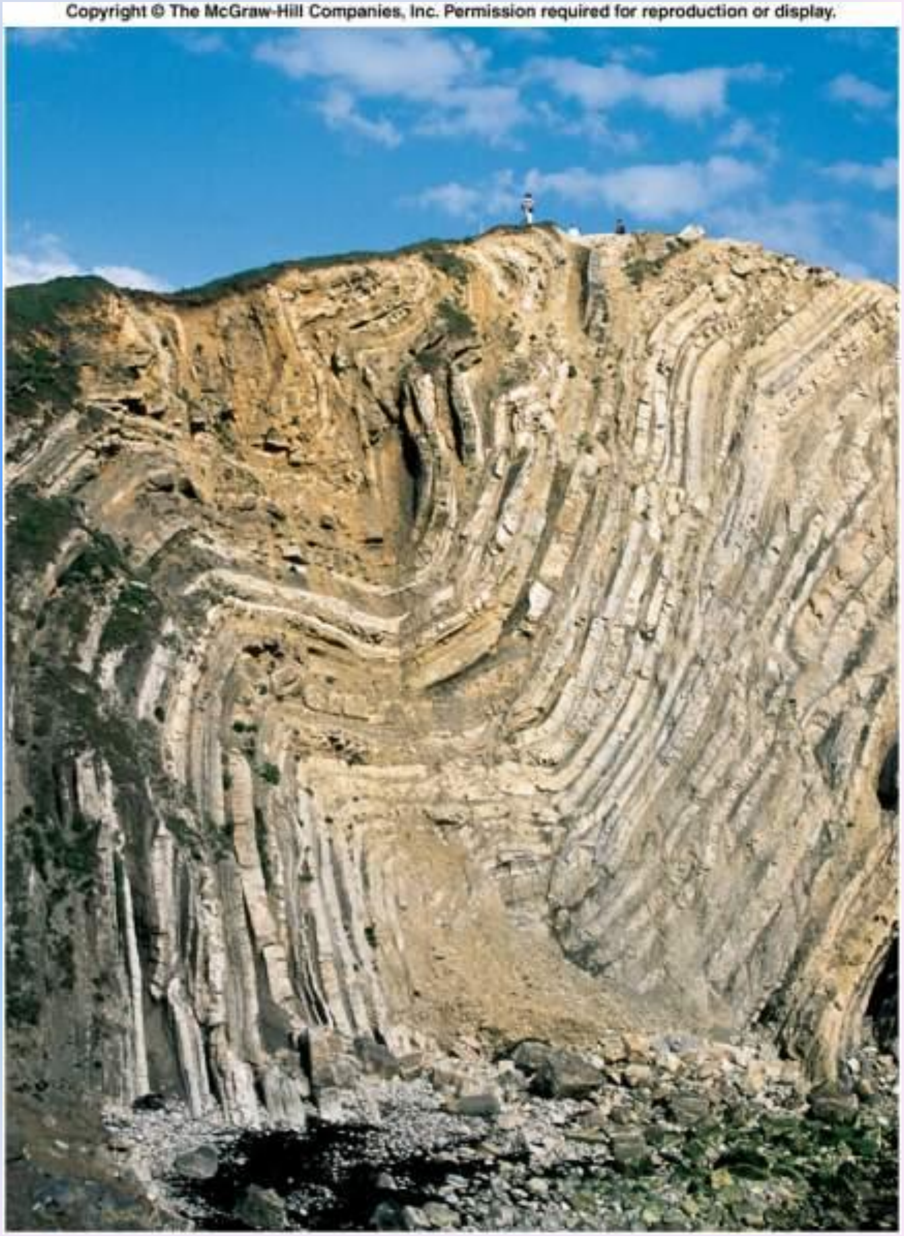
Geologic Structures

Geologic Structures

- ***Geologic structures*** are dynamically-produced patterns or arrangements of rock or sediment that result from, and give information about, *forces within Earth*
  - Produced as rocks change shape and orientation in response to applied stress
  - *Structural geology* is the study of the shapes, arrangement, and interrelationships of bedrock units and the forces that cause them

Interpreting Structures

- Rock structures are determined on the ground by geologists observing rock ***outcrops***
  - *Outcrops* are places where bedrock is exposed at the surface



Stress and Strain

I. Tectonic Forces

A. ___**Stress**___

1. *Force per unit area*
2. Acts on a body and tends to change its shape.

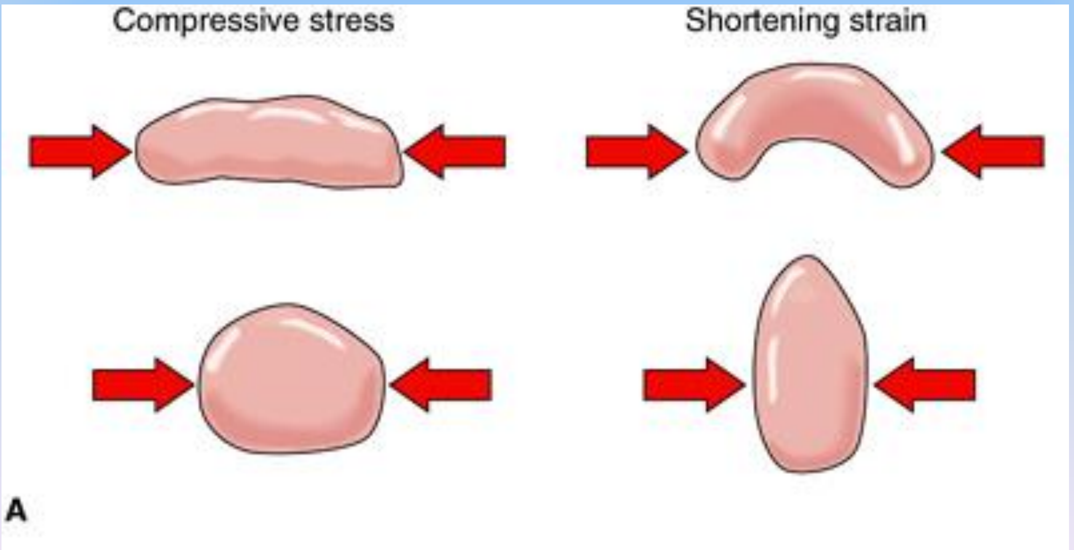
B. ___**Strain**___

1. Change in size or shape in response to stress
2. Rocks become *deformed* as a result

C. Types of Stress

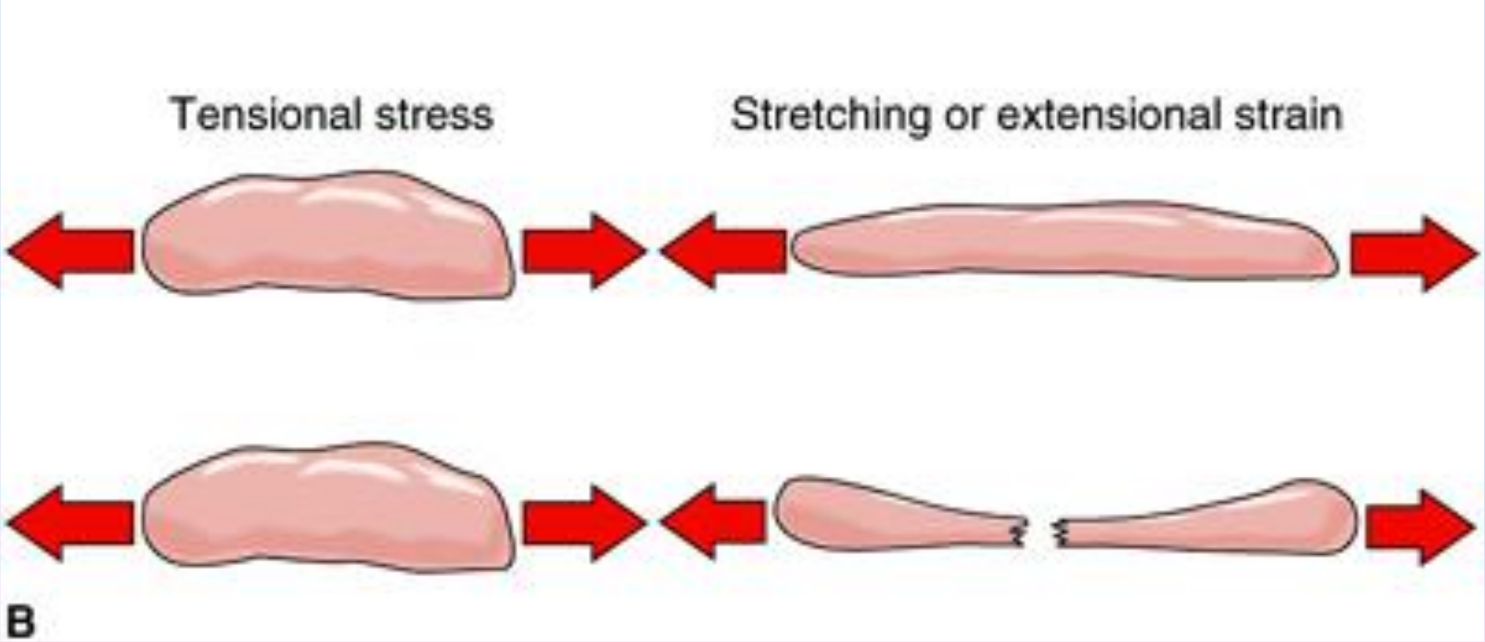
1. Compressive Stress

a) Forces from opposite directions, towards each other
b) Common at *convergent* plate boundaries and the most common type of stress.
c) Rocks are deformed by *shortening strain* parallel to the direction of stress.
d) Perpendicular to the direction of stress (vertically) deformation is elongated.



2. Tensional Stress

a) Forces pulling away from one another in opposite directions
b) Results in *stretching* or *extensional strain*.
c) Bodies elongate or stretch parallel to the applied stress.

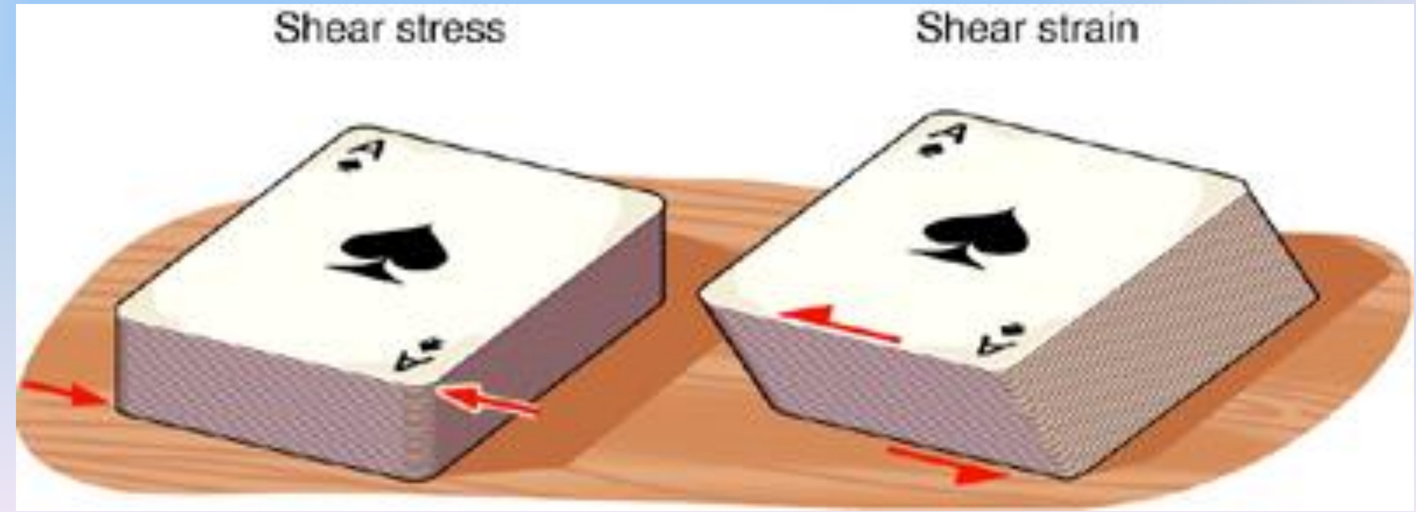


3. **Shear Stress**

a) Forces parallel to on another in opposite directions, usually along a fault.

b) Results in *shear strain* parallel to the stress direction.

c) Occurs along *transform* plate boundaries



Rock Responses to Stress and Strain

- Rocks behave as ***elastic***, ***ductile*** or ***brittle*** materials depending on:
  - –amount and rate of stress application
  - –type of rock
  - –temperature and pressure

C. Behavior of Rocks to Stress and Strain

1. **Elastic Strain**

   a) A deformed body recovers its original shape with the removal of stress.

   b) Most rocks behave elastically at low stresses

   c) The *elastic limit* of a rock defines the amount of stress beyond which the rock will no longer act elastically and will then deform permanently.

Behavior of Rocks to Stress and Strain

2. **Ductile Behavior**

   a) During stress the rock body will bend but does not return to its original shape after a reduction of stress.

   b) Folding or bending of rock is the result of ductile/plastic behavior.

