the ENERGY lab

R&D FACTS

Geological & Environmental Systems

NETL Geoimaging Characterization
CT Scanners

Background

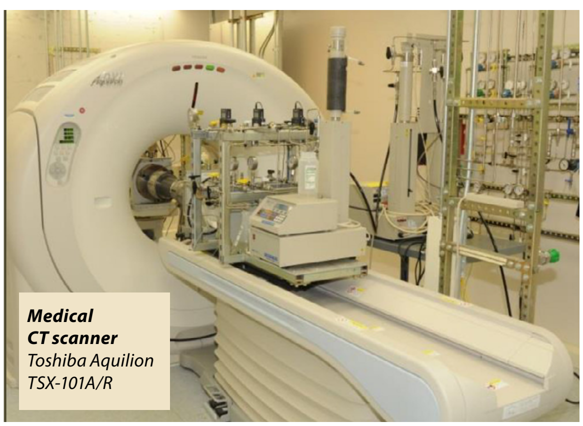
Traditional petrographic and core-evaluation techniques typically aim to determine the mineral make-up and internal structure of rock cores, as well as to analyze properties influencing fluid flow. Often this type of evaluation is destructive—physically sectioning the core in order to capture the internal composition details. The National Energy Technology Laboratory's (NETL) geoimaging laboratory provides a non-destructive alternative to these traditional methods. The lab hosts three computed tomography (CT) X-ray scanners, an assortment of supporting flow-through instrumentation, and a mobile core logging unit. These technologies work in tandem to provide characteristic geologic and geophysical information at a variety of scales. The medical CT scanner and core logger analyze bulk structure, composition, and density variations. The industrial CT scanner images pore and fracture networks. Lastly, the micro-CT scanner allows evaluation of microscopic structure and pore surfaces. Porosity, permeability, fracture roughness and aperture, overall structure, and composition can all be analyzed, yielding quantifiable and relevant parameters while leaving the sample available for further testing.

Facilities

Medical CT Scanner

Core-Scale Characterization and Fluid Flow

The state-of-the-art Toshiba Aquilion® **medical CT scanner** is used for bulk core characterization and fluid flow experiments. The 350µm (X) by 350µm (Y) by 500µm (Z) resolution of the scanner is the lowest of the three CT scanners. Despite its coarse resolution the medical scanner boasts the fastest scan times. It is also adaptable for temperature control, fluid flow, effluent collection, and the application of axial pressure to samples. With scan times lasting only seconds, the system can capture, in real time, the migration of fluids and changes in rock material at in-situ petroleum and CO_2 storage reservoir conditions, thus expanding the understanding of fluid mechanics and rock physics at those conditions.



Medical CT scanner
Toshiba Aquilion TSX-101A/R

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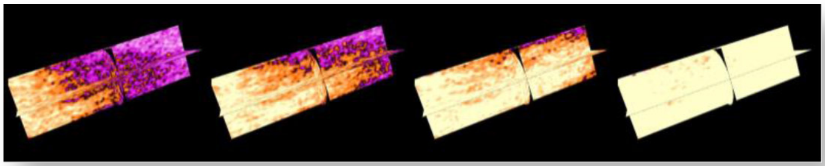
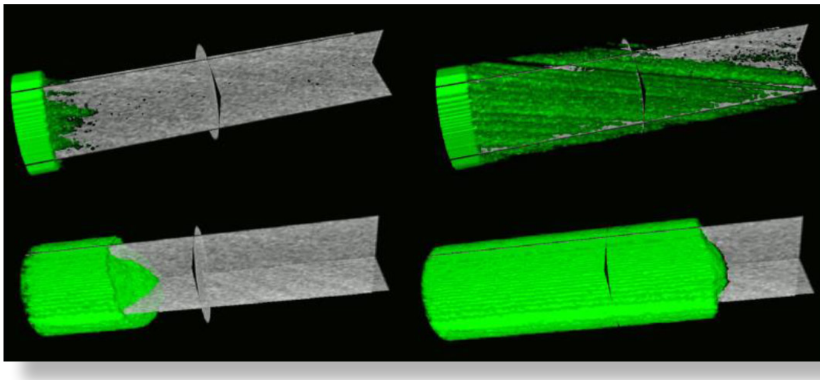


