CE6301- ENGINEERING GEOLOGY

(FOR III – SEMESTER)

UNIT – I TO V

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SCOPE OF GEOLOGY IN CIVIL ENGINEERING:

- It is defined as that of applied science which deal with the application of geology for a safe, stable and economic design and construction of a civil engineering project.

- Engineering geology is almost universally considered as essential as that of soil mechanics, strength of material, or theory of structures.

- The application of geological knowledge in planning, designing and construction of big civil engineering projects.

- The basic objects of a course in engineering geology are two folds.

- It enables a civil engineer to understand the engineering implications of certain condition should relate to the area of construction which is essentially geological in nature.

- It enables a geologist to understand the nature of the geological information that is absolutely essentially for a safe design and construction of a civil engineering projects.

The scope of geology can be studied is best studied with reference to major activities of the profession of a civil engineer which are

- Construction
- Water resources development
- Town and regional planning

GEOLOGY IN CONSTRUCTION FIELD

❖ PLANNING

➢ Topographic maps:

It’s gives details of relief features and understands the relative merits and demerits of all the possible sides of proposed structure.

➢ Hydrological maps:

This map gives broad details about distribution and geometry of the surface of water channel.

➢ Geological maps:

The petrological characters and structural disposition of rock types this gives an idea about the availability of materials for construction.

❖ Design:
The geological characters that have a direct or indirect bearing upon the designed of proposed project are,

- The existence of hard rock beds
- The mechanical properties (porosity, permeability, compressive strength, shear and traverse strength)
- Structural weakness (fault joints, folds, cleavage and lineation)
- The position of ground water table
- Seismic characters of area.

**Construction**

The geological knowledge is important for an engineer. The type of material for construction is derived from natural bed rocks, soils, banks, coastal belts and seismic zones.

**GEOLOGY IN WATER RESOURCES DEVELOPMENT**

- Exploration and water development of resources have become very important activity for scientist, technology and engineers in all parts of world.

**GEOLOGY IN TOWN AND REGIONAL PLANNING**

- The regional town planner is responsible for adopting an integrated approach in all such cases of allocation of land for developmental project.

**INTERNAL STRUCTURE OF EARTH**

- Direct observation of earth is not possible due to fact that the interior became hotter
- The deepest whole in the earth is only about 8km, this is quite negligible in comparison with radius of the earth
- The internal structures of earth is based on the existence yield at by indirect geophysical method (seismic method)
- The earth body comprises of several layers which are like shells resting one above the earth
- The layers are distinguished by the physical and chemical properties
- The interior of the earth has been obtain from the study of earthquakes waves through the earth

There are three types of earthquake waves. They are

- **P-WAVES/PRIMARY WAVES/LONGITUDINAL WAVES:**

  The waves travel in solid, liquid and gaseous medium.

  They have short wavelength and frequency.

- **S-WAVES/SECONDARY WAVES/TRANSVERSE WAVES:**
These waves travel in solid medium. They have short wavelength and high frequency.

- **L-WAVES/SURFACE WAVES/RAYLEIGH WAVES:**
  
  These are transverse waves and confined to outer skin of crust. These waves responsible for most of the destructive course of earthquake.

**THE FOLLOWING INFORMATION ABOUT THE INTERIOR OF THE EARTH:**

The shell of the increasing density are found towards the centre of the earth is **80g/cc**

Each shell is formed off different materials on the basics of seismic investigation the earth interior has been broadly divided into three major parts,

- **Crust**
- **Mantle**
- **Core**

It inferred that

A. The crust, mantle, core are separated by two sharp breaks known as major discontinuities.

B. The crust is having an average thickness of about 33kms.

C. The crust composed of heterogeneous materials.

D. The mantle extends from below the crust to a depth of 2900kms

E. The core extends from the below the mantle upto the centre of the earth is 6371kms

**CRUST**

Upper most shell of the earth is crust. The thickness ranges from organic 60 to 70kms. Its thickness oceanic areas 5 to 10 km and in continental areas is 35km. it can be divided into two layers

- Upper layer (continental crust)
- Lower layer (oceanic crust)

The Mohorovicic continuity marks the lower boundary. The boundary between SIAL and SIMA is called Conrad discontinuity,

**SIAL**

- Upper continental crust
- It consists of all types of rocks (Igneous, Sedimentary, Metamorphic rocks)
- This layer is rich in silica and aluminium
- The rocks are granitic and granodiotic composition
➢ The density of SIAL is 2.4g/cc
➢ The Conrad discontinuity which is located at the depth of 11km

SIMA
➢ Lower continental crust
➢ Thickness 23km extends from the Conrad discontinuity upto to Mohorovicic discontinuity
➢ This layer is rich in silica and magnesium
➢ The types of rocks are basaltic composition
➢ The density is 3g/cc

MANTLE
The second part of the earth is the source region of the earth internal energy and forces responsible for ocean floor spreading and continental drift and earthquake.
➢ Its thickness is about 2865kms
➢ The mantle is more dense than the overlying crustal rocks
➢ Depend on the velocity the mantle are classified into two
  Upper mantle
  Lower mantle
➢ The velocity of upper mantle is 11.32 to 11.4 km/s
➢ The velocity of the lower mantle is 13.4 km/s
➢ The lower mantle extends from 1000km to core boundary
➢ The lithosphere which separated from mantle is called asthonosphere
➢ It is situated between 70 to 220 kms depth

CORE
➢ It extends upto the very centre of the earth
➢ S-Waves do not pass through the outer core
➢ No information about the inner core
➢ Pressure and temperature are very high
➢ The temperature is around 6000 and it is believed to contain nickel and iron(NIFE)

ATMOSPHERE
◆ It is the envelope of air which surrounds the earth
Since the atmosphere is not of the density throughout and that atmosphere pressure decrease with height

TOP POSITION OF ATMOSPHERE: (DRY AIR)

Nitrogen - 78.03% by volume
Oxygen -20.99% by volume
Argon - 0.94% by volume
Co2 - 0.03% by volume
H2 - 0.01% by volume

The above composition of the atmosphere is almost uniform upto a height of 80km from the surface

STRUCTURE OF ATMOSPHERE:

The atmosphere has been divided into several types based on change in composition. Change in temperature and degree of ionization.

The atmosphere falls into five layers

A. Troposphere
B. Stratosphere
C. Mesosphere
D. Ionosphere
E. Exosphere

TROPOSPHERE:

⇒ It is the lower most layer of the atmosphere
⇒ Its height is about 12km from the surface
⇒ It is dense of all layers
⇒ It vital process create the climatic and weather condition of the earth surface

STRATOSPHERE

⇒ The zone extends in form of the boundary of the troposphere
⇒ Its height is about 55kms and temperature becomes constant upto 20kms height then it starts increasing
⇒ The upper state is rich in ozone layer which serves as a shield protecting the troposphere and the earth surface by observing most of ultra-violet radiation
⇒ The ozone layer is thicker important for the existence of life on the earth surface
The water vapour content of this stratosphere is negligible

**MESOSPHERE:**
- Above the stratosphere lies the mesosphere which is very cold region
- This layer extends upto 80 kms from the surface of earth
- At a layer of about 60 kms there occurs a layer called “radio waves observing layer”

**IONOSPHERE**
- The ionosphere extends upto a height of 1000 to 2000 km from the earth surface
- The part of ionosphere lying between 80 to 800 km is called “Thermosphere”
- In ionosphere almost all atoms are ionised
- This layer protects us from falling meteorites as it burns most of them

**EXOSPHERE**
- Above the ionosphere lies the exosphere
- It is the outermost zone of the atmosphere
- It is low density and high temperature region with minimum atomic collision
- Much about the exosphere is yet to be know

**WEATHERING**

It is defined as the process of disintegration and decomposition of rocks under the influence are physical and chemical agencies of atmosphere

**TYPES OF WEATHERING**

Physical weathering [temperature, wild]

Chemical weathering [water]

Biological weathering [vegetation and organism]

**PHYSICAL WEATHERING:**

- It is also called mechanical weathering
- It is a natural process of in-stu to disintegration of rocks into smaller fragment without change in composition
- It take place by two methods
  1. By frost action
  2. By thermal action

**EXFOLIATION**
Rocks are split into thin sheets and due to differential expansion and contraction

FREEZING OF WATER

Water as we know expands about 9.05% in volume when it freezes. The water steps down into fracture under suitable condition begins at the top of the fracture first.

A freezing continues the pressure exerted on the walls which result the fracture

This mode weathering causes where there is repeated of freezing and thawing

CHEMICAL WEATHERING

It is also known as mineral alternation consist of a number of chemical reaction

These reaction change the original silicate mineral of igneous rock

The primary mineral into new compounds (secondary compounds)

Five processes are mostly responsible for chemical weathering

Solution

Hydration and hydrolysis

Oxidation

Carbonation

Colloid formation

SOLUTION

Rock salt, gypsum, calcite when water added to them they form solution. But all rocks don’t easily soluble in pure water.

Example: limestone only acted by carbonated water

HYDRATION AND HYDROLYSIS:

Absorption of moisture is hydration, exchange or replacement of water ions is called hydrolysis. The free ion present in rocks absorbs moisture.

\[ \text{CaSO}_4 + 2\text{H}_2\text{O} \rightarrow \text{CaSO}_4.2\text{H}_2\text{O} \]

OXIDATION

Oxidation takes place in rocks which has high iron content. Example ferrous undergoes oxidation.

\[ 4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 (\text{ferric oxide}) \]

\[ \text{Fe}_2\text{O}_3 + \text{H}_2\text{O} \rightarrow \text{Fe}_2\text{O}_3\cdot\text{H}_2\text{O} (\text{ferric hydroxide}) \]

CARBONATION

Combined action of carbon-dioxide and moisture. Example granite
SPHEROIDAL WEATHERING

Formation of small rough balls on surface of rocks is spheroidal weathering

FACTOR AFFECTING WEATHERING

★ Nature of rocks
★ Climate prevailing in that area
★ Physical environment
★ Resistance of weathering

PRODUCTS OF WEATHERING

★ Eluvium
★ Deluvium
★ Regolith

ELUVIUM

End product present above the parent rock

DELUVIUM

Product formed aside the parent rock due to wind action

REGOLITH

It is both eluvium and deluvium

SOIL PROFILE

★ Top layer (consists of loose particles)
★ Second layer (not compacted much)
★ Third layer (compact layer)
★ Last layer (rocky)

ENGINEERING CONSIDERATION OF WEATHERING

It is important to know about the depth and extent of weathering

SCREE

The fragments that accumulate at the base of the heaps as commonly as scree deposits

TALUS SLOPE

The fragments that remain uneven steven over the surface of the slope. Such slope is covered by the frost formed scree are often referred to as talus slope

FLUVIAL PROCESS: (RIVER AND STREAM ACTION)
GEOLOGY WORK OF WATER:

The river originates from the mountain head region and reaches the sea

HEAD REGION

The mountainous region where from the river accurately originates and it is called head region

SOURCES OF STREAM WATER

Run off
Sub surface water
Glacial melt water

COMPONENTS OF RIVER

1. Channel
2. Velocity
3. Gradient
4. Discharge
5. Competence
6. Type of flow

CHANNEL

The path formed along the course of river

VELOCITY

The distance flowed per unit time

GRADIENT

It is also called as vertical flow of water / river
It is the slope of river starting from head region to mount

DISCHARGE

The amount of water flowing in river

COMPETENCE

The amount of materials carried or transported through it

It is define as the capacity of river to transport the material and it is represented by the largest size of particle that can be transported at given velocity

TYPE OF FLOW

_Laminar flow:_ Water moves in undistributed layer fashion
**Turbulent flow**: water flows in irregular manner due to disturbance

**STREAM EROSION:**

There are four methods

- Chemical action
- Hydraulic action
- Abrasion
- Attrition

**CHEMICAL ACTION**

It includes the solvent and chemical action of water on country rocks

The chemical decay works along the join and tracks and helps in breaking the bed rocks

**HYDRAULIC ACTION**

The flowing water hammer the uneven faces of joined rocks exposed along its channel and remove the joint blocks. This process is called hydraulic action.

