Deformation of rocks

- _____ and _____ are geologic structures.
- Structural geology is the study of the _____ of rocks and the effects of this movement.

Small Scale Folds

Small-scale Faults

Why is understanding deformation of the Earth important?

- Major part of the _____ of the earth
- Explains the origin of _____ belts
- Major factor in the trapping of hydrocarbons and the concentration of ore deposits
- Faulting is associated with _____

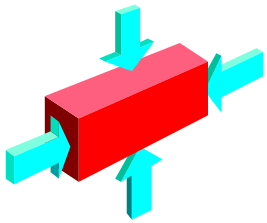
Rock Deformation

- _____
  - Compression
  - Tension
  - Shear
  - Torsion
- _____
- _____

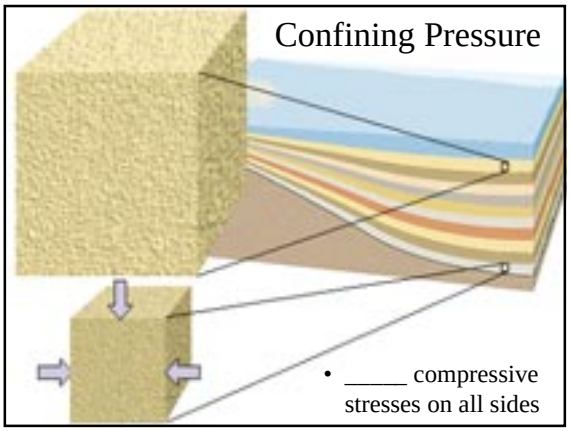
➔ Deformation

Compression

- Oppositely directed forces acting _____ each other



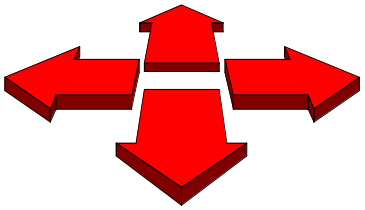
Confining Pressure



- _____ compressive stresses on all sides

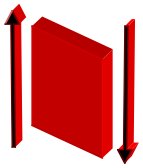
Tension

- oppositely directed forces acting _____ from each other



Shear

- oppositely directed forces acting _____ to each other across a surface in a couple



Vertical Shear

Horizontal Shear

Torsion

- oppositely directed forces acting parallel to each other in a _____ fashion

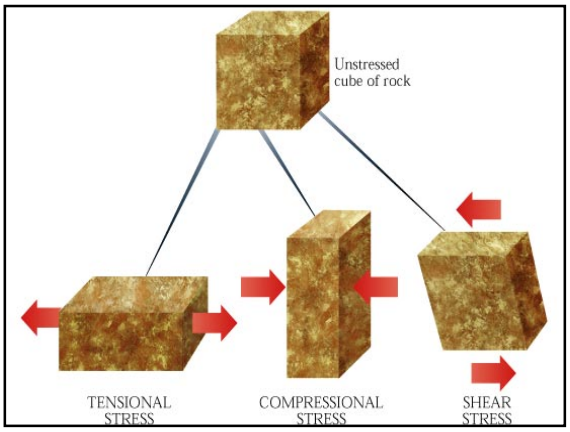
Torsion

Strength

- the ability of an object to ____ deformation
  - compressive strength
  - tensile strength
  - shear strength
  - torsional strength

What is the Relationship Among Stress, Strength, and Strain ?

- _____ will occur when
- _____ exceeds the
- _____ of the material.



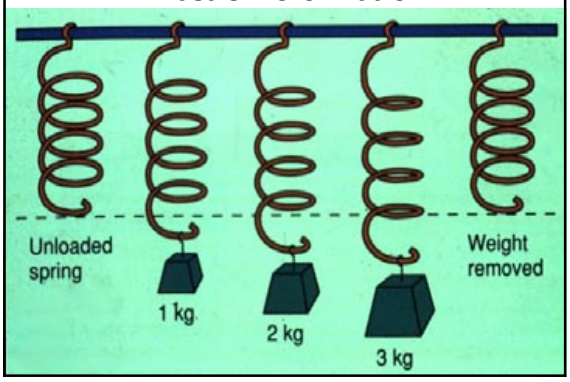
Strain

- Any change in original _____ or _____ of an object in response to stress acting on the object = _____
- Types of Deformation
  - Elastic
  - Ductile (_____)
  - _____ (rupture)

Elastic Deformation

- a _____ change in shape or size that is recovered when the applied stress is removed.
- important in _____

