UNIVERISTY OF ZAMBIA
GEOLOGY DEPARTMENT

GEOLOGIC STRUCTURES

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Introduction

This lecture is devoted to a review of **structures in rocks:**

- ✓ Layering – *bedding, foliation*
- ✓ Folds
- ✓ Joints / fractures
- ✓ Faults

Introduction.....contd.

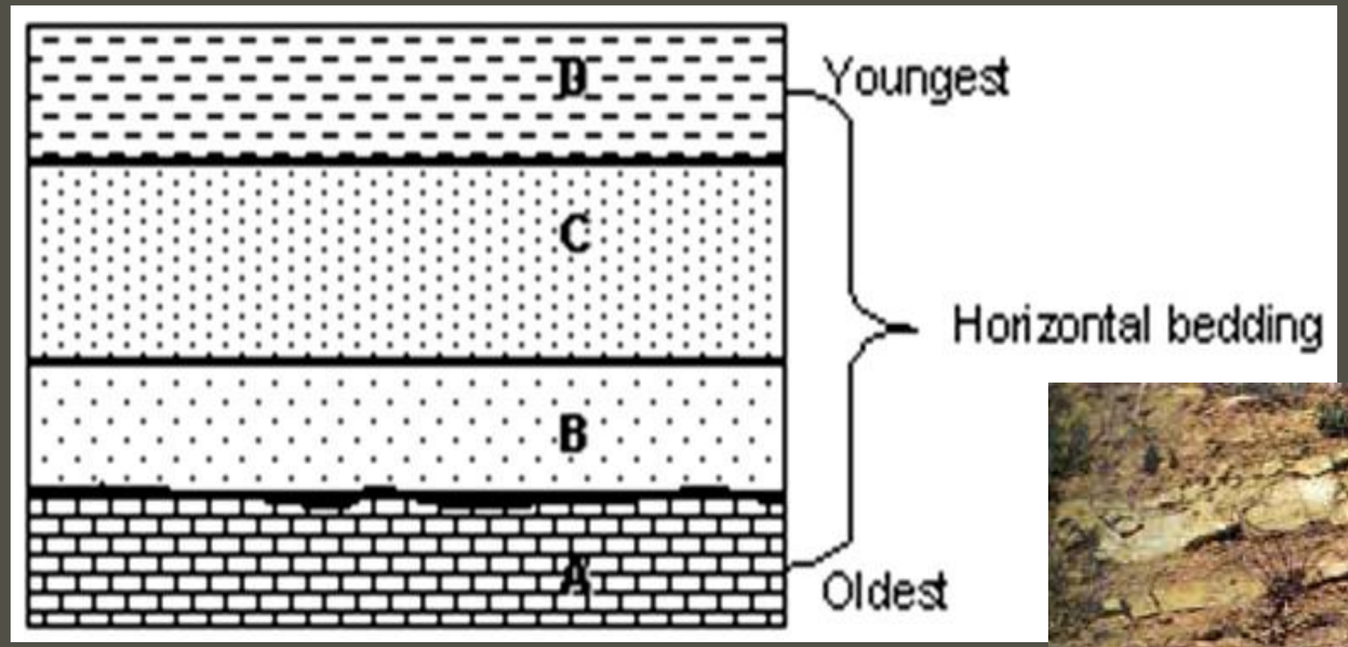
These structures may be:

- ✓ Global, macro or micro - scale
- ✓ Primary or secondary - genesis
  - ➢ *Primary Structures* – those formed at same time as rock.
  - ➢ *Secondary Structures* – those formed after formtion of rock.

Primary Structures

- **Bedding** – *in sedimentary rocks*

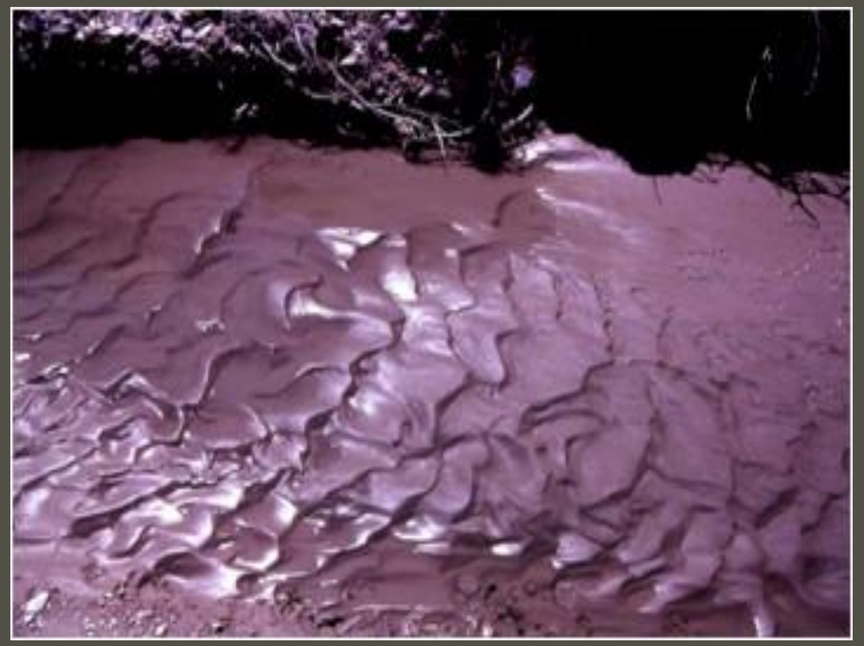
Primary Structures.....contd.



Primary Structures.....contd.

✓ **Ripple Marks** – *sedimentary rocks.*

- Formed from water [currents and waves]
- Evidence usually preserved over geological time and found in rocks



Primary Structures.....contd.

✓ **Layering** – *igneous rocks [primary]*

As indicated earlier, primary structures form at the same time as the rock.

Secondary Structures.

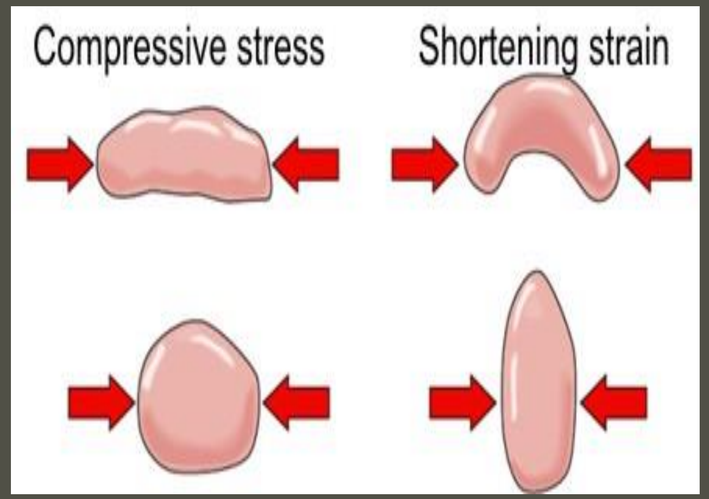
Formed:

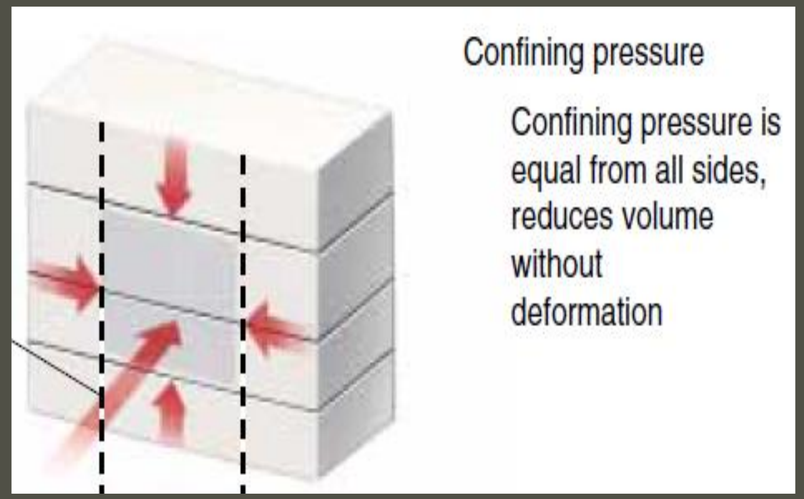
- ✓ after formtion of rock by
- ✓ tectonic stresses – confining stress / pressure – on rock/sediment due to burial:

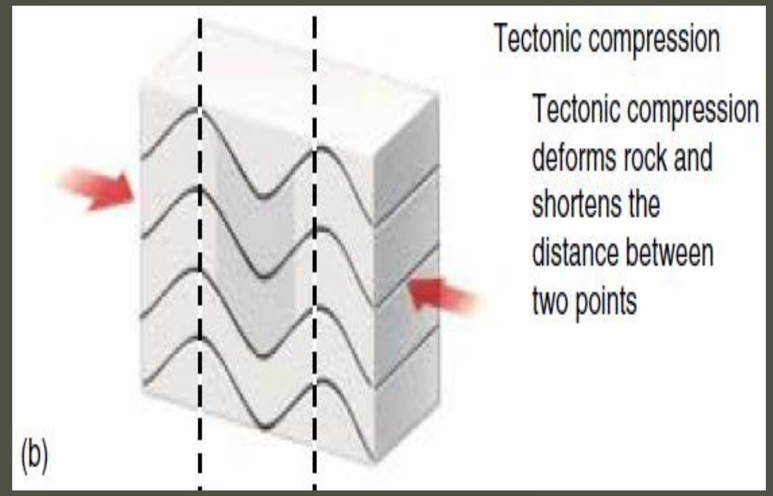
Secondary Structures.....contd.

Tectonic processes create three types of directed stress:

a) **Compressive stress** – common in convergent plate boundaries, where two plates converge and rock crumples.



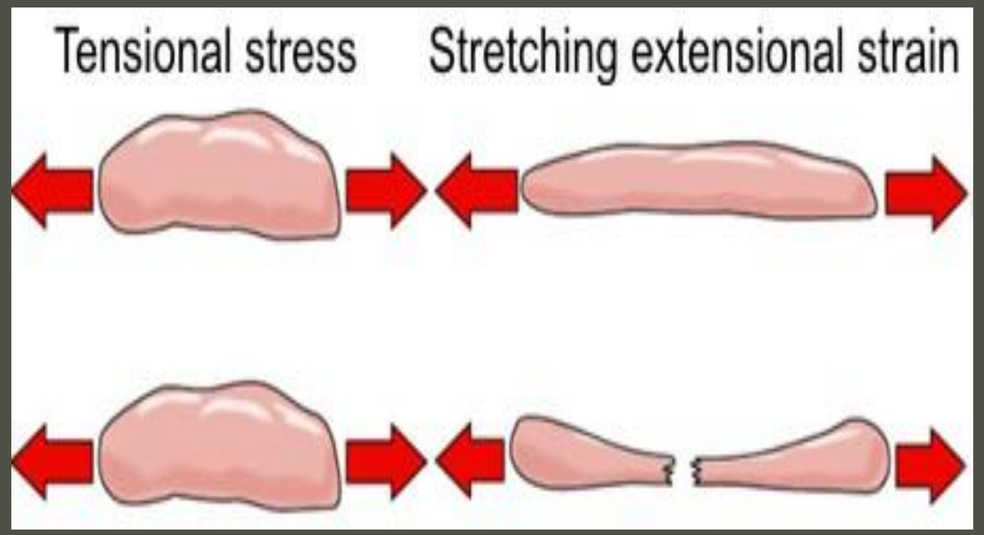


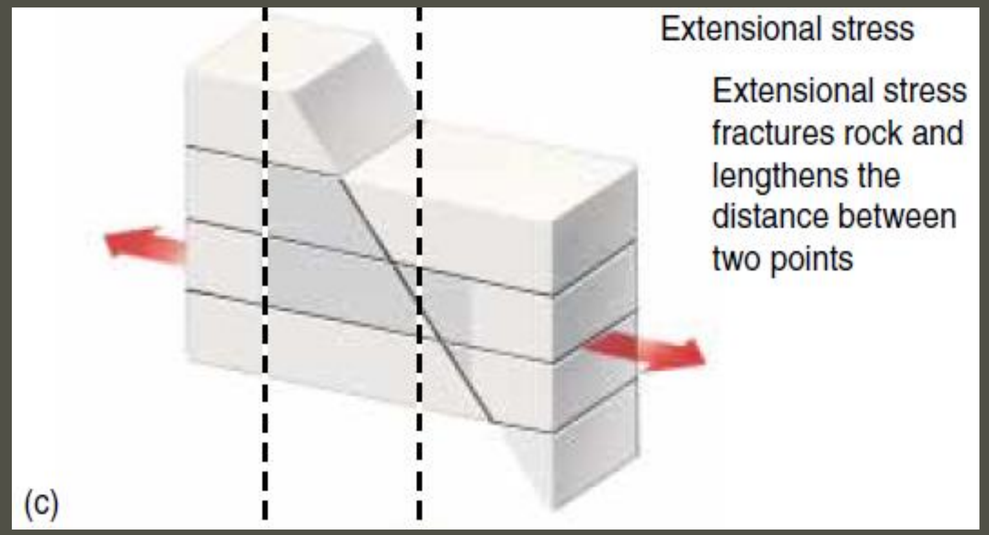


Secondary Structures.....contd.

b) Extensional stress (also called tensional stress) – pulls rock apart and is the opposite of tectonic compression.

- ✓ Rocks @ divergent plate boundary stretch and pull apart because they are subject to extensional stress.

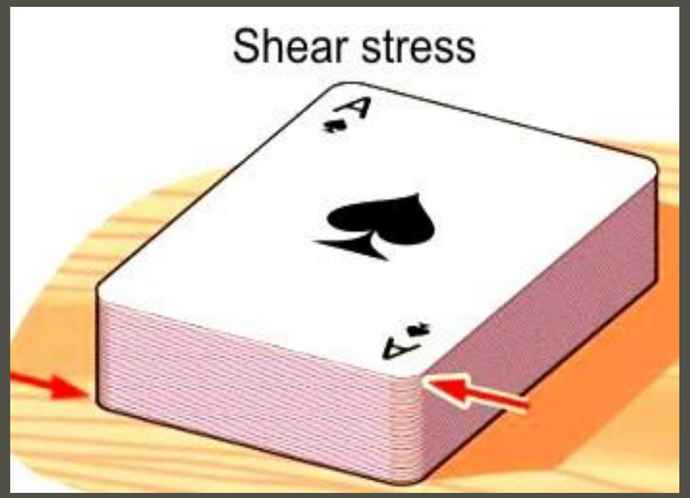


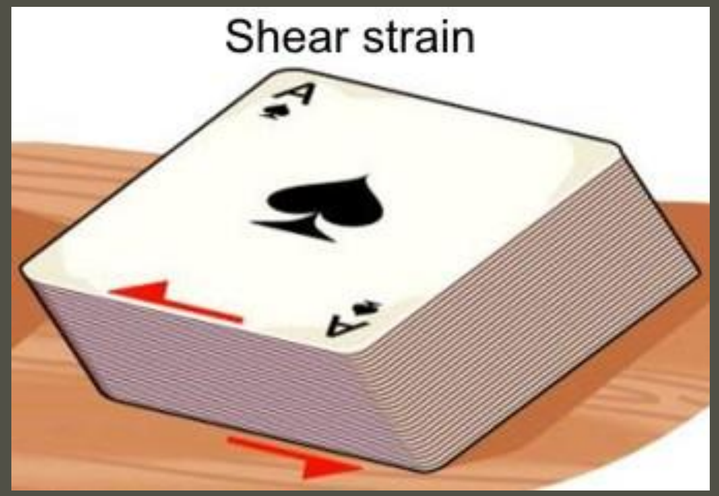


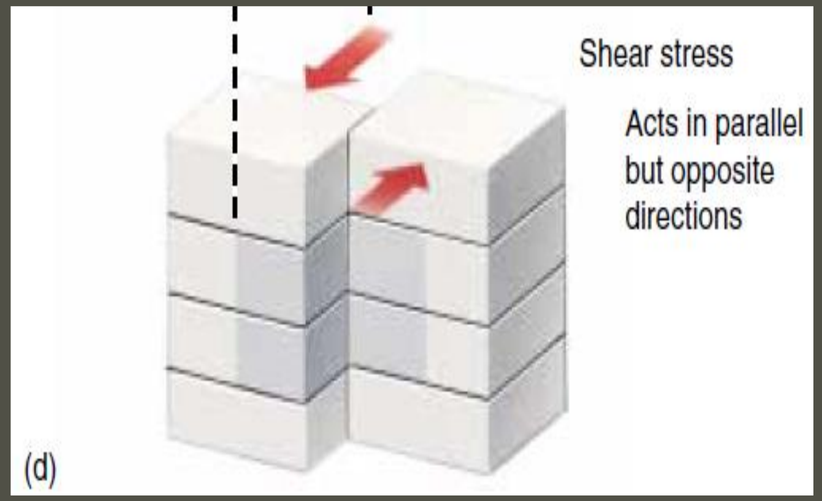
Secondary Structures.....contd.

b) Shear stress – acts in parallel but opposite directions.

