GULF COAST CARBON CENTER

Reliable Capacity Estimation: Geomechanical Implications

Project Description

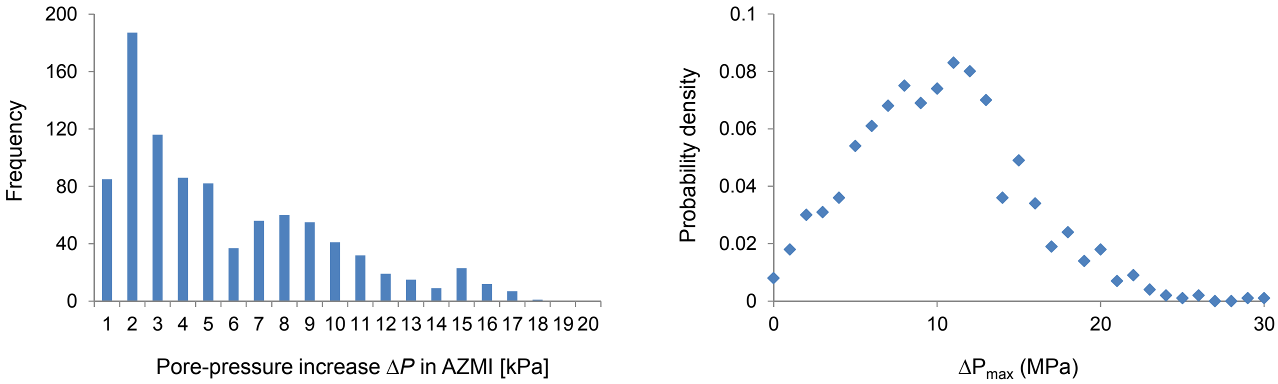
Ensuring geomechanical integrity of a CO_2 storage site is critical to the successful operation of geologic sequestration. Comprehensive analyses that incorporate poroelastic and thermal effects help to anticipate geomechanical responses of a site. Moreover, occurrences of induced seismic events can result in unfavorable public opinion for an operation. In this regard, we developed fully coupled analytical formulation and numerical simulation methods for the reliable estimation of pressure limit and thus pursued the objectives of maximizing the storage capacity while avoiding geomechanical failures.

Accomplishments

- Validated interpretation of field data measured from the SECARB Cranfield site, Mississippi.
- Developed a hydrothermo mechanically coupled numerical simulation method that is computationally powerful.
- Developed comprehensive analytical formulations to quickly and precisely determine the maximum sustainable pressure limit.

Analytical Methods

Analytical models enable us to obtain first-order estimates for geomechanical responses such as displacements and stresses, as well as maximum pressure limit. They can also be utilized for running Monte Carlo simulations and/or sensitivity analyses with minimal effort. In this regard, we compiled existing analytical models for changes in displacements, stresses, and pore pressure/stress coupling ratios driven by fluid injection. Upon compilation, we developed analytical computation tools to quickly calculate geomechanical responses at a site. We then used the products to yield a probabilistic range of increases in pore pressure in the above-zone monitoring interval (AZMI) at Cranfield, MS for various ranges of input parameters. Finally, we derived a set of equations by which maximum pressure limit can be determined. The model incorporates factors such as (1) initial state of stresses, (2) properties of fractured rock mass, (3) poroelastic effect, and (4) thermal effect.



A range of possible pore-pressure increase in AZMI at Cranfield, MS, obtained from Monte-Carlo simulations (left) and an example of the probability density of maximum increase to pressure limit at an ideal storage site (right)

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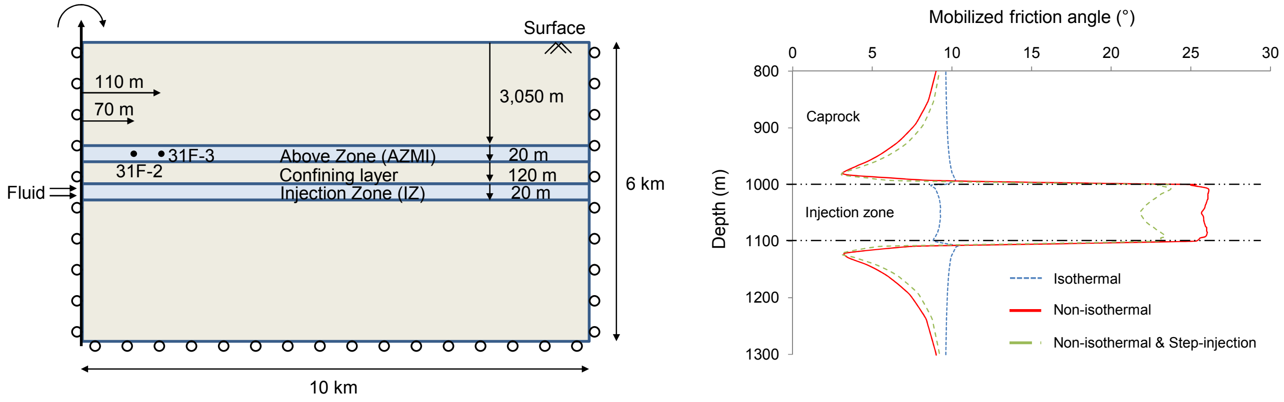
Numerical Methods

Fully coupled numerical simulation is essential to better represent a field condition during fluid injection. With the numerical simulation technique that combines fluid flow with the poroelastic model, we suggested a possible range of pore pressure increases in the AZMI at Cranfield. The results helped support the diagnosis that the measured increase was primarily due to the poroelastic effect, not to CO_2 leakage. We took steps to study the ratio of pore pressure/stress coupling driven by fluid injection. This led us to explore the ratios of change in vertical/horizontal stresses related to change in pore pressure for various material properties, boundary conditions, and structural geometry conditions. Results were used to formulate a set of equations to analytically calculate pressure limit. Fully coupled hydrothermo mechanical simulations were implemented to study geomechanical responses in caprock, as well as in an aquifer, when cold, pressurized fluid is injected. This effort will enhance our understanding of geomechanics at a storage site, greatly helping to ensure confinement of injected CO_2.



A simulation model used to represent the Cranfield site (left) and an example of mobilized friction angle along a vertical line near an injection well when isothermal or non-isothermal fluid is injected (right)

Summary

Hydrothermo mechanically coupled methods provide reliable analyses of geomechanical responses at a site. By utilizing fluid flow coupled with a poro-thermo-elastic model, we successfully modeled anticipated geomechanical responses across the base, aquifer, and caprock of an injection site. In doing so, we incorporated existing analytical models and new observations together into the analytical calculation platform to realize reliable first-order estimates of the maximum pressure limit to minimize induced seismic events and maximize storage capacity.

Selected Citations

Kim, S., and Hosseini, S.A., 2014, Above-zone pressure monitoring and geomechanical analyses for a field-scale CO_2 injection project in Cranfield, MS: Greenhouse Gases: Science and Technology, v. 4, p. 81–98.

Kim, S., and Hosseini, S. A., 2014, Pore pressure/stress coupling during fluid injection and its implications for CO_2 geological storage: under review.

Contact

Dr. Seunghee Kim
seunghee.kim@beg.utexas.edu, (U.S.) 512-232-7692
www.gulfcoastcarbon.org