Rock: Bend, Buckle, and Break

Why Is Rock Deformed?

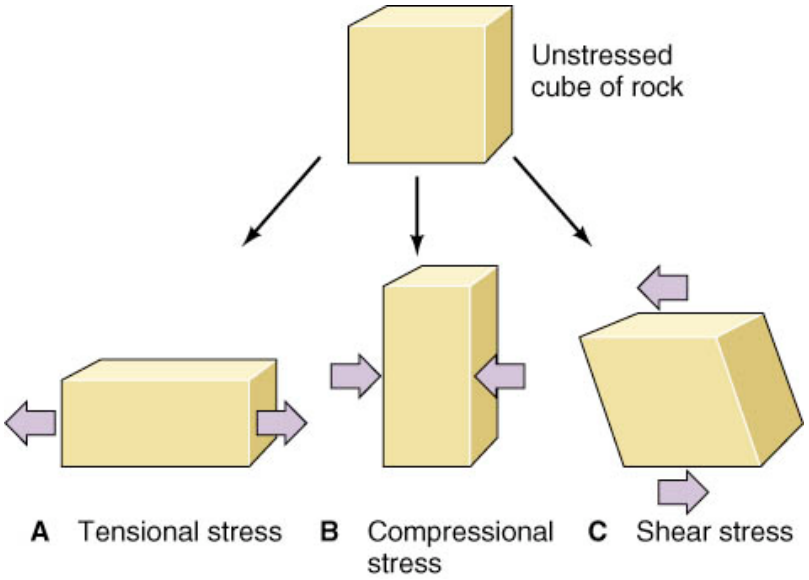
- Tectonics forces continuously squeeze, stretch, bend, and break rock in the lithosphere
- Energy source: Earth's internal heat
  - transformed into to mechanical energy

Stress

- Force per unit area
- Units:
  - Pounds per square inch
  - Bars, kilobars, megabars
  - Pascals, MPa, GPa
- Differential vs confining stress
  - Different stress in different directions
  - "pressures"

Strain

- Fractional change in dimension
  - Length
  - Angle
  - volume
- Units: dimensionless



- **strain-rate:** fractional change in dimension per time
  - 10^{-2} sec^{-1} meaning :
    - 1% length change in a second
  - Geologic Strain Rates: 10^{-14} to 10^{-17} sec^{-1}
    - at 10^{-14} sec^{-1} : 100,000 years to get 3% strain

Elastic response

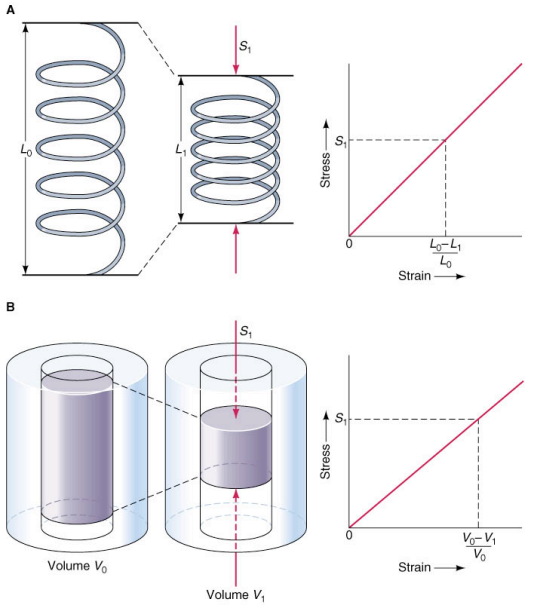
- Strain proportional to stress
  - "Hooke's Law"
- Reversible

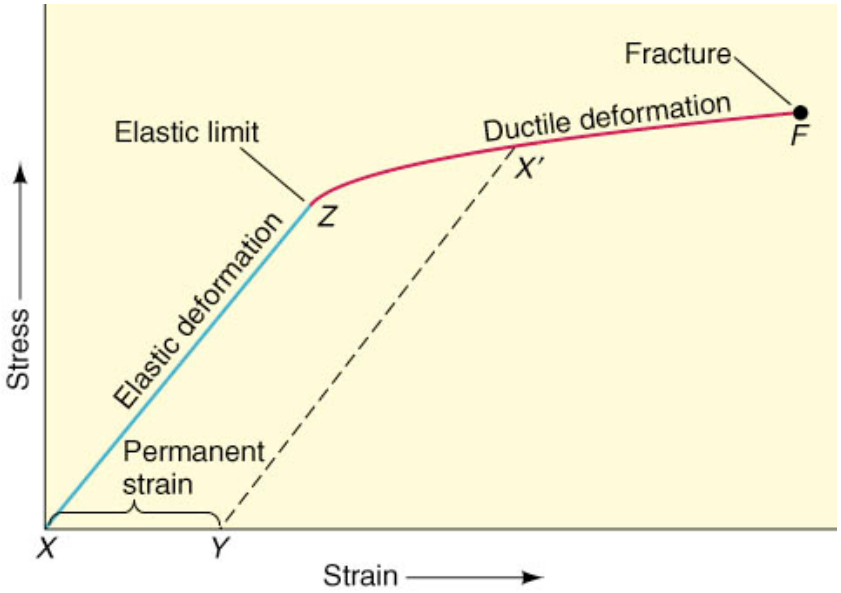
Ductile (Plastic)

