Integration of Geophysical and Geomechanical Modeling

The focus of this research was the use of different types of geophysical data (seismic and electromagnetic(EM)) with different resolutions for CO₂ monitoring. The work involved rock physics and geotechnical based modeling to conduct sensitivity analyses to determine the feasibility of seismic monitoring under different geologic settings. The proposed techniques were intermediate scale (1-100’s m) geophysical surveys providing information in between the large scale of surface seismic (km’s) and the smaller scale of well logs and core measurements (mm to m). The time-lapse seismic signature extracted from cross-well, VSP, Seismic, and EM, in certain geological settings, can be extremely useful for the monitoring of CO₂ injection and storage. The physical properties of CO₂ with reservoir pressure and temperature, and the properties of the reservoir rocks saturated with CO₂-fluid mixtures after injection, will determine the strength and the detectability of the 4D signal.

CCS through CO₂ injection continues to exhibit high costs and is associated with risks of leakage and induced seismicity during and after injection. There are several gaps in understanding the migration of CO₂ in the subsurface and the associated changes in mechanical stresses within and outside the injection layers as well as on the faults. To address these concerns, numerical modeling of multiphase flow and mechanical deformation in real-world storage systems based on rock-physics models derived from representative experiments is necessary. The team conducted such a study in this project on the Farnsworth Unit oilfield dataset. To achieve the above objectives, the project scope consists of fluid flow and geomechanical simulation, rock physics and 4-D seismic modeling, and validation of rock physics models with the field data.
**Accomplishments:**
The project outcomes may be broken down into three major products. First, a coupled multiphaseflow-geomechanical model and simulation of FWU was constructed, which may predict changes in pressure, stress, CO\(_2\) saturation, stress-dependent permeability and elastic moduli. Second, a new RTM imaging technique was derived to visualize the effect of CO\(_2\) injection, using a rock physics model to account for the effect of fluid substitution on elastic properties. Finally, geomechanical experiments performed on FWU cores provided a characterization of dynamic elastic moduli due to changes in the CO\(_2\) core pressure. This may determine constitutive model parameters in the rock-physics model and the coupled simulation model.

Work led to the development of new modeling techniques, which may lower costs and risks associated with CO\(_2\) injection in the CCS industry. Development of the rock physics models will help our understanding of how the subsurface is changed due to CO\(_2\) injection and storage processes, which can help in designing novel CO\(_2\) monitoring techniques in the future.

**NETL Collaboration:**
NETL provided access to lab facilities, conducting CT scan of core samples at Morgantown, conducting Autolab mechanical testing to measure Vp and Vs at different pore pressures and temperatures at Pittsburgh. Design and analysis of the experiments were also conducted at NETL.

**Relevant Publication:**
The team has created a Petrel database to hold the Farnsworth data. They populated the file with additional data on reservoir horizons, fault surfaces, and additional wells. Some of the findings of the project have been used as a basis for other DOE/NETL proposals.

**Benefits:**
Their work on applying a sequential solution scheme to solve the coupled equations of multiphase flow, rock deformation, and fault activation in a real 3-D field with complex intersecting faults impacts development and growth of stable and accurate solution schemes in computational geomechanics. In addition, new methods for seismic imaging and modeling were developed with significant impact on the results of this project as well as potential longer-term impacts on future projects. Likewise, the development of an ANN based techniques for porosity and density prediction had both educational and technical impact on this project as well the potential to be used in future projects. As an example, a Committee Machine Based Neural Network, with machine learning capability, is proposed to be used in a new project proposal to the DOE.