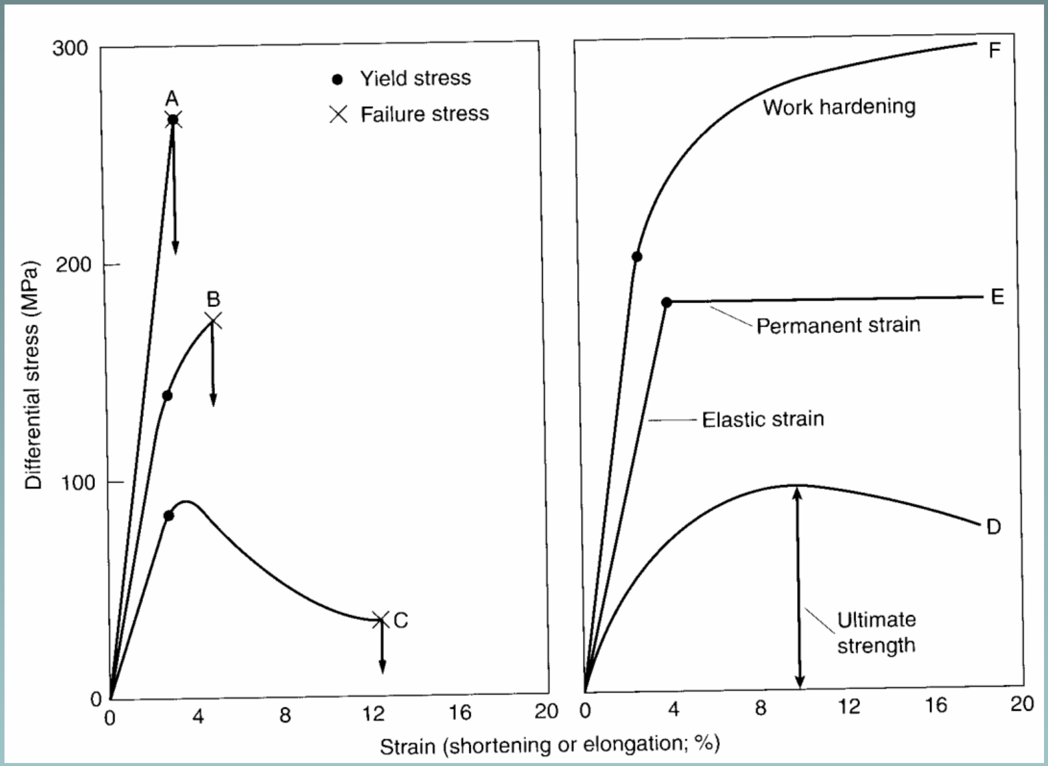
Lecture 5: Failure in Rocks
(Ref: Fossen; Twiss & Moores)

• **Failure:** Rock is unable to support stress increase without permanent deformation



