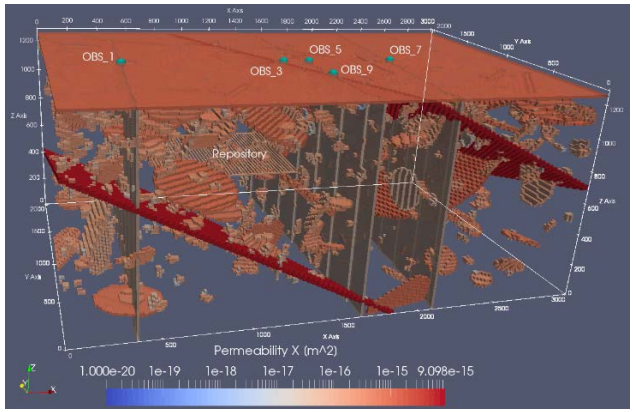


Buffer Extrusion, Erosion, and Clogging

Yifeng Wang, Paul Mariner (Sandia National Laboratories), Chun Chang (Lawrence Berkeley National Laboratory), Nathan Conroy (Los Alamos National Laboratory)

U.S. Nuclear Waste Technical Review Board
Spring 2024 Public Meeting, May 21, 2024, Knoxville, Tennessee

SAND2024-06133O

Outline

- Relevant processes and their impacts
- Bentonite swelling and extrusion
- Bentonite erosion and fracture clogging
- Implementation of buffer erosion model
- Concluding remark

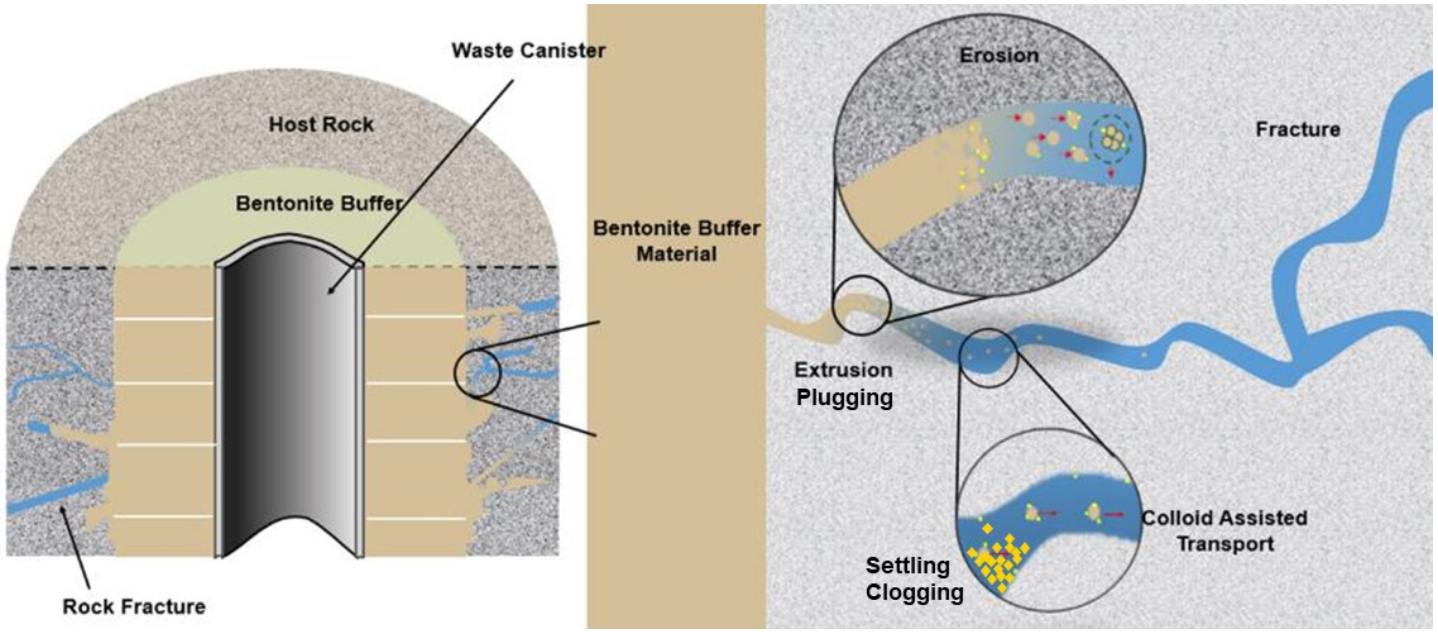
Relevant processes and their impacts

Processes

- Buffer extrusion and fracture plugging
- Buffer erosion (becoming more significant for glaciation/deglaciation)
- Particle settling and clogging
- Colloid generation
- Colloid facilitated transport

