Heterogeneity, Pore Pressure, and Injectate Chemistry: Elements of Control for Geologic Carbon Storage

Scientific Achievement

Heterogeneity, pore pressure, and injectate chemistry are three demonstrated controllable measures to optimize storage efficiency, sustainment of injectivity, and avoidance of unwanted risky consequences.

Significance and Impact

Such controllable measures are needed to mitigate hazards but also necessary for stimulation and improvements in sweep, offering a roadmap for GCS

Research Details

- Modeling, experiments, and field data are combined to show effectiveness of control measures
- Control demonstrated for both short term (engineering time scale) and long term (geologic time scale)

Reference

Dewers et al., Int. J. Greenhouse Gas Control, Accepted
Results: Control by Use of Heterogeneity

- Major aspect of control for GCS is grasping the degree to which heterogeneity will influence performance; i.e. where to or where not to inject
- Subsurface is more complex than binary “reservoir” and “caprock”
- “Waste zone” or “leaky seal” lithologies such as Selma Chalk can trap CO₂ residually yet allow injection-induced pore pressure hazards to dissipate.

*Leaky seal behavior*: Capillary entry pressure curves for Gulf Coast lithologies (A); pore scale models for Selma Chalk (B); injected CO₂ (brown, C) and residual water (blue, D), and relative permeability model for Selma for drainage (dashed) and imbibition (solid).
Results: Control by Use of Injectate Chemistry

- Few subsurface variables are as easily controllable as injectate fluid chemistry (e.g. slickwater frac)
- Chemical effects may manifest as “fast” (sub-critical weakening) or “slow”, such as (dissolution of cements) Slight sub-critical weakening is evident in the wet CO\textsubscript{2} Boise tests.
- Results from the Cranfield site demonstrate injectate chemistry leads to disruption of chlorite cements, leading to permeability modification

**Chemically Sensitive Failure surfaces** for weak sandstones influenced by pore fluid chemistry. Boise and Tuscaloosa Sandstones show similar limiting failure surfaces; Boise shows slight weakening when exposed to hydrous supercritical CO\textsubscript{2} (black dots), and chlorite-bearing lithofacies from Cranfield shows considerable weakening when exposed to scCO\textsubscript{2}-equilibrated brine (green dots).
Results: Control by Use of Pore Pressure

• Co-injection of CO2 with brine extraction is one way to mediate hazardous effects of overpressure (induced earthquakes; wellbore or caprock leakage)

• Simulations of injection and extraction well fields (upper panel) show how storage and pore pressure build-up is a function of engineering

• Heterogeneity can be a show-stopper (simulations shown in bottom panel), and necessary for characterization assessments

Co-CO2 injection/brine extraction for pore pressure control (TOP) Map view of pore pressure after 6 years of injection for homogeneous permeability field for “injection and extraction” case (left panel) and “injection only” case (right panel). (Bottom) Map view of pressure (left panel) and CO2 saturation (right panel) for heterogeneous permeability.
To address research challenges of sustaining injectivity, maximizing storage efficiency, and prevention of unwanted consequences, three control measures are evident: pore pressure; injectate chemistry, and prudent use of heterogeneity.

Such control measures can mitigate known injection hazards, such as induced seismicity, or facilitate fracture stimulation, as may have occurred at Cranfield. These could also help control unwanted leakage that could arise from hydro-chemical-mechanical coupling over long term (e.g. fluid escape pipes at left).

Seismically imaged methane escape pipes in North Sea sediments. Can such a phenomenon occur for geologic carbon storage, e.g. in the Gulf Coast???

*From Cartwright et al., 2007*