Mineralogical Controls on Fault Stability-Permeability Relationships

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- ***what is the fracture friction-permeability interaction during shear slip?***
- ***what is the influence of mineral composition on friction-permeability relationships?***

INTRODUCTION

Injection of CO_2 into deep saline aquifers or depleted oil and gas reservoirs has the potential to sequester significant mass of CO_2 in a sustainable manner **(Szulczewski et al., 2012).** Fluid injection activities (e.g., hydraulic fracturing, deep disposal of wastewater, enhanced geothermal stimulation) can reactivate pre-existing faults and induce seismicity **(Ellsworth, 2013).** Likewise, large-scale injection of CO_2 that generates overpressures and decreases effective normal stresses may reactivate pre-existing faults in caprocks (**Fig.1**). Hence, it is of particular interest to understand the evolution of permeability of caprocks as a result of seismic and aseismic deformation. In this study, we report both frictional experiments and analyses of shear slip to explore the fracture frictional stability-permeability interactions during fracture shearing. Particularly, the mineralogical controls on stability-permeability relationships are investigated.

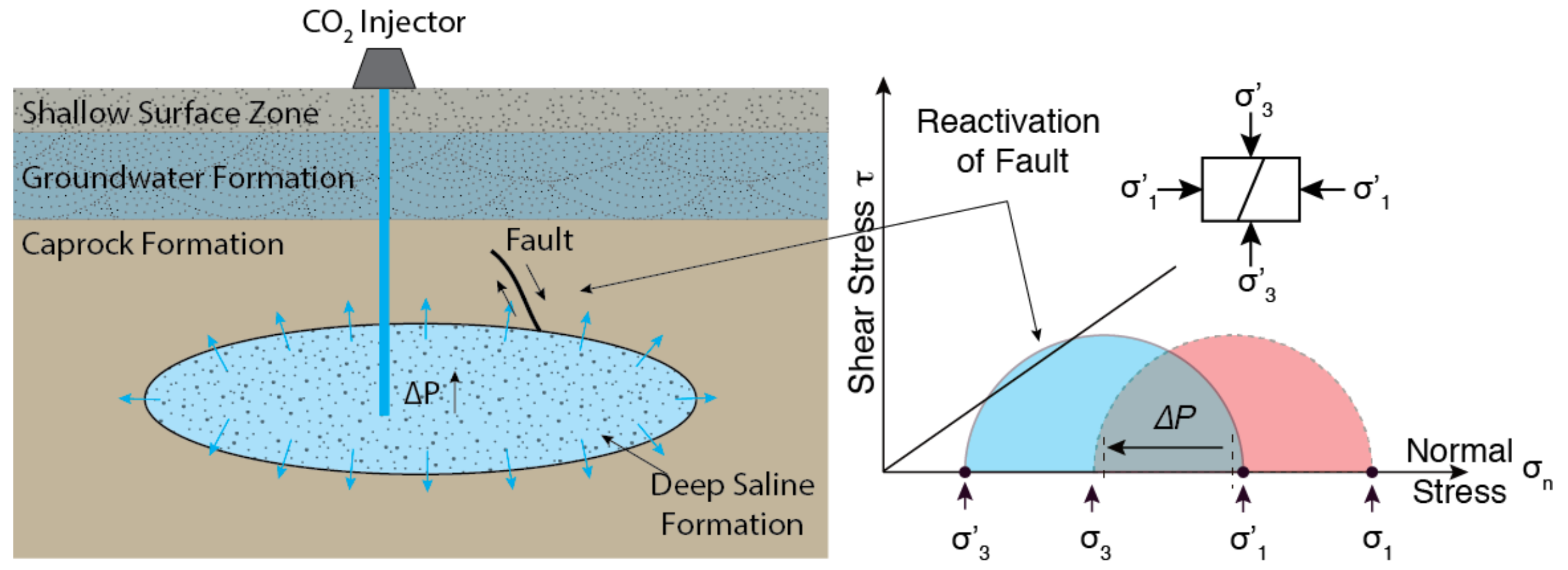

Fig.1 Injection of CO_2 and reactivate pre-existing faults

SAMPLE PREPARATION

Frictional stability-permeability experiments are performed on both natural and artificial samples. For natural samples, we use Green River Shale, Longmaxi Shale and Marcellus Shale. For artificial samples, we uniformly mix three types of mineral particles (tectosilicate, carbonate, phyllosilicate) based on the assumption that all shales are primarily composed of these three groups of minerals (**Fig.2**). The particle size is less than 100 microns and compressed in a steel press (**Fig.3**) with 100 MPa for 72 hours. The samples used for experiments are shown in **Fig.4**.

