Deformation

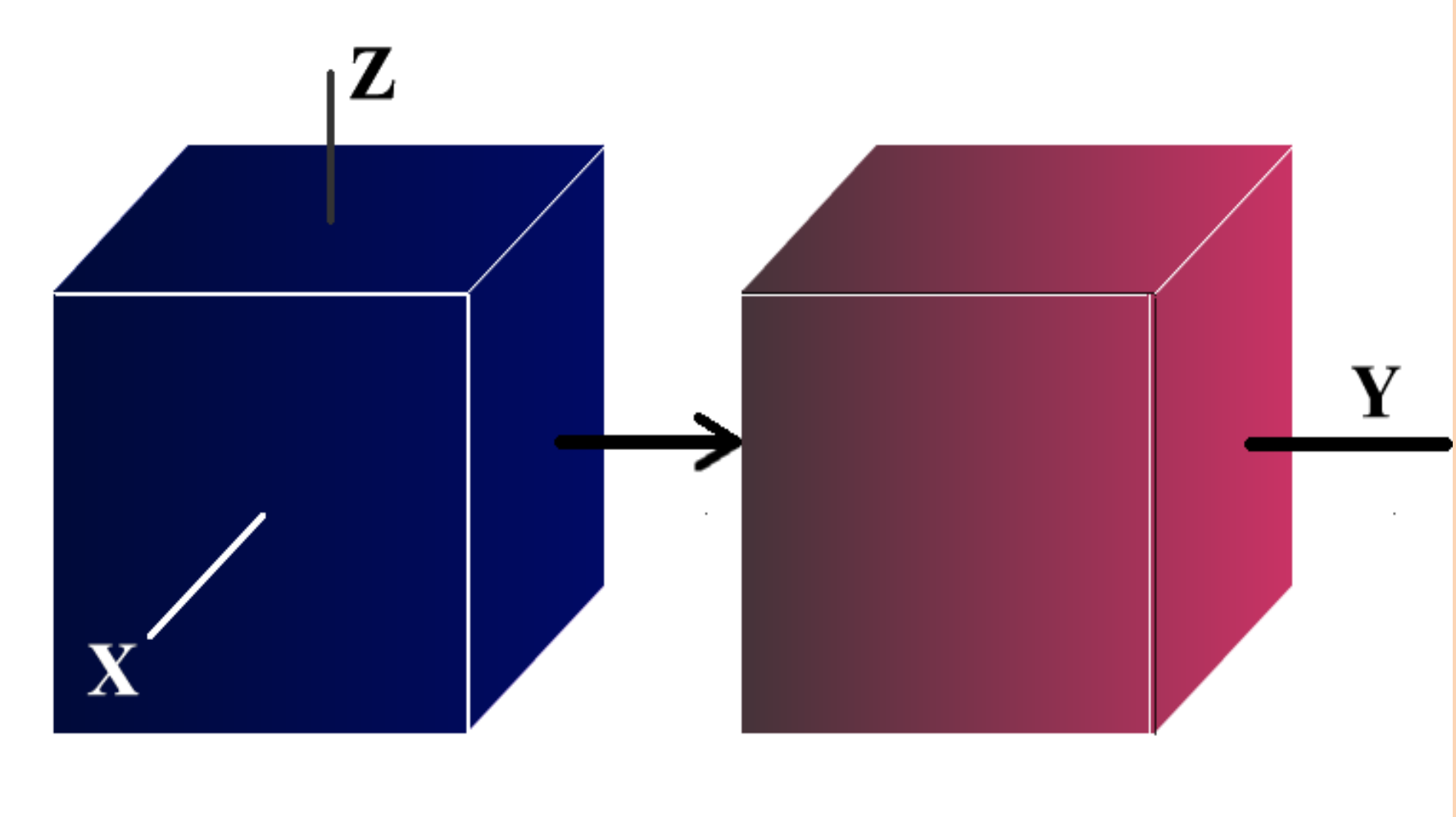
- Deformation involves any one, or a combination, of the following four components:

- **Ways that rocks respond to stress:**
  1. Rigid Body Translation
  2. Rigid Body Rotation
  3. Distortion or Strain
  4. Dilation

Rigid Body Translation

- **A rigid body deformation involving movement of the body from one place to another, i.e., change in position**
  - Particles within the body do not change relative position
  - **No rotation or strain are involved**
  - Particle lines do not rotate relative to an external coordinate system
  - **Displacement vectors are straight lines**
  - e.g., passengers in a car, movement of a fault block
- **During pure translation, a body of rock is displaced in such a way that all points within a body move along parallel paths relative to some external reference frame**