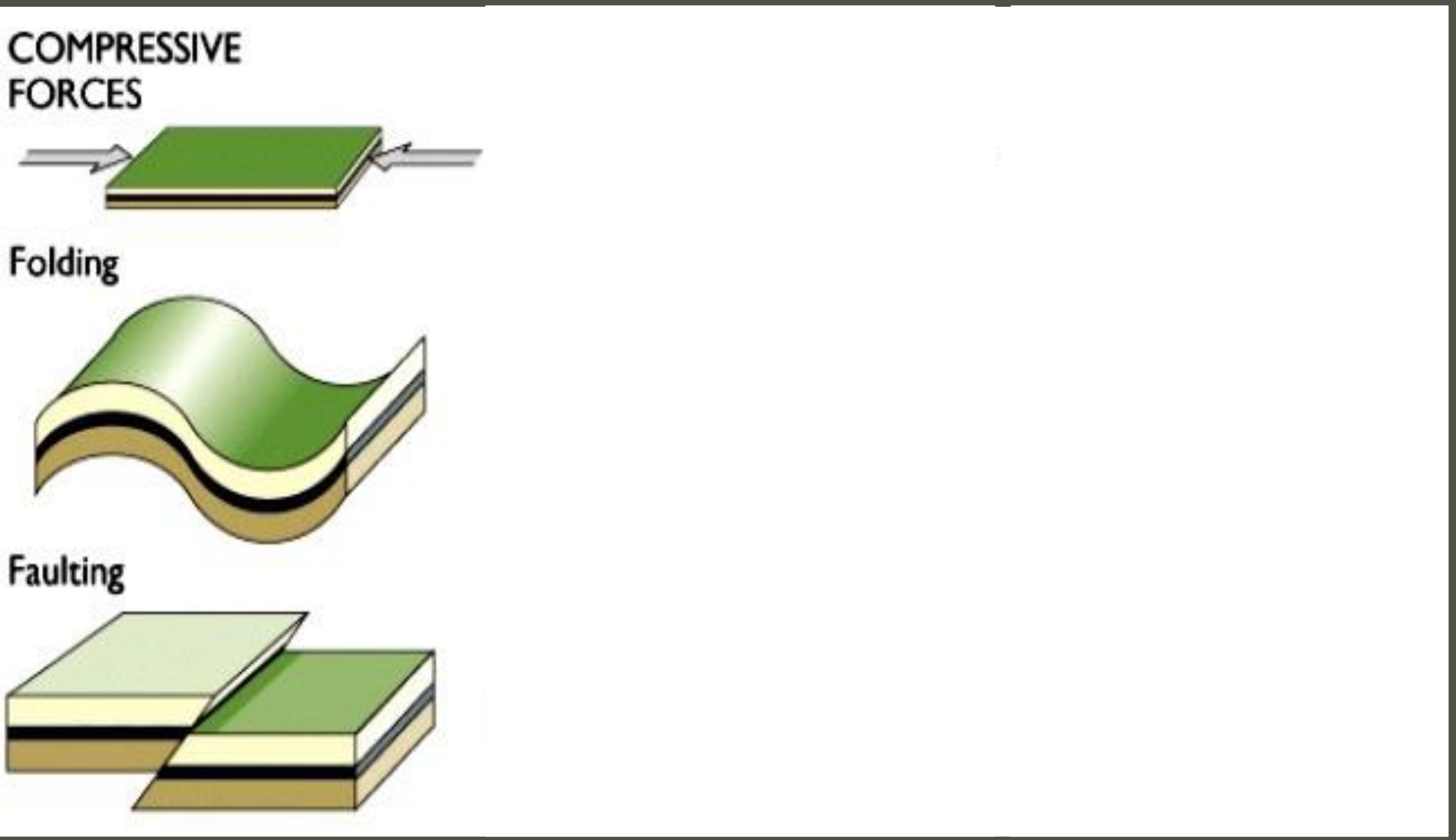
- ✓ Shearing deforms rock by causing one part of a rock mass to slide past the other part – such as at transform boundary.







Secondary Structures.....contd.



Secondary Structures.....contd.

These produce such structures as:

- ✓ *Folds*
- ✓ *Faults*
- ✓ *Joints*

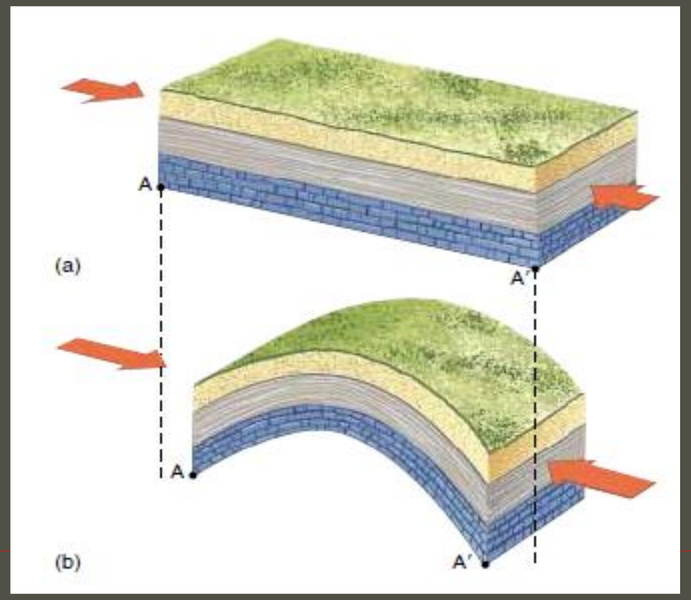
All of them occur in most rocks

FOLDS

Folds

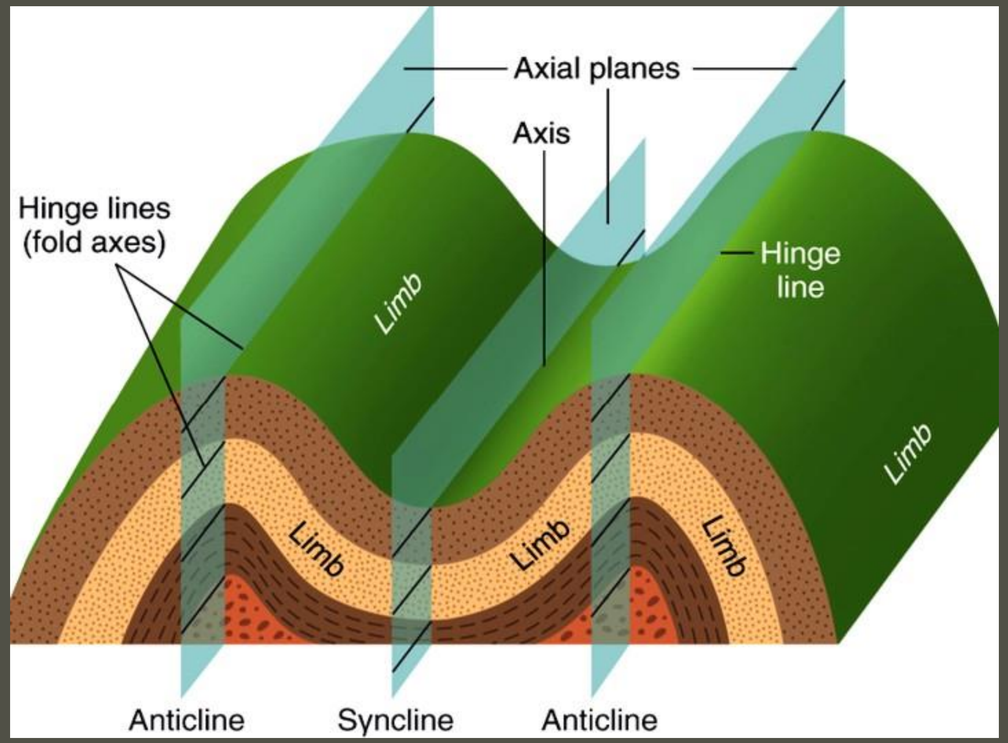
- ✓ Are bends / wave-like features in **layered rocks**.
- ✓ usually result from compressive stresses,
- ✓ usually occur as repeating patterns as in illustration using clay.

Folding always shortens horizontal distances in rock.



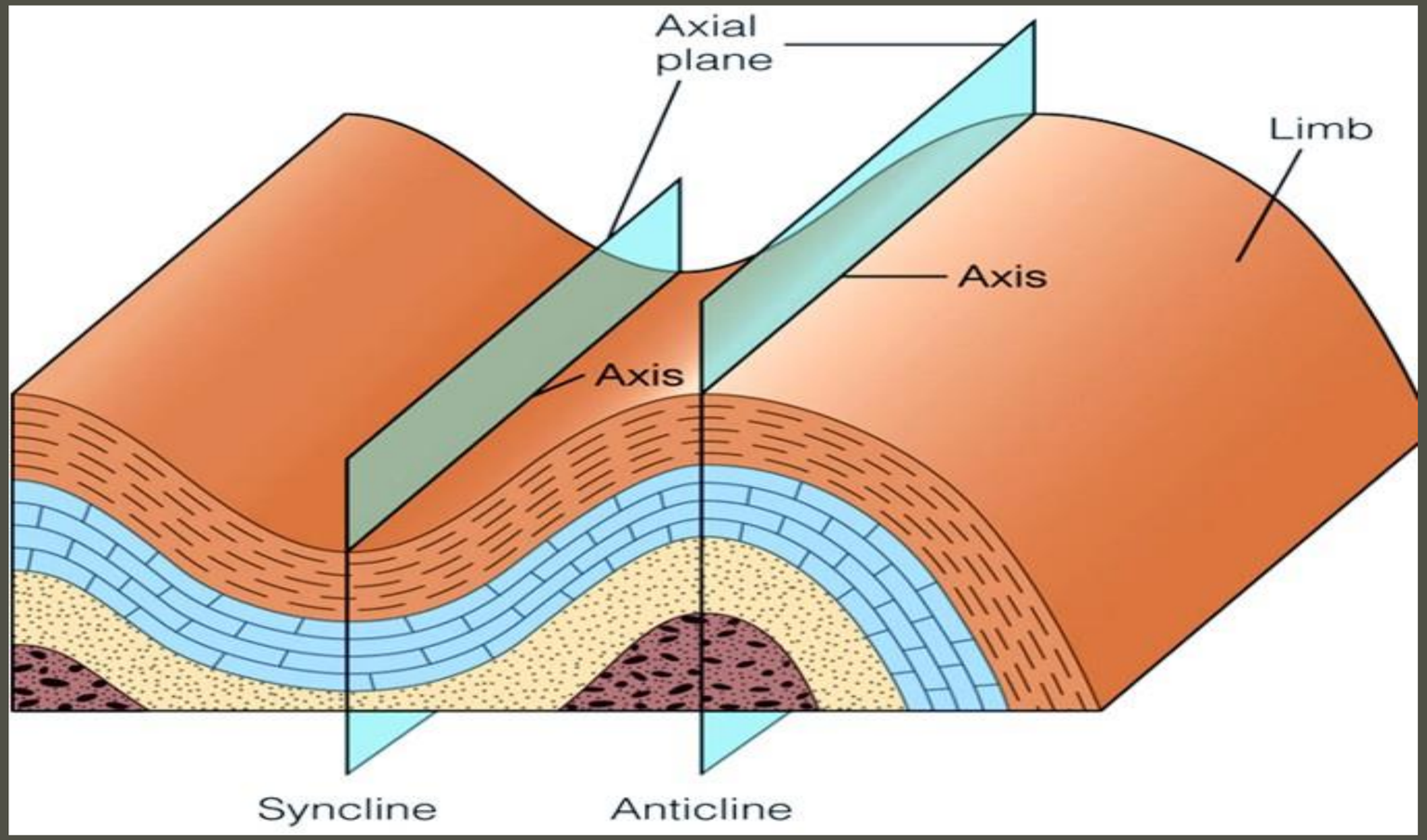
Folds.....contd.

Their Geometry includes (i) Limb, (ii) Hinge Line, and (iii) Axial Plane.



Folds.....contd.

- ✓ Fold Limbs – *Anticline & Syncline*



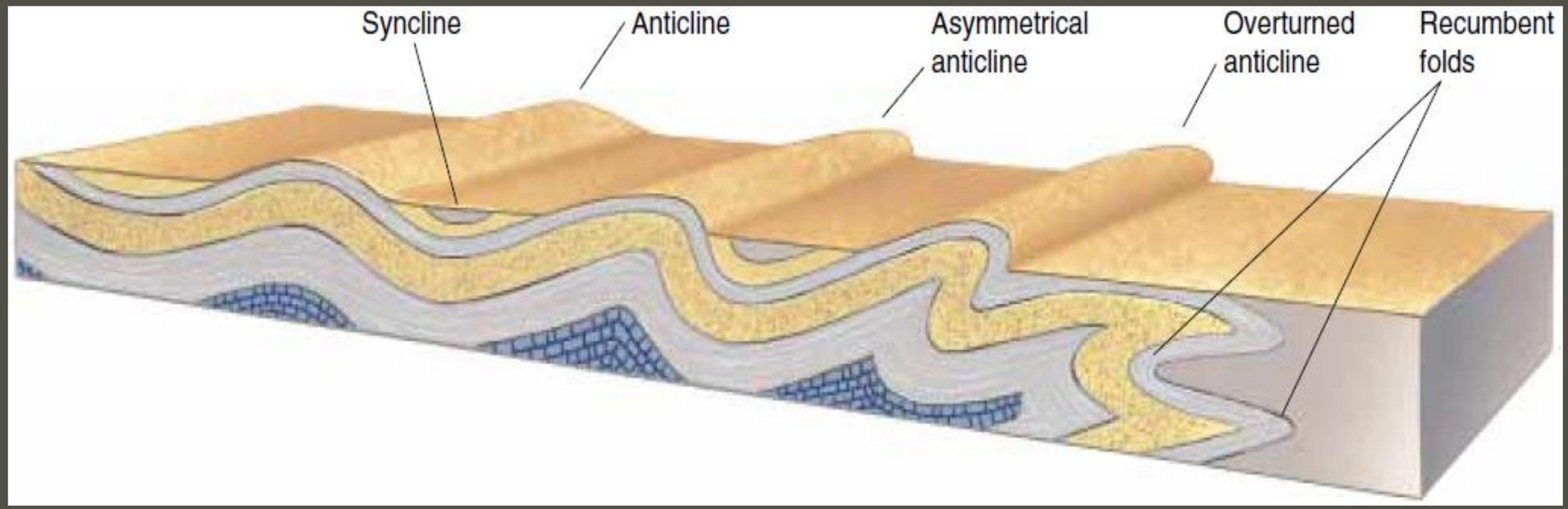
Interpreting Folds.....contd.

a) Open fold
b) Isoclinal fold

} Symmetrical Folds

c) Overturned fold
d) Recumbent fold

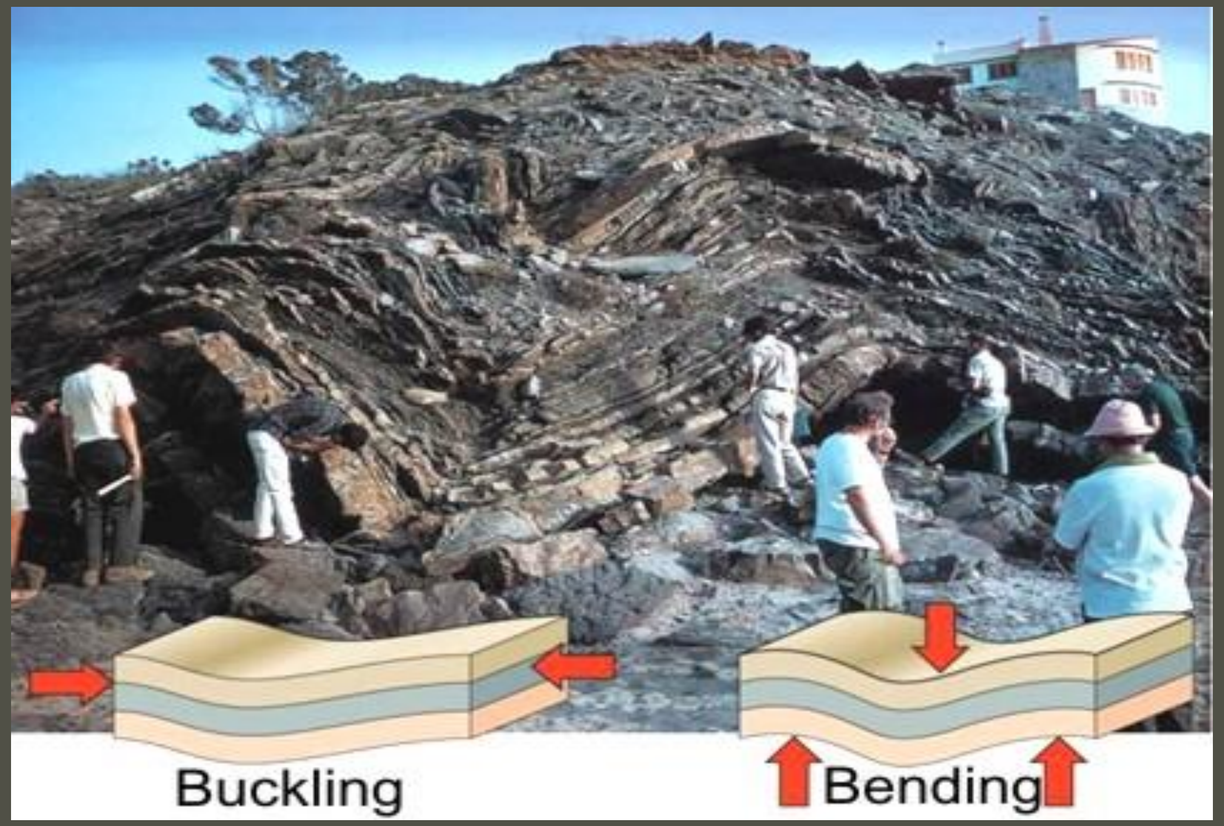
} Asymmetrical Folds



Interpreting Folds.....contd.

a) **Open folds** have limbs that have a gentle slope.

The more open the folds, the less intense the stress involved



Interpreting Folds.....contd.

