# N.B.K.R. INSTITUTE OF SCIENCE & TECHNOLOGY:: VIDYANAGAR

**(AUTONOMOUS)**

**CIVIL ENGINEERING**

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**Class-Semester: II.B.TECH-I** **Course Code: 20CE2104**

**Branch: Civil Engineering** **Course Name: Engineering Geology**

## Lecture on: Unit-IV –Basics of Structural Geology

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# UNIT IV Basics of Structural Geology

- Concept of rock deformation and plate tectonics.
- Geological Structural elements as Dip and Strike.
- Fold: classification and nomenclature, Criteria for their recognition in the field.
- Faults: Classification, nomenclature and their recognition in the field.
- Types of joints and unconformities

- Rock Mass Rating (RMR), Rock Quality Designation (RQD) and Core logging.
- Calculation of true thickness and vertical thickness of rock bed.

**CONCEPT OF ROCK DEFORMATION AND PLATE TECTONICS.**

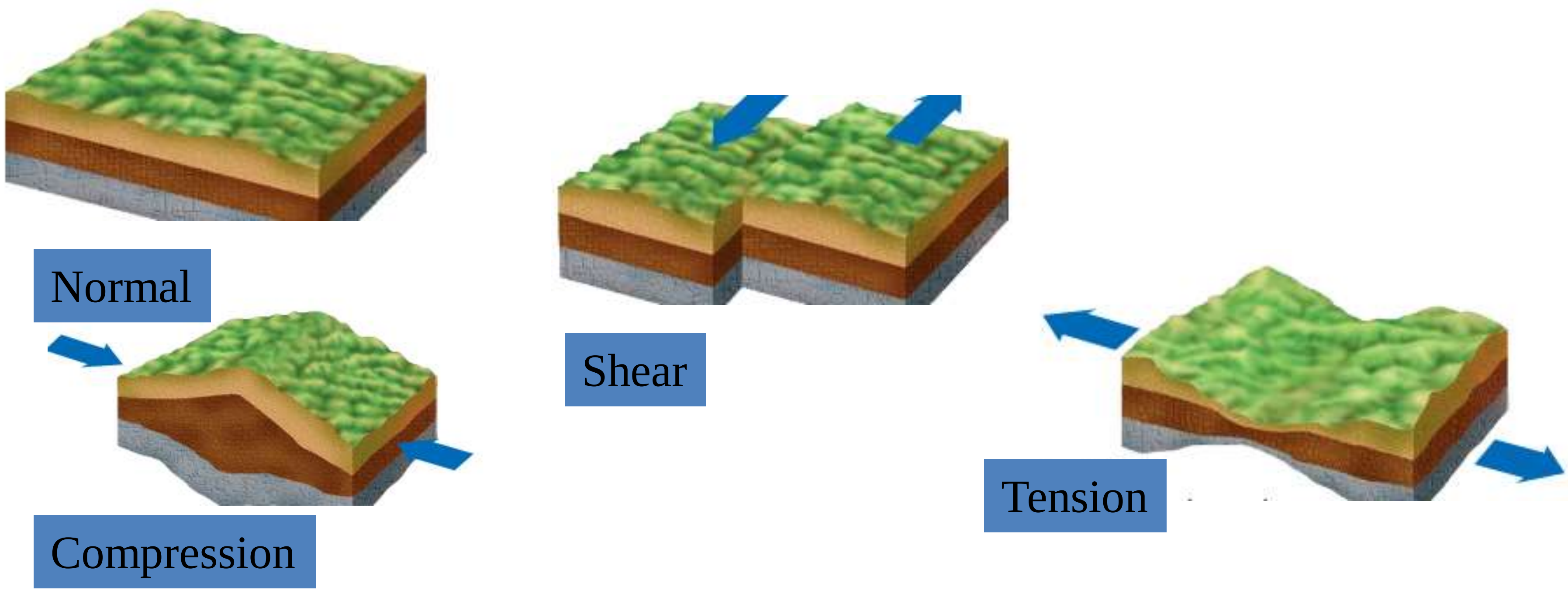
# Rock deformation:

Generally three kinds of stresses are considered in studying the rock resistivity such as

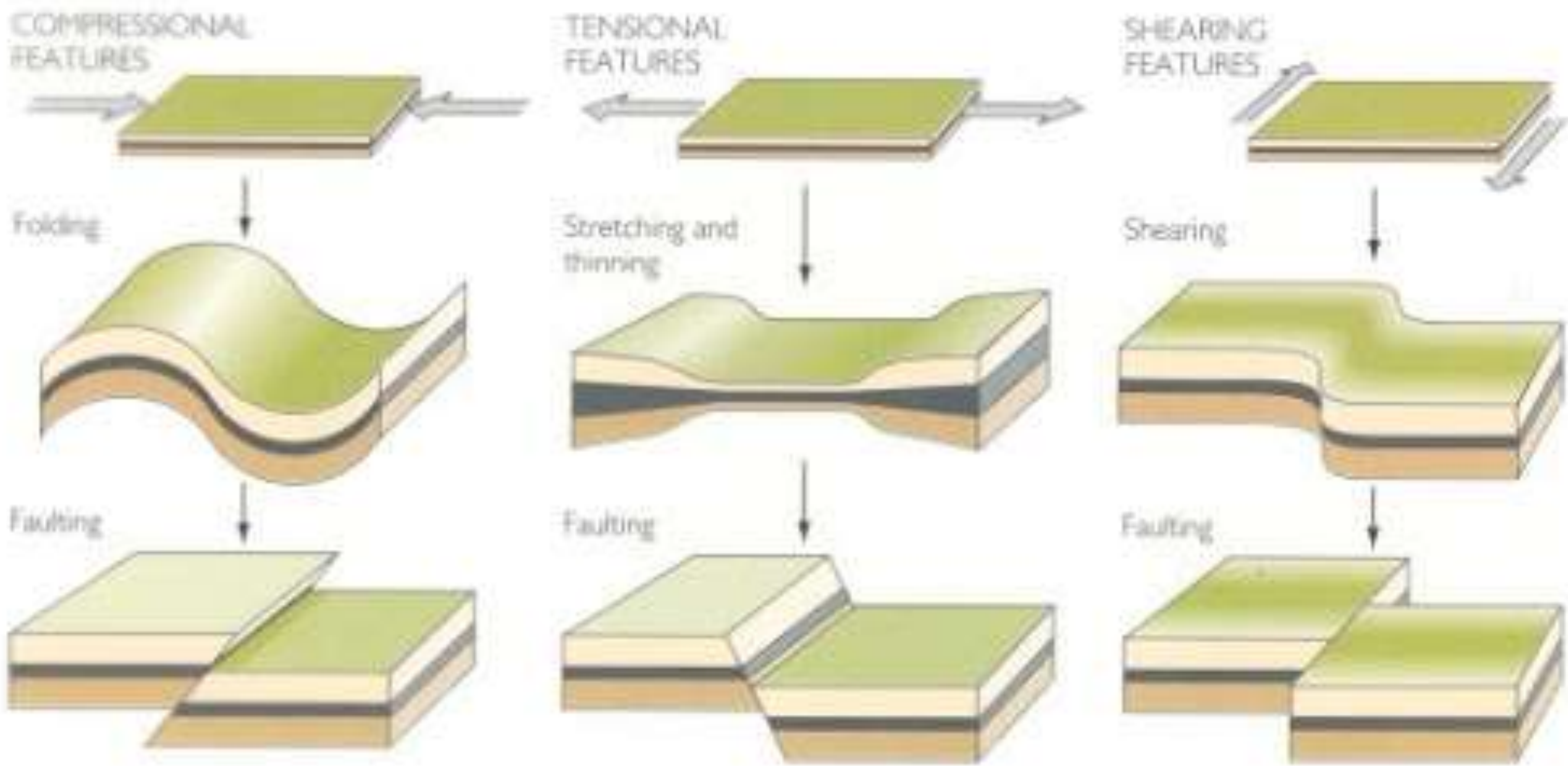
**Compressive stresses-** Tends to decrease the volume of rock material.

**Shear stresses-** Tend to move one part of the rock mass from the other make it to flow.

**Tensile stresses-** Tend to produce cracks and fissures in the rock material.



These stress causes strain in the rock through deformation and the deformed rocks shows various structures like folds,faults,joints and unconformity etc. is known as geological structures.

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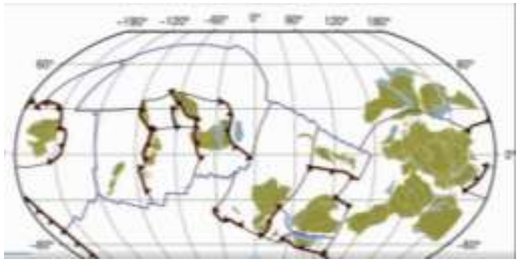
# PLATE TECTONICS:

**It is a science** describing the large-scale motion of the plates making up the Earth's lithosphere since tectonic processes began on Earth between 3.3 and 3.5 billion years ago.





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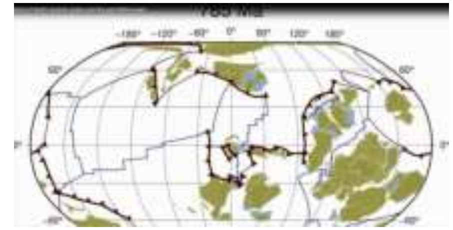

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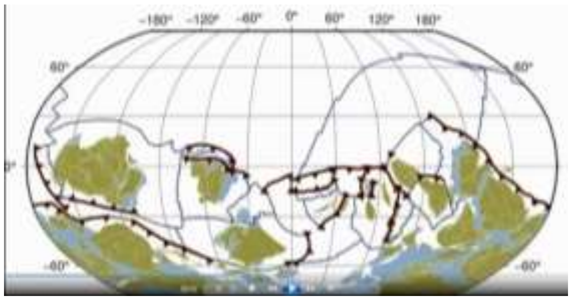

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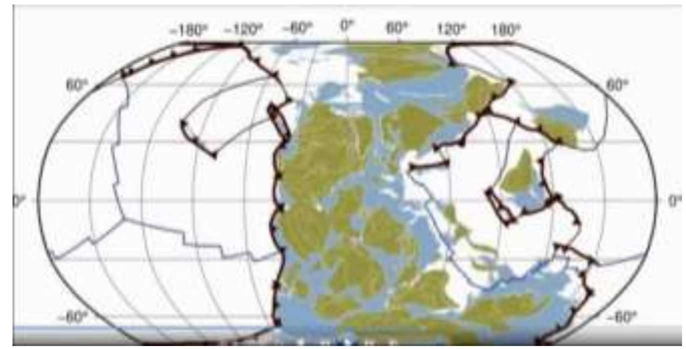


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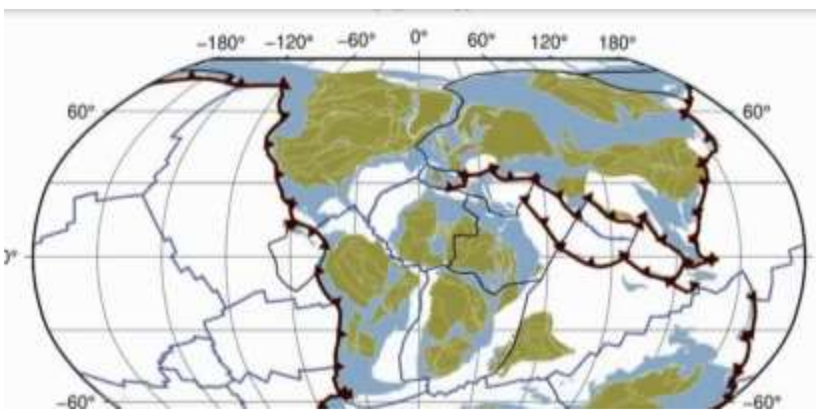


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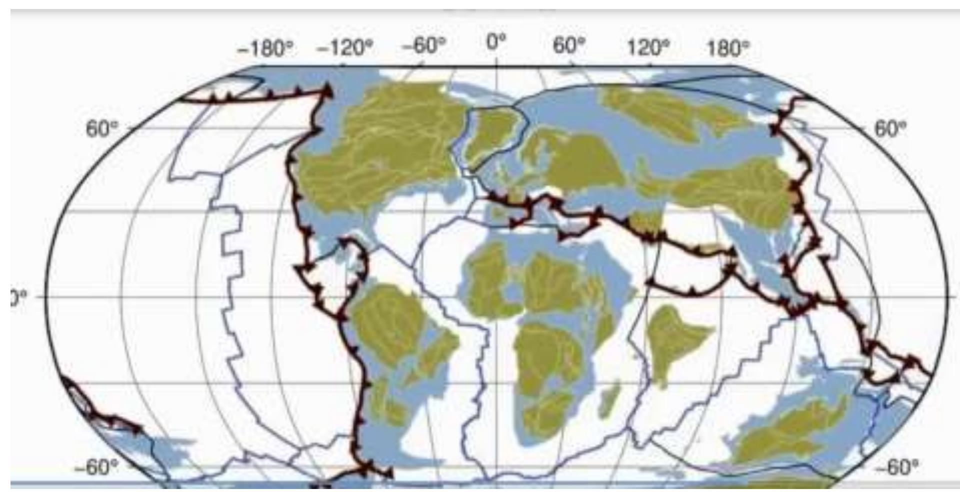


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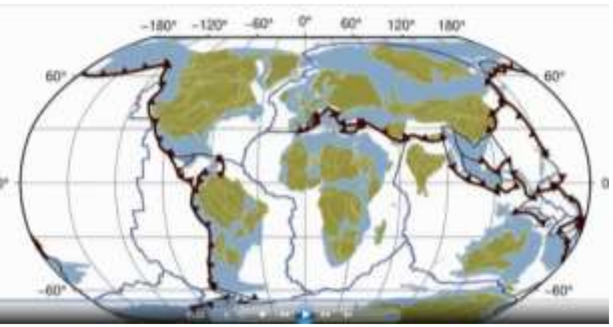

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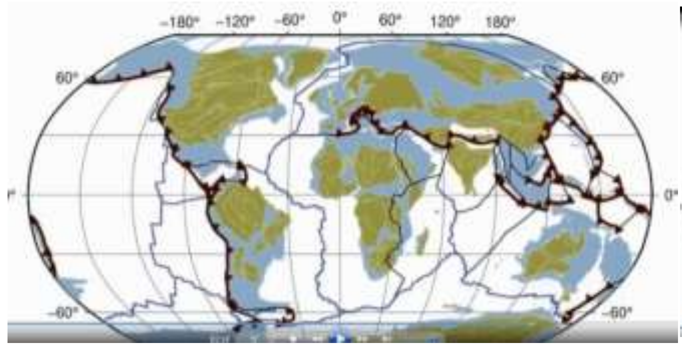

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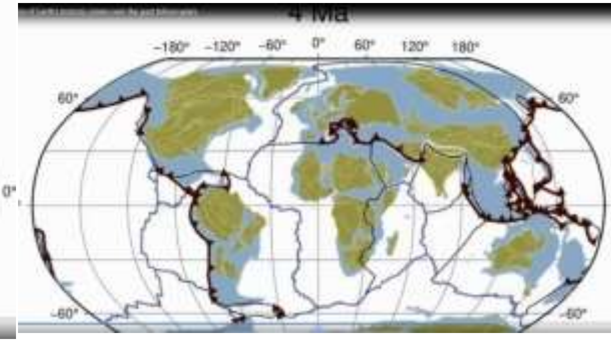

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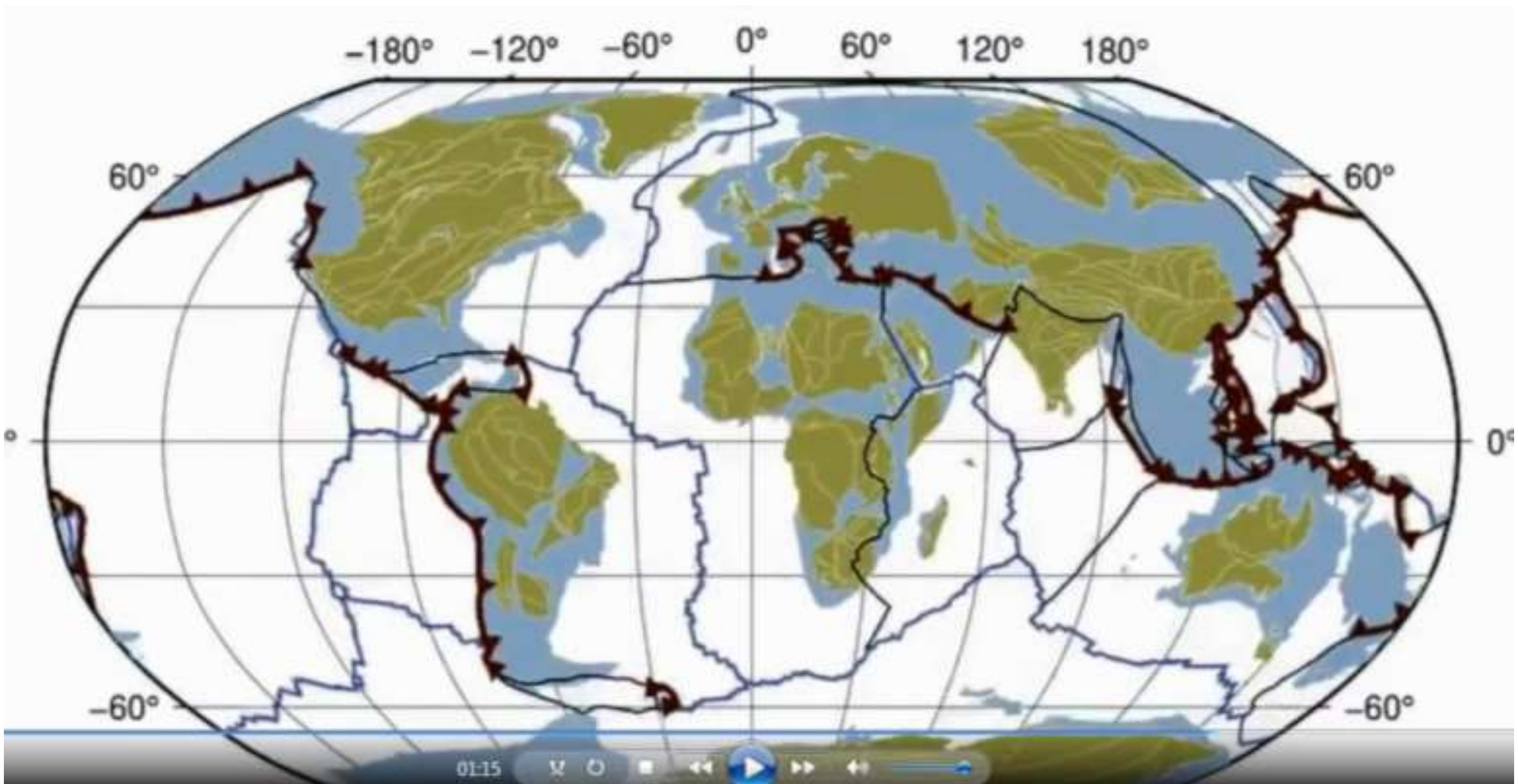



Present

**Dip and strike as elements of structural geology**

**Strike:** The direction or trend of a rock bed or layer or strata, where it intersect with horizontal plain can be defined as strike of that particular rock bed.

