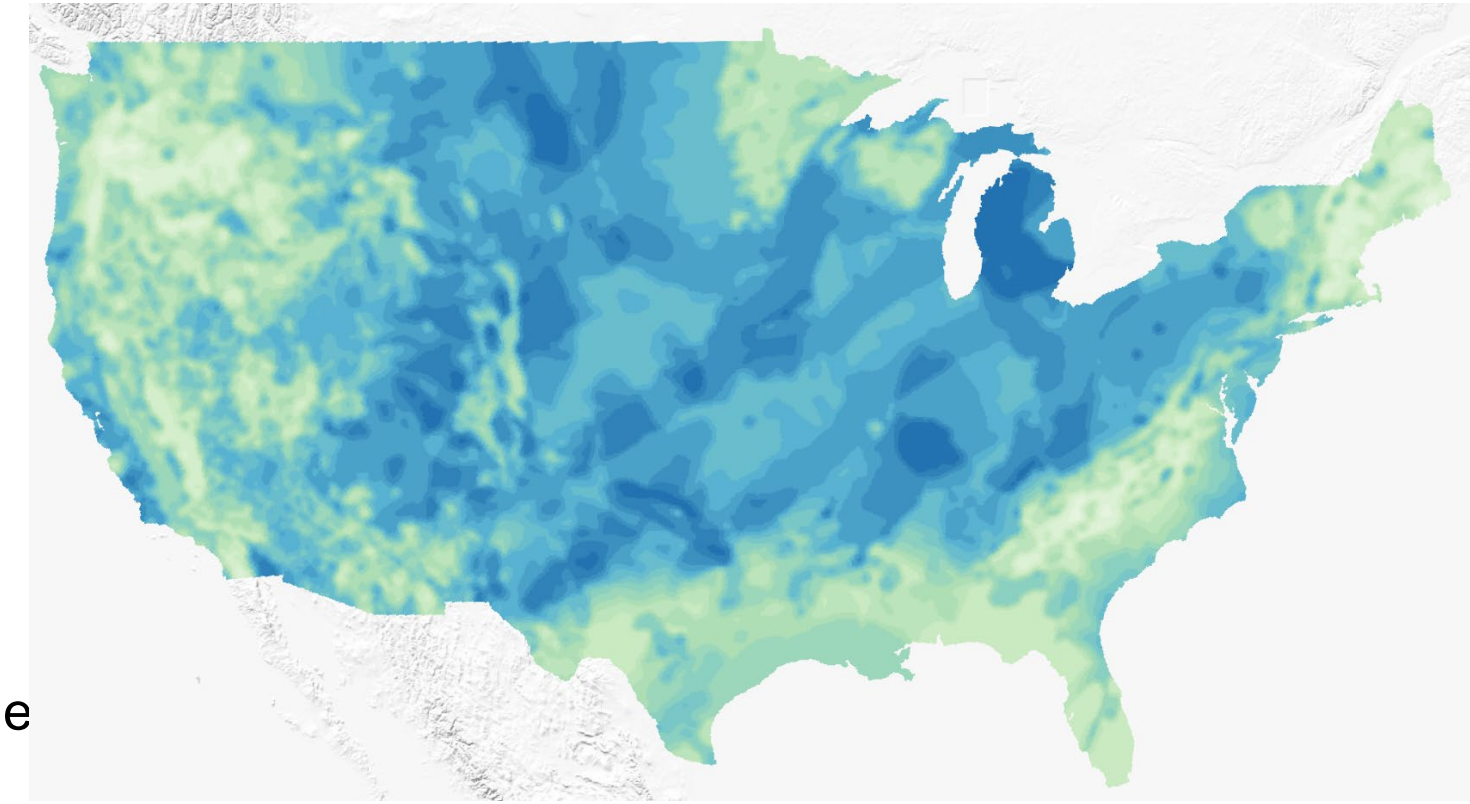
Hydrogen

The hydrogen feasibility model is a form of a play fairway model; multiple geospatial layers are overlain to identify regions that are more likely to have hydrogen accumulations (darkest zones having the highest potential resource).

Layers used here:

- Source types (12 layers):
  - Serpentinization (4 layers)
  - Radiolysis (5 layers)
  - Deep/mantle (3 layers)
- Reservoir (3 layers)
- Seals (4 layers)

Combine to form the map, but each layer can be removed to see how that affects the feasibility model.



https://energy.usgs.gov/hydrogen/

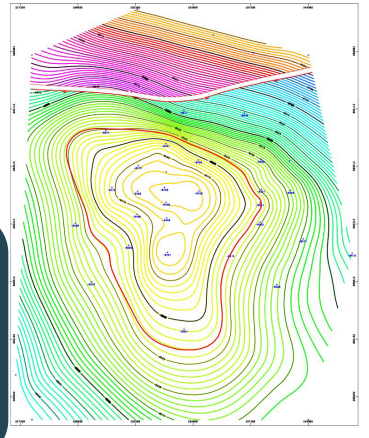
Issues with the assessment process circa 2010



The geologist gathers data through research coupled with existing proprietary and public data sources

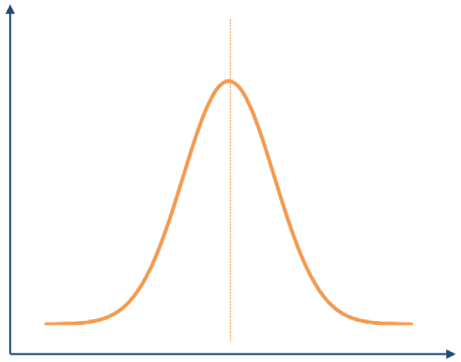


Works with data scientists to build datasets



Works with GIS specialists to feed data into geospatial data layers

Works with mathematicians to feed those data into statistical models to estimate resource.



And then everything is broadly abandoned after the assessment (and the process starts over)

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Issues with the assessment process circa 2010

Each assessment builds fit-for-purpose products that tend to stay internal.
No consistency, not centralized.

