Combined experimental interpretation and numerical investigation of the impact of fluid alkalinity on basalt carbonation during CO_2 storage

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10 December 2020

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PICS
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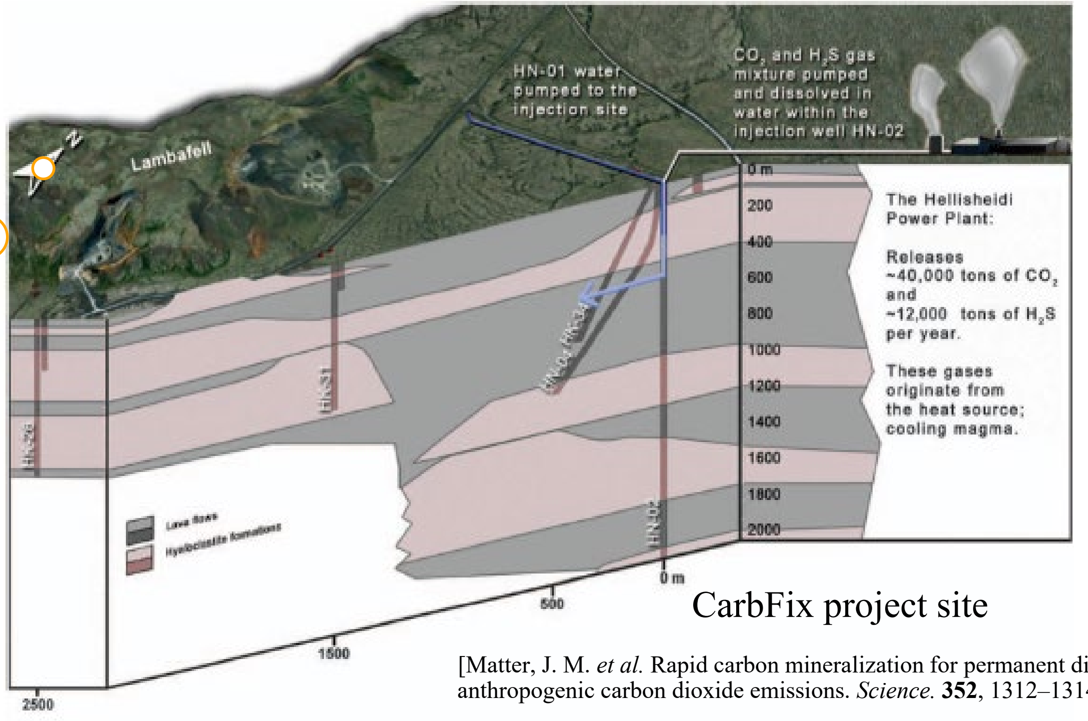
CO_2 Storage in Basalt

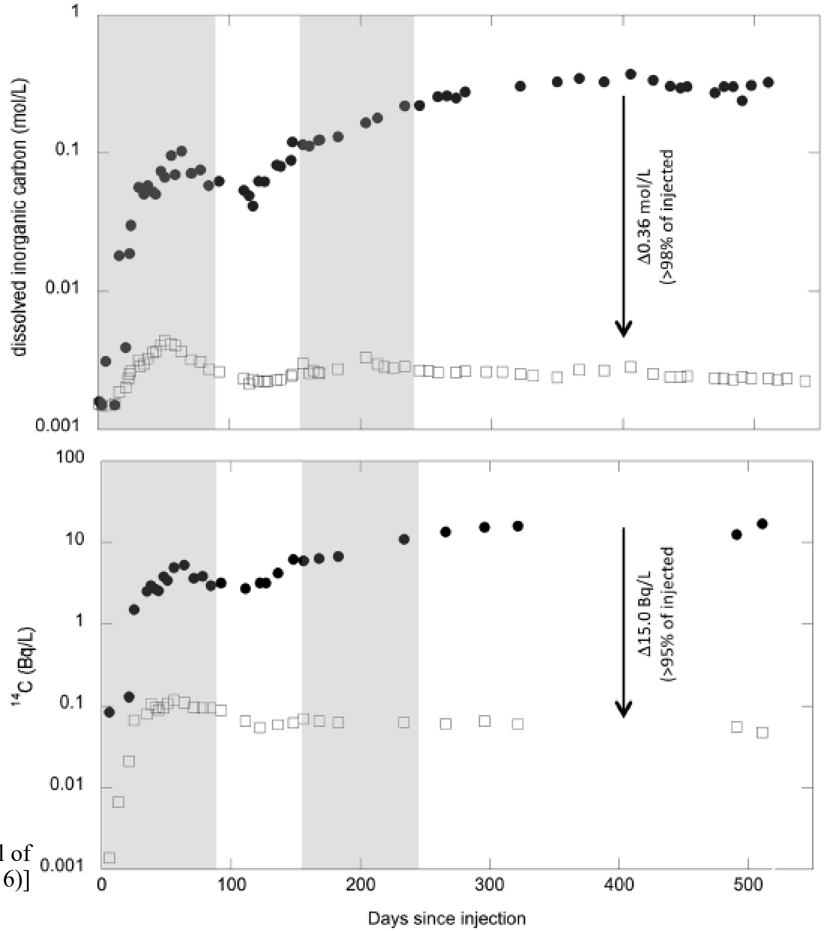
- Success reported at experimental and field-scale
- Rapid mineralization of basalt due to presence of reactive minerals – plagioclase, olivine, pyroxene

Can this performance be replicated elsewhere?



CarbFix project site

[Matter, J. M. *et al.* Rapid carbon mineralization for permanent disposal of anthropogenic carbon dioxide emissions. *Science.* **352**, 1312–1314 (2016)]