Impacts on system performance

- Barrier capability of buffer material
  - Swelling pressure
  - Channeling
- Fracture sealing → Excavation disturbed zone (EDZ) permeability
  - Fluid flow
  - Colloid filtration
- Radionuclide release



Modified from Sedighi et al. (2023)

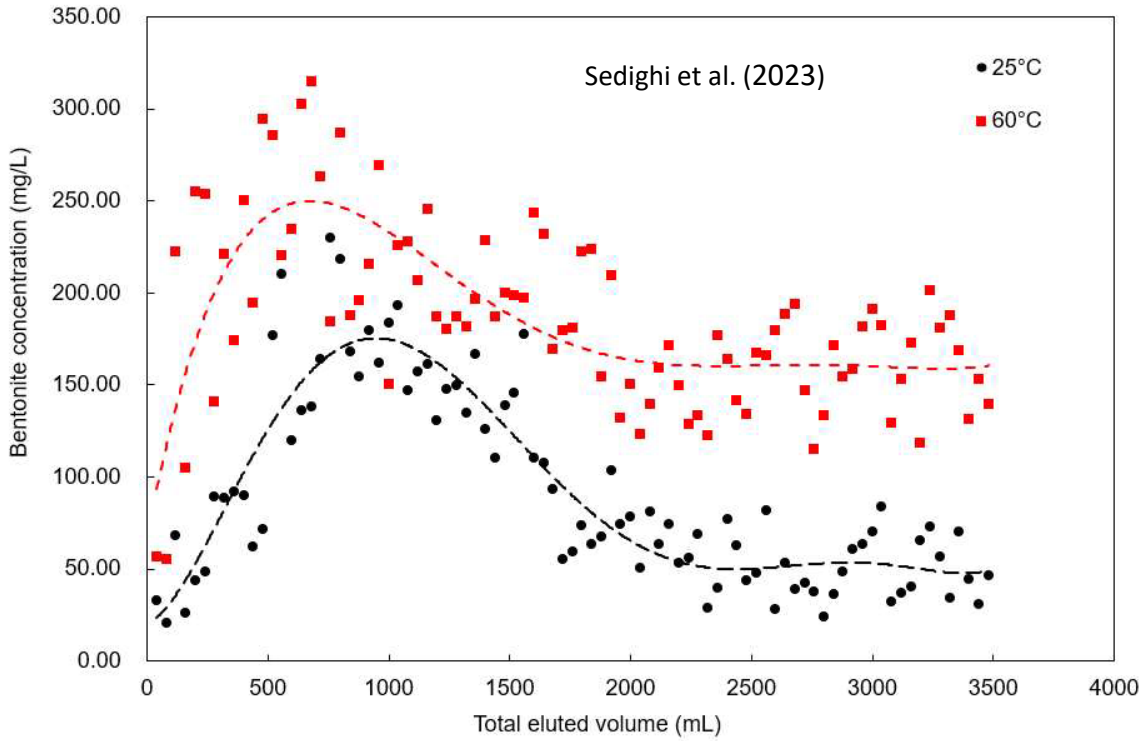
Buffer Extrusion, Erosion, and Clogging

Objective

- Develop Features, Events & Processes (FEP) argument for buffer extrusion, erosion and clogging.

