GEOLOGICAL & ENVIRONMENTAL SCIENCES ONSITE RESEARCH

OVERVIEW

The Department of Energy's (DOE) National Energy Technology Laboratory's (NETL) Geological & Environmental Systems (GES) Directorate is internationally recognized for its ability to monitor, analyze, and predict the physical, chemical, and biological structures and functions of complex subsurface environments from the field-scale down to the molecular level. This capability enables accurate assessments of the occurrence and distribution of in situ resources and predictions of the performance of engineered and natural systems over a range of time- and space-scales to produce decision-ready science.

By leveraging world-class facilities and longstanding expertise in geomaterials science, fluid flow in geologic media, multi-scale assessments, geospatial data management and analyses, and monitoring technologies, the GES Directorate's three teams investigate ways to enhance the safe and responsible production of domestic fossil fuels and mineral resources to foster energy security and cost-effectiveness. GES research concentrates on improving the efficiency of oil and gas production, ensuring proper disposal of solid and liquid waste streams, and mitigating undesired air emissions.

NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

GEOCHEMISTRY TEAM

The GES Geochemistry Team conducts research on the geochemical, microbiological, and physical effects of energy-related natural resource development and environmental mitigation strategies on natural and engineered geologic systems. By understanding these influences, the team can improve industry processes for resource recovery and environmental monitoring, protection, and mitigation, as well as inform prudent decision-making by operators and regulators.

The Geochemistry Team employs a combination of research strategies in service of its mission:

- Develops new geochemical and biogeochemical testing techniques to conduct experimentation for data collection and subsequent modeling of materials behavior in geologic environments
- Engages in onsite fieldwork and controlled laboratory studies to determine baseline conditions of geologic systems and to assess changes to those conditions
- Employs theoretical and quantitative modeling to analyze coupled processes involving fluid flow, temperature flux, chemical, and biological reactions

The Geochemistry Team has extensive research experience in geochemical surface science, mineralogy, metagenomics, electrochemistry, isotope analysis, techniques to monitor fluid-rock interactions, reactive transport processes, water quality monitoring and mitigation, and characterization of hydrate-bearing sediments. In the laboratory, the team employs world-class NETL facilities for fluid chemistry analysis, isotope analysis, microbiological DNA sequencing, subsurface process analysis, geomaterials characterization, cement and wellbore integrity investigations, and studies in high-pressure water environments. Additionally, the team relies on in-house ingenuity to develop new tools and processes to evaluate biological, chemical, and physical processes in geologic environments.

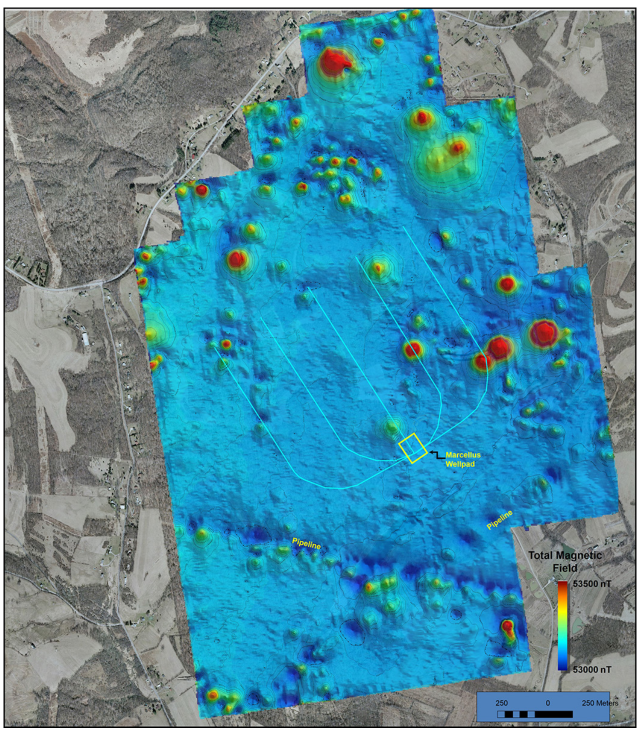

Figure 1. Magnetic survey of a Marcellus Shale well site, showing the proximity of legacy wells to the well pad and horizontal well segments.

