PART-A

UNIT - 01

Content :

MINERALOGY

- **Introduction**
- **Civil Engineering importance**
- **Interior of the Earth**

GEOLOGY & ITS IMPORTANCE IN CIVIL ENGINEERING PRACTICE

The engineering geologist has to observe and record geological information and then translate this data into practical engineering design, construction and maintenance of civil engineering projects.

The geological aspects of the civil engineering site have to be studied in detail before commencement of the project. The civil engineer and the engineering geologist have to work together in the field in various stages. However, in some stages they work separately, in other jointly. The responsibilities and nature of the work in which both engineering geologist and civil engineer are involved are listed below.

Engineering Geology and Civil Engineering

1. **Mapping:** The engineering geologist has to prepare a geological map of the area based on aerial photo and satellite imagery interpretation and field observation. Subsurface geological features are also mapped.

2. **Exploration**: In this stage the engineering geologist explore the area based on exploration techniques. The engineering geologist works from the planning stage. Supervise the exploration works and records the data for further interpretation.

3. **Project Planning**: Project planning is the most important aspect in civil engineering. The civil engineer plans the various stages. The engineering

geologists plans and prepares geologic feasibility and developmental parameters reports, which are useful to the civil engineer for planning the project schedule.

4. **Surface water**: The engineering geologist and the civil engineer together prepare surface –water mapping. Both study the volume of total runoff, drainage basin characteristics and sedimentary process in the basin. Weathered areas, silting potential and erosion potential are also estimated before planning any hydraulic structure in the basin.

5. **Groundwater**: Groundwater is the major problem in the majority of civil engineering works. The engineering geologist studies in detail the occurrence, movement, structural controls and hydro geological properties of the rocks. Hydro geological maps are prepared for civil engineering purposes.

6. **Slope Stability**: Geological parameters of possible slide regions are studies

7. **Geological Structures**: Field investigation is carried out for selection of a suitable area. Detailed surface-subsurface studies are conducted and surface and subsurface maps are prepared. The engineering geologist and the civil engineer conduct in-situ tests for foundation materials, supervise the construction methods and monitor the structure after completion of the work.

8. **Tunneling**: The tunnel site selected is based on a detailed study of the region. The civil engineer and the geologist have to conduct in-situ tests for estimation of weathered zone thickness, depth of hard rock, structural features etc.

9. **Earthquake**: The engineering geologist studies the seismic nature of the project site. He examines the seismic zoning map of the country, evaluates active and inactive faults and keeps the historical record of the earthquake of the region in which the civil engineer will prepare a seismic design of structure.

   Geological features of the civil engineering have to be studied a detail before execution of the work. The engineering geologist must work from the exploration stage to the end of the project. The civil engineer and the engineering geologist have to work in the field together either good coordination in order in order to identify the field problems and to suggest possible remedial measures in the case of problems of structures.

INTERNAL STRUCTURE OF EARTH

Our Earth is a cosmic body. It is one of the nine members of he Solar system of which Sun is the central star. The nine planets constituting the Solar system has been named as Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto.

In its shape, he Earth is commonly described as a spheroid, it has an equatorial diameter of 12,757.776km and a polar diameter of 12,713.824km and thus has an equatorial bulge. At present the Earth is the only planet believed to be sustaining life other planets have shown no signs of life on them.

For systematic scientific investigations, the earth is commonly differentiated into three parts; they are atmosphere, lithosphere and hydrosphere. Each forms an extensive field of study, volumes of information have been collected about each of these parts during last hundred years or so but findings of last three decades have made our understanding about these parts very clear. Only most important characteristics of these parts have been summarized below.

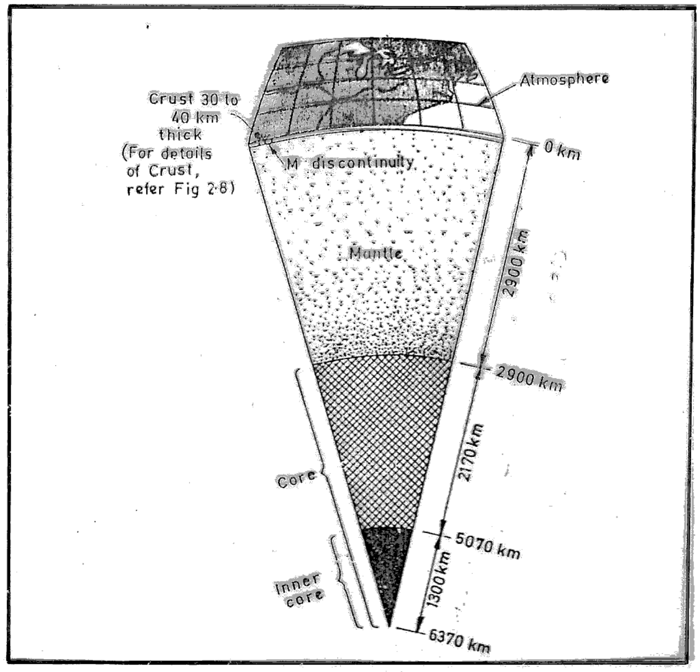
ATMOSPHERE

The outer gaseous part of earth starting from the surface and extending as far as 700km and beyond is termed atmosphere. Although extending for such great distances, the atmosphere makes only one-millionth part of the mass of earth; this is because of its gaseous composition. It is now fairly established that the atmosphere possesses a layered structure. Their well-defined layers or zones of the atmosphere are surface upward, troposphere, stratosphere and ionosphere.

LITHOSPHERE

It is the solid part of the earth and in a broader sense includes all the solid materials composing the earth from surface downwards, although sometimes-specific terms are used for deeper earth zones. Recent detailed seismic studies of the body of the earth have shown that it is composed of three well-defined shells, Crust, Mantle, Core.

INTERNAL STRUCTURE OF EARTH



The Crust: - Is the topmost shell of the earth, which has a thickness of 30-40 km in the continents and 5-6 km in the oceans. There is a striking variation in the materials or rocks, as they are called, composing the crust over the continents and ocean floors. The oceanic crust is made up of heavier and darker rocks called basalts compared to light-colored and light-density, granitic rocks of the continental crust. When considered as a part of the total structure of the earth, crust makes only an insignificant part represented by a thin layer, similar to the skin of an apple. As regards he chemical composition of the crust, analyses made by Clarke and Gold Schmith, using rocks from different geographic regions of the crust have all shown that when expressed in terms of oxides, the crust has Silica as the most dominant component, its value lying above 50% by volume in the oceanic crust and above 62% in the continental crust. Alumina is the next important oxide, varying between 13-16% followed by Iron Oxides (8%), Lime (6%), Sodium (4%), Magnesium (4%), Potassium (2.5%) & Titanium (2%). The crust itself shows a complicated structure both in make-up and compositional variations.

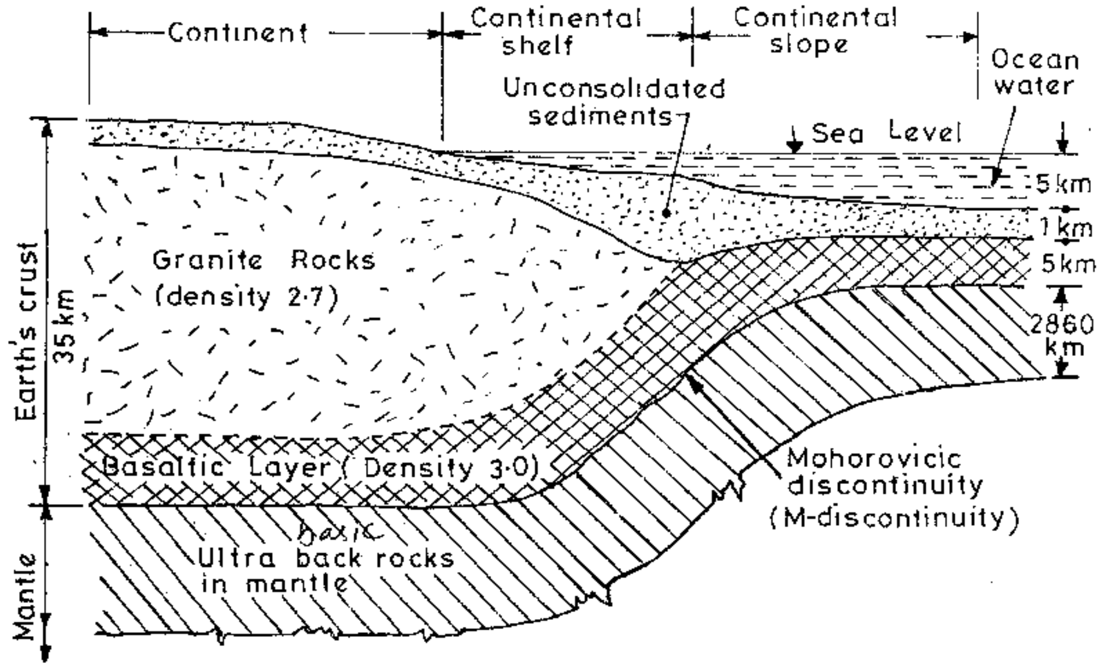


Fig. 2.8. Diagram showing the X-section of Continent and Ocean Basins (vertical scale shown exaggerated)

The Mantle: - At the base of the crust materials of the earth become greatly different in many properties from those overlying them in the crust. These materials appear to form a nearly homogeneous zone till a depth of 2900 km is reached. This zone of materials lying between crust and a depth of 2900 km is known a MANTLE. It is made up of extremely basic materials, called ultra basic rocks, which are believed to be very rich in iron and magnesium but quite poor in silica. Such rock names as Periodotites, Dunite. This One is characterized with a high density, increasing steadily with depth further; the mantle material is believed to be highly plastic in nature. Many of the most important geological process such as earthquakes and formation of mountains are believed to have their origin in this zone.

The Core: - It is the third and the innermost structure shell of the earth, which is clearly marked by the seismic evidence. It starts at a depth of 2900 km below the surface and

extends right up to the center of the earth at 6370 km. The material making g the core is found to be from seismic studies only strikingly different from that making the other two shells in one major aspect, in elastic properties. The material has no shear resistance, which makes it nearer to liquid than to a solid body. It has a very high density, above 10gms/cubic centimeter, at the mantle –core boundary. Nothing can be said about the composition of the core. According to one, widely favored view, the core is made up of Iron and Nickel alloy material.

MINERALOGY

Content :

- **Introduction**
- **Minerals**
- **Physical properties of Minerals**
- **Description of Minerals**

MINERALOGY

Minerals have been defined as naturally occurring substances, mostly inorganic, that are characterized by a definite chemical composition and a definite atomic structure. Since rocks which make up the earth are simply natural aggregates of minerals, a study of minerals is of fundamental importance understands the elements of science of geology. The branch of geology dealing with the study of minerals is designated as Mineralogy.

Each mineral is generally characterized with a set of qualities some of which are always distinctive and differentiate it from other minerals. Some of these qualities or properties may be studied from the body of the minerals, its shape, color, shine, hardness etc.; these are termed physical properties. Some other qualities like the behavior towards light require extremely thin sheets or sections of the minerals and are best studied with the help of a microscope. These are termed optical or microscopic properties. A third group of properties involving.

These are the physical properties most useful for mineral identification:

HABIT

A mineral may sometimes show a definite and characteristic arrangement in its outer appearance or physical shape. This shape is expressed by the term Habit and is typical in the case of many minerals. A few common habits with examples are given below.

Fibrous habit: -When the mineral is made up of fibers, generally separable, e.g. in Asbestos.

Columnar habit: - When the mineral is composed of thin or thick columns, sometimes flattened, e.g. in Hornblende.

Bladed habit: - The minerals appears as if composed of thin, blade like structure, e.g. in Kyanite.

Lamellar habit: - The plates or leaves are separable, e.g. Vermiculite.

Granular habit: - The mineral shows numerous grains packed together, e.g. in Chromite.
Acicular habit: - When a mineral surface is covered by large, conspicuous, overlapping prominences, e.g. in Malachite.
Mammillary habit: - When a mineral surface is covered by large, conspicuous, overlapping prominences, e.g. in Malachite.

Reniform habit: - The rounded prominences exhibit a resemblance to a kidney shape, e.g. in Hematite.

Foliated habit: - When the mineral consists of thin and separable leaves, e.g. in Mica.

Radiating habit: - When the fibers or needles are arranged around a central point, e.g. in Iron Pyrites.

Tabular habit: - The mineral is flat thatn elongated e.g. in Calcite, Orthoclase.

