TOPIC 3

Structural Geology

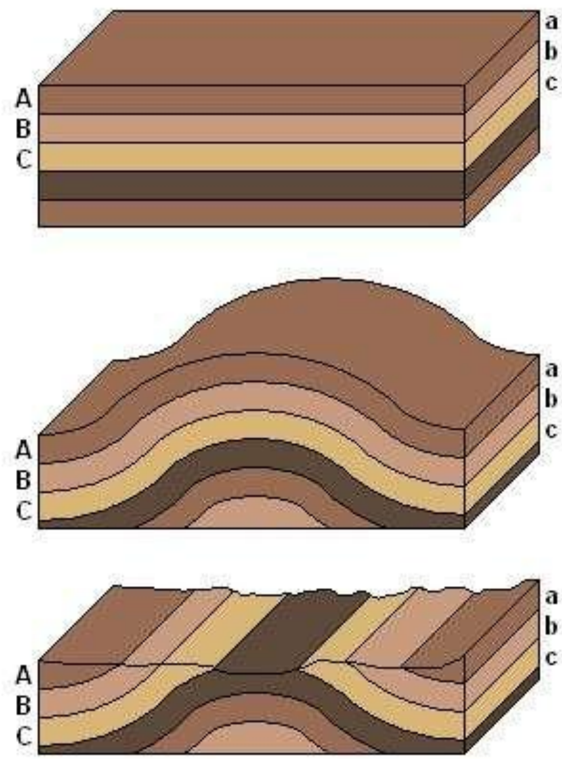
- Structural geology is the study of factors such as origin , occurrence, classification, types and effects of various secondary structures like folds, faults, rock cleavage and unconformities.
- All these structures are those which develop and occur in rock after their formation and different from those primary structures such as bedding and vesicular structure, which develop in rocks at the time of their formation itself.

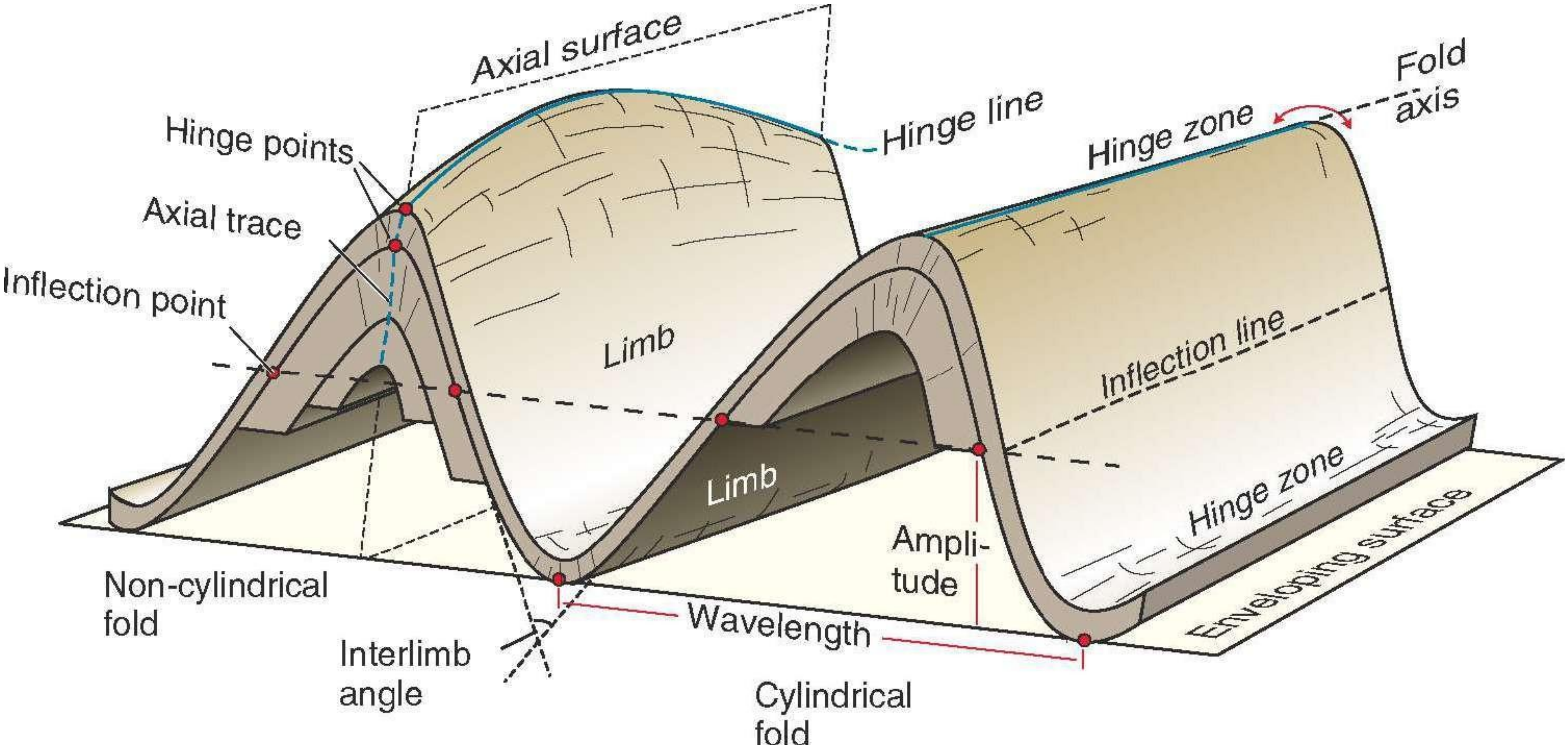
Outcrop

- Any geological formation exposed on the surface is called an outcrop.
- It is used as a general term to refer to exposed folds, faults, joints, etc.

