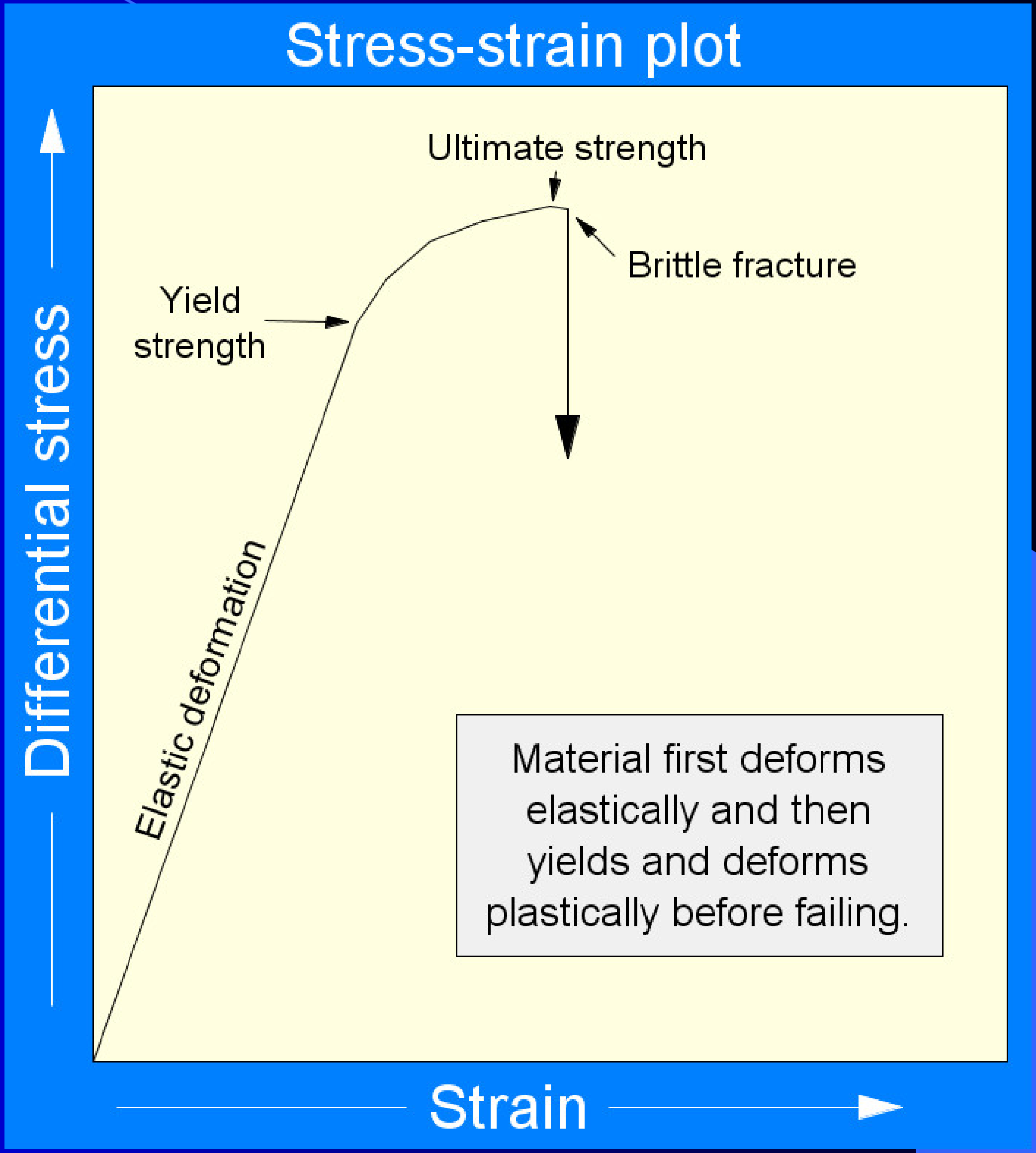
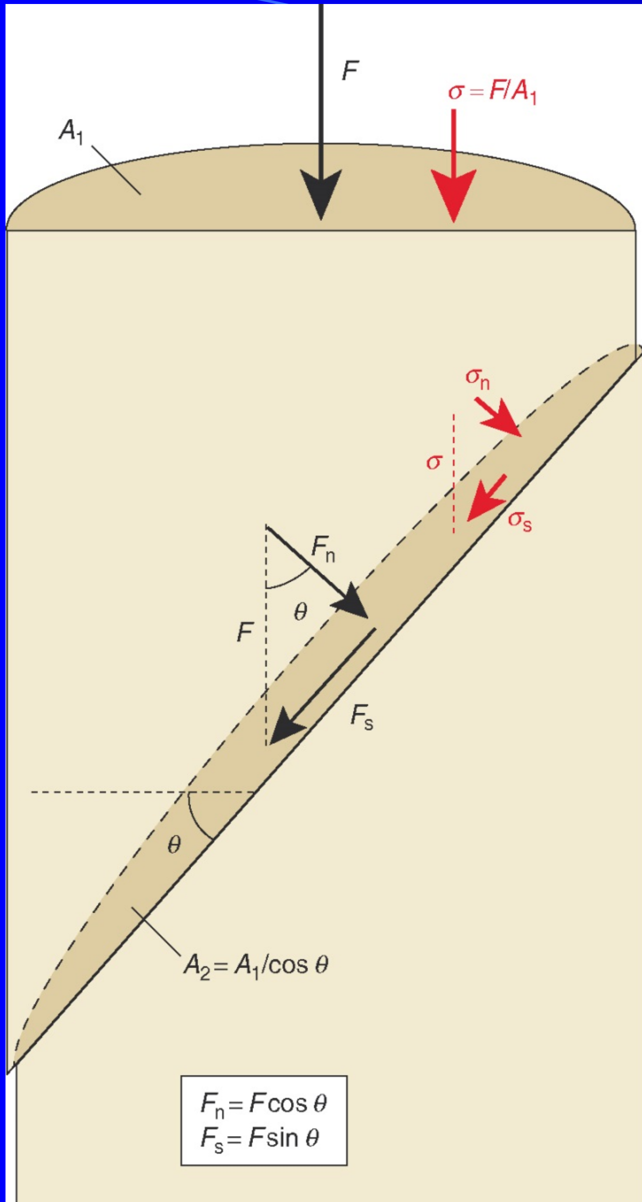
Faults and Fractures

Why do rocks break? Rock mechanics experiments – a first order understanding.

