Engineering Geology

UNIT - I

INTRODUCTION

* Geology is the science of the earth (geo = earth, logos = study (or) science).
* It deals with different aspects of the earth as a whole such as :-
  (i) origin, age, interior structure & history of earth
  (ii) evolution & modification
  (iii) Materials

→ Main & Allied Branches of Geology:-

Main Branches:-

* Physical geology
* Mineralogy
* Petrology
* Structural geology
* Historical geology (stratigraphy)
* Palaeontology
* Economic geology

Allied Branches:-

* Engineering geology
* Mining geology
* Geophysics
* Geohydrology
* Geo chemistry

* Physical geology deals with the different physical features of the earth such as mountains, valleys, rivers etc
* Mineralogy deals with the study regarding different types of minerals.
* Petrology deals with the study of rocks. (Petro = rock, logy = study)

* Structural geology is the study of various types of deformations & dislocations which occurs on the surface.

Ex:- Tsemess of Earthquake.

* Study of the earth's history through the sedimentary rocks is called historical geology.
* Strata = a set of sedimentary rocks
  graphy = description.
* Palaeontology is the study regarding different types of plants.
* Economic Geology is the study regarding the economic minerals like diamond, gems, graphite etc.
* Mining Geology is the study regarding the extent of occurence of ores, depth, direction (strike) inclination (dip).
* Geophysics deals with the study of physical properties like density & magnetism of the earth.
* Geohydrology can also be called as hydrogeology as it deals with occurence, movement, nature (quality & quantity) of ground H_2O in an area.
* Geochemistry deals with the occurence, distribution of different elements in the earth's crust.

→ Importance of geology in Civil Engineering:-

* The civil engineers aim at safety, stability, economy & life of the structures that they construct.
* Civil engineering constructions like dams & bridges will have their foundations on geological formations of the earth's surface, so their stability & safety depend on the competence of the in-situ rocks.
* Foundation rocks should be at a shallow depth for huge constructions like dams etc.
* Building materials are required in very large quantities near the site, otherwise the cost of construction will increase.
* These are some failures of constructions like
  i) with reference to Dams
  ii) with reference to Reservoirs
  iii) with reference to Tunnels
  iv) with reference to Bridges
  v) with reference to Roads & Railways.

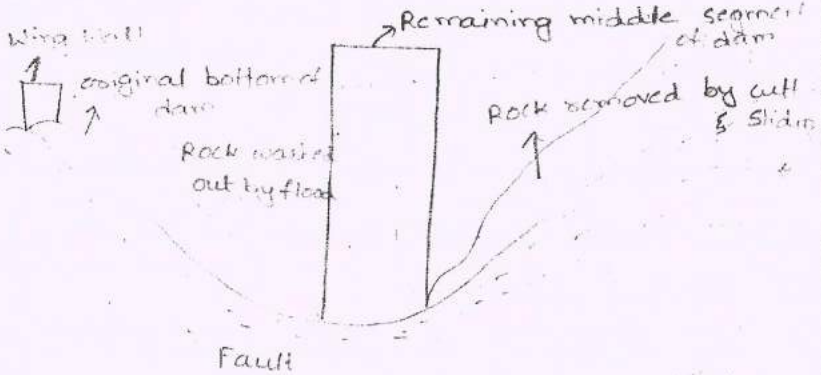
i) with reference to Dams:-

The following are a few examples of failures of dams they are:-

a) St. Francis dam of California.
b) Lafayette dam of California.
c) Austin dam of Texas.

a) Failure of St. Francis dam of California:-

* It was a concrete gravity dam.
* constructed in 1926 in California.
* Failed in 1928
* Duration :- 2 years
* Reason:- Failed due to existance of weaker rocks below the dam.



b) Failures of Lafayette dam of California:-

This dam was constructed on weak formations. Therefore it could not bear the the heavy weight so it leads to settlement & sinking of dam by 6 meters.

c) Failure of Austin dam of Texas:-

* It was a masonary dam of 68 ft Ht.
* Height 68ft, 1090 ft long & 66 ft wide at base.
* constructed in 1892.
* Failed in 1900
* Duration :- 8 years
* Reason:- Failed due to incompetent geological rocks.

WEATHERING

→ Weathering of rocks:-

The deteriorating effect of weather, climate (or) atmospheric agencies on rocks may be described as weathering of rocks.

* The rocks which are formed under different conditions undergo disintegration & decay when exposed to the earth's surface.
* The rocks which are affected by weathering will lose their strength, stability so they become unsuitable for the use of foundation & construction material.
* Weathering of rocks is responsible for the formation of soils, laterites, economic mineral deposits, ground H_2O occurence etc.
* Weathering process of rocks are important for civil engineers construction purpose.

→ Geological Agents:-

The natural forces which are responsible for the changes on the earth's surface are called as geological agents. These are of two types they are:-

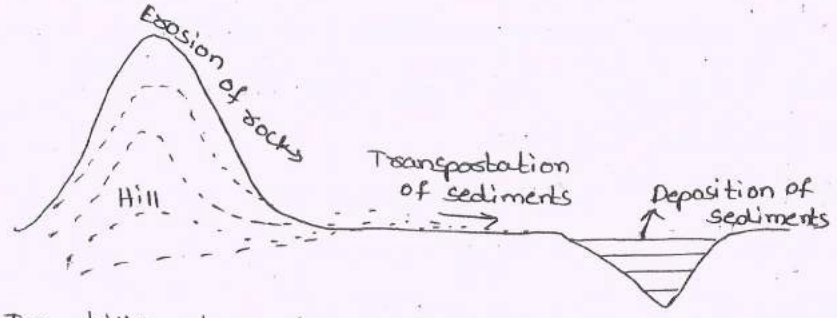
1) Exogenous (or) Epigene geological agents.

2) Endogenous (or) hypogene geological agents.

1) Exogenous geological agents:-

These agents originate on the earth's surface work slowly but steadily & erase topographic irregularities i.e ups & downs on the surface.

* Geological work in a way is systematic commences with erosion & is followed by transportation & deposition.



* In hills due to erosion, rocks are broken down into smaller pieces, which are transported & deposited in depressions (lakes (or) sea).

* Due to erosion, the height of the hill & depth of the rivers decreases and so levelled ground appears.

2) Endogenous Geological agents:-

* The nature, origin & function of endogenous geological agents are in opposite to those of exogenous geological agents. Ex:- Earthquakes etc

→ Weathering process of rocks:-

The deteriorating effect of weather, climate (or) atmospheric agencies on rocks is known as weathering of rocks.

* This happens due to different physical, chemical & biological factors of nature.

* Due to weathering, rocks becomes smaller.

* The disintegration of rocks under wind, Rivers, Glaciers, Dashing waves & tides of the sea etc comes under physical factors.

* The disintegration of rocks under hydration, reduction, oxidation, carbonation etc. comes under chemical factors.

* The disintegration of rocks under plants, animals & man is known as the biological factors of nature.

→ Weathering process of Rivers:-

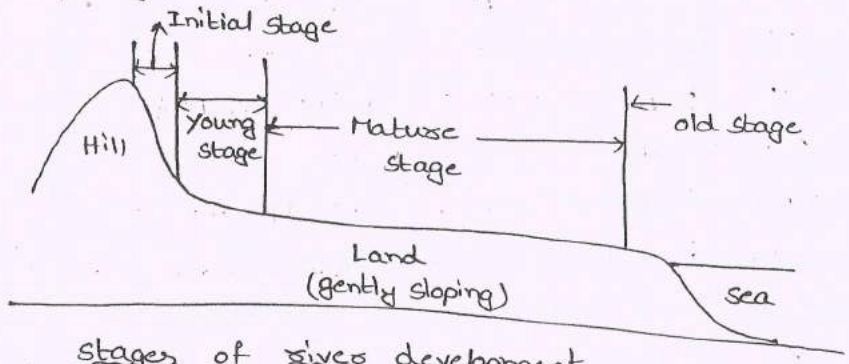
Rivers, glaciers, wind, tides & waves of the sea are the common exogenous geological agents.

→ Development of the rivers:-

* Rivers originate in mountains because mountains have higher altitude, cold climate & good vegetation.

* The annual precipitation is 30,000 cubic miles.

* The development of a rivers has fours stages :-
(i) initial stage (ii) youth stage (iii) mature stage
(iv) old stage.



Stages of rivers development

→ Initial stage :-

* In initial stage the water flows as small streams.
* In initial stage rivers is having active erosion & no deposition.

→ Young stage :-

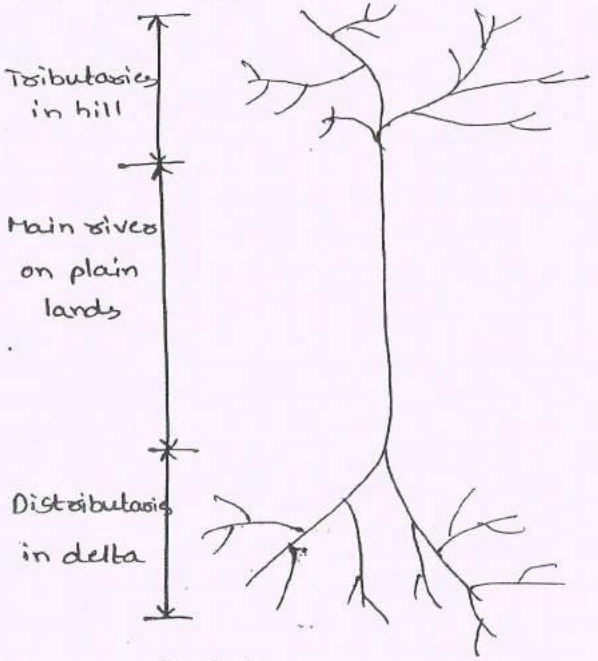
* In young stage there will be more erosion & less deposition.
* In this stage the H_2O flows as small tributaries.

→ Mature stage :-

* In mature stage there will be more deposition & less erosion.
* In this stage the H_2O flows as tributaries

→ old stage :-

* In matas old stage, deposition occurs without erosion.
* In this stage the water will reaches to the end point.
* The flow of the rivers is represented in the form of "dendritic" (like Tree)



Dendritic appearance of a rivers

UNIT - II

MINERALOGY AND PETROLOGY

→ Criteria for minerals:-

* Natural
* Solid
* Inorganic matter
* Chemical composition
* Homogeneous – same atomic structure.
* Crystalline – (3-dimensional structure)

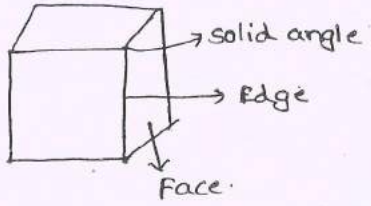
→ Definition of mineral:-

A mineral may be defined as a natural, inorganic, homogeneous, solid substance having a definite chemical composition & regular atomic structure is known as mineral.

