# Geochemical Alteration Impact on Trapping and Flow (FWP-1022403)

NATIONAL ENERGY TECHNOLOGY LABORATORY

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08/29/2023


U.S. DEPARTMENT OF ENERGY

# Disclaimer and Author List



**NETL**

- Thomas Paronish, Karl Jarvis, Magdalena Gill, Terry McKisic, Scott Workman, Rhiannon Schmidt

**WVU**

- Graham Andrews

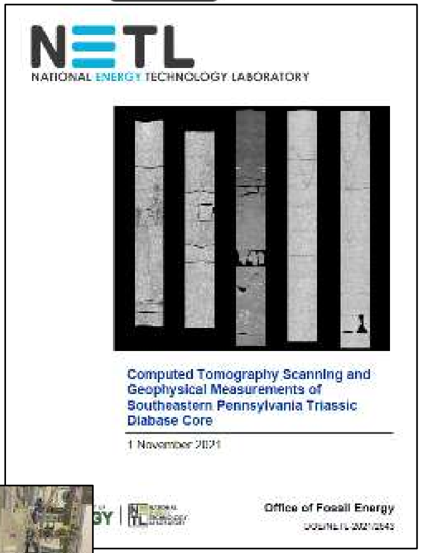
**Pennsylvania Bureau of Geological Survey**

- John Neubaum

# Project Overview

**Project Summary:** Visualize and describe dynamic evaluation of rocks due to dissolution and mineralization of $CO_2$ through fractured seals and reservoirs

- Building off of 2021 core characterization report with PA Geological Survey, examined and described the rapid mineralization of east coast mafic sills due to $CO_2$/brine exposure
    - Planned 50 day exposures. Saw pressure stabilization in less than a week
- **Schmitt, R.R., Andrews, G.D.M., Moore, J., Paronish, T., Workman, S., Gumowski, L.M., Brown, S.R., Crandall, D., Neubaum, J. (2022) Self-Sealing Mafic Sills for Carbon and Hydrogen Storage, *Geological Society, London, Special Publications Vol 528*** [https://doi.org/10.1144/SP528-2022-43](https://doi.org/10.1144/SP528-2022-43)
- Experimental system upgrade in NETL's new TESCAN DynaTOM system with heated core holder.


NETL
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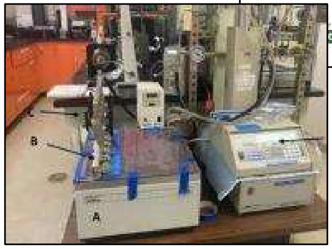
Computed Tomography Scanning and Geophysical Measurements of Southeastern Pennsylvania Triassic Diabase Core

1 November 2021

Office of Fossil Energy



# Project Milestones

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- **Abbreviated Milestone Update**

| ID | Type | Completion Date | Description | Status |
|---|---|---|---|---|
| 46.A | Project | 12/30/2022 | Shakedown NETL's TESCAN DynaTOM computed tomography scanner to evaluate supercritical $CO_2$/brine flows through rocks of interest. | Complete |
| 46.B | Project | 03/31/2023 | Perform a minimum of two tests showing the change in permeability through fractured igneous diabase from the eastern coast of the United States due to carbonated brine flow. | Delayed |

- **Challenges:**

Three of the primary researchers associated with this work are no longer at NETL.

The NETL TESCAN DynaTOM has been shut down since January due to elevated radiation external to the cabinet and equipment malfunctions.

# Prior Work

Rhiannon Schmitt (Tempke)

- **Characterization of five Triassic Diabase wells**
  - Rosser Road Borehole 1, Rosser Road Borehole 2, Waltonville Road Borehole 1, Waltonville Road Borehole 2, and Susquehanna River well
  - Included first pass non-destructive measurements (Medical CT imaging, multi-sensor core logger, and whole core Industrial CT imaging)
- **Diabase plugs were collected from representative regions**
  - Additional characterization (XRD, SEM, high-resolution CT images)
- **Samples were crushed and exposed to an aqueous $CO_2$ solution at representative subsurface pressure and temperature for 30 days**
- **Following samples were examined for mineralogy changes using XRD.**
- **Findings showed rapid carbonate mineralization in the diabase samples**

# Data from Diabase TRS

Figure 75: 2D image from industrial CT scan of the Susquehanna River core at 129.2 ft. where the red arrow indicates a mineralized fracture.

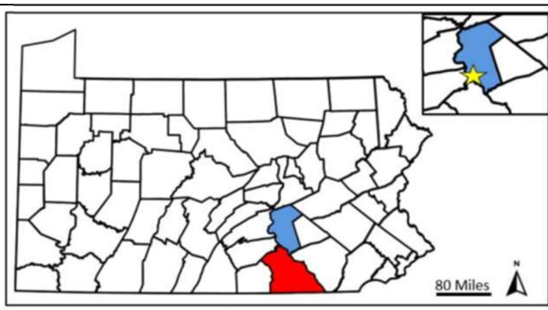



Figure 1: County map of Pennsylvania highlighting York County (blue) and Dauphin County (red). Diabase cores were obtained from the Pennsylvania Geological Survey, near Harrisburg, Pennsylvania (indicated with a yellow star).

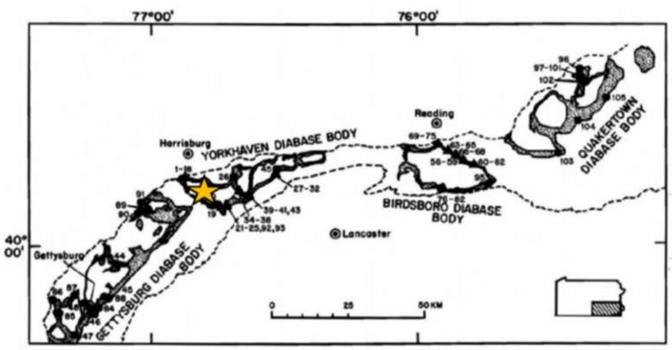
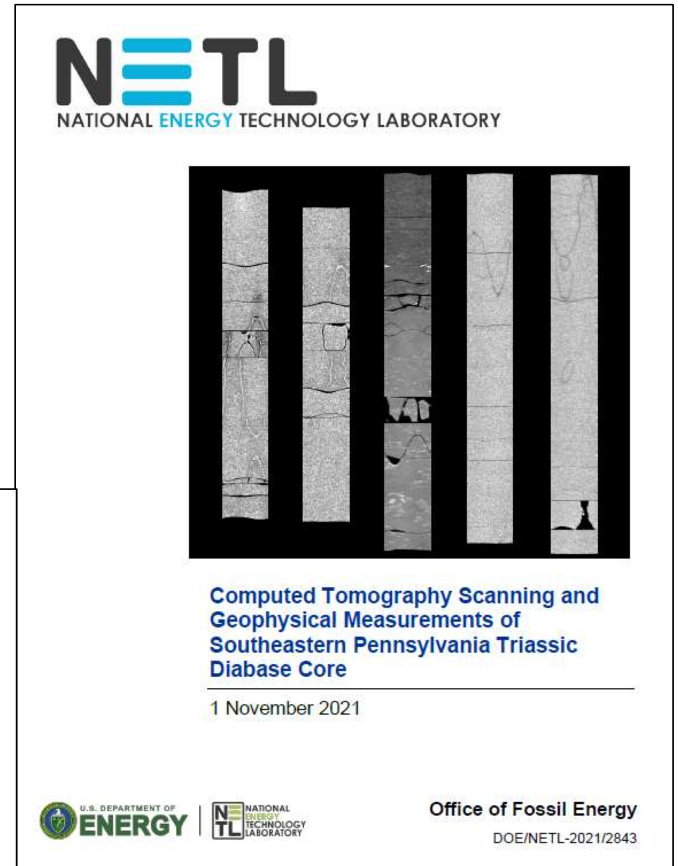



