Tensile strength of rocks

- Relatively unimportant!

- Reasons:
  - Tensile strength is low compared to compressive strength.
  - When a large enough volume of rock is considered, flaws are bound to exist making the tensile strength near zero.
  - *In situ* stress at depth is never tensile.
Opening mode fracture (Mode I)

\[ K_{Ic} \geq K_I = (P_f - S_3)\pi \sqrt{L} \]
Recall: Slip on faults

\[ \frac{\tau}{\sigma_n} = \mu \]

Coulomb failure function

\[ f = \tau - \mu \sigma_n \leq 0 \]
Critically stressed crust

© Cambridge University Press Zoback, *Reservoir Geomechanics* (Fig. 4.25, pp. 129)
Stress magnitudes controlled by frictional strength

© Cambridge University Press Zoback, *Reservoir Geomechanics* (Fig. 4.26, pp. 129)
Limits on *in situ* stress

Optimal angle for frictional sliding:

\[ \beta = \frac{\pi}{4} + \frac{1}{2} \tan^{-1} \mu \]

© Cambridge University Press Zoback, *Reservoir Geomechanics* (Fig. 4.27b,c, pp. 131)
Principle stress ratio

\[
\frac{\sigma_1}{\sigma_3} = \frac{S_1 - P_p}{S_3 - P_p} = \left(\sqrt{\mu^2 + 1 + \mu^2} \right)^{2}
\]

Assuming \(\mu = 0.6\)

\[
\frac{\sigma_1}{\sigma_3} = 3.1
\]
Stress bounds

\[
\frac{S_v - P_p}{S_{hmin} - P_p} \leq (\sqrt{\mu^2 + 1} + \mu^2)
\]

\[
\frac{S_{Hmax} - P_p}{S_{hmin} - P_p} \leq (\sqrt{\mu^2 + 1} + \mu^2)
\]

\[
\frac{S_{Hmax} - P_p}{S_v - P_p} \leq (\sqrt{\mu^2 + 1} + \mu^2)
\]
Pore pressure, stress difference, and fault slip

© Cambridge University Press Zoback, *Reservoir Geomechanics* (Fig. 4.30, pp. 136)