Focus areas

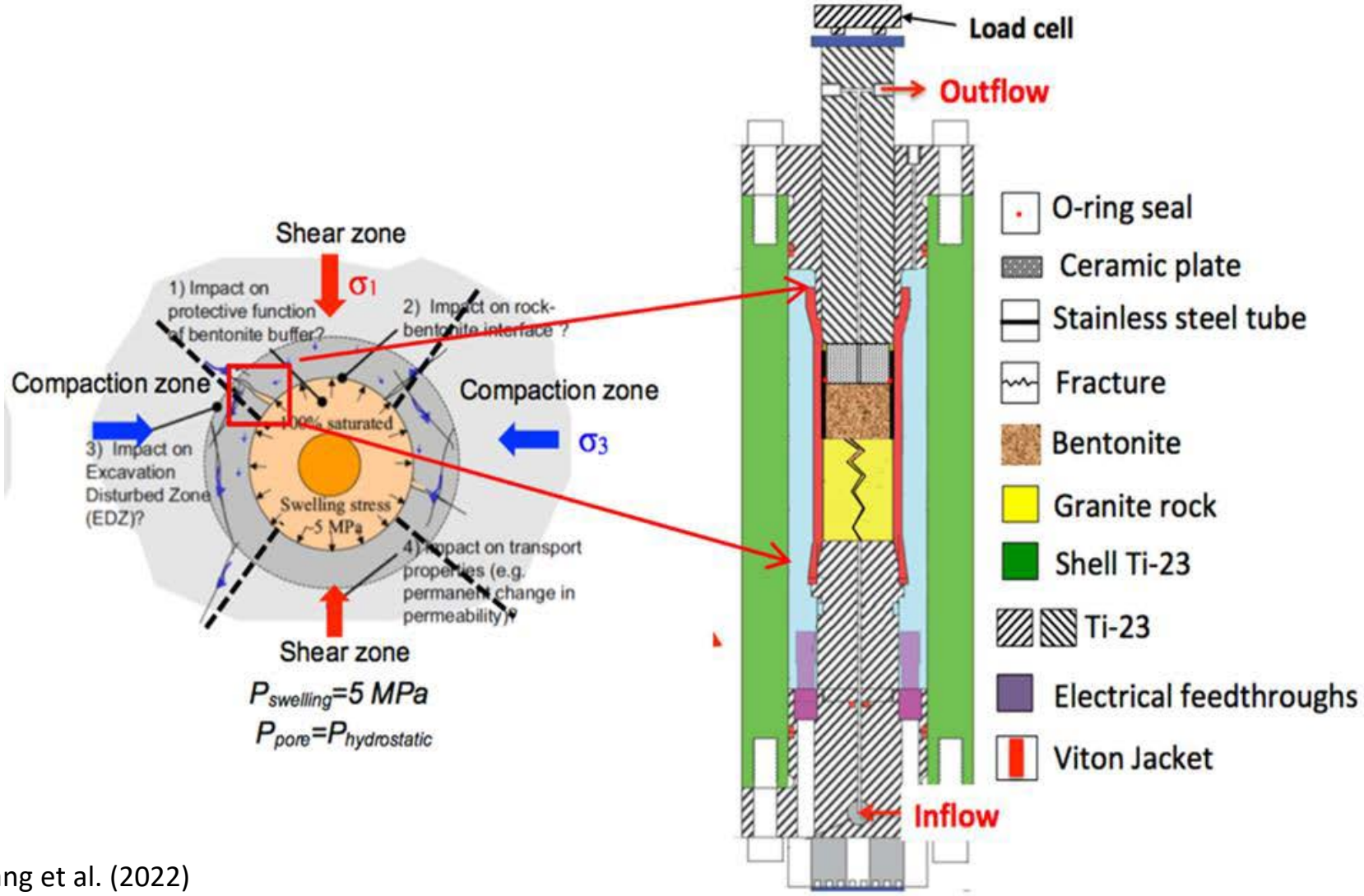
- Buffer extrusion and fracture plugging
- Particle settling and clogging
- Colloid generation
- Buffer erosion
  - Significant work done internationally
  - Process model available
- Colloid facilitated transport
  - Process model available for GDSA implementation



Related international R&D

- Colloid Formation and Migration (CFM) project at the Grimsel Test Site (Switzerland)
- SKB BELBaR project
- POSIVA
- UK