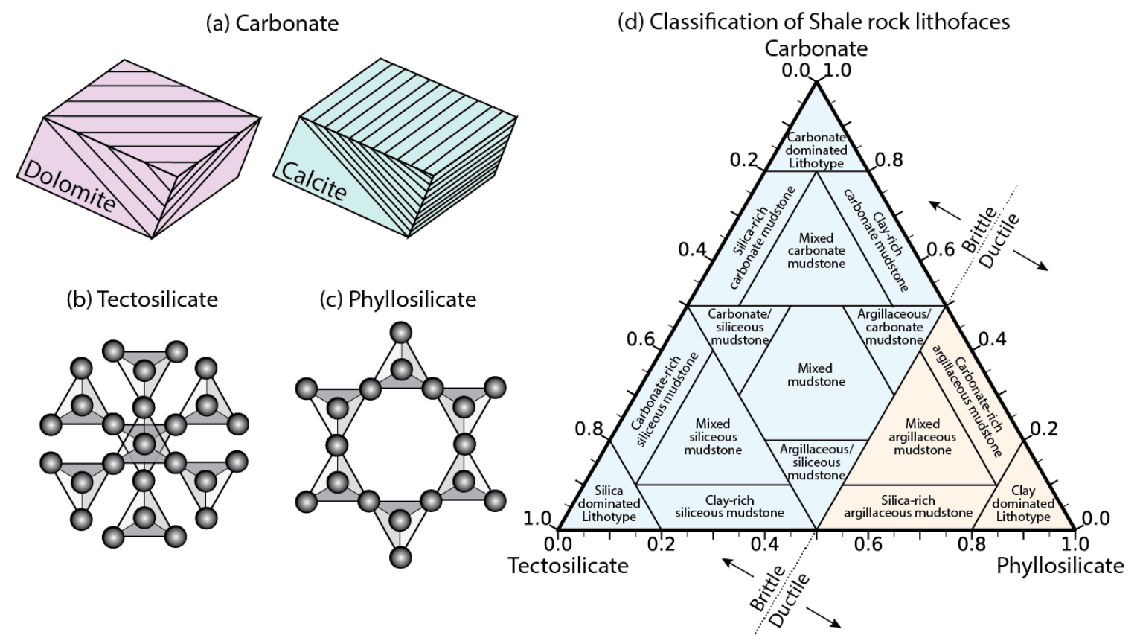

Fig.2a Classification of shale : brittle vs. ductile

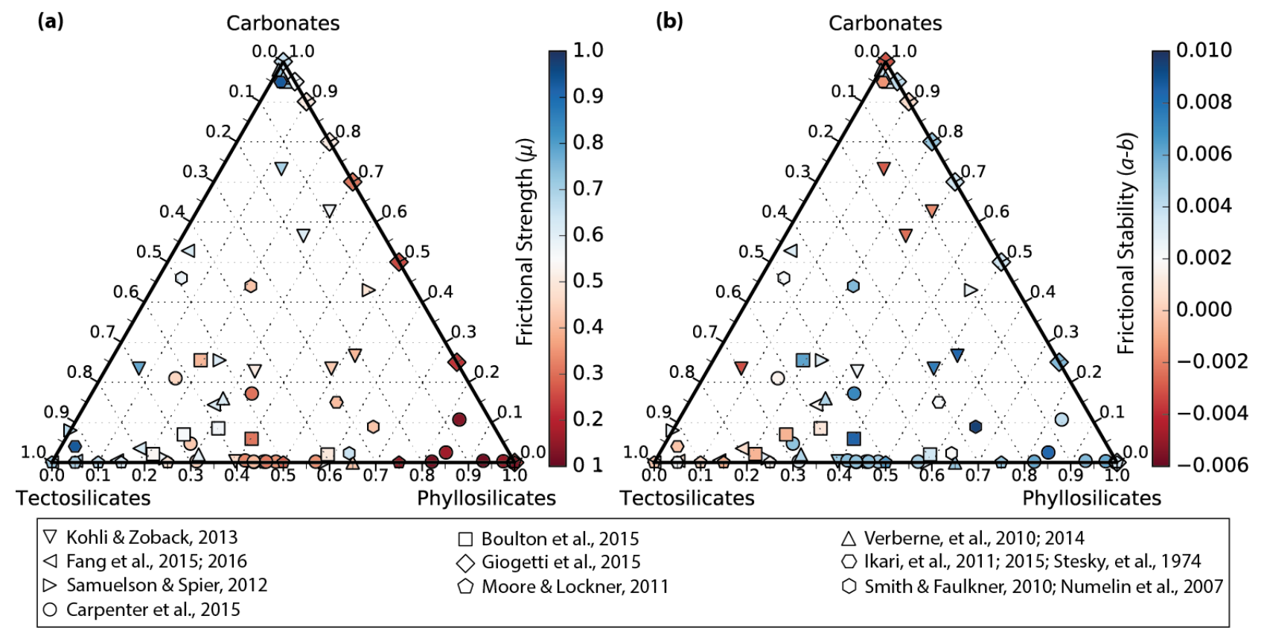

Fig.2b Ternary Diagram

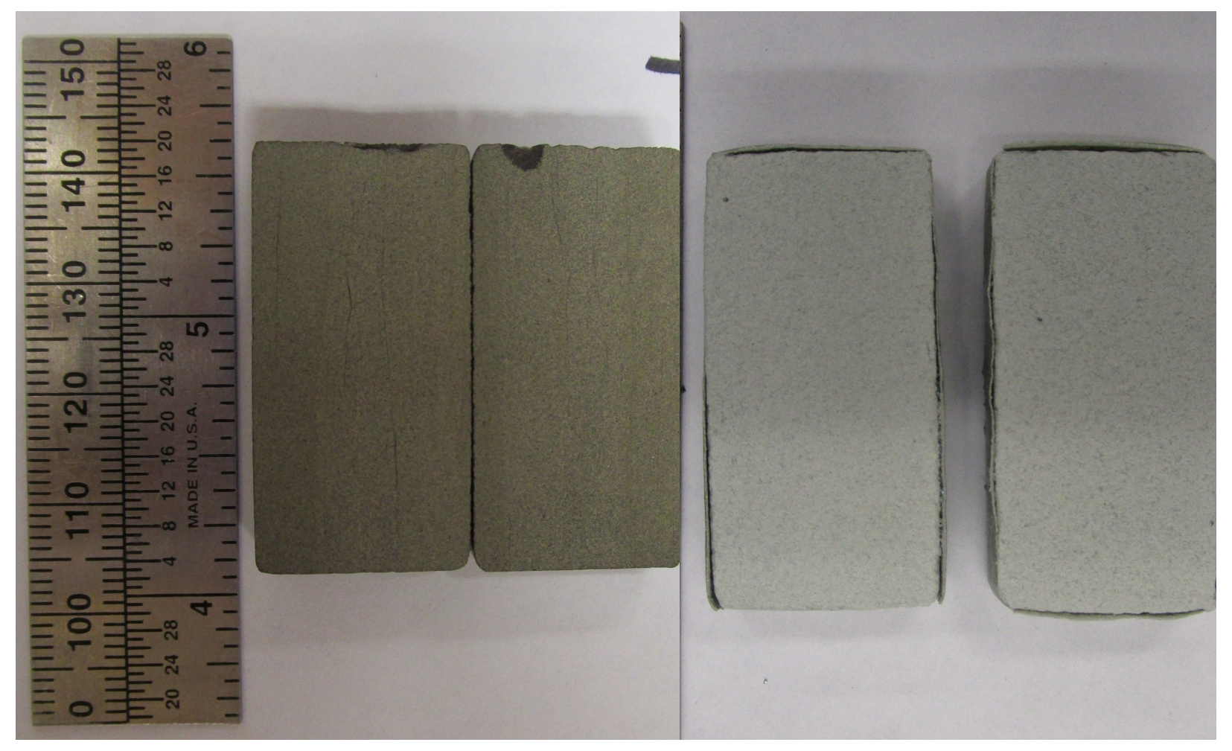

Fig.3 Green River Shale Artificial Samples

Fig.4 Compressing Cylinder

EXPERIMENTAL SETUP

Fluid-flow experiments are conducted in a triaxial pressure vessel to independently apply confining pressure, pore pressure, and shear velocity while concurrently monitoring the evolution of fracture permeability during experiments (**Fig.5**). We conduct velocity stepping experiments and capture the friction and permeability evolution when a velocity step is applied (**Samuelson et al., 2009**). The results are quantified using rate-and-state friction laws (**Scholz, 1998**)