The data could be used to build national models of:

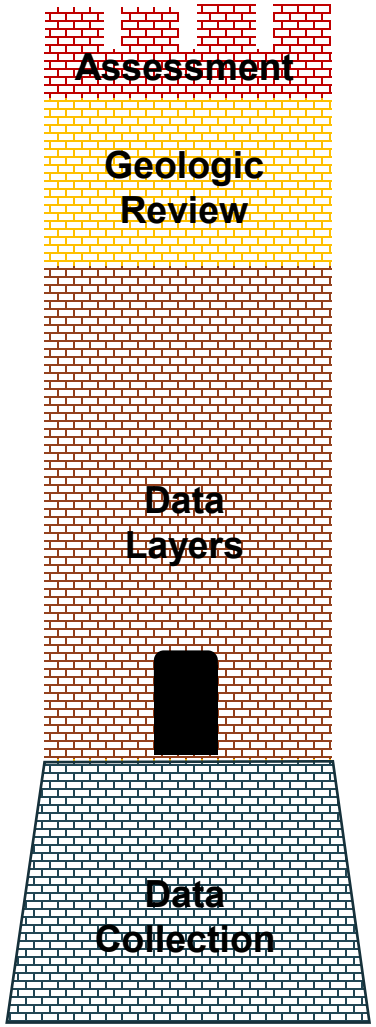
- geologic structure,
- isopachs,
- porosity trends,
- stratigraphic packages/basin models,
- thermal layers and histories,
- pressure layers and histories,
- or burial models.

Inefficient way of doing science.

Issues with the assessment process circa 2010

- When we started work on our CO_2 storage resource assessment in 2010, we reached out to the USGS Petroleum Assessment scientists for their files.
- Typically, there were no metadata.
- We were able to reuse/recycle those data (when they were available), combined with data provided by State geologic surveys.
- That is when we started to think about how we could build data layers for other energy resource assessments.
- And we started to talk about how this process could be more efficient.

Tower Model: Single Resource Assessment



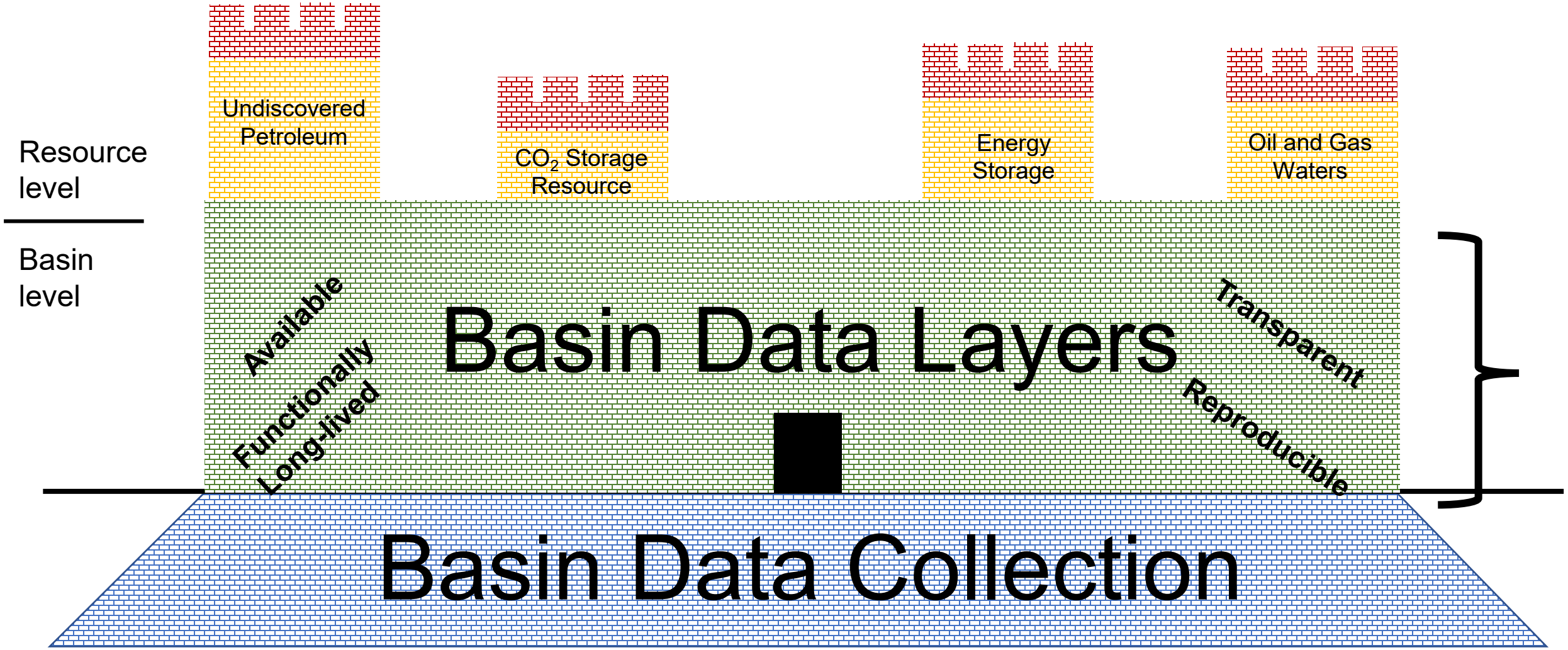
Lifecycle of the tower:

- Four tower steps
  1. Collect data (basin specific)
  2. Create data layers
  3. Geologic review
  4. Conduct assessment (resource specific)
- Publish a static product
- Neglect the tower until it is in ruin and no longer useful
- Build a new one 10 years later!