Triaxial loading system for studying EDZ-buffer material interactions



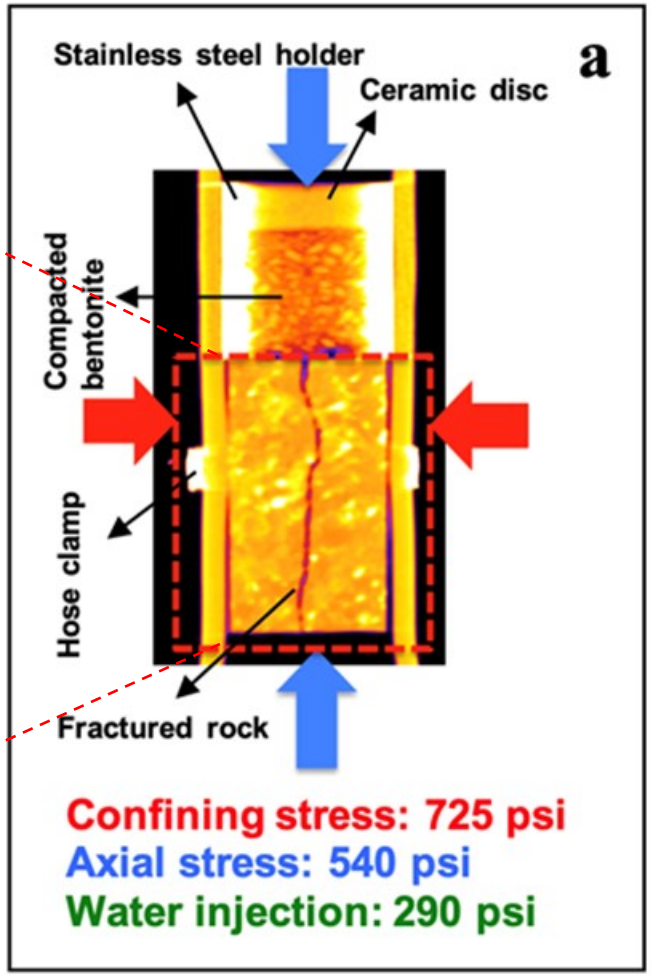
Capabilities

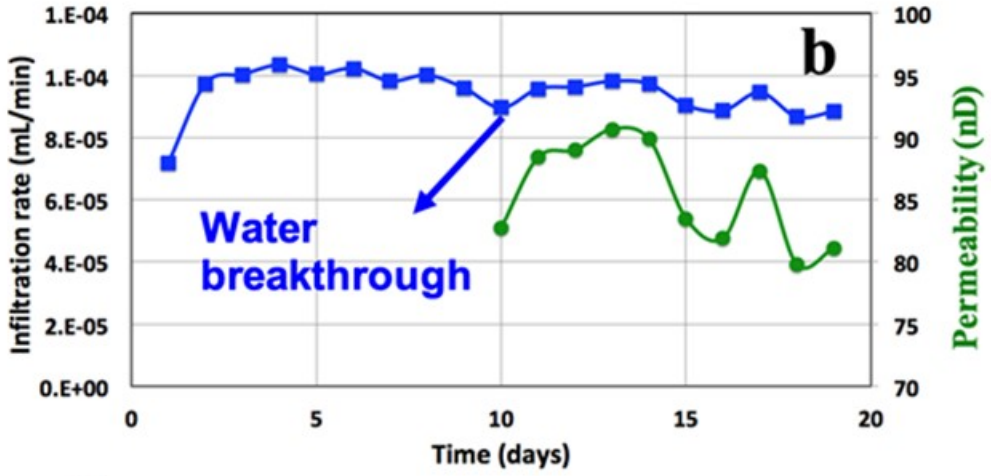
- Simulate EDZ evolution.
- Understand thermal-hydrological-mechanical-chemical (THMC) coupling of a single fracture.
- Study buffer material-EDZ interactions.

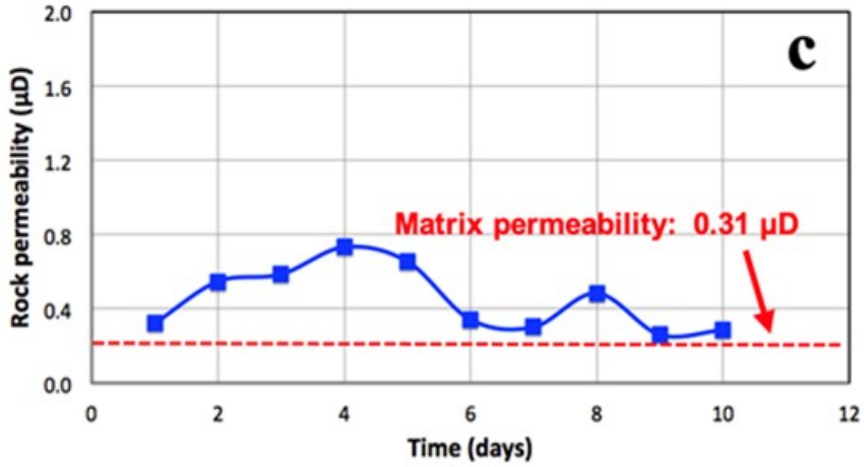
Wang et al. (2022)