Globular habit: - Or Botryoidally, when the minerals is in the form of bulbous overlapping projections, e.g. in Hematite

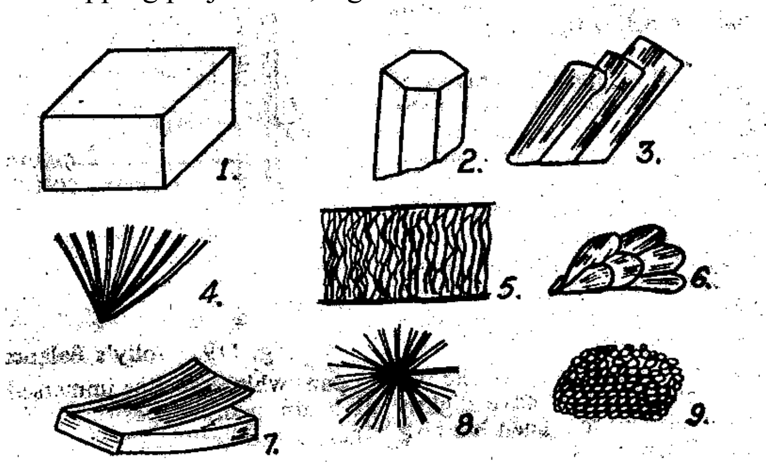


Fig. 118. Some Common Structures in Minerals
1. Tabular 2. Columnar 3. Bladed 4. Acicular
5. Fibrous 6. Reniform 7. Foliated 8. Radiating
9. Granular.

COLOUR

Minerals show great variety of colors. The color of a substance is its appearance in light and depends upon the composition and structure of the substance is its appearance in light and depends upon the composition and structure of the substance. In minerals, colors may be either of inherent of of an exotic nature; the former is related to the chemical composition and is more diagnostic whereas exotic colors are due to small traces of impurities and may vary within wide limits. Metallic minerals commonly show greater consistency in colors than the non-metallic minerals.

Some minerals show peculiar phenomena connected with color. Of these, the following are interesting and important.

Play of Colors: - It is the development of a series of prismatic colours shown by some minerals on turning about in light. The colors change in rapid succession on rotation, example: Diamond.

Change of Colors: - It is similar to play of colors except that rate of change of colors on rotation is rather slow; each color continues over a larger space in the mineral, ex: - Labradorite.

Iridescence: - Some minerals show rainbow colors either in their interior or on their surface. This termed iridescence.

Tarnish: - Sometimes the surface color is different, rather dull, than the color of the mineral as seen on freshly fractured surface; ex: Chalcopyrite, an ore of copper.

Although color is never taken as a conclusive property in the identification of minerals, it is invariably studied first and is generally helpful.

STREAK

The streak of a mineral is the color of its powder. This becomes important in the sense that for some minerals, the color is entirely different from that of their powder. This has been found true in certain or minerals, while most of the other minerals exhibit a white streak: and, streak does not help in distinguishing those minerals. The important minerals offering characteristic color-streak combinations are given in table.

Some minerals with their characteristic color-streak combinations

MINERAL NAME	ORIGINAL COLOR	STREAK COLOR
PYRITE	Brass-Yellow	Greenish Black
CHROMITE	Greenish-Black	Greenish Brown
HEMATIE	Black	Cherry-red

The streak of mineral can be readily observed by scratching it on a streak plate, which is made up of unglazed porcelain or roughened glass. While determining streak for a mineral, care should be taken to scratch it from its obscure part, and to give only a small scratch, producing a small quantity of its powder.

LUSTER

The shining surface of a mineral is called it luster. The different types of luster and their examples are given in a tabular column.

S.No..	Type of Luster	Description	Example
1	**VITEREOUS LUSTER**	A mineral having a glassy shine	Quartz and Calcite
2	PEARLY LUSTER	A mineral having a pearly shine	Muscovite Mica
3	METALLIC LUSTER	A mineral having a metallic shine	Magnetite
4	SILKY LUSTER	A mineral having a silky shine	Asbestos
5	RESINOUS LUSTER	A mineral having a greasy, oil shine	Talc
6	ADAMANTINE LUSTER	A mineral having a diamond like shine	Diamond

DIAPHENITY

Diaphaneity of a mineral may be defined as its capability to pass light through it. Hence, if an object can be seen fully and easily through a mineral, it may be called as diaphaneity. Depending upon the extent to which light can pass through a mineral, they may be classified as follows.

Type of Transparency	**Description**	Example
Transparent	Mineral which allows the light to pass fully, and objects on Other sides are seen clearly Through the mineral.	Quartz, Calcite
Translucent	A mineral which allows only some diffused light to pass through edges.	**Jasper**

Opaque	A mineral which does not pass any light, and hence through which nothing can be seen.	**Orthoclase, Hornblende**

FRACTURE

The fracture of a mineral may be defined as the appearance of its broken surface, when the mineral is hammered and broken. It is a characteristic feature of certain minerals, which help us in their identification. The different types of fractures seen in various minerals.

Type of Fracture	Description	Example
EVEN FRACTURE	When the broken surfaces of a mineral are smooth	Chert
UNEVEN FRACTURE	When the mineral breaks with very rough and coarse surface	Chromite
CONCHOIDAL FRACTURE	When a mineral breaks with curved surfaces. Infact, there will be concentric grooves and ridges resembling with the concentric lines of growth on a shell (Conch)	Quartzite
HACKLY FRACTURE	When a mineral breaks with irregular surfaces having sharp edges	Copper
EARTHY FRACTURE	When a broken surface is soft and almost smooth	Chalk

HARDNESS

Hardness is another property of a mineral, which can be used as a handy tool in the field, to differentiate between the different minerals or to recognize particular minerals.

Hardness of a mineral may be defined as the resistance, which the mineral offers to scratch. This property of a mineral is generally determined by scratching a given mineral with a mineral of known hardness, so as to obtain the comparative figure for the hardness of the given mineral. Thus for example, if a given mineral gets scratched by a mineral or metal of hardness say 6, but does not get scratched by that of hardness5, then evidently we can conclude that the hardness of a given mineral lies between 5 and 6. Moreover, the intensity of scratch procured, will help us to judge whether the hardness determined is nearer to 5 or to 6.

The hardness of minerals is generally expressed on Moh's scale of hardness, which incorporates ten minerals assigned with standard hardness.

MINERAL	HARDNESS	
TALC	1	Can be scratch even by finger nail
GYPSUM	2	Can be scratch even by finger nail
CALCITE	3	Can be scratch even by finger nail
FLUORITE	4	Can be scratch by penknife
APATITE	5	Can be scratch by penknife
ORTHOCLASE	6	Can be scratch by penknife
QUARTZ	7	Can not be scratch by penknife
TOPAZ	8	Can not be scratch by penknife
CORUNDUM	9	Can not be scratch by penknife
DIAMOND	10	It can be scratch by another diamond

SPECIFIC GRAVITY

It is defined as the ratio of its weight to the weight of an equal volume of water. Strictly speaking, the weight of water should be taken at 4o C, as the temperature variations bring a slight change in the weight of after of a certain fixed volume.

In fact, the specific gravity of a mineral depends upon the weight and spacing of its atoms. A mineral possessing heavier and closely spaced atoms will have a high specific gravity: whereas, a mineral possessing lighter and widely-spaced atoms will have a low specific gravity. The specific gravity of the mineral is thus, in fact a representation of its atomic structures. All minerals have been found to possess a specific gravity varying between 1 to 20: but most of them do have specific gravities varying between 2 to 7.

MISCELLANEOUS

Besides the above properties, minerals may show some specific and rare qualities that often become helpful in their identification. Some of these special properties are explained below:

Magnetism: - Some minerals have natural magnetism in them to an Appreciable Extent. Example is magnetite.

Electricity: - In some minerals heating may develop an electric charge. These are called pyro electric minerals. Examples quartz.

Fluorescence: - A few minerals have the property of glowing or emitting light When they are exposed to radiation. This property is called Fluorescence and mineral fluorite shows this Property.

Fusibility: - Minerals behave differently on heating to elevated temperature. Some Melt easily at lower temperatures whereas other require very high Temperature.

Physical properties of minerals

N A M E ➔ **PHYSICAL PROPERTIES**↓	**QUARTZ GROUP** (see below the table)	**FELDSPAR GROUP**		
		ORTHOCLASE	**MICROCLINE**	**PLAGIOCLASE**
FORM	Massive/granular	Tabular	Tabular/massive	Tabular/massive
COLOUR	Variable (see below)	Pink	White/greenish	White/grayish
STREAK	Colourless	Colourless	Colourless	Colourless
LUSTER	Vitreous	Vitreous	Vitreous	Vitreous
CLEAVAGE	Absent	Perfect	Perfect	Perfect
FRACTURE	Conchoidal to uneven	Uneven	Uneven	Uneven
HARDNESS	**7 (high)**	**6**	6-6.5	6
DIAPHENITY	Transparent to opaqaue	Translucent to opaque	Translucent to opaque	Translucent to opaque
SP GRAVITY	2.7 (low to medium)	2.6	2.6	2.6
COMPOSITION	SiO_2, Silicon oxide	$KAlSi_3O_8$	$KAlSi_3O_8$	$NaCaAlSio_2$
OCCURRENCE	Ig, sed. and Met. Rocks, **RFM**	Acid igneous rock, granite and pegmatite, **RFM**		
USES	**Glass making, abrasive, flux, electronic industry, radio circuits, refractories, ceramics sand papers**	Sanitary ware, Earthen ware, porcelain items, glazed tiles, flux enamel, binders		

Varieties of quartz group of minerals are as follows: (**RFM** – Rock Forming Minerals)

Crystalline variety

Cryptocrystalline variety Amorphous

1. **Rock crystal** – colourless, transparent, 1. **Agate** – different colours, opaque, 1. **Opal** - Hydrated
2. **Amythyst** – Purple/violet, translucent, semiprecious 2. **Jasper** – blood red, opaque SiO2, white
3. **Rose quartz** – pink, translucent 3. **Chert** – Green/black, opaque gray, opaque
4. **Milky quartz** – white, translucent, rock forming mineral 4. **Flint** – various shades of gray, opaque

5. **Green quartz** – Green, translucent white gray, opaque
6. **Smoky quartz** – black, translucent to opaque

5. **Chalcedony** –

Physical properties of minerals

NAME → **PHYSICAL** PROPERTIES ↓	**MICA GROUP**		**AMPHIBOLE GROUP**	**PYROXENE GROUP**	
	BIOTITE	MUSCOVITE	HORNBLENDE	AUGITE	GARNET
FORM	Flaky	Flaky	Crystal/tabular	Crystal/massive	Crystal
COLOUR	Black	Colourless	Green/brown	Black/greenish	Red, Brown
STREAK	White	White	White	White	Colourless
LUSTER	Vitreous	Vitreous	Vitreous	Vitreous	Vitreous
CLEAVAGE	Perfect	Perfect	Perfect	Good	Imperfect/none
FRACTURE	Uneven	Uneven	Uneven	Uneven	Uneven
HARDNESS	2-3	2-3	5.5-6	6	6-7.5
DIAPHENITY	Translucent	Transparent	Translucent-opaque	Opaque	Translucent-opaque
SP GRAVITY	2.5	2.5	3.0	3-4	3.5
COMPOSITION	KMgFeAlSi - OH	KAlSi - OH	Ca,Na,Mg,Fe,Al, Si – OH	CaMgFeAlSi – O	Mg,Fe,Ca,Al,Si-O
OCCURRENCE	Ig,Met rocks, **RFM**	Ig,Met rocks, **RFM**	Intrusive, Met. **RFM**	Ig, rocks, **RFM**	Met rock
USES	Electrical Insulator, furnace window,	Electrical Insulator, furnace window,			Gem stones, abrasives

Descriptive Mineralogy

N A M E ➔ **PHYSICAL** PROPERTIES ↓	OLIVINE	SERPENTINE	ASBESTOS	TALC	KAOLINE
FORM	Granular/massive	Massive/fibrous	Fibrous/massive	Massive	Earthy/granular
COLOUR	Olive green/black	Green/yellow	Greenish/white	Pale green/white	White/yellowish
STREAK	colourless	White	White	White	White
LUSTER	Vitreous	Greasy	Greasy/vitreous	Perly/vitreous	Dull
CLEAVAGE	Imperfect	None	None	None	None
FRACTURE	Uneven	Uneven	Uneven	Uneven	Uneven
HARDNESS	6-7	3	3	**1**	1
DIAPHENITY	Opaque	Opaque	Opaque	Opaque	Opaque
SP GRAVITY	3-4	2-3	2-3	2-3	2.5
COMPOSITION	MgFeSi – O	MgSi – OH	MgSi – OH	MgSi – OH	Al,Si-OH
OCCURRENCE	Basic Ig, rocks, **RFM**	ultrabasic Ig, rocks	ultrabasic Ig, rocks	ultrabasic Ig, rocks	Weathered product of Ig,Met
USES	Refractory, spark plug insulator, ornamental	Decorative, furnace repair	Refractory, heat and fire resistant, cement, acid resistant	Fillers, paper, cosmetics, furnace lining, toilet powder	Ceramic, paper industry, pottery, bricks, pesticide

