Artificial Fracture Tests at B+Tech and Erosion Issues in the Safety Case

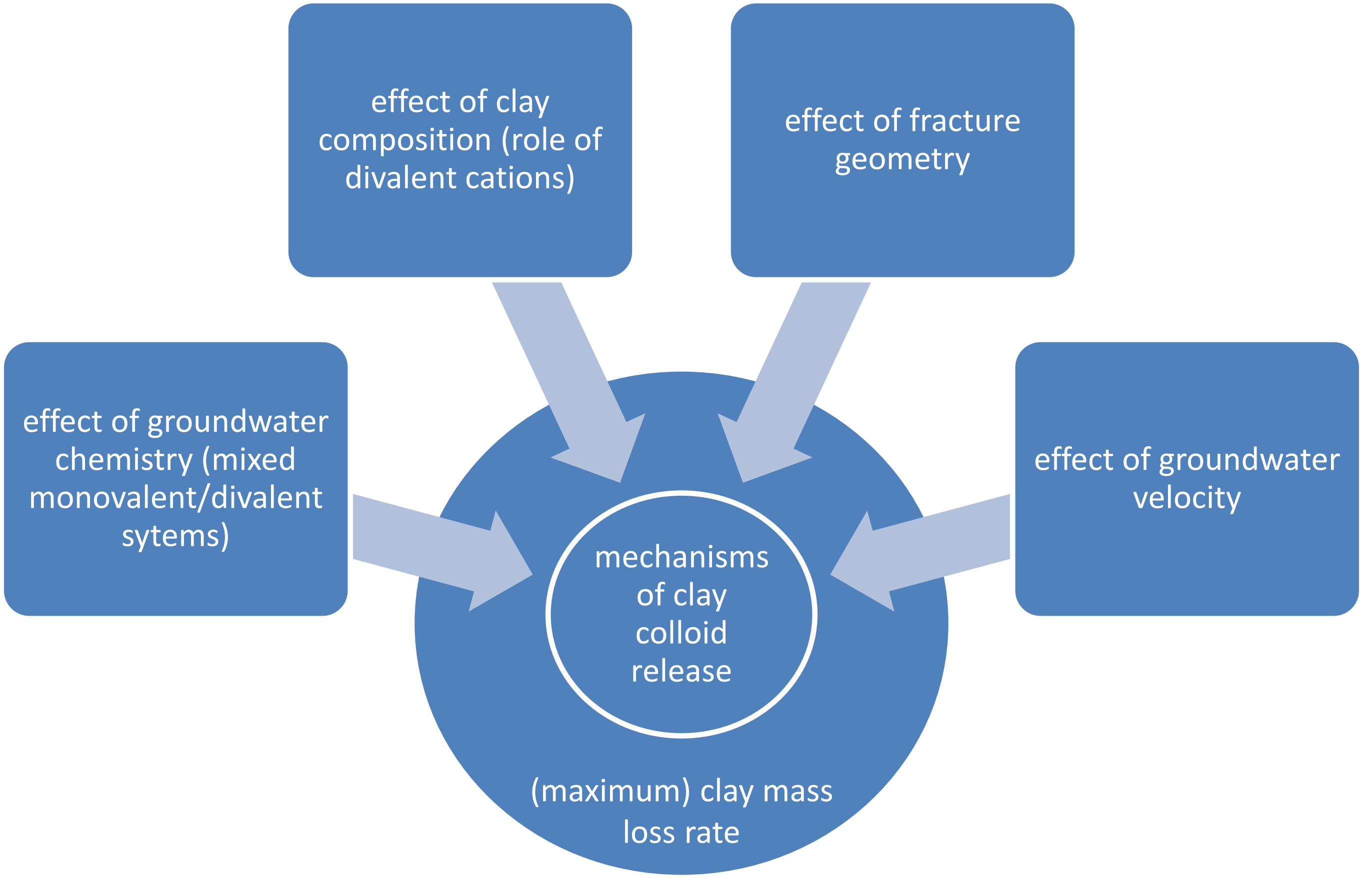
Tim Schatz

B+Tech Oy

WP2 Outcomes (1)

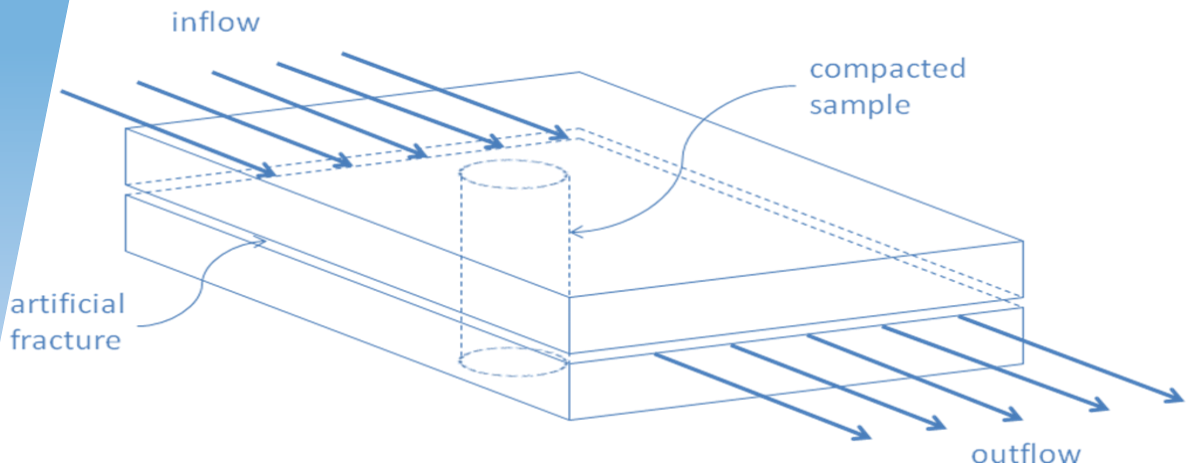
1. Mechanisms of clay colloid release.
2. The role of divalent cations (clay composition).
3. The effect of mixed monovalent/divalent systems (groundwater chemistry).
4. Verification of the dependence between the groundwater velocity and erosion rate.
5. The effect of fracture geometry on clay mass loss.
6. Maximum clay mass loss rate.