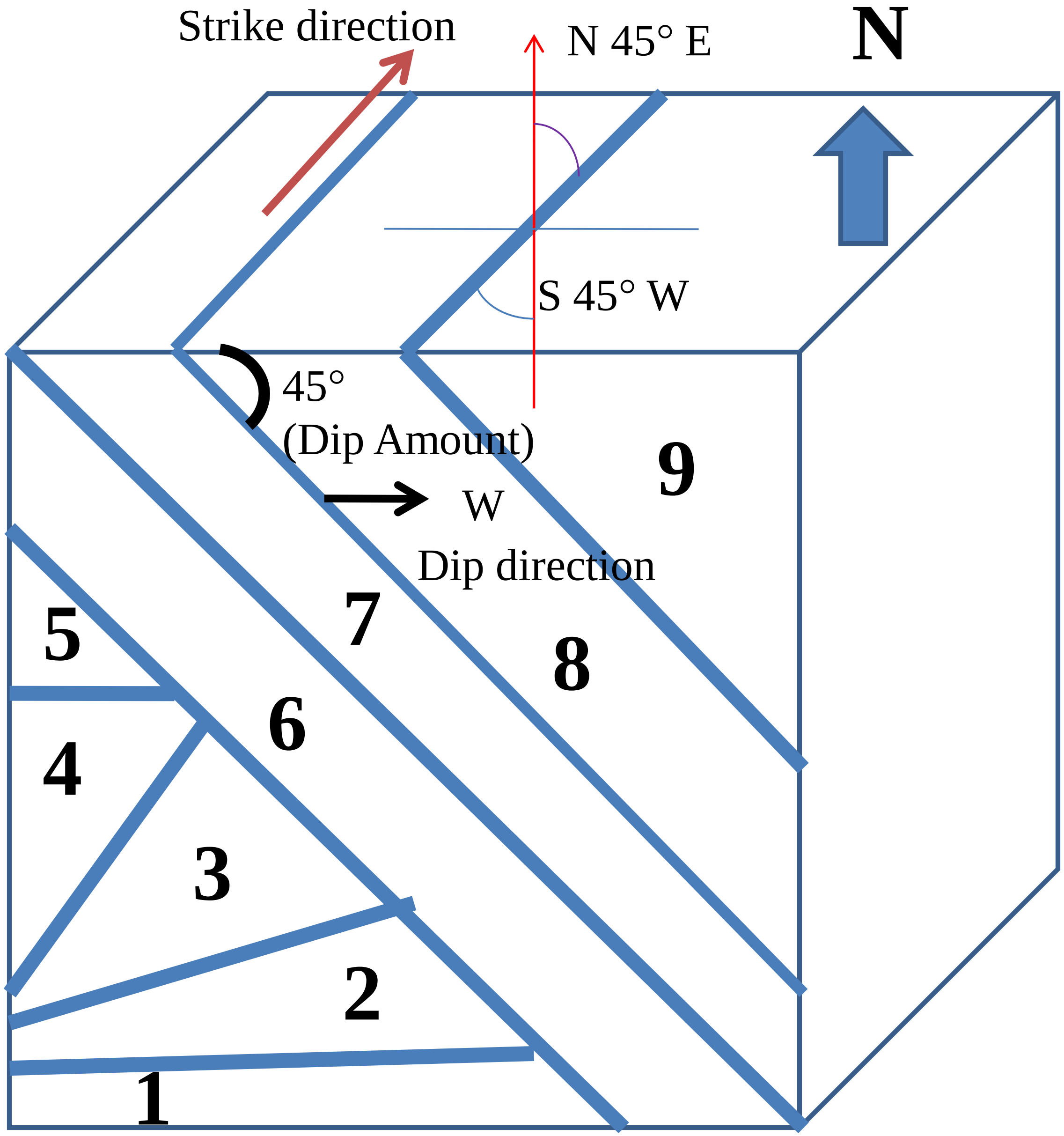
Normally strike is a direction with respect to North or South of Earth.

Strike is measured in (Degrees) N 35° E or S 35°W

**Dip:** When the rock is not in horizontal it shows inclination with horizontal plane, this inclination is known as dip of the rock bed. It has two parameters as

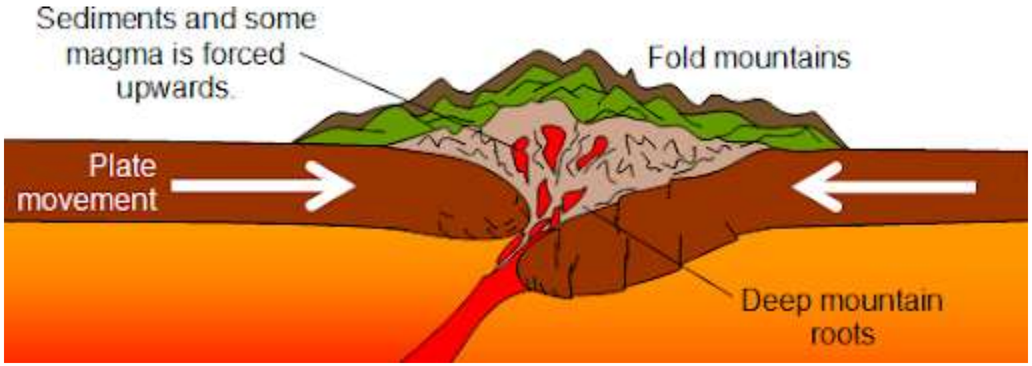
**Dip amount:** The value of inclination (vertical angle) in degrees is known as dip amount. It can be between 1°-89°, dip amount of horizontal and vertical rock beds is 0° and 90° respectively.

**Dip direction:** In which direction (horizontal direction) the rock bed is inclined or dip is known as dip direction. Dip direction measured with reference to north or south. E.g. N30° or S30° or E30° or W30°


Strike direction
N 45° E
N
S 45° W
45°
(Dip Amount)
W
Dip direction
9
7
8
5
6
4
3
2
1

**Fold:** Rocks are deformed when they subjected to compression and tension or shear, they shows a wavy structure with crest and trough is know as fold.

One or more earth's tectonic plates are moved together and may collide. At this colliding, compressing boundaries, the rocks are warped and folded into rocky out crops,hills,mountain ranges. Folded mountains are formed by the process of orogeny.




E.g.

- ➢Himalayan mountains- Here, the Indian plate is colliding northward with the Eurasian plate.
- ➢Andes-dense oceanic crust of the Nazca plate is subducting beneath the less-dense continental crust of the South American plate.
- ➢Alps- Adriatic microplate is colliding with the much larger Eurasian plate to the north.

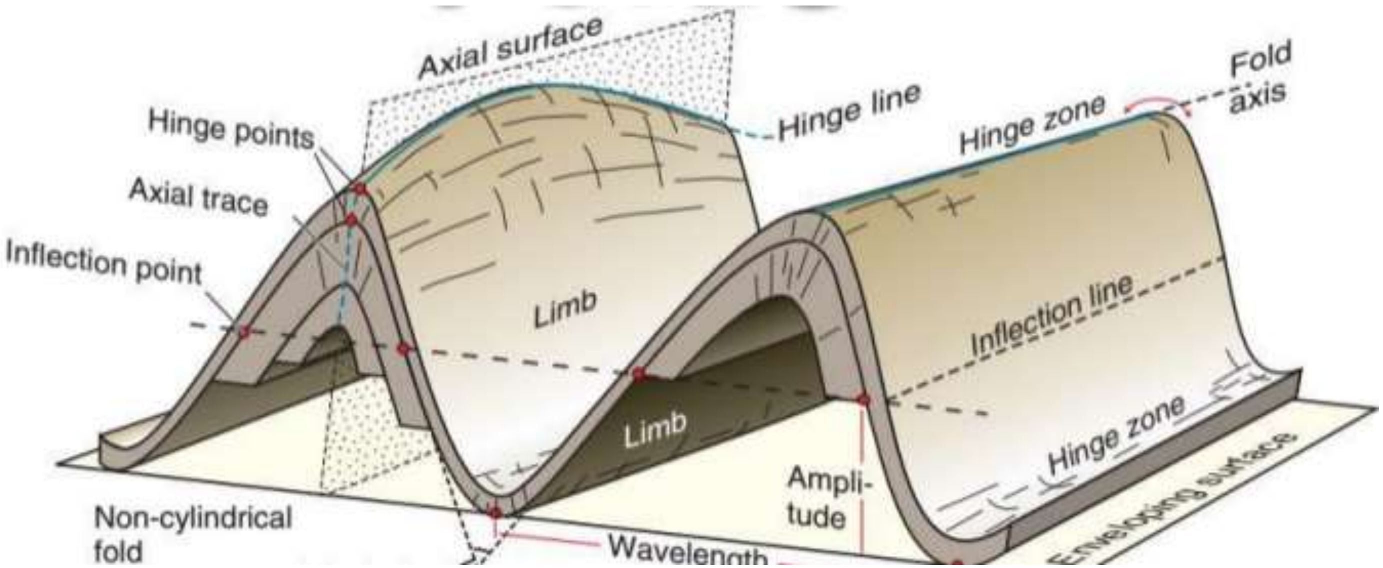
Himalaya mountains

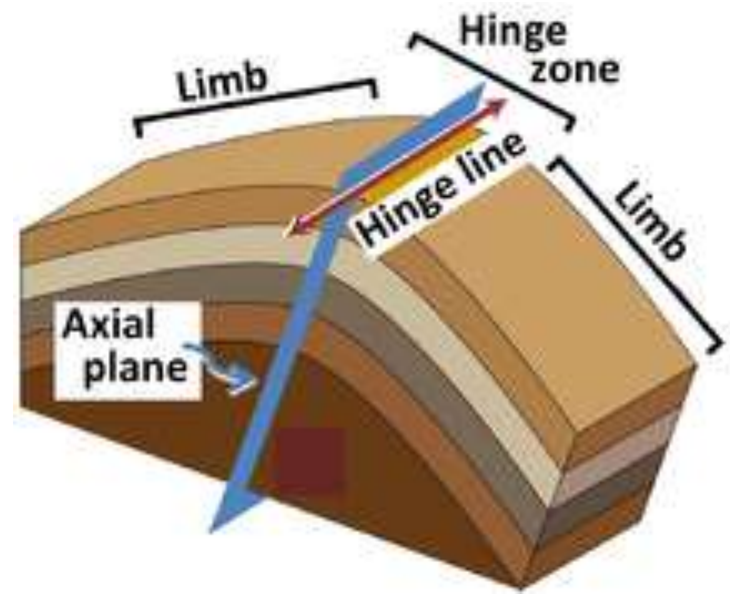
Andes mountains

Alps mountains

# Nomenclature or Parts of fold

- ✓Crest
- ✓Trough
- ✓Limb
- ✓Fold axis
- ✓Axial plane
- ✓Wavelength
- ✓Plunge

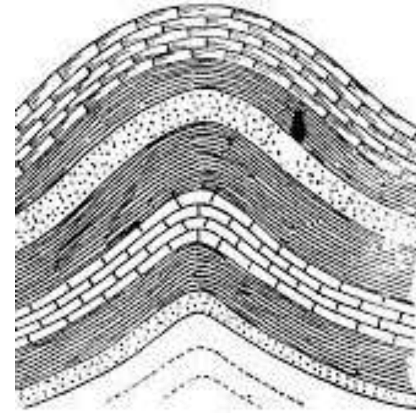


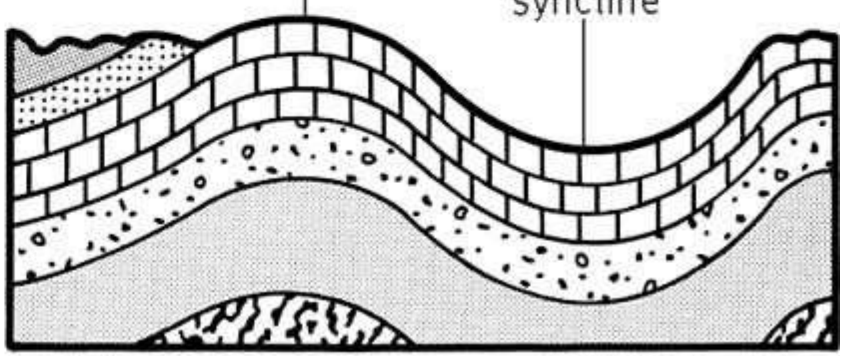



# CLASSIFICATION OF FOLDS

1. **Anticline:** A fold that is convex upward is defined as an anticline. It has older rocks in the center.
2. **Syncline:** A fold that is convex down ward is defined as syncline. It has younger rocks in the center.

Anticline

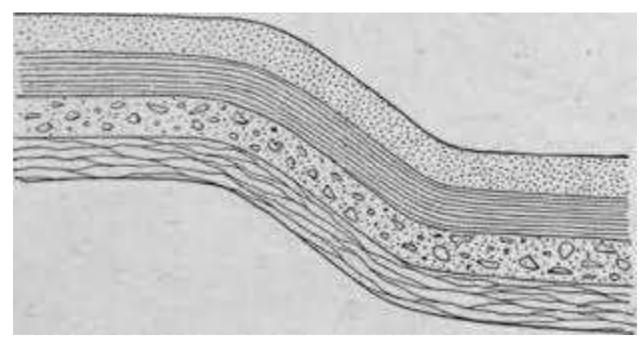





Syncline

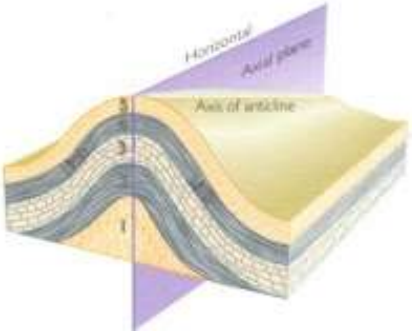
3. **Monocline:** It is a step like bending or fold in rock strata consisting the zone of steep dip within the horizontal or gently dipping sequence.

Monocline

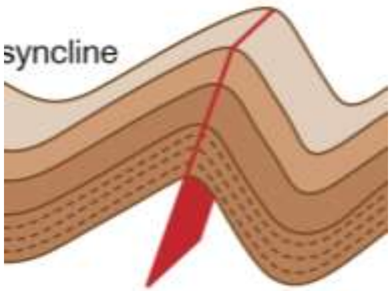


# Classification of fold

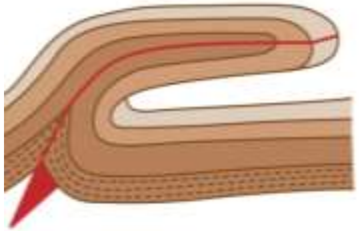
**4.** **Symmetrical folds:** A fold in which axial plane is essentially vertical or upright is known as symmetrical fold.




**5.** **Asymmetrical folds:** An asymmetrical fold is defined as one in which axial plane or surface is inclined.

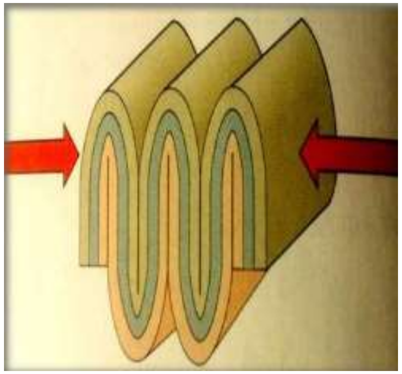



**6.** **Recumbent folds:** It is one fold in which the axial plane is essentially near horizontal.



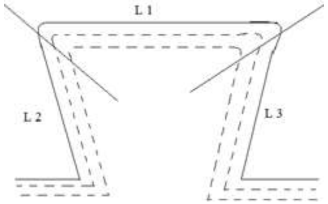
# Classification of fold

**7.** **Isoclinal folds:** Folds in which the limbs are dip at equal angle in the same direction. (These may vertical isoclinal,inlclined isoclinal and recumbent isoclinal **folds)**



**8.** **Chevron folds:** A fold with sharp hinges is defined as chevron folds.

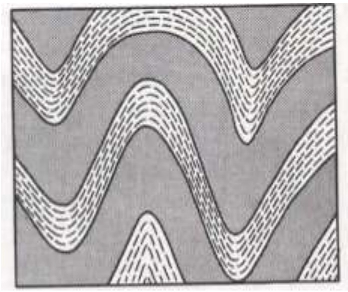
**9.** **Box folds:** The rest of the fold is flat and broad is known as box fold.



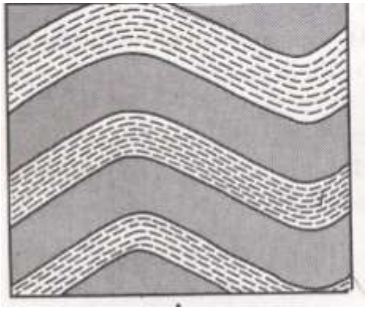

**10.** **Fan folds:** A fold in which both limbs are overturned and looks like a fan is defined as fan fold.

# Classification of fold

**11. Close or tight folds:** Due to the flowage by deformation mobile beds are become thicken and thin is known as close or tight folds.

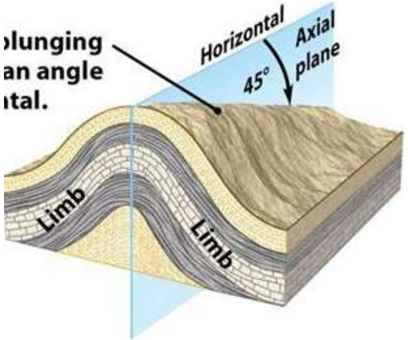


**12. Open folds:** Due to deformation without flowage, beds are shown folds is known as open folds.



**13. Drag folds:** When the competent(Hard) beds slide, incompetent (soft) bed which present between the competent beds shows minor folds due to shear is defined as drag folds.

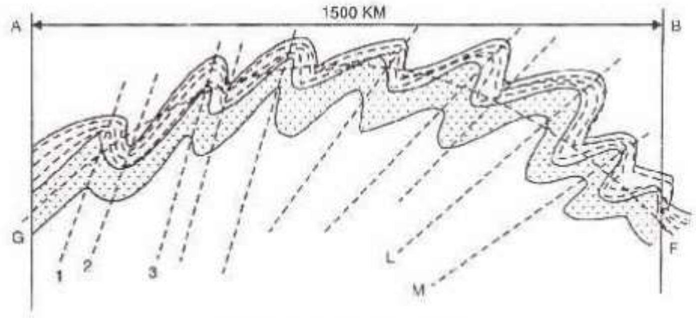
**14. Plunge folds:** A fold in which fold axis is horizontal is defined as plunge fold.



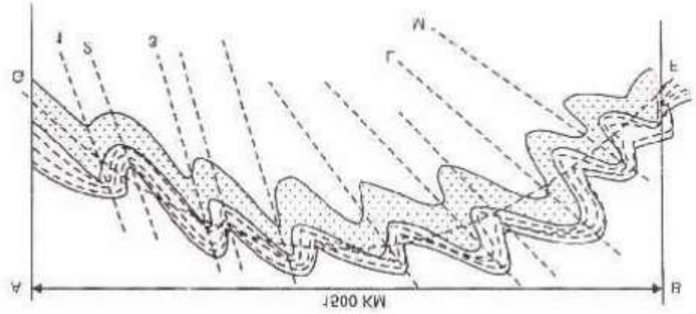
# Classification of fold

13. **Dome and basin:** Anticlinal uplift without distinct trend is called as dome. A synclinal depression that has no distinct trend is known as basin.

14. **Anticlinorium:** An antiform with various drag folds is known as anticlinorium.




15. **Synclinorium:** A major synline with numerous drag fold is known as synclinorium.



## Identification of folds in the field

1. The repetition and absence of beds also indicates the presence of fold.
2. Sometimes the flow direction of stream or river shows the presence of a fold.
3. Based on the age of the rocks present in folds.
4. Crack will be observed in the crest of the fold.

