Crustal Deformation
AKA – Structural geology
(adapted from Brunkel, 2012)

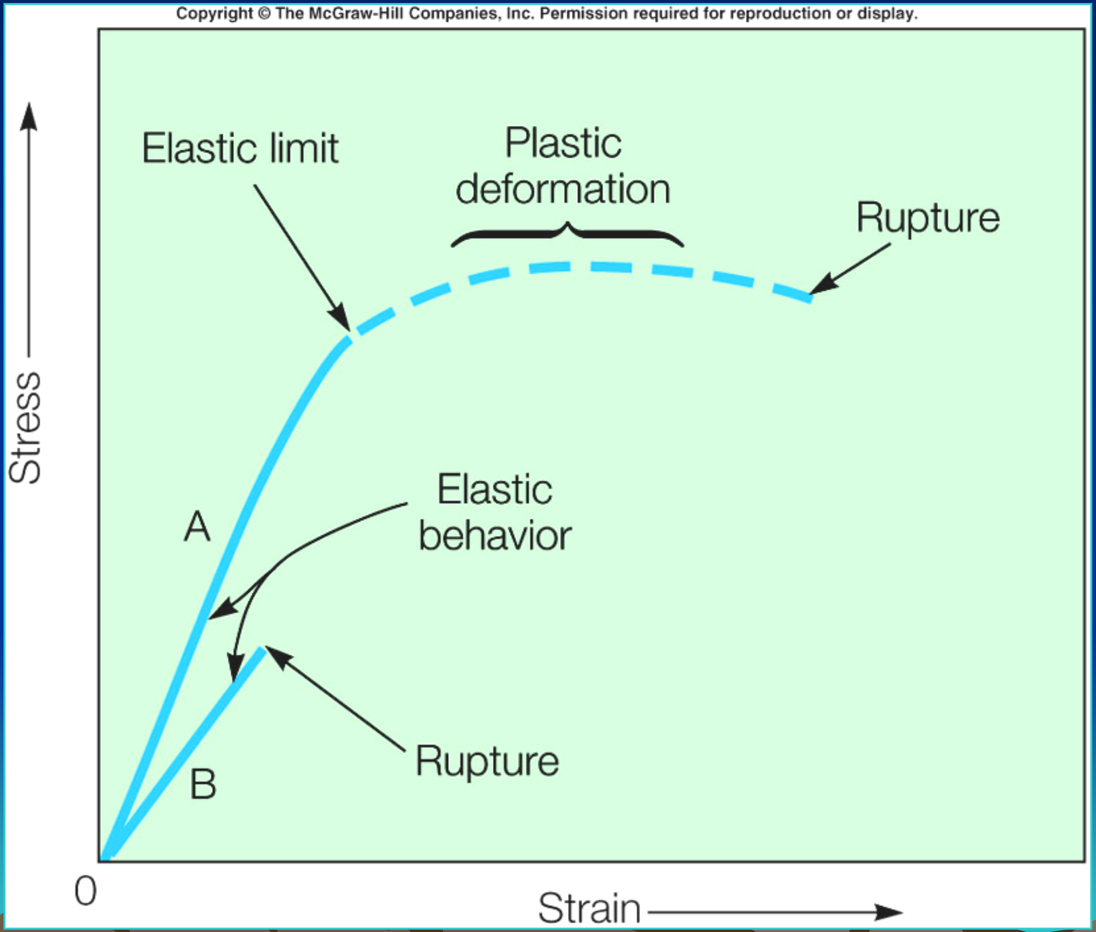
Study the architecture and processes responsible for deformation of Earth's crust.

Folding and Faulting


How Rocks Deform: 4 Controls

- **Rock Type – i.e., sandstone is more brittle than shale.**
- **Temperature – higher T = more ductile**
- **Confining Pressure – high lithostatic stress = more ductile**
- **Time – more time = more ductile (i.e., karate chop)**

Stress and Strain Relationships



The result of rock deformation can be seen at the surface as folds and faults

A few things we need to know

- Law of original horizontality
- Superposition
- Cross-cutting relationships
- Strike and dip

Law of original Horizontality

Superposition

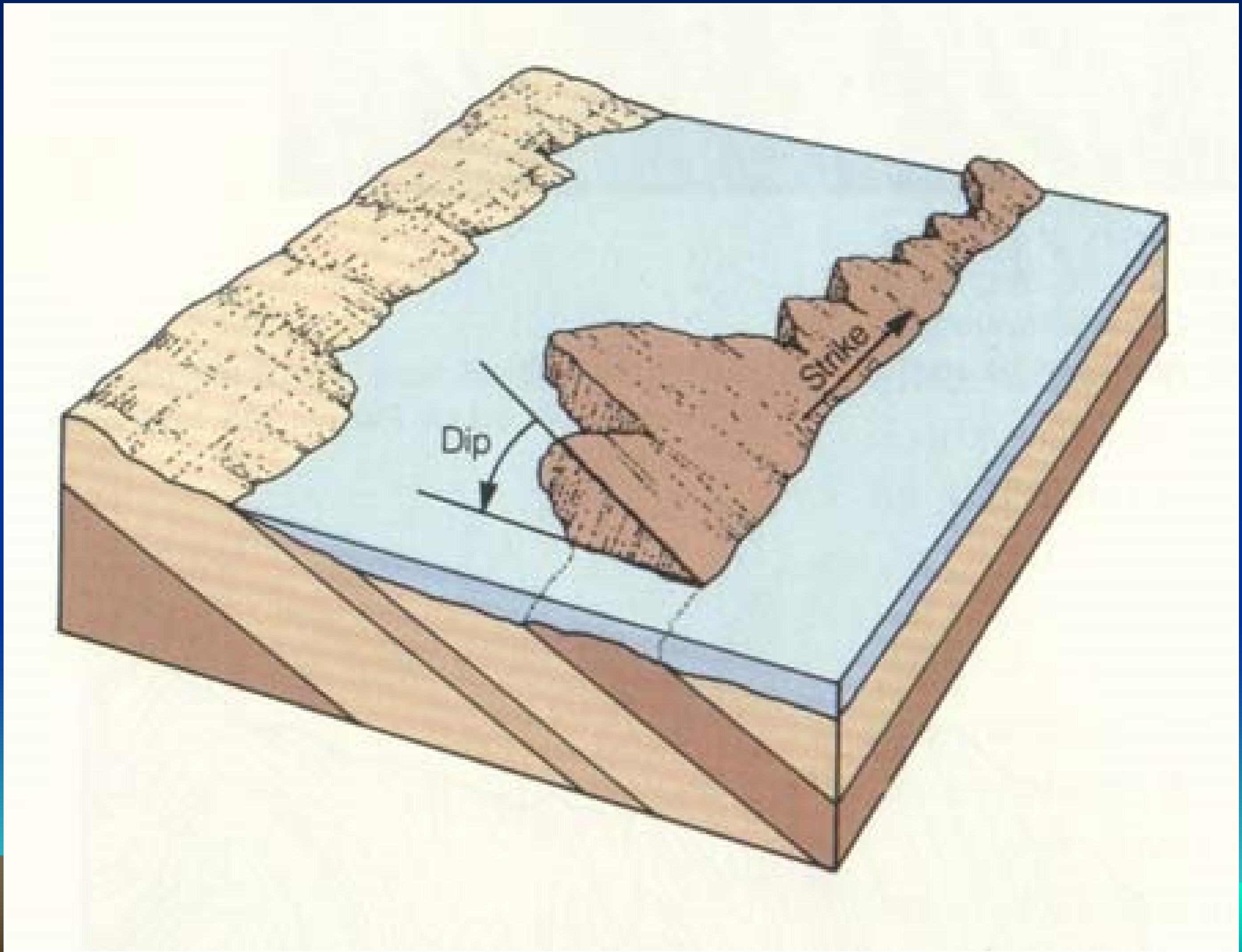
- Youngest on the top

- Oldest on the bottom

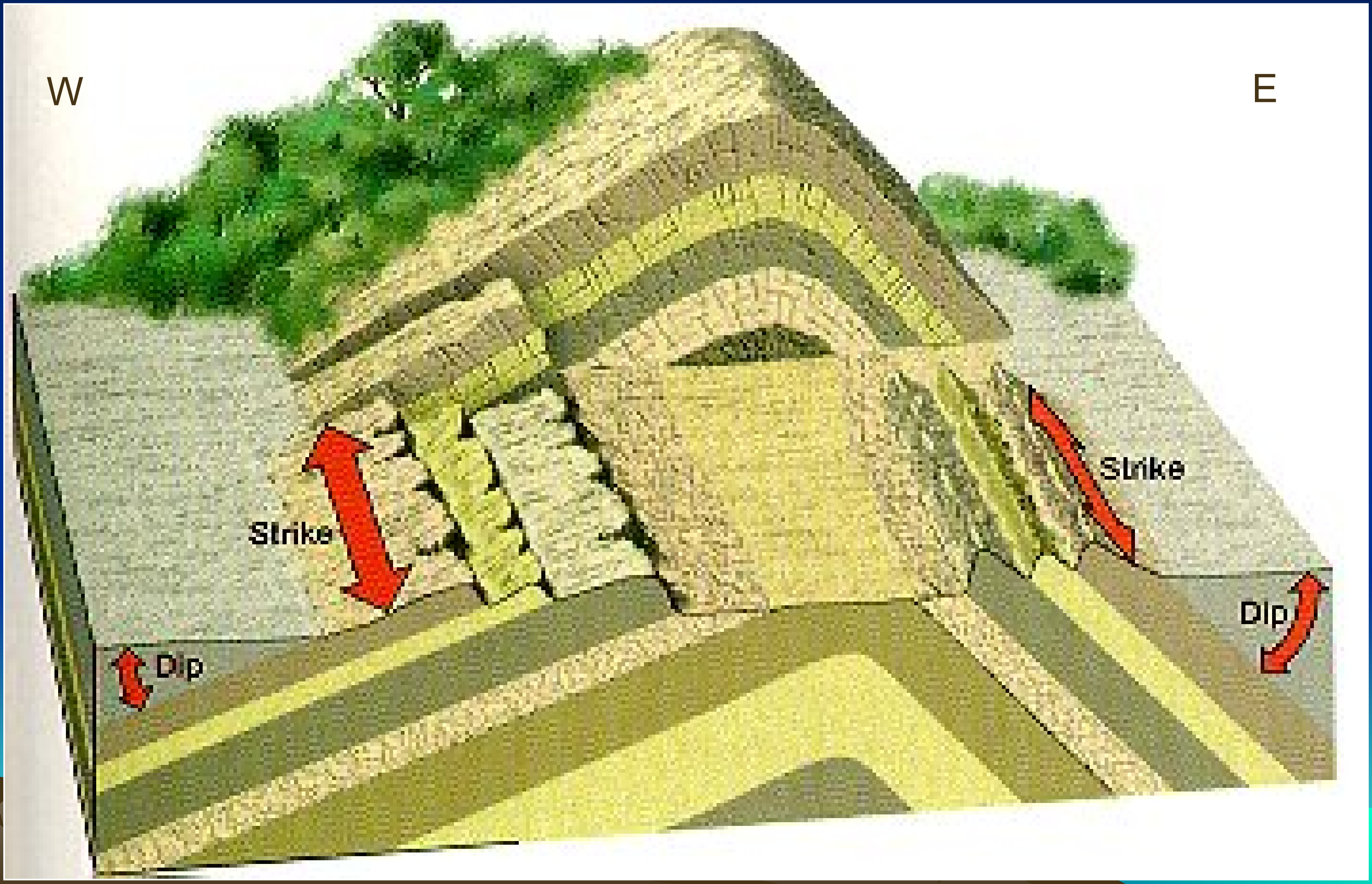
Principle of Cross-cutting Relationships

i.e., These sandstone beds were deposited as horizontal layers **before** they were faulted.