→ Definition of crystal:-

It may be defined as a natural solid body bounded by smooth & plain surfaces, arranged in an orderly pattern (i.e geometrical).

* Parts of crystal:-



→ Definition of rock:-

A rock may be simply defined as "an aggregate of minerals" (or) "a unit of earth's crust".

Ex:- Granite & basalt are two types of rocks but composed of different types of minerals.

* Quartz, alkali feldspar, soda plagioclase, hornblende & biotite are present in Granite.
* Minerals present in basalt are lime feldspar & augite
* Rocks like diorite, granodiorite, granite have same minerals but in different proportions.

→ Different methods of study of minerals:-

1) Physical property
2) Chemical property
3) X-ray property
4) Optical property.

1) Physical method:-

a) colour
b) streak – (The colour that observed on the streak plate).
c) Texture – Smooth (or) Rough
d) Hardness – Resistance to scratching
e) specific gravity
f) cleavage – (Tendency to break the minerals in different directions)
g) Transparency – (diaphaneity)
h) Lustre – (shining)

- Metallic (shining on the surface)
- Non-metallic (common in some materials)
  1) Vitreous (Glass sheet shine)
  2) Pearly lustre (shining like a pearl)
  3) Silky " (shining like silk)
  4) Resinous lustre (shining like resin)
  5) Greasy lustre (shining like grease)
  6) adamantine lustre (shining like a diamond)
  7) Earthy lustre (no shining like earth).

2) Chemical method:-

It is taken as demerit in case of mineral study.

3) X-ray method:-

It is tested under the polarised light (Wave length).

4) optical method:-

* In this method the minerals are ground very fine (standard thickness 0.03 mm).
* It is observed in microscope – a glass slide,
* Demerit in petrology.

S.No	Name of mineral species with chemical composition & crystal system	Foorm	colour	Lustre	Fracture	cleavage	Hardness	Density (Sp. Gravity)	Degree of Transparency
1.	Feldspar Aluminum silicate of K/Na/ca : mono (or) triclinic	Tabular (uniform thickness)	White	Vitreous	Even to uneven	Present	6	Medium (2.5 - 3.0)	Trans-lucent
2.	Quartz SiO_2 : hexagonal	Massive (no definite shape)	White	Vitreous	uneven	Present	7	Medium (2.65)	Trans-parent
3.	olivine $(Mg\ Fe)_2 SiO_4$, osthorhombic	Massive	Green	Dull	uneven	present	6-7	Medium (3.2 - 3.5)	opaque
4.	Augite complex silicate, monoclinic	Massive	Black	vitreous	uneven	Present	5-6	Medium (3.2 - 3.5)	opaque
5.	Hornblende complex silicate, monoclinic	Granular (Made with diff grains)	Green	vitreous	uneven	Present	5-6	Medium (3.0 - 3.5)	opaque
6.	Muscovite (mica) complex silicate, monoclinic	Lamellar (Mineral appears in thin separable layers)	White	Pearly	uneven	Present	2-3	Medium (2.7 - 3.0)	Transparent
7.	Asbestos complex silicate, monoclinic	Fibrous (Appears as thin fibres)	White	silky	uneven	Present	-	Medium	Translucent
8.	Talc $Mg_3Si_4O_{10}(OH)_2$, Monoclinic	Massive	White	Pearly	uneven	Present	1	Medium (2.7)	Translucent
9.	chlorite $(Mg,Fe)_5 Al(AlSi)_3 O_{10}(OH)_8$, Monoclinic	Foliated	Green	Pearly	uneven	Present	1.5 - 2.5	Medium (2.6 - 2.9)	opaque
10.	kyanite Al_2SiO_5, Triclinic	Fibrous	Blue	vitreous	uneven	present	4-5	Medium (3.6)	Translucent
11.	Garnet calcite $CaCO_3$, hexagonal	Rhombic	White	vitreous	Rarely found	Present	3	Medium (2.7)	Transparent

Common rock forming minerals

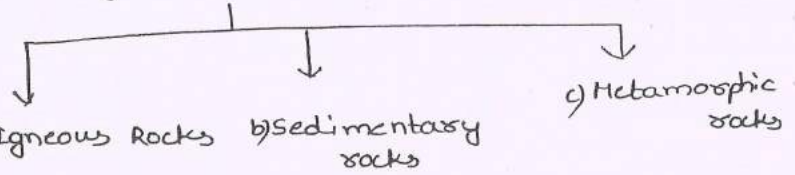
→ Table for some ore forming minerals:-

S.No	Name of Mineral species with composition & crystal system	Form	colour	Lustre	Fracture	cleavage	Hardness	Density (Sp. gravity)	Degree of Transparency
1.	Pyrite FeS_2, cubic	Granular	Brass yellow	Metallic	uneven	Present	6-7	High (5.0)	opaque
2.	Hematite Fe_2O_3, hexagonal	Massive	Steel Grey	Metallic	uneven	Absent	5-6	High (5.2)	opaque
3.	Magnetite Fe_3O_4, cubic	Granular	Black	Metallic	uneven	Absent	5-6	High (5.2)	opaque
4	chlorite $(Mg,Fe)_5Al(Al,Si)_3O_{10}(OH)_8$, monoclinic	Foliated	Green	Pearly	uneven	Present	1.5-2.5	Medium (2.6-2.9)	Nearly opaque
5.	Galena PbS, cubic	Granular	Lead grey	Splendent perfect	Rarely found	Present	2-3	High (7.5)	opaque
6.	Pyrolusite MnO_2, orthorhombic	Massive	Black	Dull	uneven	Present	Variable	High (4.5-5.0)	opaque
7	Graphite, C hexagonal	Massive	Black	Greasy	uneven	Present	1-2	Low (2.0-2.3)	opaque
8.	Chromite $FeCr_2O_4$, cubic	Granular	Black	Metallic	uneven	Absent	5-6	High (4.5-5.0)	opaque
9.	Magnesite $MgCO_3$, hexagonal	Massive	White	Dull	uneven	Absent	4-5	Medium (3.0-3.2)	opaque
10	Bauxite $Al_2O_3 \cdot 2H_2O$, amorphous	Massive	White	Dull	uneven	Absent	Nearly (4)	Medium (2.0-3.5)	opaque

→ Classification of rocks:-

1) Physical classification → Stratified (layers)
→ unstratified (No layers)

2) Geological classification



a) Igneous Rocks:- (Igneous means "Fire").

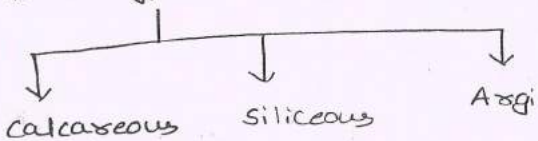
* Formed by molten lava (or) magma.
* These are the primary rocks which are formed in nature.
* High resistive towards natural calamity.
* ↑ Design period.
* It is durable.
* The solidification of magma over the earth's surface is known as extrusive Igneous rocks.
* The solidification of magma below the earth's surface is known as Intrusive Igneous rocks.

Ex:- Granite, Pegmatite, Dolerite, Basalt etc.

b) Sedimentary rocks:-

* Formed by the decomposition of decay of different types of objects when they clubed together.

* 3 Types



* Strength Low, durability Low.
* It is used in roads, white wash.
* We cannot use directly, we can use it by stabilising.

Ex:- Lime stone, sand stone, shale Laterite etc.

c) Metamorphic Rocks:-

* Meta means change, morphic means towards temperature & pressure changes.

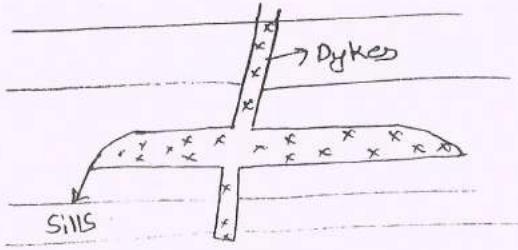
Ex:- Marble, Quartzite, Gneiss, Schist, Slate & Khondalite etc.

→ Dykes & sills:- (Forms of Intrusive Igneous rocks).

*Dykes:-

* These are 1 type of Igneous rocks.
* Dykes are discordant sheet like structure, & these may be vertical (or) horizontal (or) inclined.
* They are sheet like structure & narrow in width which has uniform thickness in 11le sides.

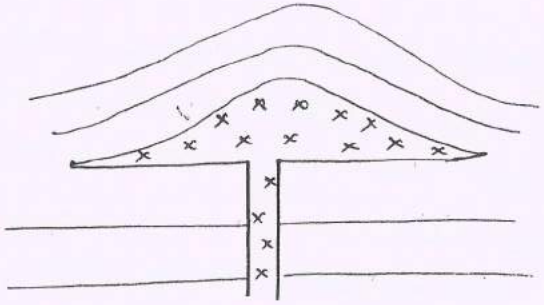
* During the forceful upward journey, the magma, intrudes into the fracture, cracks, joints & shear zones.
* Dykes may be purely vertical (or) Inclined.
* In the areas where dykes occurs, weathering is not uniform i.e weathering of dykes is more (or) less compared to the surrounding rocks.
* Importance of dykes in civil engineering point of view:-
* Dykes are like walls & act as the barriers for the flow of underground H_2O (or) any natural calamity.
* Dykes may cause oil accumulation & these by contribute to the occurance of oil & gas deposites under favourable conditions.
* As the dykes are hard in structure it is highly durable, resistance to weathering conditions which is used to make statues, Temples etc.



* Sills:-
* Sills are similar to that of dykes.
* It is also one form of Igneous rock which has concordant structure.
* Sills are formed due to the penetration of magma into the bedding planes of the rock & spelling capacity is depending upon the temperature, viscosity & weight of the overlying rock.
* Lava flows may resemble sills closely, because both are relatively thin, horizontal sheet like igneous bodies spreading over large areas.
* Some difference b/w Lava flows & sills:-
* Lava flows shows an irregular lower surface where as sills are more (or) less parallel in both the sides.
* Lava flows undergo quick cooling producing very fine grained igneous rocks, whereas sills cool down rather slowly & therefore produce medium (or) coarse grained igneous rocks.
* Sills give out tongues (i.e minor intrusions) & Whereas Lava flows do not produces the tongues.