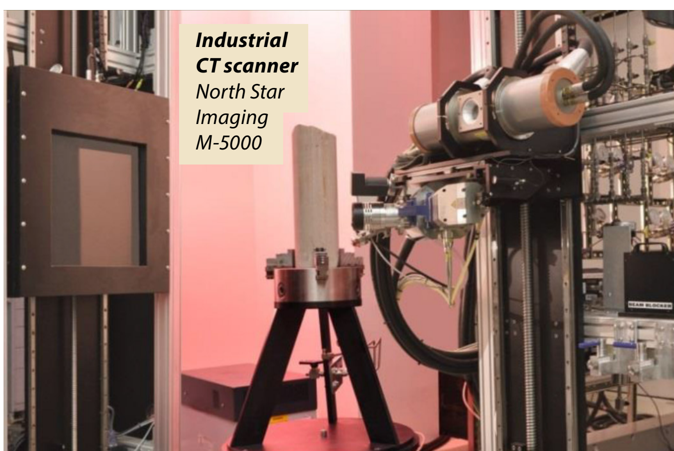
Left: ***Medical CT scanner*** *images show multiple stages of an experiment where surfactant-laden brine displaced oil in a reservoir rock, with pink indicating oil and brighter colors indicating saturation with brine.*



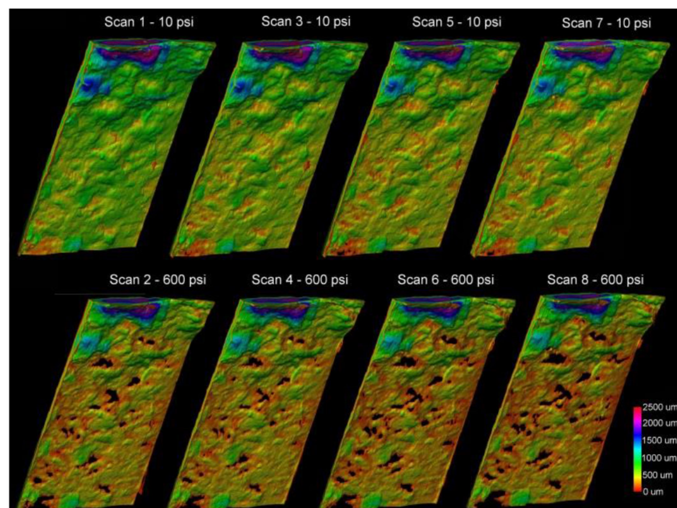
Left: These ***medical CT scanner*** *images show brine (top) and brine with surfactant (bottom) being displaced by liquid* CO_2.

Industrial CT Scanner

Pore-Scale Characterization and Fluid Flow



The NorthStar Imaging M-5000 **industrial CT scanner** bridges the gap between the medical and micro-CT scanner machines. The industrial CT scanner allows core-scale characterization of geomaterials in terms of their fundamental fluid mechanics and physical properties. It provides enhanced resolution over the medical CT scanner at 5–40 µm depending on sample size, but with significantly longer scan times of 1–2 hours. Smaller samples can be imaged at pore-scale resolution, allowing for the analysis of pore and fracture networks. Core holders allow sample imaging of in-situ pressure and temperature conditions. Coupled with the scanner's flow-through capabilities and effluent collection, samples can be imaged prior to, as well as during, a flooding experiment to quantify the physical and chemical changes taking place.

