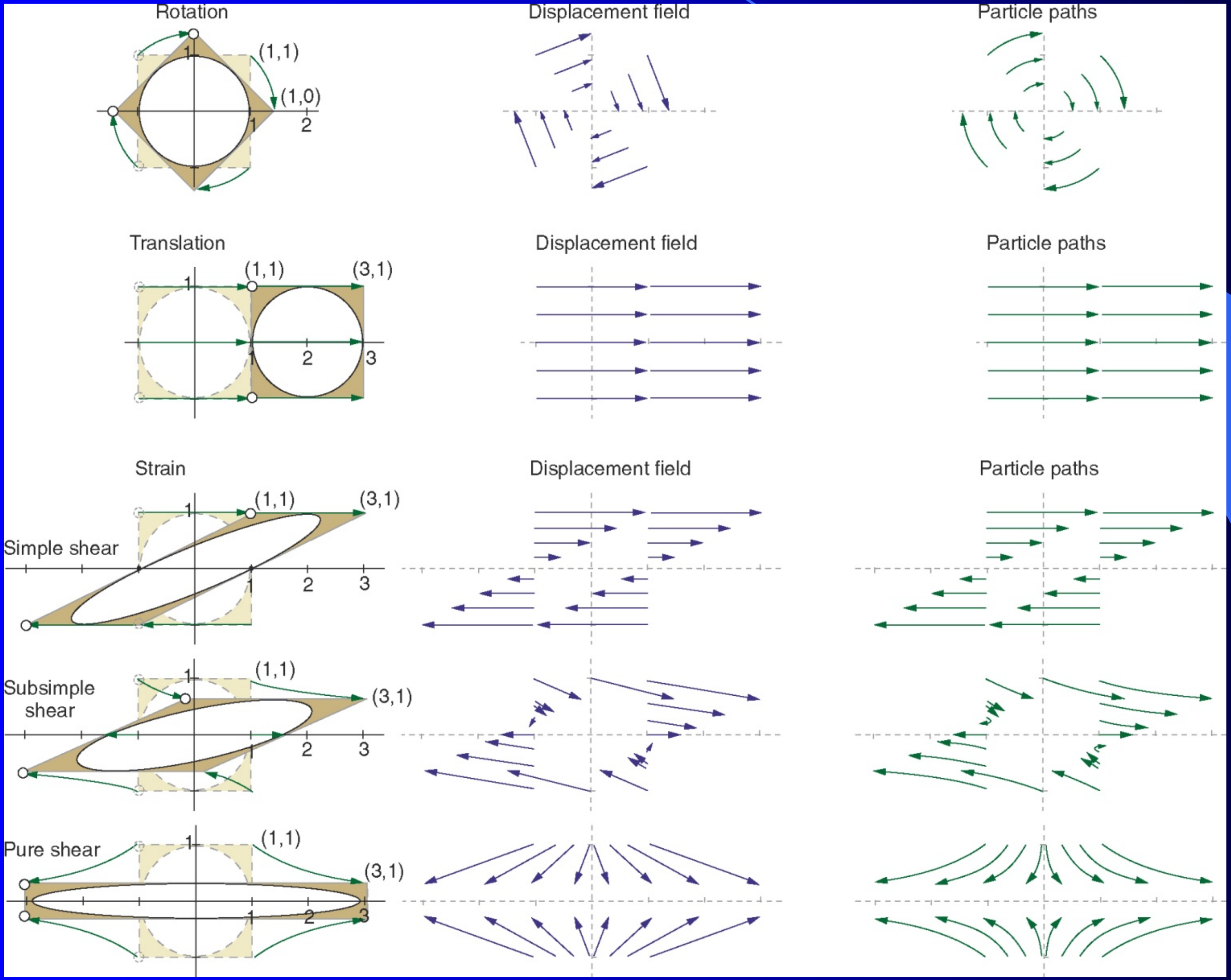
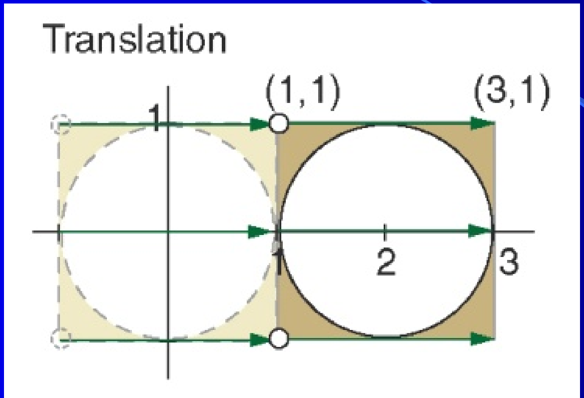
**Deformation** is the transformation from an initial to a final geometry by means of rigid body translation, rigid body rotation, strain (distortion) and/or volume change.