Descriptive Mineralogy

NAME → PHYSICAL PROPERTIES ↓	OLIVINE	SERPENTINE	ASBESTOS	TALC	KAOLINE
FORM	Granular/massive	Massive/fibrous	Fibrous/massive	Massive	Earthy/granular
COLOUR	Olive green/black	Green/yellow	Greenish/white	Pale green/white	White/yellowish
STREAK	colourless	White	White	White	White
LUSTER	Vitreous	Greasy	Greasy/vitreous	Perly/vitreous	Dull
CLEAVAGE	Imperfect	None	None	None	None
FRACTURE	Uneven	Uneven	Uneven	Uneven	Uneven
HARDNESS	6-7	3	3	**1**	1
DIAPHENITY	Opaque	Opaque	Opaque	Opaque	Opaque
SP GRAVITY	3-4	2-3	2-3	2-3	2.5
COMPOSITION	MgFeSi – O	MgSi – OH	MgSi – OH	MgSi – OH	Al,Si-OH
OCCURRENCE	Basic Ig, rocks, **RFM**	ultrabasic Ig, rocks	ultrabasic Ig, rocks	ultrabasic Ig, rocks	Weathered product of Ig,Met
USES	Refractory, spark plug insulator, ornamental	Decorative, furnace repair	Refractory, heat and fire resistant, cement, acid resistant	Fillers, paper, cosmetics, furnace lining, toilet powder	Ceramic, paper industry, pottery, bricks, pesticide

NAME → **PHYSICAL** PROPERTIES ↓	**CARBONATES**			**SULPHATES**	
	CALCITE	DOLOMITE	MAGNESITE	GYPSUM	BARYTE
FORM	Crystal/rhomb	Crystal/massive	Massive	Crystal/fibrous	Crystal/tabular
COLOUR	Colourless/white	Black	white	White/yellowish	White/grey
STREAK	White	White	White	White	White
LUSTER	Vitreous	Vitreous	Dull	Vitreous	Vitreous/perly
CLEAVAGE	Perfect	Perfect	None	Perfect	Perfect
FRACTURE	Uneven	Uneven	Uneven	Uneven	Uneven
HARDNESS	**3**	3-4	3-4	1.5	3-3.5
DIAPHENITY	Transparent	Opaque	Opaque	Opaque	Opaque
SP GRAVITY	3	3	3	2.3	**4.5**
COMPOSITION	$CaCO_3$	$Ca,Mg (CO_3)_2$	$MgCO_3$	$CaSO_4 – 2H_2O$	$BaSO_4$
OCCURRENCE	Hydrothermal/weathering, **RFM**	Hydrothermal/ weathering	Hydrothermal/weathering,	Oxidation of sulphides	Hydrothermal/weathering,
USES	Optics, building material (reacts with dil.acid)	building material, cement	Refractory, building material	**Cement**, Metullargy	Metullary, x-ray exam,

Descriptive Mineralogy

Physical properties of minerals

N A M E ➔ PHYSICAL PROPERTIES ↓	GELENA	PYRITE	CHALCOPYRITE	PYROLULSITE	CHROMITE
FORM	Crystal/granular	Crystal/granular	Massive/granular	Granular/cryptocr	Granular/massive
COLOUR	Lead grey	Brass yellow	Yellow/darkyellow	Black	Black
STREAK	Black	Black	Black	Black	Brown
LUSTER	Metallic	Metallic	Metallic	Submetallic	Submetallic
CLEAVAGE	Perfect	Indistinct	Imperfect	none	none
FRACTURE	Uneven	Uneven	uneven	Uneven	Uneven
HARDNESS	2-3	6	3	5-6	5.5
DIAPHENITY	Opaque	Opaque	opaque	opaque	opaque
SP GRAVITY	**7.5**	5	4.3	5	4.5
COMPOSITION	PbS	FeS2	CuFeS2	MnO2	FeCr2O3
OCCURRENCE	Hydrothermal	Weathering/hydrothermal	Weathering/hydrothermal	hydrothermal	Weathering/hydrothermal
USES	Ore of lead	Ore of iron	Ore of Copper and Iron	Ore of manganese, battery cells	Ore of Chromium, refractory

Descriptive Mineralogy

NAME → **PHYSICAL** PROPERTIES ↓	HEMATITE	MAGNETITE	LIMONITE	BAUXITE	CORUNDUM
FORM	Massive/granular	Massive/granular	Earthy/massive	Massive/cryptocry	Crystal/tabular
COLOUR	Black	Black	Brown/yellowish	White/yellowish	Grey/blue/black
STREAK	Cherry red	Black	Reddish	White	None
LUSTER	Sub-metallic	Sub-metallic	Dull	Dull	Vitreous
CLEAVAGE	None	None	None	None	Indistinct
FRACTURE	Uneven	Uneven	Uneven	Uneven	Uneven
HARDNESS	5.5-6	5.5-6	4	3.5	**9**
DIAPHENITY	Opaque	Opaque	Opaque	Opaque	Opaque
SP GRAVITY	5	5	3	3	4
COMPOSITION	Fe_2O_3	Fe_3O_4	$Fe_2O_3.H_2O$	$Al_2O_3 – H_2O$	Al_2O_3
OCCURRENCE	Weathering hydrothermal	Magmatic, hydrothermal	Hydrothermal/weathering	Hydrothermal/weathering	Pegmatite, Met.rocks
USES	Iron ore, dye	Iron ore	Iron ore, dye, filler	Aluminium ore, refractory, paper making, dying, ceramics	Gem/abrasive

APPLIED ENGINEERING GEOLOGY

UNIT - 02

Content :

PETROLOGY

- **Introduction Petrology**
- **Igneous Rocks**
- **Sedimentary Rocks**
- **Metamorphic Rocks**

PETROLOGY

A rock is a naturally formed, consolidated material usually composed of grains of one or more minerals. Rocks provide a historical record of geological events. Most rocks at Earth's surface are silicates. Others, carbonates, are formed from minerals extracted from water.

Petrology is a branch of Geology deals with the study of rocks. It mainly deals with the mode of formation, mineral constituents, textures and structure.

Rocks are classified into

IGNEOUS: These are primary rocks formed by solidifying from a molten magma

METAMORPHIC: pre-existing rocks are altered due to pressure and/or temperature and fluid activity.

SEDIMENTARY: result when fragments of pre-existing rocks accumulate and are cemented together or by the precipitation of mineral crystals out of water solutions.

IGNEOUS ROCKS

Igneous rocks are those, which are formed by direct solidification of liquid rock or magma. They are thus called primary rocks. Magma is a got viscous silicate melt with gases occur in the deeper part of the Earth. This magma during its upward journey tries to penetrate to thin crust. During this process magma sometimes successful in coming out and some time they arrest themselves within the crust.

Lava: The magma which is successful in coming out on the Earth's surface, it is erupted out with a great force and spreads out on the surface of the Earth is called Lava.

Classification of Igneous rocks: They are classified on the basis of 'silica' content in the magma and 'mode' of occurrence.

1. Based on silica content:
   a) Acidic Igneous rocks: It is rich in silica content (>65% of SiO_2)
      Ex: Granite, Pegmatite
   b) Intermediate Igneous rocks: Silica percentage is 55-65%
      Ex: Syenite, Diorite
   c) Basic Igneous rocks: Silica content is 45-55%
      Ex: Dolerite, Gabbro
   d) Ultra-basic Igneous rocks: Silica content is <45%
      Ex: Dunite

2. Based on mode of origin:
   a) Plutonic rocks: These are deep seated rocks formed under slow cooling and great pressure conditions. They exhibit equigranular texture because the magma has cooled slowly under uniform pressure.
      Ex: Granite, Syenite, Diorite, Gabbro
   b) Hypabyssal rocks: They are formed by the solidification of magma nearer to the surface of the Earth's crust. They show porphyritic texture because of rapid cooling of magma.
      Ex: Pegmatite, Porphyry, Dolerite
   c) Volcanic rocks: These are formed on the surface of the crust by the consolidation of the lava. Here, the minerals cannot be distinguished with naked eye because of very small grain size and is due to rapid cooling and chilling.
      Ex: Basalt

Table showing classification of igneous rocks based on silica content and mode of origin.

BASED ON MODE OF ORIGIN ↓	ON THE BASIS OF SILICA CONTENT			
	ACIDIC >65% SiO_2	INTERMEDIATE 55-65% SiO_2	BASIC 45-65% SiO_2	ULTRABASIC <45% SiO_2
PLUTONIC	Granite	Syenite, Diorite	Gabbro	Dunite
HYPABYSSAL	Pegmatite	Porphyry	Porphyry	
VOLCANIC	Rhyolite	Trachite	Basalt	Olivine basalt

Forms of Igneous rocks / Primary structures: The igneous rock bodies are broadly classified into two groups

1. Extrusive bodies 2. Intrusive bodies

1. Extrusive bodies: Igneous rocks that cool and crystallize on the Earth's surface are called **extrusive igneous rocks**. Another name for extrusive igneous rocks is **volcanic** igneous rocks. Ex: Basalt
2. Intrusive bodies: Igneous rocks that cool and crystallize beneath the Earth's surface are called **intrusive igneous rocks**. Another name for intrusive igneous rocks is **plutonic** igneous rocks. Ex: Granite

Intrusive igneous rocks are further classified based on the relations with enclosing rocks into two types

a) Concordant and b) Discordant intrusive rocks

a) Concordant intrusive bodies: If the intrusion is parallel to the structure of the country rock, they are called 'Concordant intrusive bodies'.
Ex: Sill, Phacolith, Laccolith and Lopolith

i) Sill: It is a concordant intrusive sheet like body which runs parallel to the bedding planes of the enclosing sedimentary rock. They are typical of basic magma and varies in thickness from few centimeters to several kilometers.
ii) Phacolith: It is a concordant intrusive lens shaped form found in crests and troughs of folded rocks.
iii) Lopolith: It is a concordant intrusive bowl-like bodies, which are sagged downwards due to the weight of the intruded magma
iv) Laccolith: It is a concordant intrusive mushroom like bodies which have a convex upper surface and relatively flat lower surface.

Sill

Phacolith

Lopolith

Laccolith

b) Discordant intrusive bodies: If the intrusion is cut across the structure of pre-existing country rock, thy are called ‘Discordant intrusive bodies’

Ex: Batholith, Dyke, Volcanic Neck

i) Batholith: Batholiths are known to be largest kind of discordant intrusive bodies which are spread over very large area covering several kilometers. They increase in size with depth and they are thought to be bottomless. A Stock is a small batholith of irregular and cylinder form. A stock having a circular form is called a Boss.
ii) Dyke: Dykes are discordant igneous body of more or less tabular shape and exhibit a cross –cutting relationship with the country rocks they occur commonly n the forms of wall like masses of exactly or nearly vertical attitude. If the rocks constituting the dyke are hard and compact, they can resist weathering and Eros ional process.
iii) Volcanic neck: The vents of quiet volcanoes have become sealed with the igneous intrusions and is called volcanic necks/plugs. These forms may be circular, semicircular or irregular and in varying diameter.

Batholith

Dyke

Volcanic neck

Textures in igneous rocks: Texture is an important character for identification of igneous rocks. It is defined as the size, shape and arrangement of minerals and mutual relationship between individual mineral grains.

Based on the degree of crystallization, the textures are described as

Holocrystalline, Holohyaline and Mesocrystalline

Holocrystalline: The constituent minerals are crystallize slowly and visible to naked eye.
Holohyaline: The constituent minerals are non-crystalline and are fine grained/ glassy and not visible for naked eye.
Mesocrystalline: These are intermediate type where both crystalline and non-crystalline glassy material found in the same rock.

a) Coarse grained: Average grain size is >5 mm and can be identified naked eye
b) Medium grained: Average grain size is between 5 and 1 mm and magnifying lens is used to identify

c) Fine grained: Average grain size is <1 mm and identified only using petrological microscope.
Further, when viewed under microscope, the following terms are used
Euhedral: crystals having perfect outline or boundary
Subhedral: crystals having perfect outline or boundary

Types of textures:

1. Equigranular Texture: In this type, the mineral grains are all of approximately same size. This is because all the minerals are simultaneously get consolidated.
Ex: Granite
2. Inequigranular texture: In this type, the mineral grains show marked difference in their grain size. This is because different mineral grains consolidate at different level and hence different minerals exhibit different sizes.
Ex: Syenite
3. Porphyritic texture: It is a type of inequigranular texture, where tabular or large sized minerals called phenocrysts are fully embedded within the fine grained minerals known as matrix
Ex: Syenite Porphyry
4. Poiklitic texture: This is the converse of porphyritic texture, which is characterized by the presence of fine grained crystals within the body of large sized crystals.
Ex: Peridotite
5. Ophitic texture: This is similar to porphyritic texture, which shows the phenocrysts are partially embedded within the matrix. This is observed in dolerite rock whose lath shaped of mineral Augite enclosed within small Plagioclase mineral
Ex: Dolerite
6. Pegmatitic / intergrowth texture: Here, two or more minerals crystallize simultaneously in a limited space. Here one crystal intrudes another. An alternate bands of dark and light coloured minerals are seen (quartz and feldspar)
Ex: Pegmatite
7. Vesicular / Amygdaloidal texture: Most lavas are heavily charged with gas which escapes as soon as it comes in contact with Earth's atmosphere. The escape of these gases leads to the formation of different sizes / shapes of holes in the cooled volcanic rocks. The structure developed is called vesicular structure. Sometimes, these cavities are filled with secondary minerals like quartz or calcite and it is called amygdaloids.
Ex: Vesicular Basalt.