# Faults

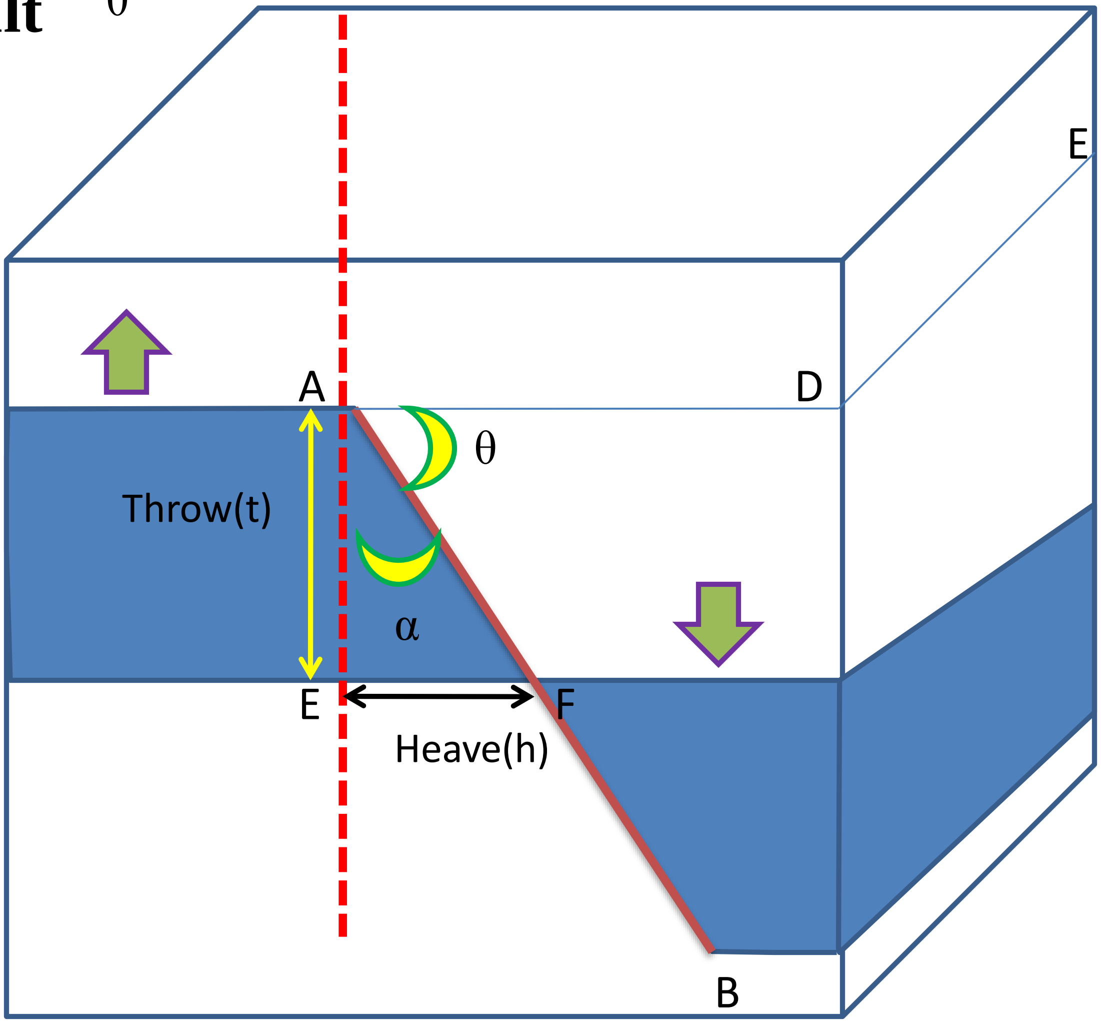
**Faults:** As rocks undergo brittle deformation, they may fracture.

If displacement occurs along these fractures are referred to as **faults.**

# Terminology of Fault

θ

- ✓Fault plane (AB)
- ✓Dip of fault (θ)
- ✓Through of the fault(t)
- ✓Heave of the fault(h)
- ✓Hanging wall
- ✓Foot wall
- ✓Hade of fault
- ✓Strike of the fault



## Classification of Fault

- ✓Normal fault
- ✓Reverse fault
- ✓Strike slip faults
- ✓Dip slip faults
- ✓Oblique slip faults
- ✓Pivotal faults or scissor faults
- ✓Horst and Graben
- ✓Low angle fault
- ✓High angle fault
- ✓Radial faults
- ✓Step faults
- ✓Parallel faults

Normal fault

**Normal fault:** A fault in which hanging wall shows down ward movement along fault plane due to gravity is defined as normal fault

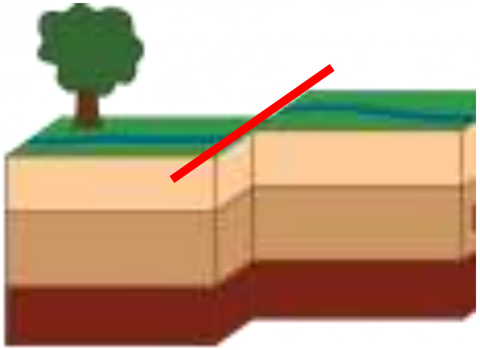
Normal fault

**Reverse fault:** Where the hanging wall shows in upward movement by the forces which are in opposite direction to gravity.


Reverse fault

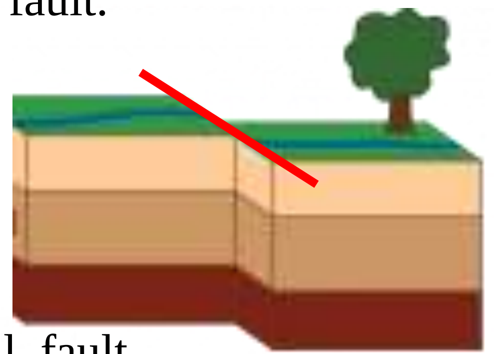
**Strike slip fault(wrench fault):** The displacement has been essentially parallel to strike of the fault is known as strike slip fault.

- ✓If the for wall side slip or moves towards right hand side of the observer, it is known as dextral fault.



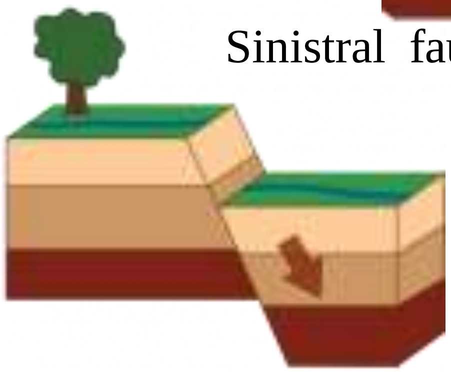
Dextral fault.

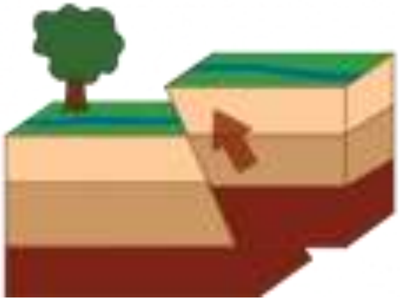
- ✓If the for wall side slip or moves towards left hand side of the observer, it is known as sinistral fault.



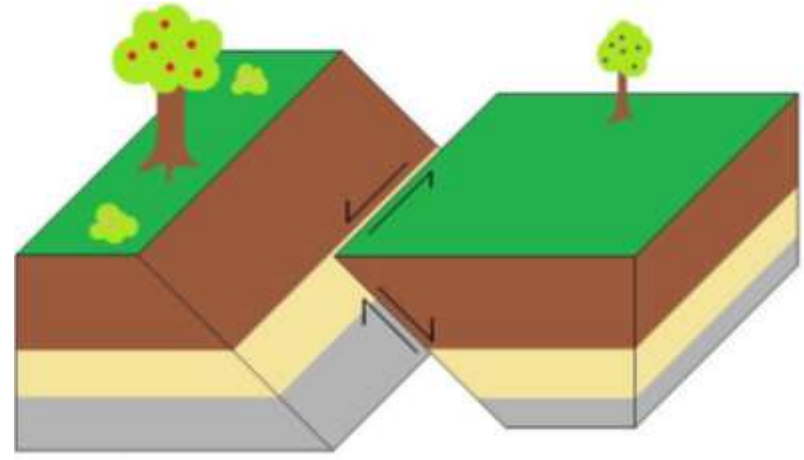
Sinistral fault.

**Dip slip fault:** In a fault slip or displacement is along dip of the fault plane is known as dip slip fault

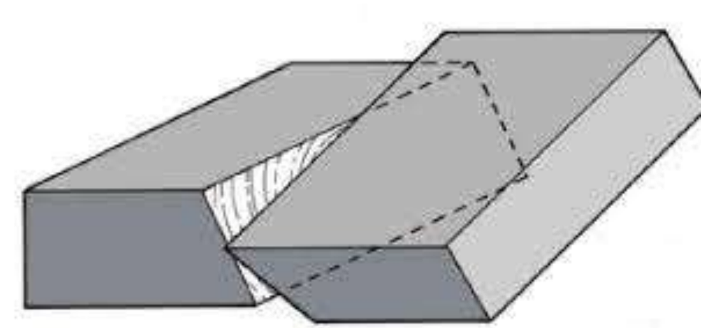


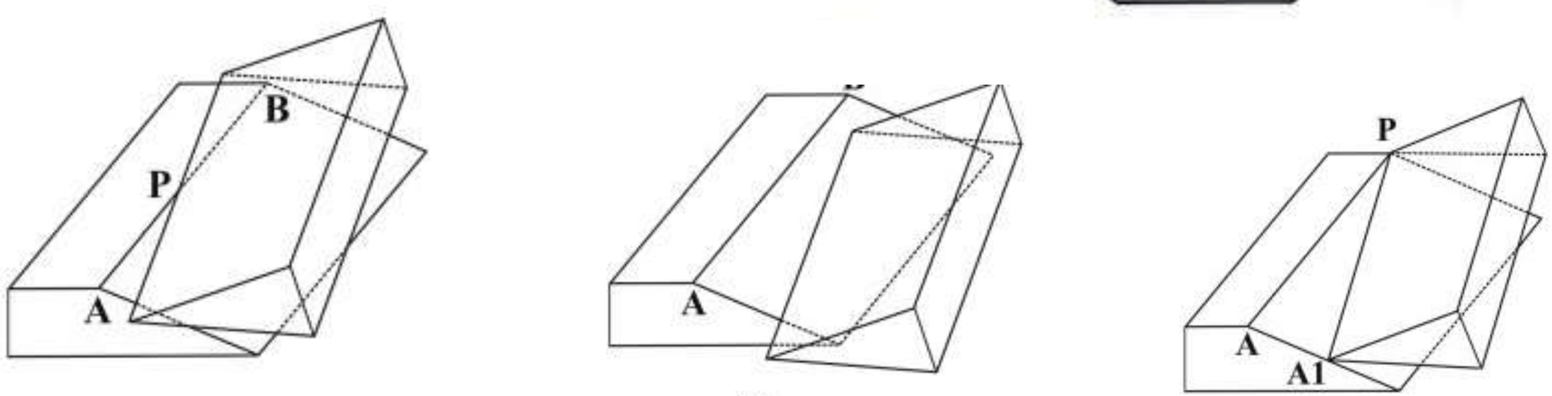


**Oblique slip fault:** In a fault both strike slip and dip slip occurred, it is known to be oblique slip fault.



**Pivotal or rotational faults :** Due to slip at a particular point on the fault plane, block shows rotational slip and these faults known as pivotal faults.

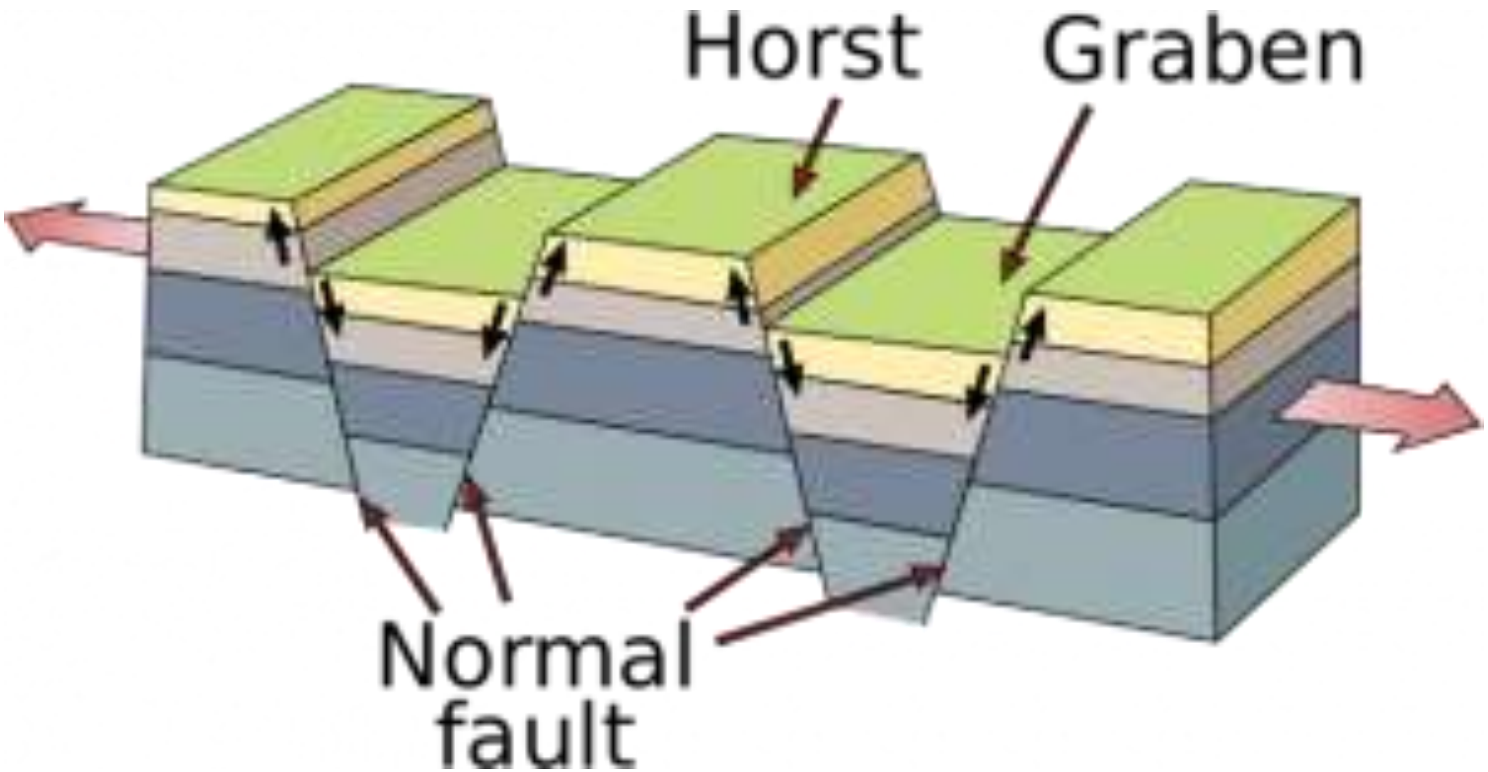




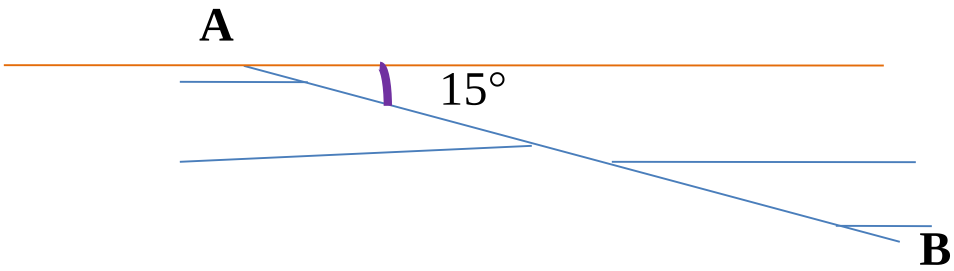
## When normal step faults occurs with opposite dip direction.

➢**Horst:** Block between these fault planes pushed upward relative to the blocks on either side is known as **horst.**

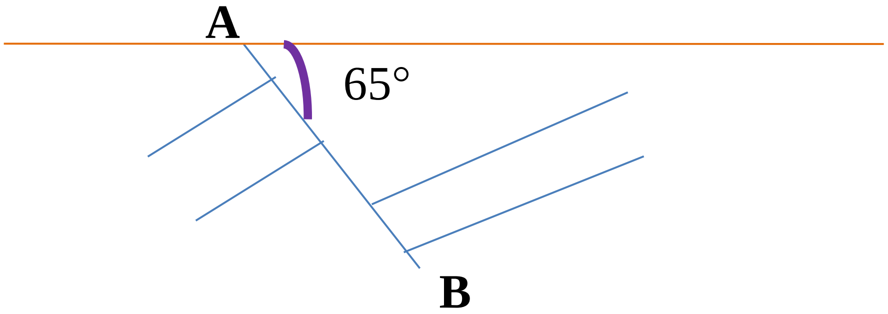
➢**Graben:** Block has been lowered relative to the blocks on either side of fault plane is termed as **graben**.



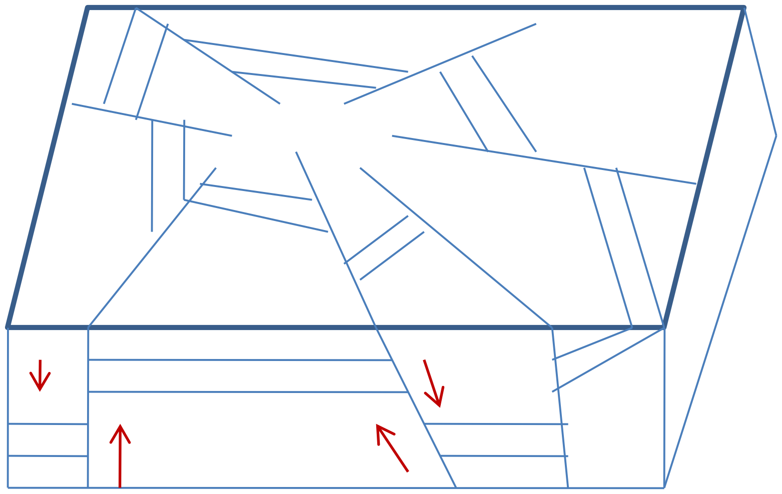
**Low angle faults:** Faults that dip <45° is known as low angle faults.



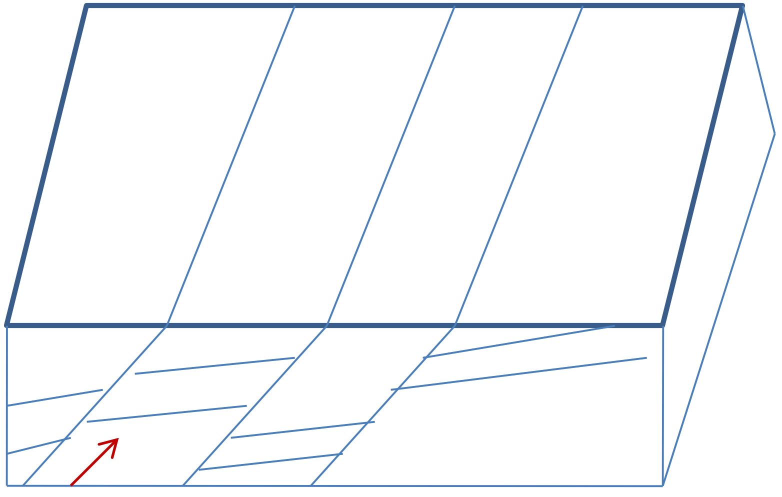

**High angle faults:** Faults, those dip is > 45 ° is known as high angle faults.



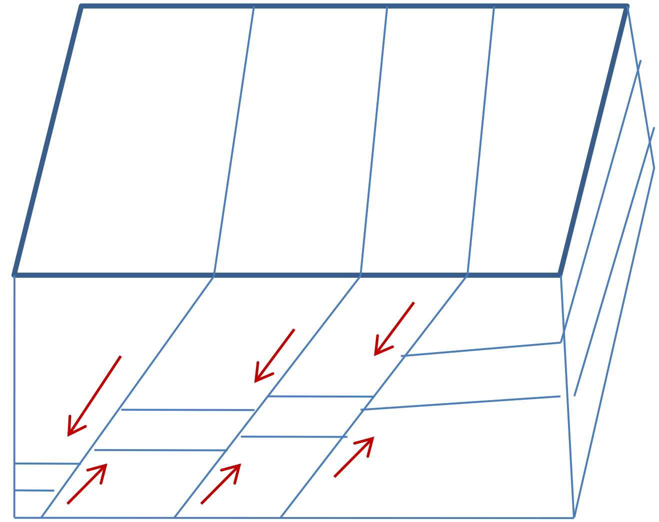
**Radial faults:** A group of faults that appear emerging outward from a common point is called radial faults.



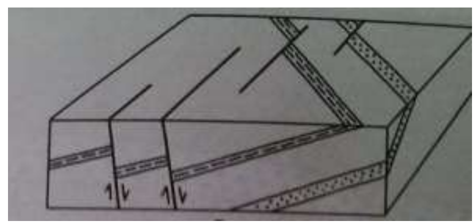
**Parallel faults:** Numerous Faults, those with same strike and dip is called as parallel faults .