Figure 2: Diabase bodies map adapted from Beck (1972) to show the location of the cores in this study indicated with a gold star.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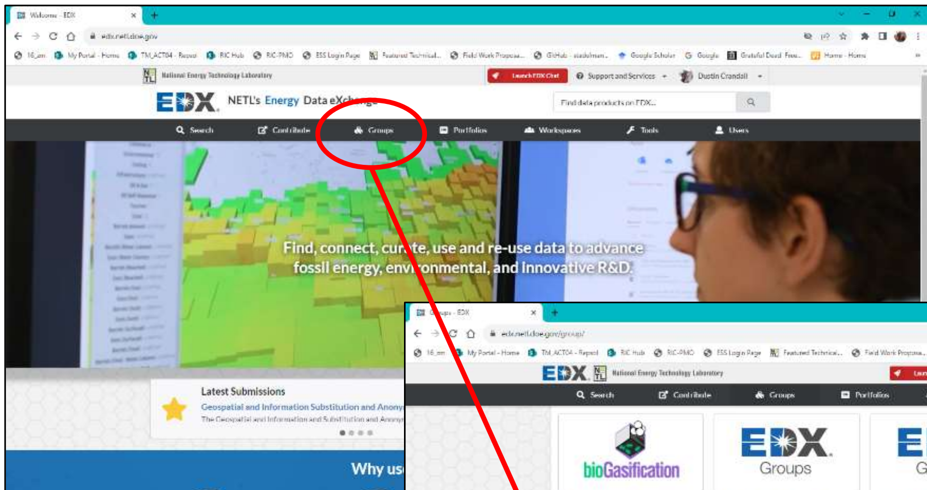
Office of Fossil Energy

