Civinnovate

Discover, Learn, and Innovate in Civil Engineering

UNIT I

1. What is meant by exfoliation? [N/D-14]

Exfoliation is a form of mechanical weathering in which curved plates of rock are stripped from rock below. This results in exfoliation domes or dome-like hills and rounded boulders. Exfoliation domes occur along planes of parting called joints, which are curved more or less parallel to the surface.

2. Name a few secondary tectonic plates. [N/D-14]

1. China Plate	2. Philippine Plate
3. Arabian Plate	4. Iran Plate
5. Nazca Plate	6. Cocos Plate
7. Caribbean Plate	8. Scotia Plate

3. Mention the thickness of Earth's crust. [N/D-15]

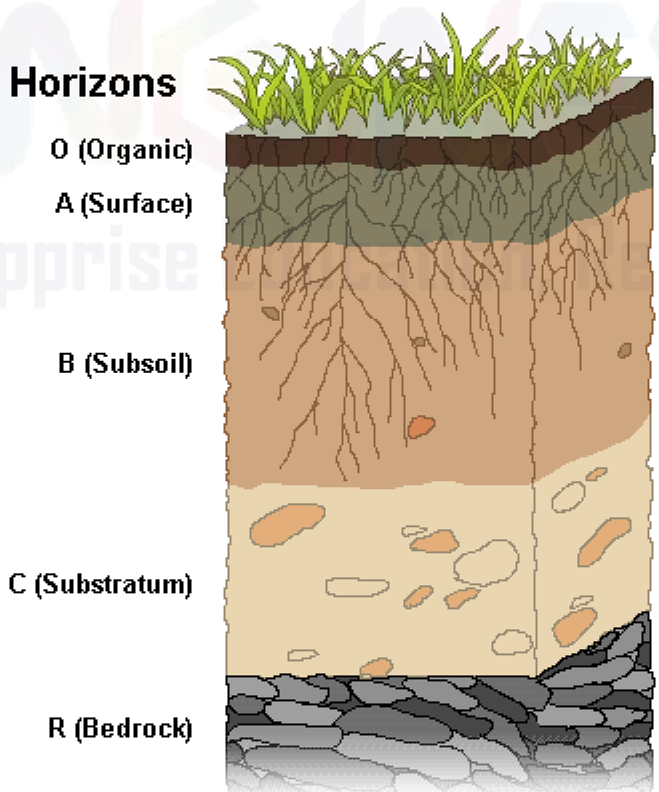
It is the innermost concentric shell of Earth as deciphered from the record of seismic wave. It s existence was first suggestd by R.D. Oldham in 1906 and subsequently confirmed by other seismologists. The core boundary begins at a depth of 2900km from the surface and the region extends to the centre of the Earth (at 6371 km). Further studies of the behaviour of seismic waves reveal that the core itself can be distinguished into at least to main zones : the outer core and the inner core. The outer core (2900km to 4580km) resembles a liquid like substance because S-wave are not transmitted through this zone at all. (It is the characteristic of S waves or shear waves that they do not travel through liquids). The inner core, with a thickness of around 1790 km is believed to be a solid metallic body.

4. How are rocks classified according to the scale of weathering?[N/D-15]

- Very soft rock
- Soft
- Medium hard rock
- Hard
- Very hard rock
- Extremely hard rock

5. What is meant by soil profile? List the information that are to be provided in soil profile.[M/J-16]

A soil horizon is a layer generally parallel to the soil crust, whose physical characteristics differ from the layers above and beneath. Each soil type usually has three or four horizons. Horizons are defined in most cases by obvious physical features, chiefly colour and texture. These may be described both in absolute terms (particle size distribution for texture, for instance) and in terms relative to the surrounding material (i.e., "coarser" or "sandier" than the horizons above and below). The differentiation of the soil into distinct horizons is largely the result of influences, such as air, water, solar radiation and plant material, originating at the soil-atmosphere interface. Since the weathering of the soil occurs first at the surface and works its way down, the uppermost layers have been changed the most, while the deepest layers are most similar to the original parent material.



6. Write a notes on sea Cliff with neat diagram.[M/J-16]

A sea cliff is defined as the high and very steep or over hanging face of rock or earth rising above the shore of the sea (Campbell 1972). Cliffs are usually produced by wave erosion. Invariably the line of contact of the headland region, causing undercutting followed by collapse of the overhanging rock mass. Sea caves are the irregular marine erosional features of recent age. Generally they are made up of calcareous sandstone and located at the high water level. Due to intensive action of waves on cliffs, at some places, sea caves are formed.

7. Differentiate between physical and chemical weathering.[N/D-16]

Physical Weathering vs Chemical Weathering

- Physical weathering does not change the chemical composition of the rock whereas chemical weathering changes the composition.
- Physical weathering may result due to temperature, pressure, snow, etc. whereas chemical weathering mainly takes place due to rain.

8. Mention about the seismic zones of India. [N/D-16]

Zone 5

Zone 5 covers the areas with the highest risks zone that suffers earthquakes of intensity MSK IX or greater. The IS code assigns zone factor of 0.36 for Zone 5. Structural designers use this factor for earthquake resistant design of structures in Zone 5. The zone factor of 0.36 is indicative of effective (zero period) peak horizontal ground accelerations of 0.36 g (36 % of gravity) that may be generated during MCE level earthquake in this zone. It is referred to as the Very High Damage Risk Zone. The state of Kashmir, Punjab,the western and central Himalayas, the North-East Indian region and the Rann of Kutch fall in this zone.

Generally, the areas having trap or basaltic rock are prone to earthquakes.

Zone 4

This zone is called the High Damage Risk Zone and covers areas liable to MSK VIII. The IS code assigns zone factor of 0.24 for Zone 4. The Indo-Gangetic basin and the capital of the country (Delhi), Jammu and Bihar fall in Zone 4.

Zone 3

The Andaman and Nicobar Islands, parts of Kashmir, Western Himalayas fall under this zone. This zone is classified as Moderate Damage Risk Zone which is liable to MSK VII. and also 7.8 The IS code assigns zone factor of 0.18 for Zone 3.

Zone 2

This region is liable to MSK VI or less and is classified as the Low Damage Risk Zone. The IS code assigns zone factor of 0.10 (maximum horizontal acceleration that can be experienced by a structure in this zone is 10 % of gravitational acceleration) for Zone 2.AA

9. What are the Erosion features by river (AUC NOV/DEC 2010)

1. Potholes
2. Plunge pools
3. Rapids
4. Waterfalls
5. Grogs

10. What is Spheroidal weathering of Rocks? (AUC NOV/DEC 2010)

When weathering occurs, part of the disintegrated rock material is carried away by running water or any other transporting agent. Some of them are left on the surface of the bedrock as residual boulders. These boulders are then rounded off to spheroidal cores by the simultaneous attack of eroding agents on all sides. It is often seen that these boulders have an onion like structure. This kind of weathering is called spheroidal weathering.

11) Distinguish between SIAL and SIMA. (AUC NOV/DEC 2010)

The upper most layers is called the crust of the earth. It has a thickness of 50 km and thus the crust is made of two layers. Silica (si) and Aluminium (Al) are the elements found in the first layer. Therefore this layer is called SIAL (Si + Al). This layer is also called 'Granitic layer.'

Below the SIAL ties a layer called SIMA which composes of silica (Si) and Magnesium (Mg). This layer is also called Basaltic layer.

12) What are plates? [N/D-16]

The surface of the earth is the crust of the earth. It is made of interlocking pieces called plates. The continents and oceans rest in these places and are separated by wide cracks. The plates move constantly.

13) What is meant by atmosphere?

The outer gaseous part of the earth starting from the surface and extending as far as 700 km and even beyond is termed atmosphere. It makes only about one-million part of the total mass of the earth.

14) Define sea floor spreading. [N/D-16]

Divergent boundaries occur at Oceanic ridges. In the process of plate separation, the magma rises up from the asthenosphere and fills the gap their created. In this way new crust is created along the trailing edges of the diverging plates. This phenomenon is called sea floor spreading.

1. Describe in detail, the process of weathering of rocks. Add a note on the effect of weathering on the strength of rocks. [N/D-14]

The process by which rocks are broken down and decomposed by the action of external agencies such as wind, rain, temperature changes etc is called as weathering.. (or) weathering is a process involving disintegration and decomposition of rocks. The disintegrated and the altered materials stay at the site of formation. If these materials are transported from the site with the help of natural agencies such as wind, running water etc, the process is called as erosion. Weathering is categorized as a mechanical, chemical, biological.

Mechanical weathering: In mechanical weathering, the process involves only fragmentation or break down of the rock into smaller fragments / pieces. In nature, the physical breaking of rocks are caused by several processes. Waterfalls, landslides during their fall cause extensive breakdown of rocks. Thus gravity contributes to mechanical disintegration of rocks. However, all the processes involve widening of the fractures, resulting in the detachment of blocks surrounded by the weak planes. The different types of processes in mechanical weathering are:

Frost wedging: The presence of water in the cracks of the rocks freezes during the night time and melts during the day time. Freezing of water involves an increase in the volume because of which the walls of cracks are wedged ultimately resulting in the detachment blocks surrounded by the weak planes.

Expansion and contraction process: Solar radiation causes heating, which results in thermal expansion during day time and drop in the temperature during the night time causes contraction. The expansion and contraction are confined only to the surface layers of the rock and results often in the fracturing and detachment of top layers of the rocks.

Fracturing through pressure releases: Rocks at depth are confined under high pressures. However, if the rock material is uplifted due to tectonic processes to relatively lesser depths, it is subjected to lesser pressure conditions. So, the release of pressure leads to the deformation of rock and generates the fractures.

Effect of vegetation: During the growth of vegetation in rocky terrains, the roots penetrate into the existing weak planes and gradually the cracks are widened leading to physical breakdown of rock masses.

Mechanical or physical weathering involves the breakdown of rocks through direct

contact with atmospheric conditions, such as heat, water, ice and pressure.

Chemical weathering: Chemical weathering involves chemical reactions resulting in the alteration of the rock leading to the formation of new alteration products. Water is the best fluid that directly affects rocks by way of Dissolution; Leaching (making porous); Hydration; Oxidation, Hydrolysis etc

Dissolution / Carbonation: In case of carbonate rocks such as limestone, dolomite, marble when the river water traverses in these rocks; carbonates are dissolved, resulting in the reduction of their sizes.

Surface water contain O_2 and its combination with water results in the formation of carbonic acid. Production of carbonic acid lowers the pH, resulting in the attack some of the minerals which are present in the rocks.

Leaching: means removable of soluble content from the rocks by water. Water is the powerful leaching agent which affects leaching for the most of the materials when come in contact with water. Eg: laterite is a porous rock and very weak when compared to its fresh parent rock.

Hydration is the process where in hydroxyl molecules are injected into the molecular structures of minerals thereby bringing about the decomposition of minerals.

$K_2\ Al_2O_3\ 6\ SiO_2 + H_2O + CO_2 \longrightarrow K_2CO_3 + Al_2O_3\ 2\ SiO_2\ 2H_2O + 4\ SiO_2$

(K – feldspars) (Hydration) (Kaoline) (silica)

Due to hydration process, anhydrous pyroxenes are changed over to amphiboles while Amphiboles may be altered to Biotite. Biotite change over to Chlorite whereas Anhydrite ($CaSO_4$) alters to Gypsum ($CaSO_4\,2H_2O$)) during hydration.

Oxidation: The decomposition of minerals in a rock during chemical weathering is brought about by O_2 in water. For eg pyroxene changes into limonite because of oxidation through the following reaction.

$$\underset{\text{(pyroxene)}}{4FeSiO_3} + O_2 + 2H_2O \longrightarrow \underset{\text{(limonite)}}{4\,FeO\,(OH)} + \underset{\text{(silica)}}{4\,SiO_2}$$

Pyrite (FeS_2) converts into Haematite (Fe_2O_3) during oxidation process

Hydrolysis: In case of decomposition of minerals, instead of water molecule, only hydrogen of water enters into the mineral structure. This is called hydrolysis.

$$\underset{\text{Orthoclase feldspars}}{K\,AlSi_3\,O_8} + \underset{\text{ion}}{H^+} \longrightarrow \underset{\text{Silicic acid}}{HAlSi_3O_8} + \underset{\text{ion}}{K^+}$$

In addition, CO_2; O_2; N_2 of atmospheric gases which take part in the weathering of rocks.

Chemical weathering, involves the direct effect of atmospheric chemicals in the breakdown of rocks, minerals...

Biological weathering involves breakdown of rocks by living organisms (Bacteria & fungi). Living organisms release organic acids viz., Oxalic acid; Phenolic acid; Folic acid, Acetic Acid, Humic acid etc.. which cause decomposition of rocks. Some of the microorganisms penetrate into mineral crystals and remove specific ions from the inter layers. Eg: removal of K^+ from mica layers by fungi is an example of this type.

Man is also responsible for unnatural weathering of rocks for construction of buildings, dams, bridges etc…

Weathering effect over the properties of rocks:

- Weathered minerals exhibit change in color intensity or different colors.
- They will be less compact, and hence their specific gravity will be less.
- Their hardness will decrease so that the minerals become softer and weak.
- They become less transparent or tend to become opaque.
- The minerals loss their original shine and exhibit a dull luster.
- Weathered minerals loose their internal cohesion & become easily powdered.

Weathered rocks usually appear as brown,red & yellow colors on the surface. Effect of weathering of a common rock GRANITE:

Among different rocks, Granite (an acidic rock) is one of the most abundant rock on the earth's surface. Therefore, it will be appropriate to analyse the process of weathering in granite.

Granite consists of quartz, feldspars (orthoclase, plagioclase), and accessory minerals (amphiboles, pyroxenes; biotite / muscovite, magnetite / haematite, rutile, zircon, apatite, garnet..)

During the oxidation, feldspars in granite converts into sericite and then to kaolinite thereby silica removed from the reaction by ground water.

Feldspars → sericite (mica) → kaolinite (clay)

Quartz minerals remain unchanged whereas muscovite or biotite becomes chlorite on decomposition. Pyroxenes (augite / diopside) decompose and pass into hornblende or breakdown into chlorite.

The above changes due to weathering causes failure of civil construction projects and hence the study of weathering of rocks is important for any civil project.

Finally, Geological considerations such as Topography and geomorphology of the site, impact of geological structures; Lithology of the formations ; Identification of weak zones in addition to weathering of rocks plays an important role in civil engineering constructions.

Effect of weathering on other rocks: On the other hand, the decomposition of basic rocks (basalt, gabbro) which contain ferro magnesium silicates produce soluble materials (clay); iron-oxides; less silica.

Disintegration (mechanical weathering) produce rough angular materials which may from form on the mountain top or accumulate at the foot hills. These loose accumulations are called TALUS or SCREE.

The finest particles are usually removed from a scree by percolating water and the fine angular fragments get cemented. So, a cemented scree is known as BRECCIA. CHERT and FLINT also may occur in residue when limestones undergo weathering.

2. Give a detailed account of the erosional and depositional landforms created by the action of a river [N/D-14]

Introduction: The water that reaches the surface of the earth due to either rainfall or to the melting of snow divides itself into three parts as fly – off, underground water and running water.

Fly – off: Of total amount of precipitation in any region, a portion is found to evaporate and is known as fly off.

Underground water: A portion of precipitation water peculates through the pore space in soil and rock and sinks down gradually to form what is known as sub surface or underground water.

Run – off: A part of rain water flow down along the slopes of the earth's surfaces forming the surface run-off, starts commonly in the form of a thin sheet of water in motion. This is known as rain wash. As soon as rainwater accumulates within valleys and begins its downward journey it becomes a stream.

Further down a number of streams, until along converging valley to form a river along its seaward course a river procures a few tributaries or joints itself a more powerful river as its tributaries and in this manner a river system is developed.

During its life from head to mouth region, the stream water performed geological work which can be studied under three phases

-Erosion of the rock

-Transportation of the eroded material

-Deposition of the load

Erosion

Erosion is meant disintegration of the rocks by a natural agent. Streams are the most powerful sub aerial agent of erosion. They perform their erosion works in the following ways

- By hydraulic action
- Cavitations
- Abrasion
- Attrititon
- Corrosion

Hydraulic action:

A breaking down of the rock masses essentially due to continuous impact of water moving with appreciable velocity along the channel and is the dominating processes of erosion along the upper part of the course of a river where the gradient is considerable.

Removal of material from the solid rock by the action of water under pressure exerted by flowing water.

Cavitations

If the stream velocity exceeds 12-14 m/s, water pressure is at the point equal to vapour pressure that is a spontaneous change from liquid to vapour state. This charge results in virtual sucking out of rock piece creating depression or holes this is called as cavitation.

Abrasion:

The rolling boulders and pebbles naturally rub themselves against the valley floor during their travel upon the floor of the river valley such impacts therefore are scheduled to bring about a mechanical wear and tear of the rocks forming the base and abutments of the channel and at the same time the impinging rock fragments are themselves worn out the processes of mechanical breaking down of the bed rocks, this impact is known as abrasion.

Attrition:

The rolling boulders and pebbles and as well as the smaller fragments traveling in suspension, often collide with one another during their transport. Such mechanical collision naturally causes further wear and tear of their own, in addition to what has

already been caused due to abrasion. The process of mechanical breaking down of the transported rock fragments due to impact among themselves is known as attrition,

Solution Activity or Corrosion:

Some soluble carbonate rocks like limestone are attacked by running water and are gradually resolved is known as Corrosion.

Rate of stream erosion:

 Velocity – Fast moving streaming are capable of exerting greater pressure on the channel rocks and cause stronger impacts by the erosive tools. The velocity of stream itself depends on gradient of channel, volume of water in the channel, the nature of the channel.

 Lithology – Some types of rocks are more easily eroded by stream water than the others under exactly identical eroding conditions. Thus, if the limestone and granite forming bedrocks of the stream, the former will be eroded at the faster rate.

 Load – If the streams are fully loaded, it is incapable of transporting any other load, and then the tendency to erode rocks on the channel will be reduced.

Features of river erosion

Prolonged erosion by streams along its channel often produces many features on the surface of the earth. The following are some of the features caused due to erosion work of river,

 Pot hole

 River valley

 Escarpments

 Waterfall

 Stream terraces

Pot Holes:

These are variously shaped depression of different dimensions in the river bed that are excavated by extensive river erosion. The formation of a pot holes are initiated by plucking out of a piece of soft rock from the river bed by the river (Figure).

River valley: In the upper part of the course of any river where it flow down the hill slopes the processes of erosion becomes very conspicuous in excavating or down cutting the valley floor at this stage. Therefore the river passes through a narrow but deep valley which may developed in the softer rock into what is known as a gorge or canyon(Figure).

Escarpments: Some regions composed up alternating beds of hard and soft rocks. The soft layers are easily and quickly eroded by the stream whereas the hard layer resist the erosion and stand projecting as ledges on the sides. These ledges are undercut by continued erosion and falls down into the river giving rise to a steep slope. This is called escarpment. In some places a steam erodes the overlying softer layer thereby exposing the underlying hard bed all along its dip is called dip slope. The combined set of escarpment and dip slope occurring adjacent is called as Cuesta. An out crop of a hard resistance rock that is very steeply inclined is called hogback. In some area, horizontally layered rocks having a cap of hard and resistant rock that has escaped erosion it is called as Mesa.

Waterfalls: The magnificent jumps made by streams at different parts of their course where a sudden and considerable drop in the gradient of river channel is called as water fall.

The height of the waterfalls is greatly variable from a few too many meters. Falls of small-scale are some time termed as rapids and cascades.

Steam terrace: Bench like ledge or flat surfaces that occur on the sides of many steam valleys are called as steam terraces. It may appear as steps of a big staircase rising from the steam up along the slopes of the valley.

Sediment transport by stream:

River is one of the powerful transporting agents of sediments. It transport the sediment into three ways.

 Suspended load

 The bed load

 The dissolved load

Suspended load: The transportation of fine sand by steam

Bed load: The transportation of coarse sandy particles by steam in saltation processes.

Dissolved load: Some of the soluble rocks dissolves in the water is called dissolved load.

Graded stream

According to transporting power of the stream three types of streams can be distinguished.

1. Degrading stream

Streams are fast flowing and have sufficient velocity, not only to carry away the entire load but also to perform considerable work of erosion these are capable of removing the irregularities of the channel and also cutting down their base.

2. Agrading stream

A stream with a velocity insufficient to transport the load present in them

are compelled to drop down a part of their load, with the deposition of the load the channel is built up, its depth becomes less a grading streams are typical low lying flat land and flood plains

3. Graded stream

They have acquired a profile where velocity is just sufficient to carry ahead whatever load they acquire through the processes of erosion. There is neither pronounced erosion nor excessive deposition.

Deposition land forms by river:

River is one the depositional agent it produces the following depositional features such as

 Alluvial forms and cones.

 Flood plain

 Deltas

 Meander and Oxbow lakes

Alluvial fans and cones: The large rock fragments of the size of boulder and babbles continue to roll down the channel so long as the velocity of the flow is considerable. These are however dropped down as soon as the river enters into the plains due to an abrupt change in the velocity and hence the transporting capacity of the river. Such accumulation of boulders and pebbles at the point where running water enters into the plains is known as alluvial fans (when slope of the deposit is below 100) and alluvial cones (when slope is from 100 - 500).

Flood plain: There are many periods of high-water-levels (floods) in a stream during which it over flows its banks and spreads over vast area on its sides. Flood waters are invariably heavily loaded with sediments of all types. They deposit most of the load in the form of a thick layer of when the flood water level reduces. Since such a process may get repeated year after year, the low lying areas surrounding major rivers are actually made up of number of deposits. These are invariably very fertile in nature and hence have been supporting population.

Deltas: When a river ultimately meets the sea or a lake, the flowing water loses its velocity and has therefore no other way then to drop down the balance of its load right at its point of entrance of the river. Such deposition naturally initiates under favorable conditions and the formation of a new land mass is approximately triangular in shape, these deposits are known as delta deposit.

Meanders and oxbow lakes: River and stream never follow a straight course they move in more or less zigzag paths and the curvatures along the course are known as meanders. Meanders are present initially along any river course since running water has the tendency

to follow the direction of maximum slope of the topography. During the later stage, the river becomes more conspicuous due to deposition of sediments along the inner curve of pre-existing meander and proportionate further excavation along the outer curve. In this manner the river ultimately takes up in the plains an extremely rounded about course and during floods the running water may cut straight through a meander and follow a shorter course abandoning its previous rounded track. Such abounded meanders containing some amount of confined water gives rise to what are known as Ox bow lakes.

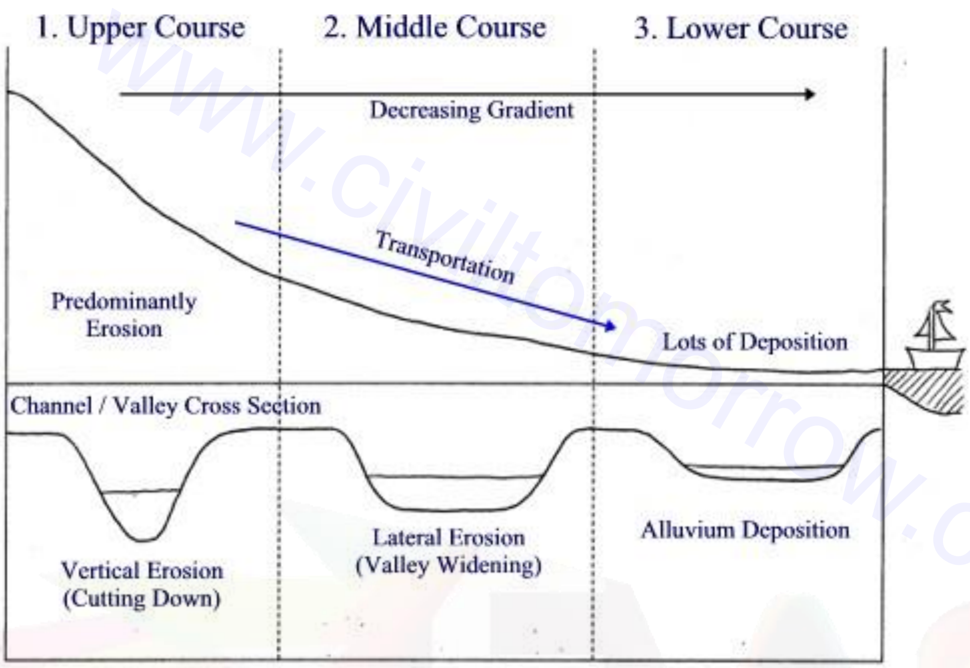
Stages of River or Normal Cycle of River Erosion

Based on erosion and velocity of river it can be classified into three stages

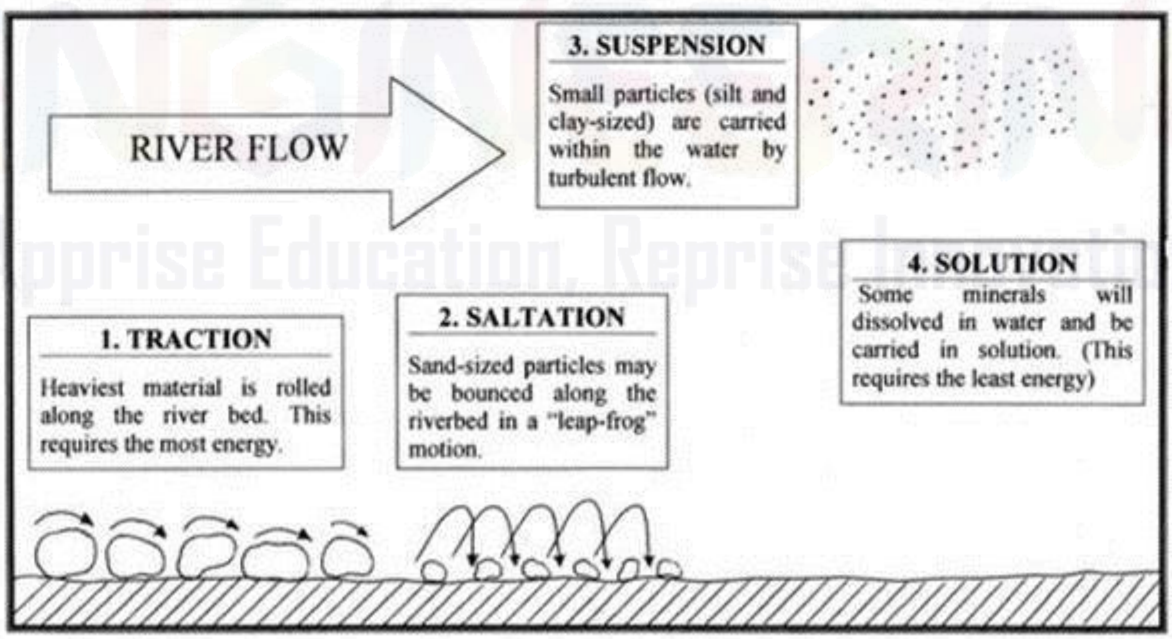
1. Youthful state

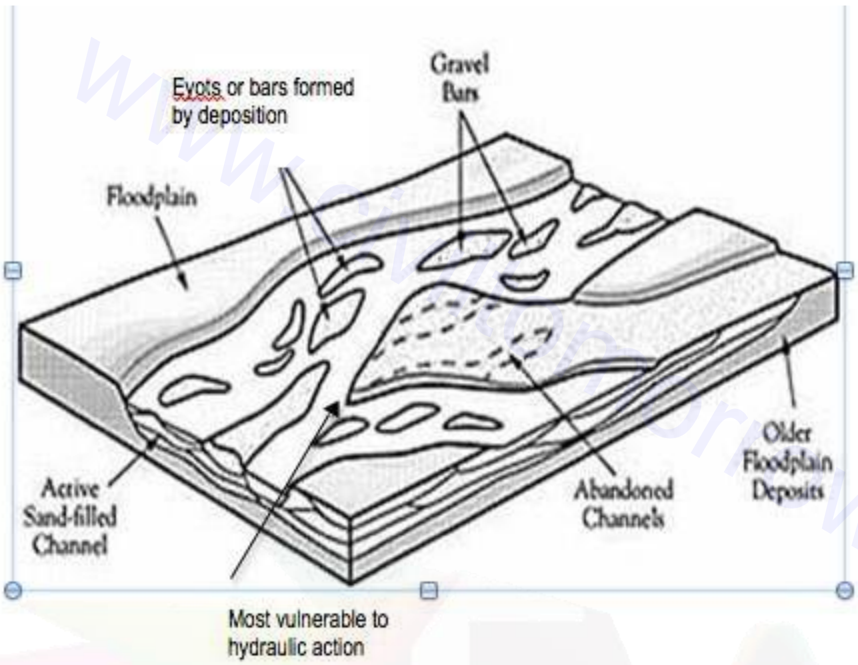
2. Mature stage

3. Older stage

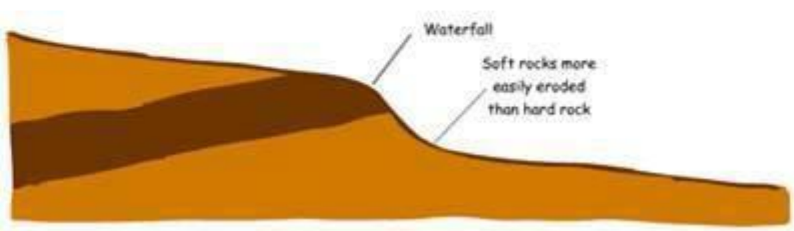


River Processes: Transportation




Eyots or bars formed by deposition
Gravel Bars
Floodplain
Active Sand-filled Channel
Abandoned Channels
Older Floodplain Deposits
Most vulnerable to hydraulic action


Horizontal hard rock layer
Undercutting weakens over-lying hard rock
Soft rock
Plunge pool


Waterfall
Soft rocks more easily eroded than hard rock

3. Describe the process of wealthering of rocks and comment on the effect of weathering ion the engineering properties of rocks. [N/D-15]

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Surface water contain O_2 and its combination with water results in the formation of carbonic acid. Production of carbonic acid lowers the pH, resulting in the attack some of the minerals which are present in the rocks.

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Hydration is the process where in hydroxyl molecules are injected into the molecular structures of minerals thereby bringing about the decomposition of minerals.

$K_2 Al_2O_3 6 SiO_2$ + $H_2O + CO_2$ ⟶ $K_2CO_3 + Al_2O_3 2 SiO_2 2H_2O + 4 SiO_2$
(K – feldspars) (Hydration) (Kaoline) (silica)

Due to hydration process, anhydrous pyroxenes are changed over to amphiboles while Amphiboles may be altered to Biotite. Biotite change over to Chlorite whereas Anhydrite ($CaSO_4$) alters to Gypsum ($CaSO_4 2H_2O$)) during hydration.

Oxidation: The decomposition of minerals in a rock during chemical weathering is brought about by O_2 in water. For eg pyroxene changes into limonite because of oxidation through the following reaction.

$4FeSiO_3$ + O_2 + $2H_2O$ ⟶ 4 FeO (OH) + 4 SiO_2
(pyroxene) (limonite) (silica)

Pyrite (FeS_2) converts into Haematite (Fe_2O_3) during oxidation process

Hydrolysis: In case of decomposition of minerals, instead of water molecule, only hydrogen of water enters into the mineral structure. This is called hydrolysis.

$K\ AlSi_3 O_8$ + H^+ ⟶ $HAlSi_3O_8$ + K^+
Orthoclase feldspars ion Silicic acid ion

In addition, CO_2; O_2; N_2 of atmospheric gases which take part in the weathering of rocks.

Chemical weathering, involves the direct effect of atmospheric chemicals in the breakdown of rocks, minerals...

Biological weathering involves breakdown of rocks by living organisms (Bacteria & fungi). Living organisms release organic acids viz., Oxalic acid; Phenolic acid; Folic acid, Acetic Acid, Humic acid etc.. which cause decomposition of rocks. Some of the microorganisms penetrate into mineral crystals and remove specific ions from the inter layers. Eg: removal of K^+ from mica layers by fungi is an example of this type.

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Weathering effect over the properties of rocks:

- Weathered minerals exhibit change in color intensity or different colors.
- They will be less compact, and hence their specific gravity will be less.
- Their hardness will decrease so that the minerals become softer and weak.
- They become less transparent or tend to become opaque.
- The minerals loss their original shine and exhibit a dull luster.
- Weathered minerals loose their internal cohesion & become easily powdered.
- Weathered rocks usually appear as brown,red & yellow colors on the surface.

The degree of weathering is controlled by several parameters. These are:

A) Rock mass characteristics: The ultrabasic and basic igneous rocks (Peridotite, Dunite, Gabbro) decompose rapidly to acidic igneous rocks (Granite).
Similarly, carbonate rocks weather rapidly due to chemical solvents. Among the metamorphic rocks, quartzite is most stable whereas weathering of schists and phyllite is relatively faster. Rocks with folding and faulting undergo rapid weathering. The weak zones facilitate mechanical and chemical weathering by natural agencies.

B) Climate: It includes temperature and rainfall. In general, weathering is faster in regions with high temperature and high rainfall

As the temperature increases the vibration of atoms and ions in the rock mineral structures are more ultimately leading to the development of cracks. Rate of chemical weathering doubles with an increase of temp by 10^{o} C.

Rainfall contributes to the growth of organisms (bacteria) which produces CO_2.

C) Relief: If the topography is undulating and the slopes are steep, the weathered material erode continuously from the site. Consequently fresh surface of the rocks expose.

Time: If the weathering has continued over a long period of time, thick zone of alteration develops. eg: Bauxite deposits results from the decay and weathering of aluminum bearing rocks often igneous rocks.

4. What is Plate Tectonism? Describe it in detail and explain its relation to earthquakes. [N/D-15]

THE UNIFYING THEORY

The theory of plate tectonics provides explanations for the past and present day tectonic behavious of the Earth, particularly the global distribution of mountains seismicity, and volcanism in a series of linear bells, seafloor spreading, polar wandering and continental dirft. From several lines of thought and evidences it is learnt that all of the natural phenomena of the earth might be the result of a single basic mechanism, i.e., convection in the mantle. How convection could cause such natural phenomena is discussed later in the chapter.

THE CONCEPT

The theory of plate tectonics supposes that the sphere of the earth is made up of 7 major and several minor plates which are in constant motion relative to each other. The motion of the plates refer to the rigid slabs of the continental and oceanic crust that slides over the plastic zone of asthenosphere of the upper mantle (chapter 9). A fractures egg shell forms a good analogy to the spherical plates of the earth. These plates are bounded by active linear zones causing volcanism and earthquakes.

HISTORICAL BACKGROUND

The theory of plate tectonics has been a recently developed theory. Recent advancement in the ocean floor studies and rock magnetism piled information on the nature of the seafloor. As with the growing data has grown the number of workers in the same filed. Constitutions made by several individuals collectively gave birth to the theory of plate tectonics. At present even scientists from Russian school who at first were against the theory, begin to show faith in the theory on seeing the evidences accumulating every day. However there are a few flaws in the theory which are yet to the reasonably explained by the theory. Thus it may need a modification to answer all questions about the earth.The theory of plate tectonics has a fore runner of continental dirft. Thus the entire idea that the Earth's external skin is subject to motion has come in to the minds in scientists when they observed the striking similarity of the opposite coasts of South America and Africa.

In 17th century Francis Bacon wondered about the coastline matching. But no work was done till late 19th Century. When the world map was redrawn in 19th century the spirit of questioning of matching coasts got fire. Antonio snider pelligrini (1858, French), Frank B.Taylor (1901, American) and affred Wegener (1915, German) contributed a lot to the idea of lateral motion of the continents over the face of the earth (chapter 22). During 1950s magnetic data become available in support of continental drift and seafloor spreading. Later it is understood that the continents themselves do not move but they are mere passengers over the sliding lithospheric slabs driven by the spreading seafloor. In 1968,Jason morgan replaced the title 'new global tectonics' by a new terminology 'plate tectonics'. Despite a few shortcomings the theory of plate tectonics gains momentum among the world scientists day by day by the overwhelming evidences. The following sections deal in details about the plate tectonics.

ELEMENTS OF TECTONISM

Seismology Permitted an insight into the Earth. As per the seismic data the Earth is composed of a few layer of different composition, density and physical nature. The earth consists of three Principal layers, namely crust, mantel and Core. Crust is divisible into oceanic and continental crust. The earth's movements involve the upper mantle also. in the upper mantle is a layer called low velocity zone which behaves like a fluid. Thus it Possesses a plastic flow. The layer is also known as asthenosphere. Continental Crust, Oceanic crust and a part of upper mantle constitute a plate which a rigid part of the lithosphere. Plates overlie the asthenosphere. Any movement in the underlying asthenosphere affects the plates.

CHARACTERISTICS OF PLATES

1. A Plate consists of crust and a part of upper mantal.
2. Size and Shape of the plates are not constant.
3. One large plate may be fragmented into many small plates may unit to form a large one.
4. plates are spherical of curved and are independent.
5. Thickness of plates vary.It is 70 km beneath oceans and 150 km beneath continents.

6. Plates are bounted by different boundaries distinguished by the relative motion of the adjacent plates.

7. Plates are enclosed by Features like mid-oceanic ridges , oceanic trenches great faults and fold mountain belts.

8. The length of the boundary is variable.

9. Plates move with respect to each other and to the axis of rotation.

10. Plates move with different velocity and in different directions. Even different parts of the same plate move at different velocities.

11. Plate margins are subject to deformation .but interior of the plate is free from deformation.

12. plates bearing continental crust will not be consumed at the boundaries.

13. Plates and boundaries are not permanent features.

WORLD PLATES

Geographical plates of the Earth are recognized as follows. Seven plates are larger and many others are smaller .

LARGE PLATES

1.Antarctic plate 2. Pacific plate

3.Eurasian plate 4.African plate

5.North American Plate 6.South American Plate

7.indian/Australian plate

SMALL PLATES

1. China Plate 2. Philippine Plate

3. Arabian Plate 4. Iran Plate

5. Nazca Plate 6. Cocos Plate

7. Caribbean Plate 8. Scotia Plate

PLATE BOUNDARIES

The surficial trace of the zone of motion is known as plate boundary. The end of the plate is called plate margin. Figure 20.2 shows the boundary and the margin There are three types of plate boundaries. These are recognized on the basis of the movement associated with the plate junctions. They are: 1. Divergent or Constructive boundaries or sources 2. Convergent or Destructive boundaries or Sinks and 3. Transform fault boundaries or conservative boundaries. With the help of seismic observations and / or magnetic lineation's plate boundaries are mapped. And they are also used to find the direction and the velocity of plate motion.

DIVERGENT BOUNDARY

Long the middle of the ocean floor their rises a ridge with a central 'V' shapped valley. The boundary line that separates the two plates runs along the valley bottom. Materials of the two flanks of these mid oceanic ridges move away from each other. This boundary is known as divergent boundary as the plates diverge with reference to the boundary line. But they are never separated. Because new material is poured out continuously and is accreted to the moving plate margins (Fig.20.3) . Upcoming material is symmetrically divided into two halves and mobilised. The symmetry may be produced in this way: A new ribbon of material is added to the margins of separating plates. The rigidity of the material is lower and lower as the centre of the ribbon is approached. Splitting may occur along the line of weak zone. Thus when the ribbon is subjected to tensional forces (because of the mobile plates) it is broken symmetrically as the plane of weakness occupies the central part of the ribbon.

CONVERGENT BOUNDARY

This boundary is developed as two plates converge towards each other and thus it is known as Convergent boundary. Since land area is lost along this type of boundary, it is known as destructive boundary. For the reason that the material is being sunken at these boundaries they are also known as sinks. Convergent Boundaries are marked by deep sea trenches and fold mountain belts. They may be Located along the northern and western border of the Pacific forming Aleutian trench, Japan trench and Tonga trench and Tonga trench, Western continent slope of the South America forming Eru-Chile trench, Himalayas f India, Mediter- tanean trench and java trench. The convergence of plates occur in two ways: 1. subduction And 2. Continental collision depending upon the nature of plates that collide. Three cases of plate collision my be expected accordingly the type of convergence differs as follows.

Crustal types of plates	Type of Convergence

1. Oceanic and oceanic	Subduction
2.Oceanic and Continental	Subduction
3.Continental and Continental	Continental Collision

1. When both the colliding plates hold oceanic crust any one of the plates slides down the other plates slide at approximately 45 degrees. The process of sliding of one of the plates beneath the other along the convergent boundary is known as subduction. 2. When the colliding plates are oceanic and continental, then it is always the oceanic plate that is subducted beneath the continental. It happens so because of the greater density of the oceanic crust of the descending plate. The plate being made up of continental crust is lighter and always tend to float over the oceanic crust holding plate 3. When both the colliding plates are composed of continental crust neither/ of the plates slips down because of low density. But on collision continental crust is evolved into fold mountain systems. A classic example of such a continental collision belt is the Himalayan belt, produced during the Cenozoic Era by the convergence of the Indian plate with Eurasian plate.

SUBDUCTION ZONE : Subduction Zone are the zones where subduction of plates occur. Obviously a sink or a destructive boundary or a convergent boundary may be a subduction zone. Plunging stab or the subducted plate is of oceanic crust. Buoyancy plays as important role in subduction zones. Back are basins are the basins developed due to the subduction. Subduction zones are characterized by active volcanism earthquake and the development of deep ocean trenches. The down-going stab is assimilated in the mantle. However, partial melting of the oceanic crust of the subducted plate generates mafic igneous intrusion. The sepentinized pillow basalts and mafic intrusions with associated deep-sea sediments occurring along with subduction zones is termed ophiolite suite. The zone where all kinds of earthquakes (shal-low, intermediate, and deep) originate is termed the Benioff zone or Benioff plane (named after hugo Benioff, and American Seismologist). Earthquakes are generated as the plate plunges creating frictional force. The Benioff zone is a thin inclined plane zone located on the top margin of the descending slab. Benioff plane dips away from oceanic trenches and toward the adjacent island arcs and continents and marks the surficial trace of the slippage of overriding and descending plates the subducted plate may be partially melted and andesitic magma may be generated. Igneous activity, crustal deformation, mountain building and metamorphism are associated with convergent boundaries. Partial fusion of oceanic crust that plunges in to the mantle generates granitic magma and continental in the roots of mountains. Since sediments of low density accretes to the overriding plate, the plate grows and thus it become constructive. Although the growth rate is 1 mm/year geologically it is significant. In the two plates of a destructive boundary plate is constructed and the other destroyed.

CONTINENTAL COLLISION : According to mattauer, intra-continental subduction can occur in three ways : 1.Crusts may be stacked one over the other; 2. Crust-mantle decollement may occur and 3. Continental lithospheric subduction may also occur. Collision of then Asian plate and Indian plate provides a best example for intra-continental subduction. The results of the recent investigations on Himalayas reveal the occurrence of subduction of continental plates in contrast to the general belief that the continental crust cannot sink owing to it low density. During initial periods of collision thickening of crust occurred along the boundary continued collision developed two strike slip faults between which a triangular northeast of India might have occupied a northern frontal location of Indian plate before collision. As collision still persists the broken plate margins of both the plates plunge into the mantle. It is estimated that about 1500km of Indian continental lithosphere has disappeared into the mantle. The rates of subduction also vary with time. During upper carboniferous period Indian plate moved at the rate of 10 cm per year. It was 5 cm per year in Eocene. But it moves 1 to 2 cm per year at present.

5. Write an essay on wealthering of rocks and its significance in engineering point of view.[M/J-16]

The process by which rocks are broken down and decomposed by the action of external agencies such as wind, rain, temperature changes etc is called as weathering.. (or) weathering is a process involving disintegration and decomposition of rocks. The disintegrated and the altered materials stay at the site of formation. If these materials are transported from the site with the help of natural agencies such as wind, running water etc, the process is called as erosion. Weathering is categorized as a mechanical, chemical, biological..

Mechanical weathering: In mechanical weathering, the process involves only fragmentation or break down of the rock into smaller fragments / pieces. In nature, the physical breaking of rocks are caused by several processes. Waterfalls, landslides during their fall cause extensive breakdown of rocks. Thus gravity contributes to mechanical disintegration of rocks. However, all the processes involve widening of the fractures, resulting in the detachment of blocks surrounded by the weak planes. The different types of processes in mechanical weathering are:

Frost wedging: The presence of water in the cracks of the rocks freezes during the night time and melts during the day time. Freezing of water involves an increase in the volume because of which the walls of cracks are wedged ultimately resulting in the detachment blocks surrounded by the weak planes.

Expansion and contraction process: Solar radiation causes heating, which results in thermal expansion during day time and drop in the temperature during the night time causes contraction. The expansion and contraction are confined only to the surface layers of the rock and results often in the fracturing and detachment of top layers of the rocks.

Fracturing through pressure releases: Rocks at depth are confined under high pressures. However, if the rock material is uplifted due to tectonic processes to relatively lesser depths, it is subjected to lesser pressure conditions. So, the release of pressure leads to the deformation of rock and generates the fractures.

Effect of vegetation: During the growth of vegetation in rocky terrains, the roots penetrate into the existing weak planes and gradually the cracks are widened leading to physical breakdown of rock masses.

Mechanical or physical weathering involves the breakdown of rocks through direct contact with atmospheric conditions, such as heat, water, ice and pressure.

Chemical weathering: Chemical weathering involves chemical reactions resulting in the alteration of the rock leading to the formation of new alteration products. Water is the best fluid that directly affects rocks by way of Dissolution; Leaching (making porous); Hydration; Oxidation, Hydrolysis etc

Dissolution / Carbonation: In case of carbonate rocks such as limestone, dolomite, marble when the river water traverses in these rocks; carbonates are dissolved, resulting in the reduction of their sizes.

Surface water contain O_2 and its combination with water results in the formation of carbonic acid. Production of carbonic acid lowers the pH, resulting in the attack some of the minerals which are present in the rocks.

Leaching: means removable of soluble content from the rocks by water. Water is the powerful leaching agent which affects leaching for the most of the materials when come in contact with water. Eg: laterite is a porous rock and very weak when compared to its fresh parent rock.

Hydration is the process where in hydroxyl molecules are injected into the molecular structures of minerals thereby bringing about the decomposition of minerals.

$K_2\ Al_2O_3\ 6\ SiO_2 + H_2O + CO_2 \longrightarrow K_2CO_3 + Al_2O_3\ 2\ SiO_2\ 2H_2O + 4\ SiO_2$
(K – feldspars) (Hydration) (Kaoline) (silica)

Due to hydration process, anhydrous pyroxenes are changed over to amphiboles while Amphiboles may be altered to Biotite. Biotite change over to Chlorite whereas Anhydrite ($CaSO_4$) alters to Gypsum ($CaSO_4\ 2H_2O$)) during hydration.

Oxidation: The decomposition of minerals in a rock during chemical weathering is brought about by O_2 in water. For eg pyroxene changes into limonite because of oxidation through the following reaction.

$4FeSiO_3 + O_2 + 2H_2O \longrightarrow 4\ FeO\ (OH) + 4\ SiO_2$
(pyroxene) (limonite) (silica)

Pyrite (FeS_2) converts into Haematite (Fe_2O_3) during oxidation process

Hydrolysis: In case of decomposition of minerals, instead of water molecule, only hydrogen of water enters into the mineral structure. This is called hydrolysis.