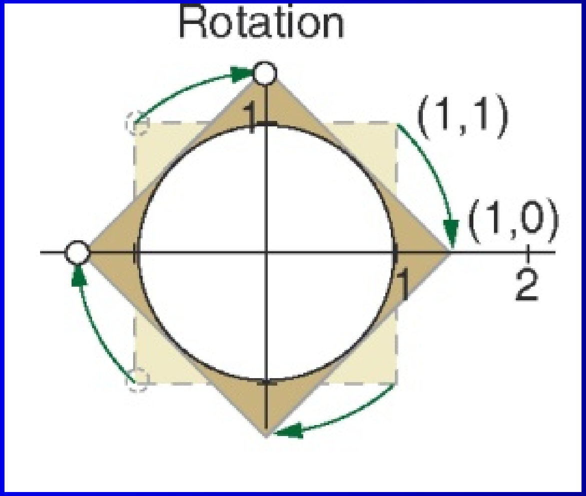


## Components of deformation:

1) Translation – every particle in the rock moves in the same direction and the same distance.




2) Rotation – rigid rotation of the entire deformed rock volume. Relative position of particles unchanged.

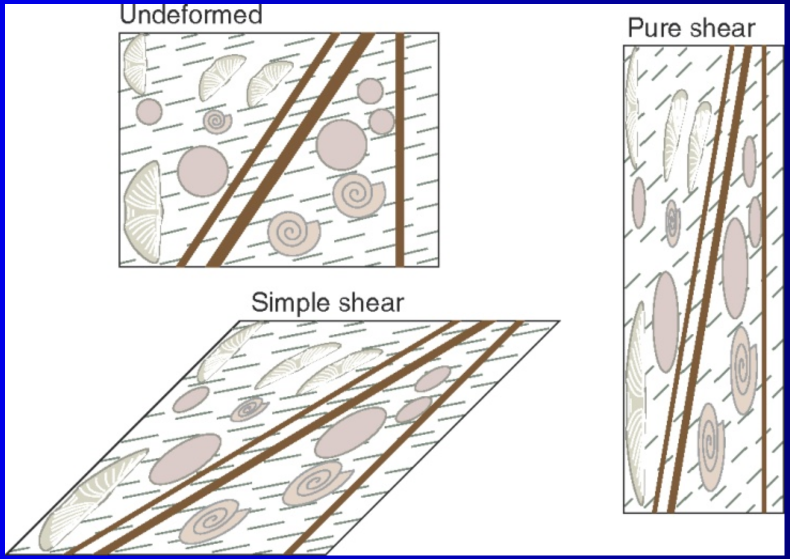


3) Strain – non-rigid deformation. Any change in shape, with or without change in volume, is referred to as strain. The particles in a rock have changed relative positions with respect to each other.

4) Pure shear – perfect coaxial deformation. Lines along the principal strain axes have the same orientation as they had in the undeformed state.

5) Simple shear – non-coaxial deformation. The orientation of the principal strain axes are different for different amounts of strain.

6) Subsimple shear – mixture of pure shear and simple shear.




7) Volumetric strain – change in volume. For example, shrinkage.

One-dimensional Strain – stretching and shortening of lines

1) Elongation

$e = (l - l_o)/l_o$ where $l_o$ = original length of line and $l$ = length after deformation

Natural elongation = $\bar{e} = \ln(e)$

2) Stretching

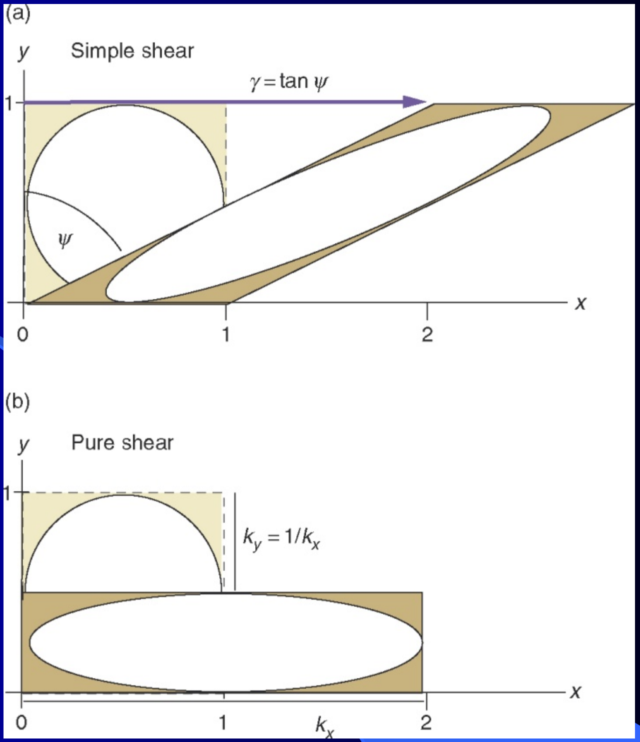
$s = 1 + e = l/l_o$ where $s$ = the stretch