**ABRASION**

The flowing water uses rock fragments such as pebbles, gravel, and sand

As a tool for grinding the sides and floor of valley

**ATTRITION**

It is the breaking of the transported material themselves due to mutual position collision

The attrition causes rock fragments to become rounder and smaller in size

**STREAM TRANSPORTATION:**

**LOAD:**

The amount of solid materials transported by a stream is called load

Transportation can be classified into three ways

1. Solution
2. Suspending
3. Bed load

**SOLUTION**: The amount of dissolved material is carried by a stream

**SUSPENSION**: The amount of uneven grains carried by stream

**BED LOAD**: Huge blocks of rocks due to the hydraulic action at a stream which normally occurs in waterfalls
STREAM DEPOSITION:
The loose rocks materials are transported by stream are deposited where the velocity of flowing water is reduced.

_The materials which are deposited as sediment is called alluvial deposits._

DEPOSITIONAL LANDFORMS:

- Alluvial fans
- Flood plains
- Natural levees
- Point bars
- Deltas

ALLUVIAL FANS:

The alluvial materials which flows down from mountains accumulates at foot hills where streams enter a plane such deposit spread out in the shape of flat fan and are called alluvial fans.

ALLUVIAL CONE:

The alluvial materials which flows down from mountain accumulates at the foot hills where stream enters a lane deposits spread out in the shape of cone fans and are called alluvial cone.

FLOOD PLAINS:

During flood a river overflows its bank and submerges the adjacent low lying area where the deposition of alluvial materials takes place.

A wide belt of alluvial plain formed in this way on either side of a stream is called flood plain.

NATURAL LEEVES:

Natural levees are the lower ridges which are formed on the both sides of the river channel by the accumulations of sediments.

POINT BARS:

In meandering rivers sediments deposits occur as a point bars. The point bars are the crescent shape deposits which occur at inside bends of a river channel.

DELTAS:

Deltas are deposits which are build at the mouth of stream.

They are triangular in shape.

When stream enters a ocean or lake the currents of flowing water dissipate quickly.
The structure of a delta deposit consist of three sets of bed.

Bottom set bed

Forest bed

Topset bed

BOTTOM SET BED:
It is thin horizontal bed which over lie the ocean bed or bottom. It composed of fine grained sediments such as silts and clay.

FORESET BED:
It is an intermediate bed the angle of the slope varies from 12 to 32 depending on the grain size of the material. These beds are composed of coarse sediment.

TOPSET BED:
These beds occupy the upper surface of the delta they are composed of coarse and fine sediment.

FEATURES OF STREAM EROSION:

Pot holes: It is circular and deep holes into solid rocks by sand grains.

Waterfalls: The falling of stream water from a height is called waterfalls. It occurs at place where the stream profile makes a vertical drop.

GORGES:
A narrow deep river valley which is called gorges. It is normally developed in hard rock terrain.

STREAM MEANDERS:
The symmetrical S-shaped loops found in the course of a river are called MEANDERS.

The meander grows due to deposition of sediment along slip off side and erosion at the undercut side.

RIVERS AND ENGINEERING CONSIDERATION:

- Rivers requires construction of bridge across them for carrying highways and railways.
- Water power of rivers can be utilized to generate hydroelectric.
- River deposits are the important sources of construction material.
- Regulations of river channel are done for navigation and for flood control.

FLOOD CONTROL:

- Construction of levees
- Longitudinal embankments which are built along the river banks.
DREDGING:

- The process of removing the sediment deposited at the bottom of the river.
- It is more expensive.

WORK OF WIND:

- The air currents in motion are called wind.
- The wind is formed due to pressure difference which is due to change in temperature, wind, volume, duration of wind and velocity of wind.

WIND EROSION:

The wind erosion is not restricted to arid and semi arid region. Wind thus erode in three ways,

Deflation

Abrasion

Attrition

DEFLATION:

Lifting and removal of loose material (dust, sand) by wind is called deflation. By this process the land surface is gradually lower.

Example:

1. **BLOWOUT**: Due to strong wind sand is transferred and causes a big depression.
2. **OASIS**: If water table itself exposed due to depression that it reaches water table of that area.
3. **HAMMADA**: Pavement like structure formed.

ABRASION:

- During dust storms the wind carries minute grains of sand in suspension.
- They dash and collide against the exposed rock masses and cause erosion.
- This process in which sand grains are used as tools for eroding rocks is called abrasion.
- **This type of erosion involves the following**,
  1. Rubbing
  2. Grinding
  3. Abrading
  4. Polishing

Examples:
1. **Yardangs**: These are elongated low lying ridges forming overhanging above local depression.

2. **Pedestal Rocks**: Pedestal rocks are the undercut vertical columns of rock which have wider tops and narrow at base.

3. **Ventrifacts**: A small size rock fragments showing one or more typically wind polished surface are called ventifacts.

**Attrition:**

- The particle that travels with wind, collide against each other.
- This mutual collisions leads to the further break down and the process is called attrition.

**Wind Transport:**

Turbulent wind can easily sweep small dust particles and carry them greater distance in suspension. However sands are transported in a series of jumps and roll along the ground such process are called saltation.

**Wind Deposits:**

The wind deposits are commonly called as ‘EOLIN’ deposit.

The wind deposits are of two types,

1. Sand dunes
2. Loess

**Sand Dunes:**

The wind deposit sand in mounds. The sand dunes are of four types,

1. **Barchans**: Its cresant shape dunes which face the wind direction.
2. **Longitudinal (Sinusoidal Dunes)**: The dunes are elongated in wind direction are longitudinal or sinusoidal dunes or seifs.
3. **Complex Dunes**: They are irregular in shape in areas where the wind direction varies complex dunes are formed

**Loess:**

The suspended loads transported by wind consist of mainly silt and clay minerals.

**Engineering Considerations:**

A sand dune causes major problem for civil engineer it may travel in any distance and diection and may causes bury agricultural land forest and even endanger township.

- Establishing frontal tracts (vegetation)
- Construction of wind breaks (walls)
Treating the sand locally with crude oil

**GEOLOGICAL WORK OF GLACIER:**

**WORK OF GLACIER:**

- A glacier is a thicker mass of ice moves over the ground under the influence of gravity.
- It originates on landforms the compaction of snow. They are found in high latitudes or high elevation.

**SNOW LINE:**

It is lower limit of accumulating snow. Below the snow line the snow melts in summer. It may occur at 6000m.

**TYPES OF GLACIER:**

**VALLEY GLACIER:** It originates near the crest of high mountains.

**PEIDMONT GLACIERS:** At the end of a hilly region a number of valley glaciers may unit to form a thick sheet of ice.

**ICE SHEETS:** Massive accumulations of ice covering extensive areas.

**MOVEMENT OF GLACIER:**

- **GRAVITY FLOW:** A mountain glacier flows down the slope much like stream of water under gravity.
- **EXTRUSION FLOW:** A glacier moves as a result of differential pressure within the ice mass.

**GLACIER EROSION:**

It is occurred by three ways,

- **PLUCKING OR QUARRYING:** while flowing over a jointed rocks surface the glacier ice adheres to blocks of jointed bed block pulls them out and carries them along.

- **ABRASION:** the moving ice grinds and polishes the rock fragments which are held firmly within the glacier.

- **FROST WEDGING:** thawing and freezing of water in cracks and joints of rocks breaks them by wedge action.

**FEATURE OF GLACIER EROSION:**

**STRIATION:**

- Glacier carry rock fragments firmly embedded in ice
- They scratch grind or groove the rock surface over which they are moved.

**V-SHAPED VALLEY:**

- Glaciers occupy valley and flow down the hills.
As they hanging erode their valleys both laterally and vertically
V-shaped valley with step walls and that floor are produced

HANGING VALLEY:
The valley of the tributary stands at the higher elevation than that of main valley

ICE BERGS:
If ice is less dense than water, it floats over water. Such floating ice hills is ice-bergs

CIRQUES:
The bowl shaped hallows present at the glacier valley heads in the mountains.

TRANSPORT OF GLACIER:
SUPER GLACIAL LOAD: The debris that falls down the valleys walls on the surface glacier.
ENGLACIAL LOAD: Sooner or later part of debris is engulfed.
SUB-GLACIAL LOAD: Debris present at the bottom of glacier
GLACIAL DEPOSIT:
There are two types
A. TILL: These are deposit directly by glacier
B. FLUVIO GLACIAL DEPOSIT: Materials deposited by glacial melt water

DEPOSITIONAL LANDFORMS:
MORAINES:
Ridges or layers of hills are moraines. They are of four types,
A. GRAND MORAINES: A layer of till deposited beneath the moving ice of the ground
B. LATERAL MORAINES: The material falls from valley accumulates sides of glacier
C. MEDIAL MORAINES: It is formed by union of lateral moraines
D. TERMINAL MORAINES: Forms at the end of glacier where ice starts melting

OUTWASH PLAINS:
In front of end moraines streams of melt water deposit sediment producing stratified deposit of sand, silt and gravel.

KETTLE HOLE:
These are basin like depression found in areas of till and outwash plains.

ICE AGE;
The Pleistocene epoch is called “ice age”. It began at least 25 million years ago.
GEOLOGICAL WORK OF EARTHQUAKE

- An earthquake is a sudden vibration of earth surface by rapid release of energy
- This energy released when two parts of rock mass move suddenly in relation of to each other along a fault.

EFFECTS OF EARTHQUAKE:

- Buildings are damaged
- Roads are fissured, railway lines are twisted and bridges are destroyed
- Rivers change their course
- Landslides may occur in hilly region.

TERMINOLOGY:

FOCUS:

- The point of origin of an earthquake within the earth crust is called focus.
- It radiates earthquake waves in all directions.

EPICENTRE:

- The point lying vertically above the earth surface directly above focus is called epicentre.
- In the epicentre the shaking is most intense.
- The intensity gradually decreases.

ISOSEISMAL LINES:

The line connecting points of equal intensity on the ground surface are called isoseismal lines.

EARTHQUAKE INTENSITY:

- It is a measure of the degree of distraction caused by an earthquake.
- It is expressed by a number as given in the earthquake intensity scale.

SEISMOGRAPHS:

Seismographs are instruments which detect and record earthquakes.

EARTHQUAKE WAVES (SEISMIC WAVES):

1. P-Waves (primary waves)
2. S-Waves (secondary waves)
3. L-Waves (surface waves)
During earthquake elastic waves are produced and are called seismic waves.

**P-Waves:**
- These are longitudinal waves having short wavelength.
- They travel very fast and reach seismic station first.
- Their velocity is 1.7 times greater than s-waves.
- They pass through solid, liquid, gaseous medium.

**S-Waves:**
- These are shear waves which are traverse in nature.
- They travel only in solid medium.

**L-Waves:**
- When p and s-waves reached the earth surface they are called l-waves.
- Here velocity is much less.

**CLASSIFICATION OF EARTHQUAKE:**

**CLASSIFICATION –I:** Depending on mode of origin

1. **DUE TO SURFACE CAUSES:** Generated by land slopes and collapse of root of underground waves.
2. **DUE TO VOLACANIC CAUSES:** It may also produce earthquakes but very feeble.
3. **DUE TO TECTONIC PLATES:** Most numerous and disastrous and caused by shocks originated in earth crust due to sudden movements of faults.

**CLASSIFICATION-II:** Depending on depth of focus

1. **SHALLOW FOCUS:** Depth of focus up to 55kms.
2. **INTERMEDIATE FOCUS:** Depth between 55-300kms.
3. **DEEP FOCUS:** Depth from 300-600kms.

The shallow earthquakes are more violent at the surface but affect a smaller area.

**EARTHQUAKE INTENSITY SCALE:**

**ROSSI FOREL SCALE:** It has 9 divisions

- **INTENSITY-I:** Weakest earthquake
- **INTENSITY-IV:** Cause damage to property
- **INTENSITY-IX:** Strongest earthquake that cause massive destruction to manmade structure and natural objects.
**Richter Scale**: Devised by Charles F. Richter an American seismologist

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>Not felt but recorded</td>
</tr>
<tr>
<td>4.5</td>
<td>Local damage</td>
</tr>
<tr>
<td>6.0</td>
<td>Can be destructive in popular region</td>
</tr>
<tr>
<td>7.0</td>
<td>Major earthquake inflict series damage</td>
</tr>
<tr>
<td>&gt;8.0</td>
<td>Great earthquake cause total destruction</td>
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**Distribution of Earthquake:**

The zones where earthquake occurs are known as seismic belts.