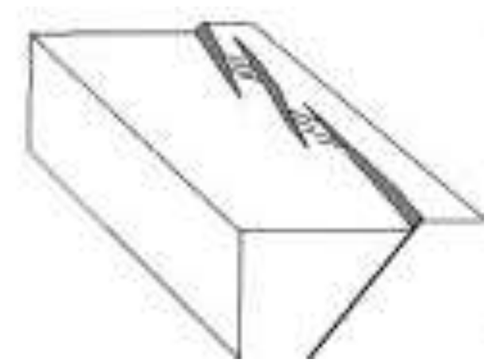


**Step faults:** Faults, which shows step like form is known as step like faults.

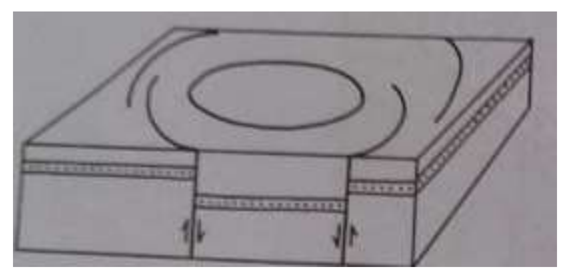


**Enechelon faults: These are short f**aults that overlap each other.





**Peripheral faults:** Faults, which are bound to circular or arcuate area.

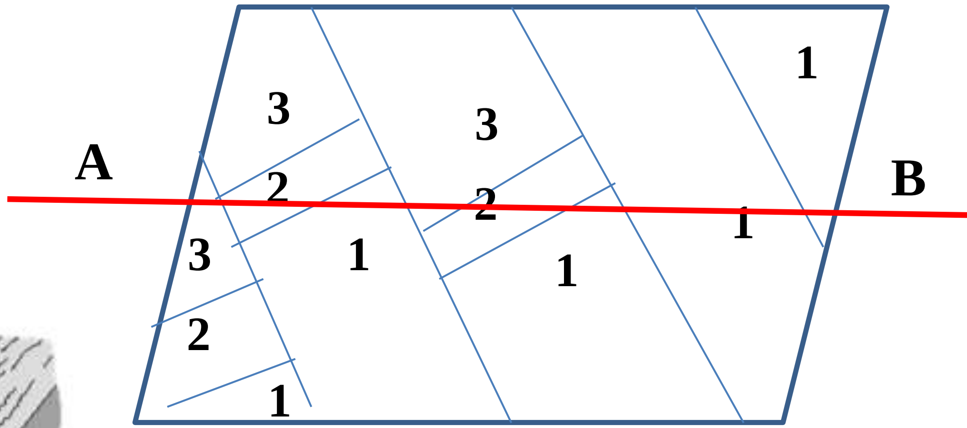


# Recognition or evidences of faults in the field

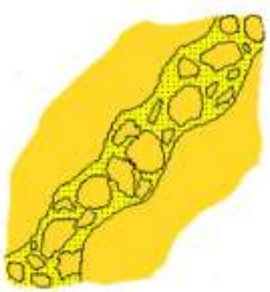
In the field, a number of criteria are used to recognize faults, such as **stratigraphic** and **physiographic** evidences .

## I. Stratigraphic evidences

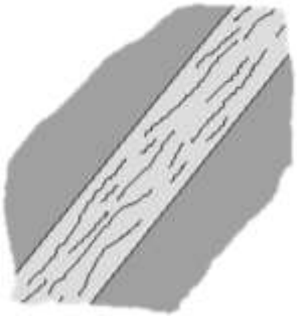
1. Discontinuity of rock beds or layers or structures.
2. Repetition or omission of rock strata.
3. Solidification and mineralization along shear zone or fault zone.
4. Presence of some characteristic features along fault plane or in fault zone.
    - ✓Slickenside
    - ✓Gouge
    - ✓Fault breccia




Slickenside



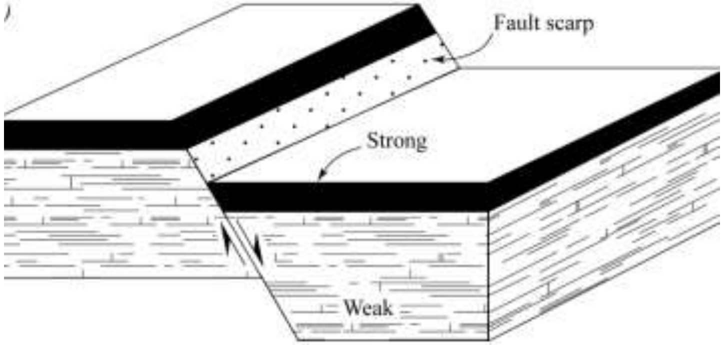
Faulted breccia



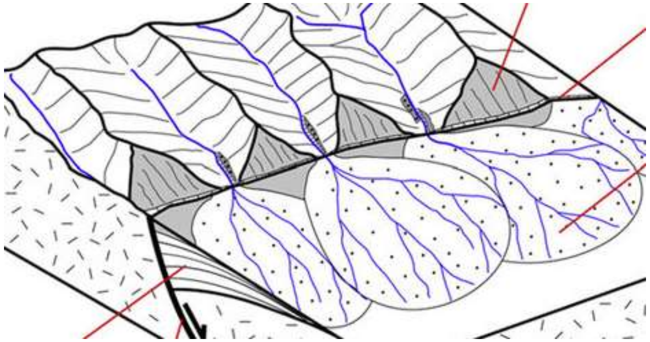
Gouge

## II. Physiographic evidences

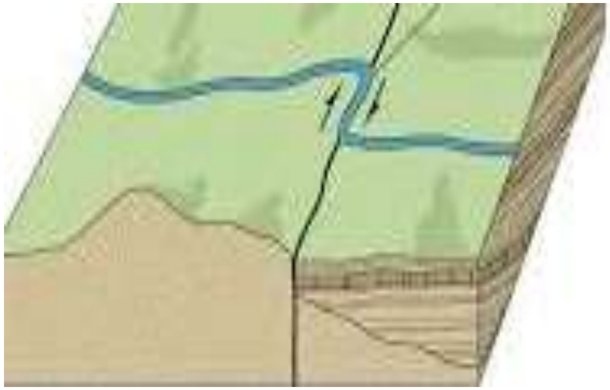
1. Fault scarp
2. Springs and hot springs(geysers)
3. Offset streams
4. A break in stream profile
5. Triangular facets




Fault scarp



Break in stream profile and triangular facets

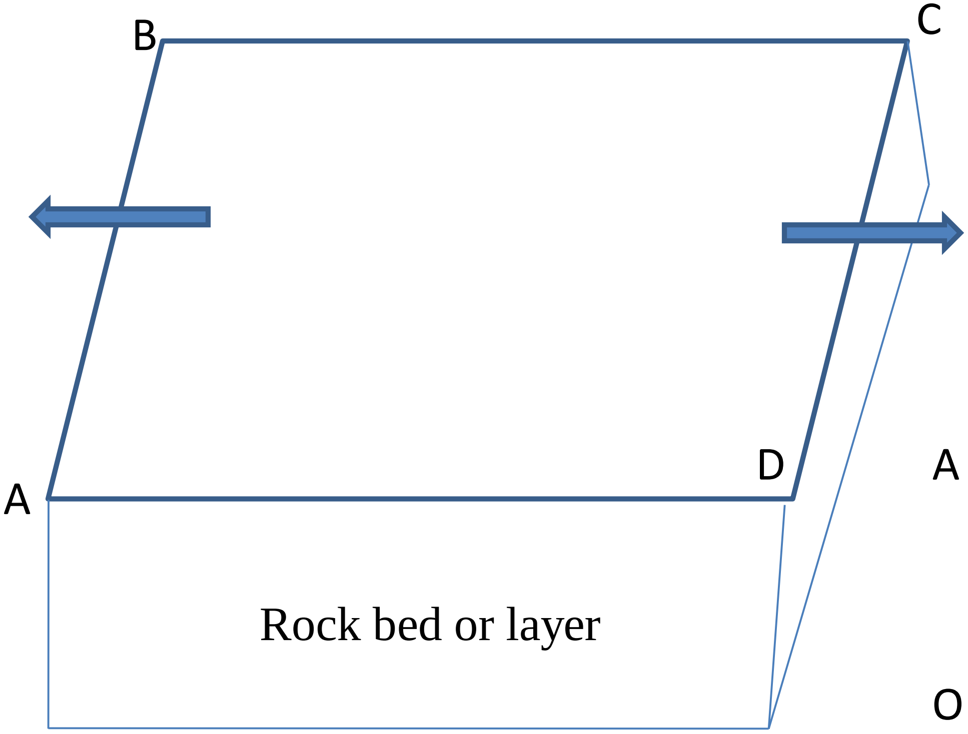


Offset stream

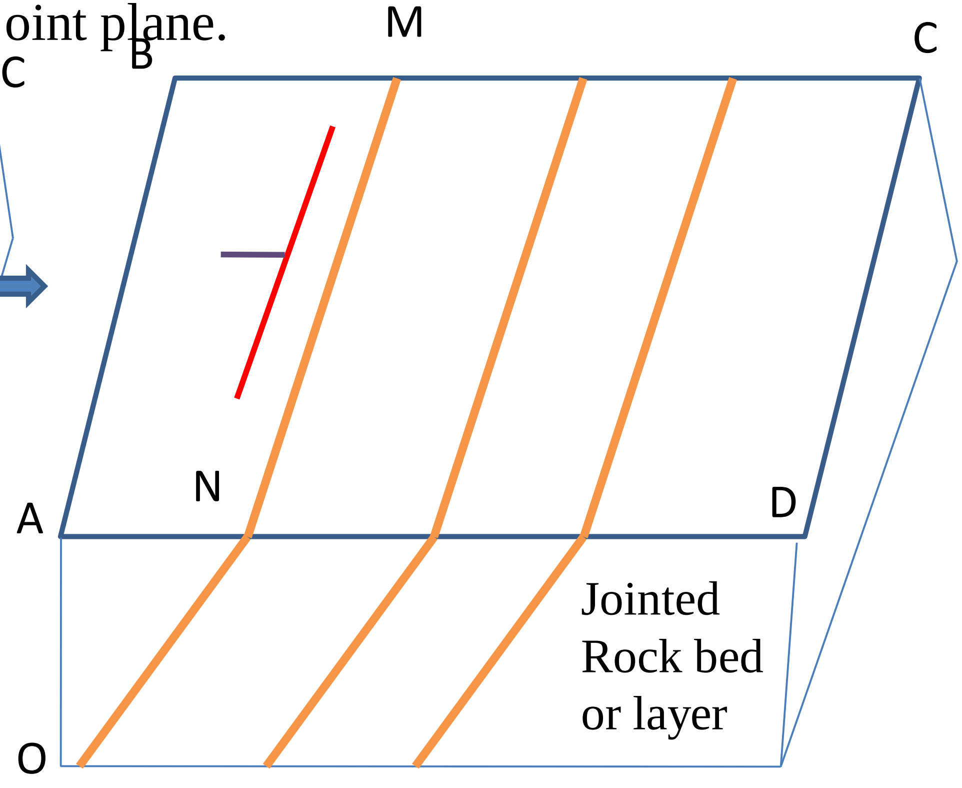
# Joints

**Joint:** When rocks are broken by closely spaced fractures. Width and length of these fractures measured in inches to fraction of inches and feet to hundreds of feet respectively is defined as joints.

Normally there has been no visible movement (practically slight movement has observed) parallel to joint plane.



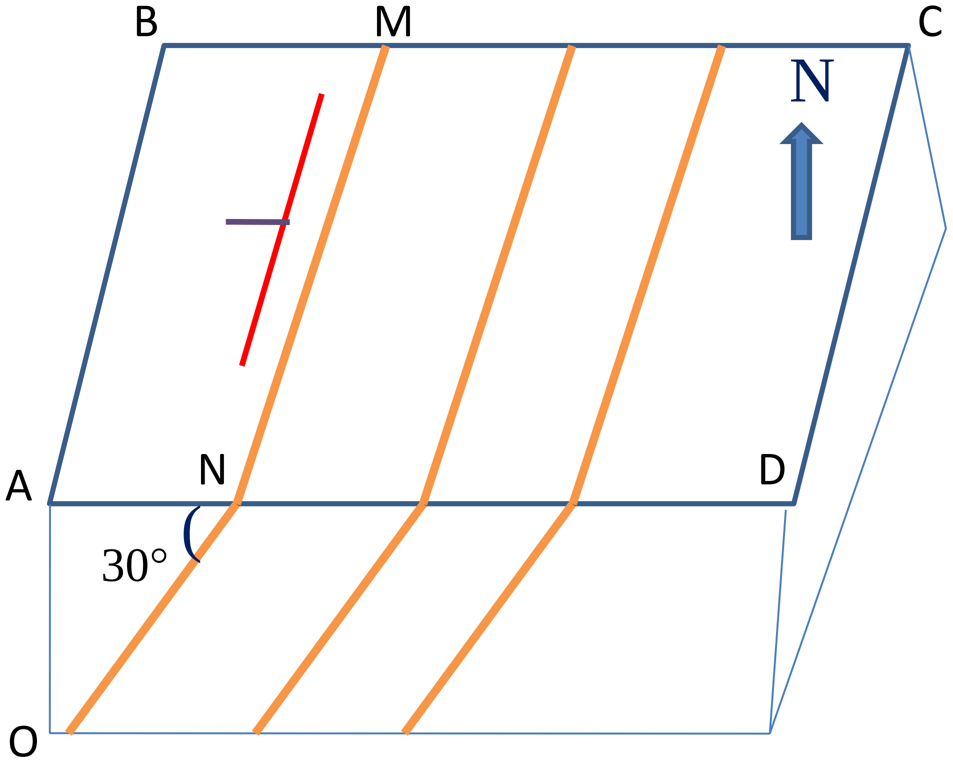

Before joints




After joints

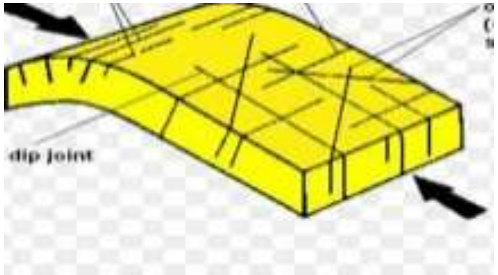
**Nomenclature of Joint:** Joint also denoted with various names as

- ✓Joint plane(MNO)
- ✓Strike of the joint(MN)
- ✓Dip of the joint(West 30°)

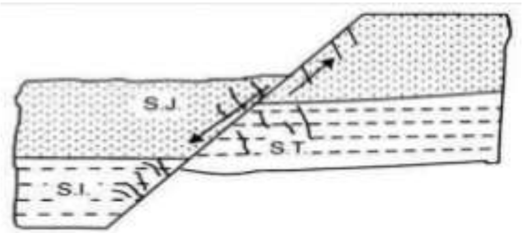


**Classification or types of Joints in rocks**

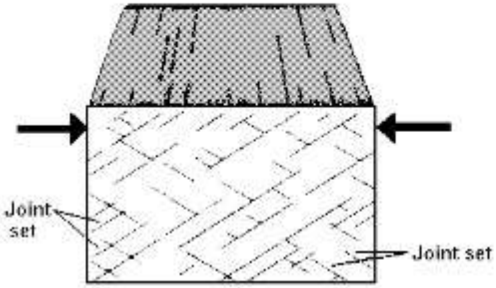
I. **Genetic joints**
   a. Tensional joints
   b. Shear joints
   c. Compressional joints
   d. Mural joints
   e. Sheet joints
   f. Columnar



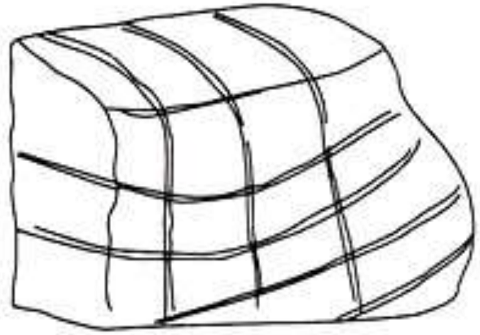

Tensional Joints



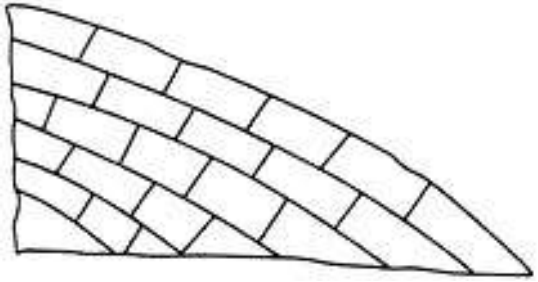

Shear Joints



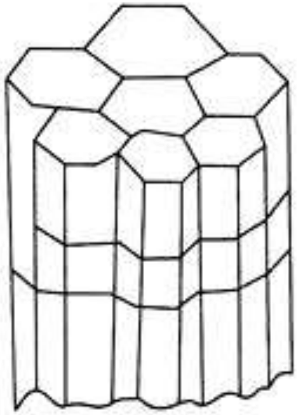

Compressional Joints



Mural Joints



Sheet Joints



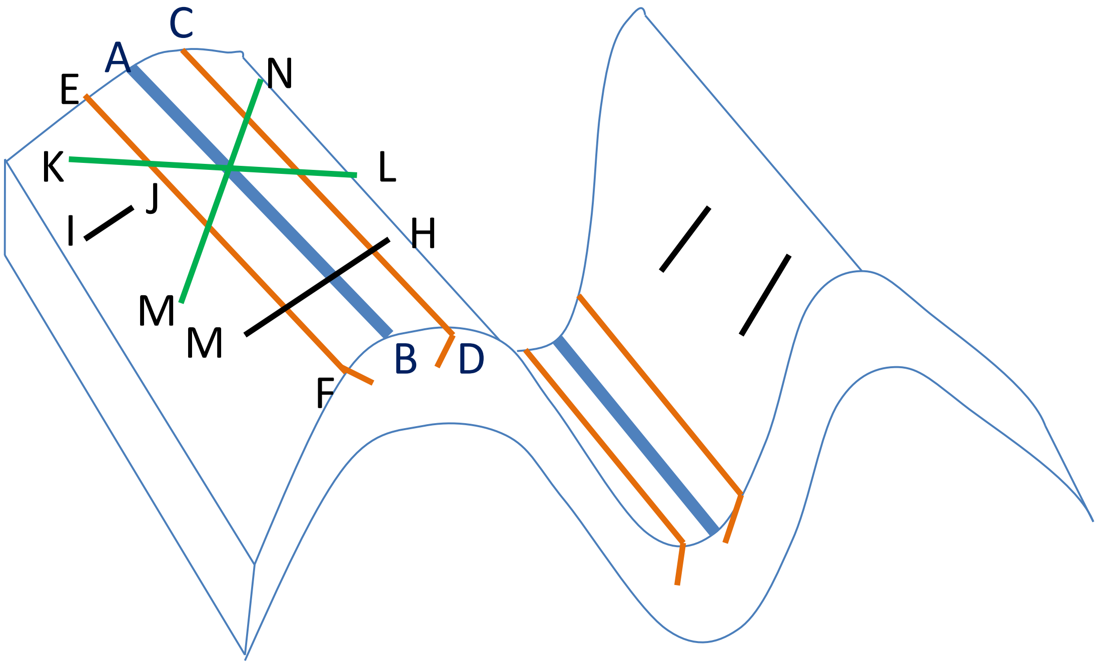
Columnar Joints

## II. Release and Extension joints(folded region)

a. **Longitudinal or released joints(CD and EF):** Joints parallel to fold axis is defined as longitudinal joints.

b. **Cross-joints or extensional joints(GH and IJ) :**Joints perpendicular to fold axis is known as cross joints.

c. **Diagonal joints:** Set of conjugate joints, those strike oblique to fold axis is called diagonal joints.