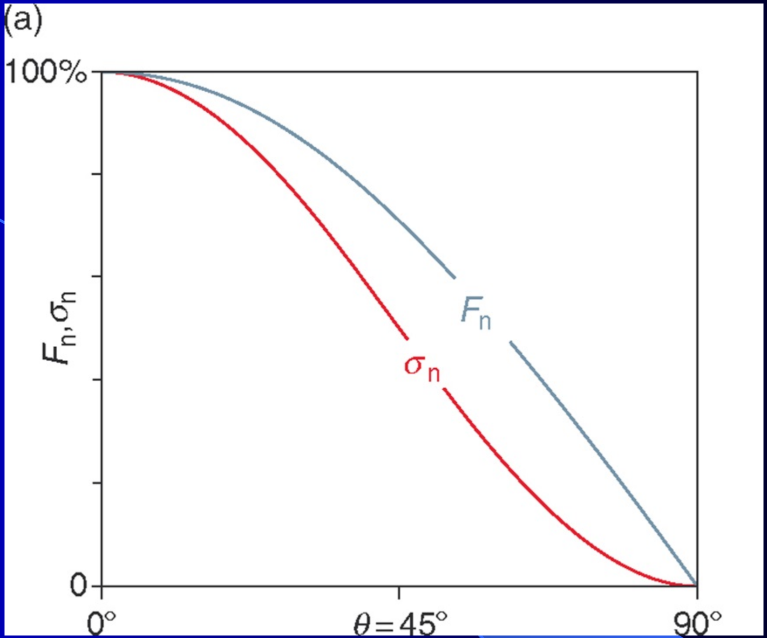


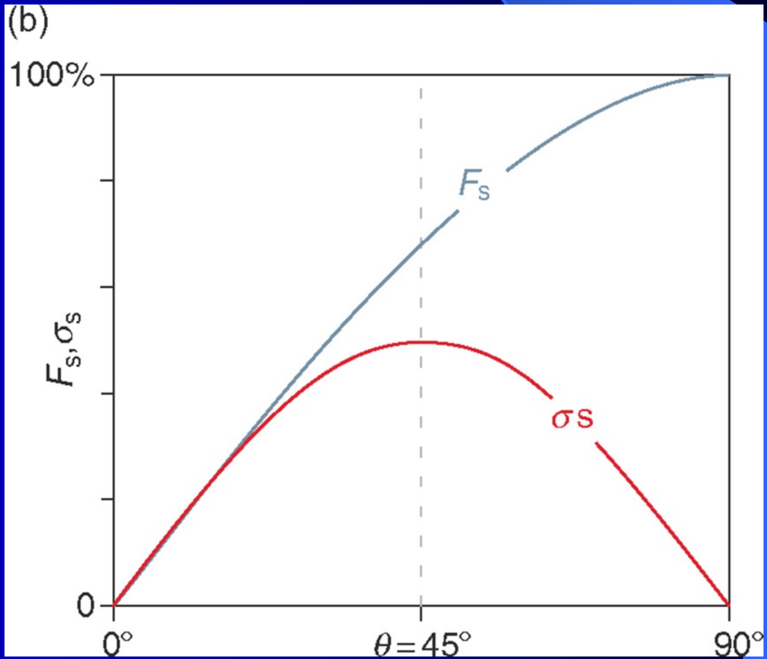


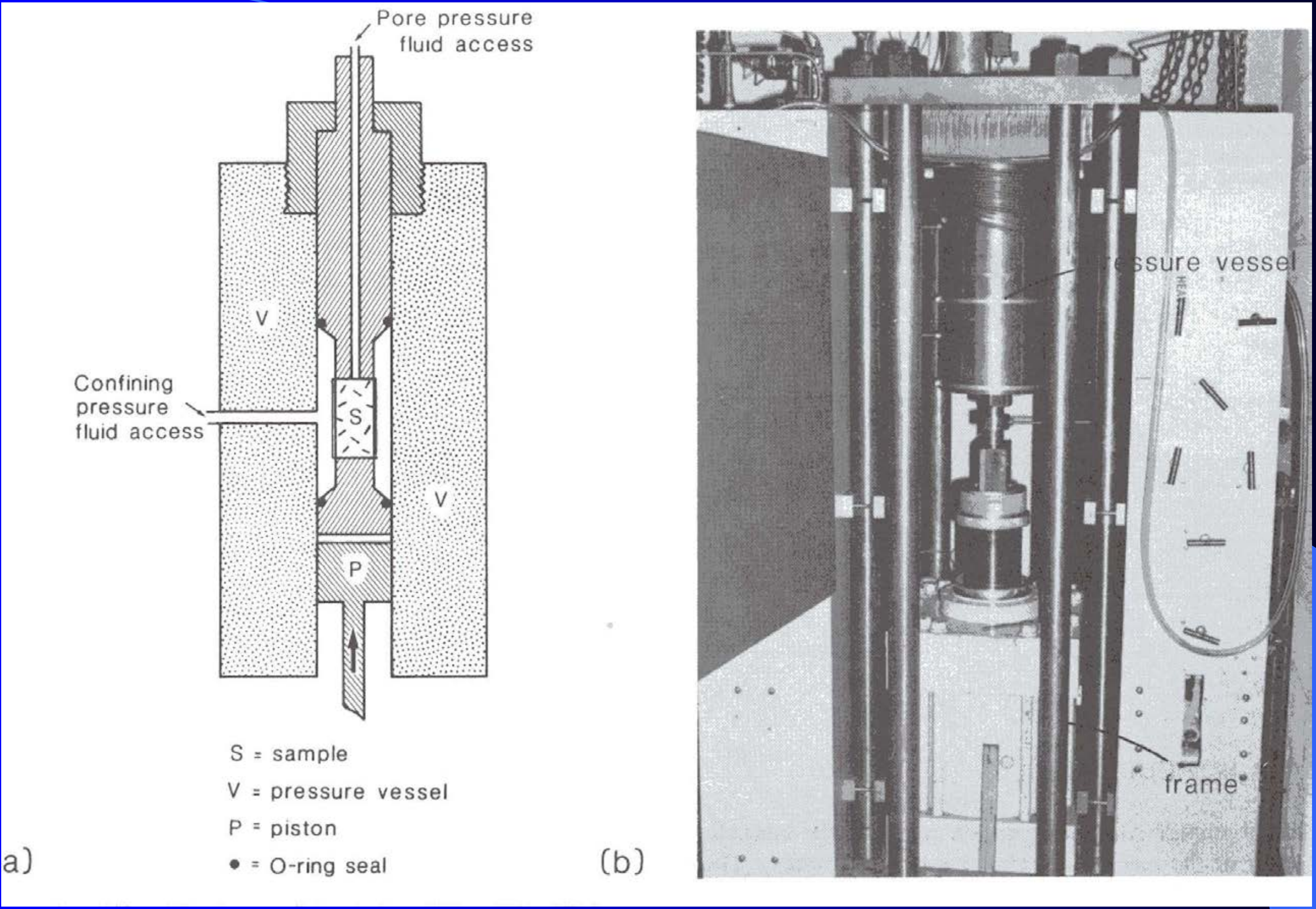
$\sigma_n = F_n/A_2 = F\cos\theta/A_2 = F\cos^2\theta/A_1 = \sigma\cos^2\theta$