Translation Parallel to the Y axis

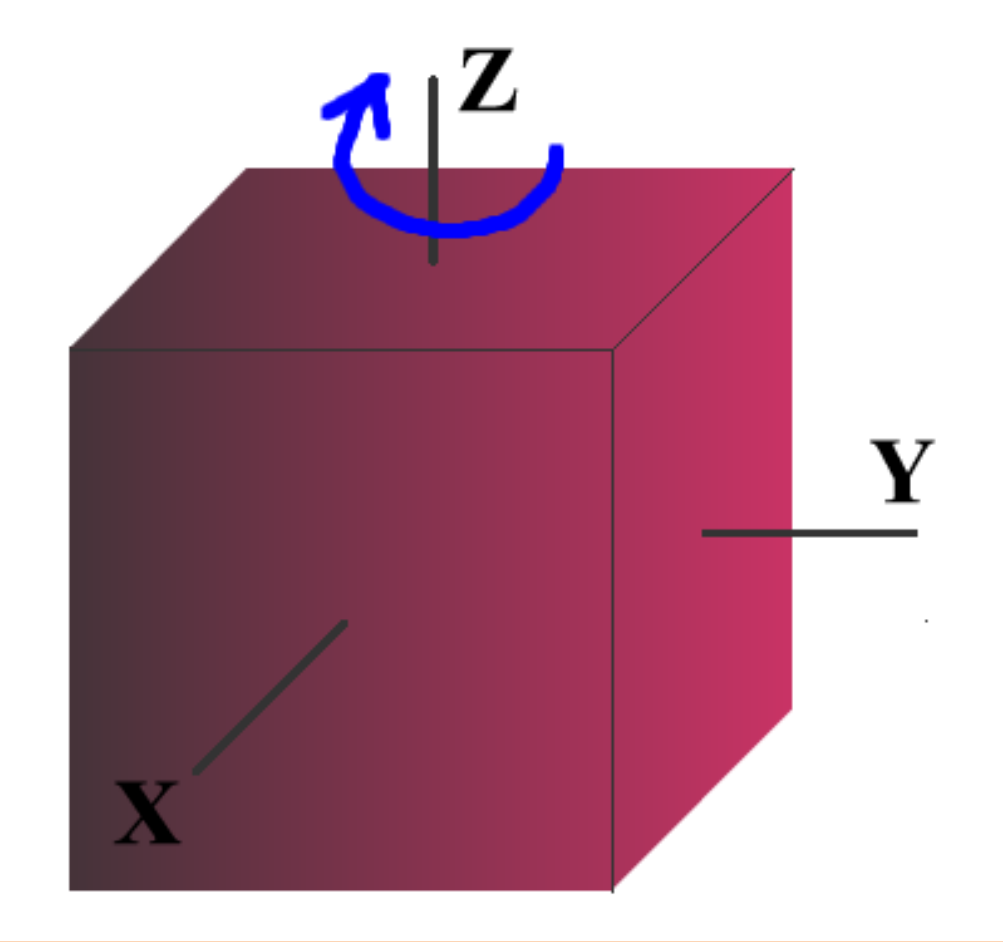


Rigid Body Rotation

- Rotation is a rigid body deformation that changes the configuration of points relative to some external reference frame in a way best described by **rotation about some axis**
- **Spin of the body around an axis**

- Particles within the body do not change relative position
- No translation or strain is involved
- **Particle lines rotate relative to an external coordinate system**
  - **Examples**
    - Rotation of a car
    - Rotation of a fault block

Clockwise Rotation about the z-axis



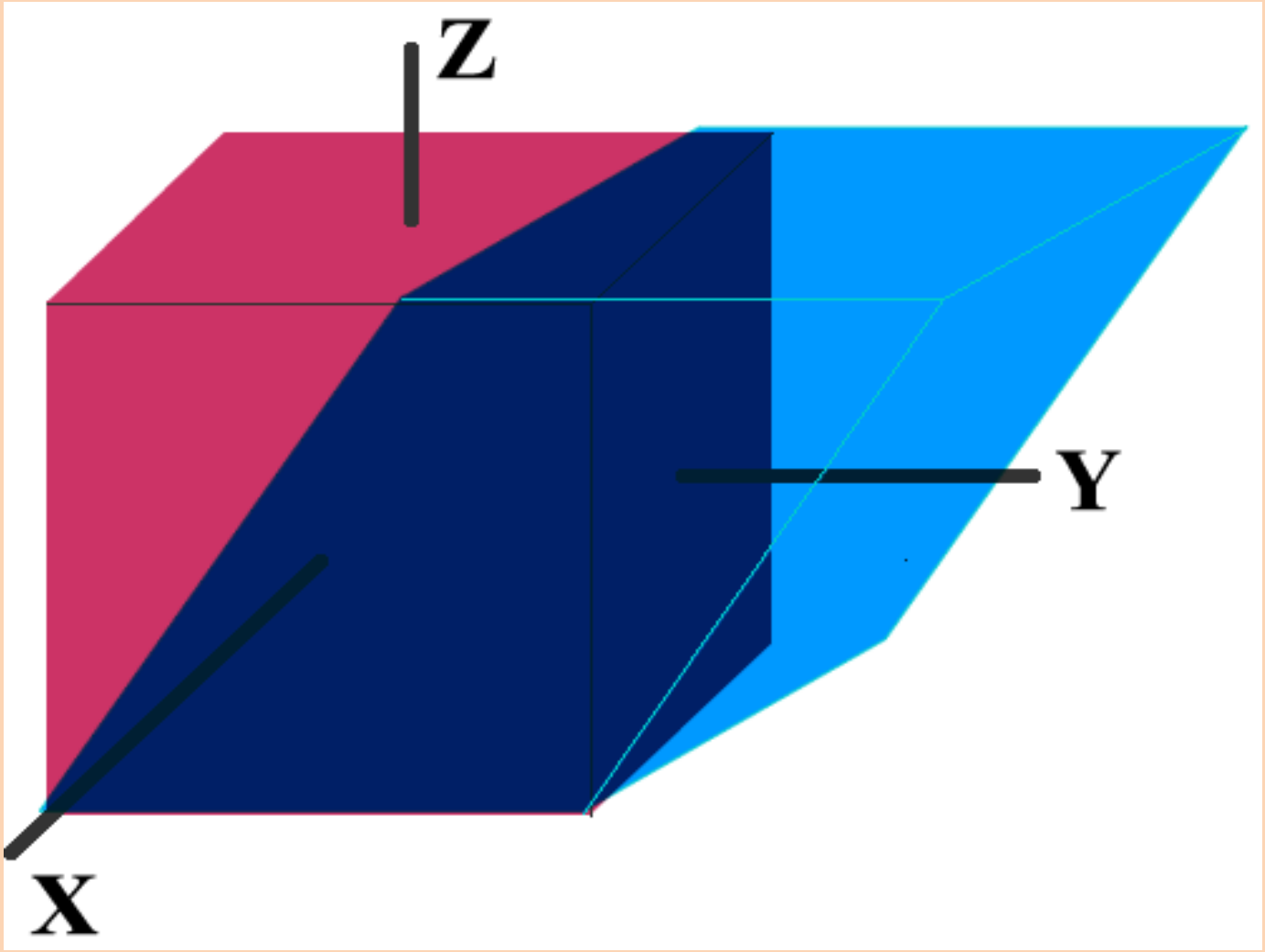
Strain or Distortion

- **Distortion is a non-rigid body operation that involves the change in the spacing of points within a body of rock in such a way that the overall shape of the body is altered with or without a change in volume**