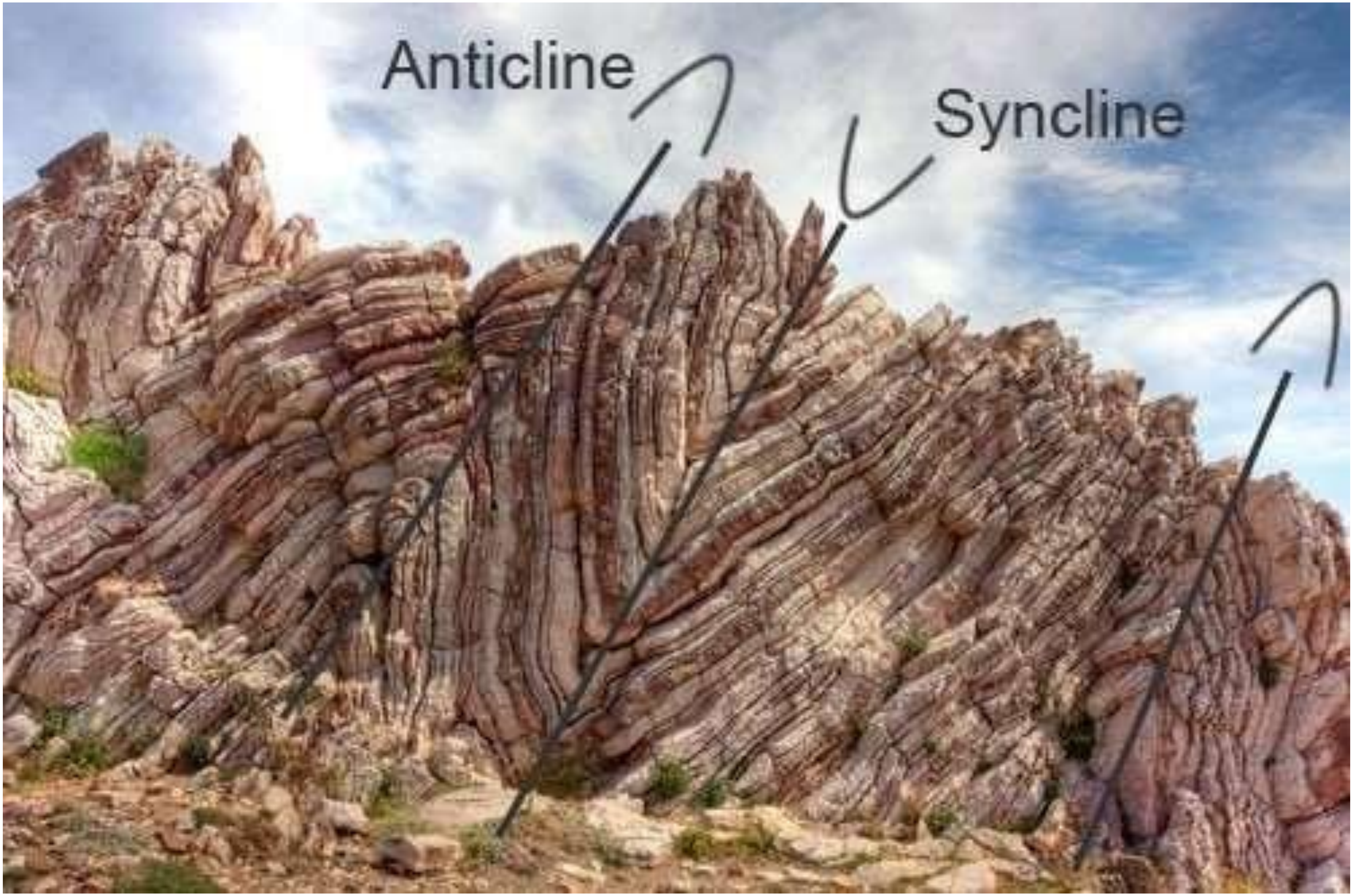
FOLDS

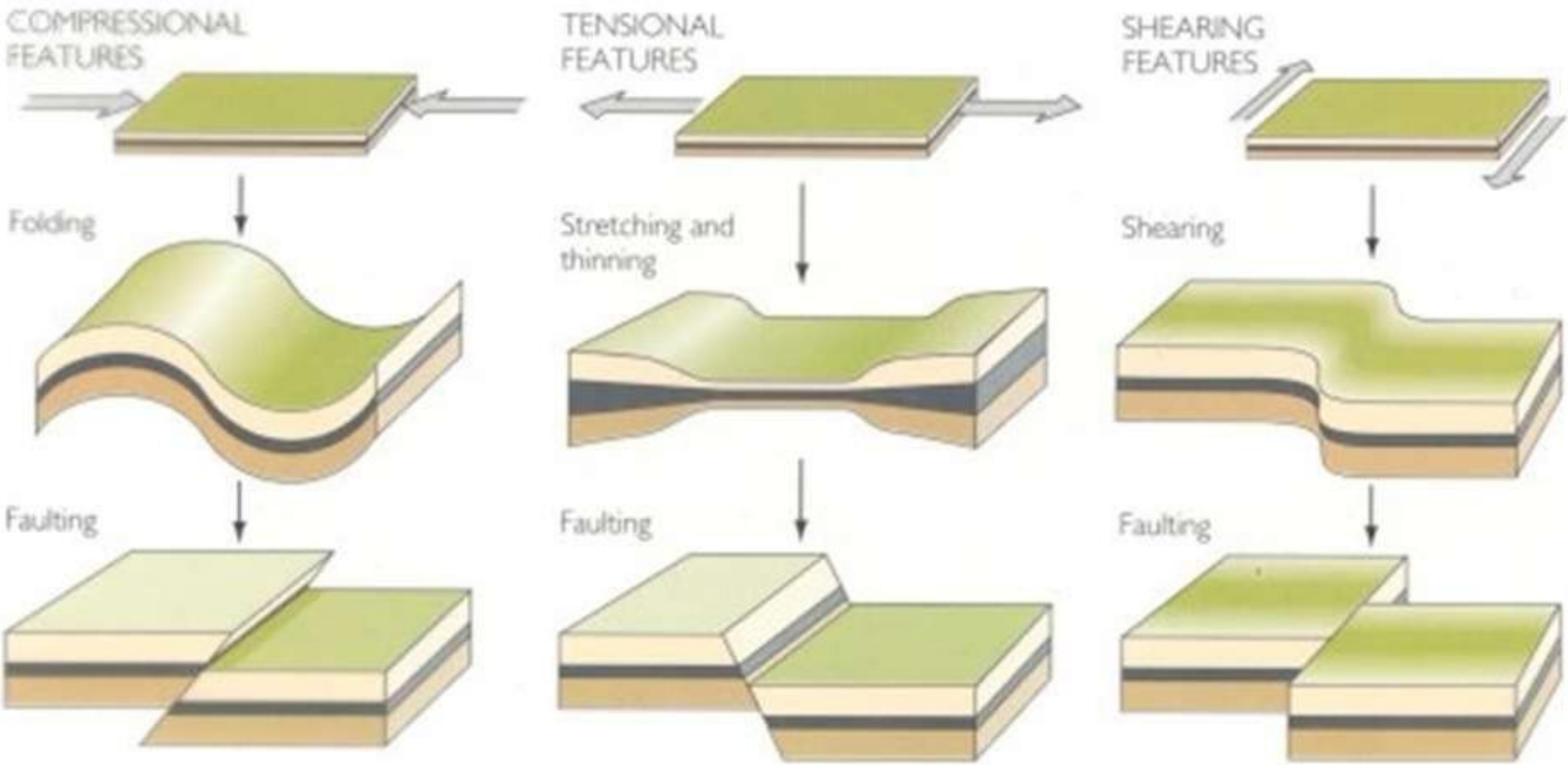
- Folds are one of the most common geological structures found in rocks.
- When a set of horizontal layers are subjected to compressive forces, the bend either upwards or downwards.





Axial surface
Fold axis
Hinge line
Hinge zone
Hinge points
Axial trace
Inflection point
Limb
Inflection line
Limb
Hinge zone
Enveloping surface
Ampli-tude
Non-cylindrical fold
Wavelength
Interlimb angle
Cylindrical fold

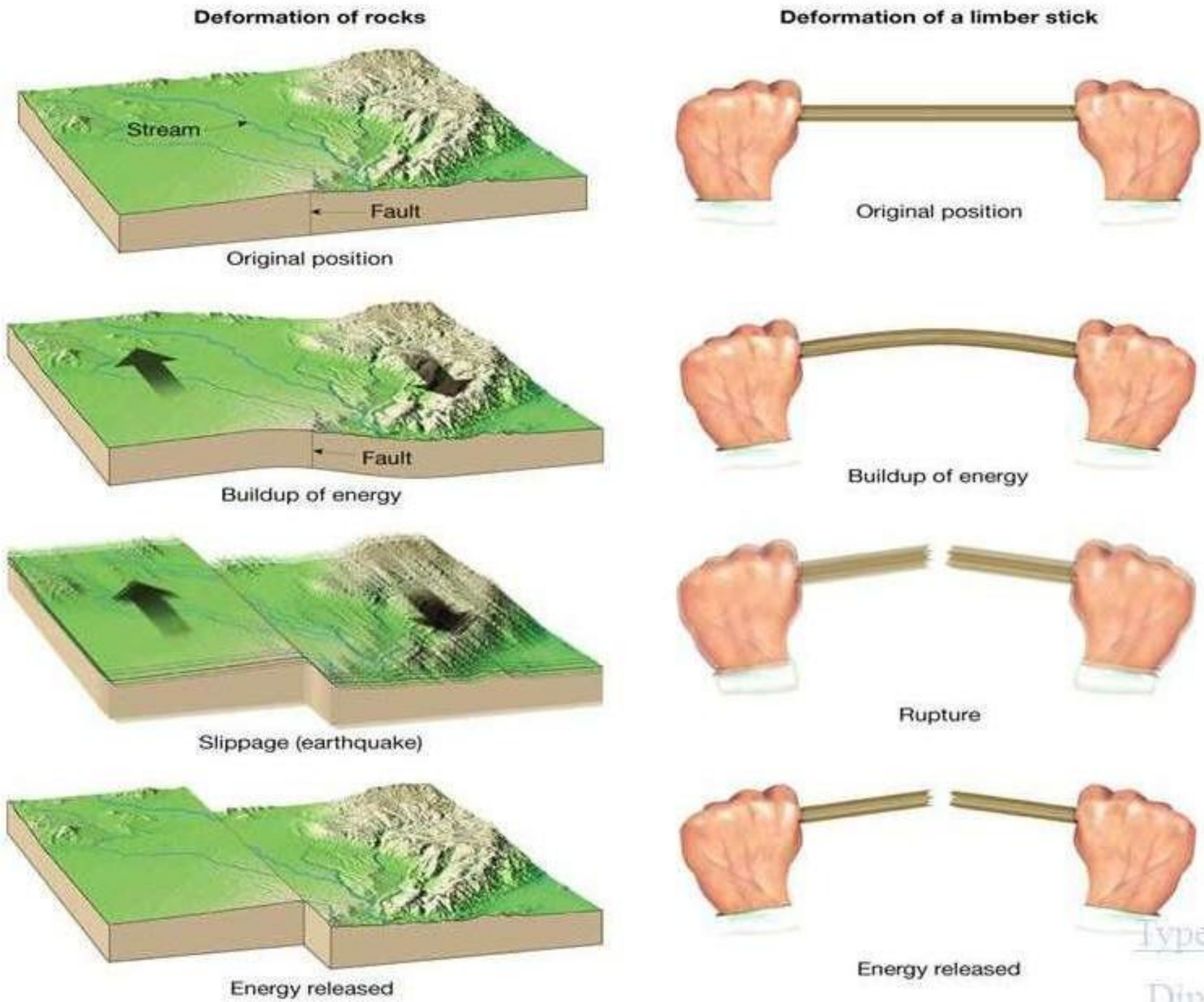

Anticline
Syncline


COMPRESSIONAL FEATURES
Folding
Faulting
TENSIONAL FEATURES
Stretching and thinning
Faulting
SHEARING FEATURES
Shearing
Faulting