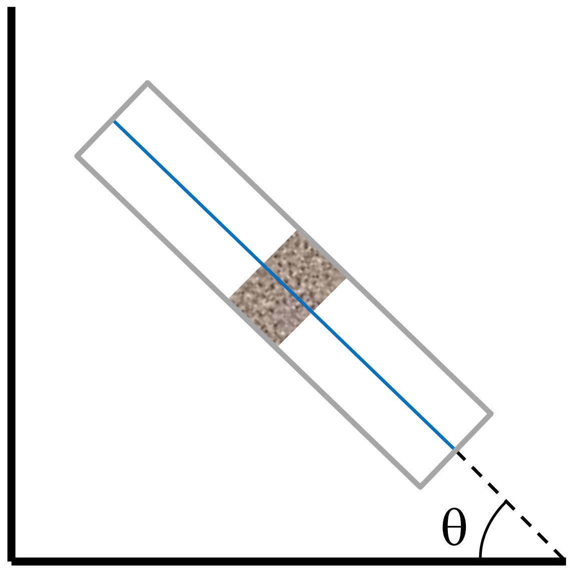
WP2 Outcomes (2)



- **On the basis of artificial fracture tests we can assess the effects of various parameters on results, which can support the determination of mass loss mechanisms and verify expectations.**

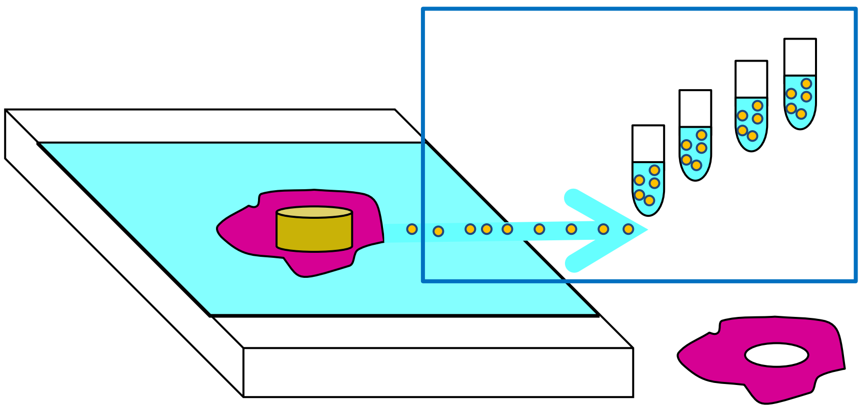
Artificial Fracture Tests





- **Directly probe buffer erosion in a ”fracture environment” under flow-through conditions relative to:**
  - **groundwater chemistry**
  - **buffer composition**
  - **groundwater velocity**
  - **fracture geometry**

Artificial Fracture Test Analysis

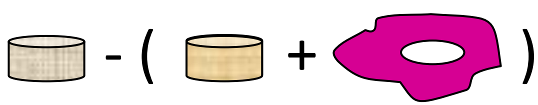


 **emplaced mass**

eluted mass

extruded mass (post mortem)

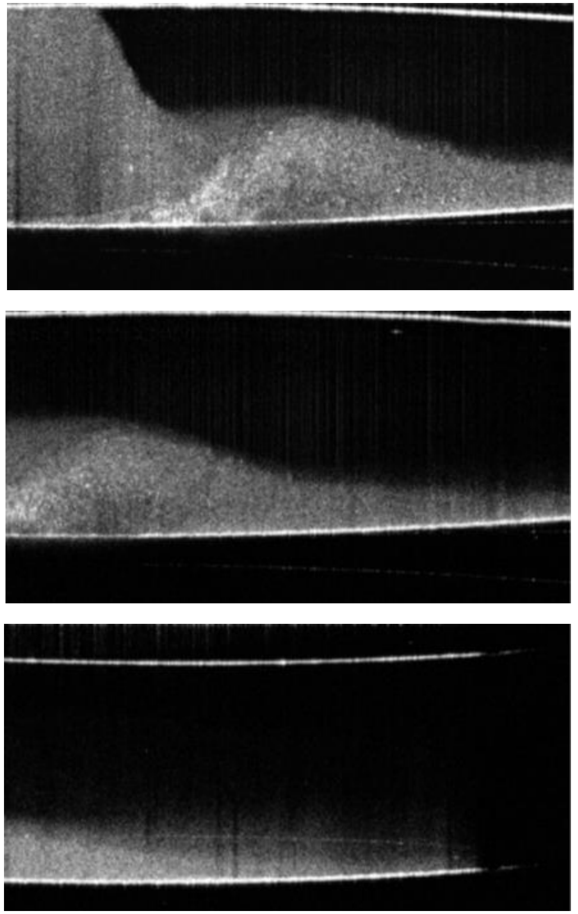
 **remaining mass (post mortem)**

) = **eroded mass** ≠ **eluted mass**

eroded mass / duration of test = average mass loss rate

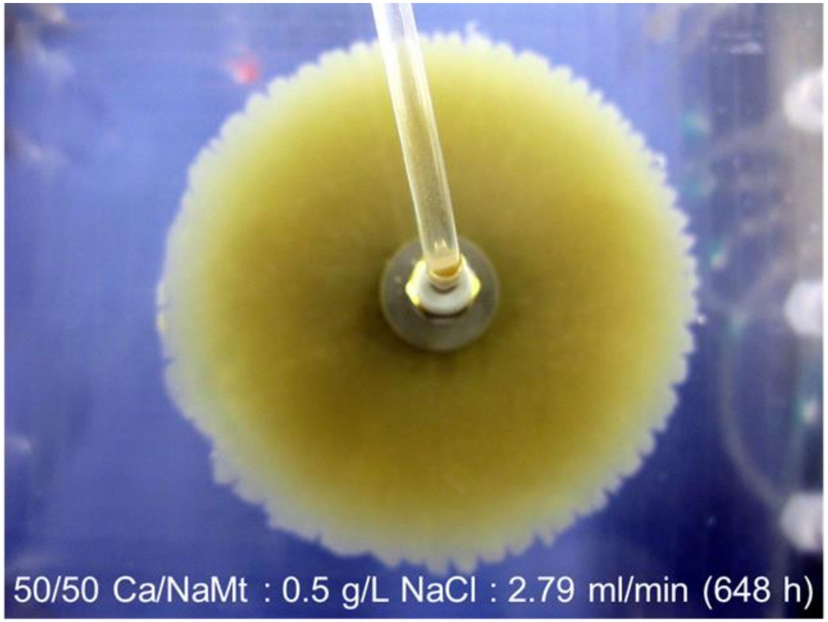
Aggregation and Sedimentation

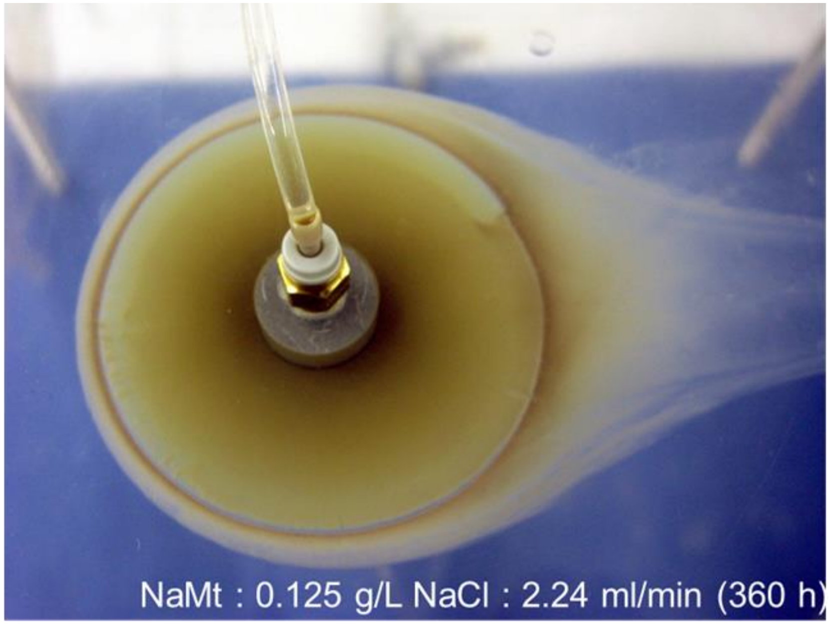
- of eroding clay



- Aggregation and sedimentation of the eroding material occurs downstream of the source; some fraction of the initially eroded mass becomes sedimented and will not be readily transported out of the near-field.