- **Changes of points in body relative to each other**
  - **Particle lines** may rotate relative to an external coordinate system
  - Translation and spin are both zero
  - Example: squeezing a paste

- **In rocks we deal with processes that lead to both movement and distortion**

Strain or Distortion

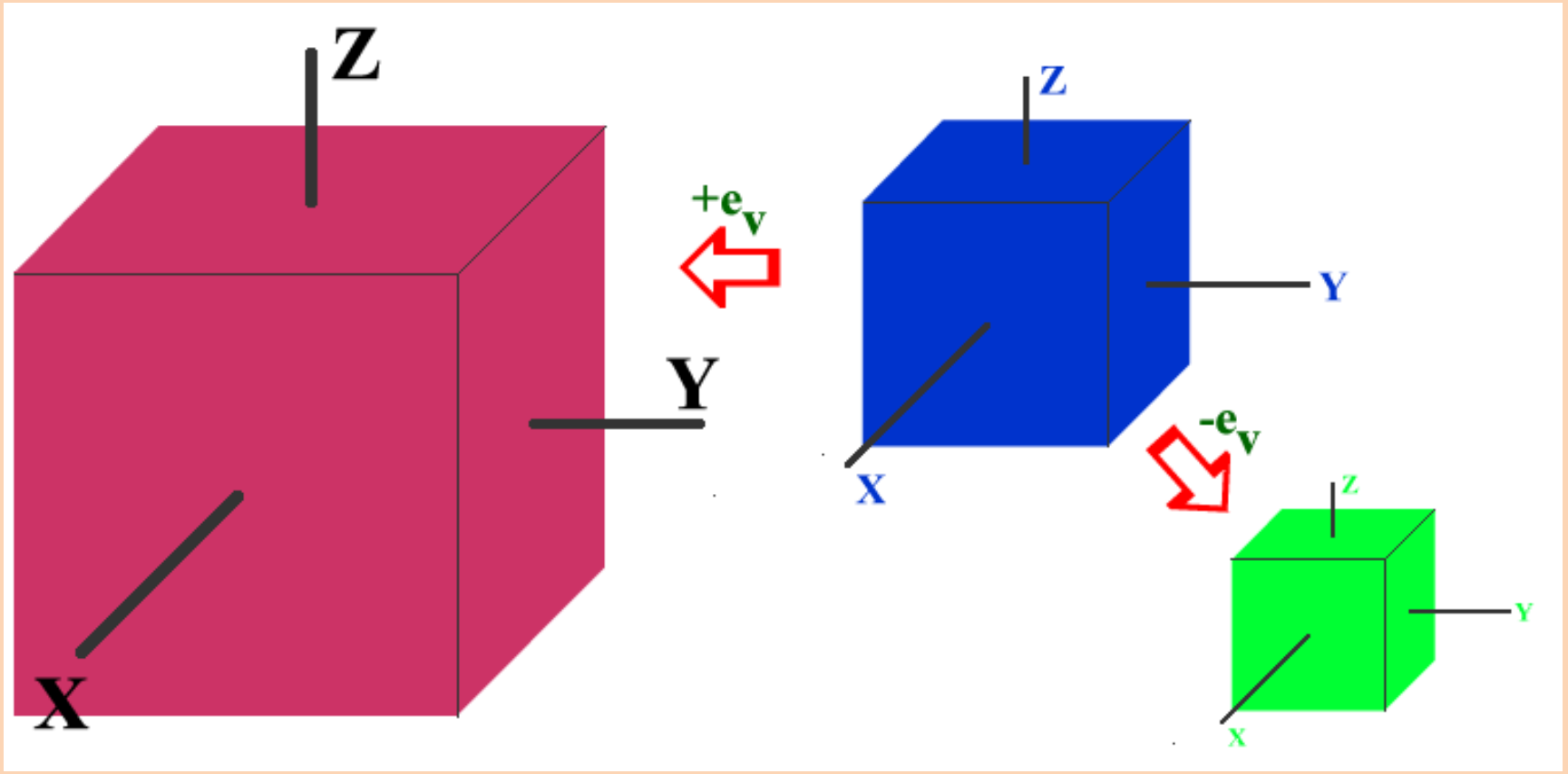


Dilation

- **Dilation is a non-rigid body operation involving a change in volume**

- **Pure dilation:**
  - The overall shape remains the same
  - **Internal points of reference spread apart** (**+e_v**) or **pack closer** (**-e_v**) together
  - Line lengths between points become uniformly longer or shorter

