Structural Geology
(Geol 305)
Semester (071)

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ROCK MECHANICS

OBJECTIVES

By the end of this unit you will be able to know the following:

- **What is Rock mechanics?**
- **Why it is important?**
- **What is Stress, Strain and Deformation?**
- **The graphical representation of Stress and Strain**
- **What is Mohr's Circle??**
- **Simple Shear and Pure Shear**
- **The Strain Markers**

ROCK MECHANICS

Is the application of physics to the study of rock materials. It deals with the properties of rocks and the relationships between forces and resulting structures and structures resulted in lab. to duplicate natural structures.

In Lab. there is control of temperatures and pressures but not time?. (geologic time).
So temperature and pressure are increased in Lab. to fasting the deformation.

STRESS

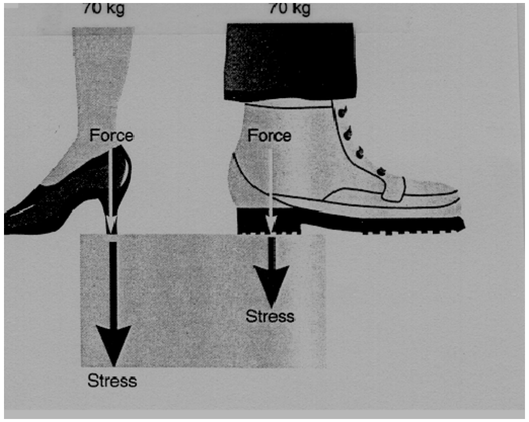
STRESS: is force applied to an area, or force per unit area

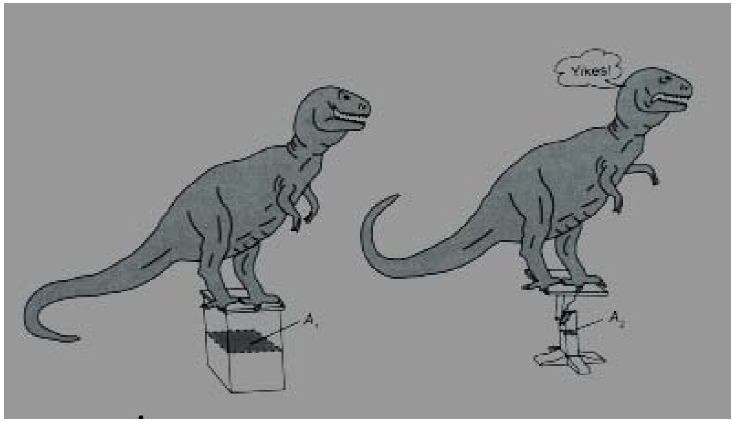
Stress is generated by the forces that move, develop, and consume lithospheric plates. It is also induced by gravity and produce different salt tectonic structures.

Tectonic structure is a product of deformation that is resulted from stress imposed on rock mass.

To understand the tectonic structures we need to understand the nature of stress (orientation and amount)

Because those stresses are not available now so experimental work that duplicate the natural structures may help to estimate the orientations and magnitude of stresses.





Mathematical Description of Stresses and Forces

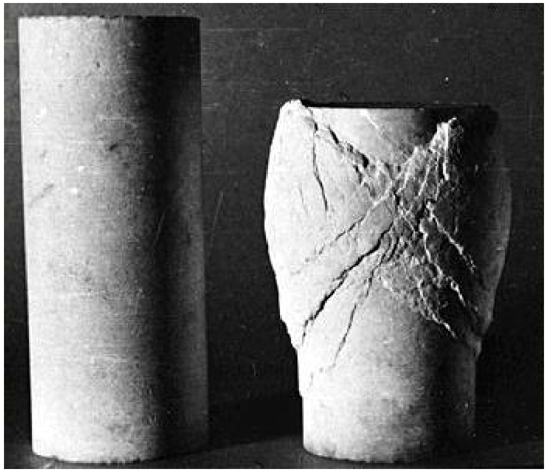
- **Scalar:** only magnitude (speed, price of oil, temperature, thickness .. etc.)
- **Vector:** both magnitude and direction (velocity, Earth's magnetic field, acceleration … etc.)
- **Stress and Force are vectors quantity**

Force is a vector that produces a change in the velocity or direction of motion of a body that may either may be stationary or may already be in motion.