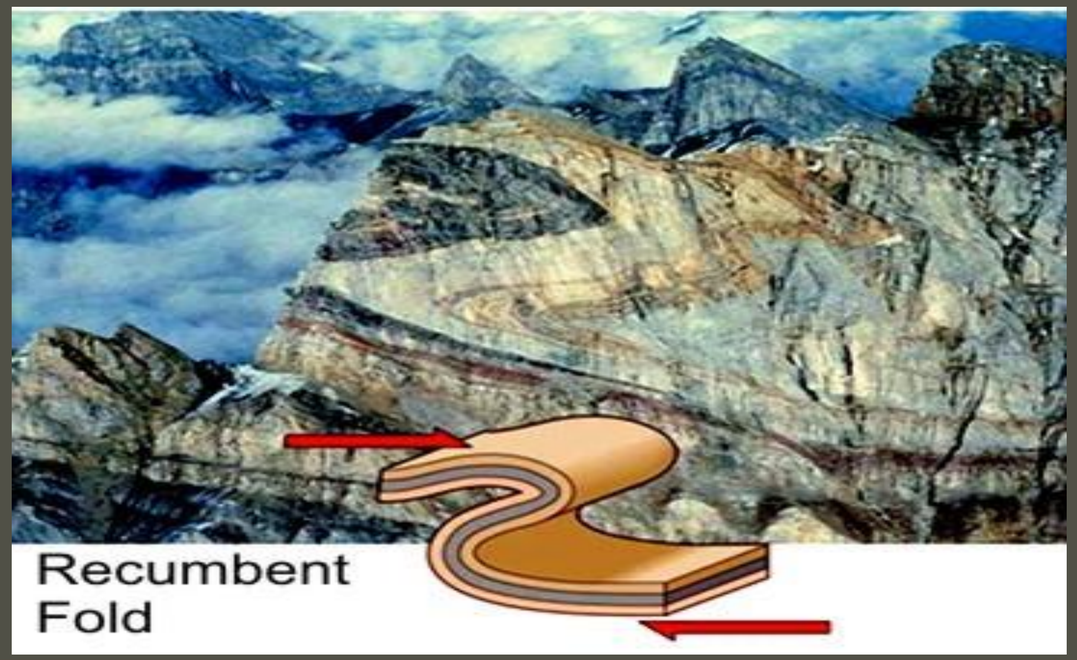
b) **Isoclinal folds** have limbs that are parallel to one another – implying intense compressive or shear stress

Interpreting Folds.....contd.

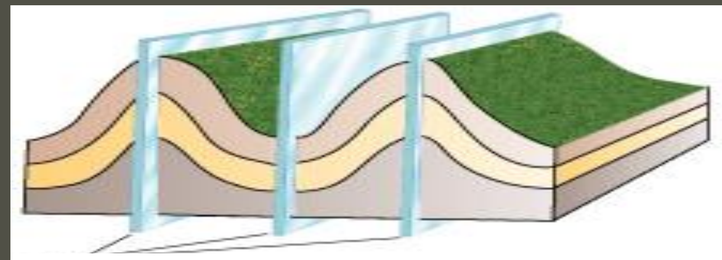
c) **Overturned folds** – when axial plane is inclined to such a degree that fold limbs **dip** in same direction – implying unequal compressive stresses…

Interpreting Folds.....contd.

d) **Recumbent folds** – those overturned to such an extent that limbs are essentially horizontal – indicating more intense compressive and/or shear stresses in one direction….



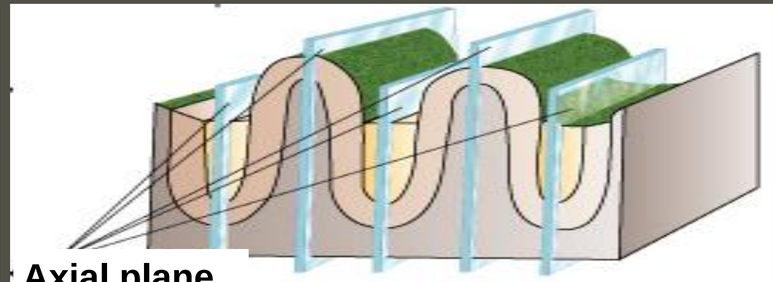
Interpreting Folds.....contd.



Axial plane

A. Open (symmetrical)

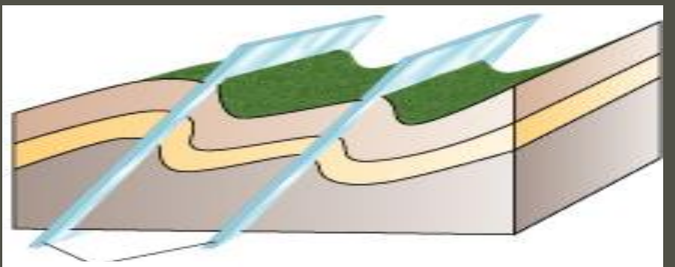
Both limbs **dip** equally away from axial plane



Axial plane

B. Isoclinal

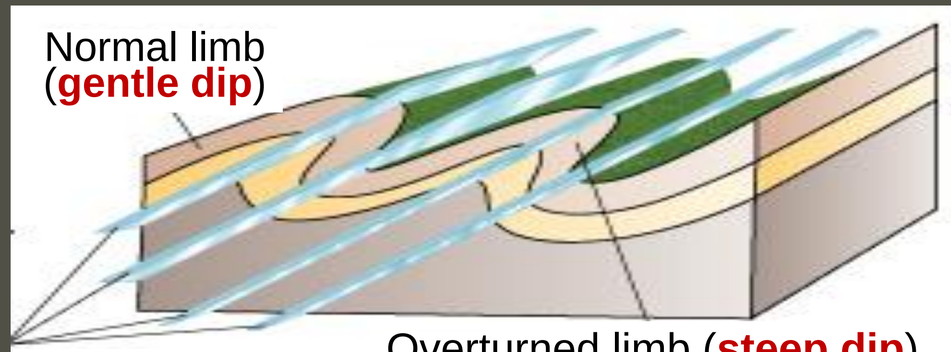
Both limbs are parallel to each other, regardless of dip of axial plane



Axial plane

C. Asymmetrical

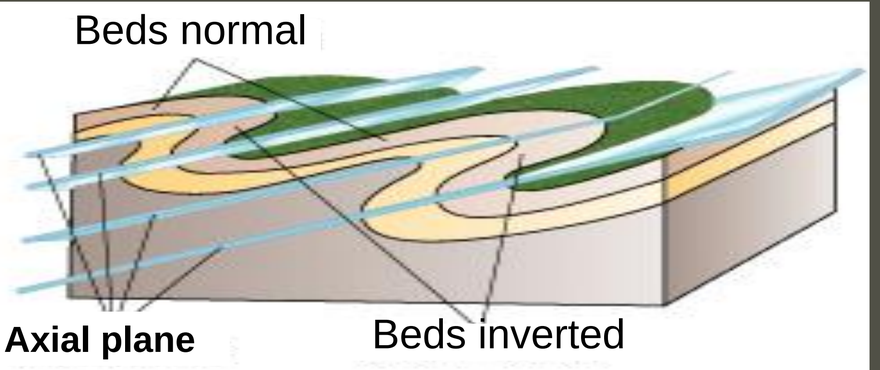
One limb of fold dips more steeply than the other.



Axial plane

D. Overturned

Strata in one limb have tilted beyond vertical. Both limbs dip in same direction but at different angles.



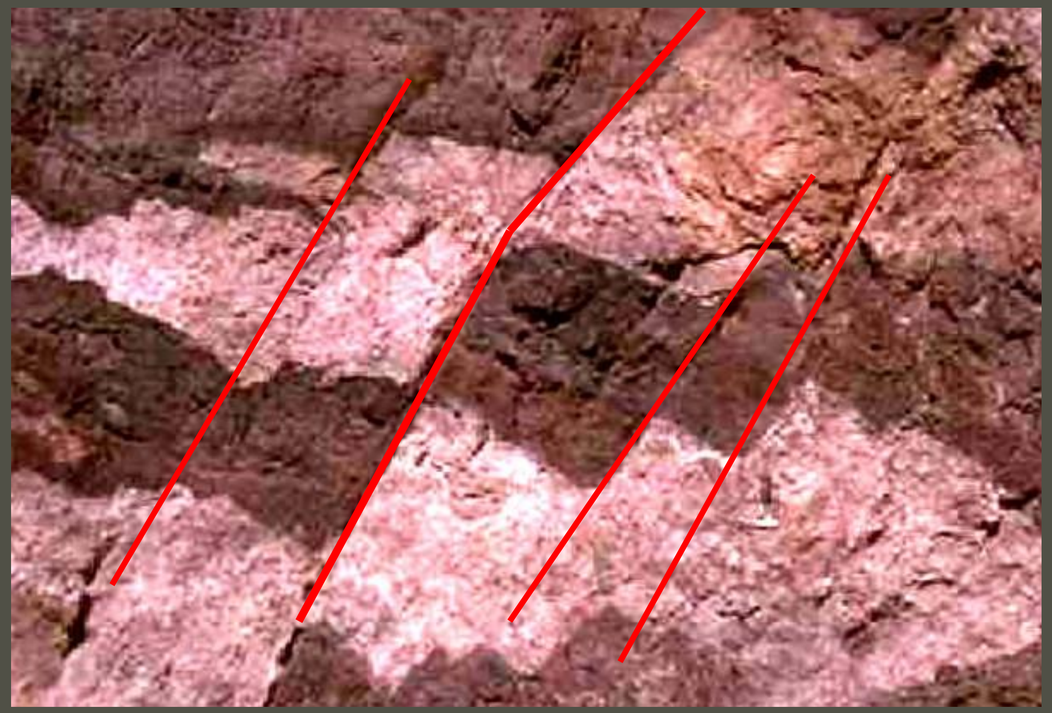
E. Recumbent

Axial planes are horizontal or nearly so. Strata on lower limb of anticline and upper limb of syncline are upside down.

FAULTS

Faults

- ✓ Structures with major displacement of rock material along cracks in a rock. Or
- ✓ Cracks in Earth's crust along which noticeable movement has occurred.

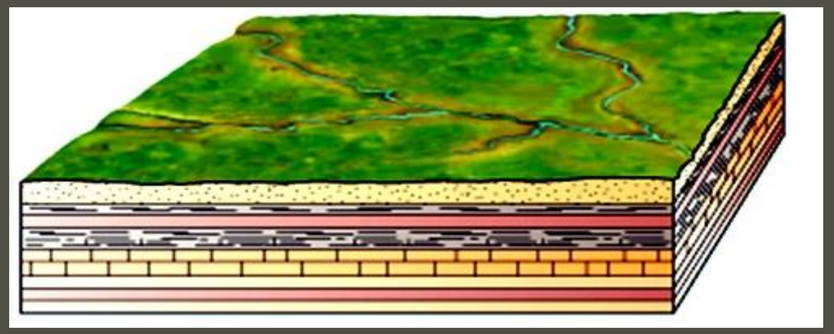


Faults.....contd.

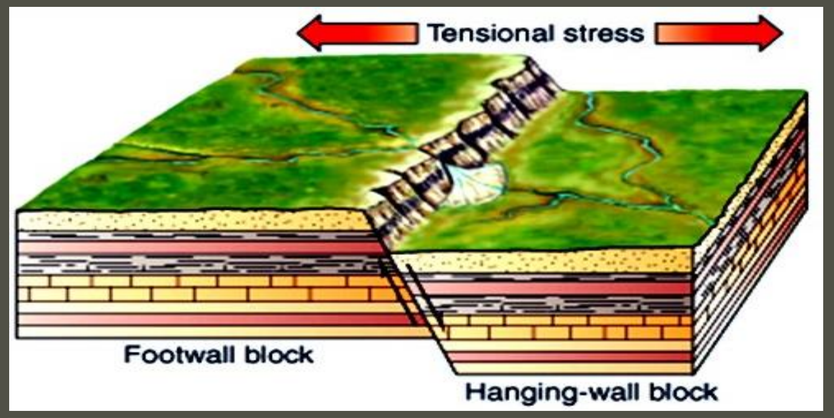
Geologists describe fault-movement in terms of direction of slippage.

- ✓ In a dip-slip fault, movement is parallel to the dip of the fault surface.
- ✓ A strike-slip fault indicates horizontal motion parallel to the strike of the fault surface.
- ✓ An oblique-slip fault has both strike-slip and dip-slip components.

Faults.....contd.



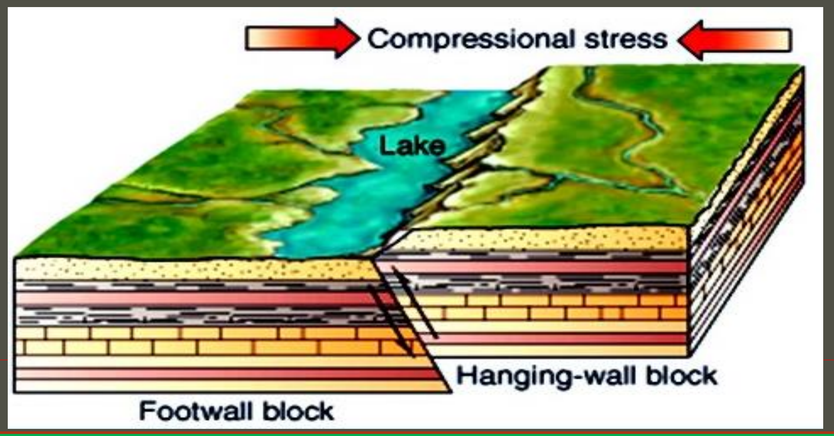
Reference block before faulting



Movement is vertical

Normal Fault

A fault generally steeply inclined, along which hanging-wall block has moved relatively downward



Reverse Fault

A fault generally steeply inclined, along which hanging-wall block has moved relatively upward

Dip-Slip Faults

- Normal Fault

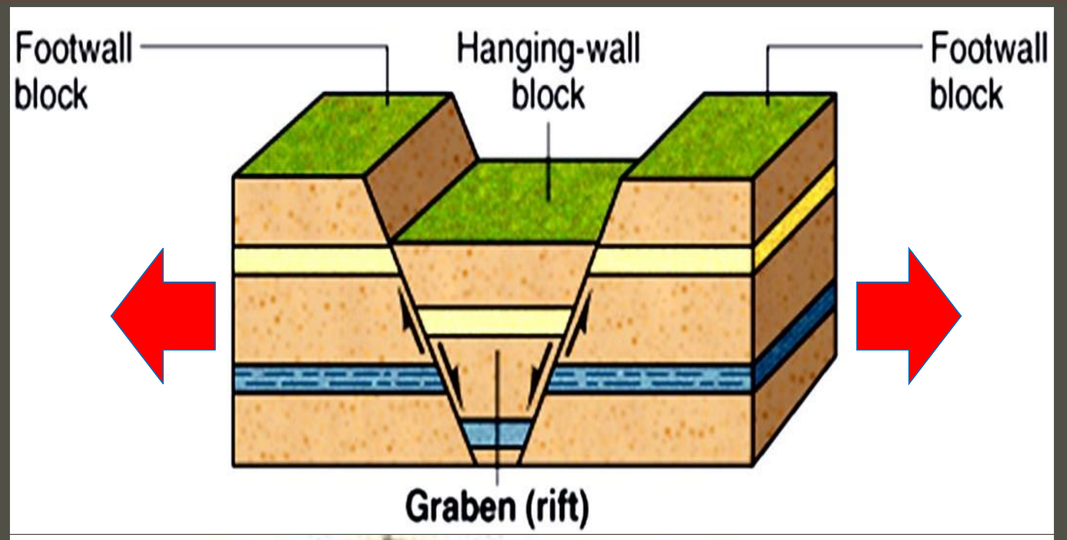
  ✓ Forces pull apart

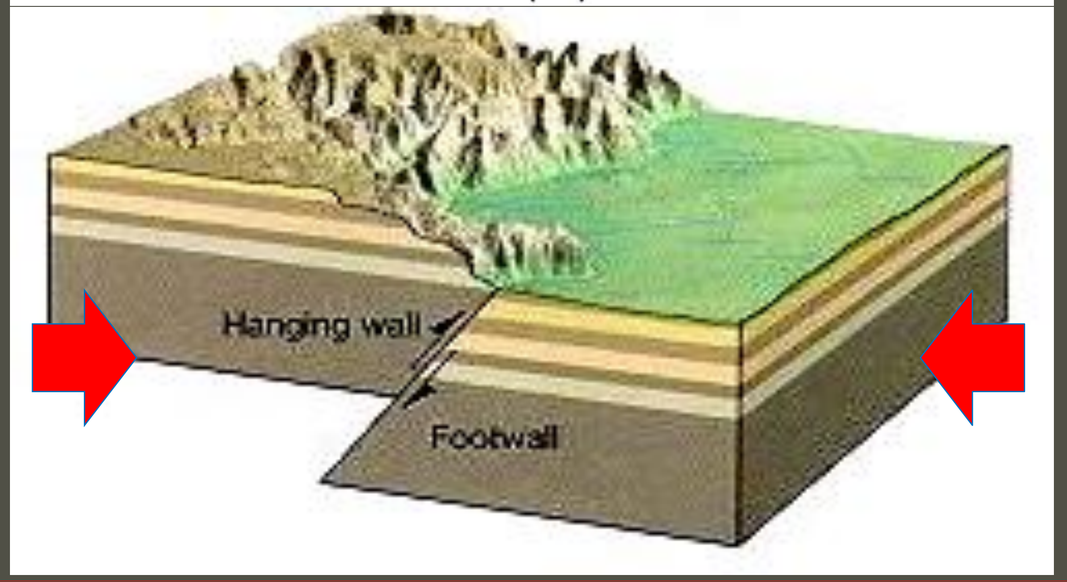
  ✓ Middle block slides down

- Reverse Fault

  ✓ Forces compress

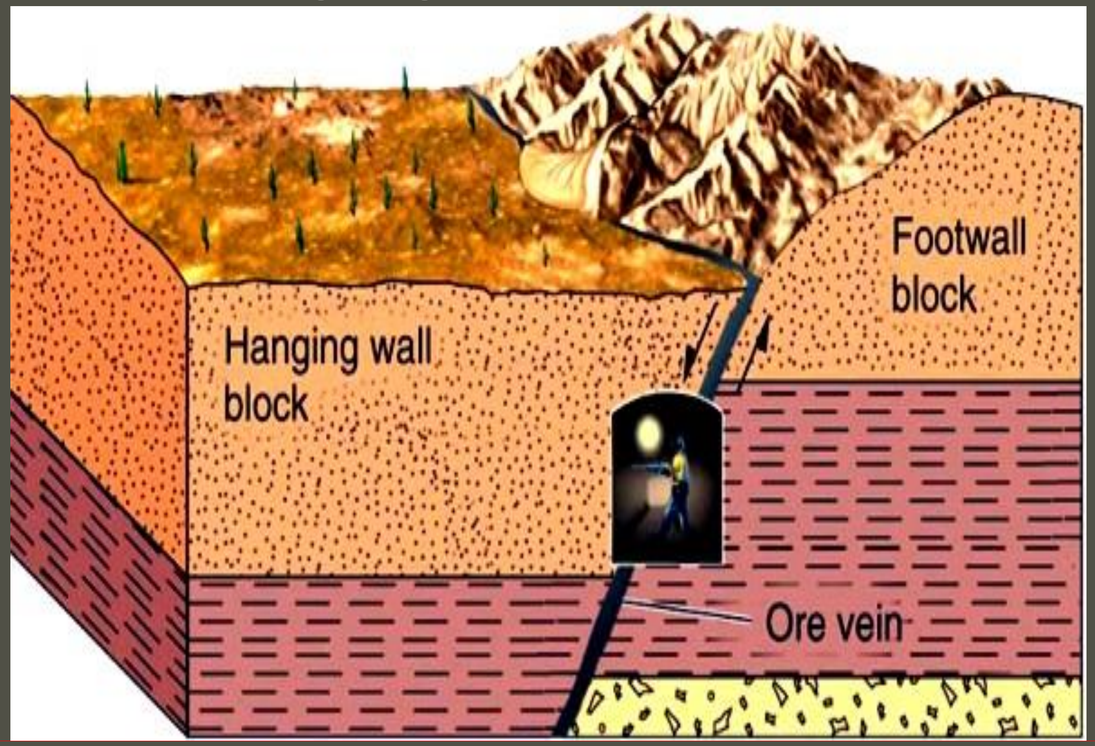
  ✓ Middle block slides up





Dip-Slip Faults.....contd.