$\sigma_s = F_s/A_2 = F\sin\theta/(A_1/\cos\theta)$

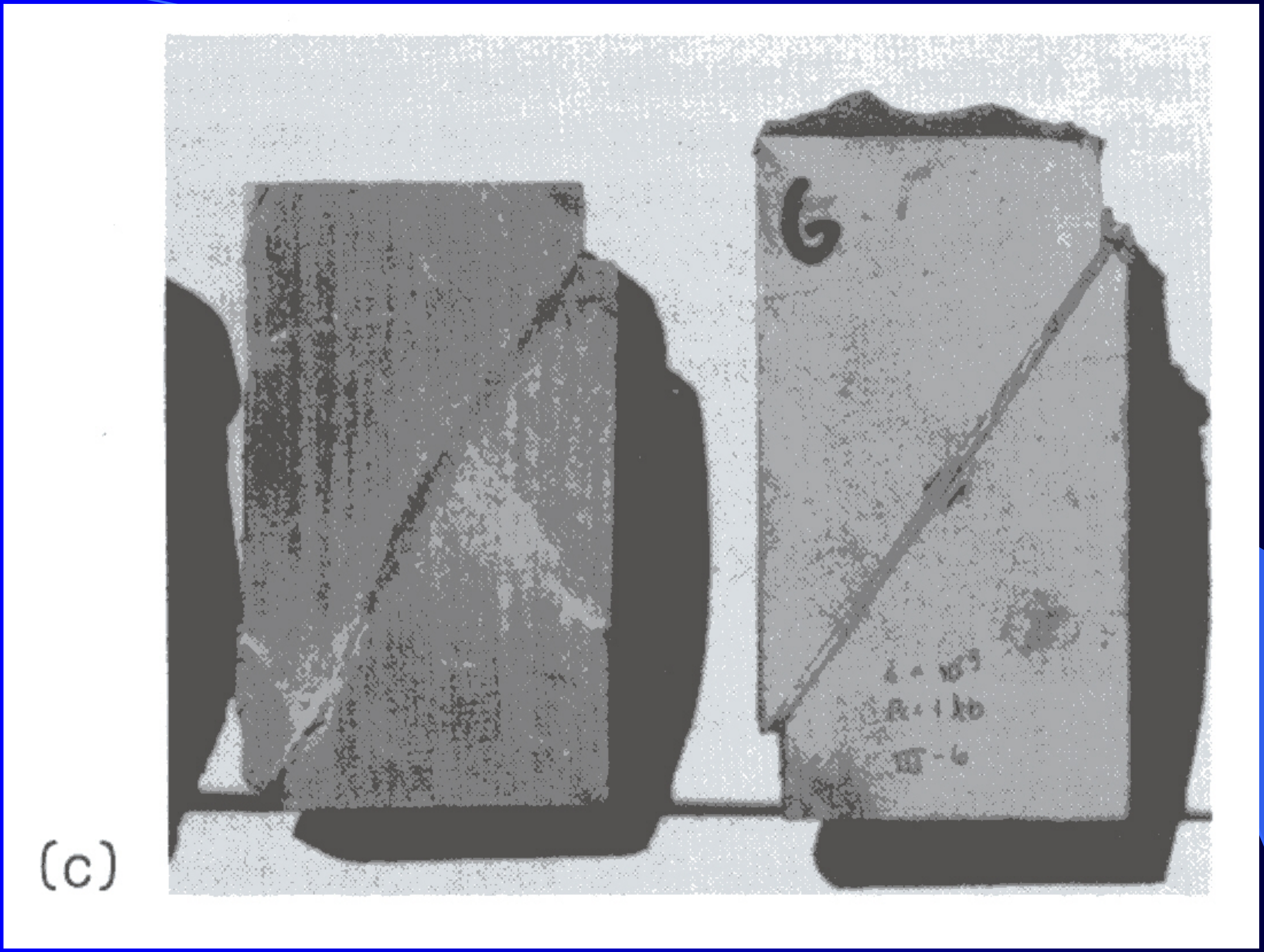
$= F\sin\theta\cos\theta/A_1 = \sigma\sin\theta\cos\theta = \sigma 1/2\sin 2\theta$





