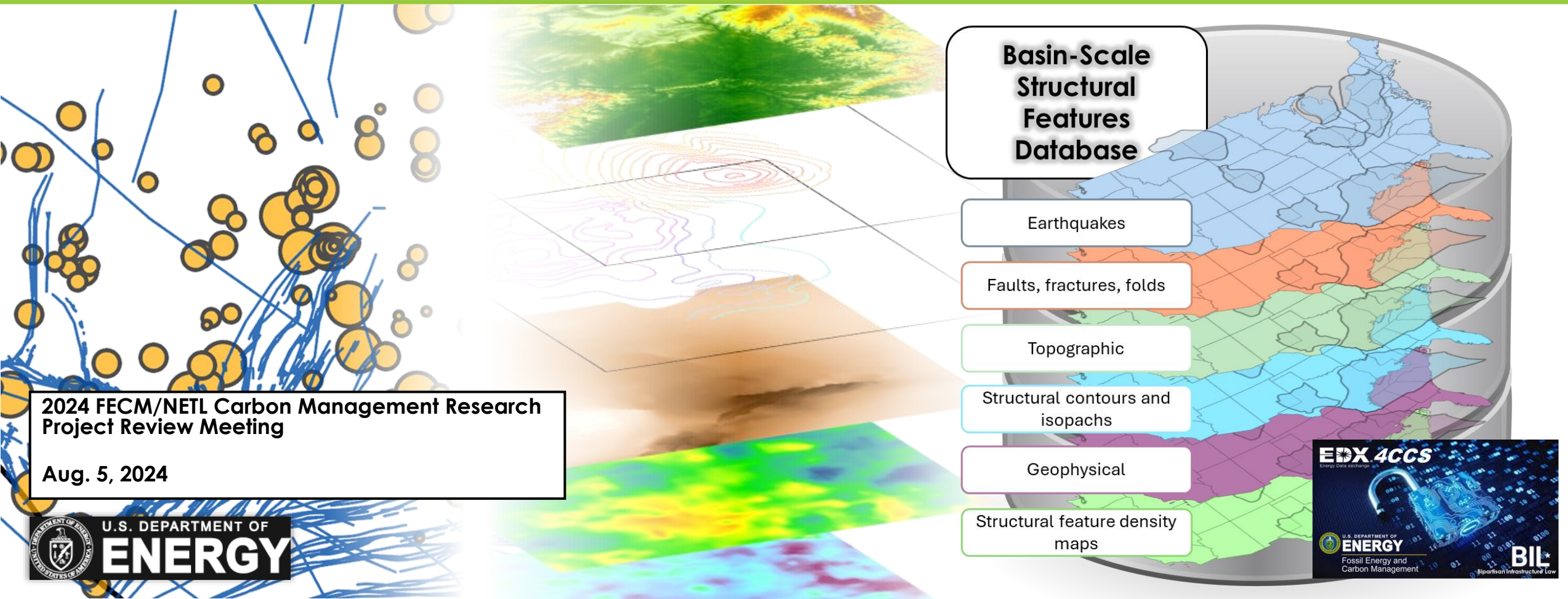# Basin-Scale Structural Features Database

Spatial Datasets to Support Carbon Storage Resource Assessments

Devin Justman

Geology/Geospatial Research Scientist/NETL Support Contractor

NETL — NATIONAL ENERGY TECHNOLOGY LABORATORY

Basin-Scale Structural Features Database

- Earthquakes
- Faults, fractures, folds
- Topographic
- Structural contours and isopachs
- Geophysical
- Structural feature density maps

2024 FECM/NETL Carbon Management Research Project Review Meeting

Aug. 5, 2024

U.S. DEPARTMENT OF ENERGY

EDX 4CCS — Energy Data exchange

U.S. DEPARTMENT OF ENERGY — Fossil Energy and Carbon Management

BIL — Bipartisan Infrastructure Law

Disclaimer

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[4]NETL Support Contractor, 3610 Collins Ferry Road, Morgantown, WV 26505, USA

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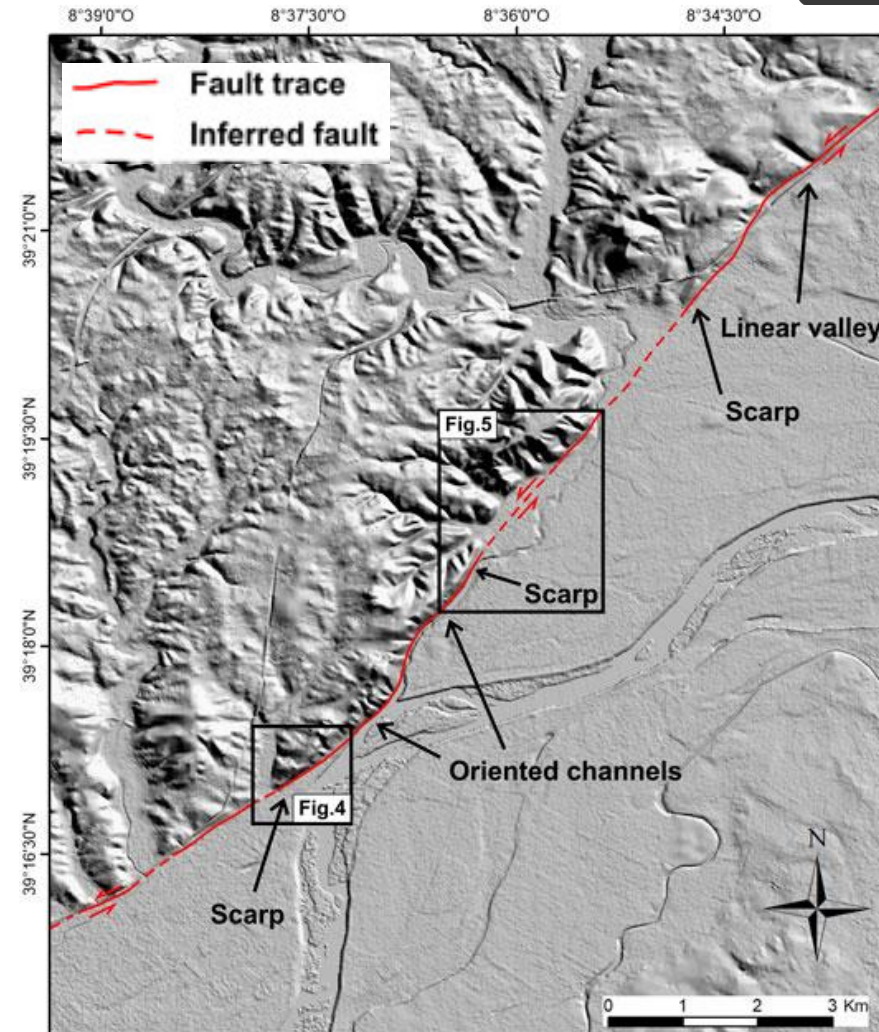
Structural Features....

What are they?

- Faults, fractures, folds...

How are they represented?

- Measured
- Inferred

Why do they Matter?