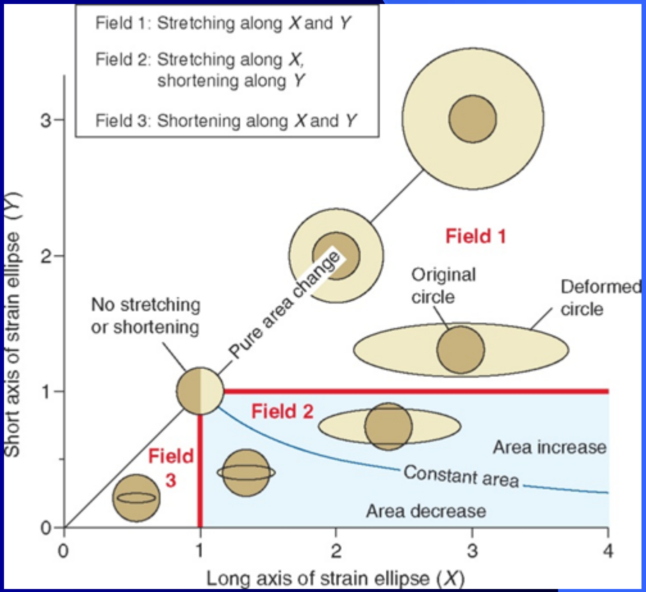
3) Quadratic elongation

$\lambda = s^2$

# Strain in Two Dimensions:

- Angular shear (ψ) = in a deformed material the angle between two originally perpendicular lines.
- Shear Strain (γ) = tan ψ
- Angular shear strain only occurs during Simple Shear.
- The strain ellipse describes the change in shape during deformation of an imaginary circle.
- The strain ellipse is describe in terms of a long (X) and a short (Y) axis.
- The two axes have lengths $X = l + e_1$ and $Y = l + e_2$
- Eccentricity of ellipse = R = X/Y
- For an area change without any strain (pure area change), R = 1 (45º line in Figure to the right)



# Three Dimensional Strain:

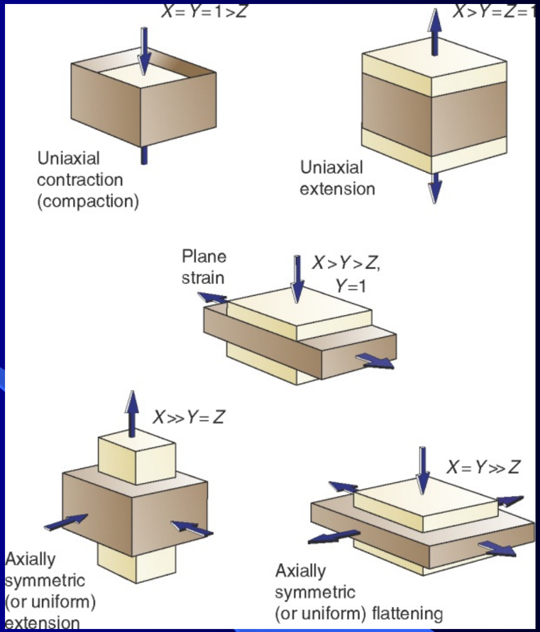
- Strain is plane (2-dimensional) when there is no length change along the Y-axis, while 3-dimensional strain implies a length change along X, Y and Z (Figure to right).