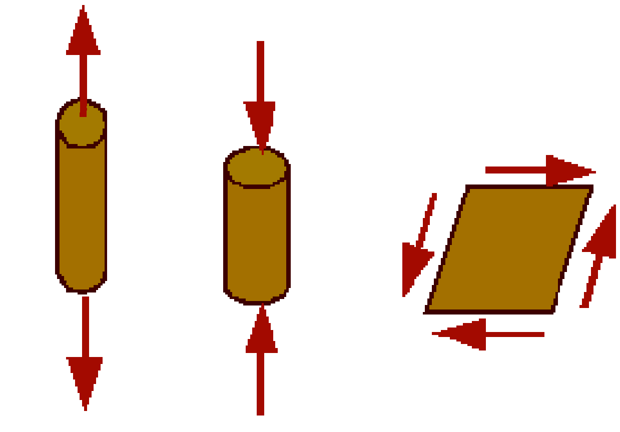
F = m a (Newton's second law)

Type of Stresses

- **Compression** (pushing together)
- **Tensional** (pulling apart)
- **Body force** act equally on all parts of a body (gravity)
- **Surface force** act on external or internal surface within rock masses and include forces acting along fault or major plate boundary.



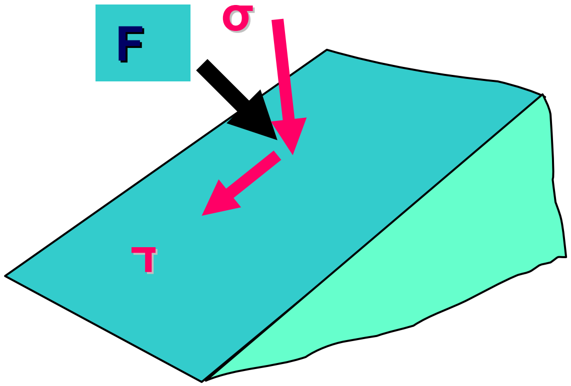
Surface force can be resolved into perpendicular components one normal to the surface and one or two parallel to the surface.



Stress acting on a surface may be resolved onto two vector components

normal stress acts perpendicular to a surface σ

shear stress acts parallel to a surface τ



Resolved Principle Stress Components (two dimensions)

