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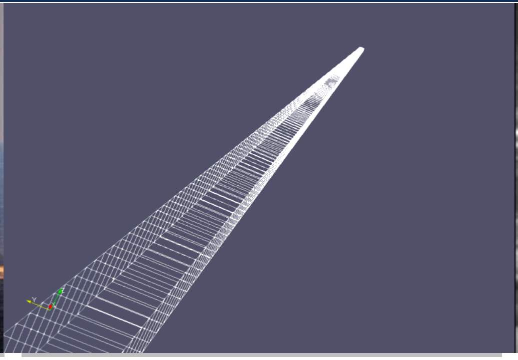


Modeling Chemical Evolution of Cement Seals

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MLEF presentation, 08/10/17

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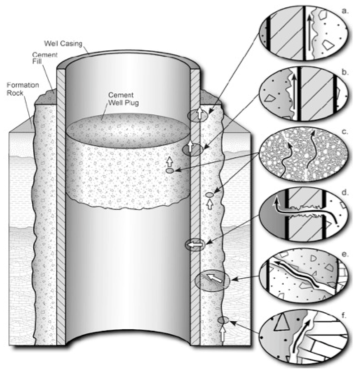
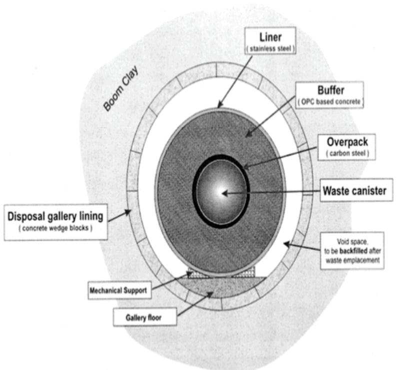
Overview: Brine with CO_2 dissolved in it is expected to dissolve and/or leach the cement fastest out of the three cases since the CO_2 is acidic in nature.

- Motivation
- Problem set up
- Methodology
- Hypothesis, mesh dimensions, and observation points
- Data
- Conclusion
- Future Work
- Questions
- References



Wellbore Seals[1]



Engineered Barrier System Components[2]

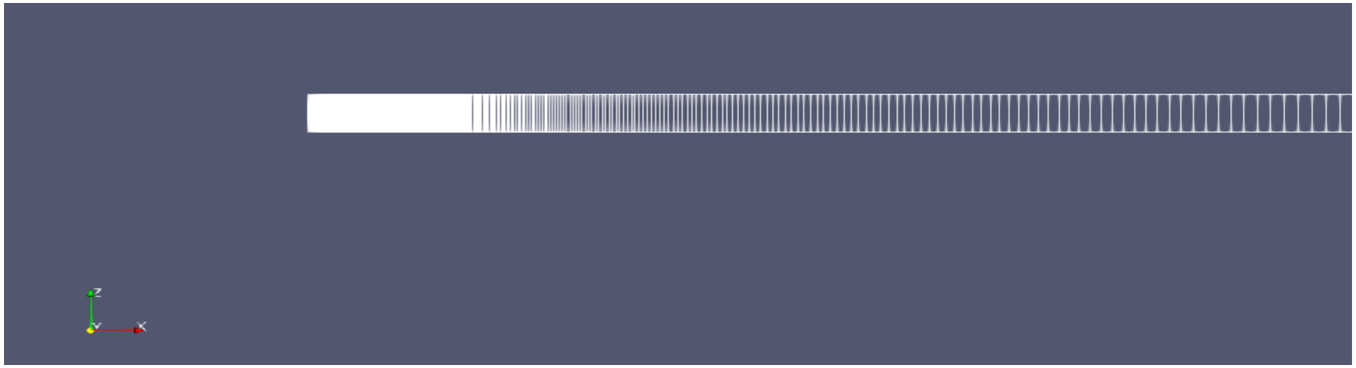
Motivation

- Interested in the prevention of the migration of subsurface fluids
- For example, CO_2 can migrate through the annuli developed in the cement seals after reacting with CO_2 for extended periods of time
- Computationally investigate the cement mineral phase alteration during exposure to CO_2 saturated brine

BP Oil spill due to failure

Problem set up

- Constant boundary condition in the fluid reservoir
- Ordinary Portland Cement (OPC) plug
- 1D, Square mesh
- 1st Case of flooding uses 0.5 Molar NaCl Brine Solution
- 2nd Case of flooding uses 0.5 Molar NaCl Brine Solution saturated with 33 milli Molar CO_2 (1 atm CO_2 pressure head)



