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CO2 Flow, Alteration And Geomechanical Response In Confining Units – An Experimental Approach

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Summary

Seal integrity during injection operations is a topic of great interest both within the CO2 storage community, for wastewater injection and traditional reservoir pressure support. The Little Grand Wash fault, central Utah, USA, provides an excellent location for studying seal bypass systems in a siliciclastic sedimentary sequence. Two mode I siltstone fractures with significantly different apertures and varying degree of sample bleaching due to alterations from reactive fluid flow are studied together with two intact rock reference samples from the same depth level in the core. The experimental work addresses fracture flow and stiffness relationships. Observed differences in fracture closure trends may be explained as a rapid decrease in stiffness and flow for altered samples due to the fluid rock interaction process altering the fracture surface contact area for this sample.

3b) for the altered fractured sample (LGW7), whereas for the unaltered fractured sample (LGW1) the measurements follow a linear trend.

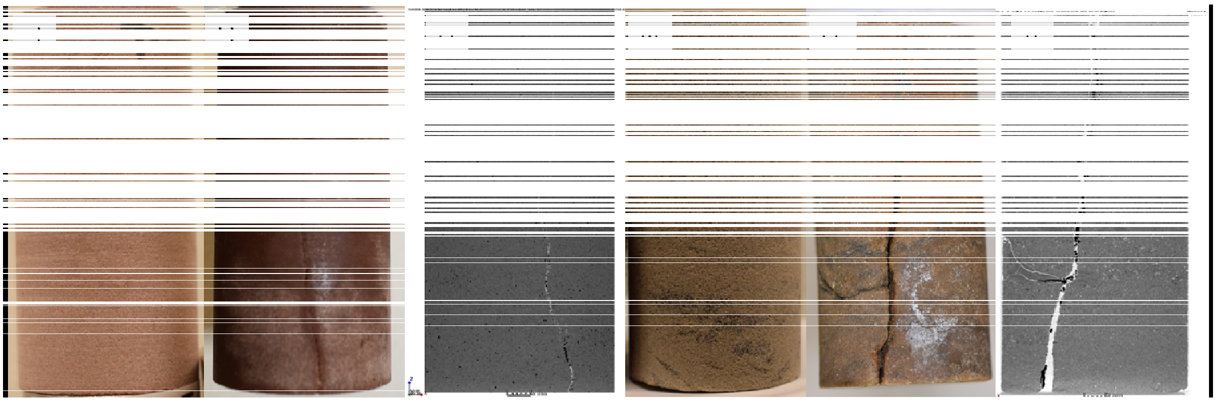

Figure 1 *Samples with 25 mm diameter used in the experimental work on an unaltered reddish siltstone and a bleached, altered siltstone. Intact unaltered host rock sample LGW2 (a), fractured unaltered sample, LGW1 (b), CT image of unaltered fractured sample LGW1 (c), intact bleached sample LGW8 (d), fractured altered host rock (LGW7) (e) and CT image of altered fractured sample LGW7 (f). In the CT images white is air and dark is dense material. A dark fracture-fill identified as oxides is observed mainly for the altered fracture in LGW7(e and f).*

Figure 2 *Measured stress-dependent flow as a function of effective isotropic stress (a) and volumetric strain (b) for fractured and intact sample. Arrows show loading direction in (a). In (b) trend lines are added to highlight the initial fast decrease in flow rate with strain for the fractured and intact bleached siltstone (LGW7 and LGW8) compared to the red siltstone where the decrease in flow rate with strain is slower.*

Discussion

Pyrak-Nolte and Morris (2000) shows that relationships between fracture specific stiffness and flow may be divided into two different categories; (1) rapid and (2) slow decrease in flow for increasing fracture stiffness. The two categories are related to the fracture aperture correlation, contact area and asperity distribution. Contact area distribution may be varying with lithology (host rock) and sample size. However, for the current experimental work both lithology and sample sizes are similar, and the difference in fracture stiffness and flow relationship might be related to the fracture alteration in a similar way as shown by Lang *et al*. (2016): The observed variation in stiffness and flow trends may be explained as a rapid decrease in stiffness and flow for altered samples due to the fluid-rock interaction process for this sample. Although the grain size distribution of the cores appears to be slightly coarser for the bleached siltstone compared to the red siltstone, both samples couplets display similar lithologies: sub-arkosic framework with abundant fine grained matrix, illitic clay-coats and pore-filling clay-mix as well as patchy, poikilotopic carbonate cement. Alteration processes related to the bleaching are removal and/or reduction of Fe-oxides, whereas pyrite and gypsum precipitates on the same fractured surface indicates alternating red-ox conditions in multiple fluid circulation episodes. For the altered fracture (LGW7), a highly uncorrelated aperture distribution is suggested, which indicate that the contact area is much smaller for the altered fracture in LGW7 than for the unaltered fracture in LGW1. A difference in contact area and aperture distribution for the two fractures is visible from the CT images (Figure 1), and may support the difference in stiffness observed for the two samples. Similar effects may be seen for the intact host rock, where the chemical processes may have changed the grain contact areas and hence the mechanical response of the material, suggesting a mechanical influence of geochemical alteration also for the bleached/altered host rock.

