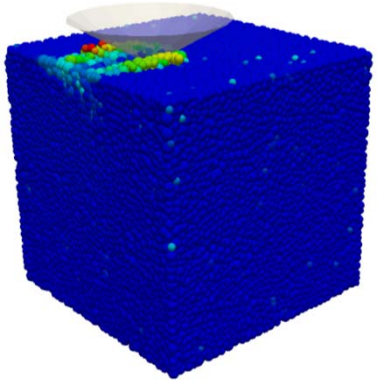
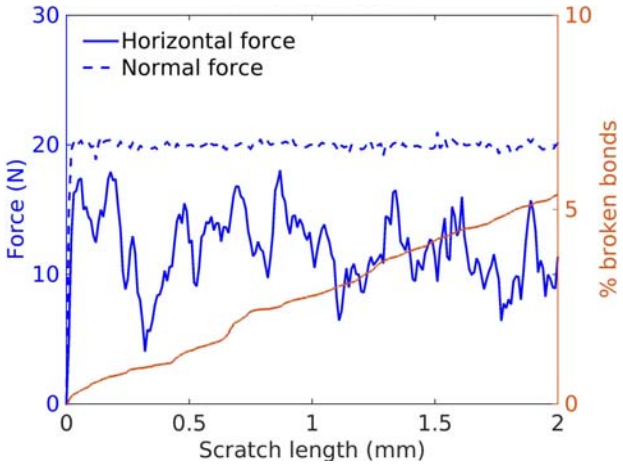
Discrete Element Modeling of Micro-Scratch Tests: Investigation of Mechanisms of CO_2 Alteration in Reservoir Rocks





Discrete element modeling of micro-scratch test

Sun, Espinoza, Balhoff, Dewers. 2017. Rock Mechanic and Rock Engineering.

Work was performed at University of Texas at Austin

Scientific Achievement

Discrete element method is applied to study CO_2-related chemo-mechanical alteration on rocks. Reductions of cement size lead to decreases of scratch toughness and an increase of ductility in the rock samples.

Significance and Impact

CO_2-related alteration on rock mechanical properties is critical to host formation structure integrity and long-term secure CO_2 storage. The mechanism and impact of CO_2-related alteration is investigated in this study.

Research Details

- Numerical model is developed to study the mechanical behavior of cemented geomaterials. The sensitivity analyses show that cement size is the most appropriate parameter representing the CO_2 alteration
- Cement size reduction results in potential fracture propagation as well as a transition from brittle to ductile failure mode.

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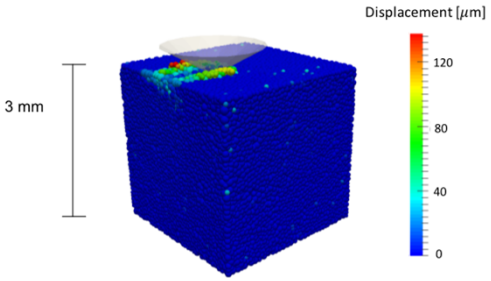
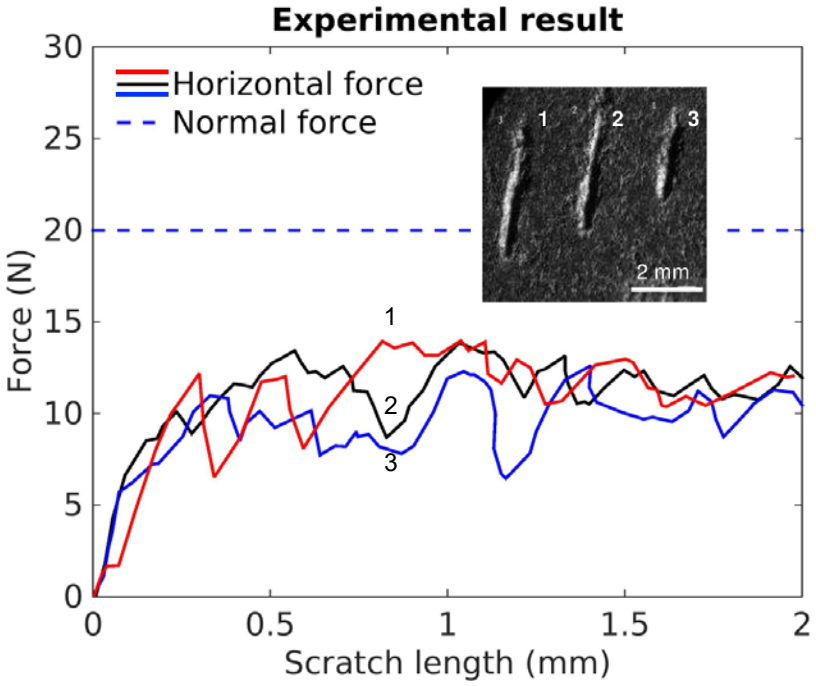
Validation against experimental scratch test

