Multi-Scale 3D Imaging for Machine Learning Property Upscaling: Mt. Simon Sandstone Case Study

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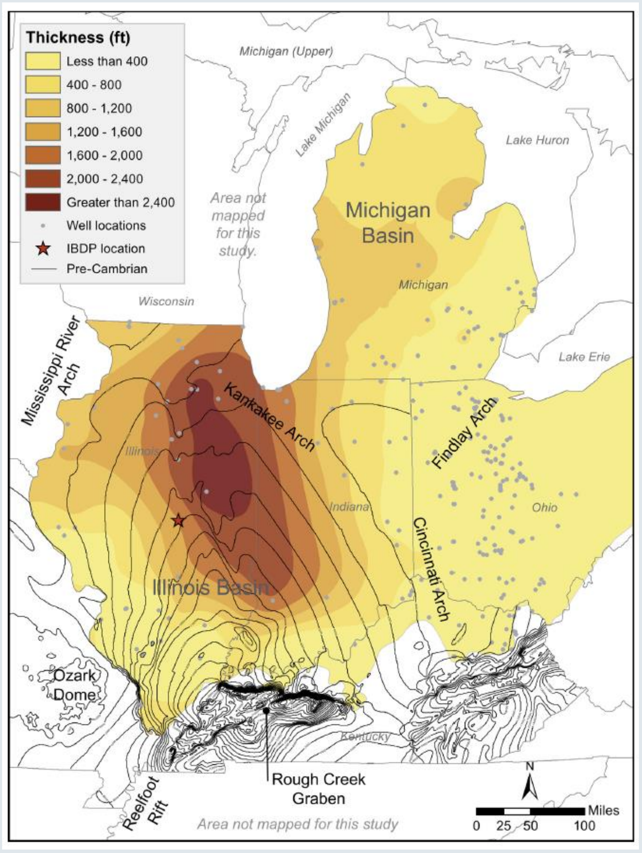
Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

Introduction



Freiburg JT, Ritzi RW and Kehoe KS, Depositional and diagenetic controls on anomalously high porosity within a deeply buried CO_2 storage reservoir - the Cambrian Mt. Simon Sandstone, Illinois Basin, USA. *Int J Greenhouse Gas Control* **55**:42–54 (2016).

Petrographic properties of target reservoirs for carbon sequestration, such as the Mt. Simon Sandstone, are relevant to broad interest groups. The Mt. Simon is a deep saline, regionally extensive Cambrian sandstone, overlain by low permeability sealing formations. Its thickness (exceeding 2,400 ft in some localities), depth, and lateral extent, combined with high porosity and permeability make it a high-priority target of multiple ongoing geologic carbon sequestration efforts in the United States of America.

The National Energy Technology Laboratory in Morgantown, West Virginia, has been engaged in characterization efforts of the Mt. Simon for over a decade, with a strong focus on Computed Tomographic (CT) data acquisition. Data generated during this period has hitherto not accessible to the public. This archival effort focused on preservation of historical CT data and associated metadata and facilitating their accessibility, culminating with the publication of the entire dataset on NETL's Energy Data eXchange (EDX) and the associated Gill et al. (2024) paper in Data in Brief.

Methods:

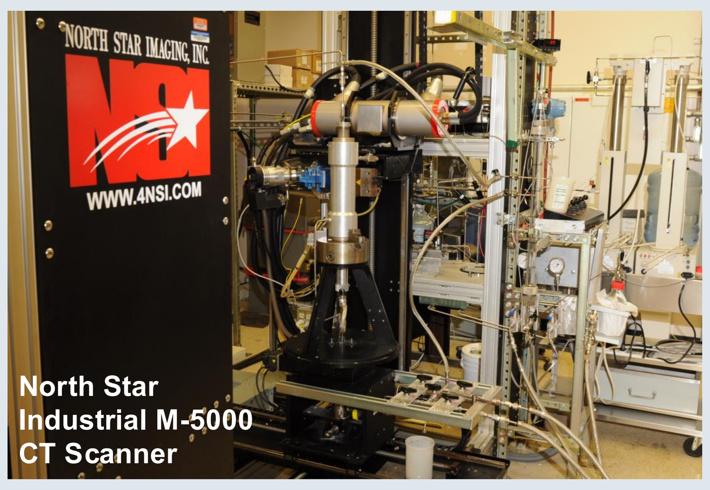
Samples were obtained from the Lower Mt. Simon Sandstone in the subsurface of the Illinois Basin, from Verification Well #1 (39°52'47.23''N, 88 °53' 36.21'' W) and Verification Well #2 (39°53'32.07''N, 88 °53'32.82''W). These monitoring wells were drilled as part of the Illinois Basin - Decatur Project to improve the understanding of CO_2 plume migration and post-injection site behavior.