- CO_2 storage, geothermal, mineral resources...
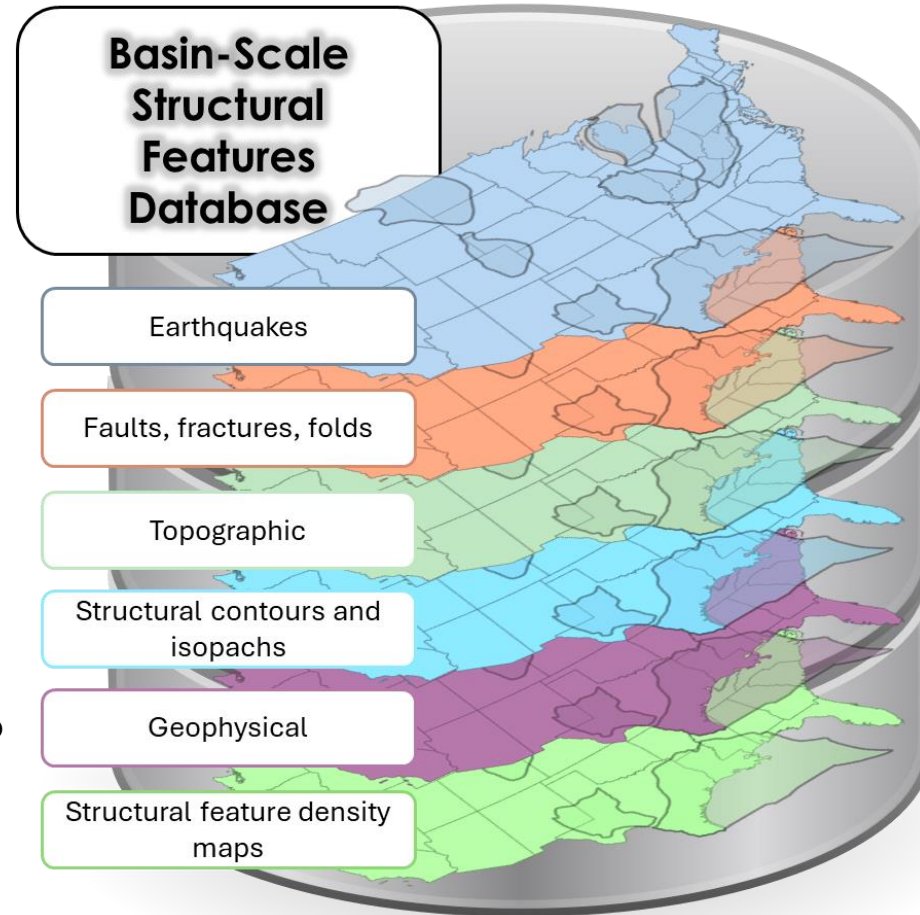- Seismic/Induced seismic hazards....

Canora et al., 2021

Basin-Scale Structural Features Database v1.0

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Purpose:

- Produce an integrated database of **basin-scale structural feature datasets**, for use in **carbon storage-based assessments**

Challenge:

- Readily, publicly available structural data are multi-sourced, multi-format

- A lack of **unified** information to better understand the influence that **basin-scale structure** will have on **long-term carbon storage security**

Basin-Scale Structural Features Database

- Earthquakes
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- Geophysical
- Structural feature density maps

User community:

- Researchers, external company project leads, and policy makers

- EDX4CCS and other BIL-funded projects

**EDX** Energy Data eXchange **4CCS**   **EDX SPATIAL**   **disco₂ver**

Potential insights for a given basin:

- Provide information about areas with limited structural feature information

- **Multiple datasets = multiple perspectives** on structural feature representation

Developing a Basin-Scale Structural Features Database

Method Overview

- **Screening method and approach to predict the potential for complex structural features to exist**

    - To better understand geo-hazards linked with faults and fractures

    - Mitigate risks associated with human-subsurface interactions

- **Tested and validated method in Oklahoma**

    - SIMPA tool- Spatially Integrated Multivariate Probabilistic Assessment (**Wingo et al., 2019**)
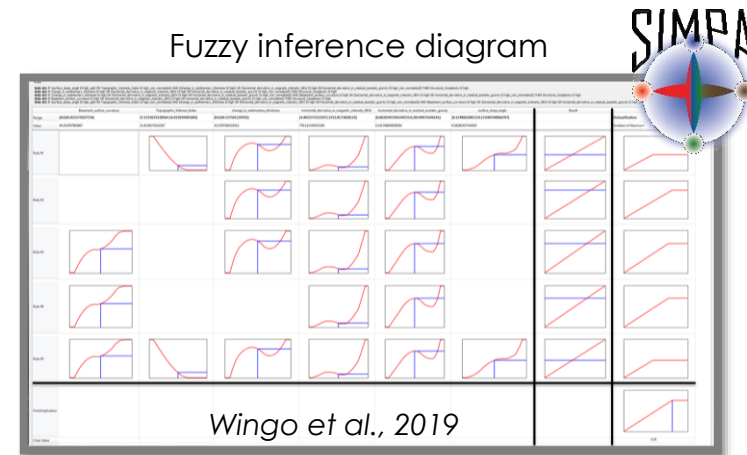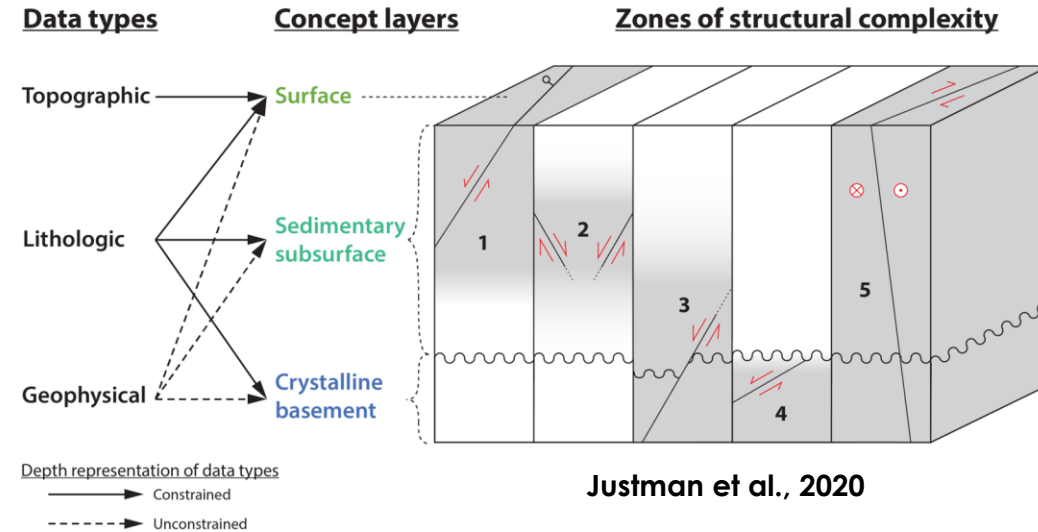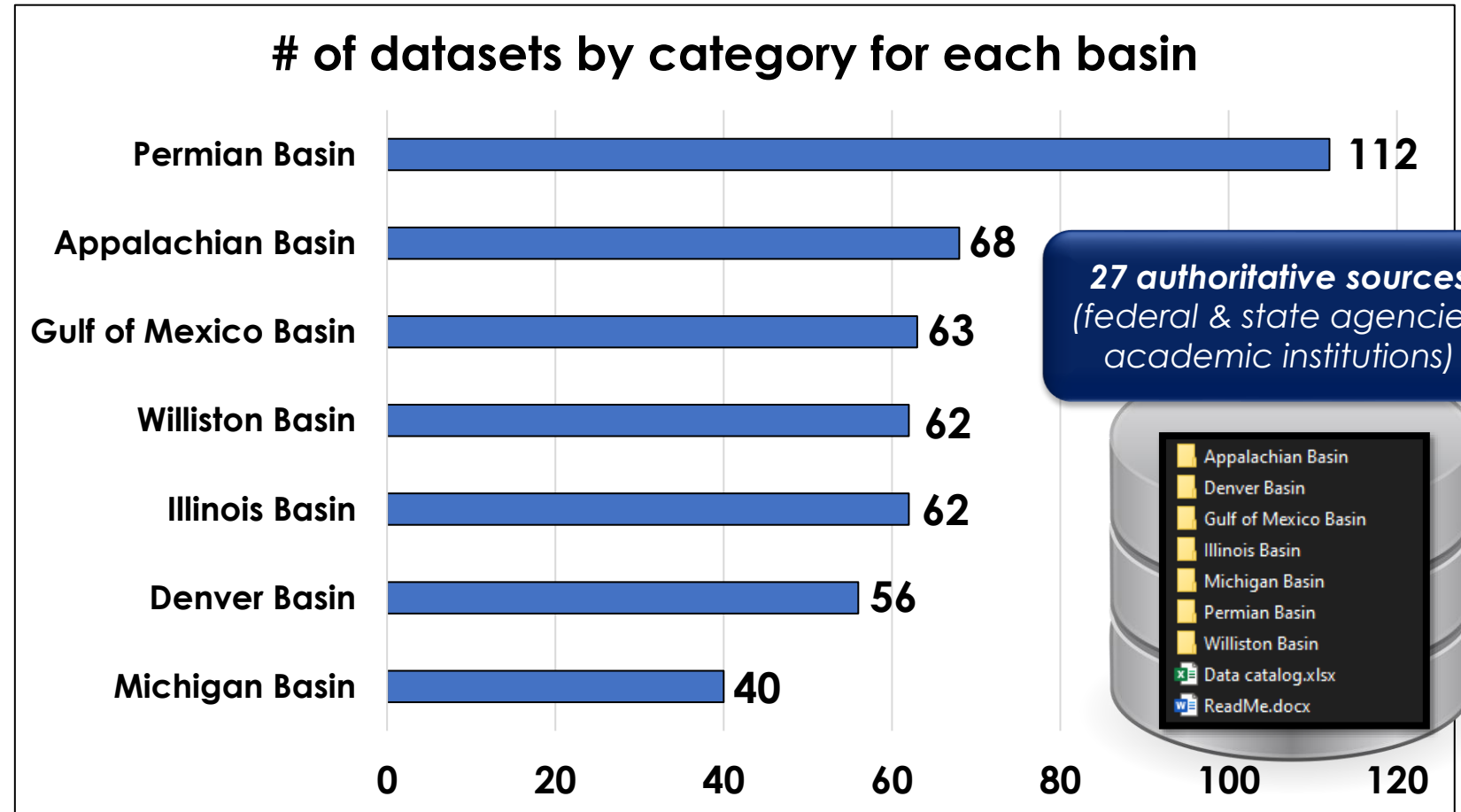
    Justman, D., Creason, C. G., Rose, K., & Bauer, J. (2020). A knowledge-data framework and geospatial fuzzy logic-based approach to model and predict structural complexity. **Journal of Structural Geology**, 141, 104153.