Non-linear behavior between stress and strain

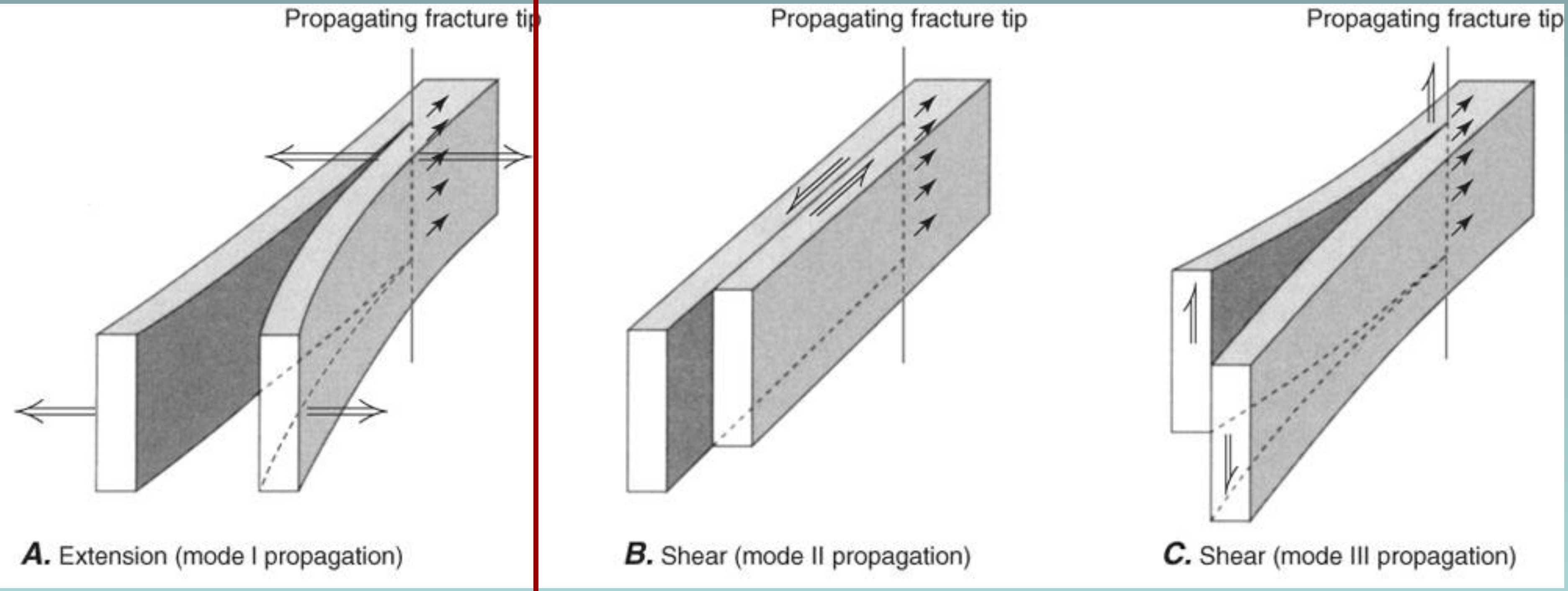
Brittle Failure – Rock breaks to form continuous fractures resulting in the loss of cohesion.

Ductile Failure – Material deforms permanently without losing cohesion.

Brittle Failure – 1. Development of new fracture in an intact rock

2. Slip on a pre-existing fracture in a previously fractured rock

Different Types of Fractures



Relative displacement is perpendicular to fracture

Relative displacement is Parallel to the fracture; perpendicular to edge of fracture

Relative displacement is Parallel to the fracture; parallel to edge of fracture

Extension Fractures (Joints)

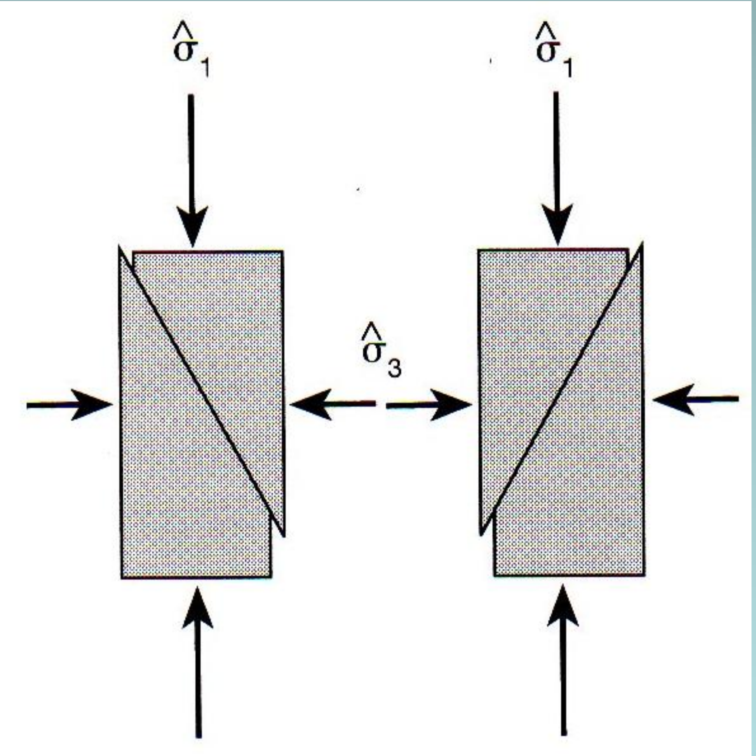
Shear Fractures (Faults/ Fault zones)

Brittle Failure

Experimental Deformation

Shear Fractures: **Form under confined compression; at angles < 45° to maximum Compressive stress σ_1; displacement parallel to fracture surface**