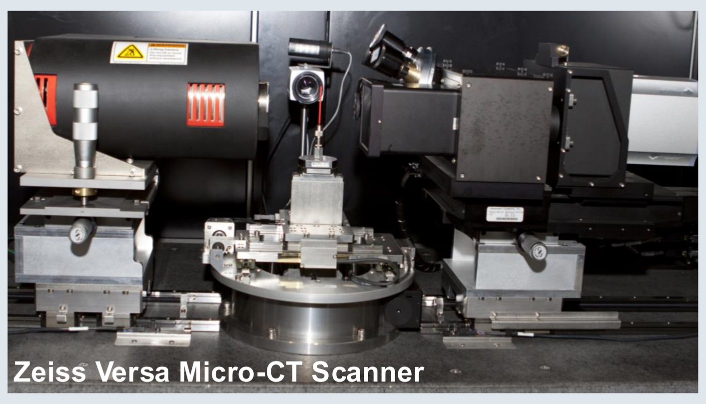
The Geocharacterization Lab at the Morgantown WV, NETL campus is focused on non-destructive geomaterial characterization and features four CT scanners, as well as a Multi-Sensor Core Logger, and experimental flow-through lab.

Samples were scanned with the North Star Industrial M-5000 CT scanner and the Zeiss Versa XRM-400 Micro-CT scanner for a range of sample sizes and resolutions.

Some cores were imaged in a dry state, while others were saturated with brine, CO_2-saturated brine, or supercritical CO_2. Multiple scans of the same sample with differing resolutions, or with different fluids present are included in the database.