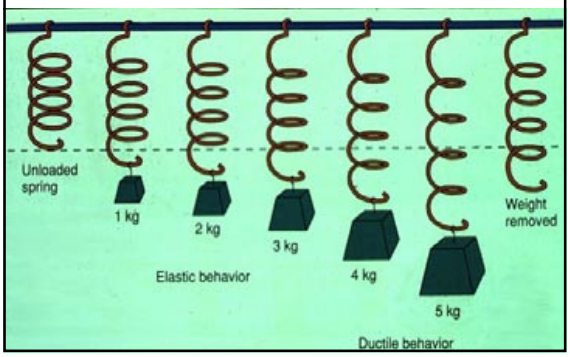
Elastic Deformation



Ductile (Plastic) Deformation

- A _____ change in shape or size that is not recovered when the stress is removed
- Occurs by the slippage of atoms or small groups of atoms past each other in the deforming material, without loss of cohesion
- i.e. it flows or _____

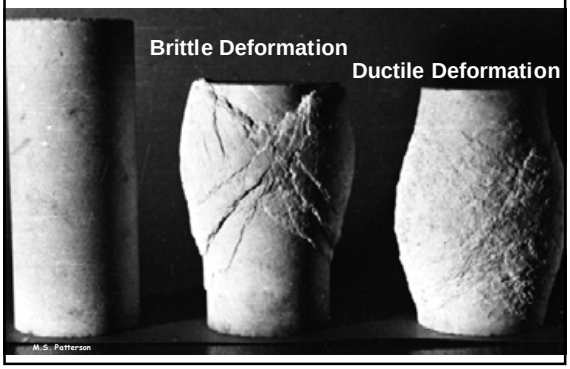
Ductile (Plastic) Deformation



Brittle Deformation (rupture)

- the _____ of cohesion of a body under the influence of deforming stress
- usually occurs along sub-planar surfaces that separate zones of coherent material
- i.e. it _____

Experimental Deformation of Marble

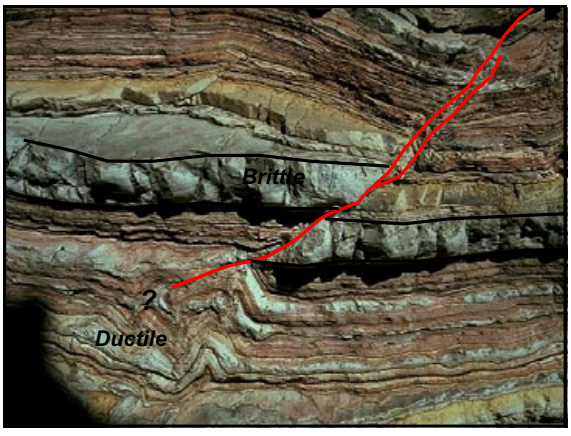


Factors Determining the Style of Deformation

- Pressure:
  - High P → _____ Deformation
  - Low P → _____ Deformation
- Temperature:
  - High Temp → _____ Deformation
  - Low Temp → _____ Deformation

Factors Determining the Style of Deformation

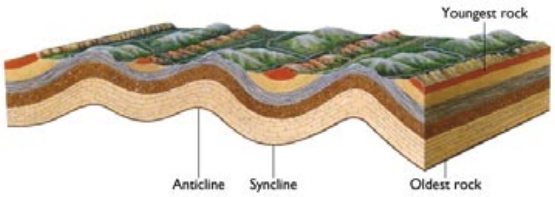
- Strain Rate:
  - High Strain Rate → _____ Deformation
  - Low Strain Rate → _____ Deformation
- Composition:
  - "Hard"(e.g. granite) → _____ Deformation
  - "Soft" (e.g. marble) → _____ Deformation
  - Some rocks are _____ than others.
    - competent: rocks that deform only under great stresses
    - incompetent: rocks that deform under moderate to low stresses

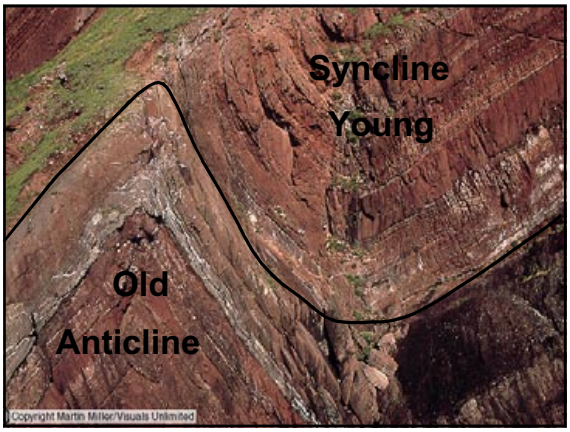


Fold terms

- Syncline
  - a sequence of folded rocks with the _____ rocks on the inside of the fold
  - generally shaped like a _____
- Anticline
  - a sequence of folded rocks with the _____ rocks on the inside of the fold
  - Generally shaped like an _____
- scale - from mm to tens of km