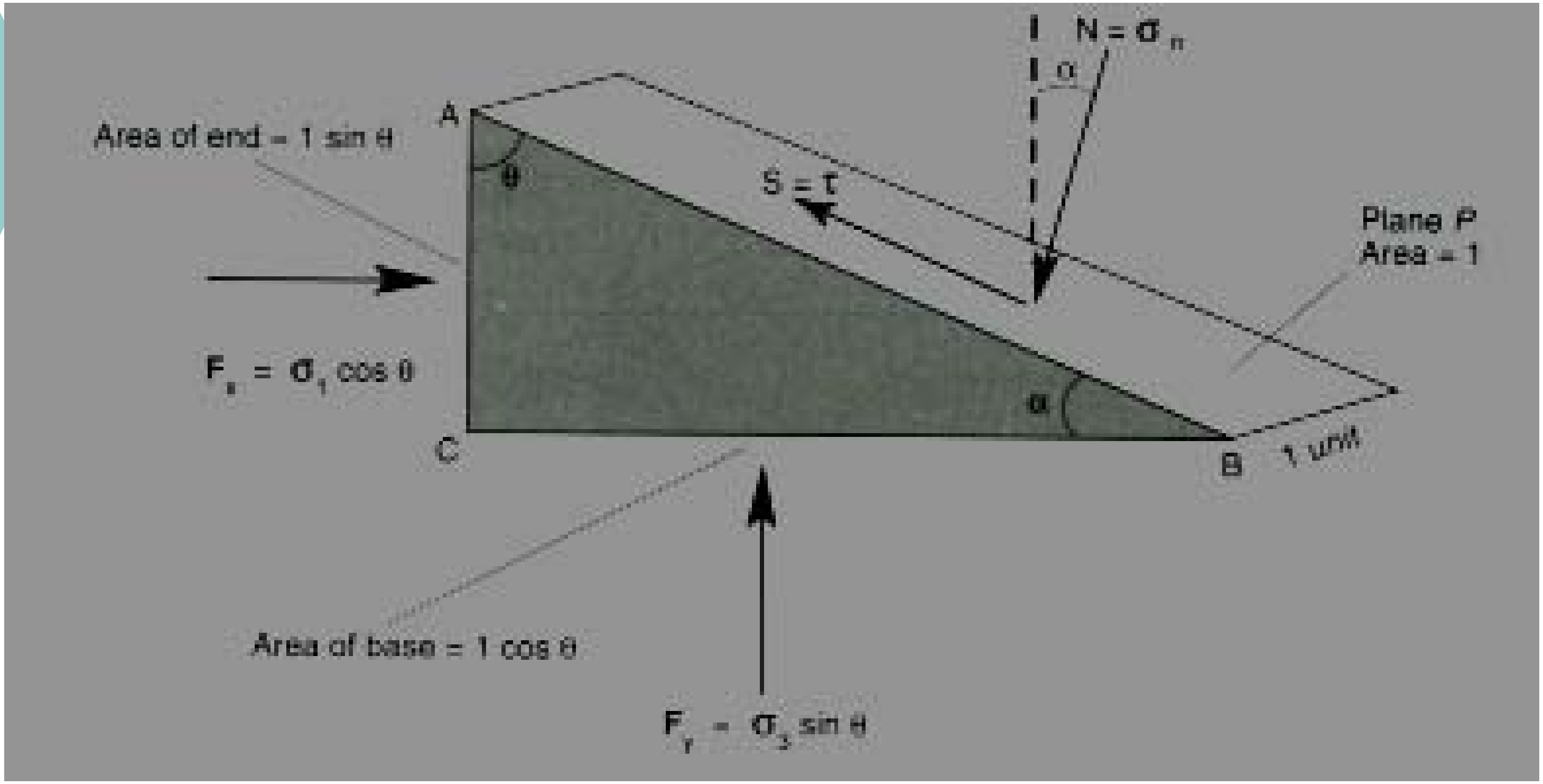


Figure from Hatcher, 1995

MOHR'S CIRCLE

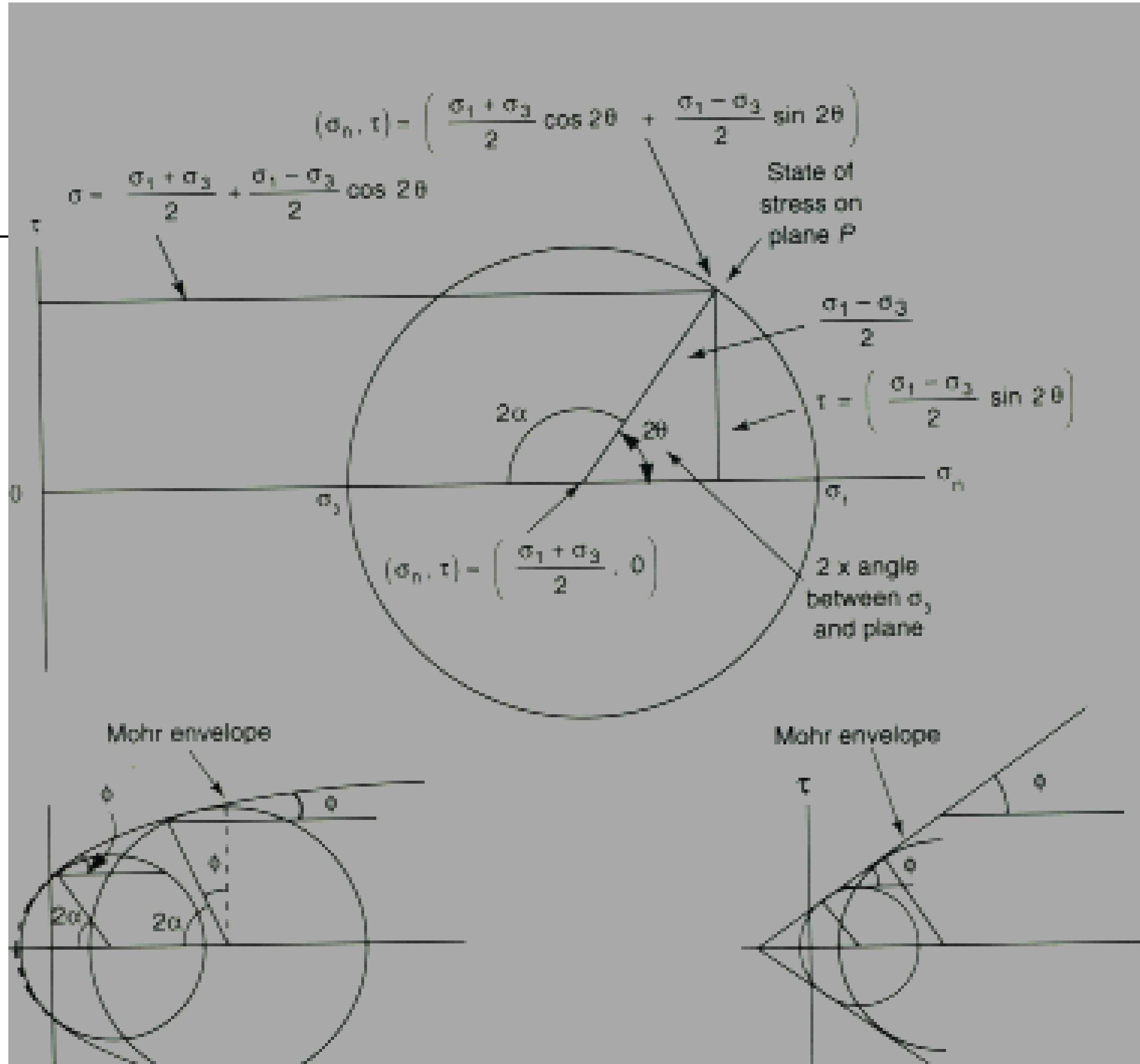


Figure from Hatcher, 1995

- Stress vectors acting across planes of zero shear stress are principal stresses **σ1, σ 2, and σ 3**
- **The three principal normal stress components are oriented perpendicular to each other and σ 1> σ 2 > σ 3**
- **Differential stress is** the difference between the maximum and minimum principal normal stresses **(σ 1- σ 3)**