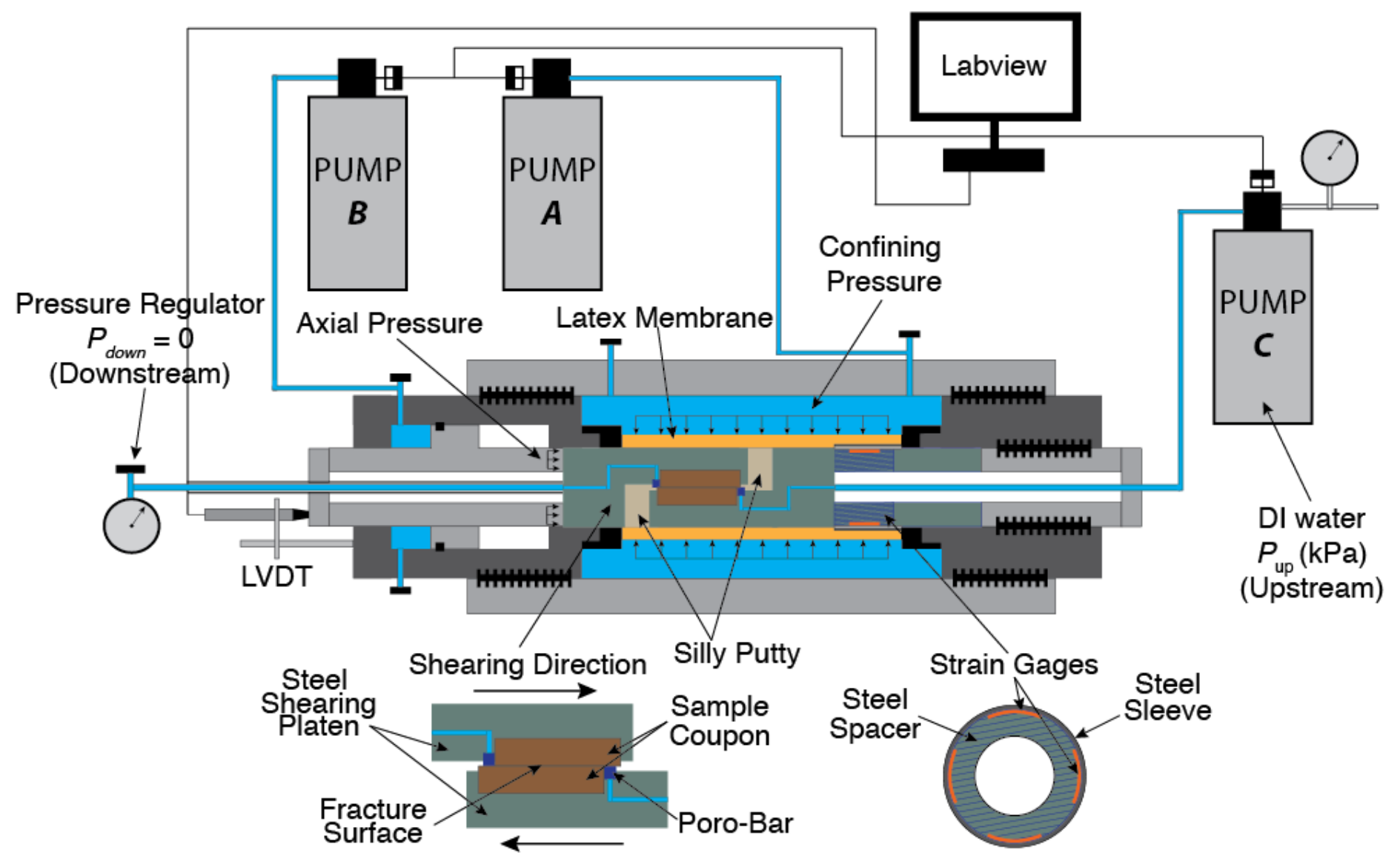

Fig.5 Experimental Setup

EXPERIMENTAL RESULTS

Experimental results for natural samples and artificial samples are presented in **Fig. 6** and **Fig.7**. The left figures are friction and permeability evolution during the shearing and right figures indicate friction