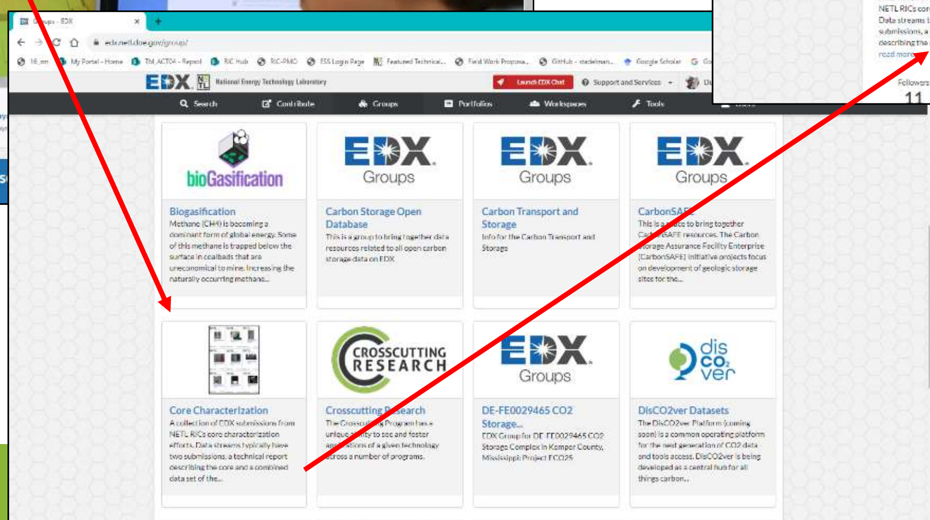
DOE/NETL-2021/2843

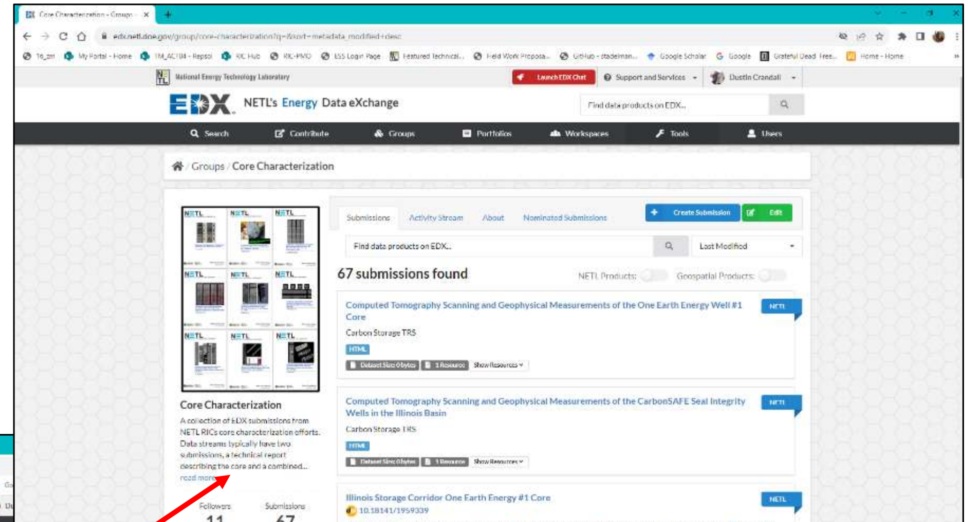
# Data Publicly Available on EDX

NATIONAL ENERGY TECHNOLOGY LABORATORY

- Start in the "Groups" at https://edx.netl.doe.gov/



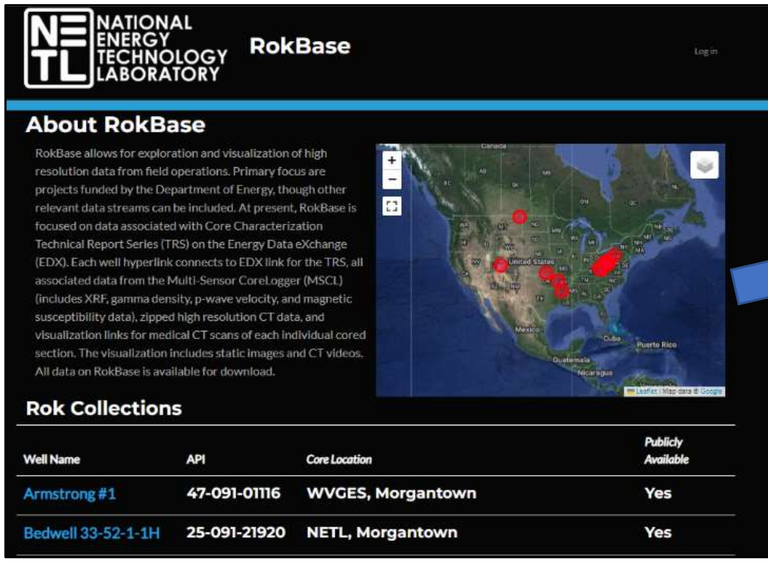



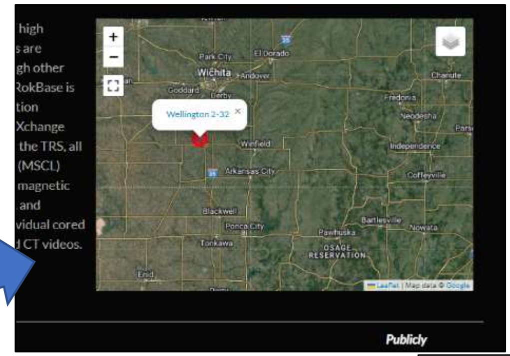

Scroll down to the "Core Characterization" group

Links to reports, the raw data, and any processed data are here

# RokBase as well

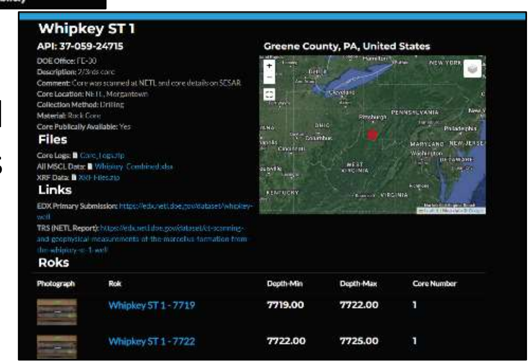



Wells shown on home screen with interactive map




Wells listed below with location and API

Links open well specific pages



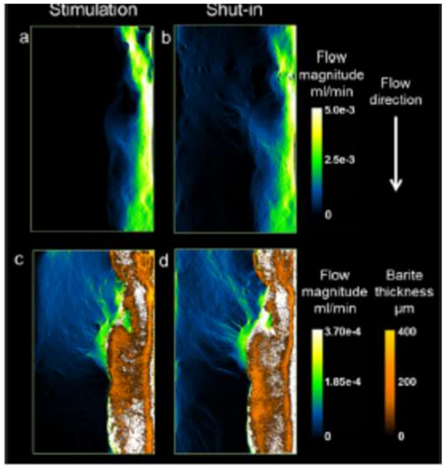

**Data available on Energy Data eXchange edx.netl.doe.gov**

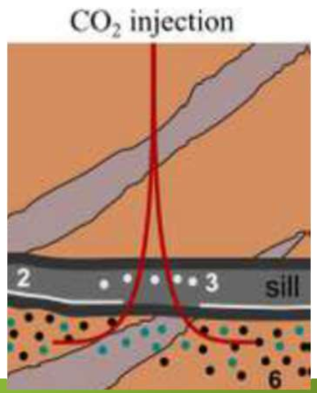
**Published Technical Reports available on Osti.gov**

**Data available on RokBase.org**

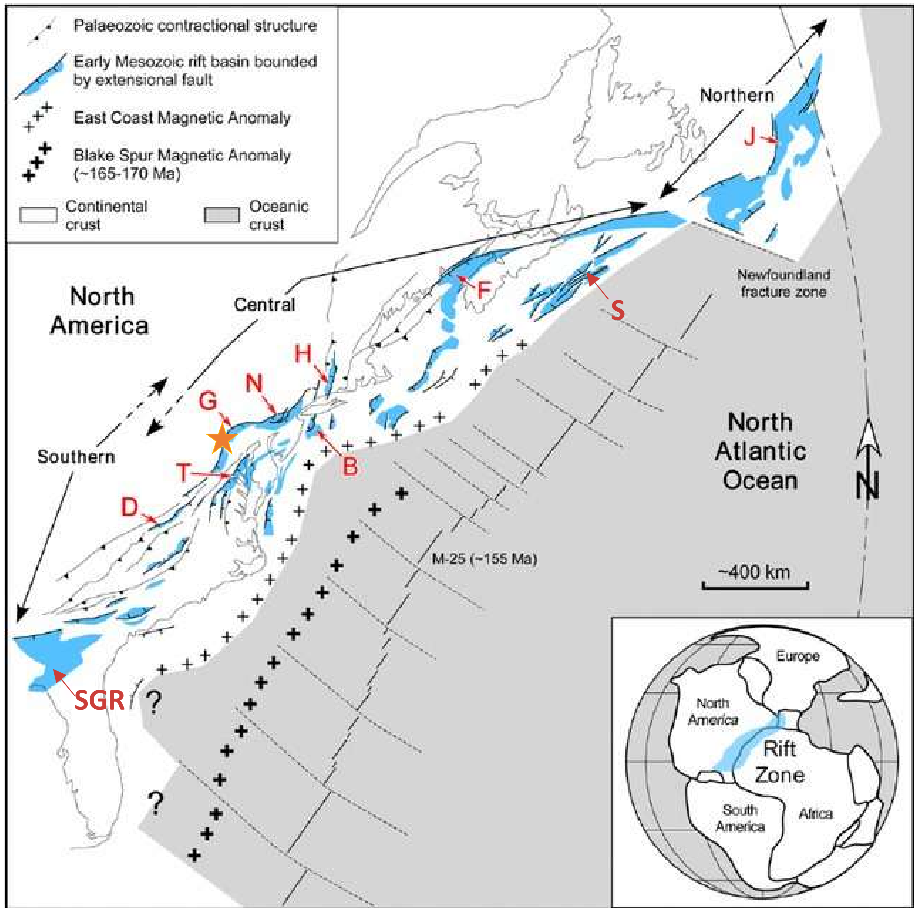
# Questions from the prior work

- **Eight samples from across two representative cores (Rosser Road B-1 and Susquehanna Rover B-1)**
  - Bore holes from gas pipelines under the Susquehanna River
  - Range of dolerite, veins and open fractures; but very uniform!
- **Very low permeability, less than 50 nD …**
- **Rapid mineralization observed.**
  - 45 day experiments; pressure stabilized in batch reactions in hours …
- **What is the potential for these to be 'self-healing seals'?**
  - Slow leak of slightly carbonated brine through fractured diabase close down permeability under what conditions?



# Nationwide relevant resources




(Withjack et al., 2013)

- **Half-graben basins present from Georgia to Nova Scotia, and even offshore into Greenland.**

  In the US:
  - South Georgia Rift (SGR)
  - Dansville Basin (D)
  - Taylorsville Basin (T)
  - Gettysburg Basin (G)
  - Newark Basin (N)
  - Hartford Basin (H)

  Outside US or Offshore:
  - New York Bright Basin (B)
  - Fundy Basin (F)
  - Scotia Basin (S)
  - Jeanne d'Arc Basin (J)

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**Updates:**

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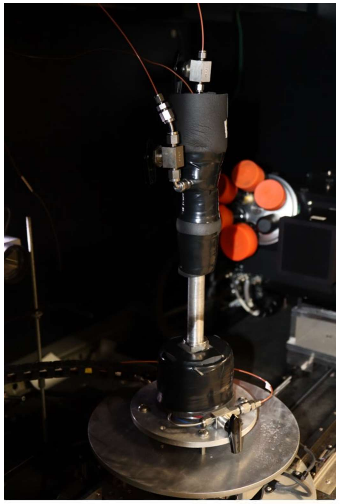

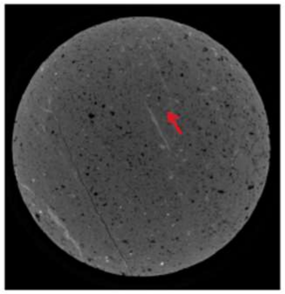

Figure 75: 2D image from industrial CT scan of the Susquehanna River core at 129.2 ft. where the red arrow indicates a mineralized fracture.