- **Mean stress is (σ 1+ σ 2+ σ 3)/3**

If the differential stress exceeds the strength of the rock , permanent deformation results.

Strength of a material is the stress required to cause permanent deformation.

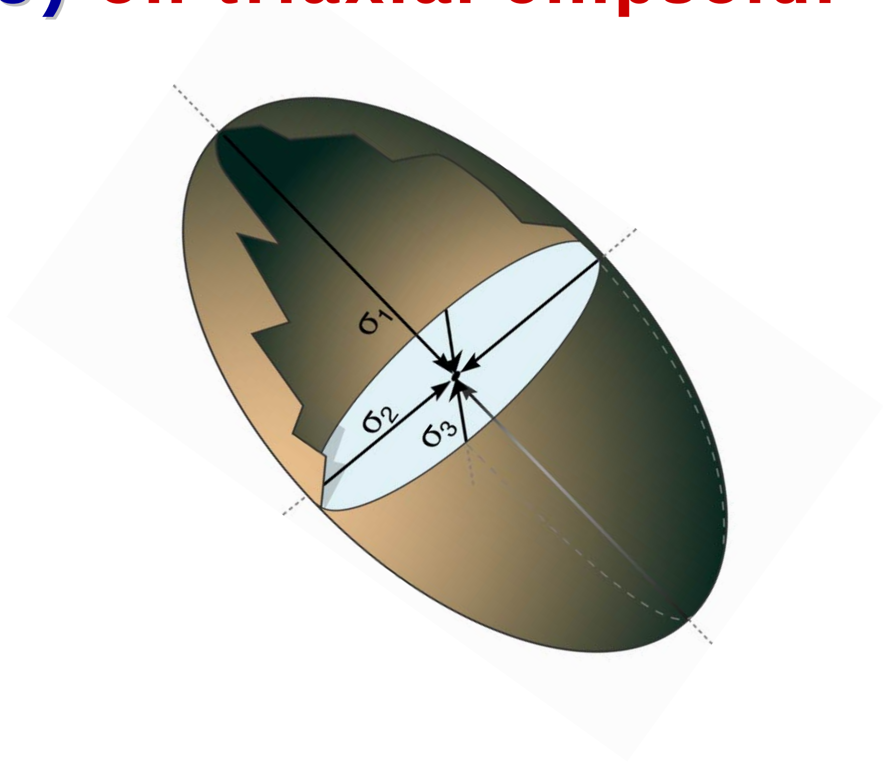
Lithostatic state of stress occurs where normal stress is the same in all directions in the Earth.

Hydrostatic pressure is the confining stress acting on a body submerged in water at known depth.

