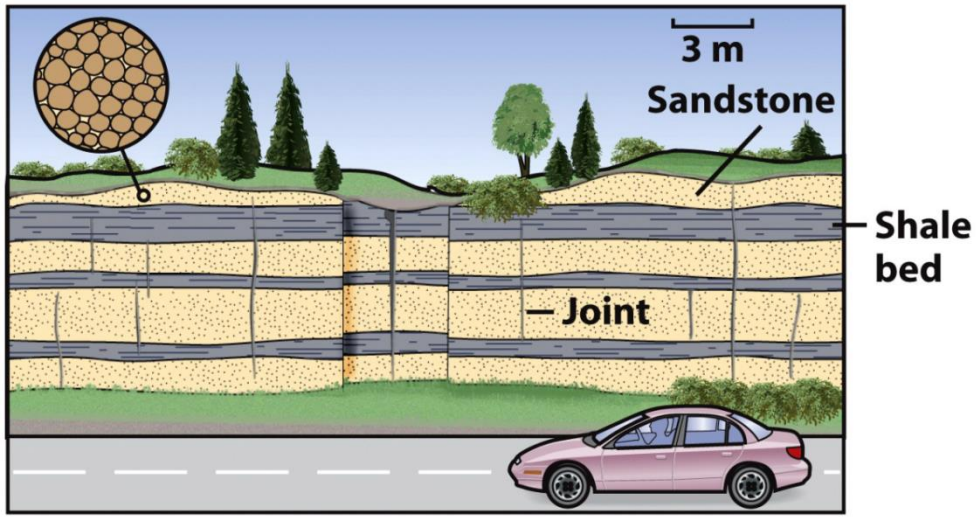
Lecture 9 –faults, folds and mountain building

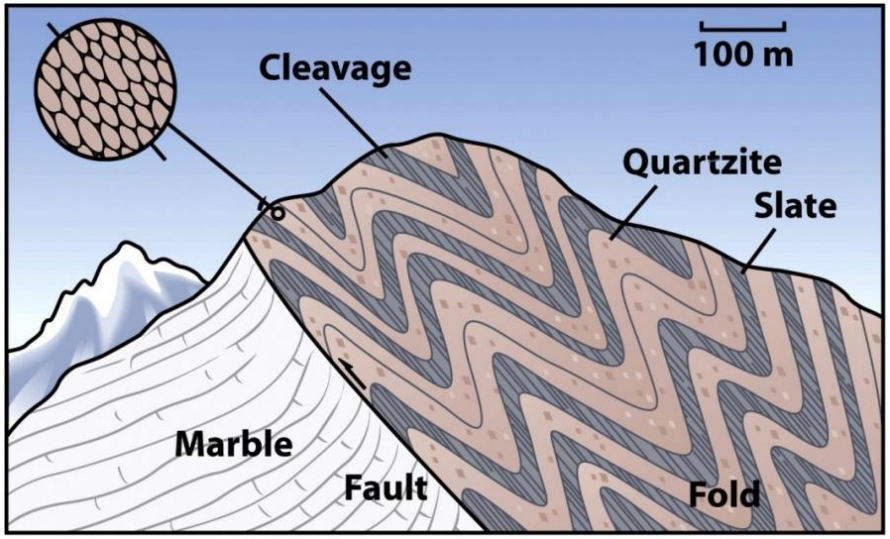
Rock deformation

- “Deformation” = all changes in size, shape, orientation, or position of a rock mass
- Structural geology is the study of rock deformation

Deformation

- Undeformed terrain (unstrained)
  - Horizontal beds, spherical grains, no folds or faults
- Deformed terrain (strained)
  - Tilted beds, metamorphic alteration, folding and faulting



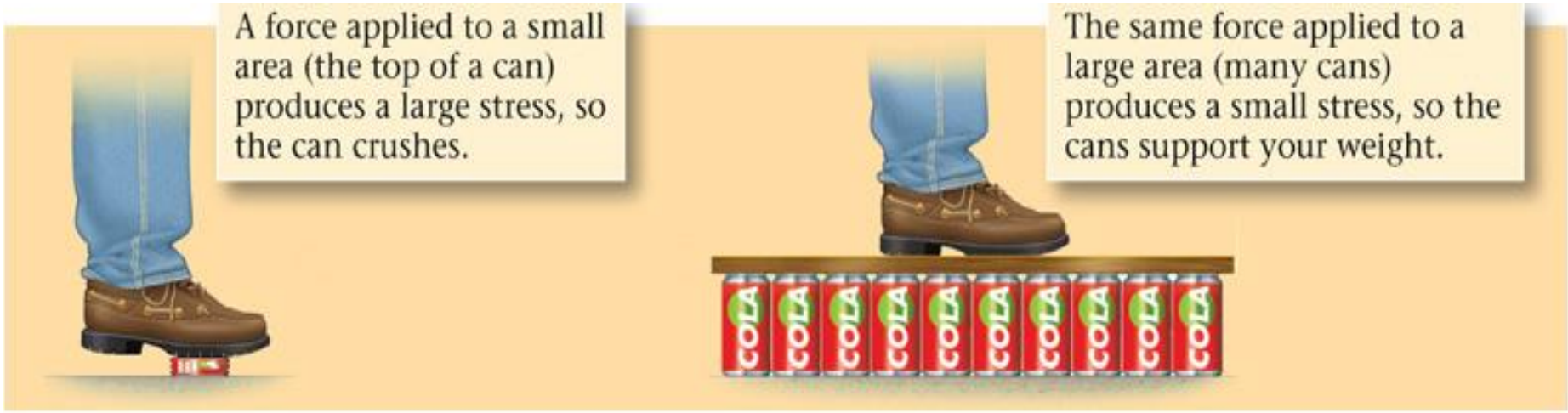


Stress vs Strain

Stress results in strain!

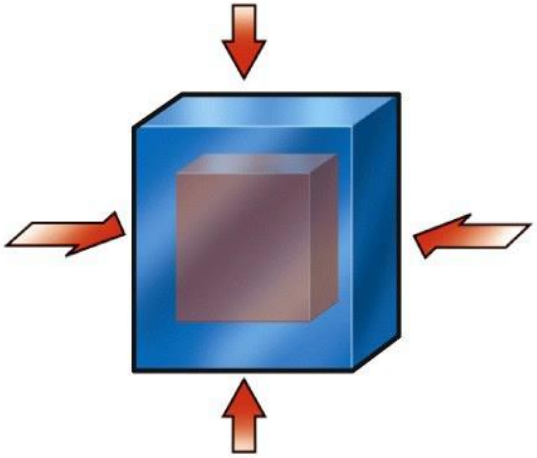
Causes of Deformation

- Stress = the amount of force applied to a given area
  - Stress can be equal in all directions (confining pressure) or stronger in one or more direction (differential stress)
- Three types of stress:
  - Compressional – Squeezing
  - Tensional – Pulling apart
  - Shear – Sliding past

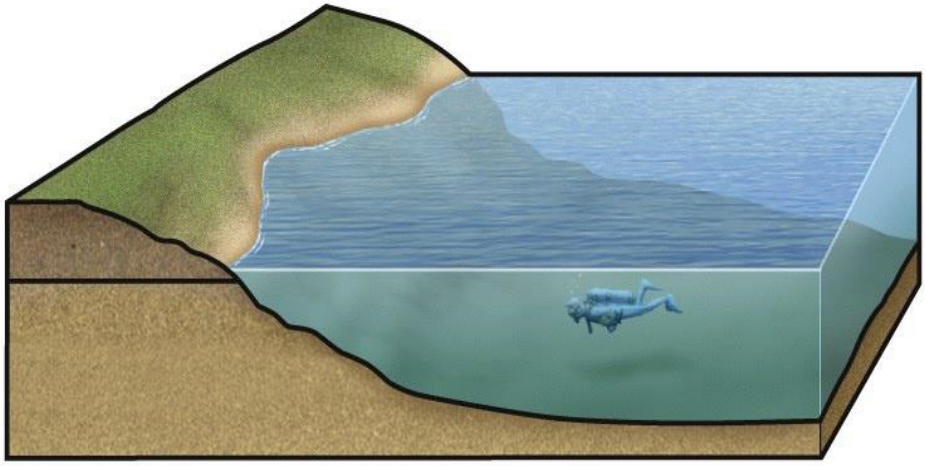


Confining Pressure

- An object feels the same stress on all sides.