* Laccolith:-

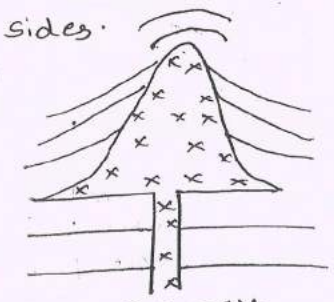
* Laccolith is form of Igneous rock.
* It is also like a sills which has concordant structure of igneous rocks.
* It is nearly flat bottom but it is convex shape upwards
* When magma is injected along the bedding planes, as it can't spread easily it pushes up the overlying rocks, because of this property it gets the shape of inverted bowl.



Laccolith

* Bysmalith:-

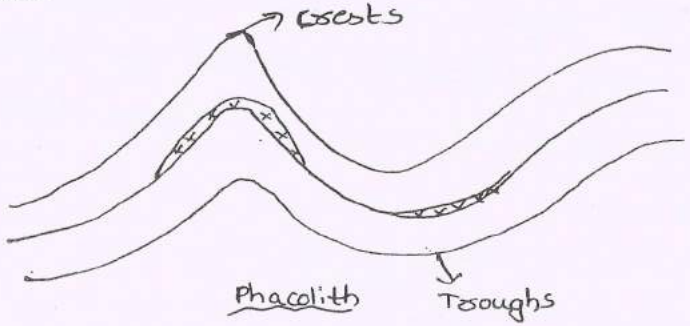
* It is also one form of Igneous rock which has concordant structure like sills.
* In this Bysmalith form when magma is highly viscous in nature the lateral spread along the bedding planes will be less.
* During its formation, sills overlying rocks push upwards more (or) less vertical, they cannot bend but there will be rupture along the sides.

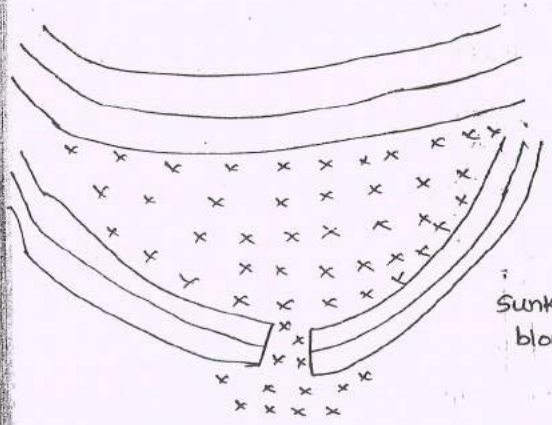


Bysmalith

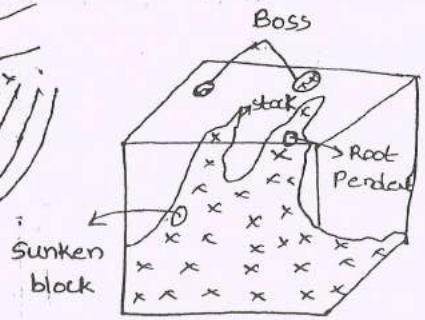
* Phacolith:-

* When sedimentary strata are folded along the crests & troughs positions the magma will be accumulated in which there is a cavity (or) gap (or) space.
* When magma is filled in crests & Troughs positions the swelling of rock will occurs which is known as phacolith
* The folding position is known as lens shaped.





Lopolith



Batholith

* Forms of Extrusive Igneous Rocks:-

* Lava flows:-

* on eruption of a volcano, lava simply flows on the surface & on consdidation give rise to Lava flows.

* Based on surface appearance, lava flows are described as block lava & ropy lava.

* Block lava has rough & irregular surface.

* Ropy lava has smooth & shiny surface.

* Pyroclasts:-

* The rock fragments thrown out at the time of volcanic eruption are called as pyroclasts.

* If the rock fragments are bigger & angular they are called volcanic blocks.

* If they are rounded means then it is known as volcanic bombs.

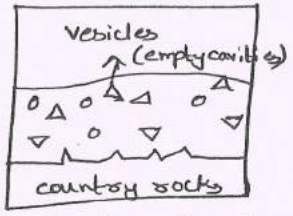
* Smaller fragments are called Lapilli (or) cinders.

* Fragments still smaller in size are called volcanic sand, volcanic dust & volcanic ash.

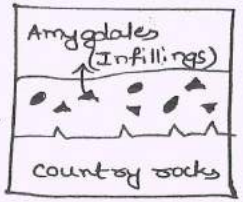
* Rocks formed out of volcanic dust & ash is called tuff.

→ common structures of Igneous Rocks:-

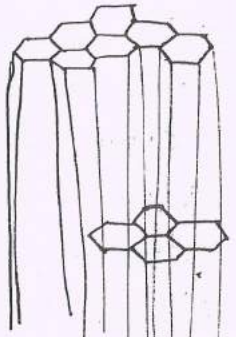
In Igneous rocks the common structures are vesicular, amygdaloidal, columnar, sheet, flow & pillow structure.



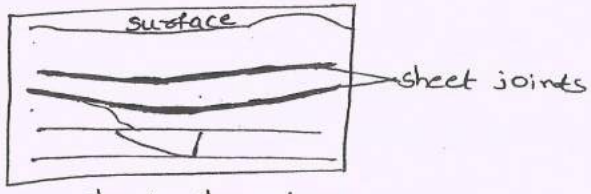
vesicular structure



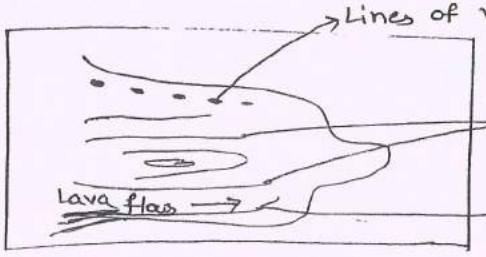
amygdaloidal structure



Columnar structure



sheet structure



Flow structure

→ Common Textures of Igneous rocks:-

The textures of Igneous rocks are given based on crystallinity, granularity & shapes of minerals in a rock.

→ Megascopic study of Igneous rocks:-

* Granite:-

* Granite is a plutonic igneous rock & are formed at greater depths.

* Minerals present in Granite:-

* Quartz, alkali feldspar, soda plagioclase, hornblende & biotite.

* Texture:-

Equigranular

* Structure:-

Massive

→ Pegmatite:-

* Minerals present in pegmatite are alkali feldspar, quartz, muscovite, biotite etc

→ Dolerite:-

* Minerals present in Dolerite are plagioclase feldspar, augite, pyroxene, biotite etc.

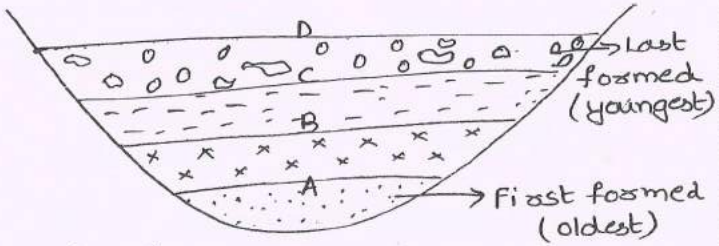
→ Basalt:-

* Biotite, hornblende. plagioclase, feldspar, augite etc.

→ common structures of sedimentary Rocks:-

* Stratification:-

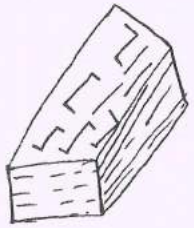
Sedimentary rocks occuring in the form of series of beds is known as stratification.



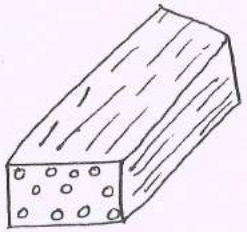
→ common structures of metamorphic rocks:-

* Foliation Structure:-

When lamellar minerals (such as chlorite, mica, talc) occur in rocks, they arrange parallel to one another & ⊥ds to the direction of pressure is known foliation.



Foliation



Lineation

* Lineation:-

When prismatic minerals (such as hornblende) occur in rocks, they arrange parallel to one another & ⊥ds to the direction of pressure is called Lineation.

UNIT - III

STRUCTURAL GEOLOGY

It is the study of geology which deals with the different types of deformations, dislocations, bending & all other changes that occuss due to the cause of natural (or) artifical calamity (or) forces.

Ex:- Earthquake, blasting, ground development works etc.

→ components of structural geology:-

components can be explained in the scientific way known as "strike" and "Dip".

*Strike:-

* It is one of the important factor which plays an important role in structural geology.
* It can be explained as when a surface is affected with the any type of force (or) pressure then allignment will be form horizontally then it is known as strike.
* In structural geology it is classified as "strike direction" & "strike amount".
* strike direction is the direction along which it acts.
* strike amount can be defined as the angle blw surface & the bedding plane.

* Dip :-

The perpendicular line formed along the strike is known as Dip (or) slope.

* It can be classified explained as direction and amount.

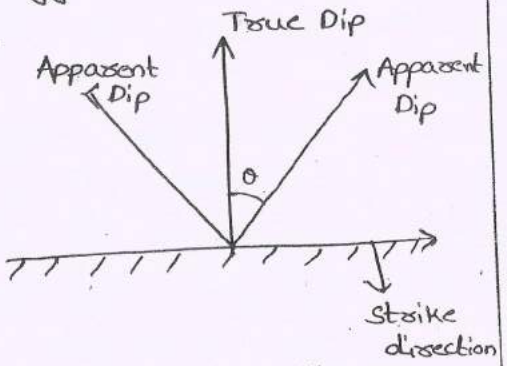
* Dip direction is the direction along which it acts.

* Dip amount can be defined as the angle b/w the surface & bedding plane.

* In structural geology there are 2 types of dip they are :-

a) True Dip

b) Apparent Dip



a) True Dip :-

The purely vertical & perpendicular line is known as True Dip.

b) Apparent Dip :-

When the direction is in between true dip & strike by forming some amount of angle 'θ' is known as apparent Dip.

→ Measurement of strike :-

The component strike can be measured by an instrument is known as "clinometer" (magnetic compass like instrument).

