Geophysical Research Abstracts
Vol. 15, EGU2013-9954, 2013
EGU General Assembly 2013


# The influence of water and supercritical $CO_2$ on the frictional strength and velocity dependence of montmorillonite and muscovite and the potential for fault zone reactivation in $CO_2$ storage reservoirs

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Recent research indicates that $CO_2$ is capable of inducing swelling in clay minerals in a similar fashion to water, though to a more modest extent. It is therefore of importance for feasibility studies of the geological storage of $CO_2$ to understand if the addition of $CO_2$ to clay rich fault zones has the potential to cause significant frictional weakening, similar to that associated with water. We conduct velocity-stepping direct shear experiments on pre-pressed plates (49 mm long x 35 mm wide x $\sim$1 mm thick), of montmorillonite and muscovite. An effective normal stress of 35 MPa is used in all experiments, which is roughly equivalent to the effective overburden stress expected in many storage projects. Temperature was held constant at $\sim$48 °C, consistent with previous experiments which indicated $CO_2$ induced swelling in montmorillonite. Pore fluid conditions are the main variable in this suite of experiments, in which the frictional strength of each clay mineral is analyzed oven-dry (attached to vacuum), saturated with deionized (DI) water, and oven-dry saturated with supercritical $CO_2$. Pore pressure is maintained at 15 MPa for the water and $CO_2$ saturated experiments ($\sigma_n$=50 MPa, $P_{\mathrm{H_20/CO_2}}$=15 MPa). Shearing velocity is varied systematically from approximately 11 $\mu$m/s to 0.2, 1.1, 11, 1.1, and 0.2 $\mu$m/s in order to determine the rate and state friction parameters, $a$, $b$, and $D_C$. Additionally, microstructural analysis of the post-shear clay gouges is conducted in an effort to understand the rheology behind changes observed in frictional properties. Preliminary results of experiments on montmorillonite show an overconsolidation peak at strains of approximately 0.3 for each of the oven-dry and water and $CO_2$ saturated experiments. Peak friction ($\mu_P$) for oven-dry montmorillonite is 0.53, decaying to a steady state friction ($\mu_{SS}$) of 0.51. For DI-saturated montmorillonite $\mu_P$=0.11 and $\mu_{SS}$=0.10. $CO_2$-saturated montmorillonite displays frictional strength between that of dry and DI-saturated montmorillonite with a peak friction of 0.44, and steady state friction of 0.34. These early results suggest that saturation with supercritical $CO_2$ may induce frictional weakening of fault zones rich in swelling clays, however such weakening is not as significant as that associated with water saturation.