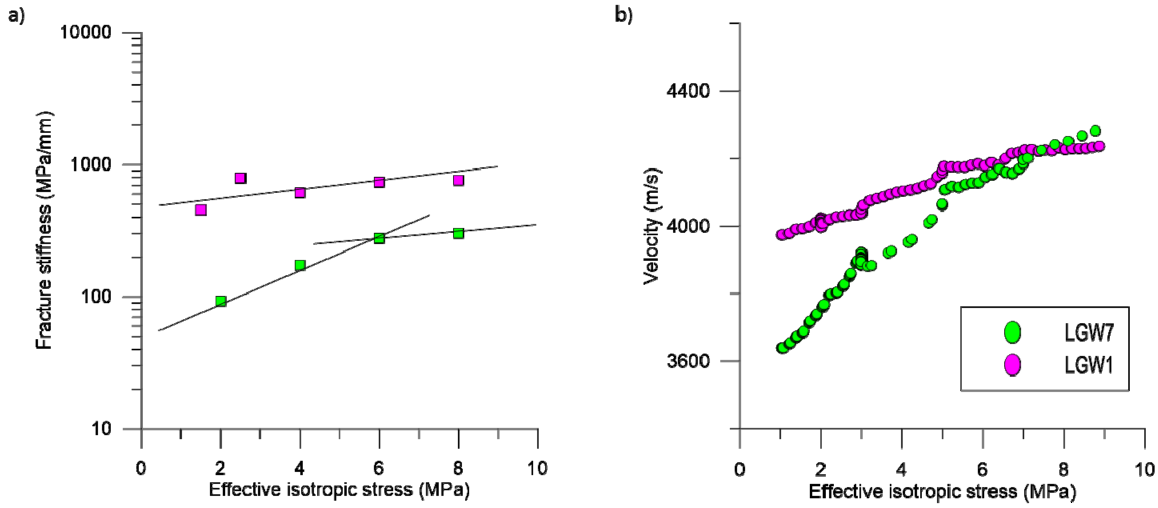

Figure 3 *Fracture stiffness, K_n, defined as $d\sigma/d\varepsilon_f$ (a) and radial S-velocity (b) for the fractured red siltstone (LGW1) and the bleached siltstone (LGW7) showing a marked change in trend during loading (closure) of the bleached siltstone fracture compared to the red siltstone.*

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References

Bjørnarå, T. I., Skurtveit, E., and Sauvin, G. (2018). Stress-dependent fracture permeability in core samples: an experimental and numerical study. In Second International Discrete Fracture Network Engineering (DFNE) Conference, 20-22 June 2018, Seattle, Washington, USA

Kampman, N., M. Bickle, A. Maskell, H. Chapman, J. Evans, G. Purser, Z. Zhou, M. Schaller, J.C. Gattacceca, P. Bertier, [2014] Drilling and sampling a natural CO_2 reservoir: Implications for fluid flow and CO_2-fluid–rock reactions during CO_2 migration through the overburden, *Chemical Geology*, 369 51-82.

Lang, P. S., A. Paluszny, and R. W. Zimmerman [2016], Evolution of fracture normal stiffness due to pressure dissolution and precipitation, *International Journal of Rock Mechanics and Mining Sciences*, 88, 12-22.

Ogata, K., K. Senger, A. Braathen, J. Tveranger, [2014] Fracture corridors as seal-bypass systems in siliciclastic reservoir-cap rock successions: Field-based insights from the Jurassic Entrada Formation (SE Utah, USA), *Journal of Structural Geology*, 66 162-187.

Peterson, F. [1988], "Stratigraphy and nomenclature of Middle and Upper Jurassic rocks, western Colorado Plateau, Utah and Arizona, In: Revisions to stratigraphic nomenclature of Jurassic and Cretaceous rocks of the Colorado Plateau", *U.S. Geological Survey Bulletin*, 1633-B, p. B13-56

Pyrak-Nolte, L., and J. Morris [2000], Single fractures under normal stress: The relation between fracture specific stiffness and fluid flow, *International Journal of Rock Mechanics and Mining Sciences*, 37(1), 245-262.

Pyrak-Nolte, L. J., and D. D. Nolte [2016], Approaching a universal scaling relationship between fracture stiffness and fluid flow, *Nature communications,* 7, 10663.