CO_2 Storage in Basalt

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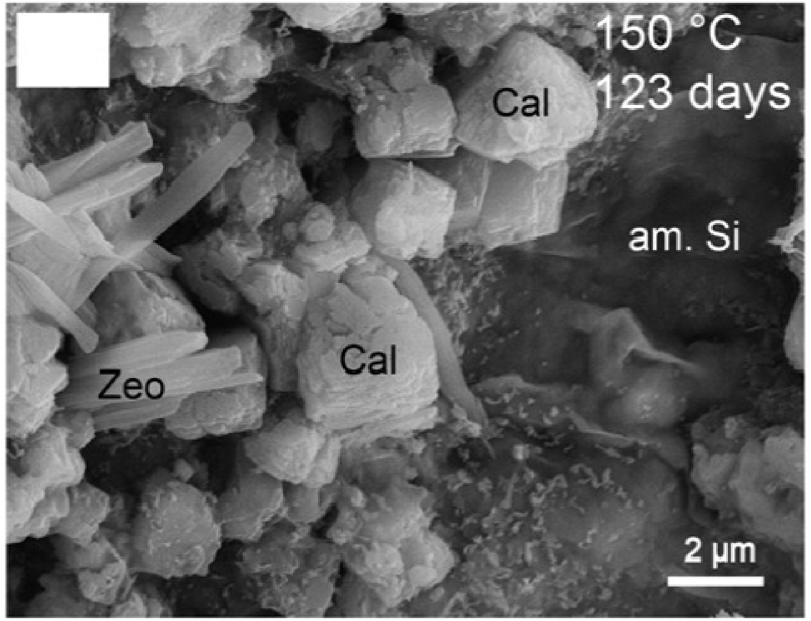
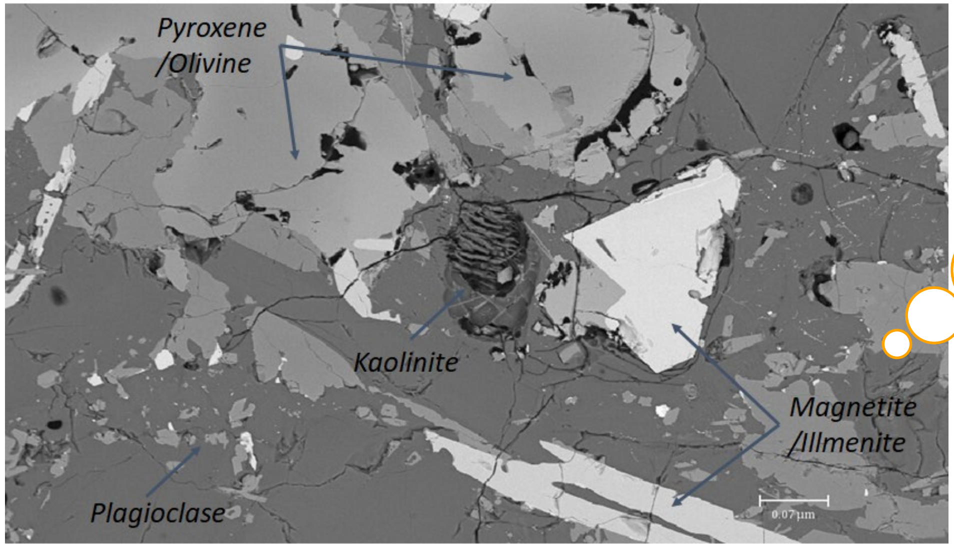
- Differences in reported studies with carbonate mineralization
- SEM images from two different studies conducted at similar Temperature

carbonate precipitation



Gysi, A. P. & Stefánsson, A. Mineralogical aspects of CO_2 sequestration during hydrothermal basalt alteration - An experimental study at 75 to 250°C and elevated pCO_2. Chem. Geol. (2012)

no carbonate precipitation



Luhmann, A. J. *et al.* Whole rock basalt alteration from CO_2-rich brine during flow-through experiments at 150°C and 150 bar. *Chem. Geol.* (2017)

What differentiate the studies and how does these factors affect carbonation?

3D Reactive Transport Modeling

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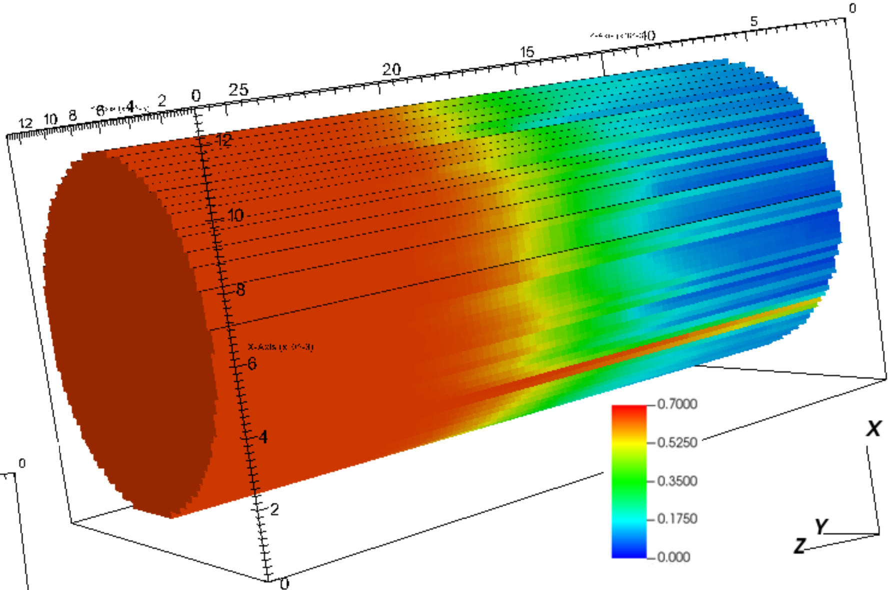
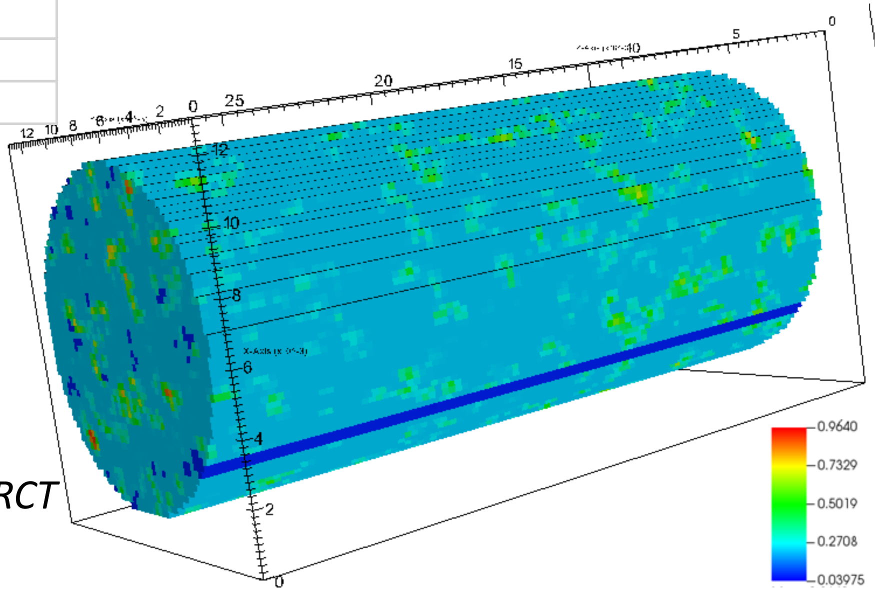
- Experiment by Luhmann et al (2017) was modeled using XCRT and effluent dataset with 1M NaCl solution