$K\ AlSi_3\ O_8 + H^+ \longrightarrow HAlSi_3O_8 + K^+$
Orthoclase feldspars ion Silicic acid ion

In addition, CO_2; O_2; N_2 of atmospheric gases which take part in the weathering of rocks.

Chemical weathering, involves the direct effect of atmospheric chemicals in the breakdown of rocks, minerals...

Biological weathering involves breakdown of rocks by living organisms (Bacteria & fungi). Living organisms release organic acids viz., Oxalic acid; Phenolic acid; Folic acid, Acetic Acid, Humic acid etc.. which cause decomposition of rocks. Some of the microorganisms penetrate into mineral crystals and remove specific ions from the inter layers. Eg: removal of K^+ from mica layers by fungi is an example of this type.

Man is also responsible for unnatural weathering of rocks for construction of buildings, dams, bridges etc…

Weathering effect over the properties of rocks:

- Weathered minerals exhibit change in color intensity or different colors.
- They will be less compact, and hence their specific gravity will be less.
- Their hardness will decrease so that the minerals become softer and weak.
- They become less transparent or tend to become opaque.
- The minerals loss their original shine and exhibit a dull luster.
- Weathered minerals loose their internal cohesion & become easily powdered.
- Weathered rocks usually appear as brown,red & yellow colors on the surface.

The degree of weathering is controlled by several parameters. These are:

D) Rock mass characteristics: The ultrabasic and basic igneous rocks (Peridotite, Dunite, Gabbro) decompose rapidly to acidic igneous rocks (Granite).
Similarly, carbonate rocks weather rapidly due to chemical solvents. Among the metamorphic rocks, quartzite is most stable whereas weathering of schists and phyllite is relatively faster. Rocks with folding and faulting undergo rapid weathering. The weak zones facilitate mechanical and chemical weathering by natural agencies.

E) Climate: It includes temperature and rainfall. In general, weathering is faster in regions with high temperature and high rainfall

As the temperature increases the vibration of atoms and ions in the rock mineral structures are more ultimately leading to the development of cracks. Rate of chemical weathering doubles with an increase of temp by 10^o C.

Rainfall contributes to the growth of organisms (bacteria) which produces CO_2.

F) Relief: If the topography is undulating and the slopes are steep, the weathered material erode continuously from the site. Consequently fresh surface of the rocks expose.

G) Time: If the weathering has continued over a long period of time, thick zone of alteration develops. eg: Bauxite deposits results from the decay and weathering of aluminum bearing rocks often igneous rocks.

IMPORTANCE OF WEATHERING

Weathering transports smaller fragments, pieces etc after the process of weathering. Weathering initiates the erosion of rock, causing alterations in minerals as well as in the surface layers. Weathering is a process that applies major role of engineering mechanics, e.g. kinematics (study of bodies which are in motion), dynamics and fluid mechanics to predict the mechanical behavior of erosion. Together, soil and rock mechanics are the basis for solving many engineering geologic problems with references to dams, reservoirs and tunnels.

Advantages of weathering from civil engineering point of view:

- Weathering produces soil which is vital for agriculture and for the production of agricultural crops.
- Weathering makes rocks into porous and permeable which allow the movement of groundwater in case of hard rocks like granites.
- Economic minerals like bauxite deposits are also form due to weathering.
- Oxidation of chemical weathering is important in the formation of some ore deposits particularly sulphides.

Disadvantages of weathering from civil engineering point of view:

- Weathering is not a welcome process, because it reduces the strength, durability and good appearance of rocks.
- Therefore, the weathered rocks are unfit to be at the site of foundation in case of civil structures like dams and bridges.
- Since weathered rocks are characterized by loose characters ie strength, durability etc, they become unfit for the formation of road metal or as a building stone.
- Weathered rocks are being weak, therefore unsuitable for tunneling.

- Occurrence of weathered zone in the upstream side creates silting problem in case of reservoirs as the accumulation of rapid silt reduces the reservoir capacity.
- Loose boulders due to weathering along steep slopes may turn out landslides which is civil engineering hazard.

6. (Give a general view of Internal Structure of the Earth as revealed by the seismological evidence.

The real interior of the earth is nowhere exposed to our direct observations. With our present scientific skills we can hardly penetrate more than a few kilometers below the Earth whereas the average radius of the Earth is taken as 6371km. As such our present views regarding the internal structure of the Earth are based on indirect geophysical methods. These involve application of very sensitive instruments, complicated calculations and imaginative interpretations. The study of seismic waves forms the single most important source of information for the interior of the Earth.

SEISMOLOGICAL EVIDENCE

Basic Facts

Seismology is a branch of geophysics that deals with the study of elastic waves generated within the body within the body of the Earth during an earthquake. Nature of these waves will be discussed in some detail in chapter on Earthquakes.

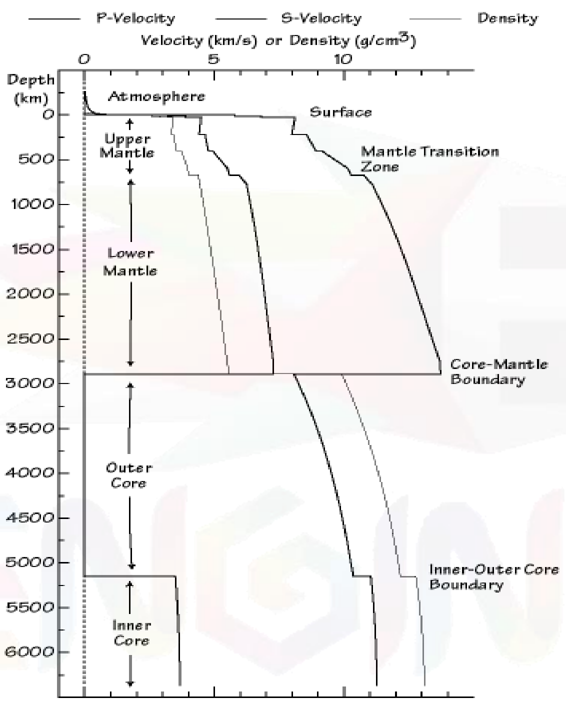
i) In every earthquake elastic waves of three main types are generated at the focus of the earthquake. These are named as P-waves, S-waves and L-waves. The P-S waves are also called body waves and the L-waves as surface waves. The seismic waves travel in all directions from the focus.

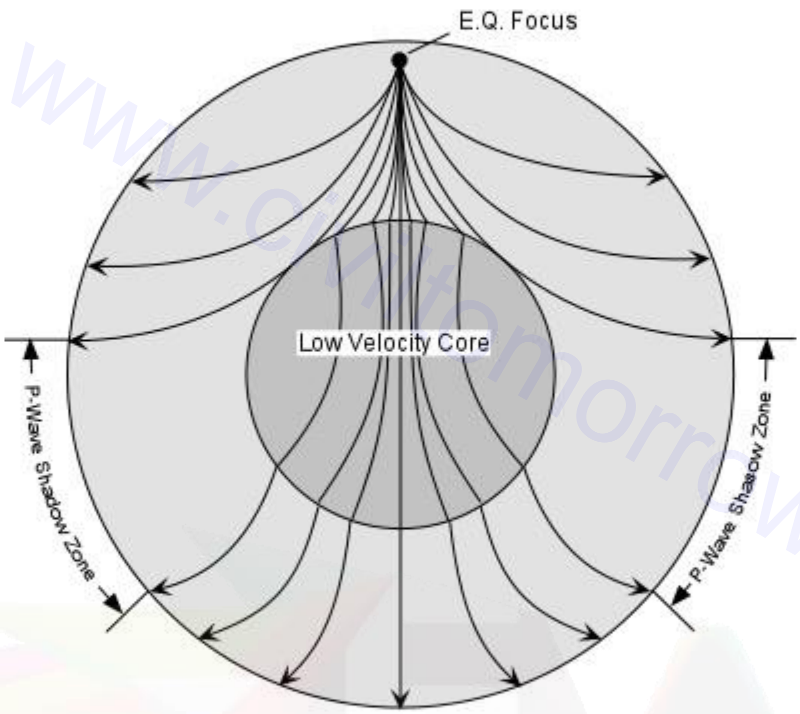
ii) The three types of seismic waves are recorded in each earthquake at various seismographic stations in a definite sequence; their record is known as Seismogram. The P and S waves are recorded on the surface after having passed through materials deep within the earth and are considered important in the study of internal structure. These waves travel with characteristics velocities through different media, so that from their arrival times many important conclusions regarding the nature of material in their paths can be broadly ascertained.

iii) From travel time curves of these waves obtained from the various earthquake records, it is possible to calculate the velocity of any one type of these waves at any depth within the earth. This gives us the very important and revealing velocity depth curves.

iv) A through analysis of the velocity depth curves, especially of the sharp and prominent changes observed in them repeatedly from different records is taken as indicative of major variations in the nature of the medium at those respective depths below the surface. The analysis when extended from surface to the centre of the earth enables us to obtain a generalized picture of the internal structure of the Earth.

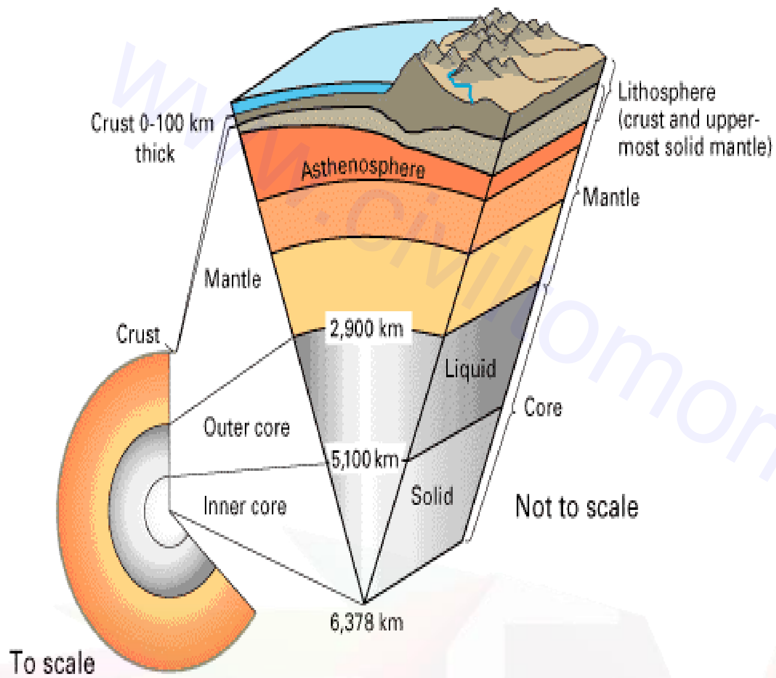
b) Interpretation: For the interpretations of seismic waves regarding internal constitution of the Earth, seismic records from a large number of earthquakes are required. The interpretation of internal structure is based on detection of abrupt changes in the velocity of P and S waves duritn thir travel. The waves reach the surface after being reflected and refracted at various depth below.

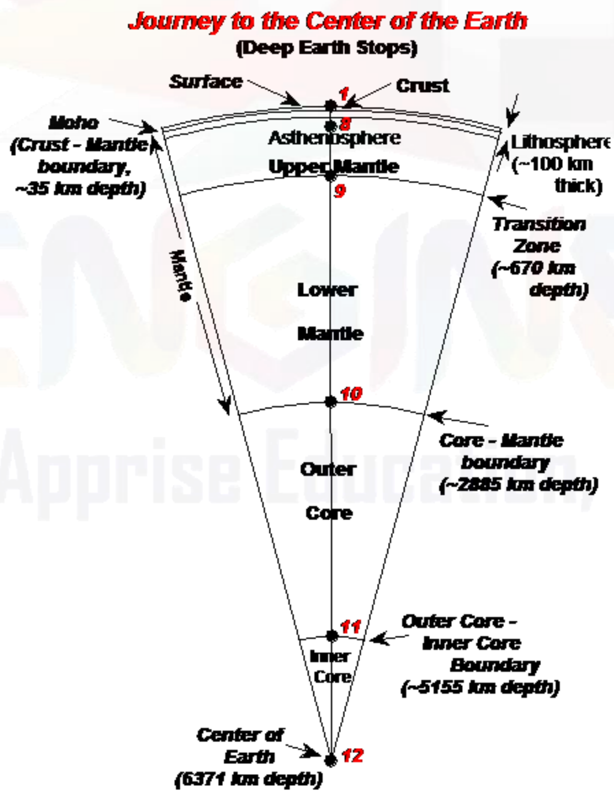




If the earth were of uniform nature from the surface t0 the centre, seismic waves traveling through it would be recorded on the opposite and without undergoing any significance changes are interruptions in their velocity during their journey. Conversely, a major change in the velocity of seismic waves at some depth below the surface can be take to mean that there is a change in the nature of the medium at that particular depth. Such a major change in the velocity of seismic waves is called a seismic discontinuity and is of fundamental importance in the interpretation of the internal structure of the Earth.

A number of such seismic discontinuities have been repeatedly observed during many earthquakes in the past and the calculated depths at which they occur show remarkable agreement. As such, these are now accepted as established facts and believed to demarcate different zones within the body of the Earth. The tow most important seismic discontinuities are : the Mohorovicic discontinuity and The Mantle-Core discontinuity. These basic discontinuities demarcate three major internal zones in the constitution of the Earth : the crust, the mantle and the core.





The mohorovicic discontinuity :

This is the first major discontinuity iin the seismic records for the earth and is named after its discover . a mohorovicic it occurs in the seismic records at depth between 30-40 km below the continents, 5-6 km below the oceans and 60-70 km below the mountains. It is observed that both p and s waves on reaching these depths sharp increase in their velocity. Thus P waves attain a velocity of 7.75 km per second from an original velocity of 5.54 km/sec in the upper layer. Similarly S waves start travelling at 4.35 km/sec from an original velocity of 3.35 km/sec in the immediate upper layer.

Thus the Mohorovicic discontinuity marks the lower limits of the uppermost shell or sphere of the earth which is named as crust. The layer is merely 35 km thick (on an average) under the continents and 5-6 km under the oceans. Comparisons of the Earth with an old large sized apple will help clarifying the conception of crust. The crust is to the Earth what skin is to the apple: a very thin hard and wrinkled sheet or covering.

The mantle-core discontinuity:

Some of the seismic waves that cross the mohorovicic discontinuity continue to travel towards the central parts of earth with almost a uniform increase in their velocities. Such a gradual and uniform increase with increasing depth is on expected lines since their velocity is related to the density of medium which all increase with depth. At the depth of 29900km, however another major discontinuity is suddenly observed in the seismic wave records. At this depth S waves are practically stopped from going any further deeper. The P waves also become very sluggish and suffer a decrease from 13.64 km/sec above 2900km to a velocity of 8.1km/sec below this depth. The zone or shell of the earth lying between these two discontinuities is called the mantle. The second discontinuity which demarcating the end of mantle also marks the beginning of the third discontinuity. It was first discovered by B.Gutenberg in 1918 and subsequently confirmed by Jeffreys in 1939.

The behaviour of P-S waves below 2900km depth throws sufficient light on the existence of the third major shell, the core, within the Earth. In every major earthquake, P and S waves are recorded at all the stations lying between the epicenter and 105° and 142° arc dutabces (11000 – 16000 km), neither P waves nor S waves are recorded; after 142° arc distance (16000 km), only P waves reappear. There is thus a shadow zone free from P and S waves in the records of each earth quake. The shadow zone indicates existence of a zone of material completely different in nature than the upper two shells of the Earth. This zone starts at a depth of 2900km, (2928 km to be precise) and continues right upto the centre of the Earth (6371 km). This is the core of the Earth. The existence of core was established first by R.D. Oldham in 1906.

Final Picture :

The final picture of the internal constitution of the Earth as developed from the seismic evidence divides it into three well defined zones or shells or spheres : the Crust, the Mantle and the Core. In each of these major zones, there are significant variations which allow their further subdivisions into layers with distinct characters. An outline about the inferred character and major facts regarding these three zones is summarized in the following paragraphs.

The Crust

It is the uppermost shell of the Earth that extens to variable depths below the surface, to a maximum depth of 75km below the mountains. The lower boundary of the crust is marked by the MOHOROVICIC discontinuity. On the basis of seismic evidence available at present, its l,ower limits are as follows:

Mountainous Areas:- 50 - 60km. Under the Himalayas the crust is believed to be 70 – 75km thick, under the Hindukush 60km and under the Andes as 75 km.

Continental Areas :- 30 – 40km. The thickness and structure of thecrust at continental slopes (that link continents with the oceans) is intermediate. For the crust, an average thickness of 35km is usually taken.

Oceanic Areas :- 5 - 19km. The deeper the ocean, the smaller is the thickness of the crust.

On seismological evidence, the continental crust is further divisible into three layers A, B and C, beginning from the surface. The upper or A-layer of the crust is relatively dense (2.4 to 2.6 g/cc). The waves attain a velocity of 5 to 6.2km/sec. This layer is also called the Granite Layer of the crust and is made up mostly of granites, gneisses and other related igneous and metamorphic rocks. At places it acquires thickness of 20km or more. In fact, at many places in the world, it is exposed on the surface because the overlying A layer has already been removed due to prolonged erosion. Since granite layer is mostly composed of light-coloured, low density, silicates of potassium and aluminium, it is also referred as SIAL (SI = Silica, AL = Alumina).Volume of granite crust is estimated at 5.8 x 10^9 km^3 The lower most layer (C layer) of the crust has a density of 2.8 to 3.3 g/cc, in which P waves attain still higher velocity of 6 to 7.6 km/sec. This layer is commonly referred as Basaltic layer of the crust, and acquires a thickness of 25 – 40km under the continents. It is made up predominantly of basic minerals, rich in magnesium silicate and is also referred as SIMA (Si for silica and MA for magnesium). Under the oceans, the crust is made up mostly of C layer for the basaltic layer; thetop sedimentary layer is either absent or is only scantly represented, whereas granite layer is practically absent. The oceanic crust is estimated to have a volume of 2.54 x 10^9 cubic kilometers. Its average density is taken as 3.0 g/cc.

The Mantle

It is the second concnetric shell of the Earth that lies beneath the crust everywhere. This zone starting from the lower boundary of the crust (The mohoroicic discontinuity) continues upto a depth of 2900km. The exact nature of the mantle is as yet incompletely understood. It has been sub-divided into an upper mantle and a lower mantle, the boundary between the two layers being placed between 900-1000km. The structure of the upper mantle is believed to be quite complex. It is assumed to be made up of two layers:

B-layer: fairly uniform in composition, and nearly400 km thick.

C-layer: about 600km thick and where limited changes in chemicatl composition are indicated. The lower mantle is believed to have a less complex structure.

Enough seismic data has been collected to suggest that density in the mantle varies between 3.3g/cc from just below the crust to about 5.7g/cc at the base of the mantle. Recent studies indicate that a part of the upper mantle, from 100 to 150km depth, is in a plastic rather than solid state. The plastic type zone of the mantle has been specifically named as asthenoshpere. It is believed to be the source of much of the volcanic activity of the Earth.

The Core:

It is the innermost concentric shell of Earth as deciphered from the record of seismic wave. It s existence was first suggestd by R.D. Oldham in 1906 and subsequently confirmed by other seismologists. The core boundary begins at a depth of 2900km from the surface and the region extends to the centre of the Earth (at 6371 km). Further studies of the behaviour of seismic waves reveal that the core itself can be distinguished into at least to main zones : the outer core and the inner core. The outer core (2900km to 4580km) resembles a liquid like substance because S-wave are not transmitted through this zone at all. (It is the characteristic of S waves or shear waves that they do not travel through liquids). The inner core, with a thickness of around 1790 km is believed to be a solid metallic body. In between the outer core and the inner core, variation in the nature of the material is also vaguely suggested by many records but nothing can be said as yet with certainty. The total mass of the core is estimated at one third of the total mass of the Earth. The density variations show interesting feature outside and inside the core.

At the base of the mantle, density isinferred as 5.7 g/cc which jumps to 9.9g/cc at the toip of the core. This value reaches a figure of 12.7 at the boundary of the inner core and attains a value of about 13.0 at the centre of the Earth. As regards the chemical composition of the core, the hypothesis that it is made up chiefly if iron and nickel has found support on many accounts. Seismologically, this is supported by velocities of the P waves observed in the core, which are similar to those recorded for nickel-iron alloys. Other, non seismological grounds suggesting to a nickel – iron core for the Earth are :

The high density of the Earth: It is fairly established that the mean density of the Earth is 5.517 g/cc. The density of the rocks of the crust is only 2.75g/cc. On the basis of calculations and observed values of seismic waves, the density of the material making the core of the earth should be above 12 g/cc to compensate for the less dense mantle and crystal rocks. The most likely materials to account for such density are iron and nickel. Hence their present in the core is a fair assumption.

7. Using diagrams and explanations, describe the internal structure and composition of the Earth.[N/D-16] [N/D-14]

The real interior of the earth is nowhere exposed to our direct observations. With our present scientific skills we can hardly penetrate more than a few kilometers below the Earth whereas the average radius of the Earth is taken as 6371km. As such our present views regarding the internal structure of the Earth are based on indirect geophysical methods. These involve application of very sensitive instruments, complicated calculations and imaginative interpretations. The study of seismic waves forms the single most important source of information for the interior of the Earth.

SEISMOLOGICAL EVIDENCE

Basic Facts

Seismology is a branch of geophysics that deals with the study of elastic waves generated within the body within the body of the Earth during an earthquake. Nature of these waves will be discussed in some detail in chapter on Earthquakes.

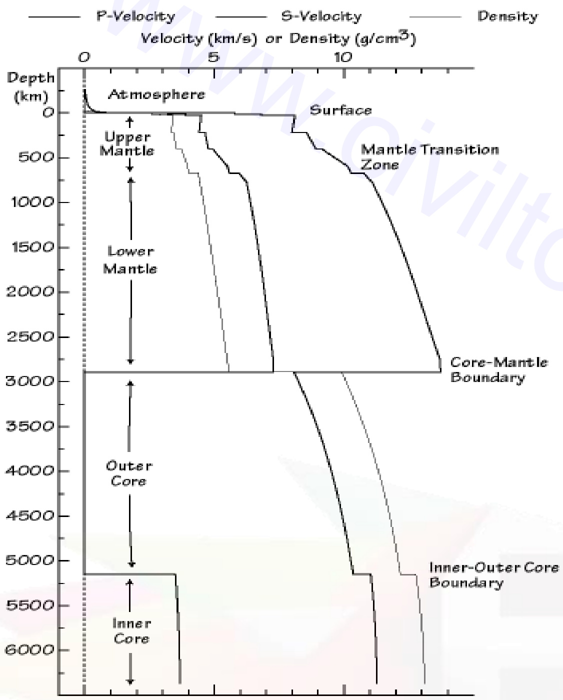
i) In every earthquake elastic waves of three main types are generated at the focus of the earthquake. These are named as P-waves, S-waves and L-waves. The P-S waves are also called body waves and the L-waves as surface waves. The seismic waves travel in all directions from the focus.

ii) The three types of seismic waves are recorded in each earthquake at various seismographic stations in a definite sequence; their record is known as Seismogram. The P and S waves are recorded on the surface after having passed through materials deep within the earth and are considered important in the study of internal structure. These waves travel with characteristics velocities through different media, so that from their arrival times many important conclusions regarding the nature of material in their paths can be broadly ascertained.

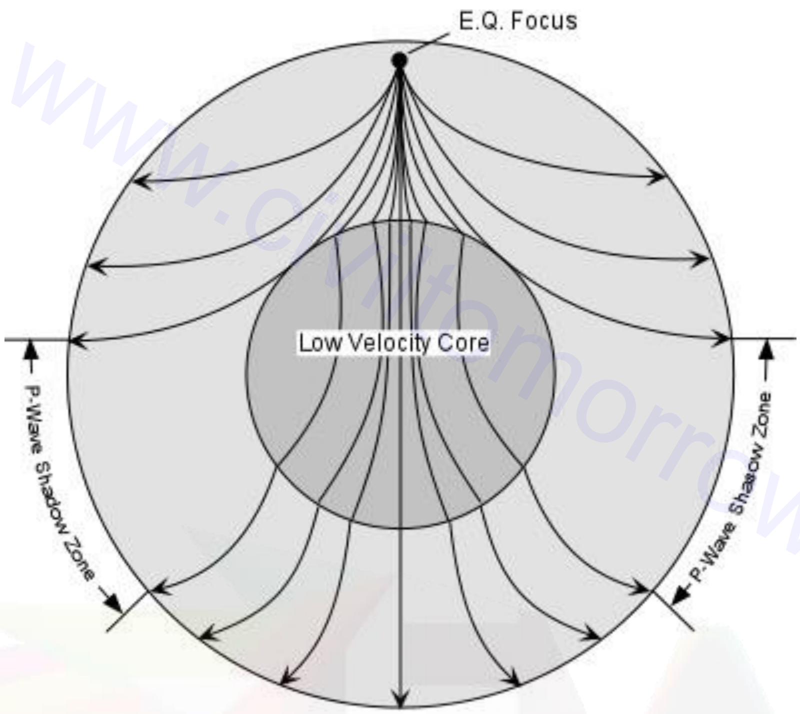
iii) From travel time curves of these waves obtained from the various earthquake records, it is possible to calculate the velocity of any one type of these waves at any depth within the earth. This gives us the very important and revealing velocity depth curves.

iv) A through analysis of the velocity depth curves, especially of the sharp and prominent changes observed in them repeatedly from different records is taken as indicative of major variations in the nature of the medium at those respective depths below the surface. The analysis when extended from surface to the centre of the earth enables us to obtain a generalized picture of the internal structure of the Earth.

b) Interpretation: For the interpretations of seismic waves regarding internal constitution of the Earth, seismic records from a large number of earthquakes are required. The interpretation of internal structure is based on detection of abrupt changes in the velocity of P and S waves duritn thir travel. The waves reach the surface after being reflected and refracted at various depth below.

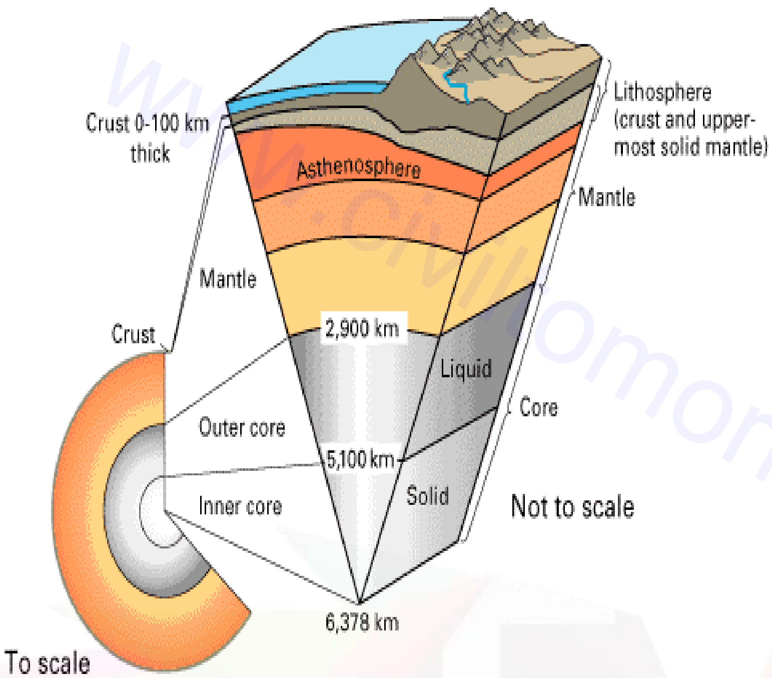


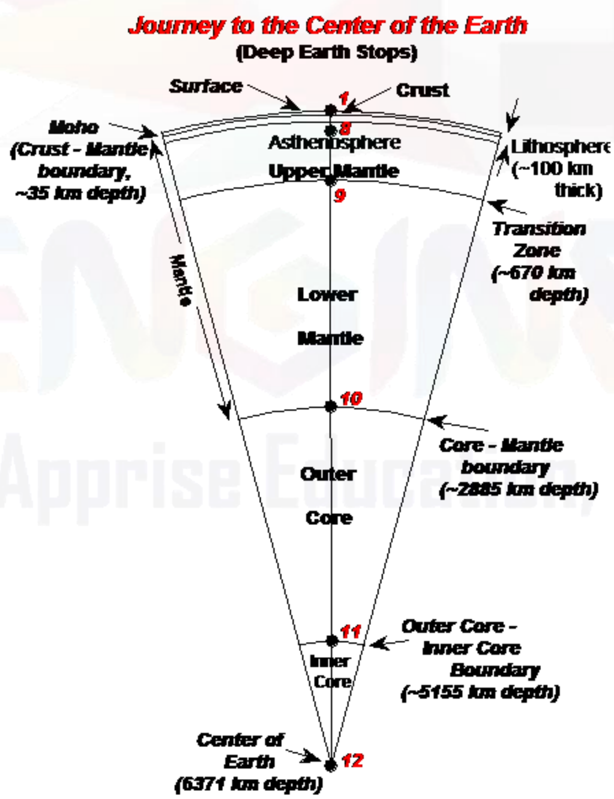
P-Velocity
S-Velocity
Density
Velocity (km/s) or Density (g/cm3)
0
5
10
Depth (km)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Atmosphere
Surface
Upper Mantle
Mantle Transition Zone
Lower Mantle
Core-Mantle Boundary
Outer Core
Inner-Outer Core Boundary
Inner Core



If the earth were of uniform nature from the surface t0 the centre, seismic waves traveling through it would be recorded on the opposite and without undergoing any significance changes are interruptions in their velocity during their journey. Conversely, a major change in the velocity of seismic waves at some depth below the surface can be take to mean that there is a change in the nature of the medium at that particular depth. Such a major change in the velocity of seismic waves is called a seismic discontinuity and is of fundamental importance in the interpretation of the internal structure of the Earth.

A number of such seismic discontinuities have been repeatedly observed during many earthquakes in the past and the calculated depths at which they occur show remarkable agreement. As such, these are now accepted as established facts and believed to demarcate different zones within the body of the Earth. The tow most important seismic discontinuities are : the Mohorovicic discontinuity and The Mantle-Core discontinuity. These basic discontinuities demarcate three major internal zones in the constitution of the Earth : the crust, the mantle and the core.





The mohorovicic discontinuity :

This is the first major discontinuity iin the seismic records for the earth and is named after its discover . a mohorovicic it occurs in the seismic records at depth between 30-40 km below the continents, 5-6 km below the oceans and 60-70 km below the mountains. It is observed that both p and s waves on reaching these depths sharp increase in their velocity. Thus P waves attain a velocity of 7.75 km per second from an original velocity of 5.54 km/sec in the upper layer. Similarly S waves start travelling at 4.35 km/sec from an original velocity of 3.35 km/sec in the immediate upper layer.

Thus the Mohorovicic discontinuity marks the lower limits of the uppermost shell or sphere of the earth which is named as crust. The layer is merely 35 km thick (on an average) under the continents and 5-6 km under the oceans. Comparisons of the Earth with an old large sized apple will help clarifying the conception of crust. The crust is to the Earth what skin is to the apple: a very thin hard and wrinkled sheet or covering.

The mantle-core discontinuity:

Some of the seismic waves that cross the mohorovicic discontinuity continue to travel towards the central parts of earth with almost a uniform increase in their velocities. Such a gradual and uniform increase with increasing depth is on expected lines since their velocity is related to the density of medium which all increase with depth. At the depth of 29900km, however another major discontinuity is suddenly observed in the seismic wave records. At this depth S waves are practically stopped from going any further deeper. The P waves also become very sluggish and suffer a decrease from 13.64 km/sec above 2900km to a velocity of 8.1km/sec below this depth. The zone or shell of the earth lying between these two discontinuities is called the mantle. The second discontinuity which demarcating the end of mantle also marks the beginning of the third discontinuity. It was first discovered by B.Gutenberg in 1918 and subsequently confirmed by Jeffreys in 1939.

The behaviour of P-S waves below 2900km depth throws sufficient light on the existence of the third major shell, the core, within the Earth. In every major earthquake, P and S waves are recorded at all the stations lying between the epicenter and 105° and 142° arc dutabces (11000 – 16000 km), neither P waves nor S waves are recorded; after 142° arc distance (16000 km), only P waves reappear. There is thus a shadow zone free from P and S waves in the records of each earth quake. The shadow zone indicates existence of a zone of material completely different in nature than the upper two shells of the Earth. This zone starts at a depth of 2900km, (2928 km to be precise) and continues right upto the centre of the Earth (6371 km). This is the core of the Earth. The existence of core was established first by R.D. Oldham in 1906.

Final Picture :

The final picture of the internal constitution of the Earth as developed from the seismic evidence divides it into three well defined zones or shells or spheres : the Crust, the Mantle and the Core. In each of these major zones, there are significant variations which allow their further subdivisions into layers with distinct characters. An outline about the inferred character and major facts regarding these three zones is summarized in the following paragraphs.

The Crust

It is the uppermost shell of the Earth that extens to variable depths below the surface, to a maximum depth of 75km below the mountains. The lower boundary of the crust is marked by the MOHOROVICIC discontinuity. On the basis of seismic evidence available at present, its l,ower limits are as follows:

Mountainous Areas:- 50 - 60km. Under the Himalayas the crust is believed to be 70 – 75km thick, under the Hindukush 60km and under the Andes as 75 km.

Continental Areas :- 30 – 40km. The thickness and structure of thecrust at continental slopes (that link continents with the oceans) is intermediate. For the crust, an average thickness of 35km is usually taken.

Oceanic Areas :- 5 - 19km. The deeper the ocean, the smaller is the thickness of the crust.

On seismological evidence, the continental crust is further divisible into three layers A, B and C, beginning from the surface. The upper or A-layer of the crust is relatively dense (2.4 to 2.6 g/cc). The waves attain a velocity of 5 to 6.2km/sec. This layer is also called the Granite Layer of the crust and is made up mostly of granites, gneisses and other related igneous and metamorphic rocks. At places it acquires thickness of 20km or more. In fact, at many places in the world, it is exposed on the surface because the overlying A layer has already been removed due to prolonged erosion. Since granite layer is mostly composed of light-coloured, low density, silicates of potassium and aluminium, it is also referred as SIAL (SI = Silica, AL = Alumina).Volume of granite crust is estimated at 5.8 x 10^9 km^3 The lower most layer (C layer) of the crust has a density of 2.8 to 3.3 g/cc, in which P waves attain still higher velocity of 6 to 7.6 km/sec. This layer is commonly referred as Basaltic layer of the crust, and acquires a thickness of 25 – 40km under the continents. It is made up predominantly of basic minerals, rich in magnesium silicate and is also referred as SIMA (Si for silica and MA for magnesium). Under the oceans, the crust is made up mostly of C layer for the basaltic layer; thetop sedimentary layer is either absent or is only scantly represented, whereas granite layer is practically absent. The oceanic crust is estimated to have a volume of 2.54 x 10^9 cubic kilometers. Its average density is taken as 3.0 g/cc.

The Mantle

It is the second concnetric shell of the Earth that lies beneath the crust everywhere. This zone starting from the lower boundary of the crust (The mohoroicic discontinuity) continues upto a depth of 2900km. The exact nature of the mantle is as yet incompletely understood. It has been sub-divided into an upper mantle and a lower mantle, the boundary between the two layers being placed between 900-1000km. The structure of the upper mantle is believed to be quite complex. It is assumed to be made up of two layers:

B-layer: fairly uniform in composition, and nearly400 km thick.

C-layer: about 600km thick and where limited changes in chemicatl composition are indicated. The lower mantle is believed to have a less complex structure.

Enough seismic data has been collected to suggest that density in the mantle varies between 3.3g/cc from just below the crust to about 5.7g/cc at the base of the mantle. Recent studies indicate that a part of the upper mantle, from 100 to 150km depth, is in a plastic rather than solid state. The plastic type zone of the mantle has been specifically named as asthenoshpere. It is believed to be the source of much of the volcanic activity of the Earth.

The Core:

It is the innermost concentric shell of Earth as deciphered from the record of seismic wave. It s existence was first suggestd by R.D. Oldham in 1906 and subsequently confirmed by other seismologists. The core boundary begins at a depth of 2900km from the surface and the region extends to the centre of the Earth (at 6371 km). Further studies of the behaviour of seismic waves reveal that the core itself can be distinguished into at least to main zones : the outer core and the inner core. The outer core (2900km to 4580km) resembles a liquid like substance because S-wave are not transmitted through this zone at all. (It is the characteristic of S waves or shear waves that they do not travel through liquids). The inner core, with a thickness of around 1790 km is believed to be a solid metallic body. In between the outer core and the inner core, variation in the nature of the material is also vaguely suggested by many records but nothing can be said as yet with certainty. The total mass of the core is estimated at one third of the total mass of the Earth. The density variations show interesting feature outside and inside the core.

At the base of the mantle, density isinferred as 5.7 g/cc which jumps to 9.9g/cc at the toip of the core. This value reaches a figure of 12.7 at the boundary of the inner core and attains a value of about 13.0 at the centre of the Earth. As regards the chemical composition of the core, the hypothesis that it is made up chiefly if iron and nickel has found support on many accounts. Seismologically, this is supported by velocities of the P waves observed in the core, which are similar to those recorded for nickel-iron alloys. Other, non seismological grounds suggesting to a nickel – iron core for the Earth are :

The high density of the Earth: It is fairly established that the mean density of the Earth is 5.517 g/cc. The density of the rocks of the crust is only 2.75g/cc. On the basis of calculations and observed values of seismic waves, the density of the material making the core of the earth should be above 12 g/cc to compensate for the less dense mantle and crystal rocks. The most likely materials to account for such density are iron and nickel. Hence their present in the core is a fair assumption.

8. Write in detail about the tectonic plates and their role in generation of earthquakes. [N/D-16] [N/D-15]

THE UNIFYING THEORY

The theory of plate tectonics provides explanations for the past and present day tectonic behavious of the Earth, particularly the global distribution of mountains seismicity, and volcanism in a series of linear bells, seafloor spreading, polar wandering and continental dirft. From several lines of thought and evidences it is learnt that all of the natural phenomena of the earth might be the result of a single basic mechanism, i.e., convection in the mantle. How convection could cause such natural phenomena is discussed later in the chapter.

THE CONCEPT

The theory of plate tectonics supposes that the sphere of the earth is made up of 7 major and several minor plates which are in constant motion relative to each other. The motion of the plates refer to the rigid slabs of the continental and oceanic crust that slides over the plastic zone of asthenosphere of the upper mantle (chapter 9). A fractures egg shell forms a good analogy to the spherical plates of the earth. These plates are bounded by active linear zones causing volcanism and earthquakes.

HISTORICAL BACKGROUND

The theory of plate tectonics has been a recently developed theory. Recent advancement in the ocean floor studies and rock magnetism piled information on the nature of the seafloor. As with the growing data has grown the number of workers in the same filed. Constitutions made by several individuals collectively gave birth to the theory of plate tectonics. At present even scientists from Russian school who at first were against the theory, begin to show faith in the theory on seeing the evidences accumulating every day. However there are a few flaws in the theory which are yet to the reasonably explained by the theory. Thus it may need a modification to answer all questions about the earth.The theory of plate tectonics has a fore runner of continental dirft. Thus the entire idea that the Earth's external skin is subject to motion has come in to the minds in scientists when they observed the striking similarity of the opposite coasts of South America and Africa.

In 17th century Francis Bacon wondered about the coastline matching. But no work was done till late 19th Century. When the world map was redrawn in 19th century the spirit of questioning of matching coasts got fire. Antonio snider pelligrini (1858, French), Frank B.Taylor (1901, American) and affred Wegener (1915, German) contributed a lot to the idea of lateral motion of the continents over the face of the earth (chapter 22). During 1950s magnetic data become available in support of continental drift and seafloor spreading. Later it is understood that the continents themselves do not move but they are mere passengers over the sliding lithospheric slabs driven by the spreading seafloor. In 1968,Jason morgan replaced the title ‘new global tectonics’ by a new terminology ‘plate tectonics’. Despite a few shortcomings the theory of plate tectonics gains momentum among the world scientists day by day by the overwhelming evidences. The following sections deal in details about the plate tectonics.

ELEMENTS OF TECTONISM

Seismology Permitted an insight into the Earth. As per the seismic data the Earth is composed of a few layer of different composition, density and physical nature. The earth consists of three Principal layers, namely crust, mantel and Core. Crust is divisible into oceanic and continental crust. The earth’s movements involve the upper mantle also. in the upper mantle is a layer called low velocity zone which behaves like a fluid. Thus it Possesses a plastic flow. The layer is also known as asthenosphere. Continental Crust, Oceanic crust and a part of upper mantle constitute a plate which a rigid part of the lithosphere. Plates overlie the asthenosphere. Any movement in the underlying asthenosphere affects the plates.

CHARACTERISTICS OF PLATES

1. A Plate consists of crust and a part of upper mantal.
2. Size and Shape of the plates are not constant.
3. One large plate may be fragmented into many small plates may unit to form a large one.
4. plates are spherical of curved and are independent.
5. Thickness of plates vary.It is 70 km beneath oceans and 150 km beneath continents.
6. Plates are bounted by different boundaries distinguished by the relative motion of the adjacent plates.
7. Plates are enclosed by Features like mid-oceanic ridges , oceanic trenches great faults and fold mountain belts.
8. The length of the boundary is variable.

9. Plates move with respect to each other and to the axis of rotation.
10. Plates move with different velocity and in different directions. Even different parts of the same plate move at different velocities.
11. Plate margins are subject to deformation .but interior of the plate is free from deformation.
12. plates bearing continental crust will not be consumed at the boundaries.
13. Plates and boundaries are not permanent features.

WORLD PLATES

Geographical plates of the Earth are recognized as follows. Seven plates are larger and many others are smaller .

LARGE PLATES

1.Antarctic plate
2. Pacific plate
3.Eurasian plate
4.African plate
5.North American Plate
6.South American Plate
7.indian/Australian plate

SMALL PLATES

1. China Plate
2. Philippine Plate
3. Arabian Plate
4. Iran Plate
5. Nazca Plate
6. Cocos Plate
7. Caribbean Plate
8. Scotia Plate

PLATE BOUNDARIES

The surficial trace of the zone of motion is known as plate boundary. The end of the plate is called plate margin. Figure 20.2 shows the boundary and the margin There are three types of plate boundaries. These are recognized on the basis of the movement associated with the plate junctions. They are: 1. Divergent or Constructive boundaries or sources 2. Convergent or Destructive boundaries or Sinks and 3.

Transform fault boundaries or conservative boundaries. With the help of seismic observations and / or magnetic lineation's plate boundaries are mapped. And they are also used to find the direction and the velocity of plate motion.

DIVERGENT BOUNDARY

Long the middle of the ocean floor their rises a ridge with a central 'V' shapped valley. The boundary line that separates the two plates runs along the valley bottom. Materials of the two flanks of these mid oceanic ridges move away from each other. This boundary is known as divergent boundary as the plates diverge with reference to the boundary line. But they are never separated. Because new material is poured out continuously and is accreted to the moving plate margins (Fig.20.3) . Upcoming material is symmetrically divided into two halves and mobilised. The symmetry may be produced in this way: A new ribbon of material is added to the margins of separating plates. The rigidity of the material is lower and lower as the centre of the ribbon is approached. Splitting may occur along the line of weak zone. Thus when the ribbon is subjected to tensional forces (because of the mobile plates) it is broken symmetrically as the plane of weakness occupies the central part of the ribbon.

CONVERGENT BOUNDARY

This boundary is developed as two plates converge towards each other and thus it is known as Convergent boundary. Since land area is lost along this type of boundary, it is known as destructive boundary. For the reason that the material is being sunken at these boundaries they are also known as sinks. Convergent Boundaries are marked by deep sea trenches and fold mountain belts. They may be Located along the northern and western border of the Pacific forming Aleutian trench, Japan trench and Tonga trench and Tonga trench, Western continent slope of the South America forming Eru-Chile trench, Himalayas f India, Mediter- tanean trench and java trench. The convergence of plates occur in two ways: 1. subduction And 2. Continental collision depending upon the nature of plates that collide. Three cases of plate collision my be expected accordingly the type of convergence differs as follows.

Crustal types of plates	Type of Convergence
1. Oceanic and oceanic	Subduction
2.Oceanic and Continental	Subduction
3.Continental and Continental	Continental Collision

1. When both the colliding plates hold oceanic crust any one of the plates slides down the other plates slide at approximately 45 degrees. The process of sliding of one of the plates beneath the other along the convergent boundary is known as subduction. 2. When the colliding plates are oceanic and continental, then it is always the oceanic plate that is subducted beneath the continental. It happens so because of the greater density of the oceanic crust of the descending plate. The plate being made up of continental crust is lighter and always tend to float over the oceanic crust holding plate 3. When both the colliding plates are composed of continental crust neither/ of the plates slips down because of low density. But on collision continental crust is evolved into fold mountain systems. A classic example of such a continental collision belt is the Himalayan belt, produced during the Cenozoic Era by the convergence of the Indian plate with Eurasian plate.

SUBDUCTION ZONE : Subduction Zone are the zones where subduction of plates occur. Obviously a sink or a destructive boundary or a convergent boundary may be a subduction zone. Plunging stab or the subducted plate is of oceanic crust. Buoyancy plays as important role in subduction zones. Back are basins are the basins developed due to the subduction. Subduction zones are characterized by active volcanism earthquake and the development of deep ocean trenches. The down-going stab is assimilated in the mantle. However, partial melting of the oceanic crust of the subducted plate generates mafic igneous intrusion. The sepentinized pillow basalts and mafic intrusions with associated deep-sea sediments occurring along with subduction zones is termed ophiolite suite. The zone where all kinds of earthquakes (shal-low, intermediate, and deep) originate is termed the Benioff zone or Benioff plane (named after hugo Benioff, and American Seismologist). Earthquakes are generated as the plate plunges creating frictional force. The Benioff zone is a thin inclined plane zone located on the top margin of the descending slab. Benioff plane dips away from oceanic trenches and toward the adjacent island arcs and continents and marks the surficial trace of the slippage of overriding and descending plates the subducted plate may be partially melted and andesitic magma may be generated. Igneous activity, crustal deformation, mountain building and metamorphism are associated with convergent boundaries. Partial fusion of oceanic crust that plunges in to the mantle generates granitic magma and continental in the roots of mountains. Since sediments of low density accretes to the overriding plate, the plate grows and thus it become constructive. Although the growth rate is 1 mm/year geologically it is significant. In the two plates of a destructive boundary plate is constructed and the other destroyed.