Clay Buffer Erosion

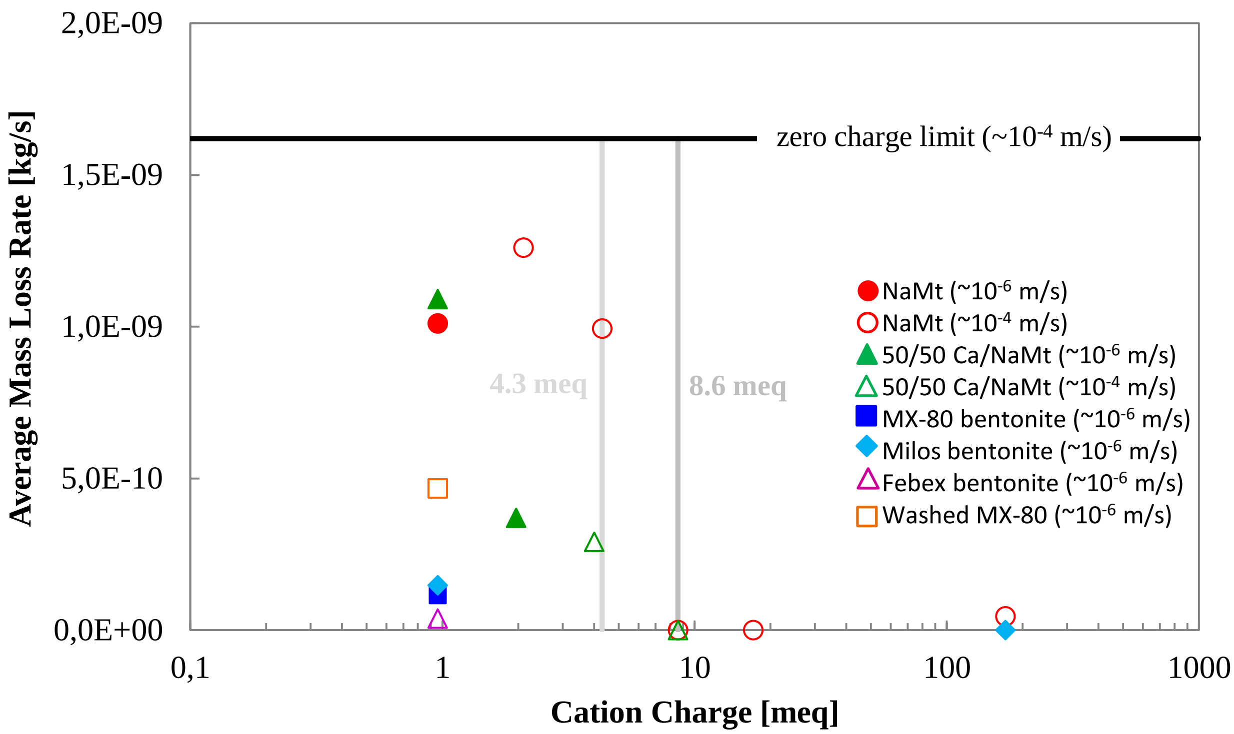




- **In order for mass loss to occur at the interface of the extruding solid network, a system where interparticle interactions are rather weak or repulsive must exist.**
- **Interaction potentials in these extruding clay systems are to be explicitly defined, but clearly there is a strong effect of electrolyte concentration.**

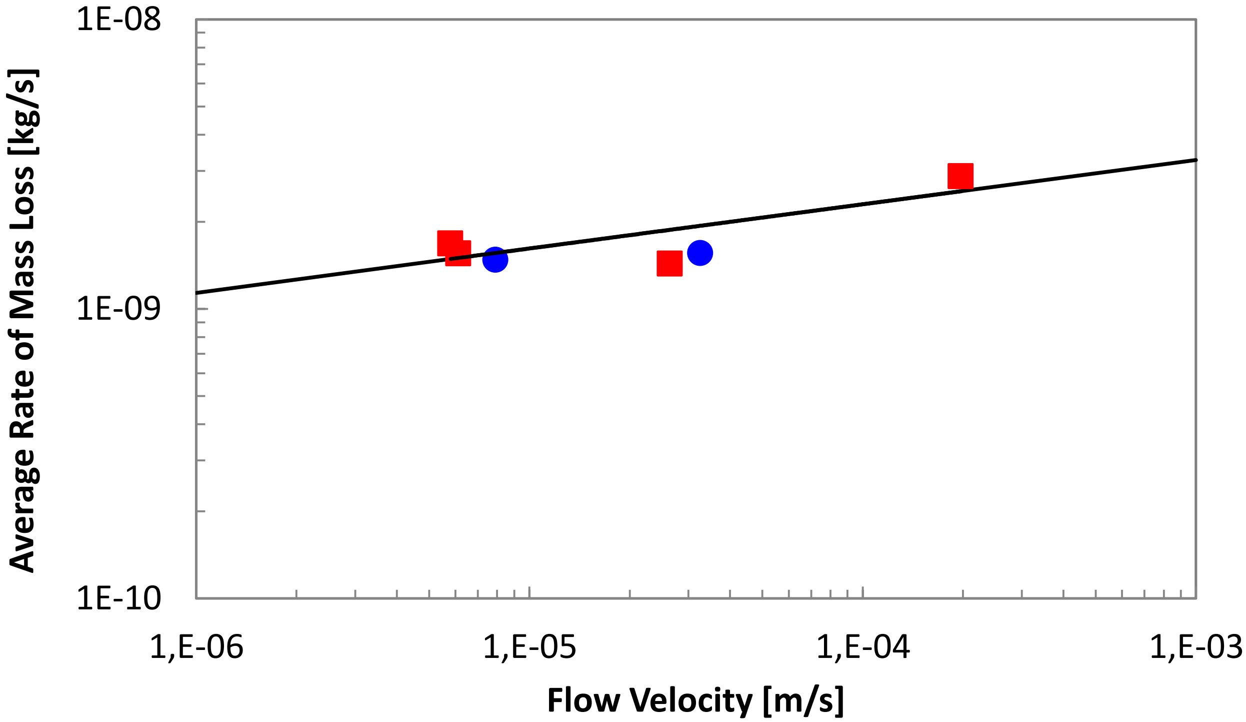
Effect of Groundwater Chemistry (1)