Mineral	Volume fraction	
Plagioclase	48.5	
Orthoclase	4.71	
Diopside	12.5	
Hypersthene	12.4	
Olivine	13.8	
Ilmenite	5.43	
Magnetite	1.13	
Apatite	1.74	
Zircon	0.09	



Model was set up to inject CO_2-rich fluid at a rate of 0.1ml/min



Porosity distribution based on XRCT image

Modeling Results

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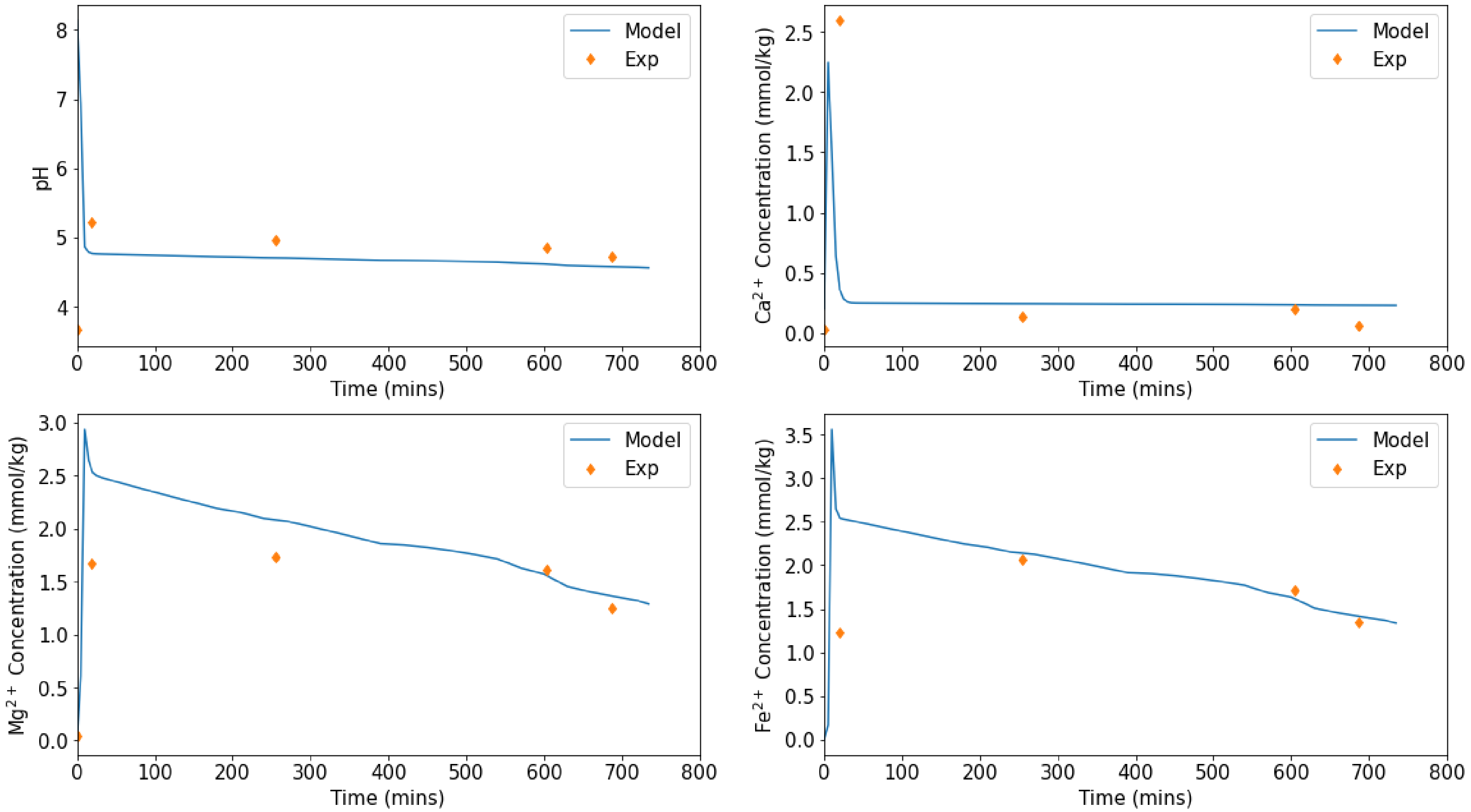
- Effluent concentration was well replicated, showing production of cations that were not initially present in the 1M NaCl solution