# Multi-Scale CT and Core Flow Facility

**POCs: [Dustin.Crandall@netl.doe.gov](mailto:Dustin.Crandall@netl.doe.gov)**

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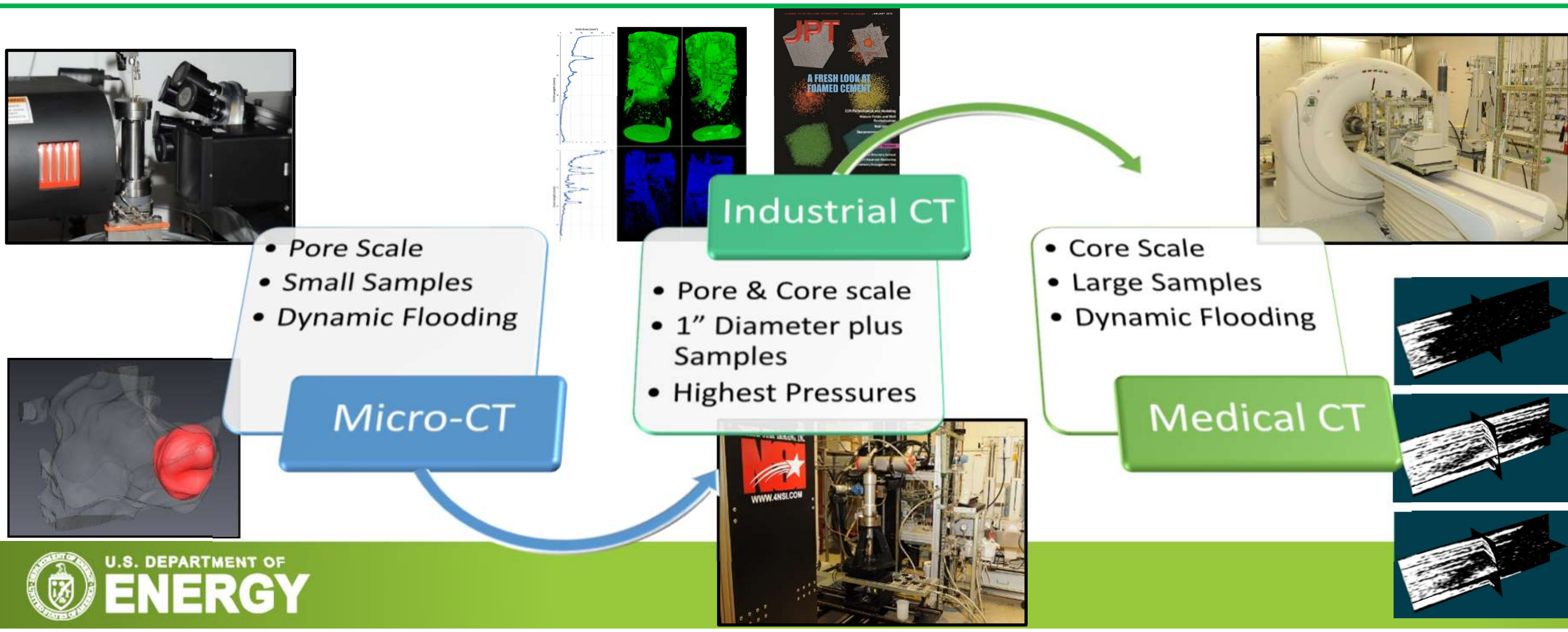
**Unique Capabilities:** Four computed tomography scanners with 3D resolution from microns to millimeters, all with ancillary core flow capabilities. Able to performed controlled multiphase flow in cores from 0.25" to 2" in diameter at conditions up to 10,000 psi and 200 ˚C. Full time technical staff to assist with rock preparation, experimentation design, setup, execution, and analysis. Plus, controlled flow systems for long term tests, and GeoTek multi-sensor core logger.

**Opportunities:** Direct examination of rocks from carbon storage sites under *in-situ* conditions with supercritical $CO_2$. Stressing of samples to understand mechanical behaviors. Examination of relationships between rock properties, geochemical alteration, and permeability (or structural properties). Scanning to complement other experiments, or to digitally and non-destructively preserve core from relevant locations.




**For More Information:**

- Equipment/Lab Factsheet (link)
- Core characterization EDX Data Group (link)
- Core characterization YouTube Video (link)
- $CO_2$ Brine Relative Permeability Accessible Database (link)

# Initial Plan with NETL's DynaTOM CT Scanner

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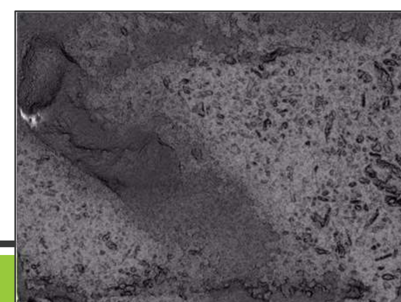
High speed CT with ~10-micron resolution

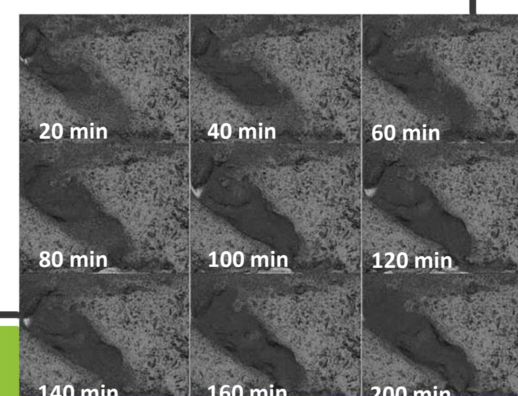
- First of its kind in the US
  - Installed 2021

**Unique rotating gantry enables CT source and detector to spin around sample**

**Reconstruction software to map low resolution scans to higher resolution base images**

Structural changes due to geochemical alteration tested with a weak acid injection in limestone

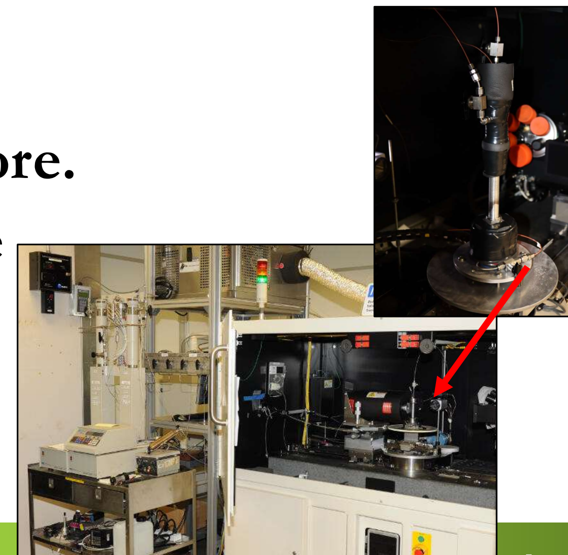




# Pivoted to Xradia and Cannon systems



- **Due equipment issues have not been able to ramp up direct study with the DynaTOM yet.**
- **This spring, pivoted to using a combination of our other scanners to get moving, develop work flow**
- **Medical CT scanner – multi-day/week flow with high precision DAQ and low resolution imaging. 1” D composite core.**
- **Industrial CT scanning – Pre/post imaging of flow core.**
- **Micro-CT scanning – Several mm diameter composite core with micron scale imaging over weeks long exposure.**



