Modelling of fluid injection into a frictional weakening dilatant fault

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Governing equations

- Elasticity (Linear elastic & isotropic)
  \[ \tau(x,t) = \frac{C}{x^2} \left[ \frac{\partial u(x,t)}{\partial x} \right] \]
  for \( |x| < a \)

- Shear weakening Mohr-Coulomb criterion
  \[ \tau(x,t) \leq f(\theta)(\sigma_0 - p_0 - p(x,t)) \]

- Width averaged fluid mass conservation in the fault (with const. permeability \( k_f \))
  \[ w_h \frac{\partial \delta}{\partial t} + \frac{\partial}{\partial x} \left( \frac{w_h}{k_f} \frac{\partial w_h}{\partial x} \right) = 0 \]

- Boundary condition
  \[ p(x = 0, t) = p_0 + \Delta p \]

- Initial condition
  \[ \tau(x = 0, t) = 0 \]

Dimensionless governing parameters

\[ \frac{\Delta \tau}{\tau_f}, \frac{\Delta p}{\sigma_0}, \frac{\Delta \psi}{\psi_f} = \frac{\tau_0}{\tau_f}, \frac{\Delta \psi}{\psi_f}, \frac{\Delta \psi}{\psi_f} \]

\[ \frac{\tau_0}{\tau_f} = \frac{\Delta \psi}{\psi_f} \rightarrow \text{sliding patch characteristic scale} \]
\[ \frac{\Delta \sigma}{\sigma_0} = \frac{\Delta \phi}{\phi_f} \rightarrow \text{fault diffusivity} \]
\[ \frac{\sigma_0}{\tau_f} = \frac{\psi_0}{\psi_f} = \frac{\psi_0}{\psi_0} \rightarrow \text{ambient normal effective stress} \]

Ultimately stable fault \( \tau_0 < \tau_f \)

Moderate overpressure: \( \Delta p/\sigma_0 = 0.5 \)

Unstable fault \( \tau_0 > \tau_f \)

Moderate overpressure: \( \Delta p/\sigma_0 = 0.5 \)

Conclusions

- For a dilatant fault, the stress wave affects the slip propagation along high slip rates.
- Dilatancy directly affects the slip propagation during high slip rates of the shallow fault.
- For an unstable fault, the stress wave is not affected by the stress wave.
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References