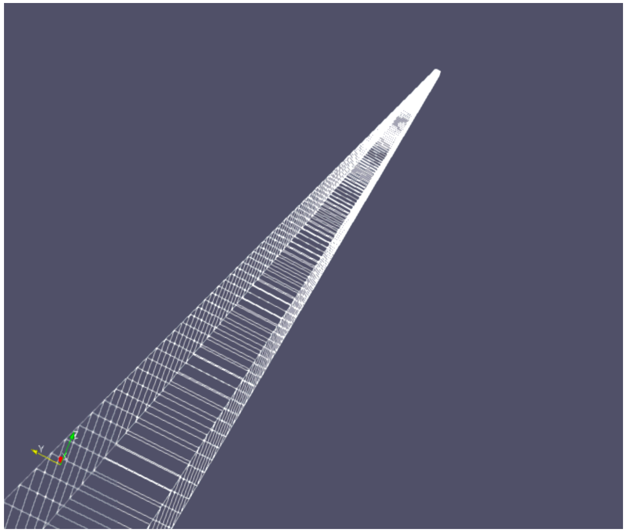
Side view of mesh orientation

Methodology

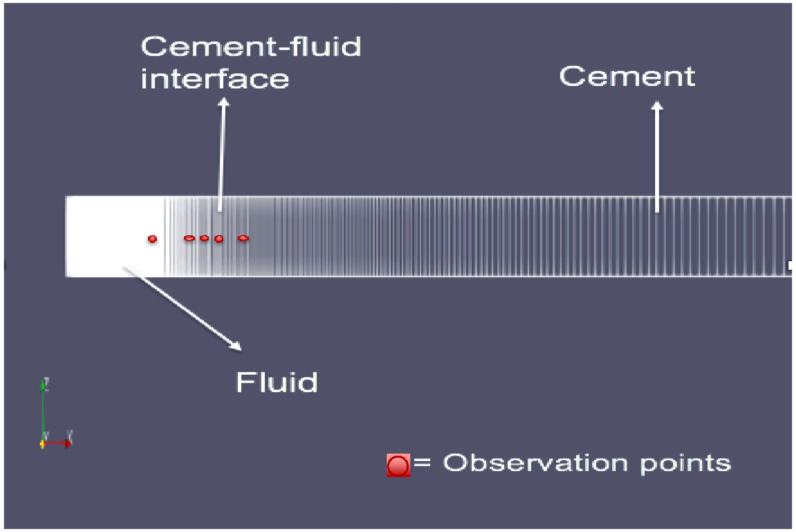
- Model is implemented in PFLOTRAN reactive transport code
- PFLOTRAN is:
  - open source
  - state-of-the-art massively parallel subsurface flow and reactive transport code
  - PFLOTRAN solves a system of generally nonlinear partial differential equations describing multiphase, multicomponent and multiscale reactive flow and transport in porous materials

Hypothesis, Mesh dimensions and observation points

- Brine with CO_2 dissolved in it is expected to dissolve and/or leach the cement fastest out of the three cases since the CO_2 is acidic in nature.
- 1:400 meters of fluid to cement ratio used in analysis
- 5 observation points in (x,y,z): (1.00, 2.5, 2.5), (1.8, 2.5, 2.5), (1.99, 2.5, 2.5), (2.00, 2.5, 2.5), and (2.3, 2.5, 2.5)

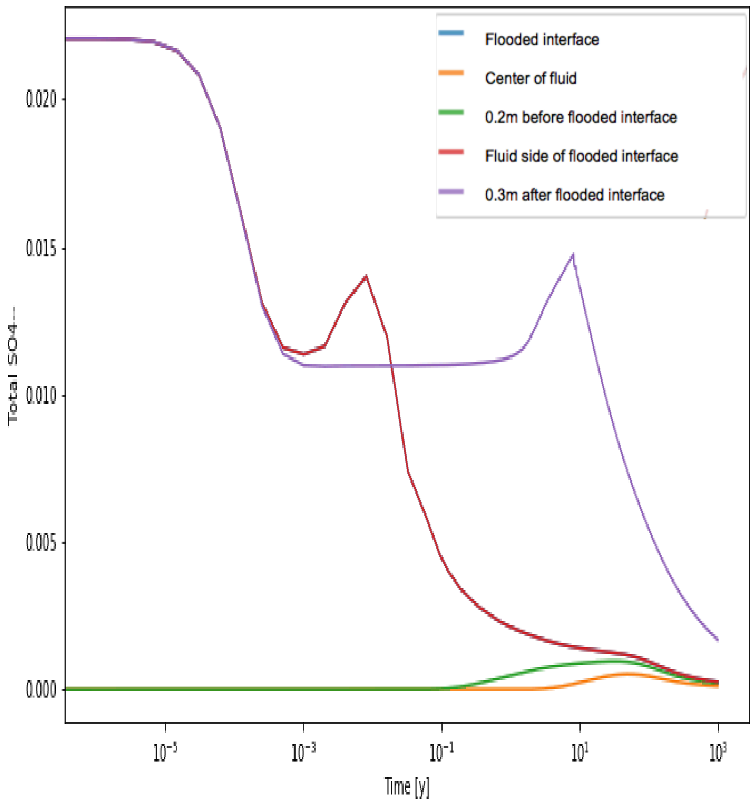


3D Observation of Mesh

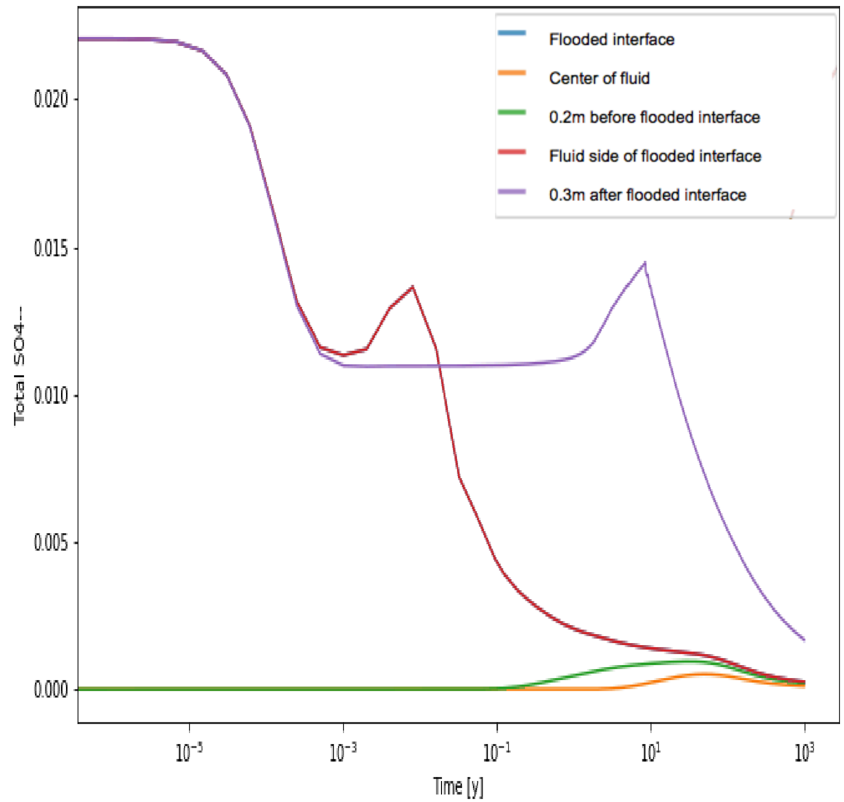


Observation point locations

Total SO_4 change without CO_2 vs. with CO_2 on log scale virtually unchanged in presence of CO_2