CONTINENTAL COLLISION : According to mattauer, intra-continental subduction can occur in three ways : 1.Crusts may be stacked one over the other; 2. Crust-mantle decollement may occur and 3. Continental lithospheric subduction may also occur. Collision of then Asian plate and Indian plate provides a best example for intra-continental subduction. The results of the recent investigations on Himalayas reveal the occurrence of subduction of continental plates in contrast to the general belief that the continental crust cannot sink owing to it low density. During initial periods of collision thickening of crust occurred along the boundary continued collision developed two strike slip faults between which a triangular northeast of India might have occupied a northern frontal location of Indian plate before collision. As collision still persists the broken plate margins of both the plates plunge into the mantle. It is estimated that about 1500km of Indian continental lithosphere has disappeared into the mantle. The rates of subduction also vary with time. During upper carboniferous period Indian plate moved at the rate of 10 cm per year. It was 5 cm per year in Eocene. But it moves 1 to 2 cm per year at present.

9. SEISMIC BELTS & SEISMIC ZONING MAP OF INDIA [N/D-14]

On a seismic map, the country has been divided into 7 zones in terms of severity (magnitude). First seismic map (zoning map) was prepared in 1962 on the basis of historical data available regarding the occurrence of earthquakes all over the country. Subsequently the zoning map was revised in 1966.

Many of the areas in zone V and VI were merged into one because of their high risk. In the zone map brought out in the year 2000, the earlier zones II and I were merged. So the number of zones got reduced from 7 to 5. Zone – I is least severe and the Zone VI is most severe.

Entire NE regions, parts of Uttaranchal, Rann of Kutch (Gujarat) & Srinagar are included in zone V where the earthquake severity is high. All regions in Southern India are included in Zone III. Rest of the parts of India are included in Zone I & II. Zone 4 is also treated as severity.

Precautionary measures for the construction of buildings, dams/reservoirs etc in seismic areas:
To make suitable constructions in seismic areas, IS codes 1893 – 2970 give guidelines.

For Construction of Buildings: In addition to the safety factors considered there are other precautionary measures which help in increasing the stability of buildings in seismic areas. They are as follows:

- Buildings should be founded on hard bedrock and never on loose soils or fractured rocks. This is so because loose ground can easily expose to earthquake vibrations.

- Foundation should be of same depth throughout for continuity.
- Buildings situated near hill sides, near steep slopes, on undulating ground or on marshy ground always suffer more when earthquake occurs. Therefore these situations may be avoided.
- Buildings should have light walls.
- Different parts of a building should be well tied together so that the whole structure behaves like a single unit to the vibrations.
- Proper proportionate of cement and mortar should be used.
- Doors and windows should be kept to a minimum and they should not be in vertical rows but preferably along the diagonals.
- The building should have uniform height and additional features such as parapets, cantilevers, domes and arches are undesirable.
- Buildings should have flat RCC roofs and they should be designed not to yield to lateral stress.
- Projections above the roofs are undesirable.

For Construction of Dams: Dams being very costly projects their consideration in seismic areas needs careful study to ensure their safety precautionary measures which are as follows:

- Forces in the dam due to reservoir water and due to the dams weight are to counter balanced by introducing additional stress in the design of the dam.
- Design of the dam is to be made such that during an earthquake they move along with the foundations below.
- Dams should not ordinarily be built along or across the faults because possible slipping along these planes during earthquakes will introduce additional complications.
- The resonance factor value (vibrations due to sound) should be given due consideration because a coincidence in the period of vibration of the dam and the earthquake vibrations can produce cumulative effects.

- FEATURES OF MARINE EROSION
- Continued marine erosion results in considerable or even total modification of the original shoreline. Due to modification of shore by marine erosion various land forms are caused such as follow:

- Headland: The strong rocks however resist total erosion for considerable time. They may get smoothen and variously modified but still standing as projected parts of the original shore line as head land.
- Bay: It is a wide inlet of sea that extends inland by the erosion action of seawater
- Sea cliffs: A sea cliff is defined as the high and very steep or over hanging face of rock or earth rising above the shore of the sea (Campbell 1972). Cliffs are usually produced by wave erosion. Invariably the line of contact of the headland region, causing undercutting followed by collapse of the overhanging rock mass. Sea caves are the irregular marine erosional features of recent age. Generally they are made up of calcareous sandstone and located at the high water level. Due to intensive action of waves on cliffs, at some places, sea caves are formed.
- Sea cliffs & Caves and Wave cut platforms
- Wave cut terrace: Along the rocky beaches, frequent wave cut platforms are observed. These features indicate marine erosional formative processes and represent flat to moderately undulating platform, predominantly made up of beach rocks and sometimes-calcareous rocks.

10. What are the features of marine deposition? [N/D 14], [N/D 12]

- Marine water is one of the powerful external agent it does erosion, transportation and deposition. The important depositional features are as follow:
- Beach: Beach is a temporary or short-lived deposit encountered along the coast. It consists partially of unconsolidated materials such as sand and silt, it may also be strewn with cobbles of shingles or mud. Sands along the beaches are expected to be the effect of waves and transported materials through river from the continent. Beaches can be classified on the basis of a wide variety of materials from which they have been derived. Beaches are characterized by the distribution of different colors of sands. The geometry of the beach is dependent on coastal history and there is a close relationship between beach characteristic and type of the coast. Long and straight beaches are typical of low sandy beaches; small pocket and shorter crescent shaped beaches are common along the rocky coastline.
- Spit: A spit is a small point of low tongue or narrow bankment, commonly consisting of sand or gravel deposited by a long-shore drifting and having one end attached to the

mainland and other terminating in the open sea. According to Campbell(1972) spit is a finger like extension of beach.

- Bar: Bars are submerged ridges of detrital sediments, which are larger, and less regular spaced than ripple marks. They are formed typically in shallow epicontinental or shelf waters by wave and current.
- Tombola: It is a form of bar. It connects a headland and islands or island with another island. Tombola is produced in the same way as spit or bar, by the deposition of materials carried away by the current to deep water from along the shore.
- CORAL REEF
- The celenterates belongs to the class Anthozoa, commonly occur in the form of colonies. Each colony consists of a number of individual small animals known as corals. This coral secrete calcium carbonate skeleton outside their body that looks like a cup within the coral lives. This cup shaped structure is called reef.
- Occurrence of Coral Reefs: The coral reefs live in shallow, warm transparent and well-illuminated oligotrophic waters like those found in the tropical regions of Indo-Pacific and Atlantic oceans.
- Classification of Coral Reefs: Darwin(1842) classified three main types of coral reefs: Fringing reef, Barrier reef and Atolls.
- Fringing reefs: It grows along the shoreline and is usually separated from the beach by a shallow lagoon.
- Barrier reefs: It develops parallel to the shore but at great distances and are separated by a deep lagoon.
- Atolls: These are open-ocean circular reefs surrounding a lagoon.
- Stoddart (1969) discussed these types of reefs in detail and suggested further subdivisions of each of them, based mainly on physical features, rock texture and composition. In 1973, he added two more reefs, found in the open ocean at or below sea surface, and called them patch reefs that sprout on sandy lagoon floors.
- Distribution of Coral Reefs: The basic explanation of the reef distribution is sea temperature. The most suitable place for the growth of the coral reefs is the area where the average monthly temperature exceeds 180 Celsius throughout the year. Although some species can tolerate temperatures down to 150 Celsius and even less, and up to 360 C (350 N and S). Such temperature conditions are found primarily between the

tropics (300 N to S latitudes). The reason for limited coral growth in low latitudes along the east coasts of oceans is the presence of cool waters that have temperatures lower than 180 C.

- Coral reefs are found in two climatic zones of the Earth:
- 1. The inter-tropical zone, from approximately 150 S to 100 – 200 deg N latitude.
- 2. The tropical zone approximately between 300 N and 300 S latitude.
- In general there are two geographical regions of distribution of coral reefs namely the (a) Indo-pacific regions and (b) Western Atlantic region.
- a) The Indo-Pacific region comprises the Red sea, Persian gulf, Kenya, Tanzania, Madagascar, Muyotte and Massacre, Islands of west Indian ocean , countries along the coastlines of Saudi Arabia, Maldives, Changos Archipelago, India, Sumatra and Java of central and Eastern Indian ocean. Malay Archipelago, Borneo, Philippines, Molasses, Gulf of Thailand, Gulf of Papua, New Guinea of South East Asia, Great Barrier Reef in Australia, Solomon Islands, New Hebrides, Fiji and New Caledonia in West Pacific Ocean, Marshall Islands in Central Pacific, Hawaiian Islands in Eastern Pacific area.
- b) The Western Atlantic region consists of Brahma Archipelago, Antilles, Jamaica and
- Caymans in Central Caribbean, Gulf of Honduras, Florida, Gulf of Mexico and Bermuda.
- Uses of Coral Reefs: Coral reefs are very sensitive and protective ecosystem in the coast. It is economically, ecologically and environment important. Coral reef act as aprotective barrier against wave actions and preventing the coastal

UNIT II

1. What are the varieties of plagioclase fedpar? [N/D-14]

It refers to a group of different minerals which possess similar chemical composition, atomic structure; physical and optical properties. These are aluminous silicates of K. Na; Ca or Ba and may be considered as isomorphous compounds.

Feldspars are sub-divided into: PLAGIOCLASE FELDSPARS and

ALKALI FELDSPARS

The Plagioclase feldspars may be defined as

Feldspar group	Range	composition	Occurrence
Albite	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$	Ab 100 - An 0	Granites; Syenites; Diorites; Rhyolites; Trachytes; Gabbros; Sandstones; Schists & Gneisses;
Oligoclase		Ab 90 – An 10	
Andesite		Ab 70 - An 30	
Labradorite		Ab 50 - An 50	
Bytownite		Ab 30 – An 70	
Anorthite		Ab 10 - An 90	

Uses: Feldspars are used in the manufacture of Porcelain; Pottery; glazes on earthware; Sanitary ware; in the manufacture of glass and ceramic industries.

2. Bring out the differences between muscovite and biotite. [N/D-14]

Name of the Mineral: 8. Muscovite

S No	Properties	Observations
1	Form	LAMELLAR (layers are separable and occurs in book form); some occur as flaky minerals.
2	Color	Brownish black, silver white, brownish yellow
3	Streak	white
4	Lustre	Vitreous, pearly
5	Fracture	EVEN / HACKLY
6	Cleavage	1 set
7	Hardness	2 - 2.5
8	Density (Sp gravity)	2.76 - 3.0

9	Varieties	PARAGONITE- SODIUM MICA LEPIDOLITE- LITHIUM MICA SERICITE is a fine grained muscovite type found in gneisses and schists. Gilbertite …… Illite, a variety of mica is found in sedimentary rocks
10	Occurrence	found in igneous rocks such as Granites, Pegmatites and Phlogophites..
11	Uses	Electrical industry,, wall finishes, thin transparent sheets are used as an insulator and used in circuit boards.
12	Chemical composition	$KAl_2(Si_3Al)O_{10}(OH,F)_2$

Name of the Mineral: 9. Biotite

S No	Properties	Observations
1	Form	LAMELLAR (layers are separable and occurs in book form); some occur as flaky minerals.
2	Color	dark brown, black, dark greenish black
3	Streak	white to gray
4	Lustre	Vitreous, pearly
5	Fracture	EVEN / HACKLY
6	Cleavage	1 set
7	Hardness	2.5 - 3
8	Density (Sp gravity)	2.7 - 3.1
9	Varieties	LEPIDOMELANE PHLOGOPITE: Mg .MICA ZINNWALDITE: LITHIUM MICA (pale white)
10	Occurrence	found in igneous ROCKS such as Granites, Diorites, Gabbros, and in metamorphic rocks viz., Biotite gneisses, Schists, Hornfels.
11	Uses	1. USED AS INSULATING MATERIAL 2. USED AS ELECTRIC COMMUTATORS
12	Chemical composition	$K(Mg,Fe)_3(Si_3Al)O_{10}(OH,F)_2$

3. Name the varieties of mica. [N/D-15]

The mica group of sheet silicate (phyllosilicate) minerals includes several closely related materials having nearly perfect basal cleavage. All are monoclinic, with a tendency towards pseudohexagonal crystals, and are similar in chemical composition. The nearly perfect cleavage, which is the most prominent characteristic of mica, is explained by the hexagonal sheet-like arrangement of its atoms.

The word mica is derived from the Latin word mica, meaning a crumb, and probably influenced by micare, to glitter.

- Biotite
- Lepidolite
- Phlogopite
- Zinnwaldite

4.List the uses of Calcite? [N/D-15]

S No	Properties	Observations
1	Form	Rhombic / tabular
2	Color	White
3	Streak	White
4	Lustre	Vitreous
5	Fracture	Even
6	Cleavage	3 sets
7	Hardness	3
8	Density (Sp gravity)	2.71
9	Varieties	Iceland spar
10	Occurrence	In limestones and marbles
11	Uses	In cement industry, manufacture of bleaching powder,, as a calcium carbide ,
12	Chemical composition	$CaCO_3$

5. What is meant by Moh's scale of hardness? [M/J-16]

Mohs scale. (mōz) A scale used to measure the relative hardness of a mineral by its resistance to scratching. From softest to hardest, the ten minerals of the Mohs scale are talc (measuring 1 on the scale), gypsum, calcite, fluorite, apatite, orthoclase, quartz, topaz, corundum, and diamond (measuring 10 on the scale).

6. Differentiate between Cleavage and fracture. [M/J-16]

Comparison between Cleavage and Fracture:

	Cleavage	**Fracture**
Definition	In cleavage, a mineral may split apart along various smooth planes. These smooth planes are parallel to zones of weak bonding.	Fracture breaks a mineral along the curved surface with irregular shapes.
Types	There are five types of cleavage: Basal or pinacoidal – It occurs parallel to the base of a crystal • Cubic Cleavage – It occurs parallel to the faces of a cube for a crystal with cubic symmetry. • Octahedral Cleavage – It occurs on the 111 crystal planes and octahedral shapes are formed. • Dodecahedral Cleavage - It occurs on the 110 crystal pleanes and dodecahedra shapes are formed. • Rhombohedral cleavage – It occurs parallel to the 1011 faces of a rhombohedron.	There are five types of fracture: • Conchoidal - A fracture resembling a semicircular shell, with a smooth, curved surface. • Uneven - A fracture that leaves a rough or irregular surface. • Hackly - A hackly fracture that resembles broken metals, with rough, jagged, points. True metals exhibit this fracture. • Splintery - This type of fracture will form elongated splinters. All fibrous minerals fall into this category. • Earthy or crumbly- This describes minerals that crumble when broken.

	• Prismatic cleavage - It is a cleavage that is parallel to a vertical prism 110.	
Examples	Halite, mica, and calcite	Quartz and obsidian
Reason	Inherent weaknesses within a mineral's atomic structures.	No planes of weakness in a mineral's atomic structure.

7. Differentiate between colour and streak of minerals. [N/D-16]

The color is the color that the mineral is naturally (make sure that it is clean so you know for sure the color) The streak of the mineral is what color that it leaves behind (you have to rub it on a hard surface), like a white rock may make a pink streak.

8. Differentiate between muscovite and biotite. [N/D-16]

Name of the Mineral: 8. Muscovite

S No	Properties	Observations
1	Form	LAMELLAR (layers are separable and occurs in book form); some occur as flaky minerals.
2	Color	Brownish black, silver white, brownish yellow
3	Streak	white
4	Lustre	Vitreous, pearly
5	Fracture	EVEN / HACKLY
6	Cleavage	1 set
7	Hardness	2 - 2.5
8	Density (Sp gravity)	2.76 - 3.0
9	Varieties	PARAGONITE- SODIUM MICA LEPIDOLITE- LITHIUM MICA SERICITE is a fine grained muscovite type found in gneisses and schists. Gilbertite ……

		Illite, a variety of mica is found in sedimentary rocks
10	Occurrence	found in igneous rocks such as Granites, Pegmatites and Phlogophites..
11	Uses	Electrical industry,, wall finishes, thin transparent sheets are used as an insulator and used in circuit boards.
12	Chemical composition	$KAl_2(Si_3Al)O_{10}(OH,F)_2$

Name of the Mineral: 9. Biotite

S No	Properties	Observations
1	Form	LAMELLAR (layers are separable and occurs in book form); some occur as flaky minerals.
2	Color	dark brown, black, dark greenish black
3	Streak	white to gray
4	Lustre	Vitreous, pearly
5	Fracture	EVEN / HACKLY
6	Cleavage	1 set
7	Hardness	2.5 - 3
8	Density (Sp gravity)	2.7 - 3.1
9	Varieties	LEPIDOMELANE PHLOGOPITE: Mg .MICA ZINNWALDITE: LITHIUM MICA (pale white)
10	Occurrence	found in igneous ROCKS such as Granites, Diorites, Gabbros, and in metamorphic rocks viz., Biotite gneisses, Schists, Hornfels.
11	Uses	1.USED AS INSULATING MATERIAL 2.USED AS ELECTRIC COMMUTATORS
12	Chemical composition	$K(Mg,Fe)_3(Si_3Al)O_{10}(OH,F)_2$

10) Define hexagonal system. (AUC APRIL/MAY 2011)
All those crystals, which can be referred to four crystallographic axes of which three axes are horizontal, equal interchangeable and intersecting each other at 1200 between the positive ends. The fourth axes are vertical and at right angles to the three horizontal axes, are grouped under hexagonal system.

11) Give the physical properties and uses of mica? (AUC APRIL/MAY 2011)
The mica group only muscovite and biotitic are of common occurrence as rock forming minerals.

S.no properties muscovite biotite

1. Colour Transparent, gey Brown to black
2. Streak Uncoloured Same as colour
3 Cleavage perfect perfect
3. Lustre Vitreous Vitreous
4. Hardness 2-2-5 2-2-5
5. Specific gravity 2.8-3.1 2.6-3.1
6. System Monoclinic Monoclinic

12 What is mean by polyhedral form? (AUC NOV/DEC2011)
The maximum symmetry elements of the system. The form is having all the faces, which have same position with regard to the crystallographic axis. The highest symmetry elements of the system. The forms present in normal class of the system are polyhedral form since it has the maximum symmetry elements than the other classes.

13) Define hexagonal system. (AUC APRIL/MAY 2011)

All those crystals, which can be referred to four crystallographic axes of which three axes are horizontal, equal interchangeable and intersecting each other at 1200 between the positive ends. The fourth axes are vertical and at right angles to the three horizontal axes, are grouped under hexagonal system.

14) Give the physical properties and uses of mica? (AUC APRIL/MAY 2011)

The mica group only muscovite and biotitic are of common occurrence as rock forming minerals.

S.no properties muscovite biotite

1 Colour Transparent, gey Brown to black

2 Streak Uncoloured Same as colour

3 Cleavage perfect perfect

4 Lustre Vitreous Vitreous

5 Hardness 2-2-5 2-2-5

6 Specific gravity 2.8-3.1 2.6-3.1

7 System Monoclinic Monoclinic

1. Discuss about the chemical composition, physical properties, origin, varieties and uses of quartz.[N/D-14]

QUARTZ: Next to feldspars and mafic minerals, quartz is the most common rock forming mineral. It is SiO_2 in composition and may be treated as an oxide or as a silicate. Structurally, it is a tectosilicate ie; in its atomic structure, the SiO_4 tetrahedra are arranged in a three dimensional network pattern.

Quartz, Tridymite and Crystabalite are important crystalline forms of silica with SiO2 composition but possess different physical properties and hence these are called POLYMORPHS.

Quartz is the most abundant and widely distributed mineral found at Earth's surface. It is present and plentiful in all parts of the world. It forms at all temperatures. It is abundant in igneous, metamorphic, and sedimentary rocks. It is highly resistant to both mechanical and chemical weathering. This durability makes it the dominant mineral of mountaintops and the primary constituent of beach, river, and desert sand. Quartz is ubiquitous, plentiful and durable. Minable deposits are found throughout the world.

Physical Properties of Quartz	
Chemical Classification	Silicate
Color	Quartz occurs in virtually every color. Common colors are clear, white, gray, purple, yellow, brown, black, pink, green, red.
Streak	Colorless (harder than the streak plate)
Luster	Vitreous
Diaphaneity	Transparent to translucent
Cleavage	None - typically breaks with a conchoidal fracture
Mohs Hardness	7
Specific Gravity	2.6 to 2.7
Diagnostic Properties	Conchoidal fracture, glassy luster, hardness
Chemical Composition	SiO_2
Crystal System	Hexagonal
Uses	Glass making, abrasive, foundry sand, hydraulic fracturing proppant, gemstones

Varieties of Quartz:

Rock crystal: Transparent form of quartz and purest.
Amethyst: Purple / violet colored; transparent form of quartz
Rose quartz: Pale pink / rose colored variety of quartz
Smoky quartz: smoky yellow / brown color of quartz
Milky quartz¨ milky white in color due to a large no. of mica cavities
Ferruginous quartz: contains iron oxides which impart reddish color

Uses: employed in jewellery (eg: amethyst); Making spectacle glasses; Sand papers; toothpaste; Pottery; silica bricks.
Depend on its piezo – electric properties, a certain type of quartz is used to control the frequency of radio-circuits. One of the most amazing properties of quartz is the ability of its crystals to vibrate at a precise frequencies. These frequencies are so precise that quartz crystals can be used to make extremely accurate time-keeping instruments and equipment that can transmit radio and television signals with precise and stable frequencies.

The tiny devices used for these purposes are known as "crystal oscillators." The first crystal oscillators were developed in the 1920s, and just twenty years later, tens of millions of them were needed each year to supply the military during World War II. Today, billions of quartz crystals are used to make oscillators for watches, clocks, radios, televisions, electronic games, computers, cell phones, electronic meters, and GPS equipment.

A wide variety of uses have also been developed for optical-grade quartz crystals. They are used to make specialized lenses, windows and filters used in lasers, microscopes, telescopes, electronic sensors, and scientific instruments. The material of beach sand is now the material of the world's most advanced electronic devices.

2. Give a detailed account of the chemical composition, physical properties, origin, varieties and uses of clay minerals. [N/D-14]

Occurrence

Soils

All types of clay minerals have been reported in soils. Allophane, imogolite, hydrated halloysite, and halloysite are dominant components in ando soils, which are the soils developed on volcanic ash. Smectite is usually the sole dominant component in vertisols, which are clayey soils. Smectite and illite, with occasional small amounts of kaolinite, occur in mollisols, which are prairie chernozem soils. Illite, vermiculite, smectite, chlorite, and interstratified clay minerals are found in podzolic soils. Sepiolite and palygorskite have been reported in some aridisols (desert soils), and kaolinite is the dominant component in oxisols (lateritic soils). Clay minerals other than those mentioned above usually occur in various soils as minor components inherited from the parent materials of those soils.
Soils composed of illite and chlorite are better suited for agricultural use than kaolinitic soils because of their relatively high ion-exchange properties and hence their capacity to hold plant nutrients. Moderate amounts of smectite, allophane, and imogolite in soils are advantageous for the same reason, but when present in large amounts these clay minerals are detrimental because they are imperviousand have too great a water-holding capacity.

Recent sediments

Sediment accumulating under nonmarine conditions may have any clay mineral composition. In the Mississippi River system, for example, smectite, illite, and kaolinite are the major components in the upper Mississippi and Arkansas rivers, whereas chlorite, kaolinite, and illite are the major components in the Ohio and Tennessee rivers. Hence, in the sediments at the Gulf of Mexico, as a weighted average, smectite, illite, and kaolinite are found to be the major components in the clay mineral composition. Although kaolinite, illite, chlorite, and smectite are the principal clay mineral components of deep-sea sediments, their compositions vary from place to place. In general, illite is the dominant clay mineral in the North Atlantic Ocean (greater than 50 percent), while smectite is the major component in the South Pacific and Indian oceans. In some limited regions, these compositions are significantly altered by other factors such as airborne effects, in which sediments are transported by winds and deposited when the carrying force subsides. The high kaolinite concentration off the west coast of Africa near the Equator reflects this effect.

Under highly saline conditions in desert areas, as in soils, palygorskite and sepiolite also form in lakes and estuaries (perimarine environments).

Ancient sediments

Analyses of numerous ancient sediments in many parts of the world indicate that smectite is much less abundant in sediments formed prior to the Mesozoic Era (from 251 million to 65.5 million years ago) with the exception of those of the Permian Period (from 299 million to 251 million years ago) and the Carboniferous Period (359.2 million to 299 million years ago), in which it is relatively abundant.

The available data also suggest that kaolinite is less abundant in very ancient sediments than in those deposited after the Devonian Period (416 million to 359.2 million years ago). Stated another way, the very old argillaceous (clay-rich) sediments called physilites are composed largely of illite and chlorite. Palygorskite and sepiolite have not been reported in sediments older than early Cenozoic age—i.e., those more than about 65.5 million years old.

Kaolinite and illite have been reported in various coals. Bentonite generally is defined as a clay composed largely of smectite that occurs in sediments of pyroclastic materials as the result of devitrification of volcanic ash in situ.

Ion exchange

Depending on deficiency in the positive or negative charge balance (locally or overall) of mineral structures, clay minerals are able to adsorb certain cations and anions and retain them around the outside of the structural unit in an exchangeable state, generally without affecting the basic silicate structure. These adsorbed ions are easily exchanged by other ions. The exchange reaction differs from simple sorption because it has a quantitative relationship between reacting ions. The range of the cation-exchange capacities of the clay minerals is given in the Table.

Cation-exchange capacities and specific surface areas of clay minerals

*Upper limit of estimated values.

Exchange capacities vary with particle size, perfection of crystallinity, and nature of the adsorbed ion; hence, a range of values exists for a given mineral rather than a single specific capacity. With certain clay minerals—such as imogolite, allophane, and to some extent kaolinite—that have hydroxyls at the surfaces of their structures, exchange capacities also vary with the pH (index of acidity or alkalinity) of the medium, which greatly affects dissociation of the hydroxyls.

Under a given set of conditions, the various cations are not equally replaceable and do not have the same replacing power. Calcium, for example, will replace sodium more easily than sodium will replace calcium. Sizes of potassium and ammonium ions are similar, and the ions are fitted in the hexagonal cavities of the silicate layer. Vermiculite and vermiculitic minerals preferably and irreversibly adsorb these cations and fix them between the layers. Heavy metal ions such as copper, zinc, and lead are strongly attracted to the negatively charged sites on the surfaces of the 1:1 layer minerals, allophane and imogolite, which are caused by the dissociation of surface hydroxyls of these minerals.

The ion-exchange properties of the clay minerals are extremely important because they determine the physical characteristics and economic use of the minerals.

Clay-water relations

Clay materials contain water in several forms. The water may be held in pores and may be removed by drying under ambient conditions. Water also may be adsorbed on the surface of clay mineral structures and in smectites, vermiculites, hydrated halloysite, sepiolite, and palygorskite; this water may occur in interlayer positions or within structural channels. Finally, the clay mineral structures contain hydroxyls that are lost as water at elevated temperatures.

The water adsorbed between layers or in structural channels may further be divided into zeolitic and bound waters. The latter is bound to exchangeable cations or directly to the clay mineral surfaces. Both forms of water may be removed by heating to temperatures on the order of 100°–200° C and in most cases, except for hydrated halloysite, are regained readily at ordinary temperatures. It is generally agreed that the bound water has a structure other than that of liquid water; its structure is most likely that of ice. As the thickness of the adsorbed water increases outward from the surface and extends beyond the bound water, the nature of the water changes either abruptly or gradually to that of liquid water. Ions and molecules adsorbed on the clay mineral surface exert a major influence on the thickness of the adsorbed water layers and on the nature of this water. The nonliquid water may extend out from the clay mineral surfaces as much as 60–100 Å.

Hydroxyl ions are driven off by heating clay minerals to temperatures of 400°–700° C. The rate of loss of the hydroxyls and the energy required for their removal are specific properties characteristic of the various clay minerals. This dehydroxylation process results in the oxidation of Fe^{2+} to Fe^{3+} in ferrous-iron-bearing clay minerals.

The water-retention capacity of clay minerals is generally proportional to their surface area (see the Table). As the water content increases, clays become plastic and then change to a near-liquid state. The amounts of water required for the two states are defined by the plastic and liquid limits, which vary with the kind of exchangeable cations and the salt concentration in the adsorbed water. The plasticity index (PI), the difference between the two limits, gives a measure for the rheological (flowage) properties of clays. A good example is a comparison of the PI of montmorillonite with that of allophane or palygorskite. The former is considerably greater than either of the latter, indicating that montmorillonite has a prominent plastic nature. Such rheological properties of clay minerals have great impact on building foundations, highway construction, chemical engineering, and soil structure in agricultural practices.

3. List the physical properties of minerals and describe each property with examples from the mineral kingdom. [N/D-15]

Study of physical properties of rock forming minerals: It is necessary to know about the common minerals which actually make up different rocks and determine their properties.

Name of the Mineral: 1. Feldspars

S No	Properties	Observations
1	Form	Tabular
2	Color	Pale pink, whitish blue, grayish
3	Streak	
4	Lustre	Vitreous
5	Fracture	Uneven
6	Cleavage	2 sets
7	Hardness	6 – 6.5
8	Density (Sp gravity)	2.6 – 2.73
9	Varieties	Plagioclase feldspars include: ALBITE; OLIGOCLASE ANDESINE LABRADORITE BYTOWNITE ANORTHITE. Potash feldspars include: Hyalophane (KAlSi3O8) Orthoclase (KAlSi3O8) Microcline (KAlSi3O8) Anorthoclase (Na KAl Si3 O8)
10	Occurrence	In granites, Syenites, diorite, rhyolite, Trachyte, sandstones, schists, gabbros, gneisses.
11	Uses	In the manufacture of porcelain & pottery, earthernware, sanitary ware, bricks manufacture, glasses, electronic products etc.
12	Chemical composition	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$

Name of the Mineral: 2. Quartz

S No	Properties	Observations
1	Form	Massive, crystals
2	Color	Quartz occurs in different colors. Common colors are white, grey, purple, brown, pink etc
3	Streak	Colorless (harder than streak plate)
4	Lustre	Vitreous
5	Fracture	Conchoidal
6	Cleavage	Absent
7	Hardness	7
8	Density (Sp gravity)	2.6 – 2.7
9	Varieties	Flint, Jasper, Amethyst (purple or violet color), Opal, rose quartz (pale pink color). Milky quartz (milky white in color) .
10	Occurrence	Occurs in almost igneous(granites, rhyolites), sedimentary (sandstones) and metamorphic rocks (quartzites).
11	Uses	Glass making, optical materials, polishing / grinding compounds, components in electronic products,
12	Chemical composition	SiO_2

Name of the Mineral: 3. Flint

S No	Properties	Observations
1	Form	Irregular nodules, massive
2	Color	Grey, brownish, black
3	Streak	Colorless (harder than streak plate)
4	Lustre	Resinous
5	Fracture	Conchoidal

6	Cleavage	Absent
7	Hardness	7
8	Density (Sp gravity)	2.65
9	Varieties	Hornstone, Chert
10	Occurrence	In sedimentary rocks such as Limestones
11	Uses	Used in tube mills, pottery industry, as road and building material.
12	Chemical composition	SiO_2

Name of the Mineral: 4. Jasper

S No	Properties	Observations
1	Form	Massive
2	Color	Red, Grey, brown
3	Streak	Colorless (harder than streak plate)
4	Lustre	Dull, vitreous, greasy
5	Fracture	Conchoidal
6	Cleavage	Absent
7	Hardness	6.5 - 7
8	Density (Sp gravity)	2.57 – 2.65
9	Varieties	
10	Occurrence	In Igneous, sedimentary & metamorphic rocks
11	Uses	Ornaments, gemstones
12	Chemical composition	SiO_2

Name of the Mineral: 5. Olivine

S No	Properties	Observations
1	Form	MASSIVE or no definite shape
2	Color	OLIVE GREEN. Mg rich types are PALE whereas iron rich types are DARK COLOURED
3	Streak	WHITE
4	Lustre	VITREOUS but OFTEN DULL
5	Fracture	EVEN TO UNEVEN
6	Cleavage	ABSENT
7	Hardness	6 – 7
8	Density (Sp gravity)	3.2 – 4.3
9	Varieties	FORSTERITE IS MAGNESIUM OLIVINE FAYALITE IS FERROUS IRON TYPE PERIDOT is a gem variety of olivine.

10	Occurrence	IGNEOUS ROCKS such as Peridotites, Dunites, Gabbro, Basalt, Dolerites.
11	Uses	PERIDOT IS a GEM VARIETY manufacture of REFRACTORY BRICKS
12	Chemical composition	$(Mg,Fe)_2 SiO_4$

Name of the Mineral: 6. Augite

S No	Properties	Observations
1	Form	granular, prismatic crystals
2	Color	Greenish black TO Brownish black
3	Streak	WHITE TO GREY
4	Lustre	VITREOUS TO SUB VITREOUS
5	Fracture	UNEVEN
6	Cleavage	2-SETS
7	Hardness	5 – 6
8	Density (Sp gravity)	3.2 – 3.5
9	Varieties	Diallage
10	Occurrence	Basalts, Andesites, Tuffs, Gabbros, Pyroxenites, Andesites
11	Uses	
12	Chemical composition	$(Ca, Na) (Mg,Fe^{+2}, Fe+3, Al) [(Si Al)_2 O_6]$

Name of the Mineral: 7. Hornblende

S No	Properties	Observations
1	Form	GRANULAR OR PRISMATIC or AGGREGATE
2	Color	DARK GREENISH BLACK
3	Streak	GREY TO GREENISH GREY
4	Lustre	VITREOUS TO SUB VITREOUS
5	Fracture	UNEVEN
6	Cleavage	2 sets
7	Hardness	5 – 6
8	Density (Sp gravity)	3 – 3.47
9	Varieties	Edenite, Paragasite
10	Occurrence	In IGNEOUS ROCKS such as Granites, Syenites, Diorites, Hornblendite and in METAMORPHIC ROCKS such as Gneisses, Schists, Amphibolites.
11	Uses	1.DECORATION 2.USED AS INSULATING MATERIAL 3.USED AS ELECTRIC COMMUTATORS
12	Chemical composition	$(Ca, Mg, Fe, Na, Al)_{7\text{-}8} (Al\ Si)_8 O_{22} (OH)_2$

4. Describe the composition, properties, varieties and uses of Gypsum, Quartz and Feldspar.[N/D-15]

Name of the Mineral: 1. Feldspars

S No	Properties	Observations
1	Form	Tabular
2	Color	Pale pink, whitish blue, grayish
3	Streak	
4	Lustre	Vitreous
5	Fracture	Uneven
6	Cleavage	2 sets
7	Hardness	6 – 6.5
8	Density (Sp gravity)	2.6 – 2.73
9	Varieties	Plagioclase feldspars include: ALBITE; | OLIGOCLASE | ANDESINE LABRADORITE | BYTOWNITE | ANORTHITE. Potash feldspars include: Hyalophane (KAISi3O8) Orthoclase (KAISi3O8) Microcline (KAISi3O8) Anorthoclase (Na KAI Si3 O8)
10	Occurrence	In granites, Syenites, diorite, rhyolite, Trachyte, sandstones, schists, gabbros, gneisses.
11	Uses	In the manufacture of porcelain & pottery, earthernware, sanitary ware, bricks manufacture, glasses, electronic products etc.
12	Chemical composition	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$

Name of the Mineral: 2. Quartz

S No	Properties	Observations
1	Form	Massive, crystals
2	Color	Quartz occurs in different colors. Common colors are white, grey, purple, brown, pink etc
3	Streak	Colorless (harder than streak plate)
4	Lustre	Vitreous
5	Fracture	Conchoidal
6	Cleavage	Absent
7	Hardness	7
8	Density (Sp gravity)	2.6 – 2.7
9	Varieties	Flint, Jasper, Amethyst (purple or violet color), Opal, rose quartz (pale pink color). Milky quartz (milky white in color) .
10	Occurrence	Occurs in almost igneous(granites, rhyolites), sedimentary (sandstones) and metamorphic rocks (quartzites).
11	Uses	Glass making, optical materials, polishing / grinding compounds, components in electronic products,
12	Chemical composition	SiO_2

Physical Properties of Gypsum	
Chemical Classification	Sulfate
Color	Clear, colorless, white, gray, yellow, red, brown
Streak	White
Luster	Vitreous, silky, sugary
Diaphaneity	Transparent to translucent
Cleavage	Perfect
Mohs Hardness	2
Specific Gravity	2.3
Diagnostic Properties	Cleavage, specific gravity, low hardness
Chemical Composition	Hydrous calcium sulfate, $CaSO_4 \cdot 2H_2O$
Crystal System	Monoclinic
Uses	Used to manufacture dry wall, plaster, joint compound. An agricultural soil treatment.

5. Give salient features and mention important properties of Feldspar group of minerals.[M/J-16]

FELDSPARS FAMILY

It refers to a group of different minerals which possess similar chemical composition, atomic structure; physical and optical properties. These are aluminous silicates of K. Na; Ca or Ba and may be considered as isomorphous compounds.

Feldspars are sub-divided into: PLAGIOCLASE FELDSPARS and

ALKALI FELDSPARS

The Plagioclase feldspars may be defined as

<table>
<tr><th>Feldspar group</th><th>Range</th><th>composition</th><th>Occurrence</th></tr>
<tr><td>Albite</td><td rowspan="7">Na Al $Si_3 O_8$
to
Ca $Al_2 Si_2 O_8$</td><td>Ab 100 - An 0</td><td rowspan="7">Granites; Syenites; Diorites; Rhyolites; Trachytes; Gabbros; Sandstones; Schists & Gneisses;</td></tr>
<tr><td>Oligoclase</td><td>Ab 90 – An 10</td></tr>
<tr><td>Andesite</td><td>Ab 70 - An 30</td></tr>
<tr><td>Labradorite</td><td>Ab 50 - An 50</td></tr>
<tr><td>Bytownite</td><td>Ab 30 – An 70</td></tr>
<tr><td>Anorthite</td><td>Ab 10 - An 90</td></tr>
<tr><td></td><td></td></tr>
</table>

Uses: Feldspars are used in the manufacture of Porcelain; Pottery; glazes on earthware; Sanitary ware; in the manufacture of glass and ceramic industries.

Name of the Mineral: 1. Feldspars

S No	Properties	Observations
1	Form	Tabular
2	Color	Pale pink, whitish blue, grayish
3	Streak	
4	Lustre	Vitreous
5	Fracture	Uneven
6	Cleavage	2 sets
7	Hardness	6 – 6.5
8	Density (Sp gravity)	2.6 – 2.73
9	Varieties	Plagioclase feldspars include: ALBITE; OLIGOCLASE ANDESINE

		LABRADORITE	BYTOWNITE	ANORTHITE.	
		Potash feldspars include: Hyalophane (KAlSi3O8) Orthoclase (KAlSi3O8) Microcline (KAlSi3O8) Anorthoclase (Na KAl Si3 O8)			
10	Occurrence	In granites, Syenites, diorite, rhyolite, Trachyte, sandstones, schists, gabbros, gneisses.			
11	Uses	In the manufacture of porcelain & pottery, earthernware, sanitary ware, bricks manufacture, glasses, electronic products etc.			
12	Chemical composition	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$			

6. Explain Amphibole group of minerals [M/J-16][N/D 12]

The amphibole group possess Si4 O11 double chain type of structure where Tetrahedra are joined together to produce chains of indefinite extent. The general formula for amphibole group is $X_{7-8}(Si_4O_{11})_2(OH)_2$ where x = Ca, Na, Mg, Fe^{+2}; Al; Fe^{+3} .

Amphiboles	Composition	Occurs in
Anthophyllite	$(Mg,Fe^{+2})_7(Si_8O_{22})(OH)_2$	Anthophyllite schists, gneisses
Cummingtonite	$(Mg,Fe)_7(Si_8O_{22})(OH)_2$	In metamorphic rocks
Grunerite	$(Fe, Mg)_7(Si_8O_{22})(OH)_2$	
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$	In Serpentinites, greenstones, Actinolite schists
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$	
Hornblende	$(Ca\ Na\ Mg\ Fe\ Al)_{7\text{-}8}Si_8O_{22}(OH)_2$	Granites; Syenites; diorites, Hbl gneisses; hbl schists, amphibolites
Glaucophane	$Na_2(Mg\ Fe)_3(Al\ Fe^{+3})Si_8O_{22}(OH)_2$	Soda rich ig rocks ie glaucophane schists
Riebeckite	$(Na_2Fe^{+2})(Fe^{+2})_3(Fe^{+3})_2Si_8O_{22}(OH)_2$	Nepheline schists, pegmatites.

HORNBLENDE: It is a silicate of aluminium, calcium, magnesium and iron with sodium represented by the formula $(Ca\ Na\ Mg\ Fe\ Al)_{7\text{-}8}Si_8O_{22}(OH)_2$. Hornblende occurs as crystals, prismatic in habit.

Varieties: Edenite is a light coloured hornblende poor in iron where as Pargasite is a dark – green or bluish green variety and basaltic hornblende is a brown or black variety containing titanium and sodium.

Occurrence: It occurs as a primary mineral in acid and intermediate igneous rocks such as granites, Syenites, diorites etc and Ultrabasic rocks viz., hornblendite and common in metamorphic rocks of hornblende – gneisses, hornblende schists and amphibolites.

7. Using appropriate examples from the mineral kingdom, describe the physical properties of minerals.[N/D-16]

Study of physical properties of rock forming minerals: It is necessary to know about the common minerals which actually make up different rocks and determine their properties.

Name of the Mineral: 1. Feldspars

S No	Properties	Observations
1	Form	Tabular
2	Color	Pale pink, whitish blue, grayish
3	Streak	
4	Lustre	Vitreous
5	Fracture	Uneven
6	Cleavage	2 sets
7	Hardness	6 – 6.5
8	Density (Sp gravity)	2.6 – 2.73
9	Varieties	Plagioclase feldspars include: ALBITE; OLIGOCLASE ANDESINE LABRADORITE BYTOWNITE ANORTHITE. Potash feldspars include: Hyalophane (KAlSi3O8) Orthoclase (KAlSi3O8) Microcline (KAlSi3O8) Anorthoclase (Na KAl Si3 O8)
10	Occurrence	In granites, Syenites, diorite, rhyolite, Trachyte, sandstones, schists, gabbros, gneisses.
11	Uses	In the manufacture of porcelain & pottery, earthernware, sanitary ware, bricks manufacture, glasses, electronic products etc.
12	Chemical composition	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$

Name of the Mineral: 2. Quartz

S No	Properties	Observations
1	Form	Massive, crystals
2	Color	Quartz occurs in different colors. Common colors are white, grey, purple, brown, pink etc
3	Streak	Colorless (harder than streak plate)
4	Lustre	Vitreous
5	Fracture	Conchoidal
6	Cleavage	Absent
7	Hardness	7
8	Density (Sp gravity)	2.6 – 2.7
9	Varieties	Flint, Jasper, Amethyst (purple or violet color), Opal, rose quartz (pale pink color). Milky quartz (milky white in color) .
10	Occurrence	Occurs in almost igneous(granites, rhyolites), sedimentary (sandstones) and metamorphic rocks (quartzites).
11	Uses	Glass making, optical materials, polishing / grinding compounds, components in electronic products,
12	Chemical composition	SiO_2

Name of the Mineral: 3. Flint

S No	Properties	Observations
1	Form	Irregular nodules, massive
2	Color	Grey, brownish, black
3	Streak	Colorless (harder than streak plate)
4	Lustre	Resinous
5	Fracture	Conchoidal
6	Cleavage	Absent
7	Hardness	7
8	Density (Sp gravity)	2.65
9	Varieties	Hornstone, Chert
10	Occurrence	In sedimentary rocks such as Limestones
11	Uses	Used in tube mills, pottery industry, as road and building material.
12	Chemical composition	SiO_2

Name of the Mineral: 4. Jasper

S No	Properties	Observations
1	Form	Massive
2	Color	Red, Grey, brown
3	Streak	Colorless (harder than streak plate)
4	Lustre	Dull, vitreous, greasy
5	Fracture	Conchoidal
6	Cleavage	Absent
7	Hardness	6.5 - 7
8	Density (Sp gravity)	2.57 – 2.65
9	Varieties	
10	Occurrence	In Igneous, sedimentary & metamorphic rocks
11	Uses	Ornaments, gemstones
12	Chemical composition	SiO_2

Name of the Mineral: 5. Olivine

S No	Properties	Observations
1	Form	MASSIVE or no definite shape
2	Color	OLIVE GREEN. Mg rich types are PALE whereas iron rich types are DARK COLOURED
3	Streak	WHITE
4	Lustre	VITREOUS but OFTEN DULL
5	Fracture	EVEN TO UNEVEN
6	Cleavage	ABSENT
7	Hardness	6 – 7
8	Density (Sp gravity)	3.2 – 4.3
9	Varieties	FORSTERITE IS MAGNESIUM OLIVINE FAYALITE IS FERROUS IRON TYPE PERIDOT is a gem variety of olivine.
10	Occurrence	IGNEOUS ROCKS such as Peridotites, Dunites, Gabbro, Basalt, Dolerites.
11	Uses	PERIDOT IS a GEM VARIETY manufacture of REFRACTORY BRICKS
12	Chemical composition	$(Mg,Fe)_2 SiO_4$

Name of the Mineral: 6. Augite

S No	Properties	Observations
1	Form	granular, prismatic crystals
2	Color	Greenish black TO Brownish black

3	Streak	WHITE TO GREY
4	Lustre	VITREOUS TO SUB VITREOUS
5	Fracture	UNEVEN
6	Cleavage	2-SETS
7	Hardness	5 – 6
8	Density (Sp gravity)	3.2 – 3.5
9	Varieties	Diallage
10	Occurrence	Basalts, Andesites, Tuffs, Gabbros, Pyroxenites, Andesites
11	Uses	
12	Chemical composition	(Ca, Na) (Mg,Fe^{+2}, Fe+3, Al) [(Si Al)$_2$ O$_6$]

Name of the Mineral: 7. Hornblende

S No	Properties	Observations
1	Form	GRANULAR OR PRISMATIC or AGGREGATE
2	Color	DARK GREENISH BLACK
3	Streak	GREY TO GREENISH GREY
4	Lustre	VITREOUS TO SUB VITREOUS
5	Fracture	UNEVEN
6	Cleavage	2 sets
7	Hardness	5 – 6
8	Density (Sp gravity)	3 – 3.47
9	Varieties	Edenite, Paragasite
10	Occurrence	In IGNEOUS ROCKS such as Granites, Syenites, Diorites, Hornblendite and in METAMORPHIC ROCKS such as Gneisses, Schists, Amphibolites.
11	Uses	1.DECORATION 2.USED AS INSULATING MATERIAL 3.USED AS ELECTRIC COMMUTATORS
12	Chemical composition	(Ca, Mg, Fe, Na, Al)$_{7-8}$ (Al Si)$_8$ O$_{22}$ (OH)$_2$

8. Describe in detail, the properties, composition and uses of Feldspar and Calcite. [N/D-16] [M/J-15]

determine their properties.