Anticlines and Synclines





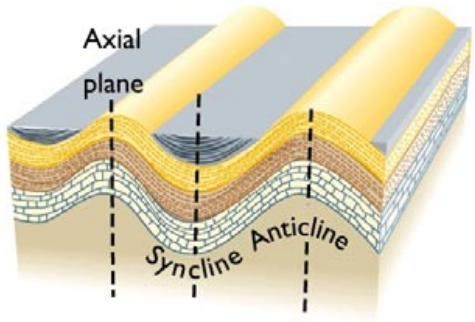
Fold Components

- _____ plane
  - the plane of mirror symmetry _____ the fold into two limbs
- _____ axis
  - line formed by the _____ of the axial plane and a bedding plane
- limbs
  - the _____ of the fold

Fold Categories

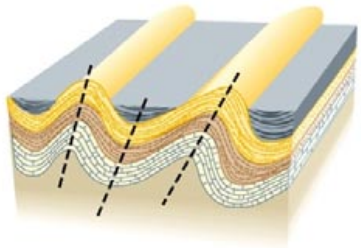
- symmetric folds
  - where the axial plane is _____
- asymmetric folds
  - beds on one limb dip more _____ than the other
- overturned/recumbent folds
  - both limbs dip in the _____ direction, but one limb is dipped beyond vertical
- horizontal fold
  - where the _____ axis is horizontal
- plunging fold
  - where the _____ axis is not horizontal

Symmetric Folds



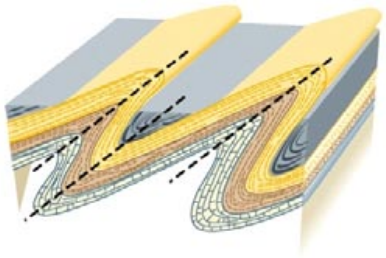
Axial plane is vertical

Assymetric Folds



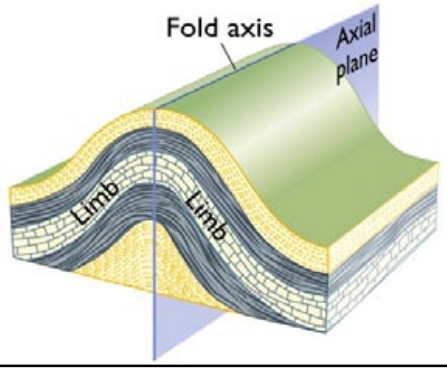
Beds in one limb dip more steeply than those in the others