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Unpublished slide courtesy of Matt Merrill

Castle Model

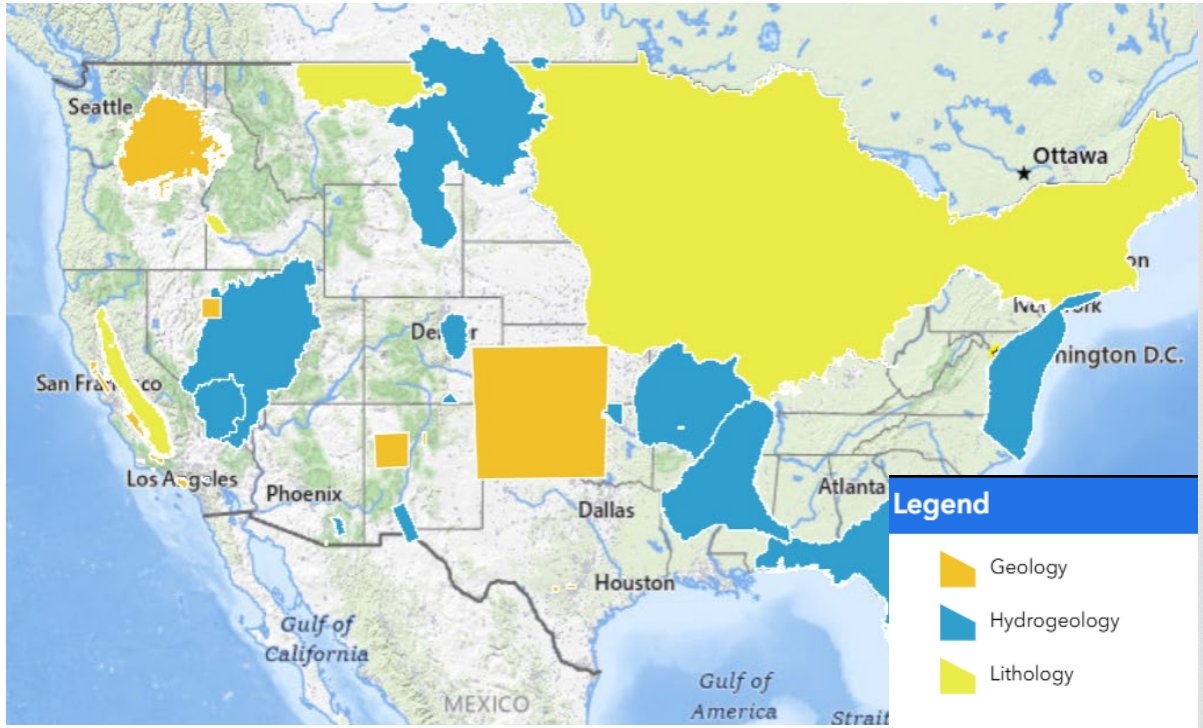


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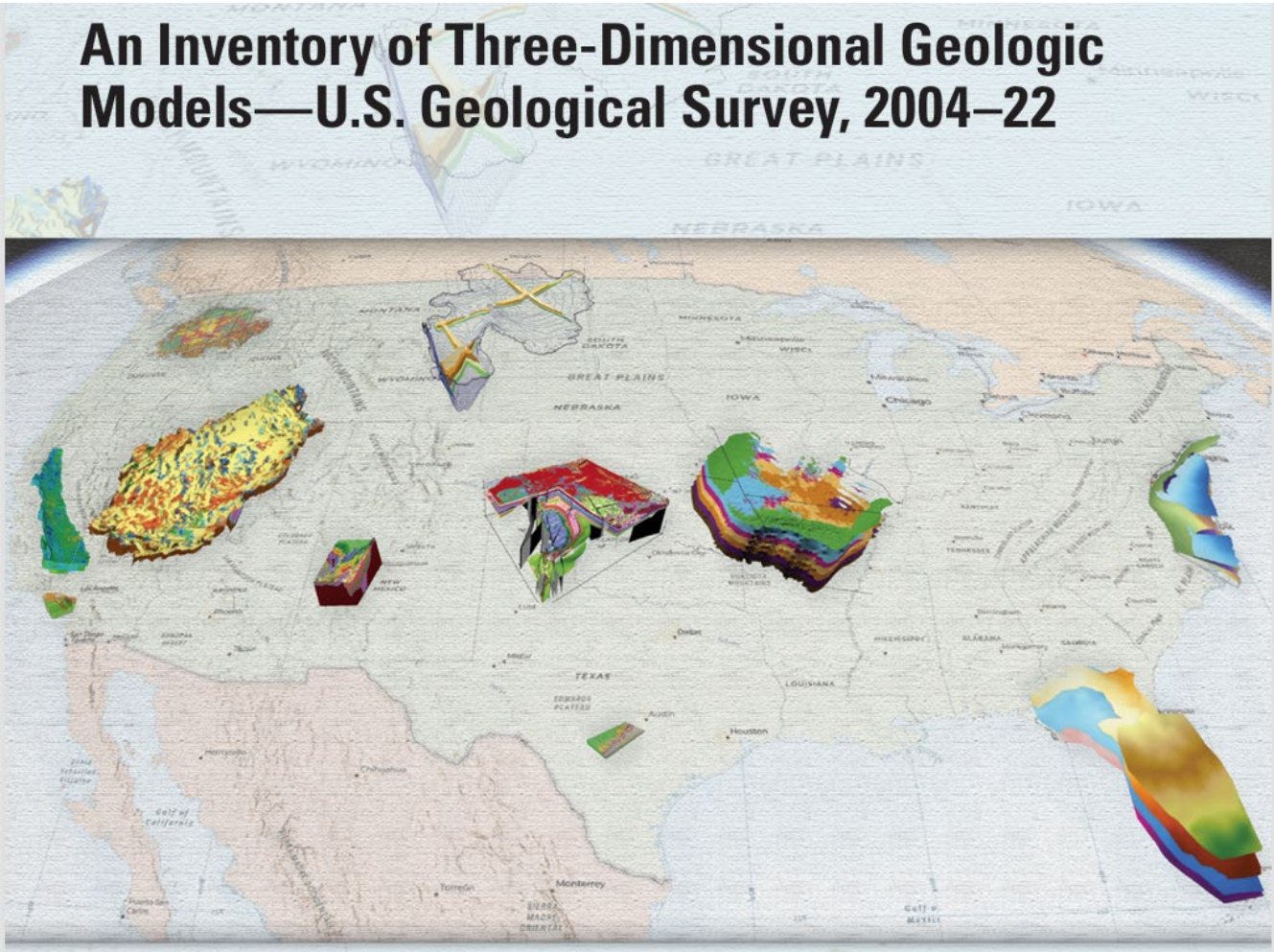
Petroleum assessments data preservation

- 3-D Data are now being preserved as Kingdom Suite projects:
  - Stratigraphic top values,
  - Wells included,
  - Structure and stratigraphy defined,
  - Well logs,
  - Temperature and pressure where defined.
- These data are being used to facilitate building of 3-D basin models by the U.S. Geological Survey National Geosynthesis project.