3. **Brittle Behavior**

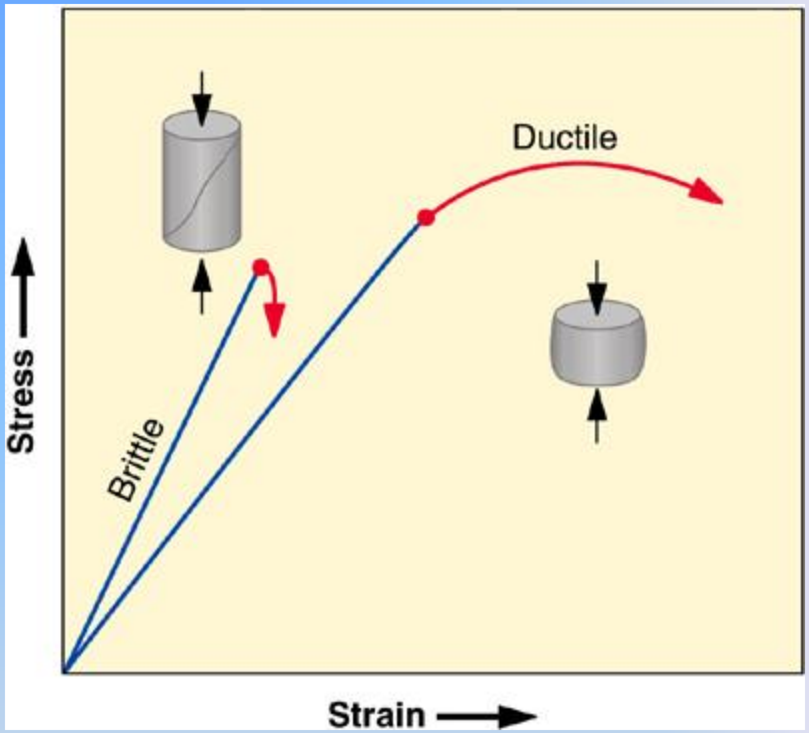
   a) Rock bodies fracture at stresses greater than the elastic limit.

   b) Occurs near or at Earth's surface under conditions of low temperature and pressure.

   c) Faults and joints are the result of brittle behavior.

Rock Responses to Stress and Strain

- Rocks behave as *elastic*, *ductile* or *brittle* materials depending on:
  - amount and rate of stress application
  - type of rock
  - temperature and pressure



•*Elastic* Behavior – straight line segments (blue)

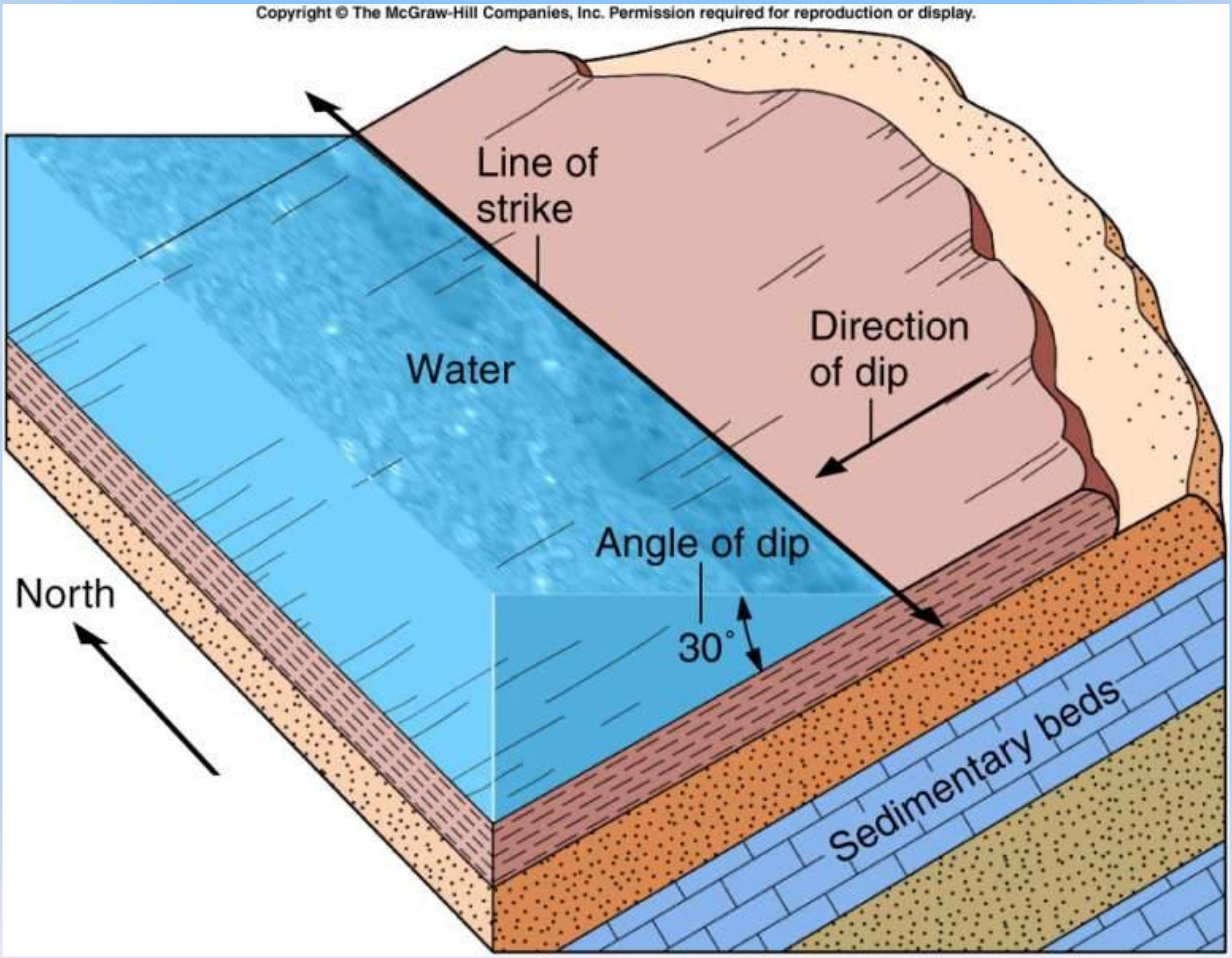
•Stresses greater than *elastic limit* (red)

Measuring and Representing Rock Units and Geologic Structures

A. ___**Attitude**___ is the orientation of a rock unit or surface.

Orientation of Geologic Structures

- *Tilted beds*, *joints*, and *faults* are planar features whose orientation is described by their *strike* and *dip*



2. Strike

a) The compass direction of a line formed by the intersection of a horizontal plane with an inclined stratum, fault, fracture, or other surface.

b) While it's bidirectional, customarily strike is expressed relative to north with the bearing in degrees (e.g., N60^{o} W, N35^{o} E)

c) Determining the strike is the same as finding the *bearing* of the line of strike.

3. Dip

a) **Angle** *of Dip*: The angle between a horizontal plane and the inclined stratum, fault, or fracture

b) **Direction** *of Dip*:

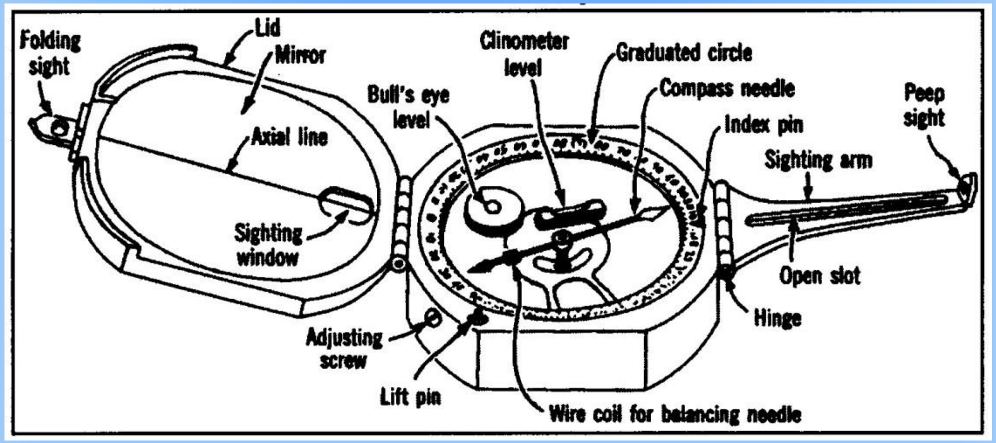
i. The compass direction in which the dip is measured

ii. Determined by the direction in which water would run down the inclined surface.

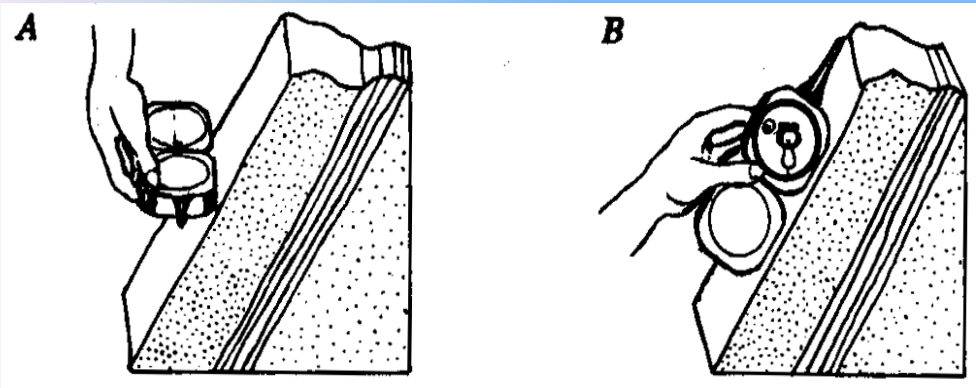
iii Always perpendicular to strike.

Dipping Rock Strata

The Brunton Compass

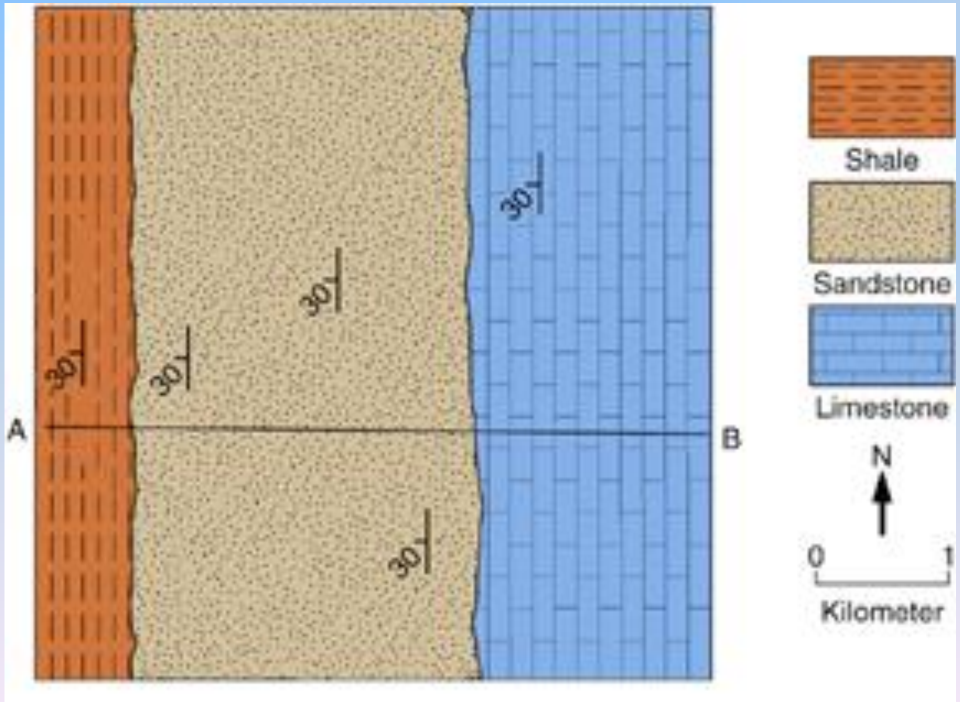


Measuring Strike and Dip With the Brunton Compass



B. Representing Rock Structures

1. **Geologic Map**
   a. Uses standardized symbols and patterns to represent rock types and geologic structures.
   b. Contour lines representing the topography are often plotted.



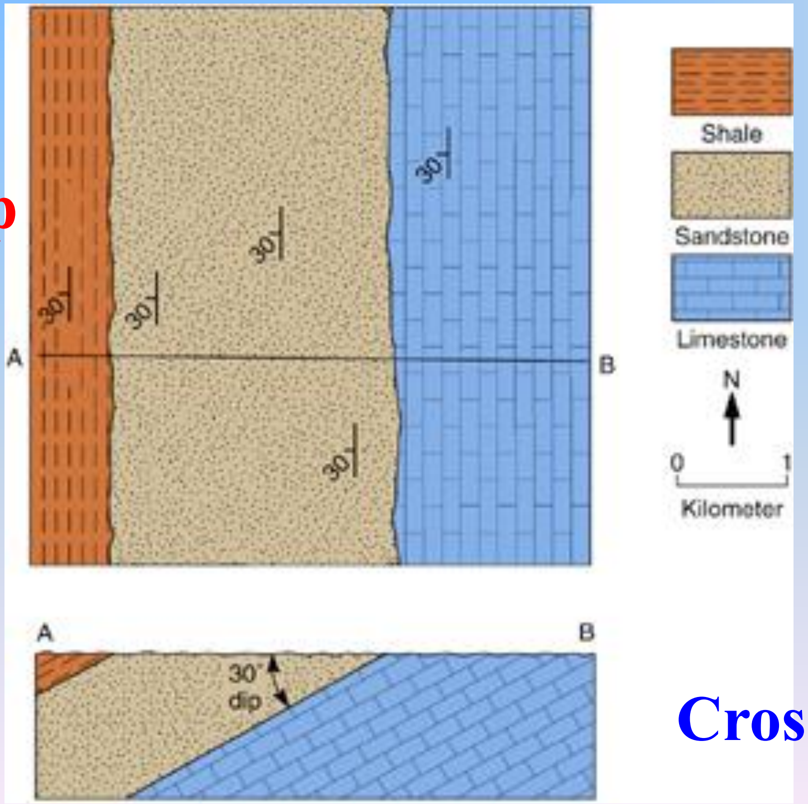
2. Cross-Section

a. Drawing of a vertical slice through a portion of Earth.