Justman et al., 2020

Fuzzy inference diagram

Wingo et al., 2019

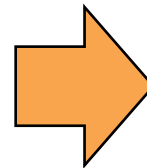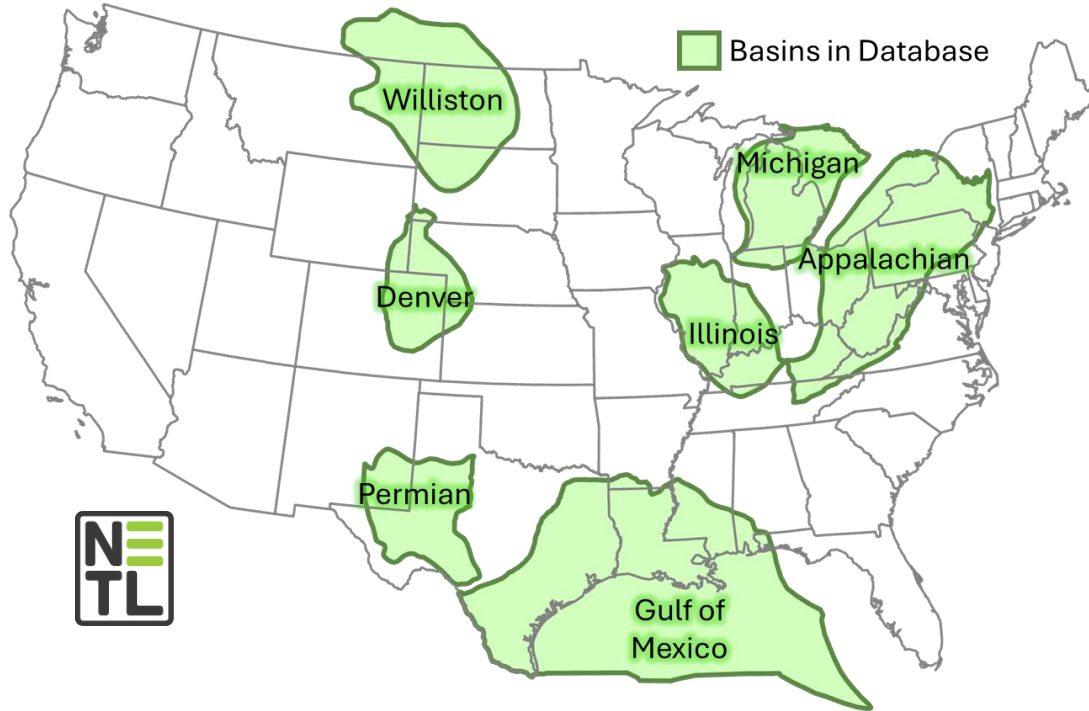# Basin-Scale Structural Features Database v1.0

What does it contain?

- **463 spatial datasets** for **7 saline basins**
  - Datasets organized by basin and category

- **Data catalog-** source and key metadata information

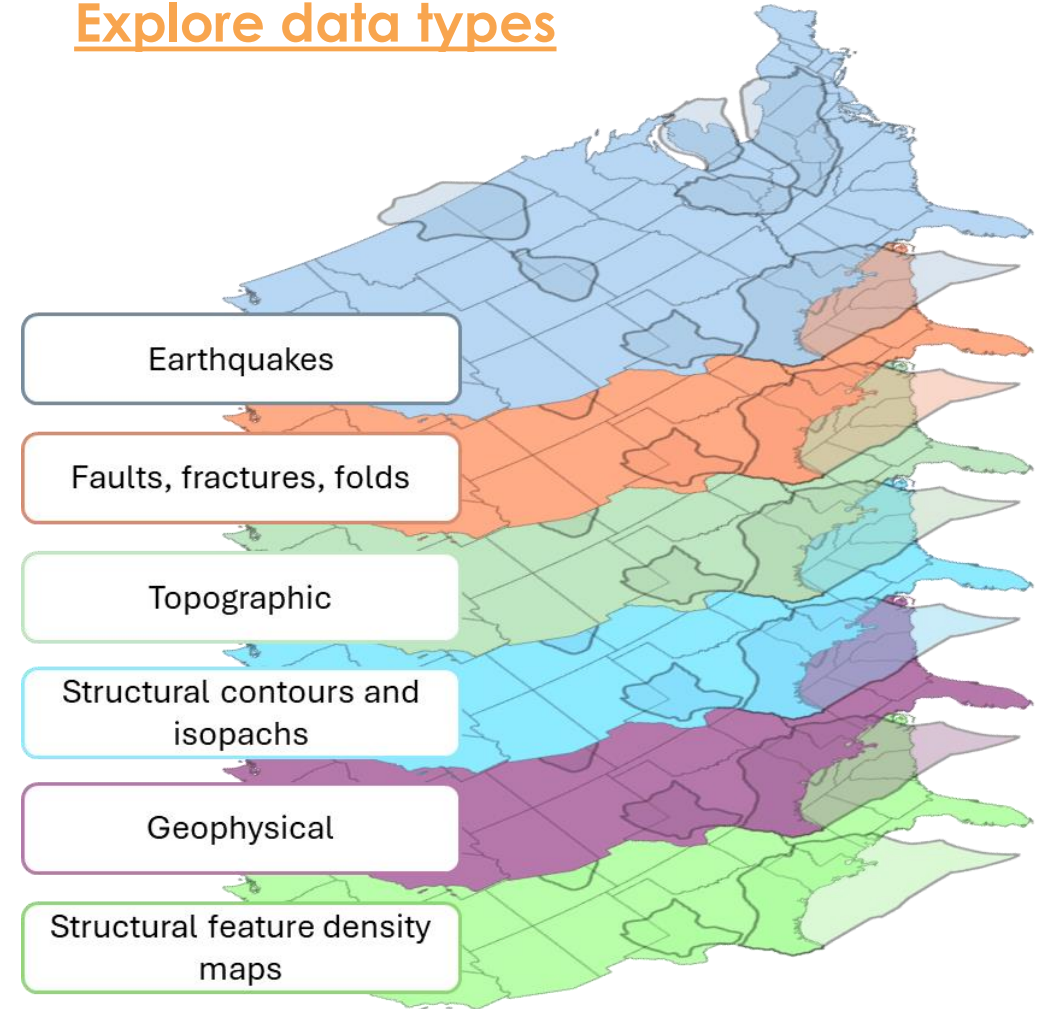- **ReadMe-** Background information, metadata, and key explanations

# of datasets by category for each basin

Basin	# of datasets
Permian Basin	112
Appalachian Basin	68
Gulf of Mexico Basin	63
Williston Basin	62
Illinois Basin	62
Denver Basin	56
Michigan Basin	40

27 authoritative sources (federal & state agencies, academic institutions)