Bentonite Swelling, Extrusion, and Fracture Clogging

1.3 µm aperture





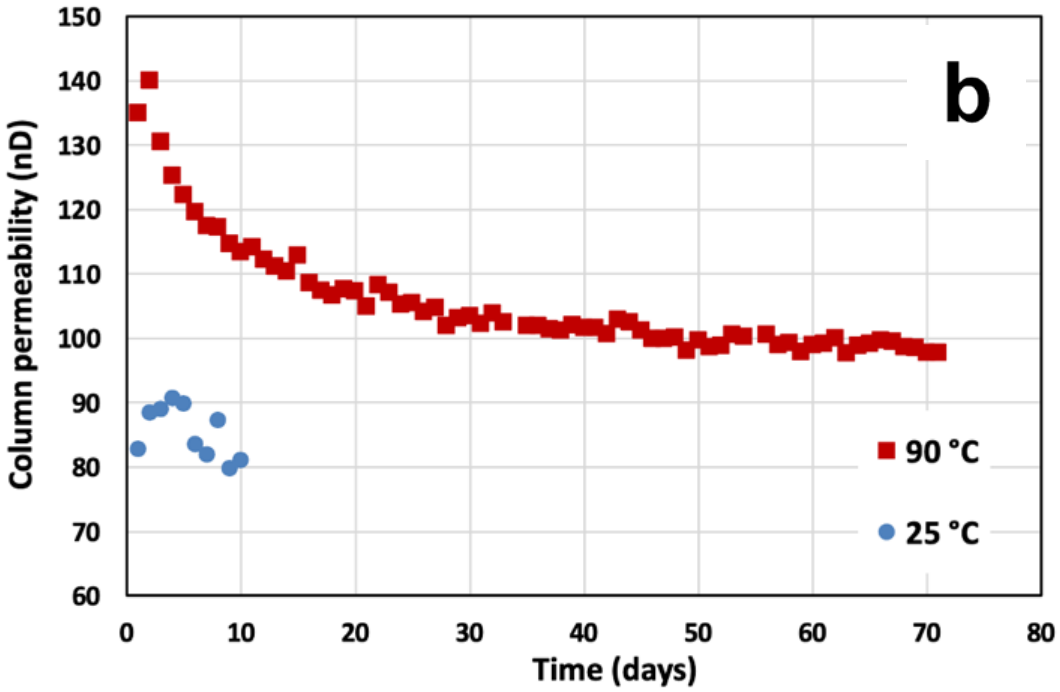


Rock ppermeability w/o bentonite extrusion = 1.56×10^5 µD

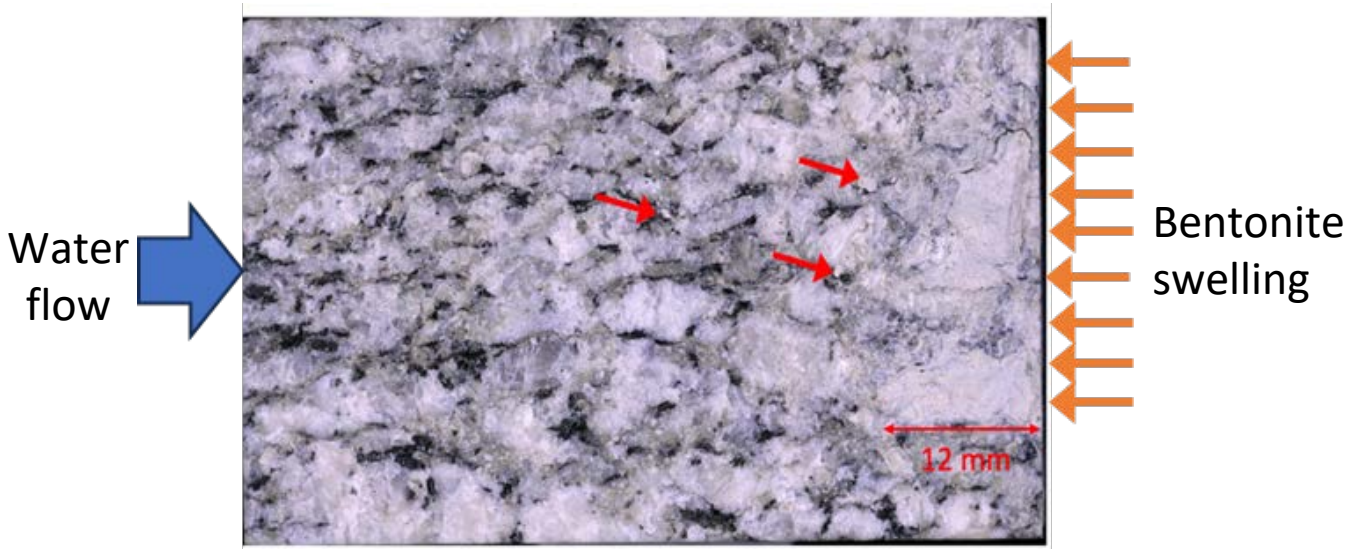
Wang et al. (2023)

~ 5 order reduction in fracture permeability by bentonite extrusion and clogging

Bentonite Swelling, Extrusion, and Clogging (cont.)