FAULTS

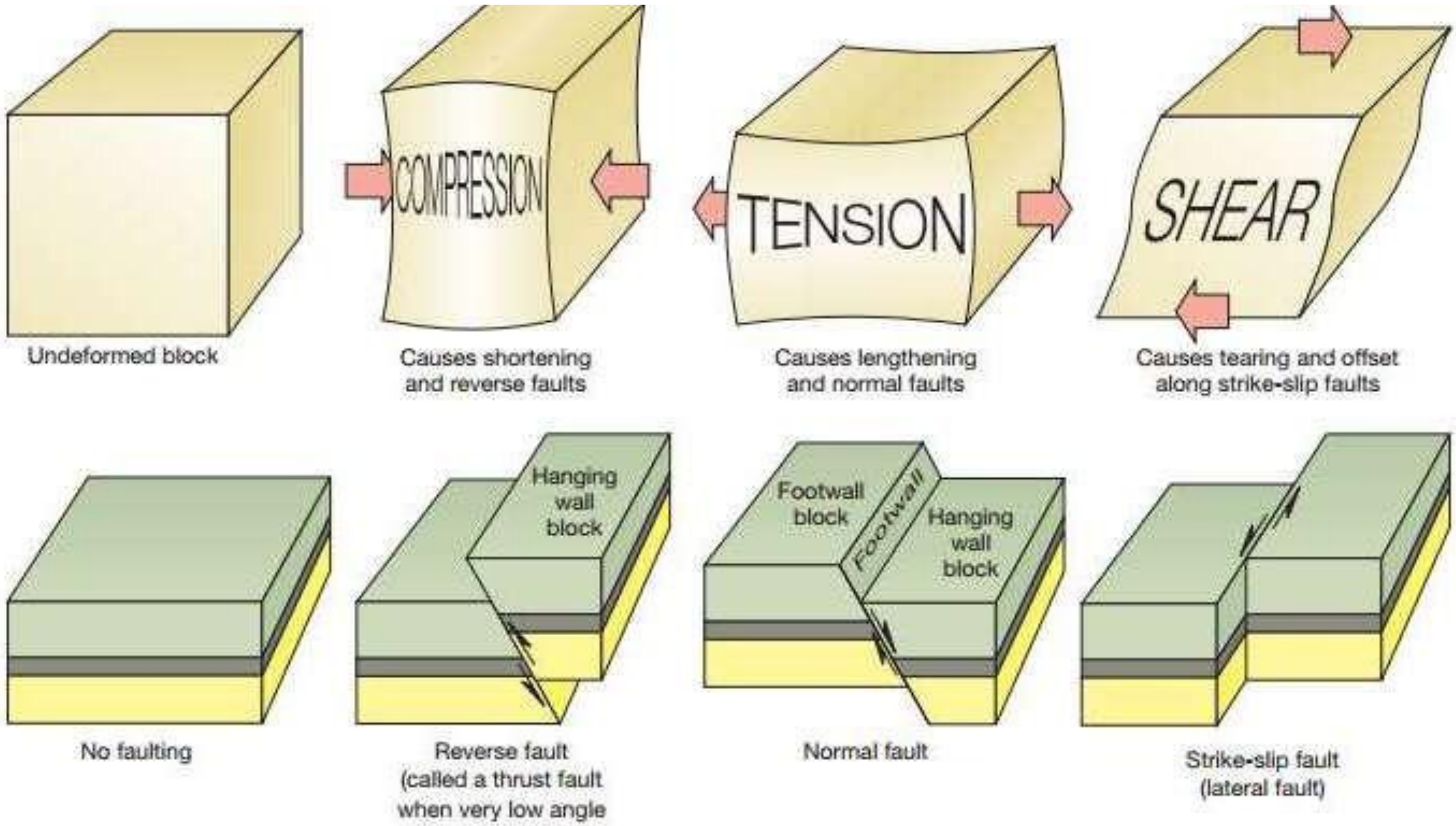
- From civil engineering point of view, faults are the most unfavourable and undesirable geological structures at the site for any given purpose, i.e., for location of reservoirs: as a foundation site for construction of dams, important bridges or huge buildings, for tunnelling; for laying roads or railway tracks etc.

Note : Folds leads to form faults.



