The Failure Envelope. If the Mohr circle that represents the state of effective stress in a rock crosses the failure envelope, then the rock will exceed its elastic limit and undergo permanent deformation. The failure envelope is divided into 4 parts.

1. At its most negative value is tensional failure. If the Mohr circle for a rock touches the envelope at this point, it will fail on purely tensile fractures - the rock will be pulled apart. Negative effective stress is required for this type of failure, and normally the amount required is \(-C_0\). Except for very near the Earth's surface, tensile stress normally can only be achieved if pore fluid pressure causes the effective stress to be negative.

2. If a rock's Mohr circle touches the envelope in the transitional tensile failure segment, then a fracture will open, and there will be shearing across the fracture.

3. If a rock's Mohr circle touches the Coulomb-Navier failure criterion segment, a brittle fault will form. The conditions for this sort of failure are given by the Coulomb - Navier failure criterion, \(\tau = \mu \sigma_n + C_0\). Byerlee's Law gives us \(\mu\) for most rock types.

4. If a rock's Mohr circle touches the Von Mises criterion segment, it will undergo ductile failure - most likely by deformation throughout the sample or along a ductile shear zone of significant width within the sample. Note that normal stress does not affect the differential stress required for failure by the Von Mises criterion, because failure and deformation is not occurring by frictional sliding along a fault. Whether Von Mises - type deformation occurs depends on several factors, most important of which are rock type, strain rate, temperature, and confining pressure. This type of deformation generally occurs below at least 15 to 20 km depth.

Stress conditions for tensile failure
\(\theta = 180\); failure occurs on fractures perpendicular to \(\sigma_1\).

Stress conditions for Von Mises Criterion ductile failure.
\(\theta = 90\); failure occurs on shear zones at 45° to \(\sigma_1\).

Stress conditions for Coulomb - Navier criterion failure.
\(\theta \sim 60°\) (given by the rock's friction angle).
Failure occurs on brittle faults at about 30° to \(\sigma_1\).