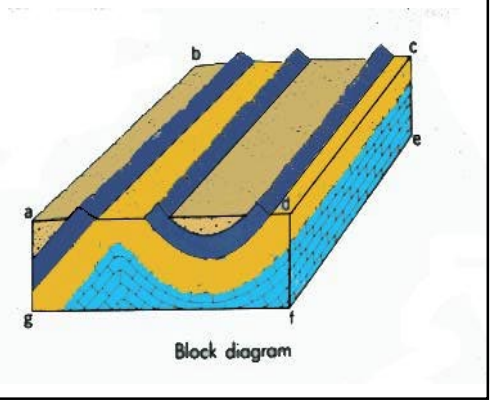
Overturned Folds

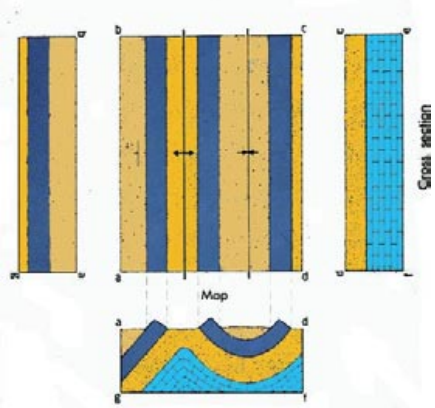


Both limbs dip in same direction but one limb has been tilted beyond vertical

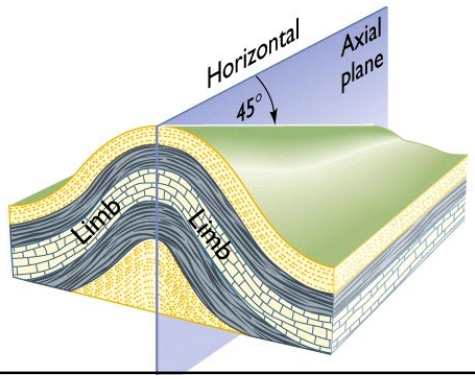
Horizontal Fold

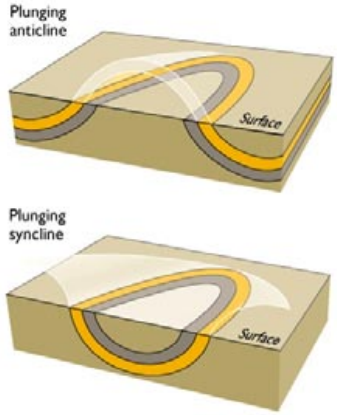






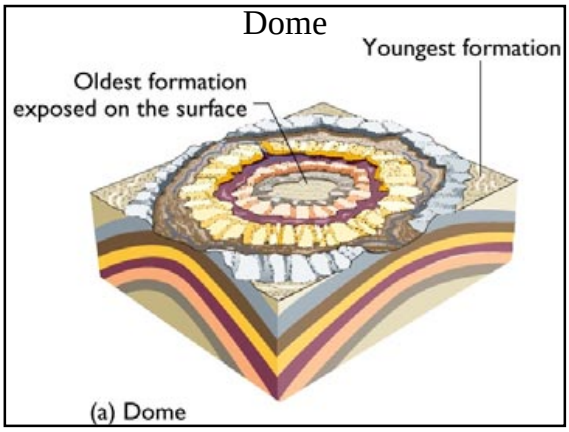
Plunging Fold



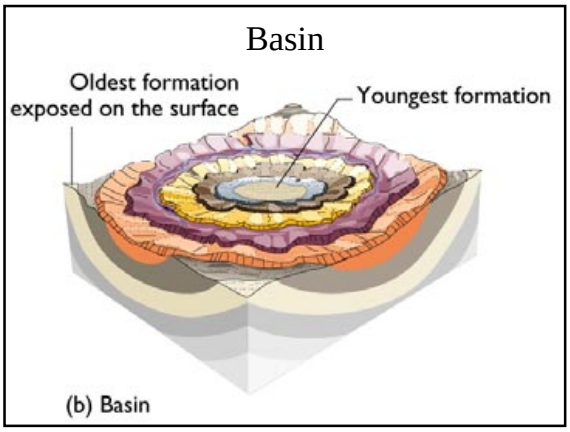


Map View of Plunging Folds

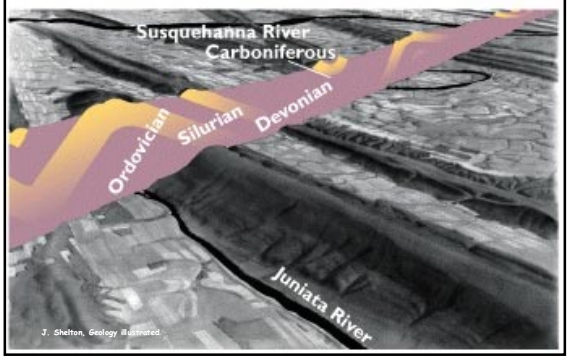
Dome



Basin



Plunging Folds in the Valley and Ridge



Joints and Faults

- Joint
  - A fracture along which _____ movement has occurred
- Fault
  - A fracture along which _____ movement has occurred
- An example of _____ failure

Joints

Fault Scarp

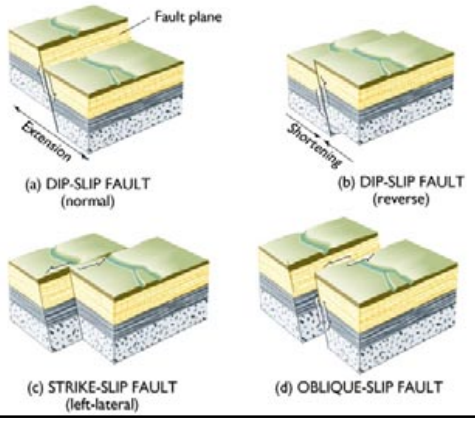
- A scarp formed by the _____ of adjacent blocks along a fault. It can be thought of a an _____ fault plane which may or may not have been modified by erosion.