b. Provides a cutaway view

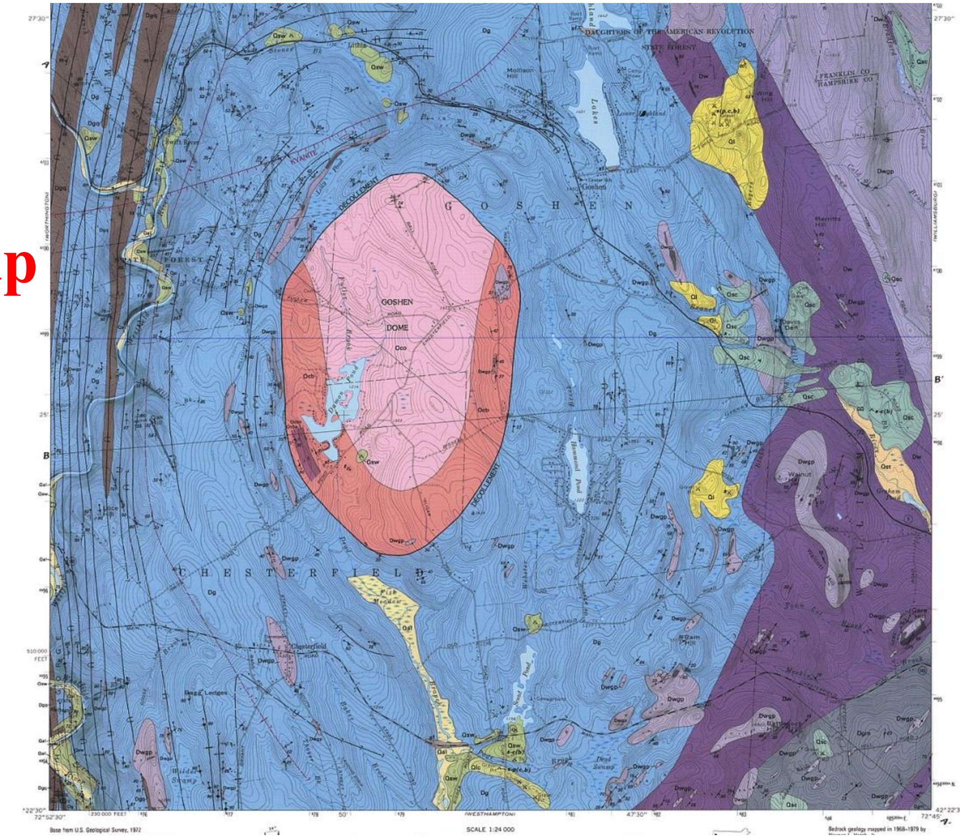
c. Constructed from geologic maps by projecting the dip of rock units into the subsurface.

Geologic Map

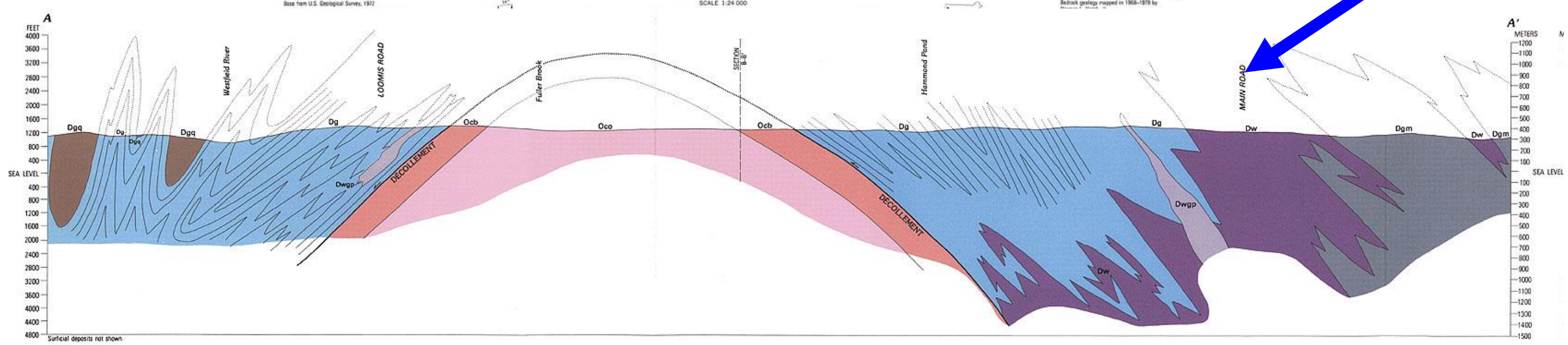


Cross-Section

Geologic Map



Cross-section



GEOLOGIC MAP OF THE GOSHEN QUADRANGLE, FRANKLIN AND HAMPSHIRE COUNTIES, MASSACHUSETTS

By

Norman L. Hatch, Jr. and Charles R. Warren

1981

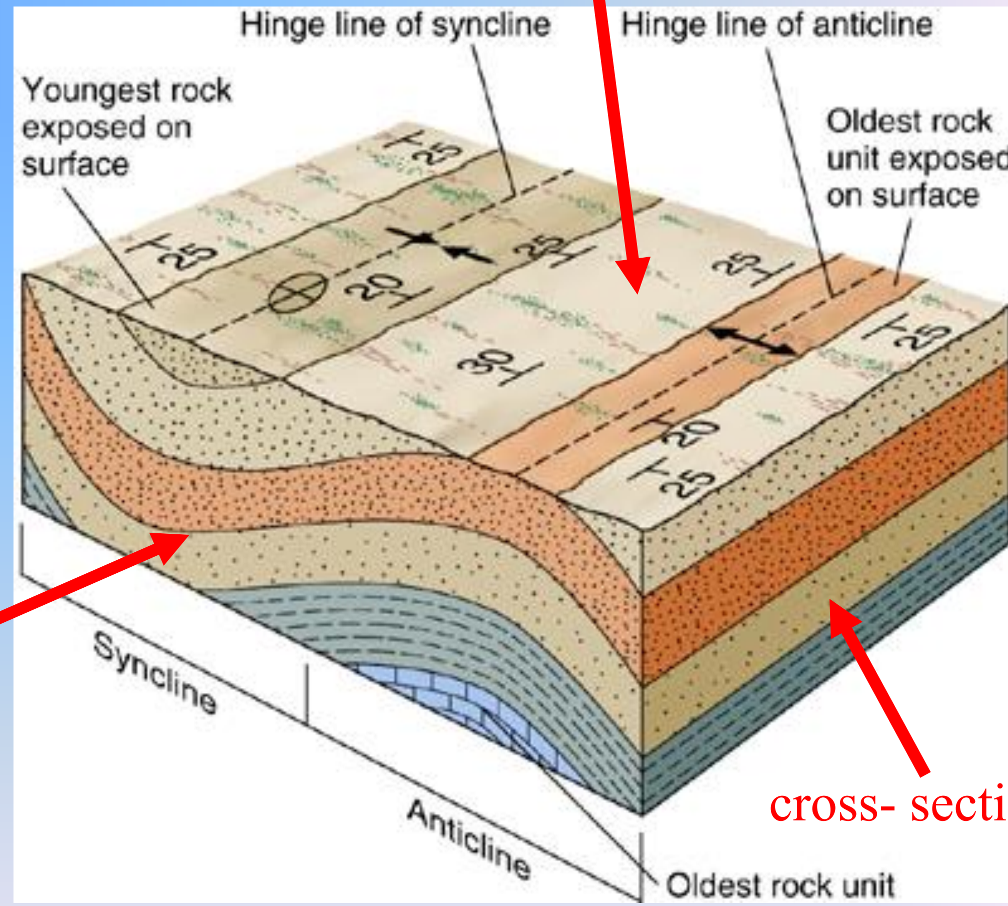
3. Block Diagram

Geologic Map is on top

a) A combination of a ***geologic map*** and a ***cross section***

b) Provides a small three-dimensional model of a portion of Earth's crust.

c) Has the appearance of a solid block



Cross-section

cross- section

A cross-section is shown on each visible side

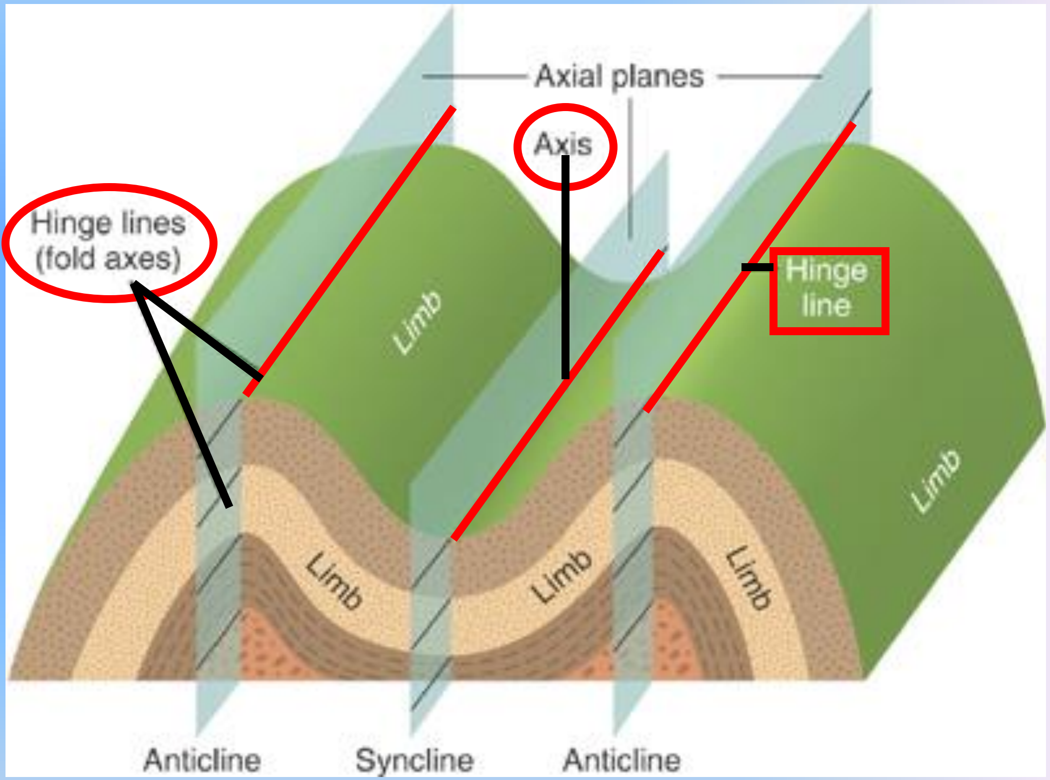
Types of Geologic Structures

A. **Folds**

Folds

Wavelike bends in layered rock

- The *axial plane* divides a fold into its two *limbs*
  - –The surface trace of an axial plane is called the *hinge line* (or *axis*) of the fold



- *Folds* represent rock strained in a *ductile* manner, usually under *compression*

3. Fold Geometry

a) **Fold Axis**

   i. Also called a **hinge line**

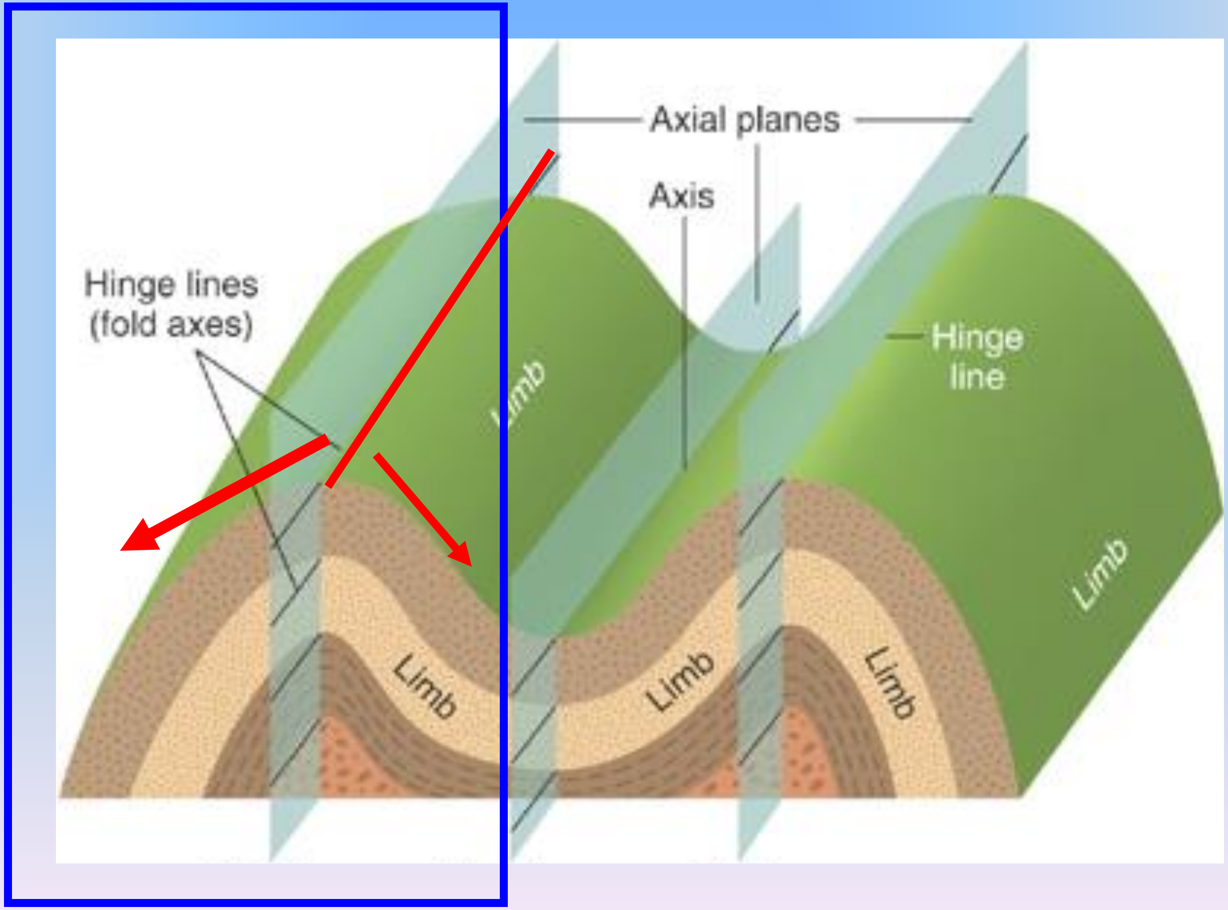
   ii. Each stratum is bent around this imaginary axis.