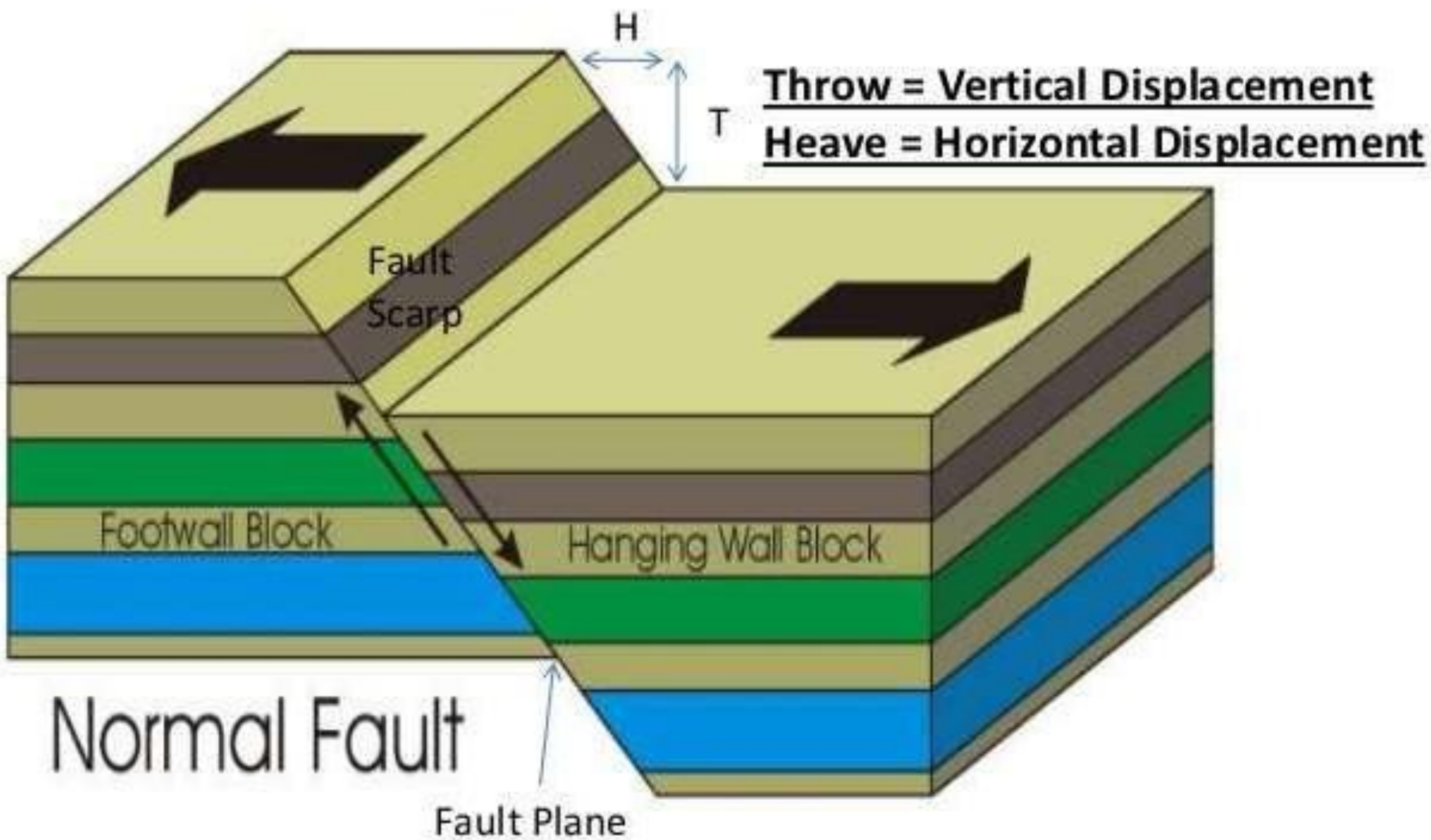
Types of Faults

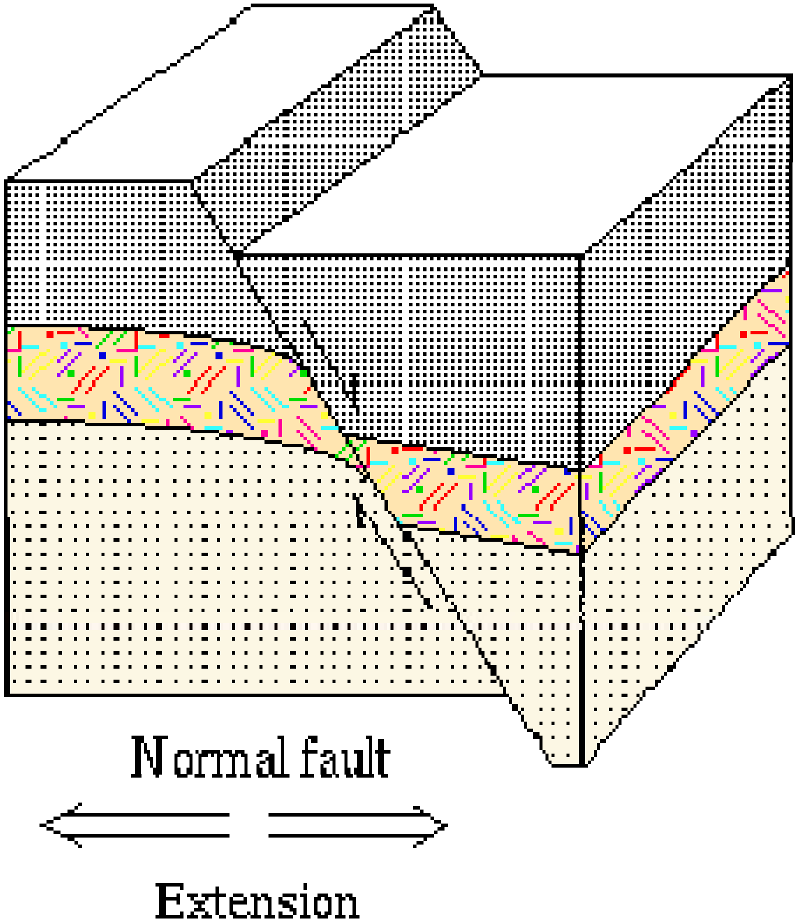
Dip-Slip Fault

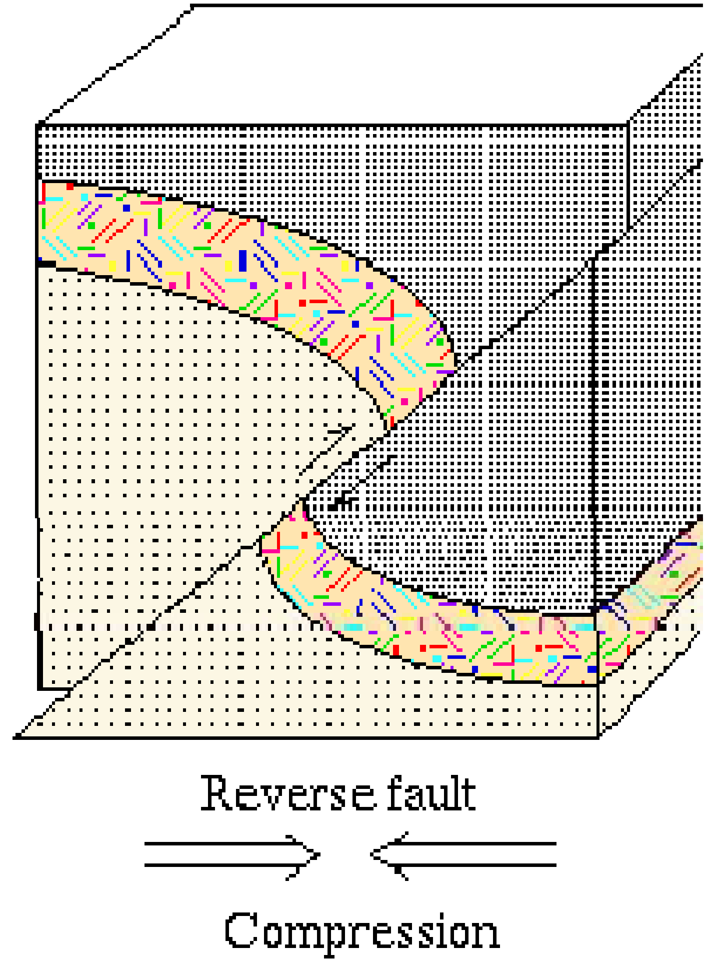

COMPRESSION
TENSION
SHEAR
Undeformed block
Causes shortening and reverse faults
Causes lengthening and normal faults
Causes tearing and offset along strike-slip faults
Hanging wall block
Footwall block
Footwall
Hanging wall block
No faulting
Reverse fault (called a thrust fault when very low angle
Normal fault
Strike-slip fault (lateral fault)

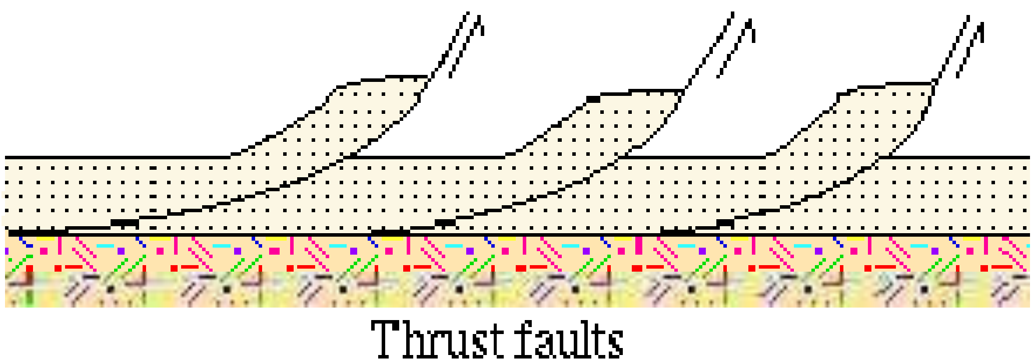
Normal Faults

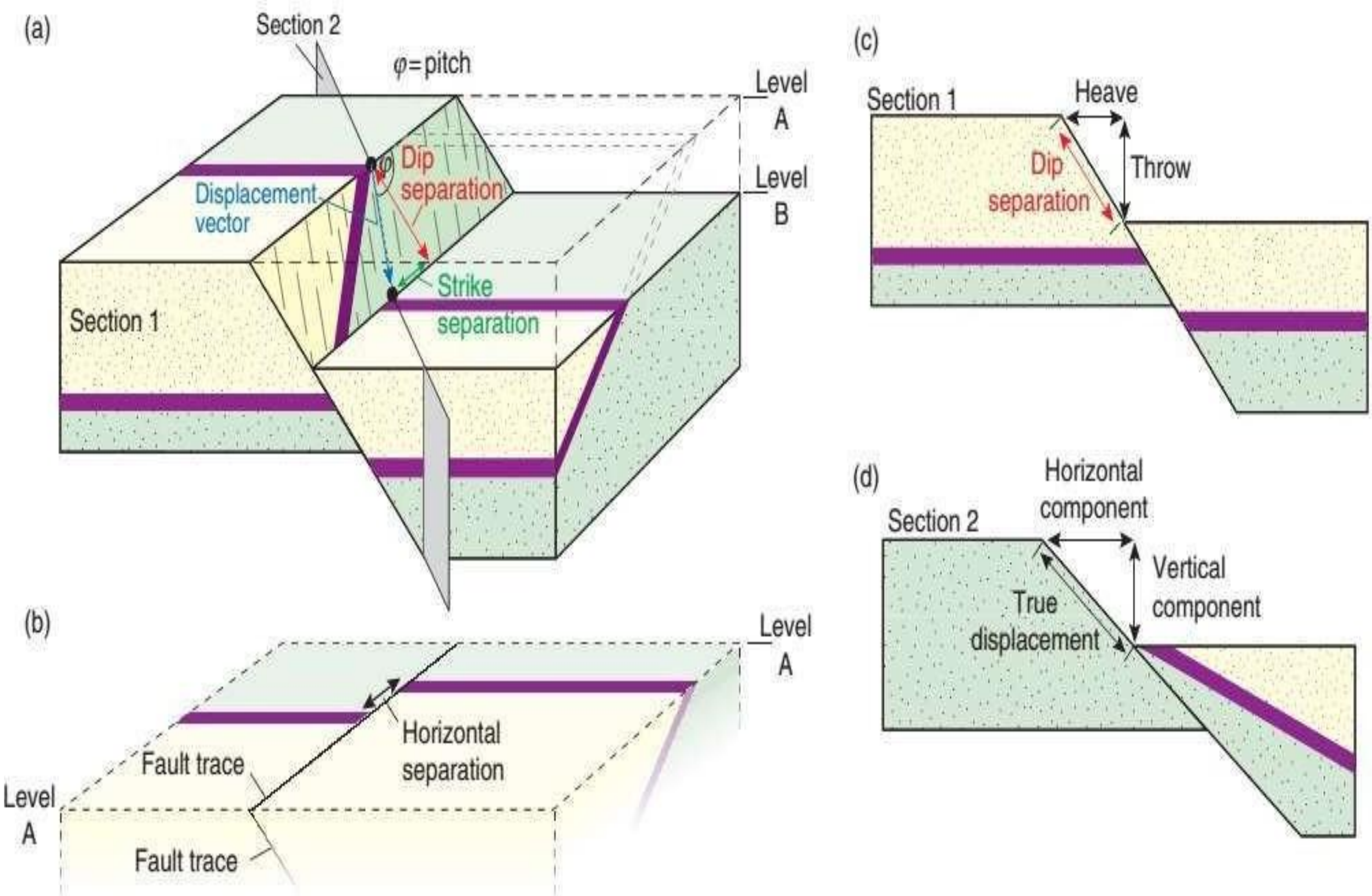
TENSION / Pulling motion = LENGTHENING



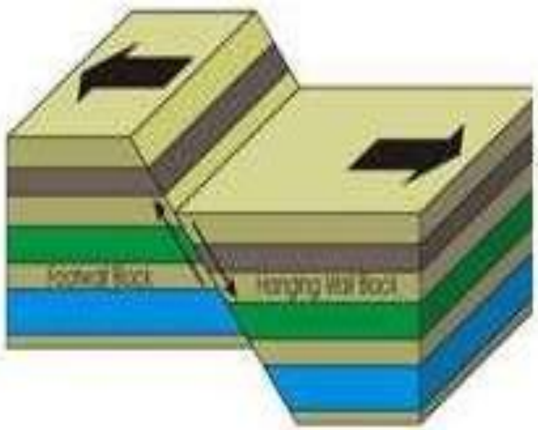

Normal fault
Extension


Reverse fault
Compression

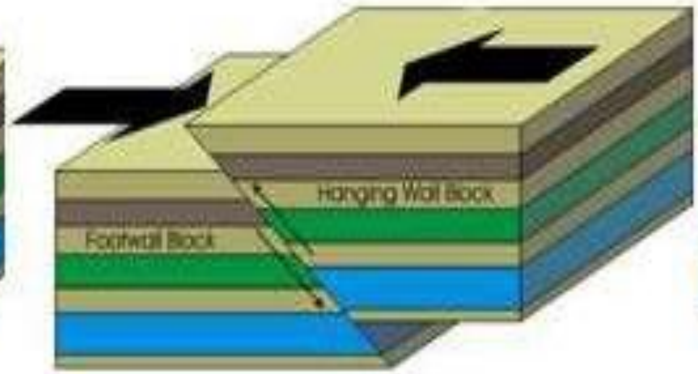

Thrust faults



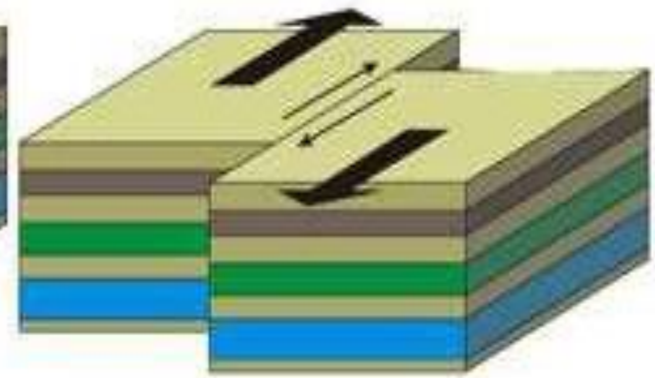
(a)
Section 2
φ=pitch
Level A
Level B
φ
Dip separation
Displacement vector
Strike separation
Section 1
(b)
Level A
Horizontal separation
Fault trace
Level A
Fault trace
(c)
Section 1
Heave
Throw
Dip separation
(d)
Section 2
Horizontal component
Vertical component
True displacement