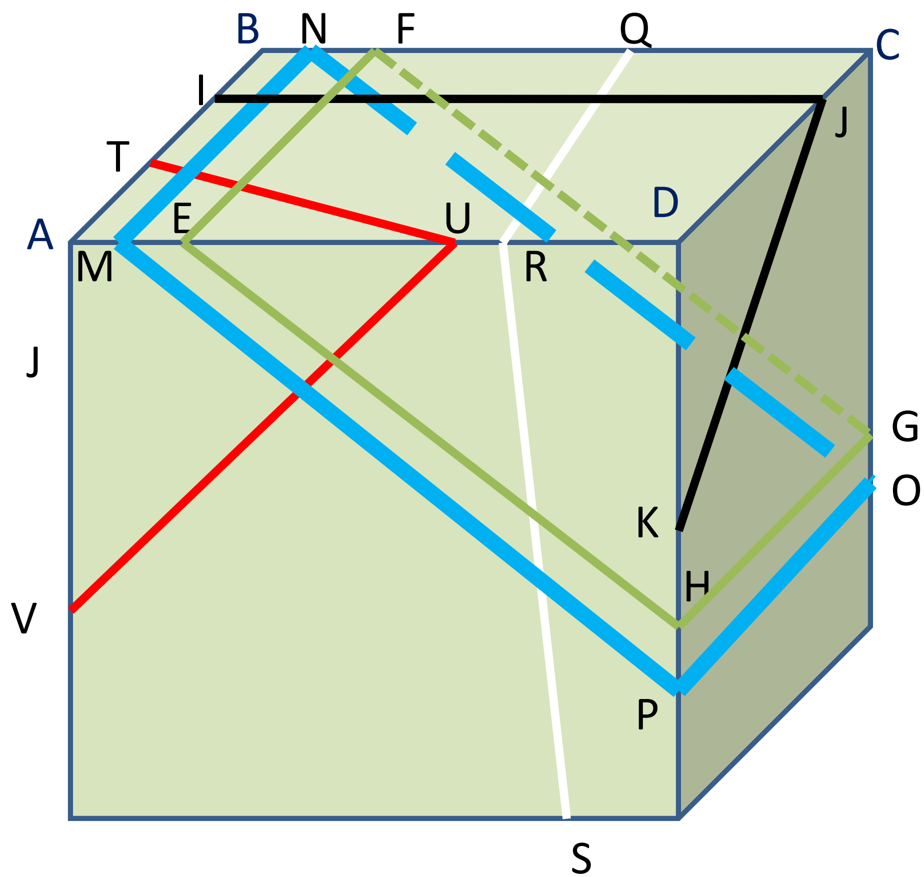
**III. Geometrical joints**

a. **Strike joints(QRS): Strike of** joint is parallel to strike of the bed is observed in strike joints.

b. **Dip joints(IJH):Joints those s**trike is parallel to dip of the bed is known as dip joints.

c. **Bedding joints(EFGH):** Both strike and dip of joint is parallel to strike and dip of the bed is known as bedding joint.

d. **Diagonal joints(TUV):** Strike and dip is diagonal to strike and dip of bed is called diagonal joint



**IV. Miscellaneous joints**

a. Tectonic joints
b. Hydraulic
c. Exfoliation
d. Unloading
e. Cooling

**Why study of joints for civil engineering**

✓ Joints have a profound control on weathering and erosion of bedrock.

✓Joints are important in the safe design of structures, development of natural resources, and environmental protection.

✓As a result, they exert a strong control on how topography and morphology of landscapes development.

✓Joints often impart a well-develop fracture-induced permeability, strongly influence and even control the natural circulation (hydrogeology) of fluids, e.g. groundwater and pollutants within aquifers, petroleum in reservoirs, and hydrothermal circulation at depth, within bedrock.

# Unconformity

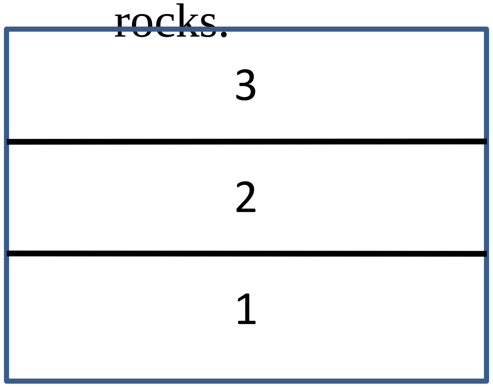
➢Non depositional or erosional surface or plane formed by the noncontinueous deposition or erosion of rock layers is defined as unconformity.

➢It separates younger strata from the older strata.

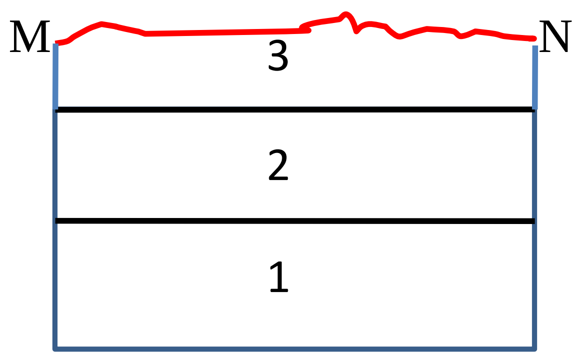
➢Various rocks, such as sedimentary, volcanic, plutonic or metamorphic rock are may participate in unconformities.

**Steps involved in formation of unconformity**

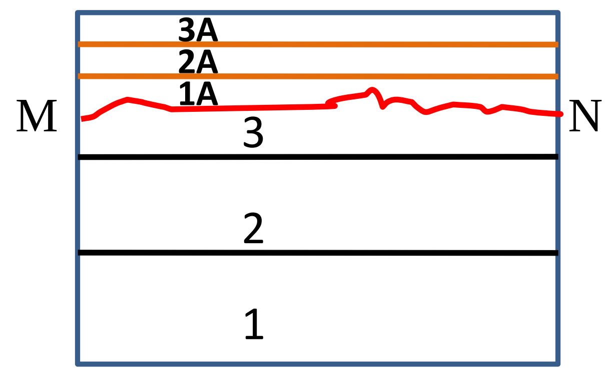
a. Formation or deposition of older rocks is first stage of an unconformity.
b. Second stage of an unconformity is an uplift and erosion of older rocks.
c. Deposition of younger strata by that it make difference in age with an older rocks.




Formation of older rocks(1,2,3 layers)



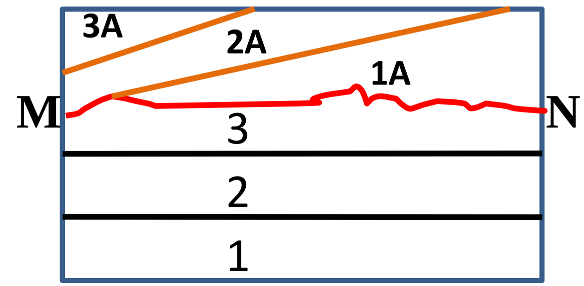

Erosion of older rocks(3) without deposition for long geological period.



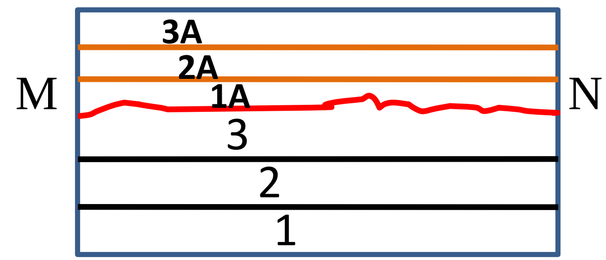

Deposition of younger rocks (1A,2A,3A)on plane of unconformity i.e. MN.

# Types of unconformities:

**Angular unconformity:** Rocks above or below the plane of unconformity is making an angle with each other is know as angular unconformity.




**Disconformity:** In a disconformity the formations or rock strata on opposite sides of an unconformity are parallel.




**Local uconformity:** It is similar to disconformity, but distinctly local in exist and short interval of time or age between older and younger rock layers of an unconformity.

**Nonconformity:** If the older rocks is in plutonic origin of an unconformity, it is defined as nonconformity.

## Recognition of an unconformity:

➢Lack of parallelism of the rock beds on either side of unconformity plane.

➢These can be observed in exposed outcrops, road cuts and quarries.

## Significance of study of unconformities:

✓ The rocks above and below the unconformity may show variation in their strength properties and affect the stability of the project.

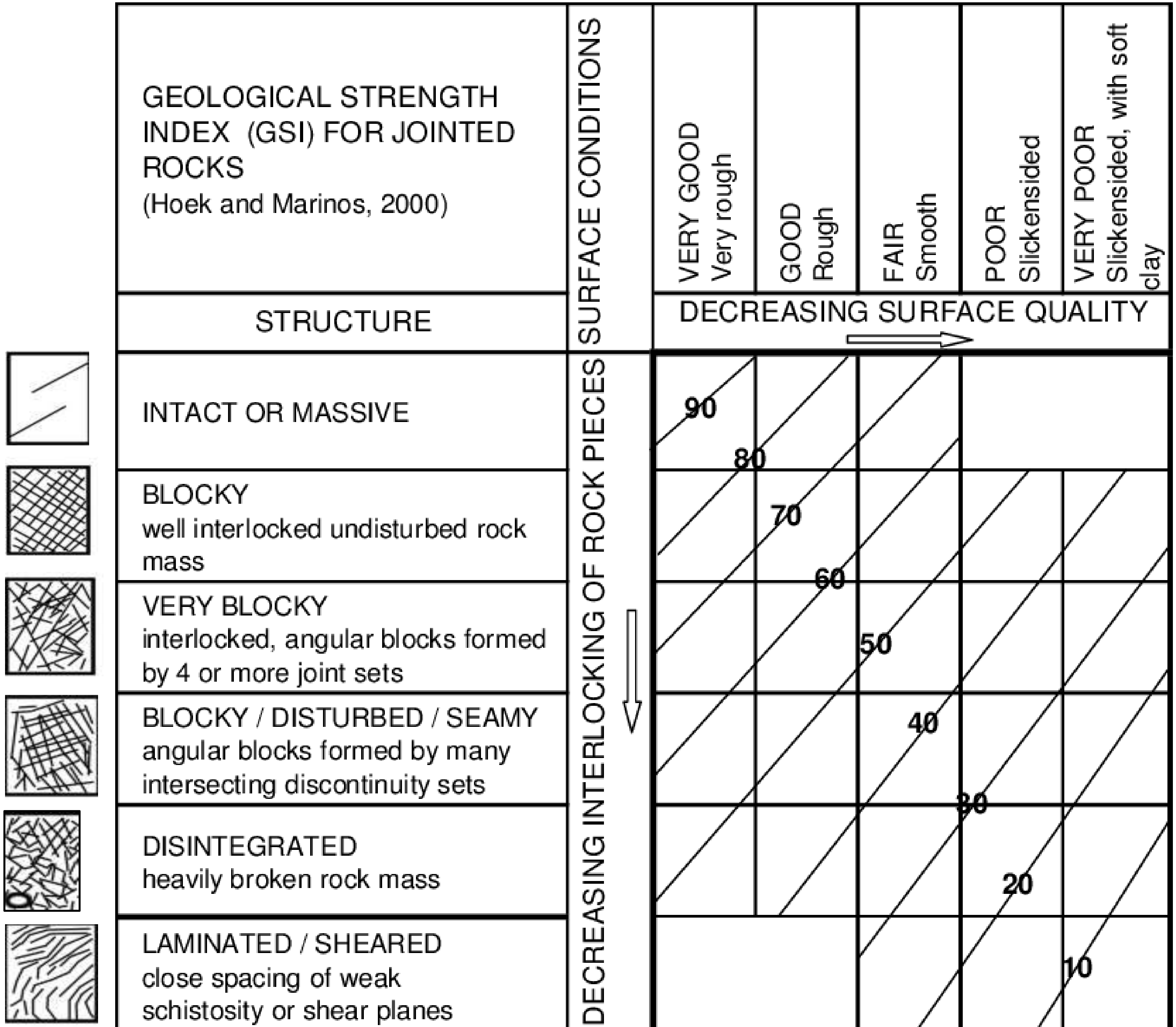
✓It is also a weak contact, which can allow percolation of water and may become fault due to forces imposed above the unconformity.

**Geological Strength Index (GSI) of Rocks:**

It is a unique rock mass classification system related to the rock mass strength and deformation parameters based on the generalized Hoek-Brown and Mohr-Coulomb failure criteria.

The GSI can be estimated using standard chart and field observations of rock mass blockiness and discontinuity surface conditions.

The first rock mass classification system in geotechnical engineering was proposed in 1946.




https://www.researchgate.net/profile/MiroslavMarence/publication/303686534/figure/fig2/AS:537344719110144@1505124372669/Geological-strength-index-GSIaccording-to-Hoek-and-Marinos-2000-simplified-version-The.png

**Rock Mass Rating (RMR):** RMR is a combination of a number of engineering and geotechnical properties which are important for engineering projects like tunnels, bridges and dams.

The rocks are classified into various classes on the basis of RMR is known as Rock Mass Classification system.

**Rock Mass Classes on the basis of Total RMR**

| **Rating** | **100-81** | **61-80** | **60-40** | **40-21** | **<20** |
|---|---|---|---|---|---|
| Class | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

**The parameters, which are used in RMR system to classify a rock mass as**

1. Uniaxial compressive strength of rock material
2. Rock quality designation (RQD)
3. Spacing of discontinuities
4. Condition of discontinuities.
5. Groundwater conditions
6. Orientation of discontinuities

Each of these parameters is assigned a value corresponding to the characteristics of the rock.

These values are derived from field surveys and laboratory tests.

The sum of all the above parameters is the "RMR value", which lies between 0 and 100.

**Objective of Rock Mass Classification**

✓Identify the significant parameters influencing the behavior of a rock mass.

✓Divide a particular rock mass into groups of similar behavior of rock mass classes of varying quality.

✓To understanding the characteristics of each rock mass class

✓Relate the experience of rock conditions at one site to the conditions encountered at other sites.

✓Derive quantitative data and guidelines for engineering design

✓Provide common basis for communication between engineers and geologists

**Benefits:**

➢Improving the quality of site investigations by calling for the minimum input data as classification parameters.

➢Enable better engineering judgment and effective communication on a project.

➢Providing quantitative information for design purposes.

➢Understanding the characteristics of each rock mass

**1.Uniaxial compressive strength of rock material:** The maximum axial compressive stress that a right-cylindrical sample of material can withstand before failing is defined as uniaxial compressive strength or unconfined compressive strength (UCS) .

**Generalized Ranges of UCS in some rocks**

| Rock Name | UCS (kN/m2) | UCS (Mpa) |
|---|---|---|
| Granite | 40000-290000 | 40-290 |
| Basalt | 180000-275000 | 180-275 |
| Sandstone | 10000-230000 | 10-230 |
| Siltstone | 25000-250000 | 25-250 |
| Shale | 6500-200000 | 6.5-200 |
| Limestone | 5000-200000 | 5-200 |
| Quartzite | 200000-350000 | 200-350 |
| Gneiss | 151000-248000 | 151-248 |
| Schist | 7500-139000 | 7.5-139 |
| Slate | 95000-250000 | 95-250 |
| Marble | 48000-230000 | 48-230 |

Strength of intact rock material for Rock Mass Rating

| **Strength of intact rock Material** | **Range Values** | | | | | | |
|---|---|---|---|---|---|---|---|
| Point load Strength index | >10 MPa | 4-10MPa | 2-4MPa | 1-2MPa | UCS preferred | | |
| Uniaxial Compressive Strength | >250MPa | 100-250MPa | 50-100MPa | 25-50MPa | 5-25MPa | 1-5MPa | <1MPa |
| Rating | 15 | 12 | 7 | 4 | 2 | 1 | 0 |

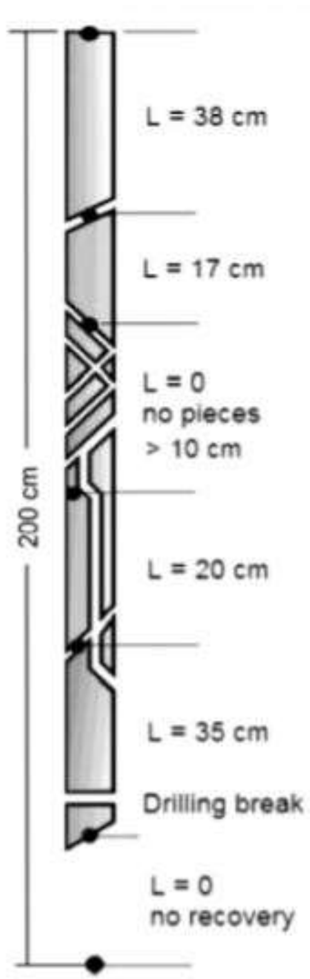
# Rock quality designation (RQD):

The Rock Quality Designation index (RQD) was developed by Deere (Deere et al 1967) to provide a quantitative estimate of rock mass quality from drill core logs.

RQD is defined as the percentage of intact core pieces longer than 100 mm (4 inches) or 10 cm in the total length of core.

The Rock Quality Designation index, is a common index used in the description of rock mass quality. Its value is used to predict the engineering properties of the rock strata.

The RQD index value was introduced for the engineering applications, such as geotechnical engineering and mining.




$$RQD = \frac{\Sigma \text{ Core pieces} > 10 \text{ cm}}{\text{Total length of core run (cm)}} \times 100$$

**Rock Quality Designation Index**

| **Range(%)** | **90-100** | **75-90** | **50-75** | **25-50** | **<25** |
|---|---|---|---|---|---|
| Classes of rocks | Excellent | Very good | Good | Poor | Very poor |

## Rock Quality Designation Index

RQD may be estimated from the number of discontinuities per unit volume.

The suggested relationship for clay-free rock masses is:
RQD = 115 - 3.3 Jv

Jv is the sum of the number of joints per unit length for all joint (discontinuity) sets known as the volumetric joint count.

Jv is defined as the number of joints intersecting a volume of one $m^3$. Where the jointing occurs mainly as joint sets

$Jv = 1/S1 + 1/S2 + 1/S3 + \ldots 1/Sn$

where S1, S2 and S3 are the average spacings for the joint sets.

$Jv = 1/S1 + 1/S2 + 1/S3 + \ldots 1/Sn + Nr/(S\sqrt{A})$ (Random joints consideration)

where Nr is the number of random joints in the actual location and A is the area in $m^2$ and S is spacing.