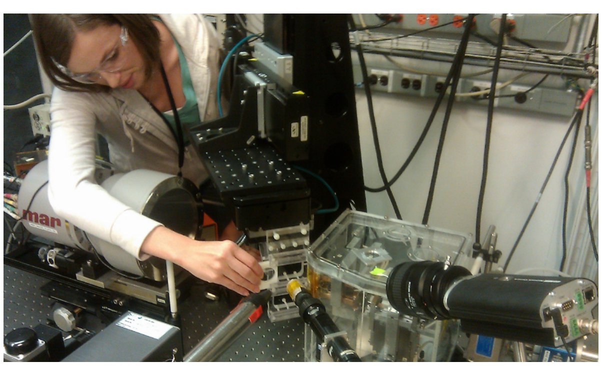

Figure 2. NETL researchers utilize synchrotron user facilities for advanced analyses of the chemical properties of geologic samples.

GEO-ANALYSIS & MONITORING TEAM

The GES Geo-Analysis & Monitoring Team performs characterization activities that support resource extraction, petroleum production, geothermal development, carbon storage and identifies, quantifies, and helps mitigate the potential environmental effects or inefficiencies that may arise from the development of subsurface resources.

Additionally, the team performs characterization and modeling through a combination of geospatial and geotemporal approaches to data that are displayed using state-of-the-art visualization methods.

Figure 3. Airborne and ground-based techniques are used in field studies to locate and test legacy wells for methane emissions.

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The Geo-Analysis and Monitoring Team employs geospatial and geotemporal analysis using a range of expertise and capabilities to accomplish these goals:

- Uses onsite and mobile laboratories to develop and secure characterization data at a variety of scales (from pore scale to regional scale) and develops subsurface maps and models of earth systems that can inform further research efforts
- Assesses impacts and risk and reduces the uncertainty of data sets and modeling results through detailed analysis of engineered-natural systems
- Possesses cumulative decades of expertise in the characterization, analysis, and interpretation of geologic systems—including subsurface mapping and model development

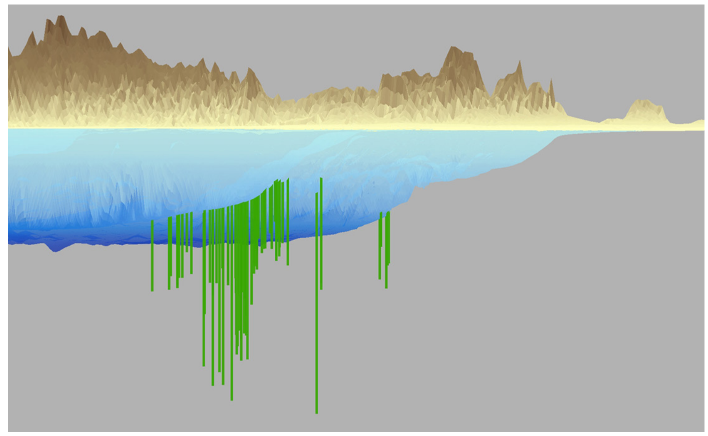
Team members have extensive expertise in laboratory investigations, airborne, ground-based, and subsurface field investigations, data mining and analysis, investigations of rare earth elements, the monitoring and modeling of air quality; quantification of methane emissions; geophysics research (seismic, magnetic, electromagnetic, radiometric, and galvanic resistivity); spectral imaging and remote sensing (multispectral, hyperspectral, night-time thermal infrared, and differential absorption Light Detection and Ranging [LiDAR]); tracers (gas, liquid, and proppant tracers); measurement of surface and groundwater quality and flow; geospatial mapping, analysis, interpretation, big data analysis and artificial intelligence with geological systems.