Dilation



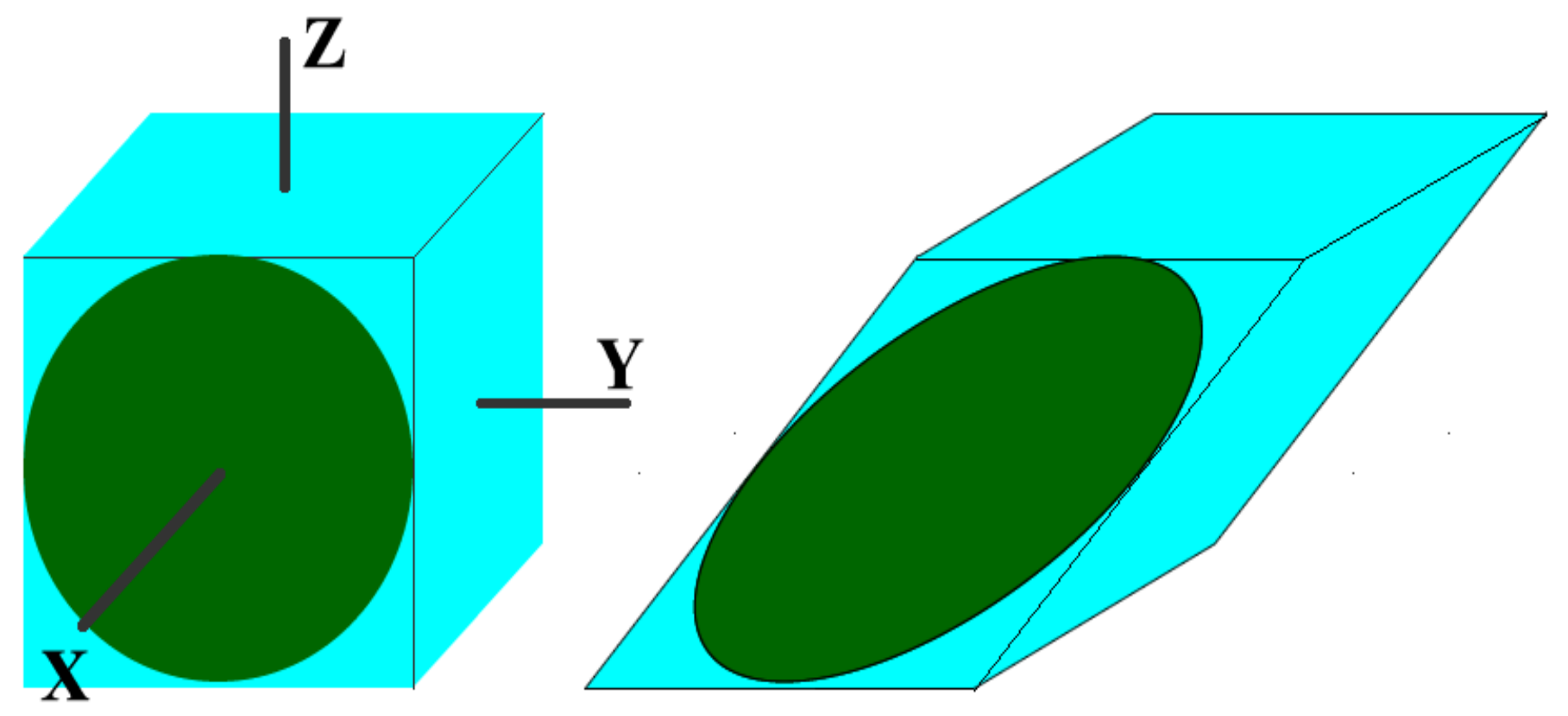
Homogeneous Strain

- **In other words, in homogeneous deformation, originally straight lines remain straight after deformation**
  - **also called affine deformation**
- Homogeneous strain affects non-rigid rock bodies in a regular, uniform manner
- **During homogeneous strain parallel lines before strain remain parallel after strain, as a result cubes or squares are distorted into prisms and parallelograms respectively, while spheres and circles are transformed into ellipsoids and ellipses respectively**
- For these generalizations to hold true, the strain must be systematic and uniform across the body that has been deformed.

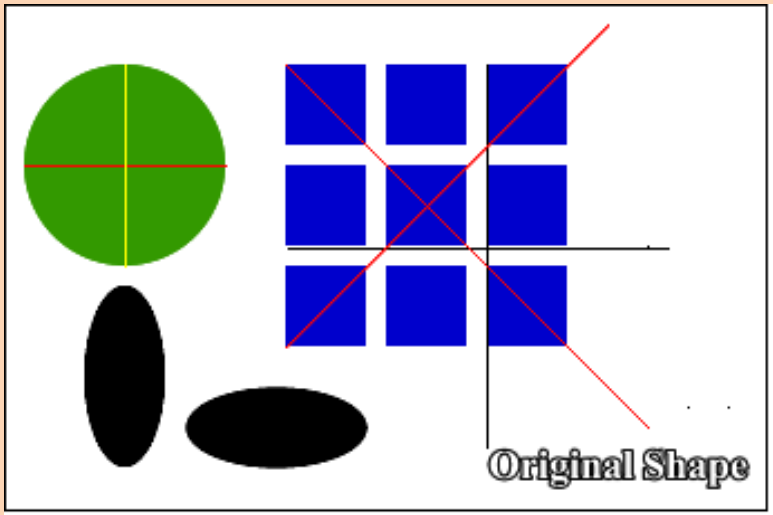
Homogeneous Deformation

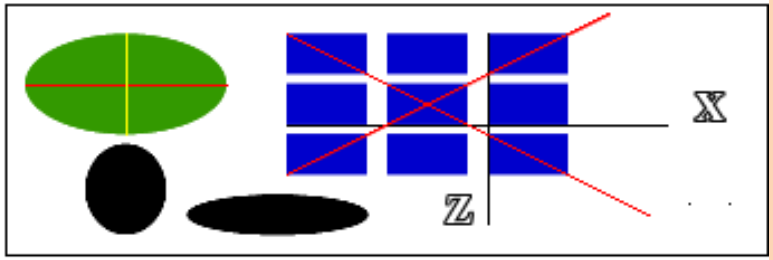
- Originally straight lines remain straight
- Originally parallel lines remain parallel
- Circles (spheres) become ellipses (ellipsoids)