Classification of the Jv is as follows

| **Rating** | **Degree of jointing** | | | | | |
|---|---|---|---|---|---|---|
| | Very low | Low | Moderate | High | Very High | Crushed |
| Jv | <1 | 1-3 | 3-10 | 10-30 | 30-60 | >60 |

**Spacing of discontinuities:**

| Rating | 20 | 15 | 10 | 8 | 5 |
|---|---|---|---|---|---|
| Spacing of discontinuities | > 2m | 0.6m-2m | 200-600mm | 60-200mm | <60mm |

Condition of discontinuities for RMR calculation

| Condition of discontinuities | Length, persistence | < 1 m | 1-3m | 3-10m | 10-20m | >20m |
|---|---|---|---|---|---|---|
| | Rating | 6 | 4 | 2 | 1 | 0 |
| | Separation | None | <0.1mm | 0.1-1mm | 1-5mm | >5mm |
| | Rating | 6 | 5 | 4 | 1 | 0 |
| | Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| | Rating | 6 | 5 | 3 | 1 | 0 |
| | Infilling(Gauge) | None | Hard filling | | Soft filling | |
| | | | <5mm | >5mm | <5mm | >5mm |
| | Rating | 6 | 4 | 2 | 2 | |
| | Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| | Rating | 6 | 5 | 3 | 1 | 0 |

Groundwater conditions

| | | | | | | |
|---|---|---|---|---|---|---|
| **Groundwater conditions** | **Inflow per 10m tunnel length** | **None** | **<10 liters/min** | **10 -25 liters/min** | **25-125 liters/min** | **>125 liters/min** |
| | Ratio of joint water pressure (Pw) to major principal stress(σ1) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 |
| | General conditions | Completely Dry | Damp | Wet | Dripping | Flowing |
| | Rating | 15 | 10 | 7 | 4 | 0 |

Orientation of discontinuities for Rock Mass Rating

<table>
<tr><th colspan="5">A. Dam Foundations</th></tr>
<tr><td rowspan="3">Dip<br>0°–10°</td><td colspan="2">Dip 10°–30°</td><td rowspan="3">Dip<br>30°–60°</td><td rowspan="3">Dip<br>60°–90°</td></tr>
<tr><td colspan="2">Dip direction</td></tr>
<tr><td>Upstream</td><td>Downstream</td></tr>
<tr><td>Very favorable</td><td>Unfavorable</td><td>Fair</td><td>Favorable</td><td>Very unfavorable</td></tr>
</table>

<table>
<tr><th colspan="7">B. Tunneling</th></tr>
<tr><td colspan="4">Strike perpendicular to tunnel axis</td><td colspan="2" rowspan="2">Strike parallel to tunnel axis</td><td rowspan="2">Irrespective of strike</td></tr>
<tr><td colspan="2">Drive with dip</td><td colspan="2">Drive against dip</td></tr>
<tr><td>Dip<br>45°–90°</td><td>Dip<br>20°–45°</td><td>Dip<br>45°–90°</td><td>Dip<br>20°–45°</td><td>Dip<br>45°–90°</td><td>Dip<br>20°–45°</td><td>Dip<br>0°–20°</td></tr>
<tr><td>Very favorable</td><td>Favorable</td><td>Fair</td><td>Unfavorable</td><td>Very unfavorable</td><td>Fair</td><td>Fair</td></tr>
</table>

Orientation of discontinuities and Rating

| Strike and Dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very unfavourable |
|---|---|---|---|---|---|---|
| Ratings | Tunnels & Mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | -60 |

## TOTAL ROCK MASS RATING AND CLASSES FROM INDIIDUAL PARAMETERS

| Rating | 100-81 | 61-80 | 60-40 | 40-21 | <20 |
|---|---|---|---|---|---|
| Class | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| Rock mass classes and corresponding design parameters and engineering properties | | | | | |
|---|---|---|---|---|---|
| Class No. | I | II | III | IV | V |
| RMR | 100–81 | 80–61 | 60–41 | 40–21 | <20 |
| Description | Very Good | Good | Fair | Poor | Very poor |
| Average stand-up time *(how long the ground will safely* ***stand*** *by itself at the heading)* | 20 years for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 h for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (MPa) | > 0.4 | 0.3–0.4 | 0.2–0.3 | 0.1–0.2 | <0.1 |
| Internal friction angle of rock mass (°) | > 45 | 35–45 | 25–35 | 15–25 | <15 |
| Deformation modulus (GPa)[a] | > 56 | 56–18 | 18–5.6 | 5.6–1.8 | <1.8 |

# CORE LOGGING

**What is core logging:**

**Core logging** is the systematic recording and measuring of information required to determine the rock types (lithology), mineralogy, potential geological history, structure and alteration zones through a tiny piece of cylindrical rock drilled and removed from rock layers.

The observation and analysis of the rock strata by a drilling of borehole and taking of core samples at various predefined depth intervals as the well is drilled is defined as core logging.

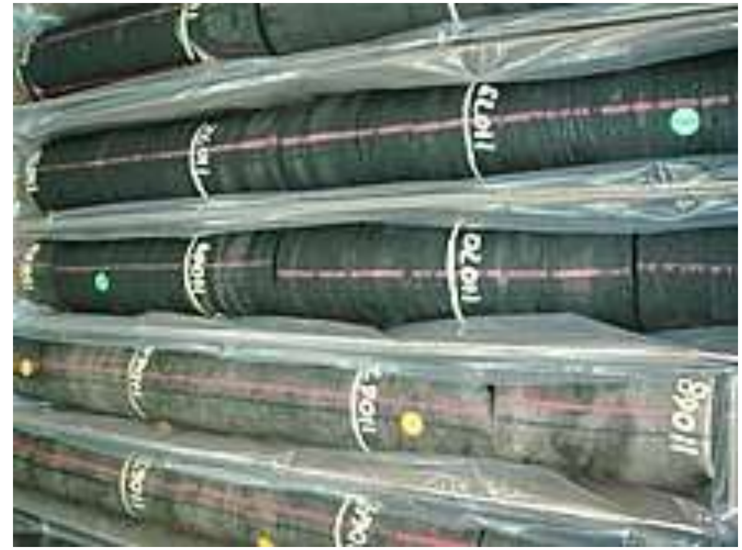
**Core:** A core is a sample as cylindrical and a naturally-occurring substance of rock .Coring is the process of obtaining an actual sample of a rock formation from the borehole.

**Logging:** Logging or a bore *well log* is a detailed record of the geologic formations penetrated by a borehole.

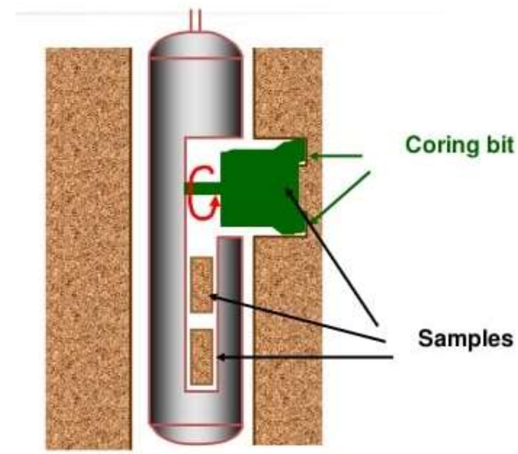
**There are two main types of coring:**

**Full coring:** In which a sample of rock is obtained using a specialized drill-bit as the borehole is first penetrating the formation.

**Sidewall coring:** Multiple samples are obtained from the side of the borehole after it has penetrated through a formation.

https://www.petroleumonline.com/modules/
m005/imgs/hl_005_002_002.jpg



## CORE LOGGING

The basic objectives of logging core are to provide

- ✓ An actual,
- ✓ An accurate, and
- ✓ Concise record of the important geological and physical characteristics of subsurface rocks for engineering significance.

To estimate the characteristics which influence deformability, strength, and water conditions of rocks, those must be recorded appropriately for future interpretations and analyses.

**Drilling equipment:**

- ✓ Drill rig (make and model)
- ✓ Core barrel(s), tube(s), special samplers (type and size)
- ✓ Bits (type and size)
- ✓ Drill rods (type and size)
- ✓ Collar (type)
- ✓ Water test equipment

**Purpose, Use, and Importance of Core Logging**

The ability of a foundation to accommodate structure loads depends primarily on the deformability, strength, and groundwater conditions of the foundation materials

Data reported in geologic logs not only must be accurate, consistently recorded, and concise, but also must provide quantitative and qualitative descriptions.

Logs provide fundamental data on which conclusions regarding a site are based. Additional exploration or testing, final design criteria, treatment design, methods of construction, and eventually the evaluation of structure performance may depend on core logs

A log may present important data for immediate interpretations or use, or may provide data that are used over a period of years.

The log may be used to delineate existing foundation conditions, changes over time to the foundation or structure

## CALCULATION OF THICKNESS OF ( HORIZONTAL, VERTICAL AND DIPPING) ROCK BEDS

**Introduction:**

Sedimentary rocks formed normally as stratums or layers or beds. These stratums may be horizontal, inclined or vertical. Therefore thickness of rock strata is very important for civil engineering structures.

**Types of thickness of rock strata**

**True thickness of rock strata:** The thickness is measured perpendicular to the plane of bedding( Tt in fig 4.1).

**Vertical thickness:** The thickness, which is measured vertically at a point for a rock strata or bed is called as vertical thickness ( Vt in fig 4.1).

**Depth of strata:** The vertical distance measured from any defined point on the surface of the earth to the top of the desired strata is defined as depth of that strata ( d in fig 4.1).

If the whole rock stratum is exposed in a cliff, the thickness may be measured directly by tape.

However, a direct measurement is impossible, and the thickness must be calculated by the data obtained from a map and using fundamental equations for calculation.

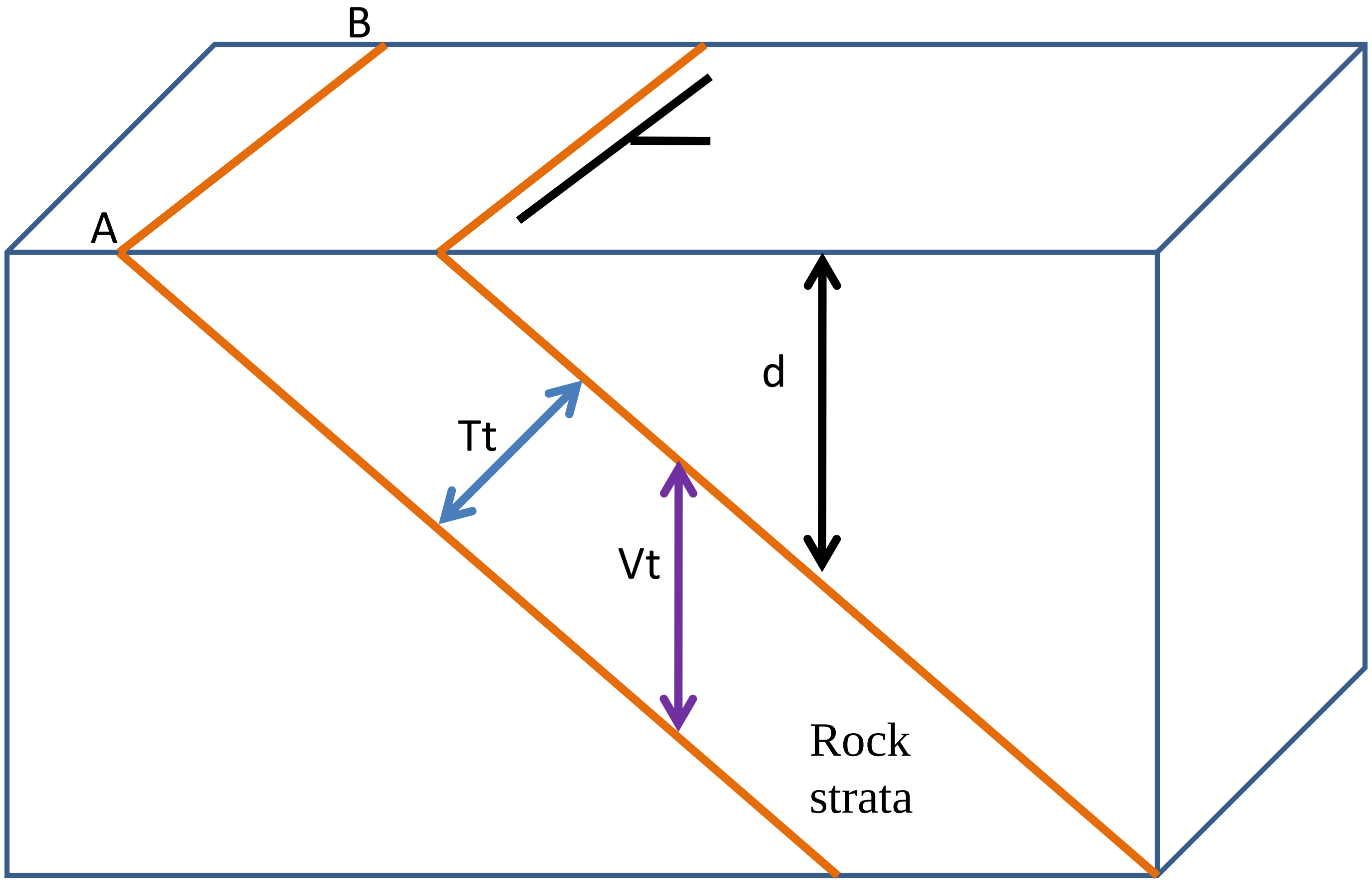
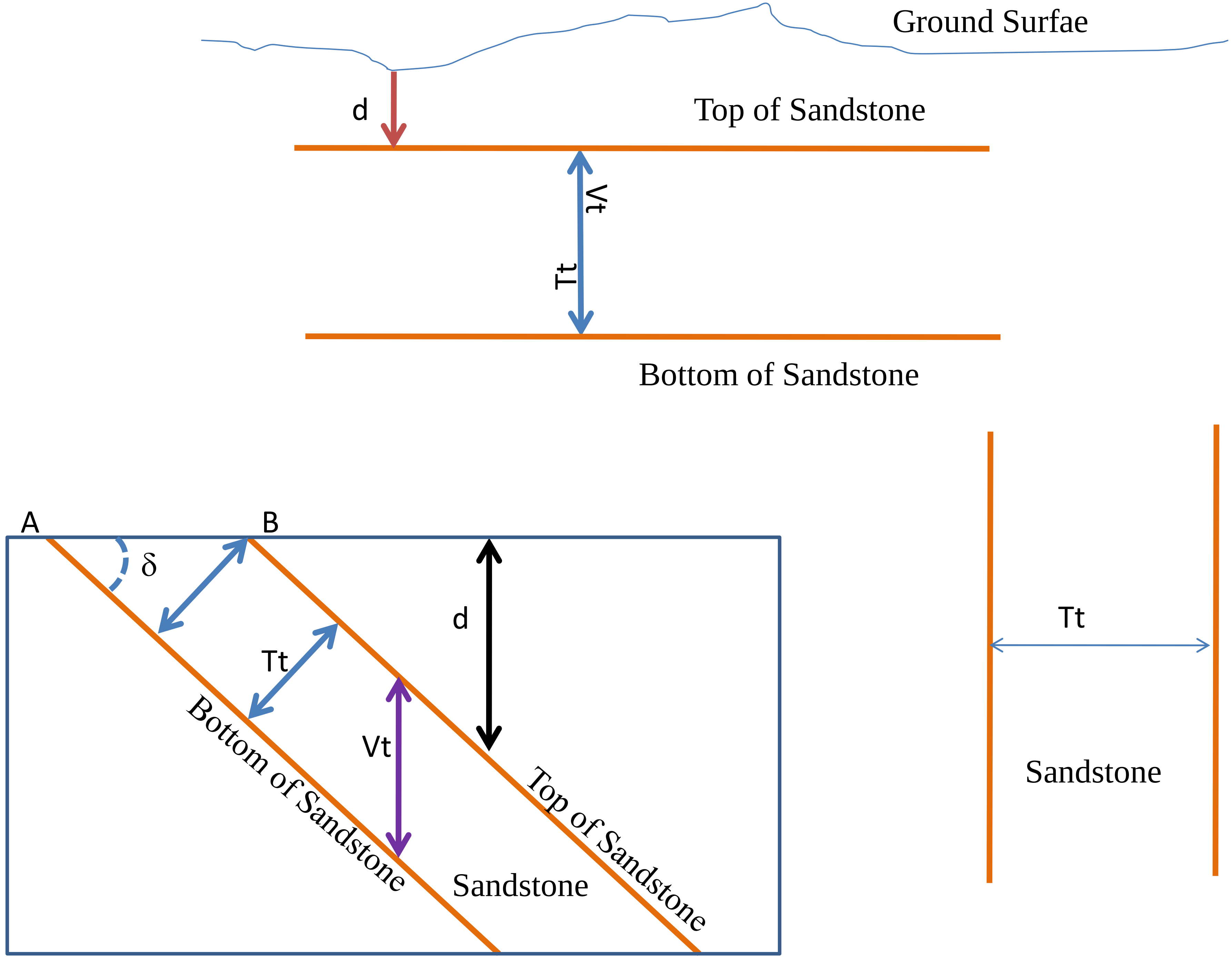



Fig 4.1.Thicness and depth of  rock strata.


Ground Surfae
d
Top of Sandstone
Vt
Tt
Bottom of Sandstone
A
B
δ
d
Tt
Vt
Bottom of Sandstone
Sandstone
Top of Sandstone
Tt
Sandstone

True thickness of rock strata (Tt) can be found using the triangle ABC from figure 1.

Tt=S*Sin δ

Where,

Tt=True thickness of rock layer

S=Exposure width of rock strata

δ=Dip or inclination of rock bed

Vt=Vertical thickness.

**Note:**

**Ground is horizontal and rock dip in any direction.**

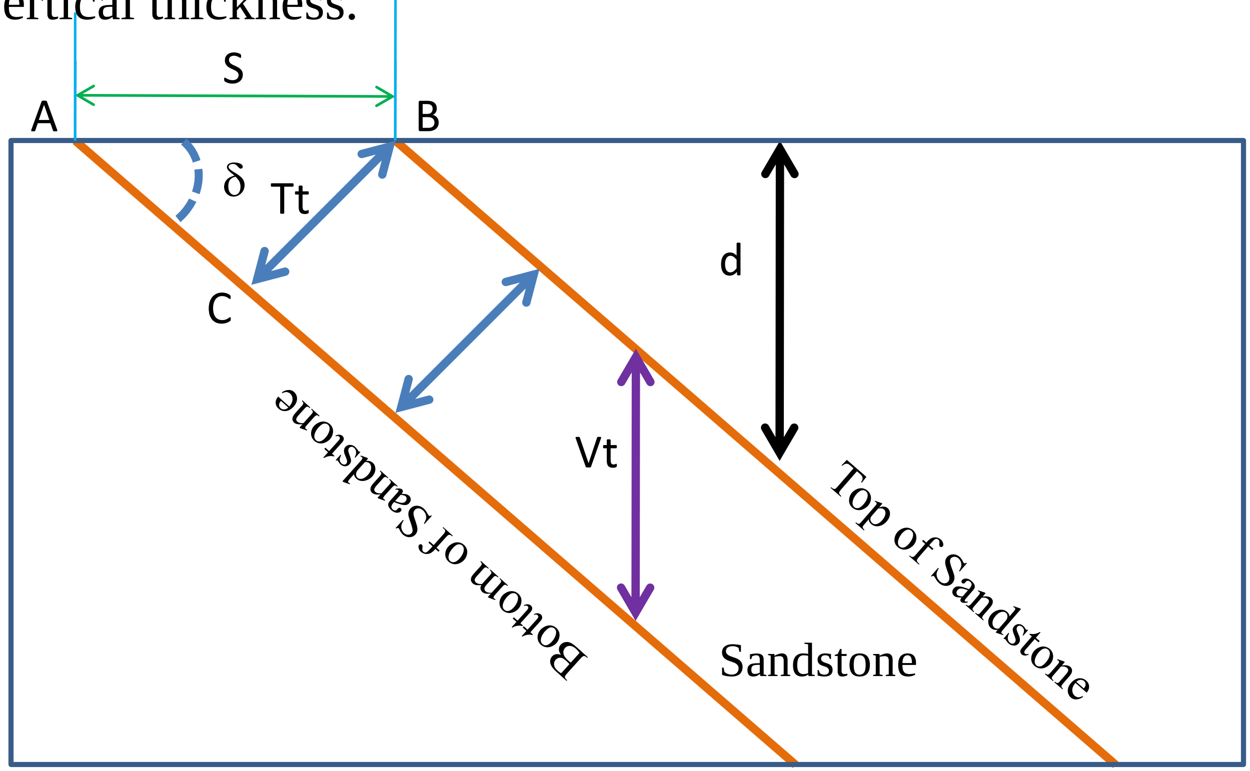



Fig 1: Thickness of rock strata, when beds exposed on the level ground and width is measured at right angles to strike direction of bed.