* By measuring with that particular instrument physically it will be recorded as strike amount & dip amount.

→ outcrop :-

outcrop can be defined as a geological formation which is exposed on the surface area.

* outcrop is a general term, which is used for explain the various classifications which are as follows :-

1) Folds

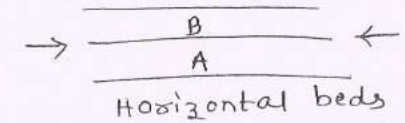
2) Faults

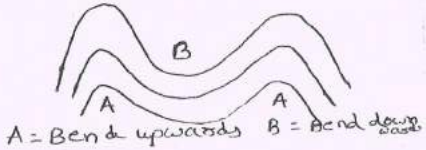
3) Joints

4) unconformities.

→ Folds :-

Fold is the most important geological structures which are especially found in rocks. Folds are formed due to heavy compressive & bending forces from upward (or) downward direction. These types of bends are known as folds.



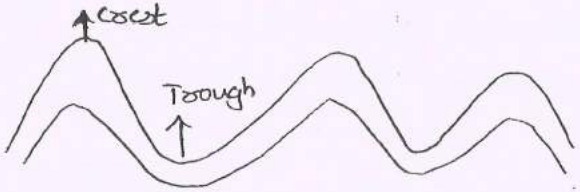


→ Parts of folds:-

Parts of fold can be explained with various basic principles which are as follows:-

1) Crest & Trough:-

It is the uppermost part of the fold (or) wave which will be in the form of wave is known as crest & correspondingly the bottom portion of the curve is called Trough.

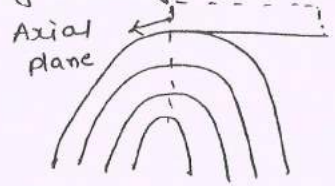


2) Limbs (or) Flanks:-

The sides of the fold is known as limbs (or) flanks

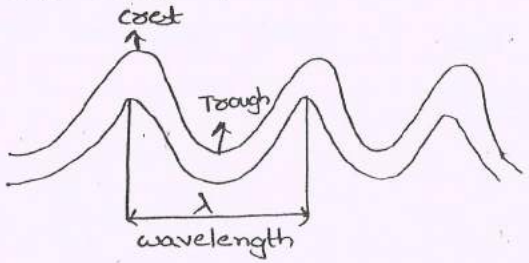
3) Axial plane:-

It is an imaginary line which will be passing through the crest (or) trough.



4) Wave length (λ):-

The distance b/w two corresponding crests & troughs.



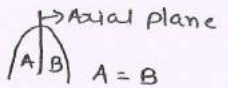
5) Axis:-

It is a line which divides a wave (or) a fold in two equal (or) unequal parts.

* Axis can be explained by two terms.

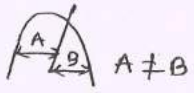
* Symmetric axis:-

When a line (or) a ray divides a wave (or) a fold in two equal parts is known as symmetric axis.



* Asymmetric axis:-

When a line divides a wave (or) a fold in two unequal parts is known as asymmetric axis.



→ classification of folds:-

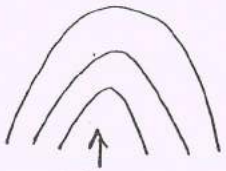
Folds can be classified based on type of load (or) amount of load etc.

1) Anticline & Syncline:-

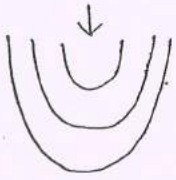
* When load is applied from upwards in the downward direction Synclines are formed.

* When the load is applied from downwards in the upward direction then anticlines are formed.

direction of fold is known as Anticlinal folding.



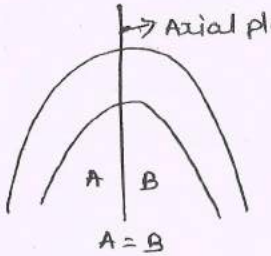
Anticline



Syncline.

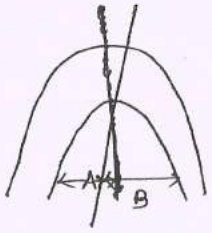
2) Symmetrical & Asymmetrical folds:-

* When a line divides the fold into two equal parts is known as symmetrical folds
* When a line divides the fold into two unequal parts is known as asymmetrical folds



A = B

Symmetrical folds

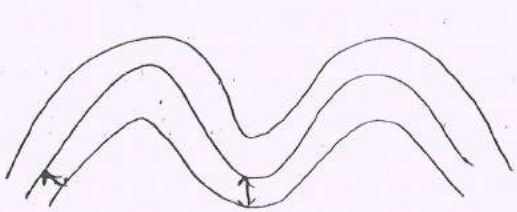


A ≠ B

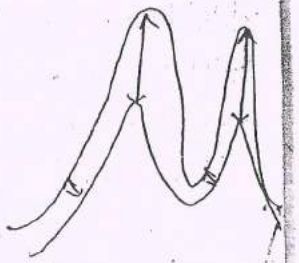
asymmetrical folds

3) Open & closed folds:-

* If the fold is having uniform thickness throughout the fold then it is known as open fold.
* If the fold is not having uniform thickness throughout the fold then it is known as closed fold.



open folds

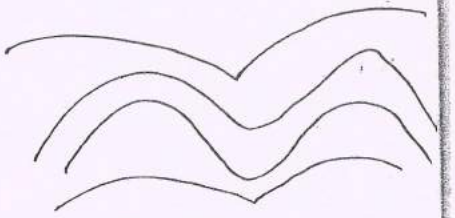


closed folds

4) Similar & parallel folds:-

* In similar folds, the shape of folds remains same at depth also.
* In parallel folds, the shape of folds at crests & troughs becomes pointed (or) angular.

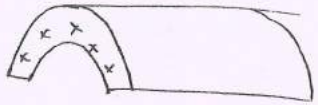
similar folds



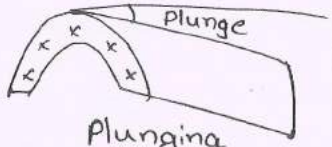
parallel folds

5) Plunging & non-plunging folds:-

When a reference line is attached from intial point of fold to last point of fold is known as non-plunging fold.



Non-plunging



Plunging

When a small angle is made with the surface, then fold is known as plunging fold.

→ Mechanism of folding:-

* The folds are formed due to the loads from upward direction (or) from downward direction.

→ Causes & effects of folding:-

* When load is applied from upwards in the downward direction then Synclines are formed.

Ex:- Valleys.

* When load is applied from downwards in the upward direction then anticlines are formed.

Ex:- Hills.

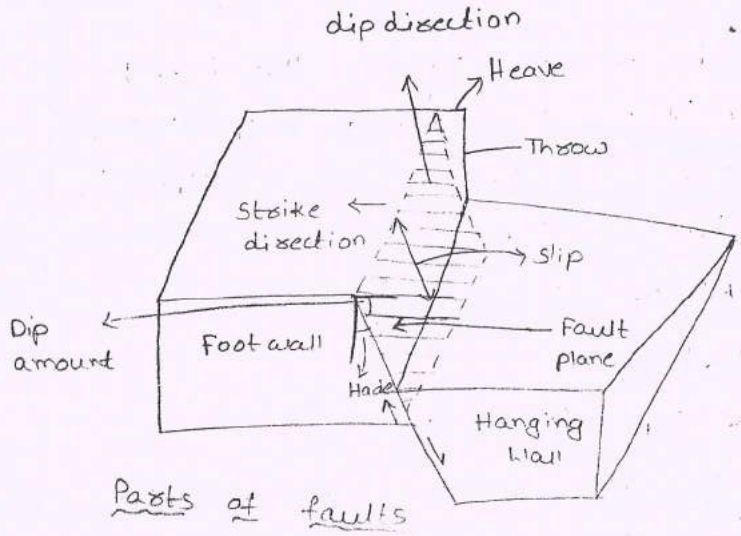
→ Faults:-

Faults are one form of structural geology & it is similar to that of folds.

* Faults are the most unfavourable & undesirable geological structures at site.
* Faults are formed when the earth surface is ruptured due to the natural calamity.
* Faults are majorly effected in the civil engineering structures for eg:- dams, reservoirs, tunnels, bridges, small calvats & railway tracks.

→ Parts of faults:-

The various parts of the fault are given below they are:-



Parts of faults

1) Fault plane:-

The plane which is adjacent to strike direction is known as fault plane.

* When the surface get ruptured (or) sliding one division will form along the strike direction.

2) Foot Wall & Hanging wall:-

(It is the structure which is formed when some natural forces will be acting from upwards and downwards direction.)

* The upward portion is known as
* When the plane is completely inclined then the surface which is below the inclined fault plane is known as Foot Wall.
* The surface which is lying above the fault plane is known as Hanging Wall.

3) Slip:-

The displacement between the two blocks (or) adjacent blocks is known as slip. The overall displacement is known as net slip. slips are again divided into two parts:-

a) Strike slip (S)

b) Dip slip (D)

a) Strike slip:- (S)

When the two surfaces are sliding horizontally then it is known as strike slip.

b) Dip slip :- (D)

When the two surfaces are sliding vertically then it is known as Dip slip.

4) Heave & throw:-

It is the part which is also known as magnitude of slope. The horizontal displacement from upward direction is known as Heave. & vertical component of displacement is known as throw.

5) Dip amount:-

The angle formed blw the bedding plane & surface is known as Dip amount.

→ Classification & Types of faults:-

The faults are classified based on the displacement, movement of foot wall & hanging wall, Type of slip, inclination of fault plane.

* Based on type of displacement along the fault plane:-

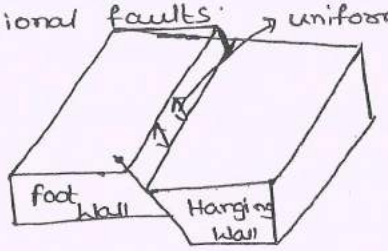
There are two types of faults they are:-

(i) Translational faults

(ii) Rotational faults.

(i) Translational faults:-

If the faults have uniform displacement blw the foot wall & Hanging wall is known as translational faults.



