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Non-isothermal Effects of a CO_2 Injection into a Geologic Reservoir

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The injection of super-critical CO_2 into the subsurface causes a disturbance in the pressure, temperature, and chemical systems within the target reservoir. How the ambient conditions change in response to a CO_2 injection ultimately affects the transport and fate of the injected CO_2. This study is focused on gaining a better understanding of the thermal effects of a CO_2 injection and how the changes in temperature affect the movement and reactivity of the CO_2, as well as to investigate the efficacy of using temperature as a proxy for CO_2 breakthrough.

Thermal Effects

Joule-Thomson Effect

Joule-Thomson cooling refers to the temperature drop that occurs when gas such as CO_2 or N_2 expands from high pressure to low pressure. This effect has been shown to to cause 4°C to 20°C temperature decrease during CO_2 injection simulations.

Oldenburg (2007)

Heat of Dissolution

The dissolution of CO_2 into water is an exothermic reaction. In terms of a CO_2 sequestration, at the edges of the CO_2 plume the CO_2 dissolves into the reservoir water and releases heat, which results in the release of ~325 kJ/kg at 40°C.

Han et. al. (2010)

Chemical Reactions

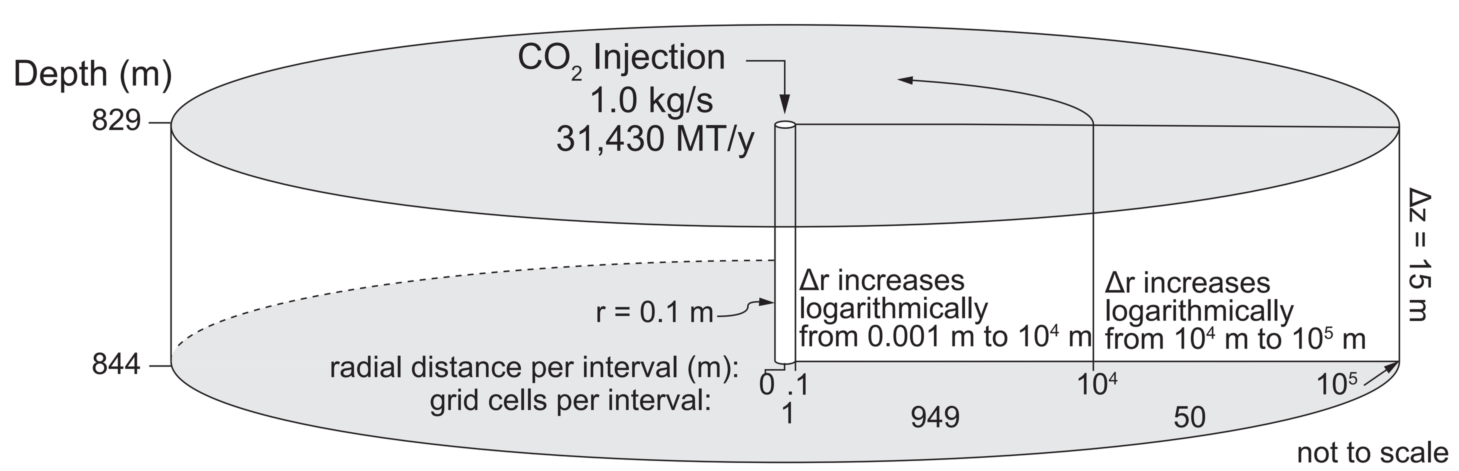
$$CO_2 + H_2O = H_2CO_3 = H^+ + HCO_3 \quad (1)$$

$$SiAl_{0.358}Fe_{0.190}Mg_{0.281}Ca_{0.264}Na_{0.079}K_{0.008}O_{3.315} + 2.63H^+ + 0.685H_2O = H_4SiO_4 + 0.358AL^{3+} + 0.190Fe^{2+} + 0.281Mg^{2+} + 0.264Ca^{2+} + 0.079Na^+ + 0.008K^+ \quad (2)$$

$$CA^{2+} + HCO_3^- = CaCO_3(s) + H^+ \quad (3)$$

Pollyea and Rimstidt (2017)