- **Generally in conjugate pairs, bisected by σ_1**



D. Conjugate shear fractures

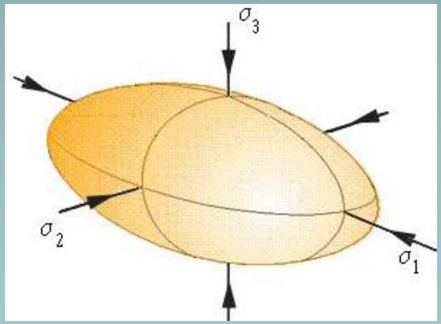
Faults

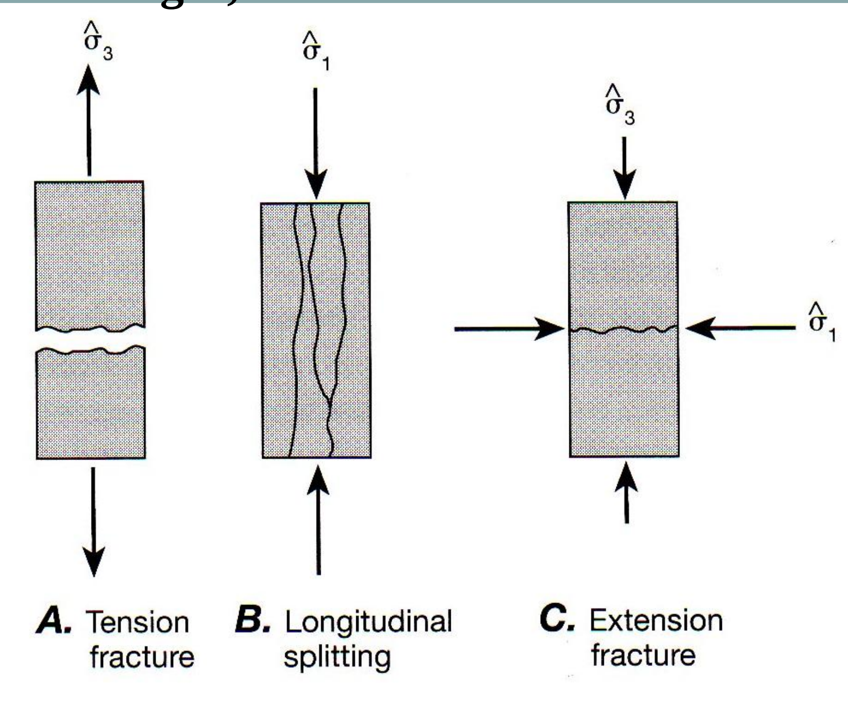
Brittle Failure

Experimental Deformation

Extension Fractures: Fracture plane perpendicular to σ_3 (minimum principal stress) & parallel to σ_1; displacement approximately normal to fracture surface.

- contain σ_1 & σ_2
- Form under low/no confining P; low differential stress
- very low strain





If σ_3 is tensile (uniaxial tension)

Near surface

σ_1 is axial stress (uniaxial compression; σ_3 is $\cong$ 0)