b) **Axial Plane**: An imaginary plane through the fold axis.

c) **Limbs**: The rock strata on either side of the fold axis (sides of the fold)

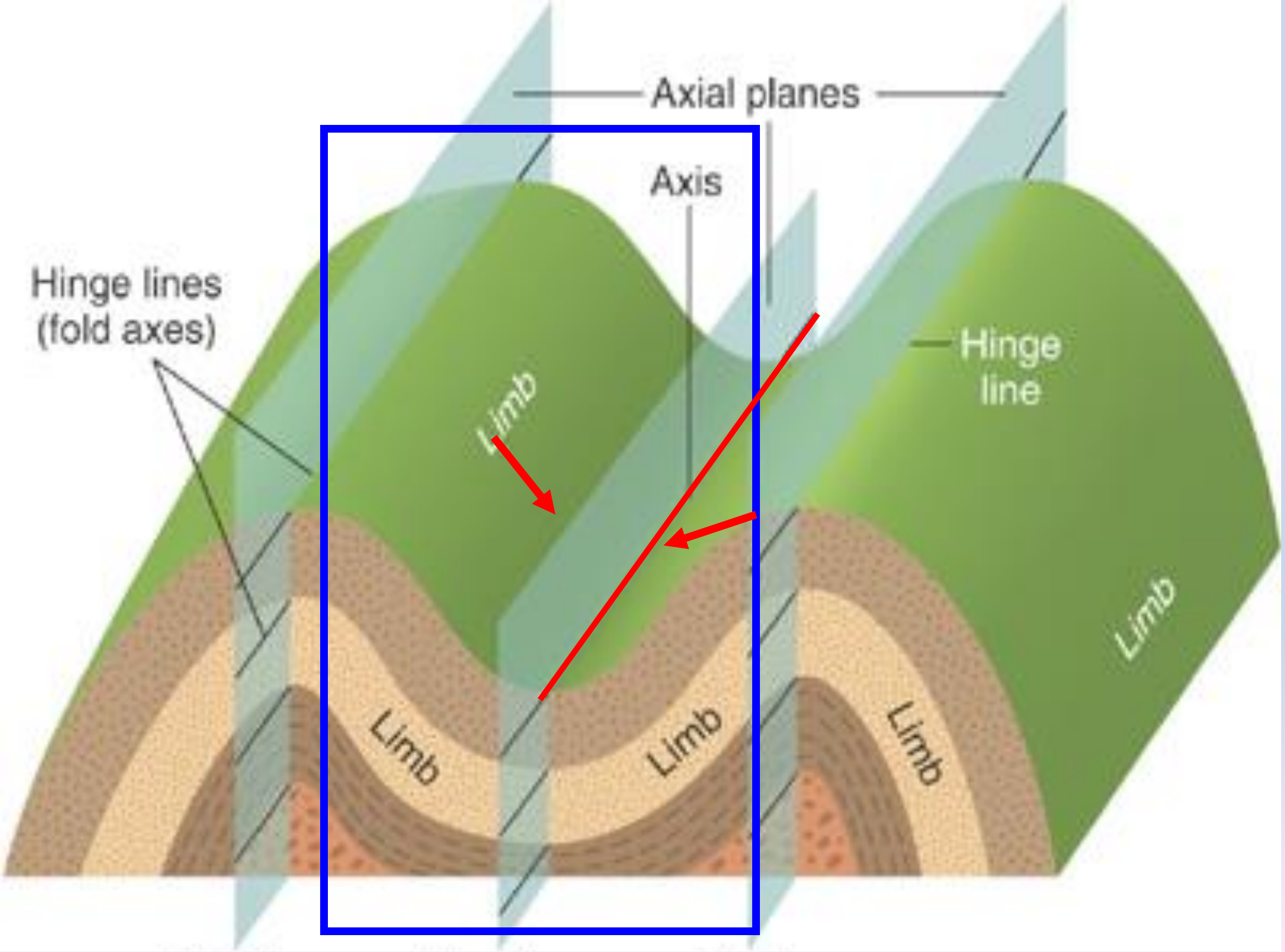
a. Anticlines

a. Upward arching fold



b. Synclines

- Downward arching fold



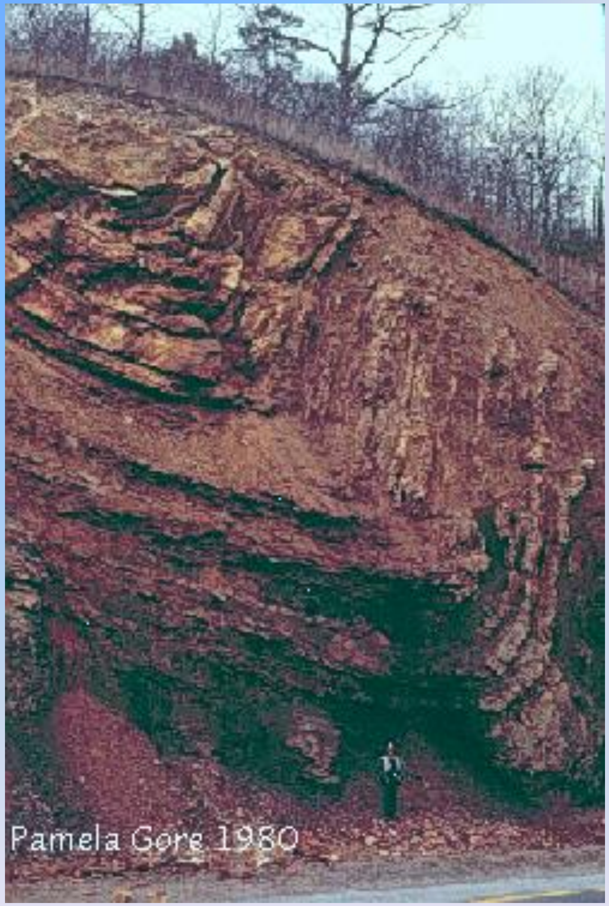
Anticlines

Anticline - Maryland

Anticline,Maryland

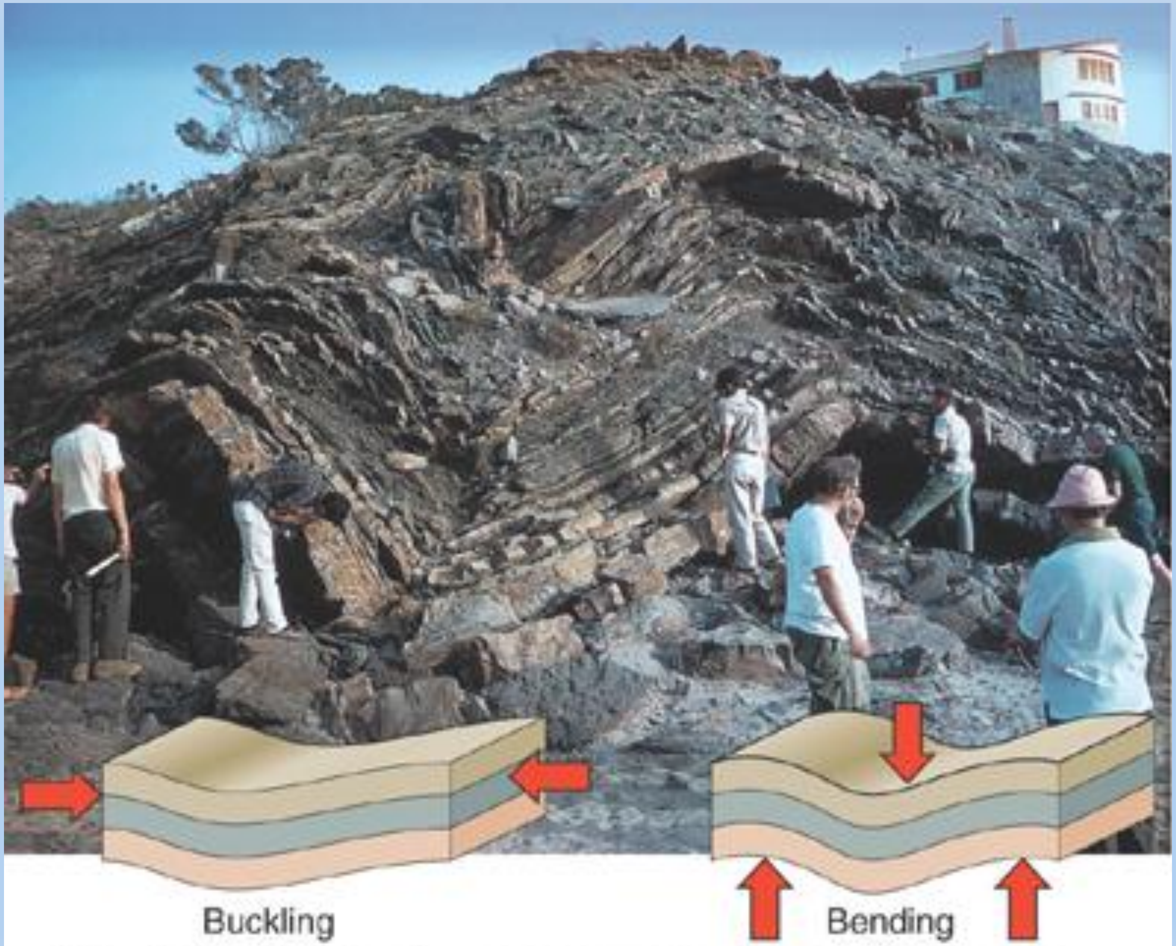
Synclines

Syncline - TN



Syncline - TN

c. Open Folds



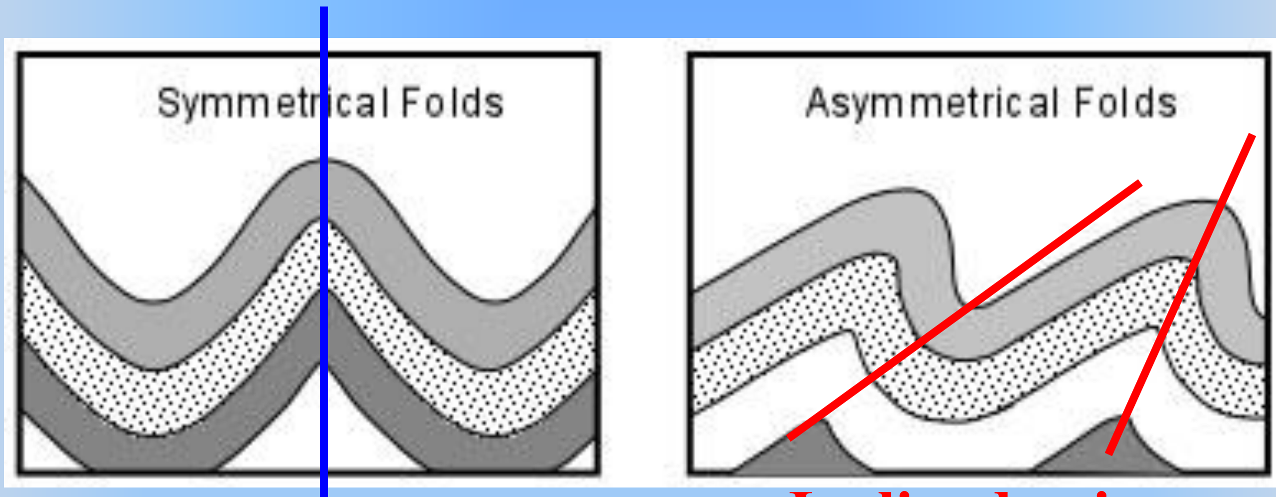
Open folds—the two diagrams show alternate ways that stresses may have been distributed to have caused the folding.

Open folds have limbs that dip gently

d. Asymmetrical Folds

Limbs of asymmetrical folds have different dip angles.