* Rotational faults:-

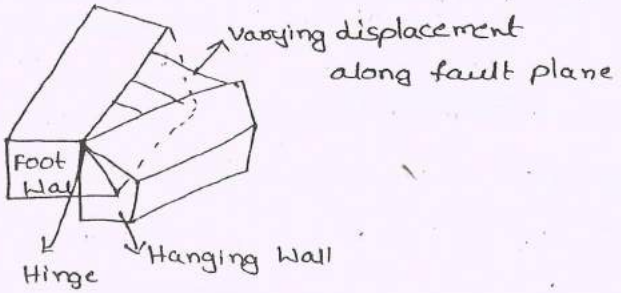
In rotational faults the displacement varies.

* In rotational faults the foot wall & Hanging wall appears to be hinged.

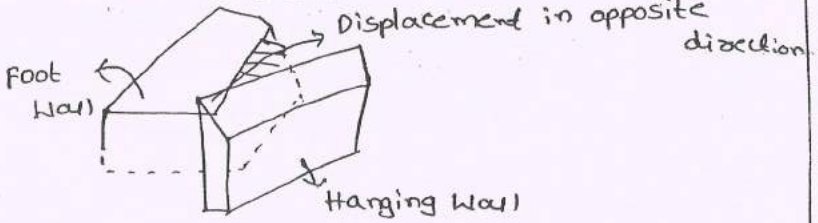
* There are two types of rotational faults they are

a) Hinge faults

b) scissors faults



Hinge faults



Scissors fault

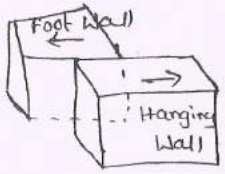
* Based on relative movement of foot wall & Hanging Wall:-

There are two types of faults based on movement they are:-

a) Dextral fault
b) Sinistral fault.

a) Dextral fault:-

* Dextral means right-hand side.
* When the hanging wall is moving right side is known as Dextral fault.



b) Sinistral fault:-

* Sinistral means left-hand side.
* When the hanging wall is moving left side is known as sinistral fault.

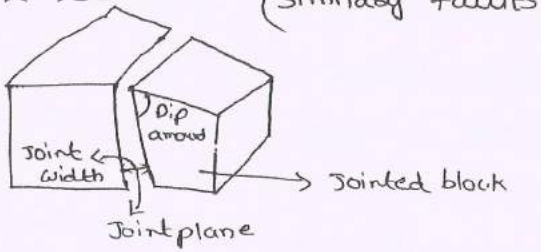
→ Joints:-

* Joints are one form of structural geology & it is similar to that of folds & faults.
* Joints are the cracks which form due to various reasons.

Ex:- Movement of tectonic plates, Natural air pressure, Blasting etc.

* Joints divide the rocks into two pieces (or) number of pieces (or) blocks.
* Group of fractures is known as joint set.
* Every set of joint should have there own strike & dip.

→ Parts of a joint:- (similary faults parts)



Note:-
* If the joints have more length then it is known as Master joints.

→ Classification of joints:-

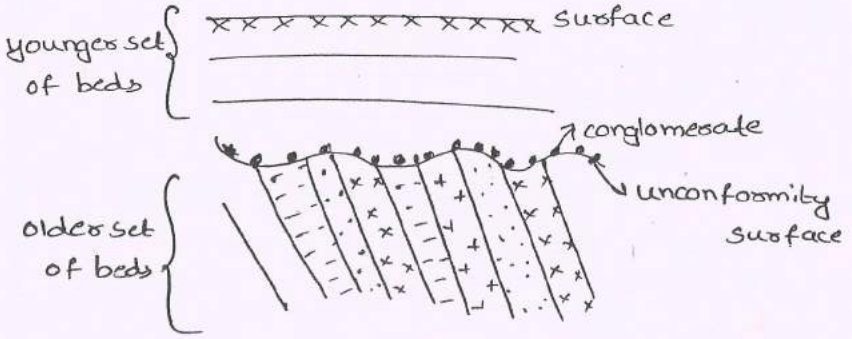
Joints are classified based on the relative attitude of joints & origin of joints.

* Based on relative attitude of joints:-
* When joints are ||le to strike direction then it is known as strike joint.
* If joints are ||le to dip direction then it is known as Dip joint.
* If the joints are not parallel to strike direction (or) dip direction then it is known as oblique joints.

→ Based on origin of joints:-
* Joints are mostly formed due to tension forces (or) shearing forces.

→ Unconformity:-
* It is one of the geological structures found in rocks.
* It is different from folds, faults & joints.
* Unconformity is a product of diastrophism & involves tectonic activity in the form of upliftment & subsidence of land mass.
* If the layers of rocks are formed without any break then it is known as conformity.
* If the layers of rocks are formed with break then it is known as unconformity.

→ Parts of an unconformity:-



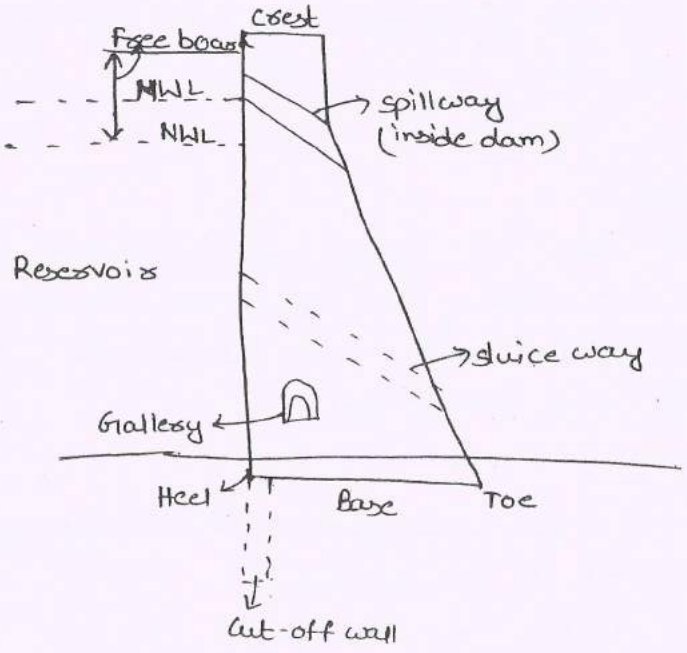
UNIT - VI

GEOLOGY OF DAMS, RESERVOIRS AND TUNNELS

Dam is a prestigious structure & it is a multi purpose civil engineering constructions.

* It delivers benefical results for long time to a mankind.
* A dam blocks the river channel & it compels the running H_2O to accumulate within the designed reservoir.
* If the H_2O exceeds the desired limit of storage in any reservoir, the surplus H_2O is allowed to flow downstream.

→ Dam & its parts:-



* Heel:-

It is the part of the dam which comes in the contact with the ground surface in the upstream side.

* Toe:-

It is the part of the dam which comes in the contact with the ground surface in the downstream side.

* Abutments:-

These are the sides of both the ends of the dam on which it is completely supported.

* Free board:-

It is the difference in level blw the top of the dam wall & storage level is known as free boarsd.

* Gallaries:-

These are the small rooms located within the dam for checking the operations, if any technical problems will occurs. It can be regulated very frequently.

* Spill way:-

It is the arrangement for controlling the H_2O level of the reservoirs.

* It is located at the top of the dam.

* Sluice way:-

It is the opening in the dam near the ground level which helps to clear the foreign matters (dust, waste).

* Cut-off wall:-

It is an underground wall like structure

* It is useful in preventing the leakage under the foundation beds & these by it avoids the under cutting the heel as well as the uplift pressure.

* By providing the cut-off wall only the complete dam will be safe for the given design period.

→ Types of Dams:-

Based on the construction material used, dams are grouped into concrete dams & earth dams.

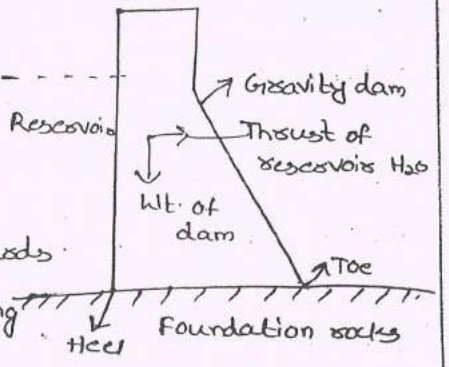
* Based on design, the concrete dams (masonry dams) may be further grouped into "gravity dams", "buttress dams" & "arch dams".

* Earth dams are divided into "earth fill dams" & "rock fill dams" based on the material used.

* The following are the different types of dams, they are:-

1) Gravity Dams
2) Buttress Dams
3) Arch Dams
4) Earth Dams.

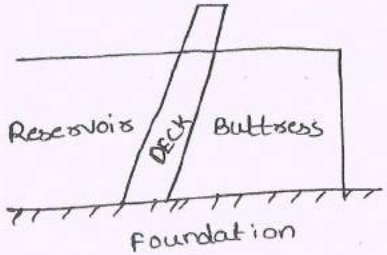
1) Gravity Dams:-



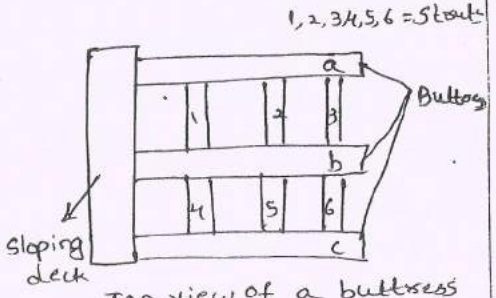
* These dams are heavy & massive wall like structures of concrete in which the whole wt. acts vertically downwards.
* The entire force acting on the dam wall is transmitted on to the small area of the foundation.
* Therefore, a dam of this nature is to be selected only in such places where very competent & stable rocks occurs.

2) Buttress Dams:-

* It is the dam which consists of concrete structures in which there is a deck sloping upstream.
* This deck takes the entire load is supported from behind by walls called buttresses.



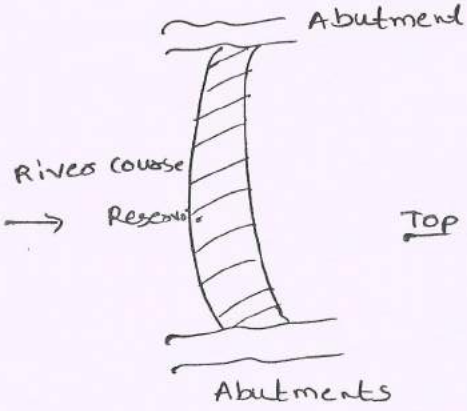
Side view of a buttress dam



Top view of a buttress dam

3) Arch dam:-

* It is the dam which will be in the shape of arch.
* The two ends arches will be supporting the abutments of the dam.
* When ever will the load applied in the middle zone, then it will be uniformly transmitted to the two end arch supports, which results the complete dam in the safe zone.