Geoimaging and Characterization Fact Sheet

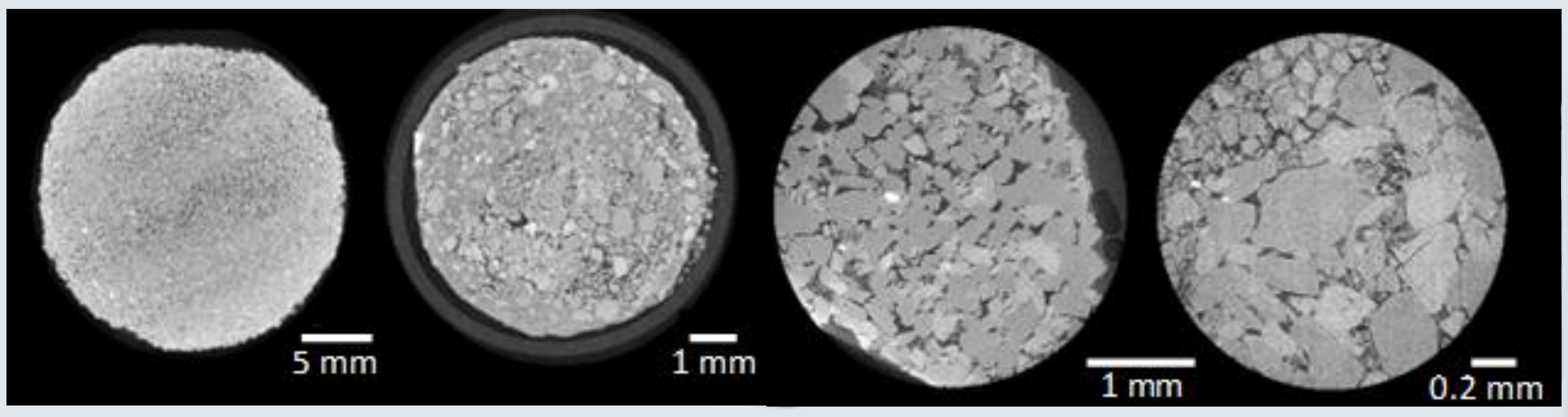




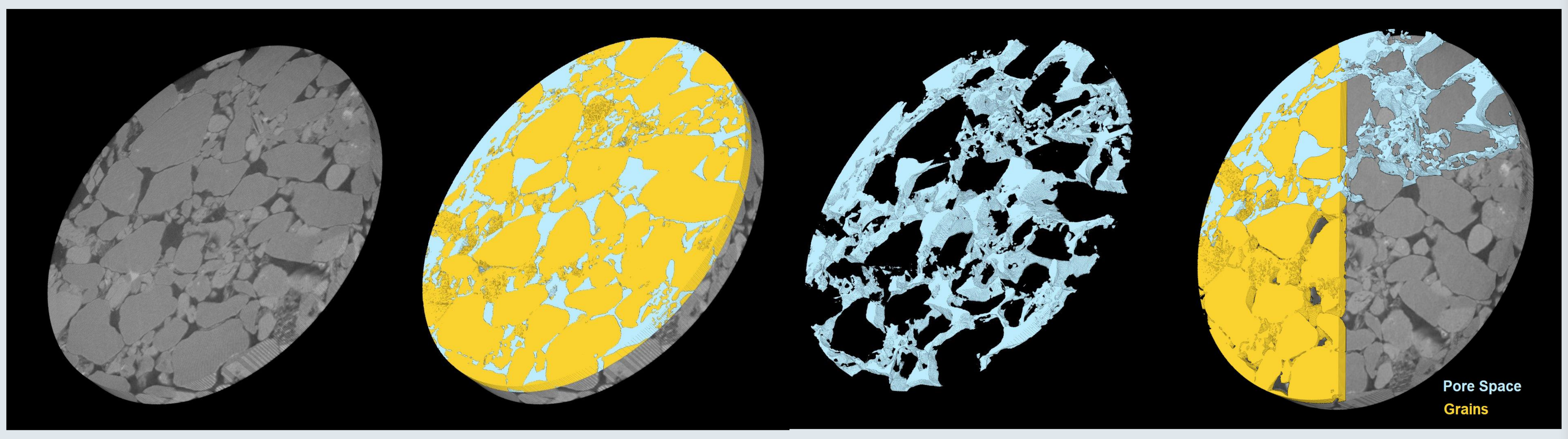
Dataset:

- Six core samples
- 37 CT scans
- 510.2 GB of raw image data
- Resolution range from high (14.79 µm) to very high (0.68 µm)
- Dry, brine or super critical CO_2 saturated cores

VW1 subcore photos



Two-dimensional (2D) slices through a selection of CT scans of Mt. Simon Sandstone cores. Leftmost image is from a lower resolution (14.79 µm) scan from the Industrial CT scanner, while the remaining images showcase the range of higher resolutions possible with the Micro-CT scanner.