This team provides a critical link between NETL's research program (including state-of-the-art facilities and computational research competencies) and the regulators and industry professionals responsible for the safe, efficient development of subsurface resources.

The team uses a three-pronged approach to realize its goals:

- Works closely with industry contacts to design and implement field experiments that answer key questions about the safety, efficiency, and environmental performance of emerging energy development methods
- Develops monitoring technologies that provide early warning of unwanted migration of fluid and gas from the subsurface to help identify and potentially mitigate environmental contamination
- Collaborates with industry to assist in the identification of potential environmental and operational vulnerabilities prior to the implementation of energy extraction operations or waste storage/disposal projects

The team also developed and manages NETL's Energy Data Exchange (EDX). EDX is a unique tool for effectively managing and sharing large quantities of data to enhance collaborative research efforts and data analysis.



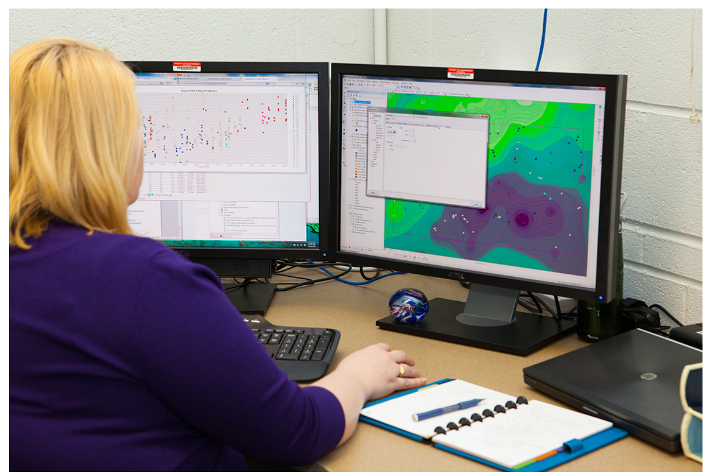


Figure 4. A geospatial researcher develops computer models to understand conditions in deep offshore oil and gas wells in the Gulf of Mexico.

RESERVOIR ENGINEERING TEAM

The GES Reservoir Engineering Team seeks to better understand underground fluid flow and deformation of solid materials. With this knowledge, researchers have an enhanced capability to predict the behavior of coupled hydrologic, geomechanical, geophysical, and geothermal processes.

The Reservoir Engineering Team applies an array of capabilities to pursue research goals effectively:

- Develops and demonstrates coupled geothermal, geomechanical and fluid-flow models for porous and fractured media at the reservoir scale, using software produced in-house and elsewhere

- Develops reduced-order models for subsurface systems-level analysis
- Employs computational modeling to analyze data and to predict and simulate reservoir behavior
- Conducts world-class research to image fluids inside rocks under various temperature and pressure conditions at the micro to macro scales
- Further develops spectroscopy (e.g., LIBS) for geoscience applications

The Reservoir Engineering Team has great expertise in the measurement and analysis of rock mechanical properties under simulated in situ conditions; the team is able to measure and simulate rock hydrologic properties on permeable and fractured cores under single and multiphase flow situations with varying stress conditions. Researchers have developed reduced-order models to simulate the behavior of reservoirs, seals, and other subsurface systems. These models include fractured reservoir modeling software (FRACGEN/NFFLOW); two-phase pore scale flow code (NETFLOW); the National Risk Assessment Partnership's Integrated Assessment Model-Carbon Storage (NRAP-IAM-CS), Reservoir Evaluation & Visualization tool (REV), and Reservoir Reduced Order Model Generator (RROM-Gen); and two seal models, the NRAP Seal Reduced-Order Model (NSealR) and the Well Leakage Analysis Tool (WLAT).