σ_3 is minimum compressive stress

Stress Distribution & Faulting

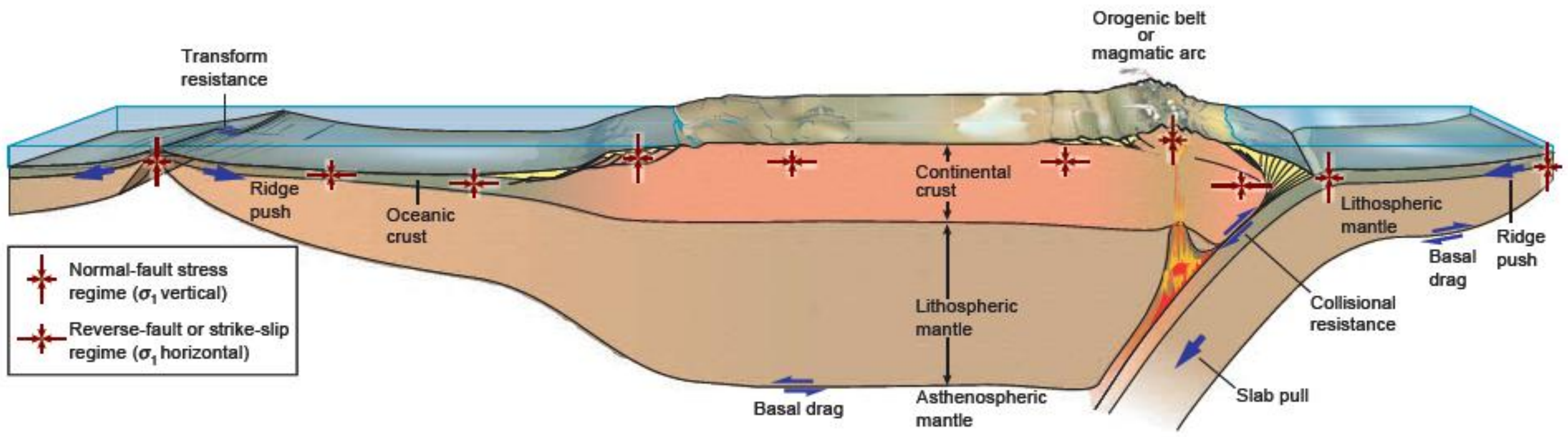


Figure 5.14 Forces related to plate tectonics (blue arrows) and stress regimes expected from these forces. The maximum stress axis in continental plates is expected to be horizontal except for the upper part of rift zones (continental rift not shown), passive margins and elevated parts of orogenic belts.

Anderson's Theory

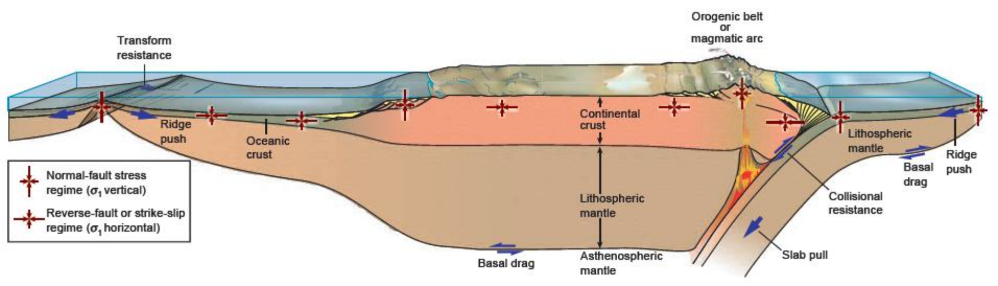
Stress Distribution & Faulting

Anderson's Fault Theory (1940's)

Some Assumptions:

- **Earth surface has no shear stress**
- **Earth surface is a principal plane of stress; principal stresses are normal & parallel to it**
- **Principal axis is perpendicular to earth's surface**
- **Isotropic material**

Anderson's Fault Theory (1940's)



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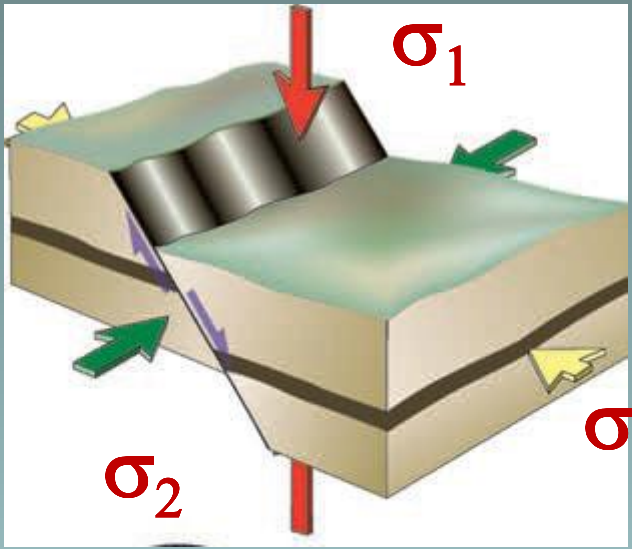