Pressure

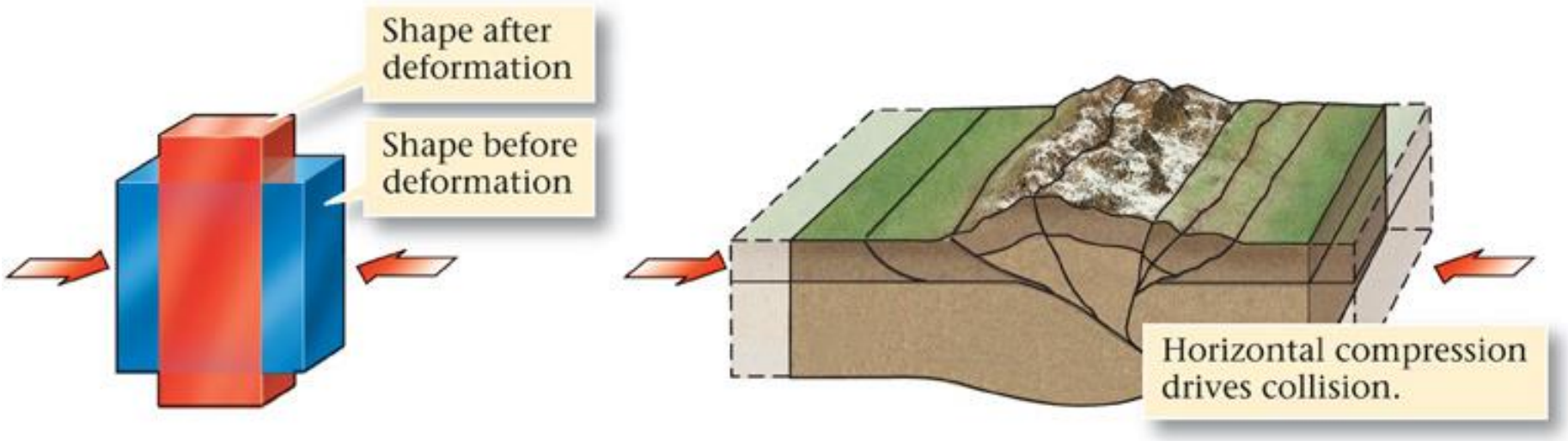


Diver underwater

https://www.youtube.com/watch?v=pRC5R1jRO58

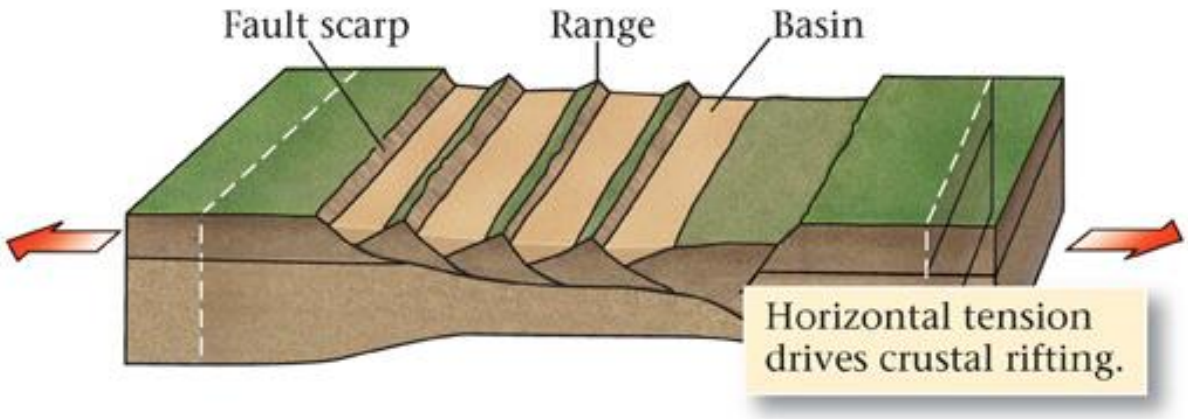
Stress: Compression

- Squeezing (greater stress in one direction).



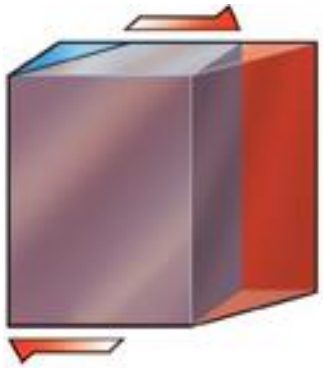
Stress: Extension (or Tensional)

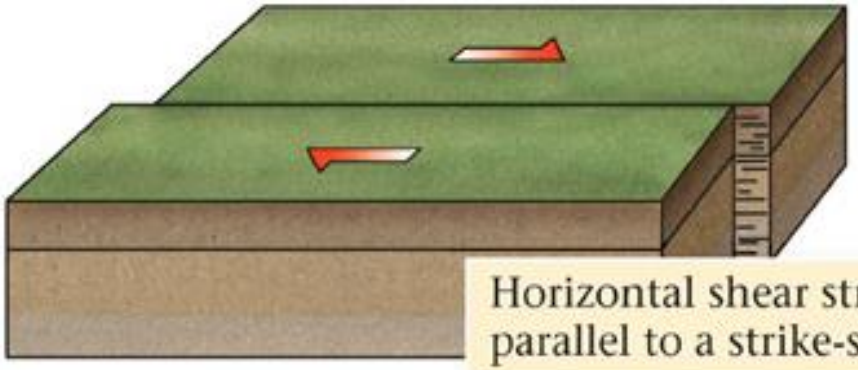
- Pull-apart (greater stress in one direction).



Stress: Shear

- Blocks of rock sliding past one another.