Name of the Mineral: 1. Feldspars

S No	Properties	Observations
1	Form	Tabular

2	Color	Pale pink, whitish blue, grayish
3	Streak	
4	Lustre	Vitreous
5	Fracture	Uneven
6	Cleavage	2 sets
7	Hardness	6 – 6.5
8	Density (Sp gravity)	2.6 – 2.73
9	Varieties	Plagioclase feldspars include: ALBITE; OLIGOCLASE ANDESINE LABRADORITE BYTOWNITE ANORTHITE. Potash feldspars include: Hyalophane (KAlSi3O8) Orthoclase (KAlSi3O8) Microcline (KAlSi3O8) Anorthoclase (Na KAl Si3 O8)
10	Occurrence	In granites, Syenites, diorite, rhyolite, Trachyte, sandstones, schists, gabbros, gneisses.
11	Uses	In the manufacture of porcelain & pottery, earthernware, sanitary ware, bricks manufacture, glasses, electronic products etc.
12	Chemical composition	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$

Name of the Mineral: 15. Calcite

S No	Properties	Observations
1	Form	Rhombic / tabular
2	Color	White
3	Streak	White
4	Lustre	Vitreous
5	Fracture	Even
6	Cleavage	3 sets
7	Hardness	3
8	Density (Sp gravity)	2.71
9	Varieties	Iceland spar
10	Occurrence	In limestones and marbles
11	Uses	In cement industry, manufacture of bleaching powder,,

		as a calcium carbide ,
12	Chemical composition	$CaCO_3$

9. Describe in detail, the properties, composition and uses of any two rock forming minerals. [N/D-12] [N/D-10]

It is necessary to know about the common minerals which actually make up different rocks and determine their properties.

Name of the Mineral: 1. **Feldspars**

S No	**Properties**	**Observations**
1	Form	Tabular
2	Color	Pale pink, whitish blue, grayish
3	Streak	
4	Lustre	Vitreous
5	Fracture	Uneven
6	Cleavage	2 sets
7	Hardness	6 – 6.5
8	Density (Sp gravity)	2.6 – 2.73
9	Varieties	Plagioclase feldspars include: ALBITE; OLIGOCLASE ANDESINE LABRADORITE BYTOWNITE ANORTHITE. Potash feldspars include: Hyalophane (KAlSi3O8) Orthoclase (KAlSi3O8) Microcline (KAlSi3O8) Anorthoclase (Na KAl Si3 O8)
10	Occurrence	In granites, Syenites, diorite, rhyolite, Trachyte, sandstones, schists, gabbros, gneisses.
11	Uses	In the manufacture of porcelain & pottery, earthernware, sanitary ware, bricks manufacture, glasses, electronic products etc.

12	Chemical composition	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$

Name of the Mineral: 2. **Quartz**

S No	**Properties**	**Observations**
1	Form	Massive, crystals
2	Color	Quartz occurs in different colors. Common colors are white, grey, purple, brown, pink etc
3	Streak	Colorless (harder than streak plate)
4	Lustre	Vitreous
5	Fracture	Conchoidal
6	Cleavage	Absent
7	Hardness	7
8	Density (Sp gravity)	2.6 – 2.7
9	Varieties	Flint, Jasper, Amethyst (purple or violet color), Opal, rose quartz (pale pink color). Milky quartz (milky white in color) .
10	Occurrence	Occurs in almost igneous(granites, rhyolites), sedimentary (sandstones) and metamorphic rocks (quartzites).
11	Uses	Glass making, optical materials, polishing / grinding compounds, components in electronic products,
12	Chemical composition	SiO_2

10. Explain forms of Silica (QUARTZ; FLINT; JASPER) [N/D-13] [N/D-15]

The forms of silica, including the hydrated forms can be grouped as:

Silica occurs in nature as crystalline (eg: Quartz; Tridymite; Cristobalite)
as cryptocrystalline (eg: chalcedony; Flint; Chert; Jasper; Agate)
as Hydrous / amorphous forms (eg: opal)

QUARTZ: Next to feldspars and mafic minerals, quartz is the most common rock forming mineral. It is SiO_2 in composition and may be treated as an oxide or as a silicate. Structurally, it is a tectosilicate ie; in its atomic structure, the SiO_4 tetrahedra are arranged in a three dimensional network pattern.

Quartz, Tridymite and Crystabalite are important crystalline forms of silica with SiO2 composition but possess different physical properties and hence these are called POLYMORPHS.

Varieties of Quartz:

Rock crystal: Transparent form of quartz and purest.
Amethyst: Purple / violet colored; transparent form of quartz
Rose quartz: Pale pink / rose colored variety of quartz
Smoky quartz: smoky yellow / brown color of quartz
Milky quartz¨ milky white in color due to a large no. of mica cavities
Ferruginous quartz: contains iron oxides which impart reddish color

Uses: employed in jewellery (eg: amethyst); Making spectacle glasses; Sand papers; toothpaste; Pottery; silica bricks.
Depend on its piezo – electric properties, a certain type of quartz is used to control the frequency of radio-circuits.

FLINT: It is a compact cryptocrystalline silica of a black color or various shades of grey occur as irregular nodules. Flint breaks with a well marked conchoidal fracture and affords sharp cutting edges.

Flint was extensively used by prehistoric man for the fabrication of weapons, chisels.. Flint generates sparks when struck with steel . Flint is used in tube mills; pottery industry; for road making and building properties. Flint nodules occur in limestone formations in North Wales.

JASPER: it is an opaque form of silica, usually of red, brown yellow color and rarely green. Egyptian or Ribbon Jasper are beautifully banded with different shades of brown. Porcelain Jasper is merely clay altered by contact with a hot igneous rocks.

UNIT III

1. What is meant by RMT? What is its significance? [N/D-14]

Radio Magnetotellurics (RMT) is an electromagnetic geophysical method for inferring the earth's subsurface electrical conductivity from measurements of natural geomagnetic and geoelectric field variation at the Earth's surface. Investigation depth ranges from 300 m below ground by recording higher frequencies down to 10,000 m or deeper with long-period soundings. Proposed in Japan in the 1940s, and France and the USSR during the early 1950s, MT is now an international academic discipline and is used in exploration surveys around the world. Commercial uses include hydrocarbon (oil and gas) exploration, geothermal exploration, carbon sequestration, mining exploration, as well as hydrocarbon and groundwater monitoring. Research applications include experimentation to further develop the MT technique, long-period deep crustal exploration, deep mantle probing, and earthquake precursor prediction research.

2. Differentiate between Gneiss and Schist.

[N/D-14]

S No	Kind of difference	Gneiss	Schist
1	Appearance	Alternating colour bands occur	Alternating colour bands do not occur
2	Minerals present	More than one mineral	Usually one mineral after which the schist is named eg: talc - schist
3	Color	Pale grey or pink	White, black, green
4	Parent rock	Granite in more cases	Igneous and sedimentary rocks
5	Proportion of platy or prismatic minerals	Relatively less	Make up bulk of the rock
6	strength	Reasonably strong	Weak and incompetent
7	Suitability for civil engineering works	Suitable	Unsuitable.

3. Compare the strength of schist and Quartzite. [N/D-15]

SCHIST: Like a gneiss, schist is also a very common metamorphic rock due to schistose structure. A few details of its physical description are as follows:

Diagnostic character: schistose structure is present.

Color: silvery white (mica-schist), jet black (biotite schist), dark green (chlorite schist)

Grain size: fine to medium and sometimes even coarse grained

Texture and Structure: Lineation or foliation texture occurs depending on when prismatic or platy minerals occur predominantly..

Minerals present: Actinolite, tremolite, hornblende, sillimanite, tourmaline make up the bulk of a schist. In addition, chlorite, muscovite, biotite, talc, kyanite etc are the common platy minerals occuring in schists.. garnet, quartz, staurolite, cordierite also occur as other minerals ..

QUARTZITE:

Color: white or pale color. Red, brown, grey, green colours also may be seen.

Grain size: fine to coarse grained

Texture and Structure: Granulose structure is common. No alternating color bands. No foliation occurs.

Minerals present: quartz usually make up the bulk of a quartzite. The other minerals which may also occasionally occur in quartzites are mica, garnet, feldspar, pyroxenes; chlorite, kyanite, epidote, magnetite etc..

4. Why is attrition test carried out on rock samples? [N/D-15]

An attrition test is a test is carried out to measure the resistance of a granular material to wear. An example of a material subjected to an attrition test are stones used in road construction, indicating the resistance of the material to being broken down under road traffic. Heterogeneous catalysts are also subjected to attrition tests to determine their physical performance in a nuclear reactor.

The test itself involves agitating the particles, typically by tumbling within a drum, vibration, or with jets of gas to simulate a fluidised bed. After a specified time, the material is sieved and the sieved material weighed to measure the proportion of material which has been reduced to below a certain size (referred to as 'fines'). The specifics of the test are defined by various standards as applicable to the purpose in question, such as those defined by ASTM.

5. Differentiate between concordant bodies and discordant bodies. [M/J-16]

Concordant or conformable, when referring to plutonic bodies, indicates that the intruding magma of sills and laccoliths lies parallel to rather than cutting across country strata, as do discordant structures such as veins, dikes, bysmoliths, and batholiths.

A concordant coastline comprises bands of different rock types that run parallel to the shore. The rock types are typically of alternating resistance, so that the coastline forms distinctive landforms, such as coves. A discordant coastline comprises rock types of alternating resistance that run perpendicular to the shore, creating distinctive landforms when the rocks are eroded by ocean waves. Less resistant rocks erode faster, creating inlets or bays; more resistant rocks erode more slowly, remaining as headlands or outcroppings.

Concordant flows at different points in a river system have the same recurrence interval, or the same frequency of occurrence. The term is most often applied to floodflows.
Labels: batholith, bysmolith, coastline, concordant, conformable, dike, discordant, laccolith, river system, sill, vein.

6. What do you mean by granulation is metamorphic petrology? [M/J-16]

Granulation is the act or process of forming into grains or granules.Granules typically have a size range between 0.2 and 4.0 mm depending on their subsequent use.

Granulation is carried out for various reasons, one of which is to prevent the segregation of the constituents of powder mix. Segregation is due to differences in the size or density of the component of the mix. Normally, the smaller and/or denser particles tend to concentrate at the base of the container with the larger and/or less dense ones on the top. An ideal granulation will contain all the constituents of the mix in the correct proportion in each granule and segregation of granules will not occur.

7. Write briefly about attrition test. [N/D-16]

An attrition test is a test is carried out to measure the resistance of a granular material to wear. An example of a material subjected to an attrition test are stones used in road construction, indicating the resistance of the material to being broken down under road traffic. Heterogeneous catalysts are also subjected to attrition tests to determine their physical performance in a nuclear reactor.

The test itself involves agitating the particles, typically by tumbling within a drum, vibration, or with jets of gas to simulate a fluidised bed. After a specified time, the material is sieved and the sieved material weighed to measure the proportion of material which has been reduced to below a certain size (referred to as 'fines'). The specifics of the test are defined by various standards as applicable to the purpose in question, such as those defined by ASTM.

8. Compare the relative strengths of shale, sandstone and quartzite. [N/D-16]

SHALES : Shales are more abundant than all other sedimentary rocks put together. These rocks are formed out of mechanically transported and deposited sediments. Shales are made up of solid particles of extremely fine grained silt and clay.

Stratification of lamination is best seen in shales because the individual layers are very thin. Shales often contain fossils of flora and fauna. Compositionally, shales are Hydrous aluminium silicates which the products of weathering of feldspars and other silicate minerals.

Field samples show different colours such as white, red, yellow, grey, brown and black. Shales are compact and extremely fine grained. Cross –bedding; ripple marks, mud cracks and fossil content are observed in some specimens of shales.

Mineralogically, shales are mainly made up of montmorillonite, kaolinite; Illite; halloysite; pyrophillite minerals.

Varieties in shales:

Siliceous shale	With considerable amount of silica
Calcareous shale	With increasing calcium carbonate content
Bituminous shale	With organic matter
Carbonaceous shale	Black color with rich in vegetal / organic matter
Mud stone	Similar to shale

Shales are highly porous (due to the presence of various clays with porosity 50 – 60%); impermeable rocks (do not yield water due to surface tension phenomenon) called as AQUICLUDES means shales contain water but do not yield groundwater when tapped.

Sandstones are abundant among sedimentary rocks but are next to shales. Sandstones are made up of sand and described as Arenaceous rocks. Sandstones are stratified and sometimes fossiliferous too. Compositionally, sandstones consist of sand grains (90% quartz) with accessory minerals of such as mica, ilmenite, magnetite, garnet, zircon, rutile, feldspars cover the rest.

In a hand specimen of sandstone, the size of sand grains may be coarse, medium or fine grained and other grains appear in different colors due to the presence of cementing material:

Grains	Appears as
Quartz	Colorless, fresh with vitreous lustre
Mica flakes	White colour with perfect cleavage
Ilmenite / magnetite	Jet black
Garnet	Red with shining
Zircon; rutile	White color with shining
Feldspars	Pale colours of brown, red, white, grey with a dull lustre

Pyroxenes & amphiboles	Pale colors

Sandstones are generally porous and permeable and considered one of the best aquifers. By virtue of their porosity and permeability, they are not only capable of holding a good quantity of groundwater but also yield the same when tapped.

QUARTZITE:

Color: white or pale color. Red, brown, grey, green colours also may be seen.

Grain size: fine to coarse grained

Texture and Structure: Granulose structure is common. No alternating color bands. No foliation occurs.

Minerals present: quartz usually make up the bulk of a quartzite. The other minerals which may also occasionally occur in quartzites are mica, garnet, feldspar, pyroxenes; chlorite, kyanite, epidote, magnetite etc..

9. Define the term metamorphism . Give Examples (AUC MAY/ JUNE 2010)
It may define as metamorphic process involving essentially formation of new minerals by the mechanism of chemical replacement of pre-existing minerals under the influence of chemically active fluids
Three major kinds of Metamorphism differentiated on the basis of dominant factors are thermal metamorphism, dynamic metamorphism and Dynamo thermal metamorphism

10. List the Few texture of Igneous Rocks (AUC MAY/ JUNE 2012)
The term texture has been defined as the mutual relationship of different mineralogical constituents in a rock. It is determine by size, shape and arrangement of these constituents within the body of rock.
1. Aphaeretic
2. Glassy or vitreous
3. Pyroclasti
4.Phaneritic
5.Pagmatite

11. Define the following term:
i. Ratites
ii. Arenites
iii. Lutites
Rudites:
There are also called rudaceous and include all coarse grained rocks of heterogenous composition. Rudites are made p of bounders, cobles and Pebbles collectively known as gravels.
Arenites:
These are also called arenaceous rocks. These are made up to sediments of sand grad (2 mm - / 16 mm)
Lutites:
These are also called argillaceous rocks. It may be defined as sedimentary rocks of the finest grains size.

12. Define conglomerates:

These are sedimentary rock at clastic nature and also belong to rudaceous group. They consist mostly of rounded fragments of various sizes but generally above 2mm. Cemented together is clays or mixed matrix.

13. What do you understand by metamorphism?

It may be defined as the response in solid rocks to pronounce charged of temperature, pressure and chemical environment. In other cases metamorphism means the partial or complete crystallization of a rock and the production of new structures.

14. What are the three kinds of metamorphism?

1. Thermal metamorphism
2. Dynamic metamorphism
3. Dynamo thermal metamorphism

1 How are rocks classified? Describe the major distinguishing properties of the major rock types. [N/D-14] [M/J 15]

CLASSIFICATION OF IGNEOUS ROCKS: Igneous rocks are the first formed rocks in the earth's crust and hence these are called PRIMARY ROCKS, even though igneous rocks have formed subsequently also.

Igneous rocks are the most abundant rocks in the earth crust and are formed at a very high temperature directly as a result of solidification of magma since magma is the parent material of igneous rocks. The temperature increases proportionately with the depth --- this is one of the reasons for the formation of igneous rocks.

Igneous rocks are usually massive, unstratified, unfossiliferous and often occur as intrusive cutting across other rocks (country rocks or host rocks). The igneous rocks are classified based on silica%, silica saturation and depth of formation

1. CLASSIFICATION BASED ON SILICA % :

Nature	Silica %	Rock examples
Acidic	➢ 65	Granite, Pegmatites; (coarse) ; Rhyolite (fine)
Intermediate	55 – 65	Syenite (coarse) ; Trachyte (fine)
Basic	45 – 55	Gabbro (coarse); Basalt (fine)
Ultrabasic	< 45	Picrite, Peridotite , Dunite (coarse)

Acidic igneous rocks:

- Composed of quartz, alkali feldspars, mica minerals and compositionally rich in Si, Al, Na, K etc but are poor in Ca, Mg, Fe
- Leucocratic due to the presence of light coloured minerals.
- Relatively lighter rocks and have a slightly higher specific gravity of 2.6

Intermediate igneous rocks:

- Lacking of quartz or a little quartz present but dominantly composed of alkali feldspars and compositionally rich Na, K.
- Mesocratic in colour due to the presence of dark colored minerals.

Basic igneous rocks:

- Dominantly composed of ferro-magnesium minerals(mafic minerals) such as hypersthenes, feldspars (plagioclase), pyroxene (Augite), amphiboles (hornblende) , biotite and compositionally rich in Ca, Mg, Fe.
- Melanocratic in color
- Quartz or olivine is generally absent or occur in small quantities.
- Due to the presence of mafic minerals, these rocks to have a slightly higher specific gravity of 3.1

Ultra basic igneous rocks:

- Composed of mafic minerals and quartz is almost absent and compositionally rich in Mg, Ca.
- Melanocratic in color.
- Higher density of about 3.6

2. CLASSIFICATION BASED ON SILICA SATURATION:

Depending on the silica content in parent magma; the mineral associations are categorized as:

Oversaturated igneous rocks: when the parent magma is rich in silica, saturated minerals like feldspars and the surplus quantity of silica crystallizes as quartz.

Unsaturated minerals like olivine, nepheline, leucite never occur in over saturated rocks. Eg: granites, granodiorites, dacite, rhyolites .

Saturated igneous rocks: when the parent magma has enough silica for the formation of minerals, the resulting rocks possess neither quartz nor any unsaturated mineral. Presence of saturated minerals (feldspars) are seen in Syenite, Diorite, Anorthosite, Gabbro.

Unsaturated igneous rocks : when the parent magma has silica less than what is required for the formation of saturated minerals. Quartz is possible to the extent, and feldspars, olivine, nepheline, leucite are present usually.

This group represents Dunites, Peridotites, Phonolite

Oversaturated rocks are equivalent to acidic igneous rocks. Saturated rocks are equivalent to intermediate igneous rocks. Under saturated rocks are roughly equivalent to basic / Ultrabasic rocks.

Doliomorphic rocks: Rarely do quartz and olivine coexist, if so such igneous rocks are described as doliomorphic rocks.

3. CLASSIFICATION BASED ON DEPTH OF FORMATION:

In terms of modes of occurrence ie depth of formation, igneous rocks can be either intrusive (plutonic), extrusive (volcanic) or hypabyssa

PLUTONIC ROCKS: The igneous rocks which have formed under high temp & pressure at greater depths in the presence of volatiles in the earth's crust are called plutonic rocks. Greater pressure ensure total crystallization of minerals formed and the hot surroundings slow down the process of solidification. The result of all these processes is the development of coarse grained texture. Eg: Granite

SLOW COOLING & SLOW CRYSTALLIZATION OF MAGMA eg: Gra ite

VOLCANIC ROCKS: The igneous rocks which have formed under low temp & pressure at shallow depths in the absence of volatiles in the earth' crust are called volcanic rocks. Rapid cooling and quick crystallization of lava makes faster the process of solidification due to heat difference. The result of all these processes is the development of fine grained texture. Eg: basalt

HYPABYSSAL ROCKS: The igneous rocks which have formed under moderate temp & pressure at shallow depths are called hypabyssal rocks. Medium rate of cooling causes for the formation of medium grained rocks. Eg: dolerite

Igneous rocks are also classified based on their cooling history (texture) and on the nature of the magma (felsic or mafic). A diagram for classification would be.. .

Composition▶ Texture▼	Felsic (light color)	Intermediate	Mafic (dark color)
Phaneritic	Granite	Diorite	Gabbro, Peridotite

Aphanitic	Rhyolite	Andesite	Basalt
Vesicular	Pumice		Scoria
Glassy	Obsidian		

Brief description of IGNEOUS ROCKS

Andesite	An igneous volcanic rock predominantly consists of plagioclase feldspars with or without silica. The Ferro-magnesium minerals (biotite, hbl, augite, enstatite, hypersthene) may be present .
Anorthosite	an igneous plutonic rock composed predominantly of plagioclase
Aplite	a very fine grained intrusive igneous rock
Basalt	a volcanic rock of mafic composition
Basalt Hawaiite	a class of basalts formed from Ocean Island (hot spot) magmatism
Basalt Boninite	a high-magnesian basalt dominated by pyroxene
Charnockite	a rare type of granite containing pyroxene
Dacite	a felsic to intermediate volcanic rock with high iron content
Diabase or dolerite	intrusive mafic rock forming dykes or sills
Diorite	a coarse grained intermediate plutonic rock composed of plagioclase, pyroxene and/or amphibole
Dunite	An ultramafic rock composed of olivine
Essexite	a mafic plutonic rock (a gabbro)
Gabbro	a plutonic rock composed of pyroxene and plagioclase
Granite	A plutonic rock composed of orthoclase, plagioclase and quartz
Granodiorite	a granitic plutonic rock with plagioclase > orthoclase
Harzburgite	a variety of peridotite; an ultramafic rock
Ijolite	An igneous plutonic rock consists of nepheline and Na-pyroxene (Aegirine Na Fe $Si_2 O_6$ and Jadeite Na Al $Si_2 O_6$
Kimberlite	a rare ultramafic volcanic rock consists of chlorite, talc and carbonates, sometimes olivine and a source of diamonds
Komatite	an ancient ultramafic volcanic rock
Lamprophyre	an ultramafic rock dominated by mafic phenocrysts in a feldspar groundmass
Lherzolite	an ultramafic rock, essentially a variety of peridotite
Monzonite	a plutonic rock with <5% normative quartz
Nepheline syenite	a plutonic rock with nepheline replacing orthoclase
Norite	a hypersthene bearing gabbro

Obsidian	a type of volcanic glass
Pegmatite	an igneous rock occurs as veins or dykes and found as granite pegmatite or syenite pegmatite consists of alkali feldspars, and quartz with tourmaline, topaz, beryl, fluorspar, apatite and Spodumene as accessories.
Peridotite	a plutonic composed of >90% olivine
Phonolite	a volcanic rock essentially similar to nepheline syenite
Picrite	an olivine-bearing basalt
Pumice	a fine grained, extremely vesicular volcanic rock
Pyroxenite	a coarse grained plutonic rock composed of >90% pyroxene
Rhyolite	a felsic volcanic rock
Scoria	an extremely vesicular mafic volcanic rock
Syenite	a plutonic rock dominated by orthoclase feldspar; a type of granitoid
Tachylyte	essentially a basaltic glass
Tephrite	a silica undersaturated volcanic rock; can be a generic term
Tonalite	a plagioclase-dominant granitoid
Trachyte	a silica undersaturated volcanic rock; essentially a feldspathoid-bearing rhyolite
Tuff	a fine grained volcanic rock formed from volcanic ash
Wehrlite	an ultramafic plutonic rock, a type of peridotite, composed of olivine and pyroxenes.

2. List the various engineering properties of rocks and describe the field and laboratory tests to be conducted to determine these properties. [N/D-14][N/D 16]

Structures and textures are physical features associated with the rocks. These occur along with the formation of rocks and are important in view of civil engineering point because

- They contribute to the strength of rocks.
- They contribute to the weakness of rocks
- They reveal mode of origin of rocks.

NOTE: The structures such as folds and faults are exempted though they are also structures since these develop after the formation of rocks due to tectonic forces.

The term structure refers to certain large scale features

1. Vesicular structure:
2. Amygdaloidal structure
3. Columnar structure
4. Sheet structure
5. Flow structure

VESICULAR STRUCTURE: This structure is due to porous in nature commonly observed in volcanic rocks. Most of the lava contains volatiles (gasses like CO_2, water vapour) which escapes into the atmosphere by creating various sizes and shapes of cavities near the surface of lava flow. These cavities are called vesicles.

Eg: SCORIA is a volcanic rock of highly porous.

Eg: PUMICE, a light rock with porosity even that floats on water.

AMYGDALOIDAL STRUCTURE: when secondary minerals such as calcite, zeolites, hydrated forms of silica (chalcedony, agate, amethyst, opal) are filled in vesicles, in such a case it is said Amygdaloidal structure. Eg: Deccan traps of India.(ie basalts).

COLUMNAR STRUCTURE: with uniform cooling and contraction causes a regular or hexagonal form, which may be interested by cross- joints. Eg: Columnar basalts, around 40 mts high are seen at Andheri, Bombay.

SHEET STRUCTURE: In this structure, the rocks appear to be made up of a number of sheets, because of the development of horizontal cracks. When erosion takes place, the overlying strata gradually disappear and ultimately the plutonic rocks exposed to the surface resulting the development of joints / cracks parallel to the surface. Thus, the horizontal joint planes are sometimes so closely spaced as to produce a sheet structure. Eg: granite.

FLOW STRUCTURE: After eruption of the lava flows, some of the bands or lines are drawn over the surface of lava to the direction of lava flow. Eg: Rhyolite.

The texture of a rock refers to the individual mineral grains of size, shape, and mutual relations of mineral constituents and glassy matter in a rock. Depending on the nature of cooling, the TEXTURES in igneous rocks are categorized into:

1. Degree of crystallinity - Rocks composed entirely of crystals are called holocrystalline; those composed entirely of glass are holohyaline; rocks that contain both crystals and glass are hypocrystalline / hemicrystalline .

2. Grain size - Overall, there is a distinction between the grain size of rocks that have crystallized at depth are medium to coarse grained (eg: gabbros) and those that crystallized at shallow depth are finer grained (eg: basalts).

Phaneric texture: if minerals in the rock are big enough to seen by the naked eye, the texture is said to be Phaneric. Eg: granite.

Aphanitic texture: if minerals are too fine to be seen the texture is said to be aphanitic. Eg: basalts.

3. Based on growth of crystals / Rock fabric - Fabric is the shape and mutual relationships among rock constituents:

1. Euhedral, refer to grains that are bounded by crystal faces

2. Subhedral grains that are bounded partly by some crystal faces
3. Anhedral, when crystal faces are absent, it is called anhedral

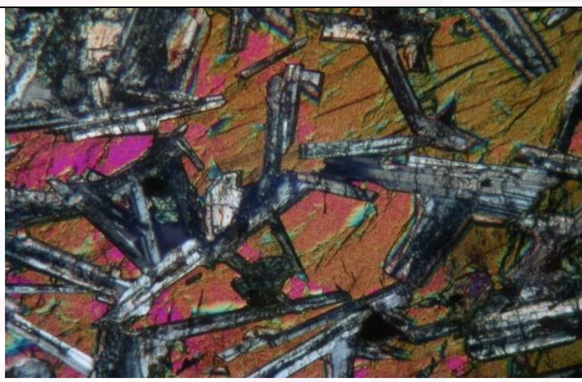
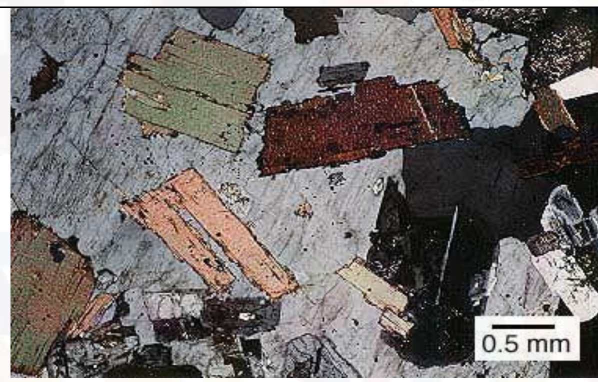
Hypidiomorphic / granular texture - the most common granular texture in which a mixture of euhedral, subhedral, and anhedral grains are present.

Ophitic texture - is one where random plagioclase laths are enclosed by pyroxene or olivine. If plagioclase is larger and encloses the ferromagnesian minerals, then the texture is subophitic . eg: basalt.

Porphyritic texture: Large crystals that are surrounded by finer-grained matrix are referred to as phenocrysts. If the matrix or groundmass is glassy, then the rock has a vitrophyric texture.

Poikilitic texture- Small euhedral crystals that are enclosed within a large mineral.

Glassy Texture. The rock displays with sharp edges like broken glass is known as Glassy Texture. No individual crystals can be seen. Eg: obsidian.

	
OPHITIC TEXTURE	POIKILITIC TEXTURE

GRANITE is a plutonic igneous rock, compact, massive and hard rock. Granites are unstratified but characterized by joints. It is a holocrystalline (completely crystalline) and leucocratic (light coloured) rock .

Composition: Granite consists of quartz (> 20 – 30 %), Feldspars (60%) include alkali feldspars (orthoclase, microcline) and plagioclase feldspars (oligoclase), micas as essential minerals and accessory minerals are mafic minerals such as hornblende, biotite / muscovite , pyroxenes of hypersthenes; augite ; diopside ; magnetite / haematite, rutile, zircon, apatite, garnet..

Texture: Granites exhibit phaneric texture (coarse grained), or graphic texture (similar to Arabic writing). Granites are usually equigranular but some times show inequigranular texture in case of Porphyritic texture (feldspars occur as phenocrysts).

Hand specimen: Granite is grayish or pinkish in color. Feldspar appears with white or brownish – red color. Quartz looks colorless. Biotite is jet black and is found as small shining flakes. Hornblende is dark greenish black.

Varieties: When quartz decreases and increase in mafic minerals, granite passes over to GRANODIORITE and then DIORITE.

When both the alkali feldspars and plagioclase feldspars are equal in quantity, the granite rock is called as ADAMELLITE.

If hypersthene is more in granite then it is known as CHARNOCKITE.
If feldspars and quartz are very large in size and exhibit interlocking texture, then it is called as PEGMATITE. Occurrence of large sized beryl, tourmaline crystals is another diagnostic feature of pegmatite.

RHYOLITE is very fined grained rock and is the volcanic equivalent of granite.

When the accessory minerals present more in quantity than normally such rocks are named as eg; biotite-granite, hornblende-granite. Based on the color of feldspars, the granites are termed as Pink granite; grey granite.

SPECIAL FEATURES:

Specific gravity of granite is 2.6 – 2.8

Density = 2500 – 2650 kg/cm3; compressive strength = 1000 – 2500 kg /sq cm

ENGINEERING POINT OF VIEW: By virtue of many desirable qualities, granite can be used in foundations of civil structures, building stone, road metal,. Tunneling through granite does not require any lining.

PEGMATITE

It is a holocrystalline (completely crystalline) and coarse grained igneous rock .

Composition: Pegmatite resemble granites in mineralogy and hence it is described as Granite Pegmatite. When pegmatites are rich in alkali feldspars, it is called as Syenite pegmatites. Occurrence of large sized beryl, tourmaline crystals is another diagnostic feature of pegmatite.

Granite pegmatite consists of alkali feldspars and quartz and rich in biotite/ muscovite of micas. In addition, rare minerals of cassiterite (tin - Sb); mispickel (arsenic–Ar); niobium, tantalum etc are also present and hence pegmatites are economically very important.

Syenite pegmatites contain rare earth elements like zirconium, cerium, lanthanum, uranium and thorium.

In Andhra Pradesh, muscovite deposits in commercial quantities occur in pegmatites of Nellore district. This mica is generally light green in color.

Texture: Pegmatite exhibit an interlocking texture.

Hand specimen: Pegmatite is generally coarse grained consist of larger sized minerals of feldspars and quartz. Feldspars are often light coloured and may appear as red, white or green . Muscovite and biotite are easily identified by their color and cleavage. Hornblende looks dark greenish black and tourmaline is jet black, and prismatic.

ENGINEERING POINT OF VIEW: Since pegmatite minerals are large in size and the rock mass cannot behave uniform throughout. Further, the presence of mica which has excellent cleavages obviously makes the rock weak. So it is unsuitable to be used as a building stone and also undesirable at the site of foundation of major constructions. However, pegmatites are economically very important due to the presence of rare and valuable minerals.

DOLERITE

Dolerite is a dark, fine grained black or dark greenish black igneous rock. It is intermediate in composition and melanocratic (dark coloured) rock . Mineralogically and chemically, dolerite is similar to Gabbro and basalt.

Composition: Dolerite consists of Plagioclase Feldspars and pyroxene (augite). Iron oxides, hypersthene and biotite occur as common accessory minerals. Olivine is some times found if the parent magma was deficit of silica.

Texture: Dolerite is a massive and compact rock. It is neither porous nor permeable. The texture in dolerites is generally equigranular. Interlocking texture is also common in dolerite. Under the microscope dolerite exhibit Ophitic or subophitic texture.

Hand specimen: Dolerite is a fine grained rock with greenish black or black coloured. Presence of pyroxene (augite) contributes the black color of a rock. Feldspars can be observed by means of their cleavage surfaces and biotite if present appears as small, jet black..

Varieties: When all the minerals of dolerite are totally altered for eg: plagioclase into zoisite or epidote and augite into chlorite / hornblende and olivine into serpentine then the rock is called DIABASE.

Plutonic equivalent of dolerite is called Gabbro.

Volcanic equivalent of dolerite is called Basalt.

Glassy equivalent of dolerite is called trachylyte.

SPECIAL FEATURES: The compact nature and rich in mafic minerals make the rock emit metallic sound when hit with a hammer. Dolerite occurs in nature as an intrusive rock ie as dyke.

ENGINEERING POINT OF VIEW: Dolerites are not common as building stones. They are suitable as road metal, railway ballast, bitumen aggregate, concrete purposes. At foundation sites of dam like structures, the presence of dolerite is considered undesirable as they become a cause for weak planes.

BASALT is a black volcanic, massive, fine grained, melanocratic rock. .

COMPOSITION: Basalt consist of plagioclase feldspars (labradorite), Pyroxenes (Augite) and iron oxides (magnetite or ilmenite). Biotite, hornblende and hypersthenes are the other accessory minerals. Pyrite may also seen sometimes. Either quartz or olivine may appear in small amounts depending on the silica content of parent lava.

Structures & Textures: Vesicular and amygdaloidal structures are common in basalts. However, Columnar and flow structures are also observed in some cases. Basalts exhibit aphanitic texture in hand specimens. (ie the minerals are too fine).

Appearance in Hand specimens: Basalt is typically black or greenish grey or greenish black. Non-vesicular, massive in nature. Exhibit a typical aphanitic texture ie extremely fine grained with or without vesicles. Basalts are always unstratified, unfossiliferous and do not react with acids.

VESICULAR BASALT: it is characterized by the presence of empty cavities or vesicles.

AMYGDALOIDAL BASALTS is a vesicular basalt with cavities filled up by secondary minerals of silica (quartz, amethyst, opal, agate); zeolites, calcite. Among these, silica minerals may be used as semi-precious gemstones.

SPILLITE is a soda-rich basalt in which plagioclase feldspar is albite or oligoclase in stead of labradorite.

Dolerite is the hypabyssal equivalent of basalt .
Gabbro is plutonic equivalent of Basalt .
Trachylite is equivalent of glassy basalt
Alkali Basalt is unsaturated basalt
Tholeite is oversaturated basalt

Uses: Massive basalts are highly durable and strongest having highest load bearing capacity. Used as building stones. Basalts are excellent for macadam and bitumen Roads.

A number of tunnels have been made across through the Deccan traps for railway lines near Bombay. They need no lining except sealing where the weak planes or joints are observed to prevent seepage.

Rhyolite is an igneous, volcanic rock of felsic (silica-rich) composition (> 69% SiO_2). It may have any texture from glassy to aphanitic . The mineral assemblage is usually quartz, alkali feldspar and plagioclase. Hornblende is a common accessory mineral.

Rhyolite can be considered as the extrusive equivalent to the plutonic granite rock, and consequently, outcrops of rhyolite may bear a resemblance to granite.

Rhyolites that cool too quickly to grow crystals form a natural glass or vitrophyre, also called obsidian. Slower cooling forms microscopic crystals in the lava and results in textures such as flow foliations, spherulitic, nodular etc.. Some rhyolite is highly vesicular pumice..

Gabbro refers to a large group of dark, coarse-grained, intrusive mafic igneous rocks chemically equivalent to basalt. The rocks are plutonic, formed when molten magma is trapped beneath the Earth's surface and cools into a crystalline mass.

The vast majority of the Earth's surface is underlain by gabbro within the oceanic crust, produced by basalt magmatism at mid-ocean ridges.

Gabbro is dense, greenish colored and contains pyroxene, plagioclase, amphibole, and olivine (olivine gabbro when olivine is present in a large amount).

The pyroxene is mostly clinopyroxene; small amounts of orthopyroxene may be present. If the amount of orthopyroxene is substantially greater than the amount of clinopyroxene, the rock is then a norite. Quartz gabbros are also known to occur and are probably derived from magma that was over-saturated with silica.

Essexites represent gabbros whose parent magma was under-saturated with silica, resulting in the formation of the feldspathoid mineral nepheline. Gabbros contain minor amounts, of iron-titanium oxides such as magnetite, ilmenite. Gabbro is generally coarse grained, with crystals in the size range of 1 mm or greater. Finer grained equivalents of gabbro are called diabase. Gabbro is usually equigranular in texture, although it may be porphyritic at times, especially when plagioclase oikocrysts have grown earlier than the groundmass minerals.

Uses: Gabbro often contains valuable amounts of chromium, nickel, cobalt, gold, silver, platinum, and copper sulfides.

Syenite is a coarse-grained intrusive igneous rock of the same general composition as granite but with the quartz either absent or present in relatively small amounts (<5%).

The feldspar component of syenite is predominantly alkaline in character (usually orthoclase) . Plagioclase feldspars may be present in small quantities, less than 10%.

When present, ferromagnesian minerals are usually hornblende amphibole, rarely pyroxene or biotite. Biotite is rare, because in a syenite magma most aluminium is used in producing feldspar.

Syenites are usually peralkaline and peraluminous, with high proportions of alkali elements and aluminium.

Syenites are formed from alkaline igneous activity, generally formed in thick continental crustal areas. To produce a syenite, it is necessary to melt a granitic flow to a fairly low degree of partial melting. This is required because potassium is an incompatible element and tends to enter a melt first, whereas higher degrees of partial melting will liberate more calcium and sodium, which produce plagioclase, and hence a granite, adamellite or tonalite.

At very low degrees of partial melting a silica undersaturated melt is produced, forming a nepheline syenite, where orthoclase is replaced by a feldspathoid such as leucite, nepheline or analcime.

Dykes and sills

Igneous rocks are formed out of hot magma or lava. The lava on solidification over the earth's surface gives rise to Extrusive igneous rocks while the magma on solidification below the earth's surface gives rise to intrusive igneous rocks.

Igneous intrusions occur in different sizes and forms depending on the conditions during the formation of intrusion. eg: Dykes and Sills are the common forms.

If the intrusion is parallel to the layering in the host rock, it is called as a sill whereas the intrusion cutting across the trend of the host rock, it is called as a Dyke.

Dykes are the common form of igneous rocks and are vertical or inclined intrusive igneous bodies. Dykes occur cutting across the bedding planes of the country rocks in which they are found. Due to forceful pressure, magma intrudes through the fractures, cracks, joints, shear zones, weak planes and subsequent solidification of this gives rise to dykes.

The dimensions of dykes vary widely. They may be long (50-60 kms) and thick (upto 30 mts). eg: dyke of midland of Scotland or t hey may be short upto to a few mts and thin a few cms.

Though different rocks may appear as dykes, dolerite dykes are the most common. Dykes are important from Civil Engg point of view for the following reasons:

1. They are undesirable at the sites of foundations of dams as their sides (contacts) turn out to be weak planes.
2. They act as barriers and interrupt the ground water movement in a region.
3. They may give rise to springs.
4. Since, the dykes are hard, durable (resisting to weathering), black in color, fine grained, they are used in making of statues, sculptures etc.

Sills are similar to dykes but are formed due to penetration of magma into bedding planes of country rocks. The spreading capacity depends on the viscosity of magma, its temperature and the weight of the overlying rocks. Sills which spread over large areas are generally thin with uniform thickness.

- Eg: 1 The great whin soil of England spreads over 3900 sq.kms
- Eg: 2 Karroo sills (dolerite composition) spreads over 510000 sq kms in South Africa.

Sills act sometimes as mineralizing bodies. eg: Barytes, Asbestos deposits of cuddapah. Sills occur as horizontal and inclined bodies.

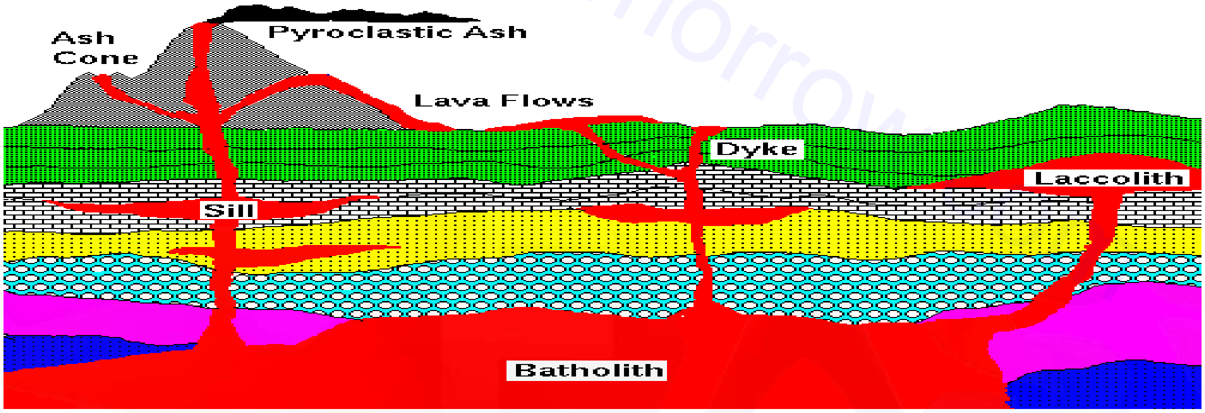
Lava flows may resemble sills closely because both are relatively thin, horizontal sheet like igneous bodies spreading over large areas. But they can be distinguished from one another as follows:

- Lava flows show an irregular lower surface whereas sills have more or less flat on both sides.
- Lava flows shows vesicular character on the upper surface, whereas sills present no such characters.
- Lava flows undergo quite cooling producing fine grained rocks whereas sills cool slowly causing coarse to medium grained rocks.
- Sills give out tongues (minor intrusions) into the overlying rock masses, whereas lava flows do not.

Other intrusives: If the intrusion takes place forcibly in stratified rock, resulting a mushroom shaped intrusive in the host rock, it is termed as Laccoliths.

In the folded rocks, if the intrusion takes place at a later stage, it occupies the openings at the crest (in case of anticlines) and trough (in case of synclines) of folds, the resulting form of intrusive is denoted as Phaccolith.

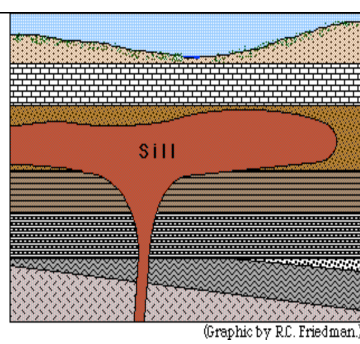
Large igneous intrusions of several kilometers in extent having a form which is the top in nearly flat and the bottom is convex downwards is known as Lopolith.

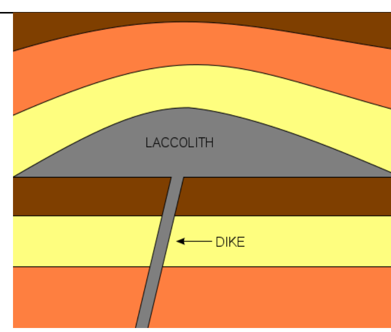


Batholiths: The term is applied to any large intrusive mass of igneous rock (eg granite). Batholiths, occupy a large area of out crop extending to greater depths with the presence of Roof Pendants and Xenoliths.

Batholiths occur usually in mountain regions and are parallel to the folded regions. Compositionally, batholiths are either granites or granodiorites. Eg: British Colombia batholiths of 1250 miles extension and a width of 50 miles. The roof pendants; Stocks; Bosses offering evidence.

Roof pendants:	cover rocks of batholiths
Stocks:	off shoot that means possessing a more or less circular cross-section
Bosses:	circular & occur at the top portion of batholiths





3. (a) List the various engineering properties of rocks. Describe the instrumentation required and the procedure for tests to determine these properties. [N/D-15]

Field testing and, to a lesser extent, geophysical surveying are major sources of both qualititive and quantitative data relating to the ground conditions. In spite of the fact that in most cases field testing is more expensive to carry out than sampling and laboratory testing, it forms an essential part of many site investigations. There are several reasons for this, probably the most important of which is because it provides, for design purposes, parameters which represent a more realistic appraisal of geotechnical ground conditions than is commonly the case with laboratory testing. Samples which are used for laboratory testing, because of their small size, may not be sufficiently representative of the ground from which they were taken. In particular, they may not contain large-scale discontinuities, present in the rock or soil mass, which significantly influence the engineering properties of the materials concerned. Furthermore, sampling inevitably involves some disturbance to the stress conditions and water content of soils and rocks so that parameters obtained in the laboratory may not be fully representative of the in situ conditions. Although not without some problems of its own, field testing overcomes many of these difficulties. However, with in situ tests it can be difficult to test materials at appropriate stresses, or in such a manner that changes in the stress, and other conditions due to engineering works, can properly be taken into account.

Penetration tests

Two types of penetration tests are recognized (Anon 1975 and 1981). The standard penetration test (SPT) is a dynamic method in which a 51 mm external diameter split tube sampler connected to drilling rods, is driven into the ground by a series of hammer blows delivered at the surface. The test is conducted at intervals during the course of boring and it provides a distributed sample for identification purposes. In the static penetration test a conical point is driven into the ground by means of a steady pressure on the top of the rods. Both tests provide an indirect measure of shear strength since the action of the tests produces a complex failure surface within the soil.

Shear strength tests

Various means of obtaining a direct indication of the in situ shear strength are available. Probably the most widely used of these is the shear vane test but brief reference will also be made to direct shear and triaxial tests. Shear vane test

Vane tests, in which a cruciform arrangement of plates mounted on the end of a rod, which may be enclosed within a guide tube, is inserted into the soil at the base of a borehole or trial pit and twisted, provide an indication of both peak and remoulded undrained shear strengths. Undrained shear strength is calculated from the relationship between torque and angular rotation, the vane dimensions and the maximum torque applied. Remoulded shear strength is measured similarly, after remoulding by rapid rotation of the vane and allowing a short period of time for pore pressures to dissipate. The test is used for very soft to firm, saturated, nonfissured, homogeneous clays.

Plate loading tests

Various forms of plate loading tests provide direct information relating to the strength and settlement characteristics of soils and rocks. They are extensively used for the investigation of soils which are dificult to sample, particularly fills. The test is carried out by monitoring the settlement of an incrementally loaded bearing plate usually between 150 mm and 1 m diameter until either failure takes place or a load equal to three times the design value has been applied. Frequently, the loading is cycled in order to study hysteresis effects. The tests are usually carried out in trial pits although they can be undertaken in large diameter boreholes. In all cases care has to be taken to ensure that the ground surface immediately beneath the plate is not in a disturbed condition (Marsland 1973b).