Model Setup



Reservoir Parameters

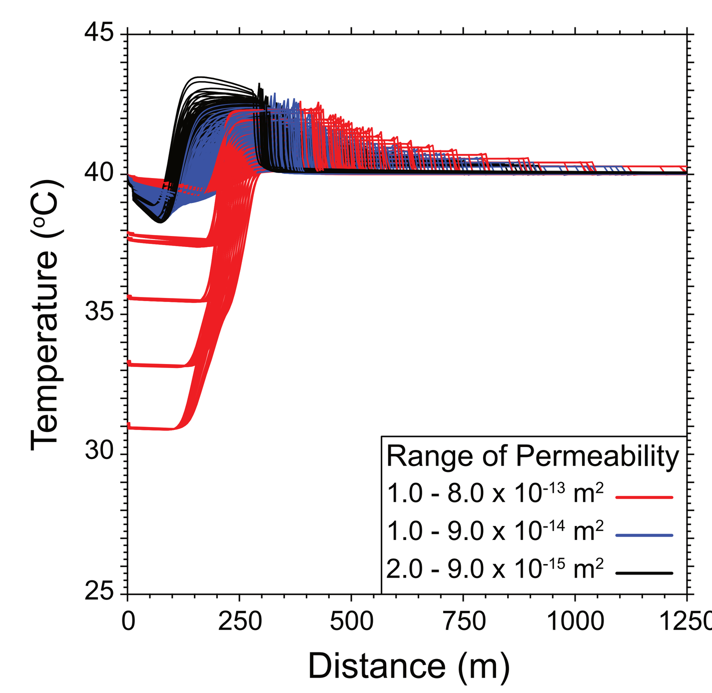
- P_r = 8.30 MPa
- T = 40.0 °C
- NaCl = 10,000 ppm
- $k = 1.0 \times 10^{-13} - 10^{-15}\,m^2$
- φ = 0.05 - 0.45

van Genuchten Parameters

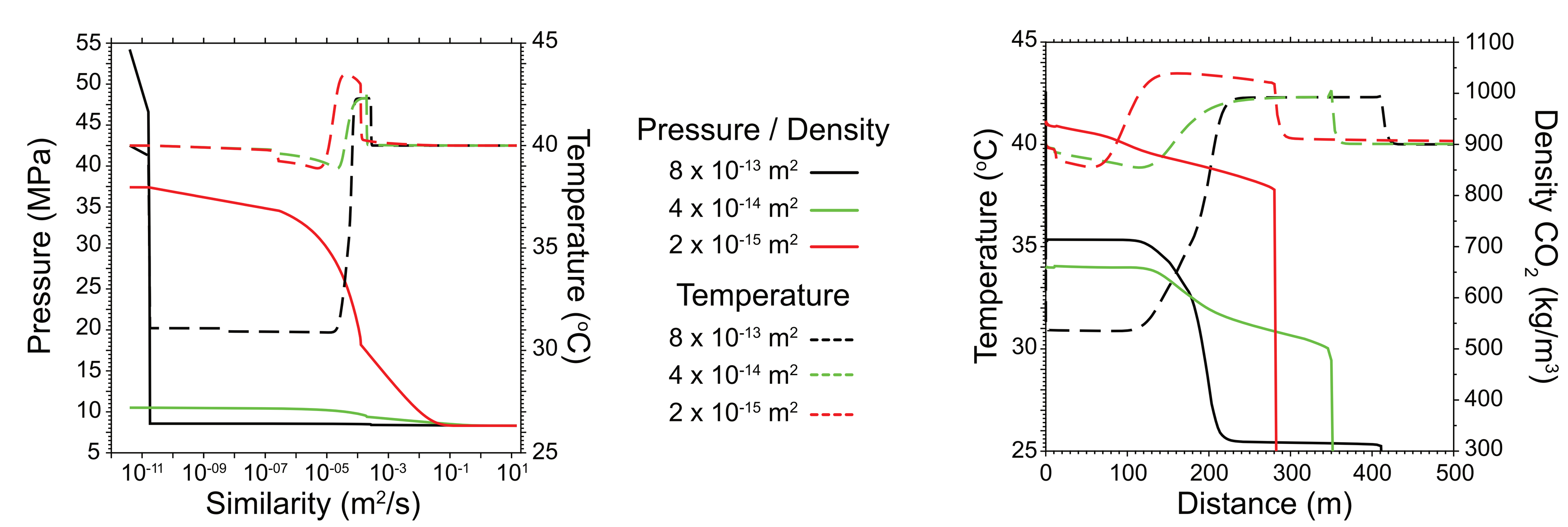
Relative Permeability	Capillary Pressure
λ = 0.550	λ = 0.500
S_{lr} = 0.30	S_{lr} = 0.0
S_{ls} = 1.0	α (Pa⁻¹) = 1.0
S_{gr} = 0.25	P_{max} (Pa) = 0.25
	S_{ls} = 0.999