- Irreversibe change
- Stressed beyond "Elastic limit"

Brittle Behavior

- Fracture when stressed beyond elastic and plastic limit





Rock Behavior

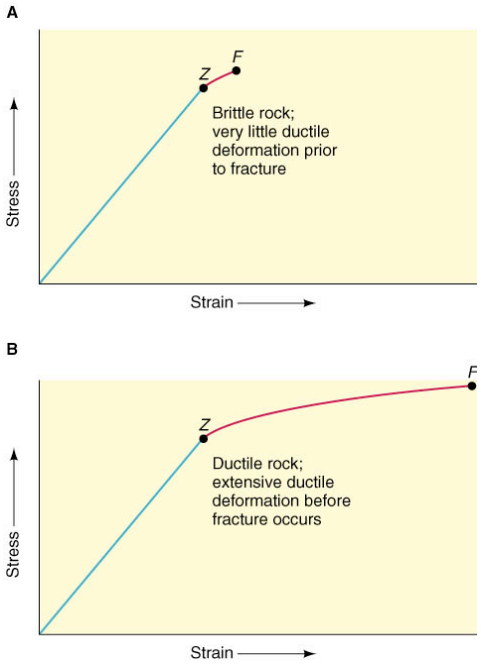
- **Elastic-plastic-brittle deformation depends on strain-rate, pressure, temperature, and composition**
  - **More ductile at:**
    - **Low strain rate**
    - **High pressure**
    - **High temperature**