- **Circum Pacific Belt**: (Pacific Ocean): 80% of the world earthquake occur in this belt
- **Alpine Himalayan Belt**: Europe to East Indies
- **Rift Valley Region**: East and Central Africa

**Magnitude**:

The total amount of energy release during an earthquake.

**Engineering Consideration**:

**Seismic History**:

- Study of seismic events in particular region to know the intensity and magnitude
- By seismic zoning, area are classified on their varying earthquake and also geological setting of areas

**Problems**:

- To know the seismic history of area
- To access the magnitude and probable loss or damage in quality or quantity due to likely seismic shocks in the period of the structure
- To introduce safety factors in new construction and possible to safeguard early structure

**Assessment of Seismic Risk**:

Seismic risk is the probability of occurrence of a critical earthquake during the projected life period

**Critical Earthquake**:

An earthquake occurred in area as past T- yans and has recorded the magnitude capable of producing horizontal and accelerate greater than a minimum value at that particular locality.

**Projected Design Period**:
The civil engineers designed structure to be in service of 500 yrs, 100 yrs, 125 yrs greater the designed to resist the vertical according of Hg by virtue of its weight only.

*Ground according due to an expected shock due to designed life of the project.*

1. Weight of structure
2. The type of construction
3. Base shear force
   
   $F = \frac{a \cdot w}{g}$

   a- Ground acceleration
   
   g- acceleration due to gravity
   
   w- weight of structure

   simplest empirical function,

   $F = [SKZIRN] \cdot W$

   S- factors depending of response spectra whose value varies 0.1283
   
   K-factor depending on nature of damage value for masonry construction between 2-4 and reinforced 0.6 to 1.6
   
   Z= seismic co-efficient lies between 0.15 and 0.02

   I= factor depending on importance of structure

   R= risk factor

   N= factor depending upon nature of soil

   W= dead load 25%

**QUAKE RESISTANCE BUILDING:**

Addition factor of safety against seismic forces.

**FOUNDATION:**

Avoiding building to build at loosen soils or sediments.

Super structure should be through out tied up with the foundation.

**BODY:**

Walls should be of stronger with reinforced rather the plain concrete

Continuity of cross walls should be maintained.

In masonry walls, they should be instead in a paper in a paper style.

**ROOF :**

Better roof is RCC roof
Projection above on beyond the roof level should be avoided

GENERAL:
All parts of same building should be tied finely.
Uniform weight architecture fracture should be avoided.

QUAKE RESISTANCE:
Force due to dams
\[ V_c = W.C \]
Force due to reservoir water
\[ P_e = C.A.W.H \]
\[ P_e = \text{hydrodynamic force at depth } y \]
\[ h. = \text{maximum depth at reservoir} \]
\[ c = \text{co efficient depending on} \]

PHYSIOGRAPHIC DIVISION OF INDIA:
India can be divided into 3 main division which may differ from one another in physiography, stratigraphy and structure.

1. Peninsular
2. Indo-gangetic plain
3. Extra peninsular India

PENINSULAR:
It lies to the south of plain of India of ganga river

Physiography:
- Peninsular has extremely various physiography they are plateaus, fold mountains, valleys and coastal plains.
- Western ghats which form a premonient physiographic features

Structure:
- Peninsular India is nearly a stable pleatue which has unaffected by the orogenic movements
- The normal and block faulting is however common

Stratigraphy:
- Peninsular is primarily made up of rocks of Archean and Precambrian age
- The Archean rocks have been metamorphosed to varying degree

INDO-GANGETIC PLAIN:
This plains extends from Assam in east, through Bengal, Bihhar and Utter Pradesh, Arabian sea upto Punjab in the east.

**Physiography:**

It is very extensive alluvial plain which sloping with a very small gradients towards the sea

**Structure:**

- The bottom of the Indo-Gangetic basin is asymmetrical
- The northern margin of the Peninsular India dips gently northward

**Stratigraphy:**

They are chiefly made up of sands and clay of Pleistocene and recent age

**EXTRA PENINSULAR INDIA:**

It lies at the northern extrinity of the country. It is made up of the Himalayan mountain ranges in north.

**Physiography:**

- It is made up of the tectonic mountains and frontal foredeep fold belt of tertiary age.
- The frontal foredeep belt is also called as “Outer Himalaya”
- The Himalayan belt extends in E-W direction and its total length is 2400Km

**Structure:**

It have been distributed greatly by the complex folding and faulting

**Stratigraphy:**

It has been sub-divided into 4 zones

- The Thyan Himalayan zone: consists of marine rock beds
- Central zone: made up of Granitic plateaus
- Lesser Himalayan zone: rocks are relatively less metamorphosed
- Foredeep folded belt: mainly made up of sediments
UNIT-II

MINERALS:

➔ Inorganic substances which has more or less definite atomic structure and chemical composition

➔ It has constant physical property which are used in the identification of mineral in the field

➔ It can be divided into 2 groups

1. Rock forming mineral: Which are found in abundance of earth crust

2. Ore forming minerals: which are economic valuable minerals

MINERAL GROPUS:

<table>
<thead>
<tr>
<th>MINERAL GROUP</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxides</td>
<td>Quartz, magnetite, haematite, etc</td>
</tr>
<tr>
<td>Silicates</td>
<td>Feldspar, mica, hornblende, augite, olivine, etc</td>
</tr>
<tr>
<td>Carbonates</td>
<td>Calcite, dolomite, etc</td>
</tr>
<tr>
<td>Sulphides</td>
<td>Pyrites, galena, sphalerite, etc</td>
</tr>
<tr>
<td>Sulphates</td>
<td>Gypsum</td>
</tr>
<tr>
<td>Chlorite</td>
<td>Rock salt, etc</td>
</tr>
</tbody>
</table>

➔ Over 4000 mineral exist in earth crust

➔ All are composed of oxygen, silicon, aluminium, iron, calcium, potassium, sodium and magnesium
PHYSICAL PROPERTIES:

- Physical properties can be determined in inspection or by simple test
- It can be determined by hand specimen
- The chief physical properties are colour, streak, lustre, hardness, habit, cleavage, fracture, odour, tenacity, specific gravity and crystal forms.
- Correct identification are made of with polarizing microscope

COLOUR:

Occur due to certain wavelength of light by atoms making of crystals. On the basic of colour of a mineral; may belong to anyone of three types,

- **IDIOCHROMATIC**: show a constant colour appear metallic crystal ex. Copper
- **ALLOCHROMATIC**: Show variable colors, appear non-metallic ex. Quartz
- **PSEUDOCHROMATIC**: Shows false colour

Some minerals viewed in different directions shows irregular changes in colour

1. **PLAY OF COLOR**: Change in rapid succession on rotation ex. Diamond
2. **CHANGE OF COLOR**: Rate of change of colours on rotation and intensity is low ex. Labrodorite
3. **IRIDESCENCE**: Shows rainbow colours in interior or exterior surface ex. Limonite, Hematite
4. **TARNISH**: Change of original colour due to oxidation ex. Bornite

STREAK:

- The streak of the mineral is the true colour of the mineral is quite helpful in identifying mineral
- The streak is obtained by rubbing a mineral against an unglazed porcelain plate

Example: Magnetite, black in colour and give blackish brown colour as streak

LUSTRE:

General appearance of a mineral surface in reflected light

1. **METALLIC**: Metallic appearance ex. Magnetite, hematite
2. **SUB-METTALIC**: Feebly displayed metallic lustre ex. Chromite
3. **ADAMANTINE**: Hard brilliant lustre ex. Diamond
4. **VITREOUS LUSTRE**: Lustre exhibited by broken glass ex. Quartz, gypsum
5. **PEARLY LUSTRE**: Lustre exhibited by pearls ex. Talc, calcite
6. **SILKY LUSTRE**: Lustre exhibited by silk fibres ex. Asbestos
7. **RESINOUS LUSTRE**: Exhibited by resin ex. Sphalerite, nephiline
8. **GREASY LUSTRE**: Lustre exhibited by grease ex. Talc

9. **DULL OR EARTHLY**: No lustre said to earthy lustre ex. Kaolin

**HARDNESS:**

- Hardness of mineral depends on chemical composition
- Determined by rubbing or scratching a mineral of unknown hardness against one of known hardness
- A numerical value is obtained by using the moh’s scale of hardness
- Here 10 minerals are arranged in order of increasing hardness

<table>
<thead>
<tr>
<th>HARDNESS</th>
<th>MINERAL</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Talc</td>
<td>Scratched by finger nail</td>
</tr>
<tr>
<td>2</td>
<td>Gypsum</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Calcite</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fluorite</td>
<td>Scratched by knife</td>
</tr>
<tr>
<td>5</td>
<td>Apatite</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Orthoclase</td>
<td>Scratched by knife scarcely</td>
</tr>
<tr>
<td>7</td>
<td>Quartz</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Topaz</td>
<td>Not scratched by a knife</td>
</tr>
<tr>
<td>9</td>
<td>Corundum</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Diamond</td>
<td></td>
</tr>
</tbody>
</table>

**CLEAVAGE:**

It is defined as a tendency of mineral to break more easily with smooth surface along plane of weak bonding. The cleavage can be classified as perfect, good, poor, and indistinct.

**Example:**

- **PERFECT CLEAVAGE**: Mica, Galena, Calcite
- **NO CLEAVAGE**: Quartz

**FRACTURE:**

The nature of the surface of a mineral is called as fracture. The common types of fracture are

1. **EVEN FRACTURE**: Surface almost flat ex. flint, chert
2. **UNEVEN FRACTURE**: Surface is irregular and rough ex. Fluorite
3. **CONCHOIDAL FRACTURE**: Curved surface showing concentric line like shell ex. Quartz
4. **HACKY FRACTURE**: Rough surface with sharp and jagged points ex. Asbestos

5. **EARTHY FRACTURE**: Smooth, soft and porous ex. chalk, kaolin

**SPECIFIC GRAVITY:**

Its number which represent the ratio of weight of the mineral to the weight of an equal volume of water.

**HABIT (FORM):** The chief habits of minerals are shown as follows,

1. **ACCICULAR**: Needle like crystal ex. Natrolite

2. **FIBROUS**: Aggregate of long thin fibre ex. Asbestos

3. **FOLIATED**: Thin separate sheet ex. Mica

4. **BLADED**: Occur as small knife blade ex. Kyanite

5. **TABULAR**: Broad flat surface ex. Gypsum, feldspar

6. **COLUMNAR**: Columnar crystal ex. Tourmaline

7. **GRANULAR**: aggregate of equi-dimension grains ex. Magnetite

8. **REINFORM**: Kidney shaped form ex. hematite

9. **OOLITIC**: Aggregate bodies resembling fish roe ex. Bauxite

10. **MASSIVE**: Structural less mass ex. Flint

**ROCK FORMING MINERALS:**

1. **SILICATE MINERALS**: CONSTITUTE 90% OF EARTH CRUST

2. **NON-SILICATE MINERALS**: There are 2 groups,
   - I. Stable (quartz group, feldspar group)
   - II. Unstable (pyroxene group, amphibole group, mica group, olivine)

**ATOMIC STRUCTURES:**

1. Neosilicates

2. Sorosilicates

3. Cyclosilicate(ring structure)

4. Inosilicate(chain silicate)

5. Phythosilicat(e-sheet structure)

6. Tectosilicates
QUARTZ GROUP:

- It is an important rock forming mineral next to feldspar
- It is a non-metallic refractory mineral
- It is a silicate group

PHYSICAL PROPERTIES OF QUARTZ:

CRYSTAL SYSTEM: Hexagonal

HABIT: Crystalline or amorphous

FRacture: Conchoidal

HARDNESS: 7

SPECIFIC GRAVITY: 2.65-2.66(LOW)

STREAK: No

TRANSpareNCY: Transparent/semi-transparent/opaque

POLymorphism transformation:
Quartz → tridymite → cristobalite → melt

COLOURED VARIETIES:

- Pure quartz is always colourless and transparent
- Presence of impurities the mineral showing colour they
  Amethyst: purple or violet
  Smoky quartz: shades of grey
  Milky quartz: light brown, pure white, opaque
  Rose quartz: rose

CRIPTOCRYSTALLINE FORMS OF QUARTZ:

CHALCEDONY: Amorphous, waxy lustre

AGATE: A banded, variety having different colours

JASPER: Dull red, yellow, massive

FLINT: Dark grey, conchoidal fracture

OPAL: Amorphous

QUARTZ FAMILY MINERALS

PRIMARY: Recrystallization process(si, al, fe)
SECONDARY: Precipitation (chalcedony, opal, chert, flint)

OCCURRENCE:
It occurs in all types of rocks igneous, metamorphic and sedimentary rocks

USES:
- Used as semi precious stone
- Form of sand in construction
- Used as abrasive in industries
- Used for making watches
- Piezoelectric crystal for frequency state

FELSPAR GROUP:
- It is most abundant of all minerals
- It is used for making more than 50% by weight crust of earth
- It is non-metallic and silicate minerals

CHEMICAL COMPOSITION:
Potash feldspar  $\text{KAlSi}_3\text{O}_8$
Soda-lime feldspar  $\text{NaAlSi}_3\text{O}_8$ (OR) $\text{CaAl}_2\text{Si}_2\text{O}_8$

VARITIES OF POTASH FELSPAR:
Orthoclase
Sanidine
Microcline

SODA LIME FELSPAR:
Albite
Oligoclase
Andecine
Amarthitite
Labrodorite

GENERAL PHYSICAL:
CRYSTAL SYSTEM: monoclinic, triclinic
HABIT: Tabular (crystalline)
CLEAVAGE: Perfect (2-directional)
FRACTURE: Conchoidal or uneven

COLOUR: White, grey, pink, green, red

LUSTRE: Vitreous

HARDNESS: 6-6.5

SPECIFIC GRAVITY: 2.56-2.58 (low)

STREAK: No

OCCURRENCE: Igneous rock

USES: Ceramics, glass, tableware, enamels, electric porcelain, false teeth

POTASH FELSPAR:

ORTHoclase:

CRYSTAL SYSTEM: monoclinic

COLOUR: red

CHEMICAL COMPOSITION: KAlSi$_3$O$_8$

MICROcline:

CRYSTAL SYSTEM: triclinic

COLOUR: flesh red

CHEMICAL COMPOSITION: KAlSi$_3$O$_8$

USES: ceramic semiprecious

SODA LIME FELSPAR:

ALBITE:

CRYSTAL SYSTEM: Triclinic

COLOR: Whitish or pinkish white

COMPOSITION: NaAlSi$_3$O$_8$

USES: Ceramic, ornamental stone

ANOrrHite:

CRYSTAL SYSTEM: Triclinic

COLOR: White

COMPOSITION: Ca Al$_2$Si$_3$O$_8$ (90%), NaAlSi$_3$O$_8$ (10%)

USES: ceramic, ornamental stone

OCCURRENCE: all types of rocks
**PYROXENES GROUP:**

- It is important group of rock forming minerals
- They are commonly occur in dark colours, igneous and metamorphic rocks
- They are rich in calcium, magnesium, iron, silicates
- It show single chain structure of silicate
- It is classified into orthopyroxene and clinopyroxene. It is based on internal atomic structure

**ORTHOPYROXENE:**

- Enstatite (MgSiO₃)
- Hypersthene [(Mg,Fe)SiO₃]

**CLINOPYROXENE:**

- Augite [(Ca, Na) (Mg, Fe, Al) (Al, Si)₂O₆]
- Diopside [CaMgSi₂O₆]
- Hedenbergite[CaFeSi₂O₆]

**AUGITE:**

- **CRYSTAL SYSTEM:** Monoclinic
- **HABIT:** Crystalline
- **CLEAVAGE:** Good (primastic cleavage)
- **FRACTURE:** Conchoidal
- **COLOUR:** shades of greyish green and black
- **LUSTRE:** vitreous
- **HARDNESS:** 5-6
- **SPECIFIC GRAVITY:** medium
- **STREAK:** white
- **OCCURRENCE:** ferro magnesium mineral of igneous rock (dolerite)
- **USES:** rock forming mineral
- **COMPOSITION:** [(Ca, Na) (Mg, Fe, Al) (Al, Si)₂O₆]
- **TRANSPARENCY:** Translucent/opaque

**AMIPHOBLE GROUP:**

- These are closely related to pyroxene group
- It shows double chain silicate structure
Rich in calcium, magnesium, iron oxide and Mn, Na, K and H

CLASSIFICATION:
1. Orthorhombic
2. Monoclinic
   a. Hornblende
   b. Tremolite
   c. Actinolite

HORNBLENDE: (COMPOUND-COMPLEX SILICATE)

CRYSTAL SYSTEM: Monoclinic
HABIT: crystalline
CLEAVAGE: good (prismatic)
FRACTURE: conchoidal
COLOUR: dark green, dark brown black
LUSTRE: vitreous
HARDNESS: 5 to 6
SPECIFIC GRAVITY: 3 to 3.5 (medium)
STREAK: colourless or white
COMPOSITION: hydrous silicates of Ca, Na, Mg, Al
TRANSPARENCY: translucent/opaque
OCCURRENCE: found in igneous rocks
USES: road material

MICA GROUP:
- Form sheet like structure
- Can be split into very thin sheets along one direction
- Aluminium and magnesium are rich
- Occupy 4% of earth crust
- Shows basal cleavage

CLASSIFICATION:

LIGHT MICA:
Muscovite-KAl₂(AlSi₃O₁₀)(OH)₂-Potash mica
Paragonite - NaAl$_2$(AlSi$_3$O$_{10}$)(OH)$_2$ - Soda mica

Lepidolite - KLiAl(Si$_4$O$_{10}$)(OH)$_2$ – Lithium mica

**DARK MICA:**

Biotite- K(Mg,Fe)$_3$(AlSi$_3$O$_{10}$)(OH)$_2$. (Fe Mg mica)

Phlogopite - KMg$_3$(Al$_3$Si$_3$O$_{10}$)(OH)$_2$. (Mg mica)

Zinwaldite - Complex Li-Fe mica

**GENERAL PHYSICAL PROPERTIES:**

**CRYSTAL SYSTEM:** Monoclinic

**HARDNESS:** 2-3

**LUSTRE:** Vitreous

**HABIT:** Foliated

**CLEAVAGE:** perfect (basal)

**LIGHT MICA:**

Muscovite:

**CRYSTAL SYSTEM:** monoclinic

**HARDNESS:** 2-3

**LUSTRE:** vitreous

**HABIT:** foliated

**CLEAVAGE:** perfect

**SPECIFIC GRAVITY:** 2.7-3

**STREAK:** colourless

**COMPOSITION:** KAl$_2$(AlSi$_2$O$_{10}$)(OH)$_2$

**OCCURRENCE:** in igneous rock (granite and pegmatite) and accessory mineral in sedimentary rock

**USES:** electrical industry

**TRANSPARENCY:** Transparent

**FRACTURE:** even

**COLOUR:** colourless

**LEPIDOLITE:**

**CRYSTAL SYSTEM:** monoclinic

**HABIT:** granular
CLEAVAGE: good
FRACTURE: even
COLOR: colorless
LUSTRE: pearly
HARDNESS: 2-3
SPECIFIC GRAVITY: 2.8-3.3
STREAK: colourless
COMPOSITION: $\text{NaAl}_2\text{(AlSi}_3\text{O}_{10})\text{(OH)}_2$
TRANSPARENCY: transparent
OCCURRENCE: In igneous rock
USES: fire proof material

DARK MICA:

BIOTITE:

CRYSTAL SYSTEM: monoclinic
HABIT: foliated
CLEAVAGE: perfect
FRACTURE: even
COLOUR: black, deep green
LUSTRE: vitreous
HARDNESS: 2.5-3
SP.GRAVITY: 2.7-3
STREAK: colourless
COMPOSITION: $\text{K(Mg Fe)}_3\text{(Al Si}_3\text{O}_{10})\text{(OH)}_2$
OCCURRENCE: commonly found in igneous rocks, sedimentary rocks
TRANSPARENCY: Translucent
USES: electrical industries

PHOGOPITE:{LIMITED OCCURRENCE}
FRACUTRE: even

COLOUR: yellow, brown red

LUSTRE: vitreous

HARDNESS: 2.5-3

SP.GRAVITY: 2.7-3

STREAK: colourless

COMPOSITION: K$_3$(Al$_3$Si$_3$O$_{10}$)(OH)$_2$

TRANSPARENCY: translucent

OCCURRENCE: in igneous rock, metamorphic rock and rarely in sedimentary rock

USES: electrical industries

IRON OXIDE MINERALS:

MAGNETITE:

Crystal system: cubic

Habit: crystalline, massive or granular

Fracture: uneven

Cleavage: absent

Lustre: metallic

Hardness: 6-7

Sp.gravity: 5.18(high)

Streak: brown

Composition: Fe$_3$O$_4$

Transparency: translucent

Occurrence: as a accessory in igneous rock

Uses: it is important ore of iron

HEMATITE:

Crystal system: hexagonal

Habit: massive

Cleavage: absent

Fracture: uneven

Color: reddish brown to black
Lustre: mettalic
Hardness: 5-6
Sp. Gravity: 5.26(high)
Streak: dark red
Composition: Fe$_3$O$_3$
Varieties: red ocher
Transparency: translucent
Occurrence: thick beds of sedimentary rocks
Uses: as iron ore and pigments

**PYRITE:**
Crystal system: cubic
Habit: cube or granular
Cleavage: absent
Fracture: conchoidal
Colour: brass yellow
Lustre: vitreous
Hardness: 6-6.5
Sp. Gravity: 5.02
Streak: greenish or brownish black
Transparency: translucent
Occurrence: common sulphide minerals found in hydrothermal veins of metamorphic rock
Uses: used in manufacture of sulphuric acid

**SIDERITE:**
Crystal system: hexagonal
Habit: crystalline, fibrous also granular
Cleavage: perfect
Colour: light to dark brown
Lustre: vitreous
Streak:
Fracture:
Hardness: 3.5-4
Sp. Gravity: 3.96 (medium)
Composition: FeCO₃
Transparency: translucent
Occurrence: massive in sedimentary deposit
Uses: in steel industries

**CARBONATE MINERAL:**

**CALCITE:**
Crystal system: hexagonal
Habit: tabular
Cleavage: perfect
Fracture: even
Colour: milky white, grey, green, yellow, colourless, etc
Lustre: vitreous
Hardness: 3
Sp. Gravity: 2.71 (low)
Streak: colourless
Composition: CaCO₃
Transparency: transparent
Uses: used for manufacture of cement and lime, it is also used as fertilizer
Occurrence: rocking forming mineral in sedimentary rocks.

**CLAY MINERAL GROUP:**

- These are phyllosilicates minerals
- Essentially hydrous aluminium silicates
- These are common weathering products
- Very common in sedimentary rock

**CLASSIFICATION:**
There are four group.

1. Kaolin
   a. Kaolinite
b. Dictite
c. Nacrite
d. Halloysite

2. Smectite
   a. Montmorillonite
   b. Nontronite
   c. Hectorite

3. Illite

4. Chorite

PHYSICAL PROPERTIES:

KAOLIN GROUP:

KAOLINITE:
   It is formed by weathering of aluminate-silicate minerals. The feldspar rich rocks are commonly weathered to kaolinite.
   
