Fracture permeability evolution in response to mechanical compaction and chemical dissolution

Scientific Achievement:
Successful prediction of dynamic evolution of fracture permeability when fractures are subjected to mechanical compaction and chemical dissolution.

Significance and Impact
Understanding mechanical and chemical response of caprock’s fractures to CO₂ storage is critical for long-time CO₂ storage.

Research Details
- Numerical model is developed for simulating fracture deformation when normal stress is applied. Fracture permeability is quantitatively related to the its mechanical property (specific stiffness) considering fracture heterogeneity.
- The theory of linear time-dependence of fracture permeability is derived when acidic fluid (CO₂-saturated brine) is in contact with carbonate fractures.


Work was performed at University of Texas at Austin
Fracture closes because of mechanical compaction

Universal relationship between fracture permeability and specific stiffness considering fracture heterogeneity and mechanical property (Young modulus)

- 7 fracture roughness $\sigma_f/b$
- 6 dimensionless correlation length $\lambda/L$
- 6 rocks with varying mech. properties: Granite, Limestone, Shale, Sandstone, Basalt, Marble
Fracture opens because of chemical dissolution

Linear time-dependence of fracture permeability: Theory and numerical validation

Theory: \( k = A \cdot S_h \cdot D_m \cdot (\bar{C} - C_{eq}) \cdot \rho_s^{-1} \cdot t \)

2D smooth fractures with different Peclet and Damköhler number

2D rough and tortuous fractures

Rough fracture

Tortuous fracture

Fracture opens because of chemical dissolution
Conclusions

• Fracture permeability is related to specific stiffness via a predictive function.

• The predictive function considers fracture heterogeneity and mechanical property.

• Theoretical connection between a linear time-dependence of permeability when fractures expand and are dissolved by acidic fluid (CO$_2$-saturated brine).

• The theory is validated by numerical simulations across a broad range of Peclet and Damköhler number through 2D rough and tortuous fractures.