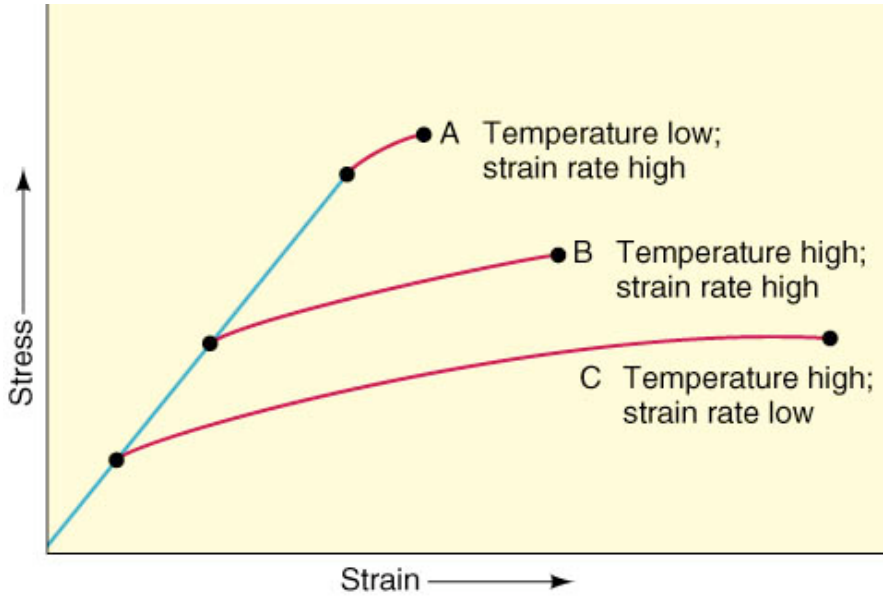
Composition

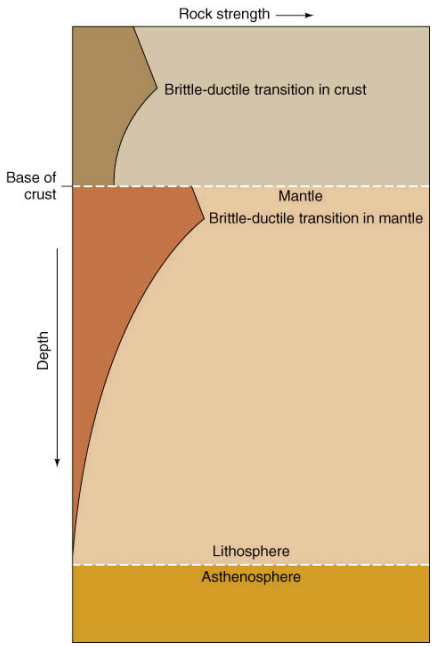
- The composition of a rock has pronounced effects on its properties.
  - Quartz, garnet, and olivine are very brittle.
  - Mica, clay, calcite,and gypsum are ductile.
- The presence of water in a rock reduces brittleness and enhances ductile properties.
  - Water affects properties by weakening the chemical bonds in minerals and by forming films around minerals grains.

General Behavior:

- **Rock are brittle at low pressure and temperature and high strain rate**
- Rocks are brittle at the Earth's surface







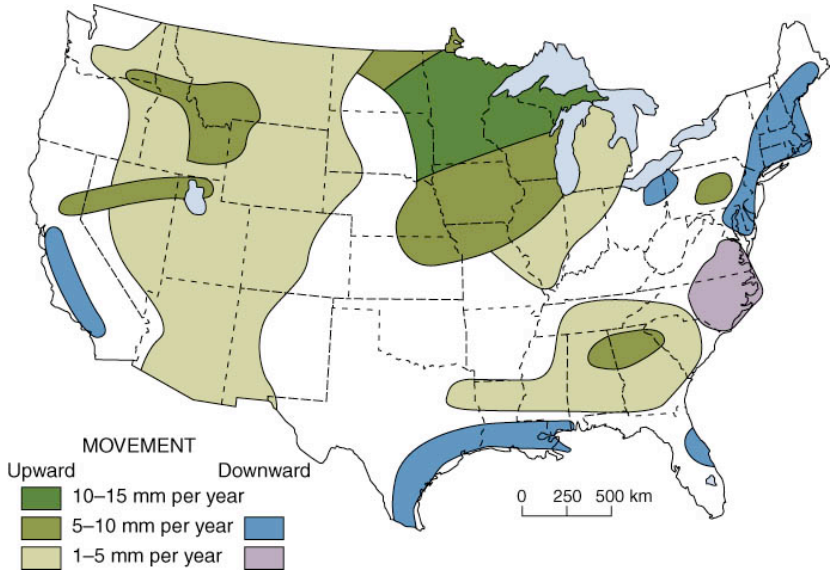
- By about 1300°C, rock strength is very low.
- Brittle deformation is no longer possible. The disappearance of all brittle deformation properties marks the lithosphere-asthenosphere boundary.
- In the crust large movements happens so slowly (low strain rates) that they can be measured only over a hundred or more years.

Abrupt Movement

- Abrupt movement results from the fracture of brittle rocks and movement along the fractures.
  - Stress builds up slowly until friction between the two sides of the fault is overcome, when abrupt slippage occurs.
    - The largest abrupt vertical displacement ever observed occurred in 1899 at Yakutat Bay, Alaska, during an earthquake. A stretch of the Alaskan shore lifted as much as 15 m above the sea level.
    - Abrupt movements in the lithosphere are commonly accompanied by earthquakes

Gradual Movement

- Gradual movement is the slow rising, sinking, or horizontal displacement of land masses.
  - Tectonic movement is gradual.
  - Movement along faults is usually, but not always, abrupt.