Normal fault



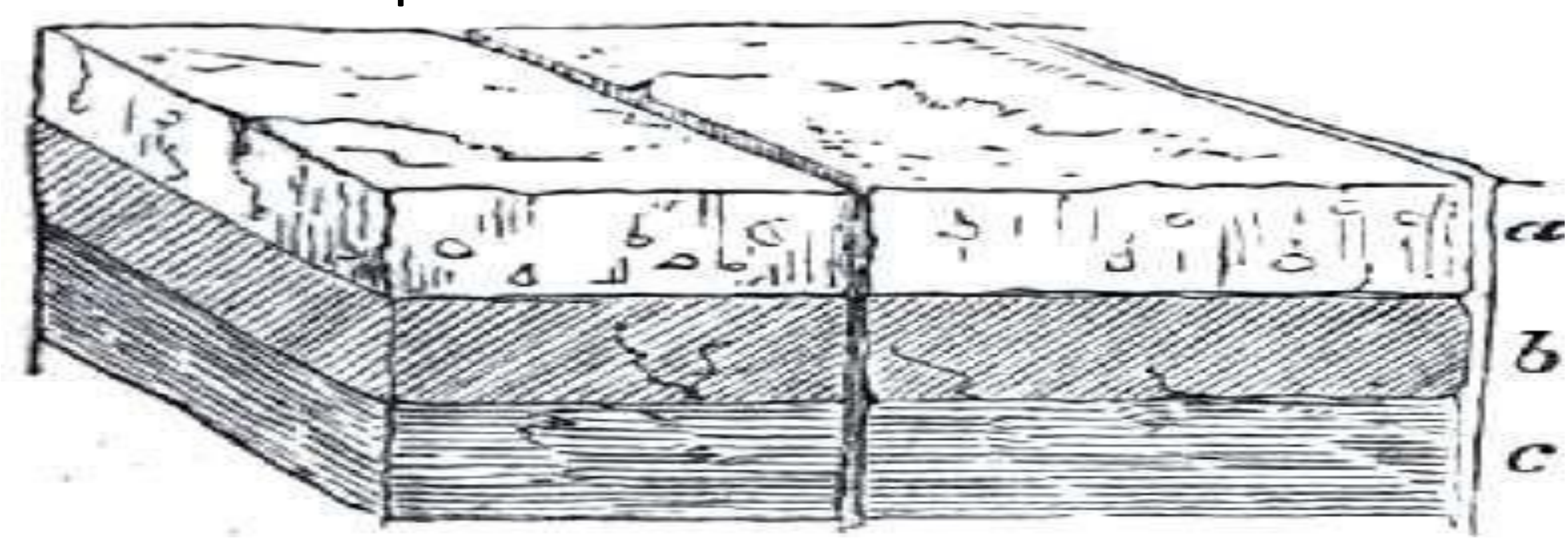
Reverse fault

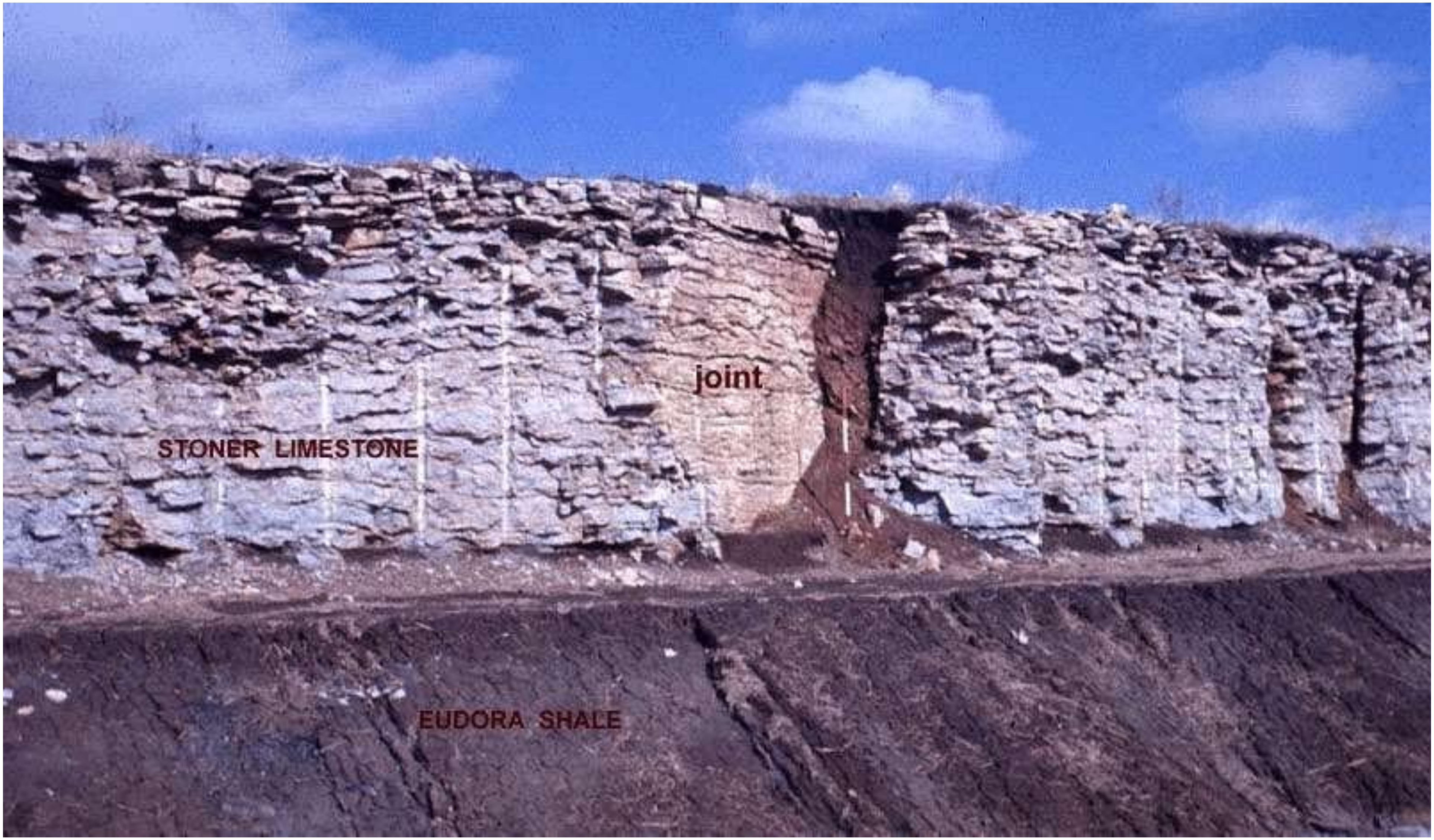


Strike-slip fault

JOINTS

- Joints are fractures found in all type of rocks.
- They are cracks or openings formed due to various reasons.
- The presence of joints divides the rock into a number of parts or blocks.




joint
STONER LIMESTONE
EUDORA SHALE


JOINT
Bedding Plane

UNIT-

Geological Maps :-

(i) The topographic maps / topo sheets incorporated with geological informations, such as their strike, dip, width etc..) are called geological maps.

(ii) Geological map plays a vital role in mining / quarrying operation and it serves as a valuable tool for a mining Engineer.

(iii) Geological maps are further classified as follows :

ⓐ Hydrogeological maps : Geological maps incorporated with ground water details.

ⓑ Contour maps : Maps with elevation details.

ⓒ Soil maps : Maps with soil details.

Applications :-

(i) Geological maps find application in quarrying / mining operations to exploit minerals successfully & profitably.

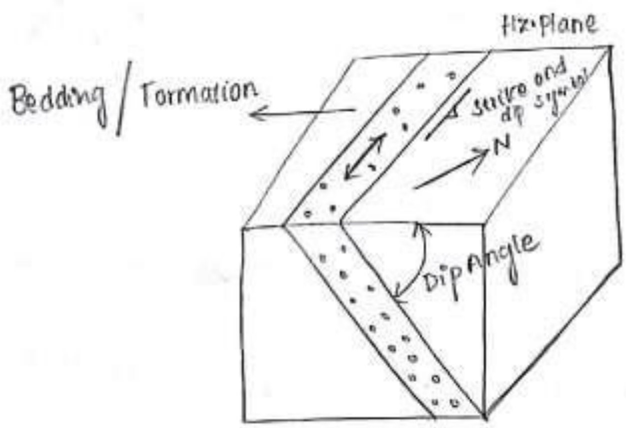
(ii) Hydrogeological maps find applications in locating ground water sources for water supply projects.