Three-Dimensional Basin Models



https://apps.usgs.gov/3d_geologic_model_inventory/



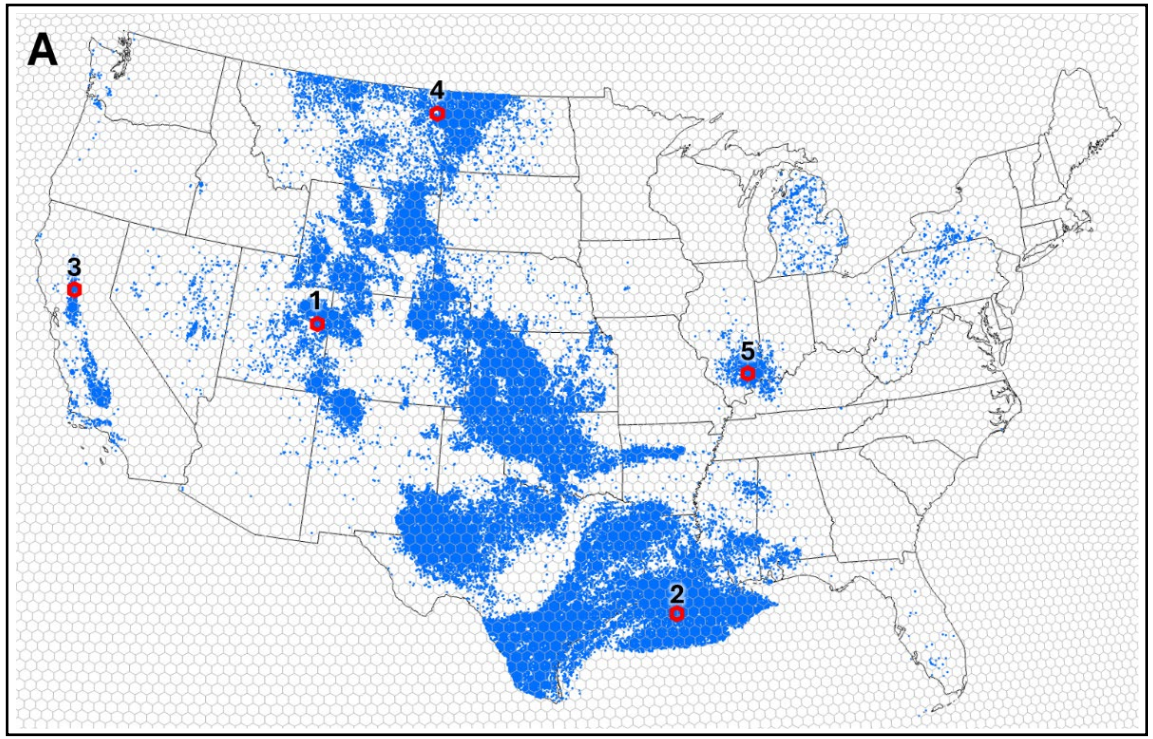
National Geologic Synthesis (NGS) - ScienceBase-Catalog

https://www.sciencebase.gov/catalog/item/62bf0e3dd34e82c548ced839

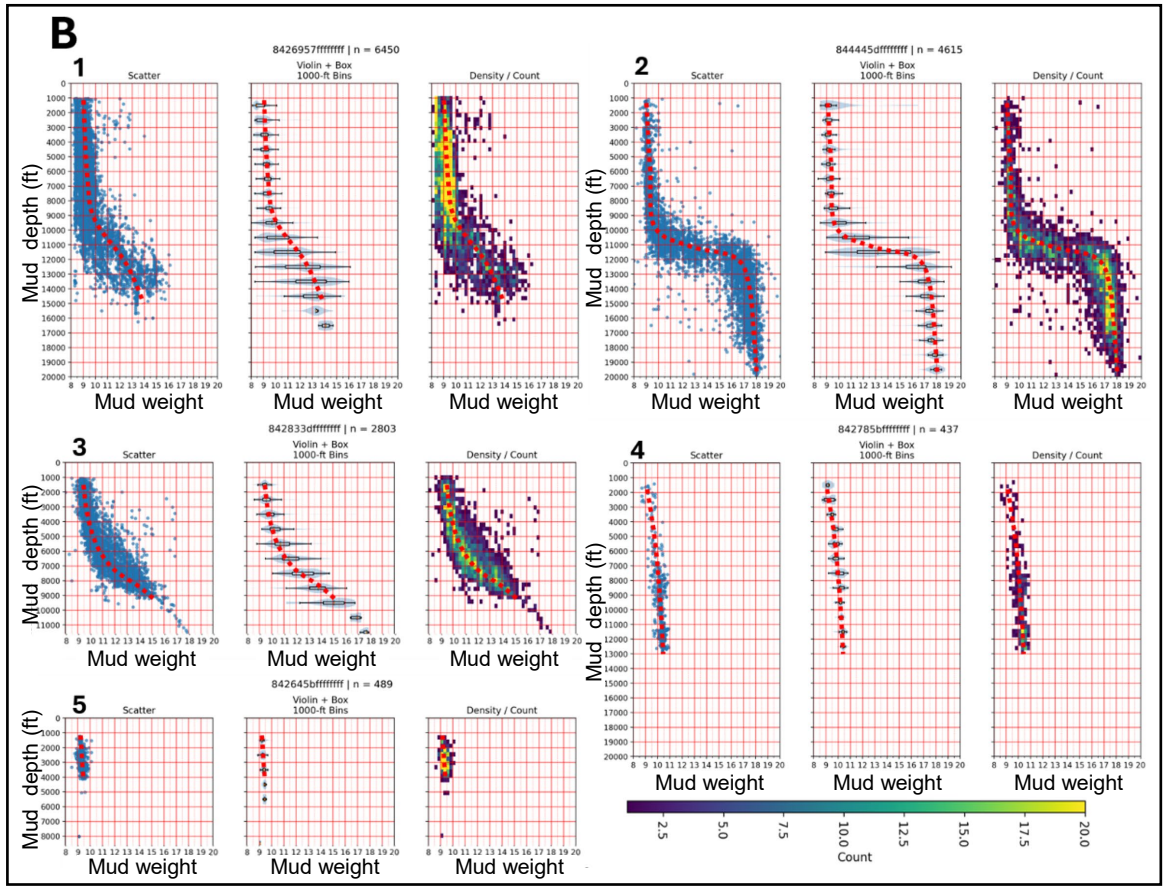
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Geopressure

