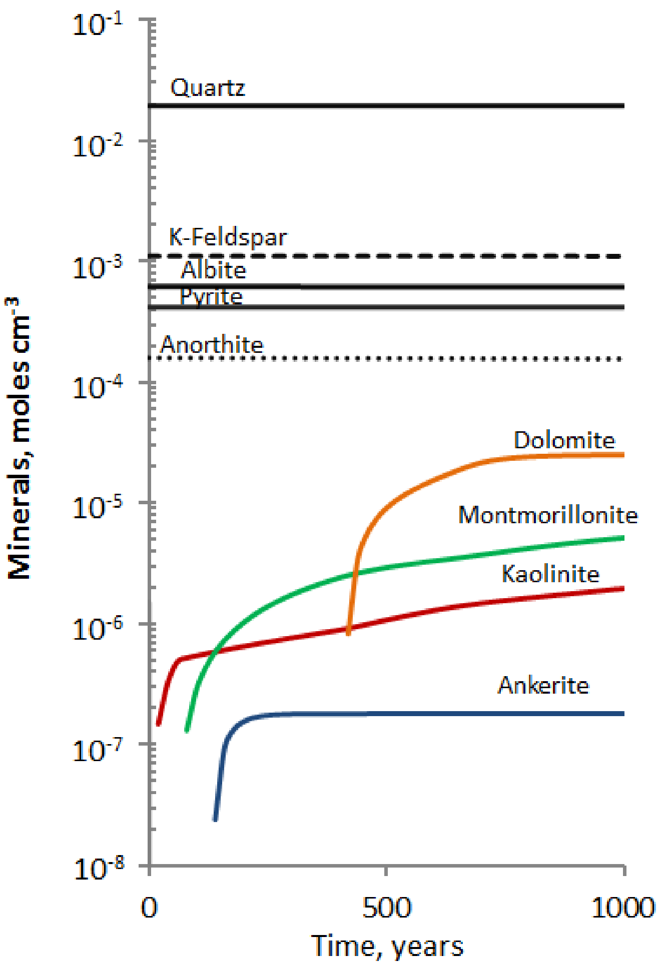
CO_2 Injection at the Frio-I Brine Pilot: Geochemical Modeling and Uncertainty Analysis



Reactive transport models over 1000 years predict precipitation of minerals kaolinite, montmorillonite, dolomite and ankerite.

Scientific Achievement

Quantified mineral dissolution and precipitation on the time scale of the field test (10 days) and long-term storage (1000 years).

Significance and Impact

Provides insight on the impact of geochemical reactions on injectivity and long term trapping, and can guide potential site selection based on the geochemistry of the site.

Research Details

Geochemical modeling (Geochemists Workbench) with custom thermodynamic database was used for the reactive transport modeling to deduce mineral dissolution and precipitation. Uncertainty was assessed when using different thermodynamic databases.

Ilgen A.G. and Cygan R.T. (2015) Accepted to International Journal of Greenhouse Gas Control.

Work was performed as part of the **Center for Frontiers in Subsurface Energy Security**

Frio-I Pilot in 2004

- Setting: salt dome flank, Frio sandstone;
- 1600 tons at 3 kg/s, 10 day injection in 1545 m deep well;
- ~ 40 water samples collected for 4 days using 1530 m deep monitoring well.

