A Microscale Exsolution Investigation

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Geologic disposal of supercritical carbon dioxide in saline aquifers and depleted oil and gas fields will cause large volumes of brine to become saturated with dissolved CO₂ at concentrations of 50 g/l or more. As CO₂ dissolves in brine, the brine density increases slightly. This property favors the long-term storage security of the CO₂ because the denser brine is less likely to move upwards towards shallower depths. While dissolved phase CO₂ poses less of a threat to the security of shallower drinking water supplies, the risk is not zero. There are plausible mechanisms by which the CO₂ laden brine could be transported to a shallower depth, where the CO₂ would come out of solution (exsolve), forming a mobile CO₂ gas phase. This significant mechanism for drinking water contamination has received little attention, and there are basic science and reservoir engineering questions that need to be addressed in order to reduce risks to underground drinking water supplies. This study investigates the conditions under which dissolved CO₂ brines can impact drinking water aquifers and develop a fundamental understanding of the fate of dissolved and exsolving CO₂ at pore scale using micromodel experiments.

Exsolution Scenario

Left: Saline aquifer containing dissolved CO₂ that is connected to a confined fresh water aquifer by a fault zone. Middle: Gas saturation in fresh water aquifer after depressurization.

Exsolution – Nucleation Types

- Homogeneous Nucleation
- Heterogeneous Nucleation
- Pseudo Classical Nucleation

Depletion Modes

Stepwise Depletion

Continuous Depletion

Experimental Results –Stepwise Depletion

1400-1200 psi

1200-1000 psi

1000-800 psi

800-400 psi

Experimental Apparatus

Micromodel Fabrication

Experimental Results

Observations
- From 1400-1200psi appearance of micro nuclei
- From 1200-1000psi nuclei growth to bubble size
- From 1000-800psi bubbles grow further and build continuous gas clusters. Gas saturation increases
- From 800-400 psi exsolution continuous and reaches maximum

Influencing Factors
- Depletion rate – stepwise vs. continuous
- Pore surface roughness and amount, crevices and particle in solute
- Supersaturation level

Experimental Setup

- Inject supersaturated water
- Deplete micromodel at:
  - Const. pressure rate [10 psi/min]
  - Stepwise pressure decline [200 psi/step]