- Methodology to estimate regional geopressure; geopressure gradient map.
- Curated a messy dataset to reduce overall uncertainty to populate a national assessment.
- Scalable, reproducible workflow.



Distribution of mud weight data in the continental United States from a commercial database (S&P Global, 2026).



Mud weight vs. depth profiles for spatial domains across several basins showing interpretations in red (after Gardner et al., 2026).

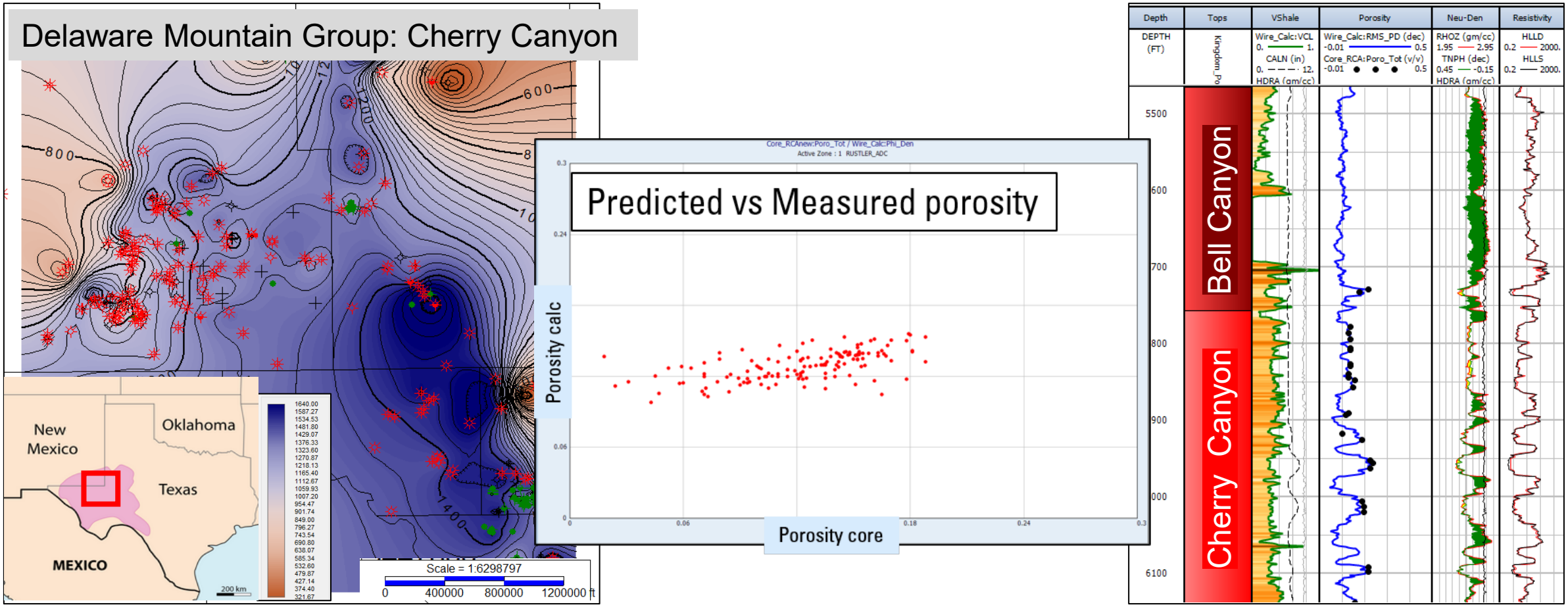
Unpublished slide courtesy of Jenny Lagesse

Porosity

Lithology and resource test case in the Permian Basin.

Deterministic approach for core and wireline database.

Efficient, scalable, adaptable workflow in multiple lithologies and energy resources.