# Description of Medical and Micro experiments

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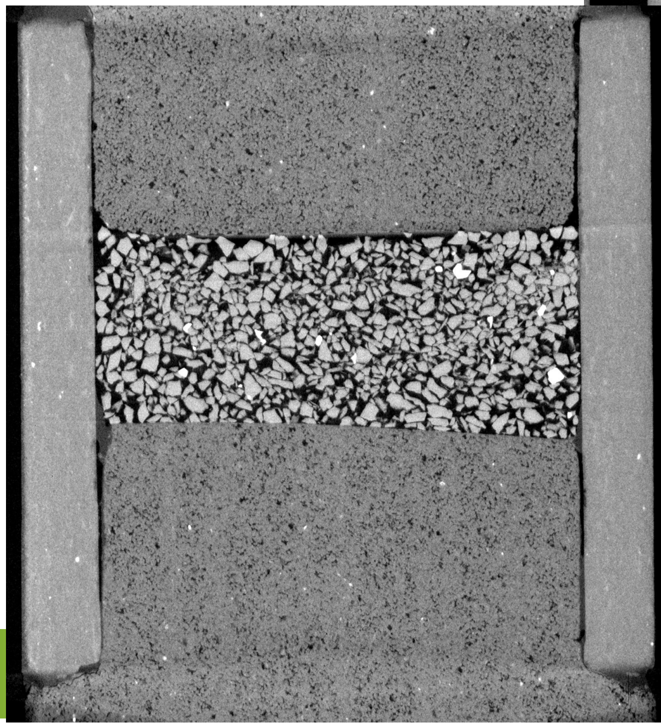
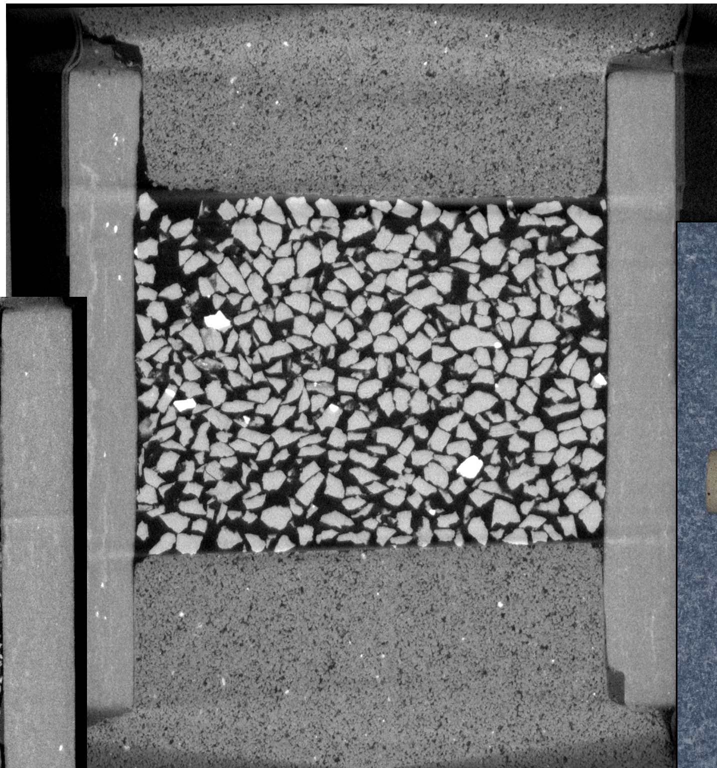
- **For methodology, prior to use of PA diabase samples, tested olivine reaction rates with low heated carbonated brine flow**
  - In order to get rapid interaction, ground samples used.
  - To use in existing core flow facilities in the micron and medical CT scanners, had to develop a unique composite core.
- **Hollow shale cylinder prepped and filled with ground olivine. Berea sandstone injection/effluent plugs fitted to the shale and epoxied in place.**
  - Worked very well to enable the ground sample to be under proper P&T and experience flow
- **Similar (and smaller) system developed for micro CT core holder system**

# Composite core system

- **High resolution cross sectional images.**
- **1” diameter**

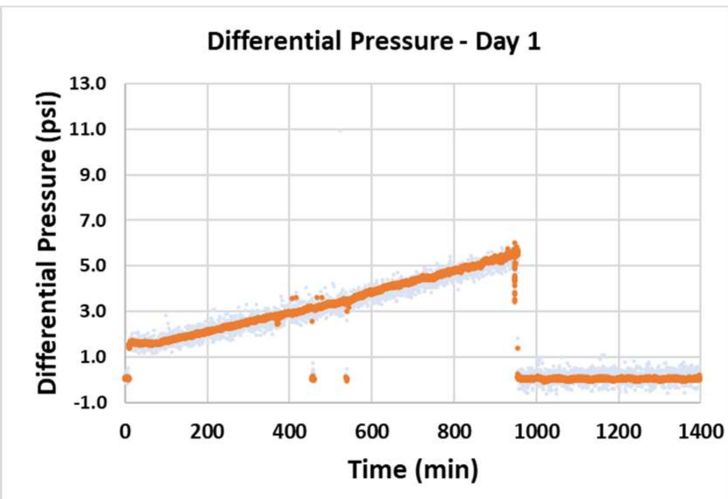


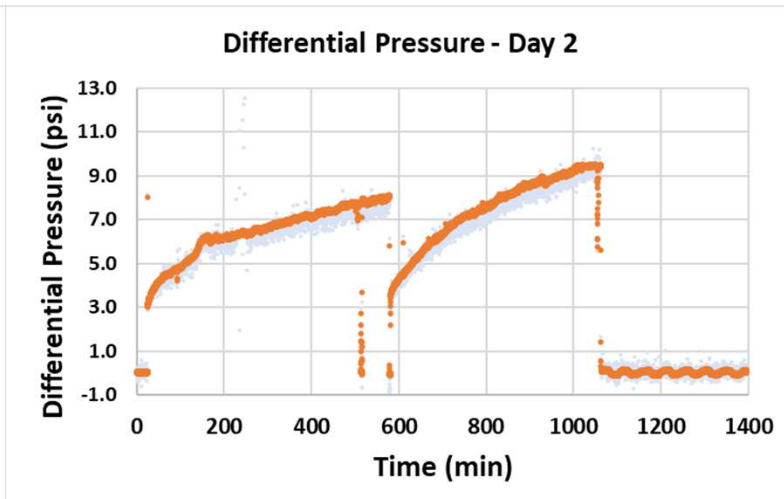


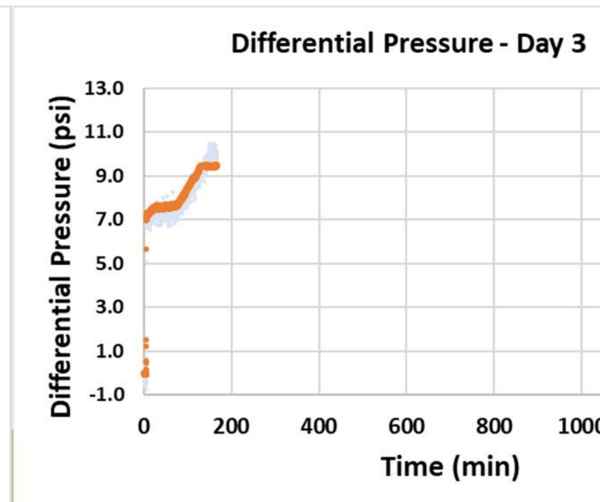
# Changes in Medical CT Measured Permeability

Work in progress!

- **Brine at temperature and pressure sparged with $CO_2$ for 24 hour min**
- **$P_{pore}$ = 3350 psi, T = 150 °F, Flow rate = 1 $^{ml}/_{min}$**
- **Preliminary examination shows rapid increase in differential pressure across core, for first examination from ~1 psi to 10+ psi 3 days (~2L injected)**