4. (b)Describe the mineralogical composition, texture, engineering properties and uses of Dolerite, Laterite, Sandstone and Limestone. [N/D-15]

DOLERITE

Dolerite is a dark, fine grained black or dark greenish black igneous rock. It is intermediate in composition and melanocratic (dark coloured) rock . Mineralogically and chemically, dolerite is similar to Gabbro and basalt.

Composition: Dolerite consists of Plagioclase Feldspars and pyroxene (augite). Iron oxides, hypersthene and biotite occur as common accessory minerals. Olivine is some times found if the parent magma was deficit of silica.

Texture: Dolerite is a massive and compact rock. It is neither porous nor permeable. The texture in dolerites is generally equigranular. Interlocking texture is also common in dolerite. Under the microscope dolerite exhibit Ophitic or subophitic texture.

Hand specimen: Dolerite is a fine grained rock with greenish black or black coloured. Presence of pyroxene (augite) contributes the black color of a rock. Feldspars can be observed by means of their cleavage surfaces and biotite if present appears as small, jet black..

Varieties: When all the minerals of dolerite are totally altered for eg: plagioclase into zoisite or epidote and augite into chlorite / hornblende and olivine into serpentine then the rock is called DIABASE.

Plutonic equivalent of dolerite is called Gabbro.

Volcanic equivalent of dolerite is called Basalt.

Glassy equivalent of dolerite is called trachylyte.

SPECIAL FEATURES: The compact nature and rich in mafic minerals make the rock emit metallic sound when hit with a hammer. Dolerite occurs in nature as an intrusive rock ie as dyke.

ENGINEERING POINT OF VIEW: Dolerites are not common as building stones. They are suitable as road metal, railway ballast, bitumen aggregate, concrete purposes. At foundation sites of dam like structures, the presence of dolerite is considered undesirable as they become a cause for weak planes.

Sandstones

Sandstones are abundant among sedimentary rocks but are next to shales. Sandstones are made up of sand and described as Arenaceous rocks. Sandstones are stratified and sometimes fossiliferous too. Compositionally, sandstones consist of sand grains (90% quartz) with accessory minerals of such as mica, ilmenite, magnetite, garnet, zircon, rutile, feldspars cover the rest.

In a hand specimen of sandstone, the size of sand grains may be coarse, medium or fine grained and other grains appear in different colors due to the presence of cementing material:

Grains	Appears as
Quartz	Colorless, fresh with vitreous lustre
Mica flakes	White colour with perfect cleavage
Ilmenite / magnetite	Jet black
Garnet	Red with shining
Zircon; rutile	White color with shining
Feldspars	Pale colours of brown, red, white, grey with a dull lustre
Pyroxenes & amphiboles	Pale colors

Sandstones are generally porous and permeable and considered one of the best aquifers. By virtue of their porosity and permeability, they are not only capable of holding a good quantity of groundwater but also yield the same when tapped.

LIMESTONES

LIMESTONES: In hand specimens, limestones show different colours of white, gray, buff, cream, pink, yellow and black. In nature, limestones occur both as porous and massive types. On the other hand, shell limestones care common and may be porous.

Types of Limestones:

Chalk: A soft, white fine grained calcareous deposit with dull lustre. It is also consists of fossils viz., foraminifera.

Stalactites result from the process when surface water with dissolved calcium carbonate pass through minute fractures and grows downwards from the roof of a cave.

If the rate of percolation of solution is excess than required evaporation, the solution falls on floor and form as a cone like deposit which grows upwards from the floor is called as Stalagmites.

If growth continues stalactites and stalagmites may come together after some time producing a pillar like structure , called a DRIP STONE.

Fossiliferous or Shell limestone: These are formed organically with hard parts of marine organisms of coral reefs or gasteropods or lamellibranchs or brachiopods etc.

5. Write an essay on engineering properties and uses of granite. [M/J-16]

GRANITE is a plutonic igneous rock, compact, massive and hard rock. Granites are unstratified but characterized by joints. It is a holocrystalline (completely crystalline) and leucocratic (light coloured) rock .

Composition: Granite consists of quartz (> 20 – 30 %), Feldspars (60%) include alkali feldspars (orthoclase, microcline) and plagioclase feldspars (oligoclase), micas as essential minerals and accessory minerals are mafic minerals such as hornblende, biotite / muscovite , pyroxenes of hypersthenes; augite ; diopside ; magnetite / haematite, rutile, zircon, apatite, garnet..

Texture: Granites exhibit phaneric texture (coarse grained), or graphic texture (similar to Arabic writing). Granites are usually equigranular but some times show inequigranular texture in case of Porphyritic texture (feldspars occur as phenocrysts).

Hand specimen: Granite is grayish or pinkish in color. Feldspar appears with white or brownish – red color. Quartz looks colorless. Biotite is jet black and is found as small shining flakes. Hornblende is dark greenish black.

Varieties: When quartz decreases and increase in mafic minerals, granite passes over to GRANODIORITE and then DIORITE.

When both the alkali feldspars and plagioclase feldspars are equal in quantity, the granite rock is called as ADAMELLITE.

If hypersthene is more in granite then it is known as CHARNOCKITE.
If feldspars and quartz are very large in size and exhibit interlocking texture, then it is called as PEGMATITE. Occurrence of large sized beryl, tourmaline crystals is another diagnostic feature of pegmatite.

RHYOLITE is very fined grained rock and is the volcanic equivalent of granite.

When the accessory minerals present more in quantity than normally such rocks are named as eg; biotite-granite, hornblende-granite. Based on the color of feldspars, the granites are termed as Pink granite; grey granite.

SPECIAL FEATURES:

Specific gravity of granite is 2.6 – 2.8

Density = 2500 – 2650 kg/cm3; compressive strength = 1000 – 2500 kg /sq cm

ENGINEERING POINT OF VIEW: By virtue of many desirable qualities, granite can be used in foundations of civil structures, building stone, road metal,. Tunneling through granite does not require any lining.

6. Write an essay on engineering between igneous rock, metamorphic rock and sedimentary rock on the basis of structure and texture. [M/J-16]

CLASSIFICATION OF IGNEOUS ROCKS: Igneous rocks are the first formed rocks in the earth's crust and hence these are called PRIMARY ROCKS, even though igneous rocks have formed subsequently also.

Igneous rocks are the most abundant rocks in the earth crust and are formed at a very high temperature directly as a result of solidification of magma since magma is the parent material of igneous rocks. The temperature increases proportionately with the depth --- this is one of the reasons for the formation of igneous rocks.

Igneous rocks are usually massive, unstratified, unfossiliferous and often occur as intrusive cutting across other rocks (country rocks or host rocks). The igneous rocks are classified based on silica%, silica saturation and depth of formation.

METAMORPHIC ROCKS

Igneous and sedimentary rocks which are formed under a certain physico-chemical environment, (they were in equilibrium) in terms of temperature, pressure and chemically active fluids. Subsequent to their formation if any of these factors changes, the existing equilibrium gets disturb in the constituent minerals of parent rocks by metamorphism. As a result of Metamorphism

1. Granite changes to Granitic Gneiss
2. Peridotite (Ultrabasic) changes to Serpentine / Talc Schist.
3. Gabbro / Dunite changes to Hornblende Schist.

4. Sandstone changes to Quartzite.
5. Limestone changes into Marble.
6. Shale changes into Slate

The process of metamorphism occuring in rocks due to the effect of high temperature, pressure and chemically active fluids and are known as metamorphic agents. These three act together to cause metamorphism and sometimes any one or two of them dominate and play an active role.

Temperature: Metamorphic changes mainly take place in the temperature range of 350°C to 850°C.

Pressure: Uniform pressure (vertically downwards) increases with depth and effect on liquids and solids at greater depths whereas the direct pressure (stress) due to tectonic forces acts in any direction i.e., upwards, downwards and side wards and effect only on solids.

Chemically inactive fluids: The most common liquid is water. Also the magma or hot hydrothermal solutions (containing various chemicals) may react directly with those rocks when they come in contact.

Types of Metamorphism:

1. Thermal Metamorphism (Heat predominant)

2. Dynamic/Cataclastic Metamorphism: When direct pressure is predominant and acts, rocks are forced to move past resisting in their crushing and granulation.

3. Geo-Thermal Metamorphism: Uniform pressure is predominant alongwith heat brings changes in oceanic salt deposits but not changes in silicate rocks.

4. Metasomatic Metamorphism (chemically active fluids predominant): This Metamorphism alters the composition of the rock significantly. Hydrothermal solutions are hot (upto 400°C) and cause for providing new minerals such as Pb, Zn, Mn etc. Tourmaline, topaz and fluorspars are produced when the volatiles involved .

   Eg: When Granite is attacked by watervapour, Boron, fluorine will suffer mineralogical changes where by feldspars replaced by tourmaline, the resultant rock may be Tourmaline Granite.

5. Dynamothermal Metamorphism: (Direct pressure and Heat pressure): When an argillaceous rock (shale) undergo Dynamo Thermal Metamorphism different minerals are produced. Eg. Gneisses and schists.

   Chlorite → Biotite → Garnet → Staurolite → Kyanite → Sillimanite

- The presence of chlorite and biotite in a metamorphic rock indicates that it had been formed under low grade Metamorphism.
- Presence of Garnet and Staurotite indicates medium grade of Metamorphism.
- Occurrence of Kyanite and Sillimanite indicates high grade of Metamorphism.

Mineral Composition: Following are the common minerals found in metamorphic rocks:

Cordite, Staurotite, Andaulusite; Sillimanite, Kyanite, idocrase formed during Metamorphism. Garnet, Chlorite, Talc, Epidote, Quartz, Feldspars, Pyroxenes, Calcite, Mica, Hornblende also occur in different ways due to Metamorphism.

FORMATION OF SEDIMENTARY ROCKS:

Sedimentary rocks are formed by simple or complex mechanical or chemical processes. Biological activity is often involved in many cases in association with these processes. Sedimentary rocks are broadly grouped into three classes depending upon their mode of formation: clastic rocks (mechanically formed); chemically formed and organically formed sedimentary rocks.

Mechanical weathering is the breakdown of rock into particles without producing changes in the chemical composition of the minerals in the rock. Ice is the most important agent of mechanical weathering. Water percolates into cracks and fissures within the rock, freezes, and expands. The force exerted by the expansion is sufficient to widen cracks and break off pieces of rock. Heating and cooling of the rock, and the resulting expansion and contraction, also aids the process. Mechanical weathering contributes further to the breakdown of rock by increasing the surface area exposed to chemical agents.

Chemical weathering is the breakdown of rock by chemical reaction. In this process the minerals within the rock are changed into particles that can be easily carried away. Air and water are both involved in many complex chemical reactions. The minerals in igneous rocks may be unstable under normal atmospheric conditions, those formed at higher temperatures being more readily attacked than those which formed at lower temperatures. Igneous rocks are commonly attacked by water, particularly acid or alkaline solutions, and all of the common igneous rock forming minerals (with the exception of quartz which is very resistant) are changed in this way into clay minerals and chemicals in solution.

Rock particles in the form of clay, silt, sand, and gravel are transported by the agents of erosion (usually water, and less frequently, ice and wind) to new locations and redeposited in layers, generally at a lower elevation. These agents reduce the size of the particles, sort them by size, and then deposit them in new locations. The sediments dropped by streams and rivers form alluvial fans, flood plains, deltas, and on the bottom of lakes and the sea floor. The wind may move large amounts of sand and other smaller particles. Glaciers transport and deposit great quantities of usually unsorted rock material as till.

These deposited particles eventually become compacted and cemented together, forming clastic sedimentary rocks. Such rocks contain inert minerals which are resistant to mechanical and chemical breakdown such as quartz. Quartz is one of the most mechanically and chemically resistant minerals. Highly weathered sediments can contain several heavy and stable minerals, best illustrated by the ZTR index.

7. Outline the various Engineering properties of rocks, and give a detailed account of the laboratory and field tests to be carried out to estimate such properties. [N/D-16]

Field testing and, to a lesser extent, geophysical surveying are major sources of both qualititive and quantitative data relating to the ground conditions. In spite of the fact that in most cases field testing is more expensive to carry out than sampling and laboratory testing, it forms an essential part of many site investigations. There are several reasons for this, probably the most important of which is because it provides, for design purposes, parameters which represent a more realistic appraisal of geotechnical ground conditions than is commonly the case with laboratory testing. Samples which are used for laboratory testing, because of their small size, may not be sufficiently representative of the ground from which they were taken. In particular, they may not contain large-scale discontinuities, present in the rock or soil mass, which significantly influence the engineering properties of the materials concerned. Furthermore, sampling inevitably involves some disturbance to the stress conditions and water content of soils and rocks so that parameters obtained in the laboratory may not be fully representative of the in situ conditions. Although not without some problems of its own, field testing overcomes many of these difficulties. However, with in situ tests it can be difficult to test materials at appropriate stresses, or in such a manner that changes in the stress, and other conditions due to engineering works, can properly be taken into account.

Penetration tests

Two types of penetration tests are recognized (Anon 1975 and 1981). The standard penetration test (SPT) is a dynamic method in which a 51 mm external diameter split tube sampler connected to drilling rods, is driven into the ground by a series of hammer blows delivered at the surface. The test is conducted at intervals during the course of boring and it provides a distributed sample for identification purposes. In the static penetration test a conical point is driven into the ground by means of a steady pressure on the top of the rods. Both tests provide an indirect measure of shear strength since the action of the tests produces a complex failure surface within the soil.

Shear strength tests

Various means of obtaining a direct indication of the in situ shear strength are available. Probably the most widely used of these is the shear vane test but brief reference will also be made to direct shear and triaxial tests. Shear vane test

Vane tests, in which a cruciform arrangement of plates mounted on the end of a rod, which may be enclosed within a guide tube, is inserted into the soil at the base of a borehole or trial pit and twisted, provide an indication of both peak and remoulded undrained shear strengths. Undrained shear strength is calculated from the relationship between torque and angular rotation, the vane dimensions and the maximum torque applied. Remoulded shear strength is measured similarly, after remoulding by rapid rotation of the vane and allowing a short period of time for pore pressures to dissipate. The test is used for very soft to firm, saturated, nonfissured, homogeneous clays.

Plate loading tests

Various forms of plate loading tests provide direct information relating to the strength and settlement characteristics of soils and rocks. They are extensively used for the investigation of soils which are dificult to sample, particularly fills. The test is carried out by monitoring the settlement of an incrementally loaded bearing plate usually between 150 mm and 1 m diameter until either failure takes place or a load equal to three times the design value has been applied. Frequently, the loading is cycled in order to study hysteresis effects. The tests are usually carried out in trial pits although they can be undertaken in large diameter boreholes. In all cases care has to be taken to ensure that the ground surface immediately beneath the plate is not in a disturbed condition (Marsland 1973b).

8. Write detailed notes on the mineral composition, texture, origin, engineering properties and uses of (i) Granite (ii) Dolerite [N/D-16] [N/D-14]

(i) GRANITE is a plutonic igneous rock, compact, massive and hard rock. Granites are unstratified but characterized by joints. It is a holocrystalline (completely crystalline) and leucocratic (light coloured) rock .

Composition: Granite consists of quartz (> 20 – 30 %), Feldspars (60%) include alkali feldspars (orthoclase, microcline) and plagioclase feldspars (oligoclase), micas as essential minerals and accessory minerals are mafic minerals such as hornblende, biotite / muscovite , pyroxenes of hypersthenes; augite ; diopside ; magnetite / haematite, rutile, zircon, apatite, garnet..

Texture: Granites exhibit phaneric texture (coarse grained), or graphic texture (similar to Arabic writing). Granites are usually equigranular but some times show inequigranular texture in case of Porphyritic texture (feldspars occur as phenocrysts).

Hand specimen: Granite is grayish or pinkish in color. Feldspar appears with white or brownish – red color. Quartz looks colorless. Biotite is jet black and is found as small shining flakes. Hornblende is dark greenish black.

Varieties: When quartz decreases and increase in mafic minerals, granite passes over to GRANODIORITE and then DIORITE.

When both the alkali feldspars and plagioclase feldspars are equal in quantity, the granite rock is called as ADAMELLITE.

If hypersthene is more in granite then it is known as CHARNOCKITE.
If feldspars and quartz are very large in size and exhibit interlocking texture, then it is called as PEGMATITE. Occurrence of large sized beryl, tourmaline crystals is another diagnostic feature of pegmatite.

RHYOLITE is very fined grained rock and is the volcanic equivalent of granite.

When the accessory minerals present more in quantity than normally such rocks are named as eg; biotite-granite, hornblende-granite. Based on the color of feldspars, the granites are termed as Pink granite; grey granite.

SPECIAL FEATURES:

Specific gravity of granite is 2.6 – 2.8

Density = 2500 – 2650 kg/cm3; compressive strength = 1000 – 2500 kg /sq cm

ENGINEERING POINT OF VIEW: By virtue of many desirable qualities, granite can be used in foundations of civil structures, building stone, road metal,. Tunneling through granite does not require any lining.

(ii) DOLERITE

Dolerite is a dark, fine grained black or dark greenish black igneous rock. It is intermediate in composition and melanocratic (dark coloured) rock . Mineralogically and chemically, dolerite is similar to Gabbro and basalt.

Composition: Dolerite consists of Plagioclase Feldspars and pyroxene (augite). Iron oxides, hypersthene and biotite occur as common accessory minerals. Olivine is some times found if the parent magma was deficit of silica.

Texture: Dolerite is a massive and compact rock. It is neither porous nor permeable. The texture in dolerites is generally equigranular. Interlocking texture is also common in dolerite. Under the microscope dolerite exhibit Ophitic or subophitic texture.

Hand specimen: Dolerite is a fine grained rock with greenish black or black coloured. Presence of pyroxene (augite) contributes the black color of a rock. Feldspars can be observed by means of their cleavage surfaces and biotite if present appears as small, jet black..

Varieties: When all the minerals of dolerite are totally altered for eg: plagioclase into zoisite or epidote and augite into chlorite / hornblende and olivine into serpentine then the rock is called DIABASE.

Plutonic equivalent of dolerite is called Gabbro.

Volcanic equivalent of dolerite is called Basalt.

Glassy equivalent of dolerite is called trachylyte.

SPECIAL FEATURES: The compact nature and rich in mafic minerals make the rock emit metallic sound when hit with a hammer. Dolerite occurs in nature as an intrusive rock ie as dyke.

ENGINEERING POINT OF VIEW: Dolerites are not common as building stones. They are suitable as road metal, railway ballast, bitumen aggregate, concrete purposes. At foundation sites of dam like structures, the presence of dolerite is considered undesirable as they become a cause for weak planes.

9. Write detailed notes on the mineral composition, texture, origin, engineering properties and uses of (iii) Sandstone and (iv) Marble. [N/D-16] [N/D-13]

BASALT is a black volcanic, massive, fine grained, melanocratic rock. .

COMPOSITION: Basalt consist of plagioclase feldspars (labradorite), Pyroxenes (Augite) and iron oxides (magnetite or ilmenite). Biotite, hornblende and hypersthenes are the other accessory minerals. Pyrite may also seen sometimes. Either quartz or olivine may appear in small amounts depending on the silica content of parent lava.

Structures & Textures: Vesicular and amygdaloidal structures are common in basalts. However, Columnar and flow structures are also observed in some cases. Basalts exhibit aphanitic texture in hand specimens. (ie the minerals are too fine).

Appearance in Hand specimens: Basalt is typically black or greenish grey or greenish black. Non-vesicular, massive in nature. Exhibit a typical aphanitic texture ie extremely fine grained with or without vesicles. Basalts are always unstratified, unfossiliferous and do not react with acids.

VESICULAR BASALT: it is characterized by the presence of empty cavities or vesicles.

AMYGDALOIDAL BASALTS is a vesicular basalt with cavities filled up by secondary minerals of silica (quartz, amethyst, opal, agate); zeolites, calcite. Among these, silica minerals may be used as semi-precious gemstones.

SPILLITE is a soda-rich basalt in which plagioclase feldspar is albite or oligoclase in stead of labradorite.

Dolerite is the hypabyssal equivalent of basalt .
Gabbro is plutonic equivalent of Basalt .
Trachylite is equivalent of glassy basalt
Alkali Basalt is unsaturated basalt
Tholeite is oversaturated basalt

Uses: Massive basalts are highly durable and strongest having highest load bearing capacity. Used as building stones. Basalts are excellent for macadam and bitumen Roads.

A number of tunnels have been made across through the Deccan traps for railway lines near Bombay. They need no lining except sealing where the weak planes or joints are observed to prevent seepage.

Rhyolite is an igneous, volcanic rock of felsic (silica-rich) composition (> 69% SiO_2). It may have any texture from glassy to aphanitic . The mineral assemblage is usually quartz, alkali feldspar and plagioclase. Hornblende is a common accessory mineral.

Rhyolite can be considered as the extrusive equivalent to the plutonic granite rock, and consequently, outcrops of rhyolite may bear a resemblance to granite.

Rhyolites that cool too quickly to grow crystals form a natural glass or vitrophyre, also called obsidian. Slower cooling forms microscopic crystals in the lava and results in textures such as flow foliations, spherulitic, nodular etc.. Some rhyolite is highly vesicular pumice..

Gabbro refers to a large group of dark, coarse-grained, intrusive mafic igneous rocks chemically equivalent to basalt. The rocks are plutonic, formed when molten magma is trapped beneath the Earth's surface and cools into a crystalline mass.

The vast majority of the Earth's surface is underlain by gabbro within the oceanic crust, produced by basalt magmatism at mid-ocean ridges.

Gabbro is dense, greenish colored and contains pyroxene, plagioclase, amphibole, and olivine (olivine gabbro when olivine is present in a large amount).

The pyroxene is mostly clinopyroxene; small amounts of orthopyroxene may be present. If the amount of orthopyroxene is substantially greater than the amount of clinopyroxene, the rock is then a norite. Quartz gabbros are also known to occur and are probably derived from magma that was over-saturated with silica.

Essexites represent gabbros whose parent magma was under-saturated with silica, resulting in the formation of the feldspathoid mineral nepheline. Gabbros contain minor amounts, of iron-titanium oxides such as magnetite, ilmenite. Gabbro is generally coarse grained, with crystals in the size range of 1 mm or greater. Finer grained equivalents of gabbro are called diabase. Gabbro is usually equigranular in texture, although it may be porphyritic at times, especially when plagioclase oikocrysts have grown earlier than the groundmass minerals.

Uses: Gabbro often contains valuable amounts of chromium, nickel, cobalt, gold, silver, platinum, and copper sulfides.

Syenite is a coarse-grained intrusive igneous rock of the same general composition as granite but with the quartz either absent or present in relatively small amounts (<5%).

The feldspar component of syenite is predominantly alkaline in character (usually orthoclase) . Plagioclase feldspars may be present in small quantities, less than 10%.

When present, ferromagnesian minerals are usually hornblende amphibole, rarely pyroxene or biotite. Biotite is rare, because in a syenite magma most aluminium is used in producing feldspar.

Syenites are usually peralkaline and peraluminous, with high proportions of alkali elements and aluminium.

Syenites are formed from alkaline igneous activity, generally formed in thick continental crustal areas. To produce a syenite, it is necessary to melt a granitic flow to a fairly low degree of partial melting. This is required because potassium is an incompatible element and tends to enter a melt first, whereas higher degrees of partial melting will liberate more calcium and sodium, which produce plagioclase, and hence a granite, adamellite or tonalite.

At very low degrees of partial melting a silica undersaturated melt is produced, forming a nepheline syenite, where orthoclase is replaced by a feldspathoid such as leucite, nepheline or analcime.

(iii)

Sandstones

Sandstones are abundant among sedimentary rocks but are next to shales. Sandstones are made up of sand and described as Arenaceous rocks. Sandstones are stratified and sometimes fossiliferous too. Compositionally, sandstones consist of sand grains (90% quartz) with accessory minerals of such as mica, ilmenite, magnetite, garnet, zircon, rutile, feldspars cover the rest.

In a hand specimen of sandstone, the size of sand grains may be coarse, medium or fine grained and other grains appear in different colors due to the presence of cementing material:

Grains	Appears as
Quartz	Colorless, fresh with vitreous lustre
Mica flakes	White colour with perfect cleavage
Ilmenite / magnetite	Jet black
Garnet	Red with shining
Zircon; rutile	White color with shining
Feldspars	Pale colours of brown, red, white, grey with a dull lustre
Pyroxenes & amphiboles	Pale colors

Sandstones are generally porous and permeable and considered one of the best aquifers. By virtue of their porosity and permeability, they are not only capable of holding a good quantity of groundwater but also yield the same when tapped.

(iv) MARBLE: It is a calcareous metamorphic rock and not hard or strong or durable. Its value is due to its pleasant color, good appearance, easy workability and the ability to take an excellent polish.

Color: Milky white. However, pleasant shades of green, yellow, brown, ;blue or grey colours also seen.

Acid test: Marbles react vigorously even with cold and dilute acids.

Grain size: Fine to medium or even coarse grained and the rock is equigranular.

Texture and Structure: Granulose structure is common. . No foliation occurs.

Minerals present: calcite usually make up the bulk of Marble. The other minerals which may also occasionally occur in marbles are serpentine, olivine, garnet, graphite, mica, talc, tremolite, pyrite. mica, garnet, feldspar, pyroxenes; chlorite, kyanite, epidote, magnetite etc..

Types: Based on their colors, different varieties of marbles are named as white marble; pink marble; green marble.

Important feature of marble: The famous Taj Mahal of Agra constructed out of marble, is regarded as one of the Seven Wonders of the World.

Origin: Marbles are formed due to thermal metamorphism of limestones.

Properties and uses of civil engineering importance: Physically, the mineral calcite is not only soft but also has three sets of well developed cleavages. This inherent weakness makes the rock split or break easily under loads. Marbles provide aesthetic beauty and a pleasing appearance to the constructions and specially chosen for face works, wall panels; flooring, statue making etc. Marbles are not used as road metal, aggregate for concrete due to soft and weak characters.

10. Explain clastic rocks: [N/D 13] [M/J 14]

These sedimentary rocks are formed through a number of steps.

(a) Decay and disintegration: preexisting rocks everywhere on the surface of the earth are exposed to natural process of decay and disintegration like weathering and erosion. The original hard coherent rocks are loosened, decomposed in some cases and the grains and particles so obtained are transported to places of deposition (sea floor, lake basins and river channels). The disintegrated product is often called detritus. Hence, these rocks are also sometimes called detrital rocks.

(b) Gradual deposition: the sediments as produced through weathering and erosion and transported to depositional basin start settling there. Those sediments which are carried in suspension settle down on the floor of the basin in accordance with their density, size and shape, forming layers. The particles that have been transported in solution are first precipitated due to evaporation and then settle down. Deposition generally takes place under ordinary temperature and pressure conditions.

(c) Compaction and consolidation - diagenesis: the sediments accumulate at first in the form of layers or heaps but gradually these get transformed into cohesive, hard and massive rocks when conditions are favorable. This process of transformation of loose particles into hard cohesive rock- like masses is called **diagenesis.** It may be achieved by either of the two methods: welding or cementation.

Welding is the process of compaction and consolidation of the sediments accumulated in a basin due to pressure. This results in squeezing out all or most of the water from in between the sediments, which are brought together so that their boundaries almost until together. Pressure is most commonly due to the load of the overlying sediments it is also due to earth movements, which if too intense, results in the formation of a metamorphic rock. The degree of packing of the grains in a sedimentary rock depends on the extent of welding undergone by the sediments.

Cementation is the process by which lose grains in a sedimentary deposit are held together by a foreign binding or cementing material. These binding substances are commonly supplied by percolating waters which are rich in carbonates of calcium and magnesium, oxides of iron and silicon, and clay.

CHEMICALLY FORMED (NON_CLASSIC)ROCKS

Water is a great solvent. Water from springs, streams, river, lakes and seas dissolves many compounds from the rocks with which it comes into contact. Under favorable conditions, a stage is reached when a part of this water may become saturated with one or more of the dissolved components. This may be followed by precipitation of salts as crystalline substances and their gradual accumulation in the basin. The Rock Salt (NaCl) is formed more or less by this method. In other cases, precipitation of a salt may take place due to loss of some constituent of the water. Limestone is formed by precipitation from carbonated water due to loss of carbon dioxide. Such chemically formed rocks fall in two categories: precipitates and evaporates. Gypsum, anhydrite, rock salt and limestone are a few examples.

(c) ORGANICALLY FORMED (NON-CLASTIC) ROCKS:

More than 70 per cent of the globe is covered by oceans and seas. These extensive and immense water bodies contain a variety of animal and plant life. The hard parts of many sea organisms are constituted chiefly of carbonates of calcium. Death and decay of these organisms within the water bodies gradually results into huge accumulations of carbonate materials. Which get compacted and consolidated with the passage of time. Limestone is very often compacted and consolidated form of remains of these organisms. Generally the evidence of the source material gets obliterated from these rock bodies due to compaction but in many cases it may be quite easy to determine the source. The coral limestones, for instance, can be easily recognized as having resulted from the tiny shells of organisms called corals. Summarising, the formation of sedimentary rocks involves the cooperative operations of processes like weathering, erosion, transportation and deposition of sediments as well as solution and precipitation as also the accumulation of organic remains.

Sediment Texture

Clastic sediment textures have been described in previous modules (i.e. Advanced Logging Procedures Workbook), and a complete understanding is necessary for both cuttings sample and core descriptions. This description will form the basis of all subsequent interpretation of the cuttings, the rock and the formation. The most commonly described clastic textures include:

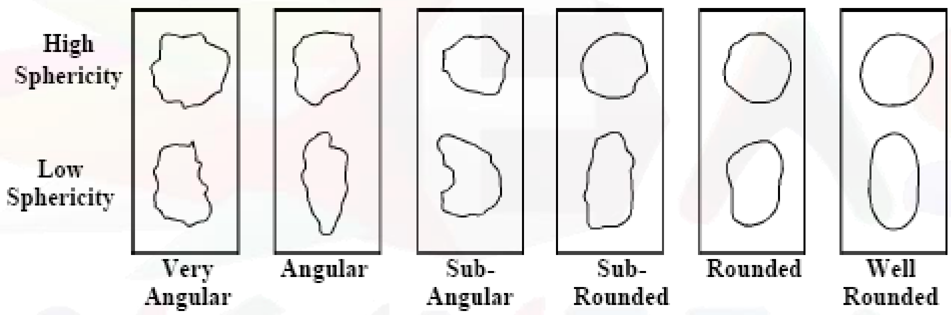
Grain Size: This parameter reflects (1) the kinds and sizes of particles available from different kinds of bedrock or pre-existing sediments, (2) the resistance of particles to weathering, erosion, and abrasion, and (3) the processes of transportation and deposition. Some authors go into great detail about the statistical analysis of grain size and sorting to predict depositional environment. Though they are not expected to perform statistical analyses at the wellsite, the geologist should understand the key words and topics concerning: 1. The scales defining the various grain size delineations 2. Frequency distribution curves depicting skewness Sorting and how the terms relate to depositional environments'

Grain Shape: Shape describes the geometric form of particles, which reflects the origin, history, and internal lattice structure of the particles. Many times qualitative information on processes can be obtained from the shape of particles. Particle shape is modified by abrasion during transport, being dependent upon; (1) initial shape when liberated from the source rock, (2) composition, (3) hardness, brittleness, or toughness, (4) inherited partings, (5) size, (6) agent of transport, (7) rigors of transport, and (8) other random effects.

Grain Texture: Transport in running water does not significantly affect the shape of hard sand-size particles. However, transport by water, wind, and glacial ice does affect the surface textures. Abrasion creates pits, fractures and various surface markings reflect the origin of the particle. As the environment\ of transport changes, or becomes affected by other lithification cycles, the surface patterns of particles can reflect a complex history. Old markings become obscured and new ones take their places. When this happens, reconstruction of the particles history using surface features is only partially feasible.

Grain Fabric: The porosity of sediments varies according to the size, shape, and fabric of the framework particles, and the presence of any cementing agentm between the particles. The fabric is affected by the manner in which the particles were laid down and the resulting structure of the inter pore connections.

Sphericity: The degree to which a particle approximates the shape of a sphere. This expresses how equal the three mutually perpendicular dimensions of a particle are to one another. The rock type controls the sphericity.



Porosity and Permeability

When one discusses porosity and permeability in the oil fields, the primary concerns are the concepts of absolute and effective porosity. A reservoir will have a given amount of void space. If these voids are not connected, production will be limited. This “effective” porosity, in conjunction with permeability, dictates the ultimate quality of the reservoir. Porosity consists of primary and secondary forms. Primary porosity is formed when the sediment is originally deposited. Secondary porosity results from diagenesis by solution and replacement. Some clastic porosity forms from tectonic activity. The primary porosity in sandstones is principally interparticle (between the grains). Though not true theoretically, as a general rule, the larger the grain size, the higher the porosity. This porosity will decrease during the formation of clays and alteration products after deposition. Compaction and cementation after deposition will also reduce the absolute porosity. Generally, porosity decreases as depth increases. However, cementation is the principal process leading to porosity loss in sandstones. There are three types of pore communication within clastics: 1. Catenary porosity - pores that have communication with others via 2 or more pore throats. 2. Cul-de-sac porosity - those that have communication via only 1 throat. 3. Closed pore communication. Types 1 and 2 make up “effective porosity”.

Darcy's law for permeability is only valid when 1 fluid phase is present. When more than one fluid is present (the norm in any reservoir) the term effective permeability is sometimes used, meaning one rock may have three permeability values; effective permeability for oil, water and gas. Permeability can vary greatly depending on orientation (e.g. vertical permeability maybe far lower than horizontal permeability) for the same rock, especially if micas are abundant. Permeability may also be strongly influenced by cross-bedding and other sedimentary structures.

Mudrocks

Although sandstones and limestones are of primary concern in oil and gas exploration, the most abundant sediments are mudrocks (shales, claystones, etc.). These comprise about half of all the sediments. Mudrocks (Table 1-1) are deposited in practically every environment, with the primary environments of deposition being river floodplains, lakes, large deltas, the continental shelves and platforms, and the ocean floors Another major type of clay mineral is the three layer group. These have sheetstructures composed of two layers of silica tetrahedra interleaved with aluminum di- and tri-octahedra. The most widely known examples are the smectite and illite groups.

Table 1-1: Chemical Analysis of Typical Clay Minerals

	Kaolinite	Montmorillonite	Illite	Chlorite	Glauconite
SiO_2	45.44	51.14	42.96	26.28	52.64
Al_2O_3	38.52	19.76	28.97	25.20	5.78
Fe_2O_3	0.80	0.83	2.27	-	17.88
FeO	-	-	0.57	8.70	3.85
MgO	0.08	3.22	1.32	26.96	3.43
CaO	0.08	1.62	0.67	0.28	0.12
Na_2O	0.66	0.04	0.13	-	0.18
K_2O	0.14	0.11	7.47	-	7.42
H_2O-	0.60	14.81	3.22	-	2.83
H_2O+	13.60	7.99	6.03	11.70	5.86

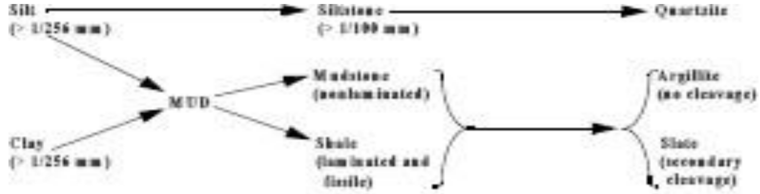


Figure 1-5 Terminology of Mudrocks

Sedimentary facies

Sedimentary environments usually exist alongside each other in certain natural successions. A beach, where sand and gravel is deposited, will usually be bounded by a deeper marine environment a little offshore, where finer sediments are deposited at the same time. Behind the beach, there can be dunes (where the dominant deposition is well sorted sand) or a lagoon (where fine clay and organic material is deposited). Every sedimentary environment has its own characteristic deposits. The typical rock formed in a certain environment is called its sedimentary facies. When sedimentary strata accumulate through time, the environment can shift, forming a change in facies in the subsurface at one location. On the other hand, when a rock layer with a certain age is followed laterally, the lithology (the type of rock) and facies will eventually change.

Shifting sedimentary facies in the case of transgression (above) and regression of the sea (below). Facies can be distinguished in a number of ways: the most common ways are by the lithology (for example: limestone, siltstone or sandstone) or by fossil content. Coral for example only lives in warm and shallow marine environments and fossils of coral are thus typical for shallow marine facies. Facies determined by lithology are called lithofacies; facies determined by fossils are biofacies.

Sedimentary environments can shift their geographical positions through time. Coastlines can shift in the direction of the sea when the sea level drops, when the surface rises due to tectonic forces in the Earth's crust or when a river forms a large delta. In the subsurface, such geographic shifts of sedimentary environments of the past are recorded in shifts in sedimentary facies. This means that sedimentary facies can change either parallel or perpendicular to an imaginary layer of rock with a fixed age, a phenomenon described by Walther's facies rule.

The situation in which coastlines move in the direction of the continent is called transgression. In the case of transgression, deeper marine facies will be deposited over shallower facies, a succession called onlap. Regression is the situation in which a coastline moves in the direction of the sea. With regression, shallower facies will be deposited on top of deeper facies, a situation called offlap. The facies of all rocks of a certain age can be plotted on a map to give an overview of the palaeogeography. A sequence of maps for different ages can give an insight in the development of the regional geography.

Sedimentary Structures

Sedimentary structures are used to identify the agents of deposition and the resulting changes in that depositional environments that the sediments experienced after they were laid down). At the wellsite, one of the most important structure that can be recognized from cores and, at times, cuttings samples is the bedding type.

Inorganic Structures Mechanical (primary)	Chemical (secondary)	Organic Structures
A. Bedding: Geometry 1. Laminations 2. Wavy Bedding	A. Solution Structures 1. Stylolites 2. Corrosion zones 3. Vugs, Oolicasts	A. Petrifactions
B. Bedding: Internal Structures 1. Cross-Bedding 2. Ripple-Bedding 3. Graded Bedding 4. Growth Bedding	B. Accretionary Structures 1. Nodules 2. Concretions 3. Crystal Aggregates 4. Veinlets 5. Color Banding	B. Bedding 1. Stromatolites
C. Bedding Plane Markings (on sole) 1. Scour or Current Marks 2. Tool Marks	C. Composite Structures 1. Geodes 2. Septaria 3. Cone-in-Cone	C. Miscellaneous 1. Borings 2. Tracks & Trails 3. Casts & Molds 4. Fecal Pellets
D. Bedding Plane Markings (on surface) 1. Wave & Swash marks 2. Rain Pits & Prints 3. Parting lineation		
E. Deformed Bedding 1. Load & Founder structures 2. Synsedimentary folds 3. Sandstone dikes & sills		

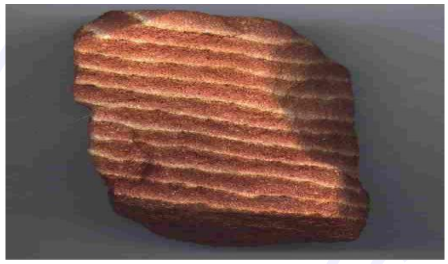
11. Explain in detail structures of sedimentary rocks: [N/D 13]

The terms structure includes some large scale features developed in the rocks during the process of their formation. These can be studied under following three headings.

Mechanical structures

These are the most prevalent structure includes some large scale features developed in the rocks during the process of their formation. These can be studied under following three specific types.

Stratification: by stratification is understood a layered arrangement in a sedimentary rock. This may be developed very prominently a can be seen from a distance or only slightly and may be detected after close examination. The different layers (also called beds or strata) may be of similar or similar or dissimilar colour, grain size and composition. The beds are separated from each other by planes of weakness- the bending planes. The thickness of each layer in a sedimentary formation may show great variation: from a few centimeters to many meters. in lateral extension, the layered structure may continue for several kilometers or even hundreds of kilometers. Further, the layers may be horizontal, slightly dipping, steeply dipping or even overturned, folded and faulted, depending upon the forces that have acted upon them after their formation.



Bedding

Bedding is probably the most important feature of a sedimentary rock, and as such is the most widely used term in describing a sedimentary sequence. A "single bed" is generally described as a sedimentation unit which has been deposited under essentially constant physical conditions. This single bed is separated from adjoining beds by bedding planes. These bedding planes are visible because of some textural or compositional change between one bed and another.

Bedding is divided into five major types for ease of description:

1. Regular or massive bedding
2. Laminated bedding
3. Graded bedding
4. Current or cross-bedding
5. Slump, or convolute bedding

For example, regular bedding is indicated by parallel bedding surfaces; that is, those divisions in the lithology indicating a pause in the normal process of sedimentation. Between a given set of bedding surfaces, formations are normally uniform, indicating a constant source and transport of sediments Another way of describing bedding is through analysis of the lithology's thickness and its lateral continuity. This allows the division of beds into four gross classifications:

1. Beds more or less equal in thickness.
2. Beds that are not equal in thickness and are laterally uniform and continuous.
3. Beds that are unequal in thickness, but still continuous.
4. Beds that are unequal in thickness and are laterally variable and discontinuous.

Although there is no absolute correlation between bed thickness and grain size, there is a significant relationship. If you look at turbidites as a case in point, the further you go away from the supra-fan channel, the finer the grains will be. This is primarily due to a significant drop in the energy available for transportation. For this same reason, the overall thickness of those beds will be less. This relation of grain size, bedding thickness, and energy (mode) of transport is true for most of the depositional processes. The dip of the bedding surfaces is characteristic and structurally significant when recognized in a core sample in the same way it is in a outcrop. Remember, the long axis of the core represents a section of formation cut\ parallel to the well bore and probably won't be vertical. Because the drill string will likely rotate during the coring process, it is impossible to determine the actual strike of the bedding, unless the core was taken using a specially oriented core barrel. Other than a bed's thickness and areal extent, the next significant features that can be examined are the internal structures. Two major types of structures are recognized, cross bedding and graded bedding (Figure 2-2). These structures can be identified in most clastic rocks, regardless of the grain size.

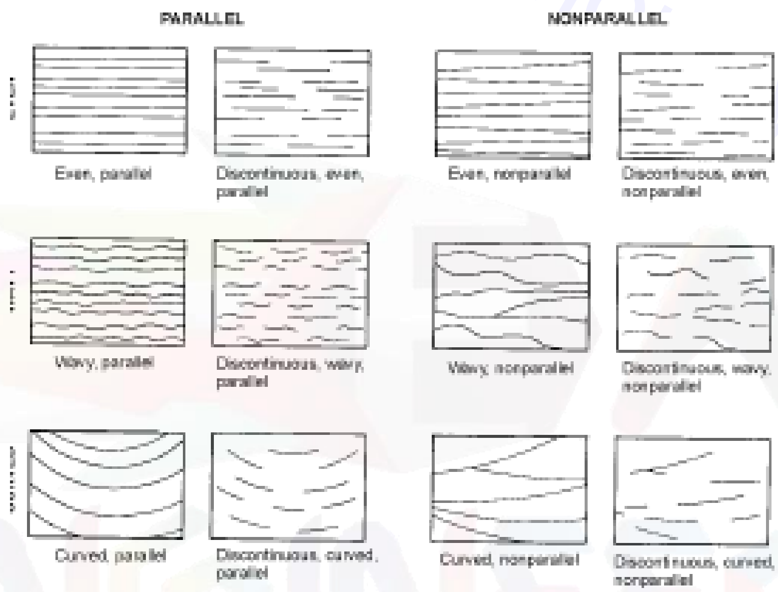


Figure 2-1 Different shapes that can be acquired by beds.

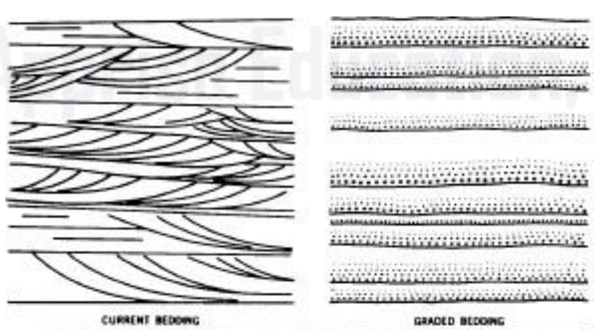
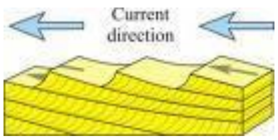


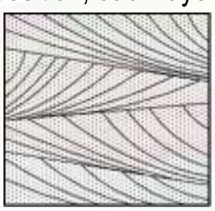
Figure 2-2 Cross Bedding and Graded Bedding.

Cross bedding: it is a sedimentary structure in which layers lying one above another are not parallel but bear an irregular, inclined relationship. Such a structure results in shallow-water deposits when the stream suffers repeated changes in its direction of flow. The structure is sometimes referred as false bedding or current bedding. it is further distinguished into following types:



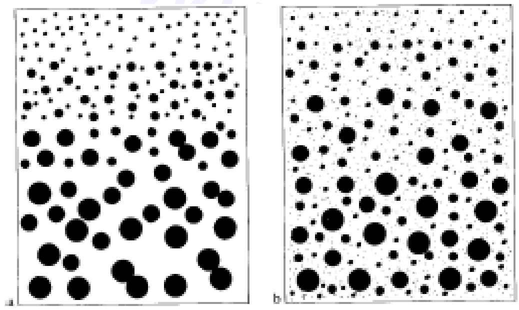
(a) **Tabular:** a type of cross-bedding in which the top and bottom surfaces are essentially parallel but the intervening strata are inclined differently.

(b) **Lenticular:** a type of cross-bedding in which the layers show extreme irregularity in their shape and disposition; each layer or set of beds may be intersected by many others lying at different angles.

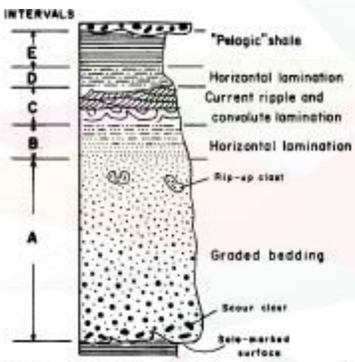


(c) **Wedge shaped:** in this case the structure is highly complex; there are sets of May layers bearing angular relationship. The layers in each set, however, are parallel to each other. The sets are inclined mutually in such a way that they give the appearance of interwoven wedges in vertical cross section.

Graded bedding, or the progressional change in grain size throughout a bed's thickness, is very important to geologists in determining the original top and bottom of a bed as it was laid down. This is especially true in deep water turbidite deposits, where the gradation from coarse to fine sand, or an opposite These beds may range from several centimeters to more than a meter thick, and usually the thicker the graded bed, the coarser the sediments will be at the unit's base. Sometimes, the basal rock is composed of gravel. Graded beds are best described using a depositional model known as the “Bouma Cycle” (Figure 2-5). Bouma recognized during his study of turbidites that the “ideal” graded bed is composed of five basic parts: 1. The lowest unit is definitely graded and is usually the thickest part of the sequence. 2. The second section commonly displays rippled cross lamination. 3. The third unit is composed of indistinctly laminated sandy or silty politic sediments. 4. A poorly defined and often not recognizable unit with horizontal lamination. 5. An upper pelitic interval. Quite often this cycle is not complete, due to the erosional affects of subsequent depositional cycles. It is not surprising, after looking at the character of the Bouma sequence, that many geologists feel that most graded beds are a result of turbidity current type sedimentation. The paleofaunal zones reconstructed from graded beds almost always suggest the sediments were laid down in deep marine waters.



