what is the fracture friction-permeability interaction during shear slip?

what is the influence of mineral composition on friction-permeability relationships?

INTRODUCTION

Injection of CO₂ into deep saline aquifers or depleted oil and gas reservoirs has the potential to sequester significant mass of CO₂ 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 CO₂ 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.

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, carbonatite, 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.

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).

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.

CONCLUSIONS

1) At low converging 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

The present study was supported in part by DOE Project ID: EERE023554). This support is gratefully acknowledged.

References

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