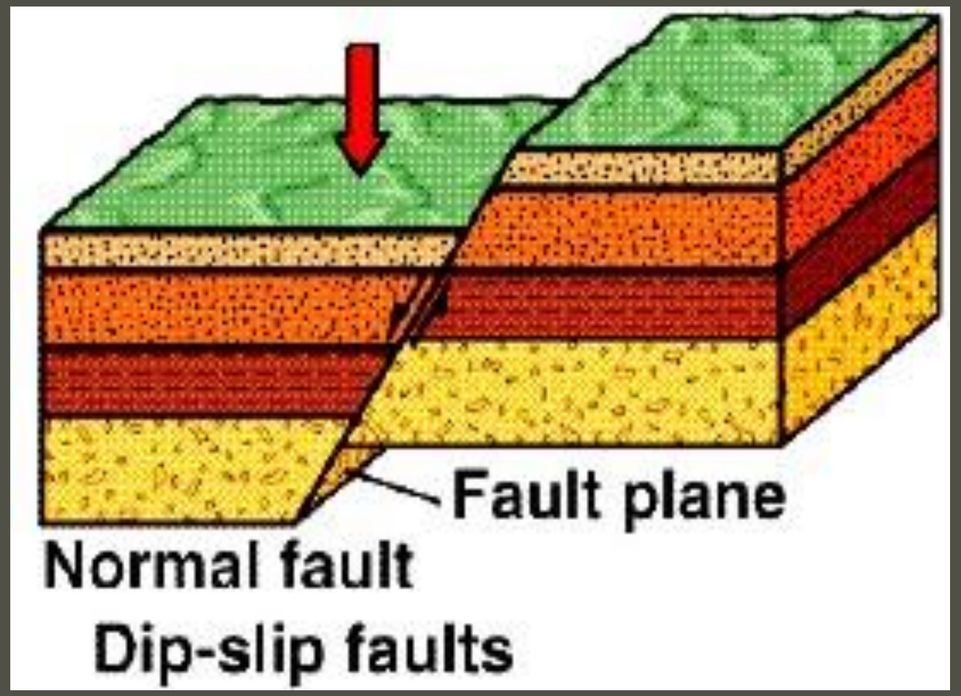
- ✓ **Normal** & **reverse faults** – most common type
- ✓ Usually distinguished from each other on basis of relative movement of the **footwall** block & **hanging wall** block.
- ✓ **Footwall** – surface underlying inclined fault plane.
- ✓ **Hanging wall** – surface overlying inclined fault plane.



Normal Faults.....contd.

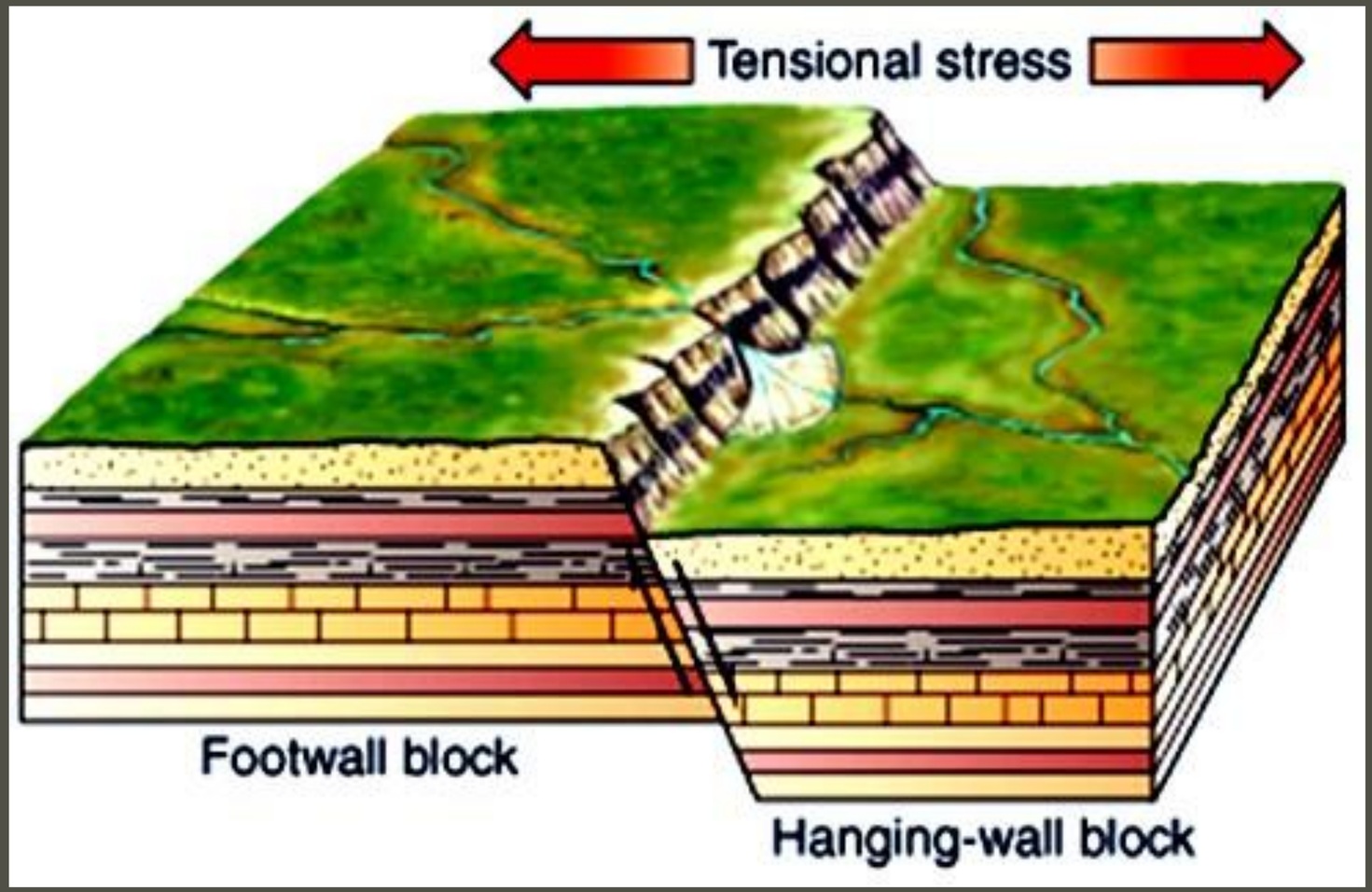
In a **normal fault**:

✓ hanging-wall block moves downward relative to footwall block.

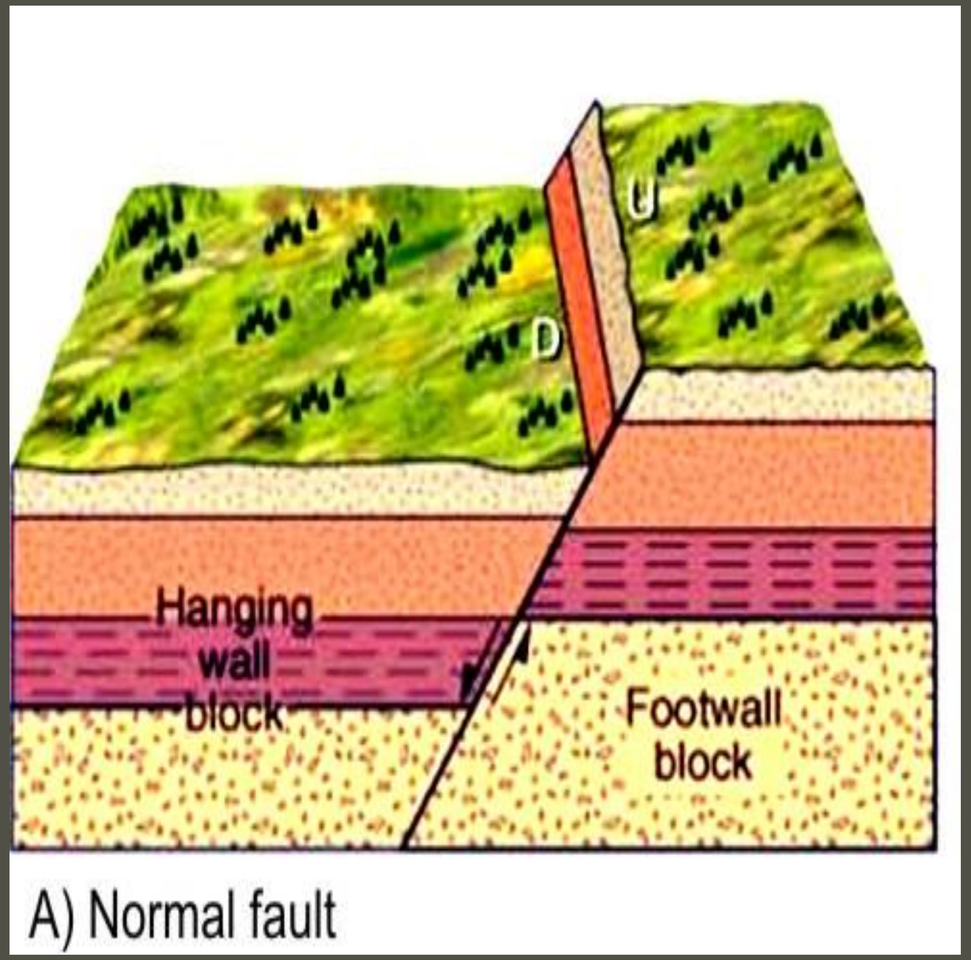


Normal Faults.....contd.

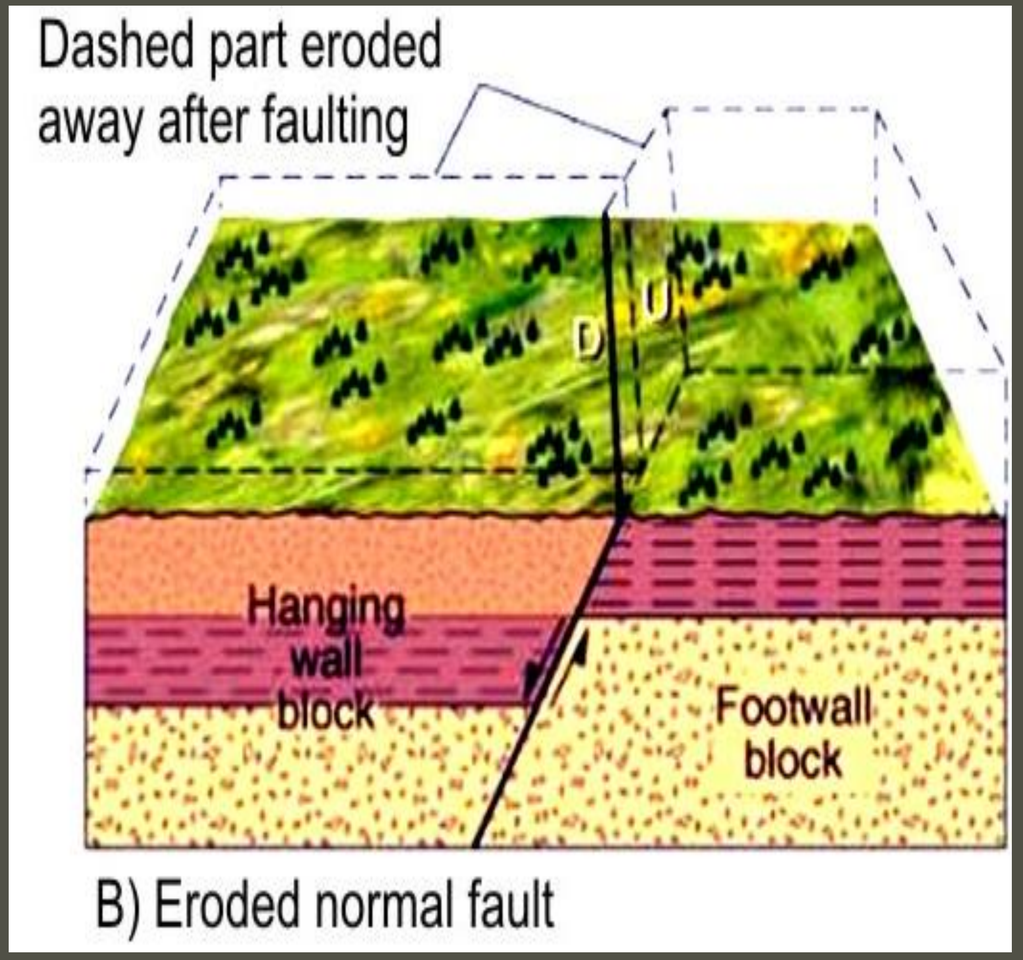
- ✓ Results from tension / extension / lengthening of crust



Normal Faults.....contd.