Effect of temperature on column permeability

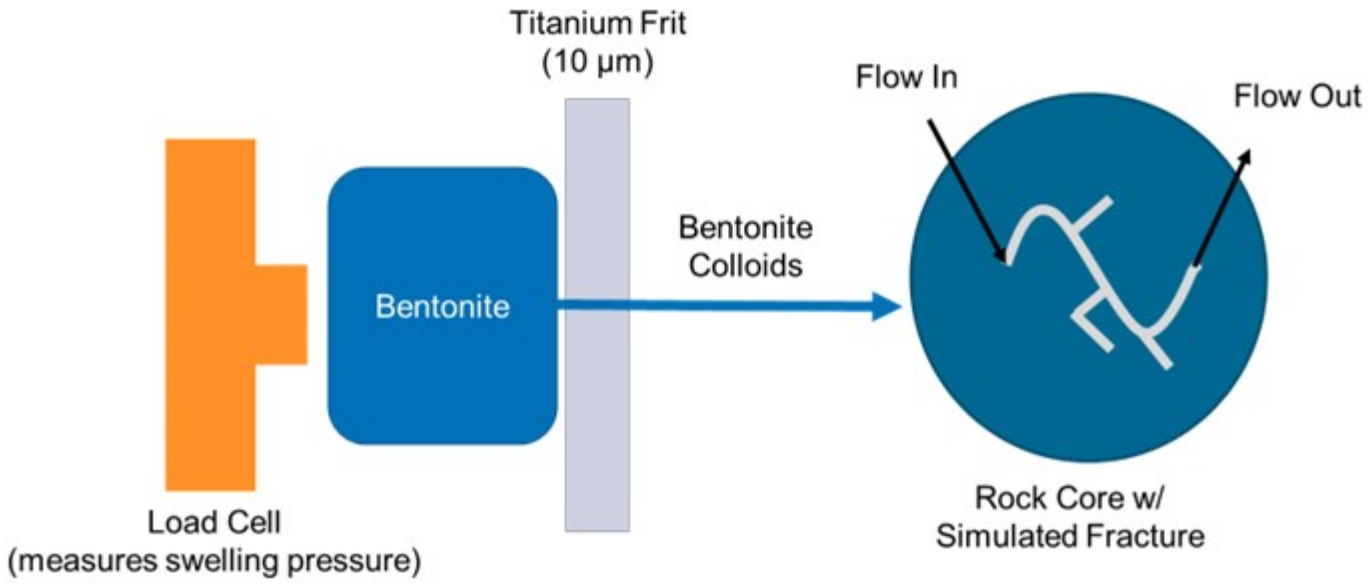


Post-experimental imaging

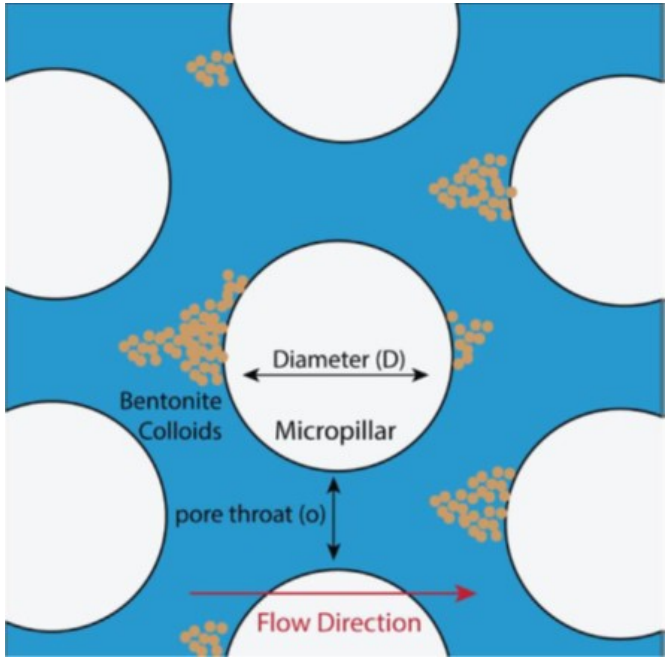
- Bentonite swells against the water pressure and invades fracture up to 1.2 cm.
- Permeability reduction is attributed to the clogging at the fracture entrance and ~1 mm deep into the fracture.

Wang et al. (2023)

Colloid generation and particle settling and clogging: Experimental setup



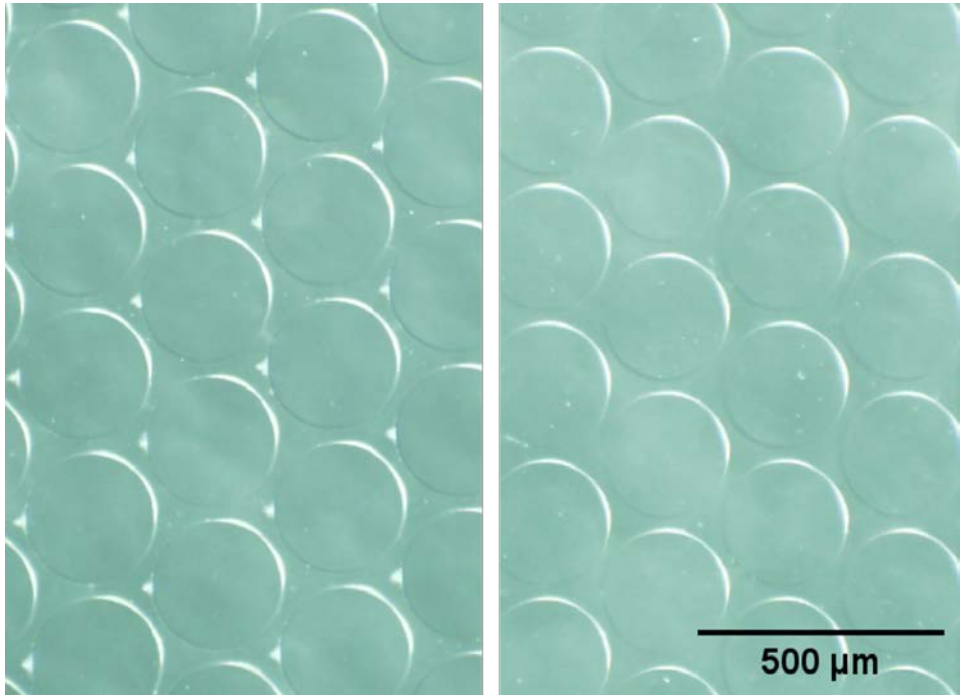
Experimental setup for bentonite erosion and colloid generation