Strike and Dip- when rocks are no longer horizontal



Strike and Dip- how do we describe their orientation

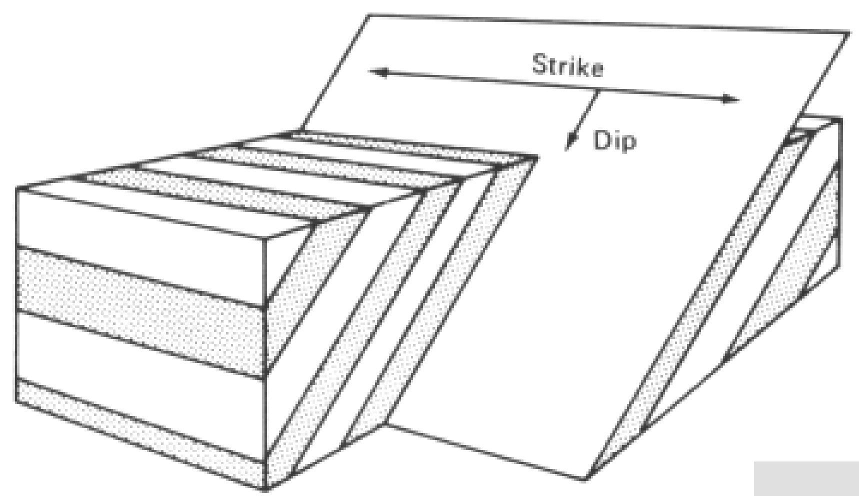


Strike and dip rules

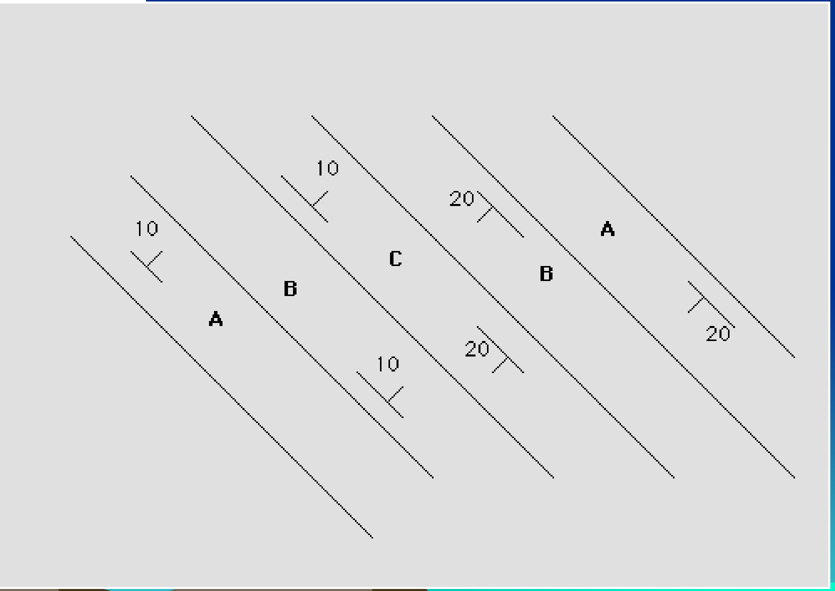
- Strike is the direction on the surface of the rock formation – described by two directions ie. N-S, E-W, NE-SW
- Dip is always perpendicular to strike and is described by only one direction – N, S, E, W or NW, SE etc.
- Often it is easier to find the dip of a rock unit first and then describe the strike

Strike and Dip

Strike and Dip



Dip and Strike
(Courtesy of Dresser Atlas)



Folds

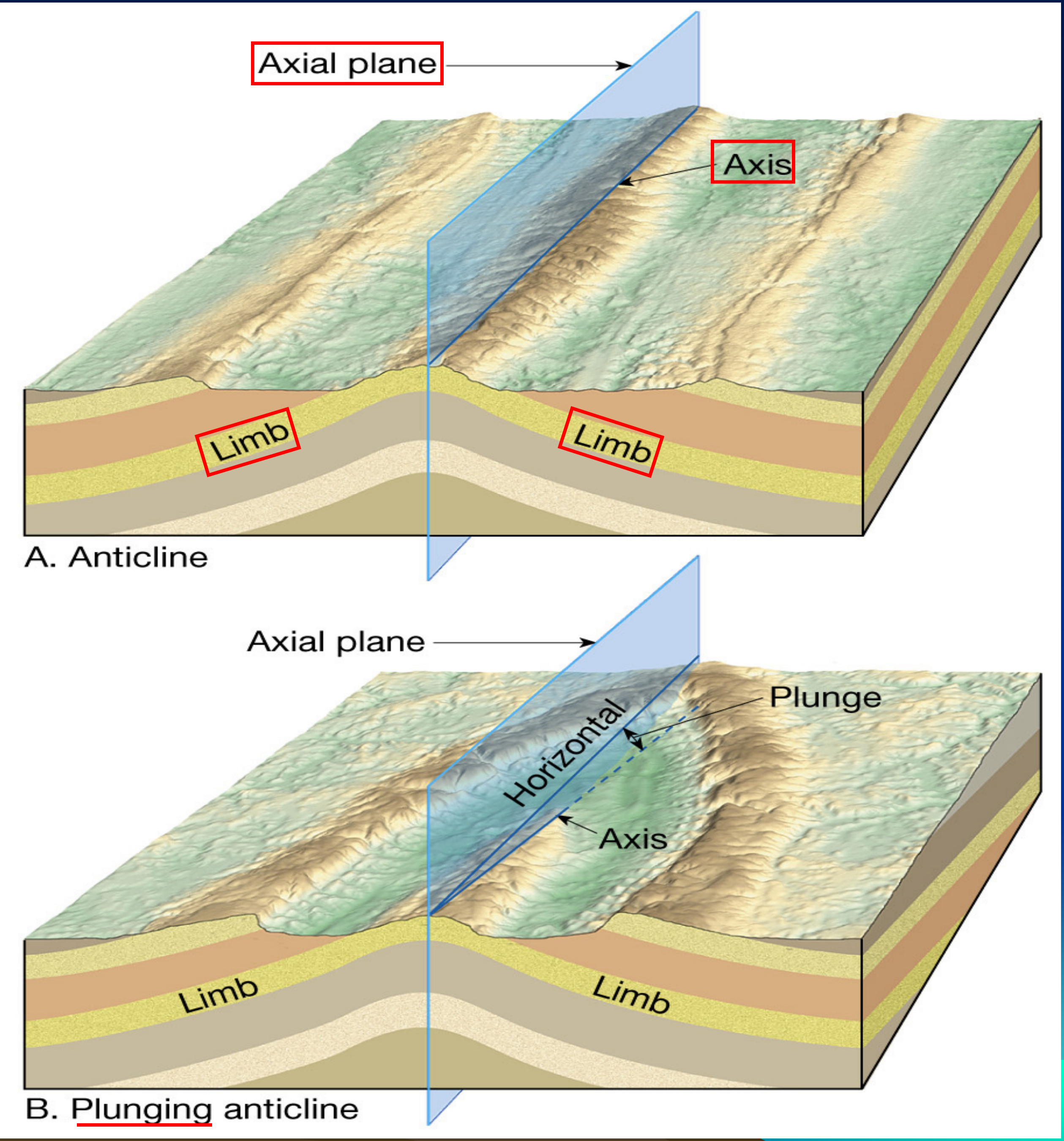
- How do rocks fold?
- Ductile deformation
- What environments lead to ductile deformation?

Folds

- **Folds** wave-like undulations in rock that form mainly from compressional stress that shortens and thickens the crust

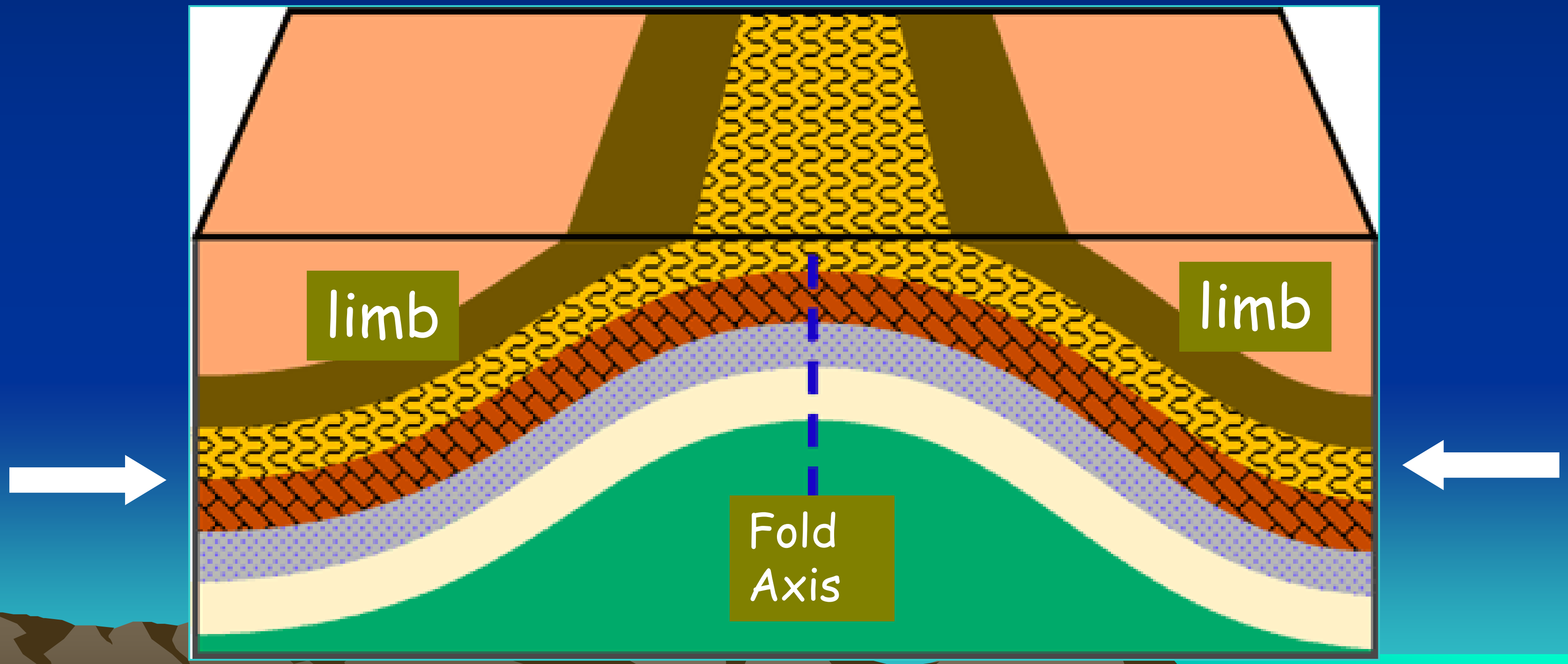
Fold Parts

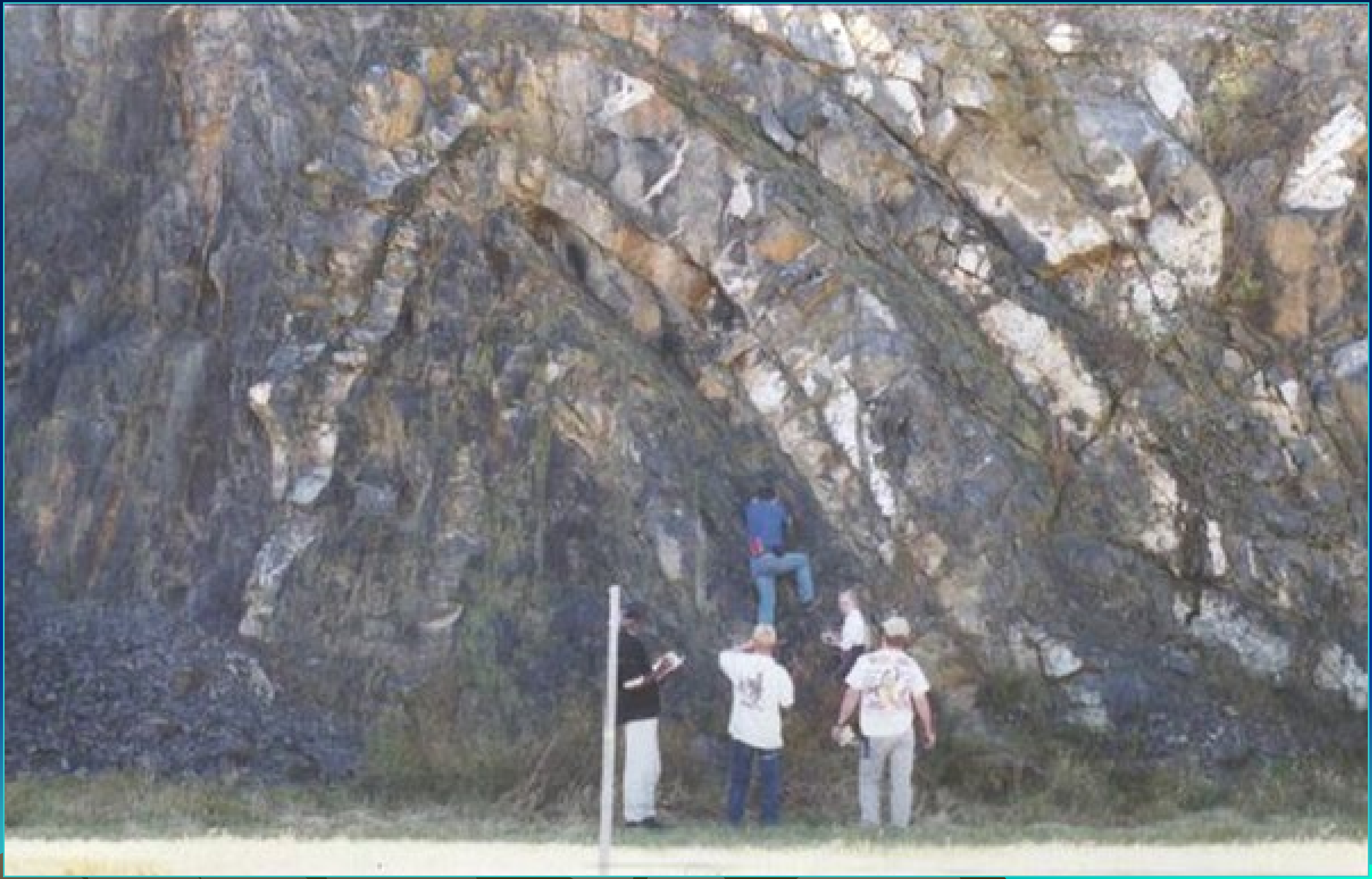
- **Limbs** –the two planar sides of a fold
- **Axis** – imaginary line marking the crest or trough of each layer
- **Axial plane** – an imaginary plane of symmetry through the center of the fold