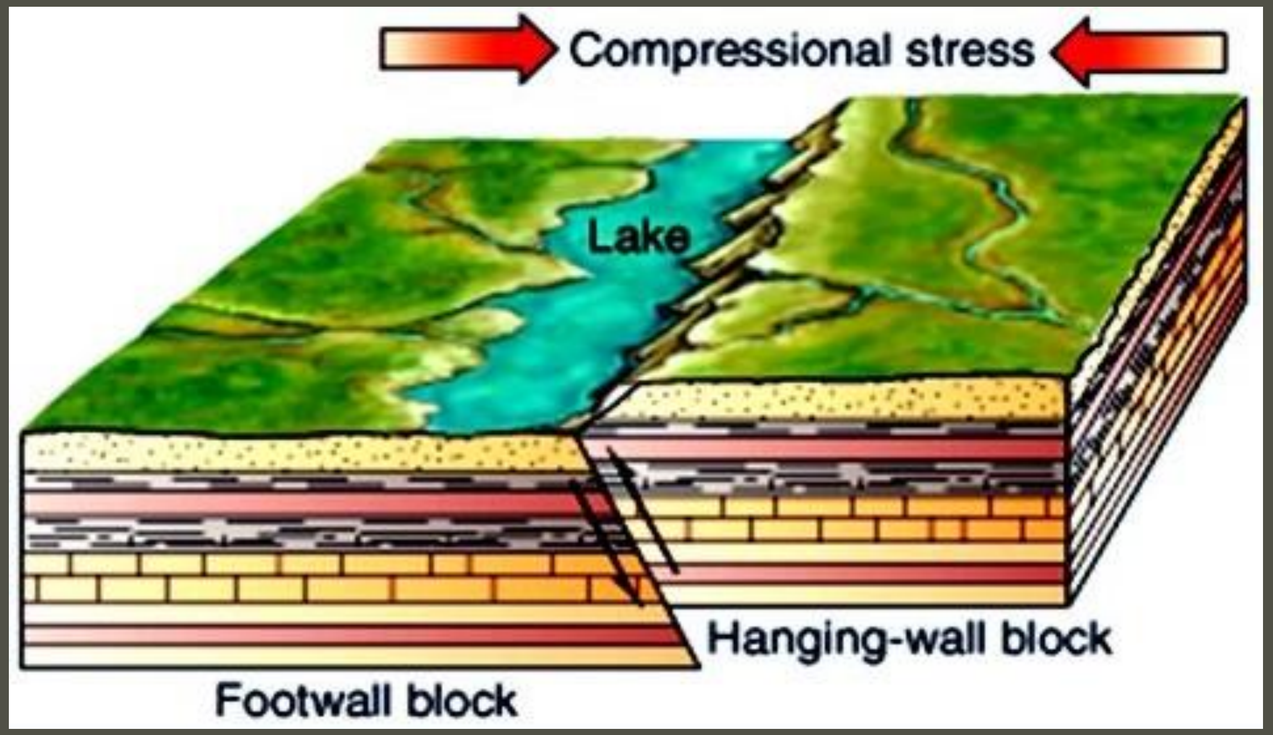
A) Normal fault



B) Eroded normal fault

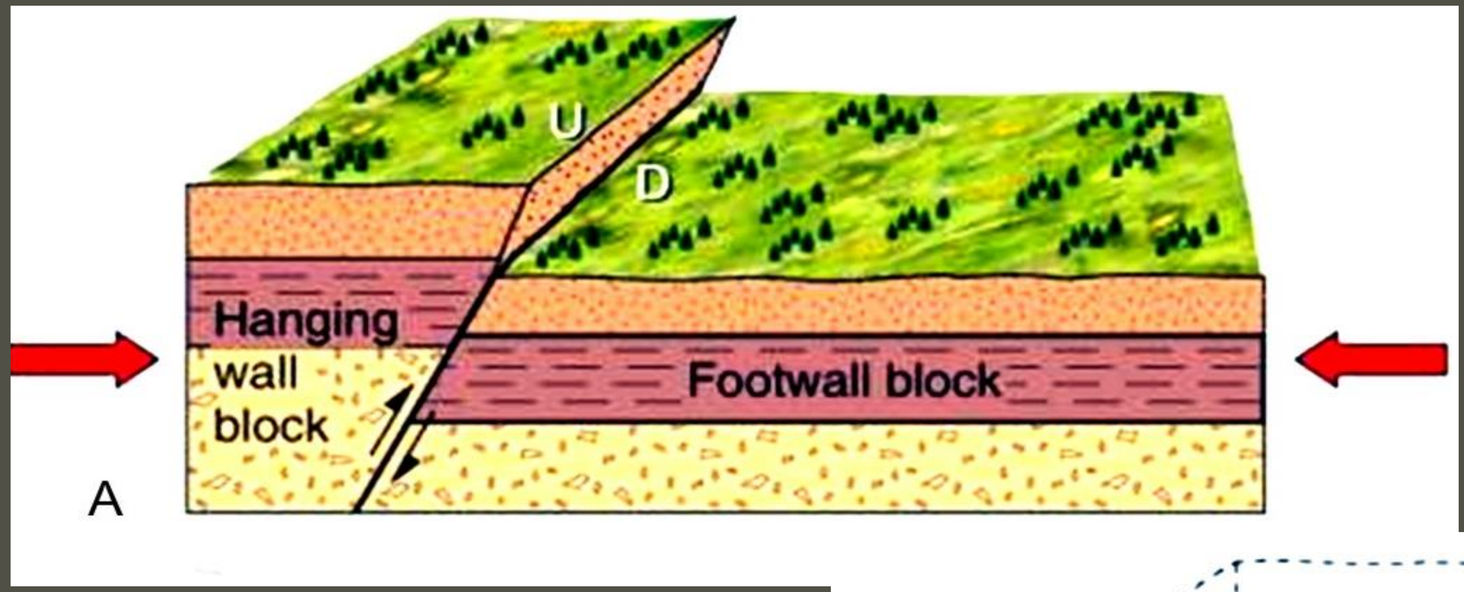
Reverse Faults

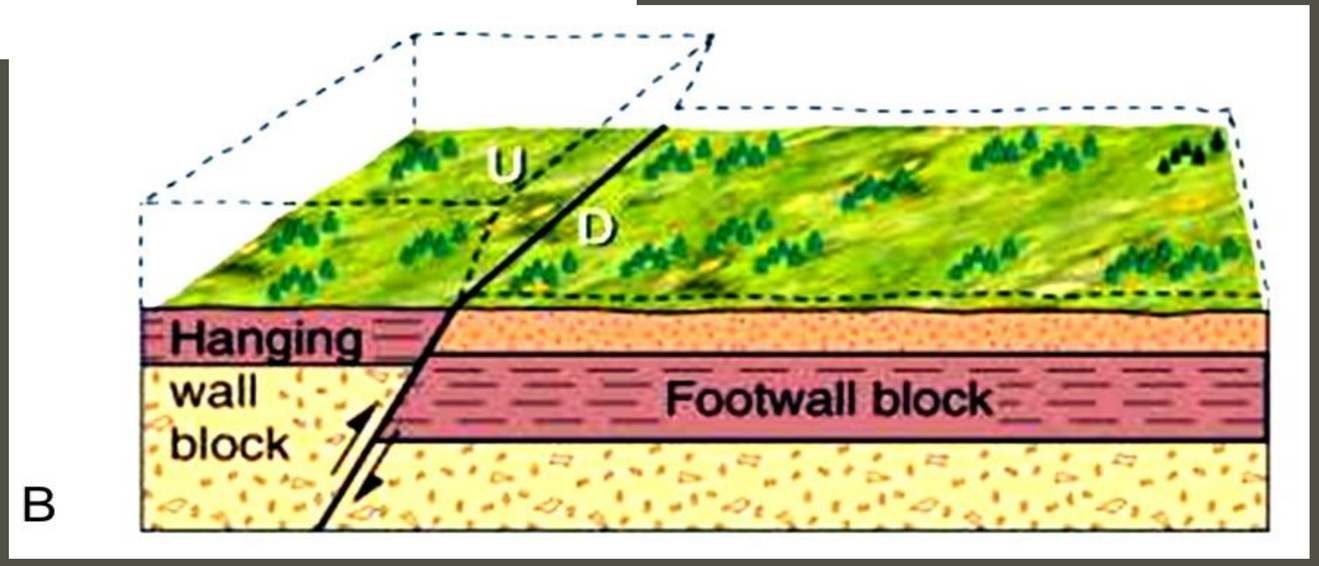
- ✓ hanging-wall block moves upward relative to footwall block.



- ✓ Results from horizontal compressive forces

Reverse Faults.....contd.



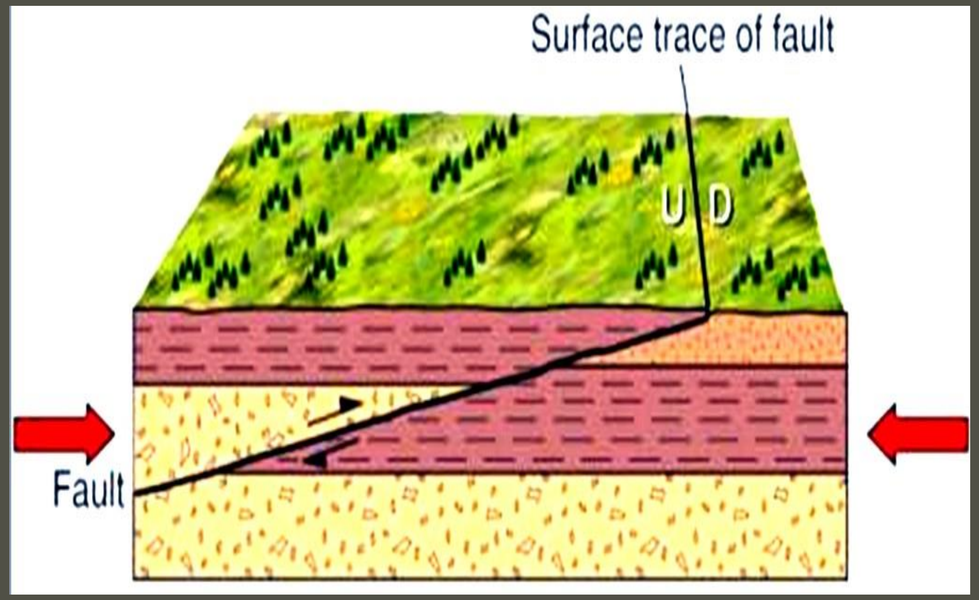


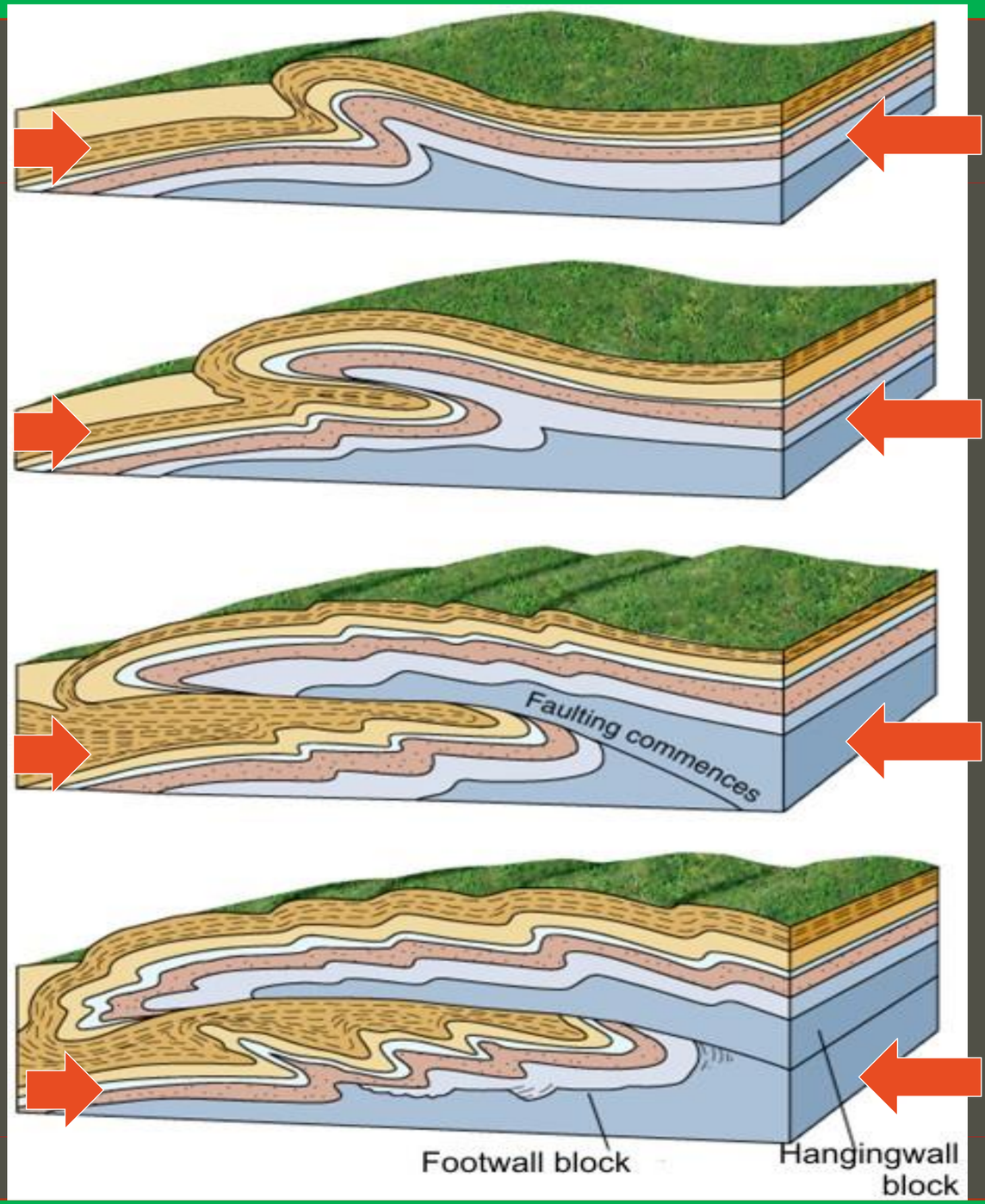
Thrust Faults

- ✓ is a reverse fault with a low dip angle (< 30^{o}) or even horizontal.
- ✓ typically moves or thrusts older rocks on top of younger rocks.
- ✓ results in an extreme shortening of crust.

Thrust Faults.....contd.

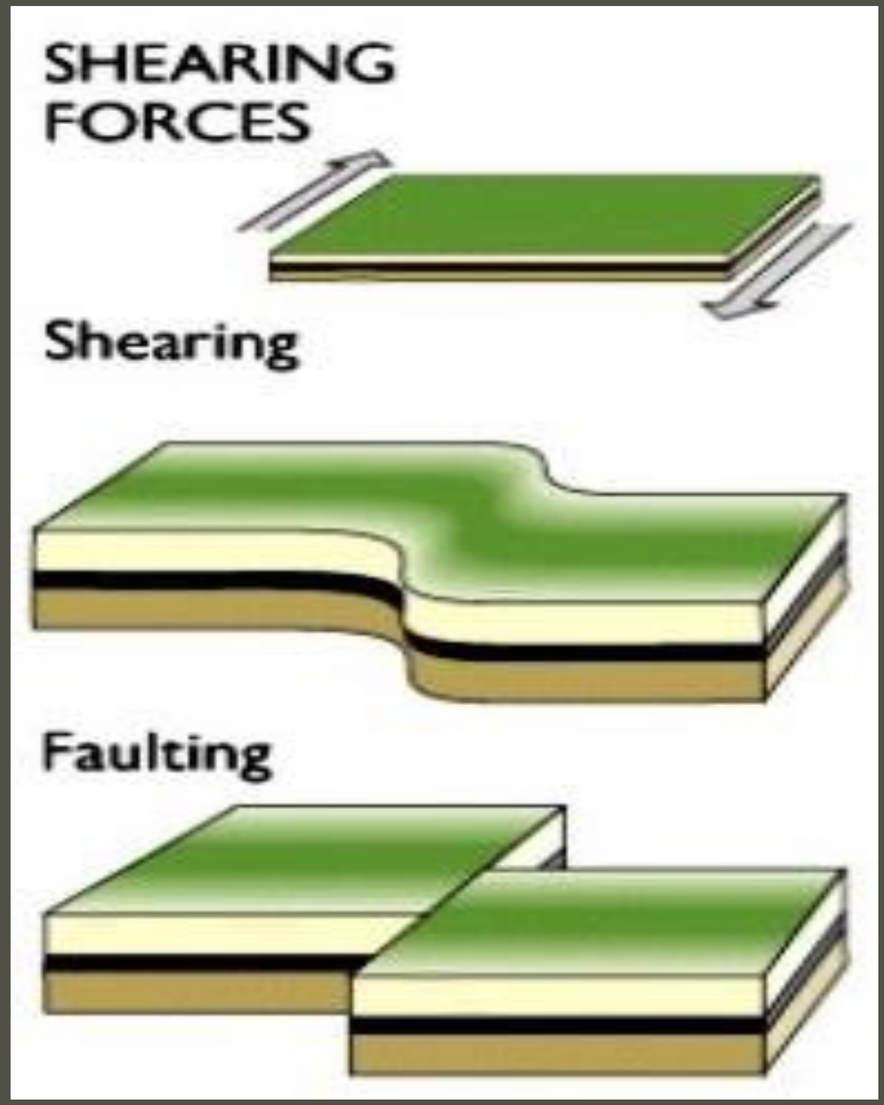
Thrust Model





Strike-Slip Faults

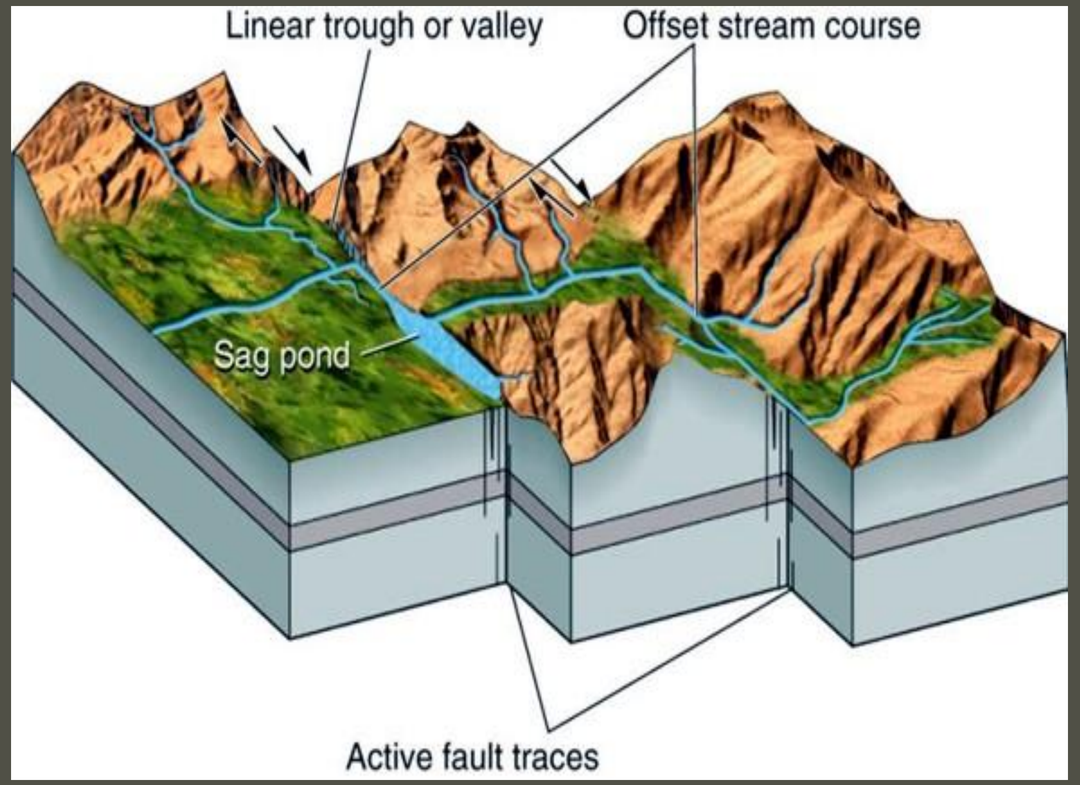
- ✓ Results from shearing forces.
- ✓ movement (or slip) is predominantly horizontal & parallel to strike of the fault.