SEDIMENTARY ROCKS

Erosion: The pre-existing rocks are subjected to the process of weathering (mechanical or physical) leading to the formation of soluble and insoluble products. The disintegrated loose. material accumulated near the source is called 'Detritus' and the rocks are called 'Introduction:

Sedimentary rocks are those, which are formed by the accumulation, compaction and consolidation of sediments. The sediments are the particles produced from the disintegration of pre-existing rocks (Igneous/metamorphic rocks).

The formation of sediments involves the following processes.

- There must be pre-existing rocks
- These rocks must be weathered
- The product of weathering must be transported to the place of accumulation
- They must be dropped particle by particle giving rise to sediments.

Formation of sedimentary rocks: The process involved in the formation of sedimentary rocks are-

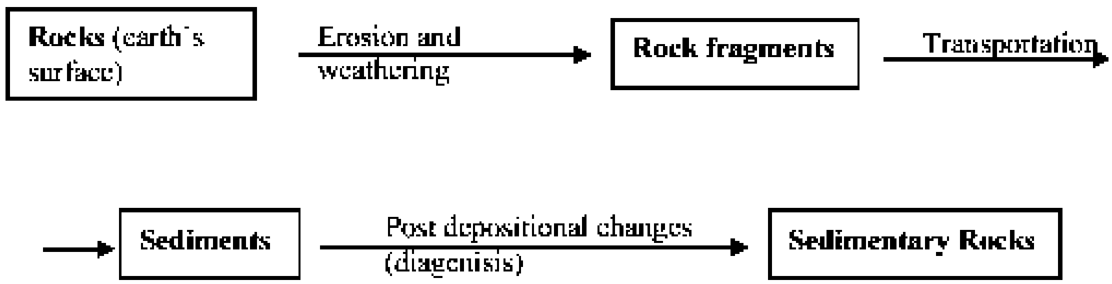
Detrital rocks'. This is disintegration of rocks or Erosion.

Transportation: Wind and the running water are the most important agents which transport the weathered product. During the course of transportation, the particle size becomes smaller and smooth because of abrasion.

Deposition: The sediments later deposited on the continents, sea shore or in the deep sea. Here, the compaction and consolidation of sediments takes place forming solid cohesive hard rock. The process of transformation of loose particles into hard rocks is called 'Diagenesis'.

The **diagenesis** is achieved by 'Welding or Cementation'

Welding: It is the process of compaction of sediment accumulation in lower layer of a basin due to the pressure exerted by the load of the overlying sediment layer.
Cementation: Here, the loose grains of sediments gets settled and held together by a binding material (FeO, CaO, SiO2 in solution)



Primary structures in sedimentary rocks

Primary structures are those which are formed at the time of deposition of sediments. Important primary structures are –

1. Stratification and Lamination
2. Graded bedding
3. Current bedding
4. Ripple marks
5. Mud cracks
6. Others – Tracks and trails, Rain prints

1. Stratification and Lamination: The sedimentary rocks are bedded in nature. A bed is called stratum and a number of beds are called Strata. A bed is a smallest rock unit generally homogeneous in composition, texture and colour. Each bed is bounded by a plane of separation both below and above. These are called Bedding planes. The different layers of beds may vary in grain size, mineral composition, colour, texture etc., depending upon the environment and formation. This feature is called stratification.

   Sometimes there will be thin layers within the bed. Such paper thin bed is called a Lamina and the feature is called Lamination. Laminae are quite common in white Sandstone and Shale.

2. Graded Bedding: In some beds at the bottom, there will be bigger particles and very fine particles at the top. There is a gradual decrease in the size of the particles from bottom to top. This phenomenon is called Graded bedding. Here individual layer is said to be graded with different particle size.
3. Current Bedding: Generally, the sedimentary beds are parallel to one another. Some times the beds are deposited slightly inclined to the major bedding plane because of change in the velocity and direction of flow of stream. This structure is known as Current Bedding.
4. Ripple Marks: This is a minor structure in sedimentary rocks formed due to mechanical origin. They are the undulations or wavy structure formed on the surface of loose sediments due to action of wind / wave in a shallow water body. It is also called wave marks. If the ripple marks are formed by stagnant water then

the feature will be symmetrical and if they are formed by moving water then they are asymmetrical.

5. Mud Cracks: These are common structural features of fine grained sedimentary rocks. The development of mud cracks is because of the drying of huge masses of fine grained sediments under sub-aerial condition. It is also called Sun cracks since they are formed due to the effect of solar heat.
6. Others: Some of the very minor structures observed in sedimentary rocks are 'Tracks and Trails, Rain Prints. The movement of organisms on the surface of loose sediments develops a marking or impression and is called 'tracks and trails'. On the other hand 'Rain prints' are formed on the top surface of loose sediments due to impact of 'drops' of rainwater.

The ripple marks, mud cracks, rain prints, tracks and trails are preserved in sedimentary rocks only under suitable conditions, i.e., these features are covered by another layer before the features are destroyed.

Classification of sedimentary rocks:

The classification of sedimentary rocks is based on the mineralogy, depositional environment, origin or mode of formation and structural features. However, for practical purpose, they are broadly classified into

1) Clastic and 2) Non-clastic rocks

1. Clastic rocks: They are mechanically formed rocks. These are formed due to the process of weathering, erosion, transportation and deposition and diagenesis of pre-existing rocks. Based on grain size, they are further classified into

   a) Rudaceous b) Arenaceous c) Argillaceous

   a) Rudaceous rocks: If the grain size of sediment / particle are more than 2 mm in dia, they are called 'Rudites' and the rocks are called Rudaceous rocks. They are further classified into

      Gravel (2-10 mm in dia)
      Pebbles (10-50 mm)
      Cobble (50-200 mm)
      Boulder (>200 mm)

      The grains may be rounded or angular / sharp which depends on the rate of transportation.

      Rounded – Example: Conglomerate
      Angular/sharp - Example: Breccia

   b) Arenaceous rocks: If the size of the particle is in between 1 and 2 mm, then such sedimentary rocks are called Arenaceous rocks. Here, the main constituent is sand (quartz and feldspar) and the cementing material is may be argillaceous, calcareous, ferruginous or siliceous material.

Example: Sandstone, Grit

c) Argillaceous rocks: If the size of the particle is < 1mm in dia, they are described as 'dust' and rocks are called Argillaceous rocks. Argillaceous rocks are formed by the accumulation and compaction of dust particles. If the particles are loose and dry, the deposits are called 'dust', if it compact and semi wet it is mud and if it is wet, it is described as clay.

Example: Shale, Mudstone

2. Non-clastic rocks: They are formed either by chemical processes or organic process. Accordingly, they are grouped into
   a) Chemically formed rocks
   b) Organically formed rocks

a) Chemically formed rocks; They are formed by precipitation, evaporation or crystallization from natural aqueous solution. They are further classified into
   i) Sileceous deposits – formed by precipitation of silica solution
      Ex: Flint, Chert, Jasper
   ii) Carbonate deposits - formed by precipitation of carbonate rich water
      Ex: Limestone, Dolomite, Magnesite
   iii) Ferrugeneous rocks- formed by precipitate of oxides and hydroxides of iron
      Ex: Bog iron ores
   iv) Phosphatic deposits- formed by sea water rich in phosphoric acid
      Ex: Phosphate compound
   v) Evapories – formed by evaporation of sea water (bays and esturies).
      Ex: Rock salt, Anhydrites, Gypsum, Borates

b) Organically formed rocks: Sedimentary rocks which are formed exclusively from remains of organisms (plant / animals).

Ex: Carbonaceous deposits – Coal and petroleum
Fossiliferous limestone

Stalactites and Stalagmites:

The underground water is charged with $CaCO_3$ in the limestone region. During its downward movement, it trickles drop by drop on the roof of the caves. If the drops are small they hang in the roofs itself and evaporate leaving a thin film of $CaCO_3$. this process continues and a hanging pillar / inverted cone like structure forms and they are called '**Stalactites**'.

If the drops are big, thy fall down on the floor of the caves and evaporates leaving a film of $CaCO_3$. This process continues and a pillar / cone like structure grows upward. This is called '**Stalagmites**'.

Kankar: In tropical and sub-tropical regions in India, where the rainy season is followed by a summer season, a peculiar deposit is formed just below the surface of the soil. The underground water is charged with CaCO3 raises up in hair like capillary tubes and it is deposited just below the surface of the soil in the form of ‘nodule’ and is called ‘Kankar’.

III- METAMORPHIC ROCKS

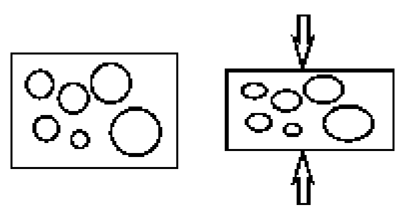
Introduction:

The word "**Metamorphism**" comes from the Greek: Meta = change, Morph = form, so metamorphism means to change form. Metamorphic rocks are those rocks that are formed as a result of transformation that takes place in the pre-existing rocks (Igneous/sedimentary rocks). When the pre-existing rocks are subjected to higher temperature, pressure and chemically active liquids and gases, the minerals present in the original rocks changes to new environmental condition. This adjustment processes continues until the minerals attain stability or equilibrium. By this, original minerals get recrystallized and the original structure and texture also changes. The process by which the metamorphic rocks are formed is known as metamorphism.

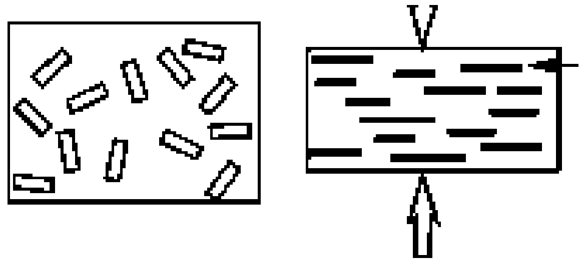
Agents or factors of metamorphism: Temperature, Pressure and Fluid are main agents responsible for metamorphism.

1. Temperature: It is responsible in bringing the recrystalllization or reconstitution of the original minerals into newer ones. Here, there is no addition or subtraction of minerals from the rocks. The metamorphic reaction takes place between temperature of 300-800°C and even more upto 1000°C.
2. Pressure: Pressure is one of the important dominant factors in metamorphic rocks and in majority of rocks it is associated with temperature. It is of two types.
   a) Load pressure – Here the pressure acts generally in a vertical direction due over burden resulting change in structure of the rocks.
   b) Direct pressure - Pressure is from different direction resulting change in volume (differential stress)

   Rounded grains (Ex.Quartz) become flattened in the direction of maximum stress.



   Flaky / elongated minerals (Mica) have preferred orientation in the direction of maximum stress



3. Fluids: Any existing open space between mineral grains in a rocks can potentially contain a fluid. The chemical solution, gases and vapours plays an important role in metamorphism which is normally associated with temperature and pressure. The chemically active fluids facilitates recrystallization of original minerals. Due to rise in pressure and temperature. Water is the most important chemically active fluid.

Metasomatism: Sometimes fluids present around the rock comes in contact with the minerals at high temperature producing many changes in composition, and structure. This process of rock/mineral alteration by the agency of solution is called metasomatism.

Kinds of metamorphism: Depending upon the factors responsible for metamorphism, different kinds of metamorphism are noticed and they are

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

1. Thermal metamorphism: Here, temperature is the dominant factor and pressure and fluid are the sub-ordinate factors. When the thermal metamorphismoccurs in the immediate contact of igneous intrusions, it is called contact metamorphism and when it occurs on a regional scale at depth it is called Plutonic metamorphism.

As a result of thermal metamorphism, recrystallization of original minerals takes place.

Ex: Limestone → Marble, Sandstone → Quartzite

2. Dynamic metamorphism: This type of metamorphism takes place in the rock by means of direct pressure / stress which is a dominant which leads to new structures. It is also called Cataclastic / kinetic metamorphism and the rock undergo mechanical breaking down and they may be crushed into smaller ones by pressure.

Ex. Shale → Slate

3. Dynamothermal metamorphism: It is a kind of metamorphism where temperature and pressure are the dominant factors which operates upon pre-existing rocks. The metamorphism may be regional / local scale and it is called Regional

metamorphism. Here, temperature promotes recrystallization as in the case of thermal metamorphism and the original mineral grains re-arrange into new minerals. Direct pressure / stress leads into the formation of new structures. Thus, the minerals developed under direct pressure are usually flat, tabular, flaky in nature.

Ex. Granite → Gneiss

Textures and Structures in metamorphic rocks

Textures in Metamorphic rocks: Texture is the mutual relationship of different mineralogical constituents in a rock. It is defined as the size, shape and arrangement of mineral grains and mutual relationship between individual mineral grains.

Texture in metamorphic rocks is based on two factors – a) shape of the minerals and b) mode of growth or arrangement of minerals.