- Erosion Stability



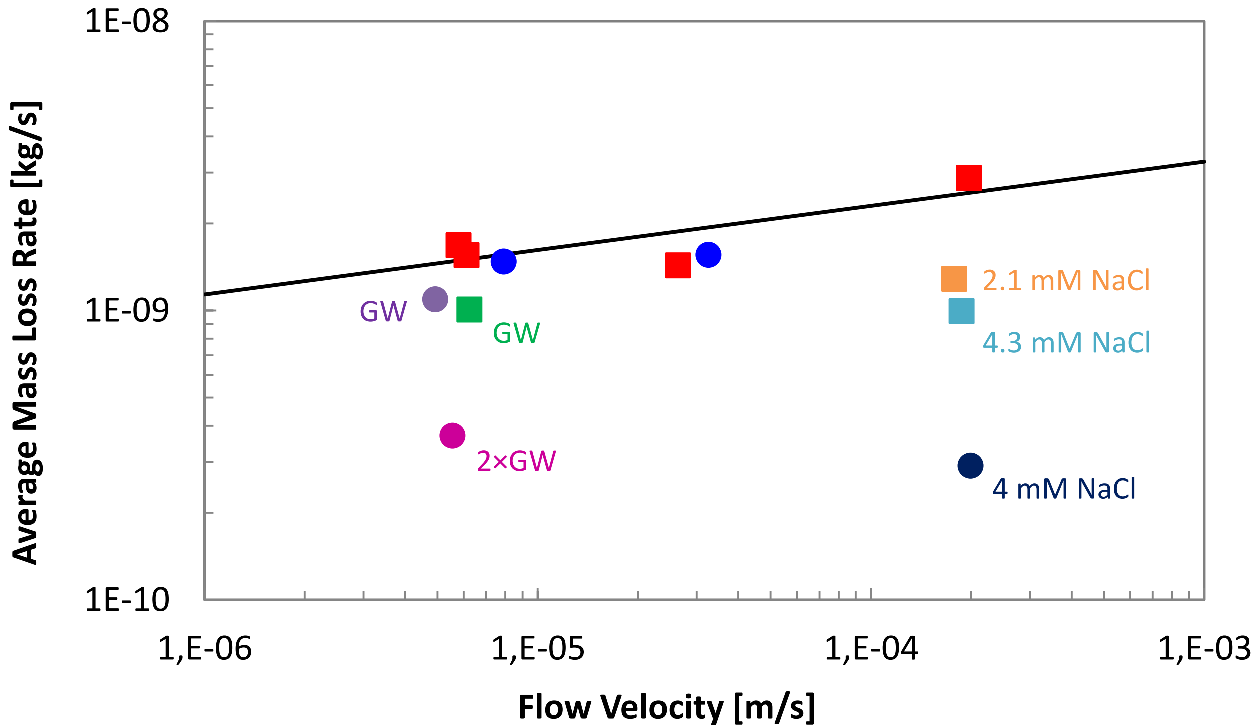
- Average mass loss rates for various sample materials from horizontal, 1 mm aperture, artificial fracture tests as a function of cation charge equivalents for solutions flowing through the fracture systems.

Effect of Groundwater Velocity (1)



- **Overall mass loss rates for (maximal) horizontal, artificial fracture tests are reasonably well-correlated to flow velocity.**

Effect of Groundwater Chemistry (2)

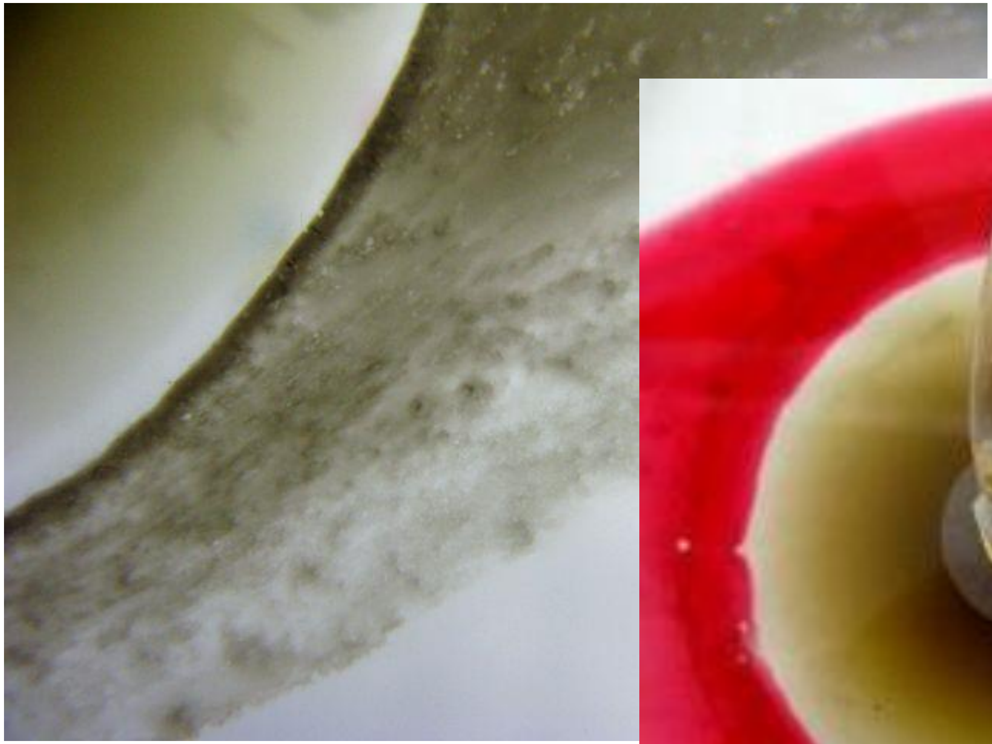


- ❑ **Average mass loss rates are sensitive to electrolyte concentration even under highly dilute conditions.**

- ➢ **Maximal case is overly conservative.**

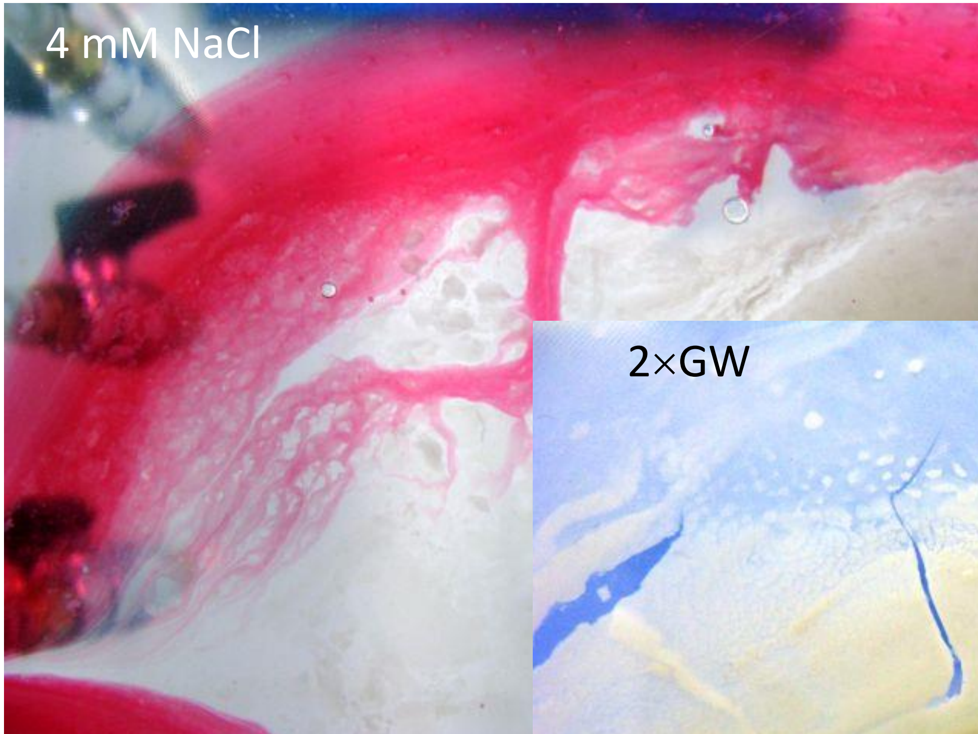
Clay Composition (1)