Results

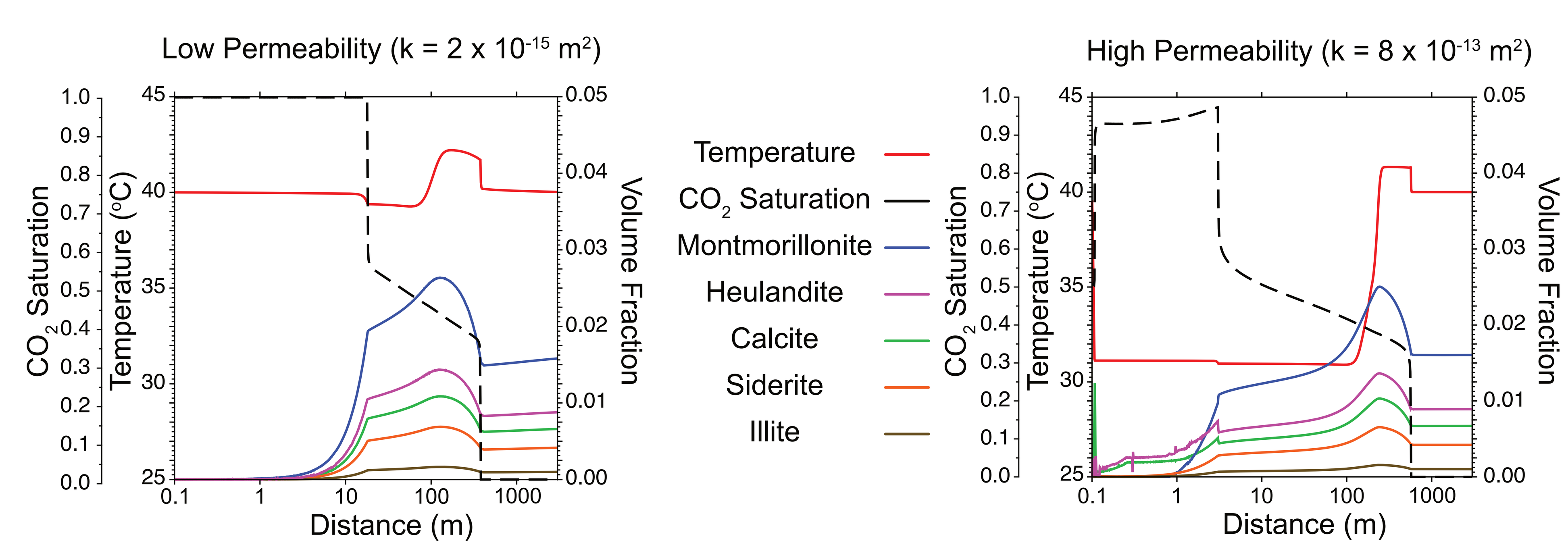
Thermal and Hydraulic Modeling



- 432 Simulations
- Maximum Temperature = 43.6°C
- Minimum Temperature = 30.8°C
- Porosity Ranges 0.05 - 0.45