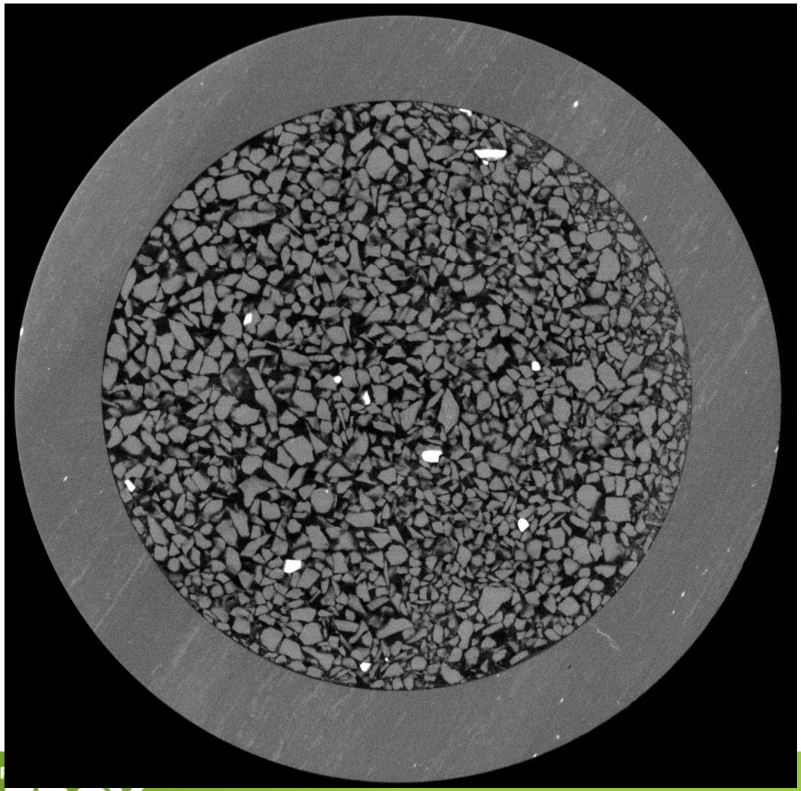


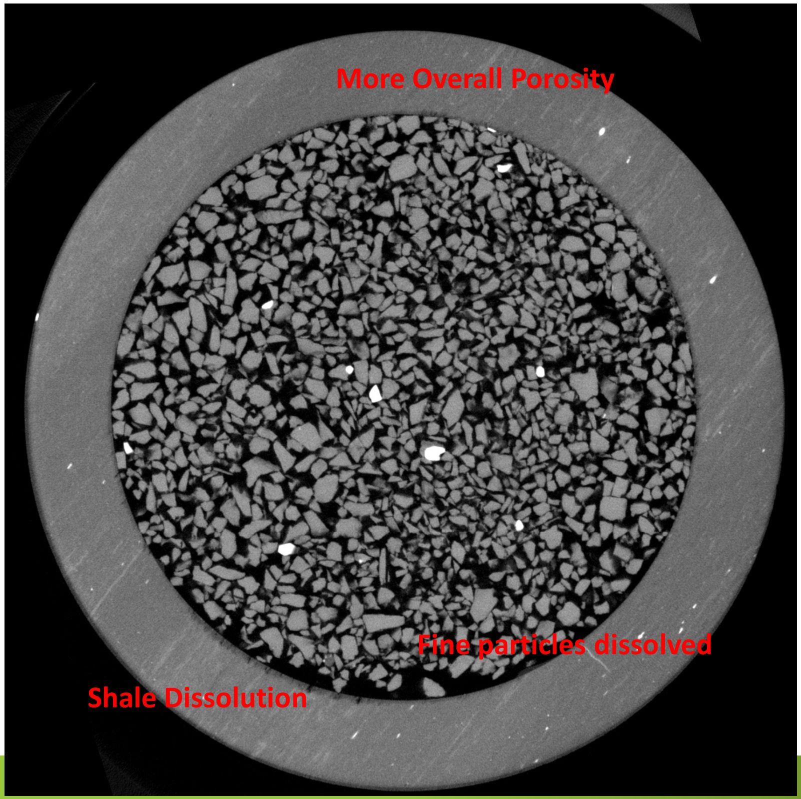



# Pre/post industrial CT scans of medical tests 1

- **Pre flow – Slice 1229 near inlet**

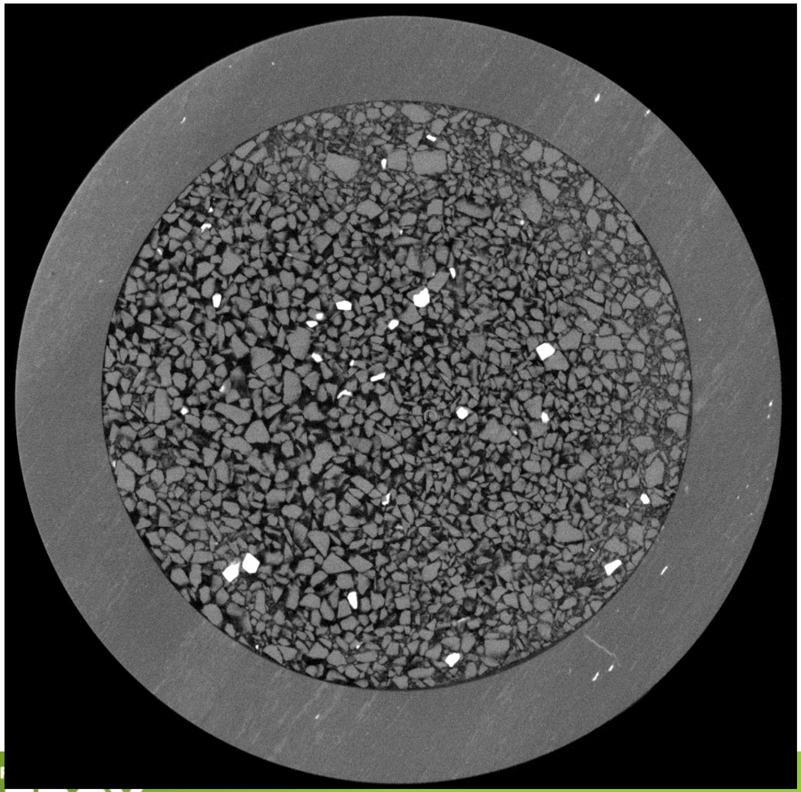


- Post flow – Slice 1215 near inlet

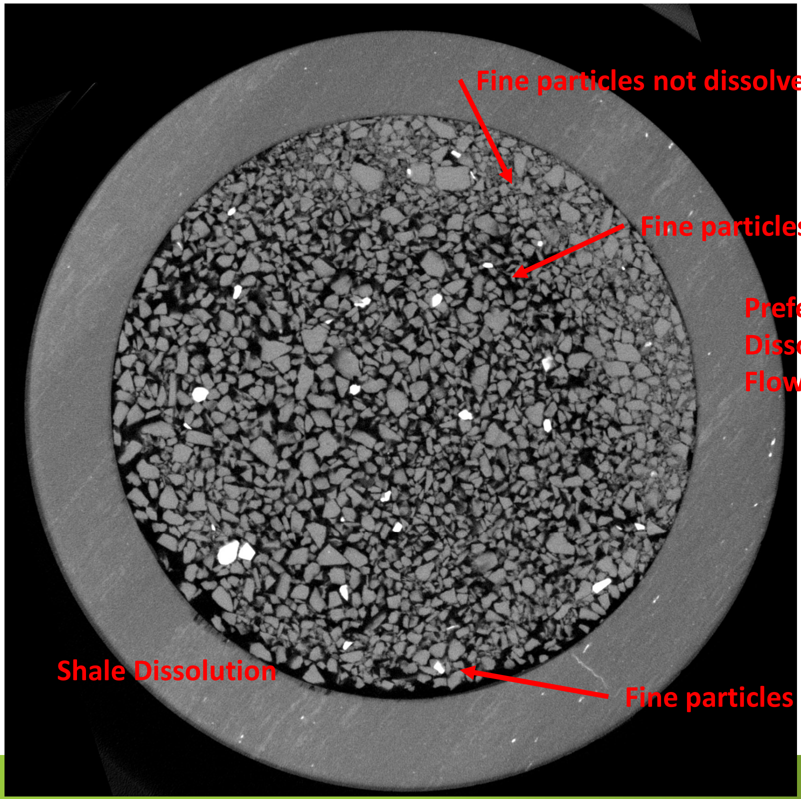


# Pre/post industrial CT scans of medical tests

- **Pre flow – Slice 1178 mid-inlet**

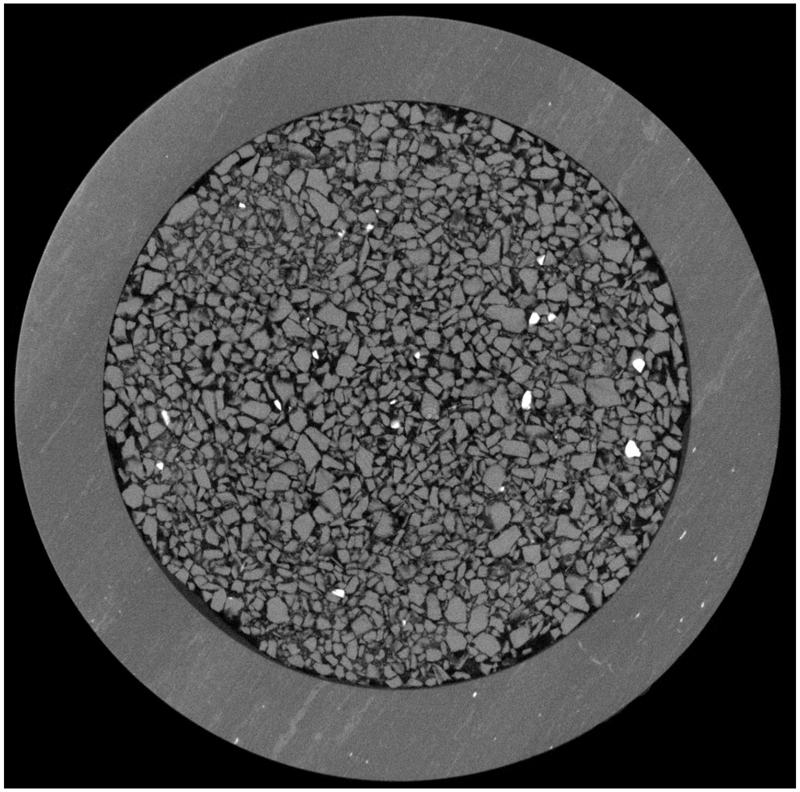


- Post flow – Slice 1147 mid-inlet

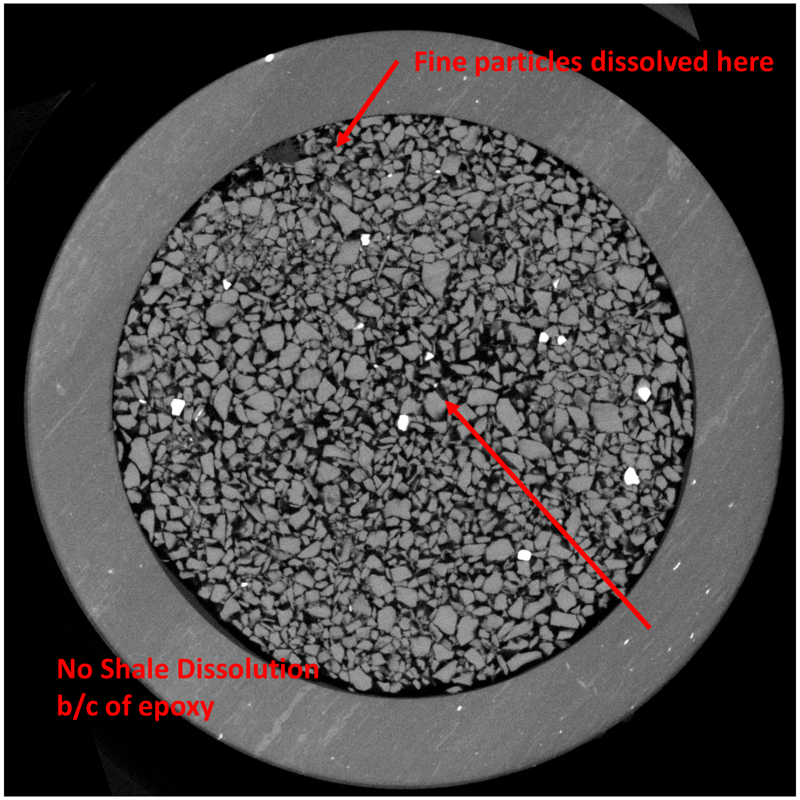


# Pre/post industrial CT scans of medical tests

- **Pre flow – Slice 1123 mid**

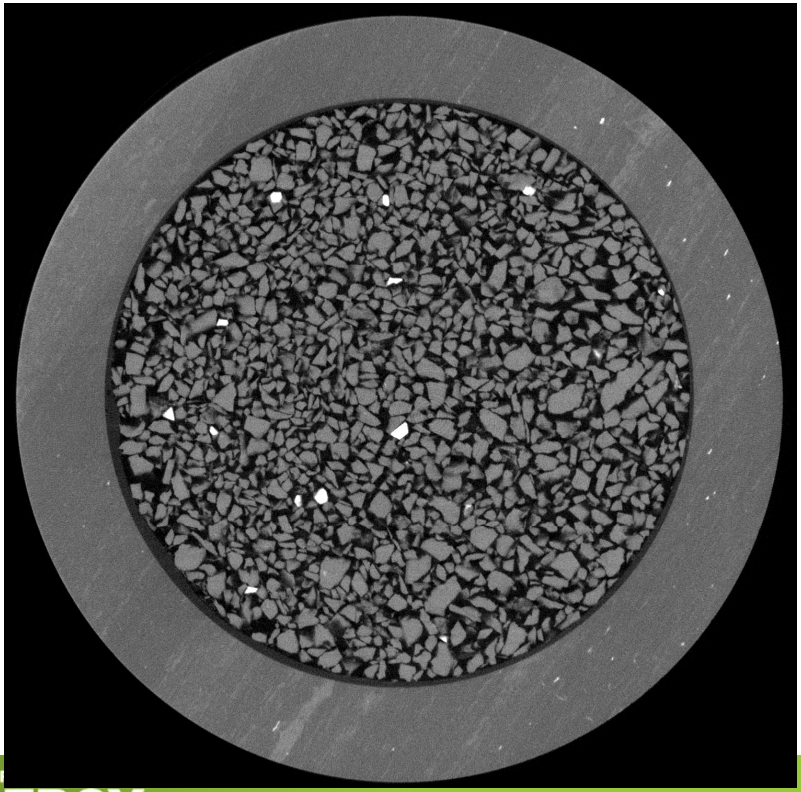


- Post flow – Slice 1180 mid

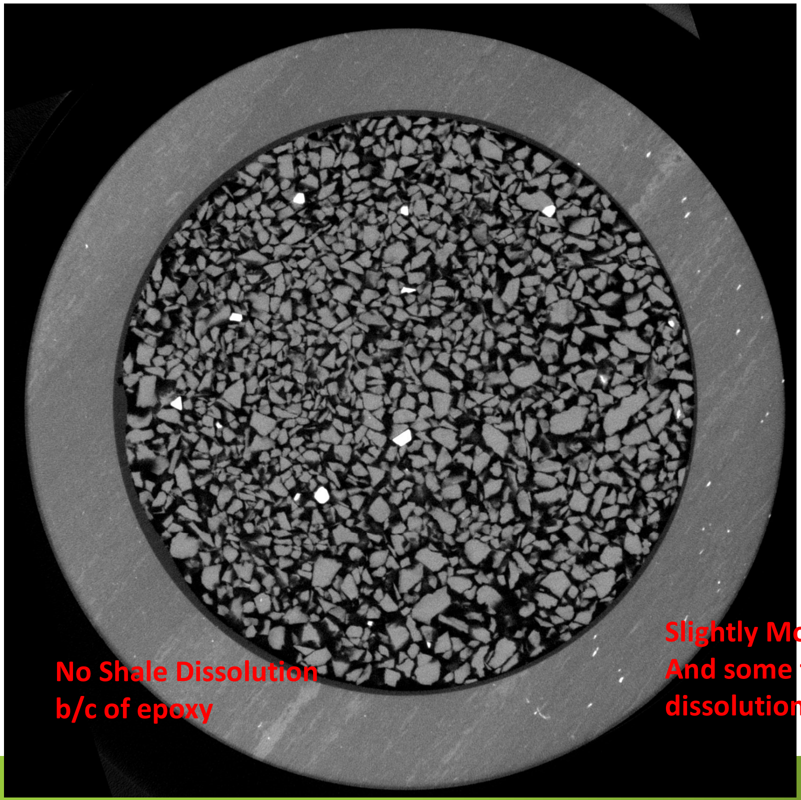


# Pre/post industrial CT scans of medical tests

- **Pre flow – Slice 862 – Near outlet**