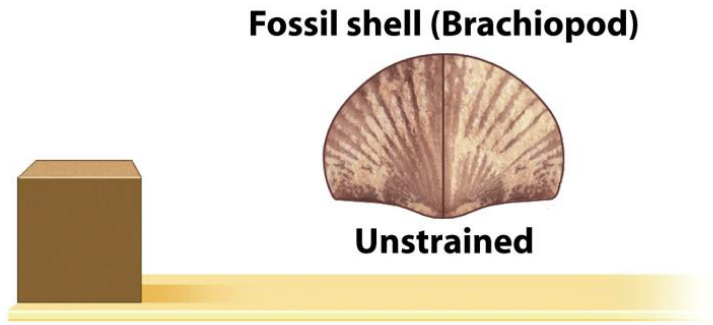


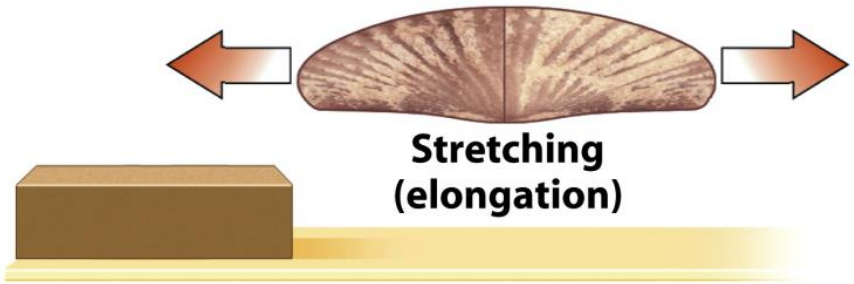


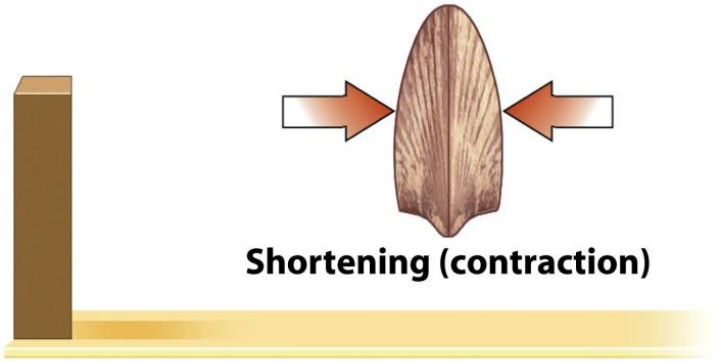
Horizontal shear stress is parallel to a strike-slip fault.

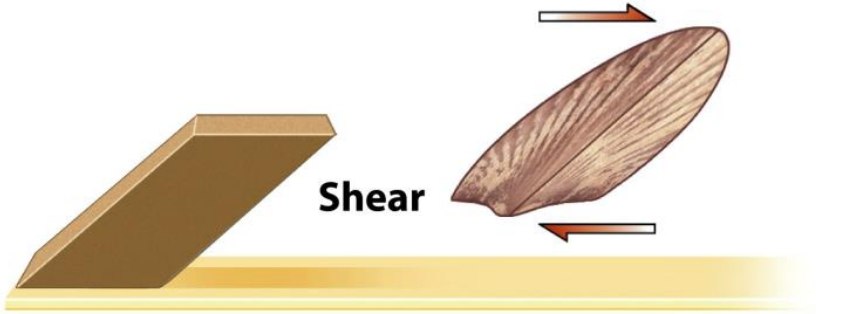
Strain

- Strain = An irreversible change in the shape and size of a rock body caused by stress
  - Stretching – Pulling apart
  - Shortening – Squeezing together
  - Shear – Sliding past









Group question

- Which of these types of stress would cause crustal thickening?

a) Confining pressure
b) Compression
c) Extension
d) Shear stress

Deformation

- Rocks subjected to stresses greater than their own strength begin to deform by folding, flowing, or fracturing

- Rocks are elastic up to a point...
  - Rocks strength is not surpassed
  - No permanent changes

- If rock's strength is surpassed it may:
  - Flow (ductile deformation)
  - Fracture (brittle deformation)

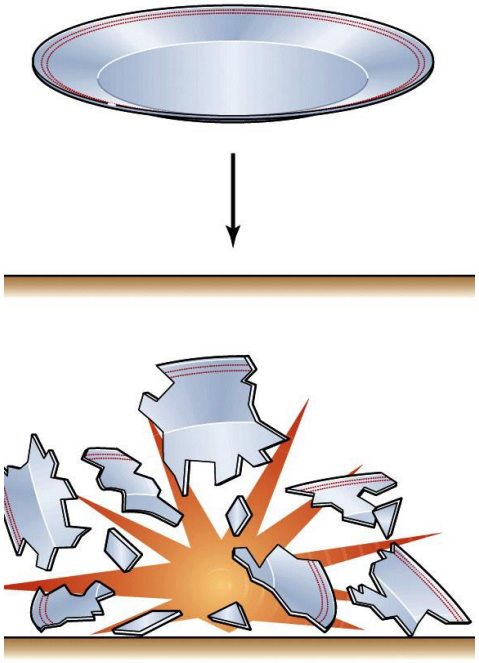
Group Question

- Folds are a result of:

a) Ductile deformation
b) Brittle deformation
c) Neither
d) Both

Deformation Types

- Two major deformation types: Brittle and ductile
  - Brittle deformation – Rocks break by fracturing
    - Brittle deformation occurs in the shallow crust



Brittle deformation

Deformation Types

- Two major deformation types: Brittle and ductile
  - Ductile deformation – Rocks deform by flow and folding
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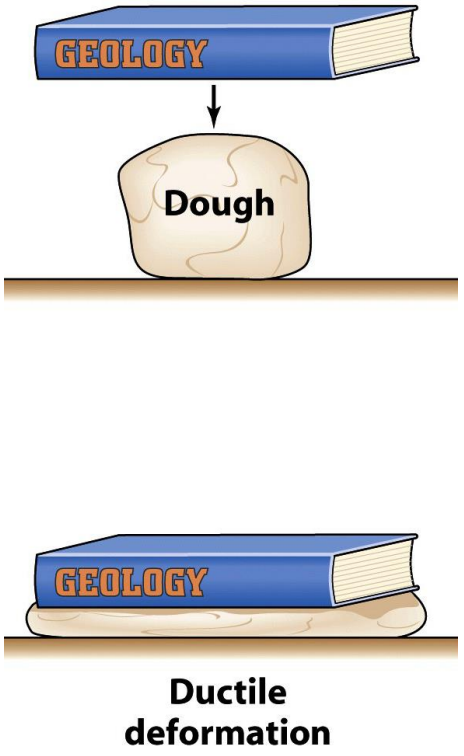
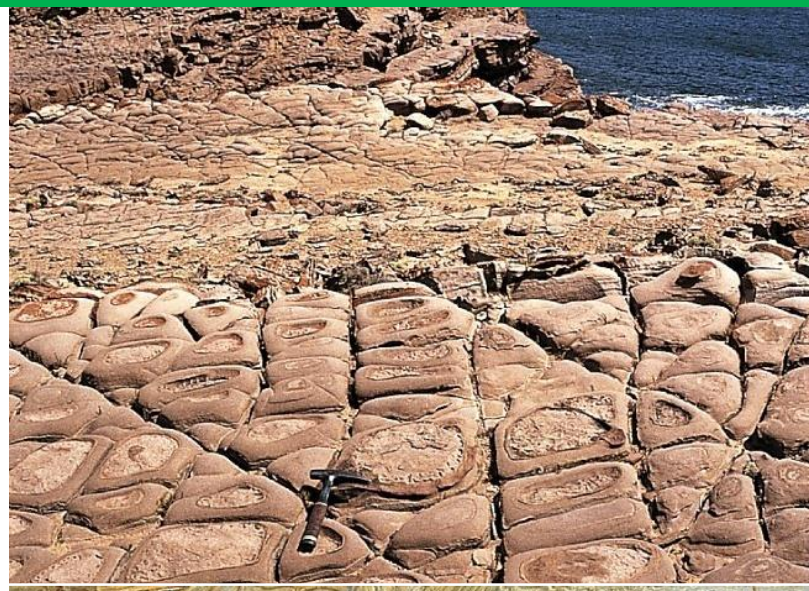
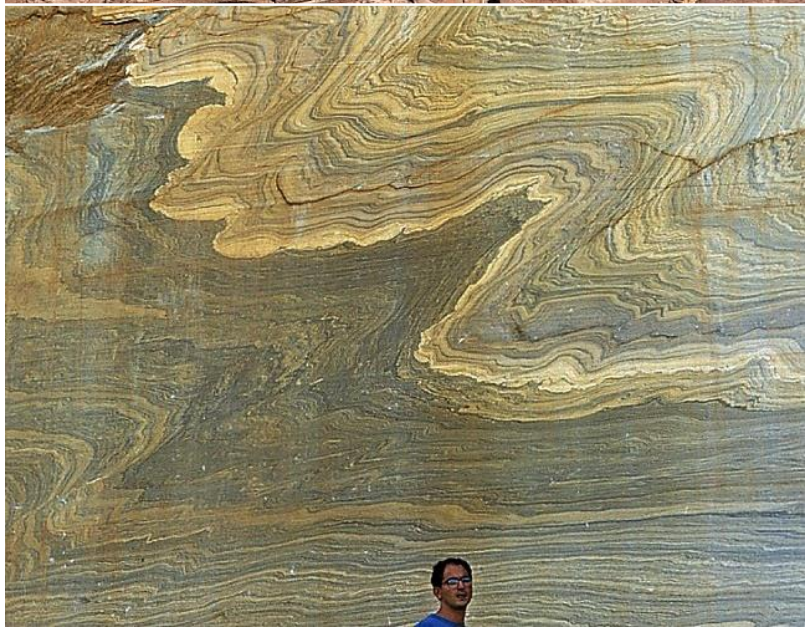