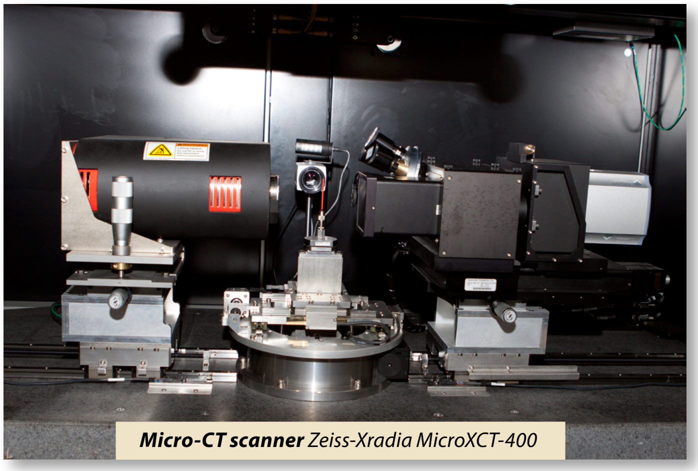


Above: NETL's ***industrial CT scanner*** *captures the changes in fracture apertures as they vary under cyclic pressure.*

Above: A calcite-filled vein with crystals (yellow and orange) and porous zones (green) is revealed through ***industrial CT scanner*** *imaging in a shale core from the Martinsburg Formation.*

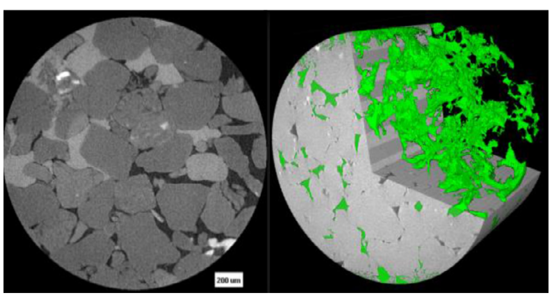
Micro-CT Scanner

Sub-pore-scale Characterization and Fluid Flow



Micro-CT scanner *Zeiss-Xradia MicroXCT-400*

The **Zeiss-Xradia micro-CT scanner** operates at the highest resolution, scanning samples ranging from the size of a pencil eraser up to 50mm. This type of analysis provides resolution at the single micron scale and has been primarily used to provide detailed porosity, structure, and mineral composition data on small samples of geomaterials such as sandstone, limestone, volcanic rock, shale, coal, and cement. This unit is also equipped with a beryllium pressure vessel that allows for flow experiments to be conducted under in-situ reservoir conditions at elevated temperatures and pressures. The trade-off for this high level of detail is the length of time for each scan, which can take days.



Above: A cross section through a calcite-cemented sandstone core (left) and a 3D reconstruction of the same core with isolated pore space shown in green (right), generated with the ***micro-CT scanner.***

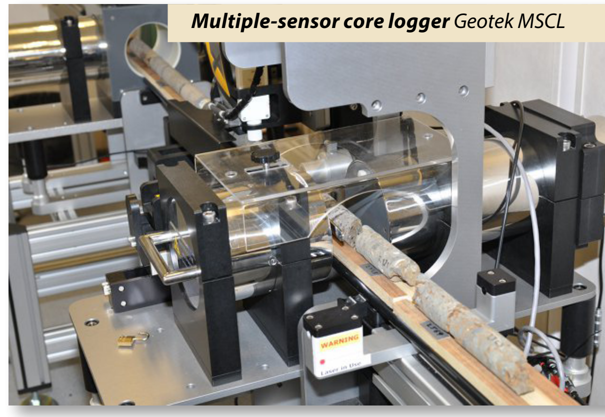
Flow-Through Capabilities

Long-Term Fluid Flow

In addition to the adaptations of the CT scanners for fluid flow, NETL's geoimaging laboratory hosts additional flow-through equipment suitable for longer-term experiments involving fluid flow. Since CT scanners are typically utilized, and down-time is rare, the additional flow-through facilities allow researchers to conduct experiments looking at long-term chemical and morphological changes. Experiments can last up to many months without putting a CT scanner out of commission for the duration. Samples can still be imaged before and after the conclusion of the experiment or, if possible, during planned interruptions in fluid flow.