   Crystal system: Triclinic
   Habit: Massive
   Colour: White sometimes brown
   Cleavage: Perfect
   Fracture: Even
   Streak: White
   Lustre: Dull earthy
   Hardness: 2
   Specific gravity: 2.6 (low)
   Transparency: Translucent
   Composition: Al₂Si₂O₅(OH)₄

   Occurrence: secondary mineral formed by alternation of alkali feldspar
   Uses: ceramic industries, medicine, cosmetics and main components in porcelain

HALLOYSITE:
   
   Crystal system: Monoclinic
   Habit: Massive
Colour: white, grey, green, yellow, red, blue

Streak:

Cleavage: imperfect

Lustre: waxy or dull

Fracture: conchoidal

Hardness: 2-2.5

Sp. Gravity: 2-2.5 (low)

Transparency: Translucent

Composition: Al₂Si₂O₅(OH)₄

Occurrence: secondary mineral formed by alternation of alkali feldspar

SMECTITE GROUPS:

MONTMORILLONITE:

- It is derived from weathering of volcanic ash
- In contact with water it expands several times its original volumes
- Act as drilling mud and it is main constituents os petronite

Crystal system: Monoclinic

Habit: Lamellar/ Globular

Colour: White, blue or yellow

Streak:

Lustre: Dull Earthy

Fracture: Uneven

Cleavage: Perfect

Hardness: 1-2

Sp. Gravity: 1.7-2(low)

Transparency: Translucent

Composition: (Na, Ca)₀.₃₃(Al Mg)₂ Si₄O₁₀(OH)₂·nH₂O

Occurrence: derived from volacanic ash also weathering of muscovite, illite, kaolinite

Uses: Mainly used for oil industry(drilling mud)

ILLITE:
The illite clay have a structure similar to that of muscovite. They form by alternate minerals like muscovite and feldspar.

**Chemical composition:** \((K, H)\) \(Al_2(Si, Al)_{10}(OH)_2 XH_2O\)

**Uses:** in oil industry

**CHLORITE:**

**Crystal system:** Foliated Monoclinic

**Habit:** Foliated

**Colour:** Grey, Green

**Streak:** White

**Cleavage:** Good

**Fracture:** Even

**Lustre:** Vitreous

**Sp. Gravity:** Low

**Hardness:** 2-3

**Transparency:**

**ENGINEERING CONSIDERATIONS OF CLAY MINERALS:**

- Montmorillonite is a dangerous type of clay cut it when found in road or tunnel since it has expandable nature which causes slope or wall failure
- Kaolinite is used in ceramic industry, it is not expandable and wont absorb water
- Clay is used as important material in construction industries both as building material and as foundation or structure
- It has poor drainage because the soil tends to stay wet and soggy when it is affected by water, while it is wet it can be easily compacted
- It has poor aeration because the soil particles are small and closely spaced, it is very difficult for air to enter or leave the soil
- It has very high nutrients reserves, reducing the need for fertilization also because clay retains water plants growing in it often more drought tolerant than plants growing in sandy soil

**ENGINEERING CLASSIFICATION OF MINERALS:**

Minerals have been classified based on their influence on the performance of rocks/soil. A partial listing of potential minerals are as follows,

**SOLUBLE MINERALS:**
Calcite (CaCO₃), Dolomite (CaMg(CO₃)₂), Gypsum (CaSO₄·2H₂O), Anhydrite (CaSO₄), Halite (NaCl₂), Zeolite

**UNSTABLE MINERALS:**
Marcasite, pyrhotite

**PONTENTIALLY UNSTABLE MINERALS:**
Nontronite (iron rich montmorillonite), Nepheline, Lucite, mica rich in iron

**MINERALS WHICH RELEASE H₂SO₄ ON WEATHERING:**
Pyrite, pyrrohotite, other sulphide minerals

**MINERALS WITH LOW COEFFICIENT FRICTION:**
Clay minerals, talc, chlorite, serpentine, mica, graphite, molybdenite

**POTENTIALLY SWELLING MINERALS:**
Clay minerals (illite, kaolinite, bentonite, montmorillonite)
Anhydrite, vermiculite

**ALKALI REACTIVE MINERALS (INTERFERE WITH CEMENT):**
Opal, volcanic glass, chert, chalcedony, gypsum, zeolite, mica, amorphous quartz

**MINERALS WITH HIGH DENSITY:**
Iron oxide, sulphide minerals, other metallic minerals, barites

**MINERAL CONTRIBUTING ARSENIC TO GROUNDWATER:**
Arseno-pyrite, arsenolite, proustite

**MINERALS RELEASE FLUORIDE INTO GROUNDWATER:**
Fluroapatite
UNIT- 3
PETROLOGY

ROCKS:

- Defined as aggregates of minerals
- Forms major part of earth crust
- Quartzite and marbles contain only one mineral but most are composed of variety of different mineral
- Boardly classified into 3 groups. They are
  1. Igneous rocks
  2. Sedimentary rocks
  3. Metamorphic rocks

IGNEOUS ROCKS:

- Formed by cooling and solidification of magma
- “Magma” is a hot viscous, siliceous melt, contains water vapour and gases
- Magma comes from great depth bellow earth surface it composed of O, Si, Al, Fe, Mg, Na and K
- When a magma comes out upon the earth surface such magma is called lava

CHEMICAL COMPOSITION:

$\text{SiO}_2$: 40-70%
$\text{Al}_2\text{O}_3$: 10-20%
$\text{Ca, Mg, Fe}$: 10%

Magma are divided into 2 groups based on chemical composition

ACID MAGMA:

Si, Na and K (rich)
Ca, Mg and Fe (poor)

BASIC MAGMA:

Ca, Mg and Fe (rich)
Si, Na and K (poor)

NATURE OF MAGMA:
LIQUID PORTION: melt
SOLIDS: any silicate minerals
VOLATILES: dissolved gases in melt, including water vapour, CO₂ and SO₂

CRYSTALLIZATION OF MAGMA:

- Cooling results in systematic arrangements of ions
- Silicate minerals resulting in crystallization forms in a predictable order and develop distinct texture and structure

BASIC CLASSIFICATION:

VOLCANIC ROCKS/ EXTRUSIVE ROCKS:
Rocks formed from lava on earth surface

PLUTONIC ROCKS/ INTRUSIVE ROCKS:
Rocks formed from magma at deep seated layer in earth

HYPABYSSAL ROCKS:
Rocks formed close to surface of earth

TEXTURE:
Overall appearance of a rock based on the size, shape and arrangement of interlocking minerals is called texture.

FACTORS AFFECTING CRYSTAL SIZE:

1. Rate of cooling:
   - Slow rate ➔ fewer but large crystal
   - Fast rate ➔ many small crystal
   - Very fast rate forms crystals

2. % of SiO₂ present

3. Dissolved gases

TYPES OF IGNEOUS TEXTURE:

BASED OF VISIBLE CRYSTALLINITY:

APHANITIC:
- Fine grained texture
- Rapid rate of cooling
★ Microscopic crystal
★ May contain visicles

**PHANERITIC:**
★ Coarse grained texture
★ Slow cooling
★ Large, visible crystals

**GLASSY TEXTURE:**
★ Very rapid cooling of lava
★ Resulting rock is called obsidian

**BASED ON VARIATION IN CRYSTAL SIZE:**

**PORPHYRITIC TEXTURE:**
Large crystals (phenocrysts) are embedded in a matrix of smaller crystals (ground mass)

**EQUIGRANULAR TEXTURE:**
All crystals are of same size

**INEQUIGRANULAR TEXTURE:**
Some of the crystals are larger than others

**BASED ON CRYSTAL SIZE:**
Coarse grained texture - crystal size >2mm
Medium grained texture - crystal size 2-0.06 mm
Fine grained texture - <0.06 mm

**OTHER TYPE OF TEXTURE:**

**PEGMATITIC TEXTURE:**
★ Coarse grained
★ Crystallization of granitic magma

**PYROCLASTIC TEXTURE:**
★ Rock fragments thrown out during volcanic process are called pyroclastic.
★ Depending on size they are ash, lapilli and volcanic bombs

**STRUCTURE FEATURES:**
PRIMARY STRUCTURES:

Structure formed at the time of formation of rock

i. **COLUMNAR JOINTS**: due to shrinkage polygonal cracks develops- divide to polygonal. Eg. Basalt, rhyolite

ii. **FLOW STRUCTURE**: presence of parallel layers/bands/streaks due to flow

iii. **PIillow STRUCTURE**: overlapping pillows like surface on rocks

iv. **RIFT AND GRAIN**: refer to 2 direction, easiest direction to break is rift and other is grain

v. **VESICULAR STRUCTURE**: holes present in rocks due to escape of gases

vi. **MIAROLYTIC STRUCTURE**: holes filled with volatile material

vii. **ROPY AND BLOCKY STRUCTURE**: ropy refers waviness, blocky represent the broken/fragments urface of rocks

viii. **ARBICULAR STRUCTURE**: appears like spheroidal

ix. **BLOCKY STRUCTURE**: Blocky lava is less mobile i.e. less viscous and has viscous and irregular surface, vesicles are few and irregular

x. **ROPY STRUCTURE**: lava is more mobile i.e. less viscous but are smooth and shiny surface

xi. **AMYGLOIDAL STRUCTURE**: These are rounded outlines reflecting their origin as bubble filling are called amygdules.

SECONDARY STRUCTURE:

These are formed due to various stress on primary rocks

i. **SHEETING**: one set of joint parallel to ground surface

ii. **SHEAR ZONES**: joints due to shear force

iii. **MURAL JOINTS**: Three set of joints dividing rock into cubical rocks

iv. **FAULT JOINTS**: formed due to shear displacements between rocks

FORMS OF IGNEOUS ROCKS (INTUSIVE ROCK):

**CONCORDANT FORMS**: intrusive rocks along bedding planes without disturbing the pre-existing

**SILLS**: intrusions along bedding planes in horizontal layers

**PACCOLITH**: along bedding planes in crest geological layers

**LACCOLITH**: Intruded magma lifts the rock layer up and form a even shaped rock mass

**DISCORDANT FORMS**: Igneous intrusion formed across the existing rock layer

**DYKES**: wall like igneous intrusion, it form as a linear feature

**VOLCANIC NECKS**: vent of volcanic seals off to form a circular rock mass
**BATHOLITHS**: exhibits both concordant and discordant characteristics. The magma digest the pre-existing rocks and forms new rock mass

**LAPOLITH**: A “Lapolith” is a saucer shaped concordant igneous body which is bent downward into a basin like shape. Its diameter is usually 10 to 20 times its thickness

**CLASSIFICATION OF IGNEOUS ROCKS:**

**BASED ON COLOUR INDEX:**

- **Leucocratic**: Light colour
- **Mesocratic**: Medium colour
- **Melanocratic**: Dark colour

**BASED ON MODE ORIGIN**:

- Plutonic
- Hypabyssal
- Volcanic

**BASED ON MINERALOGICAL COMPOSITION** (% OF SILICA SATURATION)

- Acidic rock: over saturated (>66%) eg. Granite and rhyolite
- Intermediate rock: saturated (50-66%) eg. Dacite and andesite
- Basic rock: under saturated (40-50%) eg. Gabbro and basalt
- Ultra basic rock: under saturated (>40%) eg. Picrite, komatit and perioditite

**TEXTURAL CLASSIFICATION**:

- Phanerites: coarse grained texture eg. Granite
- Porphyrites: coarse grains embedded in fine matrix of minerals eg. Granite porphyry
- Aphanerites: glassy texture eg. Basalt

**TABULAR CLASSIFICATION**:

<table>
<thead>
<tr>
<th>COMPOSITION AND MODE OF ORIGIN TEXTURE</th>
<th>ACIDIC ROCKS (QUARTZ+FELSPAR)</th>
<th>INTERMEDIATE ROCKS (FELSPAR)</th>
<th>BASIC ROCKS (FELSPAR+ FELSPOTHIDE)</th>
<th>FELSPAR+ FERROMAGNESIUM MINERALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plutonic phanerites</td>
<td>granite</td>
<td>syenite</td>
<td>gabbro</td>
<td>periodite</td>
</tr>
<tr>
<td>Hypabyssal porphyries</td>
<td>Granite porphyry</td>
<td>Syenite, diorite porphyry</td>
<td>dolerite</td>
<td></td>
</tr>
<tr>
<td>Volcanic aphanerites</td>
<td>rhyolite</td>
<td>andesite</td>
<td>phonolite</td>
<td>basalt</td>
</tr>
<tr>
<td>% silica saturation</td>
<td>&gt;66</td>
<td>50-66</td>
<td>40-50</td>
<td>&lt;40</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----</td>
<td>-------</td>
<td>-------</td>
<td>-----</td>
</tr>
<tr>
<td>colour</td>
<td>leucocratic</td>
<td>mesocratic</td>
<td>melanocratic</td>
<td>melanocratic</td>
</tr>
<tr>
<td>Sp. gravity</td>
<td>2.6-2.7</td>
<td>2.7-2.8</td>
<td>2.9-3.0</td>
<td>&gt;3</td>
</tr>
</tbody>
</table>

**PROPERTIES OF IGNEOUS ROCKS:**

**SP. GRAVITY:** 2.6-3.3

**DENSITY (DRY):** 2.6-3.3 (gr/cc)

**POROSITY:** 1-2%

**PERMEABILITY:** 1X10^{-7} - 1X10^{-12}

**COMPRESSIVE STRENGTH:** 100-300MPa

**TENSILE STRENGTH:** 4-13 MPa

**SHEAR STRENGTH:** 4-13MPa

**MODULUS OF RIGIDITY:** 0.2-1.1X10^5MPa

**USES:**
- Structural purpose: beams, columns, roofing material, lintel and sill
- Masonry
- Monuments
- Flooring
- Aggregates, ballasts
- Switch boards
- Pavement materials
- Kitchen flat forms
- Table top frame

**SEDIMENTARY ROCKS:**
- These are called secondary rock as they form from igneous and metamorphic rocks
- They are also called as stratified rocks as they form in layers
- These rocks amounts 5-8% of volume of the crust
- They occupy 75% of area of the land
MODE OF FORMATION OF SEDIMENTARY ROCKS:

CLASTIC ROCKS: (MECHANICAL FORM):
- Weathering and erosion
- Transportation of sediment
- Deposition

DIAGENESIS:
It is a process of transforming the deposited sediment by means of compaction and cementation process.