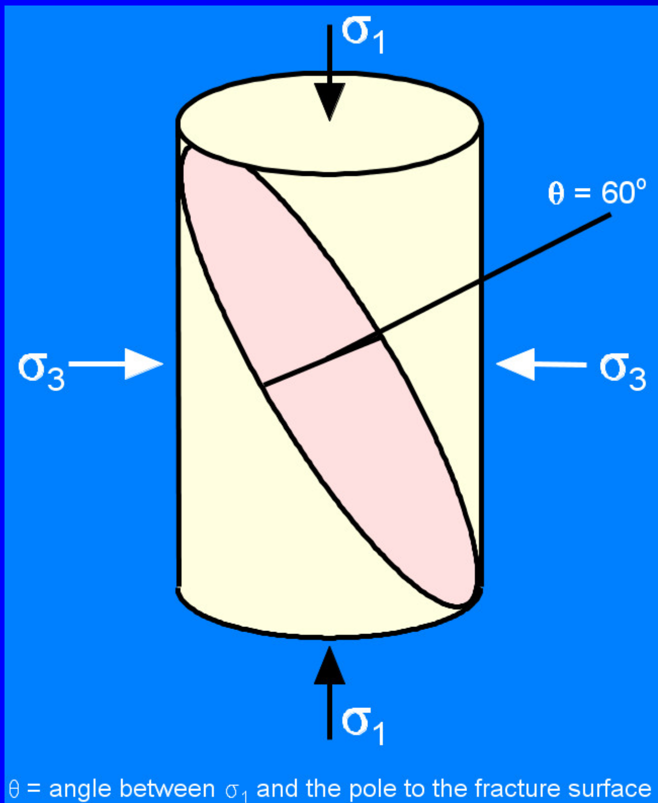


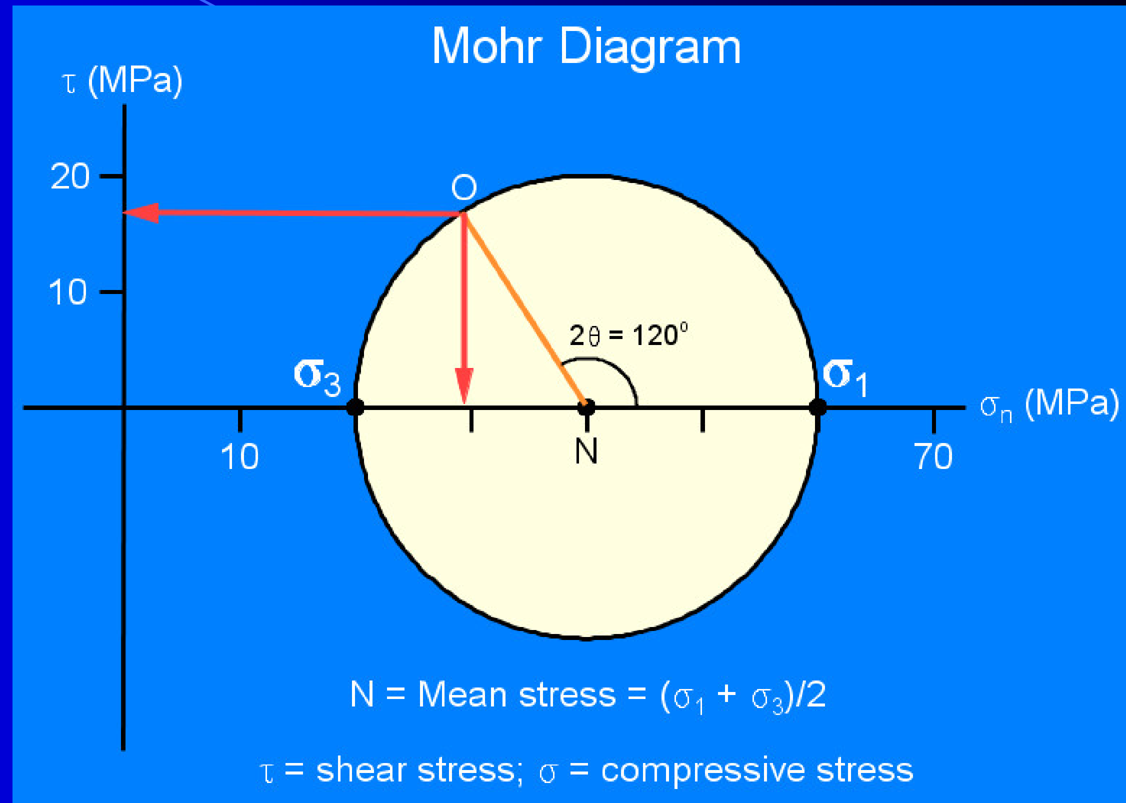
Triaxial load machine. a) cross-sectional sketch showing the pressure vessel, sample, and piston; b) photograph of machine.



Two deformed samples. L) induced fracture; R) saw-cut for friction experiments. There is a 5 mm-thick layer of gouge along the cut. Samples are 3.5" long and 2" in diameter.

Graphical representation of data from rock mechanics experiments – principal stress directions and the Mohr Diagram





Principal stress directions. Orthogonal coordinate system.

$$\sigma_1 \geq \sigma_2 \geq \sigma_3$$

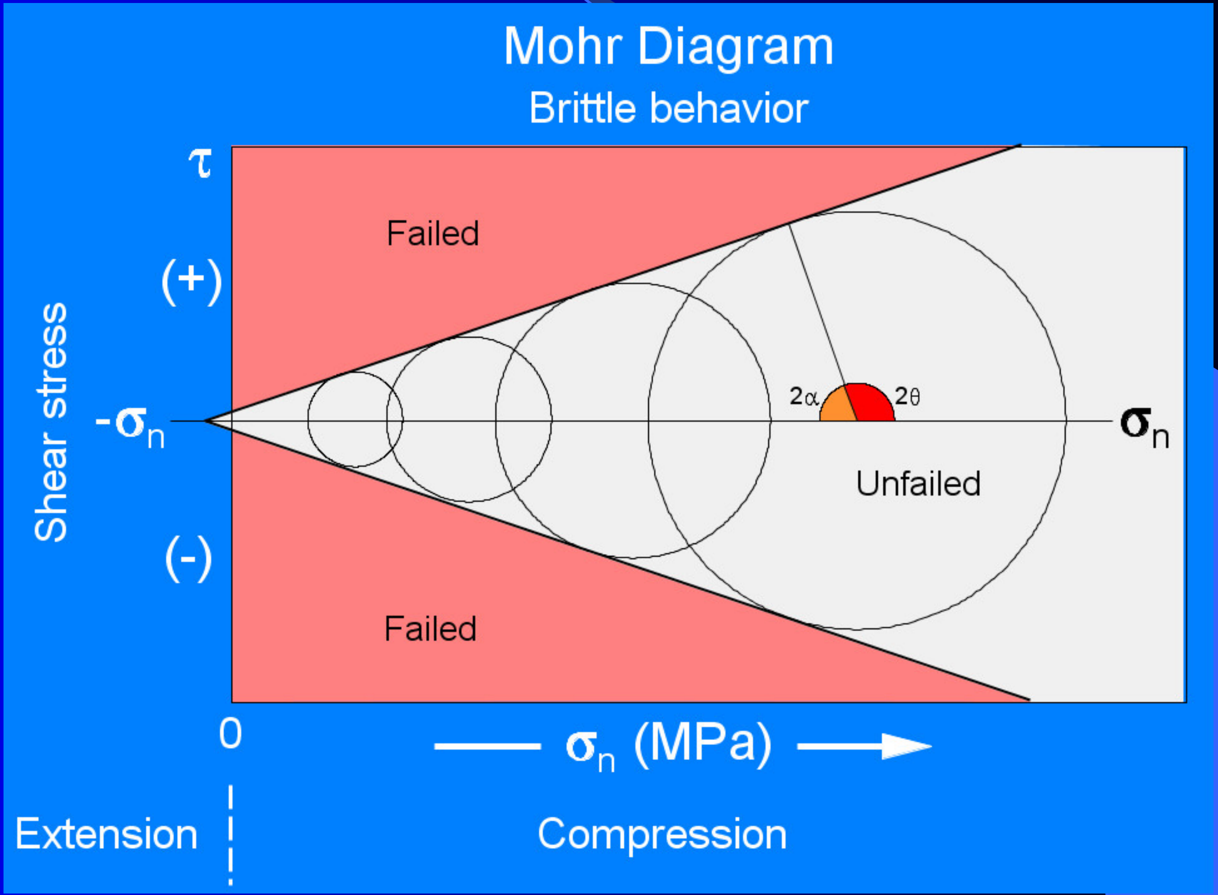
The Mohr Diagram is a graphical representation of the compressive and shear stress on a plane. In this example, θ = 60º, the angle between the principal stress direction and the pole to the plane.