Dip of the fault =60°

Normal fault

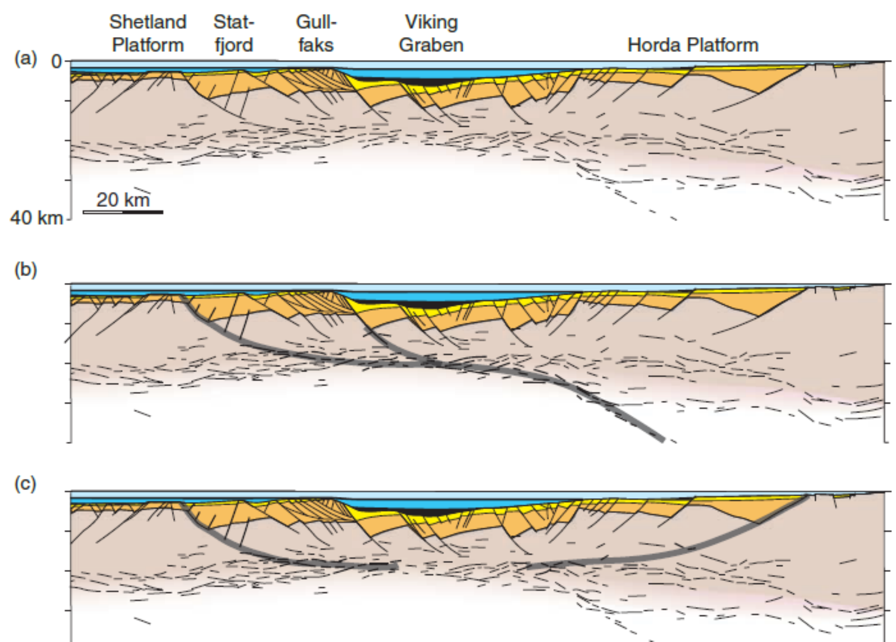
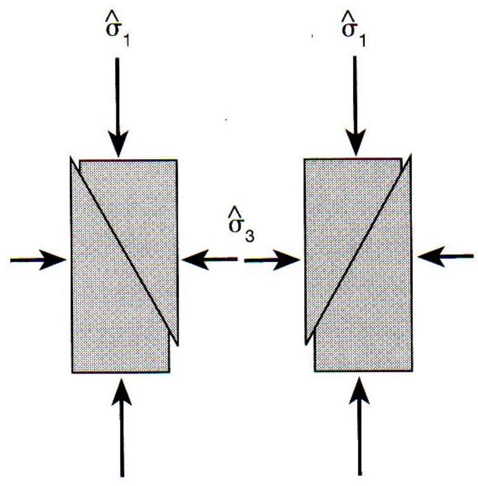
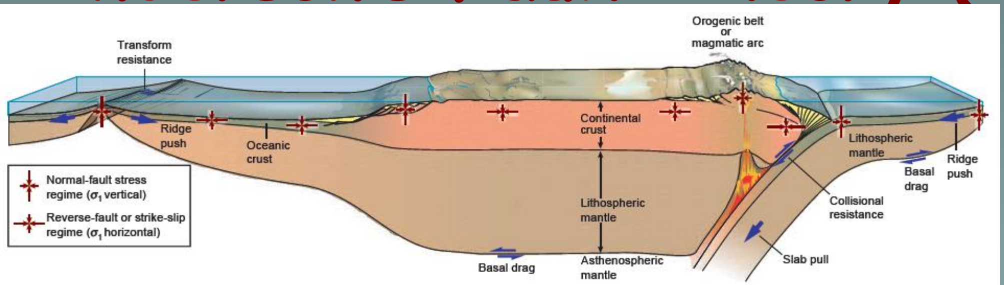


Figure 17.16 Section based on a deep seismic line across the northern North Sea. This section has been interpreted in terms of pure shear (b) as well as simple shear (c) and may be considered to contain elements of both models. Based on Odinsen *et al.* (2000).



D. Conjugate shear fractures

Anderson's Fault Theory (1940's)



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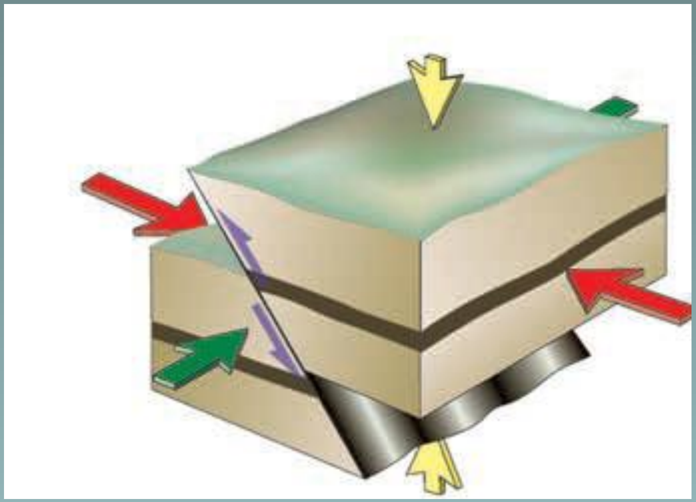
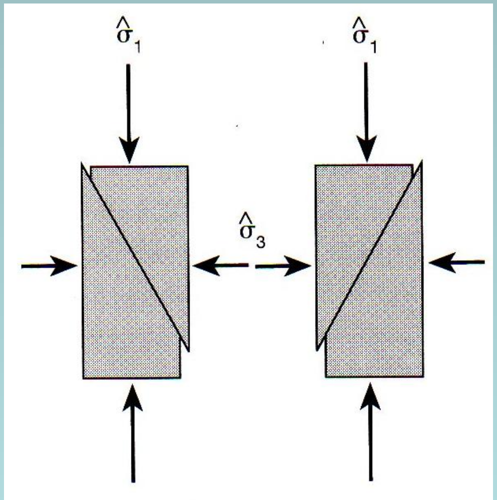