Microfluidic cell for studying fracture clogging

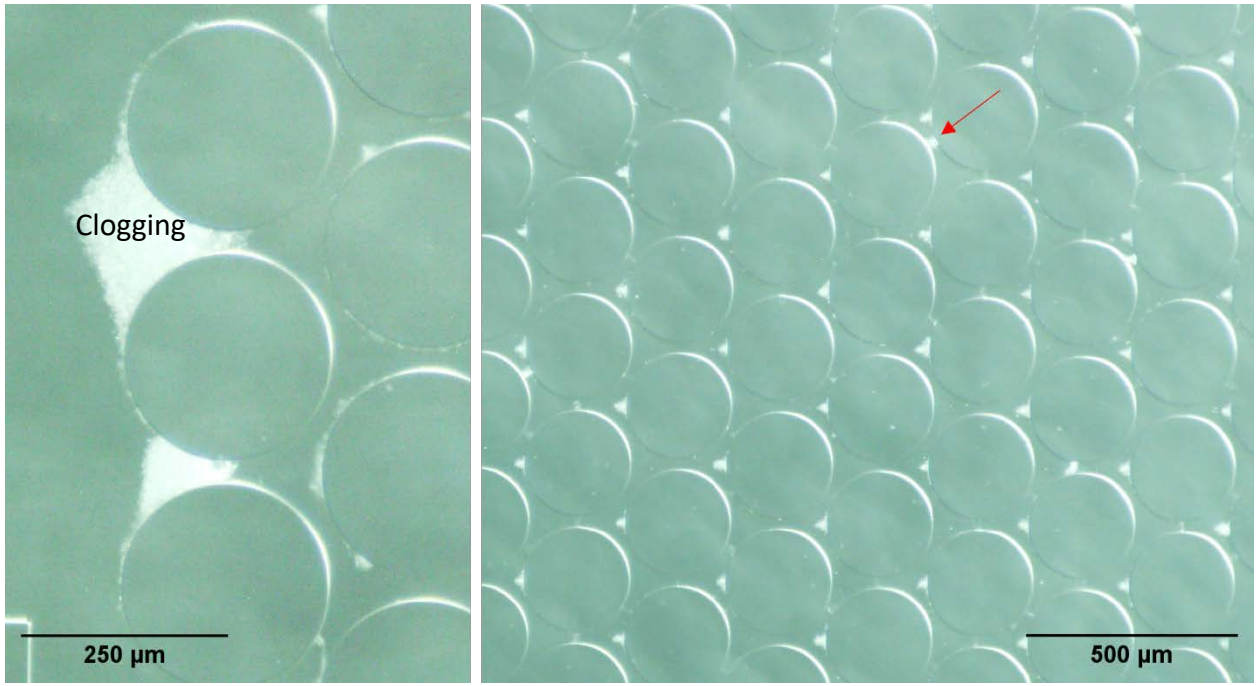
Wang et al. (2022)

Preliminary results on fracture clogging



Left: Solution containing bentonite with NaCl.

Right: Solution with bentonite only.