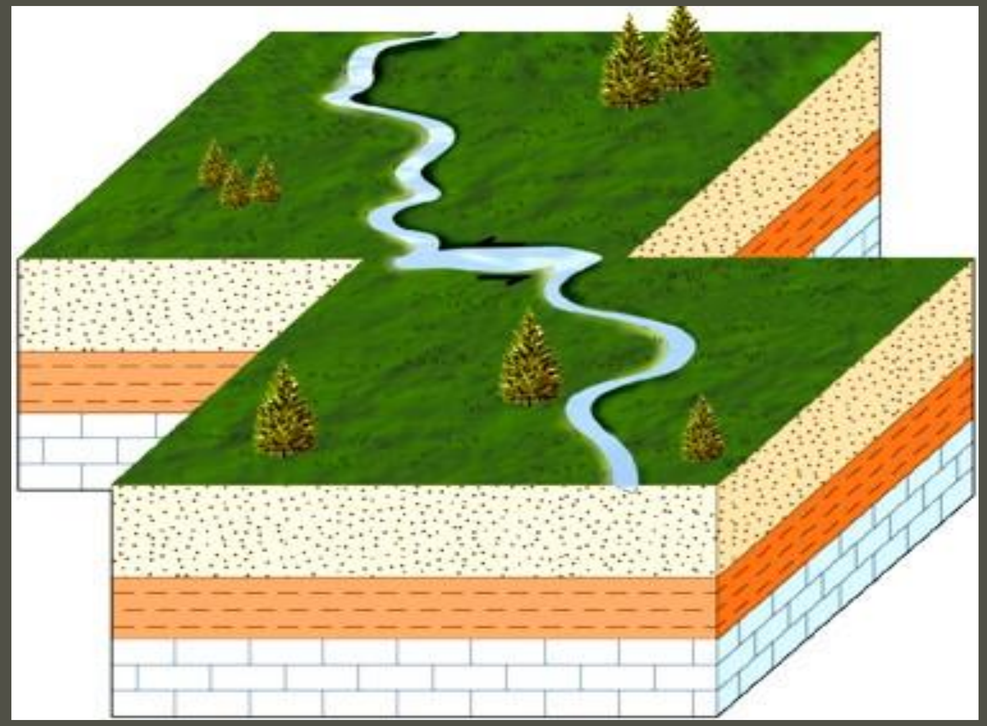
Strike-Slip Faults.....contd.

- ✓ displacement along a strike-slip fault is either left-lateral or right-lateral and can be determined by looking across fault.
  - ➢ **Left-lateral fault** – when movement on other side of fault line is to the left.
  - ➢ **Right-lateral fault** – when movement on other side of fault line is to the right.

Strike-Slip Faults.....contd.



Right-lateral fault

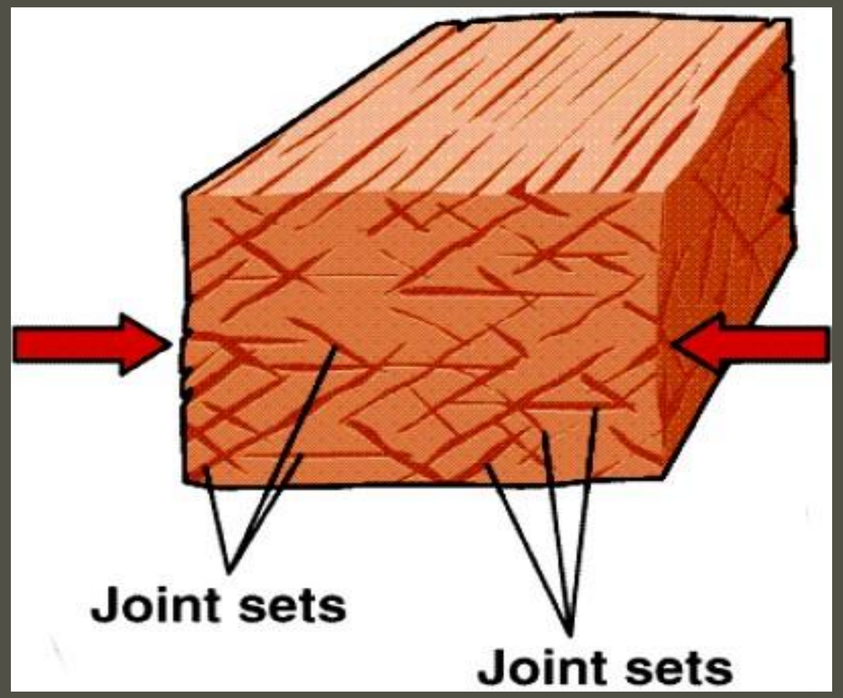


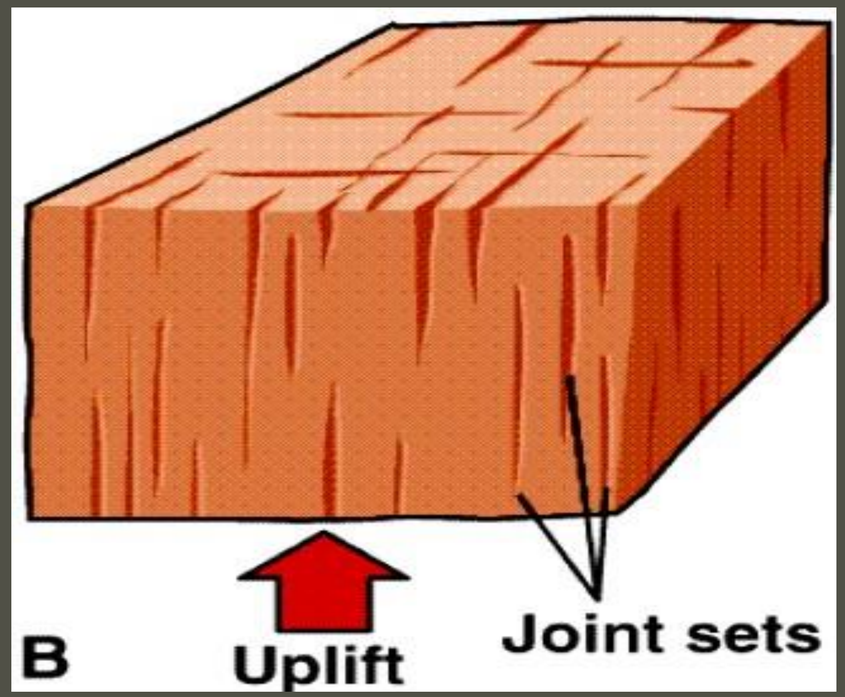
Left-lateral fault

JOINTS

Joints.....contd.

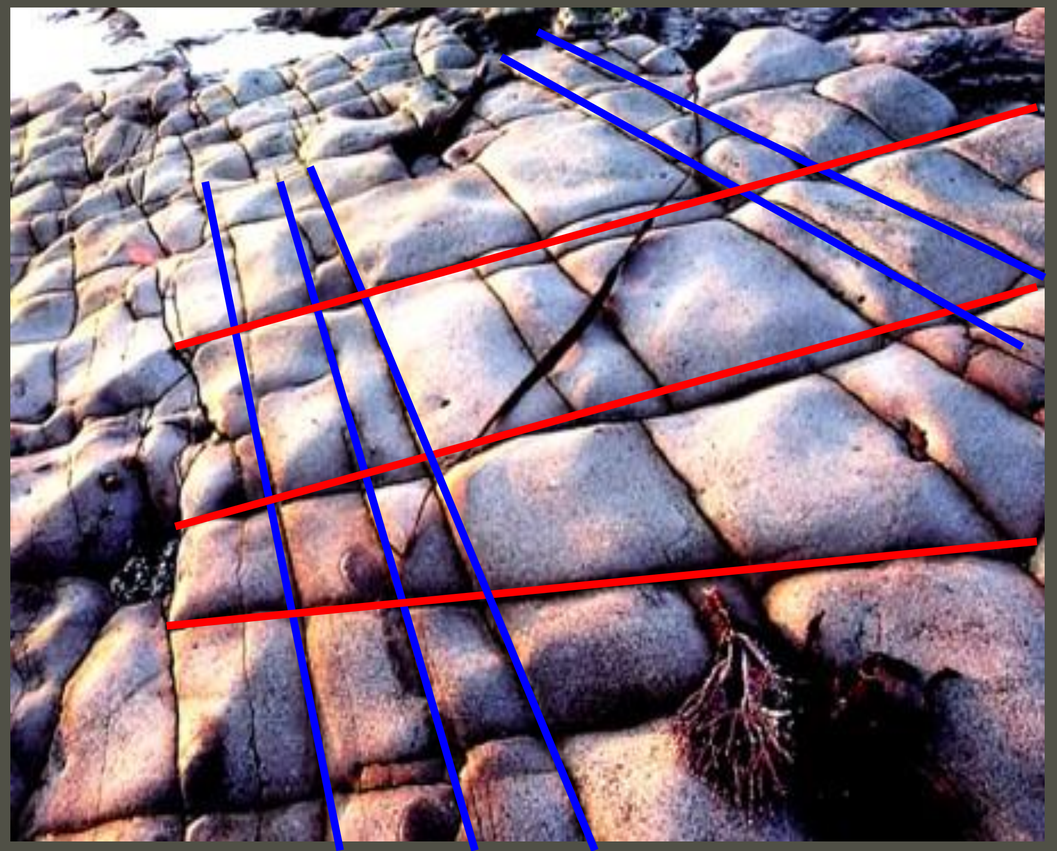
- ✓ Crack surfaces or breaks in rock *along which no movement has taken place*
- ✓ Result from tectonic forces, e.g. Compressive, tensional or shearing





Joints.....contd.

- ✓ are one of the most commonly observed structures in rocks.
- ✓ Where joints are oriented approximately parallel to one another, they are called a **joint set**



Joints.....contd.

Rock displaying Folding, jointing, faulting

MEASUREMENT OF GEOLOGIC STRUCTURES

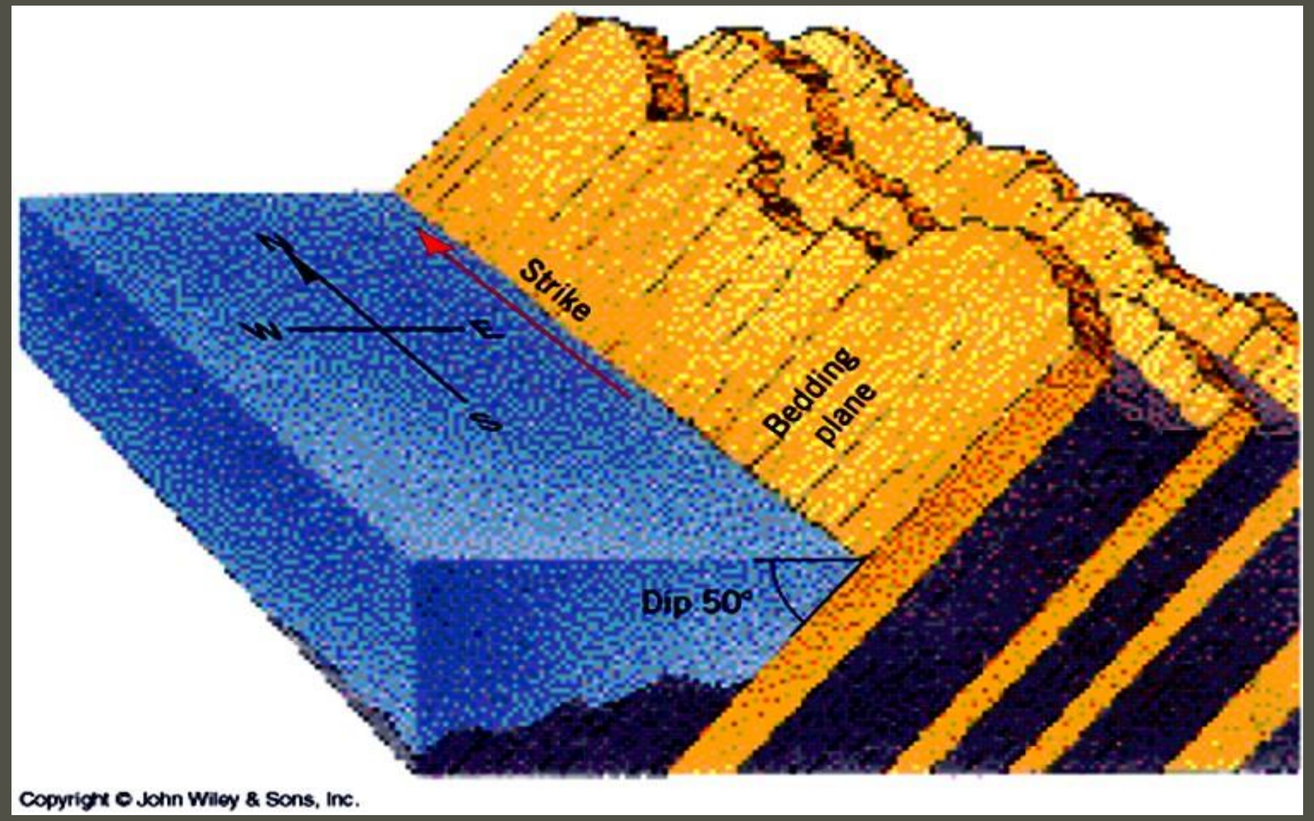
Strike and Dip

According to the principle of ***original horizontality***, sedimentary rocks are deposited as **horizontal beds** or **strata**.

- Where these **originally horizontal rocks** are found tilted, this must have occurred after **deposition** and **lithification.**

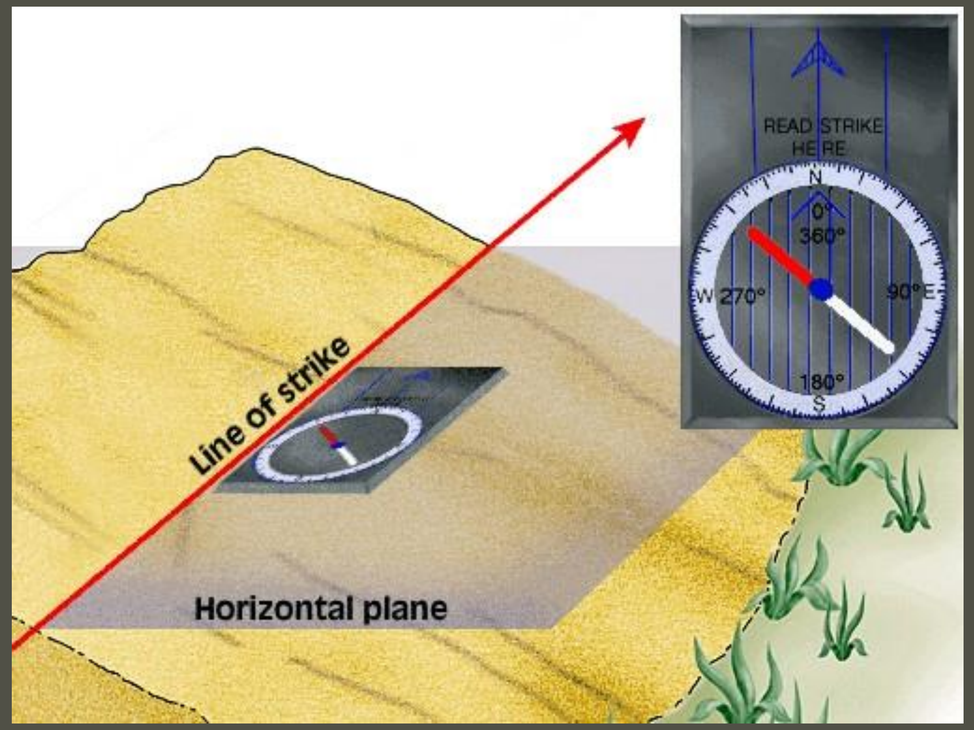
Strike and Dip.....(2)

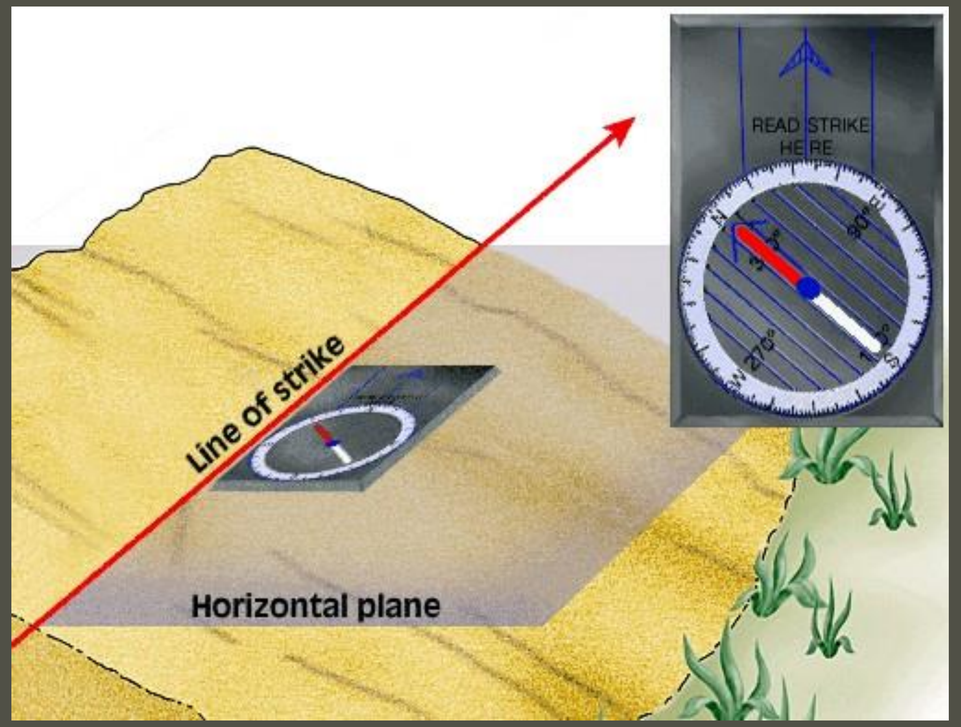
- ✓ **Strike:** the **compass direction** of a line formed by the intersection of an **inclined** plane with a **horizontal** plane.