Two basic types of graded bedding; a) no fines and b) fines present as matrix.



2-5 Graded bedding in an "ideal" Bouma cycle.

Mud cracks: these are common structural features of many fine-grained sedimentary rocks. These polygonal or irregular cracks are developed in drying muds. Subsequently, these cracked muds are covered by further layers of sediments but the cracked structure is preserved.

Rain prints: these are marks (depressions of irregular, small crater-like shape) left on the top, dried surface of fine grained muds. Like mud cracks, these also get preserved when the particular layer is covered by subsequent deposits.

Ripple marks: these are also common sedimentary structures of mechanical origin in deposits made in shallow waters. They are defined as symmetrical or unsymmetrical, wavelike undulations or irregularities in a layer. Ripple marks generally unsymmetrical, wavelike undulations or irregularities in a layer. Ripple marks generally result due to wind or wave action on the process of deposition. The fine sediments are dragged from their normal course by the waves developed in the water due to prevailing winds. Later on, these are deposited at places where the waves become weaker or die out.

Bio-genic Sedimentary Structures

Bio-genic structures result from bioturbation, the post-depositional disturbance of sediments by living organisms. This can occur by the organisms moving across the surface of sediment or burrowing into the first few centimeters. It is usually contemporaneous with deposition (Figure 2-10). The magnitude of the structures vary, from the surface trails left by large terrestrial vertebrates to burrows of small marine invertebrates. The organisms that cause these alterations in the sediments have a dual affect. They physically\ and chemically alter the original deposit, and they give some useful information about the bottom conditions at the time of deposition. Depending on the location, these animals can affect up to 90% of the sediment surface. As a result, this biological action can completely destroy primary laminations and, the original orientation of sediment particles. There are usually significant changes in the formations porosity and permeability. This can help determine the origin and magnitude of any abnormal pore pressures. It can also enhance the tendency for slumping and sliding on steep continental margins, as the sediment shear strength is decreased. On the other hand, the increased conduits for pore water migration can enhance cementation, especially in areas where calcareous sediments are deposited. The greatest variety and density of bioturbated sediments are found on marine shelf deposits. More structurally complicated, but less common bioturbation structures can be found in turbidite deposits. Simple burrows are more common in terrestrial (fresh and brackish water) sediments.

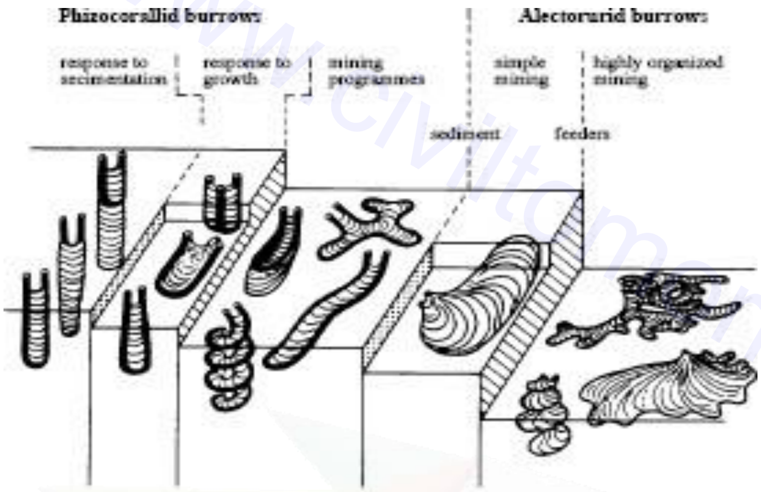


Figure 2-10 Sedimentary structures caused by living organisms.

UNIT IV

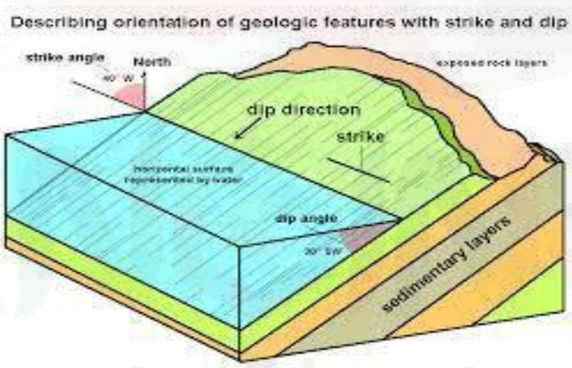
1. How do joints influence the strength of rocks? [N/D-14]

1. Joint characteristics can account for up to 70% of rock strength - a highly jointed granite can be less resistant to erosion than a compact unjointed sandstone.
2. In the absence of joints, the initial rock strength and the state of weathering become most important.

2. Using a diagram, explain the Dip and Strike of rock layers. [N/D-14]

DIP

The dip is defined as the maximum angle of slope of a bed or layer of rocks with the horizontal. It is expressed both in terms of degree of inclination and direction of inclination.



STRIKE

It is a geographic direction of extension of the layers of rocks and may be explained as the direction of intersection of the bedding plane with an horizontal plane. More precisely strike is the compass direction of a horizontal or level line exactly at right angles to the direction of true dip of the beds. A vertical cut made parallel to the strike of the beds shows them as a horizontal series. Only a vertical section cut in the direction art right angles to the strike shows the maximum inclination which is the full or true dip of the beds. Sections cut obliquily show only apparent dip.

3. Differentiate between True Dip and Apparent Dip of rock formation?[N/D-15]

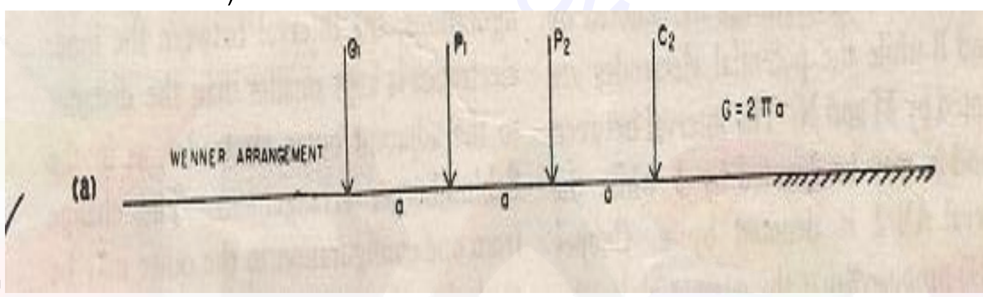
True dip is defined as the maximum angle of dip on a rock bed. It is measured in the direction at right angles to strike. Apparent dip is the dip measured in any other direction other than the true dip.

4. What is meant by Wenner Configuration? [N/D-15]

In Wenner arrangements four electrodes are used. When a current I is introduced into a homogeneous and isotropic ground by means of two electrodes C1 and C2 and the potentials are picked up by the other two electrodes P1 and P2. The voltage between the potential electrodes is given by the formula:

V= ρ /2 pi (1/C1P1-1/C2P1-1/C1P2+1/C2P2)

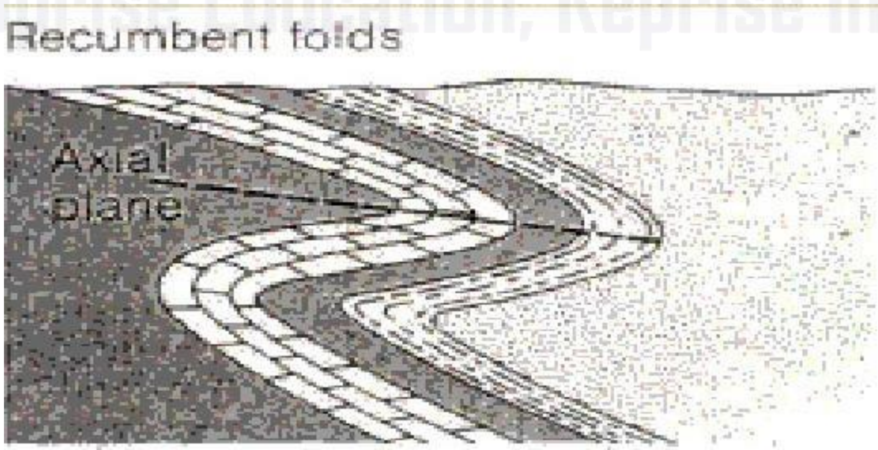
V=I ρ /2 pi (1/AM-1/BM-1/AN+1/BN)



Resistivity,ρ=V/I.2pi.1/G

5. What is meant by a Recumbent folds? Draw a neat diagram.[M/J-16]

An overturned fold, or overfold, has the axial plane inclined to such an extent that the strata on one limb are overturned. A recumbent fold has an essentially horizontal axial plane. Similarly, we can have recumbent folds, which are even more extreme than overturned folds. These are folds that are nearly horizontal. 'Recumbent' means 'lying down,' so you could think of this fold as lying down sideways.



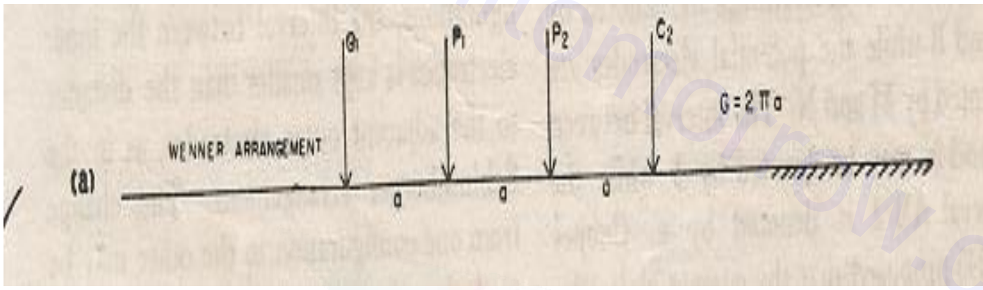
6. What is meant by Wenner's Arrangement? Draw a neat diagram. [M/J-16]

In Wenner arrangements four electrodes are used. When a current I is introduced into a homogeneous and isotropic ground by means of two electrodes C1 and C2 and the potentials are picked up by the other two electrodes P1 and P2. The voltage between the potential electrodes is given by the formula:

V= ρ /2 pi (1/C1P1-1/C2P1-1/C1P2+1/C2P2)

V=I ρ /2 pi (1/AM-1/BM-1/AN+1/BN)

Resistivity ρ =V/I.2 pi.1/G



7. What are joints in rocks? How do they influence the strength of rocks?[N/D-16].

A joint is a break (fracture) of natural origin in the continuity of either a layer or body of rock that lacks any visible or measurable movement parallel to the surface (plane) of the fracture. Although they can occur singly, they most frequently occur as joint sets and systems.

1. Joint characteristics can account for up to 70% of rock strength - a highly jointed granite can be less resistant to erosion than a compact unjointed sandstone.
2. In the absence of joints, the initial rock strength and the state of weathering become most important.

8. What is meant by Wenner Configuration? [N/D-16]

In Wenner arrangements four electrodes are used. When a current I is introduced into a homogeneous and isotropic ground by means of two electrodes C1 and C2 and the potentials are picked up by the other two electrodes P1 and P2. The voltage between the potential electrodes is given by the formula:

V= ρ /2 pi (1/C1P1-1/C2P1-1/C1P2+1/C2P2)

V=I ρ /2 pi (1/AM-1/BM-1/AN+1/BN)

Resistivity ρ =V/I.2 pi.1/G

1. Define cross bedding? [N/D 14] [M/J 15]

   Sedimentary beds or layers are generally parallel to one another. But, sometimes, it has been observed that the beds lie slightly oblique to the major bedding planes.

2. What are the classifications of joints?

a) Geometrical classification

Stricke joints, Dip joints, Oblique joints

b) Genetic classification

Tension joints, shear joints

1. Explain how faults and folds affect the choice of locations for dams and tunnels. [N/D-14]

Investigation of dam site:

Preliminary investigation is done on the site to collect the information about the disadvantages or advantages of the site. This is more flexible because the detailed investigation will be more expensive, extensive and laborious. The important information collected at this stage is based on the factors as followed:

1. Lithology
2. Structure
3. Physiography (Topography)
4. Ground water Conditions.

Lithology provides the details of rocks types occurring in the dam site. The details include the types of rock present, their nature and extent of weathering, the occurrence of soil, rock debris, etc. Lithology also gives a broad idea of the presence or absence of competent rocks, the weathering it has undergone and other related information.

The Structural study gives information on the strike and dip of the beds. It also reveals the occurrence of geological structures like folds, faults, joints, unconformities and foliation. Details of these features are very important because they have a great influence on the suitability of site for dam. Topography (Physiography) gives information about important surface features like valleys, hills, the trend of the river course, slopes and terraces present in the area. These details indicate the stability of the slope and the slope of the occurrence of landslides.

Topographic studies also help in rough assessment of the depth of the bedrock at the site. The nature of seismic activity in the region can also be known by suitable studies. Groundwater conditions are related to the study of occurrence of springs, seepages, swamps, wells etc. present in the selected area. This type of study indicates the water table position and the scope for leakage of water from the associated reservoir. This also indicates the occurrence of solution cavities, if any, in the area.

Detailed Investigation: If the Dam Sites is found to be good in the preliminary investigations, then it is taken up for detailed investigation. This process comprises of surface and subsurface investigations.

Surface investigations: The surface investigations include closer examination of lithology, structure, physiography and groundwater conditions. The thorough investigation of the above factors, with the support of laboratory studies of the materials at the dam site will reveal the conditions of outcrops, faults, joints, folds, & their attitudes, weathering details, soil occurrences, engineering properties like compressive strength, tensile strength, porosity, permeability and durability.

Subsurface investigations: These also include the factors of investigations as said above. But the studies include the study of deeper layers of the dam site for ensuring the standards and safety of the dam.

Tunnels: Tunnels are the underground passages or routes through hills, mountains or earth crust used for different purposes. These passages are made by excavating rocks below the surface or through the hills, mountains.

Types of tunnels: Tunnels are basically made to serve some specific purposes.

For instance: 1. Transportation tunnels: tunnels made across hills or high lands to lay roads or railway tracks for regular traffic and transportation purpose. 2. Traffic tunnels: Tunnels laid to reduce the distance between places of interest across natural obstacles like hills, to save time and provide convenience are called traffic tunnels. These have the advantage of leaving the ground surface undisturbed so that it can be used as desired. 3. Diversion tunnels: The tunnels layed for diverting normal flow of river water to keep the dam site dry are called diversion tunnels. 4. Pressure tunnels: these are also called as hydropower tunnels. These are used to allow water to pass through them under force, used for power generation. 5. Discharge tunnels: These are meant for conveying water from one point to another under gravity force, like across hill. 6. Public utility tunnels: These are the tunnels layed for public supplies like drinking water supply, cables laying, sewage discharge or oil supply etc.

Effect of tunnelling on the ground: Deterioration of the physical conditions of the ground is the common effect of• tunnelling. This happens because due to heavy and repeated blasting during excavatin, the rocks get shattered to a great extent and develop numerous cracks and fractures. This reduces the cohesiveness and compactness of rocks. At normal conditions the earth crust or underground rocks are under great preassre• (overburden) or they will be in association with some geological structures like folding will be at equilibrium stress holding the previaling strain intact. When the tunnel is created, such rocks which are at equilibrium gets distrubed resulting in the collapse of the roof. Freequent bursts may also occur. This phenomenon of fall of rocks in brittle and hard rocks is called Popping. Due to tunnelling, the overlying rocks deprive of support from the bottom and may• become unstable. Such unstable conditions become still more precarious if the tunnelled beds are incompetent or loose or unconsolidated or saturated with ground water.

Lining of tunnels: When tunnels are made through weak or loose or unconsolidated formations, they are provided with suitable lining for safety and stability. Lining refers to the support porvided to tunnel. Lining may be in the form of steel structures or concrete. The main purposes of lining are to resist the pressures from the surroundings and to protect the shape of tunnel. It takes care of the weaknesses of the ground. It also helps in checking leakage of ground water into tunnel. The thickness of concrete lining dependes on the extent of protection required, and the degree of weakness of the ground. It also depends on the overbreak phenomenon. Lining is provided to support weakparts of the tunnel. Lining is also provided in such places where the seepage of water into the tunnel occurs and creating problems. In the case of very weak rocks with unfavorable geological structures, lining may be necessary through out the length of the tunnel. The zones of faulting or shearing also need suitable lining to impart strength to them. Overbreak: During tunneling the excavations normally involve the removal of extra rocks or matter around the tunnel. The quantity of rock broken and removed, in excess of what is required by the perimeter of the proposed tunnel, is known as overbreak.

Factors governing the amout of overbreak: The nature of the rocks.• The orientation and spacing of joints or weak zones in them.• In the case of sedimentary rocks, the orientation of the bedding planes• Thickness of the beds with respec to the alignment of the tunnel.• Geological factors influencing the overbreak: Massive and soft rocks of a homogenous nature cause less overbreak than harder• rocks with well developed joints or weak zones. In sedimentary rocks, thin formations and those with alternating hard and soft strata• produce more overbreak. This is because, during excavation, softer rocks yield more than the hard rocks.

2. Elaborate on the electrical methods used for sub surface investigations. [N/D-14]

The electrical geophysical methods are used to determine the electrical resistivity of the earth's subsurface. Thus, electrical methods are employed for those applications in which a knowledge of resistivity or the resistivity distribution will solve or shed light on the problem at hand. The resolution, depth, and areal extent of investigation are functions of the particular electrical method employed. Once resistivity data have been acquired, the resistivity distribution of the subsurface can be interpreted in terms of soil characteristics and/or rock type and geological structure. Resistivity data are usually integrated with other geophysical results and with surface and subsurface geological data to arrive at an interpretation.

Electrical methods can be broadly classified into two groups: those using a controlled (human-generated) energy source and those using naturally occurring electrical or electromagnetic energy as a source. The controlled source methods are most commonly used for shallow investigations, from characterizing surficial materials to investigating resistivities down to depths as great as 1 to 2 km, although greater depths of investigation are possible with some techniques and under some conditions. The natural source methods are applicable from depths of tens of meters to great depths well beyond those of interest to hydrocarbon development.

Possible applications of electrical methods for the development geologist range from the investigation of soil contaminants and the monitoring of enhanced oil recovery (EOR) projects to reservoir delineation and the evaluation of geological stratigraphy and structure. The application of electrical methods has been primarily confined to the onshore environment. The offshore use of some techniques is possible, particularly for permafrost delineation and shallow marine geotechnical investigations.

Electrical properties of materials

The application, interpretation, and understanding of electrical methods requires a familiarity with the relationship between soil and rock characteristics and the resistivities obtained from electrical data. The resistivity of subsurface rock formations is one of the physical properties determined through the process of logging that is performed on most oil and gas wells, utilizing instrumentation inserted into the wellbore. The concept of formation resistivity plays an important part in log analysis. Although there is a correlation between rock resistivities measured by well logs and those measured by electrical methods, the log is used to investigate properties only in the immediate vicinity of the wellbore while electrical methods yield information on bulk properties averaged over a considerable volume of material.

The resistivity of most soils and rocks (including virtually all of the rocks of interest to hydrocarbon exploration) at the frequencies utilized by electrical methods is controlled by the fluids contained within the rock[1] (see Determination of water resistivity). This is because the dry soil or rock matrix is a virtual insulator at DC and near DC frequencies. The pore fluid is in most cases water, with dissolved salts. The salinity is the primary factor in determining the resistivity of the pore fluid, with pore configuration also playing a part. Of lesser importance at oil reservoir depths is the temperature of the formation. Oil and/or gas, when present, occur over such limited formation thicknesses that their effects on bulk average resistivity is, in most cases, undetectable.

Faulting or fracturing of porous sedimentary formations in most instances has little effect on the bulk average resistivity since the additional fracture porosity changes the already high porosity by only a small percentage. However, in very tight rocks, such as igneous, metamorphic, and nonporous carbonate rocks, where intrinsic porosity is very low, the fluids in joints, cracks, and faulted zones may become the primary conducting paths (see Porosity).

In summary, the factors affecting in situ average resistivity are the total porosity, including fault and fracture porosity, and the resistivity of the fluids present within the rock. The average resistivity can be considered constant over the frequency range of interest to most of the methods under consideration here.

Controlled source methods

Controlled source methods use generated currents or electromagnetic fields as energy sources. An advantage is the control over energy levels and the attendant positive effects on signal to noise ratio in areas of high cultural noise. A disadvantage of controlled source methods is that the complex nature of the source field geometry (the geometry of the electromagnetic field or currents induced with the earth by the transmitter) may present quantitative interpretation problems in areas of complex geology.

In the DC method, a current (usually a very low frequency square wave and not actually direct current) is injected into the earth through a pair of current electrodes, and the resulting potential field is mapped. Various geometries of current and potential electrodes have been employed, with the choice primarily based upon the depth and geometry of the survey target. The measured surface potential field is interpreted in terms of the subsurface resistivity distribution through modeling and inversion techniques.[2] Induced polarization (IP) and complex resistivity (CR) techniques are special cases of the DC method in which the induced potential field is measured and interpreted in terms of mineralogy and/or soil characteristics. IP and CR have been applied with some success to hydrocarbon exploration through the measurement of geochemical alteration halos that have been found to be related to reservoirs under some conditions.

In the electromagnetic (EM) method, an electromagnetic field is produced on or above the surface of the ground.[3] This primary EM field induces currents in subsurface conductors. The induced currents in turn reradiate secondary EM fields. These secondary fields can be detected on or above the surface as either a distortion in the primary field (frequency domain methods) or as they decay following the turning off of the primary field (time domain methods). Both loops and grounded wires are used to generate the source field. Resistivities are calculated from the observed electromagnetic field data using modeling and inversion techniques.

EM techniques have been adapted to a variety of surface and airborne configuration, with the airborne instruments generally limited in penetration to 100 to 200 m. Airborne electromagnetic surveys have proven very effective for mapping the shallow resistivity distribution, leading to cost-effective surveys over large areas. Surface loop or grounded wire systems are applicable to depths well in excess of 1 km, although high power transmitters are required as depth increases. The resolution attainable is normally considered as a percentage of penetration depth, such that absolute resolution decreases with depth.

In the controlled source magnetotelluric (CSMT) method, a low frequency electromagnetic wave is generated, and the electrical and magnetic fields are measured at some distance from the transmitter. The wave impedance of the electromagnetic wave at the receiver is calculated from the electrical and magnetic field values as a function of frequency and then interpreted in terms of the subsurface resistivity distribution. Depths of penetration in excess of 1 to 2 km are attainable under suitable conditions.

Ground probing radar (GPR) is used for detailed investigations of the shallow subsurface. An extremely short pulse is generated and transmitted into the earth and reflections are received from interfaces between materials of differing resistivity and dielectrical constant. GPR instrumentation is sophisticated but highly portable. Depth of penetration is limited from less than 0.3 m in silty soils to over 100 m in permafrost, freshwater-saturated sand, and some very low porosity rocks. Successful applications include the measurement of ice thickness, the location of cracks in ice, permafrost studies, the detailed mapping of the bedrock surface, the examination of soil stratification, and the mapping of contaminant plumes in the shallow subsurface. An important application of GPR is locating buried pipes, tanks, and other objects that reflect the radar pulse.

Natural source methods

Natural source methods take advantage of naturally occurring electrical potentials and electromagnetic fields as energy sources. Advantages of natural source methods are that there is no dependence on an artificial energy source and that the natural electromagnetic field is well understood. The principal disadvantages are the unpredictability and lack of control over energy levels and the attendant effects of cultural noise on the signal to noise ratio.

The self-potential (SP) method examines the slowly varying surface potential field caused by electrochemical and electrokinetic actions in near-surface materials.[4] Potentials can form, for example, at interfaces between materials containing fluids with different ion contents, or they can be caused by moving groundwater or by differential oxidation of ore bodies. The method has been applied successfully in geothermal and mineral exploration and in the delineation of certain groundwater contaminants. Field procedures are straightforward, with the potential measured between carefully designed electrodes using what is essentially a highly sensitive DC voltmeter. The potential field is mapped along profiles or on a grid of measurement stations. Interpretation is generally qualitative, with SP anomalies interpreted in terms of the shape and depth of the causative body or fluid flow.

Magnetotellurics (MT) is an electrical method of geophysical exploration that makes use of naturally occurring electromagnetic energy propagating into the earth to determine the electrical resistivity of the subsurface.[5][6] The low frequency electromagnetic field is measured, and the wave impedance is calculated and expressed in terms of the resistivity of the subsurface. The depth of investigation is a function of the frequency of the electromagnetic wave, taking advantage of the fundamental principle that the lower the frequency of a wave, the deeper the penetration into the crust. MT surveys generally involve applications that range in depth from a few hundred meters to 10 km or more.

The resistivity versus depth cross section developed from MT data can be interpreted in terms of rock type. Spatial variations in the resistivity-depth relationship observed at closely spaced locations on the surface can be interpreted in terms of subsurface geological structure. While MT cannot be used to detect oil directly, the identification of favorable rock types and the presence of geological structure capable of trapping hydrocarbons is critical to successful exploration. MT data are interpreted using forward and inverse modeling techniques. Resolution is considered low when compared with exploration or exploitation seismology, but may be adequate in certain instances to provide valuable information concerning reservoir geometry, rock characteristics, and a regional geological framework. For the larger deep reservoirs, MT may be considered as a possible candidate for EOR monitoring if model studies indicate that the resistivity changes over time associated with the operation are within the resolving power of the method.

Applications for development geology

The following is a brief summary of some of the many possible applications of electrical methods of interest to the development geologist:

- Evaluation of various characteristics of the shallow environment. Examples of such characteristics are the classification of unconsolidated materials based on their electrical properties, the identification of a lateral and/or vertical freshwater-saltwater boundary, the depth to bedrock, and the identification and mapping of conductive groundwater contaminants.
- Monitoring of reservoir stimulation and enhanced recovery projects, where the stimulants and propants or flood materials can be expected to modify the resistivity of the formations.
- Investigation of permafrost and ice characteristics in the Arctic.

- Investigation of stratigraphy and structure, in particular as an adjunct to seismic data and in those areas where seismic data are poor or unreliable.
- Seafloor geotechnical mapping, as an adjunct to high resolution seismic studies.

3. Classify folds in rocks and describe each type in detail. Also, give an account of the role of folds in the design of dams and tunnels. [N/D-15]

A geological fold occurs when one or a stack of originally flat and planar surfaces, such as sedimentary strata, are bent or curved as a result of permanent deformation. Synsedimentary folds are those due to slumping of sedimentary material before it is lithified. Folds in rocks vary in size from microscopic crinkles to mountain-sized folds. They occur singly as isolated folds and in extensive fold trains of different sizes, on a variety of scales.

Folds form under varied conditions of stress, hydrostatic pressure, pore pressure, and temperature gradient, as evidenced by their presence in soft sediments, the full spectrum of metamorphic rocks, and even as primary flow structures in some igneous rocks. A set of folds distributed on a regional scale constitutes a fold belt, a common feature of orogenic zones. Folds are commonly formed by shortening of existing layers, but may also be formed as a result of displacement on a non-planar fault (fault bend fold), at the tip of a propagating fault (fault propagation fold), by differential compaction or due to the effects of a high-level igneous intrusion e.g. above a laccolith.

Fold types

- Anticline: linear, strata normally dip away from axial center, oldest strata in center irrespective of orientation.
- Syncline: linear, strata normally dip toward axial center, youngest strata in center irrespective of orientation.
- Antiform: linear, strata dip away from axial center, age unknown, or inverted.
- Synform: linear, strata dip toward axial centre, age unknown, or inverted.
- Dome: nonlinear, strata dip away from center in all directions, oldest strata in center.
- Basin: nonlinear, strata dip toward center in all directions, youngest strata in center.
- Monocline: linear, strata dip in one direction between horizontal layers on each side.
- Chevron: angular fold with straight limbs and small hinges
- Recumbent: linear, fold axial plane oriented at low angle resulting in overturned strata in one limb of the fold.
- Slump: typically monoclinal, result of differential compaction or dissolution during sedimentation and lithification.
- Ptygmatic: Folds are chaotic, random and disconnected. Typical of sedimentary slump folding, migmatites and decollement detachment zones.
- Parasitic: short wavelength folds formed within a larger wavelength fold structure - normally associated with differences in bed thickness
- Disharmonic: Folds in adjacent layers with different wavelengths and shapes

(A homocline involves strata dipping in the same direction, though not necessarily any folding.)

Causes of folding

Folds appear on all scales, in all rock types, at all levels in the crust and arise from a variety of causes.

Layer-parallel shortening

When a sequence of layered rocks is shortened parallel to its layering, this deformation may be accommodated in a number of ways, homogeneous shortening, reverse faulting or folding. The response depends on the thickness of the mechanical layering and the contrast in properties between the layers. If the layering does begin to fold, the fold style is also dependent on these properties. Isolated thick competent layers in a less competent matrix control the folding and typically generate classic rounded buckle folds accommodated by deformation in the matrix. In the case of regular alternations of layers of contrasting properties, such as sandstone-shale sequences, kink-bands, box-folds and chevron folds are normally produced.

Fault-related folding

Many folds are directly related to faults, associate with their propagation, displacement and the accommodation of strains between neighbouring faults.

Fault bend folding

Fault bend folds are caused by displacement along a non-planar fault. In non-vertical faults, the hanging-wall deforms to accommodate the mismatch across the fault as displacement progresses. Fault bend folds occur in both extensional and thrust faulting. In extension, listric faults form rollover anticlines in their hanging walls. In thrusting, ramp anticlines are formed whenever a thrust fault cuts up section from one detachment level to another. Displacement over this higher-angle ramp generates the folding.

Fault propagation folding

Fault propagation folds or tip-line folds are caused when displacement occurs on an existing fault without further propagation. In both reverse and normal faults this leads to folding of the overlying sequence, often in the form of a monocline

Detachment folding

When a thrust fault continues to displace above a planar detachment without further fault propagation, detachment folds may form, typically of box-fold style. These generally occur above a good detachment such as in the Jura Mountains, where the detachment occurs on middle Triassicevaporites.

Folding in shear zones

Shear zones that approximate to simple shear typically contain minor asymmetric folds, with the direction of overturning consistent with the overall shear sense. Some of these folds have highly curved hinge lines and are referred to as sheath folds. Folds in shear zones can be inherited, formed due to the orientation of pre-shearing layering or formed due to instability within the shear flow

Folding in sediments

Recently deposited sediments are normally mechanically weak and prone to remobilisation before they become lithified, leading to folding. To distinguish them from folds of tectonic origin, such structures are called synsedimentary (formed during sedimentation).

Slump folding: When slumps form in poorly consolidated sediments, they commonly undergo folding, particularly at their leading edges, during their emplacement. The asymmetry of the slump folds can be used to determine paleoslope directions in sequences of sedimentary rocks.

Dewatering: Rapid dewatering of sandy sediments, possibly triggered by seismic activity, can cause convolute bedding.

Compaction: Folds can be generated in a younger sequence by differential compaction over older structures such as fault blocks and reefs.

Igneous intrusion

The emplacement of igneous intrusions tends to deform the surrounding country rock. In the case of high-level intrusions, near the Earth's surface, this deformation is concentrated above the intrusion and often takes the form of folding, as with the upper surface of a laccolith.

Flow folding

The compliance of rock layers is referred to as competence: a competent layer or bed of rock can withstand an applied load without collapsing and is relatively strong, while an incompetent layer is relatively weak. When rock behaves as a fluid, as in the case of very weak rock such as rock salt, or any rock that is buried deeply enough, it typically shows flow folding (also called passive folding, because little resistance is offered): the strata appear shifted undistorted, assuming any shape impressed upon them by surrounding more rigid rocks. The strata simply serve as markers of the folding. Such folding is also a feature of many igneous intrusions and glacier ice.

4. Explain how Seismic and Electrical methods help in know about sub surface features during civil engineering investigations. [N/D-15]

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Possible applications of electrical methods for the development geologist range from the investigation of soil contaminants and the monitoring of enhanced oil recovery (EOR) projects to reservoir delineation and the evaluation of geological stratigraphy and structure. The application of electrical methods has been primarily confined to the onshore environment. The offshore use of some techniques is possible, particularly for permafrost delineation and shallow marine geotechnical investigations.

Electrical properties of materials

The application, interpretation, and understanding of electrical methods requires a familiarity with the relationship between soil and rock characteristics and the resistivities obtained from electrical data. The resistivity of subsurface rock formations is one of the physical properties determined through the process of logging that is performed on most oil and gas wells, utilizing instrumentation inserted into the wellbore. The concept of formation resistivity plays an important part in log analysis. Although there is a correlation between rock resistivities measured by well logs and those measured by electrical methods, the log is used to investigate properties only in the immediate vicinity of the wellbore while electrical methods yield information on bulk properties averaged over a considerable volume of material.

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Controlled source methods

Controlled source methods use generated currents or electromagnetic fields as energy sources. An advantage is the control over energy levels and the attendant positive effects on signal to noise ratio in areas of high cultural noise. A disadvantage of controlled source methods is that the complex nature of the source field geometry (the geometry of the electromagnetic field or currents induced with the earth by the transmitter) may present quantitative interpretation problems in areas of complex geology.

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The resistivity versus depth cross section developed from MT data can be interpreted in terms of rock type. Spatial variations in the resistivity-depth relationship observed at closely spaced locations on the surface can be interpreted in terms of subsurface geological structure. While MT cannot be used to detect oil directly, the identification of favorable rock types and the presence of geological structure capable of trapping hydrocarbons is critical to successful exploration. MT data are interpreted using forward and inverse modeling techniques. Resolution is considered low when compared with exploration or exploitation seismology, but may be adequate in certain instances to provide valuable information concerning reservoir geometry, rock characteristics, and a regional geological framework. For the larger deep reservoirs, MT may be considered as a possible candidate for EOR monitoring if model studies indicate that the resistivity changes over time associated with the operation are within the resolving power of the method.

Applications for development geology

The following is a brief summary of some of the many possible applications of electrical methods of interest to the development geologist:

- Evaluation of various characteristics of the shallow environment. Examples of such characteristics are the classification of unconsolidated materials based on their electrical properties, the identification of a lateral and/or vertical freshwater-saltwater boundary, the depth to bedrock, and the identification and mapping of conductive groundwater contaminants.
- Monitoring of reservoir stimulation and enhanced recovery projects, where the stimulants and propants or flood materials can be expected to modify the resistivity of the formations.
- Investigation of permafrost and ice characteristics in the Arctic.
- Investigation of stratigraphy and structure, in particular as an adjunct to seismic data and in those areas where seismic data are poor or unreliable.
- Seafloor geotechnical mapping, as an adjunct to high resolution seismic studies.

5. Explain gravity method in geophysics. [M/J-16]

For human exploration of the solar system, instruments must meet criteria of low mass, low volume, low power demand, safe operation, and ruggedness and reliability (Meyer et al., 1995; Hoffman, 1997; Budden, 1999). Tools used for planetary exploration will need to address fundamental scientific questions and identify precious resources, such as water.

The primary goal of studying detailed gravity data is to provide a better understanding of the subsurface geology. The gravity method is a relatively cheap, non-invasive, non-destructive remote sensing method that has already been tested on the lunar surface. It is also passive – that is, no energy need be put into the ground in order to acquire data; thus, the method is well suited to a populated setting such as Taos, and a remote setting such as Mars. The small portable instrument also permits walking traverses – ideal, in view of the congested tourist traffic in Taos.

Measurements of gravity provide information about densities of rocks underground. There is a wide range in density among rock types, and therefore geologists can make inferences about the distribution of strata. In the Taos Valley, we are attempting to map subsurface faults. Because faults commonly juxtapose rocks of differing densities, the gravity method is an excellent exploration choice.

This is a generalized summary of the types of corrections that we have applied to the Taos gravity data

The Gal (for Galileo) is the cgs unit for acceleration where one Gal equals 1 centimenter per second squared. Because variations in gravity are very small, units for gravity surveys are generally in milligals (mGal) where 1 mGal is one thousandth of 1cm/s^2. Standard gravity (g_n or g_0) is taken as the freefall accelleration of an object at sea level at a latitude of 45.5° and is 980.665 cm/s^2 (or equivalently 9.80665 m/s^2). Standard gravity is therefore 980.665 Gal or 980665 mGal. It is useful to remember that 1 mGal is just a bit more than 1 millionth of g_n ($1.01972 \times 10^{-6}\, g_n$).

Observed Gravity (g_{obs}) - Gravity readings observed at each gravity station after corrections have been applied for instrument drift and earth tides.

Latitude Correction (g_n) - Correction subtracted from gobs that accounts for Earth's elliptical shape and rotation. The gravity value that would be observed if Earth were a perfect (no geologic or topographic complexities), rotating ellipsoid is referred to as the normal gravity.

$$g_n = 978031.85\,(1.0 + 0.005278895\,\sin^2(lat) + 0.000023462\,\sin^4(lat))\ (mGal)$$

where lat is latitude

Free Air Corrected Gravity (g_{fa}) - The free-air correction accounts for gravity variations caused by elevation differences in the observation locations. The form of the Free-Air gravity anomaly, g_{fa}, is given by:

$$g_{fa} = g_{obs} - g_n + 0.3086h \text{ (mGal)}$$

where h is the elevation (in meters) at which the gravity station is above the datum (typically sea level).

Bouguer Slab Corrected Gravity (g_b) - The Bouguer correction is a first-order correction to account for the excess mass underlying observation points located at elevations higher than the elevation datum (sea level or the geoid). Conversely, it accounts for a mass deficiency at observation points located below the elevation datum. The form of the Bouguer gravity anomaly, g_b, is given by:

$$g_b = g_{obs} - g_n + 0.3086h - 0.04193r\,h \text{ (mGal)}$$

where r is the average density of the rocks underlying the survey area.

Terrain Corrected Bouguer Gravity (g_t) - The Terrain correction accounts for variations in the observed gravitational acceleration caused by variations in topography near each observation point. Because of the assumptions made during the Bouguer Slab correction, the terrain correction is positive regardless of whether the local topography consists of a mountain or a valley. The form of the Terrain corrected, Bouguer gravity anomaly, g_t, is given by:

$$g_t = g_{obs} - g_n + 0.3086h - 0.04193r\,h + TC \text{ (mGal)}$$

where TC is the value of the computed Terrain correction.

Assuming these corrections have accurately accounted for the variations in gravitational acceleration they were intended to account for, any remaining variations in the gravitational acceleration associated with the Terrain Corrected Bouguer Gravity can be assumed to be caused by geologic structure.

6. Write a note on faults, their causes and effects on the engineering quality of rocks. Give an account of causes. [M/J-16]

A geological fold occurs when one or a stack of originally flat and planar surfaces, such as sedimentary strata, are bent or curved as a result of permanent deformation. Synsedimentary folds are those due to slumping of sedimentary material before it is lithified. Folds in rocks vary in size from microscopic crinkles to mountain-sized folds. They occur singly as isolated folds and in extensive fold trains of different sizes, on a variety of scales.

Folds form under varied conditions of stress, hydrostatic pressure, pore pressure, and temperature gradient, as evidenced by their presence in soft sediments, the full spectrum of metamorphic rocks, and even as primary flow structures in some igneous rocks. A set of folds distributed on a regional scale constitutes a fold belt, a common feature of orogenic zones. Folds are commonly formed by shortening of existing layers, but may also be formed as a result of displacement on a non-planar fault (fault bend fold), at the tip of a propagating fault (fault propagation fold), by differential compaction or due to the effects of a high-level igneous intrusion e.g. above a laccolith.

Fold types

- Anticline: linear, strata normally dip away from axial center, oldest strata in center irrespective of orientation.
- Syncline: linear, strata normally dip toward axial center, youngest strata in center irrespective of orientation.
- Antiform: linear, strata dip away from axial center, age unknown, or inverted.
- Synform: linear, strata dip toward axial centre, age unknown, or inverted.
- Dome: nonlinear, strata dip away from center in all directions, oldest strata in center.
- Basin: nonlinear, strata dip toward center in all directions, youngest strata in center.
- Monocline: linear, strata dip in one direction between horizontal layers on each side.
- Chevron: angular fold with straight limbs and small hinges
- Recumbent: linear, fold axial plane oriented at low angle resulting in overturned strata in one limb of the fold.
- Slump: typically monoclinal, result of differential compaction or dissolution during sedimentation and lithification.
- Ptygmatic: Folds are chaotic, random and disconnected. Typical of sedimentary slump folding, migmatites and decollement detachment zones.
- Parasitic: short wavelength folds formed within a larger wavelength fold structure - normally associated with differences in bed thickness
- Disharmonic: Folds in adjacent layers with different wavelengths and shapes

(A homocline involves strata dipping in the same direction, though not necessarily any folding.)

Causes of folding

Folds appear on all scales, in all rock types, at all levels in the crust and arise from a variety of causes.

Layer-parallel shortening

When a sequence of layered rocks is shortened parallel to its layering, this deformation may be accommodated in a number of ways, homogeneous shortening, reverse faulting or folding. The response depends on the thickness of the mechanical layering and the contrast in properties between the layers. If the layering does begin to fold, the fold style is also dependent on these properties. Isolated thick competent layers in a less competent matrix control the folding and typically generate classic rounded buckle folds accommodated by deformation in the matrix. In the case of regular alternations of layers of contrasting properties, such as sandstone-shale sequences, kink-bands, box-folds and chevron folds are normally produced.

Fault-related folding

Many folds are directly related to faults, associate with their propagation, displacement and the accommodation of strains between neighbouring faults.

Fault bend folding

Fault bend folds are caused by displacement along a non-planar fault. In non-vertical faults, the hanging-wall deforms to accommodate the mismatch across the fault as displacement progresses. Fault bend folds occur in both extensional and thrust faulting. In extension, listric faults form rollover anticlines in their hanging walls. In thrusting, ramp anticlines are formed whenever a thrust fault cuts up section from one detachment level to another. Displacement over this higher-angle ramp generates the folding.

Fault propagation folding

Fault propagation folds or tip-line folds are caused when displacement occurs on an existing fault without further propagation. In both reverse and normal faults this leads to folding of the overlying sequence, often in the form of a monocline

Detachment folding

When a thrust fault continues to displace above a planar detachment without further fault propagation, detachment folds may form, typically of box-fold style. These generally occur above a good detachment such as in the Jura Mountains, where the detachment occurs on middle Triassicevaporites.

Folding in shear zones

Shear zones that approximate to simple shear typically contain minor asymmetric folds, with the direction of overturning consistent with the overall shear sense. Some of these folds have highly curved hinge lines and are referred to as sheath folds. Folds in shear zones can be inherited, formed due to the orientation of pre-shearing layering or formed due to instability within the shear flow

Folding in sediments

Recently deposited sediments are normally mechanically weak and prone to remobilisation before they become lithified, leading to folding. To distinguish them from folds of tectonic origin, such structures are called synsedimentary (formed during sedimentation).

Slump folding: When slumps form in poorly consolidated sediments, they commonly undergo folding, particularly at their leading edges, during their emplacement. The asymmetry of the slump folds can be used to determine paleoslope directions in sequences of sedimentary rocks.

Dewatering: Rapid dewatering of sandy sediments, possibly triggered by seismic activity, can cause convolute bedding.

Compaction: Folds can be generated in a younger sequence by differential compaction over older structures such as fault blocks and reefs.

Igneous intrusion

The emplacement of igneous intrusions tends to deform the surrounding country rock. In the case of high-level intrusions, near the Earth's surface, this deformation is concentrated above the intrusion and often takes the form of folding, as with the upper surface of a laccolith.

Flow folding

The compliance of rock layers is referred to as competence: a competent layer or bed of rock can withstand an applied load without collapsing and is relatively strong, while an incompetent layer is relatively weak. When rock behaves as a fluid, as in the case of very weak rock such as rock salt, or any rock that is buried deeply enough, it typically shows flow folding (also called passive folding, because little resistance is offered): the strata appear shifted undistorted, assuming any shape impressed upon them by surrounding more rigid rocks. The strata simply serve as markers of the folding. Such folding is also a feature of many igneous intrusions and glacier ice.

7. Write in detail about the types of faults and their influence on dams and tunnels. [N/D-16][M/J 15]

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8. Discuss the operating principle of the seismic methods of subsurface investigation. [N/D-16][M/J 14]

INTRODUCTION

Seismic refraction is a geophysical method used for investigating subsurface ground conditions by utilising surface-sourced seismic waves. Data acquired on site is computer processed and interpreted to produce models of the seismic velocity and layer thickness of the subsurface ground structure. The method is commonly used for measuring the thickness of overburden in areas where bedrock is at depth, and assessing ripability parameters.

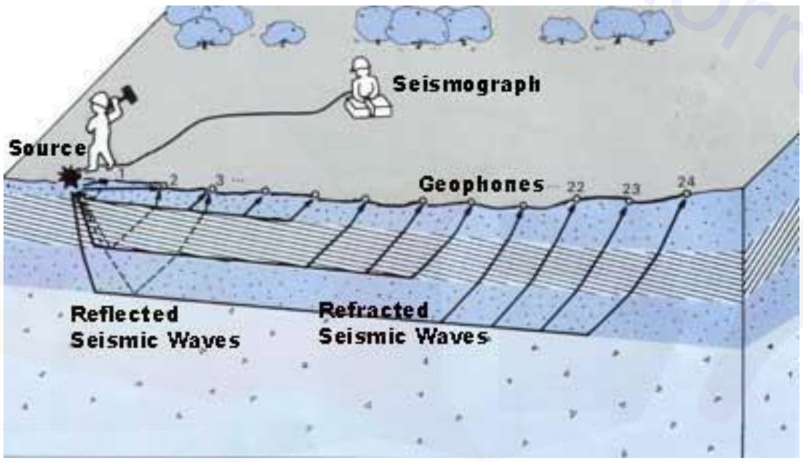
OPERATION

Pulses of low frequency seismic energy are emitted by a seismic source such as a hammer-plate, weight drop or buffalo gun. The type of source is dependant on local ground conditions and required depth penetration. Explosives are best for deeper applications but are constrained by environmental regulations.

The seismic waves propagate downward through the ground until they are reflected or refracted off subsurface layers. Refracted waves are detected by arrays of 24 or 48 geophones spaced at regular intervals of 1 - 10 metres, depending on the desired depth penetration of the survey. Sources are positioned at each end of the geophone array to produce forward and reverse wave arrivals along the array. Additional sources may be used at intermediate or off-line positions for full coverage at all geophone positions.

DATA INTERPRETATION

Geophones output data as time traces which are compiled and processed by the seismograph. The basic components of a seismic trace are the direct wave, the reflected wave and the critically refracted wave. Wave refraction occurs at interfaces in the ground where the seismic velocity of the lower layer is greater than the velocity of the overlying layer. This condition normally applies in near surface site investigations where soil or fill overlies bedrock.



At geophone positions close to the seismic source, the first seismic wave arrivals are direct waves. However, beyond a critical distance from the source, the first arrivals change to refracted waves due to the faster relative velocity of the refracted waves. Interpretation procedures involve the accurate measurement of first arrivals from the time traces recorded at each geophone position.