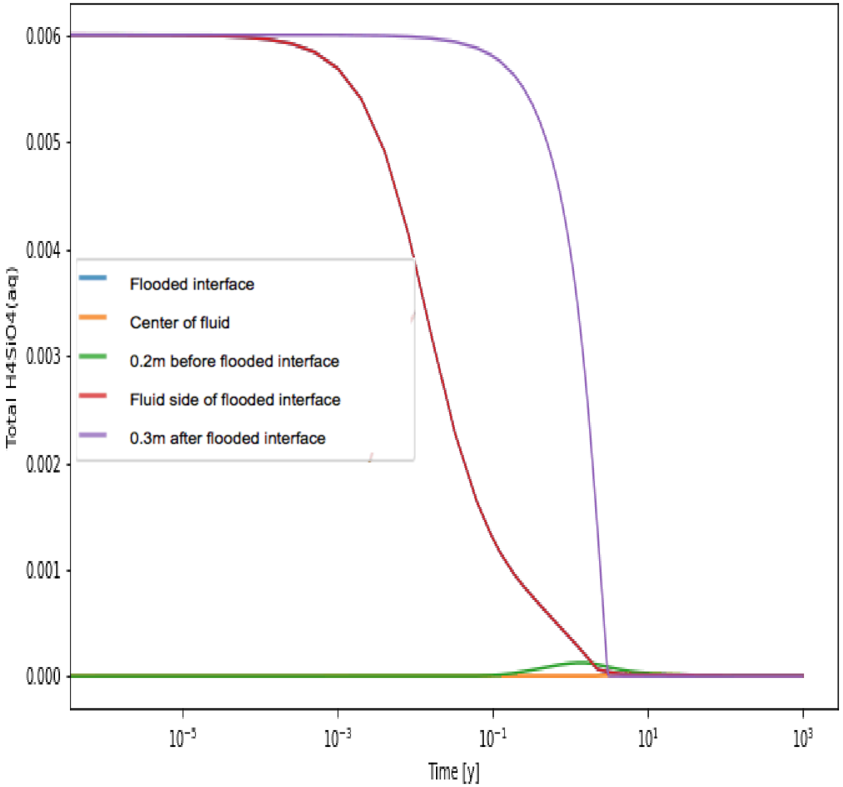


Without CO_2

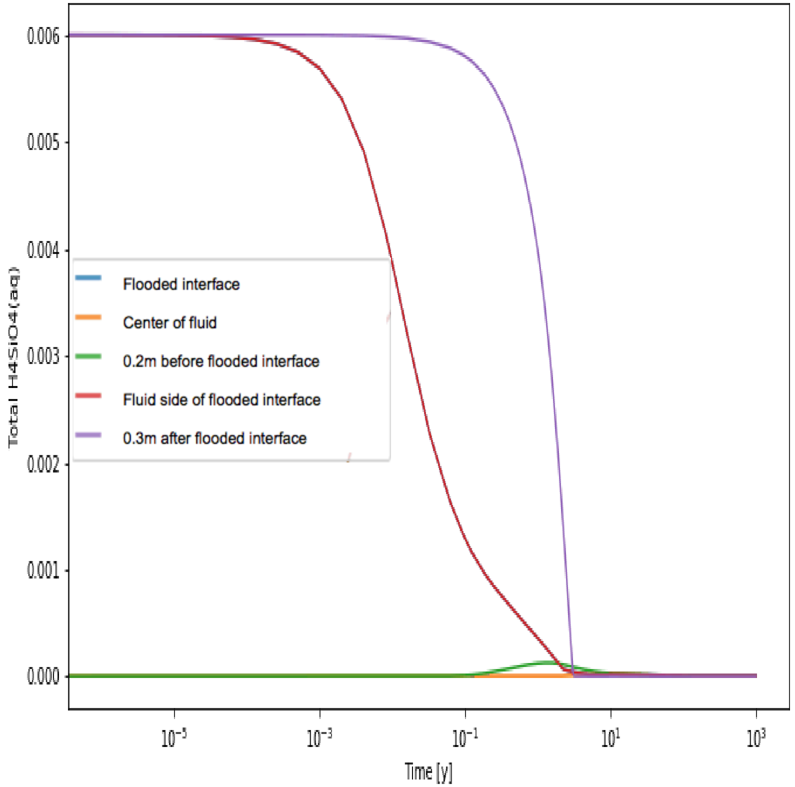


With CO_2

Total H_4SiO_4 (aq) change is virtually unchanged by CO_2 presence in brine

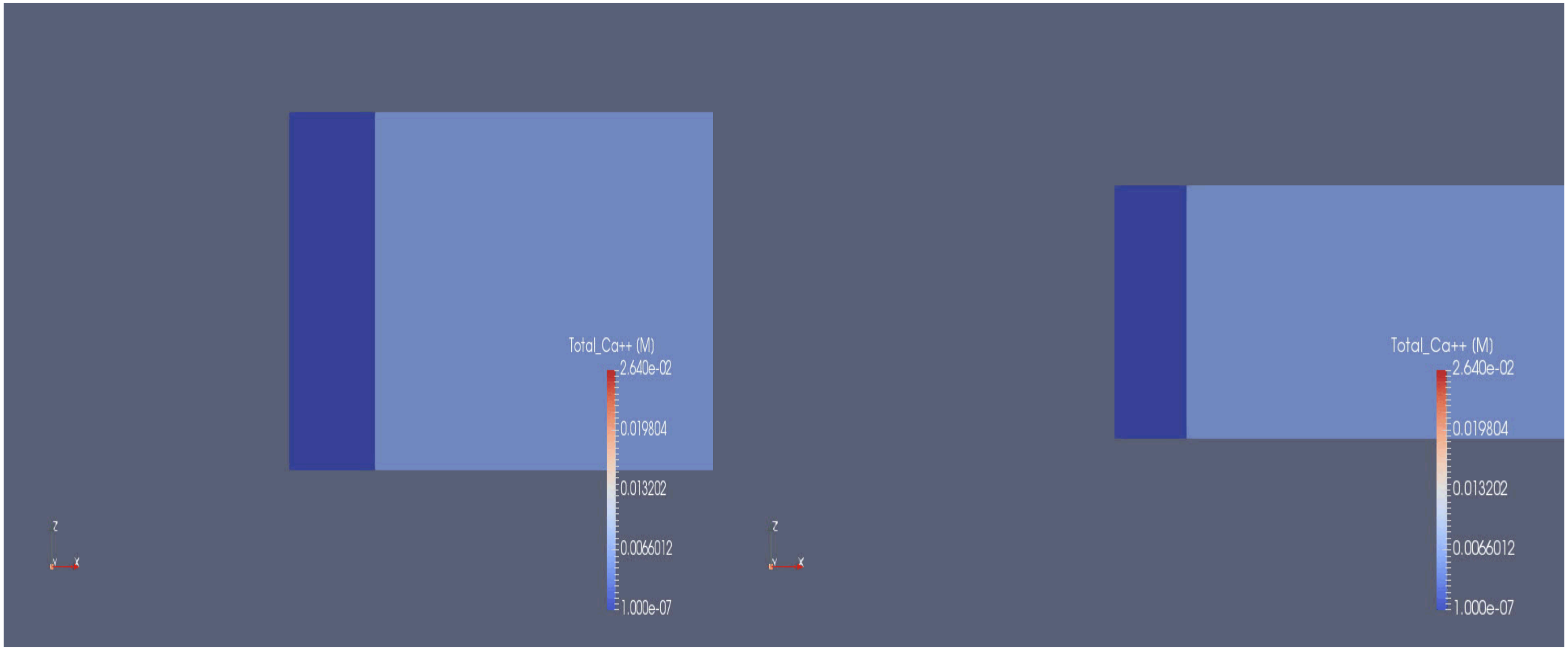