Strike and Dip.....(3)

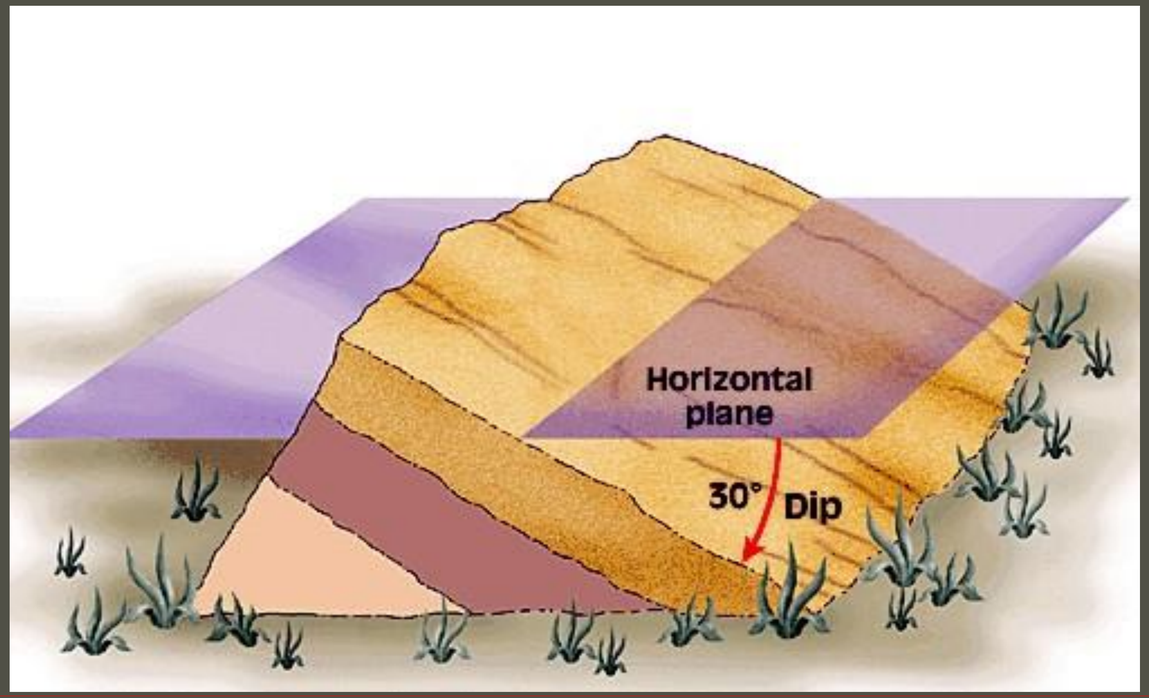
- ✓ Strike: measured in reference to northerly direction by degrees from 0^o – 90^o east or west.



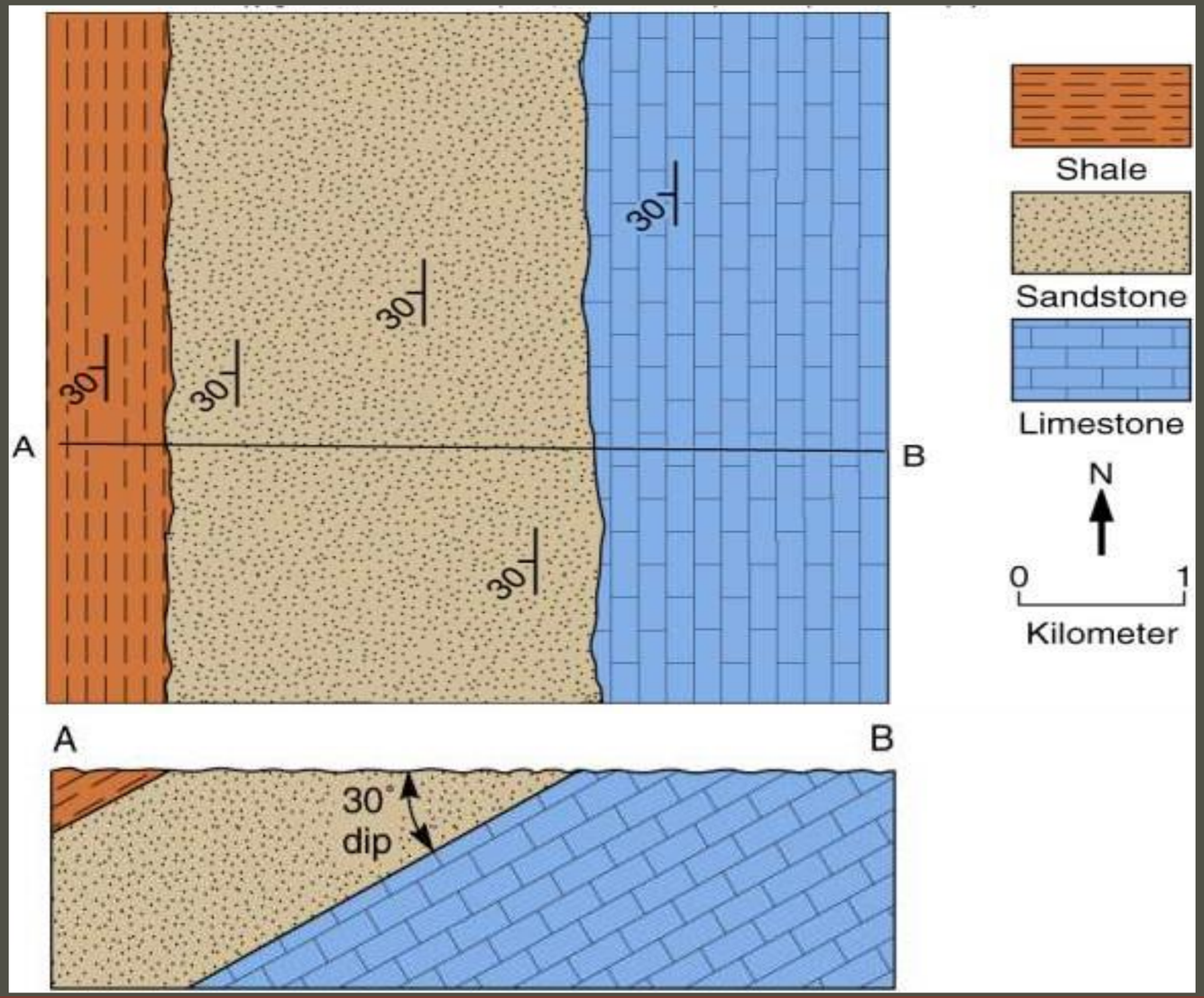


Strike and Dip.....(4)

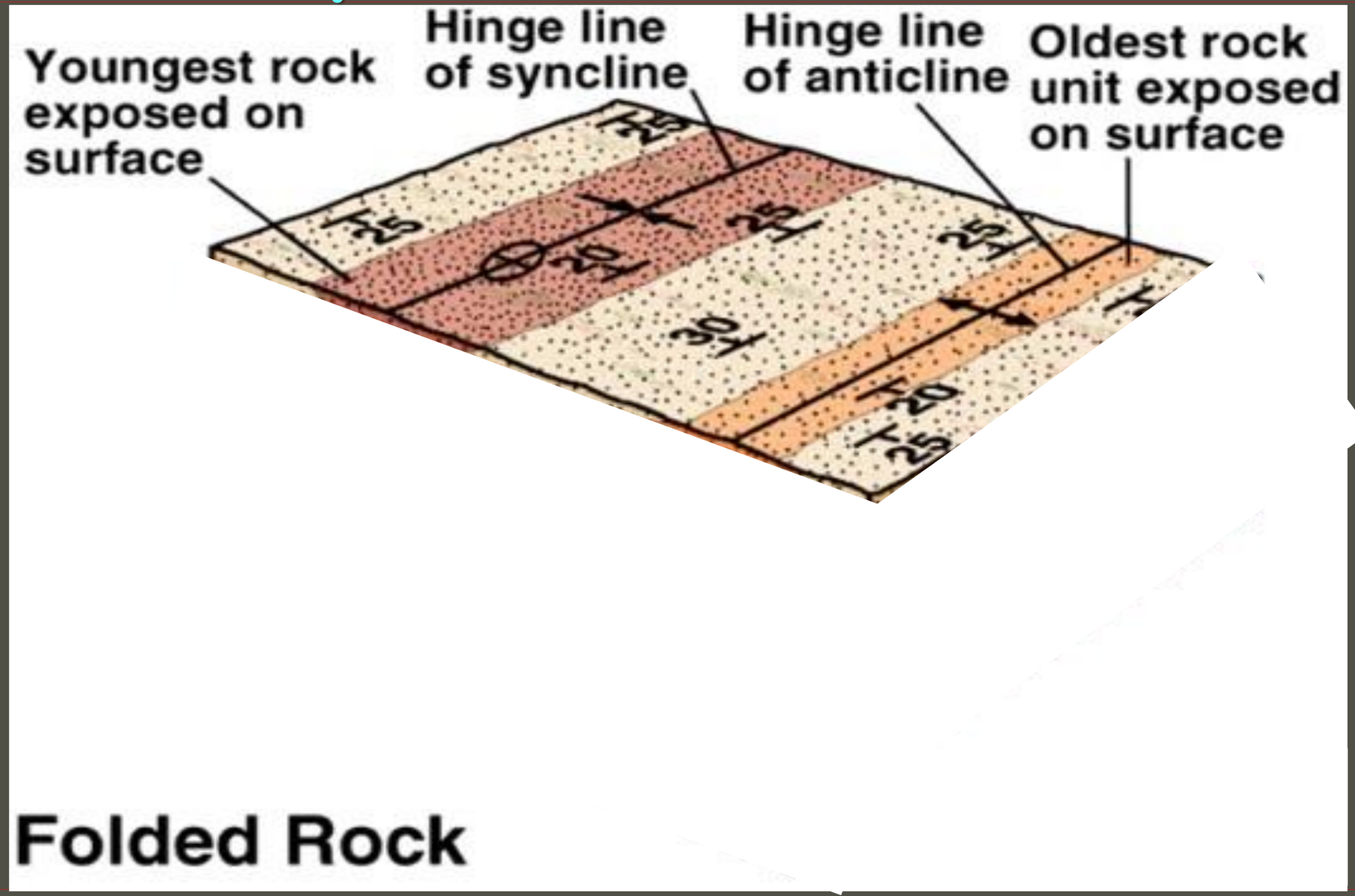
- ✓ **Angle of Dip**: a measurement downward from the horizontal plane to the bedding plane.
- ✓ **Dip Direction:** compass direction in which the angle of dip is measured.



Strike and Dip.....(10)



Strike and Dip.....(9)



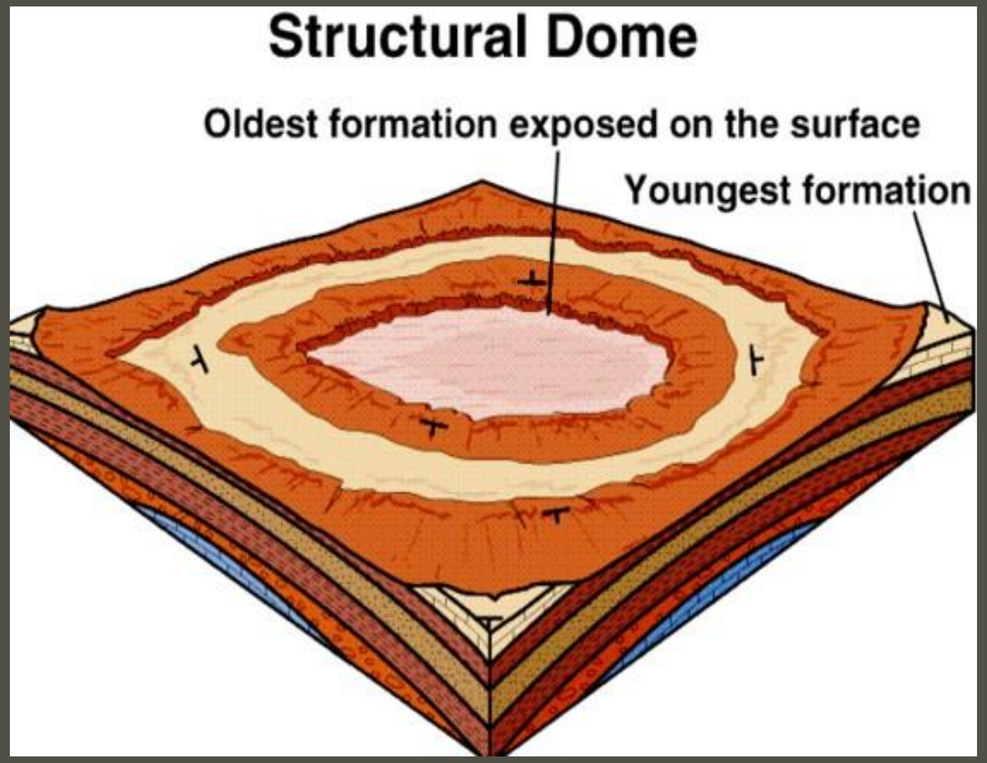
Folded Rock

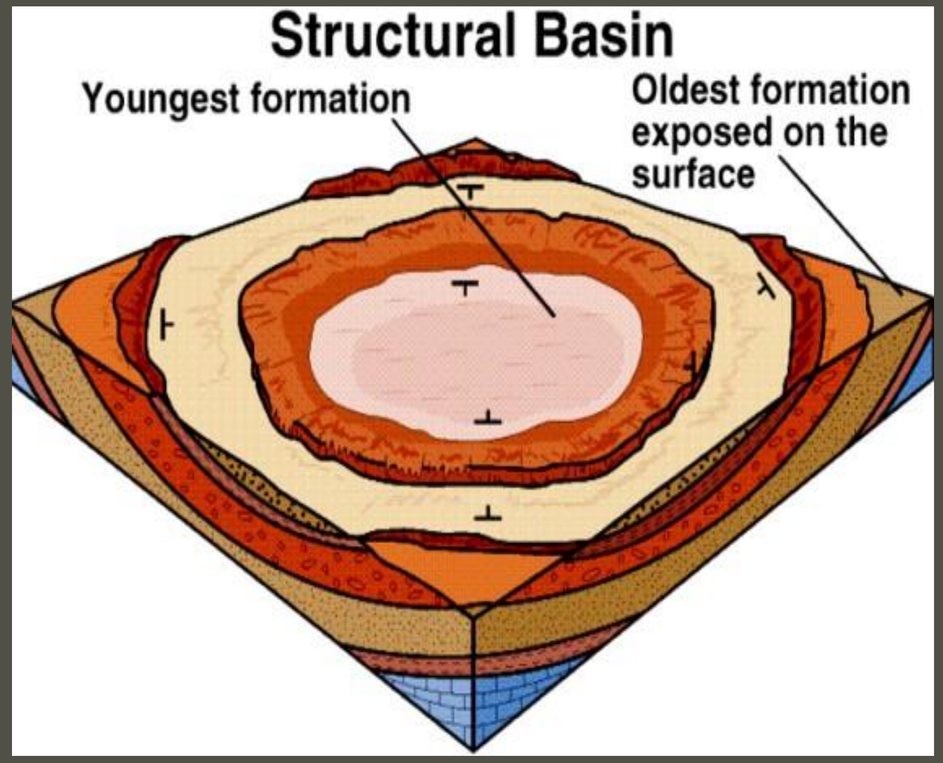
Strike and Dip.....(6)

Structural Dome / Structural Basin?

Strike and Dip.....(7)

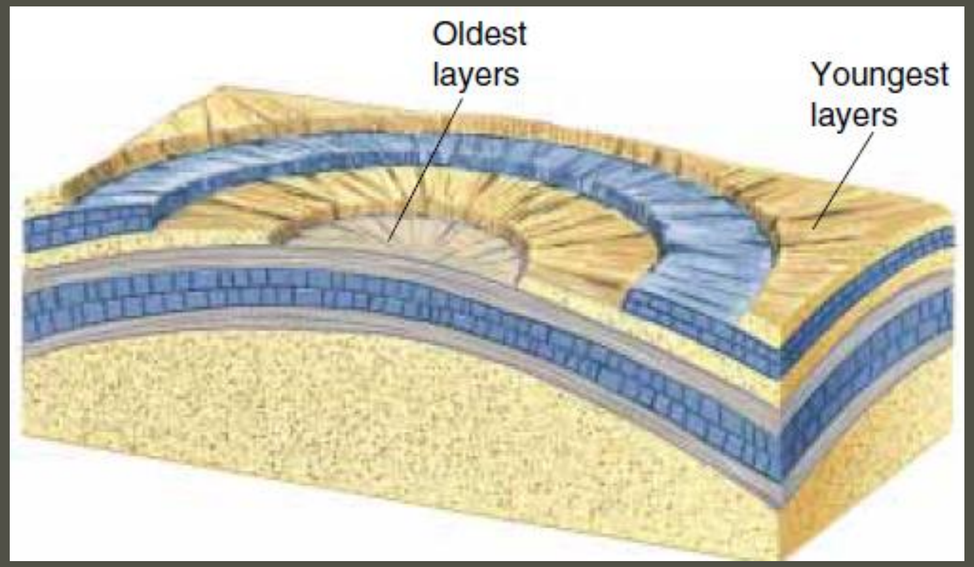
✓ Structural Dome &....