Top view of an arch dam

4) Earth dam:-

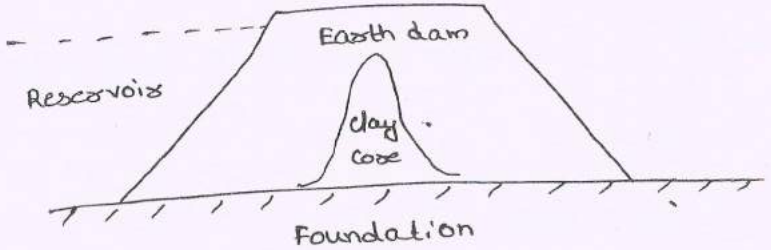
* Earth dam is a dam which will be constructed in such places where the underlying material is too weak to support masonry dams.
* The earth dams relatively of small height are lighter structures and broad based.
* The earth dams are trapezoidal in shape.
* These are mainly 2 types of earth dams

they are:-

a) Earth fill dam

b) Rock fill dam

* When most of the material used is earth, it is called an earth fill dam.
* When most of the material used is rock, it is called an rock fill dam.
* one of the largest earth dams is the famous Ft. Peck, Wyoming dam.
* It is $4\frac{1}{2}$ miles long, 4000 feet thick at the base & 250 feet high.



→ Purpose of Dams:-

The purposes of the dams are:-

1) To provide H_2O supply to meet the domestic, industrial & irrigation requirements.
2) To control floods
3) To generate power
4) To provide stream regulation.
5) To regulate stream sediment loads.

→ Geological considerations in the selection of a Dam site:-

The success of a dam is not only related to its own safety & stability but also to the based on reservoir.

* If a dam stands firmly but if its reservoir leaks then such a dam is to be treated only as a failure because the purpose for which it was constructed has not been served.

Eg:- Cedar lake dam (or) Malpasset dam.

* The success planning of reservoir & dam is important.
* The important geological considerations in the selection of a dam site are:-

1) Narrow river valley
2) occurence of the bedrock at a shallow depth
3) competent rocks to offer a stable foundation.
4) Proper geological structures.

1) Narrow river valley:-

At the proposed dam site, if the river valley is narrow, only a small dam is required which means the cost of dam construction will be less.

* If the valley is wide, a bigger dam is necessary which means the construction cost will be very high.

2) Bed rock at shallow depths:-

* The safety & stability of a dam is based on very strong & very stable rocks on which the dam rests.
* If the competent bedrocks occurs at the foundation, cost of the dam will be less.
* If the competent bedrocks occurs at the great depths, cost of the dam will be more.

3) Competent rock for safe foundation:-

* If igneous rocks occurs at the selected dam site, they will offer a safe base when compared to the sedimentary & metamorphic rocks.
* Earth crust contains 95% of rocks, but igneous occupies only 30% & remaining 70% the sedimentary & metamorphic rocks occupies

4) Proper geological structures:-

* The structure must be free from leakages.
* The dams & Reservoirs must be leakproof

→ Life of Reservoirs:

Due to silting process at the bottom of the reservoir, reduces the capacity of the reservoir to store water.

* Due to this process capacity of the reservoir to hold H_2O gradually decreases & finally reservoir contains only sediments remains but no water.
* The reservoir is designed based on the dead storage & live storage.
* The total volume of silt deposited in the reservoir is known as dead storage.
* The remaining storage is known as effective storage (or) live storage.
* The dead storage is generally more than $\frac{1}{4}$th of the total capacity.
* If reservoir is designed for 200 years, then it is used only for 40 years due to silting. (to store water without any sediments) is the actual aim of the reservoir design
* The period up to which the reservoir serves its purpose as expected is described as the "Life of the reservoir".
* "If the rate of silting is very low, the life of the reservoir will be long".

TUNNELS

Tunnels are one type of civil engineering structures similar to that of dams & reservoirs. Tunnels are constructed to minimising the distance in the under ground surfaces.

Ex:- In mountains (or) hilly areas.

→ Purpose of Tunnelling:-

Tunnels are mainly constructed for the human use as per his requirements.

1) Traffic & Transportation of goods

2) Diversion of waters:-

Diversion of H_2O referred that while constructing the dam, the dam site should be dry. If there is some flow of H_2O then the particular flow will be diverted with the help of tunnels.

3) Pressure tunnels (or) hydro power tunnels:-

Pressure tunnels & hydro power tunnels means some tunnels are provided for flowing of H_2O with certain velocity w.r.t that velocities & speed power will be generated.

4) Discharge tunnels:-

Discharge tunnels means the rate of flow of H_2O with certain velocity due to high gravity it is very convenience to transport the H_2O from one place to another place. For Eg:- It is used in the obstruction places like hilly (or) mountain ranges.

→ Effects of Tunnelling:-

Tunneling is done by the excavation method due to which it effects the surrounding as follows:-

* The tunnelling process is done by excavation method. In excavating the blasting process is involved. Blasting is done by inserting the bombs in the boulders area. Due to blasting the rocks get shattered into pieces. This process will reduce the shear strength of the ground surface.
* such unstable condition become more precarious if the blasting process is continued for longer period.
* stability of the ground may be Jeopardised when the tunnelled ground has unfavourable ground H_2O conditions.

→ Lining of Tunnels:-

The term lining means protecting layer for the structure. When tunnels are made through weak (or) Loose formation material then lining will be used. Then lining refers to the highly protective layer for the tunnels. Linings are mostly of steel as well as

concrete. The main purpose of providing lining is to resist the pressures due to natural calamity.

UNIT - IV

EARTHQUAKES, LANDSLIDES & GROUND WATER

*Earthquake :-

It is defined as the natural force which originates below the earth's surface, works randomly & creates irregularities on the earth's surface.

* It is an endogenous geological agent.
* study of earthquakes is known as "Seismology".
* The records of earthquakes are known as "seismograms" & the recording instruments are known as seismographs (In Greek seismos means shaking).

→ Earthquake Terminology:-

* The origin of the earthquake in the interior of the earth is known as focus (or) origin (or) centre (or) hypocentre.
* The place on the earth's surface, which lies exactly above the centre of the earthquake is known as the epicentre.
* The point on earth's surface diametrically opposite to the epicentre is called the anticentre.

* The imaginary line which joins the centre & the epicentre is called the "seismic vertical" (represents the minimum distance of earthquake to reach the surface of earth).

* An imaginary line joining the points of same intensity of the earthquake is called an "isoseismal".

* An imaginary line which joins the points at which the earthquake waves have arrived at the Earth surface at the same time is called a "coseismal".

* The energy released from the origin at the time of the earthquake is transmitted in all directions in the form of waves known as "seismic waves".

→ classification and causes of earthquakes:-

Earthquakes are classified based on different principles:-

* Based on the depth of their origin:-

Based on the depth of their origin earthquakes are of 3 types they are:-

1) Shallow earthquake.
2) Intermediate earthquake
3) Deep earthquake.

* Earthquakes with a origin depth less than 60 km are called shallow earthquakes.

* If depth is more than 60 km but less than 300 km they are called intermediate earthquakes

* If origin depth is more than 300km are called deep earthquakes

* Earthquakes originating at depths greater than 700 km are extremely rare.

Eg:-

* It will be interesting to know that out of the 5605 earthquakes recorded in Italy, oldham has found that 90% of them had a focus at less than 8 km depth, 8% has a depth between 8km & 30km & only 2% had a origin deeper than 30km.

* Based on the causes responsible for their occurence:-

Based on the causes responsible for their occurence, earthquakes are described as tectonic earthquakes & non-tectonic earthquakes

1) Tectonic earthquakes:-

Tectonic earthquakes occurs due to internal causes i.e due to disturbances or adjustments in geological formations in the earth's interior.

* These are less frequent but more intensity & more destructive in nature.

2) Non-tectonic earthquakes:-

* The non-tectonic earthquakes occurs due to external causes.

* These are mainly formed due to volcanic eruptions.

* These are very frequent, but minor in intensity & less destructive in nature.

* These are also formed due to tsunamis, dams & reservoirs, man-made explosions etc.

→ Effects of earthquakes:-

* Most of the earthquakes are minor and are not noticed.
* But the majors ones are responsible for heavy loss of life & property.
* The following are the various effects of earthquakes they are:-

1) Destruction of various civil engineering constructions like dams, bridges, tunnels, roads & railway tracks.

2) creation of irregularities (ups & downs) on the ground, due to this the problems will occur for the communication system.

3) Landslides will occur due to this roads & railway lines in some places may block.

4) Submarine earthquakes cause tsunamis

5) Heavy loss of life & property:-

* In Shensi province of china, in 1556 an earthquake caused the death of 800,000 people.
* In 1923, an earthquake in Japan caused the death of 1,40,000 people & a property loss of three billion dollars.

↳ Seismic Belts & shield areas:-

Seismic Belts are the places where earthquakes occur frequently.

Sheild areas are the places where earthquake occurs either rarely (or) very mildly.

* Earthquakes occurs at a place where there is a underground instability.
* Generally, the earthquakes occurs in the mountain ridges (upto 50%) & along steep coasts (40%).
* The earthquakes occurs b/w two belts, one is the "circum pacific belt" which accounts for 68% of earthquake occurence.
* The other belt is called "Mediterranean belt" which accounts for 21% of earthquake occurence
* A minor belt of epicentres occurs along the mid-Atlantic ridge.
* In India, the entire northern part of the country consisting of foot hills of the Himalayan ranges.

↳ Richter scale:-

The magnitude of earthquake is measured by the Richter scale.

* charles Richter of the California Institute of Technology proposed this scale, in which the recorded waves are measured by a Seismograph.
* Earthquake having Richter magnitude from (3 to 9) (maximum known is 8.9 only).

* Magnitude '2' is the smallest earthquake.
* Magnitude '5' may cause damage within a radius of about 8 km.
* Magnitude '7' may cause damage in a radius of 80 km.
* Magnitude '8' over a radius of 250 km.

→ Precautions of building constructions in seismic areas:-

* Deep foundation.
* Foundation should be on competent rocks.
* Raft & square foundations are suitable.
* Walls of the buildings should be continuous without any gap.
* Minimum doors & windows should be placed.