Types of folds

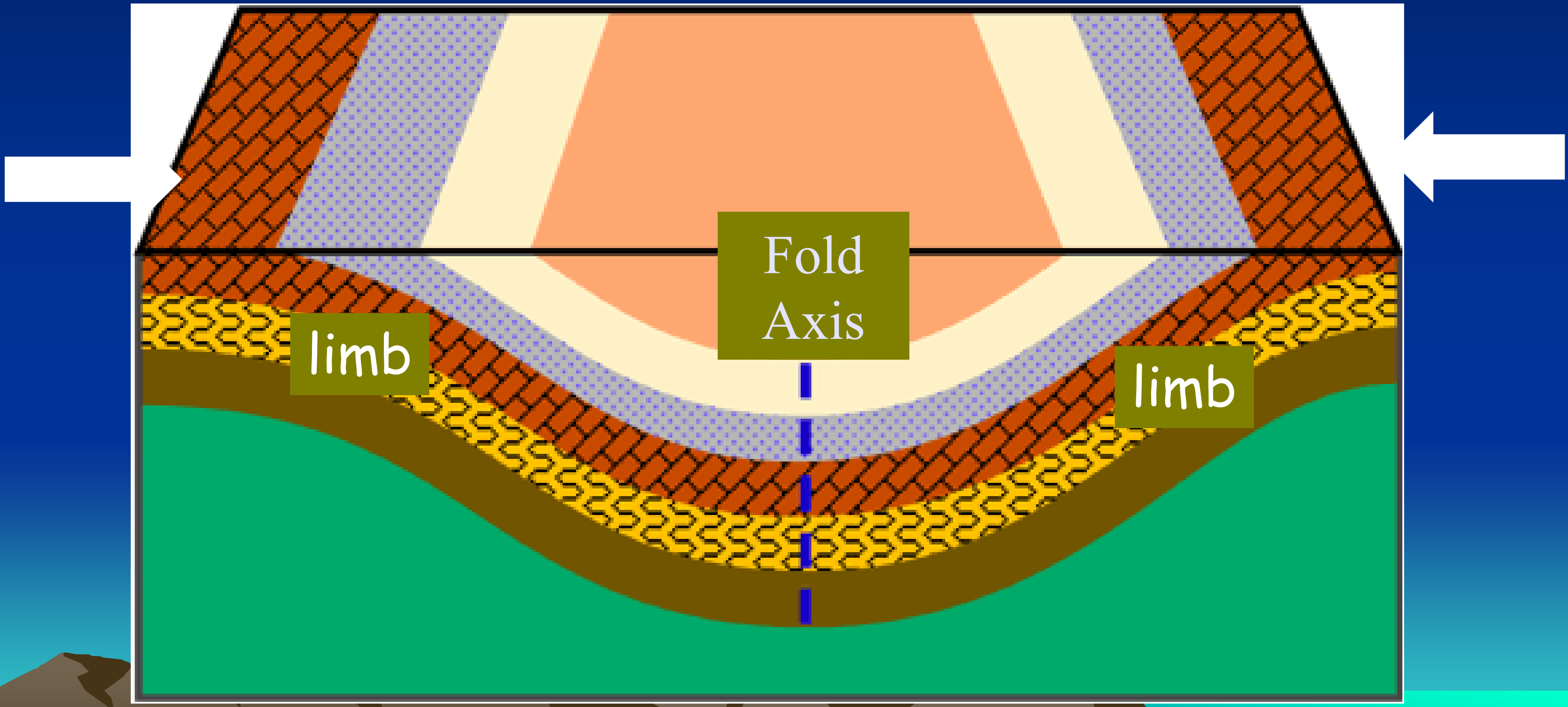
- Anticlines – “A” shape



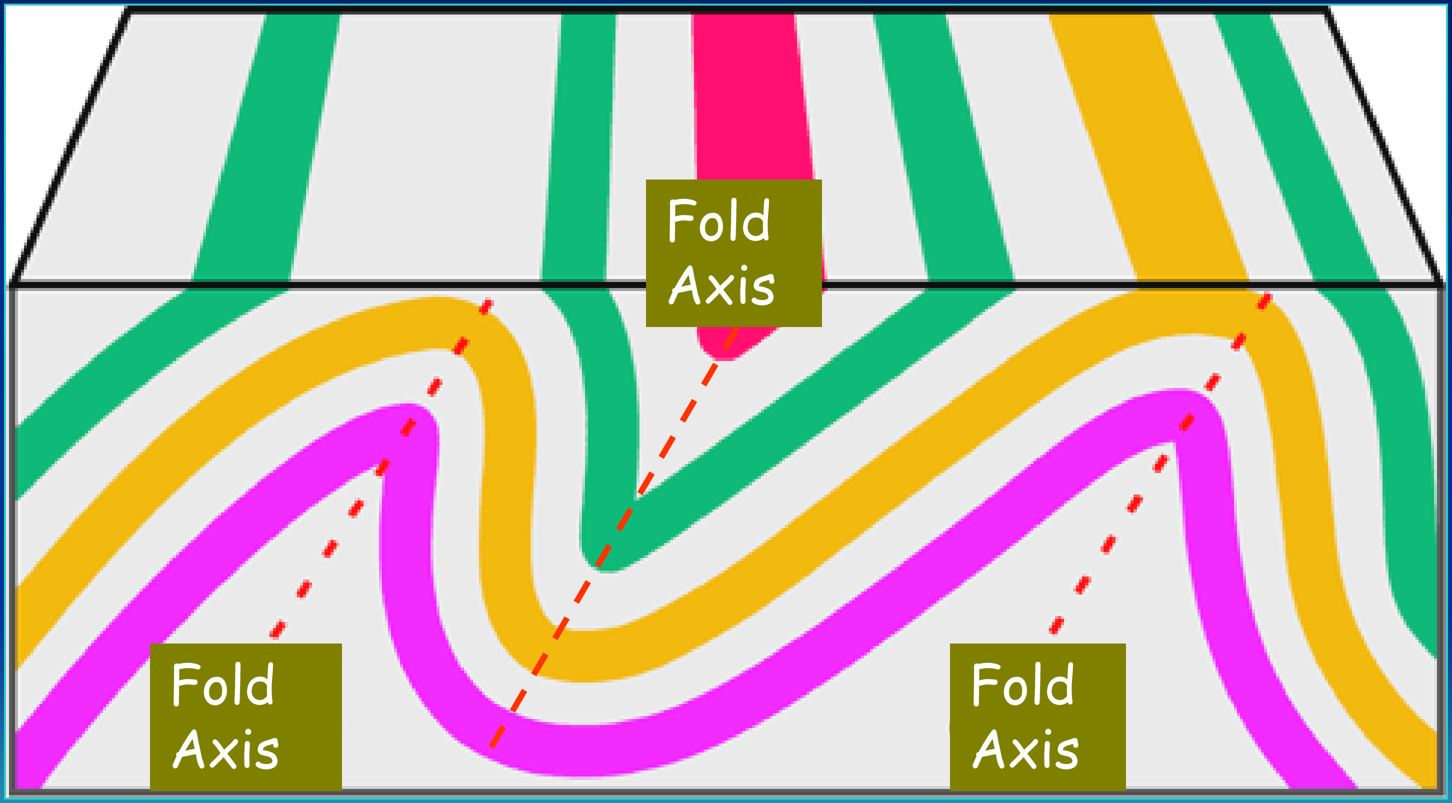


Folds

Syncline- think of a sink



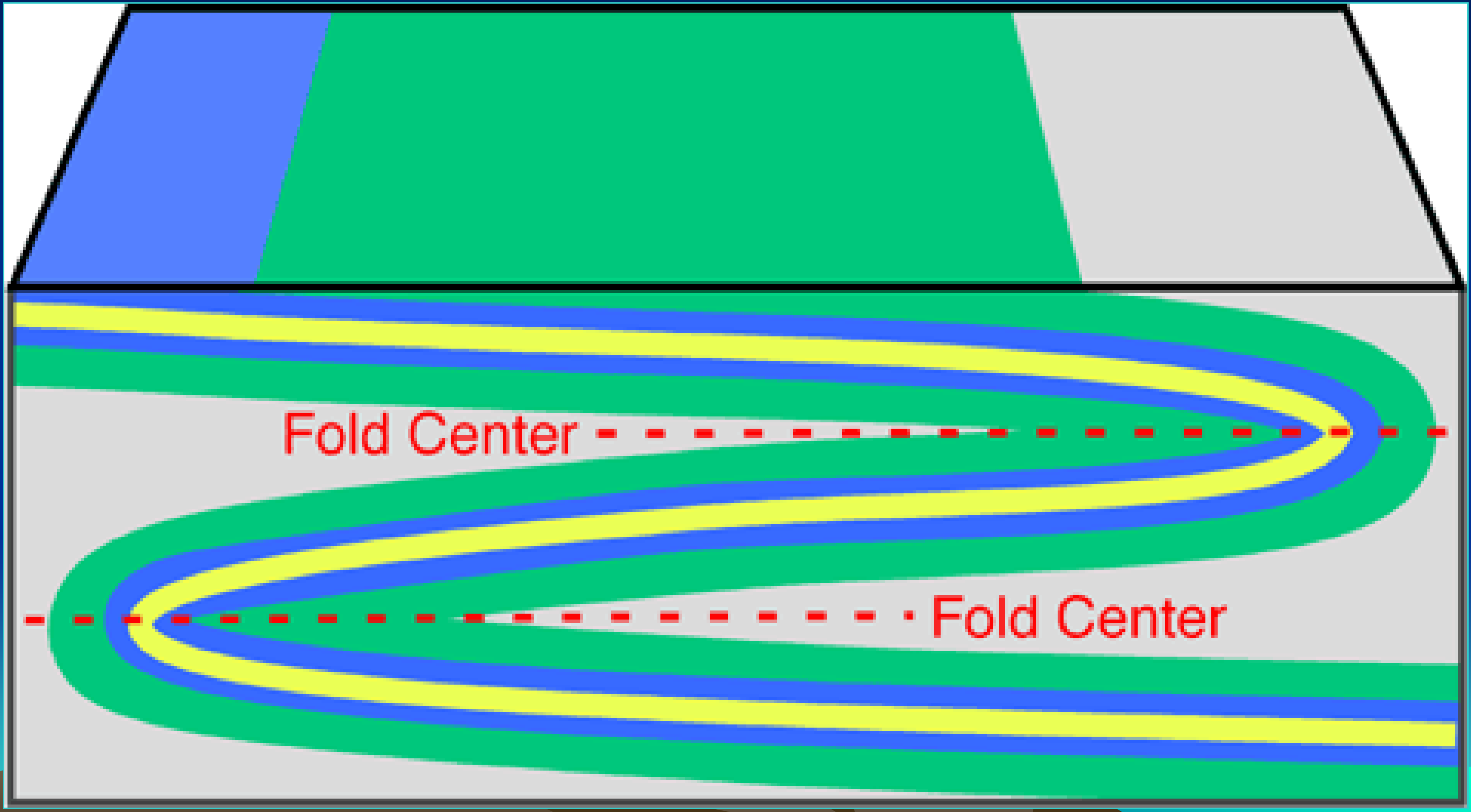
Paired and tilted anticline and syncline