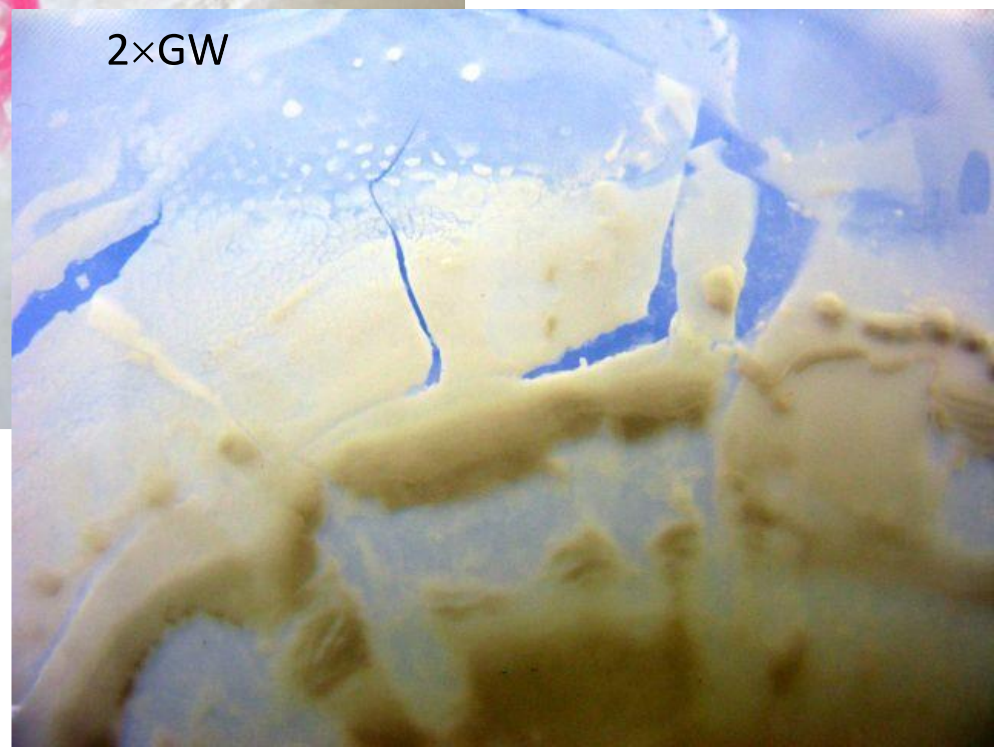
- sodium montmorillonite against deionized water



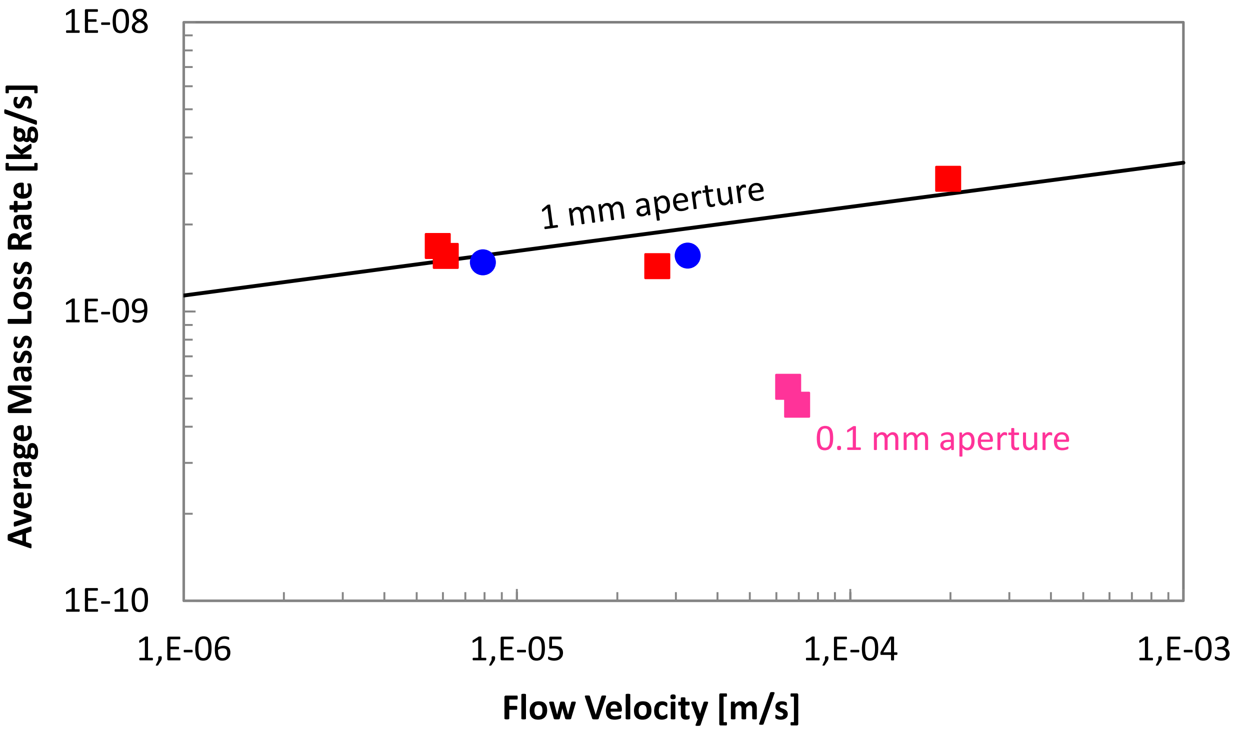
Clay Composition (2)