Without CO_2



With CO_2

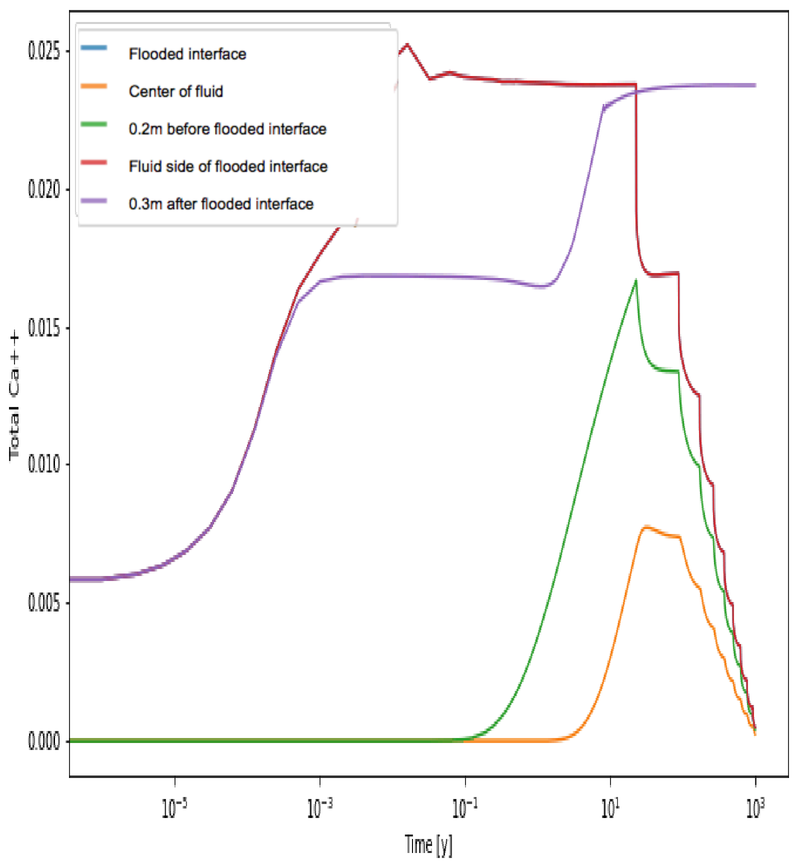
At long time, the CO_2 dissolved brine case had a higher concentration of Calcium in the cement at the fluid-cement interface