1988 Armenian Earthquake Fault Scarp

1992 Landers Earthquake Fault Scarp

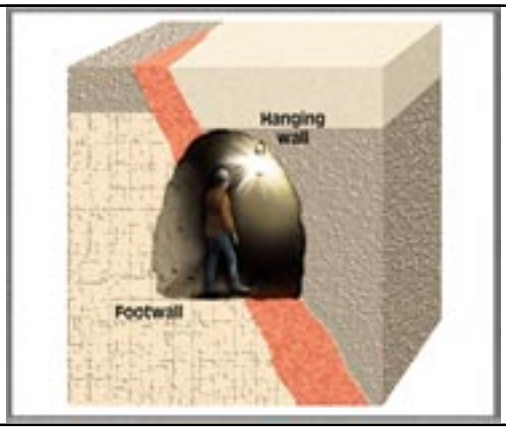
Faults

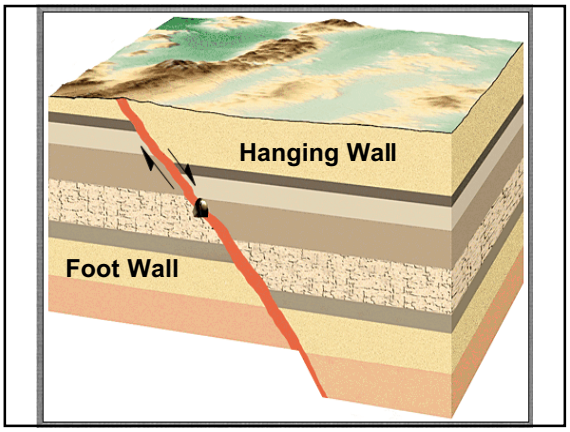
- _____-slip faults
  - normal
  - reverse
    - thrust
- _____-slip faults
  - right lateral
  - left lateral
- _____-slip faults



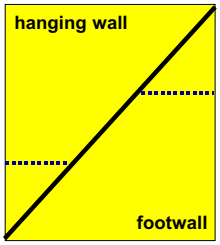
Dip-Slip Faults

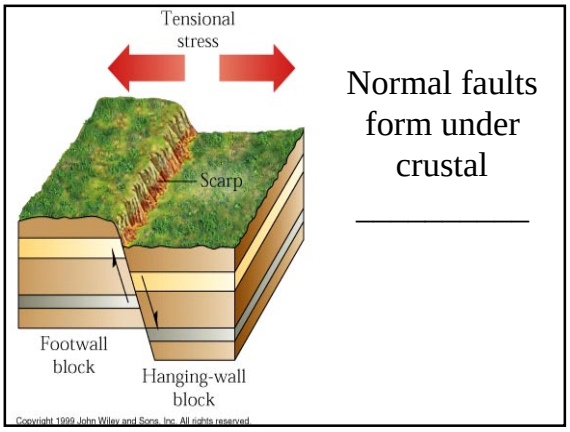
- Motion of the fault blocks is _____ to the dip direction.
- Normal Faults
  - a dip-slip fault where the hanging wall moved _____ relative to the footwall.
- Reverse Faults
  - a dip-slip fault where the hanging wall moved _____ relative to the footwall.