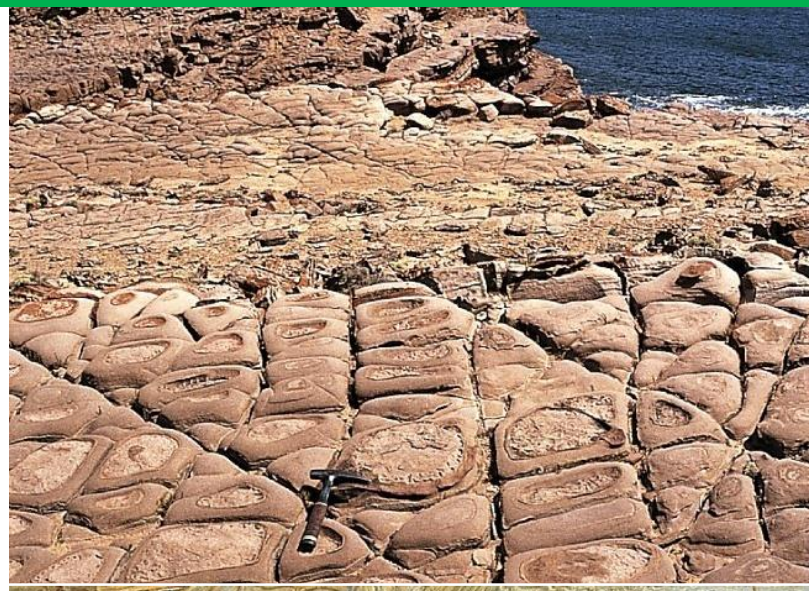
What controls brittle vs. ductile?

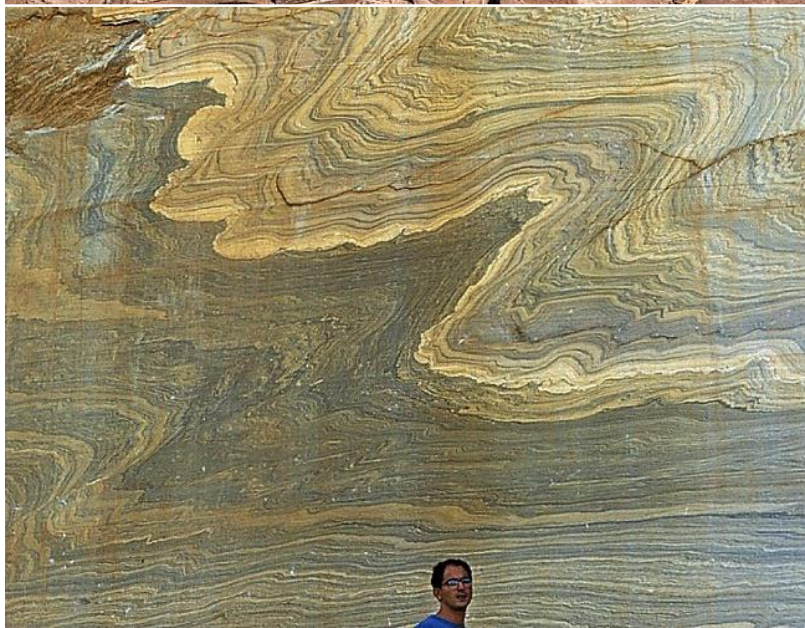




What controls brittle vs. ductile?

- Rate of deformation
- Rock strength
- Temperature
- Confining pressure





Group Question

- Which would cause more brittle behavior?

a) High temperature
b) Low pressure
c) Weaker material (softer rock types)
d) Slow deformation rate

Geologic Structures

- Geometric features created by deformation.
  - Folds, faults, joints, foliation etc.
  - Often preserve information about stress fields.
- 3-D structural orientation is described by strike and dip.
  - Strike – Horizontal intersection with a tilted surface.
  - Dip – Angle of surface down from the horizontal.

Joints

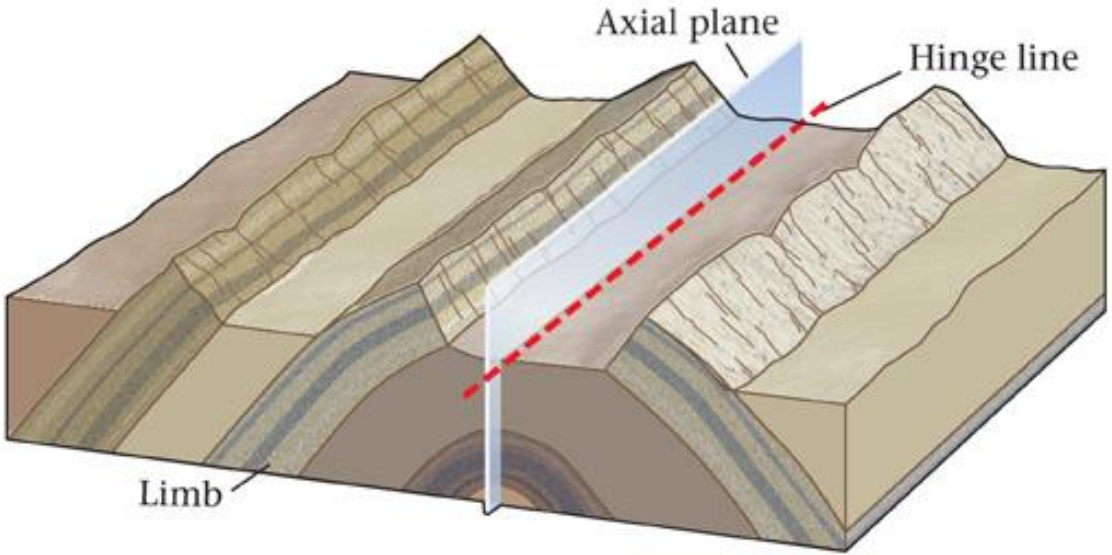
- Planar rock fractures without offset
- Result from stresses
- Systematic joints occur in parallel sets
- Minerals can fill joints to form veins
- Joints control weathering of rock