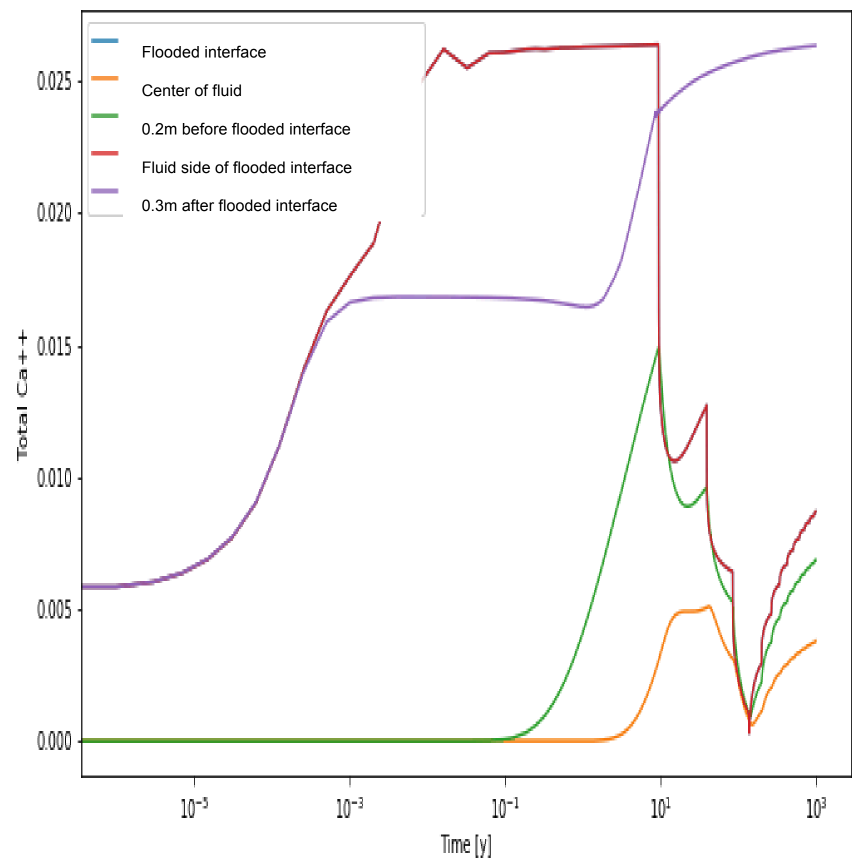
Change of Ca++ in Brine solution

Change of Ca++ in CO_2 dissolved Brine solution

Total Ca++ change without CO_2 vs. with CO_2 on log scale

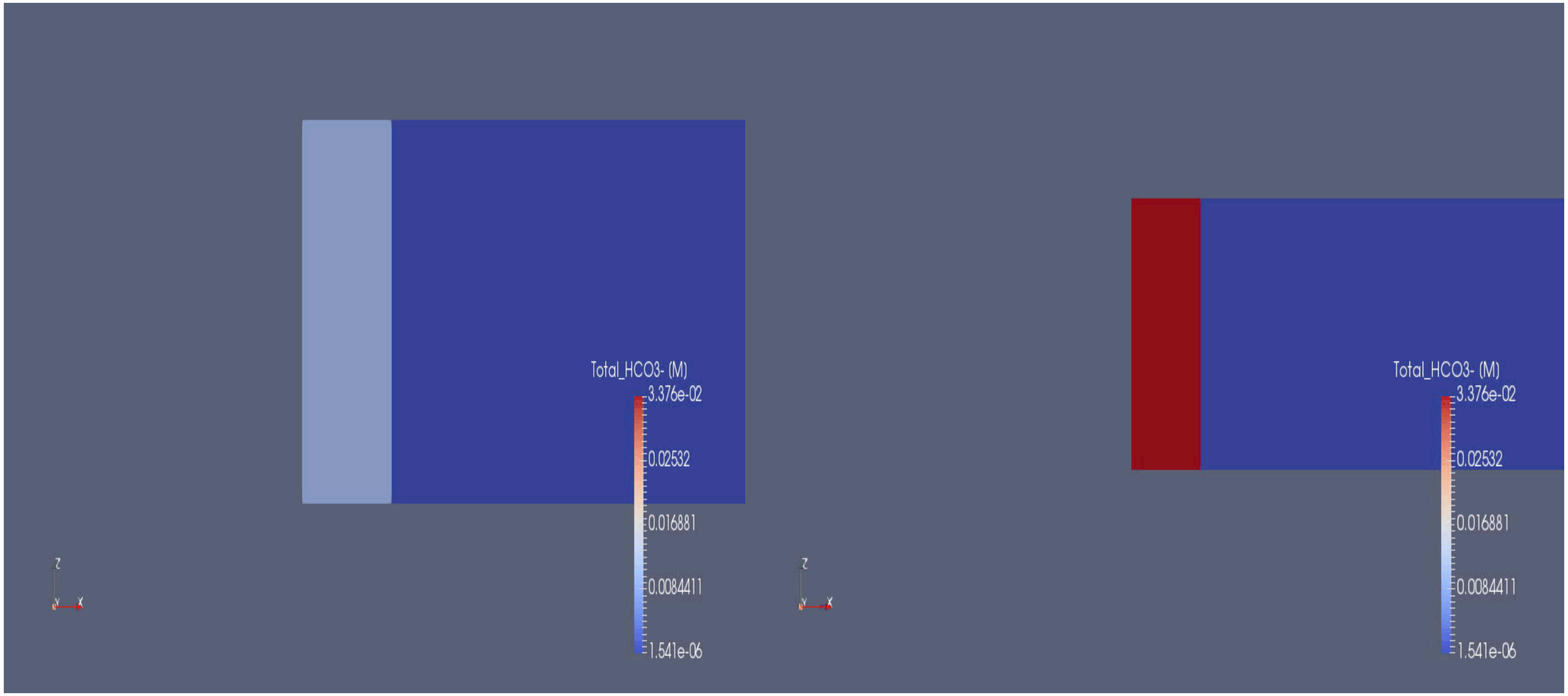


Without CO_2



With CO_2

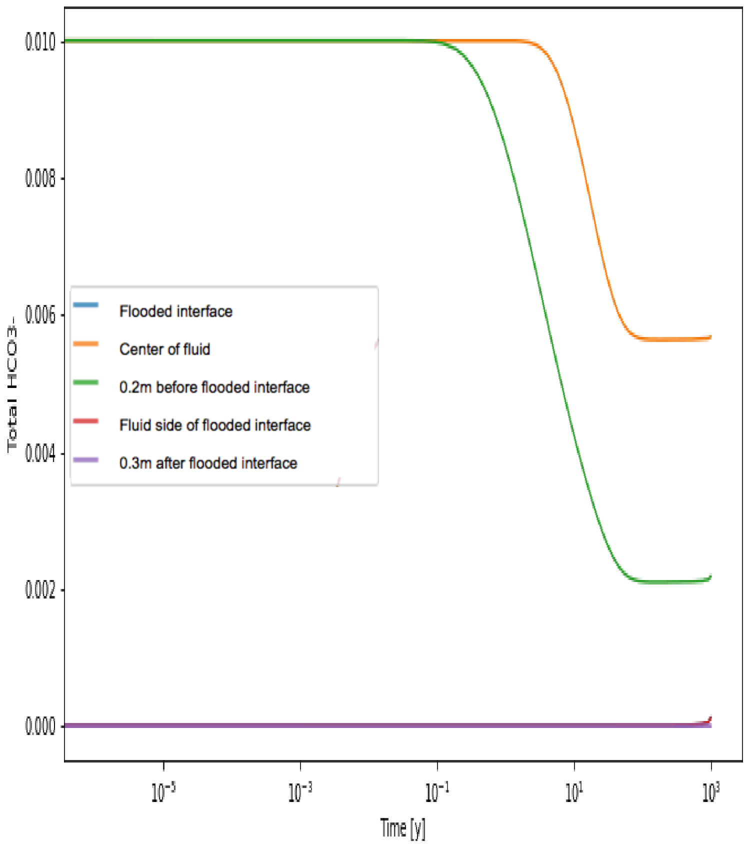