Vertical axis

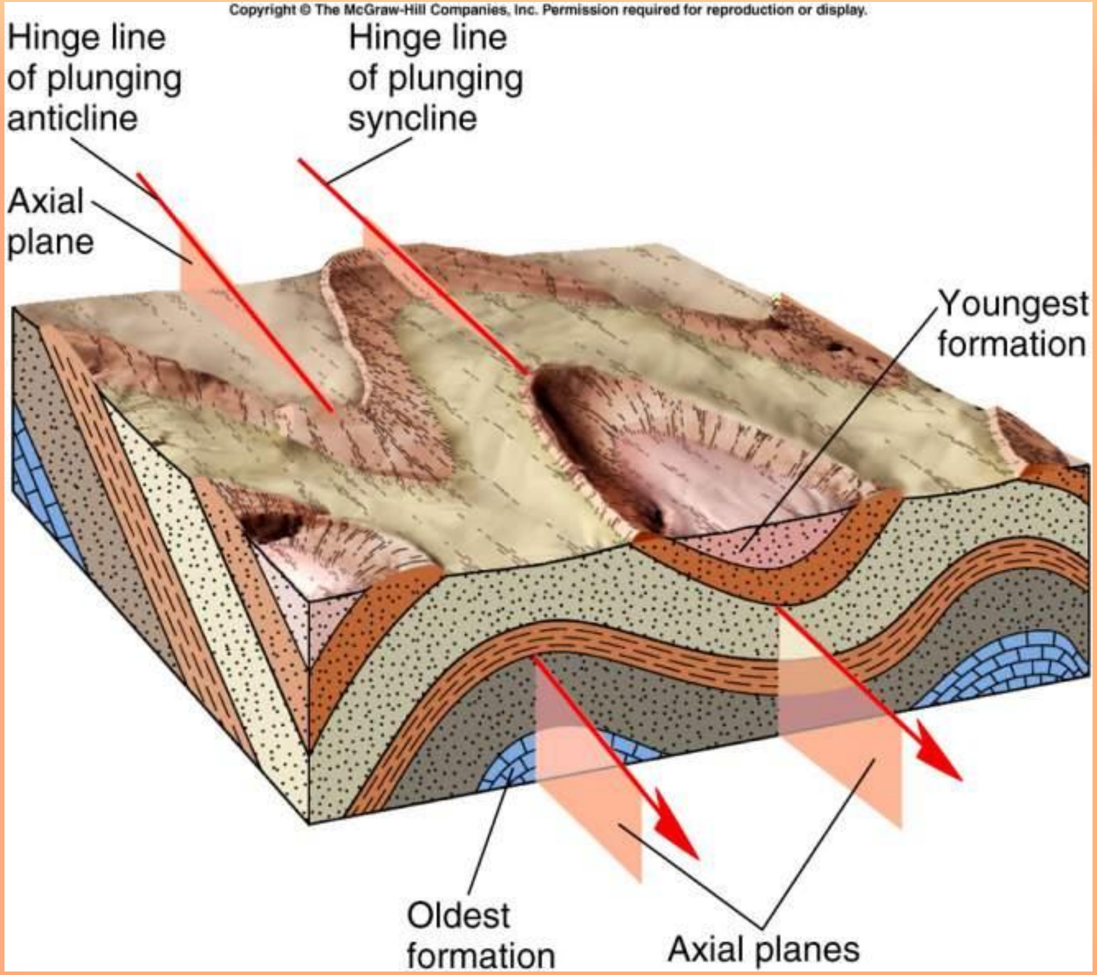


Inclined axis

Asymmetrical Anticline

Asymmetrical syncline

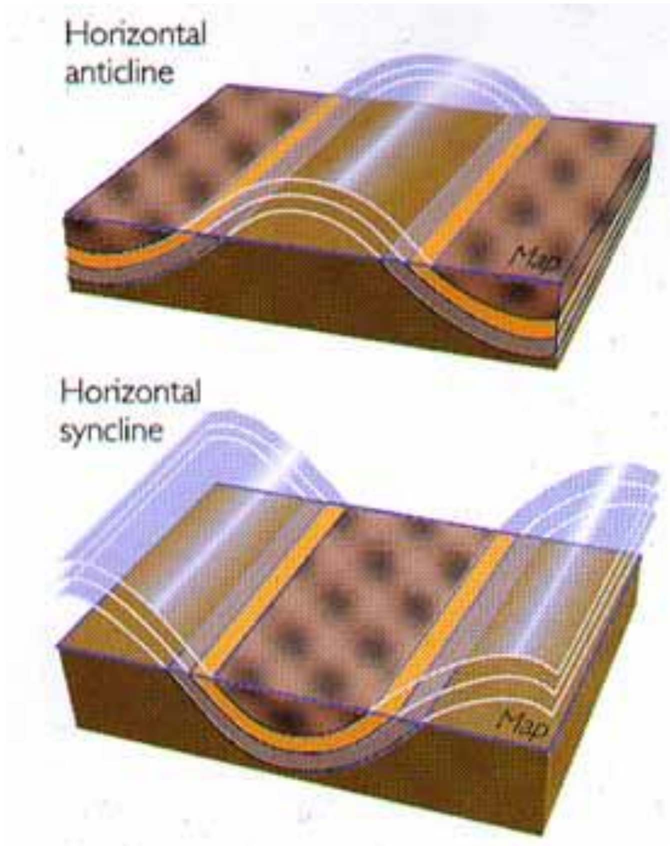
e. Plunging Folds



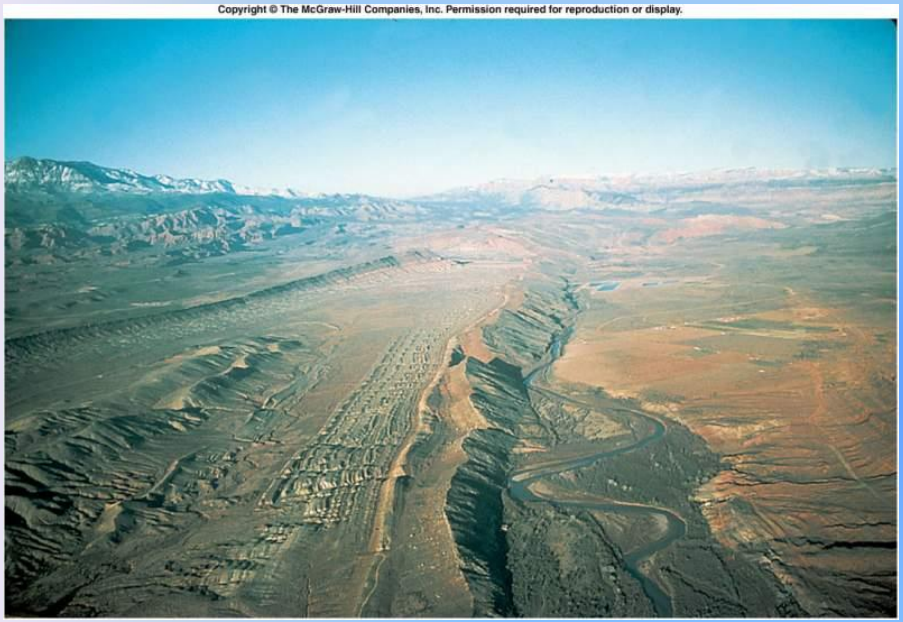
- The hinge line is not horizontal
- Erosion results in V-like or horseshoe shaped surface outcrops

Horizontal and Plunging Folds

Exposed strata have a striped pattern



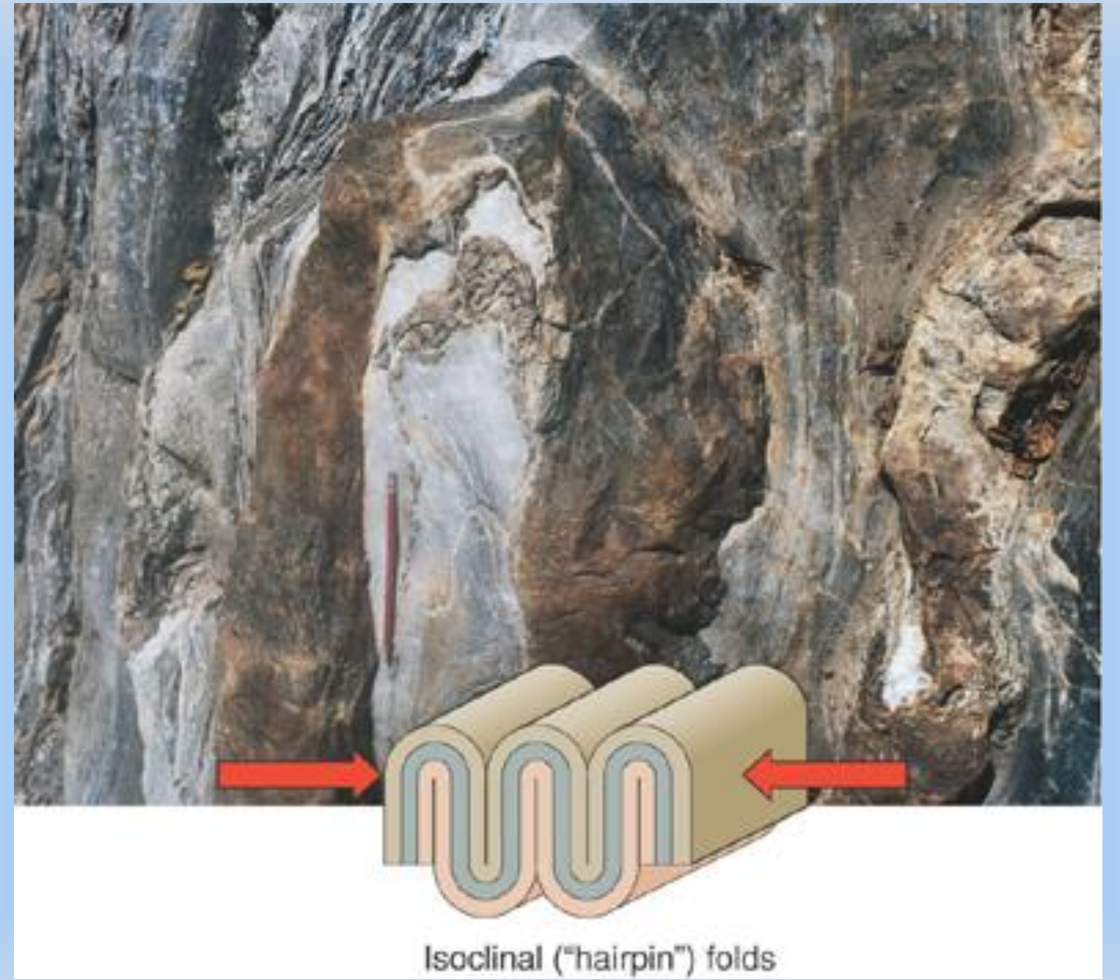
Exposed strata have a V-like or horseshoe pattern