Faults

- Faults are fractures in rocks along which appreciable displacement has taken place
- Sudden movements along faults are the cause of most earthquakes
- Classified by their relative movement……

Folds

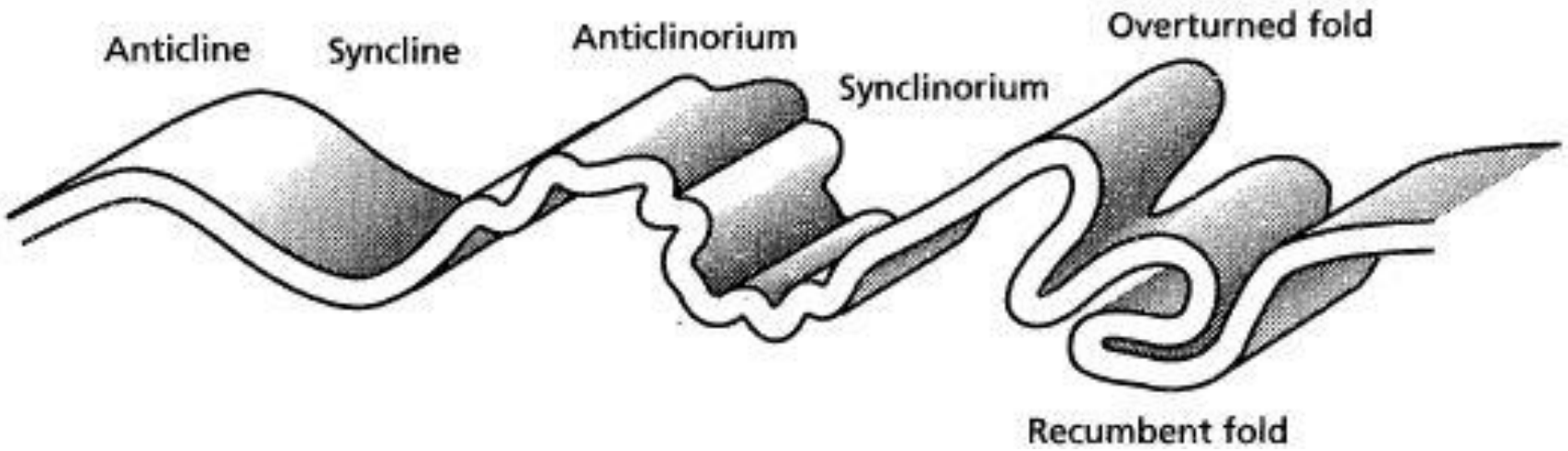
- Hinge – Portion of maximum curvature on a fold.
- Limb – Less curved “sides” of a fold
- Axial plane – Imaginary surface defined by connecting hinges of successively nested folds.



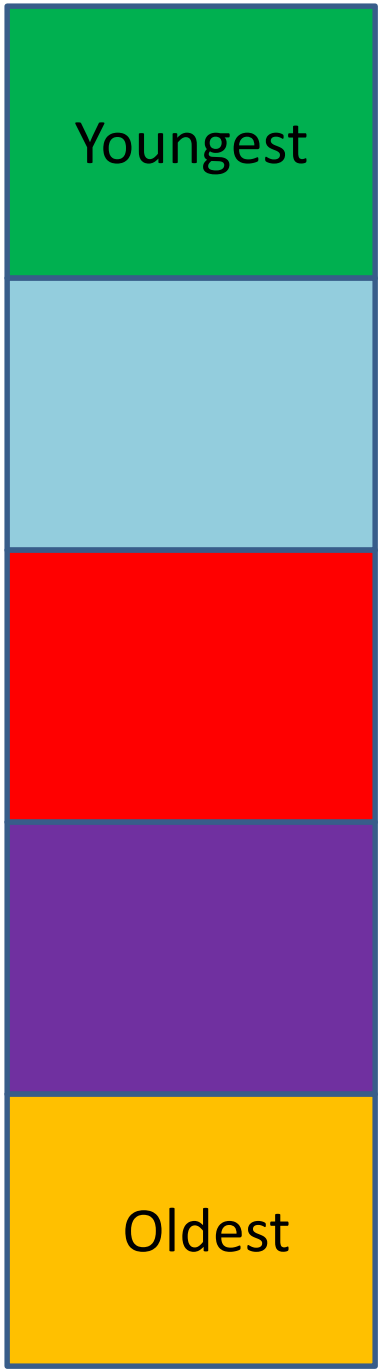
Where are the hinge lines, axial planes and limbs?

Folds

- Most folds result from compressional stresses which shorten and thicken the crust
    - Anticline – upfolds or arches rock layers
    - Syncline – downfolds or troughs of rock layers