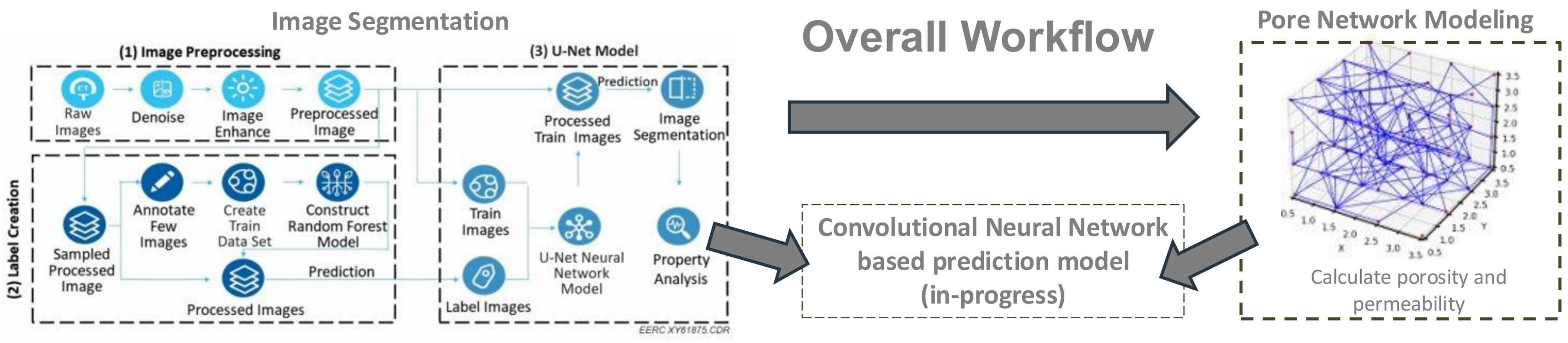


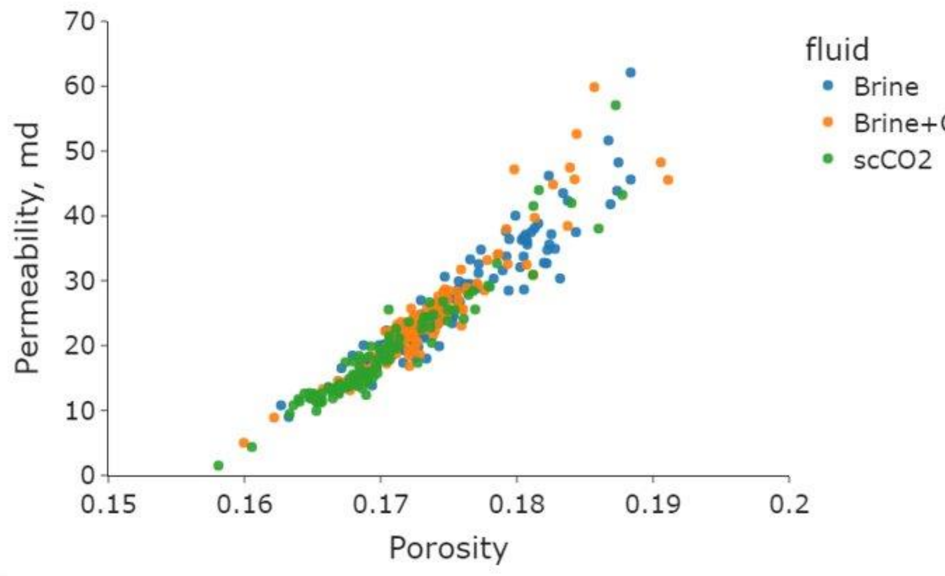
Example of segmentation from grayscale three-dimensional (3D) CT image: matrix grains in yellow, and pore space in pale blue.

Data Utility and Examples:

- High-resolution 3D CT images are a source of information on porosity and permeability in a format suitable for a variety of research and modeling needs.
- This data provides petrographic and diagenetic characteristic data, such as mineral composition, sediment maturity, and degree of cementation.
- The images are a valuable resource to researchers interested in characterizing CO_2 storage reservoirs, testing petrophysical relationships, and improving the information used to generate reservoir models for geological carbon storage.
- The range of image resolutions provides a training ground for machine learning based analysis to help improve algorithms.

Evolution of permeability while injecting sequential fluid: Brine, Brine+CO_2, sc-CO_2 *Preliminary Results from EERC*





Permeability was degraded:
by 11% after Brine+CO_2
by 35% after scCO_2 injection

Fluid	Perm, md	k_final / k_ini	Porosity
Brine	28.4		0.176
Brine+CO_2	25.5	0.89	0.174
scCO_2	18.6	0.67	0.170

Data available on Energy Data eXchange edx.netl.doe.gov

https://edx.netl.doe.gov/dataset/mt-simon-sandstone-high-resolution-ct

Disclaimer: This project was funded by the United States Department of Energy, National Energy Technology Laboratory, in part, through a site support contract. Neither the United States Government nor any agency thereof, nor any of their employees, nor the support contractor, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Gill, Magdalena, Mathias Pohl, Sarah Brown, Karl Jarvis, and Dustin Crandall. **"High-Resolution Computed Tomography Scan Dataset of Lower Mount Simon Sandstone Samples from the Illinois Basin."** Data in Brief (2024): 110643.

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