Homogeneous Strain

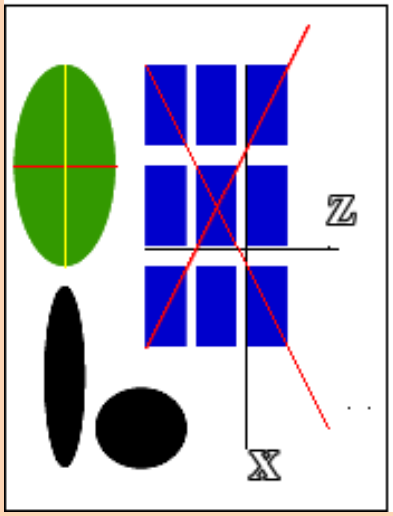


Homogeneous Deformation - Pure Shear



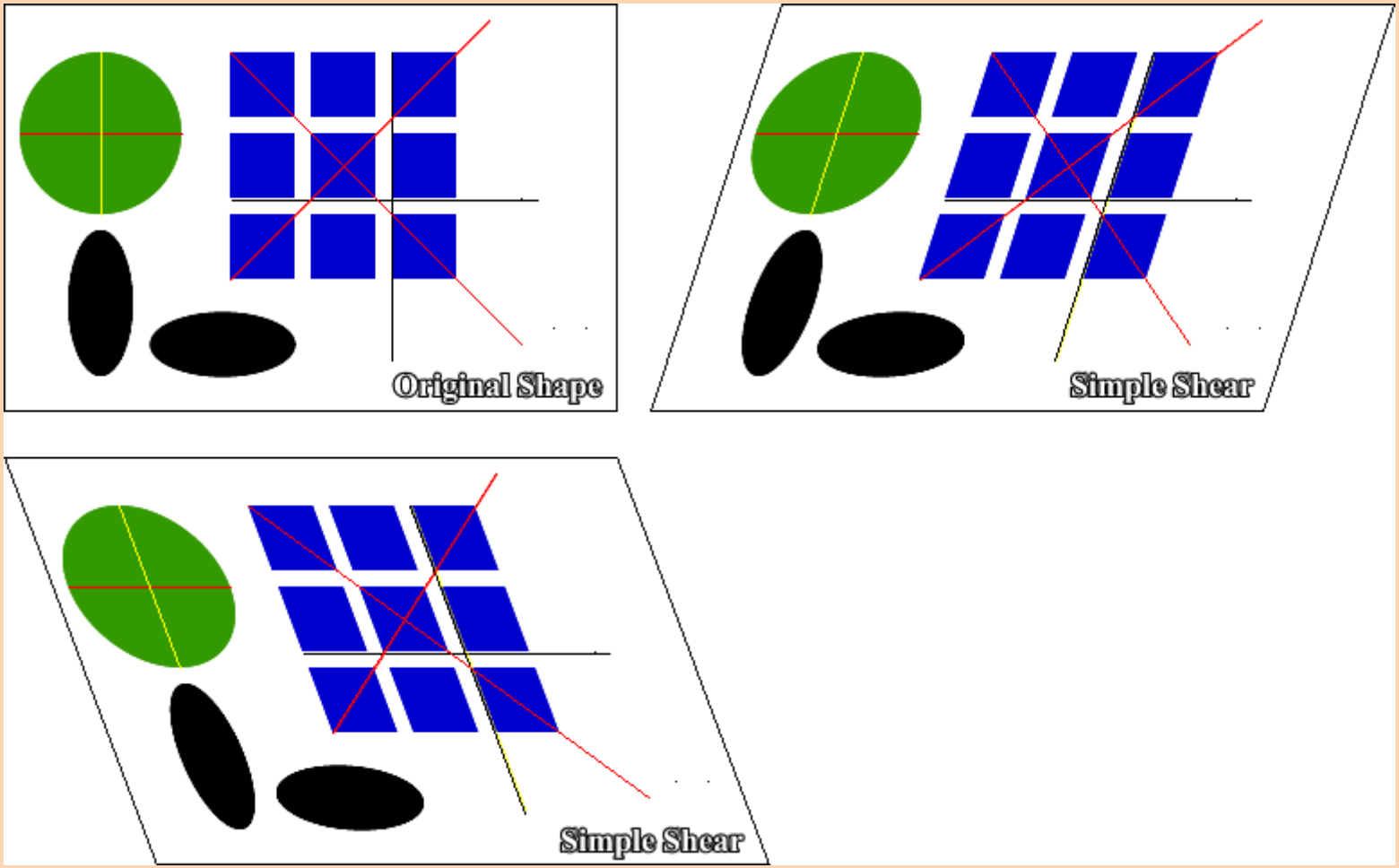


Pure Shear



Pure Shear

Homogeneous Deformation - Simple Shear



Inhomogeneous Strain

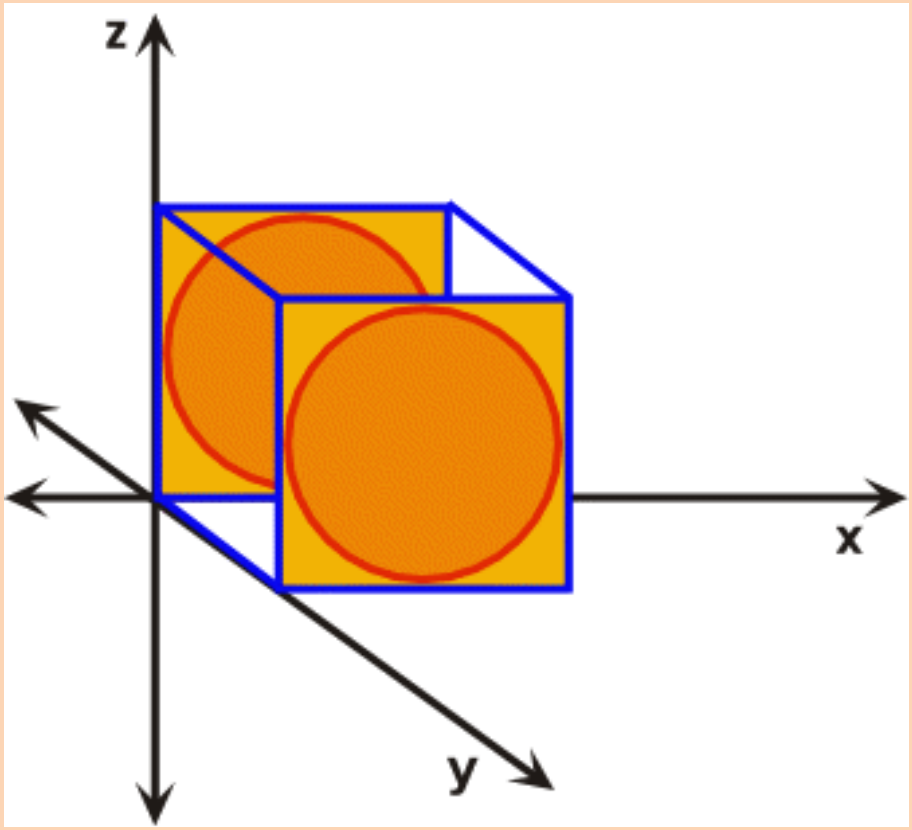
- **Heterogeneous strain affects non-rigid bodies in an irregular, non-uniform manner and is sometimes referred to as non-homogeneous or inhomogeneous strain**