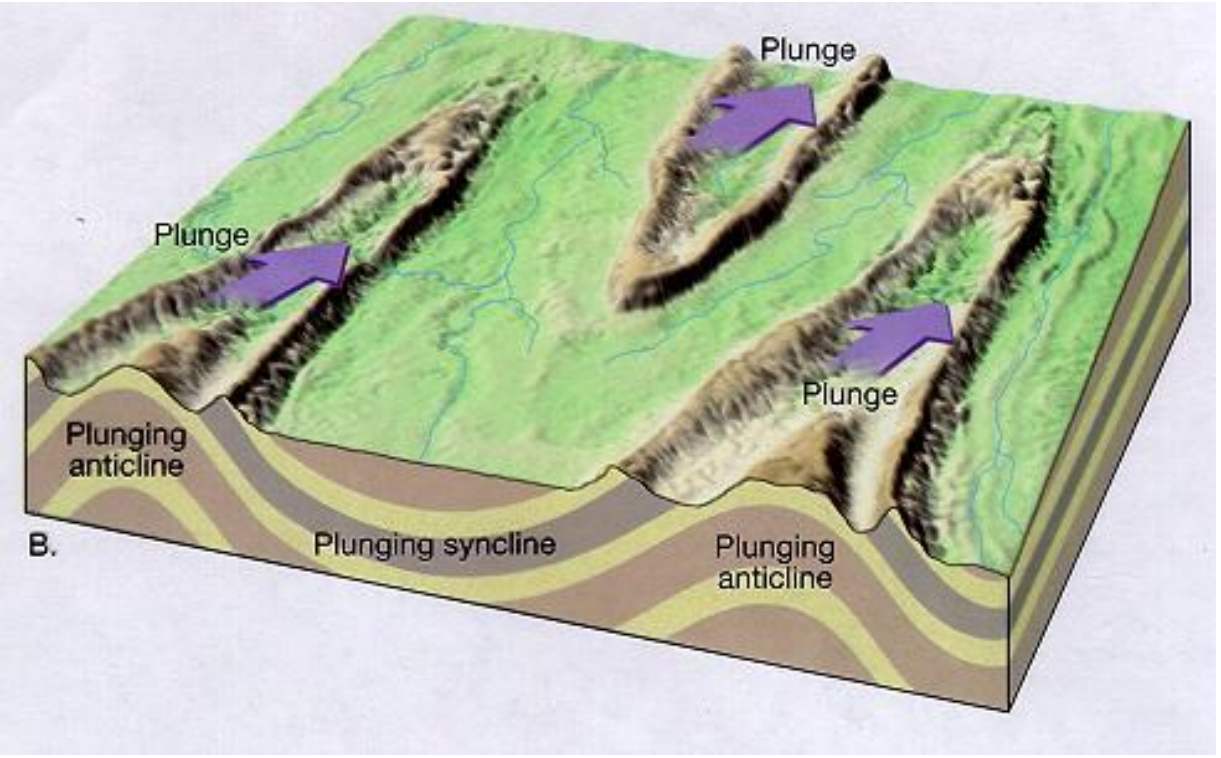


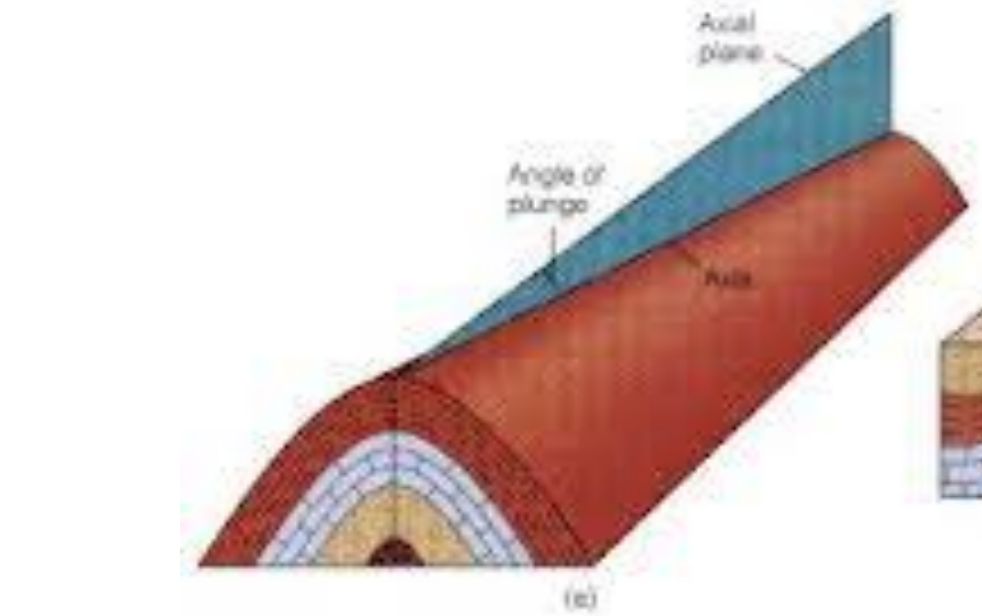
a) Syncline or b) Anticline?

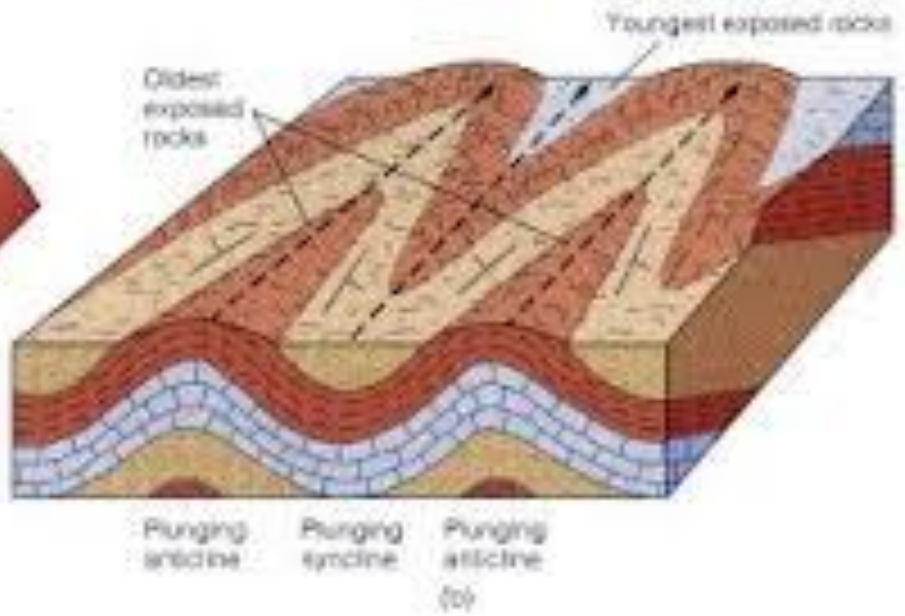


Can you draw the pattern you'd see at the surface if you had a syncline.

Now…. What would happen if the fold itself dipped in one direction….