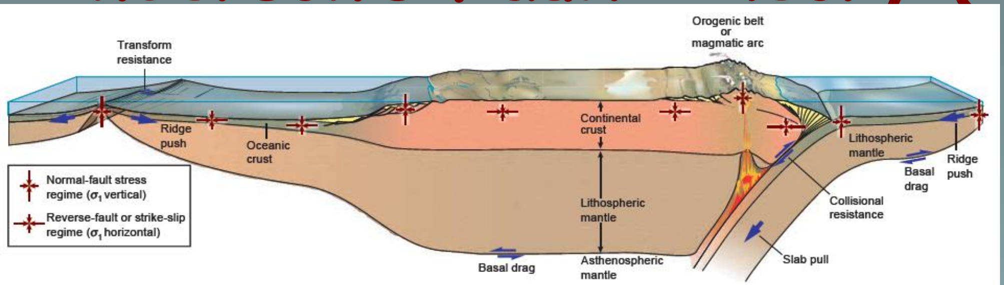
Reverse fault

Dip of the fault =30°



D. Conjugate
shear fractures

Anderson's Fault Theory (1940's)



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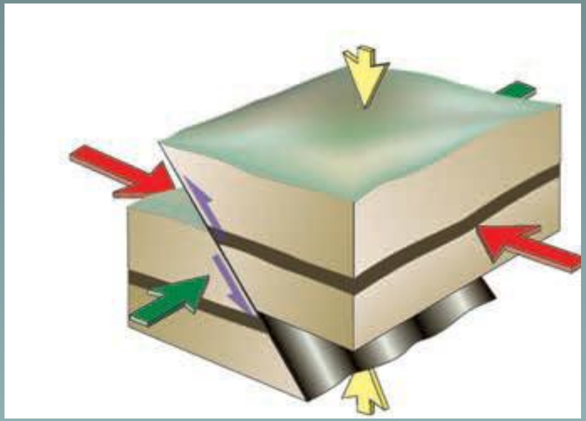
σ_3

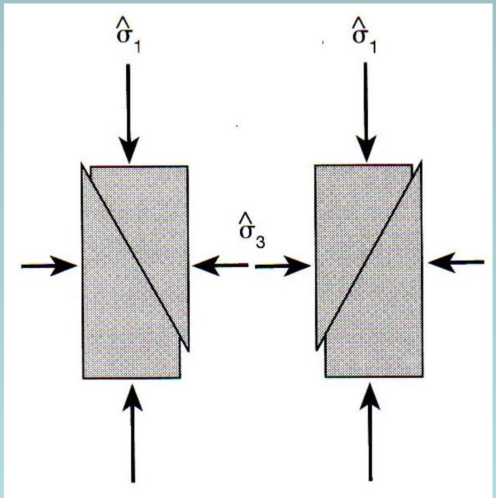


σ_1

σ_2

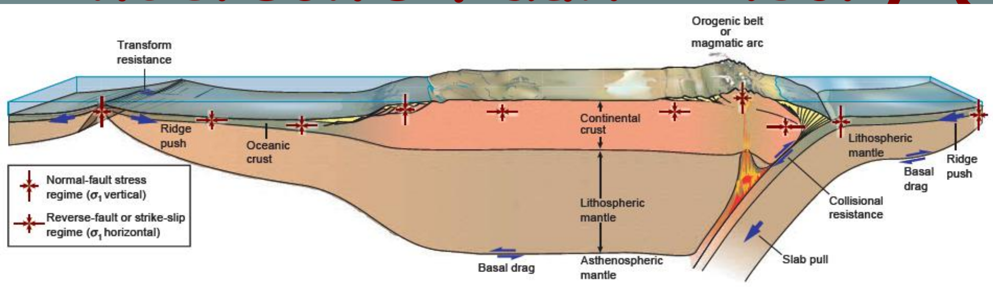
Reverse fault

Dip of the fault =30°



D. Conjugate shear fractures

Anderson's Fault Theory (1940's)