and permeability change when an up-step in velocity is applied. The stability-permeability correlations are shown in **Fig.8** and the XRD results are shown in **Fig.9**.

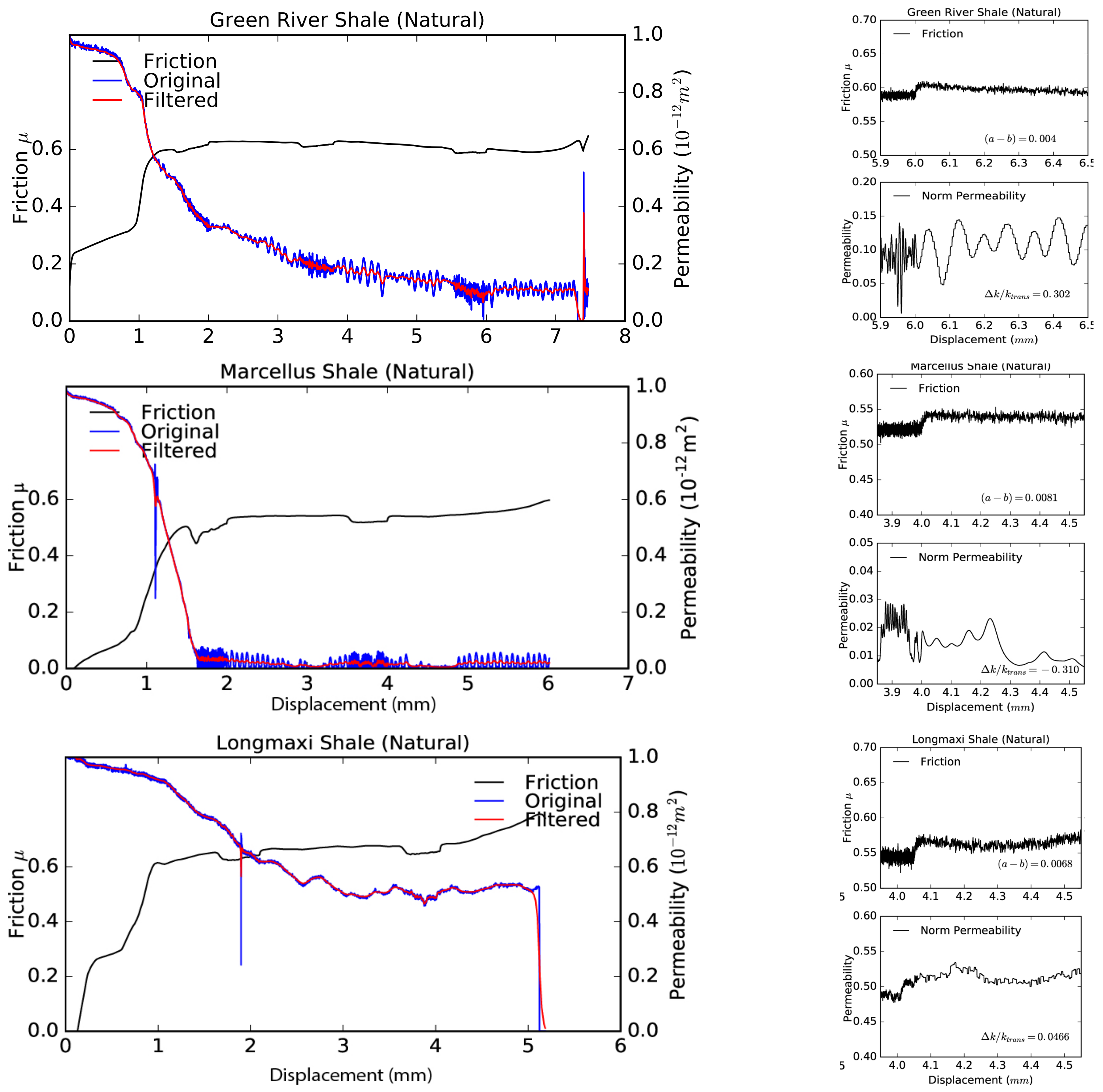

Fig.6 Experimental results of friction, stability and permeability of natural fractures