HCO_3 maps with carbonate speciation via pH



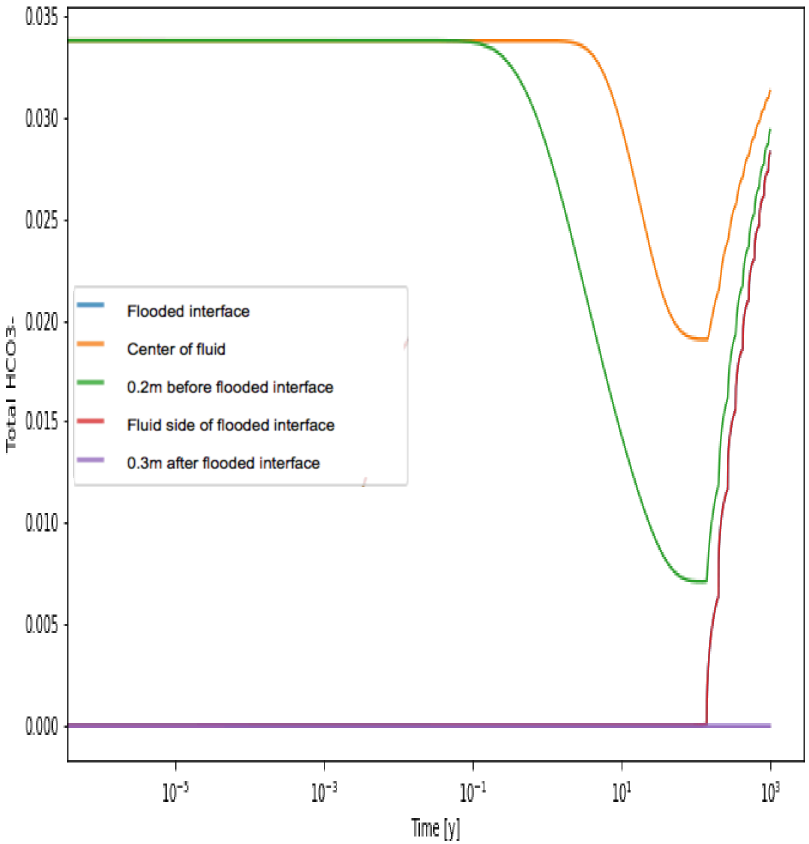
Change of HCO_3 in Brine solution

Change of HCO_3 in CO_2 dissolved Brine solution

Total HCO_3 change without CO_2 vs. with CO_2 on log scale maps with carbonate speciation via pH

