A coupled phase-field and reactive-transport framework for fracture propagation in poroelastic media

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Introduction

We present a novel approach to model hydro-chemo-mechanical responses in rock formations subject to fracture propagation within chemically active rock formations.

- The framework developed integrates the mechanisms of reactive transport, fluid flow and transport in porous media, and phase-field modelling of fracture propagation in poroelastic media.
- The solution approach integrates the geochemical package PHREEQC with a finite-element open-source platform, FEniCs.
- The PHREEQC solver is used to calculate the localized chemical reaction, including solid dissolution/precipitation. The resulting solid weakening by chemical damage is estimated from the reaction-induced porosity change.

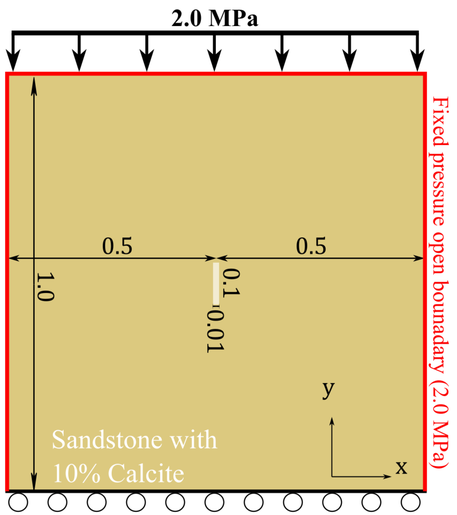

Figure 1 Schematic of the simulation domain

Methods

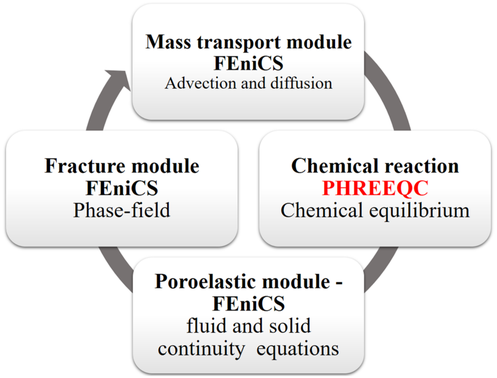

Figure 2 Flowchart of the framework

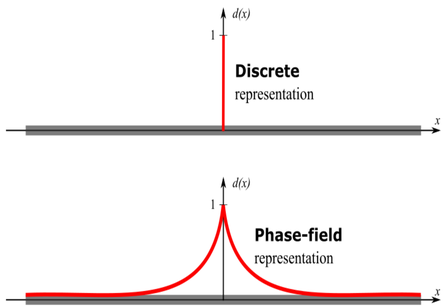

Figure 3 Sketch of a discrete fracture (top) and the phase-field representation (bottom). The phase-field representation captures the fracture by a continuous field.

Results

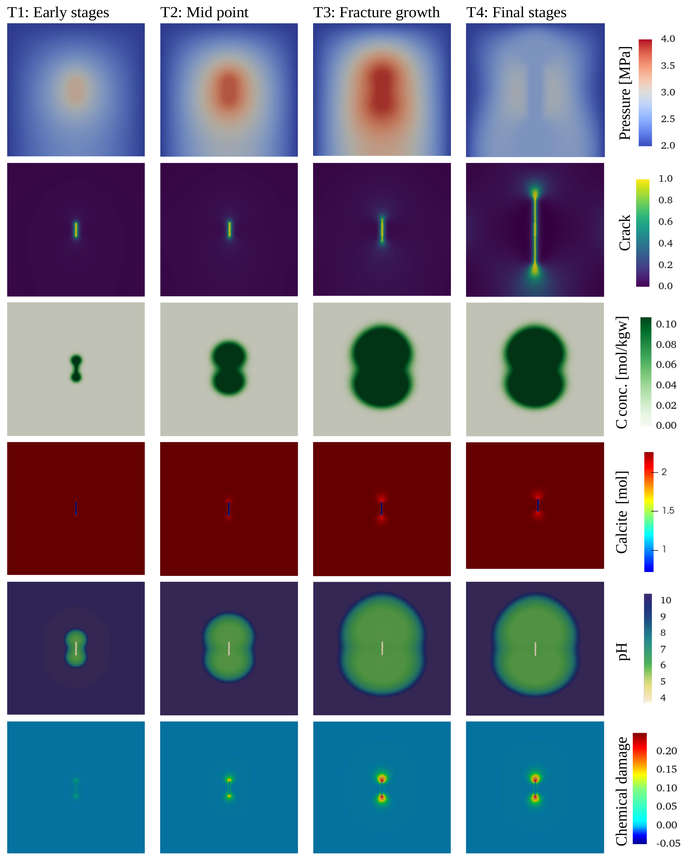

Figure 4 Contour plots showing different variables corresponding to fracture propagation at different times (T1-T4), where continuous injection of CO2 leads to pressure buildup and calcite dissolution.

Discussion

- We propose a novel hydro-chemo-mechanical phase-field framework to model complex systems involving mechanical and chemical processes in naturally fractured rocks.. .
- Chemo-mechanical interactions may cause marked changes in the rock-fracture system resulting from a previously non-resident fluid phase injected at higher pressures into a reactive formation (e.g., during CO2 sequestration).
- The injection of acidic CO2-charged water into a pre-existing horizontal fracture situated in a carbonate-rich sandstone rock exhibited dissolution/precipitation processes that degraded and mechanically weakened the rock. This process governed fracture growth.

References

Clavijo, S. P., Addassi, M., Finkbeiner, T., & Hoteit, H. A coupled phase-field and reactive-transport framework for fracture propagation in poroelastic media. Scientific Reports, 12(1), 1-15 (2022).

Schuler, L., Ilgen, A. G. & Newell, P. Chemo-mechanical phase-field modeling of dissolution-assisted fracture. Comput. Methods Appl. Mech. Eng. 362, 112838 (2020)

Haagenson, R., Rajaram, H. & Allen, J. A generalized poroelastic model using FEniCS with insights into the Noordbergum effect. Comput. Geosci. 135, 104399 (2020).

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