Geophysical Research Abstracts
Vol. 19, EGU2017-18143, 2017
EGU General Assembly 2017

Susceptibility of experimental faults to pore pressure increase: insights from load-controlled experiments on calcite-bearing rocks

Elena Spagnuolo (1), Marie Violay (2), Stefan Nielsen (3), Chiara Cornelio (2), Giulio Di Toro (4,1)

(1) Ist. Naz. Geofisica e Vulcanologia, Roma 1, Roma, Italy (elena.spagnuolo@ingv.it), (2) ENAC, EPFL, Lausanne, Switzerland, (3) Earth Sciences, Durham University, Durham, U.K., (4) University of Manchester, Manchester, U.K.

Fluid pressure has been indicated as a major factor controlling natural (e.g., L'Aquila, Italy, 2009 Mw 6.3) and induced seismicity (e.g., Wilzetta, Oklahoma, 2011 Mw 5.7). Terzaghi's principle states that the effective normal stress is linearly reduced by a pore pressure (P_f) increase σ_{eff}=$\sigma_n(1-\alpha P_f)$, where the effective stress parameter α, may be related to the fraction of the fault area that is flooded. A value of α =1 is often used by default, with P_f shifting the Mohr circle towards lower normal effective stresses and anticipating failure on pre-existing faults. However, within a complex fault core of inhomogeneous permeability, α may vary in a yet poorly understood way. To shed light on this problem, we conducted experiments on calcite-bearing rock samples (Carrara marble) at room humidity conditions and in the presence of pore fluids (drained conditions) using a rotary apparatus (SHIVA). A pre-cut fault is loaded by constant shear stress τ under constant normal stress σ_n=15 MPa until a target value corresponding roughly to the 80 % of the frictional fault strength. The pore pressure P_f is then raised with regular pressure and time steps to induce fault instability. Assuming α=1 and a threshold for instability τ_{p_eff}=μ_p σ_{eff}, the experiments reveal that an increase of P_f does not necessarily induce an instability even when the effective strength threshold is largely surpassed (e.g., τ_{p_eff}=*1.3* $\mu_p\sigma_{eff}$). This result may indicate that the P_f increase did not instantly diffuse throughout the slip zone, but took a finite time to equilibrate with the external imposed pressure increase due to finite permeability. Under our experimental conditions, a significant departure from α=1 is observed provided that the P_f step is shorter than about $<$ 20s. We interpret this delay as indicative of the diffusion time (t_d), which is related to fluid penetration length l by $l = \sqrt{\kappa t_d}$, where κ is the hydraulic diffusivity on the fault plane. We show that a simple cubic law relates t_d to hydraulic aperture, pore pressure gradient and injection rate. We redefine α as the ratio between the fluid penetration length and sample dimension L resulting in $\alpha = \frac{min(\sqrt{kt_d},L)}{L}$. Under several pore pressure loading rates this relation yields an approximate hydraulic diffusivity κ $\sim$10^{-8} m^2 s^{-1} which is compatible, for example, with a low porosity shale. Our results highlight that a high injection flow rate in fault plane do not necessarily induce seismogenic fault slip: a critical pore penetration length or fluid patch size is necessary to trigger fault instability.