Major minerals found in metamorphic rocks are

Quartz, Feldspar, garnet, pyroxene – shows granular and or elongated habit
Mica, hornblende, - shows flaky or lamellar habit

Textures in metamorphic rocks can be grouped into

1. Crystallobrastic texture: This refers to the grown of crystal during the process of metamorphism. If the crystal has irregular outline, it is referred as xenoblastic texture and if it has perfect crystal outline, then it is Idioblastic texture. Further, porphyroblastic and granoblastic texture also used which are similar to porphyritic and granulitic texture of igneous rocks.
2. Relict texture: It is a type of texture wherein the original texture of pre-existing rocks remains after the metamorphism.

Structure of metamorphic rocks: Structure of the rock is generally a field term which depends on the size, shape and orientation of the entire rock unit.

Following are some of the structures found in metamorphic rocks:

1. Granulose structure: It is formed in rocks as a result of the influence of Thermal metamorphism upon rocks. Here, the minerals are equi-dimensional and developed inter-locking arrangements. Granulose structure also called granulitic / granoblastic structure as a result of recrystallization of minerals due to influence of Temperature.
Ex. Sandstone → Quartzite, Limestone → Marble

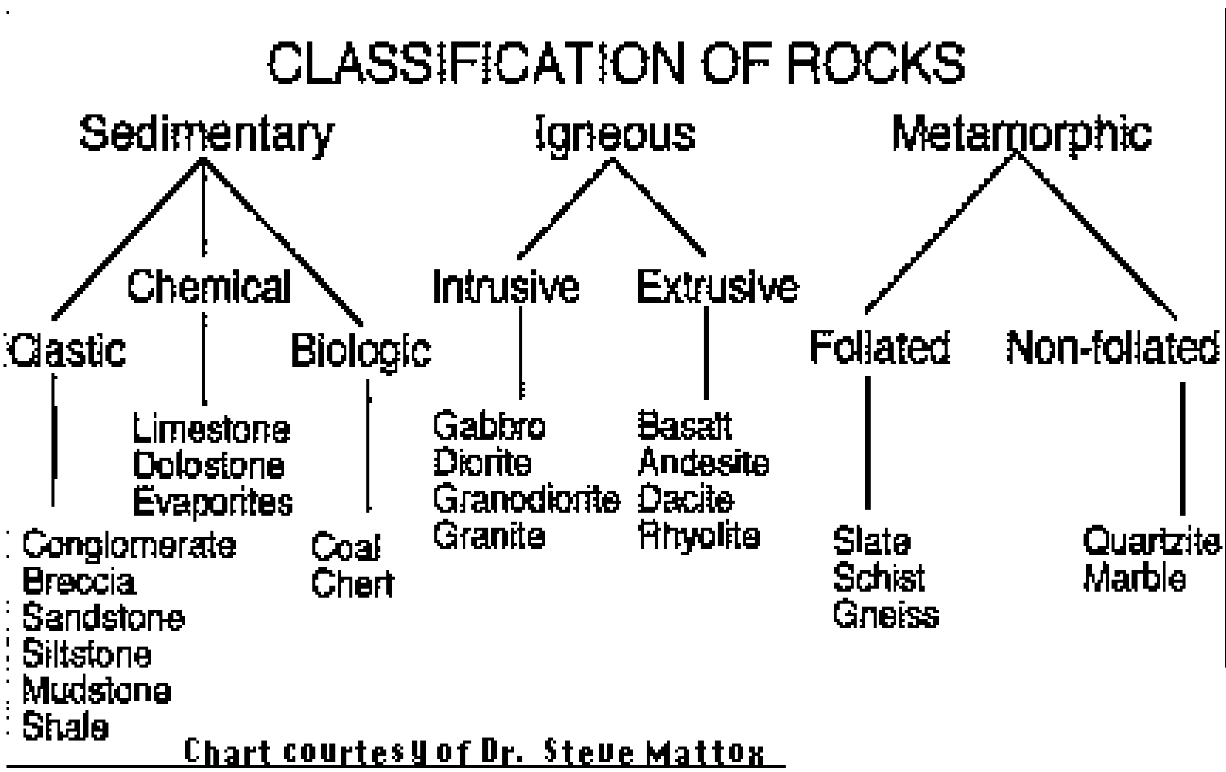
2. Schistone structure: Schistose structure is formed as a result of the Dynamo-thermal / regional metamorphism on rocks. Here, the minerals are flaky, needle shaped, lamellar,

and foliated in habit (Ex. Mica, hornblende, chlorite etc.). these minerals are elongated in a common direction. This elongation is due to direct pressure / stress
Ex. Mica schist, chlorite schist, hornblende schist

3. Gneissose structure: It is a composite structure in which both schistose and granulose structure are seen in the same rock. Here, both thermal and dynamo-thermal metamorphism predominates. Here flaky, foliated, lamellar minerals like mica, chlorite, hornblende develop schistose structure and rounded / granular minerals like quartz or feldspar develop granulose structure. It is also called gneissic structure.
Ex. Granite→ Gneiss

4. Maculose structure: This structure is formed due to effect of regional metamorphism, wherein growth of large sized crystals called porphyroblasts, within fine grained rocks. This is due to incomplete re-crystallization of minerals.
Ex. Hornfelse

Augen Gneiss: Sometimes, quartz and feldspar occurs as rounded minerals which are surrounded by mica, hornblende and the structure appears as an 'eye'. It is called Augen structure and the rock is called augen gneiss.



APPLIED ENGINEERING GEOLOGY

UNIT - 04

Content :

GEOMORPHOLOGY

- **Weathering and its types**
- **Soils**
- **Geological work of river**
- **Geological action of wind**

Weathering

It is a process that cause the breakdown of rocks, either to form new minerals that are stable on the surface of the Earth, or to break the rocks down into smaller particles. Weathering is the result of the interactions of air, water, and temperature on exposed rock surfaces and prepares the rock for erosion.

Erosion is the movement of the particles by ice, wind, or water. The particles are then transported by that agent until they are deposited to form sedimentary deposits, which can be later eroded again or transformed into sedimentary rocks. Weathering is generally a long, slow process that is continuously active at the earth's surface.

There are two kinds of weathering: mechanical and chemical.

Mechanical weathering: It is the process by which rocks are broken down into smaller pieces by external conditions.

Processes of Mechanical Weathering

A single block is broken gradually into numerous small irregular fragments and then into smaller fragments. Further it is classified into Block disintegration and Granular disintegration.

Block disintegration: - This is because of regular arrangement of atoms in a rock, due to this individual blocks are obtain.

Granular disintegration: - This is because of irregular arrangement of atoms in a rock, due to this small grains are obtain.

Thermal or heat effect: The effect of change of temperature on rocks is of considerable importance in arid and semiarid regions where difference between day- time and nighttime temperature is very high. Expansion on heating followed by contraction on cooling, repeated expansion and of the same rock body gradually breaks into smaller pieces due to stress developing by this process.

Frost action: It results due to freezing of water which are trapped in the cracks of the rocks widens and deepens the cracks, breaking off pieces and slabs.

Plant and Animal Activities: Plant roots can extend into fractures and grow, causing expansion of the fracture and eventually can break rock. Animals burrowing or moving through cracks can break rock. Plants can penetrates into the ground just a few meters whereas microorganisms can penetrate to a greater than of 10-25 mts.

Weathering Rinds - a rock may show an outer weathered zone and an inner unweathered zone in the initial stages of weathering. The outer zone is known as a weathering rind.

Exfoliation - Concentrated shells of weathering may form on the outside of a rock and may become separated from the rock. These thin shells of weathered rock are separated by stresses that result from changes in volume of the minerals that occur as a result of the formation of new minerals.

Spheroidal Weathering - If joints and fractures in rock beneath the surface form a 3-dimensional network, the rock will be broken into cube like pieces separated by the fractures. Water can penetrate more easily along these fractures, and each of the cube-like pieces will begin to weather inward. The rate of weathering will be greatest along the corners of each cube, followed by the edges, and finally the faces of the cubes. As a result the cube will weather into a spherical shape, with unweathered rock in the center and weathered rock toward the outside. Such progression of weathering is referred to as spheroidal weathering.

C**hemical weathering**: It is a process where chemical alteration or decomposition of rocks and minerals takes due to rain, water, and other atmospheric agents. Chemical weathering weakens the bonds in rocks and makes them more vulnerable to decomposition and erosion.

Processes of Chemical Weathering

The main agent responsible for chemical weathering reactions is water, oxygen and weak acids. These react with surface rocks to form new minerals that are stable in, or in equilibrium with, the physical and chemical conditions present at the earth's surface. Any excess ions left over from the chemical reactions are carried away in the acidic water. For example, feldspar minerals (which a silicate of potassium, sodium, calcium and aluminium) will weather to clay minerals, releasing silica, potassium, hydrogen, sodium, and calcium. These elements remain in solution and are commonly found in surface water and groundwater. Newly deposited sediments are often cemented by calcite or quartz that is precipitated between the sediment grains from calcium- and silica bearing water, respectively.

Water: Chemical weathering is most intense in areas that have abundant water. Different minerals weather at different rates that are climate dependent. Ferromagnesian minerals break down quickly, whereas quartz is very resistant to weathering.

Oxygen: Oxygen is present in air and water and is an important part of many chemical reactions. One of the more common and visible chemical weathering reactions is the combination of iron and oxygen to form iron oxide (rust).

Acids. Acids are chemical compounds that decompose in water to release hydrogen atoms. Hydrogen atoms frequently substitute for other elements in mineral structures, breaking them down to form new minerals that contain the hydrogen atoms. The most abundant natural acid is carbonic acid, a weak acid that consists of dissolved carbon dioxide in water. Other acids that can affect the formation of minerals in the nearsurface weathering environment are organic acids derived from plant and humus material.

Carbonic acid is produced in rainwater by reaction of the water with carbon dioxide (CO_2) gas in the atmosphere.

$H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

Carbonic acid Bicarbonate

H^+ is a small ion and can easily enter crystal structures, releasing other ions into the water.

Types of Chemical Weathering Reactions

Hydrolysis - H^+ or OH^- replaces an ion in the mineral. Example:

$KAlSi_3O_8 + 4H + 2H_2O \rightarrow 4K^+ + Al_4Si_4O_{10}(OH)_8 + 8SiO_2$

Orthoclase Clay Quartz

Leaching - ions are removed by dissolution into water. In the example above, K^+ ion was leached.

Oxidation - Since free oxygen (O_2) is more common near the Earth's surface, it may react with minerals to change the oxidation state of an ion. This is more common in Fe (iron) bearing minerals, since Fe can have several oxidation states, Fe, Fe^{+2}, Fe^{+3}. Deep in the Earth the most common oxidation state of Fe.

$3Fe_2SiO_3 + \frac{1}{2} O_2 \rightarrow Fe_3O_4 + 3SiO_2$

Pyroxene Magnetite Quartz

Dehydration - removal of H_2O or OH^- ion from a mineral.

$2FeOOH \rightarrow Fe_2O_3 + H_2O$

Goethite Hematite

Complete Dissolution - all of the mineral is completely dissolved by the water.

$CaCO_3 + H_2CO_3 \rightarrow Ca_2{}^{+} + 2(HCO_3)^{-}$

Calcite Carbonic acid Bicarbonate

REDUCTION: - The process results in the reduction of ferric iron and is brought about in the presence of special type of environment, especially in the zones where the soil is rich in decaying vegetation.

Rock	Primary Minerals	Residual Minerals*	Leached Ions
Granite	Feldspars	Clay Minerals	Na^{+}, K^{+}
	Micas	Clay Minerals	K^{+}
	Quartz	Quartz	---
	Fe-Mg Minerals	Clay Minerals + Hematite + Goethite	Mg^{+2}
Basalt	Feldspars	Clay Minerals	Na^{+}, Ca^{+2}
	Fe-Mg Minerals	Clay Minerals	Mg^{+2}
	Magnetite	Hematite, Goethite	---
Limestone	Calcite	None	Ca^{+2}, $CO_3{}^{-2}$

Soil

Soils are an important natural resource. They represent the interface between the lithosphere and the biosphere - as soils provide nutrients for plants. Soils consist of weathered rock plus organic material that comes from decaying plants and animals.

Engineers define soil as any unconsolidated material (clay through gravel size) that may be excavated without blasting. Soil contains mostly quartz and clay particles of varying sizes. The quartz sand grains help keep the soil porous, and the clay particles hold water and nutrients for plant growth.

Sand – composed of sand grains mostly without clay

Loam – Mixture of sand and clay

Clay – The finest material, mostly kaoline without sand

Importance of soils are:
1) natural resource (for agriculture, for construction material)
2) soil erosion

3) as a sediment source (via erosion)
4) as a water filter (for water infiltrating the ground)
5) as a contaminant sink
6) as a bearing material (for building on)

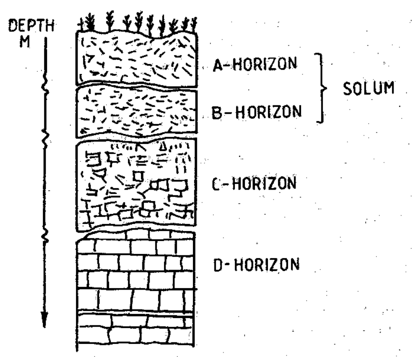
Soil Profile: When a soil develops on a rock, a soil profile develops as shown below. These different layers are not the same as beds formed by sedimentation, instead each of the horizons forms and grows in place by weathering and the addition of organic material from decaying plants and plant roots. Vertical sequence of A,B,C and D horizon is the soil profile which is as follows.