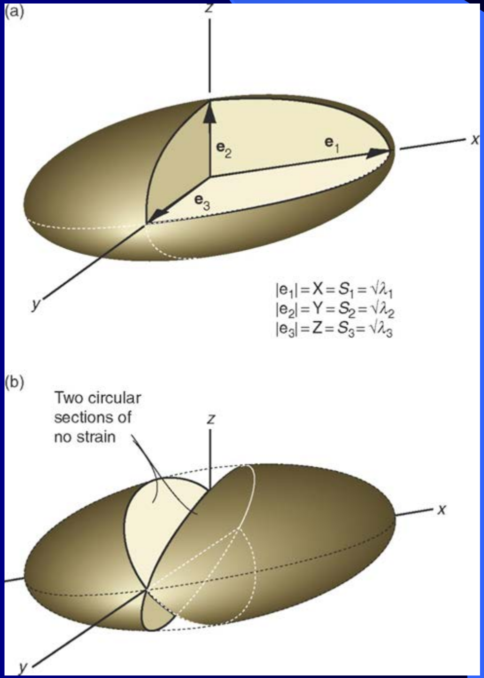
- The strain ellipsoid describes the change in shape of a spherical object during strain. It completely describes all the components of strain

- There are three principal strain axes (X, Y, Z)

- Lines that are parallel with the principal strain axes are orthogonal, and were also orthogonal in the undeformed state.

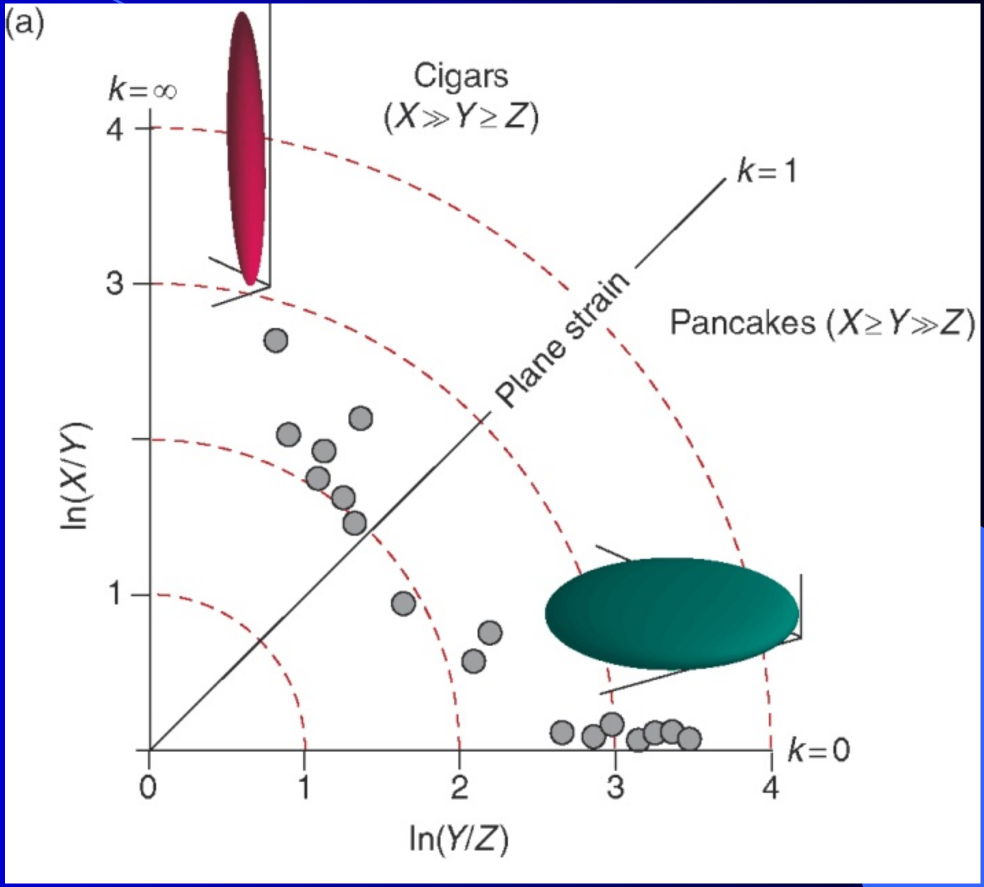
- A plane stain produces two planes in which the rocks appears to be unstrained. These are the circular sections of no strain shown in the Figure to the right.



## The Flinn Diagram can be used to illustrate strain

- The shape of the strain ellipsoid is visualized by plotting the axial ratios X/Y and Y/Z (as natural logs).
- The value k = (X/Y - 1)/(Y/Z – 1) or $(R_{xy} – 1)/(R_{yz} – 1)$
- The diagonal line represents planar strain where X/Y=Y/Z. In this case the shape does not change.
- For values greater than k = 1, the strain ellipsoid looks like a cigar (prolate). For values less than k = 1, the strain ellipsoid looks like a pancake (oblate).



Progressive simple shear (left) and progressive pure shear (right). Note orientation of the Instantaneous stretching axes (ISA) and the principal strain axes. Also note areas of Instantaneous stretching and Instantaneous shortening.