CLASTIC ROCKS:
Clastic rocks mainly comprise broken fragment of older rock. They are also known as terrigenous rock.

MATRIX: It is the fine grains or material that surround the larger clasts. It consists of either clay, silt and sand.

CEMENT: It is dissolved substance that bounds the sediments
- 1. Calcareous
- 2. Siliceous

CLASSIFICATION OF SEDIMENTARY ROCK:

*There are two major groups.*
- 1. Clastic rocks
- 2. Non-clastic rocks

CLASTIC ROCKS:
Clastic rocks mainly comprise broken fragment of older rock. They are also known as terrigenous rock. The broken fragments of pre-existing rocks ranging in size from minute particles to very large boulders.

*They are 3 groups.*
- 1. Rudaceous
- 2. Arnaceous
- 3. Argillaceous

RUDACEOUS:
- Rocks are formed by accumulation of bigger fragments such as gravels, pebbles and boulders.
- If the grains are rounded it is called conglomerate.
- If they are annular it is called breccias.

**ARNACEOUS:**
- The rocks are composed of sand grains.
- The individual grains are rounded the rock is called sandstone.
- If the grains are annular it is called grit.

**ARGILLACEOUS:**
- These rocks are made up of very fine grained sediments.
- Shale and mudstones are typical argillaceous rocks.

**SOME OTHER CLASTIC ROCKS:**

**ARKOSE:**
The amount of feldspar are present in a sandstone the rock is called arkose.

**GRAYWACKS:**
The sandstone contain some quantity of clay as well as angular quartz grains.

**NON-CLASTIC SEDIMENTARY ROCKS:**
Those sedimentary rocks which are formed by chemical precipitation of minerals from water or by accumulation of remains of animals and plants.

*It can be classified into two groups.*

1. Chemically formed rocks.
2. Organically formed rocks.

*Chemically formed rocks are further divided into.*

1. Carbonate rocks.
2. Salt rocks.
3. Ferruginous rocks.
4. Silicious rocks.

*Organically formed rocks are further divided into.*

1. Bio-chemically rocks.
2. Organically formed rocks.

**CHEMICALLY FORMED ROCKS:**

**CARBONATE ROCKS:**
Limestone and dolomite are most abundant rocks.

They are formed by chemical precipitation of CaCO$_3$ from sea water.

**SALT ROCKS:**

The salt deposit formed by the evaporation of saline lakes are called “evaporates”.

**FERRUGINOUS ROCKS:**

This group includes those which are formed by the chemical precipitation of Fe$_2$O$_3$.

Such rocks contain a high proportion of iron-bearing minerals.

**SILICEOUS DEPOSIT:**

Silicious rocks formed when silica is precipitated in water.

EG: Flint, Chert, Ag, etc……

**ORGANICALLY FORMED ROCKS:**

**BIO-CHEMICAL ROCKS:**

Shells accumulate on the oceans floor in great quantities to form rocks

EG: Shell, Limestone.

**TEXTURAL CLASSIFICATION OF SEDIMENTARY ROCKS:**

**TEXTURE:**

Texture means the size and the shape and arrangement of grains in rocks.

Grains size in important factor of the description of sedimentary rocks of factor of the description of sedimentary rocks.

**PARTICLE SIZE IN SEDIMENT**

<table>
<thead>
<tr>
<th>GRADE</th>
<th>GRAINSIZE</th>
<th>ROCKTYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pebble</td>
<td>&gt;10mm</td>
<td>Conglomerate</td>
</tr>
<tr>
<td>Gravel</td>
<td>2mm to 10mm</td>
<td>Sandstone</td>
</tr>
<tr>
<td>Sand</td>
<td>0.1mm to 2mm</td>
<td>Sandstone</td>
</tr>
<tr>
<td>Silt</td>
<td>0.01mm to 0.1mm</td>
<td>Silt stone</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;0.01mm</td>
<td>Clay</td>
</tr>
</tbody>
</table>

**GRAINSIZE OF SAND:**
Very coarse sand (>1mm)
Coarse sand [1 to 0.5 mm]
Medium sand [0.5 to 0.25mm ]
Fine sand [0.25 to 0.1mm]

Textural and minerological composition are great importance for determining the nature of environment.

*EXAMPLE:*

Shall indicates low energy and organic rich environment [lagoon].

**STRUCTURAL FEATURES OF SEDIMENTARY ROCKS:**

The important structural features are classified into two groups,

1. Mechanical structure.
2. Chemical structure.

**MECHANICAL STRUCTURE:**

1. Stratification
2. Lamination
3. Graded bedding
4. Current bedding
5. Ripple marks
6. Mud cracks
7. Rain prints
8. Tracks of terrestrial animal

**MAJOR STRUCTURE:**

**STRATIFICATION:**

All sedimentary rocks are generally characterised by stratification. Deposition of sediment into layers or bed is called stratification.

**BEDDING PLANE:**

The plane dividing different beds are called bedding plane. The thickness of bed various few cm to many m

**LAMINATION:**

Thin bedding less than 1cm in thickness are called lamination.

**GRADED BEDDING:**
In graded bedding each bed shows a gradation in grain size from coarse below to find above.

**CURRENT BEDDING:**

Current bedding is also called the cross bedding.

In this structure the beds lie at an angle to the planes of general stratification. This structure indicates the rapid changes in the velocity and direction of the flow of streams.

**RIPPLE MARKS:**

Ripple marks are wavy undulations seen on the surface of the bedding plane.

They are produced by the action of waves and current in the shallow water.

**MINOR STRUCTURE:**

**MUD CRACKS:**

It is found in the fine-grained sedimentary rocks.

They form a network of fishes enclosing polygonal areas.

**RAIN PRINTS:**

A rain print is a slightly shallow depression rimmed by a low ridge which is raised by the impact of the raindrop.

**TRACKS OF TERRESTRIAL ANIMAL:**

The marking indicating the passage of some animal over soft sediment.

**CHEMICAL STRUCTURE:**

**OOLITIC:** If they are size of a pin head [1mm]

**PISOLITIC:** They are of size of peanuts.

**METAMORPHIC ROCKS:**

Metamorphic rocks are formed from older rocks when they are subjected to increased temperature, pressure, and shearing stresses.

**SOURCES:**

Igneous rocks, soils, and other metamorphic.

**AGENTS OF METAMORPHISM / FACTORS AFFECTING METAMORPHIC:**

1. Temperature
2. Pressure
3. Chemically fluids and gases

**TYPES OF CHANGES:**
1. Change in texture
2. Change in structure
3. Change in mineralogical composition

**PROCESS OF METAMORPHISM / EFFECT OF METAMORPHISM:**

i. Recrystallization
ii. Plastic deformation
iii. Granulation
iv. Metasomatism

**RECRYSTALLIZATION:**
The formation of new mineral or formation of new crystal of the pre-existing crystal or minerals.

**PLASTIC DEFORMATION:**
When a solid is subjected to stress it shape change on the removal of spaces if the solid does not regain its original shape.

**GRANULATION:**
The process where crushing of rocks takes place without loss of coherence is called the granulation.

**METASOMATISM:**
The process in which the original composition of rocks are changed primarily by addition or removal of material.

**TYPES OF METAMORPHISM:**

1. Contact metamorphism.
   - Contact metamorphism
   - Pyrometamorphism
   - Plutonic metamorphism

2. Dynamic metamorphism/lord metamorphism.

3. Dynamothermal metamorphism

4. Metasomatism

**CONTACT METAMORPHISM:**
It is caused due to local heating of rocks by intrusion of hard igneous bodies nearby.

**PYROMETAMORPHISM:**

A localised burning or baking effect may be produced at the contact of an igneous body and country rocks.

**PLUTONIC METAMORPHISM:**

At great depth below the surface at static pressure and high temperature operate together.

**DYNAMIC METAMORPHISM:**

A metamorphism which is associated with high pressure with little increase in temperature is called dynamic metamorphism.

**DYNAMOTHERMAL METAMORPHISM/REGIONAL METAMORPHISM:**

When directed pressure and heat act together in the presence of migrating hydrothermal fluids, the rocks are metamorphosed over wider areas. This type of metamorphism is called regional or dynamothermal metamorphism.

**METASOMATISM:**

The process in which the original composition of rocks are changed primarily by addition or removal of materials due to active fluids \([\text{H}_2\text{O}, \text{Hf}, \text{HCl}\)] and gases \([\text{CO}_2]\).

**TEXTURE OF METAMORPHIC ROCKS:**

Crystalloblastic - Porphryroblastic

- Granoblastic

**CRYSTALLOBLASTIC:**

New texture developed during metamorphism.

**PORPHYROBLASTIC:**

Big crystals imbedded in fine matrix.

**GRANOBLASTIC:**

Egurigranular with interlocking arrangement.

**RELLICT TEXTURE:**

Old texture which resist the metamorphism.

**STRUCTURE:**

1. Gneissose structure
2. Schistose structure
3. maculose structure
4. cataclastic structure
5. granulose structure

GNEISSOSE STRUCTURE:
Presence of dark colour and light colour minerals in alternate layers.

SCHISTOSE STRUCTURE:
The parallel arrangement of platy or flaky minerals.

SUB STRUCTURE: SLATY STRUCTURE.
Presence of foliated and parallel cleavage.

MACULOSE:
Presence of dotted or spotted appearance due to coarse grain embedded in fine matrix of minerals.

CATACLASTIC STRUCTURE:
Presence of very fine grain minerals.

GRANULOSE STRUCTURE:
Minerals with interlocking arrangement rich in equi-dimensional minerals such as quartz, feldspar, pyroxene, calcite, etc and absent in foliated minerals like mica.