- Appalachian Basin
- Denver Basin
- Gulf of Mexico Basin
- Illinois Basin
- Michigan Basin
- Permian Basin
- Williston Basin
- Data catalog.xlsx
- ReadMe.docx

Database Content

Choose a Basin

- Williston
- Michigan
- Appalachian
- Denver
- Illinois
- Permian
- Gulf of Mexico

Basins in Database

Explore data types

- Earthquakes
- Faults, fractures, folds
- Topographic
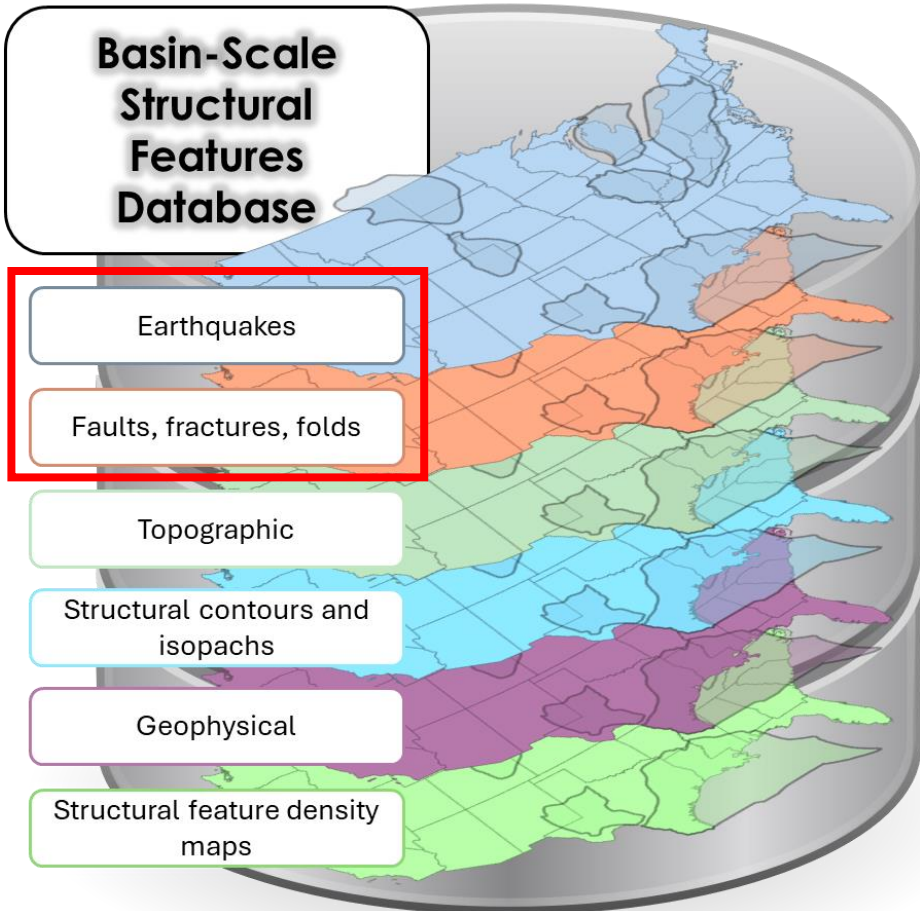- Structural contours and isopachs
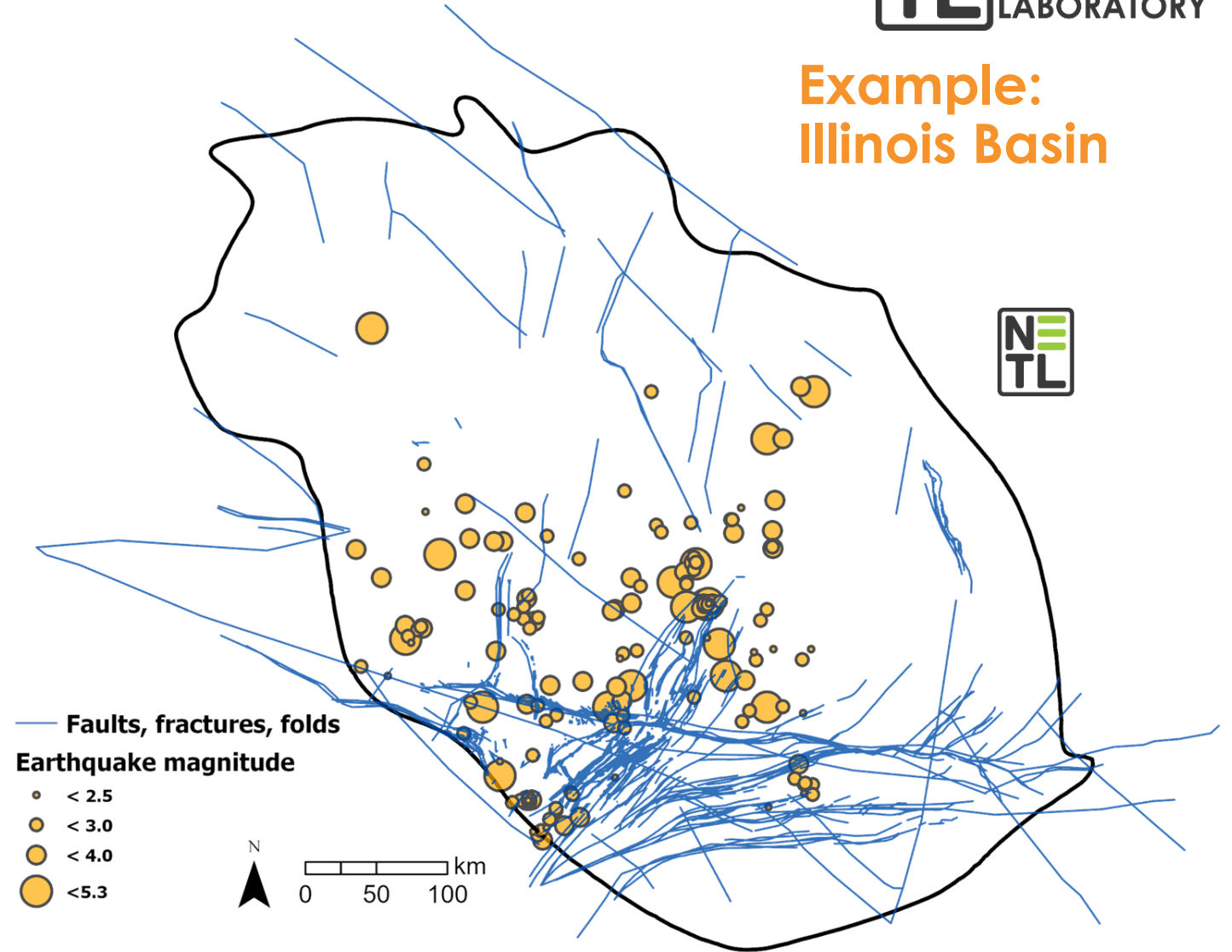- Geophysical
- Structural feature density maps