- 50/50 calcium/sodium montmorillonite



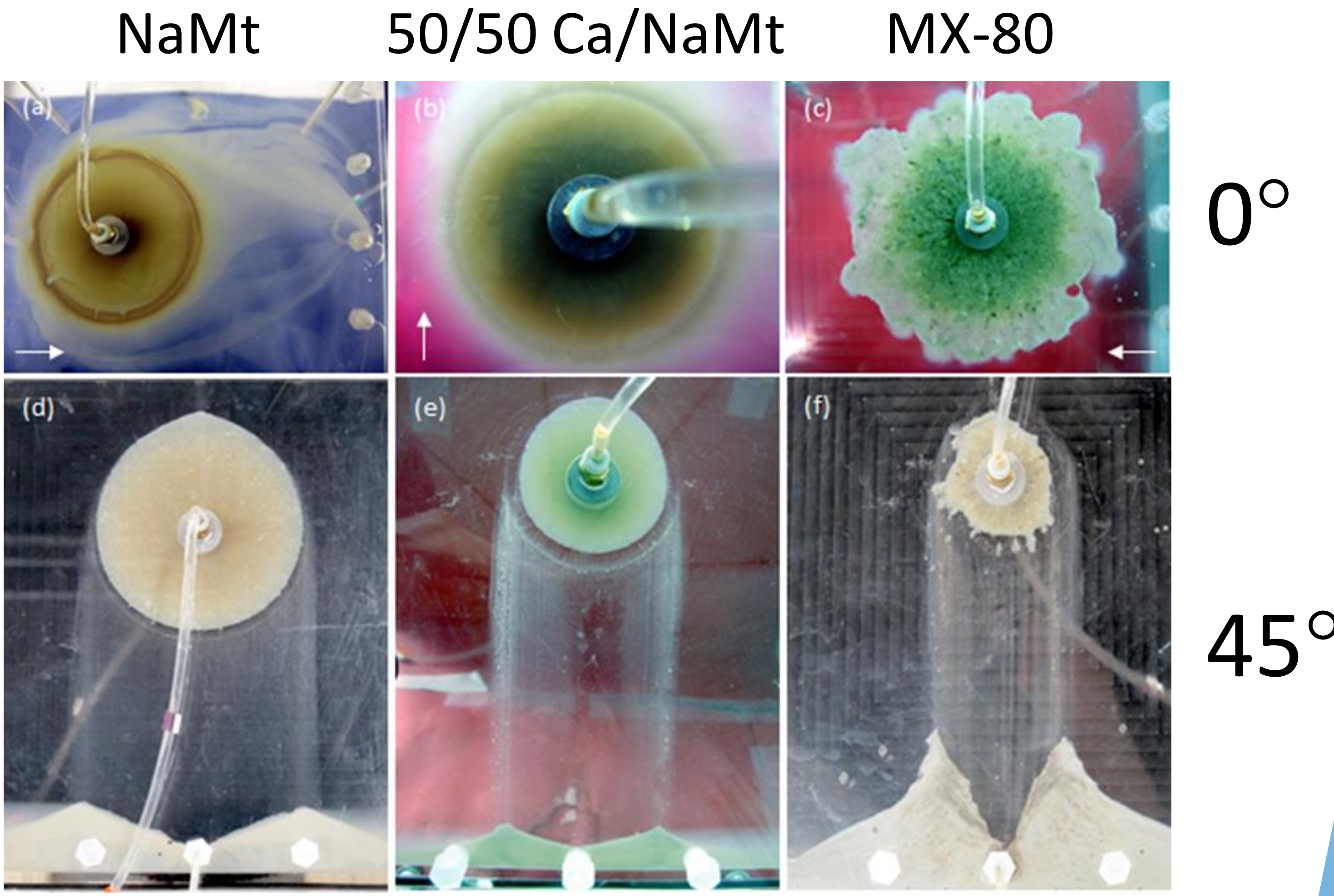


Effect of fracture aperture



- **Consistent with surface-area controlling effect on mass loss.**

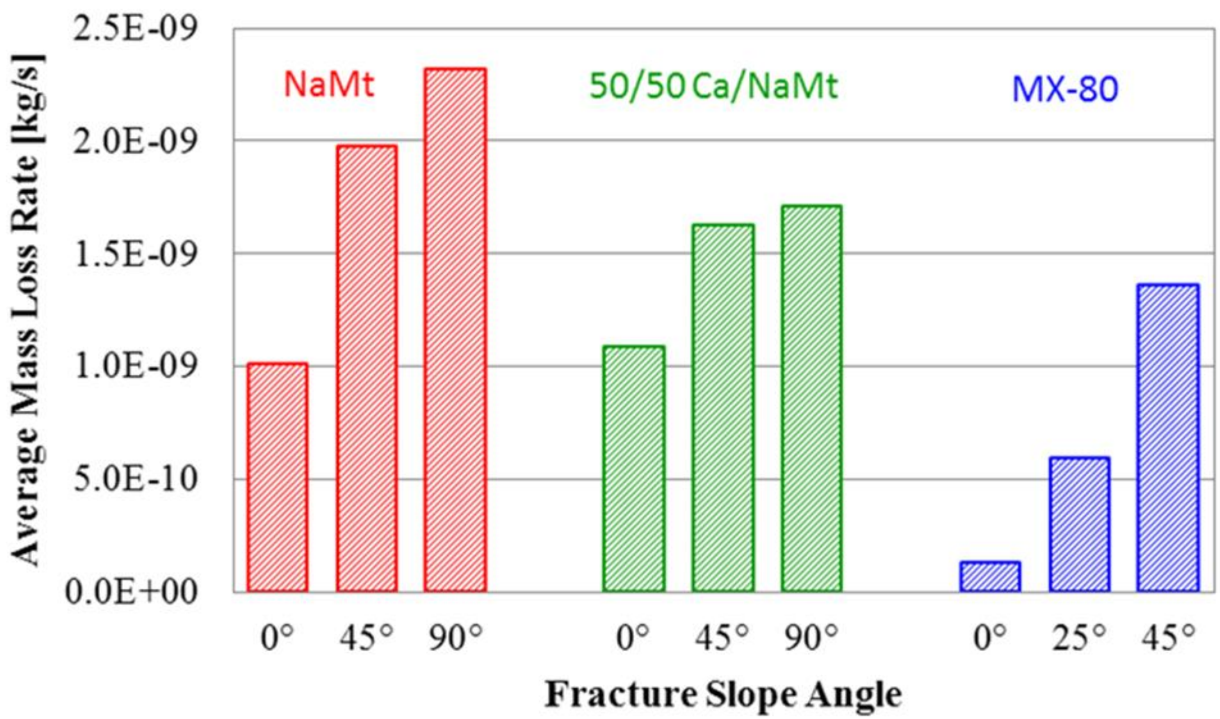
Effect of Fracture Slope Angle



- Strong effect of gravity on mass loss in sloped fractures.
- Dispersion/diffusion versus collapse under gravity

Effect of Fracture Slope Angle (2)