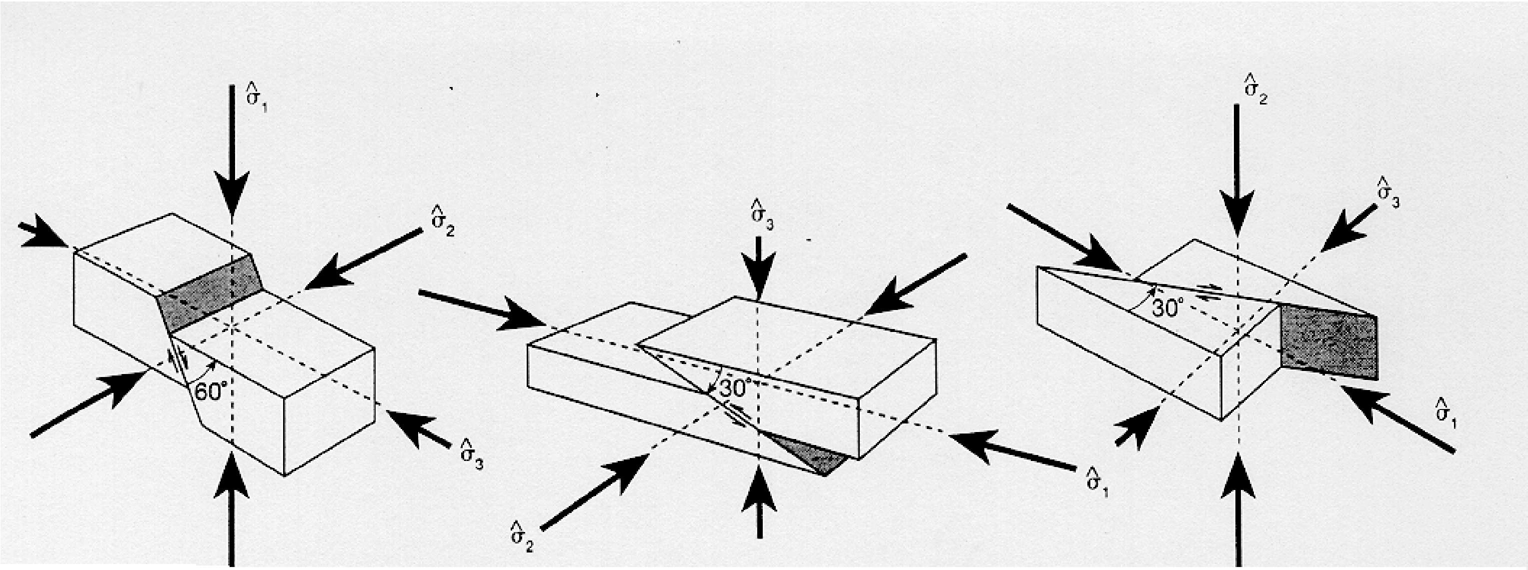
Lithostatic pressure is the column of rock per unit area above a body buried in the Earth.

Stress Ellipsoid

Stress ellipsoid is a graphic representation of principal stresses (σ 1, σ 2 & σ 3) on triaxial ellipsoid.



Distribution of Principle Stresses



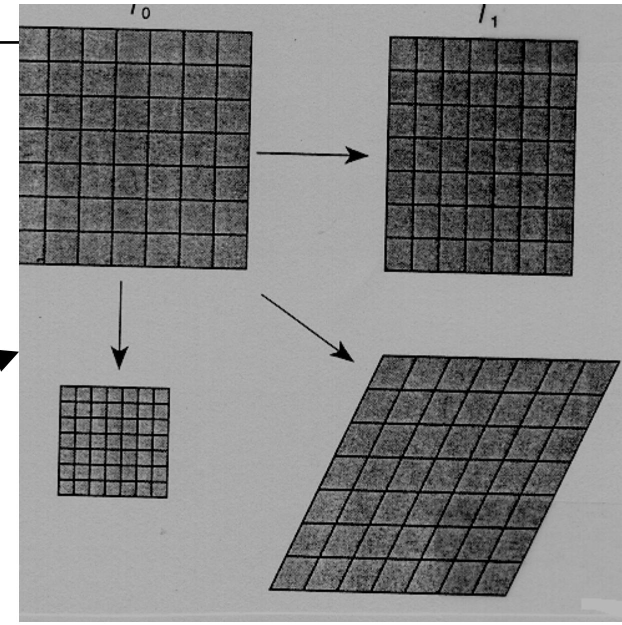
Planes of maximum shear stress are always parallel to σ 2 and at 45 to σ 1 and σ 3.