Interpretation techniques are applied to the first arrival times to calculate the seismic velocities of the layers and the depths of individual refracting interfaces. The interfaces are correlated with real physical boundaries in the ground, such as the soil-bedrock interface and other lithological boundaries, to produce a model of the subsurface ground structure. The final interpretation is presented in a format that is easily understood by engineers.

APPLICATIONS

- **Measures Bedrock Depth & Overburden Thickness**
- **Determines Rippability Parameters**

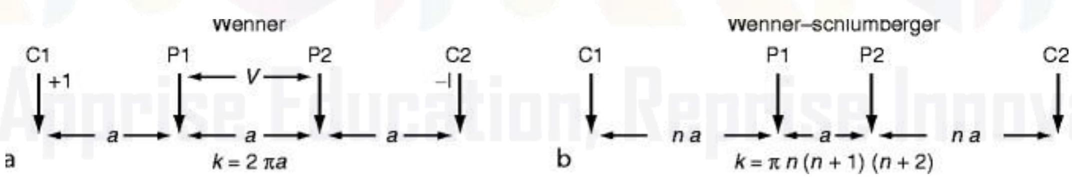
- **Investigates Pipeline Routes**
- **Locates Geological Structures**
- **Evaluates Sand & Gravel Deposits**
- **Defines Ancient Landfill Sites**

9. Differentiate between wenner and Schlemberger method. [M/J 14] [ND 15]

- In Wenner arrangements four electrodes are used. When a current I is introduced into a homogeneous and isotropic ground by means of two electrodes C1 and C2 and the potentials are picked up by the other two electrodes P1 and P2. The voltage between the potential electrodes is given by the formula:
  V= ρ /2 pi (1/C1P1-1/C2P1-1/C1P2+1/C2P2)
  V=I ρ /2 pi (1/AM-1/BM-1/AN+1/BN)
  Resistivity ρ =V/I.2 pi.1/G

Schlumberger arrangement:

Here two electrodes are placed with the large interval than that between the two inner potential electrodes. The current electrodes are denoted by A and B and potential electrode are denoted by M and N. The interval between M and N may be denoted by b while the interval AB/2 is denoted by a. Cooper proposed that the current electrodes AB may be placed as inner electrodes and MN as outer electrodes. This arrangement has the advantage that in depth soundings, long current carrying cables may be avoided. Schlumberger arrangement is used in the continent of Europe and in the Soviet Union.



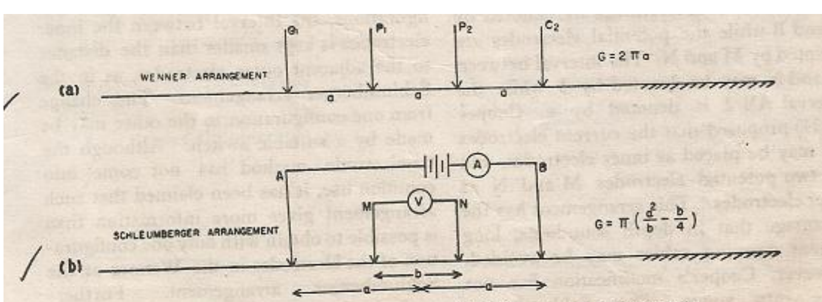
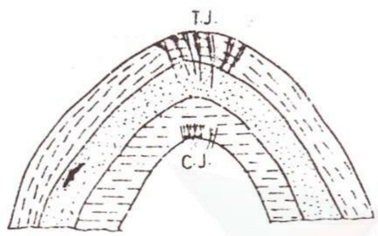


Fig. 20. (a) Wenner Arrangement. (b) Schlumberger Arrangement.

10. Differentiate between tension joint, shear joint and compression joint. [M/J 16] [ND 14]

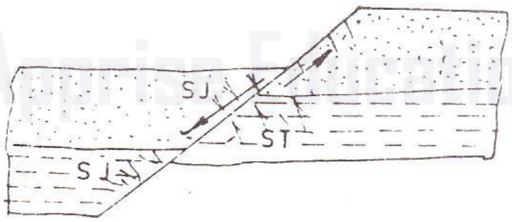
Tensional joints:

These joints are developed due to the tensile forces acting on the rocks. The most common location of such joints in folded sequence is on the outer margins of crests and troughs.



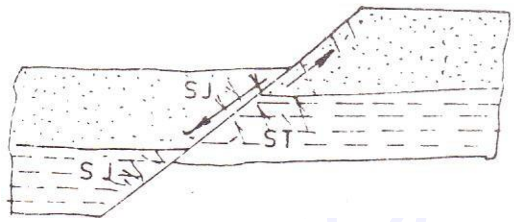
Shear joints:

These are commonly observed in the vicinity of fault planes and shear zones where their relationship with shearing force is clearly established. The fractures which are developed in the footwall and hanging wall during their time of relative displacement.



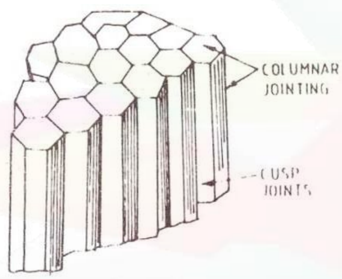
Sheet joints:

In granites and other related igneous rocks, a horizontal set of joints often divides the mass in such a way as to give it an appearance of a layered sedimentary structure, called in this case as a sheet structure.



Columnar joints:

These kinds of joints are occurs in volcanic igneous rocks. These joints are also called prismatic joints. These joints divide the rock mass into polygonal blocks, each block being bounded by three to eight sides. Generally these kinds of joints are vertical.



Joints cause the leakage of water in case of reservoir. Joints may pose groundwater problems in tunneling. The orientation of joints is very significant in engineering projects. Large joint dipping in the construction site cause a landslide. Quarry operations obviously greatly influenced by the joints.

Jointed rocks allow the movement of fluids and may act as AQUIFERS. Bore wells drilled in civil construction areas for water supply will be more productive in highly jointed rocks than in less jointed rocks

C6301- ENGINEERINGGEOLOGY

UNIT V

1. What is meant by "stand up time" in tunneling? [N/D-14]

"Stand-up time" is the amount of time a newly excavated cavity can support itself without any added structures. Knowing this parameter allows the engineers to determine how far an excavation can proceed before support is needed, which in turn affects the speed, efficiency, and cost of construction. Generally, certain configurations of rock and clay will have the greatest stand-up time, while sand and fine soils will have a much lower stand-up time.

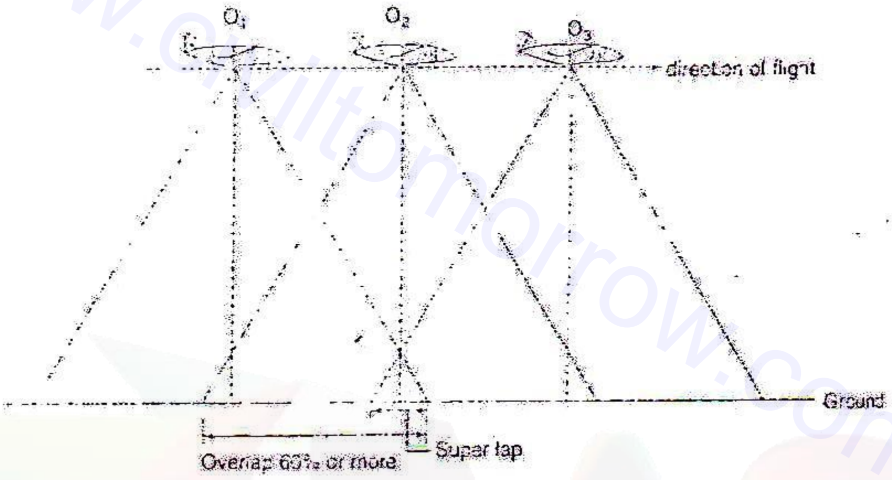
2. List of least four measures to prevent coastal erosion. [N/D-14]

The following measures are some management measures for coastal protection:

- To create awareness among the coastal communities in the study area, in order to protect and conserve the coastal area through effective involvement of educational institutions and NGOS
- Stringent measures need to be under taken with immediate effect to ban coastal and coral mining and to take into task those involved in or those who encourage the exploitation of corals for any purpose. Patrolling the coast to check coral and coastal mining should be carried out.
- Law should be enacted to regulate and stop trawl boat operation in the zone earmarked for non-mechanized boat. The Department of Forest and the Department of Fisheries should take steps to stop anchoring of vessels on coral reefs, pair trawling and dynamite fishing.
- Indiscriminate picking of budding seaweeds need to be banned.
- Commercial shell collection should be controlled and closely monitored.
- Marine Resource Management Centers should be established to improve the skills of fishermen communities in areas other than coastal mining, which in turn will lead to efficient management of coast.
- Deforestation along the coast and islands should be banned. The forest Department should take up a forestation along the coast and islands to protect soil erosion.
- Discharging of untreated sewage and urban wastes into the coastal waters should be totally banned.
- Construction of embankment walls along the coast to prevent the coastal erosion etc.

3. What is meant by the term 'overlap' in remote sensing? [N/D-15]

A stereo or three-dimensional view is essential to photo-interpretation in order to obtain the elevation/height of objects. The effective interpretative use of aerial photographs cannot be made without interpretation. In order to obtain stereo-photographs, the aerial exposures are made such that each picture overlaps the previous one by at least 60% (fig). This overlap is usually known as forward overlap. Thus, each object on the ground will appear on at least two consecutive aerial photographs, such object can be studied in three-dimension to get its height.



The number of photographs taken in a single flight direction is known as a strip of photographs. Overlap is also kept to minimum of 25% between the two consecutive strips of photographs, and is known as side lap. The overlaps are very useful in planning triangulation/traversing schemes for a large area.

4. List the causative factors of landslides. [N/D-15]

Causes of Landslides:

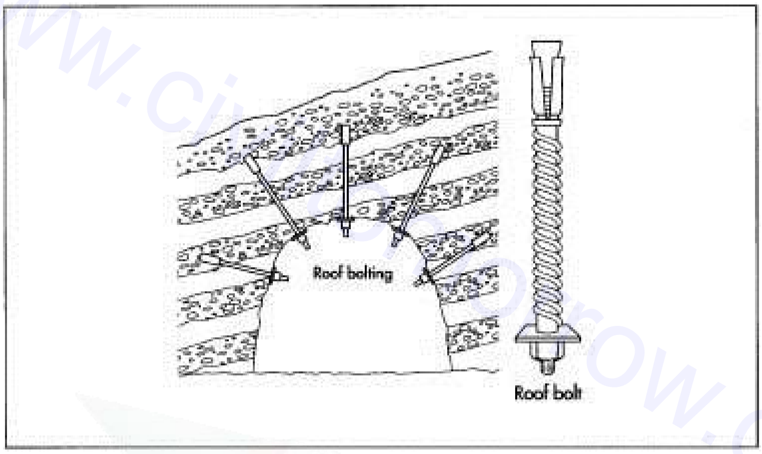
Many factors are known to cooperate in causing a mass of materials to flow or fail or fall, some of them play a direct role and are easily understood whereas other are indirectly responsible for the instability of the land mass, Bases on this the land landslides operated by internal forces and external forces

5. Define the term Dead storage on reservoir. [M/J-16]

The capacity, volume or storage of a reservoir is usually divided into distinguishable areas. Dead or inactive storage refers to water in a reservoir that cannot be drained by gravity through a dam's outlet works, spillway or power plant intake and can only be pumped out.

6. What is meant by "Rock bolting"? Draw a neat diagram. [M/J-16]

A rock bolt is a long anchor bolt, for stabilizing rock excavations, which may be used in tunnels or rock cuts. It transfers load from the unstable exterior to the confined (and much stronger) interior of



the rock mass.

7. What is over break in tunneling? How can it he controlled? [N/D-16]

Over break

Rock excavated in excess of the neat lines of a tunnel or cutting. Quick, simple, reliable, and inexpensive measurements of overbreak and underbreak are needed for proper evaluation of tunnelling by the drill and blast method. Problems causing rock damage can be identified and remedied while the work is still in progress. The measurements are also useful in identifying causes of overbreak and overbreak, and in helping to settle contractual disputes relating to payment for replacement concrete and secondary blasting of 'tights' (zones of underbreak). A newly developed method to measure underbreak and overbreak is presented here. The light sectioning method (LSM) uses a radial sheet of light to define the tunnel profile. An image of the final tunnel profile is acquired and digitized, using digital image analysis. This profile is superimposed over the design profile, and from this zones of overbreak and underbreak are identified, quantified, and presented graphically.

8. Mention a few coastal protection structures. [N/D-16]

Shore protection wors in general are:

- Sea walls and bulheads
- Protective beaches
- Sand dunes
- Groynes
- Off shore breakwater

9. What are the classifications of land slides?

Presence or absence of a definite slip plane, materials involved and their water content, kind and rate of movement.

10. What are the parts of atypical slides

Crown, scrap, head, slip plane, flanks, transverse ridges, fool, toe, length, width, height, depth.

11. Write short notes on subsidence.

Subsidence is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to a datum such as sea-level. The opposite of **subsidence** is uplift, which results in an increase in elevation. Ground **subsidence** is of concern to geologists, geotechnical engineers and surveyors

12. Differentiate between soil creep and mud flows.

Soil creep:

It is a type of slow flowage and consists of gradual, almost imperceptible down slope transit of soil and sometimes takes place even under the cover of vegetation. The rate of downgrade movement may vary from1 mm to several cms a year. In most cases soil creep is essentially a phenomenon in which only the top of one metre or so of the soil is involved in failure.

13. What is mass movement?

Mass movement or **mass** wasting is **movements** of masses of bodies of soil, bed rock, rock debris, soil, or mud which usually occur along steep-sided hills and mountains because of the pull of gravity. This slipping of large amounts of rock and soil is seen in landslides, mud slides, and avalanches.

14. What are the various types of landslides?

1. Roatational Landslides
2. Translational Landslide

1. Using case studies, give a detailed account of the application of remote sensing in civil engineering. [N/D-14]

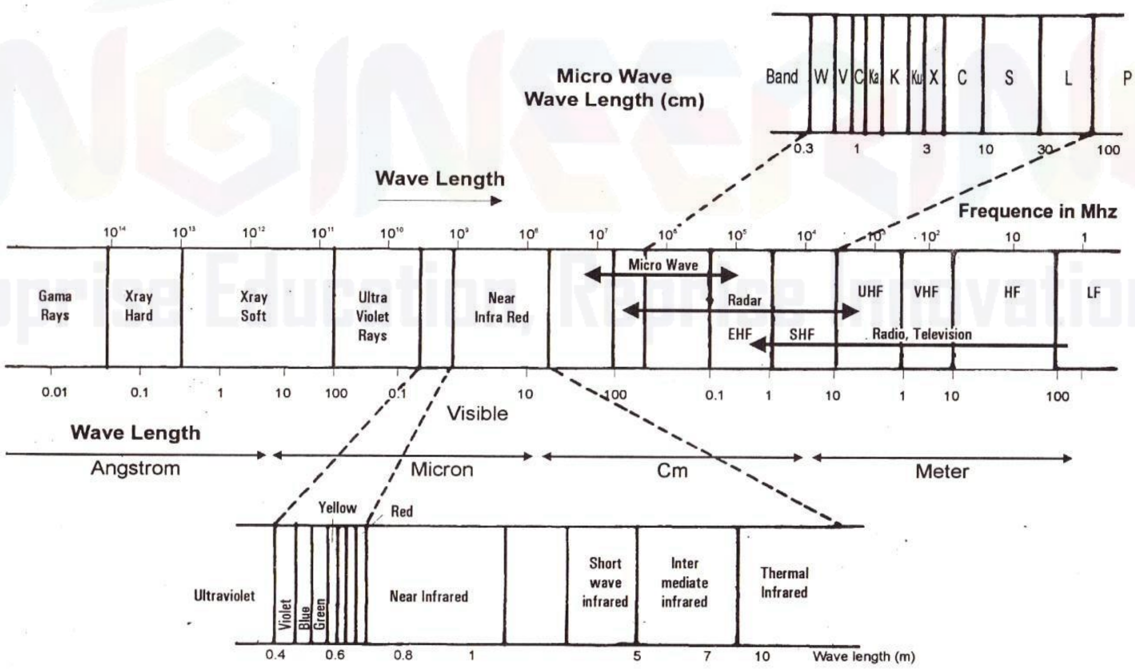
REMOTE SENSING TECHNIQUES

Remote sensing is the science, art and technology of obtaining information about the object, through the analysis of data acquired by a device this is not in contact with the object under the investigation.

Various objects are identified with the help of variation in the reflected electromagnetic radiation reflected by different earth's objects. A remote sensing system, therefore, must be sensitive enough to capture the changes in the reflected electromagnetic energy. An ideal remote sensing may have the following components.

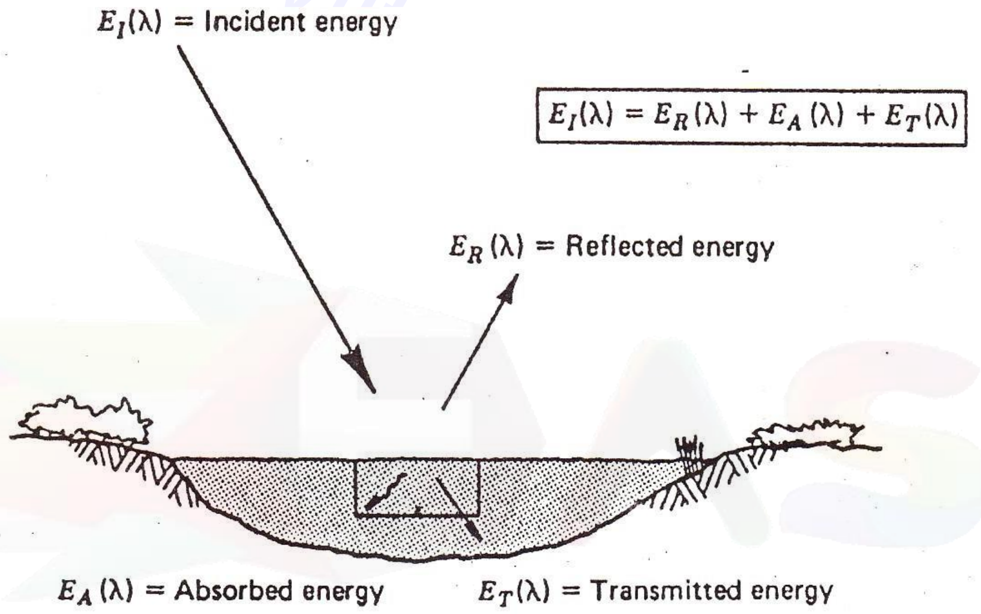
Source of electromagnetic energy
Medium which interacts with this energy
Ground objects
Sensor to detect and record the changes in electro-magnetic energy

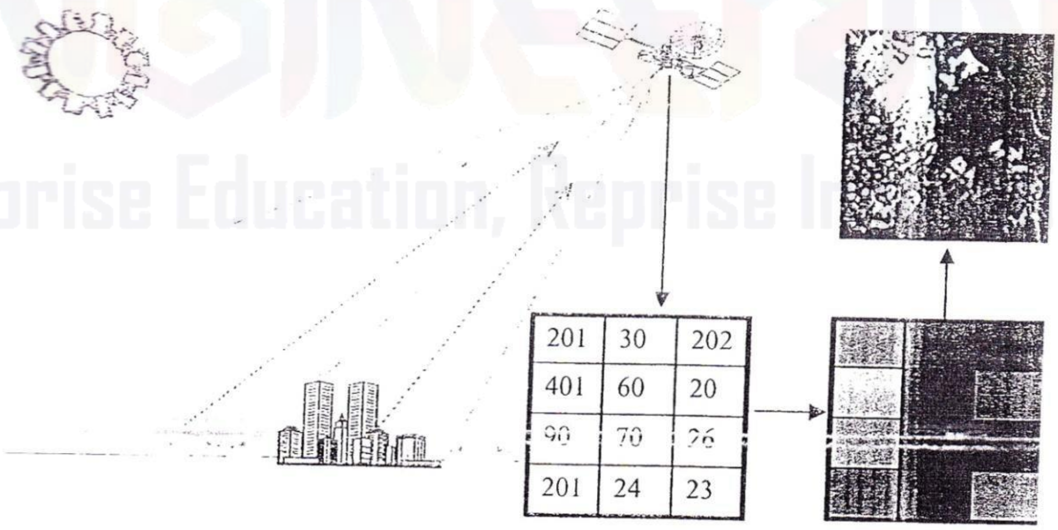
Electromagnetic radiation: Sun is the source of light. It radiates the heat and light energy in the form of electromagnetic radiation, the EMR comprises various rays such as , X- rays UV, Visible, Infrared, thermal inferred, microwave and radio wave. , X- rays and UV are observed and reflected by upper layer of atmosphere, which is most useful for remote sensing hence it is known as atmosphere window.



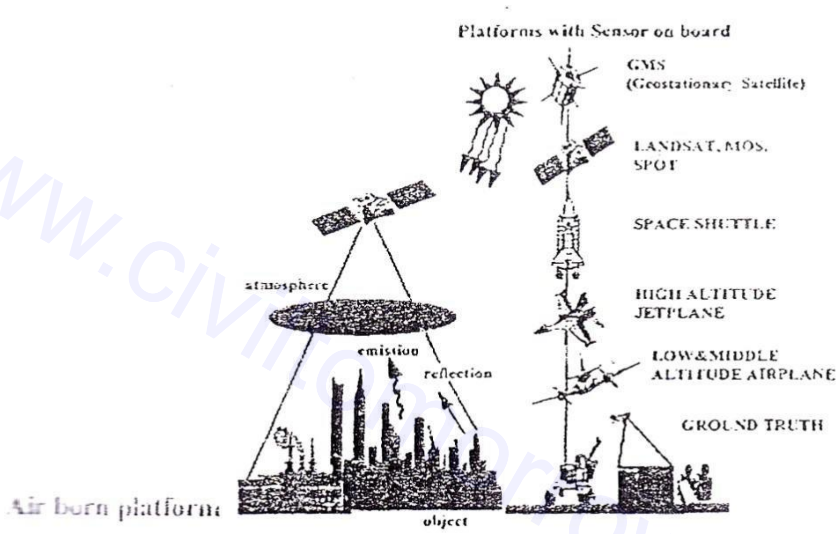
The part of the electromagnetic radiation from visible to microwave is called electromagnetic spectrum (EMS). Various components of an electromagnetic spectrum with their wavelength and frequency are shown in the above figure.

Principle: All objective on the earth reflective absorb or radiate energy in the form of electromagnetic waves coming directly from the sun. The electromagnetic radiation (EMR) reflected from the objective is transmitted through the atmosphere. The remotely placed sensors can pickup the transmitted energy, record and form an image. This image data is sent to the earth recording stations, where all the data is recorded on high density digital tapes. Information about an object depends upon its spectral characteristic, which itself depends upon the nature of the object and its environment. The electromagnetic radiation travelling through the atmosphere gets modified by absorption and or scattering.





Remote sensing plate form: Plate form is defined as a stage of sensor or camera. They play vital role in remote sensing data acquistation. They are necessary to correctly position the sensors that collect data from the objects of interest. The platforms may be air-borne, or space-borne, depending upon the objects under study on earth surface and also on the sensor employed. Ballons, Aircraft, and Satellites are the common remote sensing platform.



Balloons: These are designed and used for specific projects. Through the use of balloon is commonly restricted by meteorological factors, there application in resource mapping has been significant useful. Balloons are usually of two types, a) Free balloons and b) Threaded balloons.

Aircraft: aircraft are commonly used as remote sensing plate forms for obtaining aerial photographs. They considered useful for regional converge and large scale mapping.

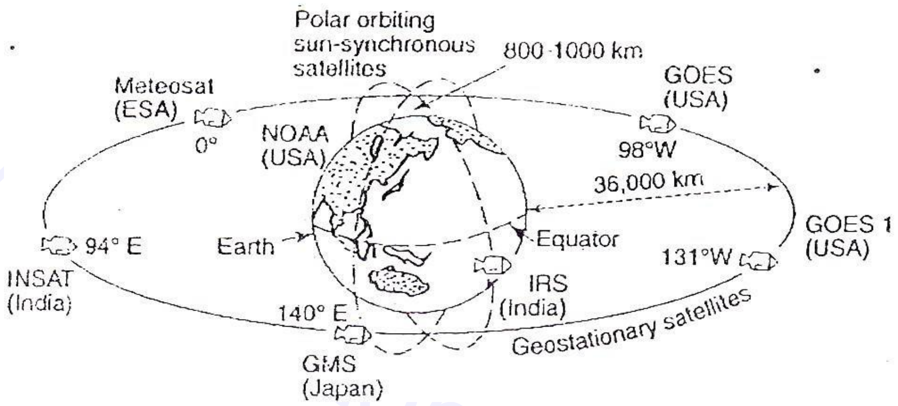
Space born plate form: Satellite has provided to be vital use in natural resource mapping, meteorological and communication application applications. Satellites are free- flying orbiting vehicles, whose motion is governed by the gravity, and atmosphere based on well-known kepler's law's. Broadly, satellites can be grouped under two categories depending upon the types of orbits in which they move.

Geostationary satellite

Altitude - 35,000km
Orbital Movement - Parallel to Earth Rotation
Uses - Communication
Example - GOBS, GMS, INSAT etc

Sun-Synchronous or Polar orbiting satellite

Altitude - 800-900km
Orbital Movement - Pole to Pole
Uses - Earth Observation
Example - LANDSAT, SPOT, IRS, IKNAS, QUAKE BIRD etc



Sensor system: In remote sensing, the acquisition of data is dependent upon the sensor system used. Various remote sensing platforms are equipped with different sensor systems. It is a device that receives electromagnetic radiation, converts it into a signal and presents it in a form suitable for obtaining information about the land or earth resource as used by an information gathering system. Sensor can be grouped, either on the basis of energy source or on the basis of wave bonds employed. Based on the energy source, sensor are classifies as follows.

Sensor Classification

Based on the energy source Sensor May be classifies in to the followings:

- Active Sensors (Sensor which produce the EMR by its own i.e RADAR)
- Passive Sensors (Sensor depends the suns EMR i.e., MSS, TM, XS, LISS, PAN, WiPS etc)

Passive Sensor further divided into number of following types based on function of sensor in EMR>

- Photographic Camera (Operated in single band from 0.4-0.7mm)
- Return Beam Vidcon (Operated in Green, Red, NIR)- RBV in Landsat and TV in Bhaskara
- Thermal Sensor (Operated in Thermal Infrared Region)
- Optical and Mechanical Sensors (Operated in 0.5-1.1 mm) MSS and XS Radar and Microwave Sensor (Operated in Microwave Region) SLAR, SAR
- Advanced Remote Sensor (Operated in GBR and IR) LISS-II, LISS-III, LISS-IV, WiPS, PAN, TM

Parameter of sensor:

Spatial Resolution : The minimum detectable area on the ground by a detector placed on a sensor

Spectral Resolution : The small amount of spectral changes be detected by the sensor.

Radiometric Resolution : The presence of grey level

Temporal Resolution : Smaller period of repetitive coverage

Remote Sensing Satellite: Remote sensing, as conceived today for natural resource mapping was started with the launching of the first earth resource. Technology's satellite (ERTS) now known as

LANDSAT-1, by USA in 1972 since then, with the advancement in sensor technology, a number of remote sensing earth resource satellite have been launched. The important milestones crossed so far in achieving end-to-end capability are LANDSAT Series, 1, 2, 3, 4, 5, 6 and 7; Frances satellite 1, 2, and 3, Indian polar satellite Bhashkara 1&2, IRS 1A/ IRS 1B/IRS 1C/IRS 1D/IRS P2/IRS P3/IRS P4/IRS P5/IRS P6& Indian meteorological satellite INSAT 1A/1B/1C/1D and 2A/2B/2C/2D/2E etc.,

2. (Classify landslides and discuss about the causative factors of landslides. Also, add a note on the measures for mitigation of landslides. [N/D-14]

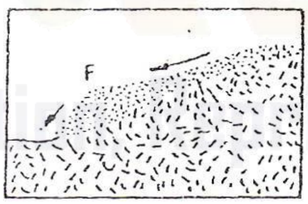
LANDSLIDES

A temporary instability of superficial mass of soil and rocks, consolidated or unconsolidated, may leave their original position abruptly or extremely slowly and start either a downward movement or vertically downward sinking thus giving rise to baffling situation. These movements may entitle to loss to property and life. Such movements of the ground have been termed as Landslides or Land slip or Mass Movement

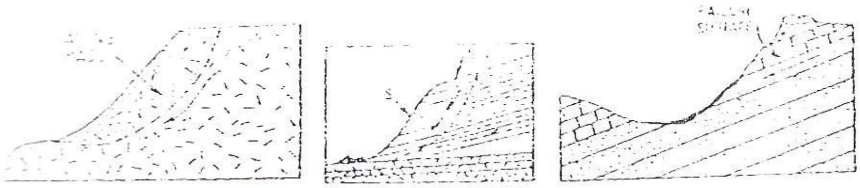
Type of Landslides

The landslides can be classified into three namely 1) Flowage 2) Sliding and 3) Subsidence based on the rate of movement, nature of the mass involved in failure and degree of saturation where applicable

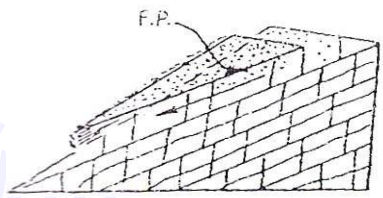
Flowage: It is defined as downgrade movement of mass along no defined surface of failure. Mass involved in this type of failure is primarily unconsolidated or loosely packed or disintegrated and decay materials and these materials behave as if it has its own shear failure surface. The result is that the movement is highly irregular (Fig). Flowage is further distinguished into slow and rapid flowage. In the first group, is not easily perceptible. The rapid flowage, however the movement of failing mass may be easily visible and it moves few meters a day



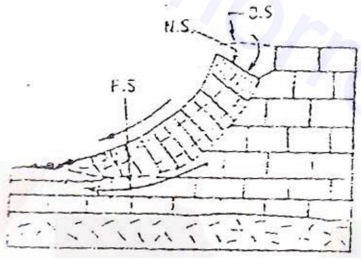
Sliding: It is means of mass failure in which a superficial mass falls by moving as a whole along a definite surface may be planar or semicircular in outline. The mass above the failure surface is generally unconsolidated deposits, loose, inherently weak rock masses and weathered top surface, sliding commonly takes place along circular surface. But when the mass involved is hard and brittle shear surface planar in character (Fig). The slides are further classified into 1) Translational, 2) Rotational slides and 3) Rock Toppling and falls.



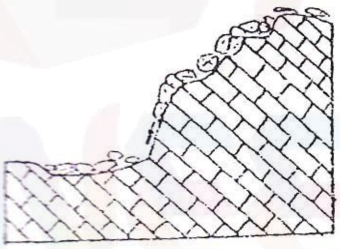
Translational slides: The surface of failure is generally planner in character, speed of failure is quite rapid and the nature of mass involved in failing may be rock block, rock slab, debris and soil cover or even a mixture of all of them.



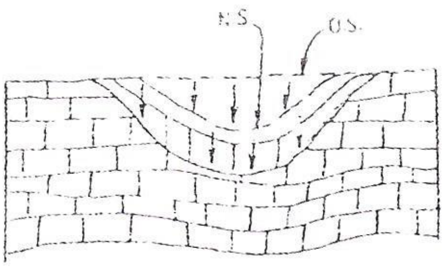
Radial Slides: In such slides, the failing surface is generally curved in character and the speed of failure is also quite rapid. The materials involved in failure tilt at the rear end and heaves up at the front or toe.



Rock Toppling and falls: Surface layer of rock and soils on the steep slopes that are likely to fail in the form of falls.



Subsidence: It is defined as sinking or setting of the ground in almost variously downward direction which may occur because of removal of natural support from the underground or due to compaction of the weaker rocks under the load from overlying mass. As a result the natural ground fill suffers a sinking, downward movement.

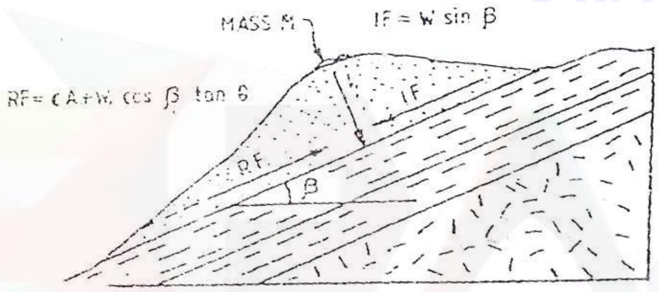


Causes of Landslides:

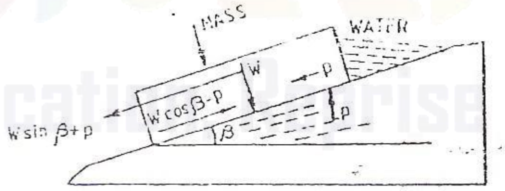
Many factors are known to cooperate in causing a mass of materials to flow or fail or fall, some of them play a direct role and are easily understood whereas other are indirectly responsible for the instability of the land mass, Bases on this the land landslides operated by internal forces and external forces

Internal Forces: It includes nature of the slope and the water content are very crucial in defining the stability of ground anywhere. The composition of the ground materials and the geological character of the area are other two internal factors that determine to a great extent if a land mass in a given area would be stable or not. The role these natural factors play in the stability of the land mass are as follow.

The Nature of Slope: Some slopes are very stable even when very steep, whereas others are inherently unstable, and may fail repeatedly even at very gently angles. Since a great majority of mass failures are confined to slope only, it is reasonable to conclude the nature of a slope may be a deciding factor in defining the stability or otherwise of a land mass.



The Role of Water: Both surface and subsurface water causing mass movement. Water that penetrates the soil and rocks thought seepage and moves into the pores of the mass may be the causes of uplift or pore-pressure within the mass under consideration. Water that accumulates at the back of a mass may exert a pressure, parallel to the direction of flow and add to the shearing forces causing instability.



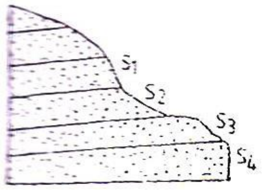
Composition of the Mass: Some materials are stable in a given set of conditions of slope and water content whereas other may be unstable. Crystalline igneous rocks like granites and gabbros, metamorphic rock like marbles, quartzite and gneisses may be stable even with vertical slopes whereas the same cannot be said about chalk- a soft variety of limestone, or shale or clay stone or soil. It is, therefore, obvious that a fundamental character that is responsible for the stability of mass is its composition, which has both physical and chemical implication.

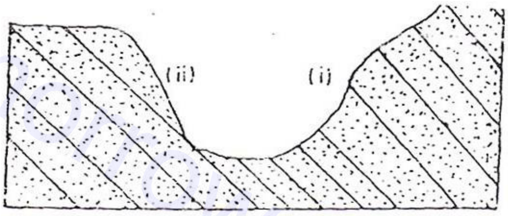
Geological Structure: Geological structures are of great significance in defining the stability of mass, especially in rocks. These structures may be divided into three classes,

1. The bedding plane in structure,

2. The Schistosity and
3. The jointing Structure

i). Bedding plane in structure: Many sedimentary rocks are layered or stratified and thickness of layers may range from a few centimeters to many meters. The dip of the stratified rocks exerts very important influence on the stability of slopes. If the layer is horizontal, such rock slopes of the natural valleys and artificial cuts are stable at all the angle up to 90°. When they fall it may be due to presence of secondary joints or related features.





If the layers are inclined, in such a situation, assuming that the rock is free from any other type of discontinuities, the stability of a slope will depend primarily on the condition whether the layer are dipping backwards into the mountain or forward into the valley.

ii). Schistosity: Schisotsity, foliation and cleavage structures are behaving as surface of weakness and are prone to failure. This is primarily due to the fact that weathering in these rocks takes place along these planes.

iii). The Jointing structures: Joints of any type are always to be studied with great caution in rocks making slope for two reasons:

Firstly, very few rocks are free from these structures which may occur due to tension, compression or shear to which these rocks have been subjected since their formation.

Secondly, they occur in sets or groups effecting the rock from the surface to considerable depth and eventually reducing the shear strength of the rock mass considerably.

External Forces: The external features are also influence the cause of landslides.

Vibration: A mass perched on slope may be stable but critically; the gravitative forces have not yet overcome its frictional resistance. A slight vibration or jerk to the mass may be sufficient to disturb this equilibrium and the mass becomes unstable. Such vibrations are easily available from heavy blasting and heavy traffic on hill roads.

Another important external factor is the removal of the support at the foot of the slope, as during excavation for road widening, without due regard to the critical condition of stability. The slope that might have been previously stable becomes hazardous after such an excavation.

3. Discuss the geological processes that result in coastal erosion. Further, give a detailed account of the various coastal protection structures that are in practice. [N/D-15]

COASTAL PROTECTION

Coast is defined as a boundary between sea and mainland. It has been shaped by varying influence of tectonic activity and instability of sea level. Coast is associated with the sea and may include areas of cliffs, dune, beaches and even hills and plains and it has been affected by marine processes such as tides, winds, waves and current. In general coasts that are composed of soft, unconsolidated materials, such as sand which changes more rapidly than coasts composed of rock.

Types of Coast

According to Johnson, the coast may be classified in to two types that is a) Submerged coast and b) Emerged coast. It is based on sea level related with climate and tectonic activity. The submerged coast is the coastal interior; the land immediately behind the shore zone (whose inner limit is defined by the highest storm and tide waves) has an intermediate inner limit. The erosional features like Cliffs, Sheets and Gullies are seen along the erosional coast. While in the case of an emerged coast, the coastal tract where the seaward migration of the coastal tract is a low land, depositional features like deltaic sedimentation, estuarine, marsh and sand dunes are the characteristic features.

Importance of Coast

The coastal environment is very dynamic with many cyclic and random processes owing to a variety of resources and habitats. Further the coastal ecosystems are the most productive ecosystems on earth. About 60 percent of world population lives near the coast and in one way or other depends directly or indirectly on the coastal zone and its resources (Like Coral reefs, Mangrove, Seaweeds, Sea grass, Salt marsh, Beach etc). Thus the coastal zone plays a vital role on the nation's economy.

Coastal Problems in India

The coastal area in India faces a wide range of problems. A recent regional survey conducted by International Ocean Institute, Operational Center at Chennai revealed several problems. As per the survey, in India, population pressure has been considered as the most important problem. Environmental degradation such as destruction of mangroves along with pollution and urbanization is considered as the next serious problem.

Traditionally, coastal areas are highly populated and developed. In India, out of the 3-mega cities with population more than 10 million, Delhi (13.2 M), Bombay (16 M) and Calcutta (16.5 M) two are coastal cities i.e., Bombay and Calcutta. The population density is also more coastal areas than the national average. For example, in the state of Tamilnadu, the population density in coastal area is 528 per sq.km against 372 per sq.km which is state average. In parts of coastal metros like Bombay, Calcutta and Madras, the population pressure led to resource depletion and environmental degradation.

The major activities that are responsible for coastal population in India are discharge and disposal of domestic and industrial wastes, discharging of coolant waters, harbor activities such as dredging, cargo handling, dumping of ship wastes, spilling of cargo's such as chemical and metal ores, oil transport and fishing activity, etc. Domestic waters are discharged mostly in untreated conditions due to lake of treatment facilities in most of t he cities or towns. India is one of the largest industrialized nations in the world. Major industrial cities and town such as Surat, Bombay, Cochin, Chennai and Visakhapatnam and Calcutta are situated on or near the coastline. The estimated total quantity of waste discharged by these industries is estimated to be approximately 700 million cu.m

The coastal erosion is caused by wave braking, reduction in sediment input to coast, tectonic upheavals and rise in sea level. These causes are not only natural, but also, due to human influence. In west coast, erosion is very severe along Kerala coast. In Karnataka, about 73 km of the coast is affected by erosion. Along the east coast the coastal erosion is moderate. In Tamilnadu, about 80 km of the coastline is affected. In Orissa, about 30 to 40 km are affected. In West Bengal, erosion occurs in 180 km, along the coastline stretching from the confluence of the river Hooghly in the west to the confluence of the river Jadgan in the east. The rate of erosion is as high as 30 m/year.

In India, nearly 150 million people are prone to natural hazard in coastal areas. Bay of Bengal is one of the five cyclone prone areas of the world. The coastal regions surrounding this bay are frequently affected by flooding from the sea as well as the rivers due to tropical cyclones and related storm surges and heavy rainfall. Between the year 1990 and 1995 in the state of Andhra Pradesh, more than 1100 human lives were lost and properly worth of Rs.23, 000 million were damaged. In Tamilnadu during the year 1990 and 1995, the damages caused to property were worth of Rs. 5, 800 million and the loss of human lives was more than 500.

Shoreline Erosion and Accretion

Shoreline is one of the most rapidly changing landforms of the earth. The geomorphic processes of erosion and accretion, periodic storms, flooding and sea level changes continuously modify the shoreline. The rate of shoreline-change varies depending upon the intensity of the causative forces, warming up of oceanic water and melting of continental ice sheets etc, which result in submergence or emergence of land.

The coastal erosion and accretion processes are not new phenomena. Generally the main causes of these processes can be thought of (i) beach configuration; (ii) tectonic movements in the coastal belt and the near shore (iii) presence of mud blanks, (iv) gradual climate changes, (v) reduction in the discharging of sediments from rivers and (vi) manmade activities along the coast.

Tamil Nadu with a coastal length of 980 km is the second largest coast in India. This state experience two monsoon periods, one is active from mid-June to mid-September (i.e, southwest monsoon) and the other is active from mid-October to mid-January (i.e., northeast monsoon). All the districts of the study area are affected by cyclonic storms almost every alternative year (For example, during the period 1877-1977, the coast has been hit by the storms for at least 50 times). During certain years, the coast has been hit by cyclonic storms even more then once.

Management measures of Coastal protection

The following measures are some management measures for coastal protection:

- To create awareness among the coastal communities in the study area, in order to protect and conserve the coastal area through effective involvement of educational institutions and NGOS
- Stringent measures need to be under taken with immediate effect to ban coastal and coral mining and to take into task those involved in or those who encourage the exploitation of corals for any purpose. Patrolling the coast to check coral and coastal mining should be carried out.
- Law should be enacted to regulate and stop trawl boat operation in the zone earmarked for non-mechanized boat. The Department of Forest and the Department of Fisheries should take steps to stop anchoring of vessels on coral reefs, pair trawling and dynamite fishing.
- Indiscriminate picking of budding seaweeds need to be banned.
- Commercial shell collection should be controlled and closely monitored.
- Marine Resource Management Centers should be established to improve the skills of fishermen communities in areas other than coastal mining, which in turn will lead to efficient management of coast.
- Deforestation along the coast and islands should be banned. The forest Department should take up a forestation along the coast and islands to protect soil erosion.
- Discharging of untreated sewage and urban wastes into the coastal waters should be totally banned.
- Construction of embankment walls along the coast to prevent the coastal erosion etc.

Coastal protection structures

Necessity for protection

Incessant natural phenomena such as winds, waves,currents and cyclones occurring continuously affect the shore line . due to these phenomena there may be erosion or accretion of shore materials. Change in the shore line caused due to excessive siltation at ports, demand removal of excess material b dredging. On the other hand erosion may lead to scoring of neighbouring structures. Compared to structures in the interior land , costal structures are subjected to more severe forces and need constant maintenance. Hence the shore line has to be protected so as to maintain the requirement.

Shore protection works

Shore protection works are involved in

1. To protect an exposed beach line
2. To stabilize the existing beach
3. To restore eroded beach
4. To create and stabilize artificial beach

   Shore protection wors in general are:

   14. Sea walls and bulheads

15. Protective beaches
16. Sand dunes
17. Groynes
18. Off shore breakwater

Sea walls and bulheads

These are the structures constructed parallel to the shore line special to separate land area from water area. These are constructed to stop further recession of shore line.

Alignment of such wall should be straight as far as possible and may be curves. Abrupt change in direction may cause added wave forces. Bulk head are meant to retain the earth behind from sliding and also provides a wave protection device.

Sea walls are used where the land to be protected in a developed one and waves effects are severe. Sea walls are ver massive and expensive. These walls prevent shoreward movements of high water line. sheet pile walls or solid reinforcement mason walls ma be used.

Inclined shores are provided with stone rivertment.lie sea walls revetments are used mainl to protect the land and upland propert against wave action and also function as a retaining wall.

Protective beaches

Beaches of suitttable dimensions are effective in dissipating energy and alsop provide protection to the adjacent upland. Eroded beaches an be wade good b planning beach fill so as toensuresandsuppl at the required rate.

Periodic repleinishment of stockpile is called artificial beach nourishments. It also maes good the deficiencies in natural sand suppl and protects the shore beond the beach at a low cost.

Sand dunes

The are formed along the coast which prevent the free movement of tides and wavws into the area behind it. Sand dunes with time may migrate to the adjacent areas and damage the propert. Dune sand ma stabilize by vegetation. Under severe weather conditions the formation will be different.

Gyrones

It is another shore protection tructures. This is used to built a protection beach to retard erosion.it also protect the toe sea walls or bulkheads

Gyrones are constructed well into the sea perpendicular to shore line .Gyrones

Ma also be constructed with certain angle to shore line.

A series of Gyrones acting together to protect a shore line is called Gyronessstem. Spacing between Gyrones is such that the length and spacing are in the ratio of 1:1 to 1:3. Closer spacing and spacing beond 1: 3 are inefficient.

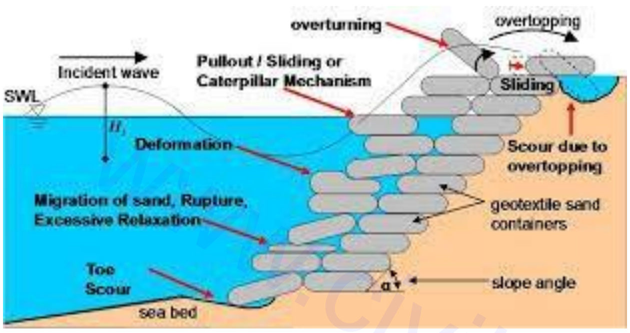
Gyrones are expected to resist wave action and sand pressure. Gyrones can be constructed of timber piles or steel sheet piles.

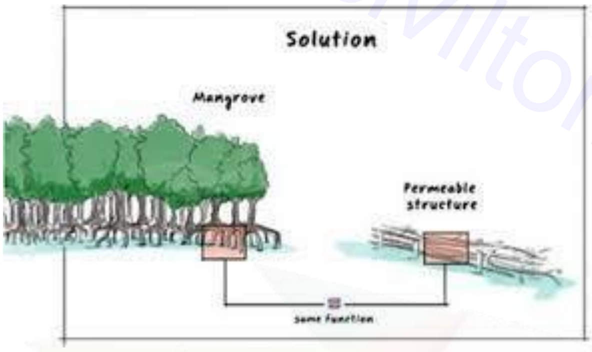
Off-shore breakwaters

Off-shore breakwaters serve in several wasy such as,

1. Protecting an area from wave action
2. Shore protection structure
3. Acts as a trap for littoral drift

These are of mound type breakwaters which provide protection to harbor entrances. Some times offshore breakwaters are constructed off shore of sea walls so as to reduce the determined forces on the sea walls. Littoral movements are very effectively intercepted by off shore break waters





4. Using case studies, explain how groundwater investigation and exploration is carries out by civil engineers. [N/D-15]

GROUNDWATER INVESTIGATIONS

In addition to pumping tests, Groundwater Engineering provides a complete service for a wide range of groundwater investigation techniques.