Plunging Anticline, Utah

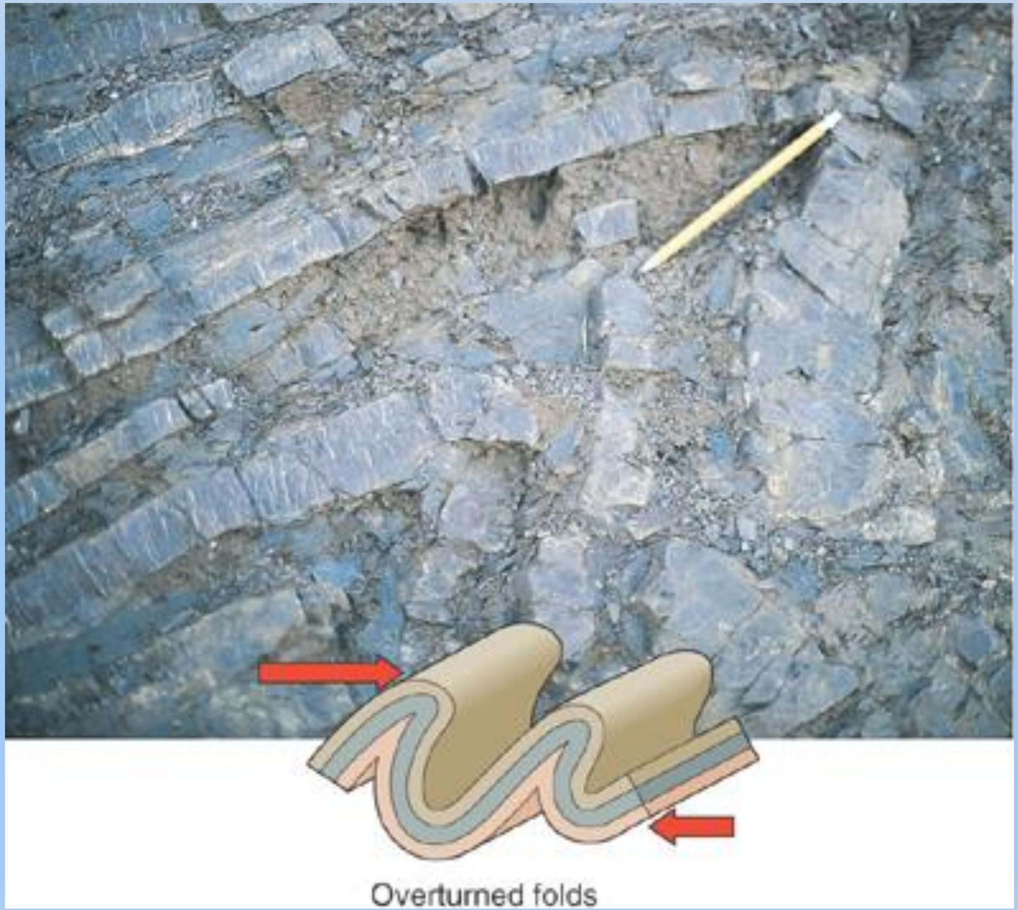
Plunging Anticline, Wyoming

f. __Isoclinal__ Folds



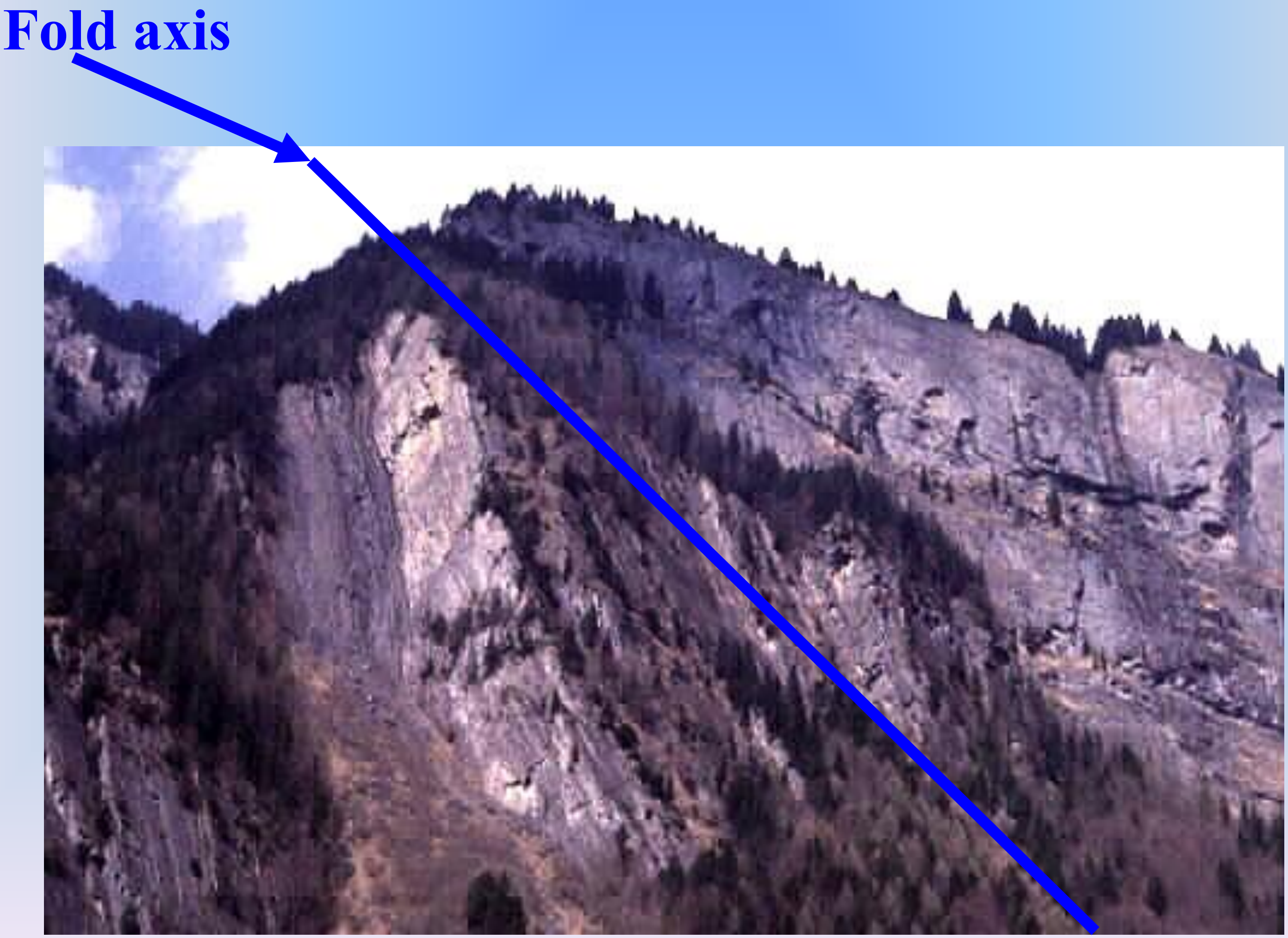
- ***Isoclinal folds*** have parallel limbs due to ***compressive stress***.
- The axial planes is *vertical*.

g. __Overturned__ Folds

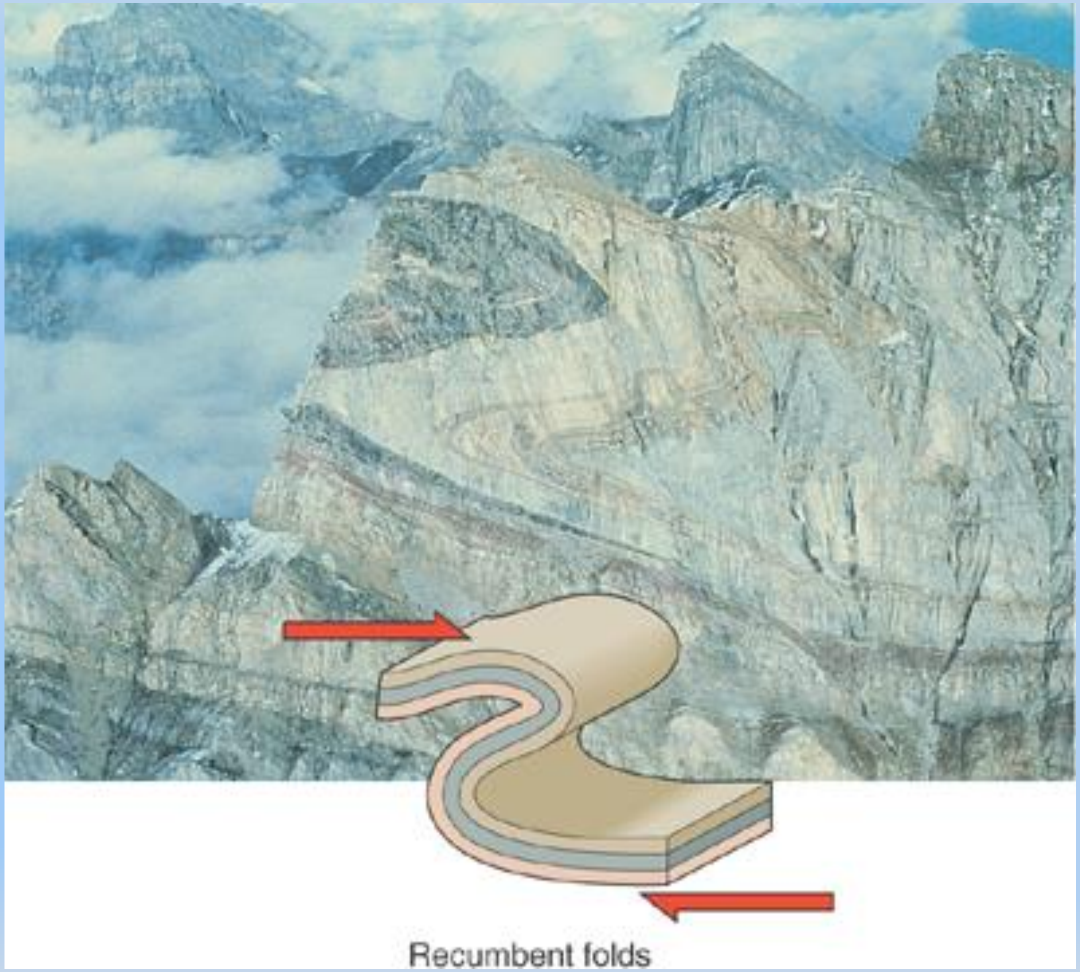


- Limbs dip in the same directions
- Older rock strata can be found *on top* of younger strata.

Overturned Fold

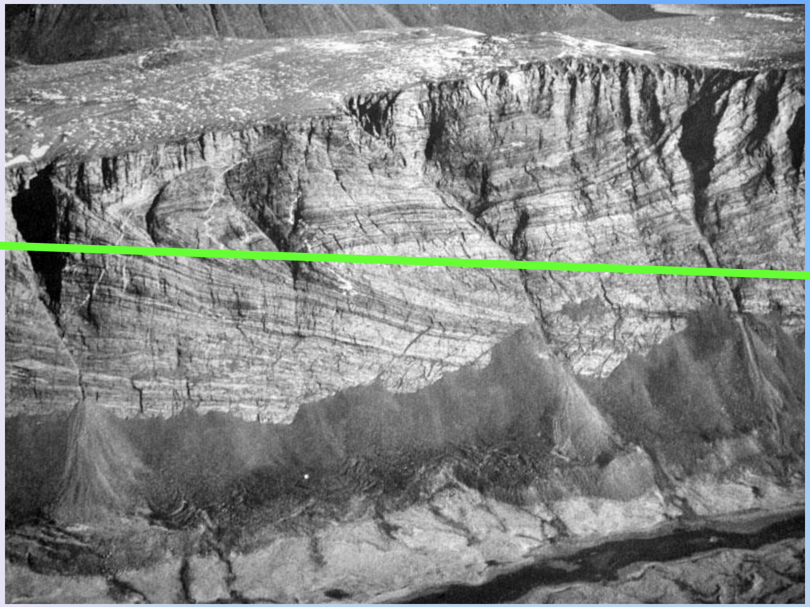


h. <u>**Recumbent**</u> Folds



Recumbent folds are overturned to the point of being horizontal.

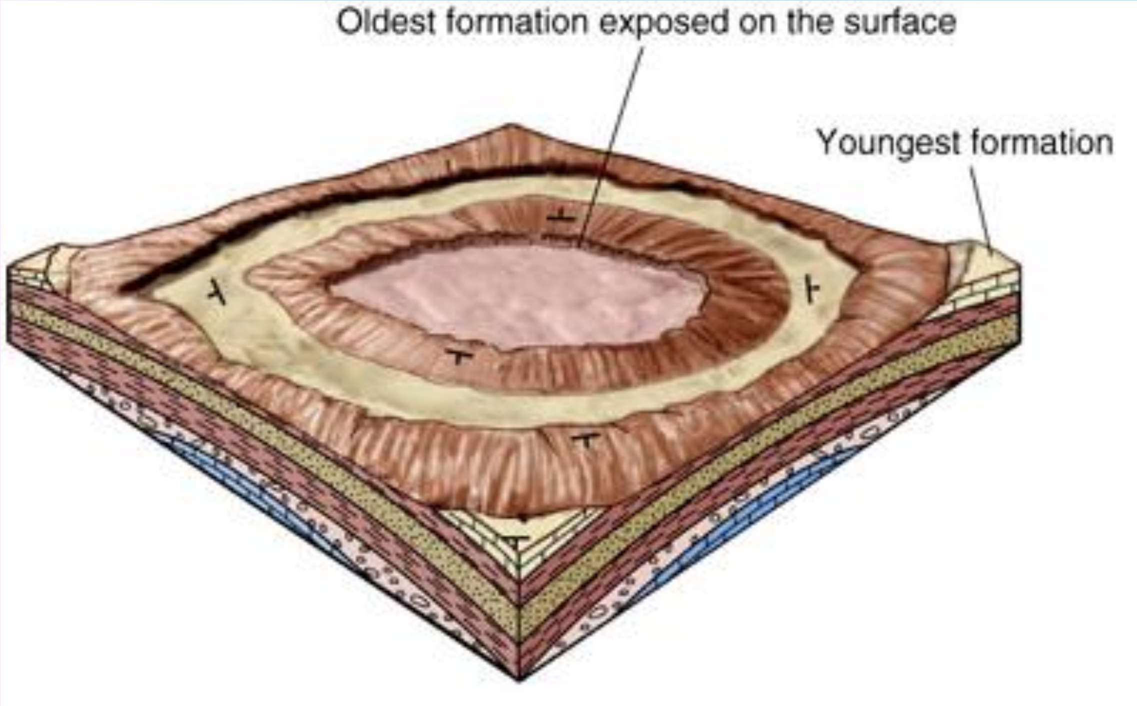
Recumbent Folds



Greenland

Newfoundland

5. Structural Domes

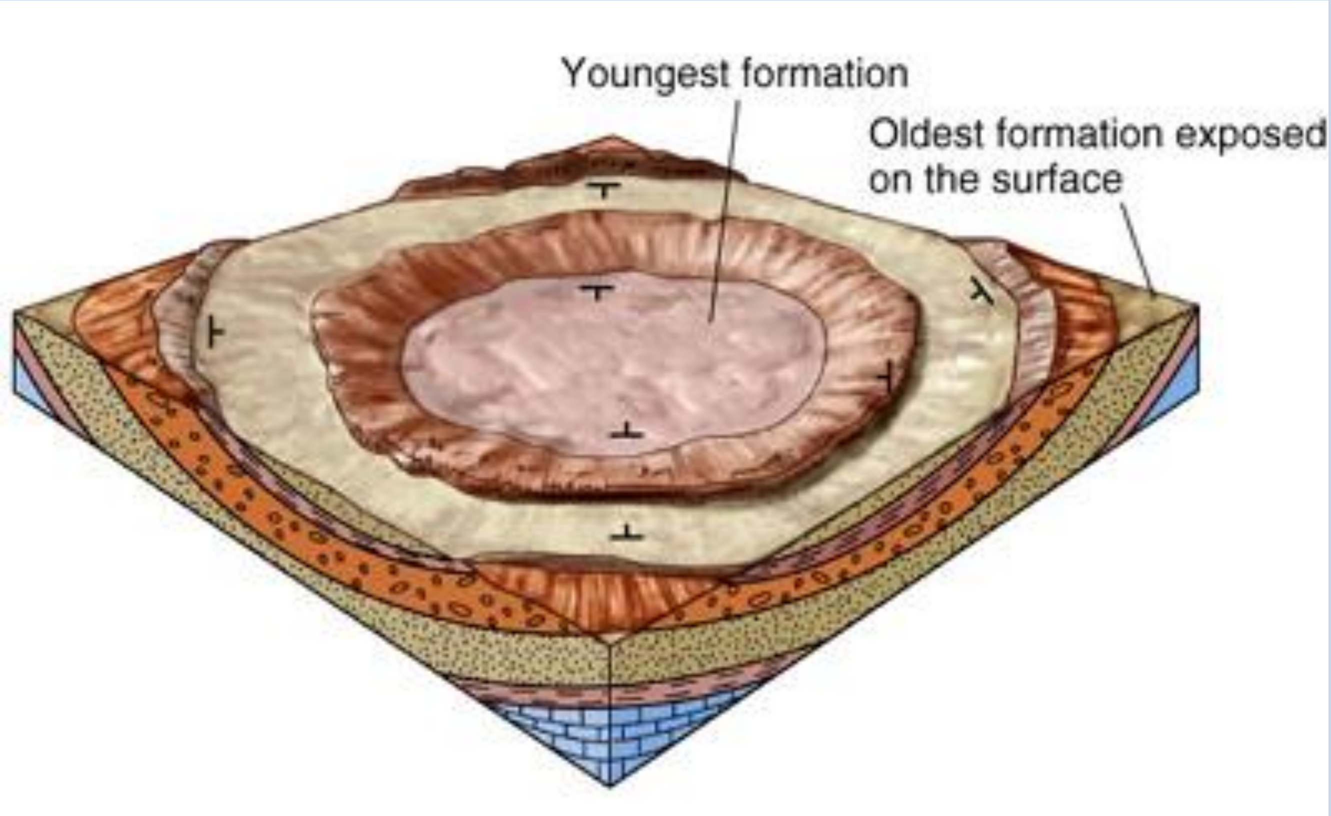


Dome near Casper, WY

- ***Domes*** are structures in which the beds dip away from a central point
  - Sometimes called doubly plunging anticlines