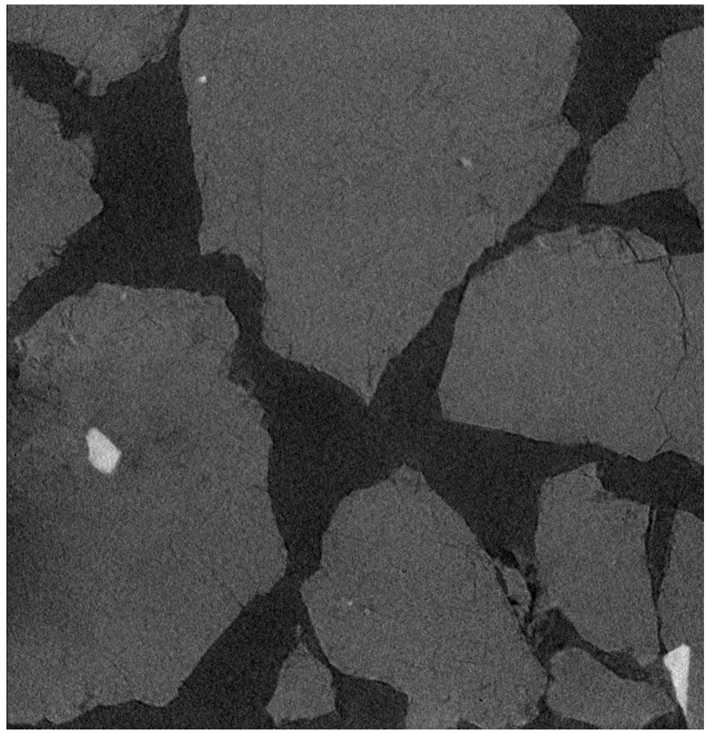


- Post flow – Slice 796 – Near Outlet

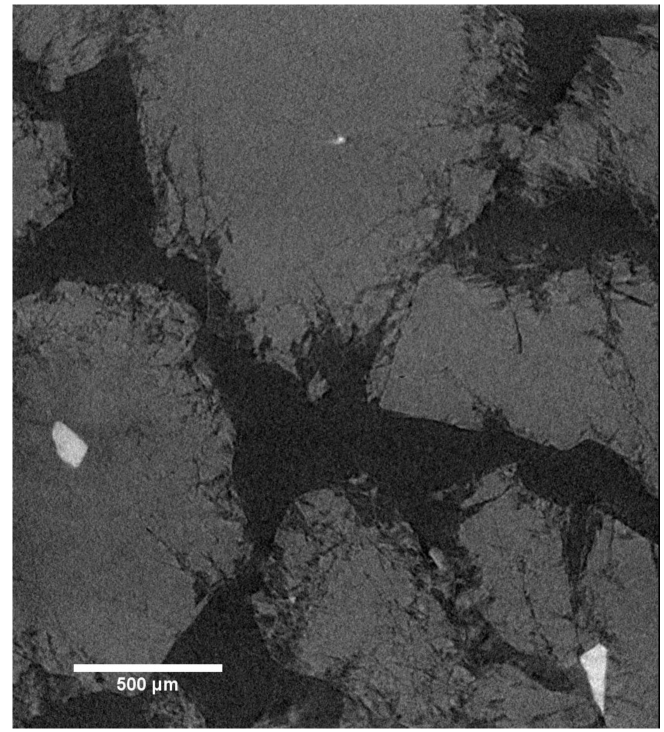


# Pore-scale olivine dissolution from Xradia MicroCT

- Dissolution around grain edges
- Pre-existing fractures and weak zones are primary sites for initial dissolution
- Some shifting of smaller grains as they lose structural integrity



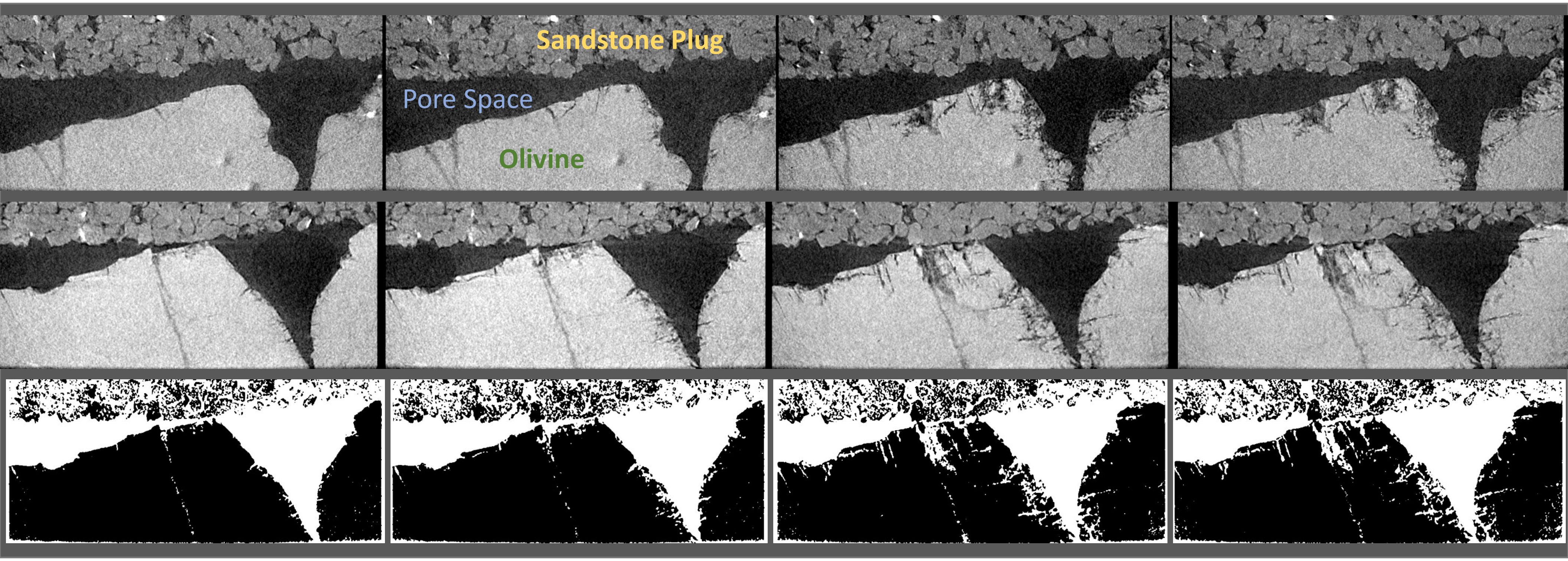
Experiment Start:
July 10th




Experiment End:
Aug 7th

# Volumetric Changes during Olivine dissolution from Xradia MicroCT

Preliminary results suggest up to 25% of olivine volume was dissolved




| Experiment Start: July 10th | Day 11: July 20th | Day 25: Aug 3rd | Experiment End: Aug 7$^{th}$ |
|---|---|---|---|

# Overall summary

- **We've got the systems in place to examine fracture sealing dynamically for these potential self healing seals**
- **DynaTOM may be functional in the next weeks, but we're also not going to fully rely on this moving forward.**
  - Can hope! But also need to make sure we're moving.
- **Analysis of rates of changes in permeabily with change in sieved size of olivine samples to constrain the rates of injection for diabase samples**
- **Ramping up for analysis of cores from Duke University in Fall 2023/Winter 2024**
  - Active drilling on campus into the Durham Basin

## Thank you!

# Questions?

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

Published Technical Reports available on Osti.gov

Data available on RokBase.org