A-Horizon: Top soil, organic layer

B-Horizon: Rich in mineral matter, zone of accumulation of clays, colloids, iron and aluminium oxides. The horizon A and B is combined is called Solum which is a true soil zone.

C-Horizon: Weathered material

D-Horizon: Solid rock (fresh parent rock)



SOIL CLASSIFICATION

Soils are basically divided into two main groups:

Residual and

Transported soils

1). **Residual soils:** - A soil that is formed by weathering of the parent rock and still occupies the position of the formed, which it has been formed, is called a residual soil.

The important types of residual soils are,

1). Red Soils 2). Black Soils 3). Lateritic Soils

1). Red Soils: - These are residual soils derived mainly from the disintegration and decomposition of ancient granites and geneisses and contain coarse grains of quartz and mica and fines mainly kaolinite. Red Soils are generally heavily stained red with iron oxides grading into brown, yello gray and even black. These are fairly rich in potash, porous and contain no salts and free carbonate and moderately fertile. Red Soils occur extensively in peninsular India covering the states of Bihar, West Bengal, Orissa, Parts of Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu.

2). Black Soils: - These are residual soils mainly from the alteration of basalts. Black soils are typically highly clay. Black soils are fine grained, porous, sticky and swell when wet and contracts on drying with the development of a network of deep cracks. These highly fertile and excellent for cotton cultivation, hence called black cotton soil locally. In India black soils are derived from the alteration of Deccan Basalts and occur over a very wide are of over 200,000 sq miles in western and central parts covering the states of Gujarath, Maharashtra, parts of M.P , Orissa, A.P and Karnataka.

3. Laterites are highly leached, residual soils that form in tropical regions. The high temperature and rainfall result in deep and intense weathering. The laterite is typically bright red and composed of iron and aluminum oxides that are the most resistant to leaching. Valuable metals such as aluminum, copper, silver, gold, nickel, and iron are concentrated in laterites through secondary enrichment and can sometimes be mined economically. Secondary enrichment works in two ways: It can remove many of the other elements from the rock, which enriches the remaining valuable elements in place, or it can leach valuable elements such as copper and gold and deposit them at a particular level lower in the laterite.

2). Transported soil

Any soil that has been transported from place of origin by wind, water & glaciers and redeposit in another place. This type formation is known as transported soil.

Formational Processes: - The origin of transported soils involve three important process, they are Erosion, Transportation and Deposition.

Erosion: - The dynamic process by which the sub-aerial soil and rock materials are disintegrated by abrasion and shifted by wind, glaciers or rivers assisted by gravity.

Transportation: - The actual removal and conveyance of loose eroded rock materials called sediment in solution, suspension or by rolling on ground by wind, glaciers or rivers and streams.

Deposition: - Natural accumulation of rock materials, collected, conveyed and dropped by wind glaciers or rivers, and chemical precipitation or evaporation of dissolved materials when the transporting velocity of the agents drops below the minimum necessary to carry further. Wind and rivers are by far the most powerful and very effective natural transporting agents. These transport enormous quantities of materials to very long distances with sea as destination with many halts on the way against local obstacles like elevated land, foothill regions, shrubs and trees, rivers beds and large water bodies where some quantity of insoluble materials are dropped. These on accumulation from the transported soils of the area or region.

Soils are further classified according to the transporting agency and method of deposition,

Alluvial deposits: - Soils deposited from suspension in running water

Lacustrine soil: - Soils deposited from suspension in quiet fresh water lakes

Marine soils: - Soils deposited from suspension in seawater

Aeolian soil: - Soils transported by wind

Glacial soils: - Soils transported by Thick mass ice

SOIL EROSION AND ITS CONTROL: -

By soil erosion is meant the removal of soil particles by the natural agents o transport like wind, water and ice. Most serious threat, however, comes from water erosion, which may manifest itself in any of the two forms,

Sheet erosion

Gully erosion.

Sheet erosion: - Rainfall on an artificially prepared soil, especially on gently sloping fields, generally results in sheet erosion. In this process, many soil grains are pounded loose and made free to float away during the initial stages of rainfall. This process starts simultaneously over a large area so that after some time during the rain, a huge thick sheet of water flows down slope gaining acceleration and hence greater capability of further erosion of soil underneath.

Gully erosion: - This signifies formation and evolution of down slope valleys, often in multitudes, that develop on sloping soil covers with passage of time due to continued soil erosion. Gullying is, in fact consequence of sheet erosion. Uniform sheet erosion over any surface for longer periods is impossible even on perfect smooth surfaces because neither the flow velocities about the entire surface could be uniform not the surface could be absolutely perfect. Hence rater of erosion along different lines would be different creating conditions for excessive concentrated erosion along some lines. These lines of excessive erosion virtually into gulleys with the passage of time.

Prevention and Control

Methods adopted for prevention and control of soil erosion fall under two categories,

Agronomic practices

Engineering practice

Agronomic soil conservation method is adopted mainly to protect the top/surface soil which includes

Crop Rotation: - In which different crops are grown in the same area by rotation, which is one after another. A sequence commonly followed is, for example, a cultivated crop, s small grain and the grass. After this. Cultivated crop may again sow.

Strip cropping: - In which cultivated crops and the cover crops are sown in alternate strips during the same period in the same field. These strips are generally made parallel with the contours.

Engineering soil conservation method is adopted mainly to regulate and minimize the rate of run off water. They are

Excavation of ditches - These can be described as artificially created channels excavated at suitable locations to divert the excess of water from approaching the effected areas, especially in steeply sloping regions.

Two types of ditches commonly made for controlling soil erosion are

Diversion ditches: - Which are excavated above the cultivated portion of a sloping area with a view of diverting the run off away from the field.

Interception ditches: - Made at regular and suitable intervals across the cultivated field. By draining away volume of water from small strips, these ditches don't allow formation of thick sheets of water capable of doing great damage by away of sheet erosion.

Terraces: - Are constructed a long suitable location across the slope of hillsides with essential function of collecting and conducting the run-off to an erosion outlet.

Spacing of terrace requires careful consideration. First terrace is generally built near enough to the upper limit of the slope. This prevents the initiation of erosion; terraces should always be uniformly graded as to prevent pounding of water on the one hand and development of erosional velocities on the other hand.

Check Dams: - Small check dams constructed out of various materials like stones, timber and steel etc. have found especially useful I combating gulling. Such dams serve the purpose of reducing the velocity of run-off and cause deposition of the material, which may ultimately support vegetation. This may contribute positively for controlling gulling, especially when vegetation is re-established. Trees should comprise the bulk of such vegetation. This is so because their quickly spreading root system provides powerful grip to the affected soil particles.

GEOLOGICAL WORK OF RUNNING WATER

Water reaches the Earth's surface in the form of rainwater or snow can be divided into three parts.

a portion of precipitated water evaporates (Fly-off)

a portion percolates in soil/pore spaces of rocks (subsurface/underground water)

remaining portion neither percolates nor evaporates, flow along the slopes of the Earth's surface (Run-off)

Streams: Small surface bodies of water flowing in channels of their own are called streamlets/streams. Many streams join to form a single major channel called RIVER. Streams and rivers in a given region form the DRAINAGE SYSTEM.

River Profile: The tendency of any river is to flow towards the sea. The longitudinal section of a river-valley from a source to mouth is known as its longitudinal profile. The highland/mountainous region where the river actually originates is called the HEAD region. Later it flows through decreasing slopes and then through flat lands before it actually enters into the sea. The place where a river enters a sea is called its MOUTH.

The whole length of the course of any river is broadly divided into 3 major parts

UPPER part: It is the first part where river starts its journey and flows through hills and converging slopes of the valleys to reach the plains. This state is called Youth stage

MIDDLE part: Flow of running water in the plain regions. This stage is called Mature stage

LOWER part: Flow of running water near to its mouth where the land has practically no slope. This stage is called Old stage

The flowing river during its course ERODES the land cover, TRANSPORTS the rock debris and finally DEPOSITS the material under favourable conditions (ETD).

Thus the geological work of Running Water can be broadly divided into 6 processes and they are:

Hydraulic action

Abrasion

Attrition

Solution

Transportation

Deposition

First four processes belongs to EROSION.

Hydraulic action: Here breaking down and removal of rock masses due to continuous impact of water moving with some velocity in the Upper part of the course of river. In general, the greater the velocity of the water and the steeper the grade, the greater the hydraulic action capabilities of the stream.

Abrasion: The rock debris formed by hydraulic action naturally rub themselves against the valley floor and bring about mechanical wear and tear of base rock. The mechanical breaking down of bed rock due to impact of flowing rock debris is called abrasion.

Attrition: It is the mechanical wear and tear of rolling or transported materials (boulders/pebbles) into the smaller fragments due to mutual impact and collision.

Solution: Rocks susceptible to the chemical weathering process of solution can be dissolved by the slightly acidic water of a stream. Limestones and sedimentary rock cemented with calcite are vulnerable to solution.

Hydraulic action, abrasion, attrition and solution pertains to Erosional process. Following are some of the features of River Erosion.

Pot holes: These are bowl like cylindrical depression with the dimension of few inches to several feet formed due to ABRASION of softer rocks. Initially small depression forms and later the pebbles and gravels are caught in Eddis and thrown into a swirling / churning motion and causing deepening and widening of the holes.

Gorges and Canyons: A valley is a low land surrounded on sides by inclined hill slopes and mountains. Valley deepening occurs due to cutting down of river bed which depends on the velocity of streams

GORGES are due to valley deepening and they are very deep and narrow valleys with very steep and high walls on either side.

CANYONS are a specific type of gorge where the layers cutdown by a river are essentially stratified and horizontal in altitudes.

Waterfalls: -A step descent of a river at a particular point in its course, especially in mountainous regions is called a waterfall. Water falls range in size from a small descent or jump called a rapid to a succession of rapids over a steep gradient called cascades to shear deep majestic vertical falls of hundreds of meters.

Escarpments: This feature is found in regions of alternate beds of hard and soft rocks. The softer rocks erodes quickly and hard rocks resist and projects as ledges. Escarpment is the steep slope caused by falling of undercut ledge of hard rocks. CUESTA is the term used for escarpment and Dip slope.

Hogback: It is a feature due to erosion process where carved surface develops on hard rodks.

Mesa and Butte: These features are found in alternate layers of soft and hard rocks which are almost horizontal. MESA is an erosional feature of cap like structure (large size) in the hard rocks. The small sized Mesa which are isolated are called BUTTE.

Transportation: A river is a most powerful agent of transportation and transport all the product of erosion.

Load: The product of erosion ranging from boulders and pebbles to fine sand, silt, clay and also solution. The total quantity of rock particle transported by a stream, in saltation, suspension and soluble constitutes Load.

Running water transports its Load due to kinetic energy. As soon as the velocity decreases, its transportation capacity reduces and hence parts of the load drops. The larger fragments drops immediately and smaller/lighter transported far away and deposit. This is SORTING of sediments

The suspended load is the fine-grained sediment that remains in the water during transportation. The heavier, coarser-grained earth material that travels along the bottom of the stream is the bed load. Earth material that has been dissolved into ions and carried in solution is the dissolved load.

6. **Deposition**: A stream's sediment load is typically deposited, eroded, and redeposited many times in a stream channel, especially during climatic variations such as flooding. Sediments are deposited throughout the length of the stream as bars or floodplain deposits.

Bars. It form in the middle of the channel or along the banks of a stream at points where the velocity decreases, resulting in the deposition of some of the sediment load. Bars are ridges generally made up of gravel- or sand-sized particles. A subsequent flood event will erode bars, transport the sediments, and redeposit the material as a new bar farther downstream.

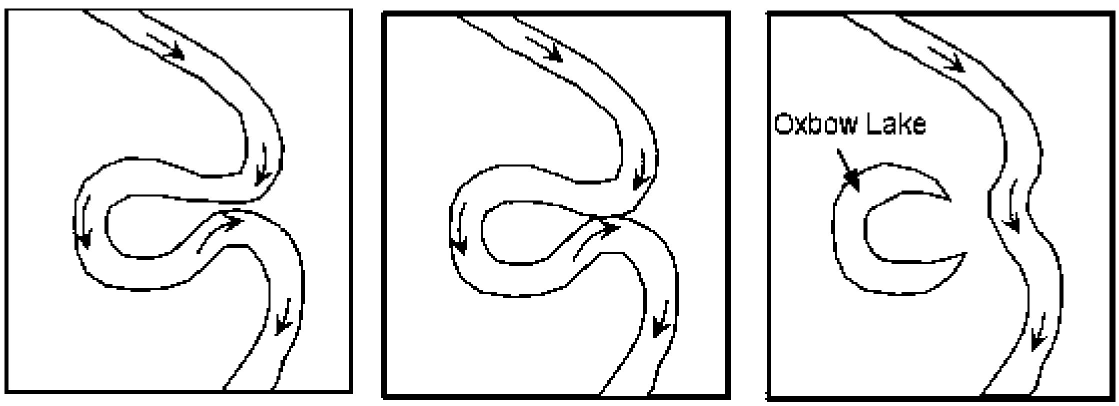
Alluvial Fans - When a steep mountain stream enters a flat valley, there is a sudden decrease in gradient and velocity. Sediment transported in the stream will suddenly become deposited along the valley walls in an alluvial fan. As the velocity of the mountain stream slows it becomes choked with sediment and breaks up into numerous distributary channels.