LAND SLIDES

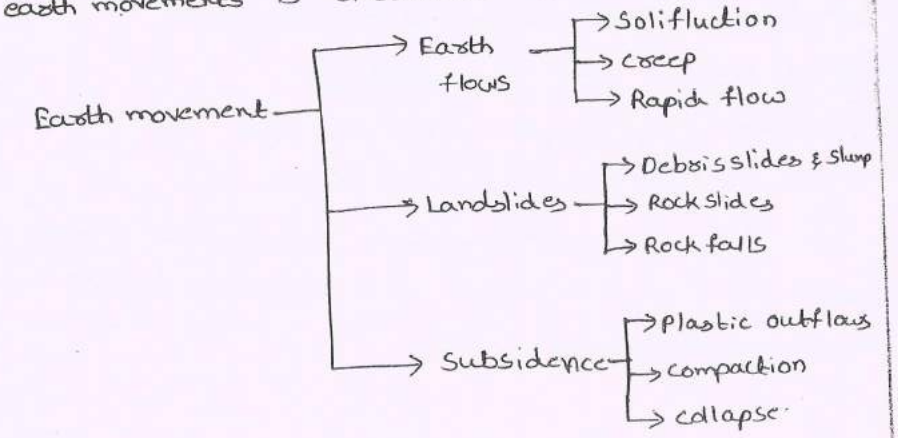
The term landslide refers to the downward sliding of huge quantities of land masses. Generally sliding occurs along steep slopes of hills. It may be sudden (or) slow. Loose & unconsolidated material undergoes sliding.

→ Importance of sliding:-

* Landslides occur in uninhabited places & is not taken into consideration.
* If Landslides occurs in places such as highways, railway lines, valley, reservoirs, leads to blocking of traffic, collapse of buildings etc.
* In our country landslides occur in Kashmir, Himachal pradesh & in the mountains of UP.

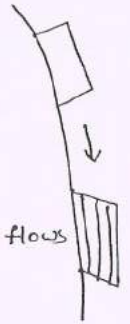
→ Classification of Earth movements:-

Based on the type of movement the earth movements is classified into three types:-



1) Earth flows:-

In earth flows, the movement is distributed throughout the displaced mass.



Earth flows

* There are three types of earth flows they are:-
  a) Solifluction
  b) Creep
  c) Rapid flow.

* 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 surfacial matter. It is always limited to the surface, just below it.

Creep

* Rapid flows are similar to creep but differ with respect to the speed & depth of the of material

(Ex:- * Near St. Thurbe, Quebec (canada), where the river bank 25' to 35' high gave way during heavy rain & some 3 1/2 million cubic yards of clay & sand flowed out into river Blanche, leaving an area of 1700' x 3000' excavated to a depth of 15' to 30'.)

2) Land slides:-

If a mass of earth (or) rock moves along a definite zone (or) surface, the failure is called a Landslide.

* There are 3 types of landslides:-
  a) Debris slides & slump
  b) Rock slides
  c) Rock falls

Landslides

* Debris slides are the failures of unconsolidated material on a surface of rupture. These are common along the sides of rivers, lakes etc.

* Debris slides of small magnitude are called slumps.

* Rock slides are the movements of material (recently detached bad rocks).

* Rock falls refers to the blocks of rocks of varying sizes suddenly crashing downwards along steep slopes.

3) Subsidence:-

It refers to the downward movement of the surface.

Subsidence

* There are 3 types of subsidence they are!-

a) Plastic outflows

b) Compaction

c) Collapse.

* Plastic outflows occurs beneath heavy loads & due to disturbance surface settlement takes place.

* compaction takes place due to loads. Excessive pumping out of H_2O & oil from ground cause subsidence.

* Collapse takes place at excessive mining (Removing a large volume of material).

→ Causes of Landslides:-

Landslides mainly causes due to two types:

1) Internal causes (or) Inherent causes

2) immediate causes

* Internal causes are responsible to the extent of creating favourable conditions for landslide occurence.

* Immediate causes of landslides occurs due to the sudden jerk.

(* Internal causes may occurs due to effect of slope, water, lithology, associated structures, human factors.

→ Effects of Landslides:-

The effects of landslides are!-

(i) Blocking of transport, communication system etc.

(ii) obstruction to the river flow in valleys, leading to floods.

(iii) Damage to pipelines.

(iv) Destruction of buildings

→ Preventive measures for Land slides:-

* Retaining walls must be constructed against the slopes.

* Proper drainage system should be provided.

* The weak materials must be either covered (or) grouted.

* Growing vegetation, plants & shrubs on loose ground helps in keeping the loose soil together

GROUND WATER

→ Introduction:-

The H_2O which is available under the ground is known as ground water.

* 97.2% of H_2O occurs in sea.
* 2.0% of H_2O occurs in ice bodies
* 0.8% of H_2O occurs as surface H_2O & ground H_2O in this 1/3rd is in the form of surface H_2O & 2/3rd is in the form of ground H_2O.
* 99.2% of available H_2O on earth is saline (or) as solid ice, so it is unsuitable for direct use.
* Remaining 0.8% of water is available for direct use.

→ Uses of water:-

* 75% of water is used for irrigation purpose
* 20% of water is used for in industries.
* only 5% of water is used for domestic purposes.

So as the earth contains 0.8% of fresh water they must be used carefully without any wastage of H_2O.

* 1000 tons of H_2O — For producing 1 Ton of grain
* 2000 tons of H_2O — " " 1 Ton of rice
* seas & oceans contains 330 million cubic miles of H_2O.

→ Water Table:-

Due to weathering of rocks, the land surface is covered by a loose soil. Below the loose soil there is a fractured zone of rocks exists below the soil zone.

* Below the fractured zone the bed rocks occurs which is free from fractures.
* It consists of a vertical section containing of loose soil (at top), fractured rock (in middle), Bedrock (at bottom).
* When rainfall occurs, some percentage of H_2O moves downwards through fractures, under the influence of gravity, until it reaches the bedrocks
* Then, the percolation of rain H_2O leads to the development of a zone of saturation above the bedrock, in which all openings are filled with H_2O. This water is known as "ground water."
* The upper surface of this zone of saturation is called "water table."
* Above the zone of saturation & below the ground surface is the "zone of aeration" in which H_2O fills only a portion of the pore space.
* The different types of ground H_2O which occurs in the zone of aeration:-

1) Soil water — (Root of plants)
2) Pellicular H_2O (Sticks to the sides of fracture).

3) Vadose H_2O (or) gravity H_2O – (Percolated H_2O due to gravity reaches the water table).

4) Perched H_2O – (zone of aeration)

5) Capillary H_2O – (H_2O in openings just above & in contact with the water table).

* The different types of ground H_2O which occurs in the zone of saturation :-

1) unconfined (or) free ground water :-

This H_2O lies below the water table under atmospheric pressure only This H_2O moves freely upwards (or) downwards.

2) confined H_2O :-

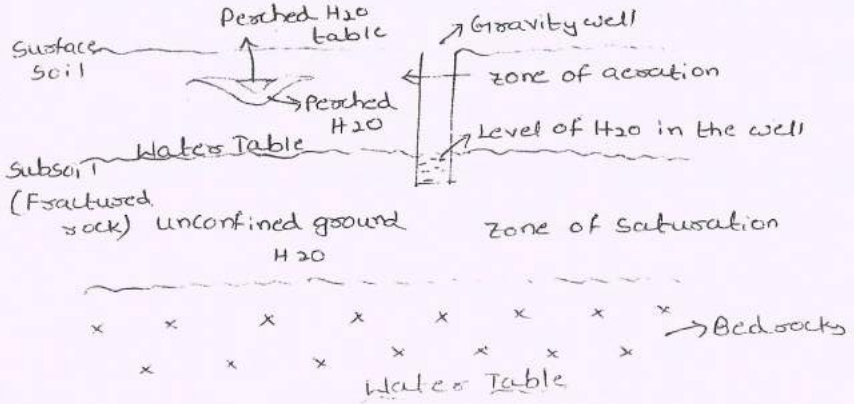
This H_2O lies below the H_2O table & is present b/w impervious beds.

3) Fixed ground H_2O.

4) connate H_2O : H_2O Held within the rocks from beginning.

5) Interal H_2O :- H_2O occuring at great depths.

6) Juvenile H_2O :- (Magmatic source)



→ Porosity :-

It is defined as the ratio of volume of the voids (V_v) in a rock mass to the total volume (V) of the rock.

$$\therefore n = \frac{V_v}{V}$$

* It is denoted by 'n'.
* It is expressed in %.
* These are two types of porosity :-
  a) Primary porosity (Right from formation) b) secondary porosity (In middle like joints, faults, folds).
* If porosity is < 5% – Less (or) small porosity
* " " > 20% – More porosity
* " " b/w 5-20% – Medium porosity.

→ Permeability :-

It is defined as the ability to transmit the water to pass through it.

* The coefficient of permeability is denoted by 'K'.
* Permeability depends upon the porosity.

→ Geological control of ground H_2O movement :-

The movement of ground H_2O takes place at the zone of aeration & zone of saturation under the influence of gravity.

* Depends on permeability.
* Depends on porosity.
* " Bedding on rocks
* Dykes, sills etc.

→ Ground H_2O exploration techniques :-

The ground water can be explored by using two methods

1) H_2O divining → (Y-shaped twig) Sometimes

2) Scientific studies

- Geological
  - * Study of rocks
  - * Topography
  - * Weathering
  - * Geological structures
  - * Geological mapping
- Geophysical
  - * Folds, Faults
  - (* Electrical resistivity)
  - (* Seismic refraction method).
- Hydrological
  - * H_2O Table
  - * Surface H_2O
  - * Quality of H_2O.

→ Classification of rocks based on porosity & permeability :-

Based on porosity & permeability properties, rocks are grouped into four types namely :-

1) Aquifers — Both porous & permeable.

2) Aquifuges — Neither porous nor permeable

3) Aquicludes — Porous but not permeable.