- Provides stakeholders with multiple structural data types for multiple perspectives on geologic structure within single unified database to view, conduct further research, and download
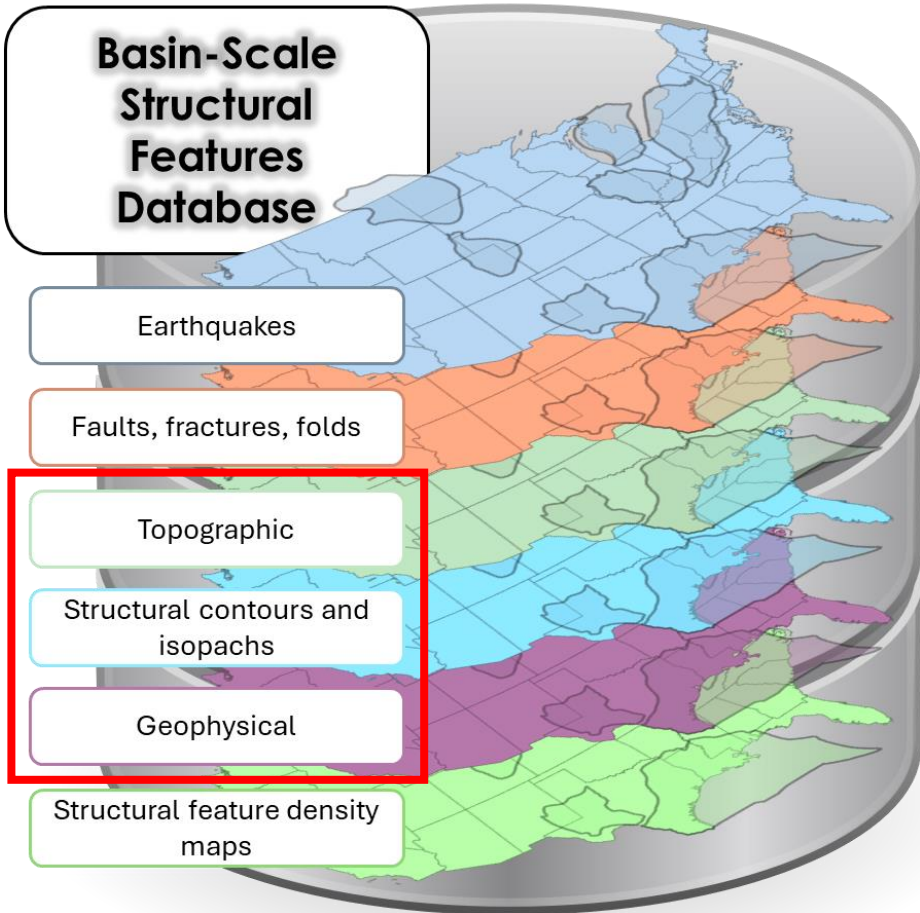
Measured structural feature data

Example: Illinois Basin

Basin-Scale Structural Features Database

- Earthquakes
- Faults, fractures, folds
- Topographic
- Structural contours and isopachs
- Geophysical
- Structural feature density maps

— Faults, fractures, folds

Earthquake magnitude
- ∘ < 2.5
- ∘ < 3.0
- ○ < 4.0
- ◯ < 5.3

N

km
0   50   100

Inferred structural feature data

Example: Illinois Basin

Basin-Scale Structural Features Database

- Earthquakes
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Ground elevation

Formation surface elevations

Formation Isopaches

Basement surface elevation

Gravity anomalies

Magnetic anomalies
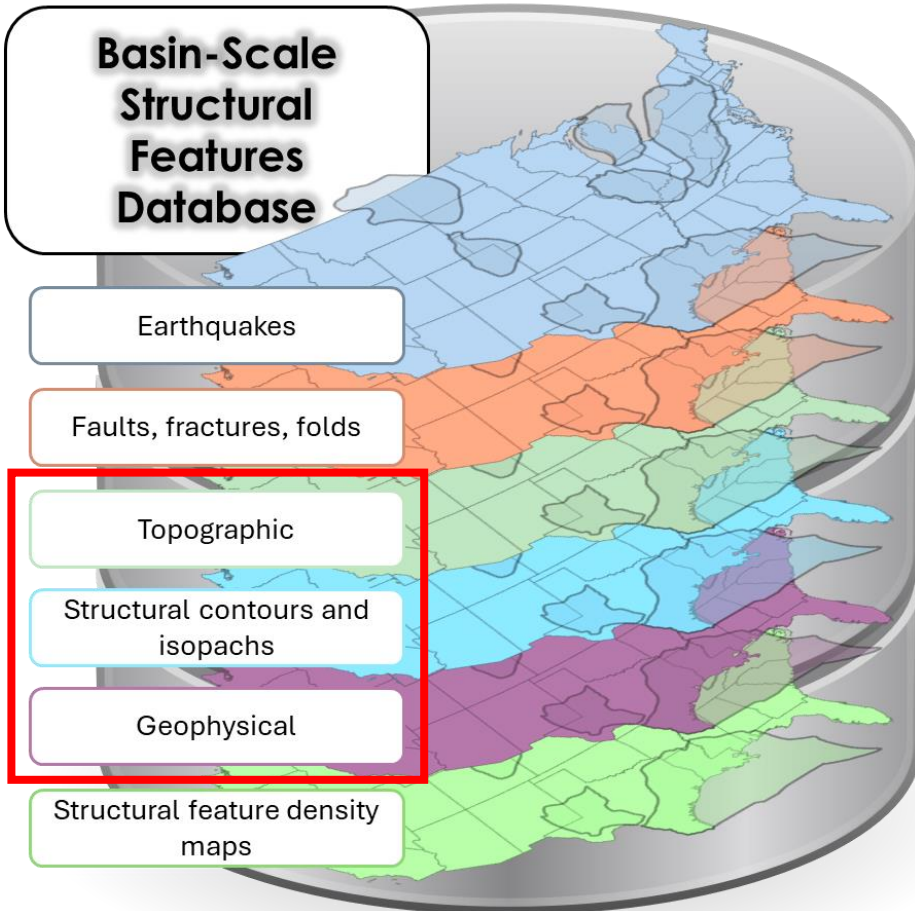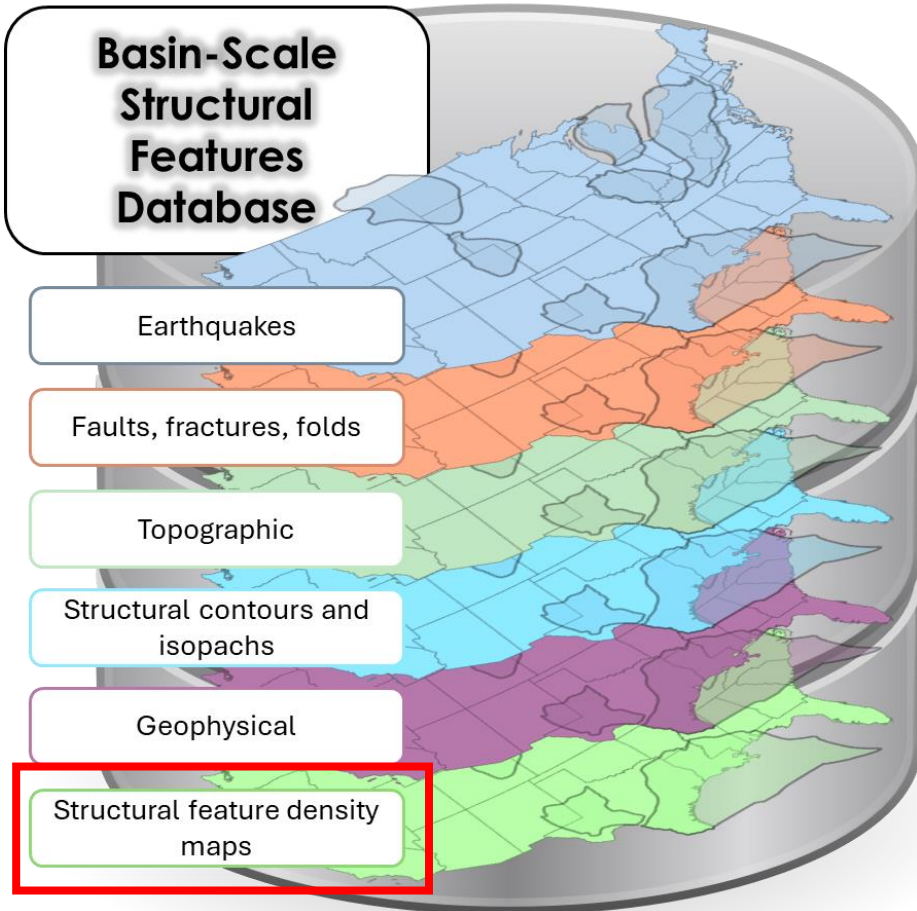
Inferred structural feature data derivatives

Example: Illinois Basin

Basin-Scale Structural Features Database

- Earthquakes
- Faults, fractures, folds
- Topographic
- Structural contours and isopachs
- Geophysical
- Structural feature density maps

Ground slope	
Topographic Wetness Index	
Formation surface curvature	
Change in formation thickness	
Change in sedimentary overburden thickness	
Basement surface curvature	
Horizontal derivative in gravity anomalies	
Horizontal derivative in magnetic anomalies	

Structural feature density assessment data

Basin-Scale Structural Features Database

- Earthquakes
- Faults, fractures, folds
- Topographic
- Structural contours and isopachs
- Geophysical
- Structural feature density maps

Measured structural data

Inferred structural data

Structural Feature Density (SFD) scores

- A score describing the **relative spatial density of structural features** for each basin ranging from 0 (lower density) to 1 (higher density).