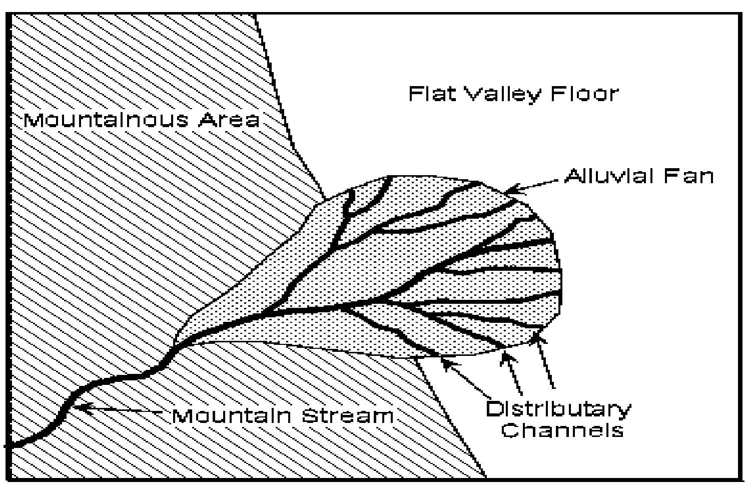
Deltas - When a stream enters a standing body of water such as a lake or ocean, there is a sudden decrease in velocity and the stream deposits its sediment in a deposit called a delta. As the velocity of a stream decreases on entering the delta, the stream becomes choked with sediment and conditions become favorable to those of a braided stream channel, but instead of braiding, the stream breaks into many smaller streams called distributary streams.

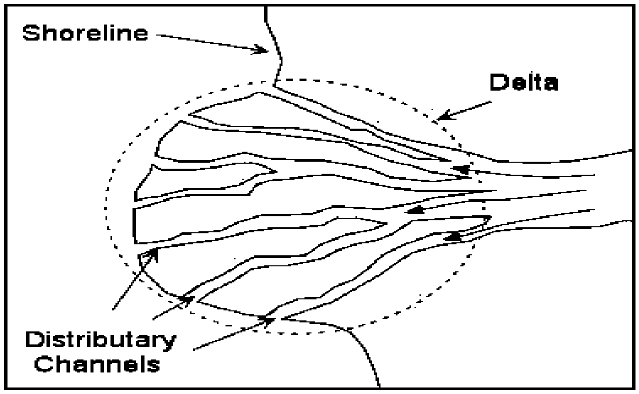
Meanders and oxbow lakes: When a river is sluggishly flowing in the plains, it has very little energy to remove the obstructions. Its course gets deviated / deflected due to slight irregularities. As a result, the river develops prominent beds which may further swell into big loop. This process will transform a gentle curve into a hairpinlike feature called meander and the phenomenon is called Meandering.

Erosion will take place on the outer parts of the meander bends where the velocity of the stream is highest. Sediment deposition will occur along the inner meander bends where the velocity is low. Such deposition of sediment results in exposed bars, called point bars.

Oxbow lake: Meanders continuously change location as they swing back and forth across a valley or migrate downstream over time. If erosion on the outside meander bends continues to take place, eventually a meander bend can become cut off from the rest of the stream. When this occurs, the cutoff meander bend, because it is still a depression, will collect water and form a type of lake called an oxbow lake.







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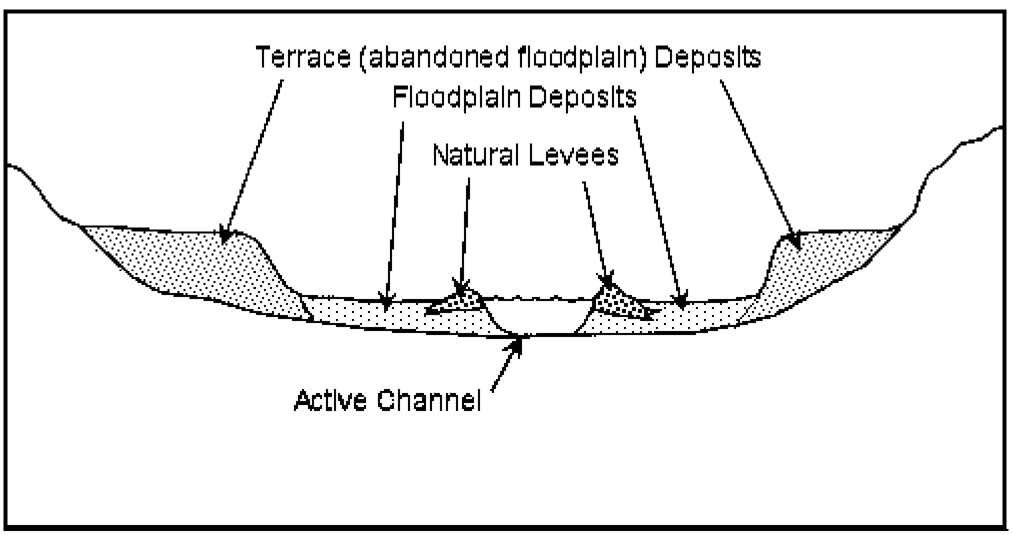
Stream terraces. Stream terraces are steplike benches that occur above the stream bed and floodplain. They are cut into bedrock or are remnants of older river sediments that have since been eroded. Terraces form in response to flooding or changes in base level.



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APPLIED ENGINEERING GEOLOGY

UNIT - 04

Content :

GEODYNAMICS

- **Earthquakes**
- **Costal Land forms**
- **Tsunamis**
- **Landslides**

<u>EARTHQUAKE</u>

An earthquake is a sudden and rapid shaking of the ground due to passage of vibrations beneath caused by transient disturbance of elastic or gravitational equilibrium of rocks.

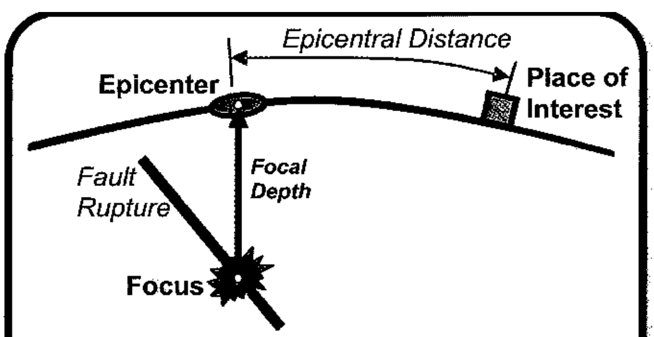


Figure 1: Basic terminology

An earthquake is the vibration of the earth produced by the rapid release of energy. Although earthquake occurs occasionally, but destruction they cause through loss of life and property. The exact spot underneath the earth surface at which an earthquake originates is known as its **FOCUS**, while the point on the earth surface lying above the focus is defined as the **EPICENTRE**.

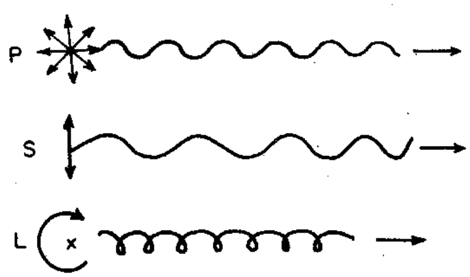
Depth of Focus:- Earthquake focus is described

Shallow: - When it is less than 70km below ground surface

Intermediate: - Between 70 and 300 km and

Deep: - below 300 to 700km most earthquakes originate within the upper 250km and none below 700km below the ground surface.

EARTHQUAKE WAVES: - The strain energy released by an earthquake sets up several types of pulses (wave motion) at the focus. These called seismic or earthquake waves travel in all directions in different paths, modes and speeds proportional to the densities of the materials through which they travel. The speed increases with density.



When the waves reach the ground surface they spread out in ever widening circles around the epicenter like water waves from a point of impact in a pond and cause that span of the ground to shake.

P-waves (primary or push and pull waves): - These are high frequency short wavelength longitudinal compressive type, like sound waves. These take the quickest path and are transmitted by oscillations in the direction of propagation. P-waves travel through solids, semi-solids and liquids, i.e the crust the mantle and the core of the earth at speeds 5 to 15km/s

S-waves (Secondary or shake waves): -These are high frequency short wave-length transverse eaves like polarized light transmitted by oscillations perpendicular to the direction of propagation. These also take the quickest path but travel through solids and semisolids, only, i.e the crust and the mantle and are deflected at the core, S-waves travel at speeds 3 to 8km/s.

L-waves (Long or surface waves): - These are low frequency long wavelength waves produced by reflections and refractions of P and S waves in the immediate neighborhood of the epicenter. These travel with a rotary movement in the vertical plane, like sea waves and are transmitted along the periphery of the earth at speeds 3 to 5km/s.

EARTHQUAKE MOTION

Earthquake motion consists of two components- a vertical and a horizontal. The seismic vibrations. Earthquake waves arise vertically from the focus below and cause oscillations of the ground, at the epicenter. As the vibrations advance the horizontal component increases in proportion to the vertical.

EARTHQUAKE MAGNITUDE AND INTENSITY

Magnitude: - Magnitude of an earthquake is an instrumental rating of the energy (the size or strength of the quake) released by it. Magnitude varies with the wave amplitude of an earthquake recorded by a seismograph. By knowing the distance from a seismograph station to the epicenter and the maximum amplitude recorded, an empirical quantitative rating is estimated.

The intensity of an earthquake is a numerical index describing the degree of ground shaking and effects on life and property at any given locality. Intensity is essentially a function of an earthquake and local geological conditions. Intensity is severe at and around the epicenter area and decreases away from it.

Intensity number	*Designation of shock*	*Effects*	*Magnitude (Approx.)*
I	Instrumental	detected by instruments only	—
II	Feeble	felt by observers and by a few people at rest	2
III	Slight	generally felt by many	—
IV	Moderate	felt by all Utensils, glassware clink and clash window shutters rattle	3.5
V	Fairly strong	buildings tremble,, parked vehicles rock, wall clocks stop	3.5 – 4.3
VI,	Strong	sleeping people awakened,, disturbance of furniture	4.3 – 4.9
VII	Very strong	violent disturbance of furniture, walls crack, hanging objects swing,, church bells ring	4.9 – 5.5
VIII	Destructive	moving objects, vehicles, trains over thrown, rails twisted,, monuments,, chimneys,, towers sway crack and fall down,	5.5 – 6.5
IX	Ruinous	heavy damage to buildings, begin to collapse reservoirs sway	6.2 – 7.0
X	Disastrous	Buildings razed to ground, life lines destroyed	7 – 7.3
XI	Very Disastrous	only a few structures left,, dams affected breeched or overthrown,, ground cracked,	7.4 – 8.1
XII	Catastrophic	complete destruction, ground badly twisted	8.1

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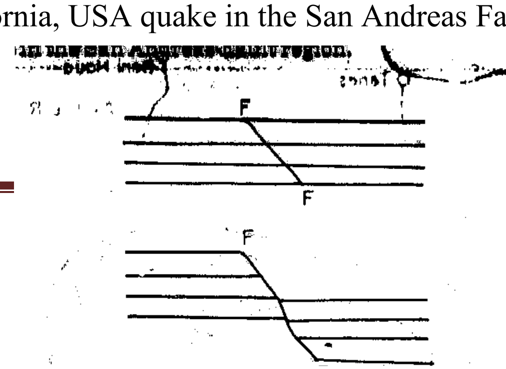
c). Tectonic EQ: - These are the most common, powerful, highly destructive and responsible for loss of life and property in inhabited areas. The origin or causes of tectonic quakes is explained by the following theories.

(i). Elastic rebound theory: -This theory propounded by A C Lawson 1906, and modified by professor H F Reid 1908 is based on the detailed field study of the great 1906 San Francisco, California, USA quake in the San Andreas Fault region.



According to this theory when segments of rocks at depths of a few kilometers below the ground surface, strained beyond the limits of their elastic deformation yield suddenly by faulting and snap back to unstrained positions much like a broken spring called elastic rebound with the release of enormous strain energy. This produces powerful vibrations that spread out form the local area in all directions inducing ground shaking until they reach relatively unstrained area.

(ii). Plate Tectonic Theory: -According to this theory the earth's crust is broken into a dozen or more large rigid blocks down to a depth of about 100km called crustal plates. These carry Land, Sea or both and are in constant motion on the viscous mantle overriding, one plunging beneath the other colliding with each other or brushing one past another. Some segments of a adjacent plate, however, remain immobile and locked together for years only to break free in, great lurches(faulting) and produce seismic vibrations long plate boundaries, with deafening noise and everything around, ground hills, riverbed, building, roads and living being and their belonging are destroyed.