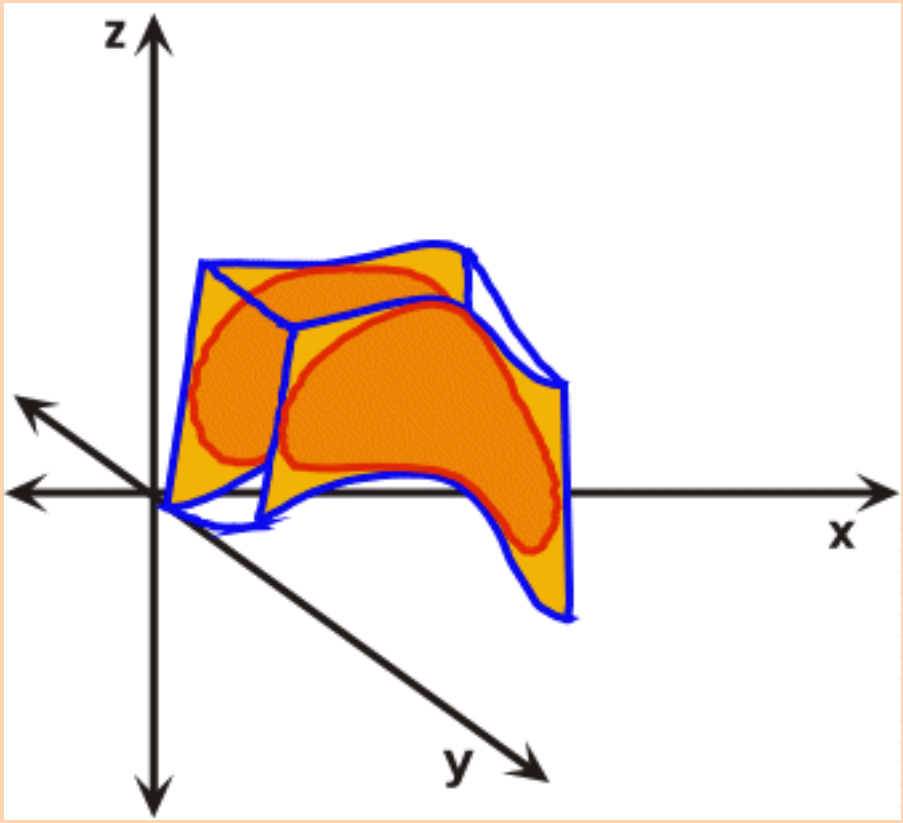
- During heterogeneous strain, parallel lines before strain are not parallel after strain

- **Circles and squares or their three-dimensional counter parts, cubes and spheres, are distorted into complex forms**