DEFORMATION

- **DEFORMATION:**

is the displacement field for tectonically driven particle motion and involves the processes by which the particle motion are achieved.

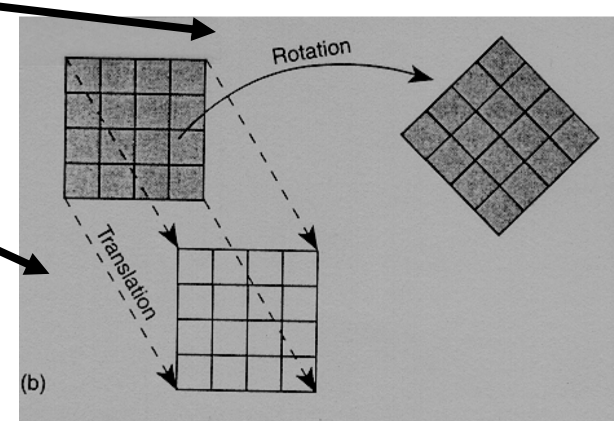
Type of Deformation



Continuous deformation: lines are not broken.

Discontinuous deformation: lines are broken.

- ***DISTORTION:*** change in shape.
- ***ROTATION:*** change in orientation.
- ***TRANSALTION:*** change in position.

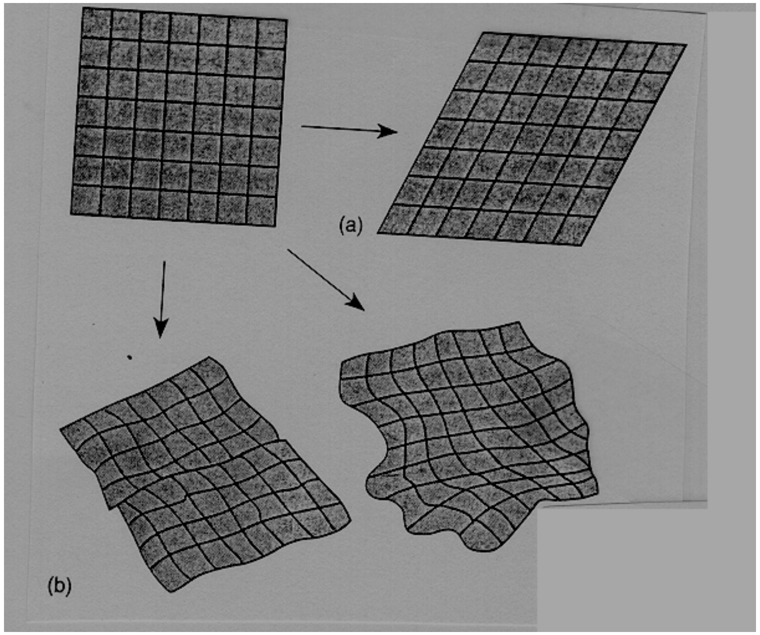


STRAIN

- **STRAIN:** aspects of shape change measured as changes in line length, changes in angular relationships between lines or as volume changes.
- *Homogeneous strain:* lines that are straight and parallel before the deformation remain straight and parallel after deformation.
- *Inhomogeneous strain:* lines that are straight and parallel before deformation don't remain parallel or straight and bay be broken..

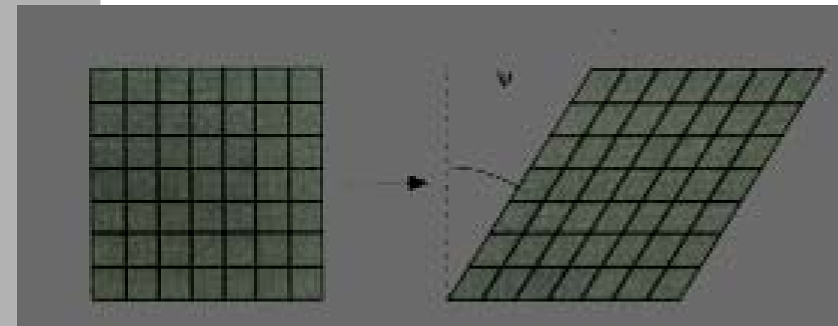
Homogeneous strain in a scale of several kilometers may be resolved into inhomogeneous in scale of centimeters.