Modeling Results

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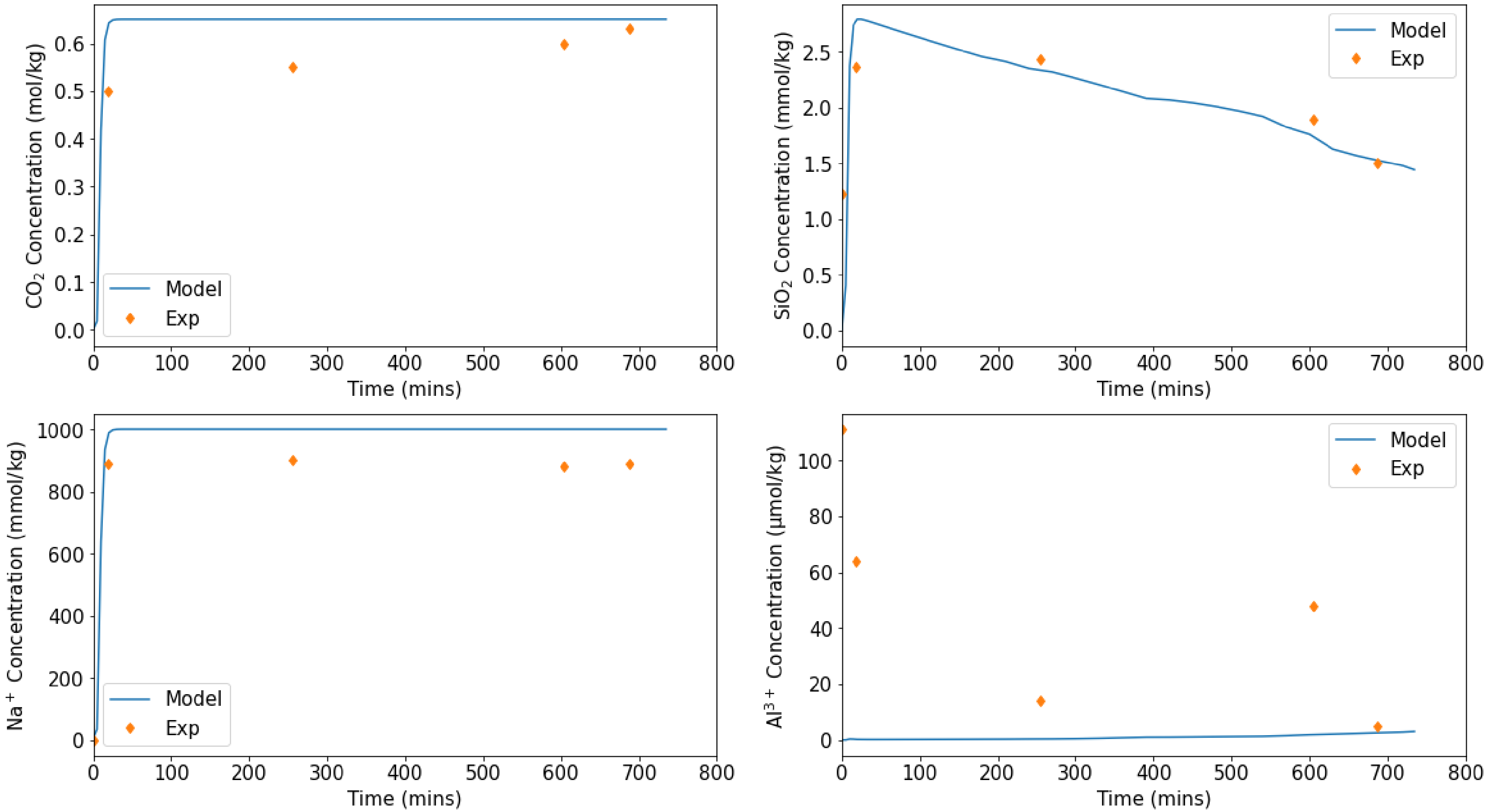
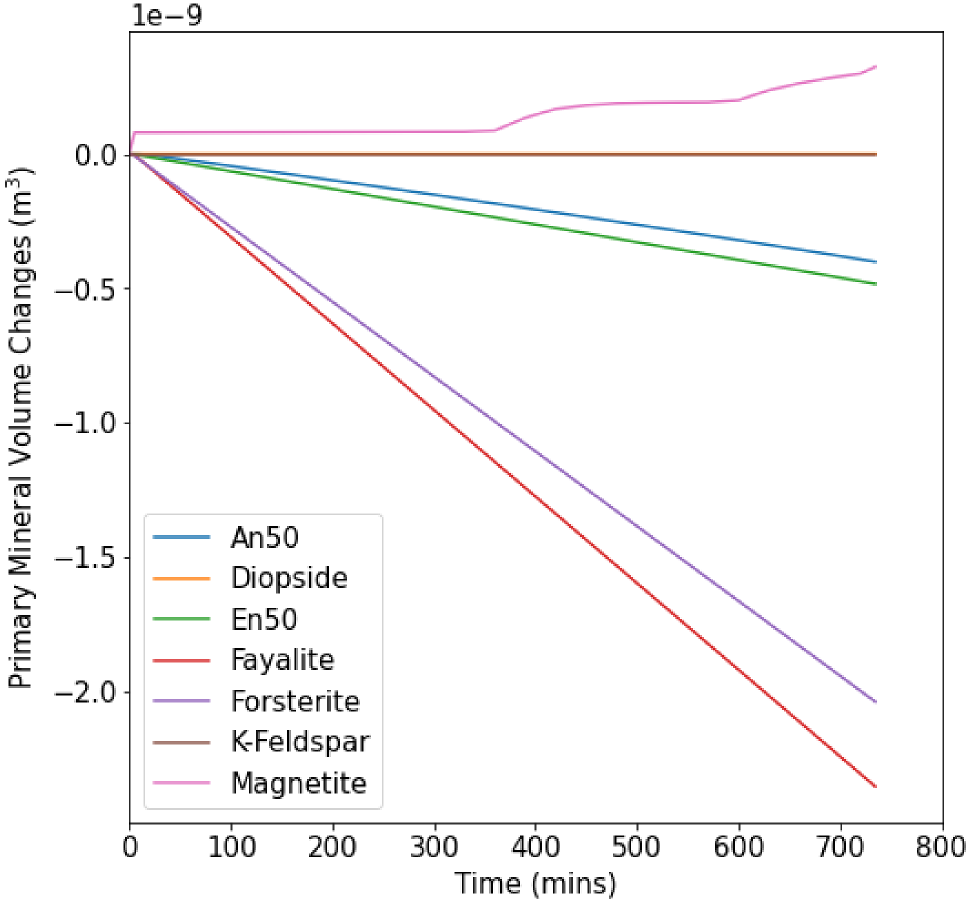
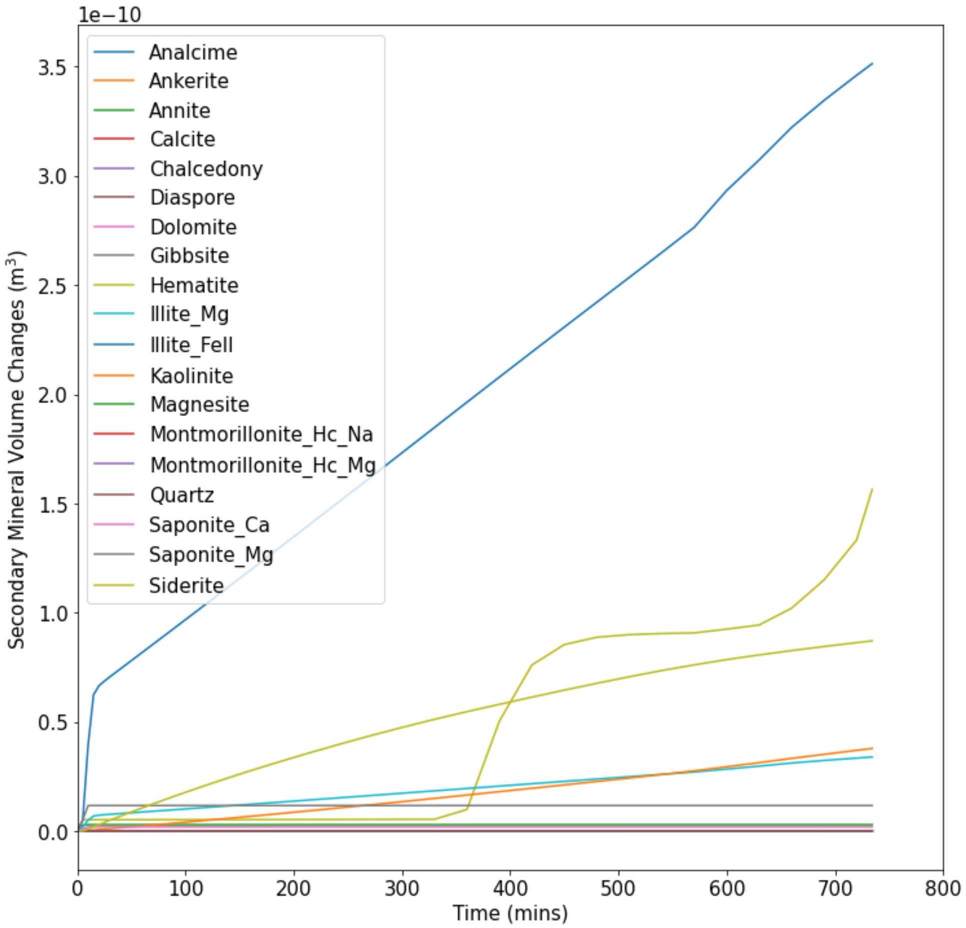
- Similar trend observed for cations (Mg and Fe) was also noted for Si due to high initial dissolution of olivine minerals