Provisional data and figures,
publication in process by Jenny LaGesse

Energy Storage

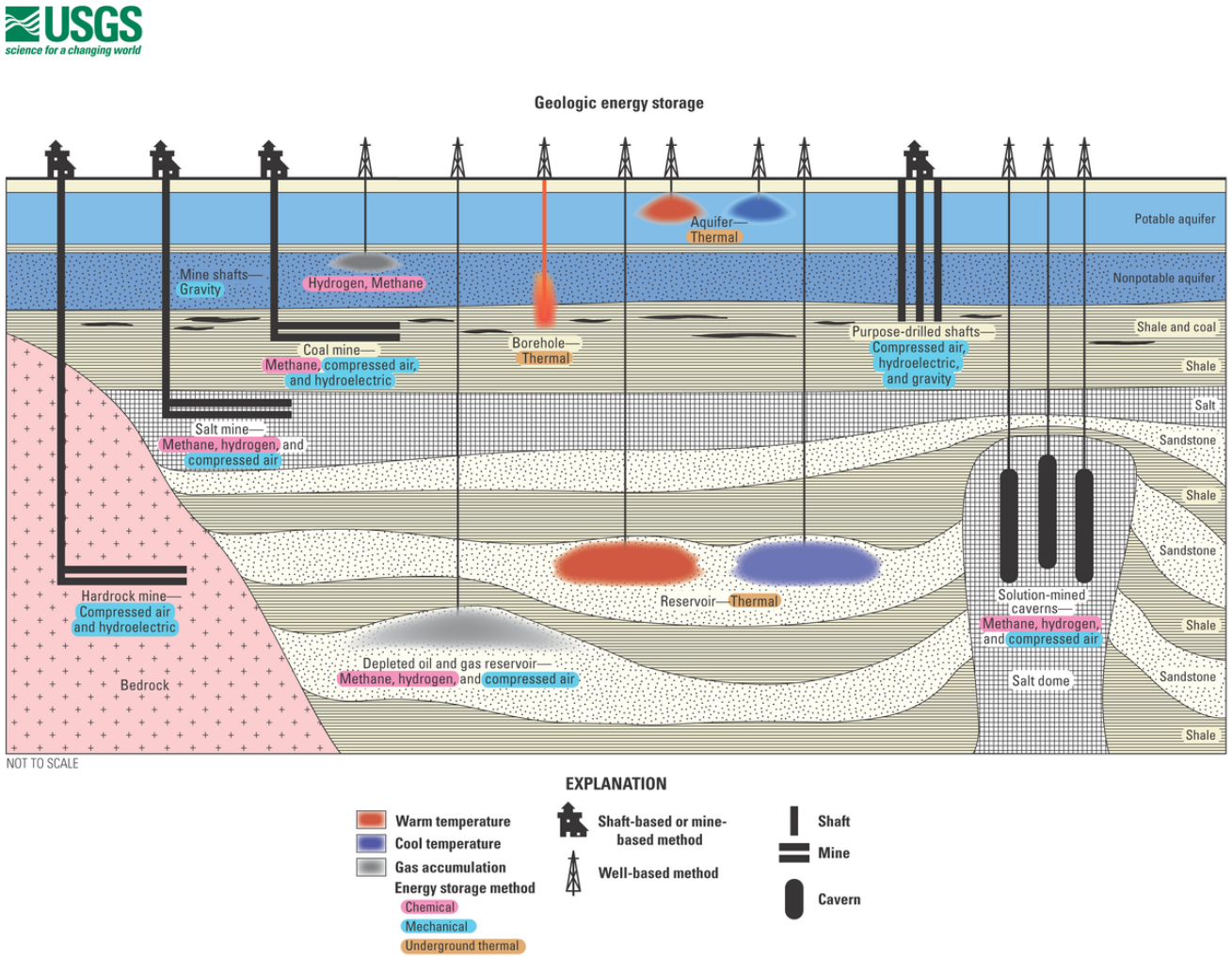
Store energy in the subsurface for later use (chemical, thermal, mechanical).

First step has been to identify abandoned natural gas reservoirs.

Can use those for storing:

- Natural Gas,
- Hydrogen,
- Geothermal storage.

Also, non energy storage potential: CO_2 or wastewater.

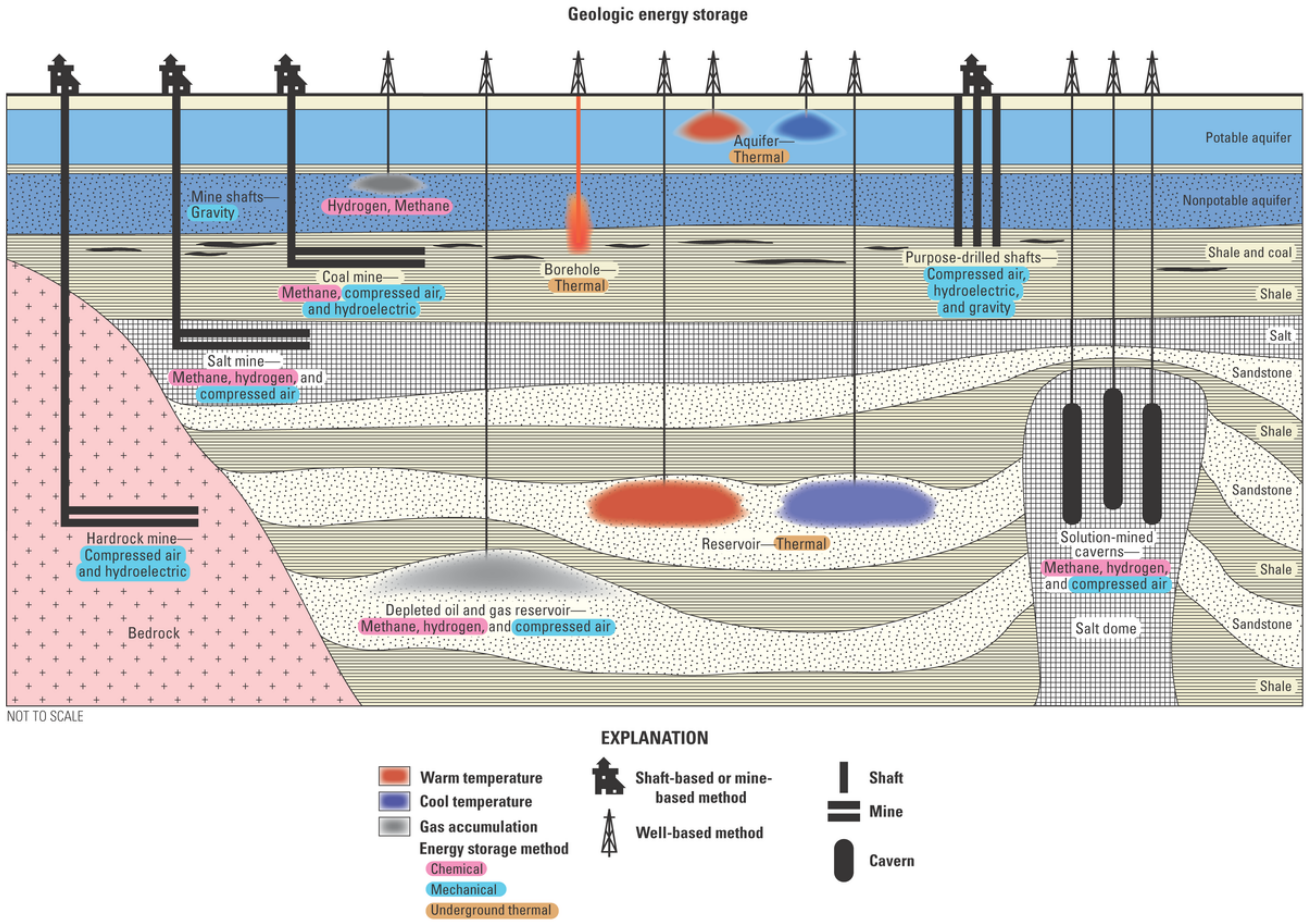


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Fact Sheet 2022-3082
(https://doi.org/10.3133/fs20223082)

Geothermal Energy Storage

- Aquifer Thermal Energy Storage (ATES).
- Reservoir Thermal Energy Storage (RTES).
- Both need:
  - Porosity layers,
  - Permeability info,
  - Fluid present and flow rate.
- Potential for abandoned reservoirs to be used for thermal energy storage.