Measured SFD score maps

Predicted SFD score maps

Measured structural feature density assessment data

Types of structural feature density

Bend damage (extensional)

Intersection damage

Tip damage

Linking damage (contractional step)

Distributed damage

Bend damage (contractional)

Linking damage (extensional step)

Wall damage

Approaching damage
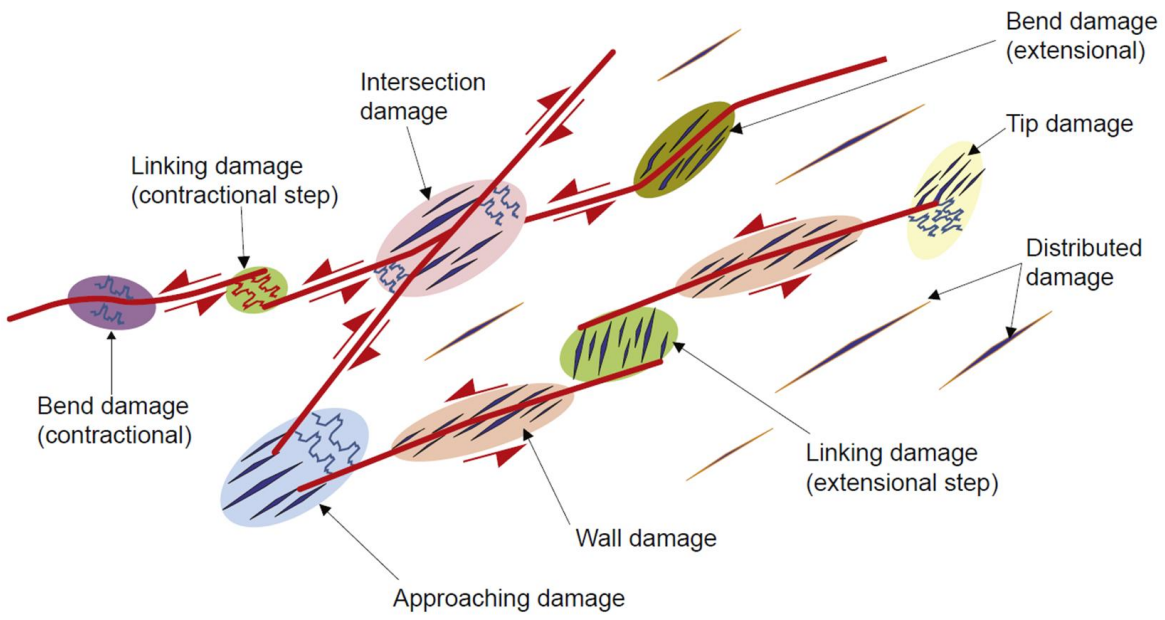
"Complex zones" or "damage zones" are areas with high fracture intensity/linkage and high variation in fracture orientations in contrast with surrounding areas and occur across a variety of tectonic setting, lithologies and scales.
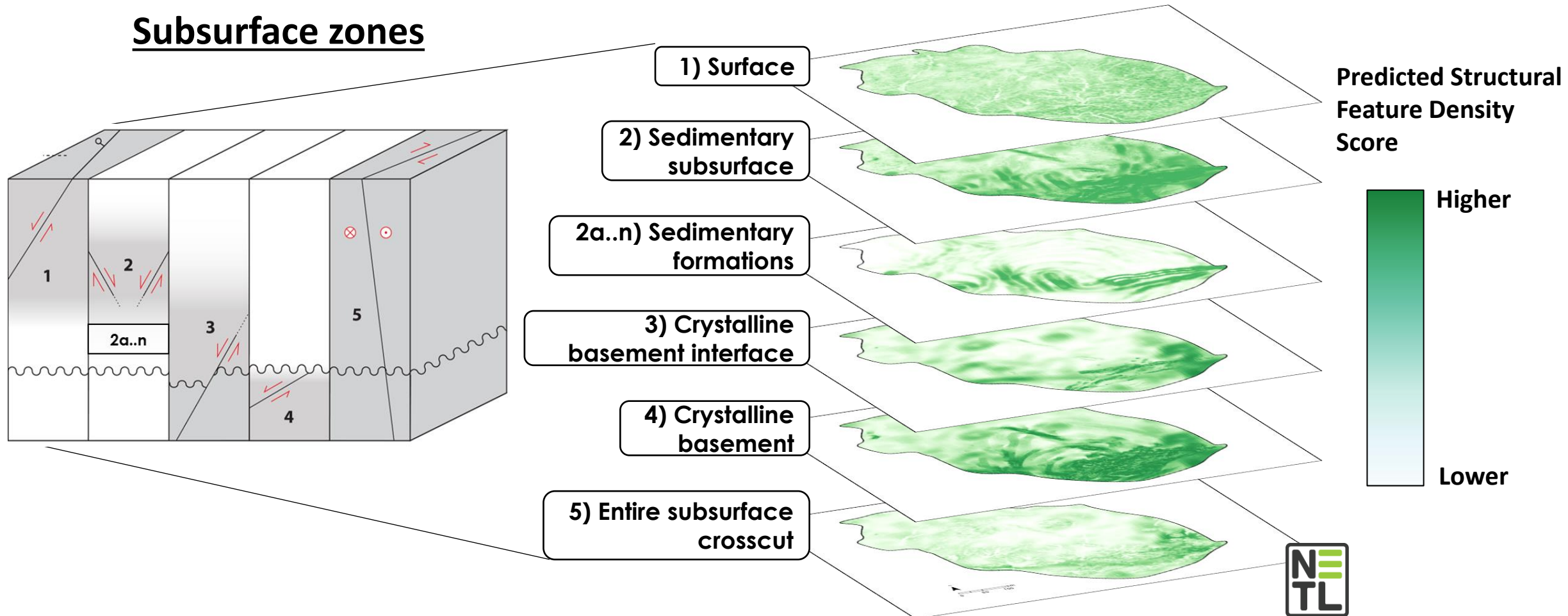*Peacock et al. (2017)*

Example: Illinois Basin
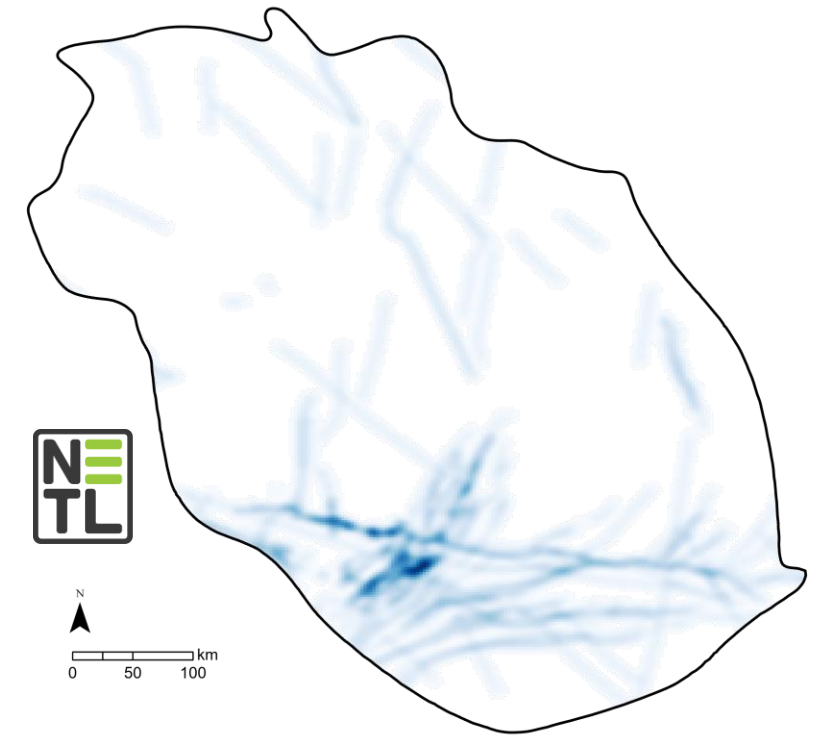
Measured Structural Feature Density Score

Lower ▭ Higher
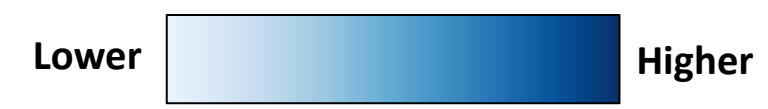
Predicted structural feature density assessment data

Example: Illinois Basin

Subsurface zones

- 1) Surface
- 2) Sedimentary subsurface
- 2a..n) Sedimentary formations
- 3) Crystalline basement interface
- 4) Crystalline basement
- 5) Entire subsurface crosscut

Predicted Structural Feature Density Score

Higher

Lower

Multiple Data Perspectives

Example: Illinois Basin

Faults, fractures, folds	Fault lines
Earthquakes	Earthquake locations
Topographic	Ground elevation
Structural contours and isopachs	Formation surface elevations
	Formation Isopaches
	Basement surface elevation
Geophysical	Gravity anomalies
	Magnetic anomalies

AOI

Structural feature density maps	**Known** structural feature density
	Predicted structural feature density

- At any given location, users can explore multiple data types representing structural features for a variety of use cases
  - Potential CS site locations, CS technical viability, etc.