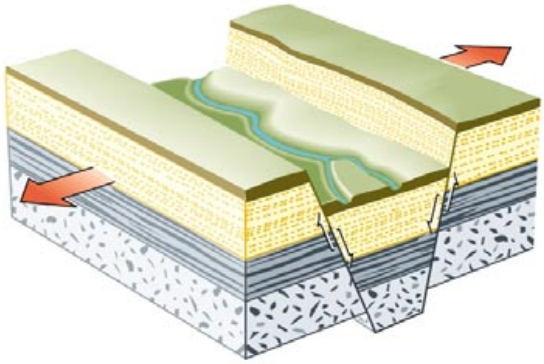
Normal Fault



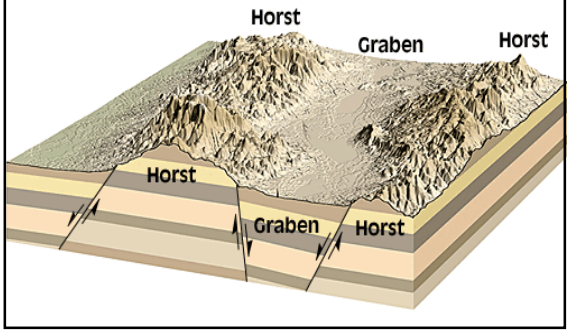


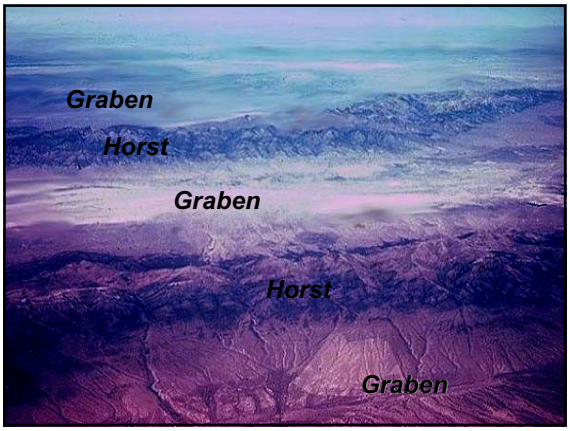
Normal faults form under crustal _____

Rift Valley Formed by Extension

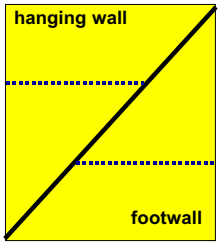


Horsts and Grabens

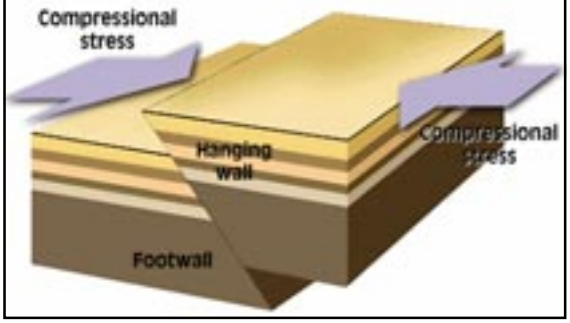




Reverse Fault

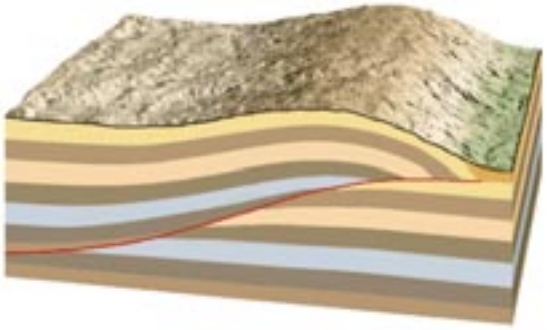


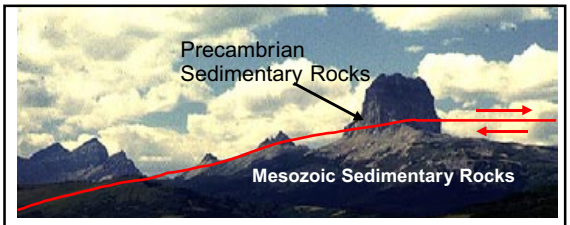
Reverse faults form under crustal _____

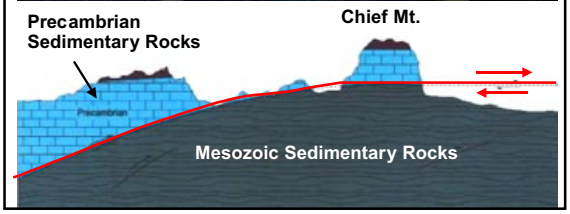


Thrust Fault

- a low-angle reverse fault



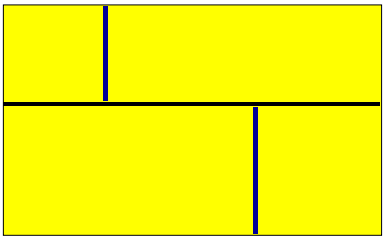




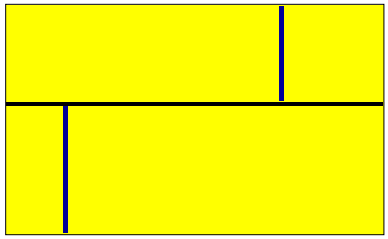
Types of Strike-Slip Faults:

- Motion of the fault blocks is _____ to the strike direction.
- _____-lateral Fault
  - a strike-slip fault where the opposite block has moved to the _____, relative to the observer.
- _____-lateral Fault
  - a strike-slip fault where the opposite block has moved to the _____, relative to the observer.