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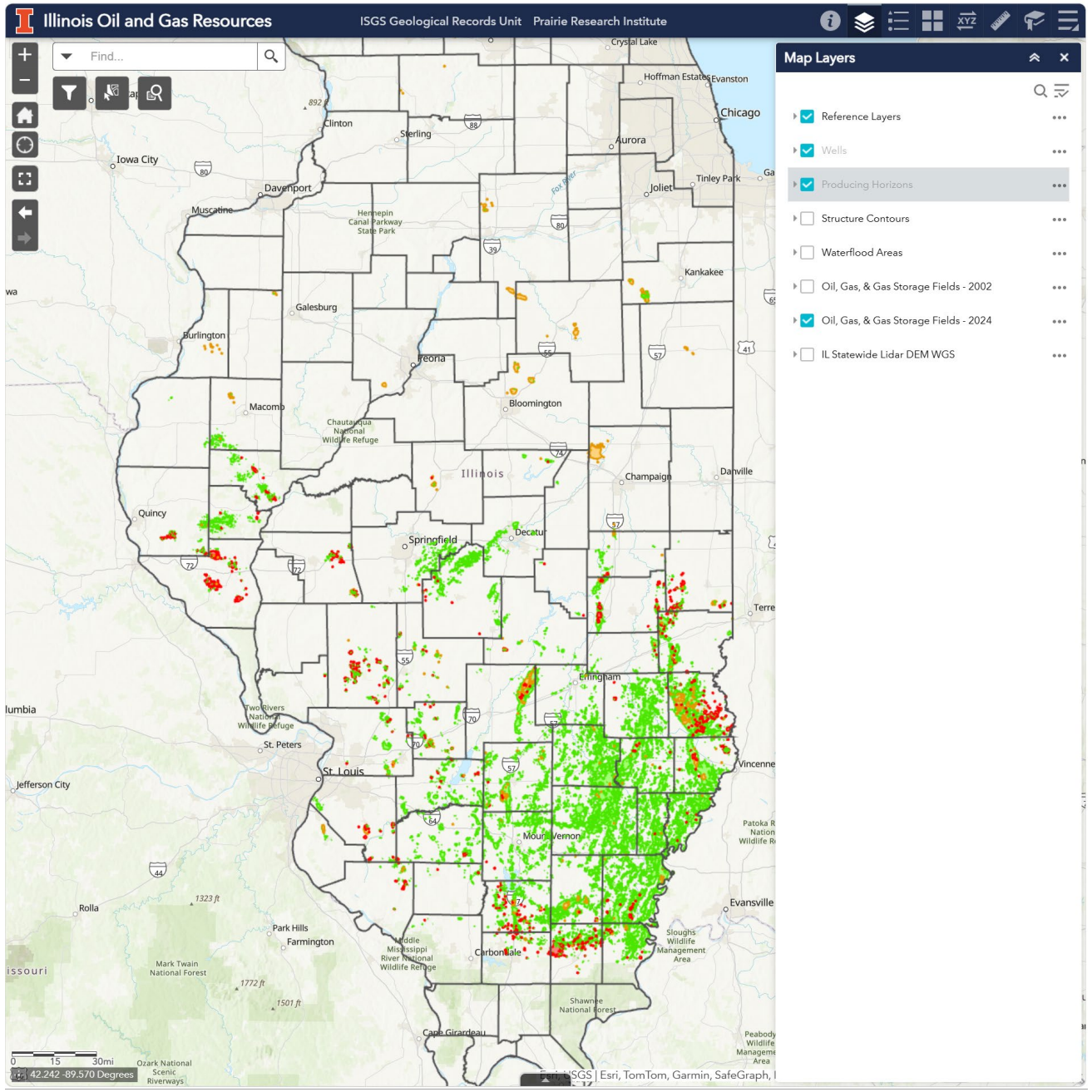
Collaboration: State Level Data

There is a wealth of data within State geologic surveys and petroleum production regulators that could be harvested. They provide data to the proprietary data sources we use (S&PG, our rapidly aging Nehring dataset).

States (like Illinois) have started to make data easily accessible.

However, some states (like Illinois) are charging for the data because of funding constraints and the cost of generating interpretative data.

And the metadata in the publicly available Illinois data is appreciated.