Results of a triaxial load machine experiment. In this case the material exhibited brittle behavior. Coulomb-Mohr envelope is bounded by straight lines.

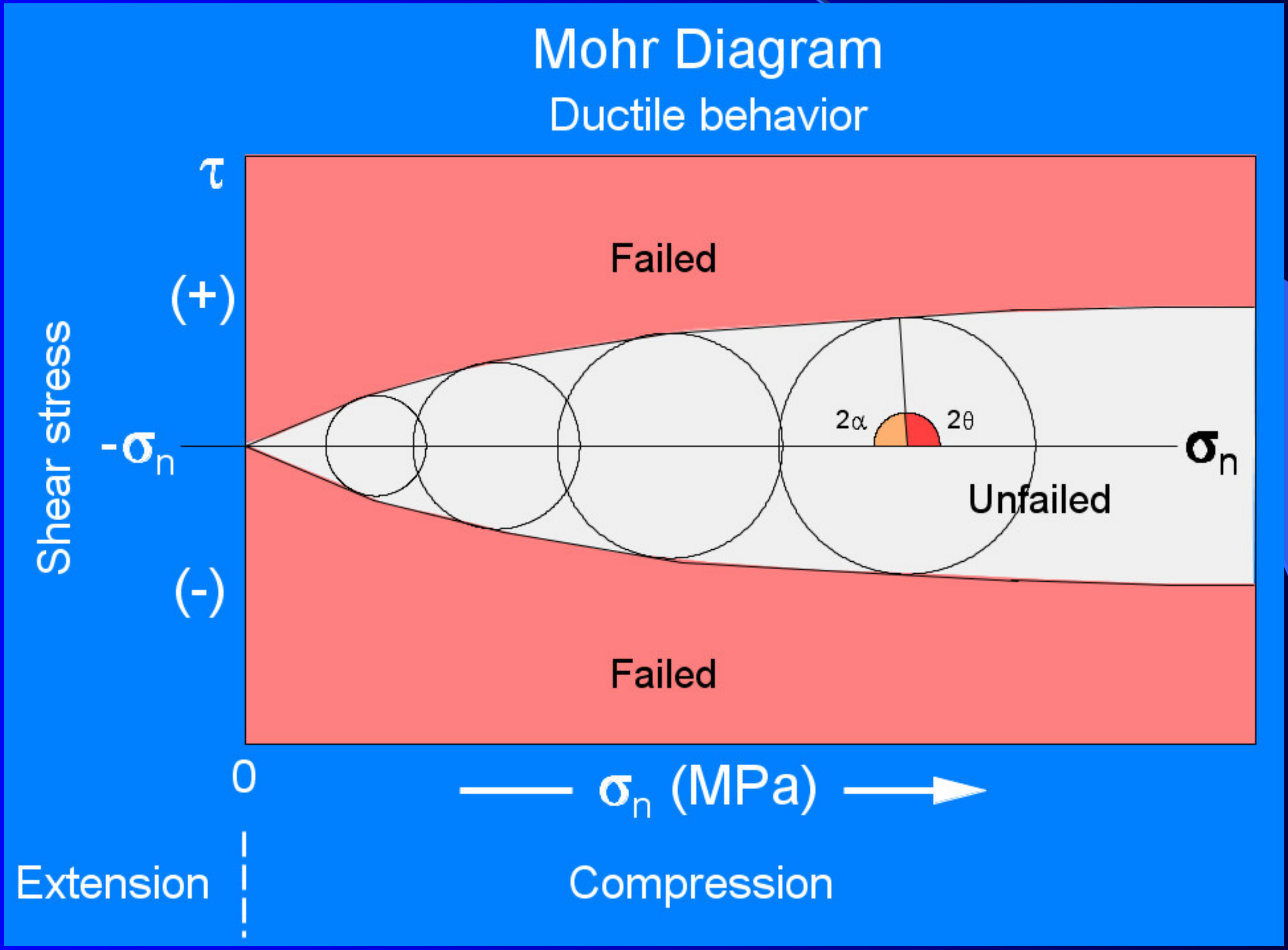
Experimental Data

σ_1 and σ_3 at failure

Test Run	σ_3 Mpa	σ_1 MPa
1	75	175
2	160	325
3	270	545
4	420	840



Results of a triaxial load machine experiment. In this case the material exhibited ductile behavior. Coulomb-Mohr envelope is bounded by curved lines.



What happens if fractures are present in the rock?

Equations for friction sliding:

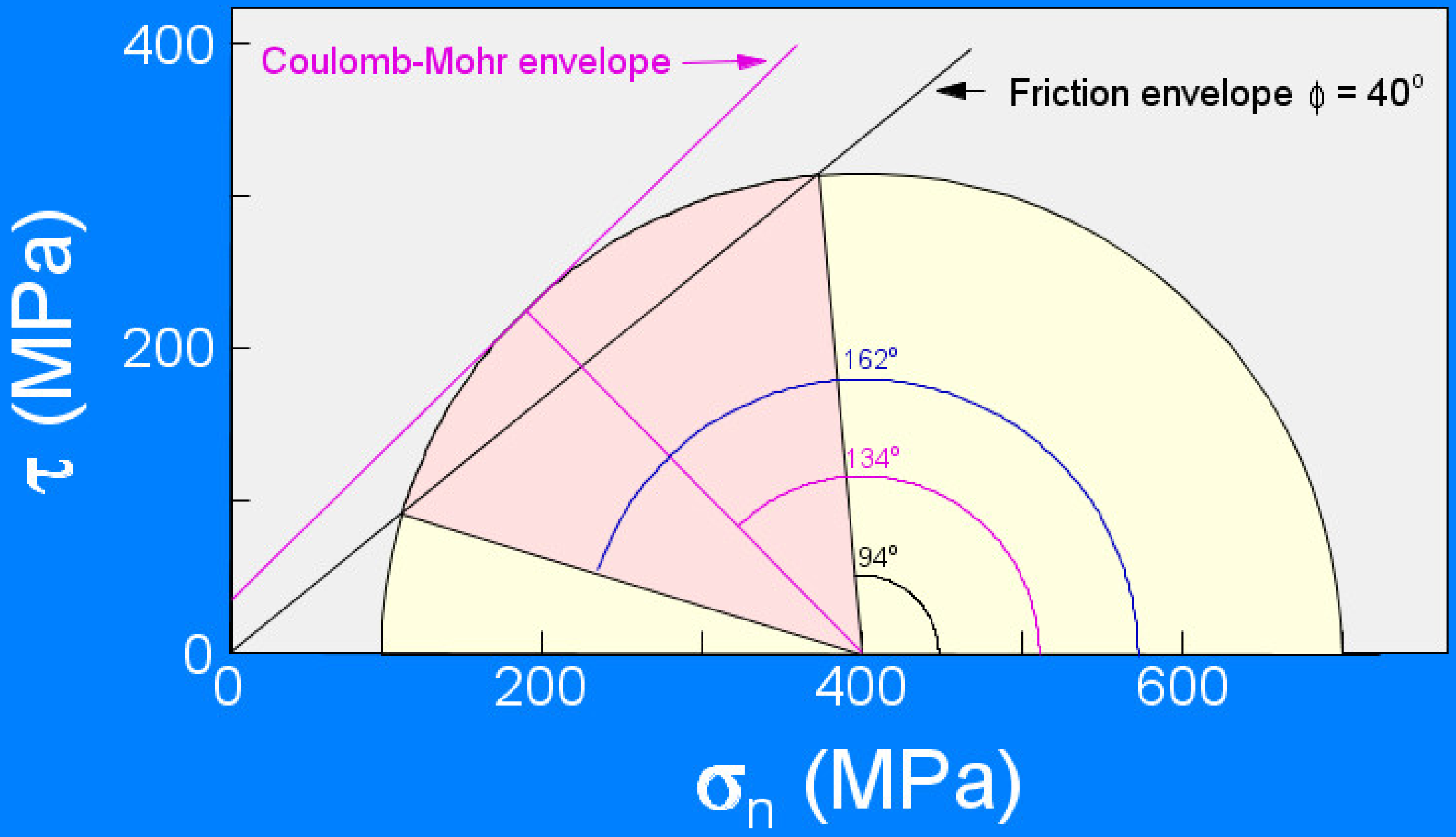
1) Mean Stress < 200 MPa (Depth < 7.5 km)

$$\tau = 0.85(\sigma_n)$$

2) Mean stress > 200 MPa (Depth > 7.5 km)

$$\tau = 50 + 0.6(\sigma_n)$$

These are empirical equations based on rock mechanics experiments.



Movement will occur along existing fault planes dipping between 47º and 81º (friction envelope). If fault planes with these orientations are not present in the rock, fracture will occur at 67º when the stress (as represented by the Mohr circle) reaches the Coulomb-Mohr envelope.

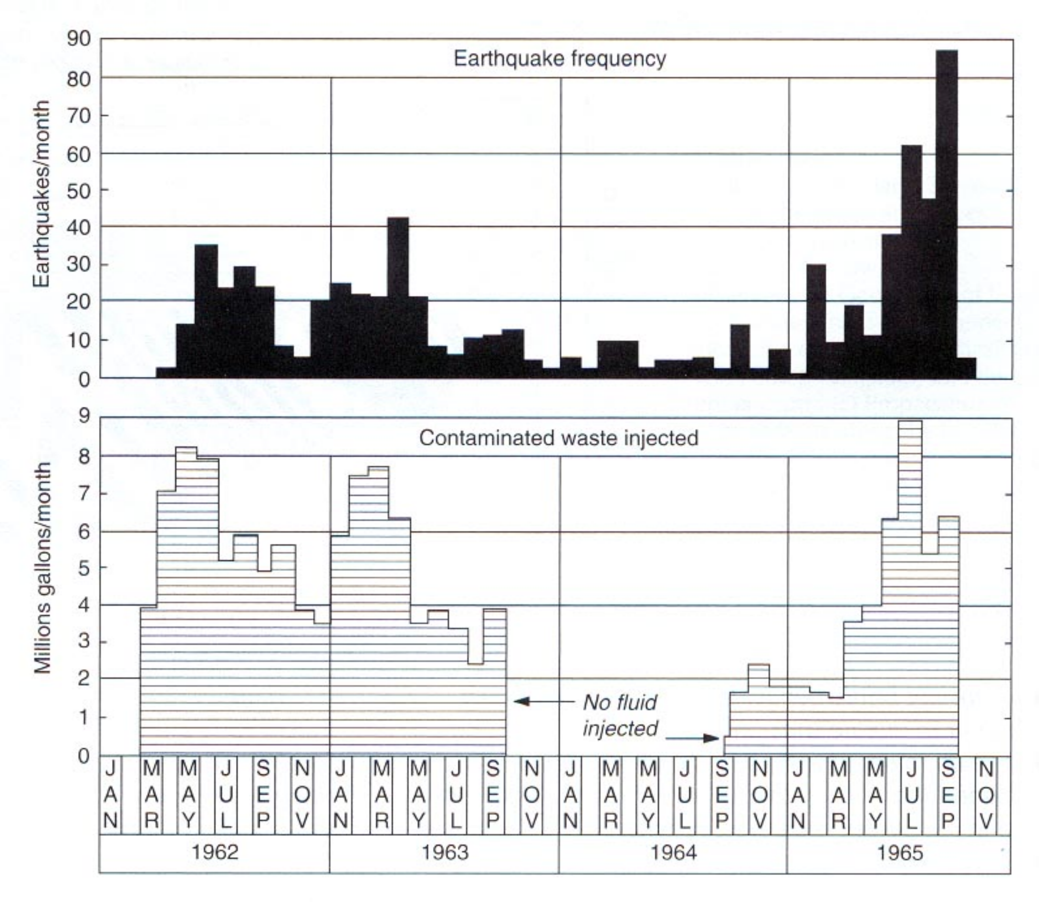
Fluids and earthquakes

If water, or another fluid, occurs in a fault zone

$$\tau = \mu(\sigma_n - P_w) = \mu S$$

where P_w = fluid pressure and $(\sigma_n - P_w)$ = effective normal stress S.

The famous beer can experiment – you must be 21 or older to try this experiment.



Rocky Mount Arsenal deep waste-disposal well and Denver earthquakes.