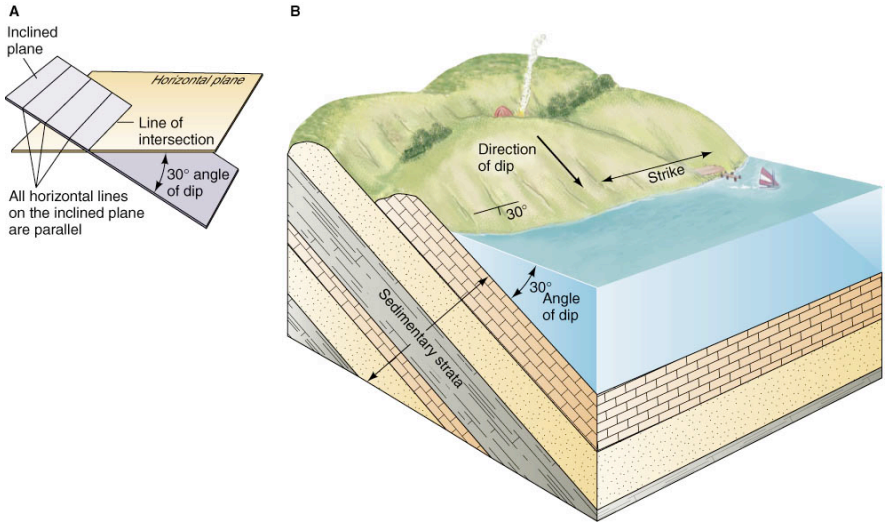


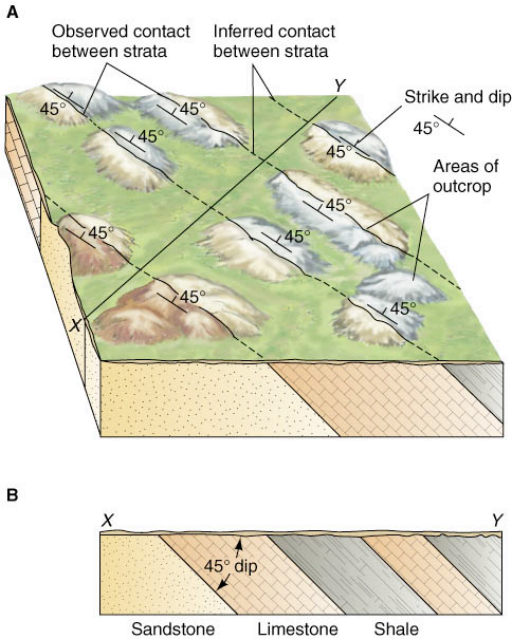
Evidence Of Former Deformation

- Structural geology is the study of rock deformation.
- The law of original horizontality tells us that sedimentary strata and lava flows were initially horizontal.
- If such rocks are tilted, we can conclude that deformation has occurred.

Dip and Strike

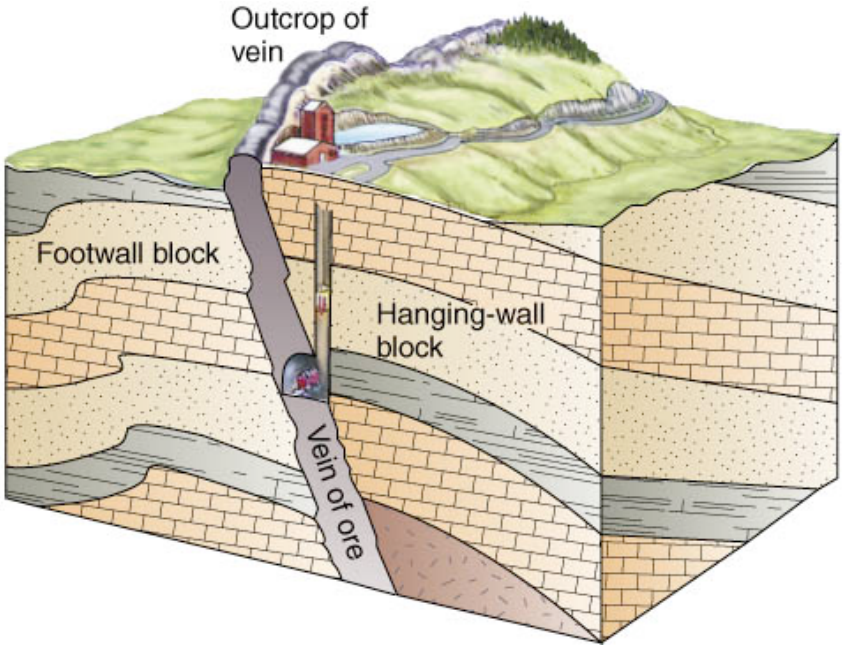
- The **dip** is the angle in degrees between a horizontal plane and the inclined plane, measured down from horizontal.
- The **strike** is the compass direction of the horizontal line formed by the intersection of a horizontal plane and an inclined plane.