Heterogeneous or Inhomogeneous strain

- **Leads to distorted complex forms**



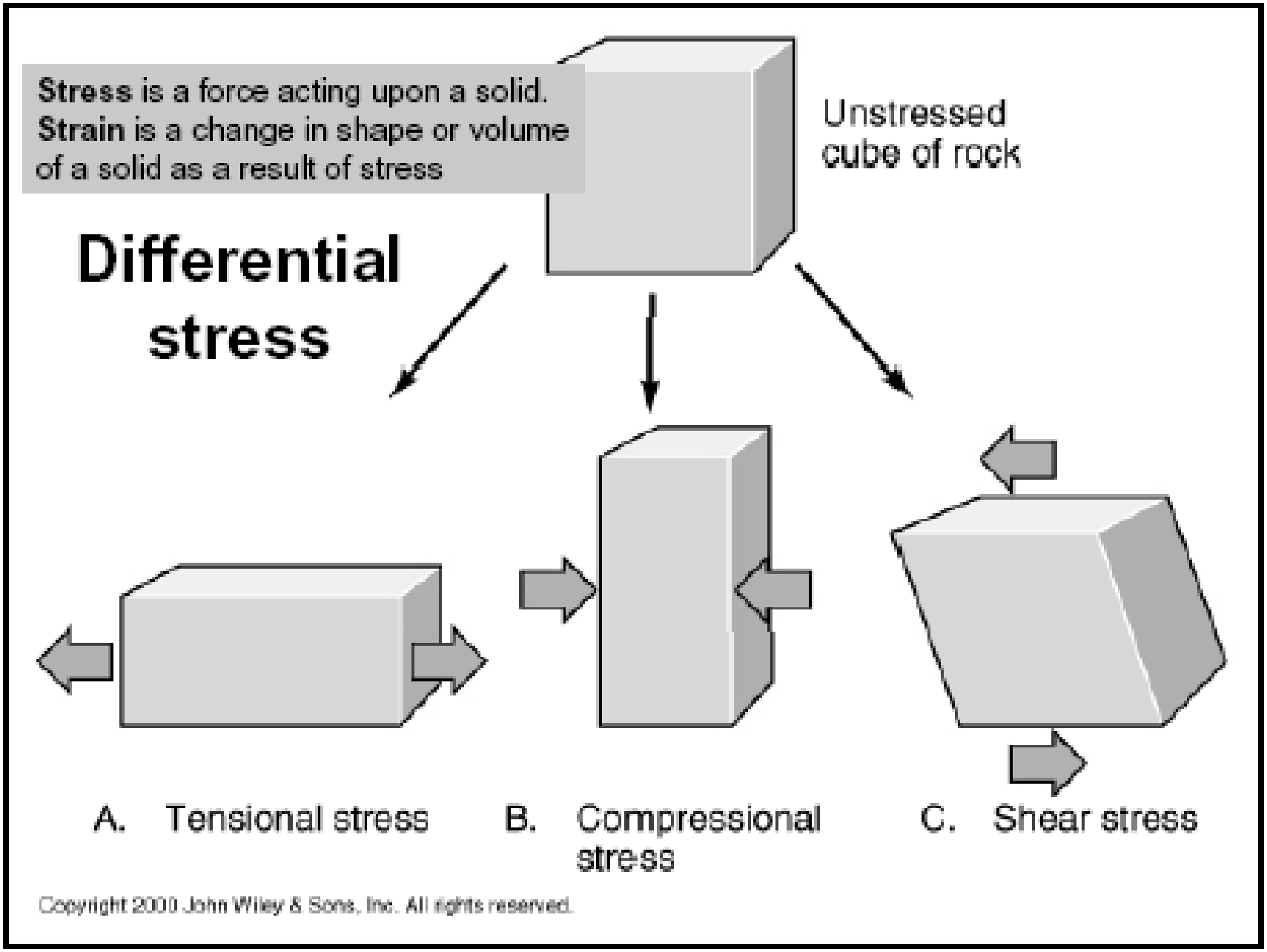


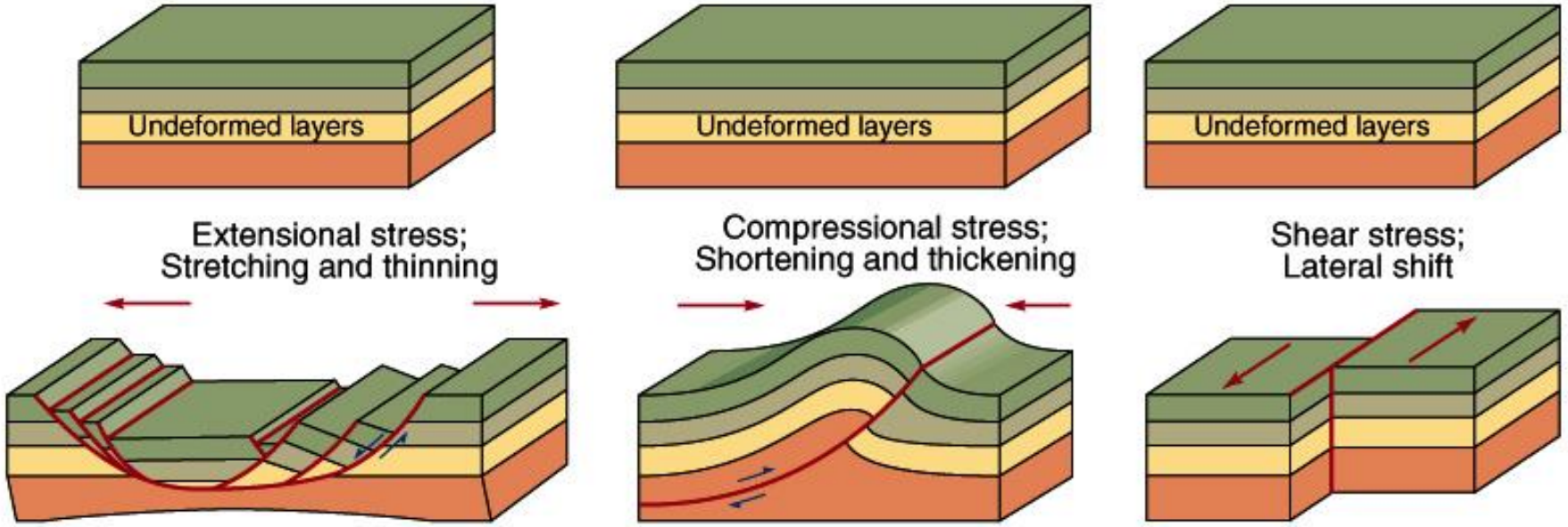
Rock Deformation

* Stress: the pressure or force applied to rocks that cause deformation
* Uniform (confining) stress is equal in all directions
* Differential stress is not equal in all directions

- Three types of differential stress
  - *Tensional* - pulling apart
  - *Compressional* - squeezing together
  - *Shear* - slipping, twisting, or wrenching

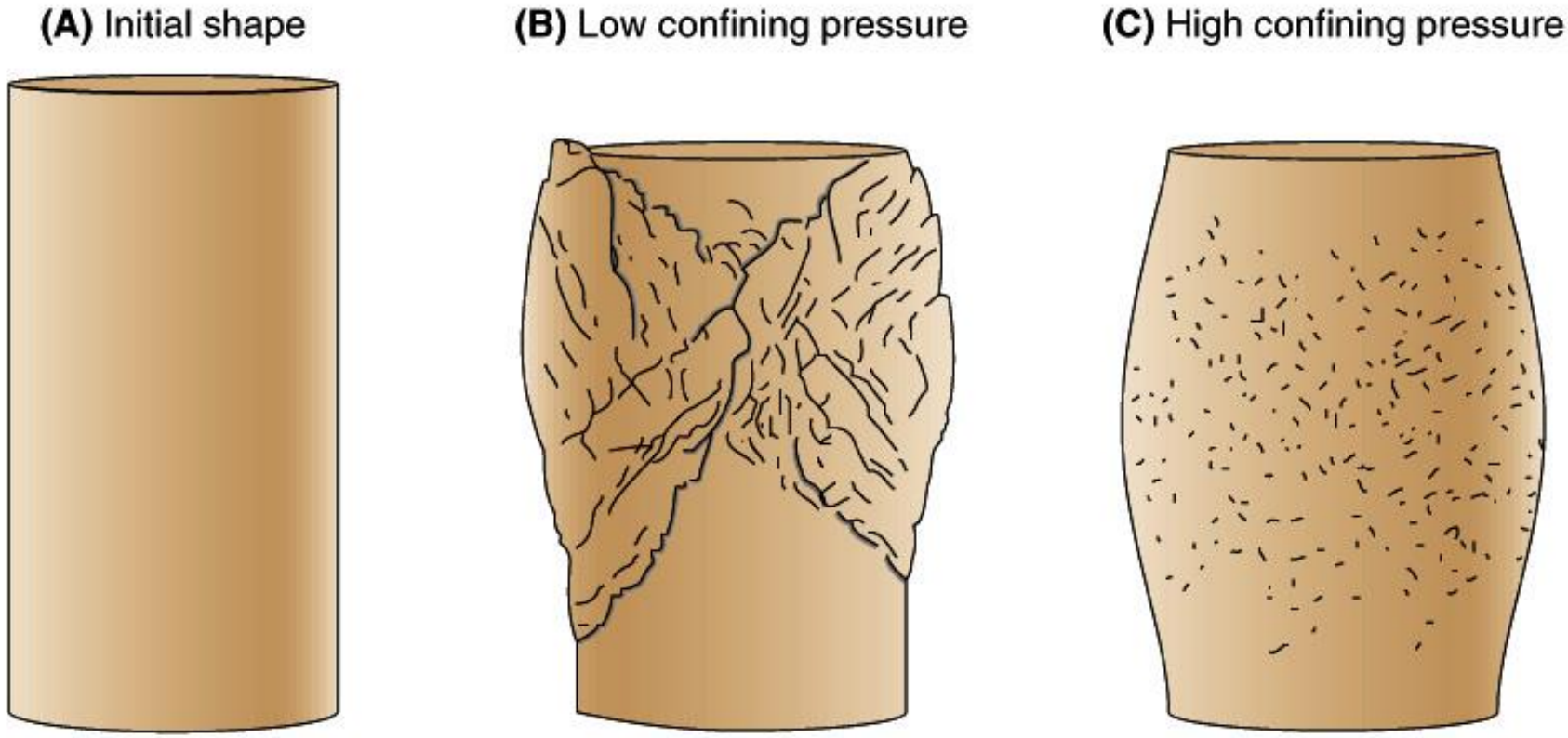
- Strain is the result of applying a stress to a rock
  - The change in size and/or shape of a solid