Structural Dome, Wyoming

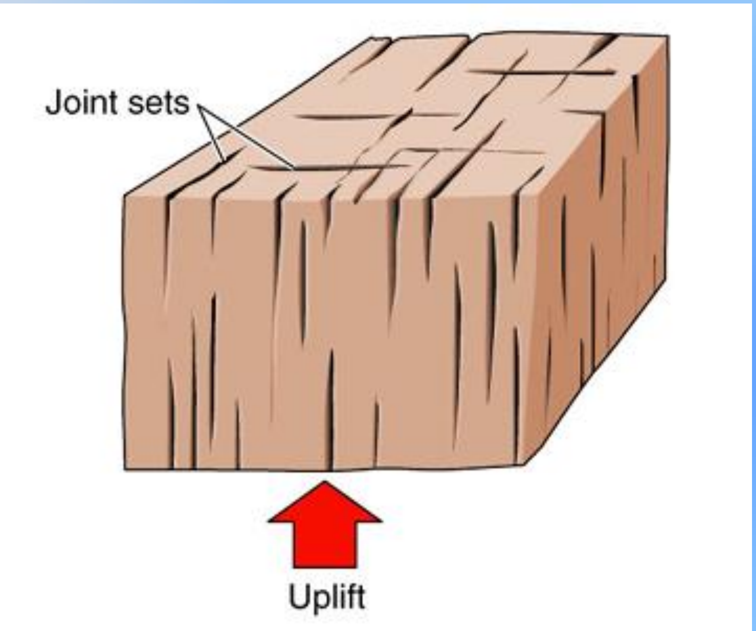
6. Structural Basins



- *Basins* are structures in which the beds dip toward a central point
  - Sometimes called doubly plunging synclines

B. Fractures in Rock

1. Joints



Vertical joints – Colorado plateau

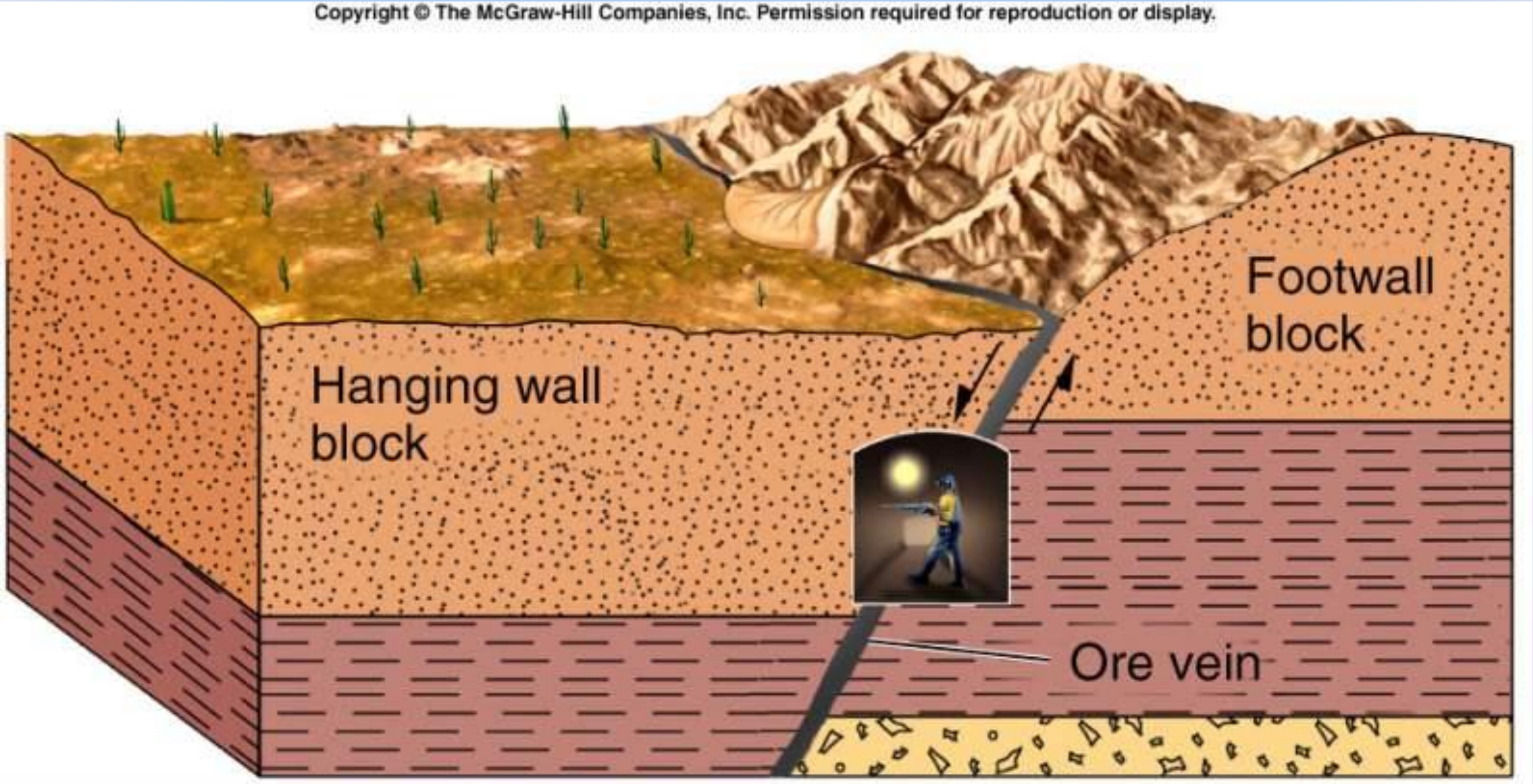
- *Joints* are fractures or cracks in bedrock along which essentially no movement has occurred
  - Multiple parallel joints are called *joint sets*

2. Faults

Fault – Big Horn Mountains, WY

- *Faults* are fractures in bedrock along which **movement** has occurred
  - Considered "active" if movement has occurred along them within the last 11,000 years (since the last ice age)
  - Categorized by type of movement as *dip-slip*, *strike-slip*, or *oblique-slip*

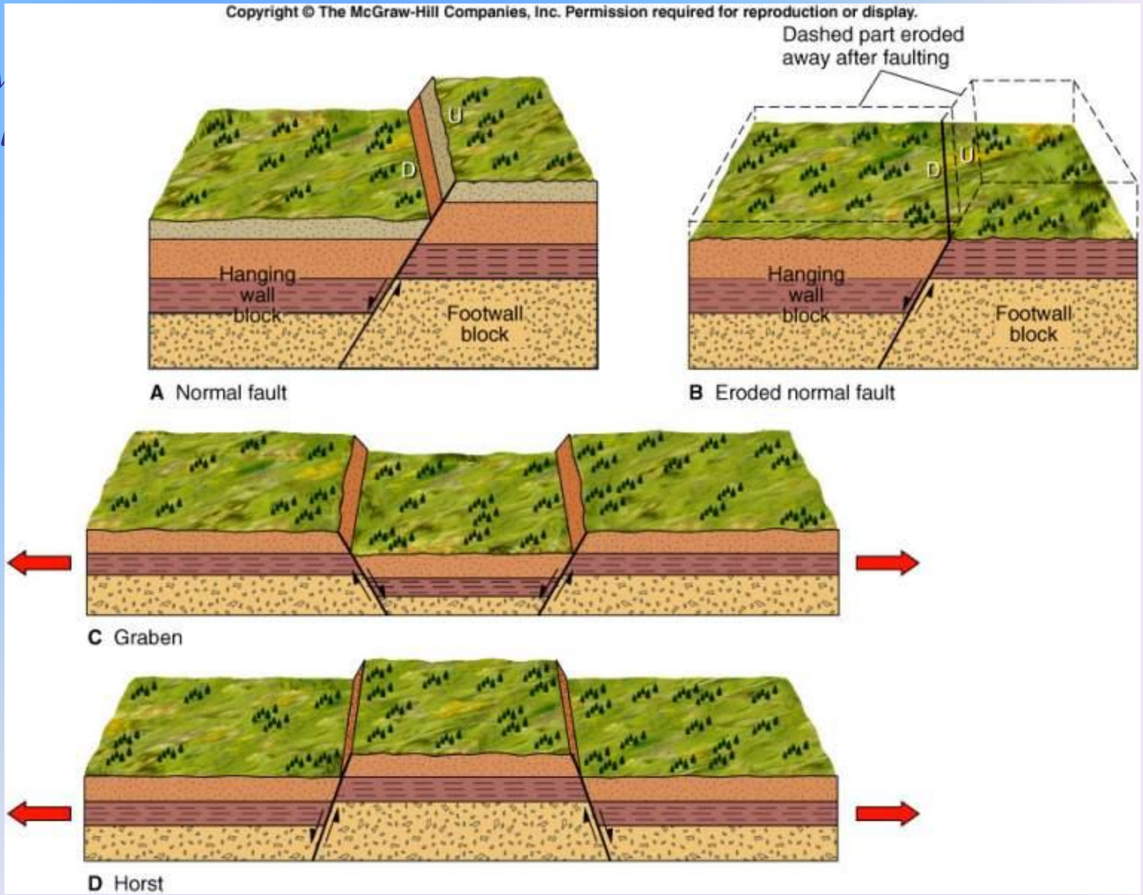
b. Dip-slip Faults



Movement of blocks is parallel to the dip of the fault plane

(a) Normal Faults

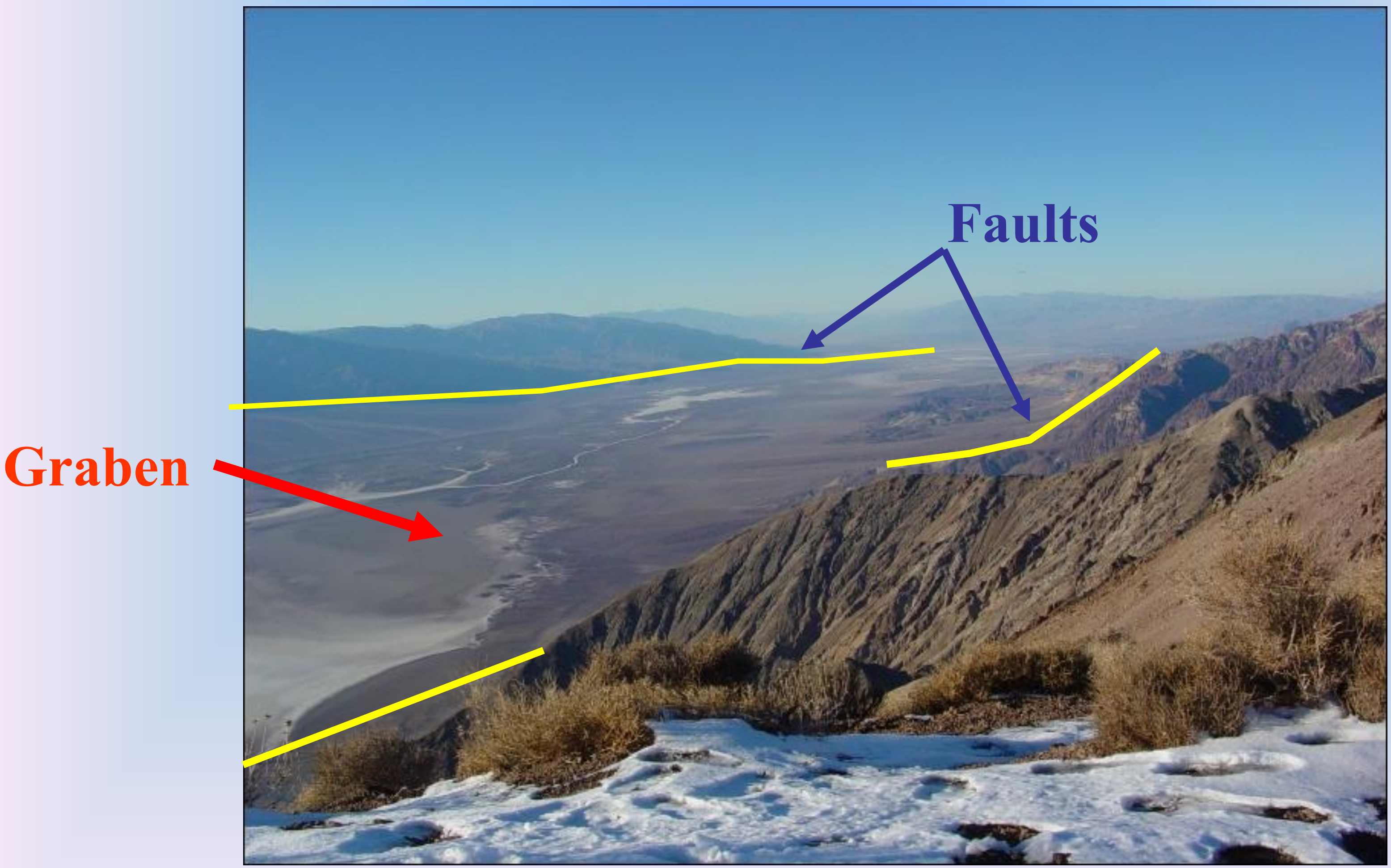
- In *normal faults (gravity faults)*, the *hanging-wall block* has moved down relative to the *footwall*
  - Associated with *tensional* forces
- Fault blocks, bounded by normal faults, that drop down or are uplifted are known as *grabens* and *horsts*, respectively
  - Grabens associated with divergent plate boundaries are called *rifts*