- Raw data are processed to develop new datasets to represent **measured** and **predicted** structural feature density based on published methods (*Journal of Structural Geology; Justman et al., 2020*)

- Provides users with synthesized results to gain new insights into where potential structural features may exist

Basin-Scale Structural Feature Database v1.0

Next steps

- Develop datasets for additional saline basins

- Develop digital web atlas of database(12/31/2024) to:
  - Host, visualize, and explain the database for improved stakeholder engagement

- Publish updated database (3/31/2025)
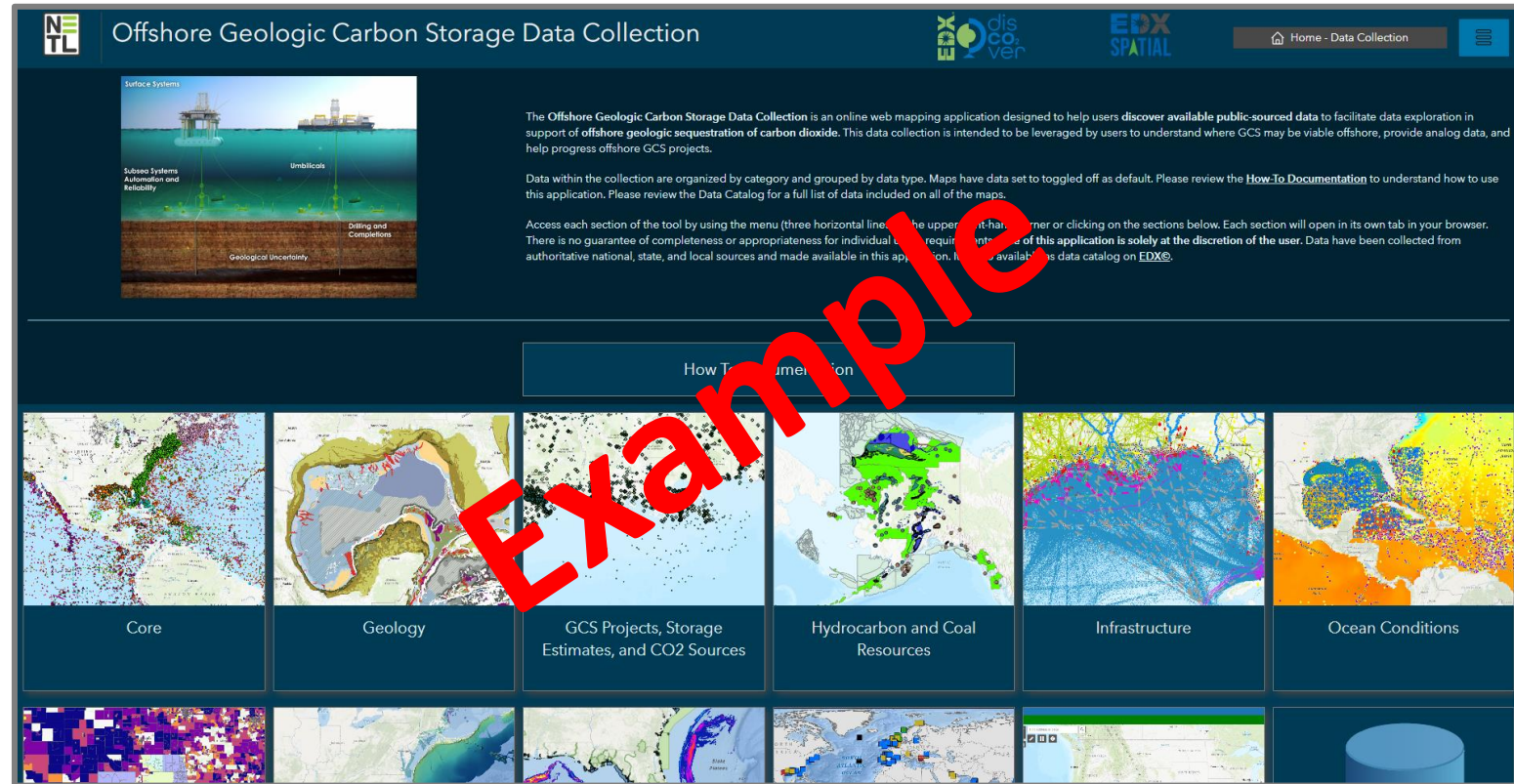
Julia Mulhern, MacKenzie Mark-Moser, Kelly Rose, Offshore Geologic Carbon Storage (GCS) Data Collection Web Application , 5/28/2024, https://edx.netl.doe.gov/dataset/offshore-geologic-carbon-storage-gcs-data-collection-web-application DOI: 1018141/2367369
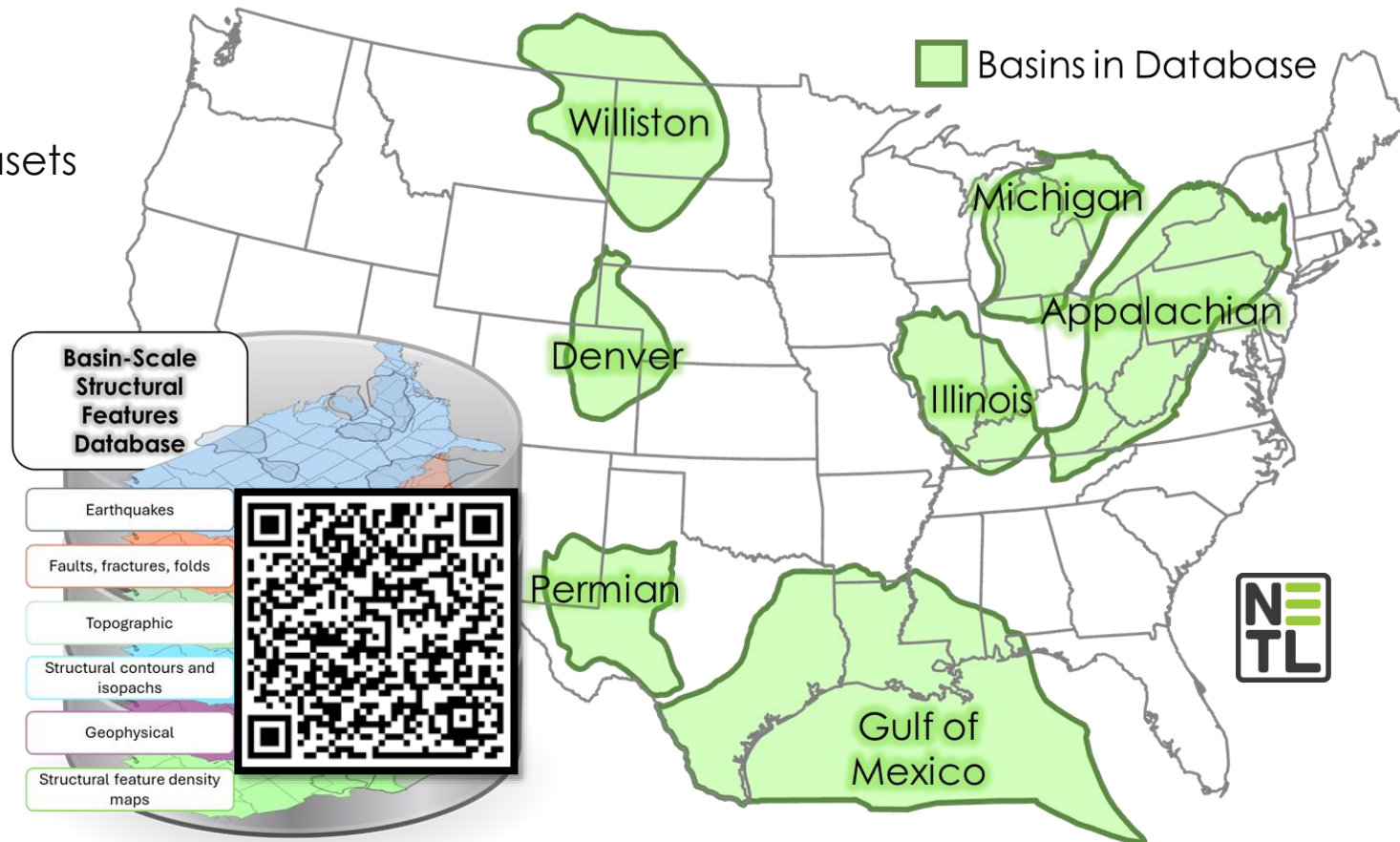
Basin-Scale Structural Feature Database v1.0