Orientation of present-day US principal stresses

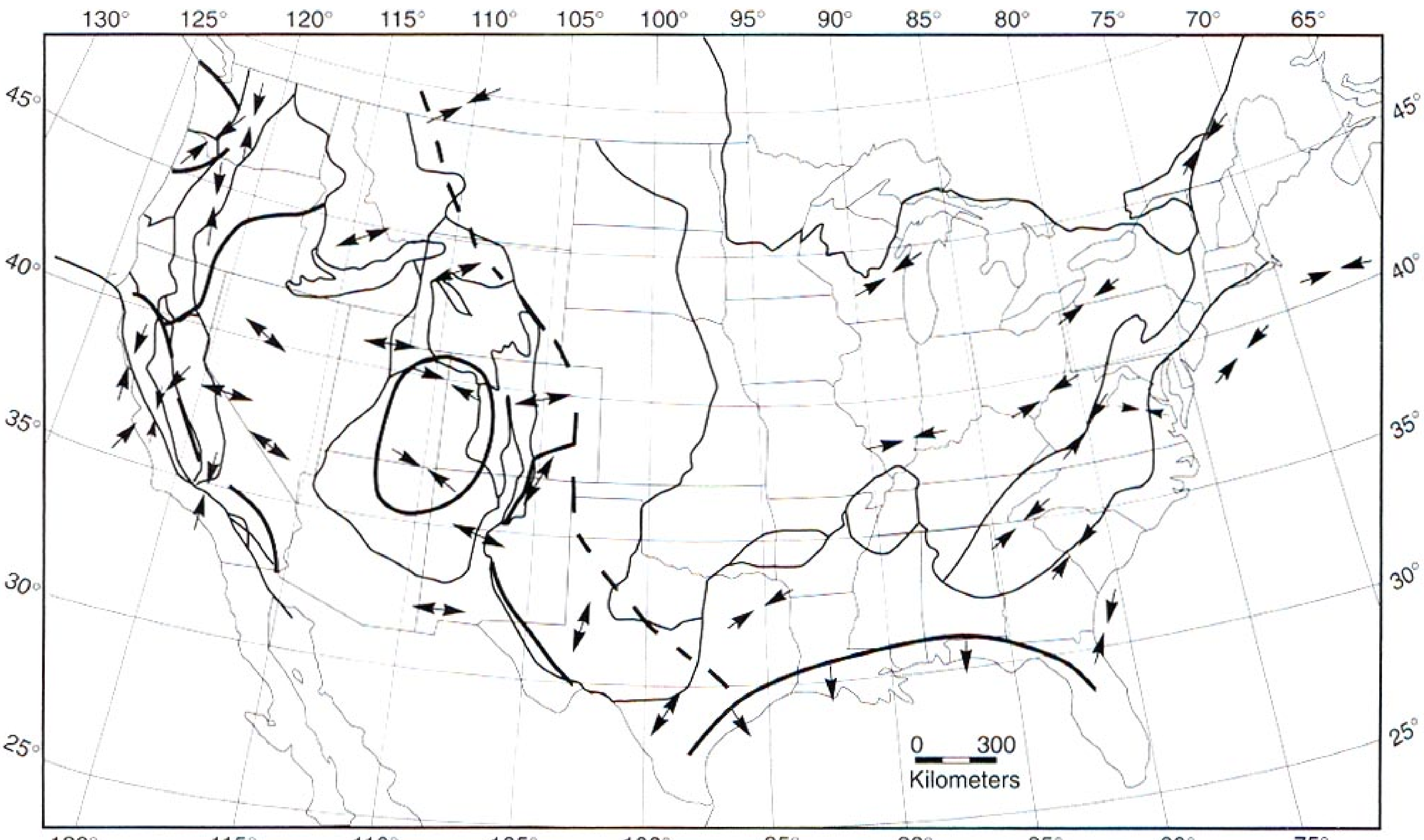
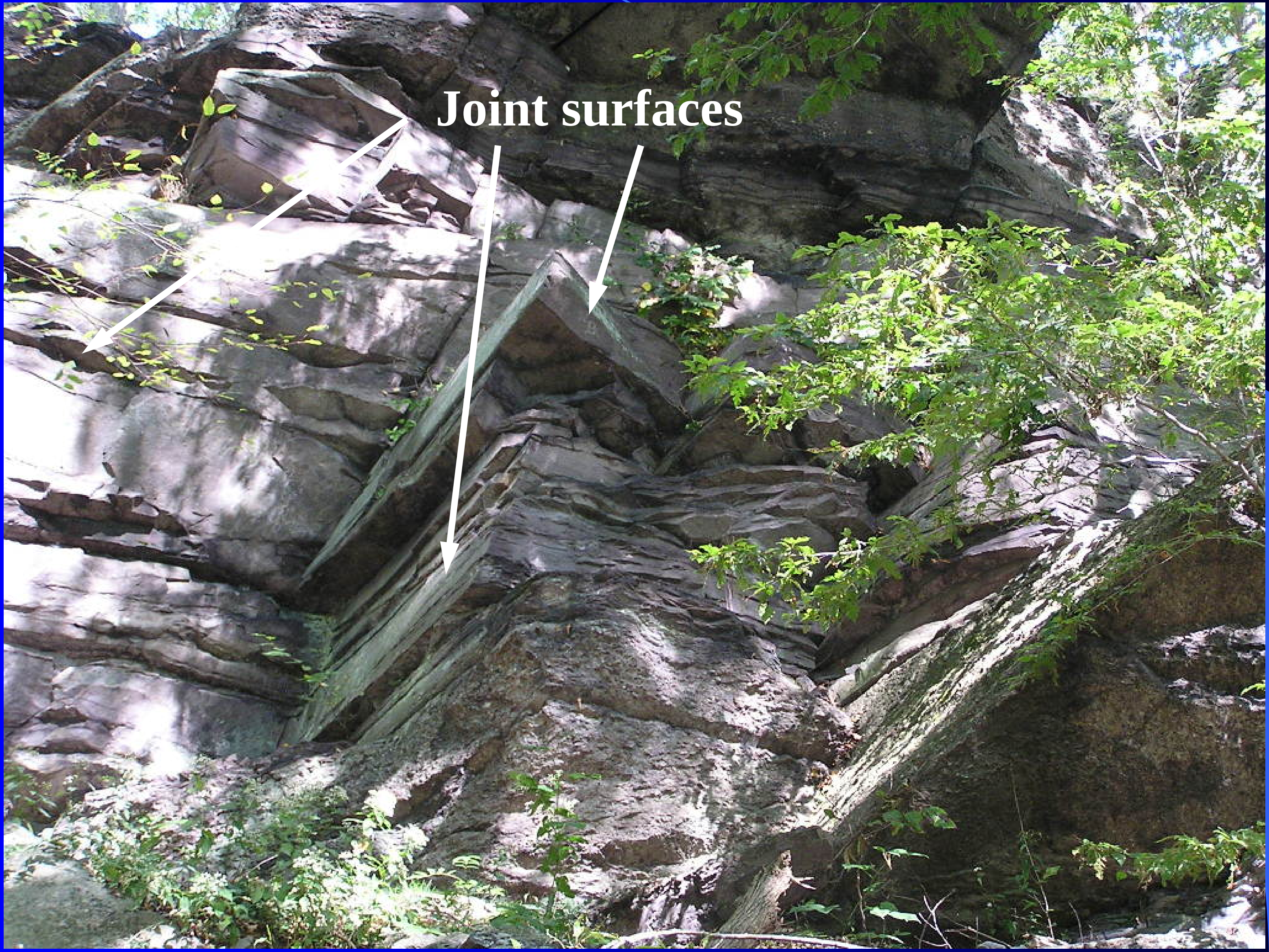