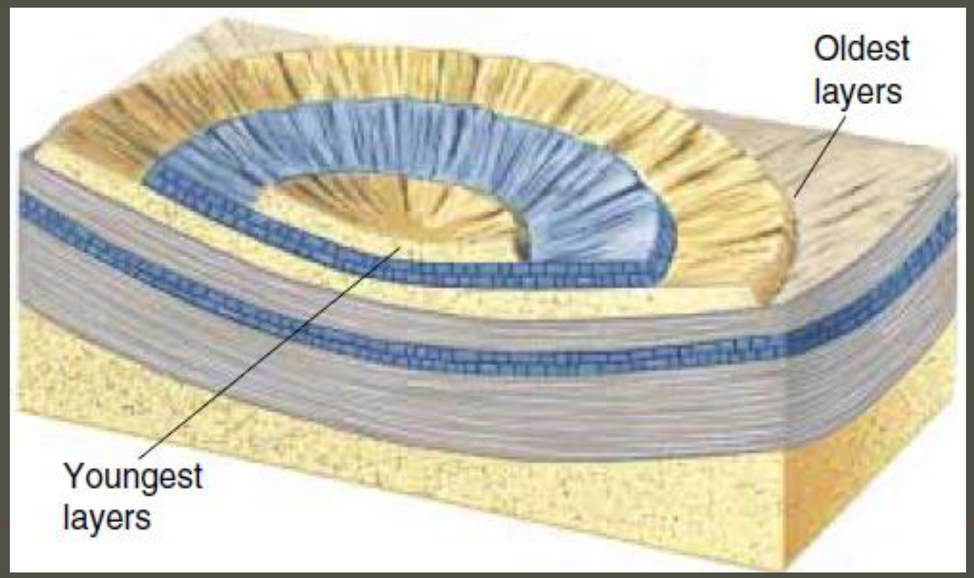


➢ ...Structural Basin

Strike and Dip.....(8)



Sedimentary layering dips away from a dome in all directions, and the outcrop pattern is circular or elliptical.



Layers dip toward the centre of a basin.

Recap on Dip and Strike

Strike :

- Strike is a geographic direction given by the line of intersection of a horizontal plane with a bedding plane of a layer of rock.
- It is measured in field with the help of a compass.

Dip:

- Is defined as the max angle of inclination with the horizontal. It is expressed both in terms of degree of inclination and direction of inclination.
- The amount of dip is called angle of inclination, which a bedding plane makes with a horizontal plane.

Recap on Dip and Strike

True Dip:

- when the dip of the layer is measured in a direction that is essentially at right angles to the strike of the particular layer, then It is called TRUE DIP.

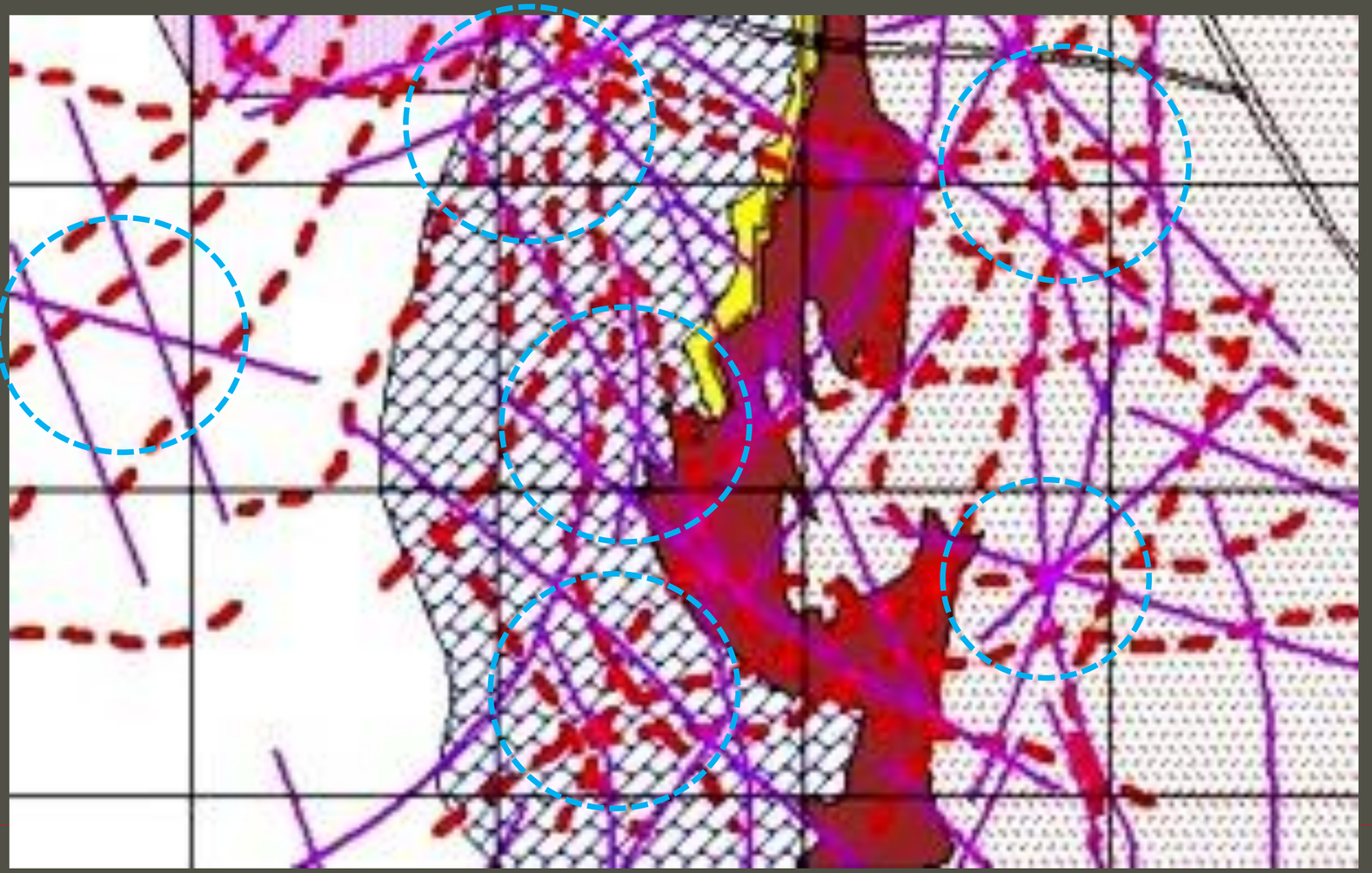
Apparent Dip:

- When the dip of the layer is measured in any other direction which is not a right angles to the strike direction is called APPARENT DIP.

SIGNIFICANCE OF GEOLOGIC STRUCTURES IN ENGINEERING PRACTICE

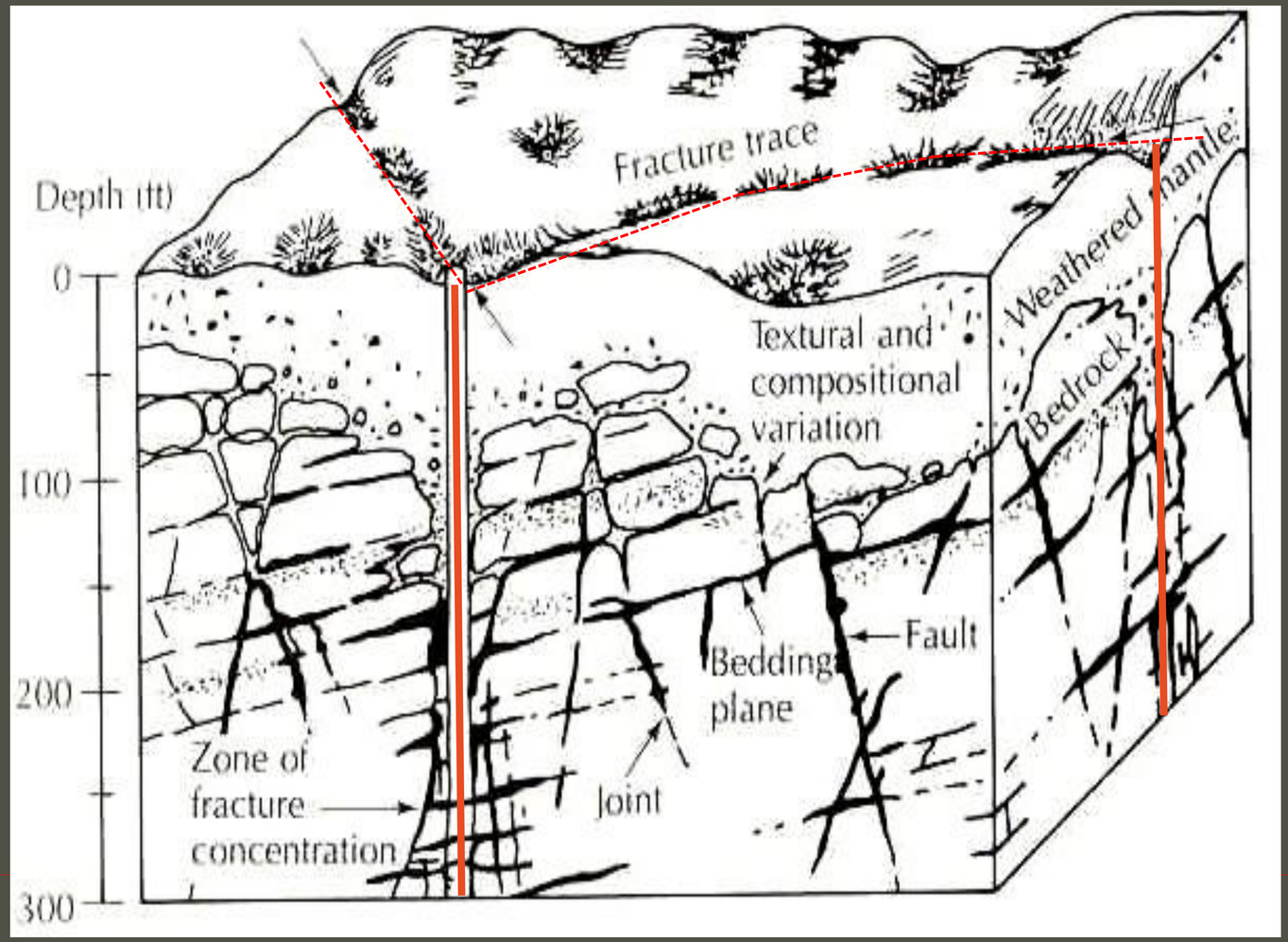
Challenges posed by Geologic Structures...

a) They act as conduits & stores for groundwater



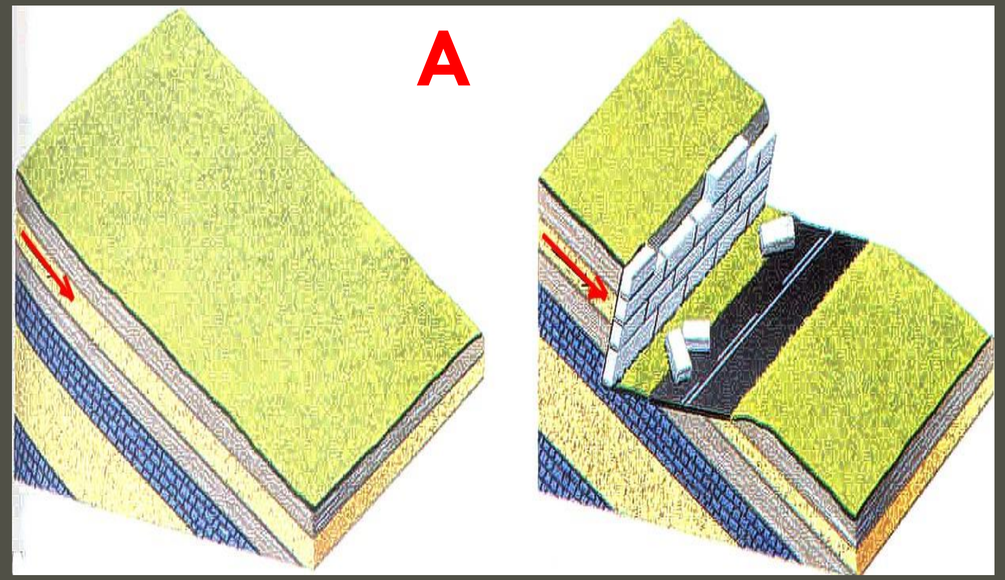
Challenges posed by Geologic Structures...

a) They act as conduits & stores for groundwater

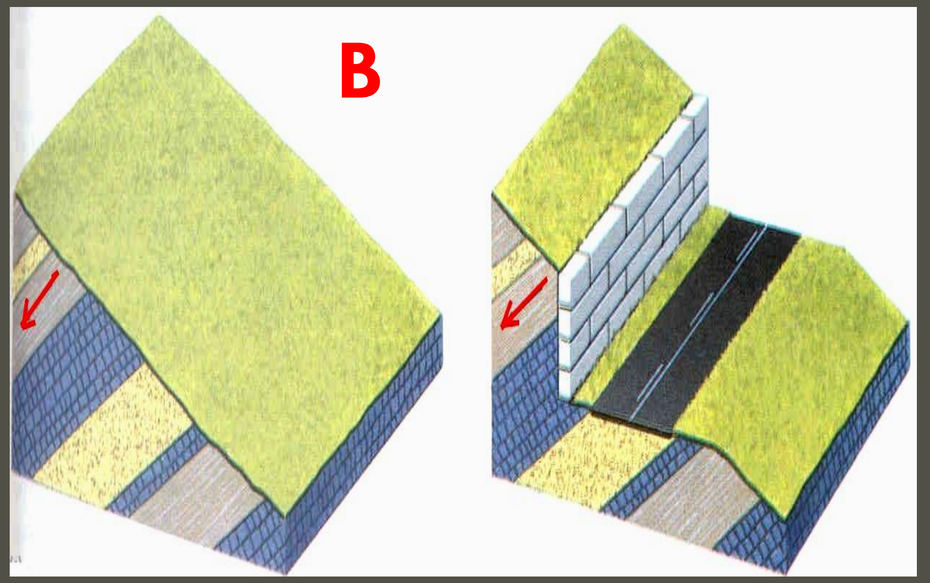


Challenges posed by Geologic Structures...

If sedimentary rock layers dip in the same direction as slope, upper layers may slide over the lower ones.



(A) If road cut undermines slope, where rocks dip parallel to slope, dipping rock provides good sliding surface.



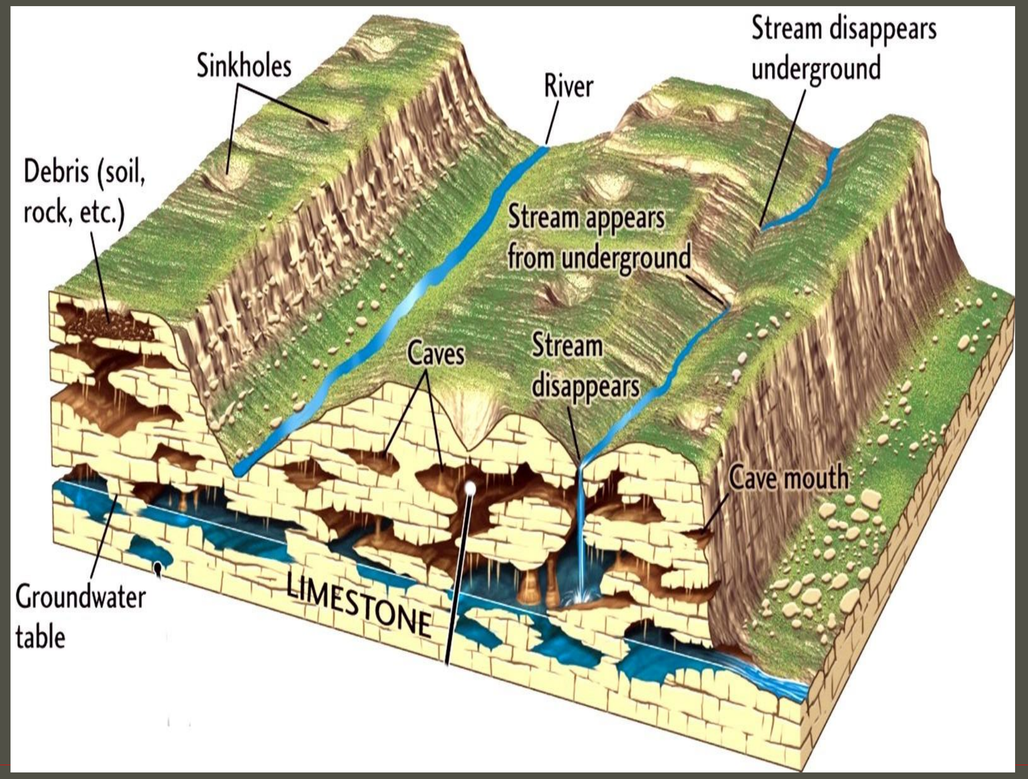
(B) Slope will remain stable even when undermined if rock layers dip away from cut.

Challenges posed by Geologic Structures...

- ✓ They may impair performance of engineering structures, if not adequately taken into consideration

Challenges posed by Geologic Structures...

- ✓ They may act as conduits for contaminants to the groundwater store (aquifer)



Challenges posed by Geologic Structures...

G.S. can also be a problem to mining. For instance;

- ✓ occurrence of joints, bedding and/or faults might cause failure of slopes in open pit excavations or mine tunnels.
- ✓ they might allow water to flow from surface into mine openings. This inflow might not only add costs to operations, but may also flood mines….

Some Concluding Remarks

Geologic structures:

- ✓ come in different forms – folds, faults, joints, etc
- ✓ can pause problems in drilling for water such as hole collapse;
- ✓ act as passages for solutions from which mineral deposits are formed by precipitation.

End of Lecture