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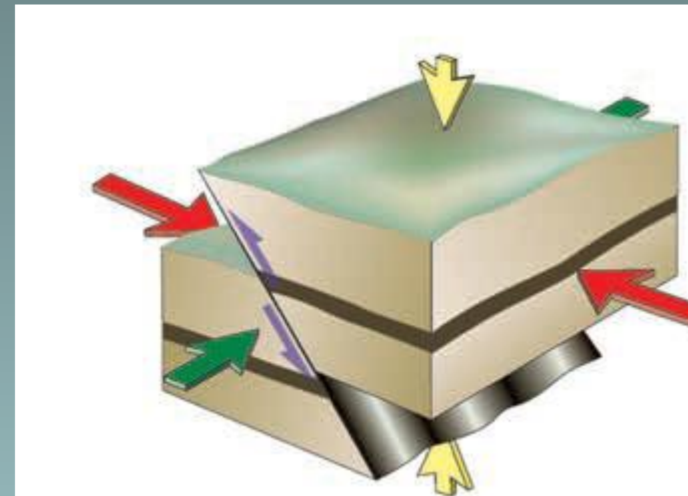
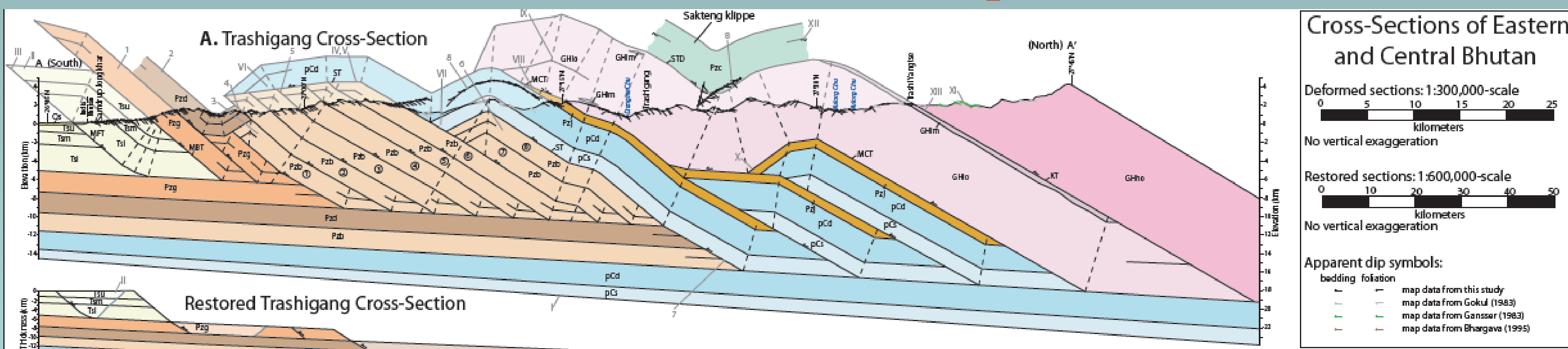


Reverse fault

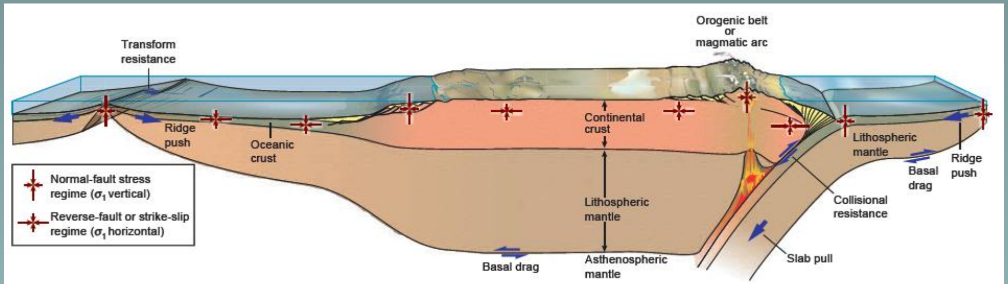
Dip of the fault =30°



(Long et al., 2011)

Anderson's Fault Theory (1940's)