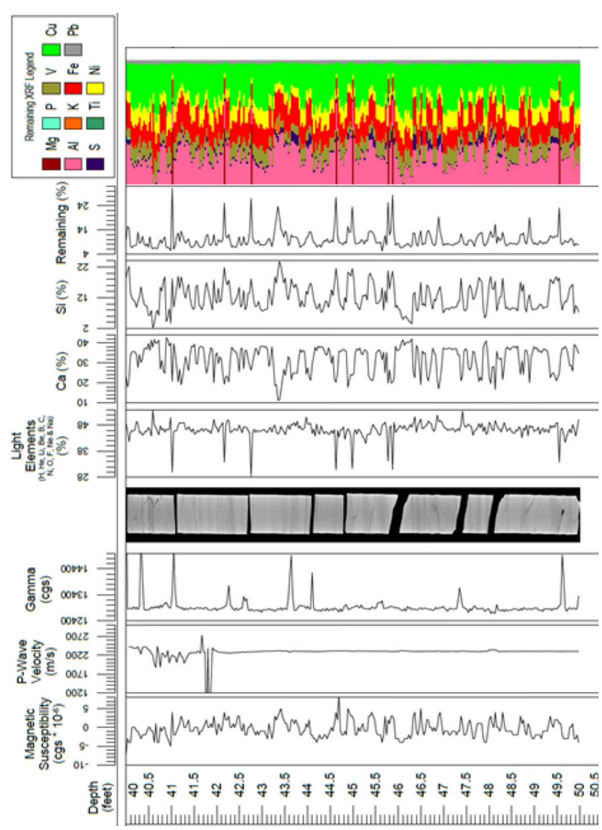
Multiple-Sensor Core Logger

Bulk Geophysical Properties



Multiple-sensor core logger *Geotek MSCL*

NETL's multiple-sensor core logging (MSCL) unit measures bulk physical properties of geologic materials in a comparable fashion to industrial methods, producing data akin to that from borehole well-logs. The NETL logger is able to rapidly obtain high-resolution data including p-wave velocity, gamma-density, natural gamma, resistivity, magnetic susceptibility, and chemical composition using X-ray fluorescence spectrophotometry on whole-round and split core samples. These measurements assist in understanding characteristics of rocks and sediment that are meaningful for geologic, fluid flow, and physical analysis purposes.



Above: Data obtained with the ***MSCL*** *on a fractured Martinsburg Formation shale core.*

Past and Present Research

NETL researchers work with many regional, international, university, and industry partners on projects ranging from pilot carbon sequestration to improving the safety of deep offshore wells. Some of the projects include:

- Characterization of foamed cements used to seal wells in the oil and gas industry with the goal of improving well safety; this research project was featured on the cover of the January 2015 issue of *Journal of Petroleum Technology*
- Evaluation of storage potential in CO_2 target formations in the Ordos Basin of China in partnership with the Chinese Academy of Sciences
- Real-time imaging of CO_2 injection into a brine-saturated reservoir rock
- Observation of dissolution on fracture surfaces due to the interaction with reactive CO_2-saturated brine
- Evaluation of coal interactions with CO_2 at varying pressures

Capabilities and Goals

The suite of geoimaging technologies available at NETL provides researchers with access to comprehensive non-destructive testing and evaluation of a wide variety of geo-materials, including but not limited to sandstones, limestones, carbonates, coals, gas shales, and cements. The facilities enable the experimental examination of complex processes, such as enhanced oil recovery, carbon sequestration, sealing formation integrity, wellbore safety, geothermal energy production, hydrate formation, and shale gas development. Many of these real-world applications can be examined in the laboratory using actual core samples and fluids from specific target formations at pertinent temperature and pressure conditions, thus allowing researchers to study the changes within both the geologic samples and the fluids they contain.

The resulting data can then be used to improve numerical simulation efforts, leading to more realistic models, economic valuations, and field characterization efforts. Ultimate goals include improving oil recovery techniques, furthering research on carbon sequestration, addressing safety concerns in the oil and gas industry, reducing oil costs, extending domestic oil supplies, and reducing dependence on foreign oil, while also informing policy-makers in the energy field.

For more information on evaluating geologic materials at NETL, please see our NETL Geomaterials Research Facilities fact sheet (R&D176).

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