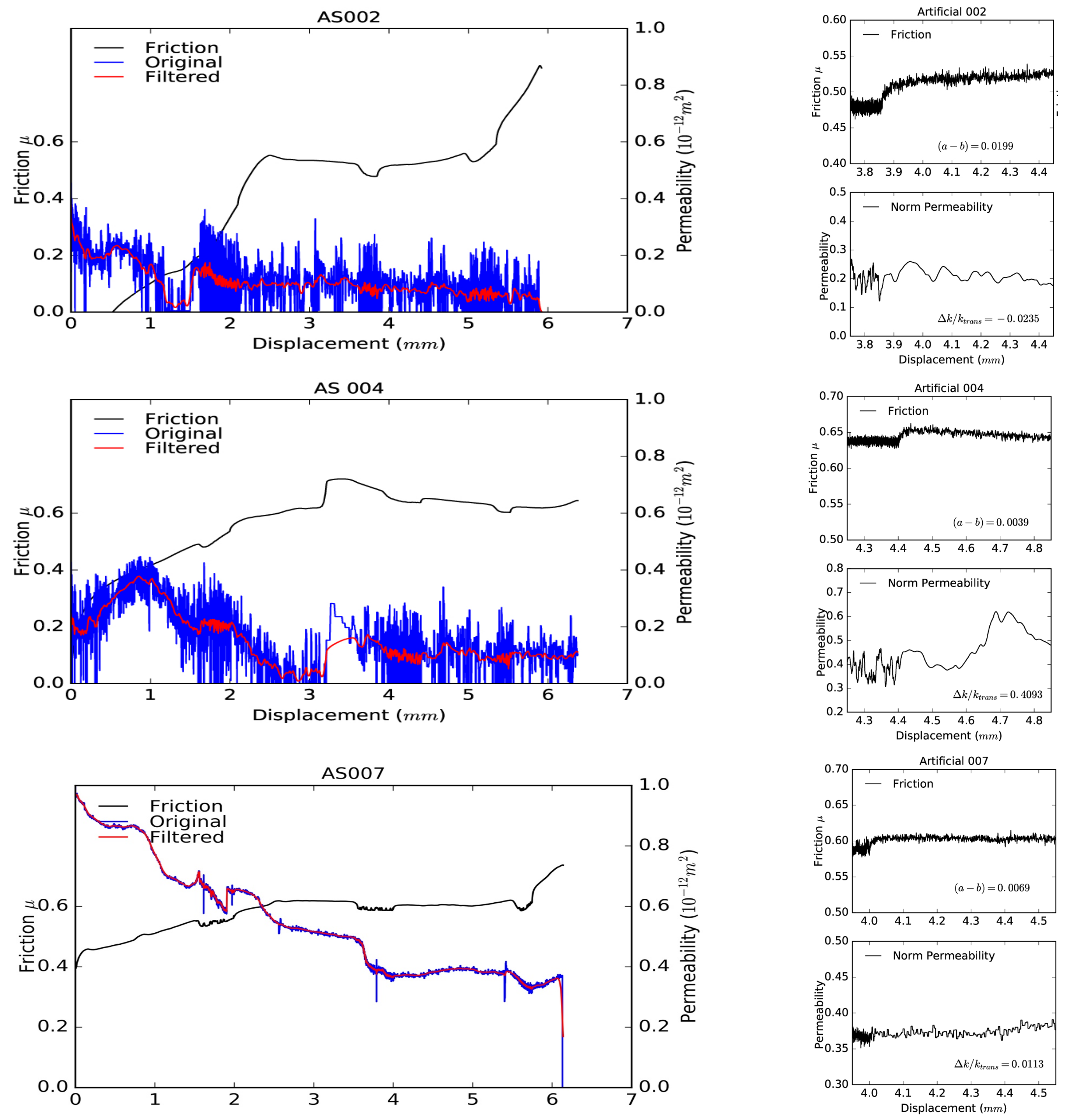

Fig.7 Experimental results of friction, stability and permeability of artificial fractures