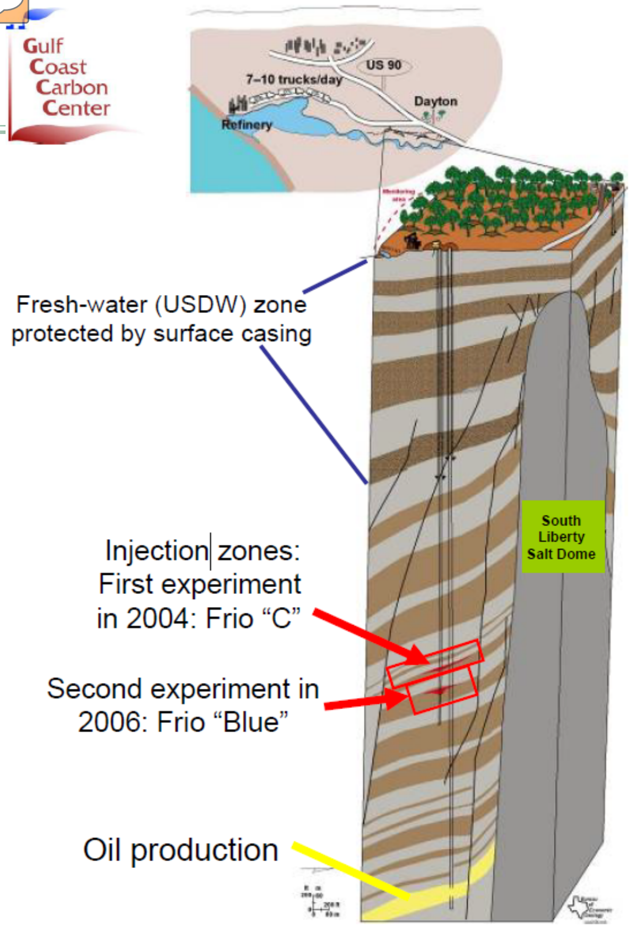


Figure from presentation by T. Meckel (2008)

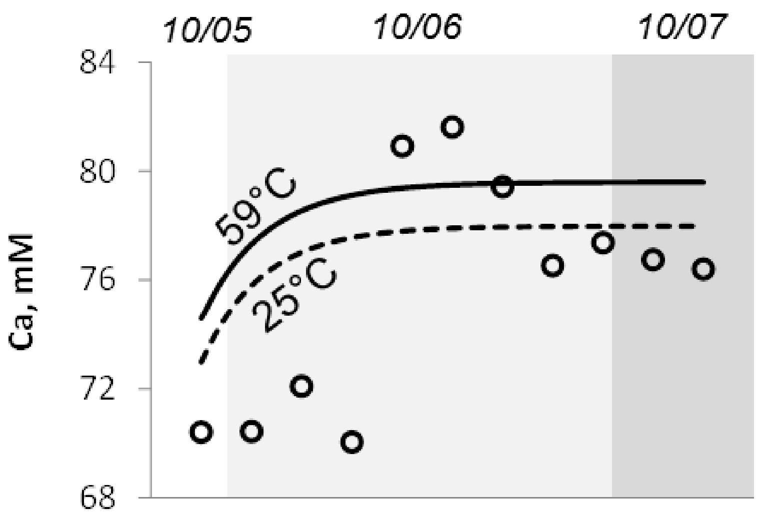
Water chemistry

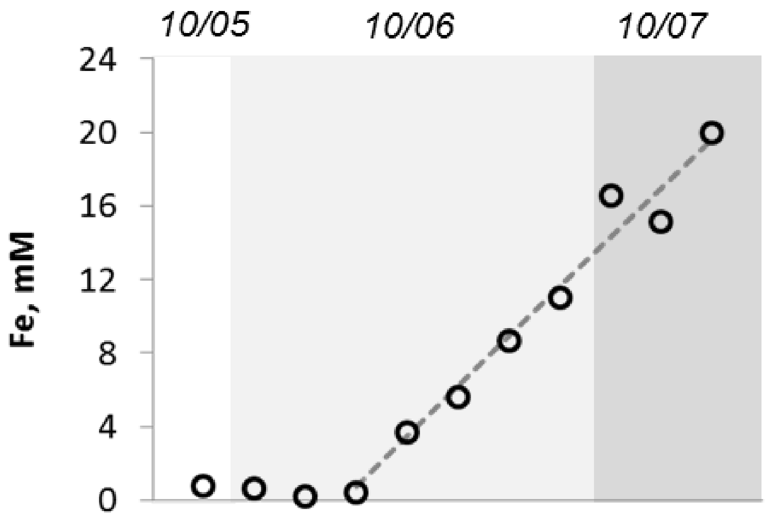
Component	Concentration (mol/kg H_2O)
Ca^{2+}	6.6×10^{-2}
Mg^{2+}	2.2×10^{-2}
Na^{+}	1.35
K^{+}	4.53×10^{-3}
Iron	4.63×10^{-4}
$SiO_2(aq)$	2.50×10^{-4}
Carbon	5.04×10^{-2}
Sulfur	4.20×10^{-5}
Al^{3+}	1.56×10^{-8}
Cl^{-}	1.49
$O_2(aq)$	4.88×10^{-68}
pH	6.7
Temperature	59 °C

Minerals

Quartz	Oligoclase	Illite
Kaolinite	K-feldspar	Na-smectite
Calcite	Chlorite	Hematite