Strike-slip fault



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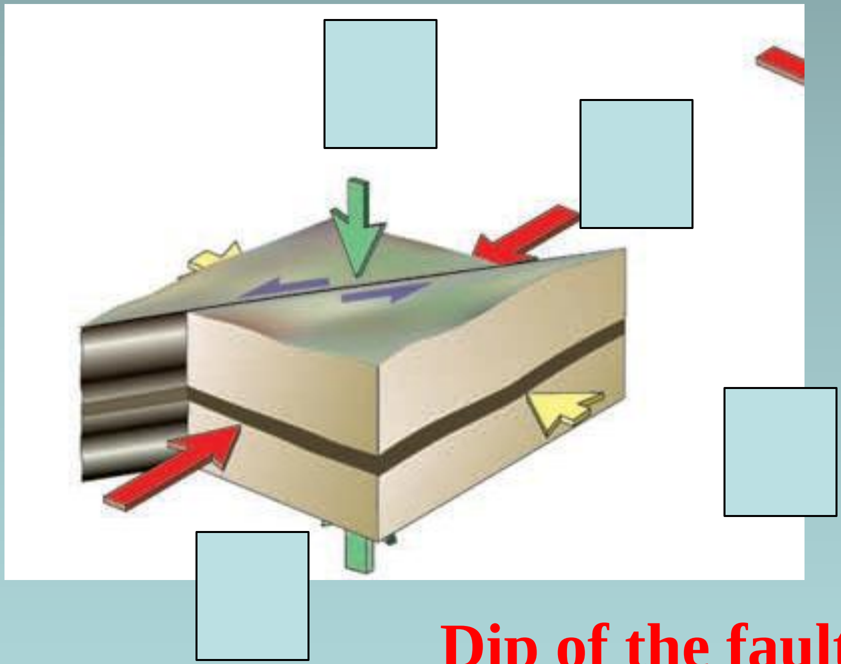
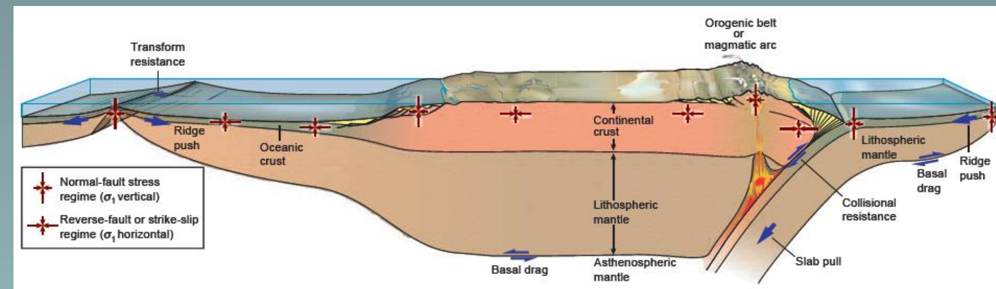


Dip of the fault =90°

Anderson's Fault Theory (1940's)

Strike-slip fault



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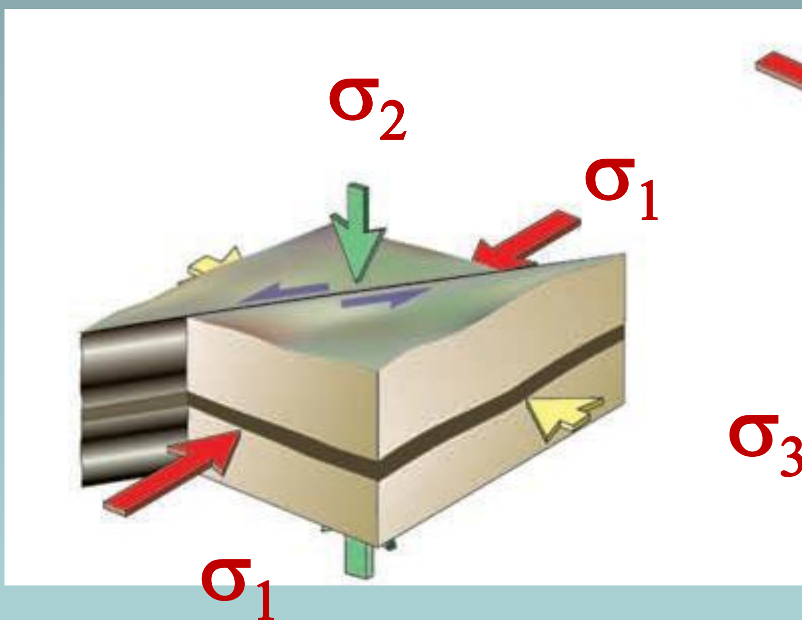

Dip of the fault =90°