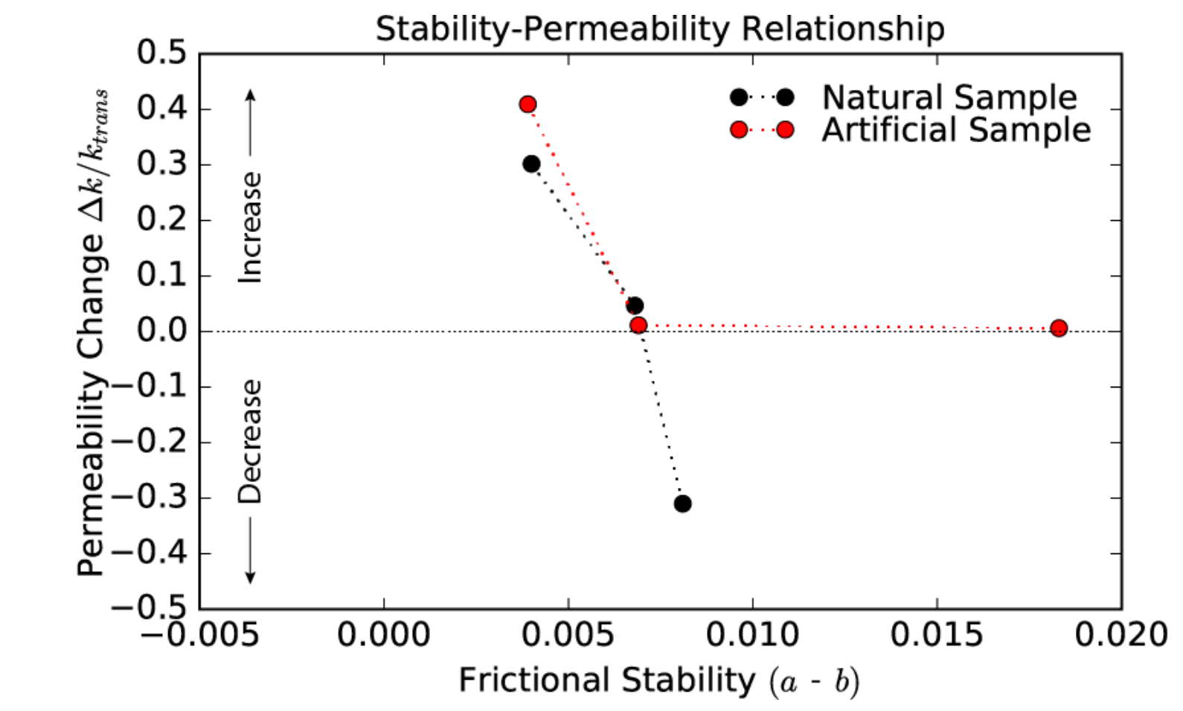

Fig.8 Stability-permeability relationship for all samples

Sample Name	Tectosilicate (wt. %)	Carbonate (wt. %)	Phyllosilicate(wt. %)
Green River Shale	45.44	51.96	2.60
Longmaxi Shale	54.95	20.16	24.77
Marcellus Shale	37.93	0	62.07
AS002	10.0	10.0	80.0
AS004	33.3	33.3	33.3
AS007	60.0	20.0	20.0

Fig.9 XRD results

CONCLUSIONS

1) At low confining stresses (3MPa), all of the samples indicate velocity-strengthening behavior (aseismic slip).
2) For fractures composed of clay-rich weak minerals (phyllosilicate), the strong swelling effect results in significant permeability damage.
3) For tectosilicate-dominant rocks, a velocity up-step leads to a permeability increase while a velocity down-step results to a permeability decrease.
4) For phyllosilicate-dominant rocks, a velocity up-step leads to a permeability decrease while a velocity down-step results to a permeability increase.

Acknowledgement

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