Mineral dissolution during injection



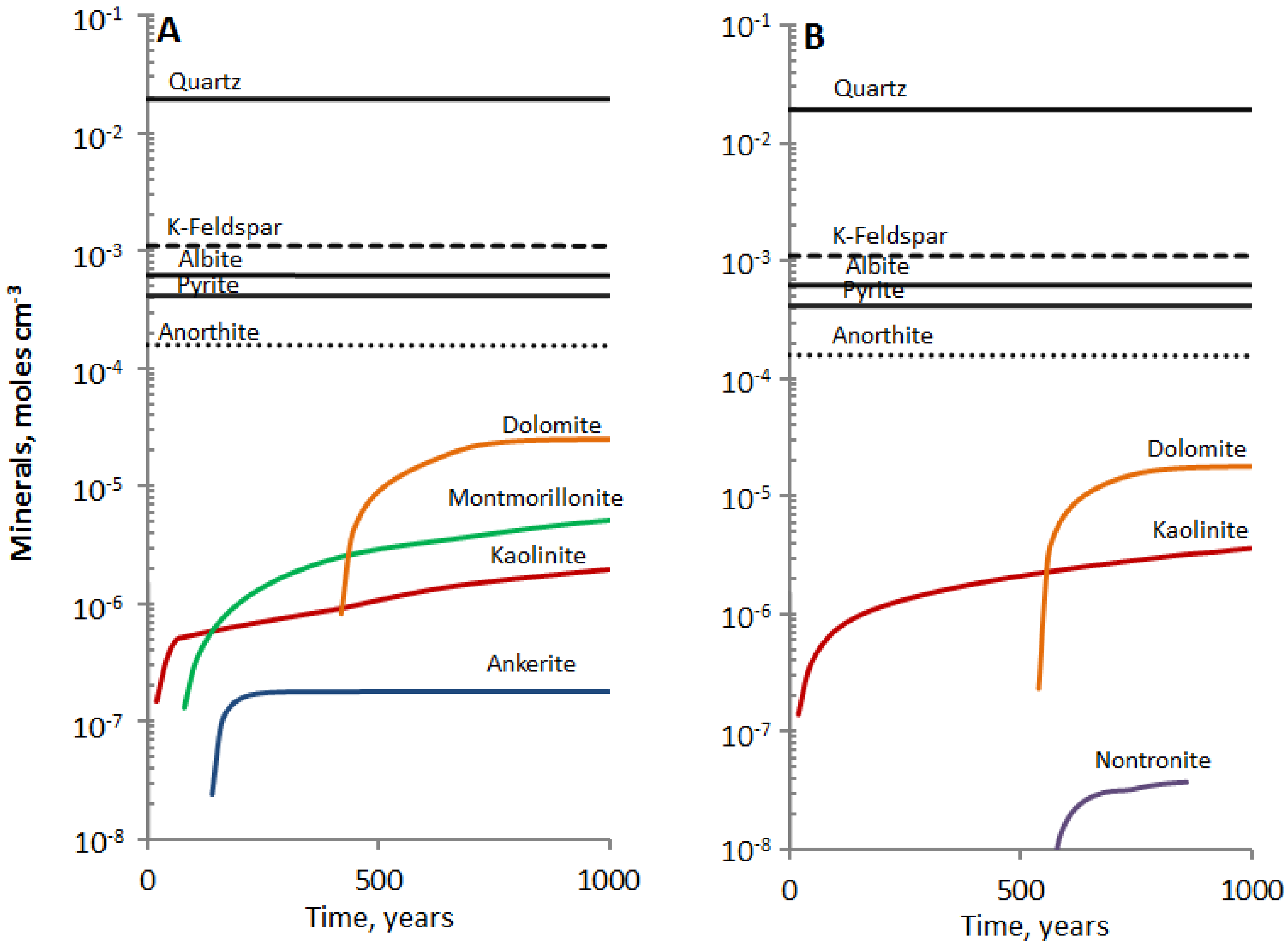


Changes in the aqueous concentration of Ca in the monitoring well (points) and proposed reaction path models (lines); Ca is released during kinetically controlled calcite dissolution, calcite dissolution rate constant k = 10^{-8} mol cm^{-2} sec^{-1}.