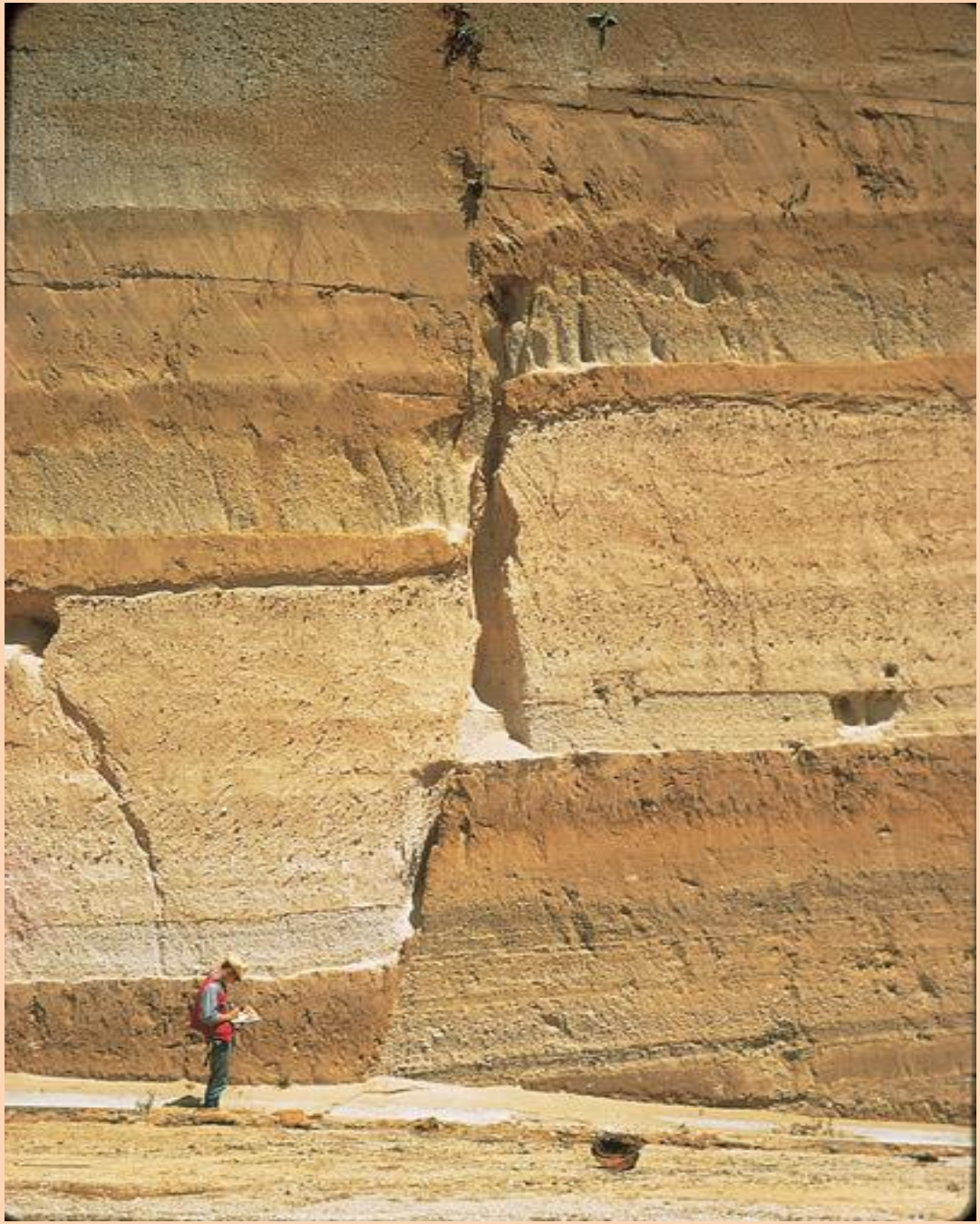



Undeformed layers
Undeformed layers
Undeformed layers
Extensional stress;
Stretching and thinning
Compressional stress;
Shortening and thickening
Shear stress;
Lateral shift

Nature of Materials

- Ductile deformation
  - Irreversible change in size and/or shape
  - Volume and density may change
- Brittle deformation - Fracture
  - Stress exceeds the ductile limit
  - Irreversible


(A) Initial shape
(B) Low confining pressure
(C) High confining pressure



Fault