Ultimate Outcomes

- A database of *basin-scale* structure datasets for selected saline basins

- Digital atlas of structural features

- Published on **EDX DisCO$_2$ver Platform**

Stakeholder Benefit

- Provide information about areas with limited structural feature information

- **Multiple datasets = multiple perspectives** on structural feature representation

- Results can be leveraged to inform carbon storage resource and feasibility assessments and many other subsurface applications

Basins in Database

Williston
Michigan
Appalachian
Denver
Illinois
Permian
Gulf of Mexico

Basin-Scale Structural Features Database
- Earthquakes
- Faults, fractures, folds
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https://edx.netl.doe.gov/dataset/basin-scale-structural-features-database

disCO$_2$ver
Data Infrastructure to Accelerate CCS

https://edx.netl.doe.gov/sites/disco2ver-alpha/

the stats

54 RIC PRESENTATIONS

22 POSTERS

30 TOOL DEMOS

MONDAY

Presentations
(10:30AM – 5:25PM)

- 16 disCO2ver presentations

TUESDAY

Presentations
(10:30AM – 5:45PM)

- 17 SMART presentations
- 2 disCO2ver presentations
- 2 Geographic focus/tool presentations

Posters
(5:45PM – 7:45PM)

- 18 CTS Posters
- 2 PSCC Posters
- 1 CDR Poster
- 1 MLEF Poster

Tool Demos
(5:45PM – 7:45PM)

- 30 Tool Demos
  - SMART
  - NRAP
  - EDX
  - EDX4CCS

WEDNESDAY

Presentations
(2:10PM – 4:30PM)

- 3 transport, research, development, and demonstration activities presentations
- 1 transport modeling presentation
- 1 secure storage (basalts/mafic) presentation

THURSDAY

Presentations
(10:30AM – 5:20PM)

- 8 NRAP presentations
- 2 NETL RIC Presentations
- 2 Offshore presentations

https://edx.netl.doe.gov/disco2ver

NETL Carbon Storage Outreach Example
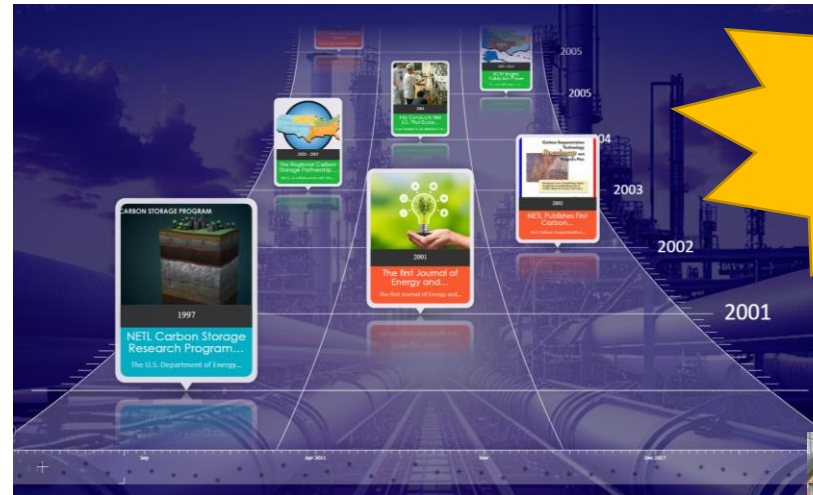
100+ DOE-sponsored CTS presentations

Presentations on EY23 CTS work:

- Advanced Storage FWP
- Carbon Storage Data FWP
- Carbon Storage Analysis FWP
- Multi-Modal Transportation FWP
- EDX4CCS
- NRAP
- SMART

Open to the public

**Attendees from government agencies, utilities, research, universities, industry**

Poster and tool/app demo session – Tuesday Aug. 6th evening

Aug. 5-9, 2024 Pittsburgh Convention Center

Carbon Storage Timeline summarizing field, lab and computational contributions to CTS' digital future
Live, interactive demo at the booth!
Source: NETL

Stop by the CTS booth in the exhibit hall to learn more!

Take-aways, information, expertise in one stop shop
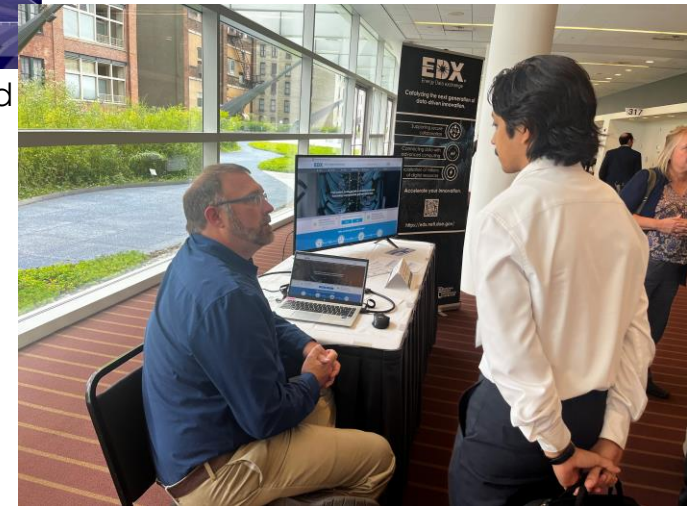
Multiple tool demos will be hosted
Source: NETL

References

- Justman, D., Creason, C. G., Rose, K., & Bauer, J. (2020). A knowledge-data framework and geospatial fuzzy logic-based approach to model and predict structural complexity. Journal of Structural Geology, 141, 104153. https://doi.org/10.1016/j.jsg.2020.104153

- Wingo, P., Justman, D., Creason, G., Jones, K., Bauer, J., and Rose, K., *SIMPA*, 2019-03-29, https://edx.netl.doe.gov/dataset/simpa-tool, DOI: 10.18141/1503876

- Julia Mulhern, MacKenzie Mark-Moser, Kelly Rose, Offshore Geologic Carbon Storage (GCS) Data Collection Web Application , 5/28/2024, https://edx.netl.doe.gov/dataset/offshore-geologic-carbon-storage-gcs-data-collection-web-application DOI: 1018141/2367369

- Dimmen, V., Rotevatn, A., Peacock, D.C., Nixon, C.W. and Nærland, K., 2017. *Quantifying structural controls on fluid flow: Insights from carbonate-hosted fault damage zones on the Maltese Islands.* Journal of Structural Geology, 101, pp.43-57.

- Peacock, D. C. P., Dimmen, V., Rotevatn, A., & Sanderson, D. J., 2017. *A broader classification of damage zones.* Journal of Structural Geology, 102, 179-192.

- Canora, C., Vilanova, S. P., De Pro-Diáz, Y., Pina, P., & Heleno, S. (2021). Evidence of surface rupture associated with historical earthquakes in the lower Tagus valley, Portugal. Implications for seismic hazard in the Greater Lisbon area. Frontiers in Earth Science, 9, 620778.

Acknowledgments

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