Normal Faults

Normal fault in southern Oregon

Death Valley

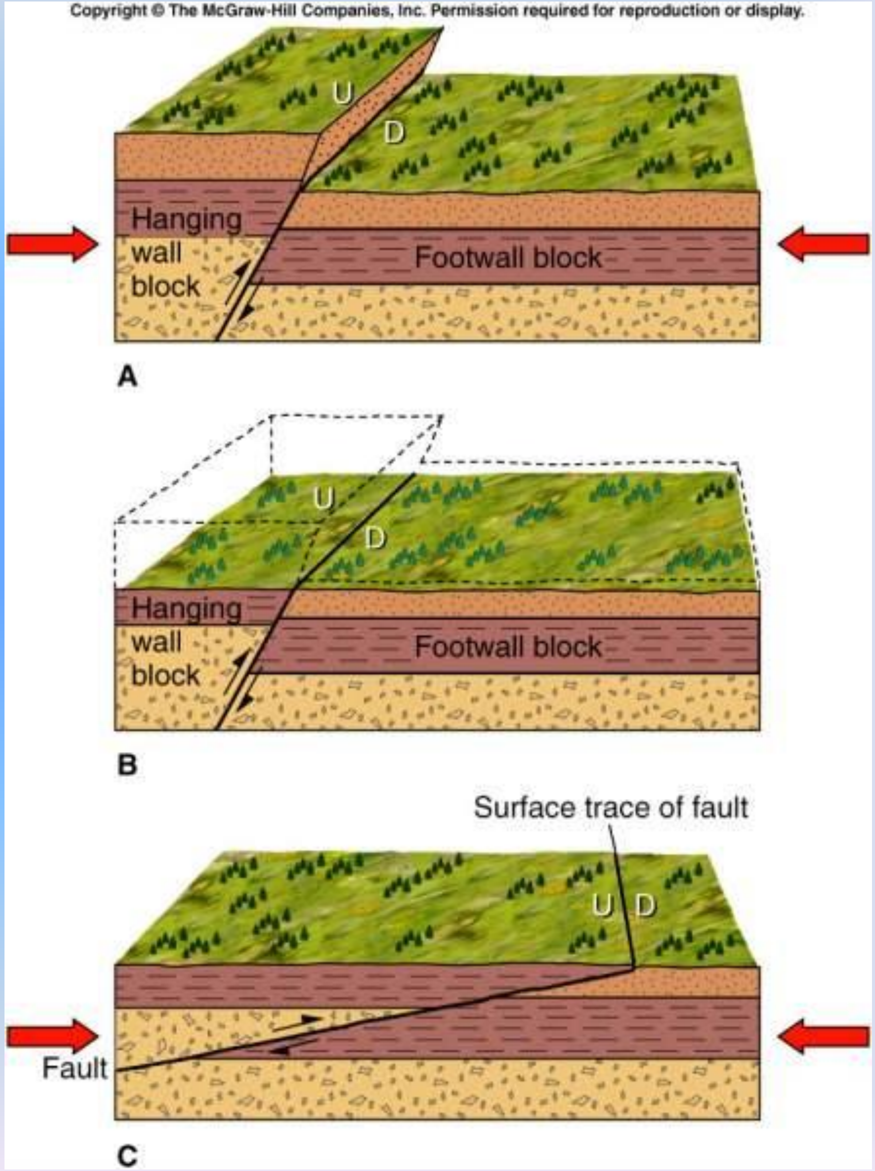


Graben in Utah

(b) Reverse Faults

- The hanging-wall block has moved up relative to the footwall block

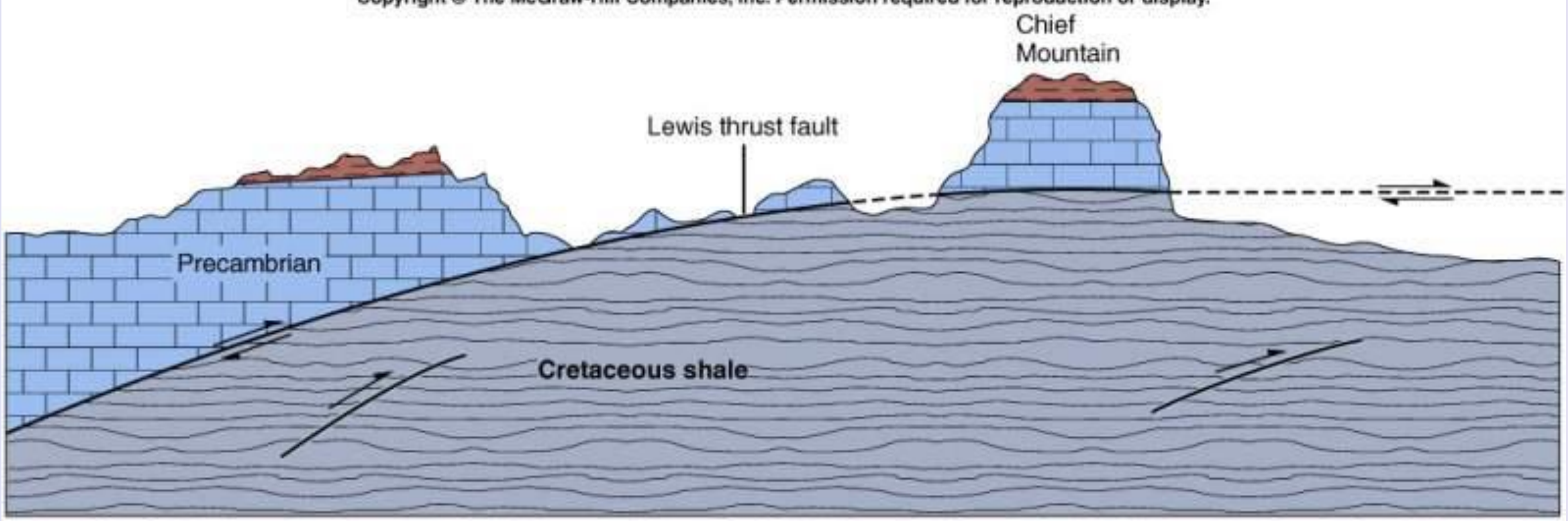
- *Thrust faults* are reverse faults with dip angles *less than 30°* from horizontal



Reverse Faults

Chief Mountain, Glacier National Park, Montana

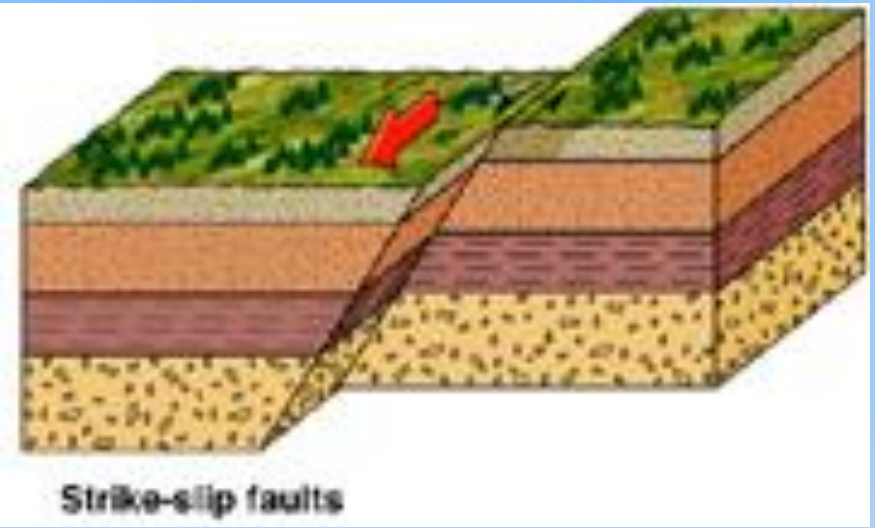
A



B

- Erosional remanant of a thrust fault
- Cross section shows older Precambrian rocks thrust over younger Cretaceous rocks

c. **Strike-Slip** Faults



- Movement is parallel to the strike
- Displacement is predominantly **horizontal** and parallel to the strike of the fault plane
- Caused by ***shear stress***.

Varieties of Strike Slip Faults

Right Lateral Fault

- A viewer looking across to the other side of a *right-lateral* strike-slip fault would observe it to be offset to their right

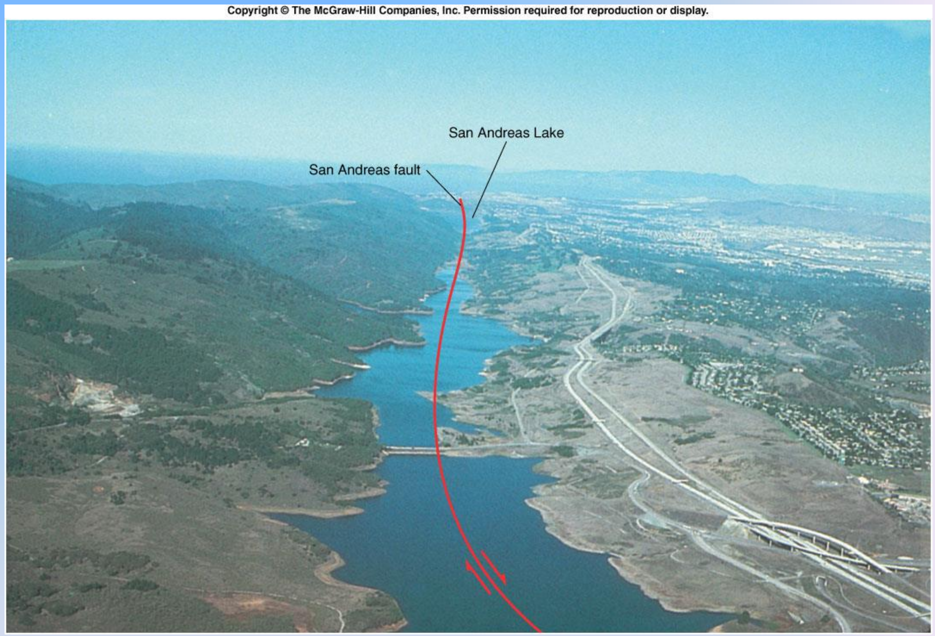
Right-lateral San Andreas Fault

Varieties of Strike Slip Faults

Left Lateral Fault

- A viewer looking across to the other side of a *left-lateral* strike-slip fault would observe it to be offset to their left

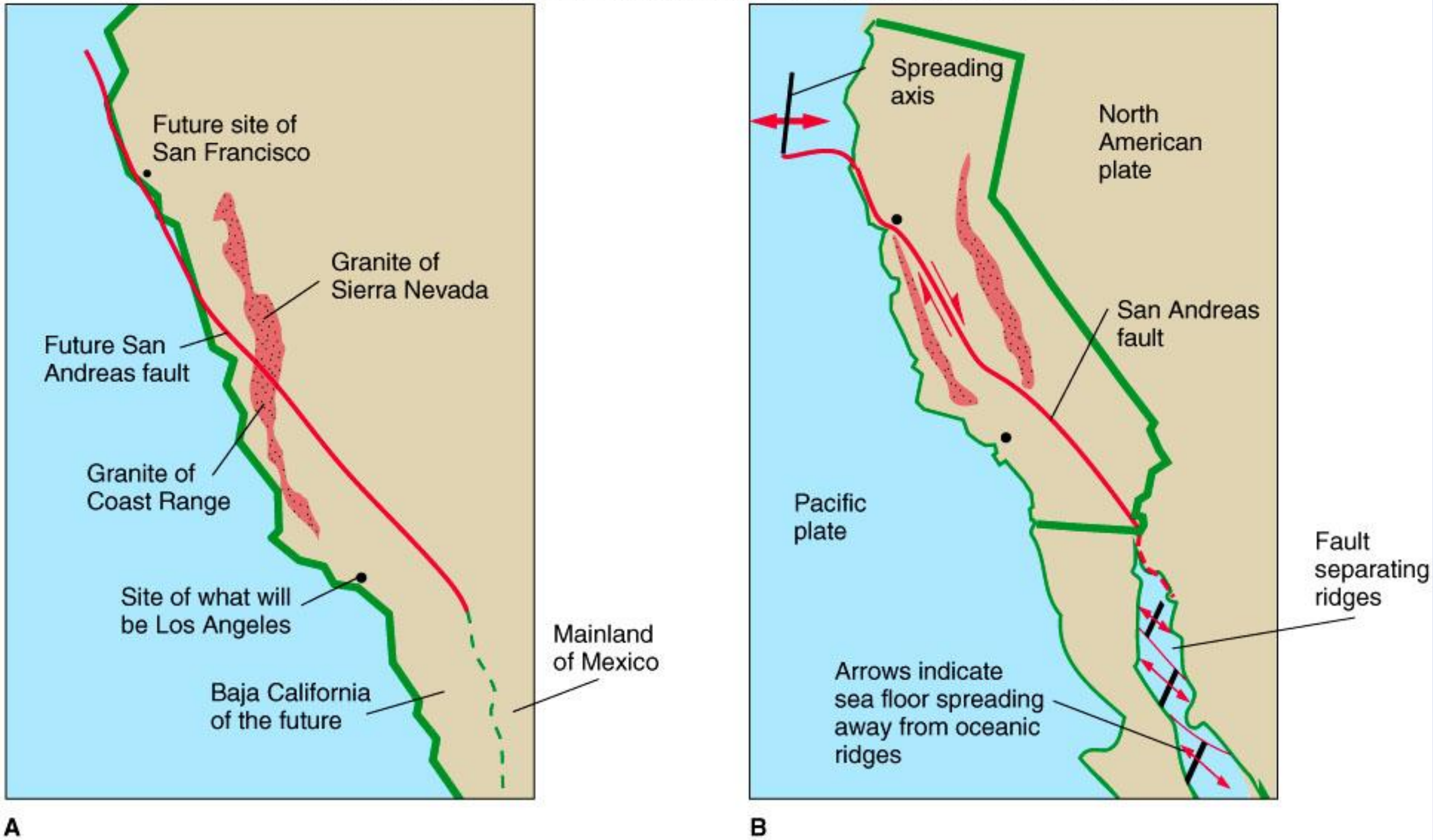
The San Andreas Fault



University of CA Berkeley's Memorial Stadium

- This structure is bisected by the Hayward Fault
- Rate of 1/20 in (1.2 mm) per year.
- Over the years several large cracks have opened in the walls of the stadium including the opening shown here that's bridged by a metal plate.
- Offset is also apparent in the floor below the seats as shown by the white arrow

California and Mexico Before and After Faulting



Oblique-slip faults

- Displacement has components parallel to both the strike and dip of the fault plane

Oblique Fault in NV