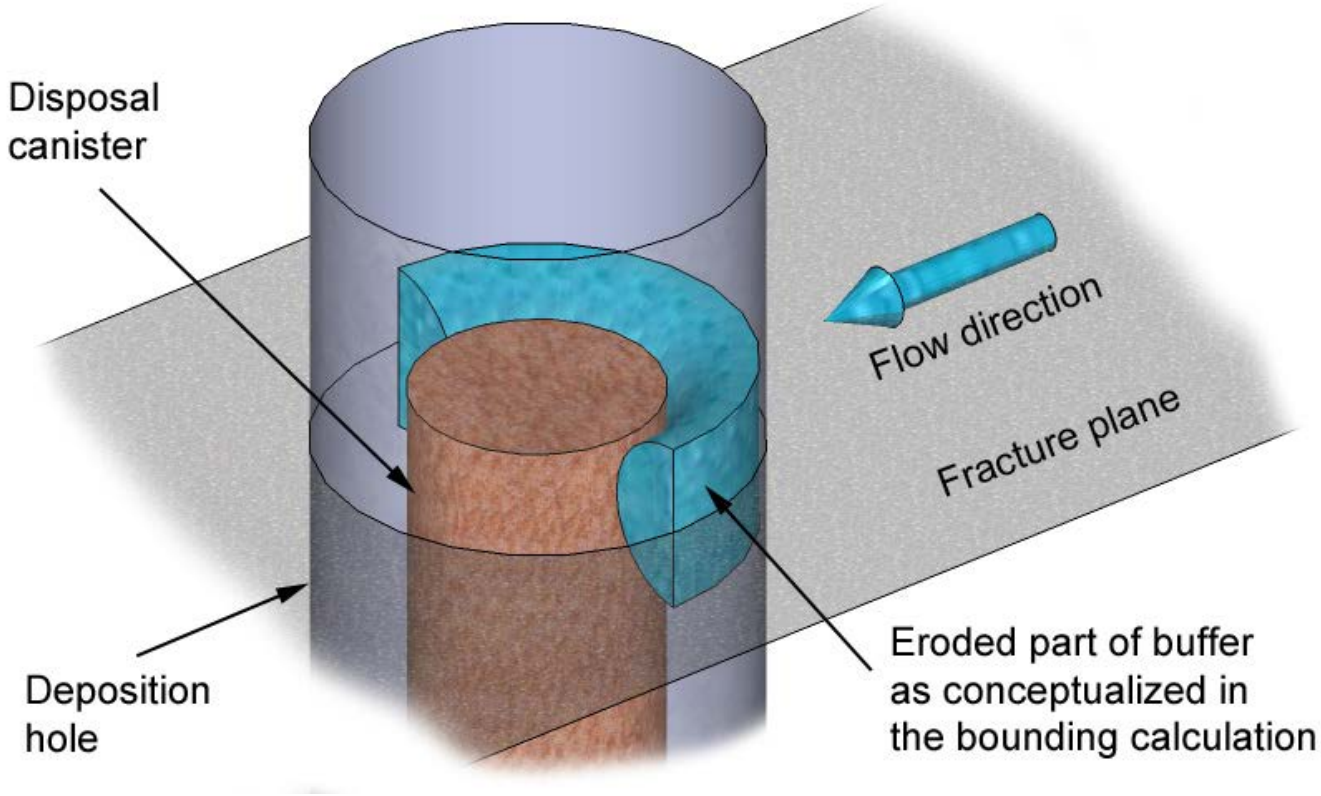
Left: Large bentonite clogs in the inlet of the cell after 30 minutes of flowing a bentonite suspension in 1 M NaCl solution.

Right: Smaller clogs occurring further away from the inlet.

Wang et al. (2023)

Implementation of buffer erosion model in GDSA

- Conceptual model
  - Perenties et al. (2017)
  - Flowing fracture intersects drift or deposition hole (see figure)
  - If ionic strength low (<0.004 M)
    - Buffer erosion
    - Otherwise, no buffer erosion
  - Buffer erosion rate is a function of
    - Fracture aperture and angle
    - Water velocity in fracture
    - Diffusion of colloidal particles
- Capability
  - Being implemented in PFLOTRAN
- Inclusion in reference case
  - Expected in future



Conceptual model of buffer erosion due to a flowing fracture (Posiva 2013)

Concluding remark

- Experimental capabilities have been developed for studying buffer material extrusion, erosion and clogging.
- Bentonite swelling and extrusion can significantly reduce the permeability of a fracture that intercepts the buffer material layer.
- Preliminary buffer erosion model has been implemented in GDSA.
- Future work
  - Systematic testing of bentonite extrusion and fracture clogging and development of a related model.
  - Systematic investigation of colloid generation from buffer erosion.
  - Comprehensive understanding of clay particle settling and clogging in fractures.

References

- Posiva (2013). Safety Case for the Disposal of Spent Nuclear Fuel at Olkiluoto - Models and Data for the Repository System 2012. POSIVA 2013-01. Posiva Oy, Eurajoki, Finland.
- Sedighi, M., He, L., Wang, Z., Yan, H., Hadi Mosleh, M., Jivkov, M. (2023) Temperature effects on the erosion of bentonite, Proceedings of the 9th International Congress on Environmental Geotechnics, 25-28 June, 2023, Chania, Greece.
- Wang, Y. et al. (2022) Modeling and Experimental Investigation of Spent Fuel Disposal in Crystalline Rocks: FY22 Progress Report. M2SF-22SN010302072, SAND2024-02203O.
- Wang, Y. et al. (2023) Modeling and Experimental Investigation of Spent Fuel Disposal in Crystalline Rocks: FY22 Progress Report. M2SF-23SN010302072, SAND2024-02202O.

Acknowledgment

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.