PROPERTIES OF METAMORPHIC ROCKS:
Sp. Gravity: 2.7-4
Porosity: 1-2%
Permeability: 1x10⁻⁸
Compressive strength: 100-360MPa
Tensile strength: 3 to 20 MPa
Shear strength: 3.5-10MPa
Modulus of elasticity: 0.2-1.1x10⁵MPa

STUDY OF IMPORTANT ROCKS: (ROLE OF PETROLOGY IN CIVIL ENGINEERING)

IGNEOUS ROCK:
1. granite
2. syenite
3. diorite
4. gabbro
5. pegmatite
6. dolerite
7. basalt

SEDIMENTARY ROCKS:
1. sandstone
2. limestone
3. shale
4. breccias
5. conglomerate

METAMORPHIC ROCKS:
1. gneiss
2. quartzite
3. marble
4. slate
5. schist
6. phyllite

IGNEOUS ROCKS:
GRANITE:
Origin: plutonic
Colour: leucocratic (light colour)
Texture: phaneritic, porphyritic
Structure: -
Mineral composition:
Essential minerals: quartz and feldspar
Accessory minerals: mica or hornblende
Varieties: granite are named according to the main accessory minerals
Example: biotite (rich)- biotite granite
          Hornblende (rich)- hornblende granite
Occurrence: commonly occur as major intrusive bodies such as batholiths and stocks

SYENITES:
Origin: plutonic
Colour: melanocratic(dark colour)
Texture: medium- grained, holocrystalline, porphyritic
Structure:-
Mineral composition:
Essential minerals; feldspar
Accessory minerals: apatite, zircon and sphene
Varities:
Types of syenite has been recognized on the basis of presence of particular accessory mineral
Occurrence: it has been formed from silicic magma that has beenesilified because of reaction with the associated limestone.
USES:
   ➢ substitute for granite in building stones.
   ➢ Neptheline syenite is used as abrasuie.
   ➢ Neptheline syenite is used as batch raw materials in ceramic industry.
   ➢ It is also used as functional.
   ➢ Filler in paint, putly, chalk.

IGNEOUS ROCKS: DIORITE
ORIGIN: Hypabyssal and volcanic equivalents.
COLOUR: Melanocratic [dark colour].
TEXTURE: Coarse to medium grained and holocrystalline.
STRUCTURE: -
MINERALOGICAL COMPOSITION: Felspax.
ESSENTIAL MINERALS: Biotite, hornblend and some pyroxenes.

VARITIES:

HYPABYSSAL EQUIVALENTS: Aplites and granophyres.

VOLCANIC EQUIVALENTS: Rhyolites.

OCCURRENCE: Occur as small intrusive bodies like dikes, sills, stocks, and irregular intrusive masses.

MINERALS COMPOSITION:

ESSENTIAL MINERALS: Plagioclase feldspar.

ACCESSORY MINERALS: Augite, hornblende, olivine, biotite and iron oxides.

VARITIES: Norite, gabbro, anorthosite, eucrite, essexite, troctolite, dunite

OCCURRENCE: hypabyssal and volcanic equivalents.

USES:

➢ Bright polished gabbro are used to make cemetery markers, floor facing stone.
➢ Mined to yield nickel, chromium and platinum.

IGNEOUS ROCKS: PEGMATITE:

ORIGIN: Hydrothermal solution from magma, complex composition.

COLOUR:

TEXTURE: Invariably coarse grained inequigranular.

STRUCTURE: Tonal structure.

MINERAL COMPOSITION:

ESSENTIAL MINERALS: Quartz and feldspar.

ACCESSORY MINERALS: Tourmaline, mica, topaz, fluorite, spodumene, beryl, cassiterite, eolvframite, columbite and tantalite.

OCCURRENCE: Occur in variety form as dykes, veins, lenses, patches of irregular mass.

USES:

➢ Precious stones
➢ Ores of the earth
➢ Heavy metal besicles industry grade muscovite.

DOLERITES:

DEPARTMENT OF CIVIL ENGINEERING/SEC/FMCET 58
ORIGIN: Hypabyssal
COLOUR: Melanocratic
TEXTURE: Ophitic and porphyritic.
Structure:-
Mineral composition:
Essentially minerals: calcic plagioclase
Accessory mineral: augite, olivine and iron oxide
Occurrence: as sills and dykes
Uses: crushed stone and as ornamental stone

**BASALT:**
Origin: volcanic igneous rocks(extrusive rocks)
Colour: melanocratic
Texture: fine grained
Structure:
Mineral composition:
Essential mineral: calcic, plagioclase feldspar
Accessory mineral: augite, olivine, hornblende and iron oxide
Varieties: olivine rich- basanite
                      Olivine free- zepherite
Occurrence:
    i. Occurs oceanic divergent boundaries
    ii. Occurs at oceanic hotspots
    iii. Mantle plumes and hotspot beneath continents
Uses:
  ➢ As an aggregate in construction
  ➢ Slabs of basalt were used in floor tiles, building veneer and monuments

**SEDIMENTARY ROCKS:**

**SANDSTONE:**
Origin: mechanically formed
Texture: clastic (fine to medium grained)
Structure: mechanical structure
Mineral composition: quartz, feldspar, mica, garnet, magnetite
Types:
1. Based on type of building material
2. Based on mineralogical composition
   Alkose- rich in feldspar
   Greywacke- rich in fragments of granite
   Flagstone- rich in mica
3. Based on type of binding material
   a. Siliceous sandstone
   b. Calcareous sandstone
   c. Ferruginous sandstone
   d. Argillaceous sandstone
Uses:
- Masonry
- Pavement material
- Flooring
- Wall facing material

**LIMESTONE:**
Origin: bio-chemically and mechanically
Texture: non-clastic
Mineral composition: calcite, dolomite, quartz, feldspar minerals
Types: chalk, shelly limestone, argillaceous limestone, lithographic limestone, kankar and calc-sinter
Occurrence:
1. Biothermal formation
2. Biostromal limestones
3. Pelagic limestone

Uses:
- Primary source in Portland cement
- In metallurgical industries as flux

**Shale:**

Origin: compaction and consolidation of silt and clay minerals

Texture: fine grained

Mineral composition: quartz, clay minerals and oxides of iron

Structure: fissility/lamination

Types:
1. Based on origin
2. Based on mineralogical composition
3. Based on predominant group

Uses:
- Manufacture of bricks
- Place source for paraffin

**Breccia:**

Origin: mechanically formed

Texture: angular

Mineral composition: clay minerals

Structure: angular fragments

Types: basal breccias, fault breccias and agglomerate breccias

Uses:
- Used as ornamental in walls and columns

**Conglomerate:**

Origin: mechanically formed

Texture: clastic, rounded

Mineral composition: siliceous, and calcareous minerals
Structure: rounded

Types:
1. Based on dominant grad
2. Based on sources
3. Based on lithological

Uses:
- Used in construction, inside walls, etc

**METAMORPHIC ROCKS:**

**GNEISS:**
Nature: it is coarse grained, irregularly banded, metamorphic rocks and light in colour
Texture: coarse crystalline texture
Structure: gneissose
Mineral composition: quartz, feldspar, mica, amphiboles, pyroxenes
Types: ortho- gneiss, para- gneiss and banded
Uses:
- Roofing material
- Monuments
- Flooring materials

**QUARTZITE:**
Nature: formed by recrystallization of pure sandstone
Texture: granular
Structure: granulose
Mineral composition: quartz, mica, felsparvand some amphiboles
Types: orthoquartzite and paraquartzite
Uses:
- Crushed quartzite is usd in railway ballast
- Decorative stones

**MARBLE:**
Nature: recrystallised by limestone
Texture: fine to coarse grain
Structure: granulose
Mineral composition: calcite, olivine, serpentine, garnet
Types: pink marble, white marble and black marble
Uses: used for making sculpture and building stone

SLATE:
Nature: fine grained metamorphic rocks
Texture: fine grained
Structure: -slaty
Mineral composition: mica, chlorite, oxide of iron
Uses:
  ➢ Roofing slabs
  ➢ Slate tile used in interior and exterior.
  ➢ Electrical insulators, fireproof material, switch board, electrical motor.

SCHIST:
NATURE: Foliated metamorphic rocks. Flaky and platy minerals arranged in parallel or subparallel layers or bands.
TEXTURE: coarsed crystalline, porphyroblastic, lineation.
STRUCTURE: schistose
MINERAL COMPOSITION: mica, chlorite, hornblente, tremolite, actinolite, kyanite.
VARITIES:
  1. Based on predominant of minerals
  2. Based on degree of metamorphism
  3. High grade schist.
USES:
  ➢ Rarely used as building material in flooring and garden decoration.

PHYLLITES:
NATURE: Fined grained foliated rods of complex silicate crystalae, formed by dynamothermal metamorphic

TEXTURE: medium to fined grained.

STRUCTURE: schistose

MINERAL COMPOSITION: chlorite, muscouite, quartz.

USES: counter tops

UNIT-IV

STRUCTURAL FEATURES:

★ Out crop
★ Strike
★ Dip

OUTCROP:
The rock exposure on the surface of the earth.

STRIKE:
The trend of the rock bed on the ground surface is strike.

DIP:

⇒ The angle of inclination of a rock bed with the horizontal plane is called dip.
⇒ It measured in a plane perpendicular to the strike line.

There are two types of dip.

★ True dip
★ Apparent dip.

TRUE DIP:
It is a perpendicular plane to the strike line.

APPARENT DIP:
It is a dip measured in any other direction than the true dip is called apparent dip.

FOLDS
Fold may be defined as the curve or zigzag structure shown by rock beds. In other words, wavy undulation in rock beds are called folds.

**CAUSES OF FOLDING:**

1. **FOLDING DUE TO TANGENTIAL COMPRESSION:**
   a. Lateral compression
   b. Flexure folding due to compression of incompetent layers against competent layers.
   c. Flowage flowing
   d. Shear flowing
2. **FOLDING DUE TO INTRUSION OF MAGMA**
3. **FOLDING DUE TO DIFFERENTIAL COMPACTION**

**COMPONENTS OF FOLDING:**

- Limbs
- Axial plane
- Axis of folds
- Crest
- Trough

**CLASSIFICATION:**

1. Basic classification
2. Detailed classification

**BASIC CLASSIFICATION**

a. Syncline
b. Anticline.

**DETAILED CLASSIFICATION**

**BASED ON THE POSITION OF AXIAL PLANE:**

a. Symmetrical fold
b. Asymmetrical fold
c. Overturned fold
d. Recumbent fold
e. Isoclinal fold

**BASED ON DEGREE OF COMPRESSION:**

a. Open folds
b. Closed folds

**BASED ON MODE OF ORIGIN:**

a. Basin
b. Dome
c. Axticlinorium
d. Synclinorium
e. Geosyndinorium
f. Geoaclinorium.

**BASED ON PLUNGE OF FOLD**

a. Plunging fold
b. Non-plunging fold

**BASED ON THE BEHAVIOR OF THE FOLD WITH DEPTH:**

a. Concentric/parallel fold
b. Similar fold.

**ENGINEERING SIGNIFICANCE OF FOLD:**

**COMPONENTS OF FOLDING/ ELEMENTS OF FOLDING:**

**LIMBS;**

The sloping sides of a fold from crest to trough are called the limbs.

An individual fold will have a minimum of two limbs.

**AXIAL PLANE**

It is an imaginary plane or a surface which divides a fold into two equal halves.

**AXIS OF FOLDS**

An axis of fold is defined as the line of intersection between the axial plane and the surface of any of the constituent rocks bed.

**PLUNG OF FOLD:**
Fold having inclined axis are called plunging fold.

The angle of inclination of a fold axis with the horizontal is called angle of plung.

CLASSIFICATION:

SYNCLINE:
It is the down fold where the limbs dip towards the axis of fold on either side.

ANTICLINE:
It is an up fold where the limbs dip away axis of fold on either side.

DETAILED CLASSIFICATION:

1. BASED ON POSITION OF AXIAL PLANE:

A. SYMMETRICAL FOLD
   ➔ These are also called normal fold.
   ➔ The axial plane is essential vertical.
   ➔ The limbs are equal in length
   ➔ And dip equally in opposite direction.

ASYMMETRICAL FOLD:
An asymmetrical fold in which the limbs are unequal in length and these dip unequally on either sides.

OVERTURNED FOLD:
It is an asymmetrical fold whose one limbs is TURNED PAST THE VERTICAL.

In this case the axial plane is inclined and both the limbs dip in the direction.

The amount of dip of the two limbs may or may not be same.

RECUMLENT FOLD:
It is described as extreme type of overturned folds.

In this type both the limbs become almost horizontal.

The amount of dip may or may not be same.

ISOCLINED FOLD:
Folds that have parallel limbs are called isoclinals fold

In this case limbs dip at the same angle and in the same direction.