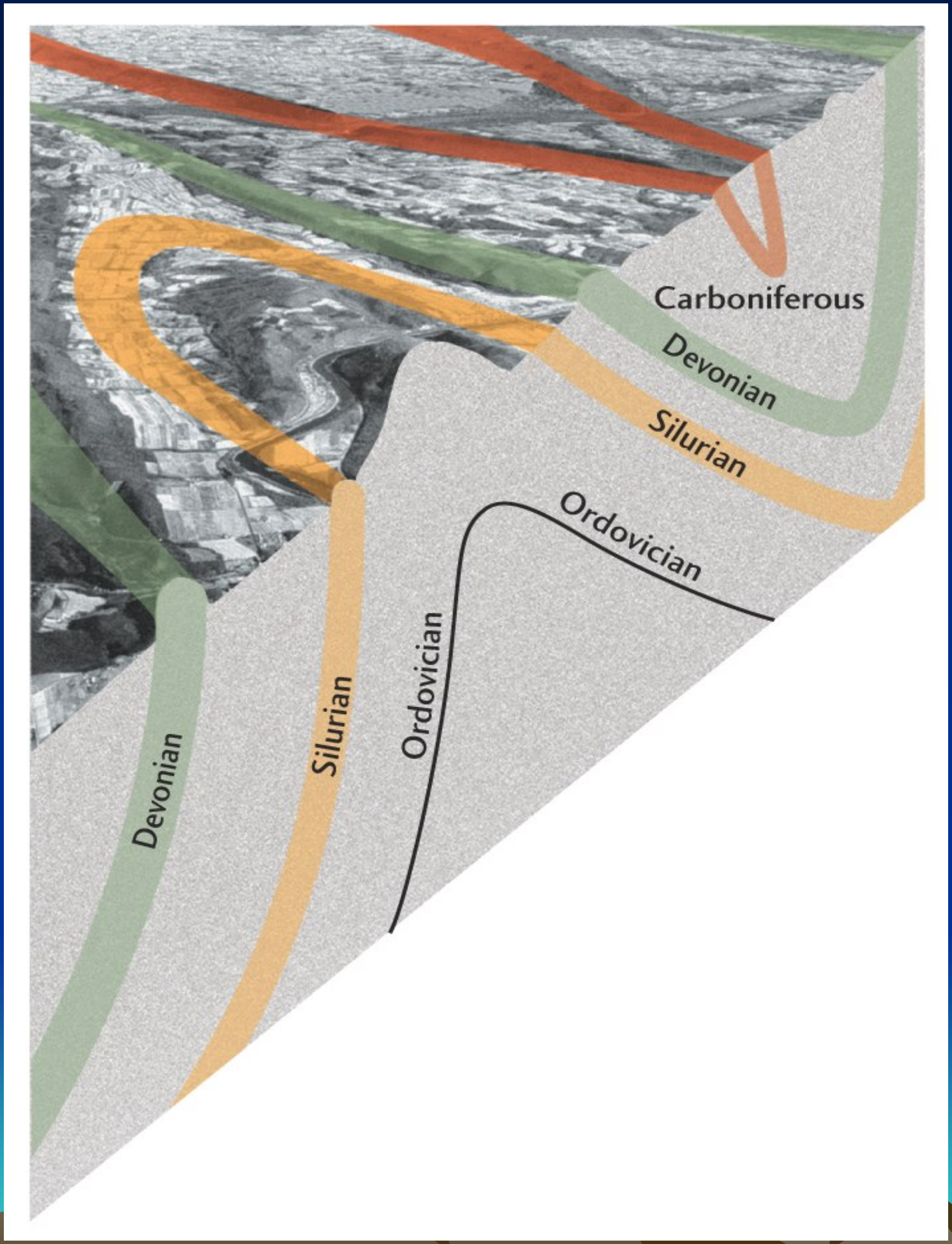
folds

folds

Overturned folds

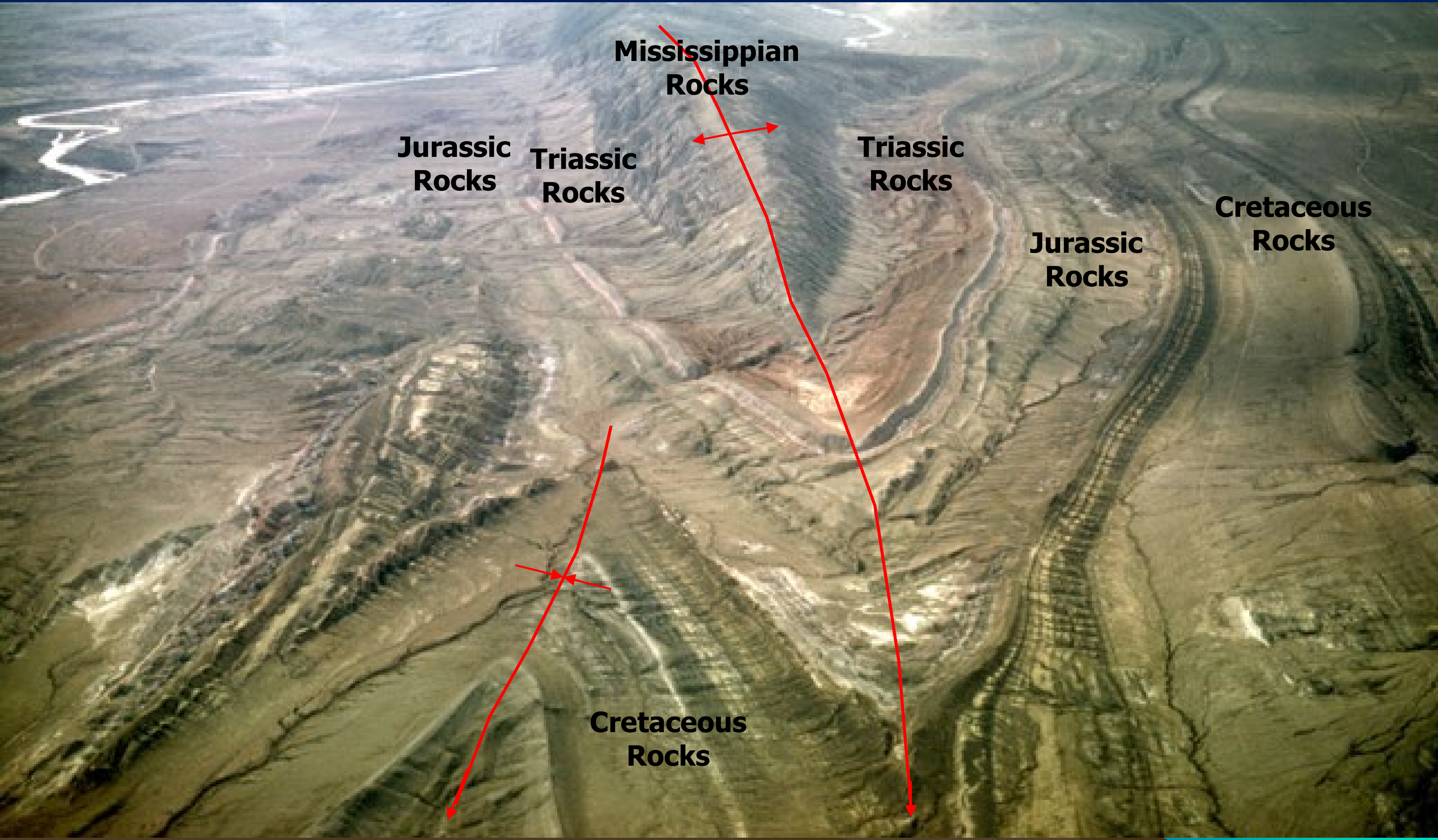


folds

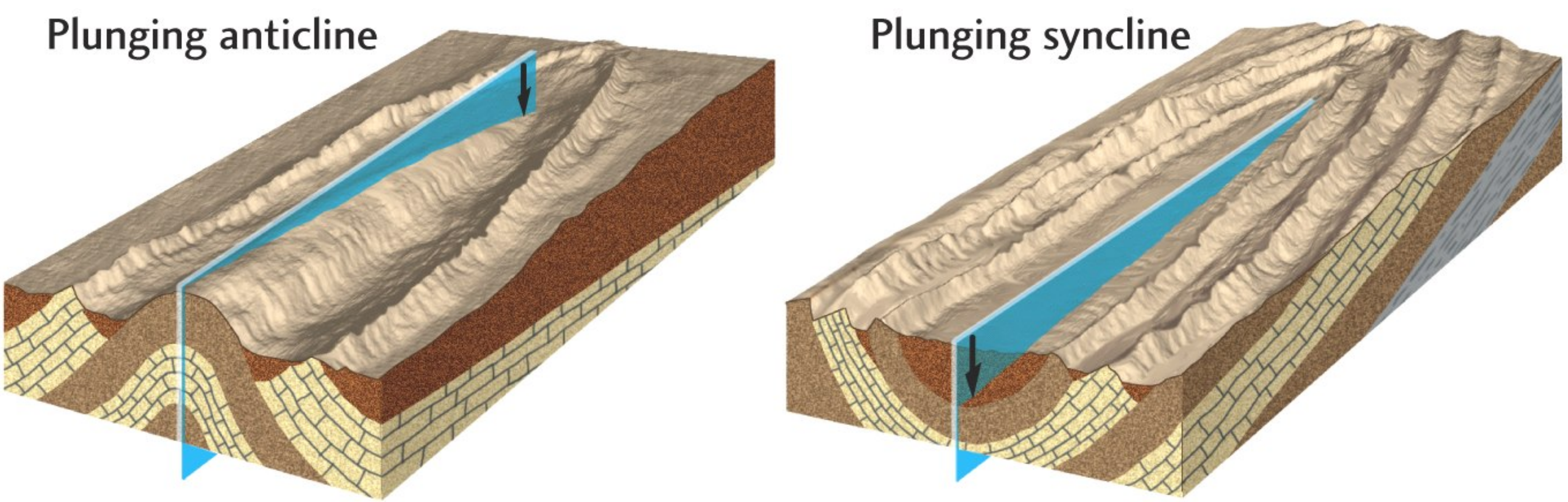


Folding on a large scale to produce large landforms

- Sheep Mountain, WY: <u>Plunging Anticline & Syncline</u>
  - Note Outcrop "V"s, Plunge Arrows, Anticline Symbol, Syncline Symbol
  - Note Oldest & Youngest Layers