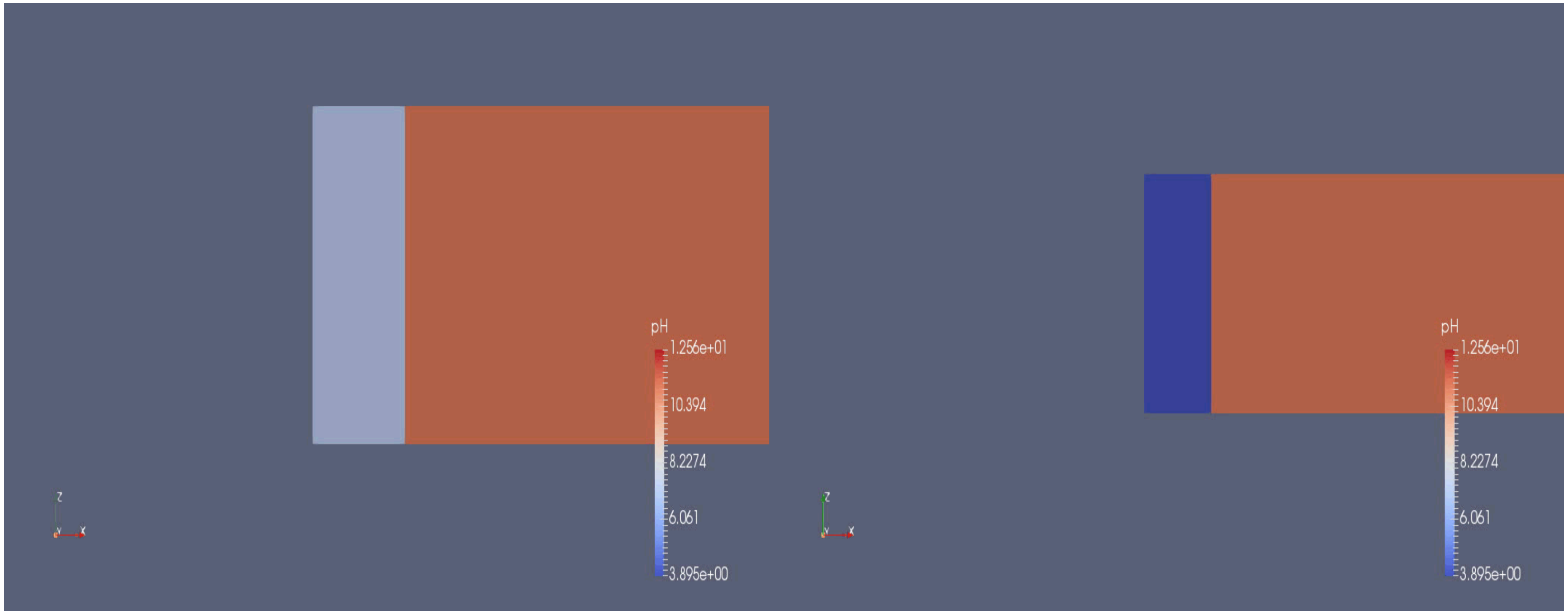


Without CO_2



With CO_2

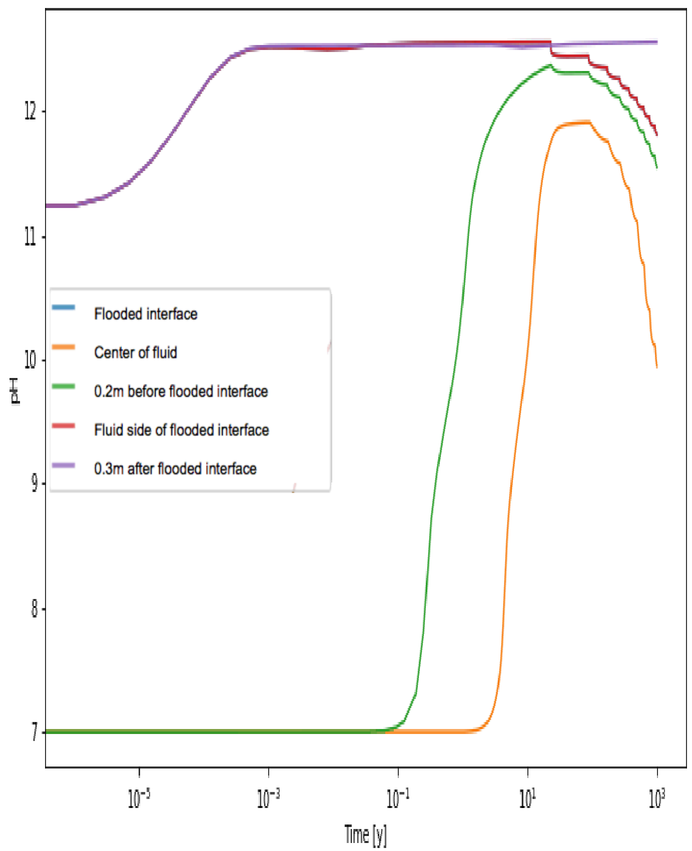
pH evolution in the fluid reservoir reflects base neutralization capacity of the respective fluids



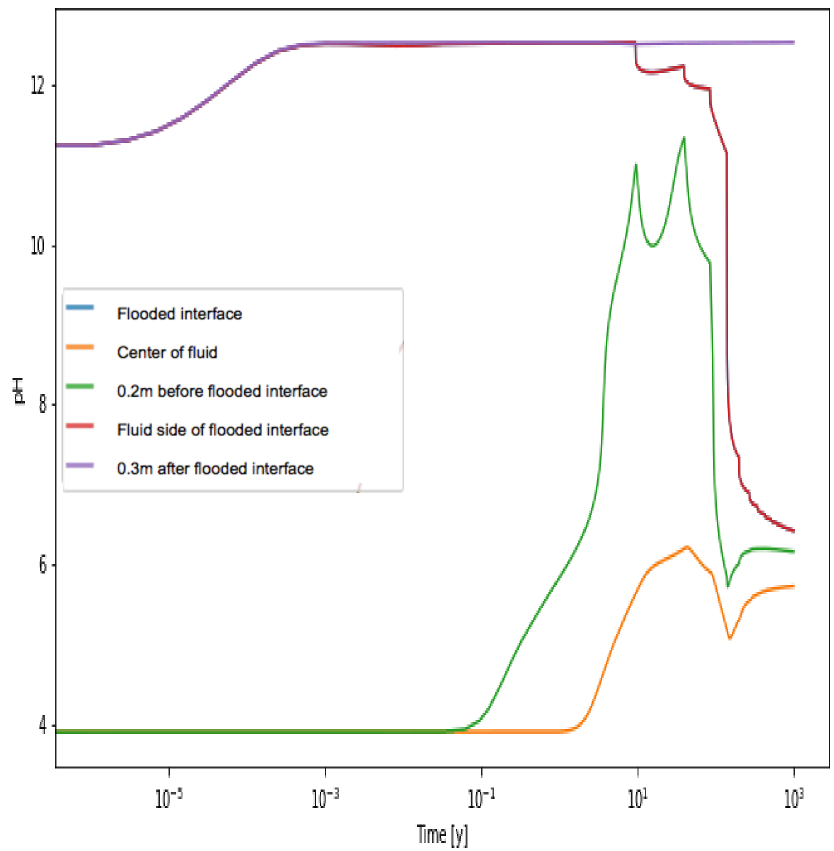
Change of pH in Brine solution

Change of pH in CO_2 dissolved Brine solution

Total pH change without CO_2 vs. with CO_2 on log scale maps with the carbonate speciation