(iii) Contour maps find applications in knowing elevation details required for laying pipelines, construction of roadways in hills, etc..)

(iv) Soil maps find application in knowing soil types, required for foundation design of civil Engineering structures.

Attitude of Beds :-

The attitude of beds is expressed by their strike and dip.



The dip direction and strike direction are always ⊥r.

True dip :-

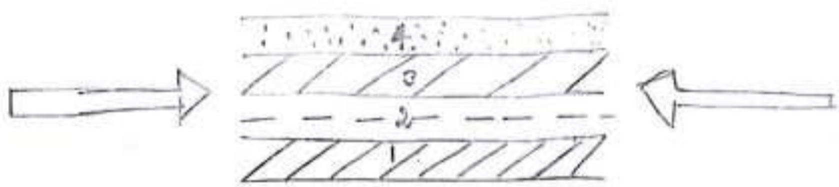
The dip measured in a direction, at right angles to the strike direction is called true dip.

Apparent dip :-

The dip measured in any other direction other than the true dip direction is called Apparent dip, which is essentially less than the true dip.

Study of Structures – Folds :-

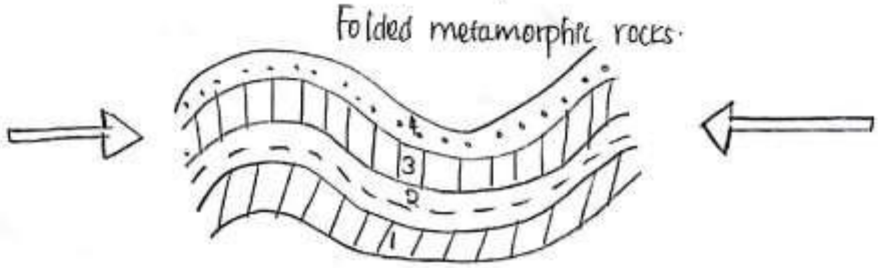
Folds are wavy undulations developed in country rocks, whenever the region is subjected to severe pressure / stress.



① – Oldest formation.

④ – Youngest formation.

After deformation / Folded metamorphic rocks.



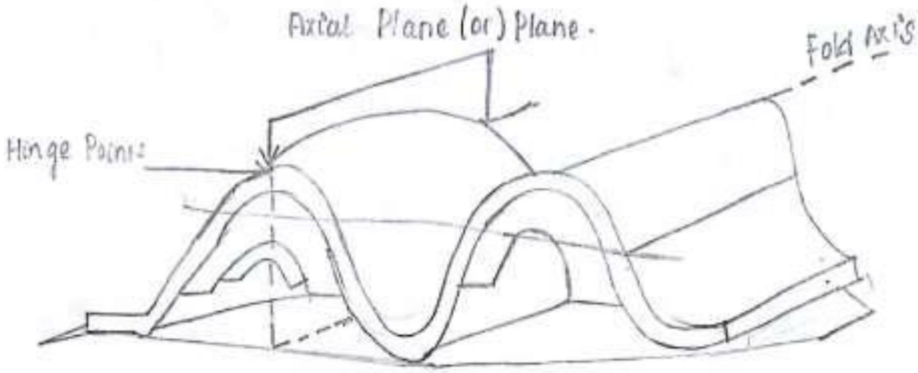
The sides of a fold / the stretch of rocks beds lying b/n any crest and any of the adjacent troughs on either side is called a limb.

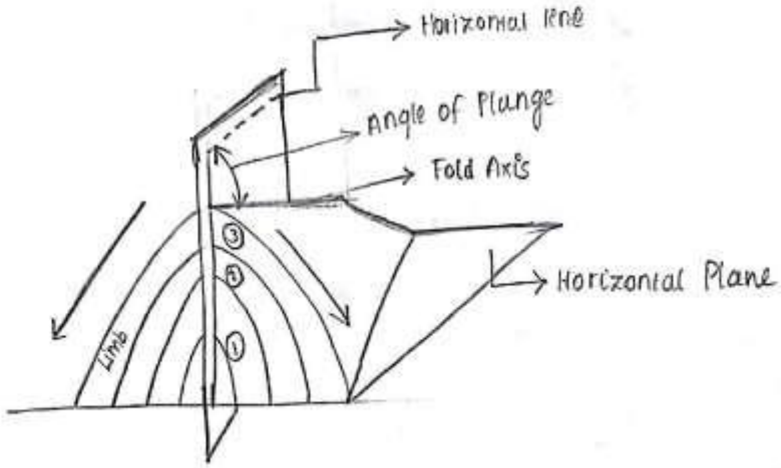
Axis of fold :-

It is the direction of line about which the fold is bent on either side.

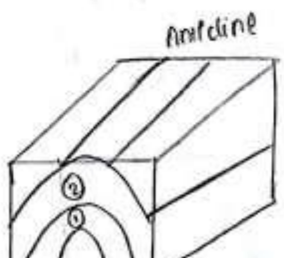
Axial Plane :-

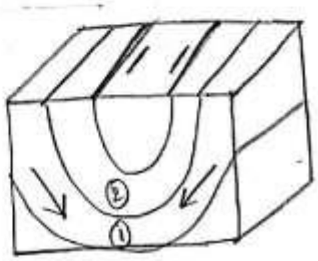
The plane which divides the fold into two equal halves is known as its axial plane.





(1) → Older bed, (3) → Younger most bed.





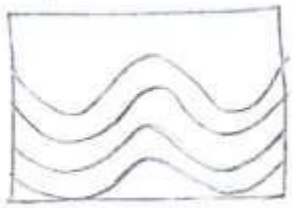
(1) → Older Bed

(2) → Younger most bed

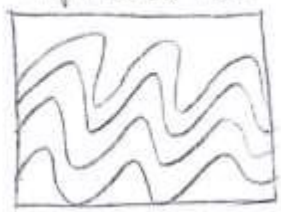
(1) → Older Bed

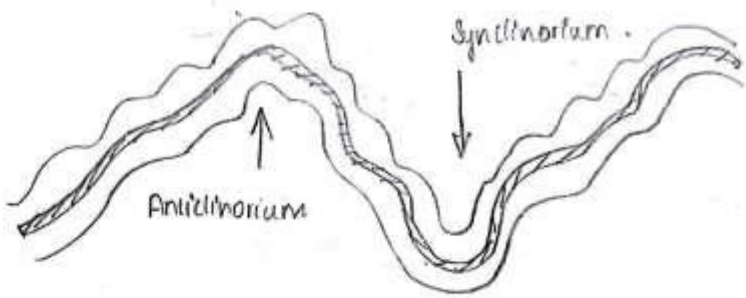
(2) → Younger most bed.

Symmetrical Fold

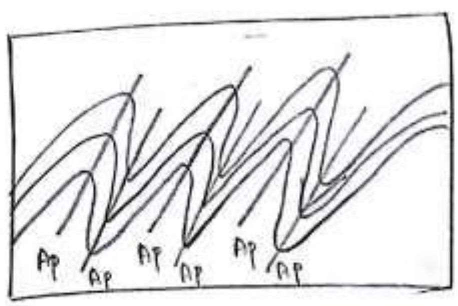


Asymmetrical Fold.

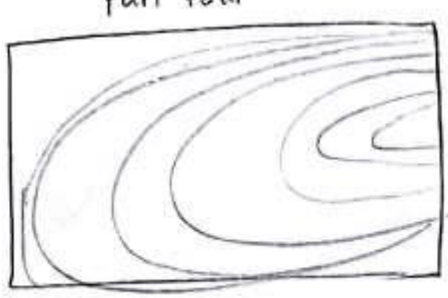




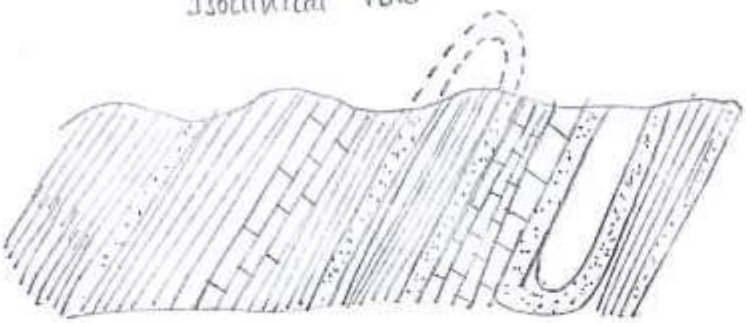
Overturned Folds:



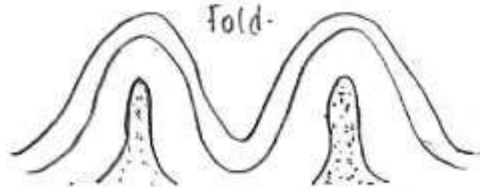
Fan Fold

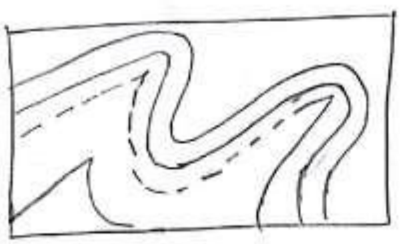


Isoclinical Fold.