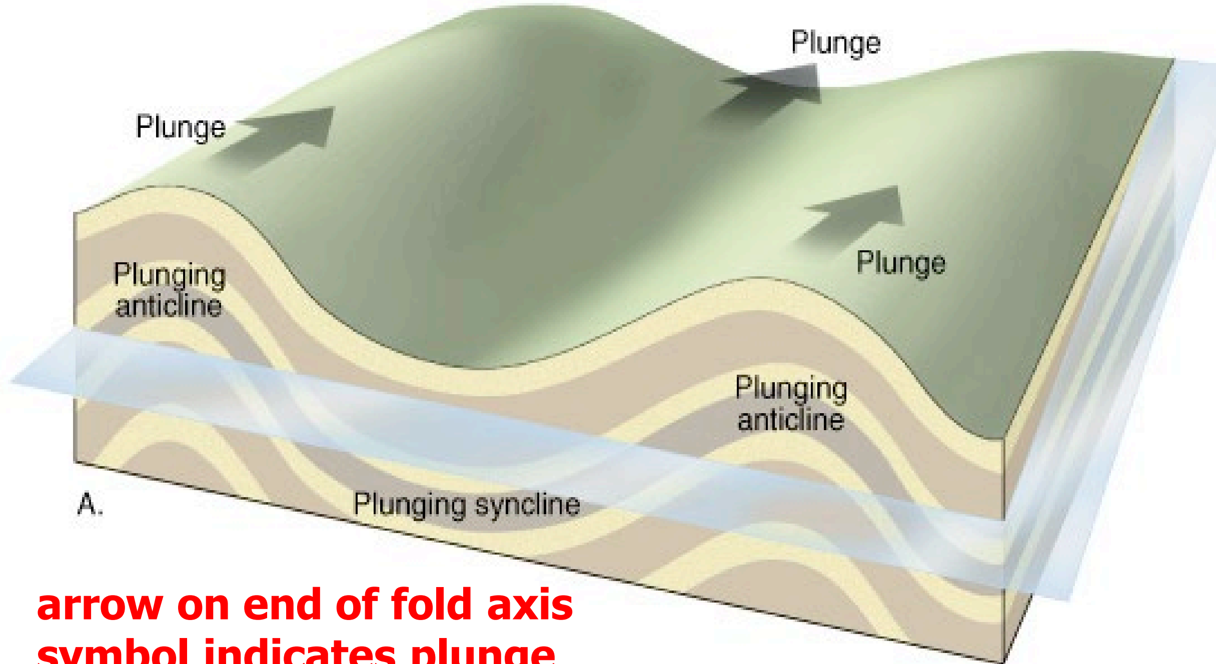


Plunging folds

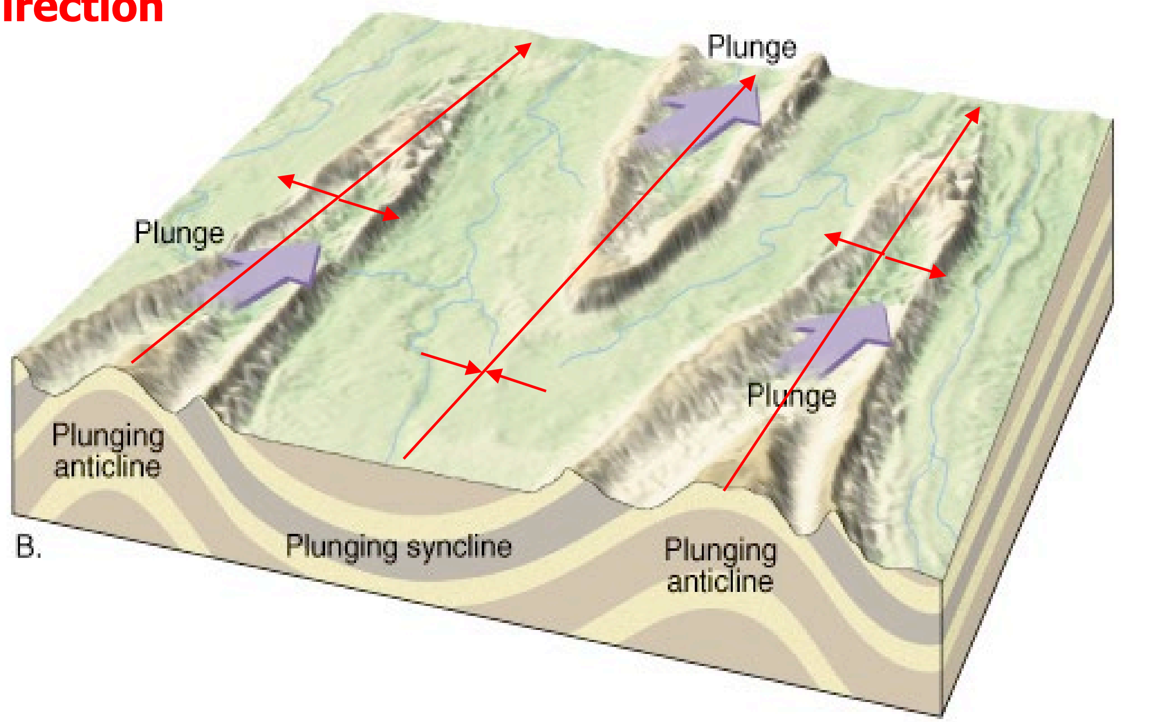


- Fold axis dips below the surface

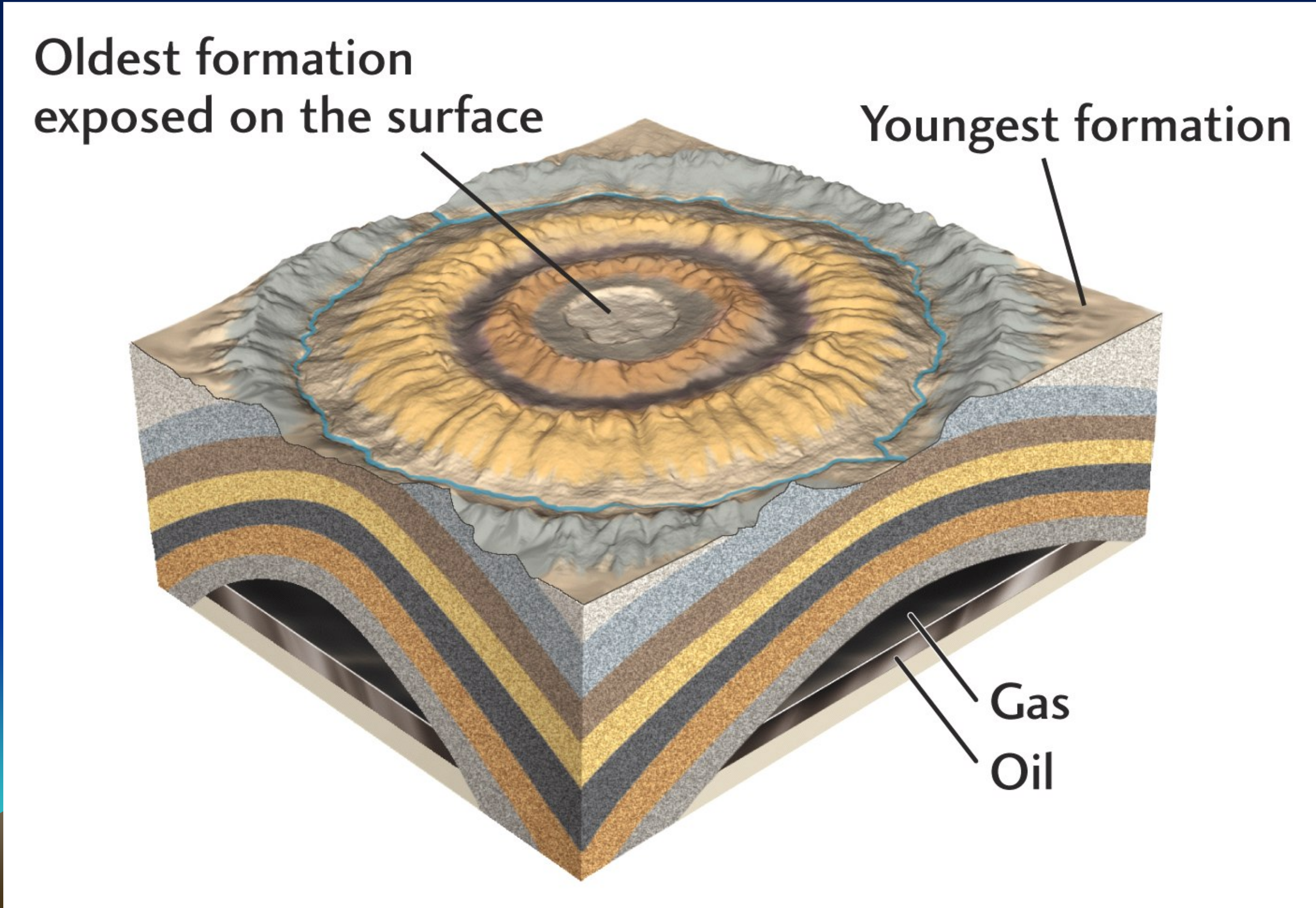
- **Anticline** – upfold
  - Oldest rock in center
  - Point of mapped outcrop "V" in the direction of plunge.
- **Syncline** - downfold
  - Youngest rock in center
  - Open end of mapped outcrop "V" is in the direction of plunge.

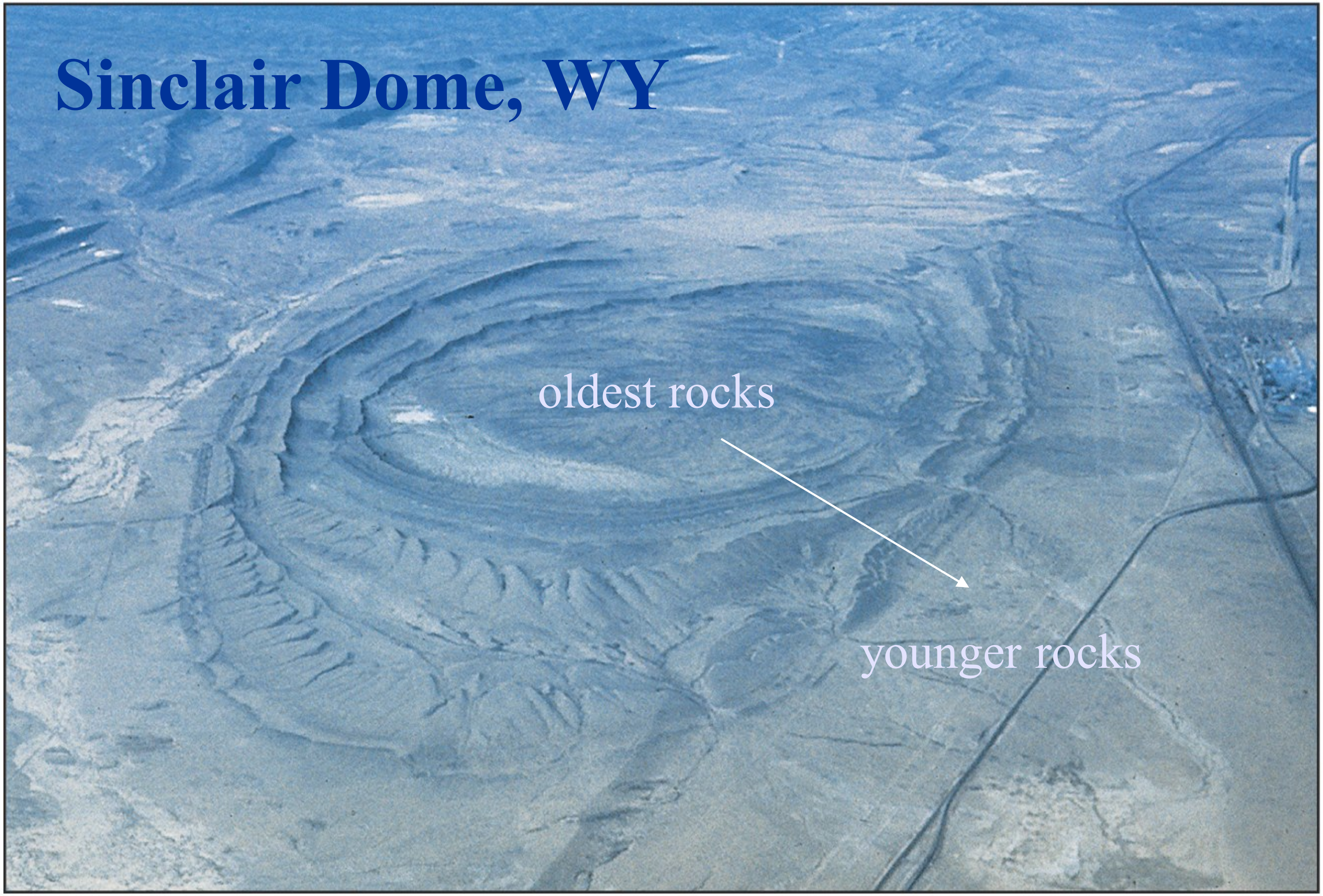


arrow on end of fold axis symbol indicates plunge direction



DOME


Oldest formation
exposed on the surface
Youngest formation
Gas
Oil


Sinclair Dome, WY
oldest rocks
younger rocks

Folds in map view

Anticlines - eroded tops of anticlines reveal a characteristic map pattern of rock ages

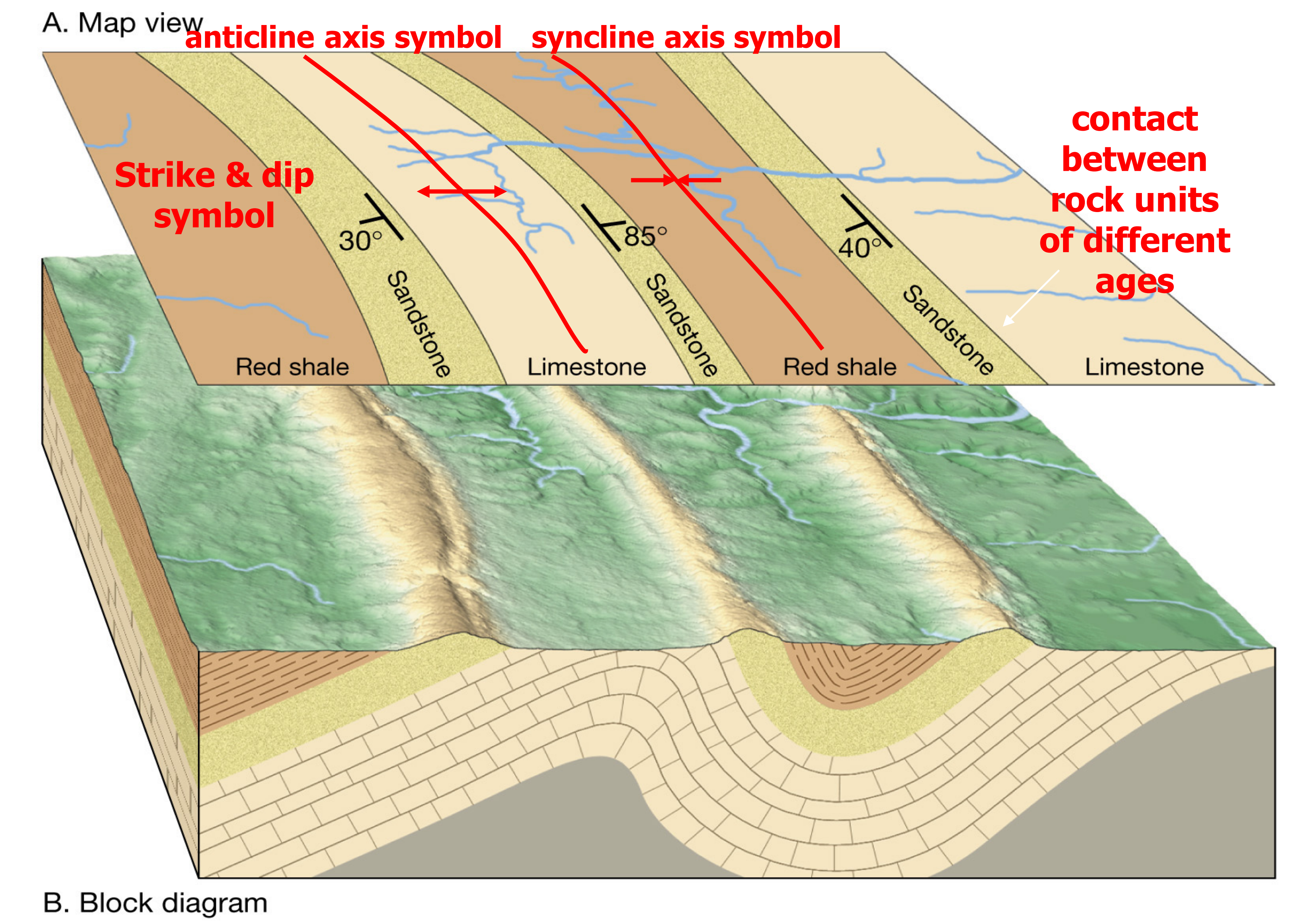
- Oldest rocks exposed in the middle with bands getting younger as you go out
- e direction of dip of the bed will provide clues to what type of structure it is