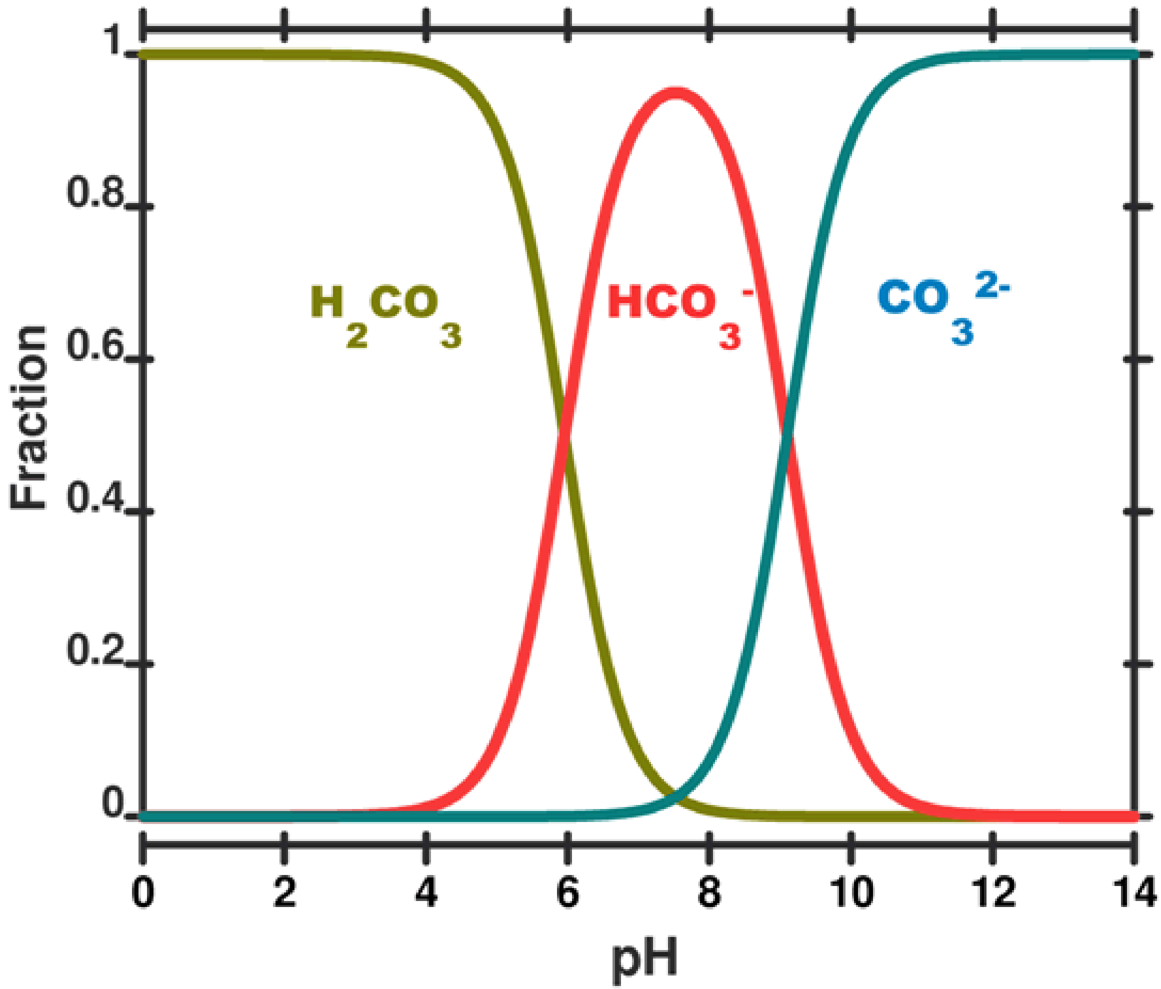


Without CO_2



With CO_2

Carbonate Speciation Map



Conclusions

- Total change in SO_4 is not very responsive to the presence of CO_2
- Total change in H_4SiO_4 is not very responsive to the presence of CO_2
- Total change in Calcium, the CO_2 dissolved brine had the highest concentration of Calcium at the fluid-cement interface
- Total change in HCO_3 maps with carbonate speciation via pH
- pH maps with the carbonate speciation via HCO_3

Future Work

- Investigation of solid precipitates during the HCO_3 and pH speciation mapping

Questions?

References

- [1] Gasda, S., M. Celia, and S. Bachu (2004). Spatial characterization of the location of potentially leaky wells penetrating a deep saline aquifer in a mature sedimentary basin. Environmental Geology. Vol. 46, 6-7, 707-720.
- [2] Hardin, E., J. Blink, H. Greenberg, J. Carter, M. Dupont, M. Sutton, M. Fratoni, R. Howard. Generic Repository Design Concepts and Thermal Analysis (FY11). SAND Report: SAND2011-6202. Sandia National Laboratories.