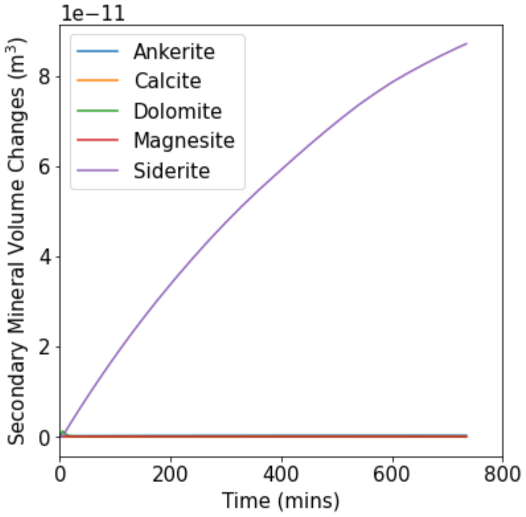


Modeling Results

- Primary basalt minerals dissolved, mostly clay and smectites precipitated, and a small amount of siderite (only carbonate) considerably precipitated

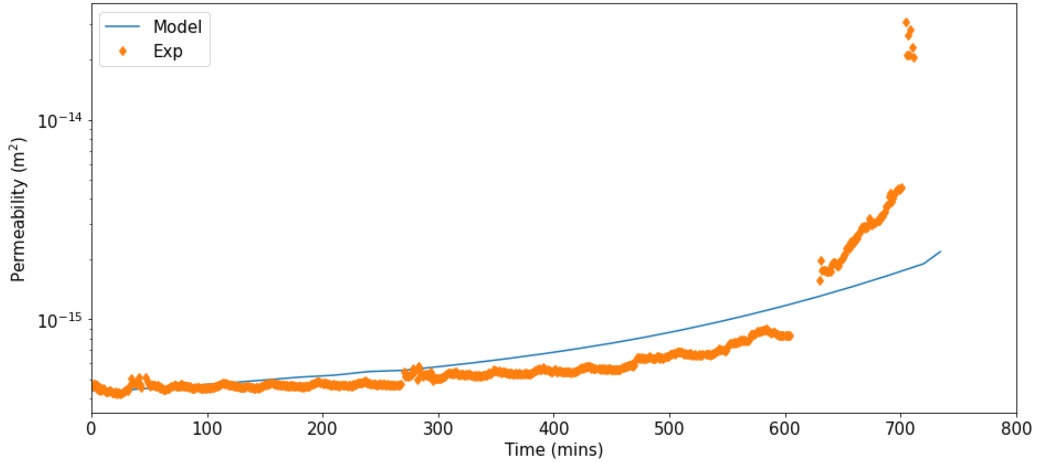


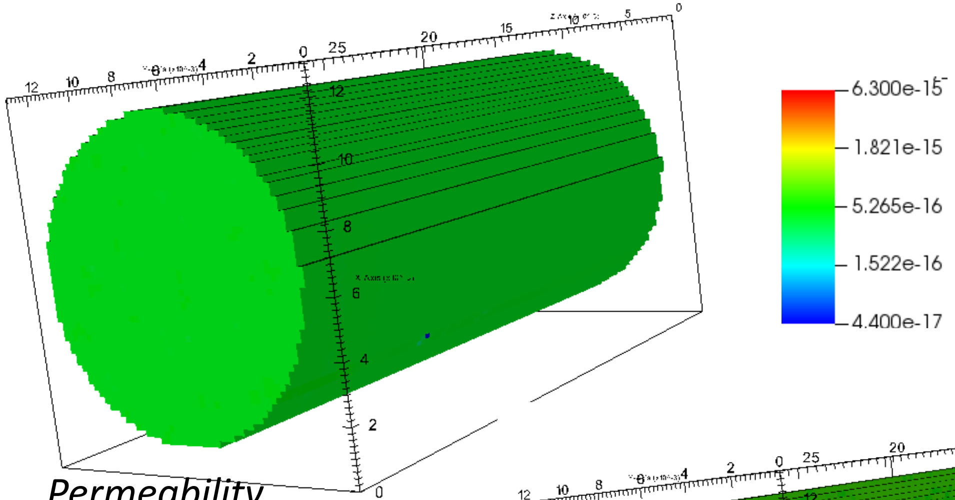




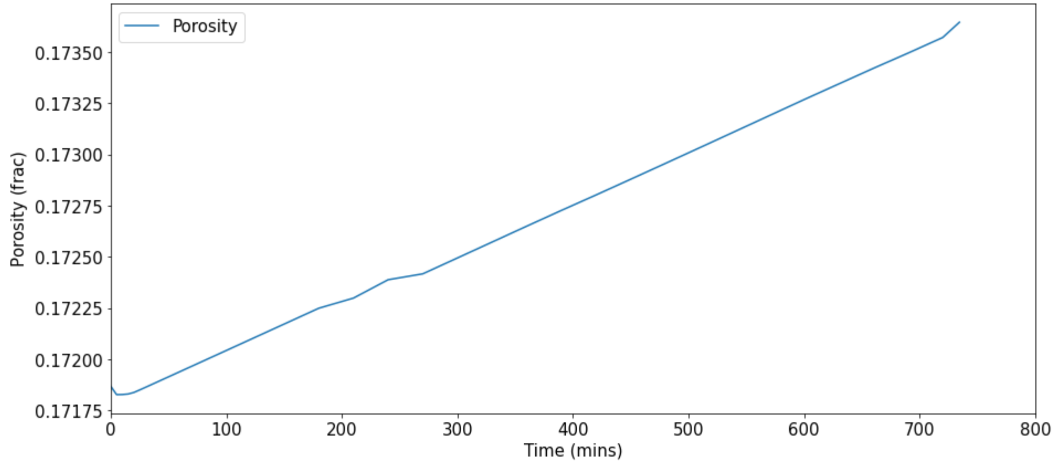
Modeling Results

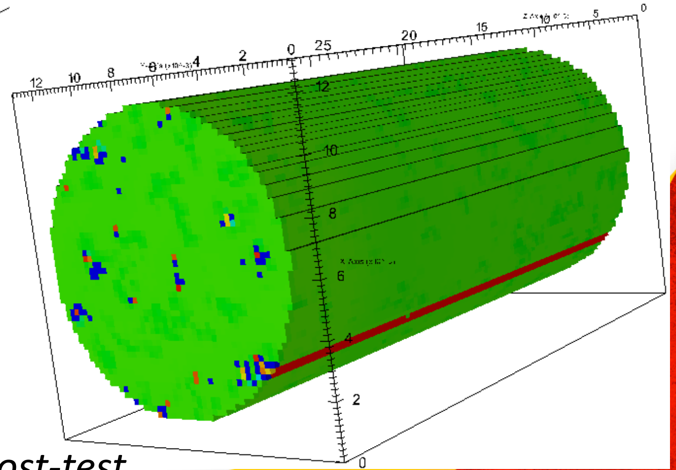
- Permeability and porosity increase due to dissolution of basalt minerals was replicated by the model