Folds in map view

Synclines -eroded synclines reveal a characteristic map pattern of rock ages

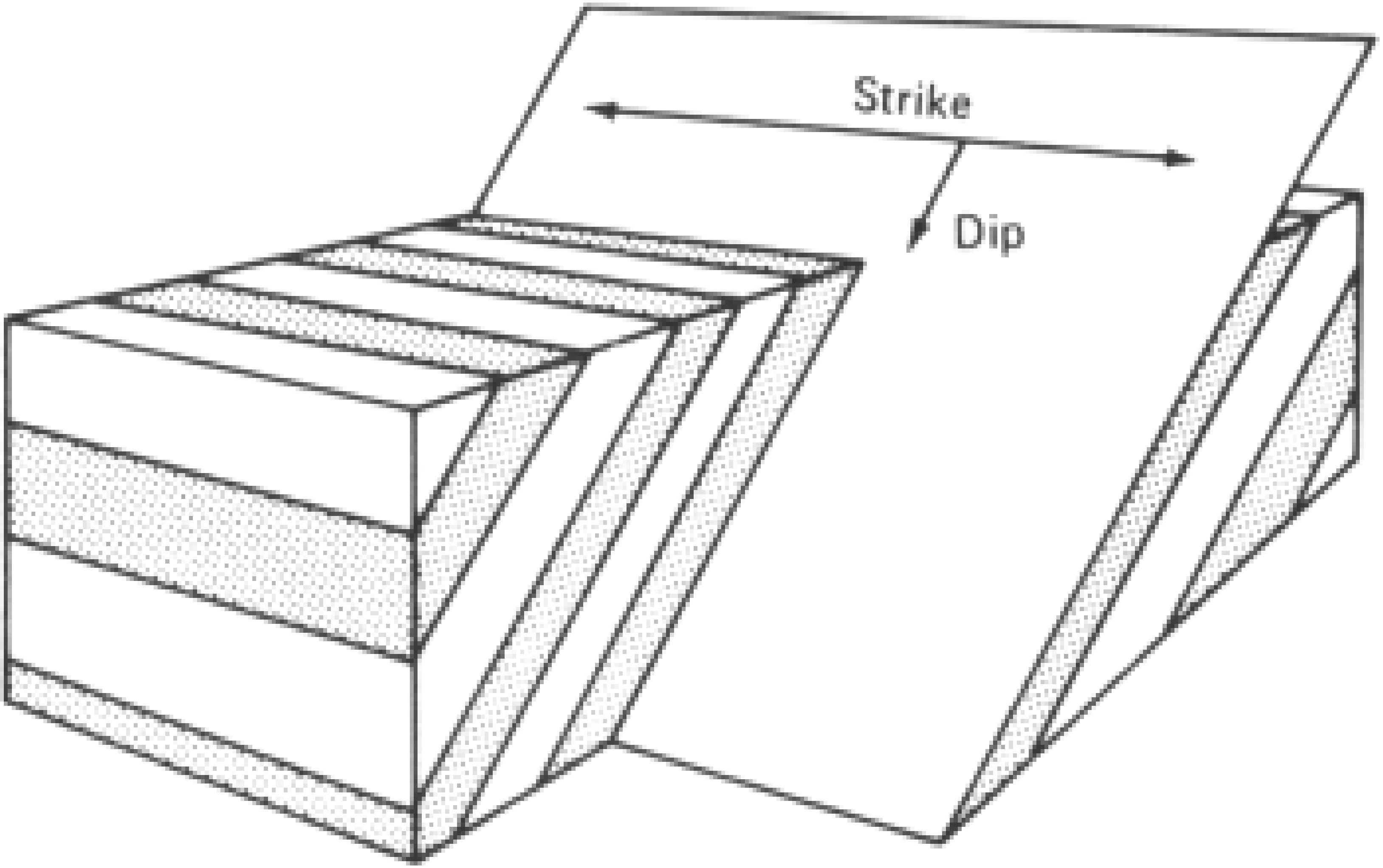
- Youngest rocks exposed in the middle with bands getting older as you go out
- The direction of dip of the bed will provide clues to what type of structure it is

Geologic Maps



Faults

- **Faults** - **fractures** in rocks along which appreciable displacement has taken place – brittle deformation of the rock or layers of rock
  - 2 basic Types:
    - **Dip Slip** – Movement is mainly parallel to the **dip** of the fault surface
    - **Strike Slip** - Movement is mainly parallel to the **strike** of the fault surface



Dip and Strike

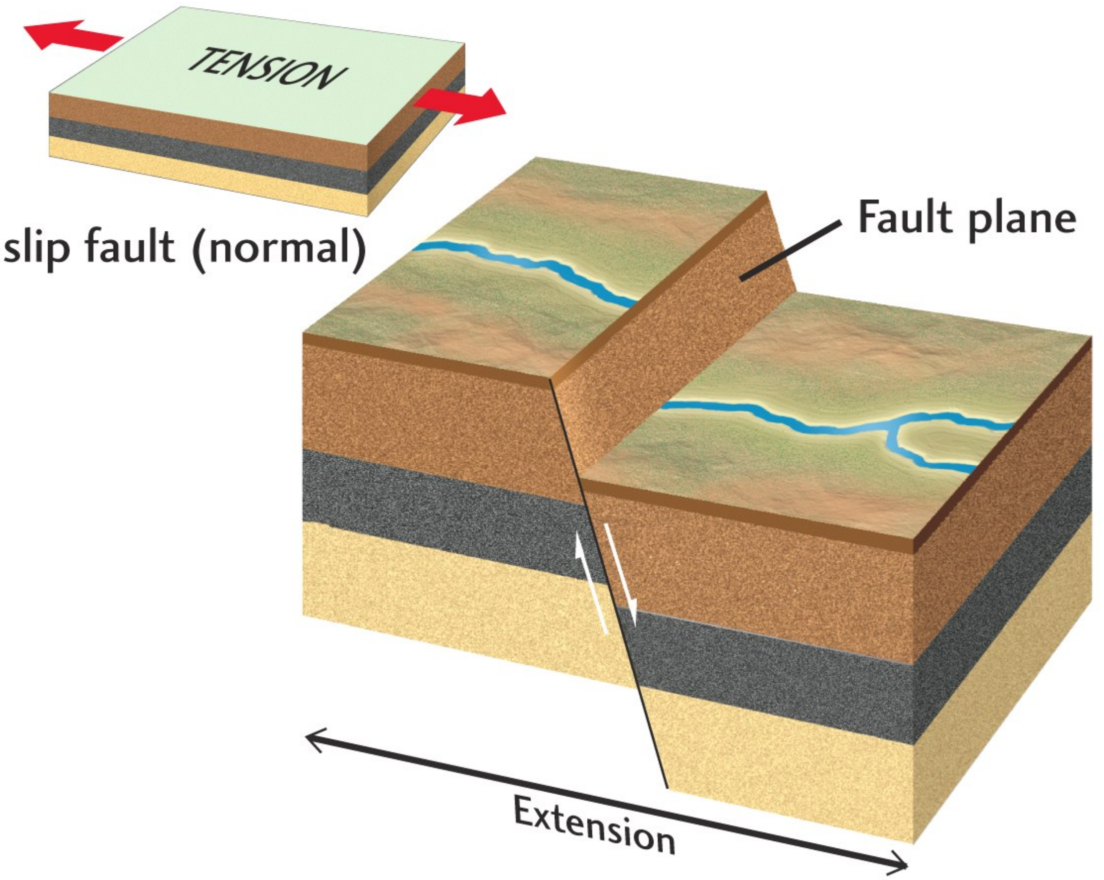
(Courtesy of Dresser Atlas)

Dip-Slip Faults

- Two main types –
- Normal – Hanging wall moves down in relation to foot wall
- Reverse or Thrust – Hanging wall moves up relative to footwall

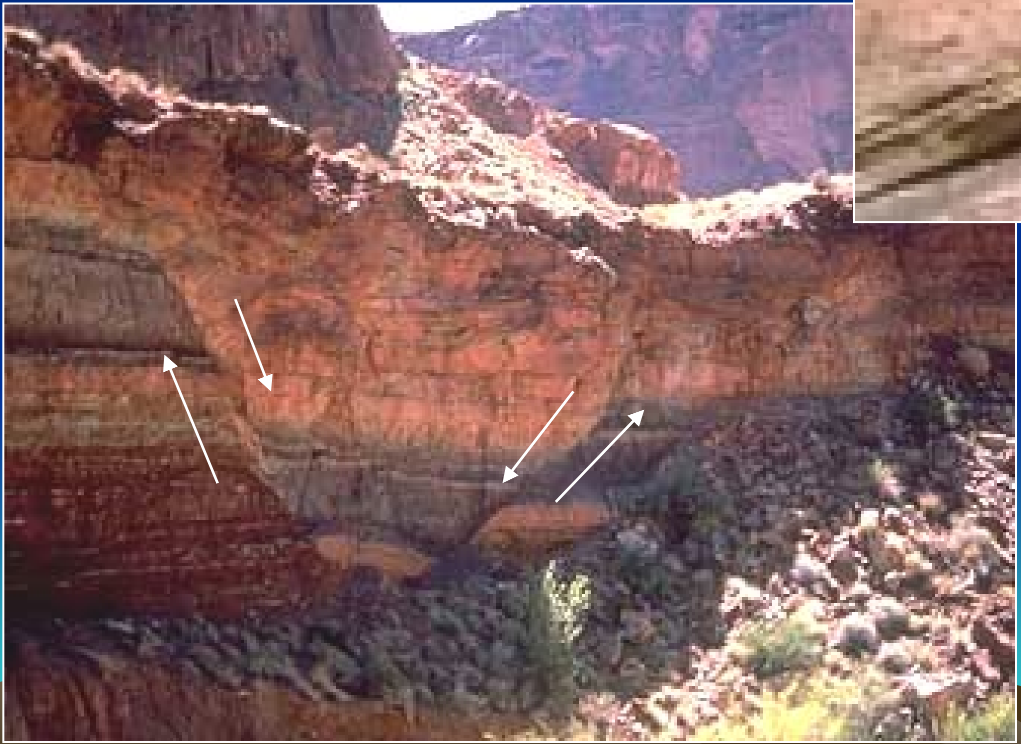
Faults

- Tensional forces cause normal faulting



(a) Dip-slip fault (normal)

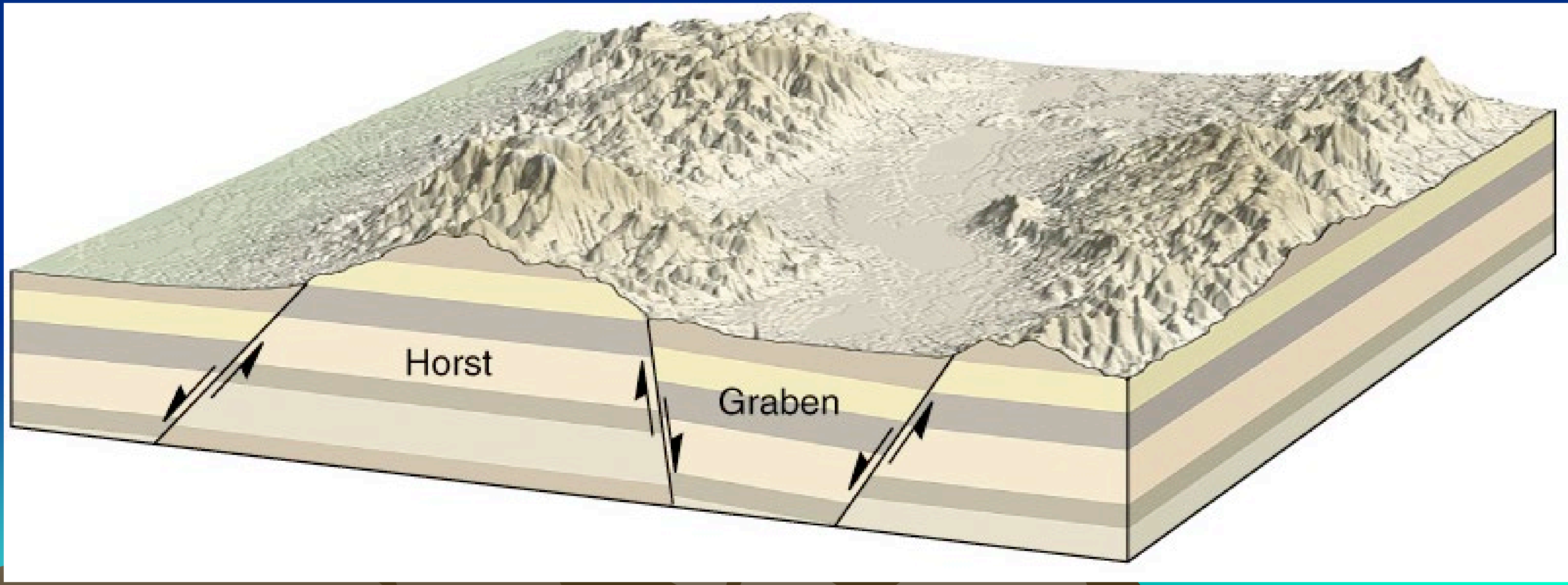
Normal Faults



Scarps

Normal Faults

- Form **fault-block mountains**
- Horst = high upthrown block
- Graben = low downthrown block