True thickness of rock strata (Tt) can be found using the triangle ABC from figure 2.

$$Tt = S * \sin(\delta - \alpha)$$

Where,

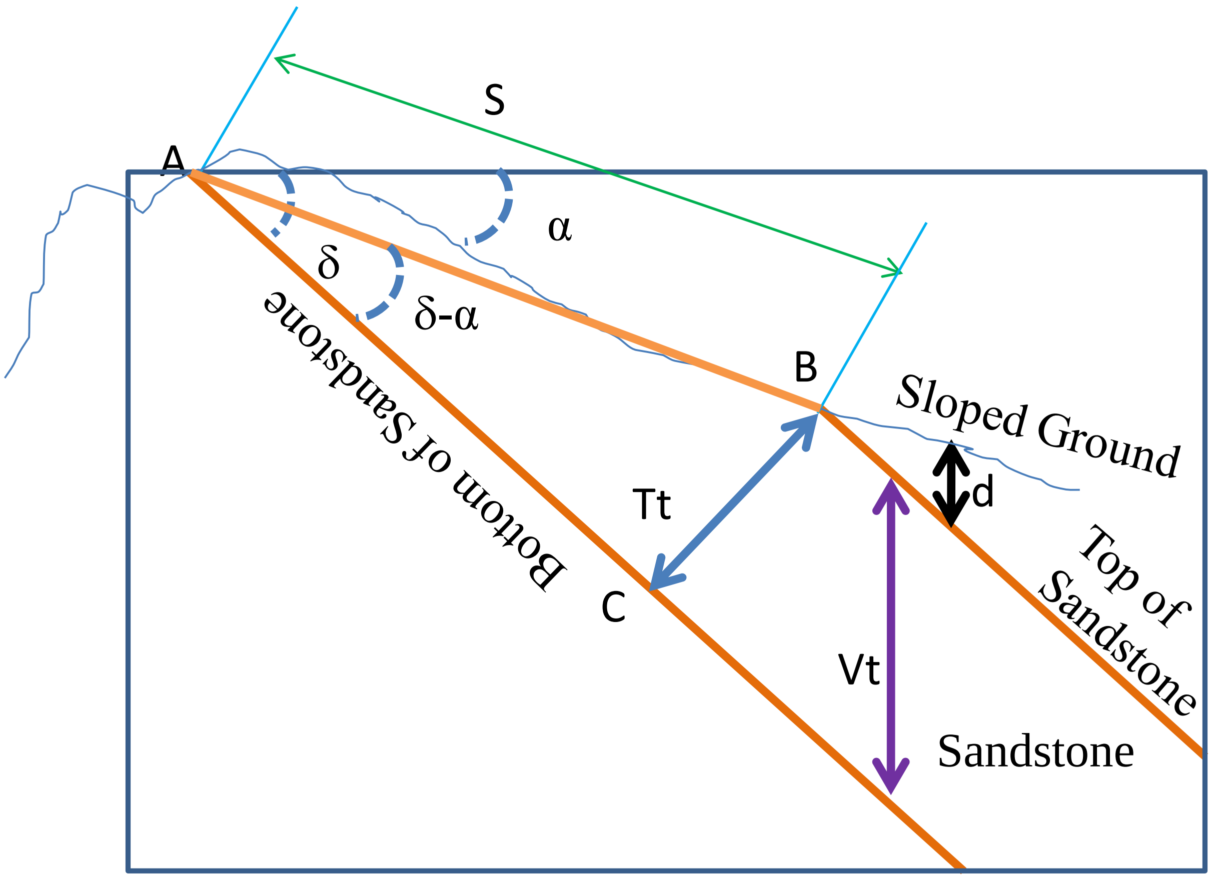
Tt=True thickness of rock layer

S=Exposure width of rock strata

δ=Dip or inclination of rock bed

α=Dip or slope of the ground

Vt=Vertical thickness.




**Note:**
**Dip of rock formation and slope of the ground is in same direction**

Case 2: Thickness of rock strata, when beds exposed on the sloped ground and width is measured at right angles to strike direction of bed.

True thickness of rock strata (Tt) can be found using the triangle ABC from figure 2.

$Tt=S*Sin(\delta+\alpha)$ Where,

Tt=True thickness of rock layer

S=Exposure width of rock strata

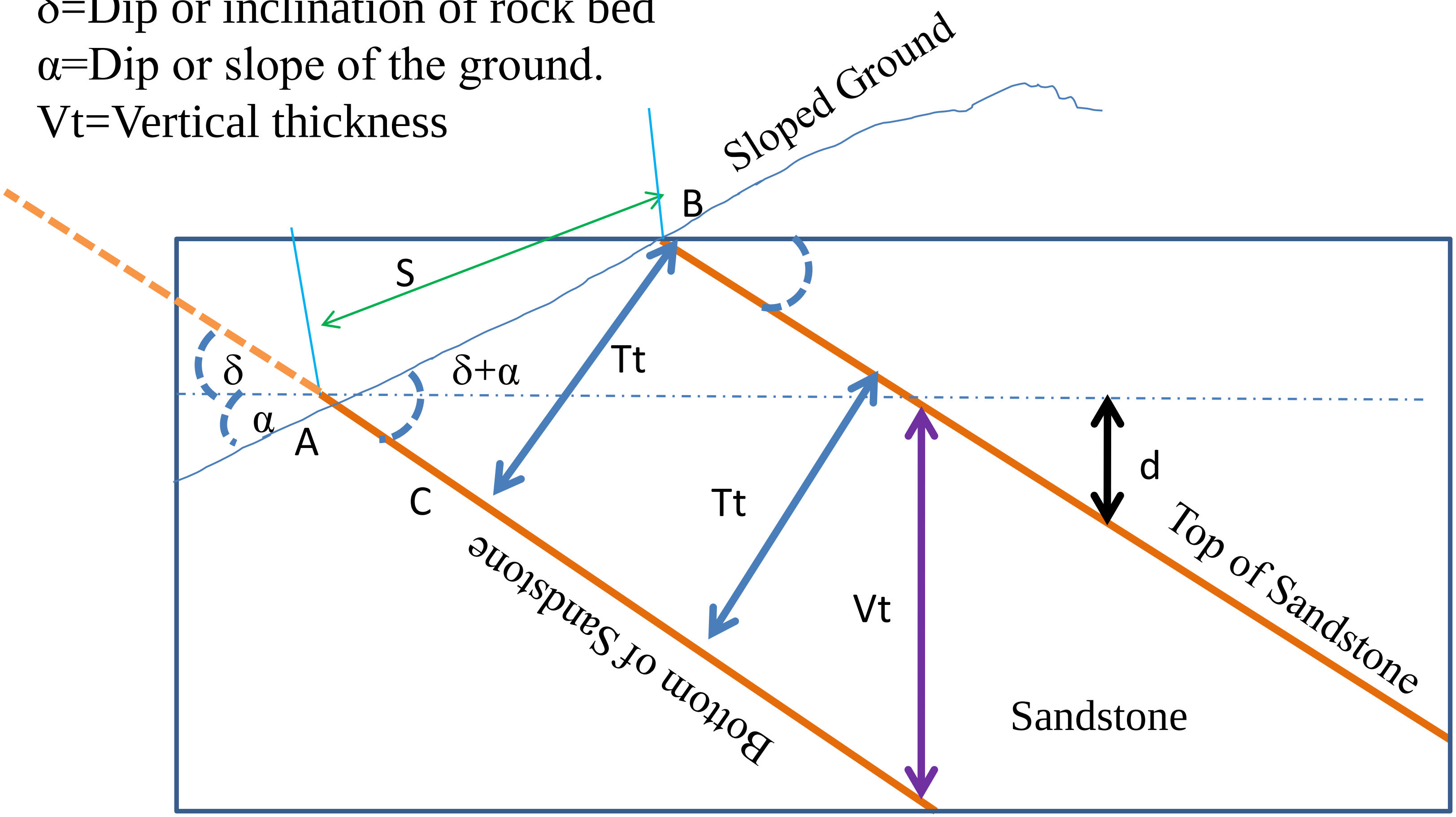
δ=Dip or inclination of rock bed

α=Dip or slope of the ground.

Vt=Vertical thickness

**Note:**

**Dip of rock formation and slope of the ground is in opposite direction**




Case3: Thickness of rock strata, when beds exposed on the sloped ground and width is measured at right angles to strike direction of bed.

1. A coal seam dips in 40° W on 10° W sloped ground. Exposed width is 60m. Find out true thickness and vertical thickness of coal seam.(scale 1cm=10m).

**Given data**

Slope of the ground = 10° W (α)

Dip of coal seam = 40° W (δ)

Exposed width of coal seam= 60m (s)

**Procedure**

**Step 1**

Draw a horizontal reference line on a sheet of paper and mark reference point as A on this horizontal line.

**Step 2**

Measure the slope of ground 10° in west direction from the point A, and extend as AB line. AB named as ground surface.

**Step 3**

Measure the dip of coal seam i.e 40° in west direction from point A, which considered as one exposure of coal seam. AC line represent one contact of coal seam.

**Step 5**

Measure the exposed width of coal seam i,.e 6cm from A along the sloped ground AB line and mark as point D, which is another exposure of coal seam on the sloped ground. Through point D draw

1.A coal seam dips in 40° W on 10° W sloped ground. Exposed width is 60m. Find out true thickness and vertical thickness of coal seam.(scale 1cm=10m).

**Given data**

Slope of the ground = 10° W (α)

Dip of coal seam = 40° W (δ)

Exposed width of coal seam= 60m (s)=6cm

**Procedure**

**Step 01:** Draw a horizontal reference line on a sheet of paper and mark reference point as A on this horizontal line.

**Step02:** Measure the slope of ground 10° in west direction from the point A, and extend as AB line. AB named as ground surface.

**Step3**: Measure the dip of coal seam i.e 40° in west direction from point A, which considered as one exposure of coal seam. AC line represent one contact of coal seam.

**Step04:**Measure the exposed width of coal seam i,.e 6cm from point A along the AB line to get another exposure as D. Draw a line DE from point D, which is parallel to AC to get another contact of coal seam.

**Step05:** Draw a perpendicular between AC and DE at point D, mark it as DF and it considered as true thickness of coal seam.

**Step06**

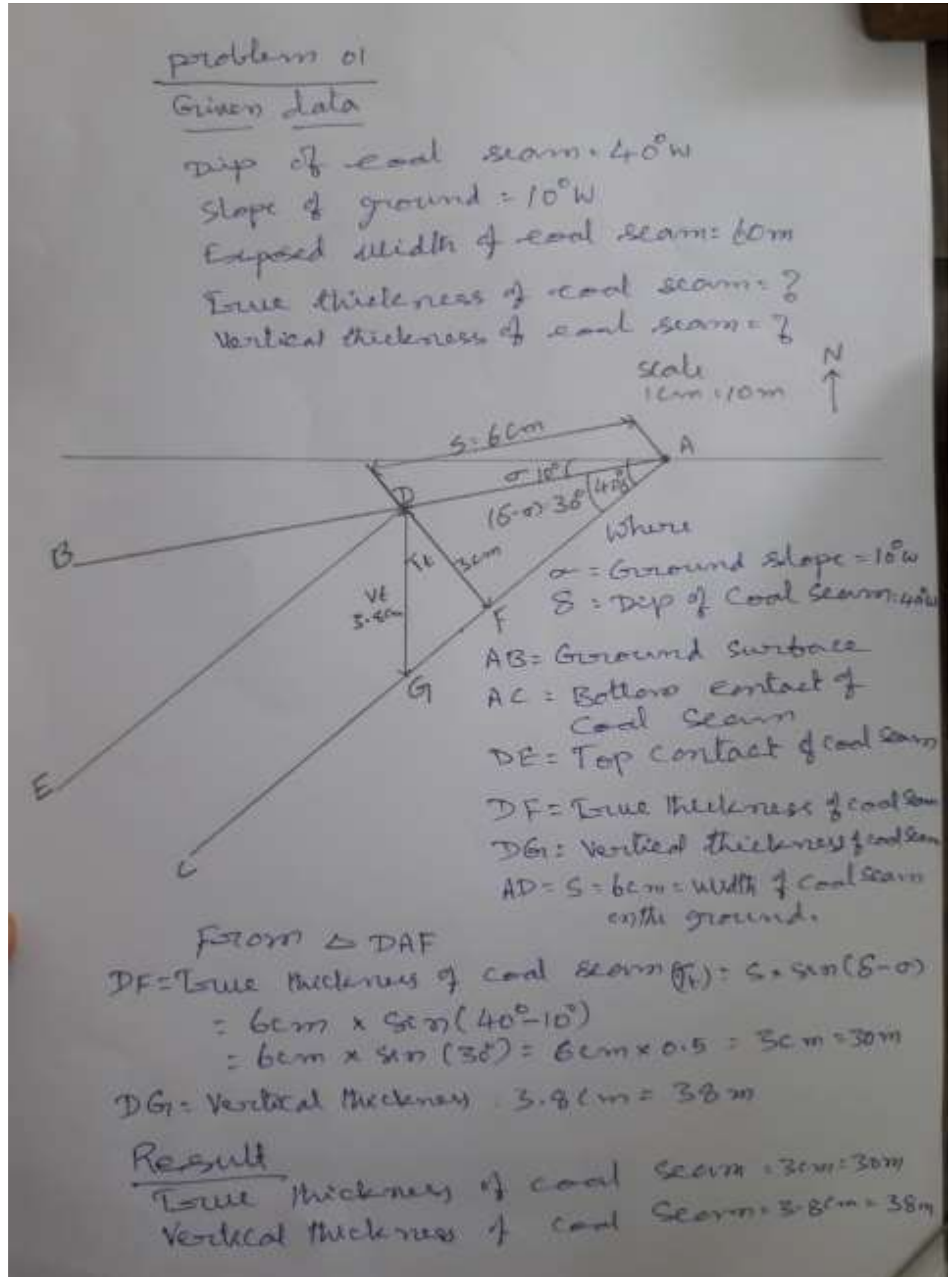
Mathematically true thickness can be found from the triangle ADF.

$\sin(\delta - \alpha) = DF/S = Tt/S$

$Tt = S * \sin(\delta - \alpha) = 6cm * \sin(40-10)$

True thickness of coal seam=3cm=30m

1.A coal seam dips in 40° W on 10° W sloped ground. Exposed width is 60m. Find out true thickness and vertical thickness of coal seam.(scale 1cm=10m).



problem 01

Given data

Dip of coal seam = 40°W

Slope of ground = 10°W

Exposed width of coal seam = 60m

True thickness of coal seam = ?

Vertical thickness of coal seam = ?

scale 1cm = 10m

N

S = 6cm A σ 10° (δ−σ) 30° 40° D B Tt 3cm VE 3.8cm F G E C

where

σ = Ground slope = 10°w

δ = Dip of Coal seam = 40°w

AB = Ground surface

AC = Bottom contact of coal seam

DE = Top contact of coal seam

DF = True thickness of coal seam

DG = Vertical thickness of coal seam

AD = S = 6cm = width of coal seam on the ground.

From △ DAF

DF = True thickness of coal seam (Tt) = S × sin(δ − σ)

= 6cm × sin(40° − 10°)

= 6cm × sin(30°) = 6cm × 0.5 = 3cm = 30m

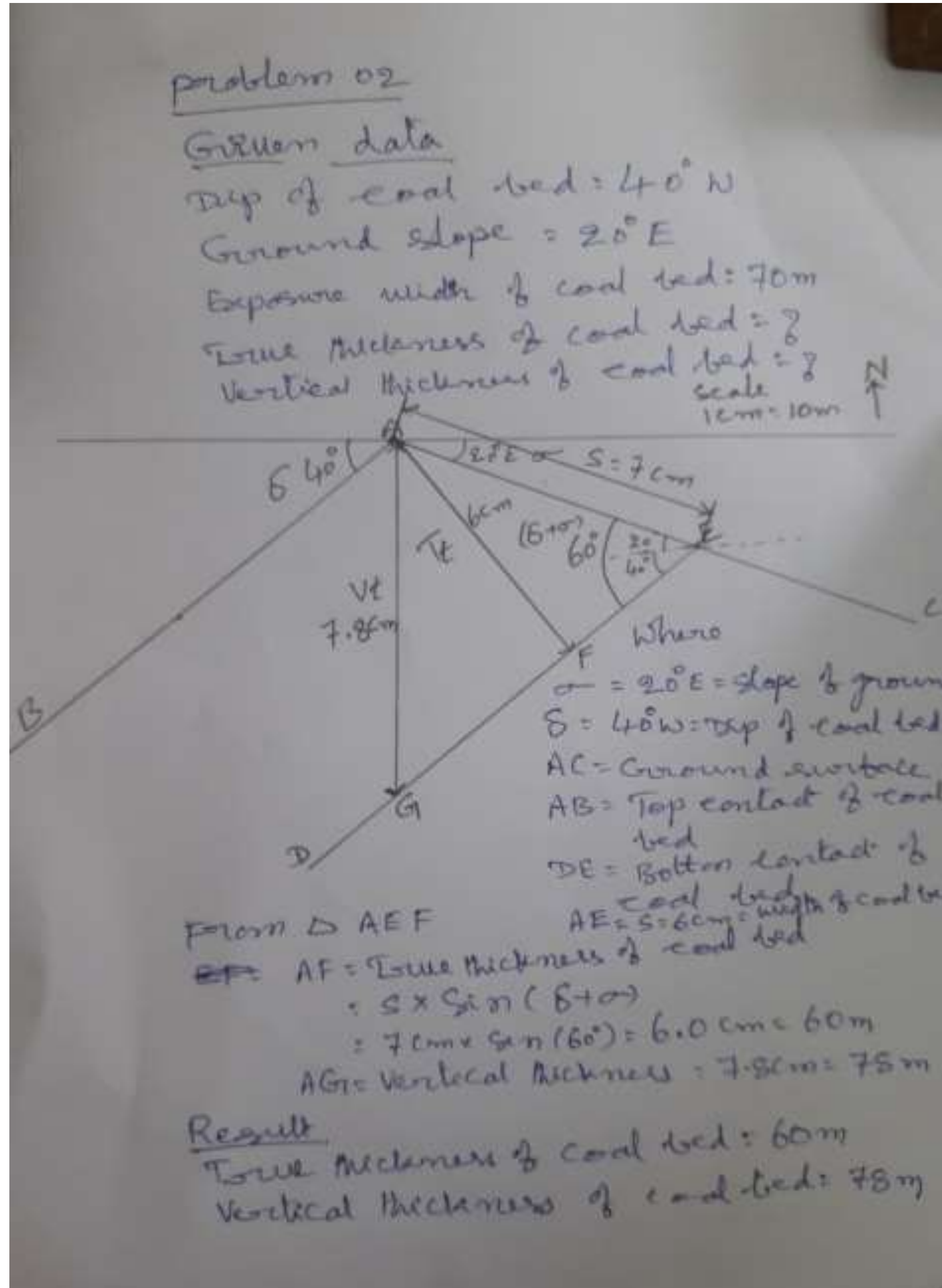
DG = Vertical thickness 3.8cm = 38m

Result

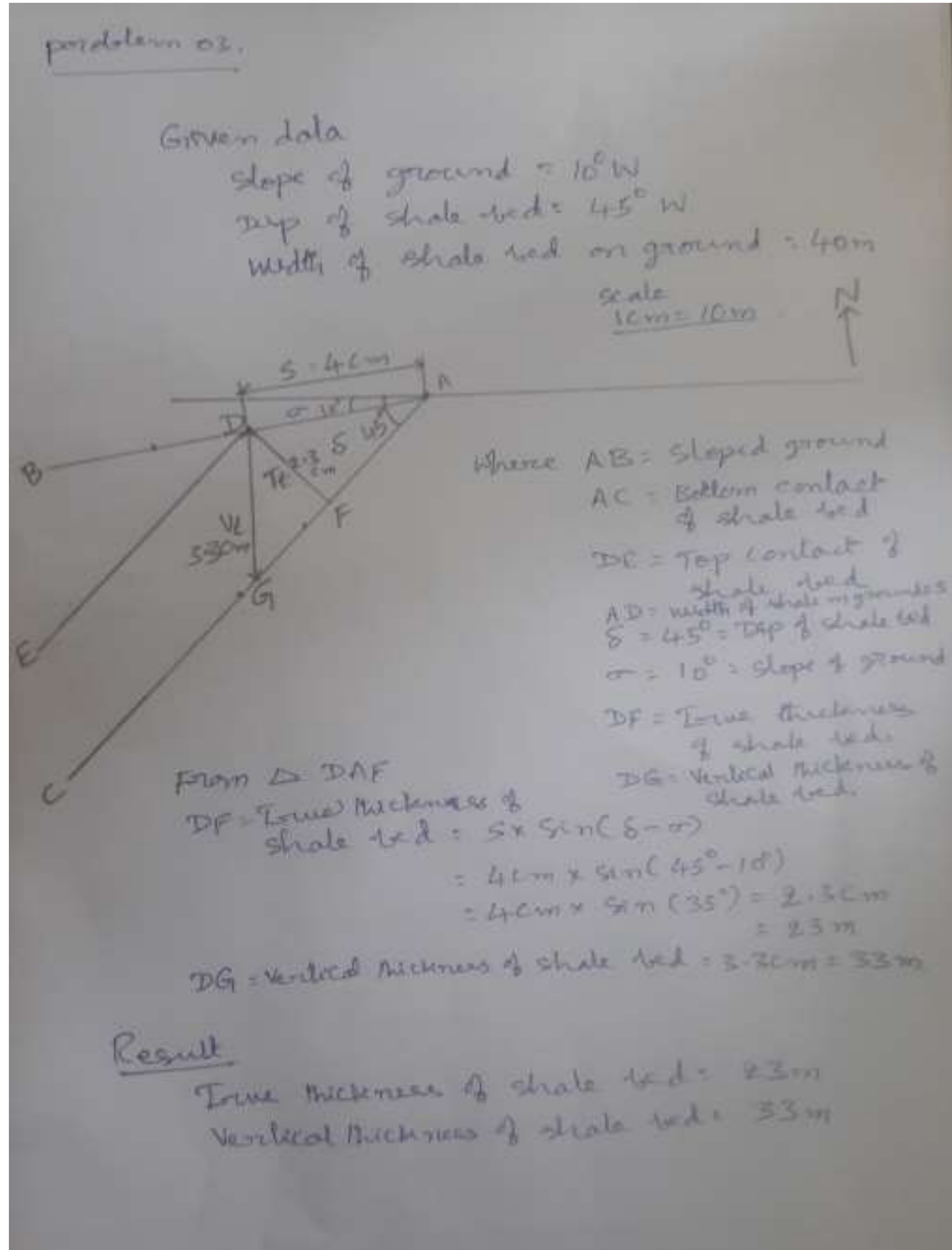
True thickness of coal seam = 3cm = 30m

Vertical thickness of coal seam = 3.8cm = 38m

2.A coal bed dips 40° in West on 20° East sloped ground. Exposed width is 70m. Find out true thickness and vertical thickness of coal bed.