Permeability distribution pre-test

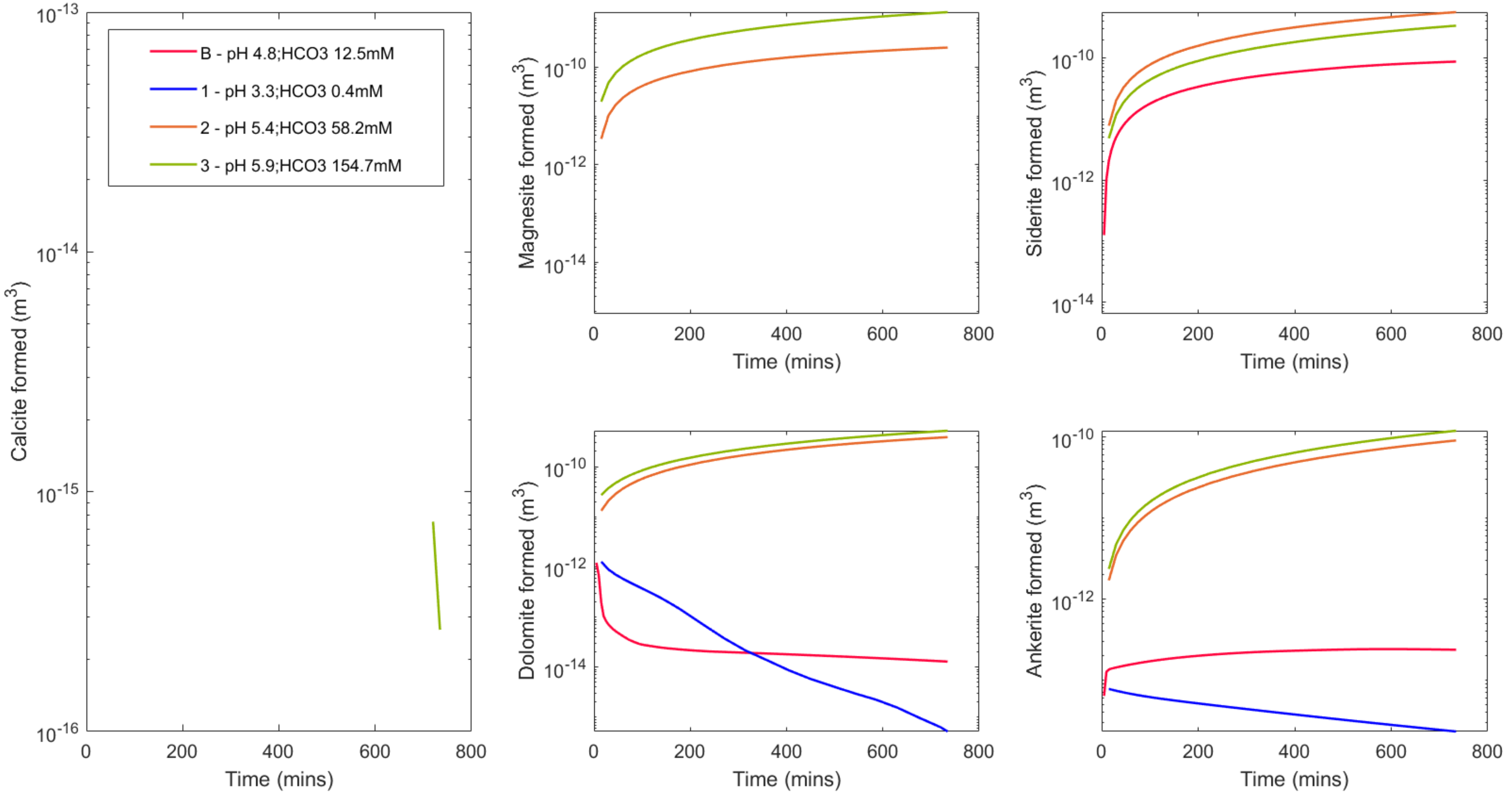




Permeability distribution post-test

Sensitivity Results

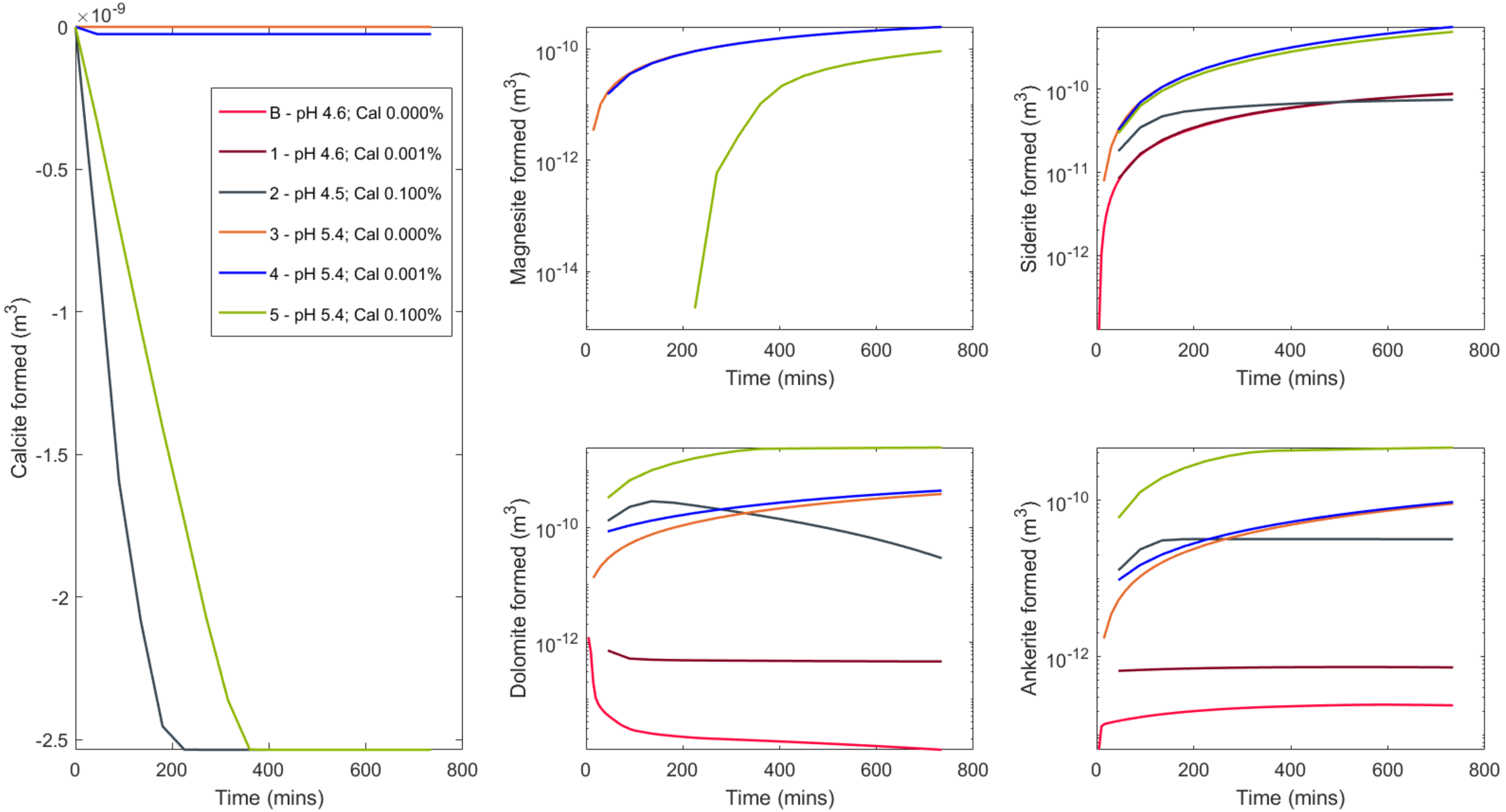
- To evaluate the impact of Alkalinity on basalt carbonation, the bi-carbonate