Homogeneous and Inhomogeneous Strain



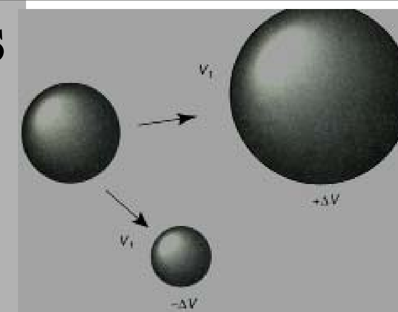
- **Shear strain:** changes in angular relationships develops when differential movement occurs along a set of parallel lines

$$Y = \tan \psi$$



- **Dilational strain:** volume changes

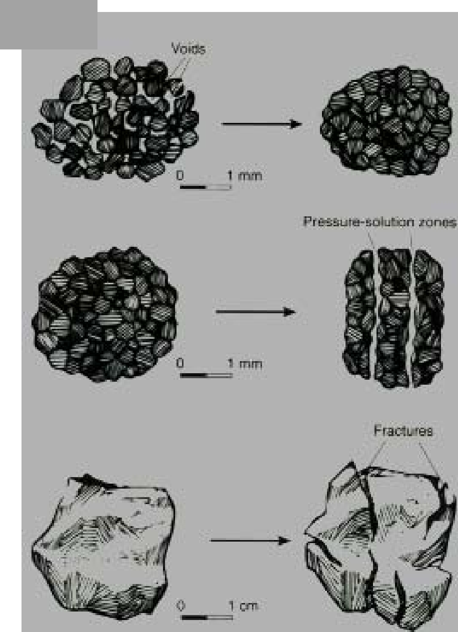
$$\Delta = (V1-V0)/V0 = \delta V/V0$$



closing voids between grains (negative volume change)

dissolving away part of the rock mass by pressure solution (negative volume change)

fracturing the mass of rock (positive volume change)



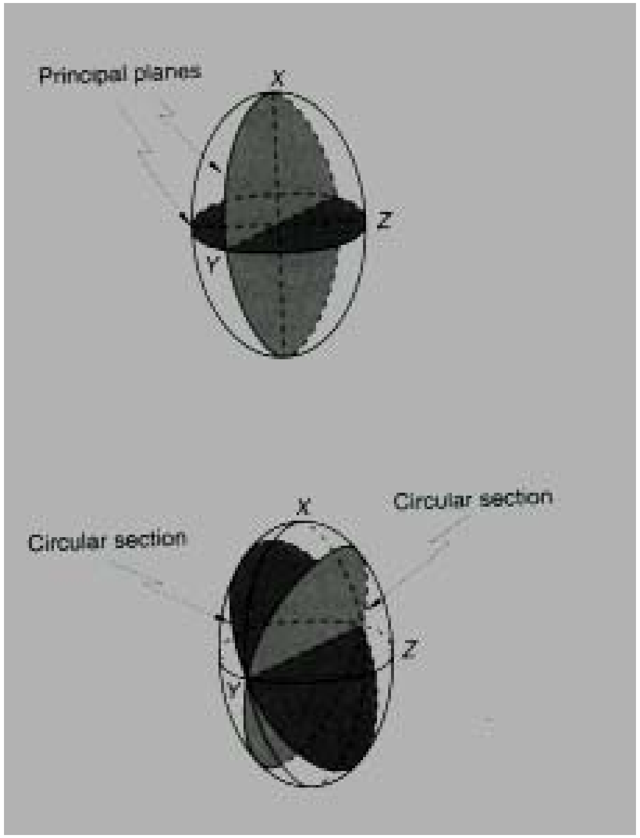
Strain Ellipsoid

Is a graphical tool that provides a reference object for estimating shape change from an assumed initial sphere. The ellipsoid is referred to three perpendicular axes x, y, and z

- x is the greatest principle strain
- y is the moderate principle strain
- z is least principle strain

Three types of ellipsoids

- ***triaxial ellipsoid x>y>z***
- ***oblate biaxial spheroid x=y>z***
- ***prolate biaxial spheroid x>y=z***