Changes in the aqueous concentration of Fe in the monitoring well (points) and proposed reaction path models (lines); the reaction path models assume Fe is released during simple Fe(III) oxide dissolution.

Total of 0.023 wt % of rock mass was lost due to calcite and Fe(III) oxide dissolution during Frio-I Brine Pilot.

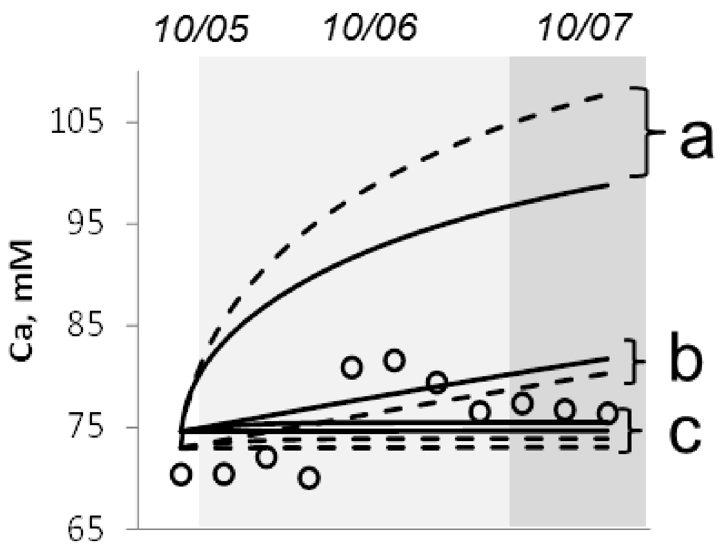
Reactive Transport Models



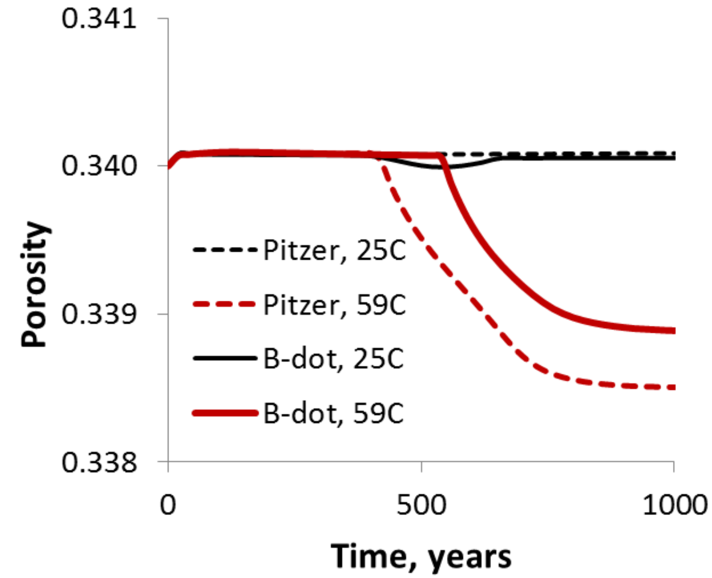
Reactive transport models for 1000 years predict precipitation of clay minerals kaolinite, montmorillonite and nontronite, and carbonates dolomite and ankerite. Model "A" constructed using Pitzer activity correction model (database compiled for this study), and model "B" uses B-dot activity correction model (*thermo.dat*). Temperature was set at 59 °C for both models.

Geochemical Modeling Uncertainty

Calcite dissolution during injection



Porosity changes due to mineral dissolution and precipitation predicted for 1000 years



Uncertainties due to uncertain calcite dissolution rate constant and reactive surface area. Group "a" – 0.001 wt.% calcite, k = 10^{-8} mol cm^{-2} sec^{-1}, group "b"- 0.1 wt.% calcite, k = 10^{-10} mol cm^{-2} sec^{-1}, group "c" – 0.001 wt.% calcite, k = 10^{-8} and 10^{-10} mol cm^{-2} sec^{-1}. Dashed lines – models calculated at 25°C, solid lines – at 59°C.

Cumulative effect of uncertainties associated with using different thermodynamic databases, activity correction models, and extrapolating to the reservoir temperature.

The uncertainties are evident in the total volume of predicted mineral precipitation, or in the total porosity vs. time.

The relatively low reactivity of the Frio "C" mineral assemblage causes geochemical reactions in this system to have minimal impact on total porosity, and therefore injectivity and long term trapping.