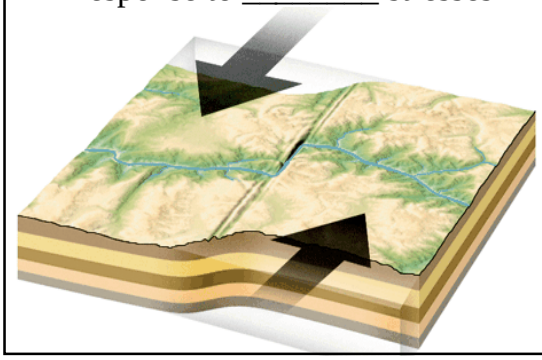
Left-lateral Strike Slip Fault

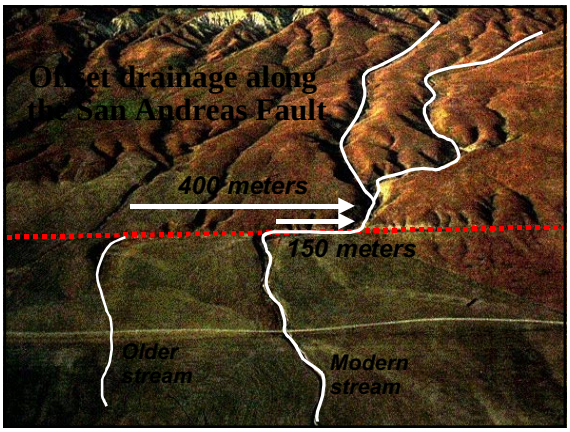


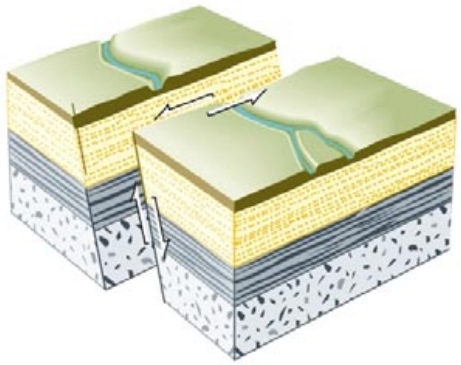
Right-lateral Strike Slip Fault



Strike-slip faults form in response to _____ stresses







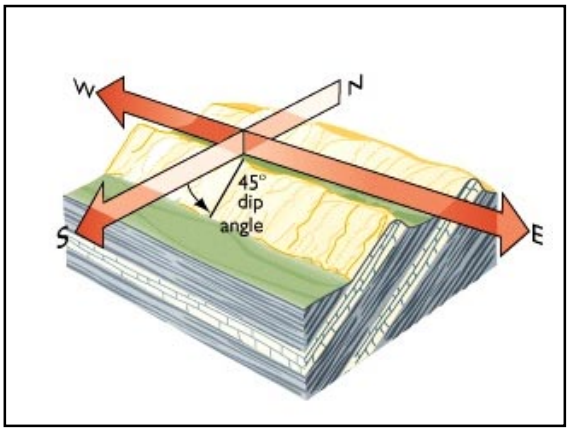
(d) OBLIQUE-SLIP FAULT

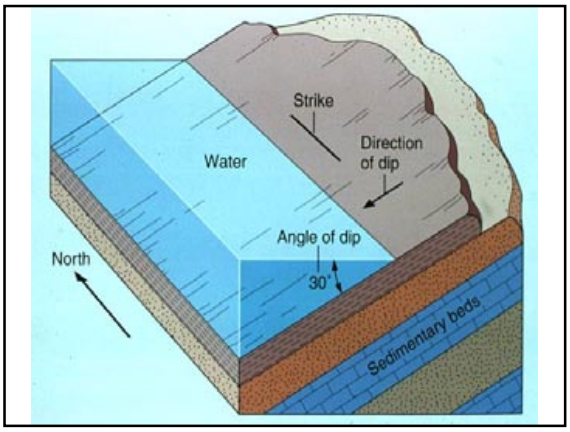
Geologic Maps Show

- The geologic units _____ at the surface (usually delineated by lithology and age), and
- The _____ of these units in space using geologic symbols.

Orientation of Deformed Rocks

- We need some way to describe the distribution of geologic structures
- _____
  - _____ of a line defined by the intersection of the plane in question and the horizontal
- _____
  - maximum acute _____ between the plane and the horizontal, measured perpendicular to strike