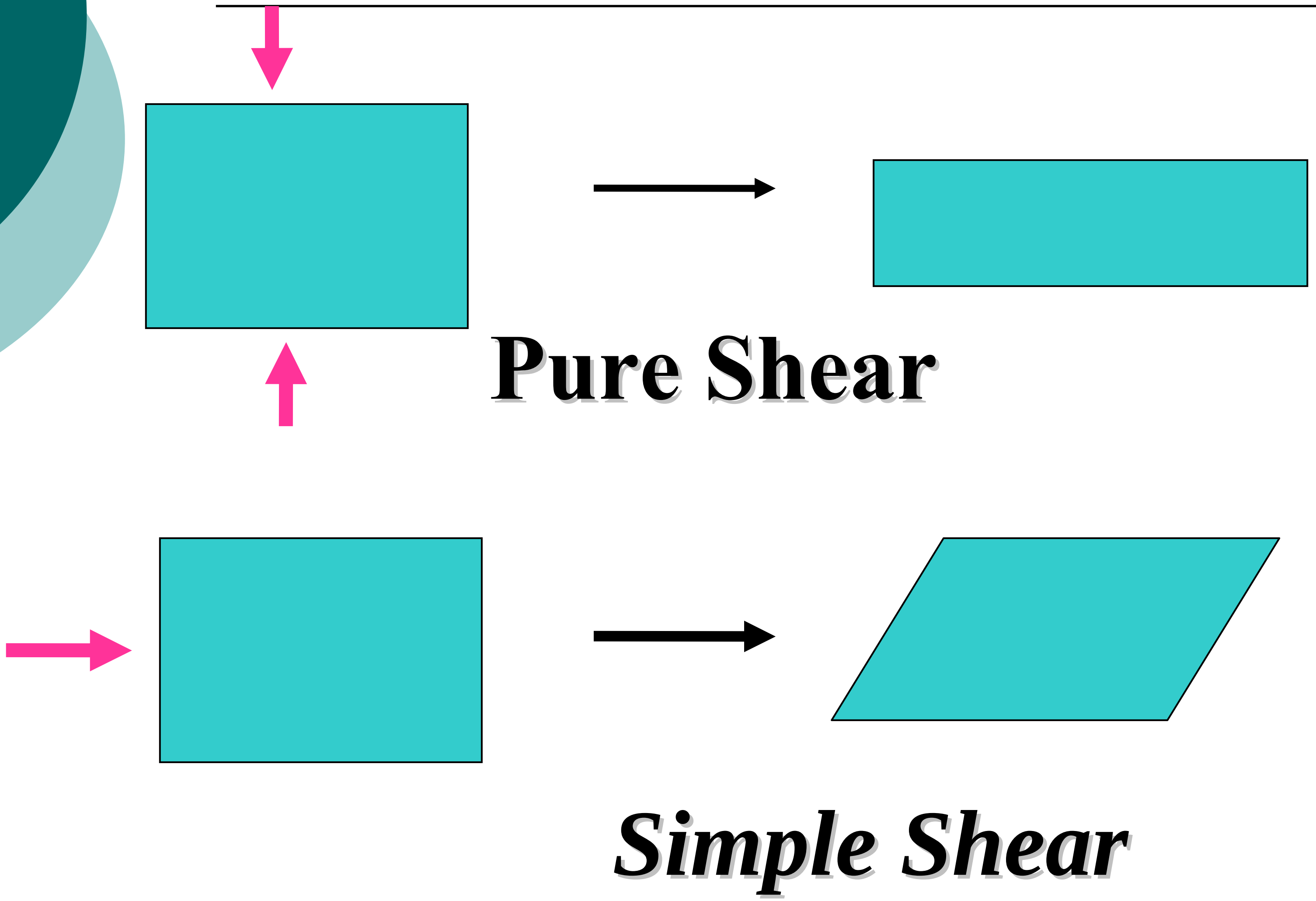


Shear types

- ***Simple shear:*** **line lengths are unchanged parallel to the y axis during deformation, and all strain is in xz plane (two dimensional deformation) (example movement in cards deck)**
- ***Pure shear:*** **results by distortion by homogeneous deformation in which the principle axes do not rotate (angle between the principle axes remain unchanged)**

If rotation or translation is added pure shear becomes simple shear.

Simple and Pure Shear



Strain Markers

STRAIN MARKERS:

Any deformed features in a rock mass in which the original shape can be quantitatively compared with the present deformed shape may be use as strain marker.

- ***Reduction*** spots: small mostly spherical features in fine-grained sediments, (shale, slate, and mudstone)where the red oxidized sediment has been chemically reduced to a greenish color.
- ***Pebbles:*** Usually in conglomerate rocks and they are mostly ellipsoidal.
- ***Oods and pisolites:*** They are mostly formed in carbonate rocks and ironstone.

Strain Markers

- ***Fossils***
- ***Vesicles***
- ***Pillows***
- ***Burrows:*** almost cylindrical burrows oriented normal to the sea bottom in clean sand environment.