ion was spiked in the co-injected brine solution



There's a considerably increase in the amount of carbonates formed as compared to the base case

Sensitivity Results

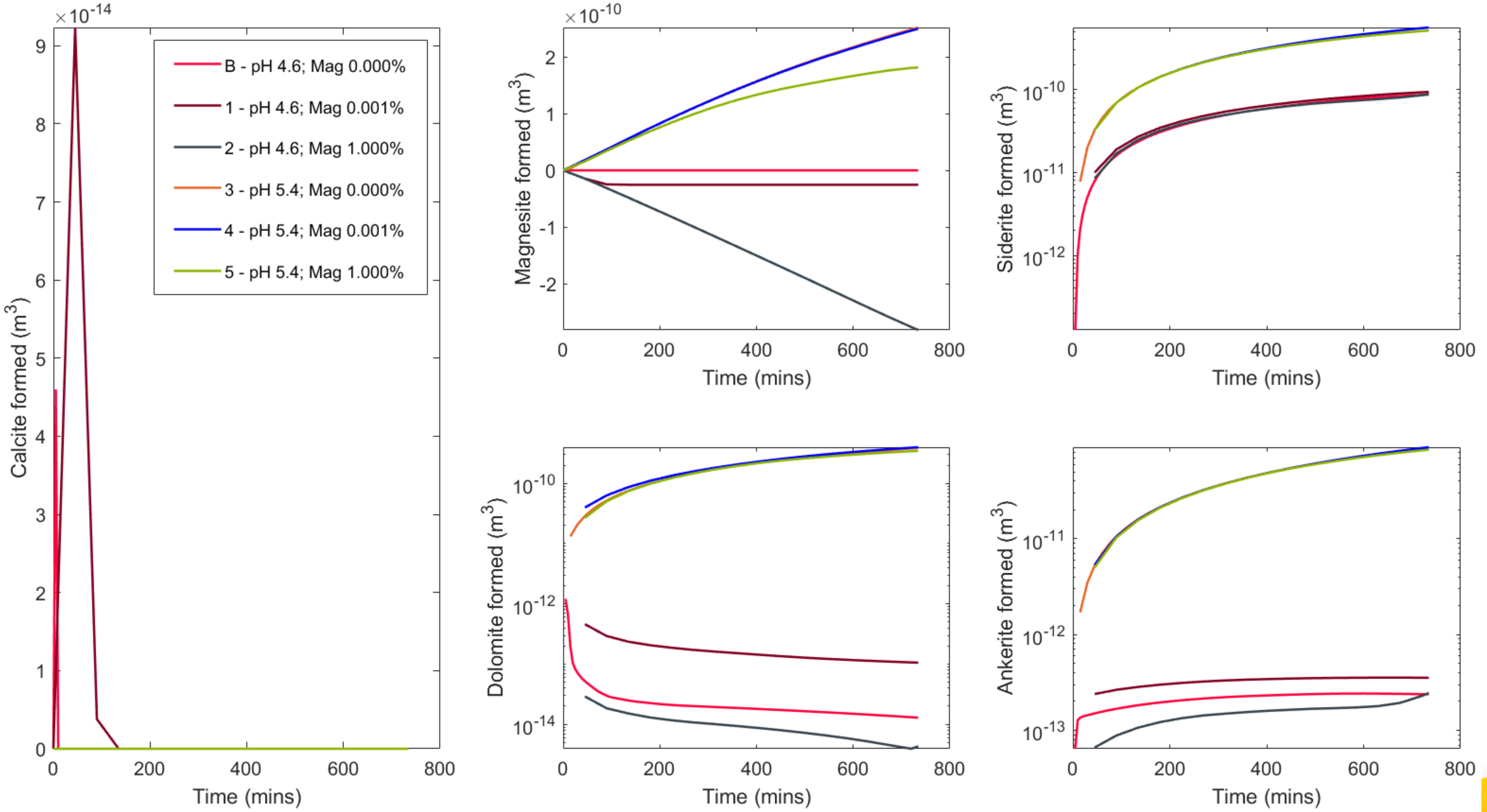
- Initial calcite concentration variation