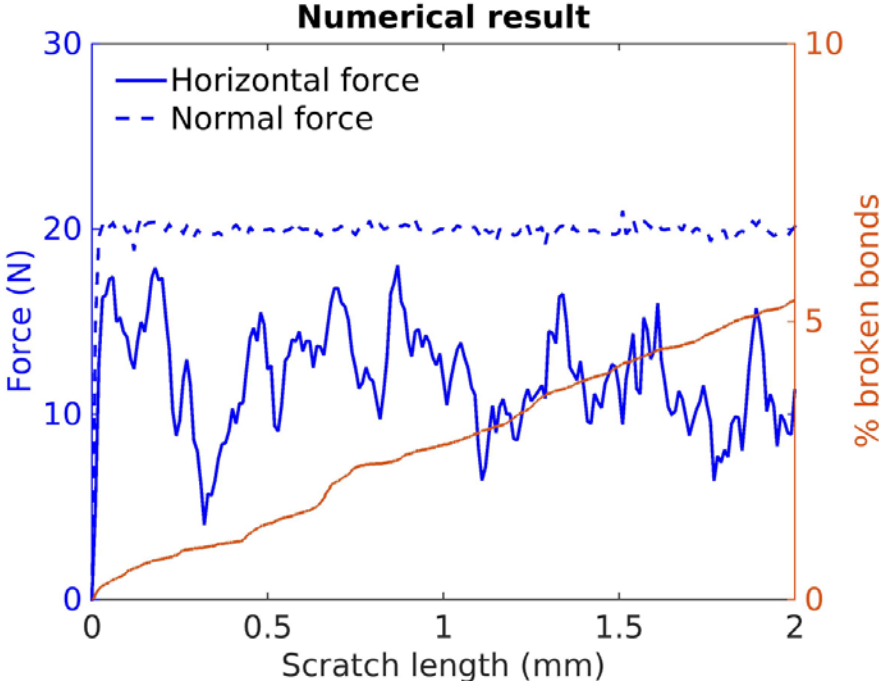
Schematic of micro-scratch test



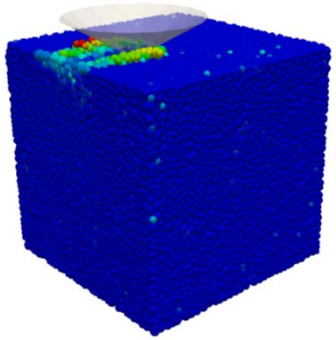
$K_c = 2.6 \ \ \mathrm{MPa \cdot m^{1/2}}$



$K_c = 3.0 \ \ \mathrm{MPa \cdot m^{1/2}}$

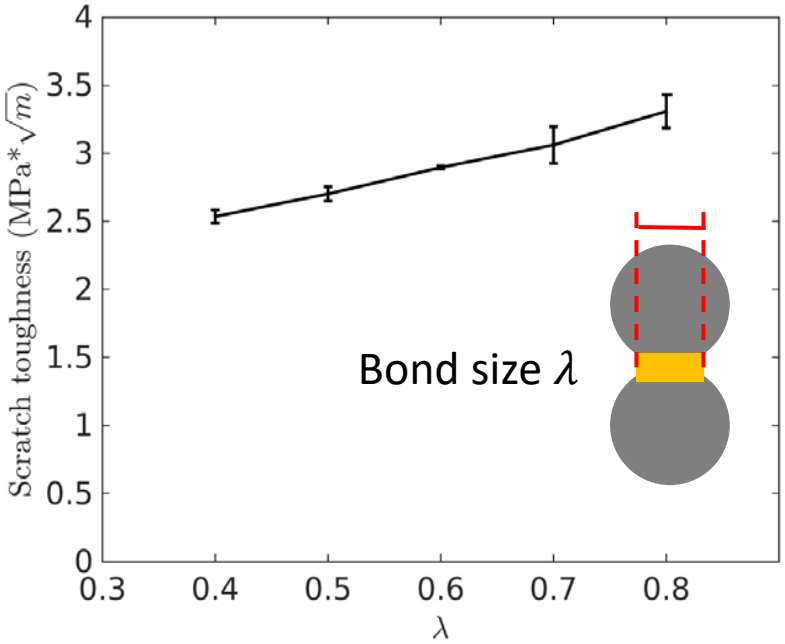


Impact of cement bond size (λ)