Plunge
Plunge
Plunge
Plunging anticline
B.
Plunging syncline
Plunging anticline

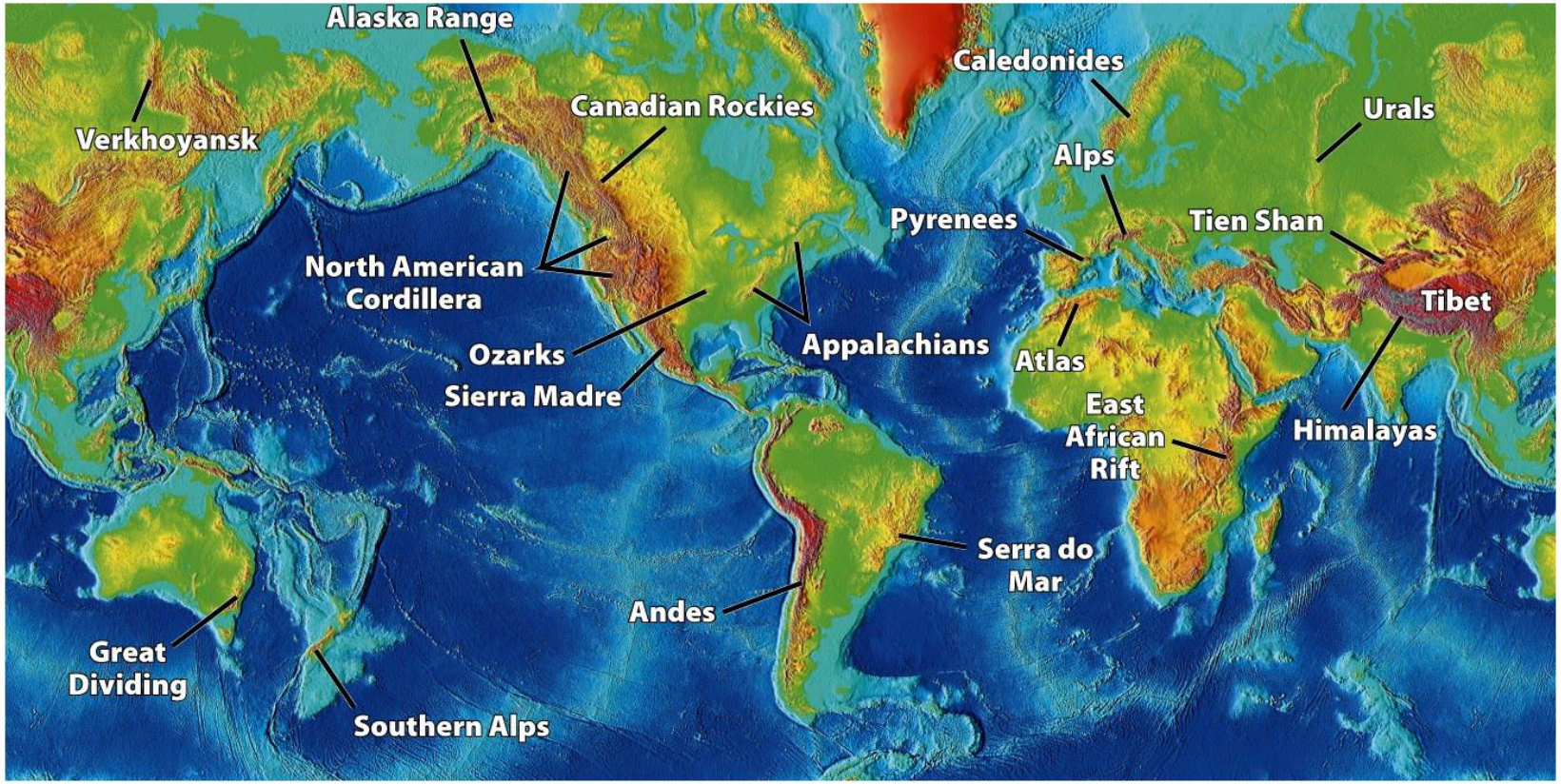

Axial plane
Angle of plunge
Axis
(a)


Youngest exposed rocks
Oldest exposed rocks
Plunging anticline
Plunging syncline
Plunging anticline
(b)

Rock Deformation and Mountain Building

Mountain Belts

- Occur in linear belts
- Constructed by tectonic plate interactions - orogenesis



Mountain building (uplift)

- Construction of mountains requires substantial uplift
  - Mt. Everest (8.85 km above sea level)
  - Comprised of marine sediments (formed below sea level)
- Tall mountains are supported by a thickened crust

Erosional Sculpting

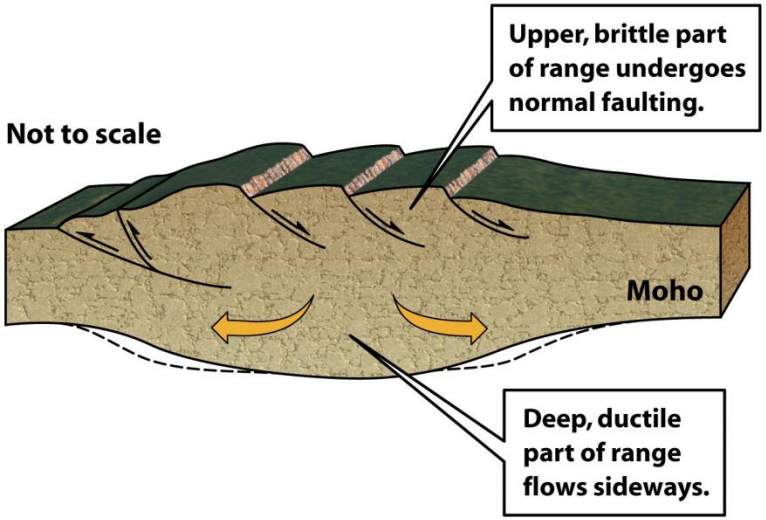
- Mountains reflect a balance between uplift and erosion
- Mountains are steep and jagged due to erosion
- Rock characteristics control erosion
  - Resistant layers form cliffs
  - Easily eroded rocks form slopes

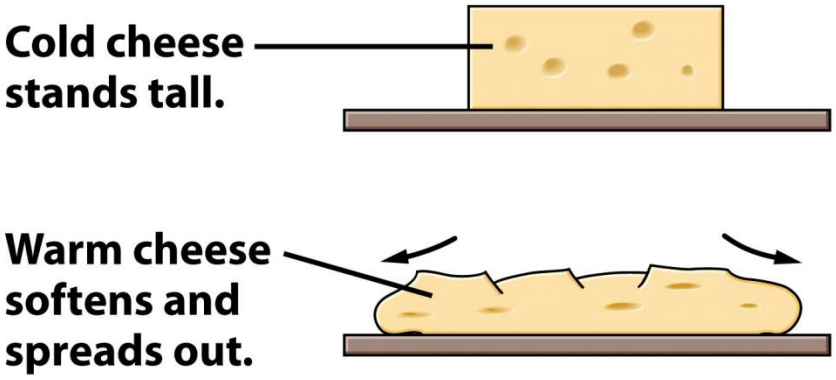
Orogenic Collapse

- Could the Himalayas keep increasing in height forever?