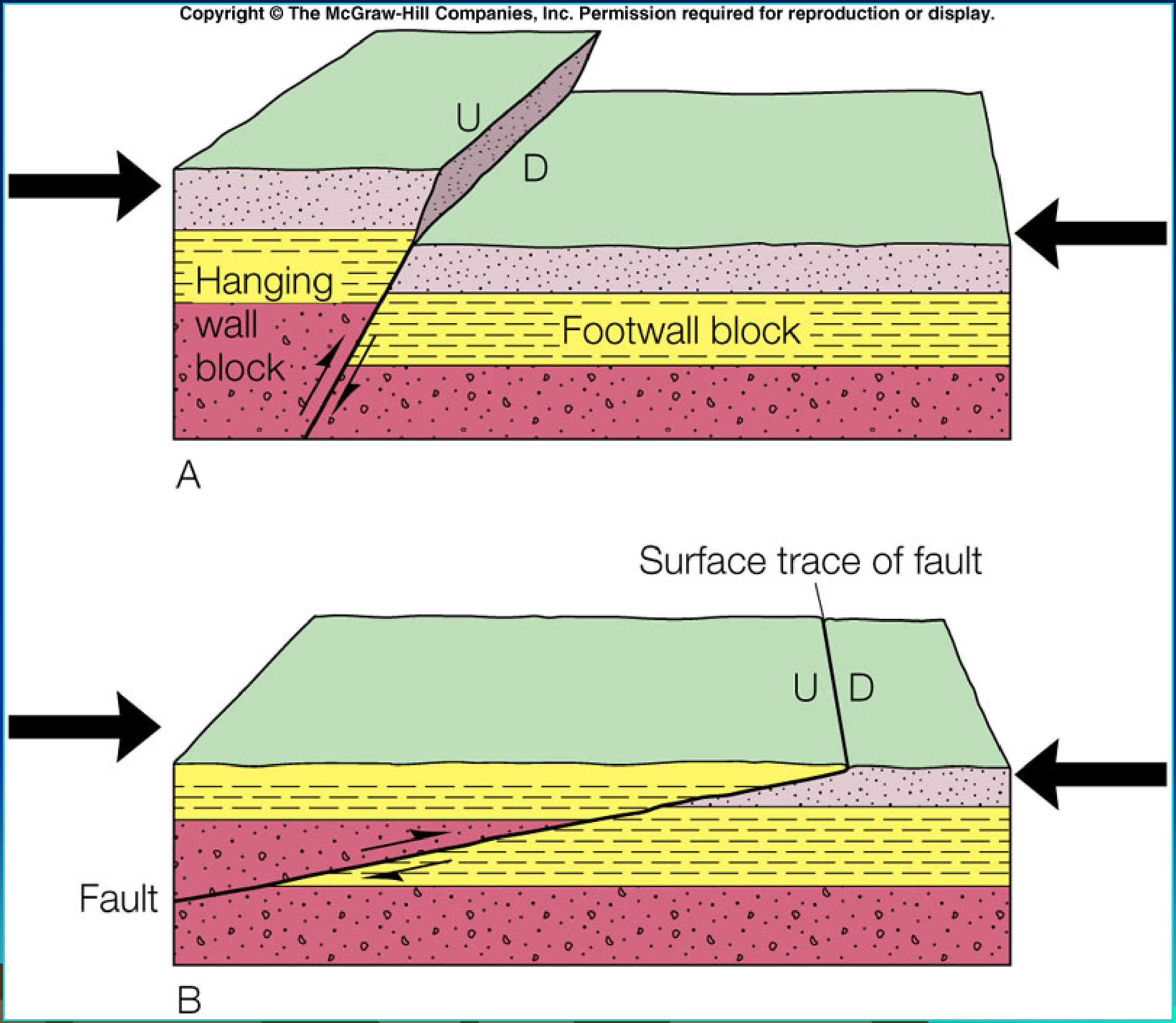



Grand Tetons, WY- fault block mountains

Reverse Faults

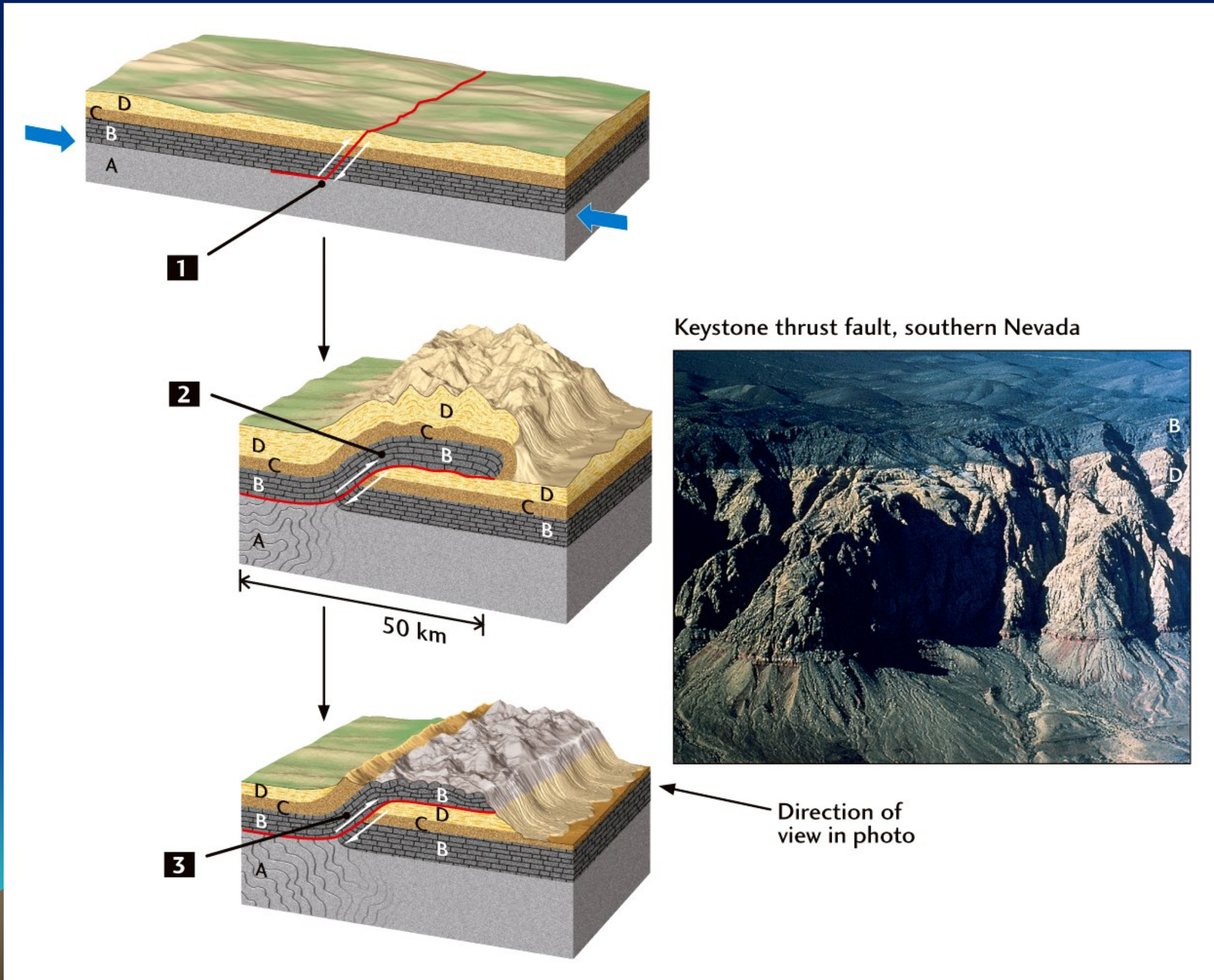
Reverse Fault

Thrust Fault

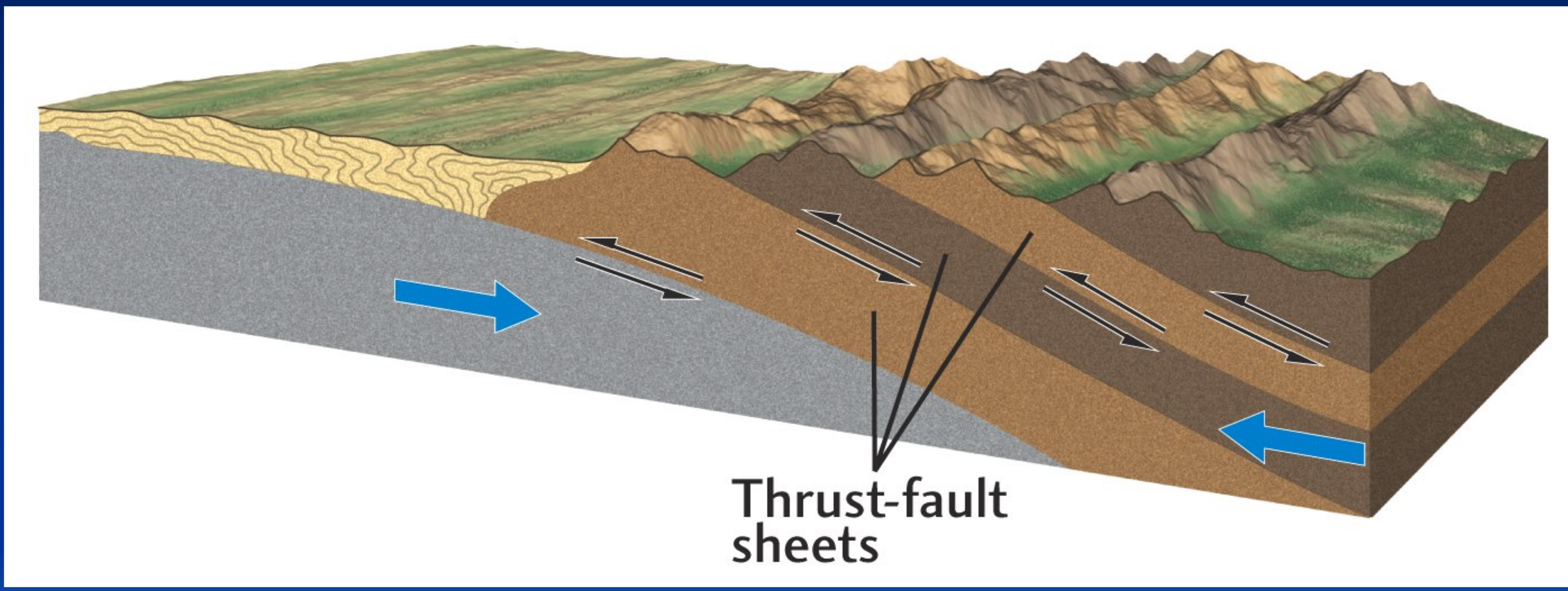


Faults

- Thrust Faults are a low angle reverse fault

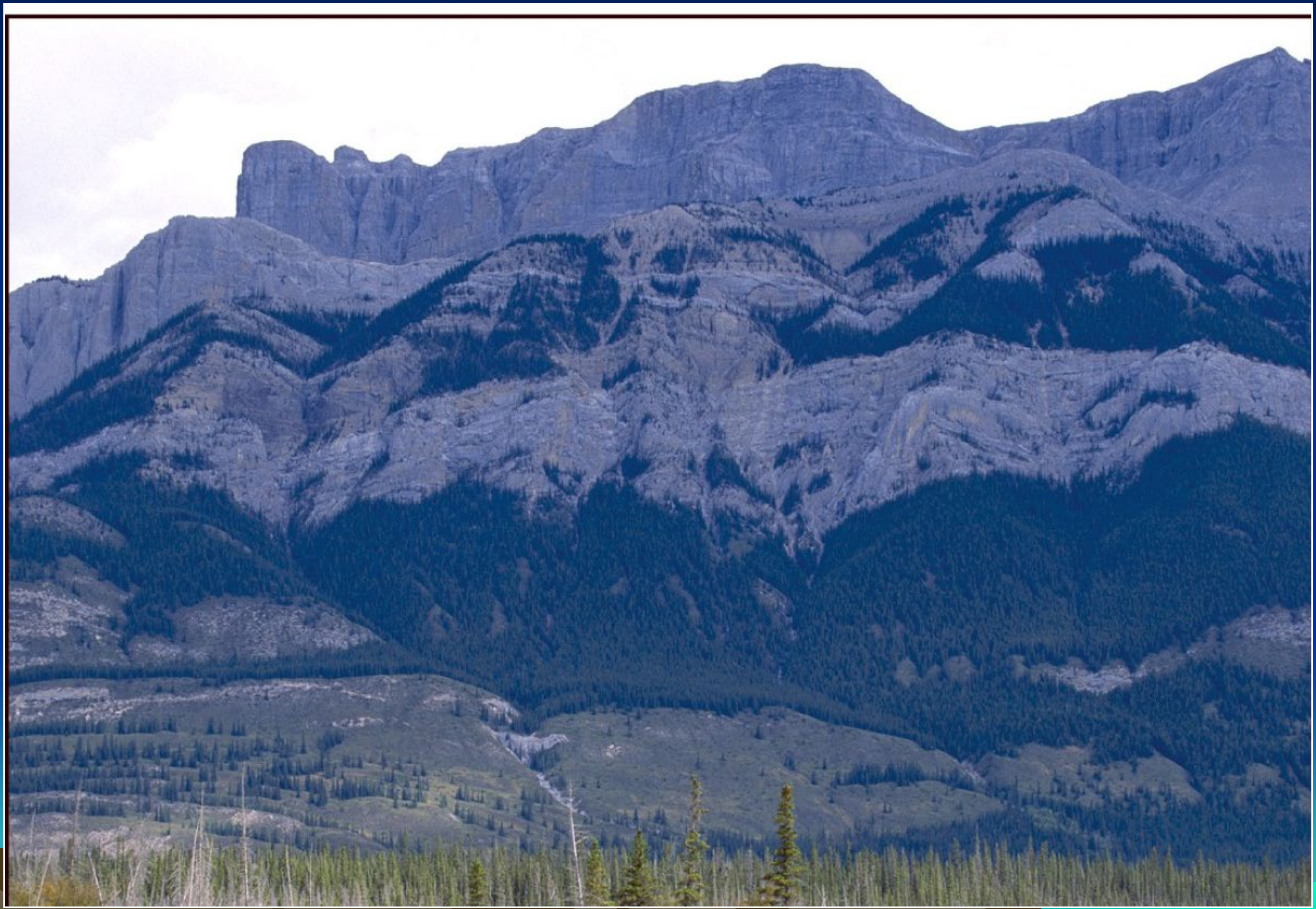


Overlapping thrust sheets build up mountain ranges



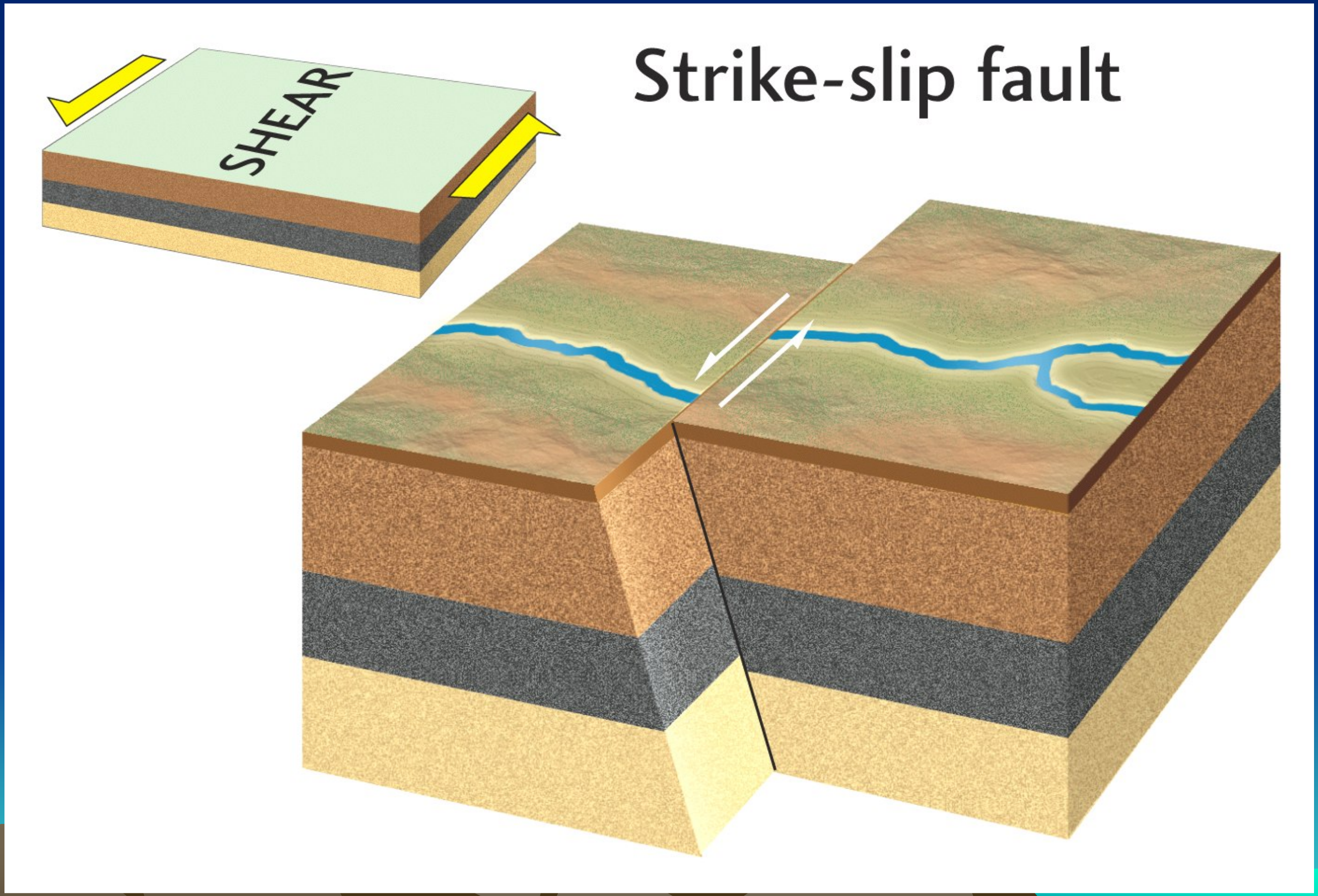
Thrusts are low angle reverse faults

The Canadian Rockies were built up as a series of thrust sheets



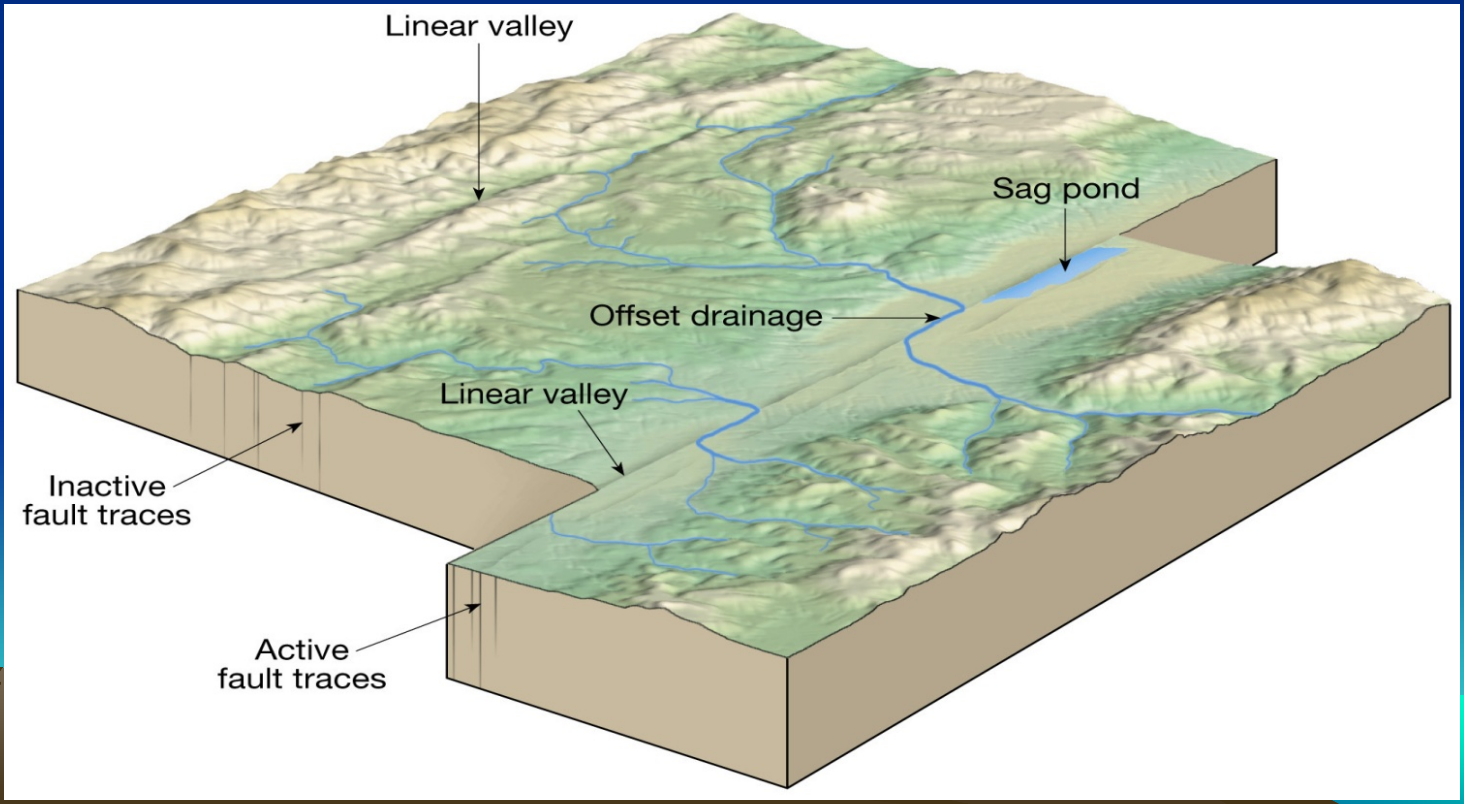