Calcite dissolved with higher initial concentrations and more carbonates (aside calcite) precipitated, especially with higher alkalinity

Sensitivity Results

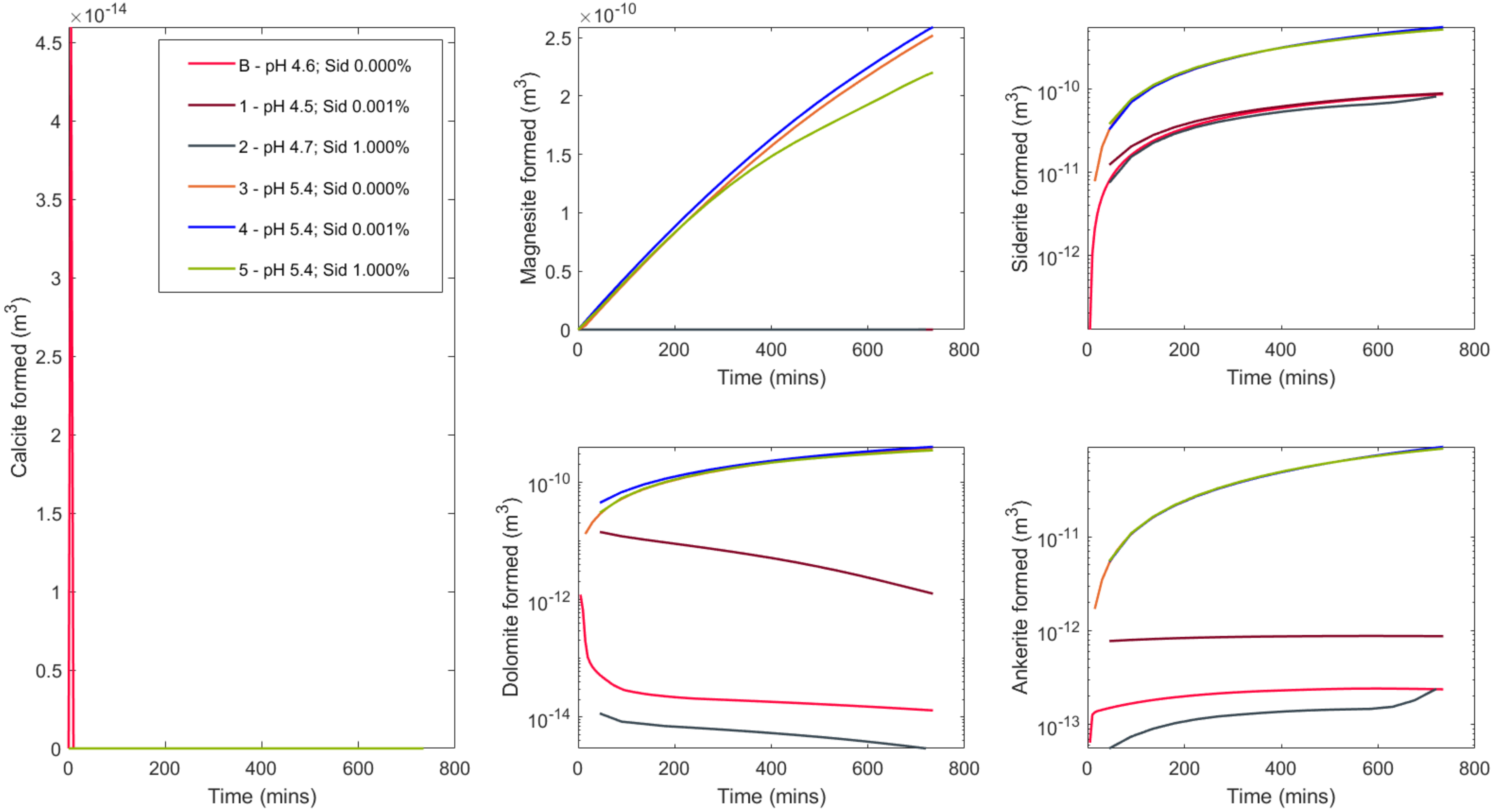
- Initial magnesite concentration variation



Magnesite dissolved at lower pH. No considerable changes in carbonate formation with magnesite variation except at low fluid alkalinity

Sensitivity Results

- Initial siderite concentration variation



No considerable changes in carbonate formation with siderite variation except at low fluid alkalinity

No siderite dissolution was observed due to excess Fe in fluid solution

Concluding Remarks

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- Increasing the injected fluid alkalinity yielded higher rates of carbon mineralization

- With an initial volume fraction of Calcite, basalt carbonation is enhanced. This means at high enough alkalinity; calcite formation will further enhance basalt carbonation.

Thank you for listening!

https://www.ucalgary.ca/reactive-transport/group-members

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