3.Find out true thickness and vertical thickness of a shale bed which dip in 45° in the direction of west on 10° west sloped ground. Exposed width of shale is 40m.



problem 03.

Given data
Slope of ground = 10° W
Dip of shale bed = 45° W
Width of shale bed on ground = 40m

scale
1cm = 10m

S = 4cm

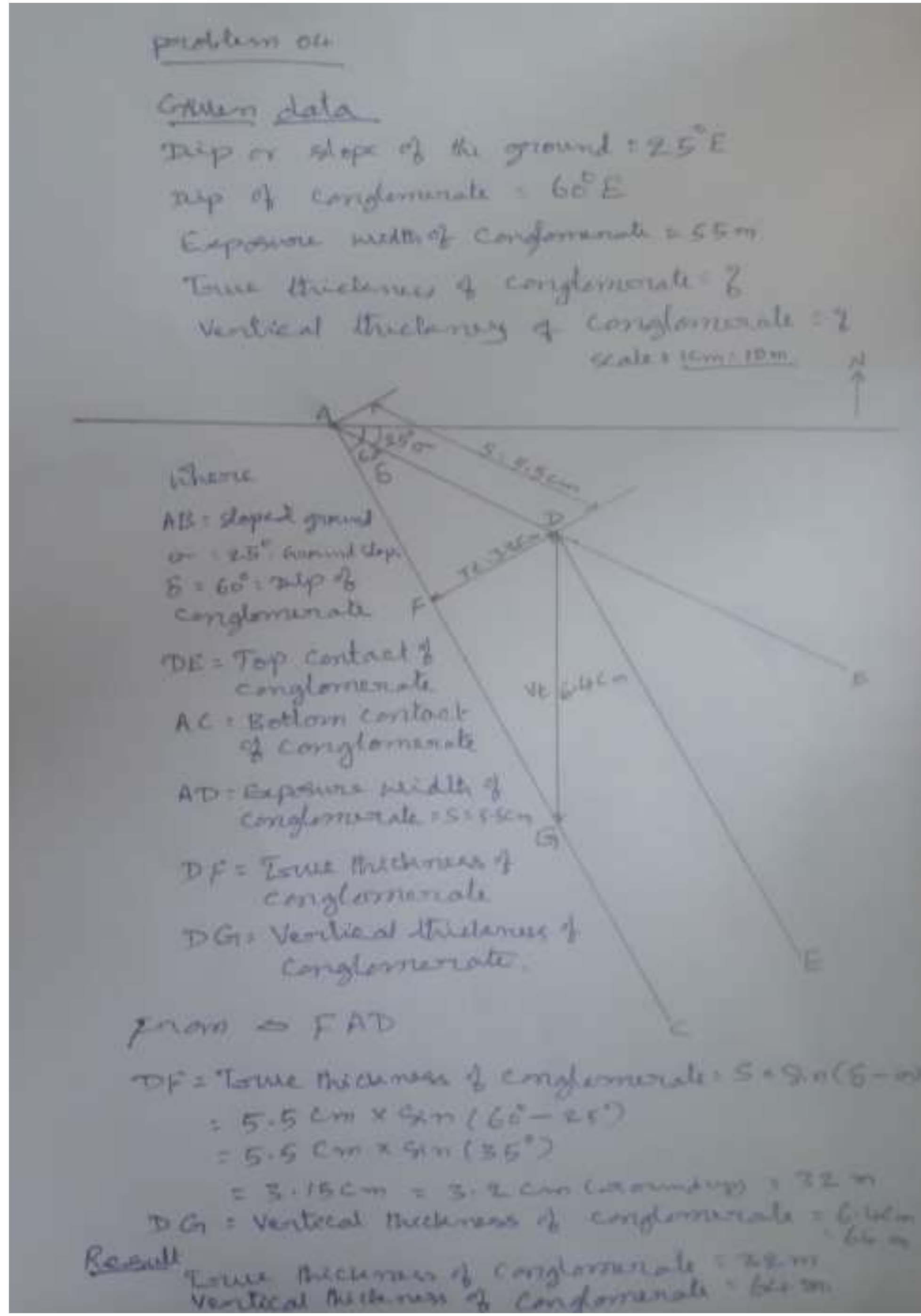
Where AB = Sloped ground
AC = Bottom contact of shale bed
DE = Top contact of shale bed
AD = width of shale on ground
δ = 45° = Dip of shale bed
σ = 10° = slope of ground
DF = True thickness of shale bed.
DG = Vertical thickness of shale bed.

From △ DAF
DF = True thickness of shale bed = S × sin(δ − σ)
= 4cm × sin(45° − 10°)
= 4cm × sin(35°) = 2.3cm
= 23 m

DG = Vertical thickness of shale bed = 3.3cm = 33m

Result
True thickness of shale bed = 23m
Vertical thickness of shale bed = 33m

4. A conglomerate is exposed on a 25° E sloped ground at the width of 55 m. Dip of conglomerate is 60°E. Find out true thickness and vertical thickness of conglomerate.


problem 04

Given data

Dip or slope of the ground = 25° E

Dip of conglomerate = 60° E

Exposure width of conglomerate = 55 m

True thickness of conglomerate = ?

Vertical thickness of conglomerate = ?

Scale = 1cm = 10 m.



where

AB = sloped ground

α = 25° Ground slope

δ = 60° = Dip of conglomerate

DE = Top contact of conglomerate

AC = Bottom contact of conglomerate

AD = Exposure width of conglomerate = S = 5.5cm

DF = True thickness of conglomerate

DG = Vertical thickness of conglomerate.

From △ FAD

DF = True thickness of conglomerate = S × Sin(δ − α)

= 5.5 Cm × Sin (60° − 25°)

= 5.5 Cm × Sin (35°)

= 3.15 Cm = 3.2 Cm (rounding) = 32 m

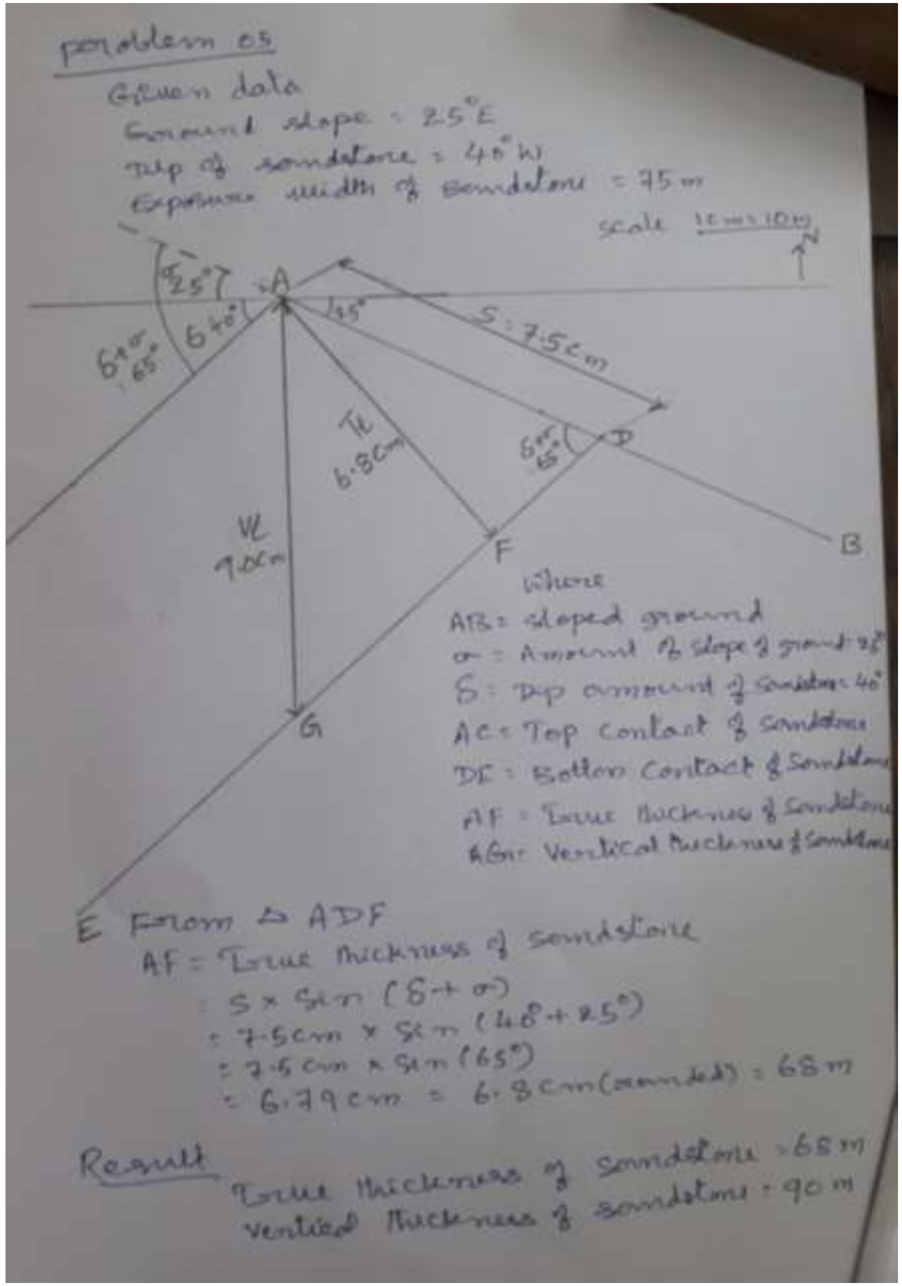
DG = Vertical thickness of conglomerate = 6.6cm = 66 m

Result

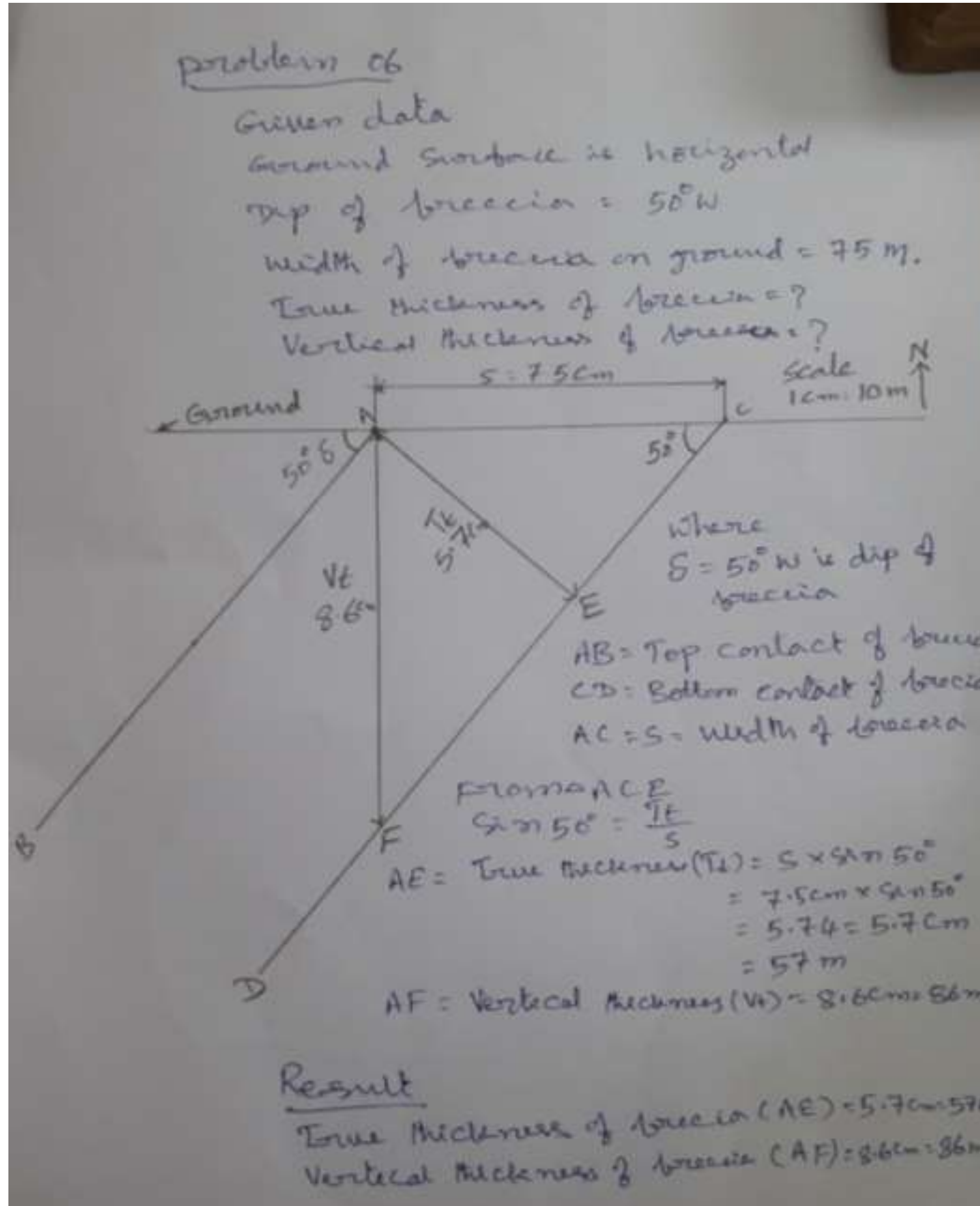
True thickness of conglomerate = 32 m

Vertical thickness of conglomerate = 66 m

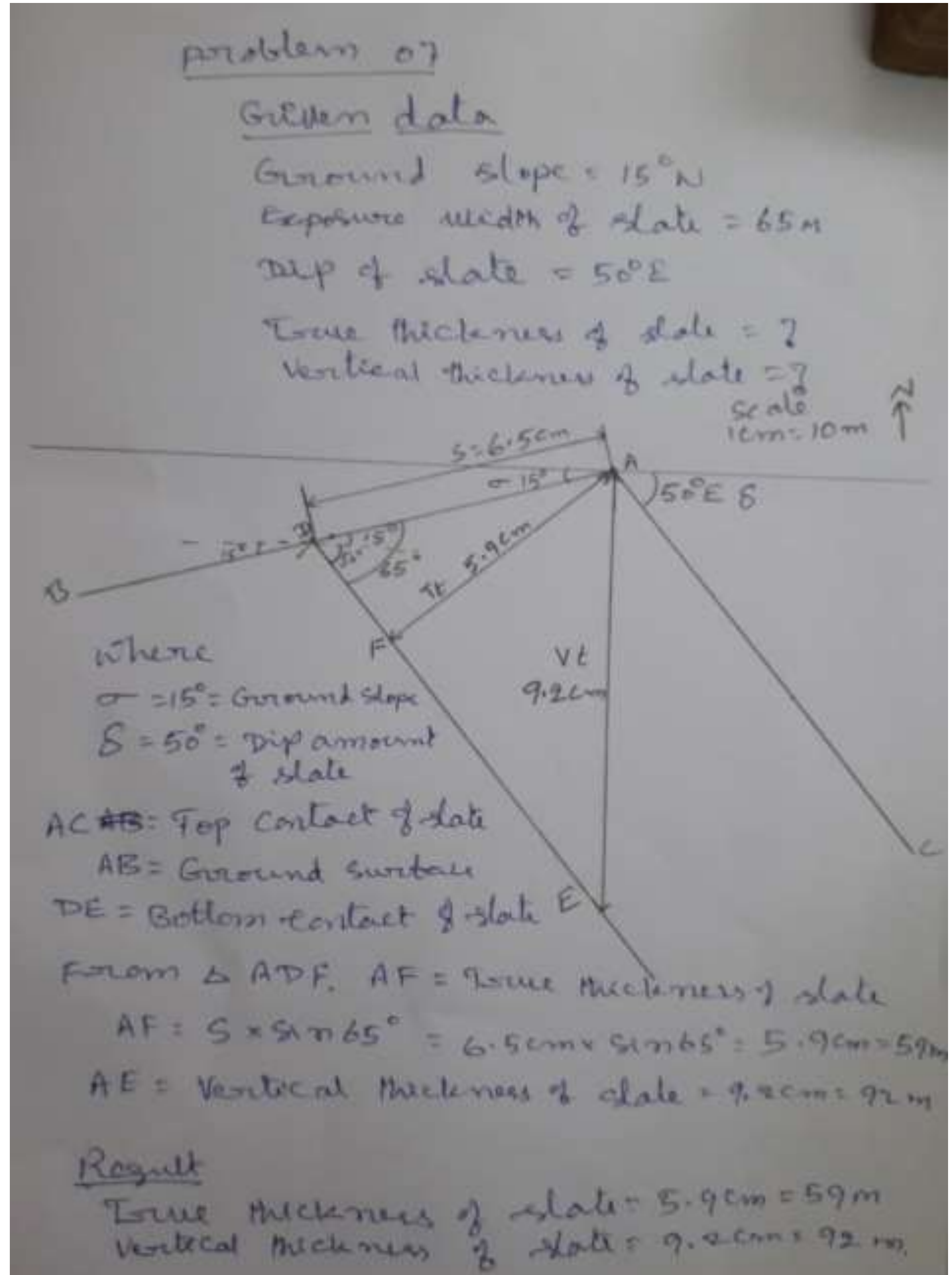
5. A sandstone is exposed on a 25° E sloped ground at the width of 75 m. Dip of sandstone is 40°W. Find out true thickness and vertical thickness of sandstone.



6. A breccia is exposed on level ground at the width of 75 m. Dip of sandstone is 50°W. Find out true thickness and vertical thickness of breccia.



7. A slate rock is exposed on ground with slope of 15° W, at the width of 65 m. Dip of slate is 50°E. Find out true thickness and vertical thickness of slate.



problem 07

Given data

Ground slope = 15°N

Exposure width of slate = 65 m

Dip of slate = 50°E

True thickness of slate = ?

Vertical thickness of slate = ?



where

σ = 15° = Ground slope

δ = 50° = Dip amount of slate

AC: Top contact of slate

AB = Ground surface

DE = Bottom contact of slate

From △ ADF, AF = True thickness of slate

AF = S × Sin 65° = 6.5cm × Sin 65° = 5.9cm = 59m

AE = Vertical thickness of slate = 9.2cm = 92 m

Result

True thickness of slate = 5.9cm = 59m

Vertical thickness of slate = 9.2cm = 92 m.

# Review Questions

1. Can you define strike and dip with an illustration?
2. What do you remember about true dip and apparent dip, explain?
3. What is mean by folds?
4. What is an Anticline and Syncline?
5. What are types of folds, illustrate with sketches?
6. Define Faults? How would you classify the faults?
7. How the various criteria are used for the recognition of a fault in the field?
8. What is mean by Master joints? How can you classify the joints in the rocks?
9. Define unconformity and illustrate the types of unconformities?
10. How do you explain the nomenclature or parts of the fold, fault and joints?