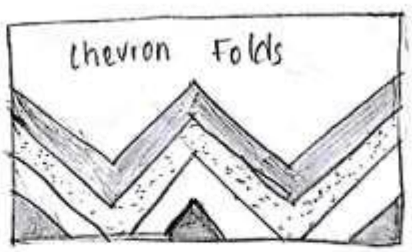


Isoclinical Fold.





Recumbant Folds



Folds are wavy undulations developed in country rocks whenever the region is subjected to severe pressure / stress.

Axis of fold :-

It is the direction of line about which the fold is bent on either side.

Axial Plane :-

It is the plane divides the fold into two equal halves is known as its axial plane.

Types of fold :-

I) Anticline :-

(a) Anticline is the fold which is convex upwards.

(b) In anticlines, both the limbs are dipping away from each other.

(c) Progressively older beds are found to occur towards the center of curvature of the old.

II Syncline :

(a) Syncline is a fold which is convex downward

(b) The limbs of the fold are dipping towards each other.

(c) Progressively younger beds occur towards the center of curvature of the fold.

III) Symmetrical fold :-

It is a fold in which the axial plane is essentially vertical and both the limbs have the same amount of dip.

IV) Asymmetrical fold :-

In symmetrical fold (whether anticline/syncline), the axial plane never remains vertical.

So both the limbs have unequal dips.

V) Anticlinorium :-

A large anticline with a number of minor secondary folds developed on it is known as anticlinorium.

VI) Synclinorium :-

A large syncline in which a number of minor secondary folds are developed is called a synclinorium.

VII) Overturned fold :-

A fold in which one of the limbs appears to be rotated and completely overturned from its normal position, is called overturned fold.

In this fold, both the limbs dip towards the same direction.

VIII) Fan Fold :-

If, in any fold, both the limbs are overturned, the same assumes the shape of a fan and is known as fan fold.

IX) Isoclinal fold :-

If both the limbs of a fold have the same amount of dip towards same direction, it is called an isoclinal fold.

X) Recumbent fold :-

If the axial plane of a fold is horizontal, it is called recumbent fold.

XI) Chevron fold :-

If the crests and troughs of a fold are sharp and angular, it is described as chevron fold.

FAULTS :-

Faults are well defined cracks along which the affected rock-masses on either side have suffered relative displacement.

This desplacement may occur in any direction, due to translatory / rotational movement of fractured blocks.

The faults may be vertical / Inclined.

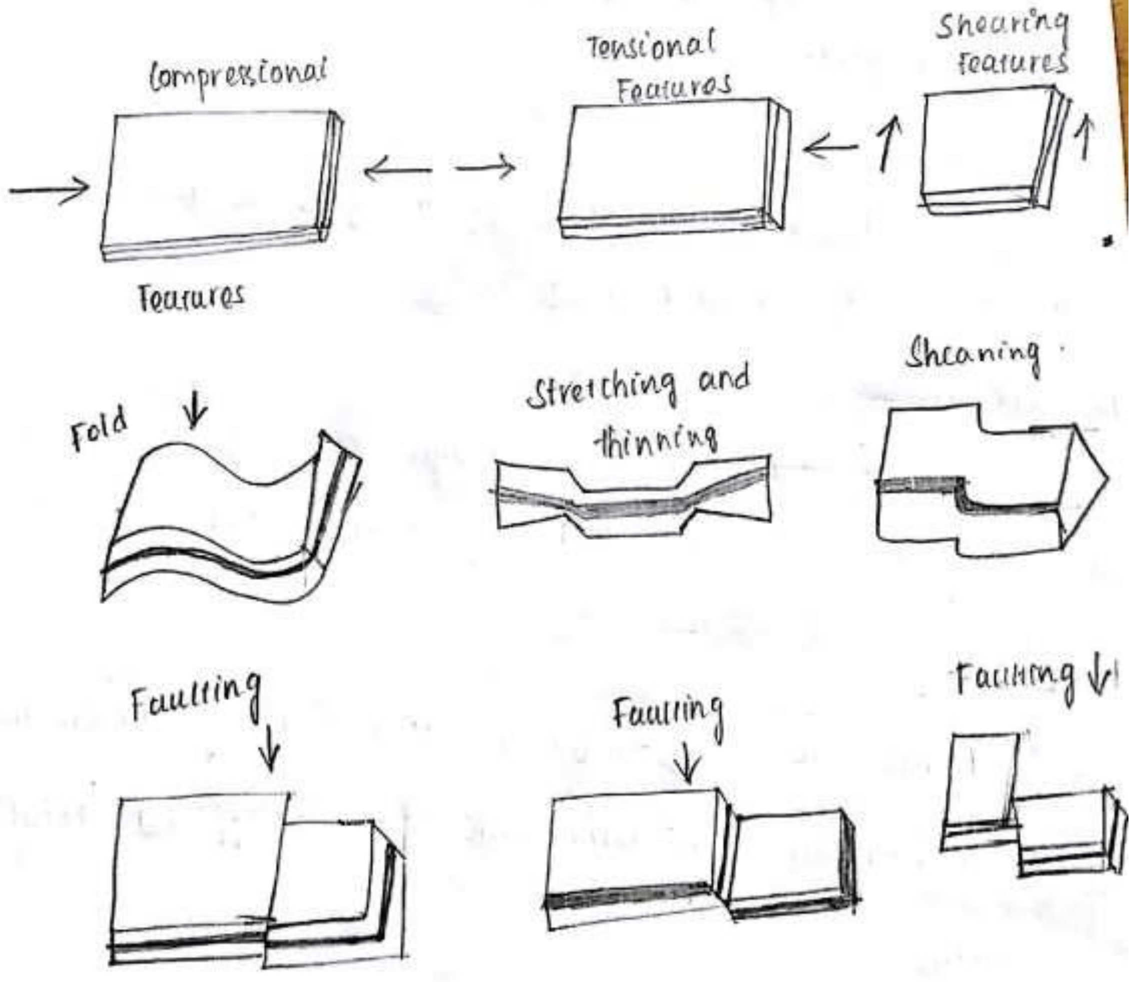
Faults are formed in all three types of rocks, namely igneous, sedimentary and metamorphic rocks.

Forces responsible for formation of faults :-

→ Tensional forces

→ Compressional forces.

→ Shear forces.



Dip slip, Strike slip and Net slip :-

The total displacement due to a fault is described as its net slip. If the displacement is along dip direction, it is referred as dip slip, and if along strike direction, strike slip.

Hanging wall and Foot wall :-

The two blocks lying on either side of an inclined fault - plane are dissimilar in outlook.

Of these two blocks, one appears to rest on the other the former is known as Hanging wall side and the later, which supports the hanging wall side is known as foot wall side.

Down throw and upthrow :-

Along fault planes, one of the dislocated block appears to have been shifted downwards in comparison with the adjoining blocks lying on the other side of the fault plane.

If the movement of block is downwards, it is referred as downthrow and if upwards, upthrow.

Heave, throw and Hade :-

The Heave of a fault is the hz. component of apparent displacement of a bed, measured along the direction of dip of the fault.

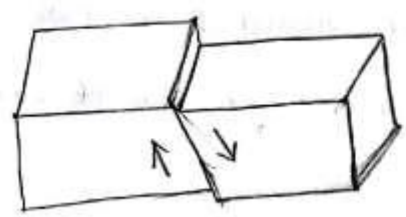
The throw of a fault is the vertical component of apparent displacement of a bed, measured along the direction of dip of the fault.

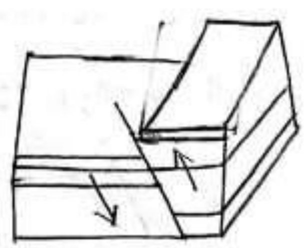
The Hade is the angle b/n the fault plane and any plane striking in the same direction of fault. Hence hade and dip of the fault are complementary to each other.

Types of faults :-

i) Normal Fault and Reverse fault :-

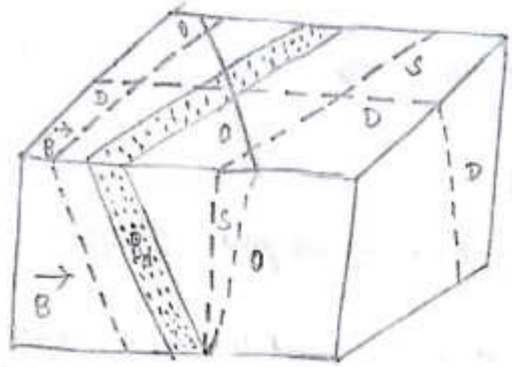
Normal Fault





Reverse fault.

Bedding fault :-



B_d → Bedding / Formation, O → Oblique / diagonal fault.

B → Bedding fault

S → Strike fault.

D → Dip fault

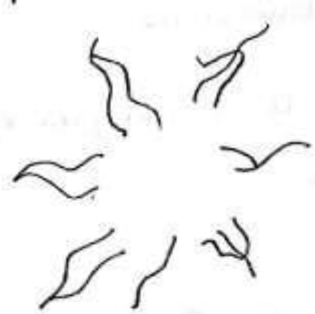
A bedding fault neccessarily runs ∥le to the bedding planes of the country rocks.

It has the same dip and strike as that of the country rocks.

It is a special type of strike fault.

Radial fault :-

A number of faults showing a radiating pattern is said to form a group of radial faults.



Recognition of faults :-

① Appearance of fault scrap (steep slopes) on the topography.