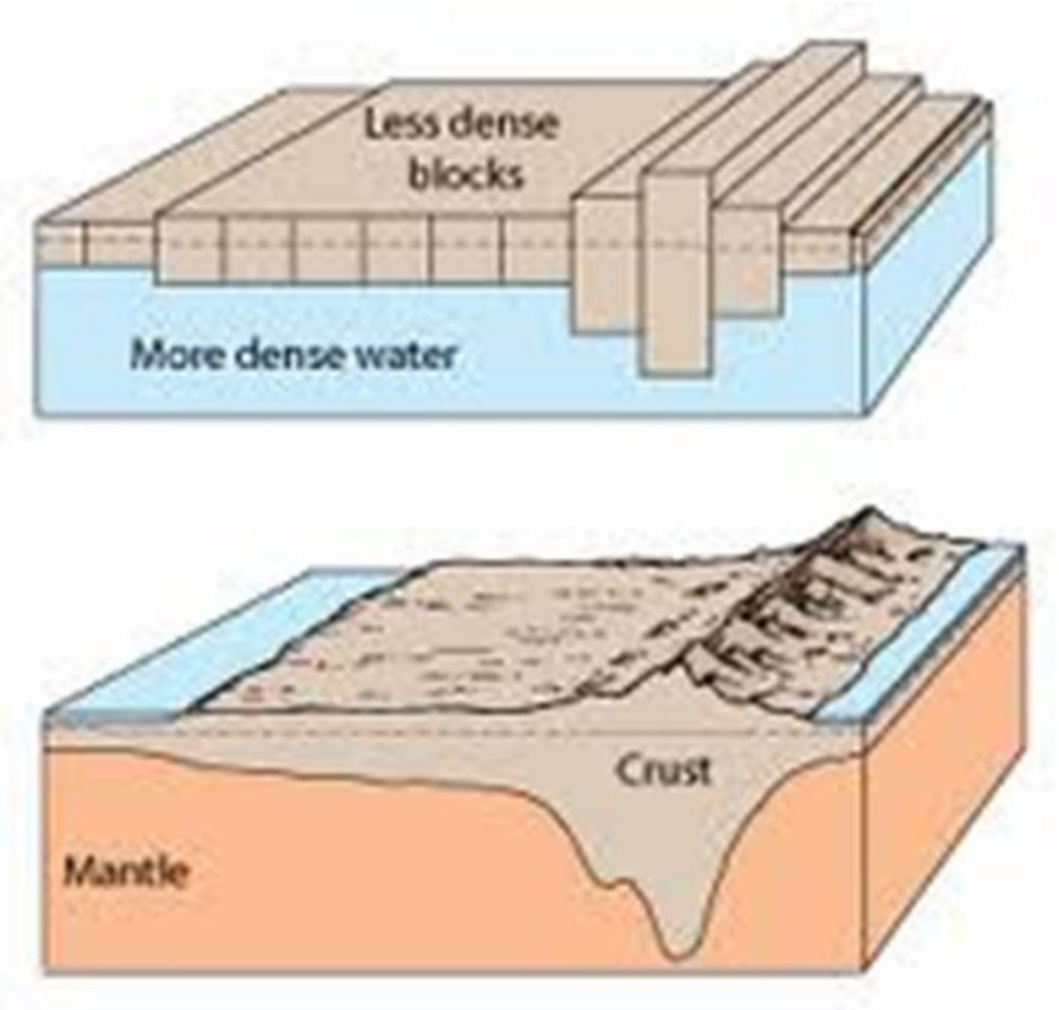
Orogenic Collapse

- There is an upper limit to mountain heights
  - Erosion accelerates with height
  - Weight of high mountains overwhelms rock strength
    - Deep, hot rocks eventually flow out from beneath mountains
    - The mountains then collapse downward like soft cheese
- Uplift, erosion, and collapse exhume deep crustal rocks



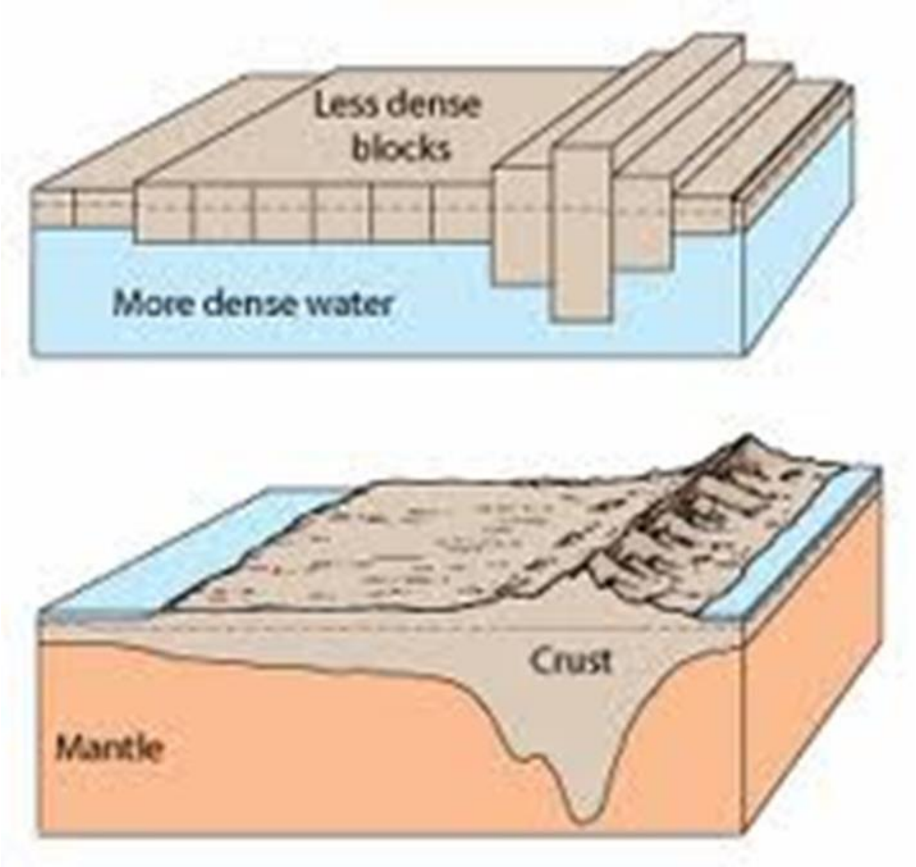


Isostasy



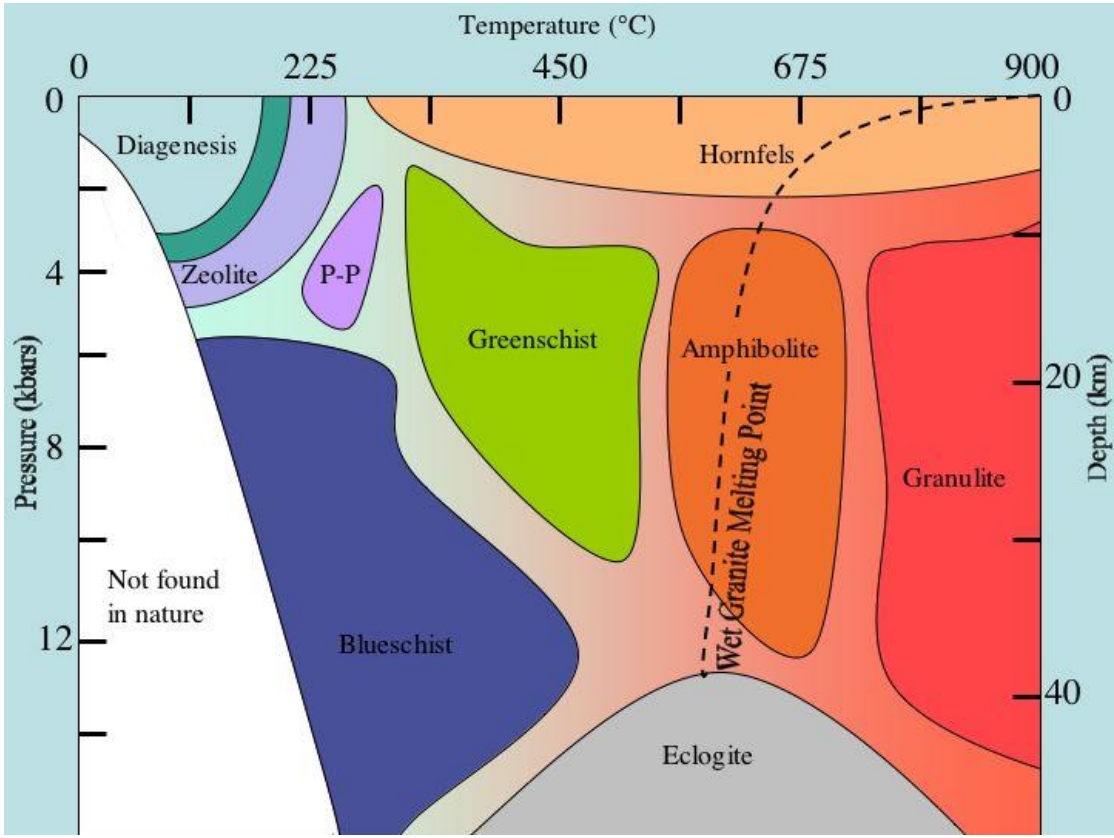
Isostasy

- What happens as mountains stop building and erosion starts to lower them?



Isostasy

- You are a researcher in the Himalayas. You find rocks with mineralogies that place them in the greenschist facies.
- Using U-Pb radioactive dating the rock is about 10 Myrs.
- What is the maximum exhumation/uplift rate?
- What could this uplift rate tell us?



a) 0.03 km/Myrs
b) 3 km/Myrs
c) 30 km/Myrs