Desk top studies and research into existing information can be a very cost effective way to identify groundwater problems at an early stage. Numerical groundwater modelling can be used to assess likely flow rates, distance of influence and the potential for adverse environmental impacts.

INSTALLATION OF MONITORING WELLS

Monitoring wells and specialist piezometers installed in advance of dewatering works can provide valuable information on hydrogeological conditions at a site.

PUMPING TESTS

Pumping tests are a reliable way of determining the mass permeability of soils and rocks, and of providing other information on groundwater conditions.

BOREHOLE PERMEABILITY TESTS

A range of tests can be carried out in individual boreholes, including rising and falling head tests, constant head tests, Lugeon tests, Lefranc tests and packer tests. When carried out in accordance with relevant published standards and interpreted appropriately, such tests can provide some indication of permeability values and groundwater conditions.

GROUNDWATER MONITORING SYSTEMS

Groundwater monitoring systems can play an important role in construction projects to allow groundwater conditions to be monitored and to provide data for design purposes.

Groundwater potential evaluation for a given area/basin requires integrated approach. Detailed quantification of the amount of groundwater demand a detailed water balance study and defining the boundary conditions, establishment of the lateral and vertical extent of aquifers and confining beds. In the absence of detailed hydro meteorological and hydrogeological data, groundwater potential evaluation tends to be more semi-quantitative mainly based on geophysical investigation.

The method followed in this study, for the most part, was depending on the short-term field hydrogeological investigation and surface geophysical surveying. Both approaches provide information on the availability of groundwater in a semi-quantitative sense.

Geophysics provides no information on the exact amount of groundwater available in the subsurface. The amount can only be estimated when the geophysical survey is supported by the local hydrogeological features such as recharge potential, availability of permeable rocks, catchments areas, etc.

All the interpretations shown in the geophysical part of this study are made semi-quantitatively by integrating the hydrogeological field observations with the geophysical signature obtained from the VES data. The recommendations of the likely depth of drilling are made on the basis of the VES data and the nearby well data. The supervisor/ hydro geologist can recommend the accurate drilling depth during the drilling operation. For instance in some sites where geophysics does not give conclusive answers on the total depth of the aquifers, yield of the well can be defined by using provisional tests with the compressor of the drilling machine.

5. Give an account of causes of inherent weakness in rocks. How rock qualities could be improved by artificial treatment. [M/J-16]

In the majority of cases the main trigger of landslides is heavy or prolonged rainfall. Generally this takes the form of either an exceptional short lived event, such as the passage of a tropical cyclone or even the rainfall associated with a particularly intense thunderstorm or of a long duration rainfall event with lower intensity, such as the cumulative effect of monsoon rainfall in South Asia. In the former case it is usually necessary to have very high rainfall intensities, whereas in the latter the intensity of rainfall may be only moderate - it is the duration and existing pore water pressure conditions that are important. The importance of rainfall as a trigger for landslides cannot be underestimated. A global survey of landslide occurrence in the 12 months to the end of September 2003 revealed that there were 210 damaging landslide events worldwide. Of these, over 90% were triggered by heavy rainfall. One rainfall event for example in Sri Lanka in May 2003 triggered hundreds of landslides, killing 266 people and rendering over 300,000 people temporarily homeless. In July 2003 an intense rain band associated with the annual Asian monsoon tracked across central Nepal, triggering 14 fatal landslides that killed 85 people. The reinsurance company Swiss Re estimated that rainfall induced landslides associated with the 1997-1998 El Nino event triggered landslides along the west coast of North, Central and South America that resulted in over $5 billion in losses. Finally, landslides triggered by Hurricane Mitch in 1998 killed an estimated 18,000 people in Honduras, Nicaragua, Guatemala and El Salvador. So why does rainfall trigger so many landslides? Principally this is because the rainfall drives an increase in pore water pressures within the soil. The Figure A illustrates the forces acting on an unstable block on a slope. Movement is driven by shear stress, which is generated by the mass of the block acting under gravity down the slope. Resistance to movement is the result of the normal load. When the slope fills with water, the fluid pressure provides the block with buoyancy, reducing the resistance to movement. In addition, in some cases fluid pressures can act down the slope as a result of groundwater flow to provide a hydraulic push to the landslide that further decreases the stability. Whilst the example given in Figures A and B is clearly an artificial situation, the mechanics are essentially as per a real landslide.

6. What do you understand by a ‘dam disaster’? discuss these geological situations which when ignored could be the cause of the possible dam disaster. [M/J-16]

Dams may be defined as a solid barrier constructed at a suitable geological location across a river valley.

Objectives of Dam Construction

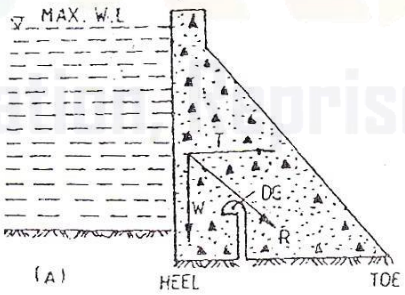
The followings are the objectives of the dam construction:

4. Generating the hydroelectricity
5. Providing water for irrigation
6. Providing water supply for industries
7. Fighting drought and controlling of floods
8. Providing navigational facilities

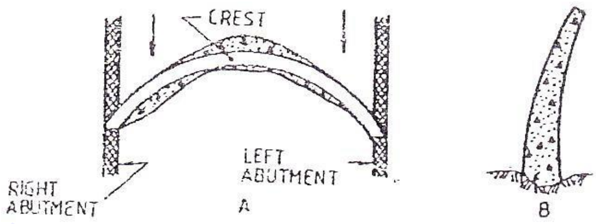
Classification of Dams

Dams are classified 1) Gravity Dams, 2) Arch Dams and 3) Embankment Dams. This classification is based on design, materials, and size of the construction.

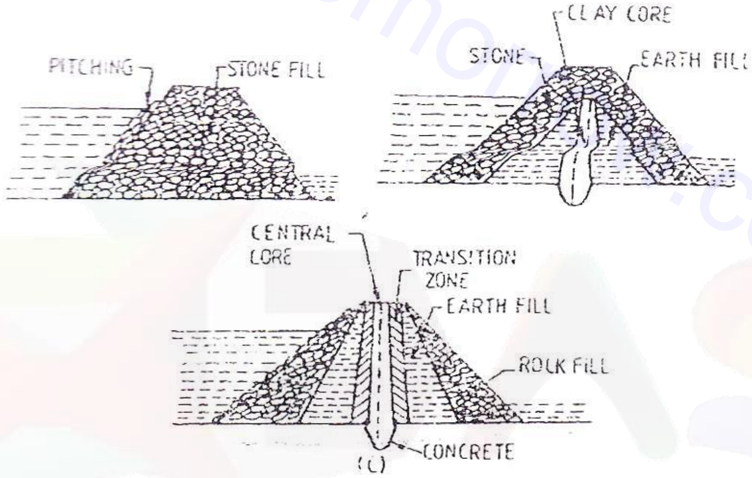
Gravity Dams: It is a solid masonry or concrete structure, generally of a triangular profile, which is so designed that it can withhold a particulate volume of water by virtue of its weight. All force arising in such a dam as due to the thrust of the impound water and the massive weight of the dam materials are assumed to the foundation rocks. This kind of dams is always very important and costly structure, therefore its design and construction should always be done very carefully.



Arc Dams: It is arc-Shaped solid structure mostly of concrete, which is designed in such a way that a major part of the thrust forces acting on the dam are transmitted mainly by the arch action, on to the abutment rocks, that is rock forming the left and right sides of the stream valley. Hence such dames can be built even on those sites where the foundation rocks may not be sufficiently strong.



Embankment or Earth Dams: The embankment dams are generally trapezoidal in section constructed of selected soil or earth obtained from the borrow pits of the adjoining areas. Sometimes an embankment dams also contains a hard rock-fill, depending upon the height, base width and length of the dam as shown in the figure.



Suitable Geological Site for Dam Construction

To select suitable site for dam construction some preliminary geological survey of the entire catchments area to be done followed by detailed geological mapping by remote sensing method. It can gives the information of 1) Topographic features, 2) Natural Drainage pattern, 3) General Character, 4) Structural features of rocks, such as fold, fault and joints and 5) trend and rate of weathering. Such a study when interpreted properly, would ruled out some sites for the dam placement and help in identifying the most suitable locations topographically and economically, where further detailed geological investigation could be carried out. For obtaining the above information, remote sensing and conventional geological survey need to be conducted.

Geology of the site

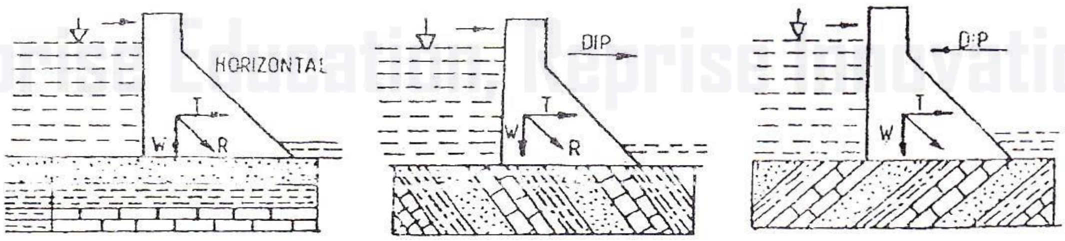
Lithology: To understanding the lithology of the area is very important to select the site for dam construction. It can be possible through conventional and remote sensing methods. Such study reveals the type, composition and texture of the rocks exposed along the valley floor, yet it is of great significance to know what class of rocks makes up the area; igneous, sedimentary or metamorphic. Lithology interpretation is to identify information of rock unit with reference to their physical characteristics, topography, etc. This is based primary on photo-interpretation elements, e.g, tone, pattern, size, texture, shape and relationship condition in photos and image and terrain parameters and associated features with convergence of evidence.

Examples: Intrusive rocks can be identified from satellite imagery using the following interpretation key:
Colour/Tone - Light tone or medium red
Texture - Coarse to fine
Pattern - Sub dendrite
Bedding - Non-bedding
Boundary - Round cliffs
Structure - Lineament, syncline and anticline.

Structure: The interpretation of structural features is very important for sit selection for dam. The structural features like folding, faulting, joints, shear zones and fault zone and associated features can be identified through remote sensing method.
Example: The fault is easy to pick up on aerial data and satellite image by sharp topographic break and linear alignments of structure, water bodies or vegetation. Dip and Strike, Fault, Folds and Joints are some important features of rocks for dam foundation.

Dip and Strike: The bedded rocks are stronger in composition, and can bear greater stress when applied normal to the bedding planes than the stress applied along the bedding planes. Thus the desired conditions are that the resultant thrust, should be perpendicular to the bedding plane. The bedding generally upstream offer best resistance to the resultant thrust and also obstructs the leakage of water than those dipping down-stream as shown in figures.

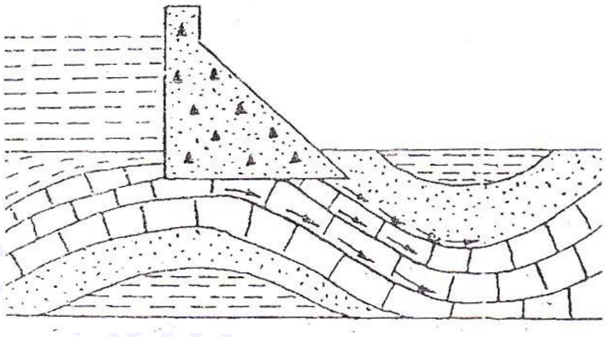
Folds: The folded rocks are always under a considerable strain, and the same is released whenever any kind of excavation is done through them or they are distributed by some external forces or stress. It is therefore desirable that a highly folded rock should always be avoided. If the engineer is compelled to adopt such a site, he should see that the foundations of his dam should rest on the upstream limbs of the fold, if the fold is anticlinal in nature as shone in figure. But the fold is synclinal in nature; the foundations of the dame should rest on the downstream limbs of the fold as shown in figure.



A B C

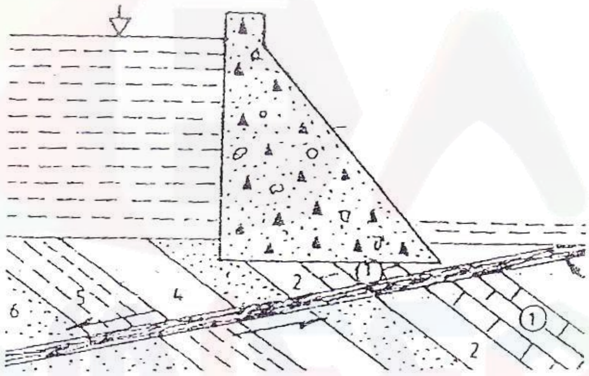
Different possible positions of a gravity dam

A. On horizontal bed rocks – suitable condition
B. On down stream dipping rocks – unsafe
C. On upstream dipping condition – safe against R



Effect of folding on dam site

Fault: It is always to avoid risk by rejecting a site on a fault, as the movement along the existing fault plane is much easier than along the any other plans. Even a slight disturbance may damage the structure constructed on Fault. If the engineer is completed by the circumstances to adopt such a situation, then he should see that the site has the fewest disadvantages or no serious defects. It is advisable in such cases to place the foundation of a dame upstream of the fault and not downstream of it as shown in figure.



Joints: No sites are totally free from joining. Hence, sites cannot be abandoned, even if profusely jointed. However, the detailed mapping of the aspects and character of joints as developed in the rock of proposed site has to be taken up with the great caution. The geometry of joints, their intensity, nature and continuity with depths all must be established, and their effect on the site rocks are to be evaluated and remedial measurement to be taken in advance. Occurrence of micro joints has to be source of many risks.

Engineering properties

Lithological and structural studies are not sufficient for the selection of site for dam. A through testing both in laboratory and in situ of the site rock for their most important engineering properties has to be carried out such as compressive strengths, shear strength, modulus of elasticity, porosity and permeability and resistant to disintegration on repeated weathering and drying.

7. What are the effects of the action of sea waves on the coastal zones? Add a note on the Various coastal protection structures. [N/D-16]

Coast is defined as a boundary between sea and mainland. It has been shaped by varying influence of tectonic activity and instability of sea level. Coast is associated with the sea and may include areas of cliffs, dune, beaches and even hills and plains and it has been affected by marine processes such as tides, winds, waves and current. In general coasts that are composed of soft, unconsolidated materials, such as sand which changes more rapidly than coasts composed of rock.

Types of Coast

According to Johnson, the coast may be classified in to two types that is a) Submerged coast and b) Emerged coast. It is based on sea level related with climate and tectonic activity. The submerged coast is the coastal interior; the land immediately behind the shore zone (whose inner limit is defined by the highest storm and tide waves) has an intermediate inner limit. The erosional features like Cliffs, Sheets and Gullies are seen along the erosional coast. While in the case of an emerged coast, the coastal tract where the seaward migration of the coastal tract is a low land, depositional features like deltaic sedimentation, estuarine, marsh and sand dunes are the characteristic features.

Importance of Coast

The coastal environment is very dynamic with many cyclic and random processes owing to a variety of resources and habitats. Further the coastal ecosystems are the most productive ecosystems on earth. About 60 percent of world population lives near the coast and in one way or other depends directly or indirectly on the coastal zone and its resources (Like Coral reefs, Mangrove, Seaweeds, Sea grass, Salt marsh, Beach etc). Thus the coastal zone plays a vital role on the nation's economy.

Coastal Problems in India

The coastal area in India faces a wide range of problems. A recent regional survey conducted by International Ocean Institute, Operational Center at Chennai revealed several problems. As per the survey, in India, population pressure has been considered as the most important problem. Environmental degradation such as destruction of mangroves along with pollution and urbanization is considered as the next serious problem.

Traditionally, coastal areas are highly populated and developed. In India, out of the 3-mega cities with population more than 10 million, Delhi (13.2 M), Bombay (16 M) and Calcutta (16.5 M) two are coastal cities i.e., Bombay and Calcutta. The population density is also more coastal areas than the national average. For example, in the state of Tamilnadu, the population density in coastal area is 528 per sq.km against 372 per sq.km which is state average. In parts of coastal metros like Bombay, Calcutta and Madras, the population pressure led to resource depletion and environmental degradation.

The major activities that are responsible for coastal population in India are discharge and disposal of domestic and industrial wastes, discharging of coolant waters, harbor activities such as dredging, cargo handling, dumping of ship wastes, spilling of cargo's such as chemical and metal ores, oil transport and fishing activity, etc. Domestic waters are discharged mostly in untreated conditions due to lake of treatment facilities in most of t he cities or towns. India is one of the largest industrialized nations in the world. Major industrial cities and town such as Surat, Bombay, Cochin, Chennai and Visakhapatnam and Calcutta are situated on or near the coastline. The estimated total quantity of waste discharged by these industries is estimated to be approximately 700 million cu.m

The coastal erosion is caused by wave braking, reduction in sediment input to coast, tectonic upheavals and rise in sea level. These causes are not only natural, but also, due to human influence. In west coast, erosion is very severe along Kerala coast. In Karnataka, about 73 km of the coast is affected by erosion. Along the east coast the coastal erosion is moderate. In Tamilnadu, about 80 km of the coastline is affected. In Orissa, about 30 to 40 km are affected. In West Bengal, erosion occurs in 180 km, along the coastline stretching from the confluence of the river Hooghly in the west to the confluence of the river Jadgan in the east. The rate of erosion is as high as 30 m/year.

In India, nearly 150 million people are prone to natural hazard in coastal areas. Bay of Bengal is one of the five cyclone prone areas of the world. The coastal regions surrounding this bay are frequently affected by flooding from the sea as well as the rivers due to tropical cyclones and related storm surges and heavy rainfall. Between the year 1990 and 1995 in the state of Andhra Pradesh, more than 1100 human lives were lost and properly worth of Rs.23, 000 million were damaged. In Tamilnadu during the year 1990 and 1995, the damages caused to property were worth of Rs. 5, 800 million and the loss of human lives was more than 500.

Shoreline Erosion and Accretion

Shoreline is one of the most rapidly changing landforms of the earth. The geomorphic processes of erosion and accretion, periodic storms, flooding and sea level changes continuously modify the shoreline. The rate of shoreline-change varies depending upon the intensity of the causative forces, warming up of oceanic water and melting of continental ice sheets etc, which result in submergence or emergence of land.

The coastal erosion and accretion processes are not new phenomena. Generally the main causes of these processes can be thought of (i) beach configuration; (ii) tectonic movements in the coastal belt and the near shore (iii) presence of mud blanks, (iv) gradual climate changes, (v) reduction in the discharging of sediments from rivers and (vi) manmade activities along the coast.

Tamil Nadu with a coastal length of 980 km is the second largest coast in India. This state experience two monsoon periods, one is active from mid-June to mid-September (i.e, southwest monsoon) and the other is active from mid-October to mid-January (i.e., northeast monsoon). All the districts of the study area are affected by cyclonic storms almost every alternative year (For example, during the period 1877-1977, the coast has been hit by the storms for at least 50 times). During certain years, the coast has been hit by cyclonic storms even more then once.

Management measures of Coastal protection

The following measures are some management measures for coastal protection:

- To create awareness among the coastal communities in the study area, in order to protect and conserve the coastal area through effective involvement of educational institutions and NGOS
- Stringent measures need to be under taken with immediate effect to ban coastal and coral mining and to take into task those involved in or those who encourage the exploitation of corals for any purpose. Patrolling the coast to check coral and coastal mining should be carried out.
- Law should be enacted to regulate and stop trawl boat operation in the zone earmarked for non-mechanized boat. The Department of Forest and the Department of Fisheries should take steps to stop anchoring of vessels on coral reefs, pair trawling and dynamite fishing.
- Indiscriminate picking of budding seaweeds need to be banned.
- Commercial shell collection should be controlled and closely monitored.
- Marine Resource Management Centers should be established to improve the skills of fishermen communities in areas other than coastal mining, which in turn will lead to efficient management of coast.
- Deforestation along the coast and islands should be banned. The forest Department should take up a forestation along the coast and islands to protect soil erosion.
- Discharging of untreated sewage and urban wastes into the coastal waters should be totally banned.
- Construction of embankment walls along the coast to prevent the coastal erosion etc.

Coastal protection structures

Necessity for protection

Incessant natural phenomena such as winds, waves,currents and cyclones occurring continuously affect the shore line . due to these phenomena there may be erosion or accretion of shore materials. Change in the shore line caused due to excessive siltation at ports, demand removal of excess material b dredging. On the other hand erosion may lead to scoring of neighbouring structures. Compared to structures in the interior land , costal structures are subjected to more severe forces and need constant maintenance. Hence the shore line has to be protected so as to maintain the requirement.

Shore protection works

Shore protection works are involved in

5. To protect an exposed beach line
6. To stabilize the existing beach
7. To restore eroded beach
8. To create and stabilize artificial beach

Shore protection wors in general are:

19. Sea walls and bulheads

20. Protective beaches
21. Sand dunes
22. Groynes
23. Off shore breakwater

Sea walls and bulheads

These are the structures constructed parallel to the shore line special to separate land area from water area. These are constructed to stop further recession of shore line.

Alignment of such wall should be straight as far as possible and may be curves. Abrupt change in direction may cause added wave forces. Bulk head are meant to retain the earth behind from sliding and also provides a wave protection device.

Sea walls are used where the land to be protected in a developed one and waves effects are severe. Sea walls are ver massive and expensive. These walls prevent shoreward movements of high water line. sheet pile walls or solid reinforcement mason walls ma be used.

Inclined shores are provided with stone rivertment.lie sea walls revetments are used mainl to protect the land and upland propert against wave action and also function as a retaining wall.

Protective beaches

Beaches of suitttable dimensions are effective in dissipating energy and alsop provide protection to the adjacent upland. Eroded beaches an be wade good b planning beach fill so as toensuresandsuppl at the required rate.

Periodic repleinishment of stockpile is called artificial beach nourishments. It also maes good the deficiencies in natural sand suppl and protects the shore beond the beach at a low cost.

Sand dunes

The are formed along the coast which prevent the free movement of tides and wavws into the area behind it. Sand dunes with time may migrate to the adjacent areas and damage the propert. Dune sand ma stabilize by vegetation. Under severe weather conditions the formation will be different.

Gyrones

It is another shore protection tructures. This is used to built a protection beach to retard erosion.it also protect the toe sea walls or bulkheads

Gyrones are constructed well into the sea perpendicular to shore line .Gyrones

Ma also be constructed with certain angle to shore line.

A series of Gyrones acting together to protect a shore line is called Gyronessstem. Spacing between Gyrones is such that the length and spacing are in the ratio of 1:1 to 1:3. Closer spacing and spacing beond 1: 3 are inefficient.

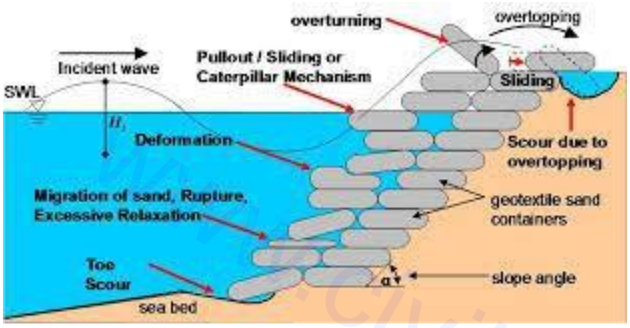
Gyrones are expected to resist wave action and sand pressure. Gyrones can be constructed of timber piles or steel sheet piles.

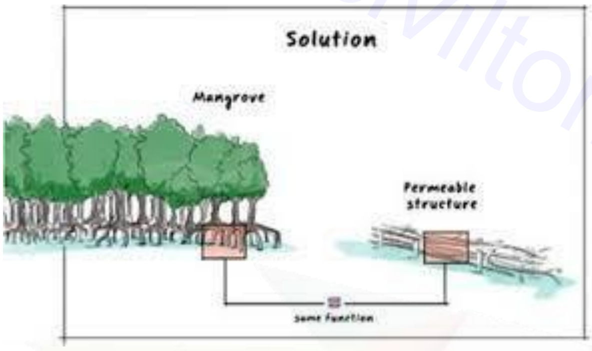
Off-shore breakwaters

Off-shore breakwaters serve in several wasy such as,

4. Protecting an area from wave action
5. Shore protection structure
6. Acts as a trap for littoral drift

These are of mound type breakwaters which provide protection to harbor entrances. Some times offshore breakwaters are constructed off shore of sea walls so as to reduce the determined forces on the sea walls. Littoral movements are very effectively intercepted by off shore break waters


overturning
overtopping
Incident wave
Pullout / Sliding or
Caterpillar Mechanism
Sliding
SWL
Deformation
Scour due to
overtopping
Migration of sand, Rupture,
Excessive Relaxation
geotextile sand
containers
Toe
Scour
slope angle
sea bed


Solution
Mangrove
Permeable
structure
same function

8. List the causes of landslides. Also, classify landslides and give a detailed account of the methods of preventing them. [N/D-16][M/J 13]

The term landslide refers to the downward sliding of huge quantities of land masses. Such sliding occurs along steep slopes of hills or mountains.. It may be sudden or slow in its occurrence. Also, in magnitude, it may be major or minor.

Often, loose and unconsolidated surface material undergoes sliding. But sometimes, huge blocks of consolidated rocks may also be involved. If landslides occur in places of importance such as highways, railway lines, valleys, reservoirs, inhabited areas and agricultural lands leads to blocking of traffic, collapse of buildings, harm to fertile lands and heavy loss to life and property. In India, landslides often occur in Kashmir, Himachal Pradesh and in the mountains of Uttar Pradesh.

CLASSIFICATION OF EARTH MOVEMENTS: All movements of land masses are referred to as landslides and grouped them under "earth movements". The classification of earth movements us as follows:

EARTH MOVEMENTS	EARTH FLOWS	Solifluction
		Creep
		Rapid flows
	LANDSLIDES	Debris slides and slump
		Rock slides
		Rock falls
	SUBSIDENCE	Compaction
		Collapse

Earth Flows: There are three types of earth flows viz., solifluction; creep and rapid flows.

Solifluction refers to the downward movement of wet soil along the slopes under the influence of gravity.

Creep refers to the extremely slow downward movement of dry surface material. This is very imp from the civil engg point of view due to slow movement of mass. On careful examination, bending of strata ; dislodgement of fence posts ; telephone poles, curvature of tree trunks; broken retaining walls etc offer clues to recognize creep.

Rapid flows are similar to creep but differ with reference to the speed. Rapid flows generally accompany heavy rains. Mud flows are similar to rapid flows.

Landslides include Debris slides, rock slides and rock falls.

Debris slides are common along the steep sides of rivers, lakes. Debris slides of small magnitude are called slumps..

Rock slides are the movements of consolidated material which mainly consists of recently detached bedrocks. For eg: a rock slide that took place at Frank, Alberta in 1903 killing 70 people.

Rock falls refer to the blocks of rocks of varying sizes suddenly crashing downwards along steep slopes. These are common in the higher mountain regions during the rainy seasons.

Subsidence may take place to the compaction of underlying material or due to collapse.

Subsidence due to compaction: Sediments often become compact because of load. Excessive pumping out of water and the withdrawal of oil from the ground also cause subsidence.

Subsidence due to collapse: In regions where extensive underground mining has removed a large volume of material, the weight of the overlying rock may cause collapse and subsidence.

CAUSES OF LANDSLIDES: Landslides occur due to internal causes (inherent). The internal causes are again of various types such as Effect of slope; Effect of water; Effect of Lithology; Effect of associated structures ; Effect of human factors etc..

1. Effect of slope: This is a very important factor which provides favourable conditions for landslide occurrence.

Steeper slopes are prone to land slips of loose overburdens due to gravity influence. However, it should be remembered that hard consolidated and fresh rocks remain stable even against any slope.

2. Effect of water: The presence of water greatly reduces the intergranular cohesion of the particles of loose ground causing weakness of masses and prone to landslide occurrence.

Water, being the most powerful solvent, not only causes decomposition of minerals but also leaches out the soluble matter of rocks. This reduces the compaction of rock body and makes it a weak mass.

3.Effect of Lithology; Rocks which are highly fractured, porous and permeable are prone to landslide occurrence because they give scope for the water to play an effective role. In addition, rocks which contain clay minerals, mica calcite, glauconite, gypsum etc are more prone to landslide occurrence because, all these minerals are easily leached out.

4.Effect if associated structures ; The geological structures such as bedding planes, joints, faults or shear zones are planes of weakness and cause landslide occurrence.

5.Effect of human factors Human beings sometimes, interfere with nature by virtue of their activities and cause landslides. For eg: laying roads ; railway tracks etc..

When construction works are carried out on hill tops, the heavy loads on the loose zone of overburden create a sliding of rock masses.

Land slides in India: Land slides are reported in the hilly terrains in different regions of India. The most disastrous land slides that have taken place in recent past are in the Himalayan terrain in the North and the Nilgiri hill region in south.

In July 1970, heavy debris from Patalganga valley has been transported into Alaknanda in the Garhwal region of Uttaranchal. The flooding in Alaknanda due to these landslides has resulted in a silt and rock fragment accumulation of about 9 M cum.

Another disastrous land slide took place on 18th Aug 1998 in Malpa village which is located on the banks of Kali River in Pithorgarh district of Kumaon Himalayas. The piled debris was around 20 m in height.

In 1968, numerous landslides occurred during heavy rainfall of about 500 to 1000 mm in the Darjeeling and Sikkim regions where the 60 km highway between Darjeeling (West Bengal) and Gangtok (Sikkim) was disrupted.

EFFECTS OF LANDSLIDES: From the civil engineering point of view, landslides may cause

(1) disruption of transport

(2) damaging roads and railways and telegraph poles

(3) obstruction to the river flow in valleys

(4) damaging sewage and other pipe lines.

(5) destruction of buildings and civil structures

Recent landslides in the Himalaya terrain are listed below:

Himachal Pradesh region:

Nathpa (Nov 1989): Road destroyed about a km

Kullu (Sep 1995): Road 1km destroyed and 32 persons killed

Uttaranchal region:

Kalisaur (July 1968): Road damaged extensively

Malpa (Aug 1998): Road to Manasarovar damaged & 205 persons killed

Jammu & Kashmir region:

Nashri (Jan 1982) Every year causes damage to the roads

Malori (Jun 1995): National Highway 1-A damaged and 6 persons killed

West Bengal Region:

Kalimpong, Darjeeling (Aug 1993):40 persons killed with heavy loss of property

Arunachal Pradesh Region:

Itanagar (July 1993): 2 km road damaged and 25 persons killed

Mizoram region:

Aizwal (May 1995): 25 persons killed and road extensively damaged

Nagaland region:

Kohima (Aug 1993): 200 houses and 5 km road damaged. 500 persons killed.

Selected landslides in South India are listed below:

Major Land slides took place in the Nilgiri Hill region include Runnymede, Glenmore, Coonoor areas. Amboori landslide in Kerala: On Nov 9th, 2001, a disastrous land slide occurred around Amboori (20 km from Thiruvananthapuram) due to heavy rains and water logging.

PREVENTION OF LANDSLIDES:

1. Provision of adequate surface and subsurface to enable water to freely drain out . Construction of suitable ditches and waterways along slopes to drain off the water from the loose overburden.
2. Construction of retaining walls against slopes, so that the rock masses which rolls down is not only prevented from further fall but also reduces the slope.
3. Modifying the slopes to stable angles.

4. Growing vegetation to hold the material together.
5. Avoiding heavy traffic and blasting operations near the vulnerable places naturally helps in preventing the occurrence of landslides.

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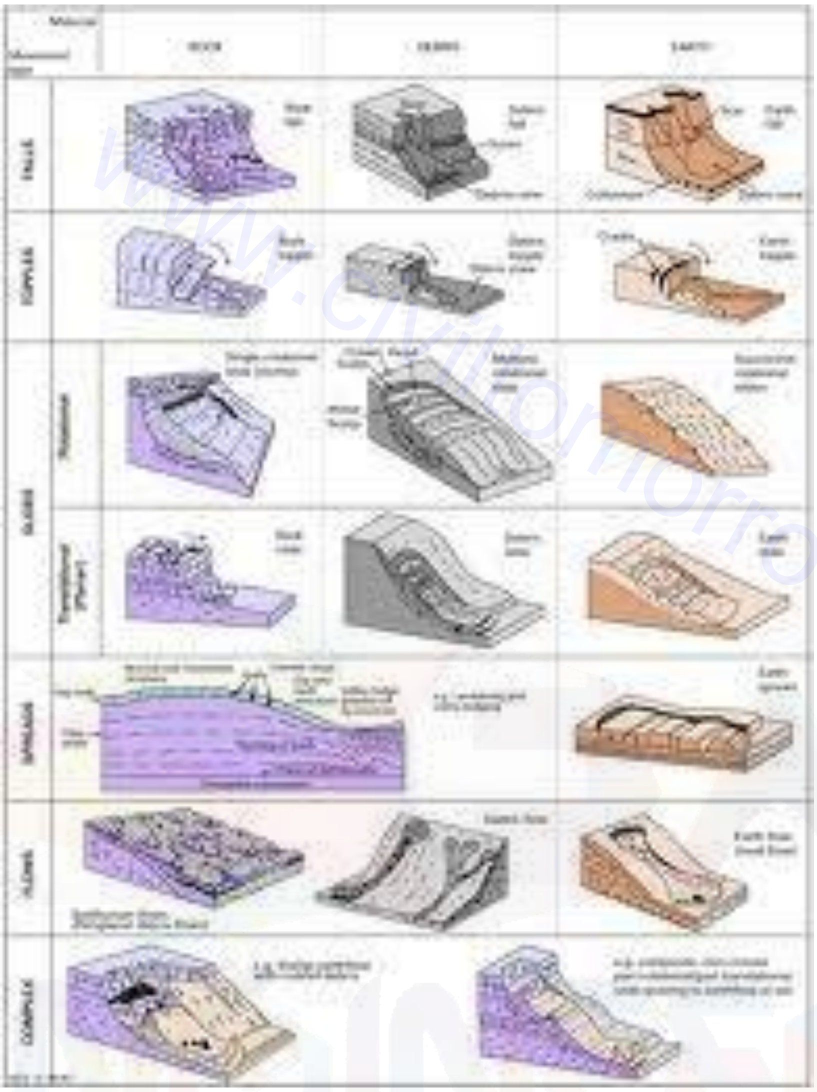
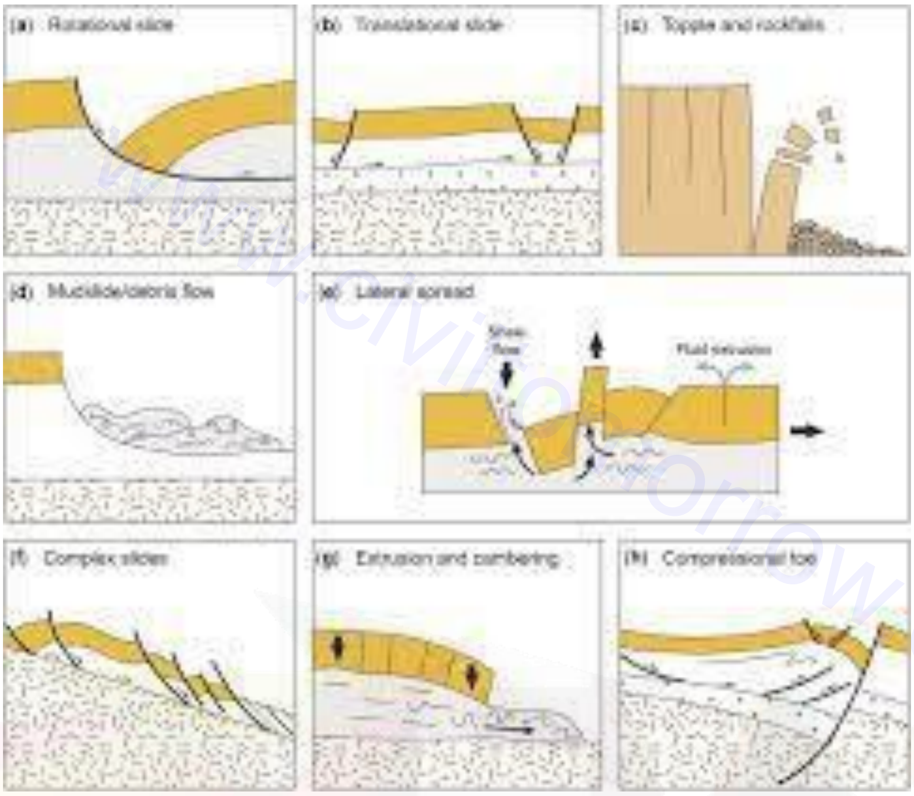
1. 


(a) Rotational slide
(b) Translational slide
(c) Topple and rockfalls
(d) Mudslide/debris flow
(e) Lateral spread
Shear flow
Fluid extrusion
(f) Complex slides
(g) Extrusion and cambering
(h) Compressional toe

9. Using case studies of structural failures, discuss the importance of geological investigations for the design and construction of large civil structures.[N/D-16][M/J 15]

Ground-related factors have often been the origin of contractual claims with significant time and cost overruns on both large and small construction projects. According to European statistics, between 80% and 85% of all building failures and damages are related to unforeseen and unfavourable ground conditions. Without adequate site investigation, clients are always exposed to the risk of costly delays, redesign and late project delivery arising out of unforeseen ground conditions; You pay for a ground investigation whether you have one or not . In 1994, the Latham Report stated that risk ...can be managed, minimised, shared, transferred or accepted; it cannot be ignored . Unfortunately, when it comes to the risk of unforeseen ground conditions, ignorance on behalf of both the contractor and employer often seems commonplace. As unforeseen ground conditions represent a huge area of risk, a construction contract either has to allocate the risk to a single party or distribute it between the parties. The traditional method of controlling such risks has been through the use of thorough site investigation and competent geotechnical design, aiming to produce a robust scheme, well-matched to the expected ground conditions.

When selecting the construction site of a hydro dam, many factors are involved such as technical, social and environmental. In this paper we focus exclusively on the technical aspects that concern the pre-construction stages and the volume of direct and indirect exploration of the ground. The purpose of the exploration is to obtain a geological model as clear as possible that serve to characterize the geotechnical site and so the planning, budgeting and perform the structural design of the works as well as obtain sufficient information to establish a safe and economic project. Geological risk management and its economic consequences can lead to major losses beyond the physical repair of the work which rely on a good investigation of the site . Referring to geotechnical instrumentation and monitoring works, Allen mentions difficult conditions to detect (with exploration methods) the presence of lenses made of soft material, highly compressible areas and pockets of high pore pressure, which can cause faulting in the rock mass. From here, it is important to remark the need of the exploration as even for the location of the monitoring zones must follow criteria based on direct or indirect examination. This work shall consider direct exploration of the site though drilling (exploratory boreholes), geotechnical testing of permeability in wells and excavations of galleries or tunnels. Drilling is a great support to define the stratigraphic and structural model for the site and to identify basic geotechnical parameters for design of the work, being carried out on both margins and the river bed, according to the location of the works. The objectives of the sampling site with exploratory drills with core recovery usually include the following: stratification on the site, vertical or lateral variations in subsurface geological conditions, sampling for laboratory testing, verification of the interpretation of geophysical measurements and placement of instruments in situ for geotechnical, geophysical and geohydrological testing. The interpretation of the evidence can be presented to anticipate areas of instability conditions. Geotechnical testing of permeability in the wells by injecting pressurized water constitute a substantial proportion of direct examination and focuses on the competition of the rock mass and its ability to facilitate or prevent leakage of water from the dam.

10. Natural disasters in India can be understood better and controlled well, if geology is understood well. Give your opinion about this statement using appropriate case studies. [N/D-16][N/D 14]

Landslides are very common indeed in the Lower Himalayas. The young age of the region's hills result in labile rock formations, which are susceptible to slippages. Rising population and development pressures, particularly from logging and tourism, cause deforestation. The result is denuded hillsides which exacerbate the severity of landslides; since tree cover impedes the downhill flow of water.[3] Parts of the Western Ghats also suffer from low-intensity landslides. Avalanches occurrences are common in Kashmir, Himachal Pradesh, and Sikkim.

Floods in India Floods are the most common natural disaster in India. The heavy southwest monsoon rains cause the Brahmaputra and other rivers to distend their banks, often flooding surrounding areas. Though they provide rice paddy farmers with a largely dependable source of natural irrigation and fertilisation, the floods can kill thousands and displace millions. Excess, erratic, or untimely monsoon rainfall may also wash away or otherwise ruin crops. Almost all of India is flood-prone, and extreme precipitation events, such as flash floods and torrential rains, have become increasingly common in central India over the past several decades, coinciding with rising temperatures. Meanwhile, the annual precipitation totals have shown a gradual decline, due to a weakening monsoon circulation as a result of the rapid warming in the Indian Ocean and a reduced land-sea temperature difference. This means that there are more extreme rainfall events intermittent with longer dry spells over central India in the recent decades.

Cyclones in India Intertropical Convergence Zone, may affect thousands of Indians living in the coastal regions. Tropical cyclogenesis is particularly common in the northern reaches of the Indian Ocean in and around the Bay of Bengal. Cyclones bring with them heavy rains, storm surges, and winds that often cut affected areas off from relief and supplies. In the North Indian Ocean Basin, the cyclone season runs from April to December, with peak activity between May and November. Each year, an average of eight storms with sustained wind speeds greater than 63 kilometres per hour (39 mph) form; of these, two strengthen into true tropical cyclones, which have sustained gusts greater than 117 kilometres per hour (73 mph). On average, a major (Category 3 or higher) cyclone develops every other year.

During summer, the Bay of Bengal is subject to intense heating, giving rise to humid and unstable air masses that produce cyclones. Many powerful cyclones, including the 1737 Calcutta cyclone, the 1970 Bhola cyclone, the 1991 Bangladesh cyclone and the 1999 Odisha cyclone have led to widespread devastation along parts of the eastern coast of India and neighboring Bangladesh. Widespread death and property destruction are reported every year in exposed coastal states such as Andhra Pradesh, Orissa, Tamil Nadu, and West Bengal. India's western coast, bordering the more placid Arabian Sea, experiences cyclones only rarely; these mainly strike Gujarat and, less frequently, Kerala.

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In terms of damage and loss of life, Cyclone 05B, a supercyclone that struck Orissa on 29 October 1999, was the worst in more than a quarter-century. With peak winds of 160 miles per hour (257 km/h), it was the equivalent of a Category 5 hurricane. Almost two million people were left homeless; another 20 million people lives were disrupted by the cyclone. Officially, 9,803 people died from the storm; unofficial estimates place the death toll at over 10,100.

10. Explain Landslides. [N/D 14] [M/J 12]

The term landslide refers to the downward sliding of huge quantities of land masses. Such sliding occurs along steep slopes of hills or mountains.. It may be sudden or slow in its occurrence. Also, in magnitude, it may be major or minor.

Often, loose and unconsolidated surface material undergoes sliding. But sometimes, huge blocks of consolidated rocks may also be involved. If landslides occur in places of importance such as highways, railway lines, valleys, reservoirs, inhabited areas and agricultural lands leads to blocking of traffic, collapse of buildings, harm to fertile lands and heavy loss to life and property. In India, landslides often occur in Kashmir, Himachal Pradesh and in the mountains of Uttar Pradesh.

CLASSIFICATION OF EARTH MOVEMENTS: All movements of land masses are referred to as landslides and grouped them under "earth movements". The classification of earth movements us as follows:

EARTH MOVEMENTS	EARTH FLOWS	Solifluction
		Creep

		Rapid flows
	LANDSLIDES	Debris slides and slump
		Rock slides
		Rock falls
	SUBSIDENCE	Compaction
		Collapse

Earth Flows: There are three types of earth flows viz., solifluction; creep and rapid flows.

Solifluction refers to the downward movement of wet soil along the slopes under the influence of gravity.

Creep refers to the extremely slow downward movement of dry surface material. This is very imp from the civil engg point of view due to slow movement of mass. On careful examination, bending of strata ; dislodgement of fence posts ; telephone poles, curvature of tree trunks; broken retaining walls etc offer clues to recognize creep.

Rapid flows are similar to creep but differ with reference to the speed. Rapid flows generally accompany heavy rains. Mud flows are similar to rapid flows.

Landslides include Debris slides, rock slides and rock falls.

Debris slides are common along the steep sides of rivers, lakes. Debris slides of small magnitude are called slumps..

Rock slides are the movements of consolidated material which mainly consists of recently detached bedrocks. For eg: a rock slide that took place at Frank, Alberta in 1903 killing 70 people.

Rock falls refer to the blocks of rocks of varying sizes suddenly crashing downwards along steep slopes. These are common in the higher mountain regions during the rainy seasons.

Subsidence may take place to the compaction of underlying material or due to collapse.

Subsidence due to compaction: Sediments often become compact because of load. Excessive pumping out of water and the withdrawal of oil from the ground also cause subsidence.

Subsidence due to collapse: In regions where extensive underground mining has removed a large volume of material, the weight of the overlying rock may cause collapse and subsidence.

CAUSES OF LANDSLIDES: Landslides occur due **to internal causes** (inherent). The internal causes are again of various types such as Effect of slope; Effect of water; Effect of Lithology; Effect of associated structures ; Effect of human factors etc..

1.Effect of slope: This is a very important factor which provides favourable conditions for landslide occurrence.

Steeper slopes are prone to land slips of loose overburdens due to gravity influence. However, it should be remembered that hard consolidated and fresh rocks remain stable even against any slope.

2.Effect of water: The presence of water greatly reduces the intergranular cohesion of the particles of loose ground causing weakness of masses and prone to landslide occurrence.

Water, being the most powerful solvent, not only causes decomposition of minerals but also leaches out the soluble matter of rocks. This reduces the compaction of rock body and makes it a weak mass.

3.Effect of Lithology; Rocks which are highly fractured, porous and permeable are prone to landslide occurrence because they give scope for the water to play an effective role. In addition, rocks which contain clay minerals, mica calcite, glauconite, gypsum etc are more prone to landslide occurrence because, all these minerals are easily leached out.

4.Effect if associated structures ; The geological structures such as bedding planes, joints, faults or shear zones are planes of weakness and cause landslide occurrence.

5.Effect of human factors Human beings sometimes, interfere with nature by virtue of their activities and cause landslides. For eg: laying roads ; railway tracks etc..

When construction works are carried out on hill tops, the heavy loads on the loose zone of overburden create a sliding of rock masses.

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