Deformation By Fracture

- Rock in the crust tends to be brittle and to be cut by innumerable fractures called either joints or faults.
- Most faults are inclined.
  - To describe the inclination, geologists have adopted two old mining terms:
    - The **hanging-wall block** is the block of rock above an inclined fault.
    - The block of rock below an inclined fault is the **footwall block.**

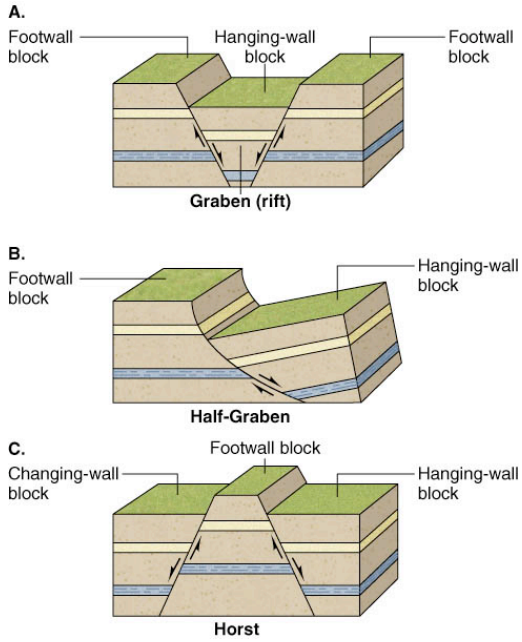


Classification of Faults

- Faults are classified according to:
  - The dip of the fault.
  - The direction of relative movement.

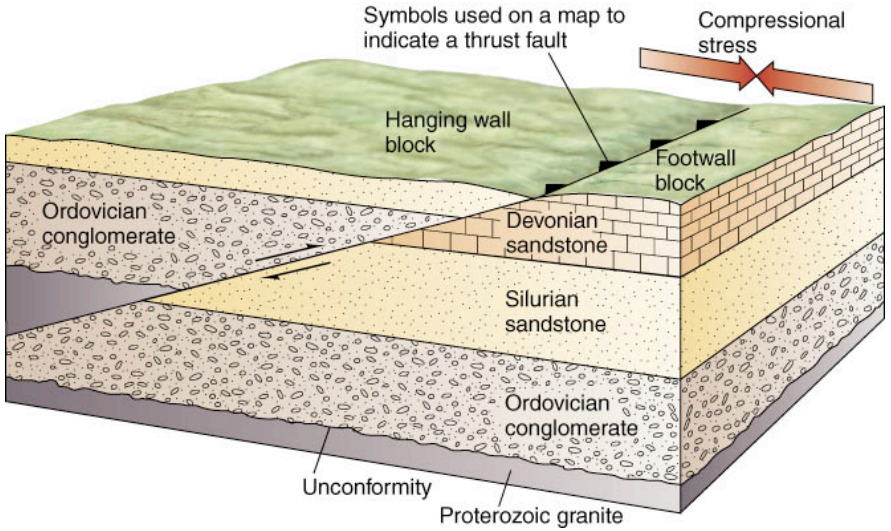
Normal faults

- Caused by tensional stresses that tend to pull the crust apart, as well as by stresses created by a push from below that tend to stretch the crust
- The **hanging-wall** block moves down relative to the footwall block

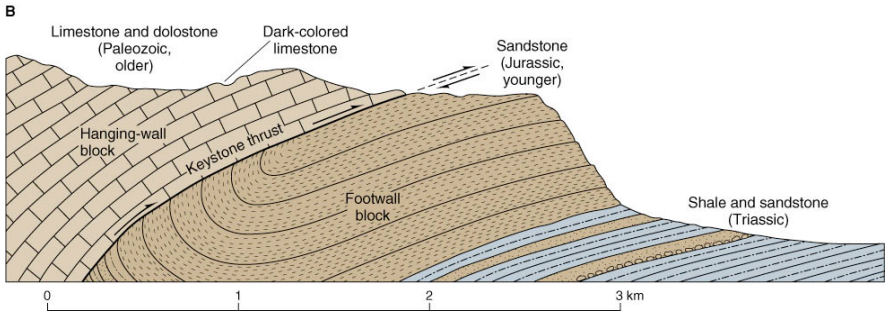


Reverse faults

- Caused by compressional stresses
- Movement on a reverse fault is such that a hanging-wall block moves up relative to a footwall block.
- Reverse fault movement shortens and thickens the crust



- **Thrust faults are low-angle reverse faults with dip less than 15°.**
  - Such faults are common in great mountain chains.
- **Strike-slip faults are those in which the principal movement is horizontal and therefore parallel to the strike of the fault.**
  - Strike-slip faults arise from shear stresses.
  - The San Andreas is a right-lateral strike-slip fault.
    - Apparently, movement (more than 600 km) has been occurring along it for at least 65 million years.



Keystone Thrust
Red Rock Canyon
Las Vegas, NV