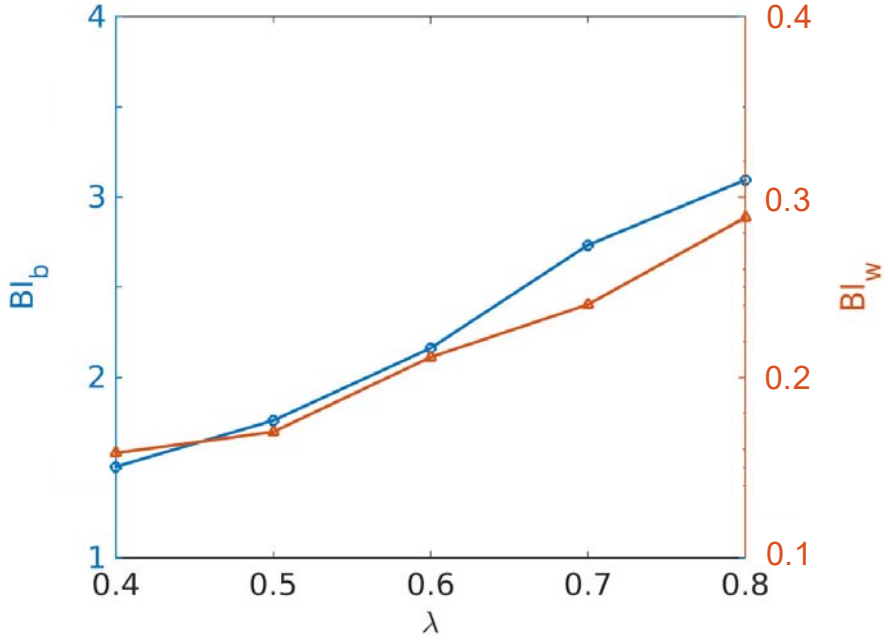


- Cement bond size reduction affects scratch toughness and failure mode.
- Brittleness indices calculated based on bond breakage rate (BI_b) and the ratio of brittle energy and total energy (BI_w).

Scratch toughness reduction



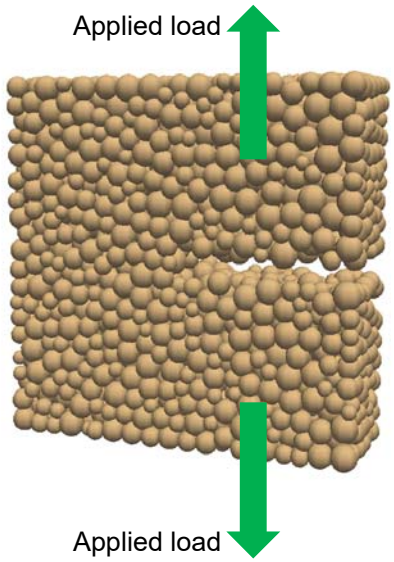
Brittle to ductile transition



Effect of mineral dissolution on fracture propagation

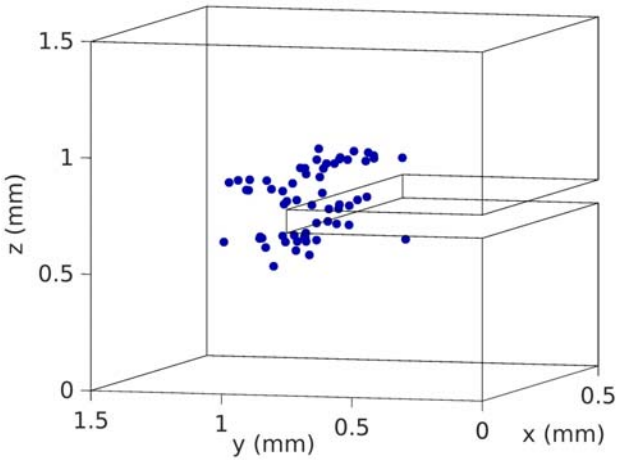
- Cement size reduction mimics the dissolution of cements. $\lambda_0 = 0.8$.
- Mode-I stress intensity is $K_I = 1.7$ MPa·m$^{1/2}$

Notched digital sample



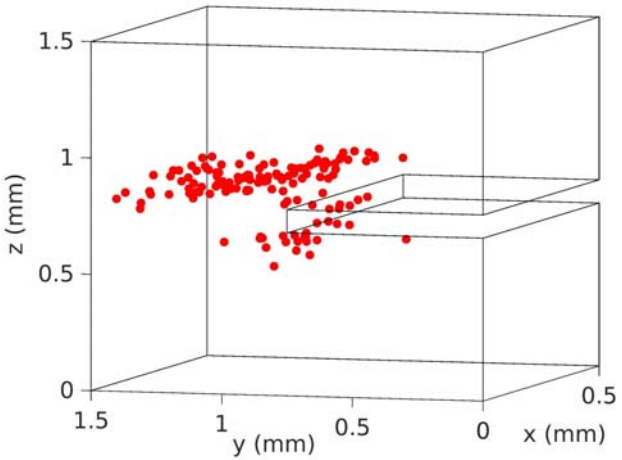
Fracture initiates

$\lambda = 0.65$



Entire sample fails

$\lambda = 0.5$



Conclusions

- **The bonded-particle model can model scratch tests with a constant vertical load on cemented sandstones.**
- **Scratch toughness decreases as the cement size is reduced, which is associated with the brittle to ductile transition.**
- **A simple approach to quantify the brittleness is proposed based on the coefficient of variation of bond breakage rate in DEM simulations.**