② Appearance of aligned springs.

③ Presence of polished surfaces along the fault planes.

④ Repetition and omission of strata.

⑤ In the downthrough side of a fault, an younger bed occurs against an older bed in the corresponding upthrow side.

Study of structures - joints :-

The regular / irregular cracks, developed in rocks, due to tensional / compressional forces acting within the crust, with no relative displacement b/n the affected rock blocks are called joints.

Joints occur in all types of rocks - Igneous, Sedimentary and metamorphic.

Joints may be vertical, inclined / horizontal in attitude.

Types of joints :-

(a) Primary joints :-

The joints developed in Igneous rocks, due to cooling and contraction of magma-mass are known as primary joints.

(b) Master joints :-

A very large joint, that can be traced over an extensive area, is called a master joint.

(c) Dip Joint :-

A dip joint necessarily strikes parallel to the direction of dip of the beds forming the country.

(d) Strike joint :-

A strike joint strikes parallel to the strike of the country rocks.

(5) Oblique / Diagonal joint :-

An oblique / diagonal joint strikes neither parallel to the strike of the country rock nor IIle to its dip direction (ie) its strike direction lies in b/n the dip and strike.

(6) Joint System :-

Two/ more joint sets together constitute a joint system.

(7) Columnar Joints :-

Columnar joints are developed, due to tensional forces, in lava flows.

They are developed due to intersection of two/more vertical joint sets within the affected rock mass.

As a result, the country rock is split up into a number of vertical columns which are square, rhombic, triangular, hexagonal / polygonal in outline.

(8) Conjugate joint system :-

Whenever two intersecting joint sets (whether vr. / inclined) are oriented @ rt. angles to each other, they are said to form a conjugate joint system.

(9) Sheet jointing :-

A number of closely spaced ll^le joints which are horizontal in attitude are called sheet joints.

They are well developed in granites.

When they are broken, they give rise to thin sheets / layers of rocks.

(10) Mural Joints :-

When three sets of joints (2 vr. and 1 hz.) are developed with equal spacing b/n them, they split up the rock masses into cubical blocks. Such a jointing pattern is called mural jointing.

A vertical / Inclined fault along which the hanging wall side appears to have moved relatively downwards in comparison with the adjoining foot-wall side is said to be a normal fault.

A vertical / Inclined fault along which the foot wall side appears to have been shifted downwards in comparison with the adjoining hanging wall side is said to be a Reverse fault.

Formation of normal fault :-

(1) Downward movement of the hanging wall side with the footwall stationary (or)

(2) Upward movement of the footwall side with the other block stationary (or).

(3) Downward movement of both the blocks with more pronounced subsidence of the hanging wall side (or)

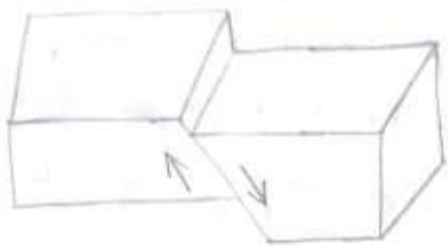
(4) Upward movement of both the blocks with more remarkable uplift of the foot wall side.

Formation of reverse faults :-

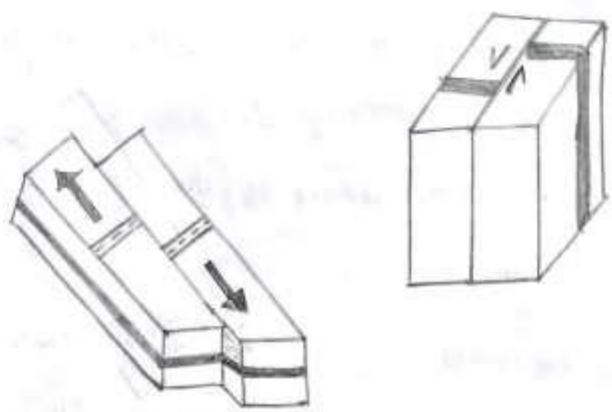
Reverse faults, on the other hand, originate due to movement of the fractured blocks in a manner exactly opposite to what have been described above.

Dip fault & Strike fault / Strike slip fault.

A vertical / inclined fault striking ||le to the direction of dip of the country rocks is known as dip fault.



Normal fault & Dip fault



Strike Slip fault

A vertical / inclined fault striking necessarily ||le to the strike of rock beds forming the country is called strike fault and if movement takes place along strike direction, it is called strike slip fault.

Oblique / Diagonal fault :-

A vertical / inclined fault striking in any direction other than the directions of dip and strike of the country rocks is described as oblique / diagonal faults.

Engineering Importance :-

As far as water supply projects are concerned, regions of jointed strata are considered to be suitable for groundwater exploration, because jointed zones will serve as aquifers.

In case of dam & reservoir project, the foundation should be made on a sound massive bed rock.

On the other hand, if the rock strata is heavily jointed, there will be significant leakage of stored water in the reservoir of dam.

For tunnel projects, the rocks should be free from joints.

If the roof / walls of a tunnel are highly jointed there will be seepage of water into the tunnel.

Lining of tunnels may be required in such cases.

In hilly terrains, jointed rocks cause instability of slopes, leading to landsliding. Many landslides and slope failure are due to the jointed nature of rocks.

In all the above cases, a treatment is required called grouting to improve the strength of the rocks.

Electrical and Seismic methods for Civil Engg. Applications.

Electrical and seismic refraction methods are employed and used in various Civil Engineering applications.

Applications :-

For ground water prospecting, required for various Govt. water supply schemes.

For soil exploration studies, required for foundation design of various Civil Engg. structures.

Bed rock investigation, required for dam & reservoir projects etc.

Electrical Resistivity Method :-

It is based upon the principle of ohm's law. (ie. $V=IR$) and universally employed for groundwater prospecting, required for various water supply schemes.

Groundwater prospecting / Investigation is carried by

(i) Electrical resistivity.

(ii) Seismic refraction methods.

Principle :-

All the materials (whether soil / rock) will conduct (or) resist current.

If they conduct current, it will be in various proportions, based on their composition and moisture content present.

The conductivity of any rock / soil is the reciprocal of its resistivity. Knowing the resitivity values, different rocks strata present in earth's crust is inferred and their aquifer characteristics are studied.

Ohm's law is the basis for the principle of this method.

Equipment Used :-

1) Resistivity meter.
2) Two current electrodes & two potential electrodes.
3) Power pack.
4) Cables, Hammers, etc.

Types / Methods of resistivity survey :-

There are two methods of resistivity survey, they are

Wenner electrode array.

Schlum burger Electrode array.

Procedure :-

In both the methods, all the four electrodes are erected firmly into the ground and a known current (I) is sent into the ground through the two current electrodes (C_1 & C_2) and the potential difference (V) b/n the two potential electrodes (P_1 & P_2) is measured.

In the case of Wenner configuration of electrodes, all the four electrodes are equally spaced whereas in case of schlumberger configuration, the potential electrodes are closely spaced and current electrodes are placed further apart.

Schlumberger array :-

Only two current electrodes are shifted laterally. In order to increase the depth of exploration, and at every shifting of electrodes, current is sent and potential difference b/n electrodes is measured. This process is repeated till the total depth of exploration is reached.

After reaching certain depth of exploration (say 50m) the potential electrodes are shifted to 1/5 th distance of current electrodes (say 10m) and the procedure is repeated.

Seismic refraction method :-

Seismic refraction and reflection methods are based on the principle that seismic / elastic waves travel with higher velocity through denser media and with lower velocity in denseless / rarer media.

Procedure :-

An explosion pit is made (shot point) in the investigation site.

A no of geophones / detectors are placed over the ground laterally. The number of geophones depends upon the depth of exploration required.

All the geophones are connected to the recording device, which is placed away from the shot point.

The explosive is fired / detonated.

The elastic waves generated, due to the detonation of explosives will start travelling in all direction.

Some waves generated due to the detonation and are generated directly reaching geophones travelling through the top soil. They are called direct waves.

Critical time :

The time taken by the wave, after detonation to get refracted from its original path is called critical time.

Critical distance :-

The distance from the shot point beyond which refraction of waves takes place is called critical distance.

For Civil Engg. applications in foundation design and (or) groundwater aquifer studies for water supply projects, the depth to bed rock should be known. So the depth of different layers of rock, is calculated.

A travel time graph (time V_s distance from geophone) is drawn and t_1, t_2, x_1 and x_2 values are obtained.

Application in Civil Engineering :-

For foundation studies :-

Soil and rock strata below the surface of the earth are inferred. Knowing the soil type and their characteristics, the type of foundation for buildings and other civil Engg. structures may be decided.

The foundation design of any civil Engg. structure also depends on the above studies

For Dam & Reservoir Projects :-

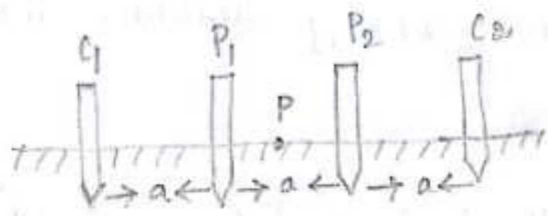
The depth to bed rock is inferred from seismic refraction studies, which help in selection of site for a dam & reservoir projects.

For water supply projects :-

Aquifer and its characteristics can be inferred and studied, from the interpretation of seismic data.

Hence seismic refraction method plays a significant role in locating suitable sites for extraction of ground water for water supply schemes.

Wenner array



Schlumberger array