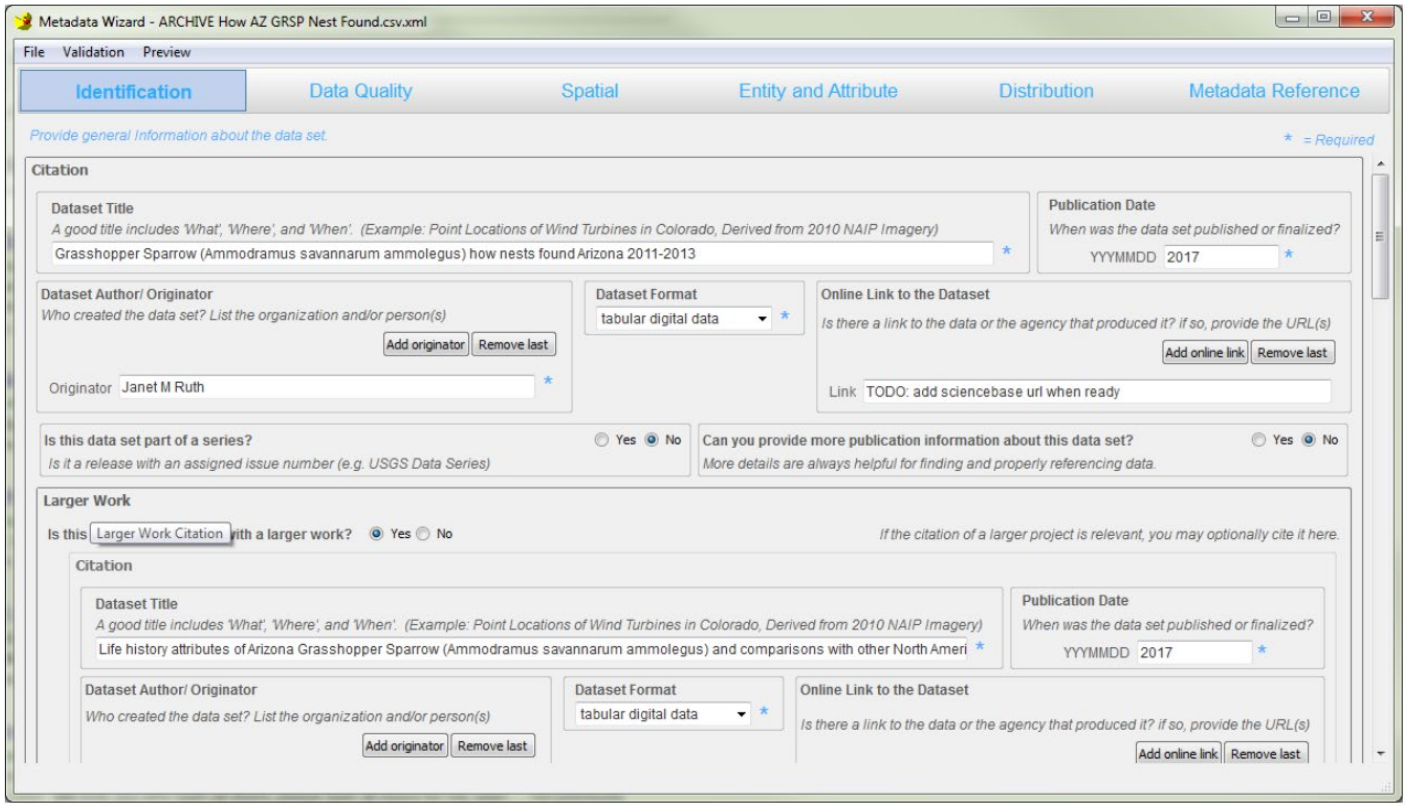


https://go.illinois.edu/iloil

Do not forget about metadata!

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Metadata Wizard

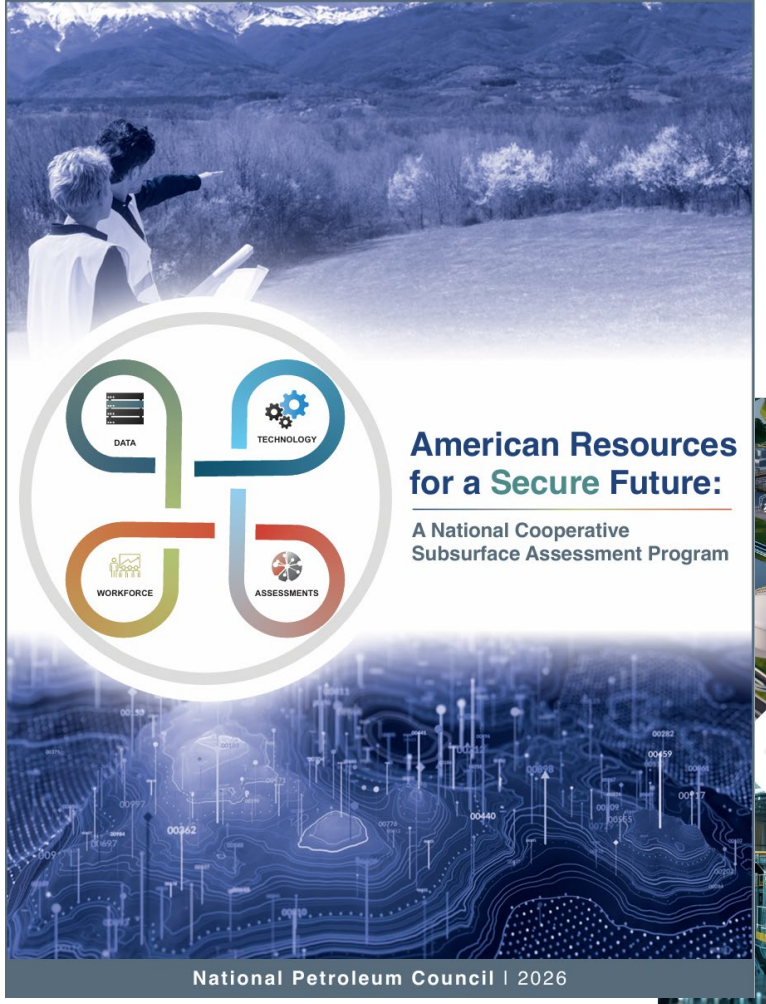


Next steps

- We are working on preserving assessment data at the USGS.
- Pressure data are the farthest along.
  - Those will be served in a hexagonal cellular model.
- Geospatially differentiated data is the path forward. As best we can.
  - But needs some standardization.
- Starting to work towards a three-dimensional data model, even if they are stovepipes in some cases.
  - Stovepipes being data delivered in geocellular model, showing trends with depth.
- Three-dimensional data served within geologic strata would be ideal to move away from stovepipes.

Next steps

- Continue building these layers and models; serve them to the public.
- Many at the USGS are working on these efforts but they need more internal coordination.
- How can we coordinate similar efforts throughout the U.S.?
- Ultimately serve data not just within individual basins, but across the U.S. and between the basins.





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