Three types of isoclinals folds are
1. Vertical isoclinals [symmetrical]
2. Inclined isoclinals [asymmetrical isoclinals]
3. Recumbent isoclinals.

BASED ON DEGREE OF COMPRESSION:

OPEN FOLD:
These fold in which the thickness of the rocks is not affected during the process.

CLOSED FOLD:
These fold in which the thick end crest or trough and thinner limbs.

BASED ON MODE OF ORIGIN:

BASIN:
It is defined as down flow syclined folds are converted into basin in which the limbs dip towards the trough.

DOME:
It is defined as up fold anticline fold are converted into dome in which limb dip away from crest.

ANTICLINORIUM:
It is the anticline fold, which is large in size occupying several 100s of square kilometre also various types of minor folds can be seen on the limbs.

SYCLINORIUM:
It is the syclined quite large in size to anticlinorium with minor folds on the limbs.

GEOSYCLINORIUM:
It is bigger in size than syclinorium.

EXAMPLE: Gangetic valley.

GEOANTICLINORIUM:
It is bigger in size than anticlinorium.

EXAMPLE: Himalayan hill range.

BASED ON PLUNG OF FOLD:

PLUNGING FOLD:
In this fold the fold axis exhibits some amount of inclination.
NON PLUNGING FOLD:
The fold axis is horizontal.

BASED ON BEHAVIOR OF FOLD IN DEPTH:

CONCENTRIC FOLD / PARALLEL FOLD:
Thickenss of folder layer remains same but the shape of fold vary with depth.

SIMILAR FOLD:
Thickness in the larger changes but the shape remains same with depth.
1. Fold create the complication in design structure.
2. During compression, tessile, shear joints will be developed in the folder rocks.
3. The joints reduce the shear resistance of rock mass.
4. Joint reduce the stability of rock mass.
5. Joint will increase the porosity and permeability of rock levelling to excessive seepage.
6. Syclined fold create favourable condition for the ground water resource development.
7. Anticlined fold serves as the storage reservoirs of petroleum deposits.

FAUTS:
The relative displaceament between two rock blocks along the plane of failure is called fauts. It forms due to shear, compression and tessile forces acting on geological layers.

TERMINOLOGY:
1. Fault plane
2. Foot wall
3. Hanging
4. Striking of fauts
5. Dip
6. Throw
7. Heave
8. Hade
9. Slip
10. Slickers slides
11. Fault gauge
12. Fault bruccia

CLASSIFICATION:

BASED OF APPARENT MOVEMENTS OF FAULTS

a. Normal fault
b. Reverse fault
c. Transcurrent fault
d. Vertical fault

BASED ON THE AMOUNT OF DIP:

A. High angle fault
B. Low angle fault

BASED ON THE ATTITUDE OF FAULT

a. Strike fault
b. Dip fault
c. Oblique fault
d. Bedding plane fault

BASED ON MODE OF OCCURRENCE:

a. Peripheral fault
b. Ralial fault
c. Parallel fault
d. Enchelon fault

TERMINOLOGY:

FAULT PLANE:
The fracture surface along which relative movements has taken place is called a fault plane.

DIP:
The dip is the angle,
The fault makes with the horizontal surface.

STRIKE:
The strike of a fault is a direction of its continuity on the ground surface.

THROW:
The vertical displacement of fractured rock blocks is called throw of fault.

HEAVE:
The horizontal displacement of is called heave.

NET SLIP:
The total displacement measured along the fault plane is called the net slip.

HADE:
The angle inclination of fault plane measured from vertical

STRIKE SLIP:
The movement which is parallel to the strike of the fault plane is called strike slip.

DIP SLIP:
The movement which is parallel to the direction of dip of the fault plane.

HANGING WALL:
The term hanging wall is used for that faulted block which lies on the upper surface of the fault plane.

FOOT WALL:
The term foot wall is used for that faulted blocks which lies on the under surface of the fault plane.

SLICKER SLIDES:
The movements of one wall against another results in polishing and grooving of fault surface.

FAULT GAUGE:
It is finally pulvurised clay like powder rock material which occurs or near the base of the faulted zones.

FAULT BRECCIA:
It is a crushed angular fragmentory material produced during faulting.

Classification:

Based On The Apparent Movements Of Rocks:

A. NORMAL FAULT:
The hanging wall moves downwards with respect to foot wall
The dip in the normal fault vary from 45 degree to90 degree it form due to tension.

HORST:
The wedge shaped central block is projected of with respect to side blocks.

GRABEN:
The central wedge shaped block moves down with respect to side blocks.

B. REVERSE FAULT.
The hanging wall moves upwards relatives to foot wall
The dip of fault varies from 40 degree to 45 degree
It is also called crest fault
It form due to compression

TRANSCURRENT FAULT:
The foot and hanging wall moves horizontally against each other

VERTICAL FAULT;
The fault plane is essentially vertical that is the dip of the fault plane is 90 degree

BASED ON ATTITUDE OF FAULT:

A. STRIKE FAULT
This are the fault that develop parallel to the strike of the strata.

B. DIP FAULT
A fault which strikes approximately parallel to the clip direction of beeds is called dip fault

C. BEDDING PLANE FAULT:
The fault surface parallel to the bedding plane.

D. OBIQUE FAULT
The strike of the fault is oblique to strike of adjacent beds this are sometimes called diagonal faults

E. HIGH ANGLE FAULT
The slip of the fault is greater than 45 degree is called high angle fault.

F. LOW ANGLE FAULT
The dip of the fault is less than 45 degree is called low angle fault.
BASED ON DIRECTION OF SLIP:

A. Strike slip fault
B. Dip slip fault
C. Oblique slip fault

STRIKE SLIP FAULT:
Slip of the fault in the direction of strike.

DIP SLIP FAULT:
Slip of the fault in the direction of dip.

OBLIQUE SLIP FAULT:
A fault in which the direction of movement is diagonal to both the dip and strike of fault.

BASED ON MODE OF OCCURRENCE:

PERIPHERAL FAULT:
A group of fault concentrated along the periphery of the area.

RADIAL FAULT:
A group of fault originating from the common central region.

PARALLEL FAULT:
A group of fault in which strikes of plane are parallel.

ENCELEON FAULT:
A group of fault that overlap each other.

EFFECTS OF FAULTS

- Changes in elevation
- Omission of strata
- Repations of strata
- Displacement of stream channel.
- Raised terraces and water falls.

RECOGNISED OF FAULTS IN FIELD

1. Slicker slided
2. Fault breccia
3. Fault gauge
4. Water falls

ENGINEERING SIGNIFICANCE OF FAULTS

1. Presence of faults creates the heterogeneity in the geological rock layers making the design of structure complicated and also differential settlements in foundation.
2. Fault create abrupt changes or variation in ground water table.
3. The fault zone reduce the strength of rocks.
4. The presence of rocks initiates the landslide activity.
5. Fault zone act as huge reservoir of ground water and petroleum.

JOINTS

A joint are fracture along which no displacements are occurs.

JOINT SET:

A group of joints that are parallel is called joint set.
A joint system is a group of more joint set.

BASED ON SPATIAL RELATIONSHIP:

A. SYSTAMATIC JOINTS:

A JOINT PLLANE ARE PARALLEL OR SUB PARELLEL.

NON- SYSTAMATIC JOINTS:

Joint planes are not parallel.

BASED ON GEOMENTARY:

1. Strike joints
2. Dip joint
3. Oblique joint

STRIKE JOINT

Strike of joint is parallel to strike of adjacent beds

DIP JOINT:

Strike of joint is parallel to the dip of adjacent beds

OBLIQUE JOINTS

The strike of joint is oblique to the strike of adjacent beds
BASED ON THE NATURE OF JOINT

OPEN JOINT
The joint which divides the rock mass into two blocks

CLOSED JOINTS
The joint which tappers out at depth and fail tto divides the rocks.

JOINT IN ROCKS

IGNEOUS ROCK

1. Sheet joint
2. Columnar joint
3. Mural joint

A horizontal set of joint divides the rockmass in such a way as to give it an appearance of layers sedimentary rocks

COLUMNAR JOINT:
These are formed in tabular igneous rock such as dykes, sills, and lava flows.

These joint divide the rock mass into hexagonal, square and triangular

MURAL JOINTING:
It may occur 3 sets of joints in such a way that 1 set is horizontal and other 2 sets are vertical all three sets being mutually at right angles to each other. This joint dividing the rock mass into cubical mass.
UNIT-5

SEDIMENTARY ROCKS:

1. Mud cracks
2. Tensile shear joints

METAMORPHIC ROCKS:

1. Mural joints
2. Sheet joints
3. Shear joints

One set of joint are dominant then they are called primary joints,

ENGINEERING SIGNIFICANCE OF JOINTS:

1. Spacing of joints
2. Length of joints
3. Block size

4. Width of joints

5. Seepage of water through joints

6. Filled materials and its nature
   - The presence of more number of joint set increase porosity and permeability of rock layer leading to excessive seepage
   - Joint reduce the stability of rocks
   - Presence f joints enhances the possibility of landslide on hill slopes
   - Joint in sub surface rock layer craetae favourable condition to deve:lop groundwater resources

UNCONFORMITY:
It is defined as a surface of erosion or non deposition occurring within a sequence of rocks.

TYPE OF UNCONFIRMITY:
Angular unconformity
Disconformity
Non- conformity
Local unconformity
Regional unconformity

ANGULAR UNCONFORMITY:
The different inclinations and structural features above and below the surface of unconformity
The sequence below the unconformity may be steeply inclined folded and faulted.
This represent to older formation. The sequence above the surface of unconformity represent the younger formation

DISCONFORMITY:
In this type of unconformity in which the beds lying below and above the surface of erosion are nonn deposition such an unconformity become evident only after through investigation involving drilling through the strata

NON-CONFORMITY:
In bedded sedimentary rocks overly the non beded igneous mass this structure is called non conformity
LOCAL CONFORMITY:

When an unconformity is trackable only in a small area

REGIONAL UNCONFORMITY:

When an unconformity is trackable over a large area expanding for 100 of kms

EVIDENCE OF UNCONFORMITY:

- Different in structure
- Presence of conglomerate
- Angular relation
- Difference in grade of metamorphism

ENGINEERING CONSIDERATION:

- The behaviour of rock above and below the unconformity will necessarily shows the variations in the mechanical properties and hence affect stability of object.
- Unconformity marks a weak contact which will allow perpillation of water

OUTLIER:

An outlier is a patch of younger rocks surrounded older rocks on all sides

INLIER:

It may be defined as a patch of older strata which is surrounded on all sides by younger strata.

GEOPHYSICAL METHODS AND ITS APPLICATION

- In geophysical prospecting certain physical properties of the underground rocks are measured from surface
- The properties are density magnetism electrical conductivity and elasticity
- The measured data are then interrupted to give information about the presence of ore bodies buried anticlines, faults, igneous intrusions and other geological structure
- The main geophysical prospecting methods
  1. Gravity methods
  2. Magnetic method
  3. Electrical method
  4. Seismic method
  5. Radioactive method
ELECTRICAL METHOD:
It is used mainly for exploration of metallic mineral deposits. There are four types
1. Self potential method
2. Equi potential methods
3. Electromagnetic method
4. Resistivity method

ELECTRICAL RESISTIVITY:
It is used to measure the fluid content and porosity of rocks.
It help in making distinguished between saturated and unsaturated rocks

WENNER METHOD:
In resistivity surveying various electrode arrangement in show by wenner widely used, spacing between electrode are kept equal. The spacing is designated ad “d”.
The current introduced into the ground by two currents electrodes $C_1$ and $C_2$. The potential difference between the inner electrode $P_1$ and $P_2$ is measured
All the four electrode are place in lines

USES OF RESISTIVITY METHOD:
Resistivity survey is very effective in investigation of horizontal or gently dipping rocks these are used in detecting following
1. The thickness of overburden or depth to bed rocks is determined
2. It have been used in the exploration of glacier deposit and bedded deposit
3. Exploration of ground water, pressure of aquifers can be determined
4. Fault zone may be determined as they contain electrolyte in solution
5. Discovering the sub surface structure and lithology. Buried anticline can be traced by determine depths to strata of greater or lesser resistivity. used in exploration of petroleum.