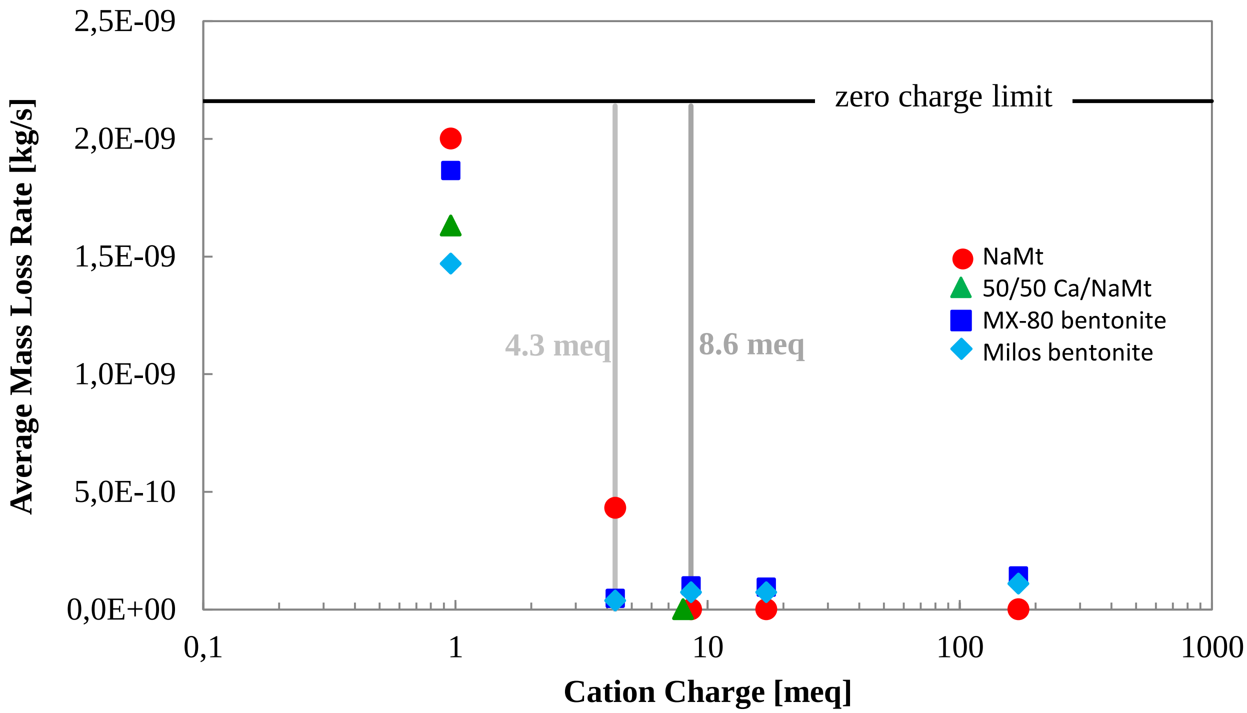
- Average mass loss rates among a series of artificial fracture tests with sodium montmorillonite, 50/50 calcium/sodium montmorillonite and MX-80 bentonite from 0° to 90° slope angles against GW at ~10^{-6} m/s.



- In every case conducting tests, that in all other respects are identical, at larger slope angles leads to increased mass loss rates.

Effect of Groundwater Chemistry (2)

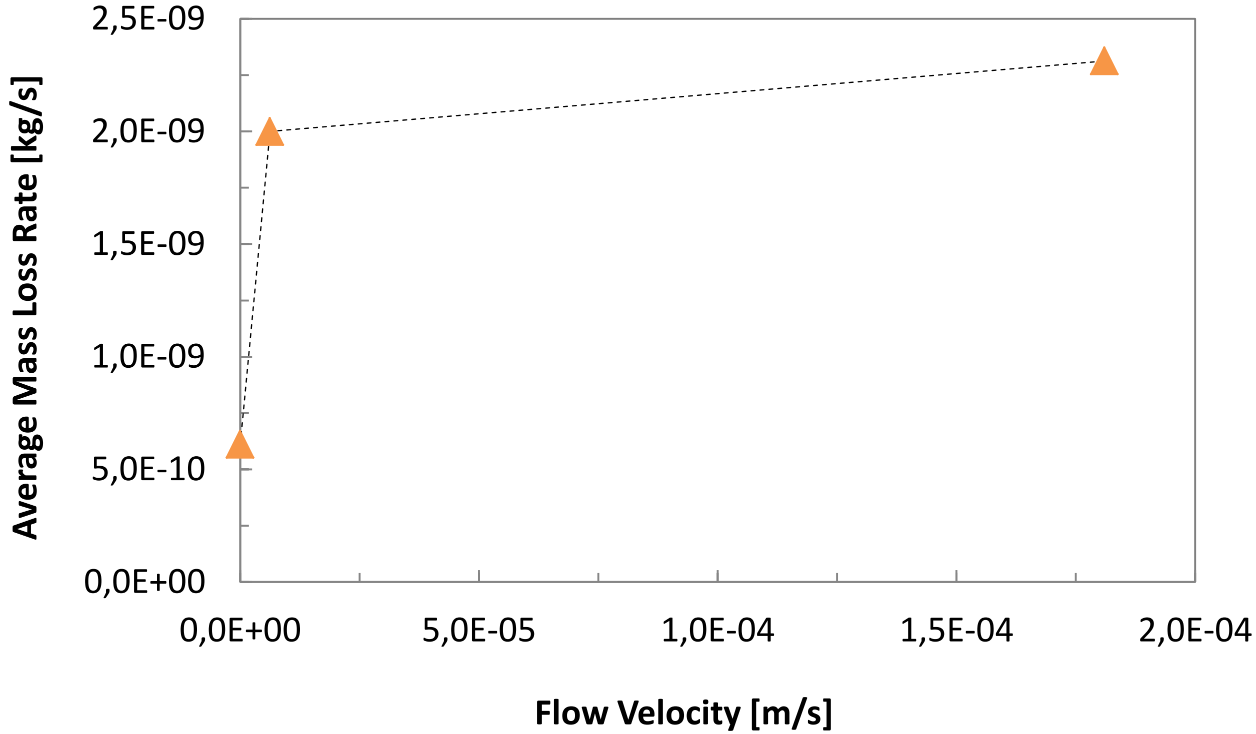
- **Erosion Stability (sloped fracture case)**



- **Average mass loss rates for various sample materials from 45° slope angle, 1 mm aperture, artificial fracture tests as a function of cation charge equivalents for solutions flowing at ~10^{-6} m/s down the fracture systems.**