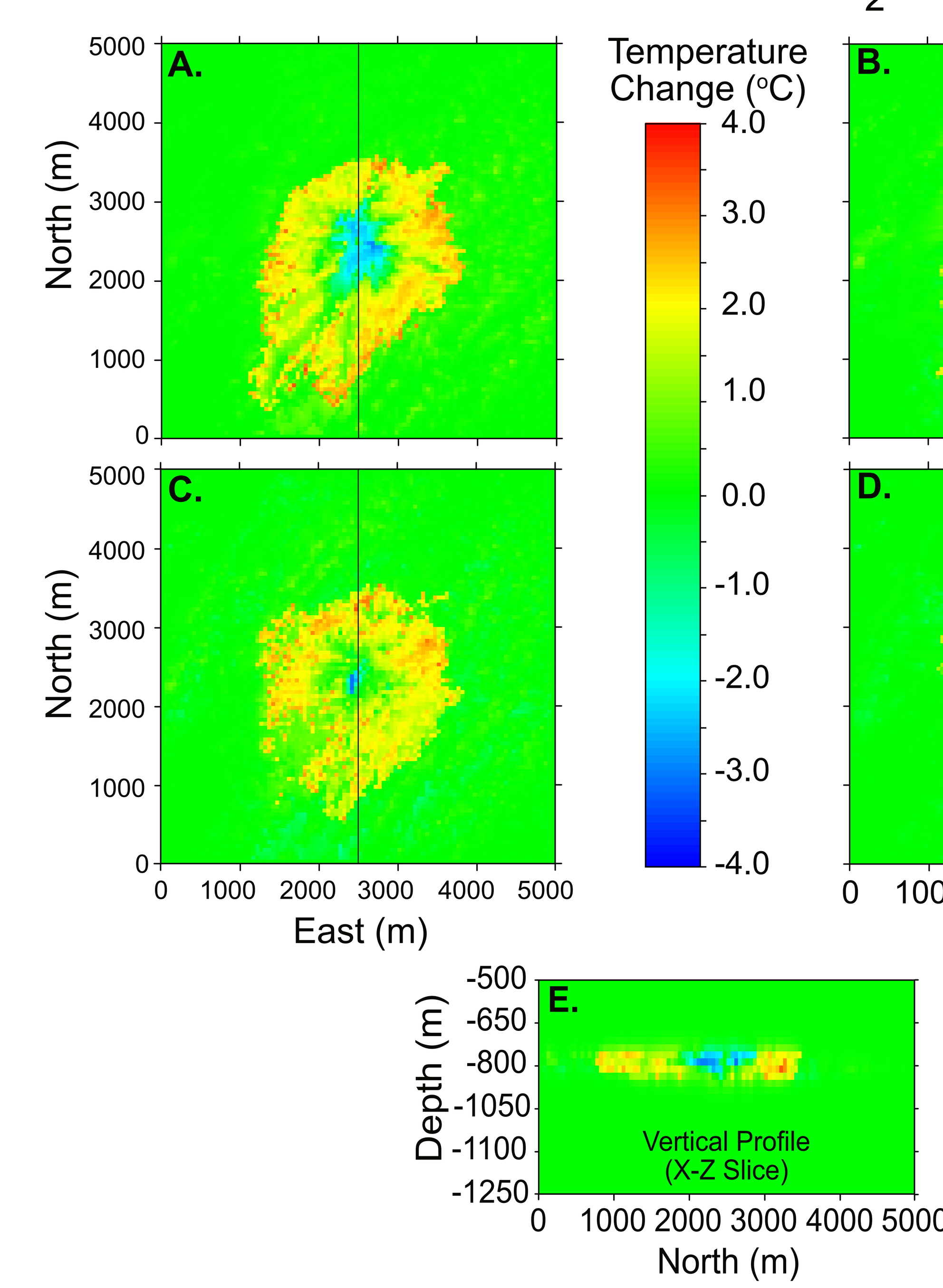


Thermal, Hydraulic, and Chemical Modeling



Implications

Reservoir-Scale CO_2 Injection



Jayne et. al. (In Press)

Conclusions/Future Work

1) During injection phase, heat of dissolution effects may be an effective proxy for CO_2 breakthrough.
2) Joule-Thomson cooling may exhibit some control on the precipitation of secondary mineral phases.
3) Due to the Joule-Thompson effect and the pressure drop in the far-field basalts exhibit self-sealing behavior.
4) How do heterogeneities in reservoir affect mineralization?
   - Near the well
   - Far-field and fractures (i.e. self-sealing behavior)

References

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