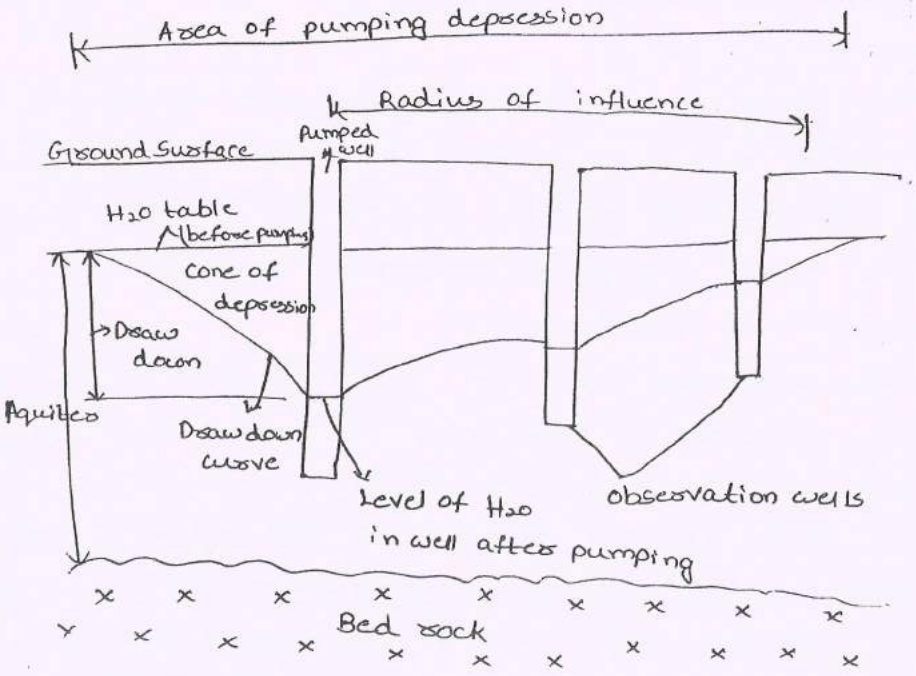
4) Aquitards — (both Aquifuge & aquicludes).

→ Fluctuation of the H_2O table level in unconfined aquifers :- Two types they are :-

1) Seasonal — (Rainy season)

2) Cone of depression

→ Cone of depression (or) Cone of exhaustion :-



In any gravity well (i.e well dug in an unconfined aquifer), the level of H_2O coincides the H_2O table level of the surrounding aquifer

* When H_2O is pumped out from well, the level of H_2O decreases in the well & the depression in the H_2O table around the well is in the form of an inverted cone.

* This phenomenon is called the cone of depression.

* This is a temporary fluctuation in the level of H_2O table because the original position is restored within a short period

due to the seepage of ground H_2O from the sides of the well.

* The shape of this cone of depression on the H_2O table around a pumped well depends upon the permeability nature of the aquifer body.
* For highly permeable materials, the cone of depression is nearly flat.
* Less permeable aquifers — very steep
* The boundary of the cone of depression is known as the ground H_2O divide.
* The area enclosed by ground H_2O divide is known as the area of pumping depression.
* The distance b/w well & the ground H_2O divide is termed as the radius of influence
* The values of the radius of influence for unconsolidated sediments are;-

1) In coarse gravel = 400 to 800 metres
2) In fine gravel to coarse sand = 200 to 400 metres
3) In fine sand to medium sand = 100 to 200 metres.
4) In silt = 30 to 100 metres.

Therefore, the decrease in the level of H_2O in the well is known as hydraulic gradient.

UNIT - V

GEOPHYSICS

Geophysics is the study of earth by using the principles of physics.

→ Branches of geophysics:-

It has two branches they are;-

1) General geophysics.
2) Exploration geophysics.

1) General geophysics:-

It is defined as the study of the earth as a whole & its major features.

* It deals with the gravity field, magnetic field & geothermal field of the earth.
* It gives the information about the physical state & composition of matter in the interior of the earth.

2) Exploration geophysics:-

It is defined as the study regarding the shallow subsurface inhomogeneities & structure
* It helps in exploration of oil & gas, ore deposits ground H_2O.
* It is also known as "geophysical prospecting" (or) "applied geophysics."

→ Importance of Geophysical Investigations:-

Geophysical investigations are important because it solves the variety of problems.

* Large areas can be investigated in a short period of time.
* The geophysical instruments used in the field are simple, portable & can be operated easily.
* It is economical in gravity, magnetic & electrical methods of investigations.
* It is used in military applications i.e for placing enemy guns, submarines etc.
* "Exploration Geophysics" are divided into five branches namely:- (i) Regional geophysics
  (ii) oil & gas geophysics
  (iii) ore geophysics
  (iv) Ground H_2O geophysics
  (v) Engineering geophysics.

→ Classification of Geophysical Methods:-

The geophysical methods are mainly classified into 6 major groups they are:-

1) Gravity Methods.
2) Magnetic Methods.
3) Electrical Methods → Electrical resistivity method
   → Electro magnetic method
   → self-potential method
   → Induced polarization method
4) Seismic Methods → seismic reflection (or) refraction methods
5) Radiometric Methods → Gamma Methods
   → Emanation methods.
6) Geothermal Methods.

(* Well-logging Method:-
Valuable technique to exploit the above physical properties)

1) Gravity Methods:-

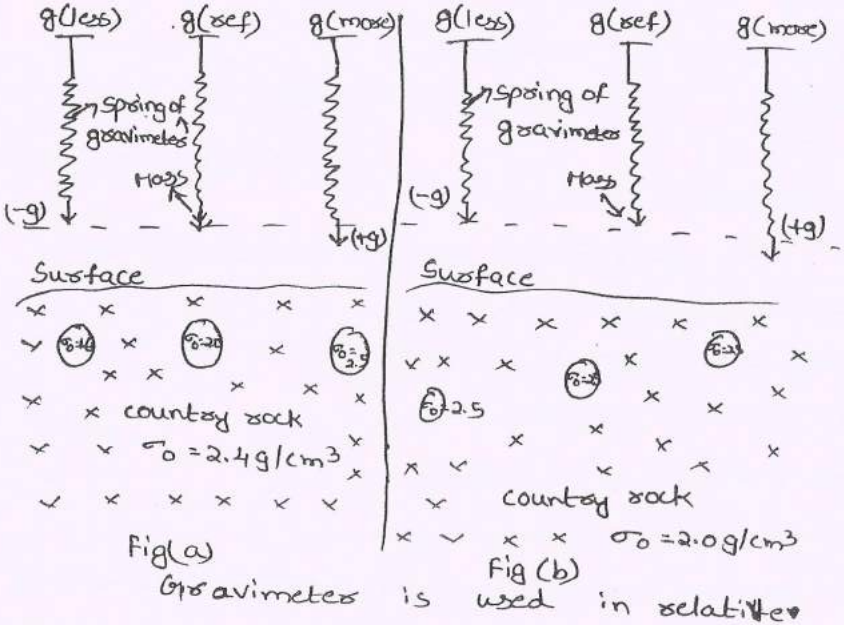
In Gravity method, natural gravity field of the earth is used.

* Controlling physical Property:- * Density, is the controlling physical property.

* Principle:-

In gravity methods, the nature of distribution of gravity 'g' on the surface is analysed.

* Gravity is positive when body is heavier, larger & occurs at shallow depth.



Fig(a) Fig(b)

Gravimeter is used in relative gravity measurements is a mass loaded spring.

* If subsurface has a relatively heavier body the gravity pull is more there (+g) & spring extends longer.

* If subsurface has relatively a lighter body there the gravity pull is less (-g) & spring contracts becoming shorter.

* Parameters:-

The physical parameters of gravity, which are measured during investigation are:-

(i) variation of gravity field (Δg).

(ii) horizontal gradient of gravity field (U_{xz})

(iii) curvature of equipotential surface (U_{zz}).

* 'Δg' is measured in the units of "milligals" (one gal = 1000 milligals)

* others are measured in terms of "Eotvos unit". (Geophysical units)

* Methods:-

The differents kinds of methods used during investigations are:-

(i) (ground) gravity prospecting

(ii) gravity Logging

(iii) Airborne gravimetry

(iv) Shipborne gravimetry.

* The process of applying various corrections which is obviously necessary is known as reduction of gravity data.

* Equipment:-

The following instruments are used in investigations:-

1) "Pendulums" for absolute & relative gravity measurements.

2) 'Gravimeters' for relative gravity measurements.

3) 'Torsion balances' for gradient & curvature measurements.

4) 'Gradientometers' for gradient measurements.

Among these gravimeters are very popular because of their advantages.

* Applications (uses):-

Gravity investigations are useful for:-

(i) Exploration of ore deposits

(ii) Exploration of oil & natural gas deposits.

(iii) Study of isostasy, shape of earth

(iv) Structural mapping

(v) Solving regional geological & engineering problems.

* C.G.S units:- g/cc (Density).

→ Magnetic methods:-

In magnetic method, natural gravity field of the earth is used same as the gravity method.

* Controlling physical property:-

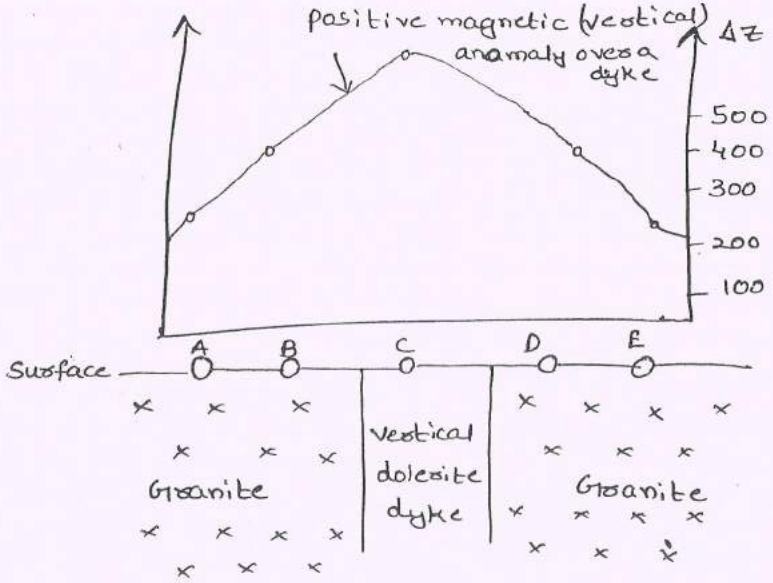
* Magnetic susceptibility

* Natural remanent magnetism are the controlling physical properties.

* Principle:-

In the gravity methods, the contribution of magnetic body is directly proportional to the

magnetic moment of the body & its size & is inversely proportional to the depth of its occurrence.



Principle of magnetic method of prospecting