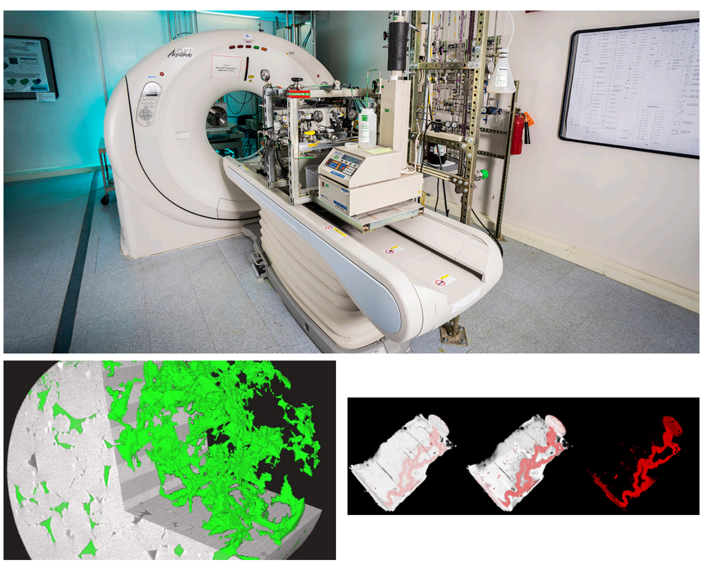


Figure 5. NETL's CT scanners are used to image geomaterials and understand interactions with fluids. Two examples—3D structures of CO_2 reacted zones in cement fractures, and pore space in reservoir rock—illustrate these capabilities.

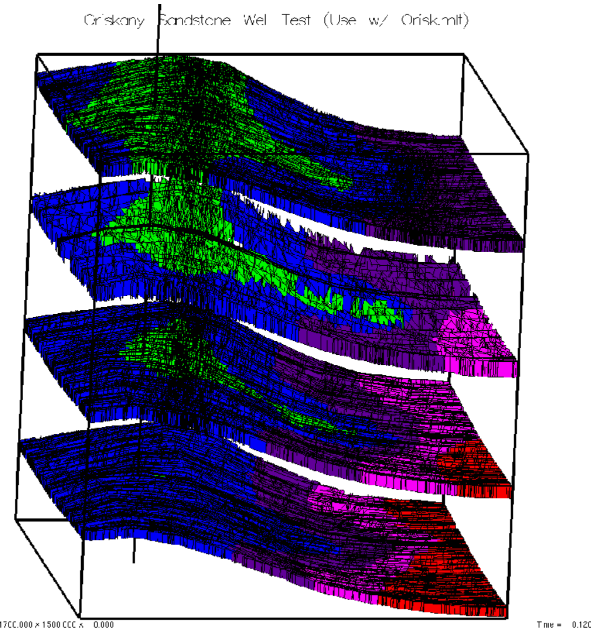


Figure 6. Reservoir simulation output shows pressures in four layers of a naturally fractured and folded sandstone. Simulation of the injection of carbon dioxide for storage.

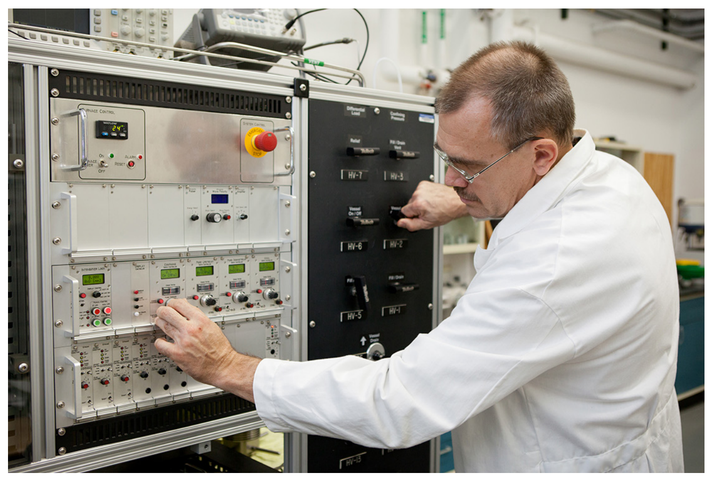


Figure 7. Scientist uses multipurpose lab instrument to analyze geomechanical rock properties.

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