Faults

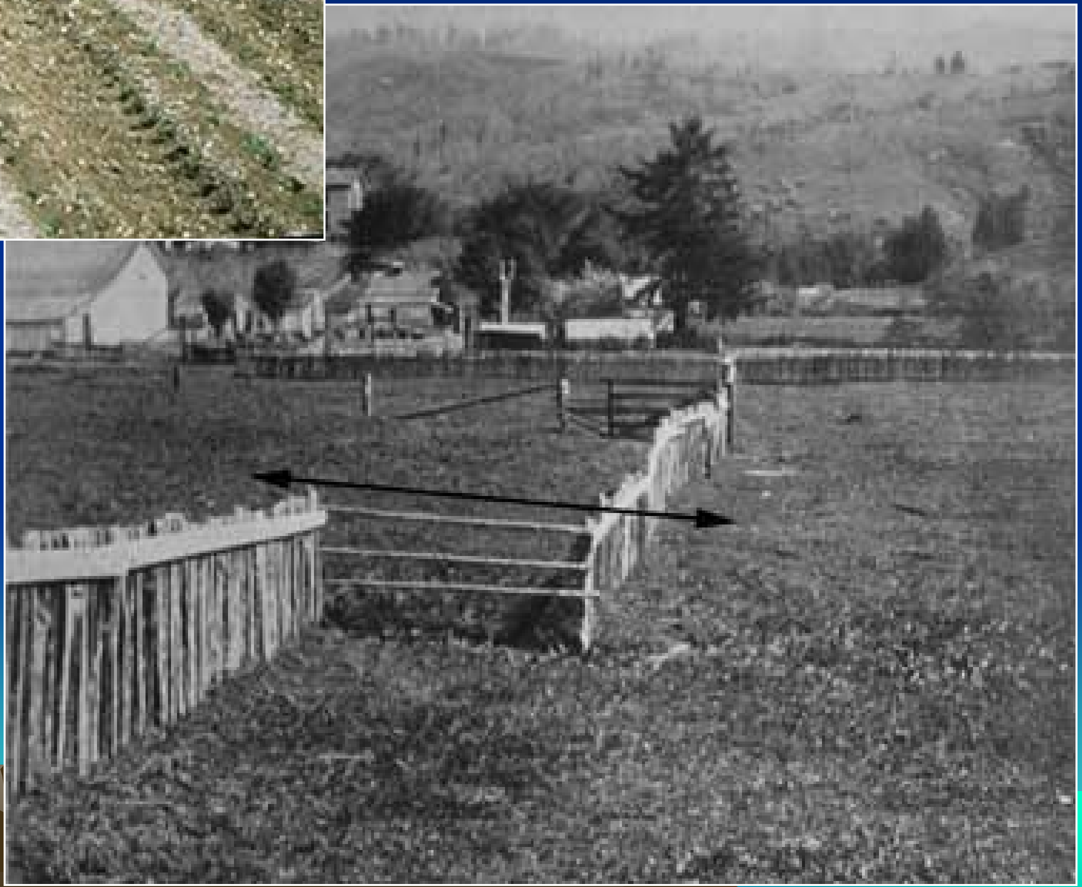
- Shear stresses cause strike-slip faulting



Strike-Slip Faults

- **Right-lateral** – as you face the fault, the block on the opposite side of the fault moves to the right
- **Left-lateral** – as you face the fault, the block on the opposite side of the fault moves to the left




SAN ANDREAS FAULT
large right lateral offset
in drainage pattern
small-scale drainage pattern
also shows right lateral offset

Engineering and Faults

- Fractures to Faults
- Shear Zones