Strike and Dip Symbols for Inclined Beds

Strike N40E

Dip SE 30º

30

N

Strike and Dip Symbols for Horizontal and Vertical Beds

Vertical

Strike: N40E
Dip: 90º

Horizontal

Strike: N/A
Dip: 0 º

N

Fault Symbols

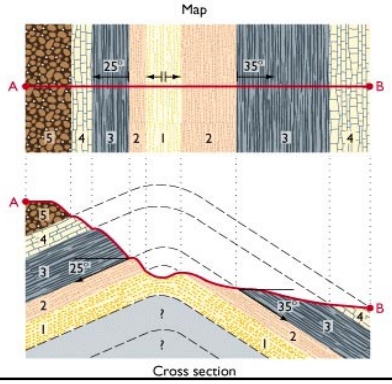
U
D
Normal Fault

D
U
Reverse Fault

Left-lateral

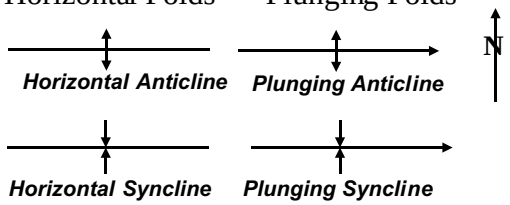
Right-lateral

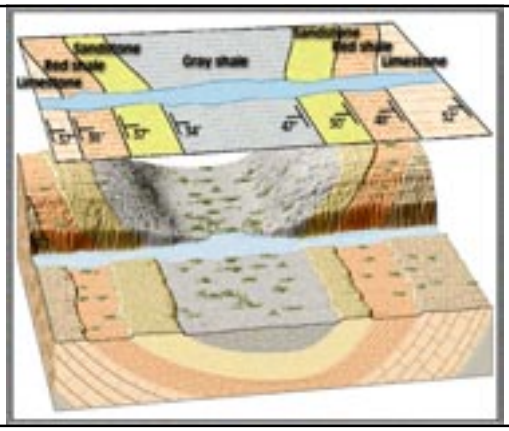
Geologic Map and Cross Section



Fold Symbols

Horizontal Folds | Plunging Folds

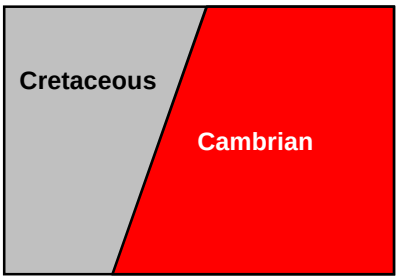




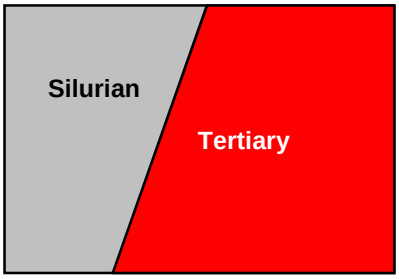
Dating the order of deformation

- Use geometry:
  - Inclusions
  - Cross-cutting relationships
- Combine with fossils and radiometric dating

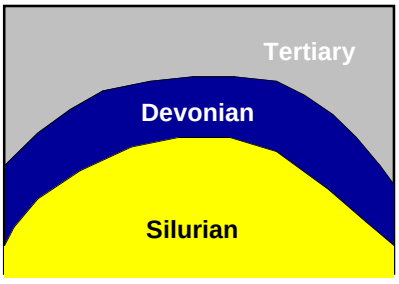
What type of fault?



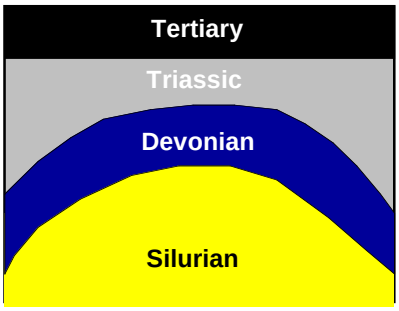
What type of fault?



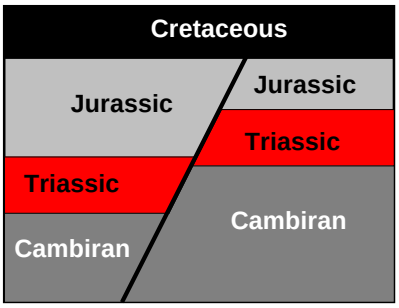
What type of fold?



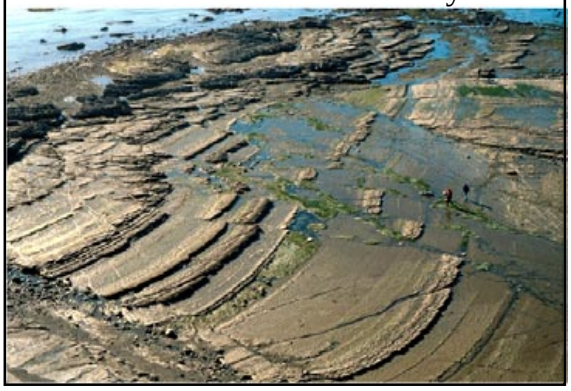
When did the folding occur?



When did the faulting occur?



Folded and Faulted Sedimentary Rocks



Tectonic Forces &
Resulting Deformation