- **Similar stability limits to horizontal case.**

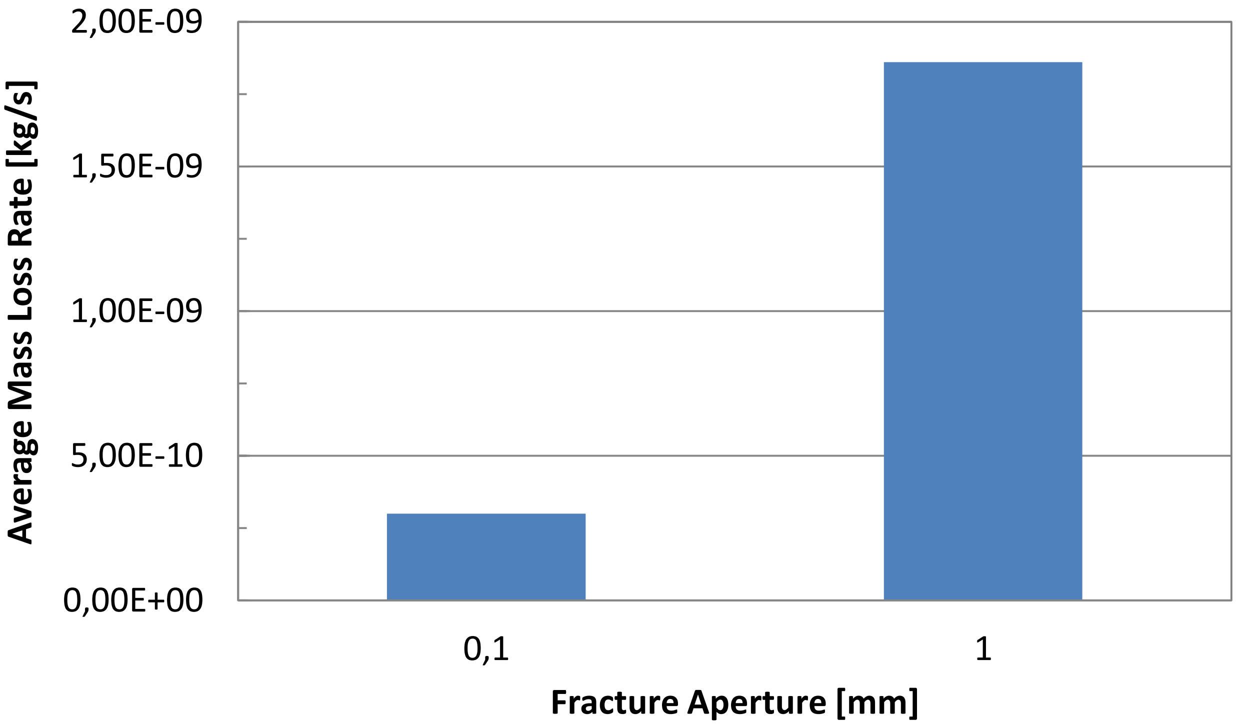
Effect of Groundwater Velocity (2)



- Increasing the flow down the fracture from zero (stagnant) to 10^{-6} m/s results in a 3x increase in mass loss; further increasing the flow velocity by roughly two orders of magnitude yields only a 15% additional increase in mass loss.
- By contrast, a similar, two order of magnitude flow velocity increase in horizontal fracture systems leads to an 80% increase in mass loss.

Effect of fracture aperture

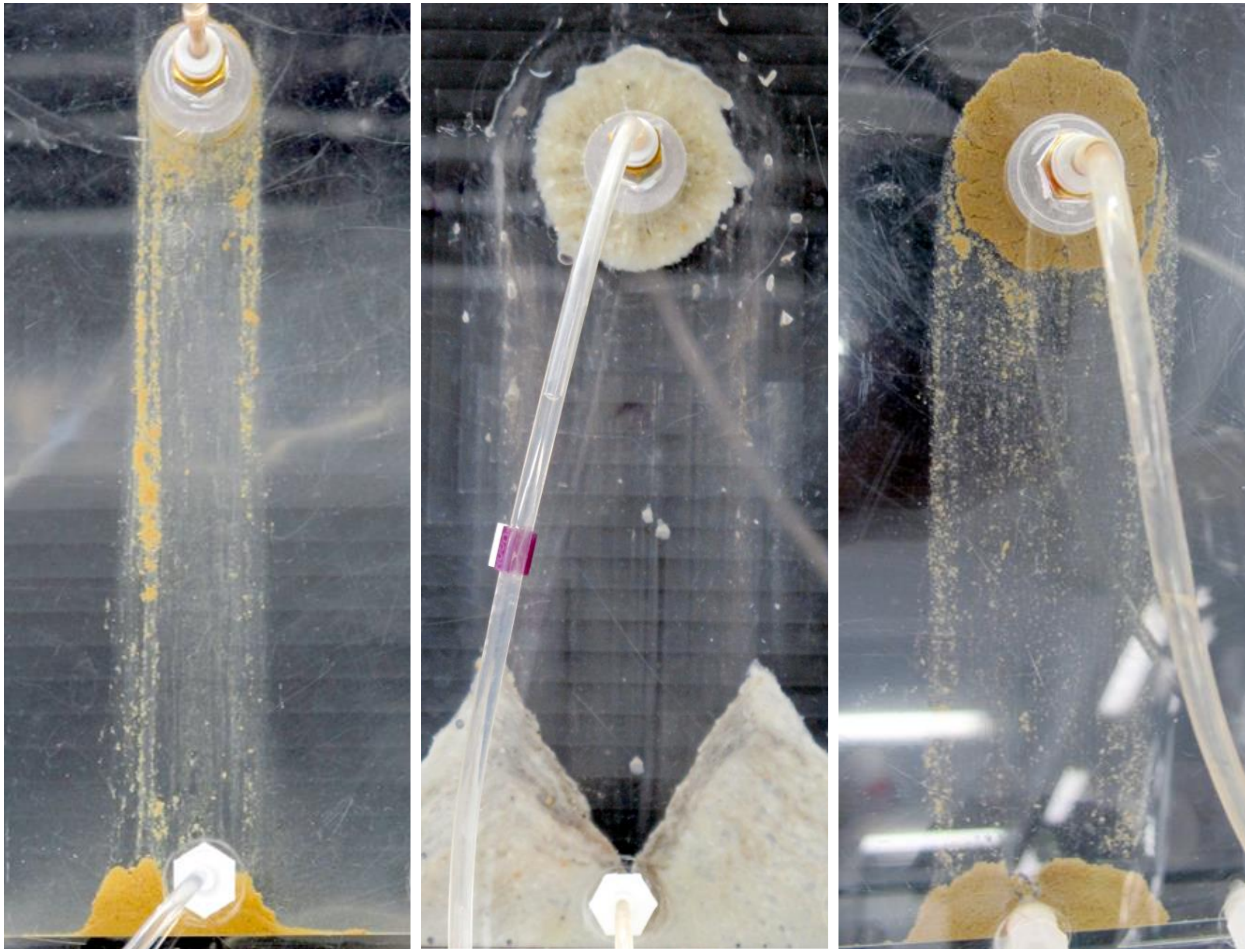
- 45° Slope Angle Fractures (MX-80)



- Again consistent with surface-area controlling effect on mass loss.

Clay Composition (5)

- Alternative Materials



Clay Composition (4)

- Vermiculite and saponite are more negatively charged than montmorillonite and these charges are more localized in the tetrahedral layers of the minerals

- Both vermiculite and saponite lose mass, i.e., erode, significantly less (nearly two orders of magnitude) than MX-80.

- Saponite swells and extrudes (as does MX-80) into the fracture space whereas vermiculite does not do so appreciably.

- Insofar as neither vermiculte or saponite is prone to colloidal dispersion, these materials should display even more significant erosion resistance in horizontal fracture systems.

Questions/Limitations

- Small-scale, mass-limited tests.
  - Scaling?
- Other posssible mitigating effects not captured in tests:
  - effect of rough, rock surfaces
  - self-filtration