FIGURE 3E–3

Domains of common orientation of present-day maximum (compressional) and minimum (extensional) principal stress in the United States. Arrowheads indicate whether stress is extensional or compressional. (From M. L. Zoback and M. D. Zoback, 1989, Geological Society of America *Memoir 172*.)

What is the origin of the observed stress field? – Movement of tectonic plates.

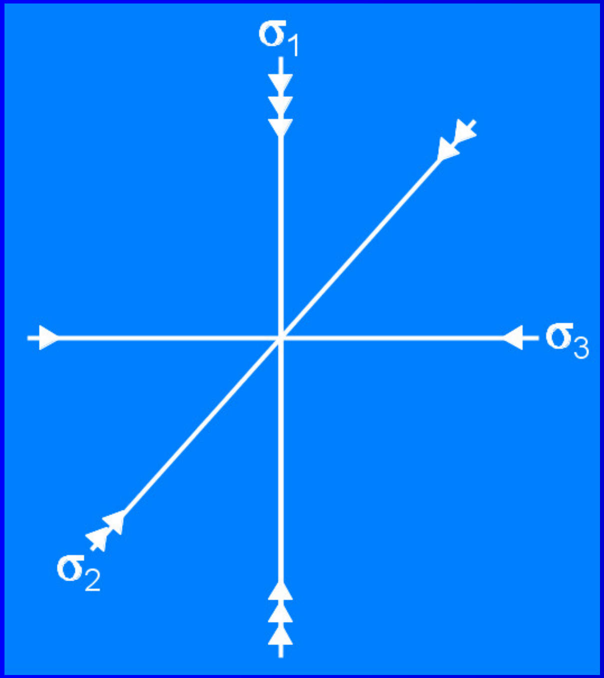
Joints – fractures in rocks along which there is negligible movement.



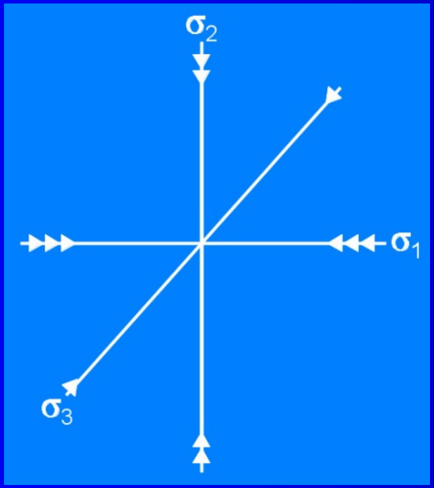
Types of Faults

Normal fault. Left side moved down relative to right side.

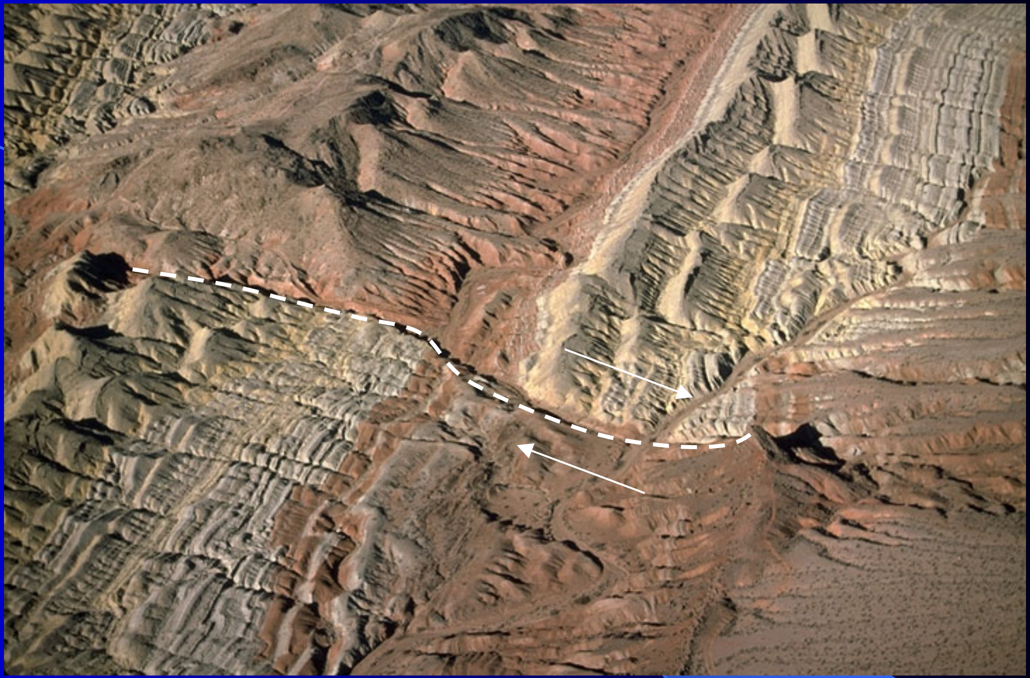
Principal stress orientations



Right lateral **strike-slip fault**.

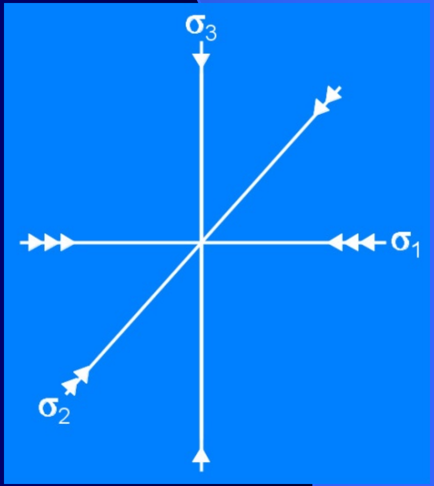


Principle stress orientations



Thrust fault. Block on left thrust up and over the block on the right.

Principal stress orientations



Slickensides show sense and direction of movement on a fault plane.

Direction of movement