DISTRIBUTION OF EARTHQUAKE: - It is estimated that over 150000 quakes occur round the world every year. Several of them are terribly destructive involving heavy tolls and property damages.

World distribution

1). The Circum Pacific Seismic Belt,
2). The Mid Atlantic Seismic Belt,
3). The alpine-Himalayan trans Asiatic Seismic Belt

Indian distribution

1). Kutch Gujarath 1819
2). Assam, 1897
3). Bihar1934
4). Anjar-Gujarath,
5). Peninsular India (South India)

Indian continent is divided into (based on earthquakes)

Zone of Maximum Intensity: - Which comprises the Northeastern regions, especially the folded chains of Himalayas, geographically this area covers Assam, Himachal Pradesh, Kashmir, U.P, Nagaland.

Zone of Intermediate Intensity:- Which covers the regions of indo-Gangetic basin. This zone of moderate Intensity comprises the remaining areas of Punjab, West Bengal and Bihar.

<u>Zone of Minimum Intensity</u>:- No land mass is free from earthquake, all the regions are highly affected by this activity.

EARTHQUAKE HAZARDS

The energy released by an earthquake travel along the earth's surface, it causes the ground to vibrate in a complex manner by moving up and down as well as from side to side. The amount of structural damage attributable to the vibrations depends on several factors including

The intensity and duration of the vibration

The nature of the material upon which the structure arrest

The design of the structure

Earthquake effects are remarkable and directly proportional to the intensity of the tremblers and geologic setting of the affected area. Earthquake effects comprise of changes super induced upon land and sea levels, topography and surface and groundwater regimes as a result of readjustments of certain, components of the crust in order to restore equilibrium. The hazards are due to two important seismic events are Ground shaking and Tsunami generation.

Violent ground shaking induces topographic changes and ground failure by landslides, fissuring surface faulting and soil liquefaction. Ground shaking is maximum in epicenter regions. Generally topography of the affected areas is transformed partly or totally. Hill ranges rise or fall or rented. The ground is thrown into terraces or wave like a choppy sea and extensional cracks.

FIRE HAZARDS

The loss of life and property that accompany great quakes often is mainly due to secondary cause especially fire. If a quake strikes a modern town or city today it may cause uncontrollable fire due to electric short circuit severance of gas and water mains and flooding with attendant serious damages.

STRANGE BEHAVIOR OF ANIMALS

There are reports of fauciful behavior of animals sometimes before and during an earthquake. Tigers and chimpanzees scream. Domestic animals horses and cows become restless and run abut madly stampeding or seek highlands. Dogs and cats howl and huge closer to people. Rats disappear, pigs rush out in swarms. Rabbits try to climb walls and fences. Zoo animals refuse to get into their cages and shelters.

EARTHQUAKE SOUNDS

Earthquake records frequently refer to strange sounds that accompany ground shaking. It is reported that earthquake sounds are due to the shaking ground beating upon the air above like the membrane of a drum. The near vertical incident of P-waves is supposed to be responsible for the sounds with the ground behaving like an enormous loud speaker driven by them. It is observed that earthquakes occurring in areas of crystalline rocks like granite or gneiss produce strong high frequency sounds and those in thick sedimentary terrines produce softer low frequency sounds

TYPES OF EARTHQUAKE PROOF STRUCTURES

Quake proof models: - TO bear the strain due to earthquake shocks and prevent or minimize damages and death two opposite methods of anti-earthquake construction in earthquake regions are recommended, they are Light and elastic constructions and Heavy and rigid constructions

Light and elastic constructions: - In India and elsewhere in earthquake countries most people in countryside live in non engineered mud huts or timber structures. The mud habitats usually are constructed with mud walls and sloping thatched roof, in some cases bamboo walls with plaster or crude brick or rubble masonry. These fail in earthquakes with disastrous effects. Mud structures are very popular in India, especially in Kashmir, Kutch, Maharashtra, Bihar and Assam regions.

Timber frame structures and Brick Masonry

Heavy and rigid constructions: - These are well built structures of brick and stone masonry, RCC frames with filler brick walls, and single or multistoried buildings. The main object of these is to construct stronger than ordinary building in order to prevent their collapse and loss of life and property, especially those of large selling's, schools, office building, hospitals, business complexes community halls etc. Where commonly good number of people assembles at a time and also certain vital or critical installations like powerhouses nuclear facilities.

<u>Safety measures to be adopted for buildings to be construction in seismic areas</u>.

As stated earlier, an earthquake resultant building must be strong and sturdy. Hence, besides incorporating these additional safety factors in the design of such buildings the following other points must be given due attention to

1. Good quality materials, strictly according to the specifications, should be used.
2. The foundation should not be on soft ground and rather it should preferably be on the solid rocks. The depth of foundation should also be uniform.

3. The walls should be continuous in nature. The long walls and cross wall be erected simultaneously without any joints.
4. Doors ad windows should be minimised.
5. Height of the building should be kept uniform.
6. All parts of the buildings, particularly its edges and corners should be well tied, so that it moves as a single unit during an earthquake vibration.
7. Construction of cantilevers, Chimneys, Arches and other extra projections should be avoided.

EARTHQUAKE AND CIVIL ENGINEERING

An earthquake is a vibratory motion having components in all directions. The vertical components are more dominant near the epicentral tracts and the horizontal components away from these tracts. Hence strong structures have to withstand bigger forces near the epicenter and soft and flexible structures are safer, away from the epicenter flexi bile structure suffer severe damage while hard structures as safer. Extensive research has been carried out in the last 50 years to develop new methods to minimize losses.

Buildings: - Steel – framed tall buildings in which the frame supports all wall and floor loads usually behave well during earthquake. Reinforced concrete buildings may develop cracks in walls and piers houses with roofs; wall and foundations tied into one strong unit behave safely during earthquake. Houses built with wood and flexible materials of construction absorb earthquake shocks. In our country modern methods are increasingly being adopted and reinforced brick buildings are built against earthquake forces. This method increases the construction cost 2-5%, but simultaneously saves buildings and lives. Even more recently by a new direction in research ahs developed insulators for absorbing energy transmitted by ground motion to reduce damage to structure. Some of these methods are useful for rigid structures.

Foundations: - The amount of damage caused by ground shaking depends on the type of foundation below the building or structure. These are built in low-strength roc materials such as sand and silt tend to absorb much of the shaking motion, hence buildings have not been designed to cope with strong shaking but rather to accommodate large foundation movements. Such buildings have to provide competent footings, adequate drainage and flexible power, water and sewage connections.

Unconsolidated sandstone may saturate as a result of earthquake vibrations, sometimes the entire structure is destroyed.

Slopes and embankments: -Settlement of embankments can be minimized by careful compaction control during construction but even then settlement can occur. Landslides due to earthquakes have resulted in loss of loves and property. So embankment has to be designed with extra care. Highways and railway cuttings and avoidance of steep slopes for residential development re necessary in high seismic areas.

Dams: -Rock fill dams usually stand up well to earthquake shocks. A river valley project may consist of a dam or barrage, tunnel, powerhouses, buildings and bridges of various types, which may fail during strong earthquake.

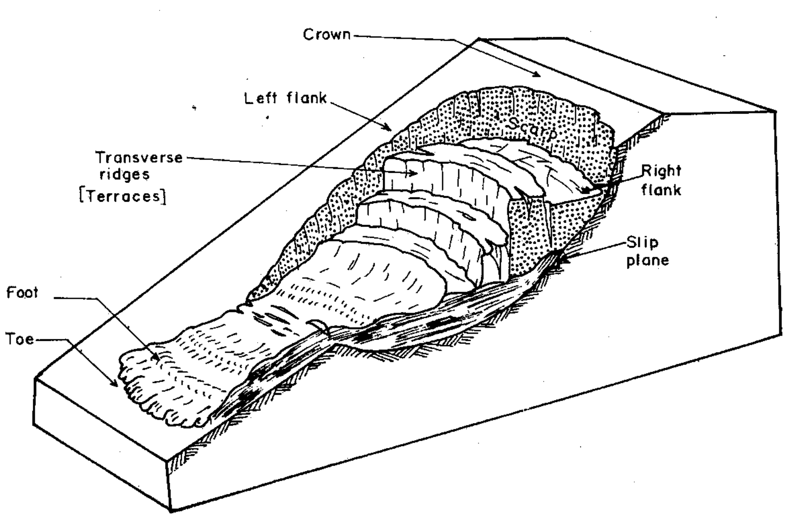
Tunnels: - Tunnels, which intersect at geological fault, are often seriously affected by earthquake movement. Special tunnel deigns are necessary in seismically active zones. Generally rupture of the lining may cause flooding of partial dislocations. Earth tunnels are less affected by earthquake movements but the chances of liquefaction of the surrounding materials are real.

LANDSLIDE

A landslide is a slow or sudden downhill movement of slope forming rock and soil material under the force of gravity. Landslides or sloope failures are natural Erosional process. They occur in hillsides valley slopes, seacoasts, riverbanks and bends, on the slopes of volcanic cones and in earthquake prone areas. They also occur underneath as on lake or sea floor. Man in his urban and regional development activities also trigger landslides. Such as excavations, fills quarries, cuttings of roads, railway and canals etc. Landslides as natural erosional process not only modify the existing topography and landscape, they also cause immense damages to manmade structures and heavy loss of life.

PARTS OF TYPICAL SLIDE

A typical slide exhibits the following parts or regions



CROWN: - The upper portion still in place from which solid rock and soil materials are torn away from the rest of the slope.

SCARP: - The steep wall of the undisturbed material below crown around the periphery of the slide material

HEAD: - The upper part f the slide material

SLIP PLANE: - The shear surface – the surface of movement down hill of the slide material

FLANKS: - Sides of a slide, left flank and Right Flank

TRANSVERSE RIDGES: - Terrace or step like pressure or compression ridges

FOOT: - The line of intersection of the lower part of the slip plane and the original ground surface

TOE: - The lower portion in which the rock or soil material is heaped up

LENGTH: - Horizontal distance from crown to toe.

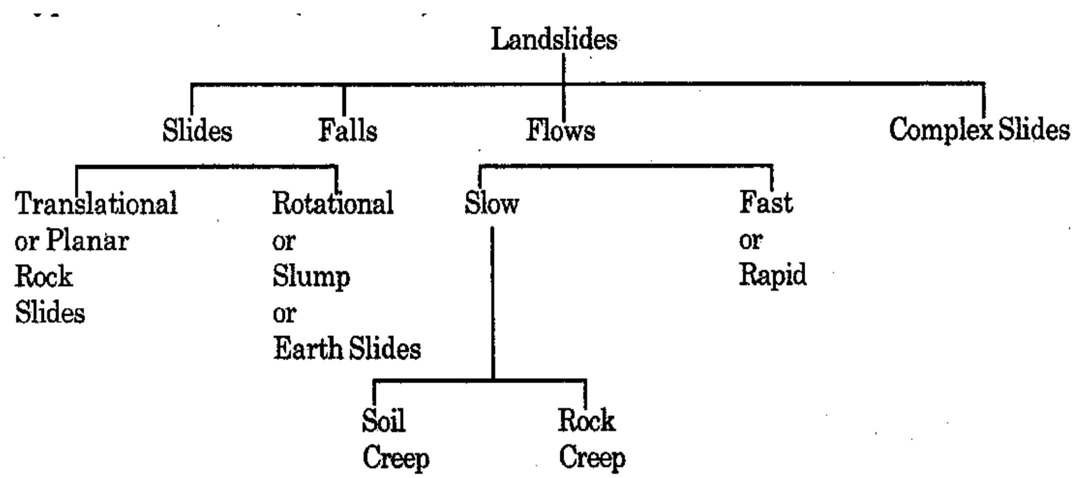
WIDTH: - Horizontal distance form flank to flank

HEIGHT: - Vertical distance, crown to toe

DEPTH: - Thickness of the slide mass between crown and foot.

CLASSIFICATION AND TYPES OF LANDSLIDES

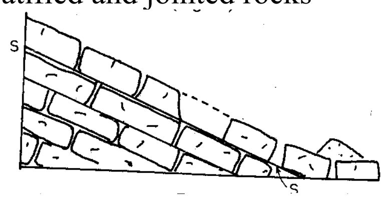
Landslides are of many types and are broadly classified according to their characteristic parameters
-Presence or absence of a definite slip plane
-Materials involved and their water content
-Kind and rater of movement.



SLIDES: - Sudden downhill movements of rock and or unconsolidated rock material on a definite identifiable water lubricated or not down slope inclined plane called a shear or slip plane between the separating and remaining masses. The slip plane may be a bedding plane, joint plane, fault plane, and schistose or cleavage plane.

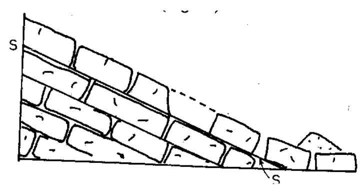
Slide movement: Slide movements are of two kinds according to the nature of the slip plane.

Translational Movement: - In which the slip plane in relatively a plane surface characteristic of stratified and jointed rocks



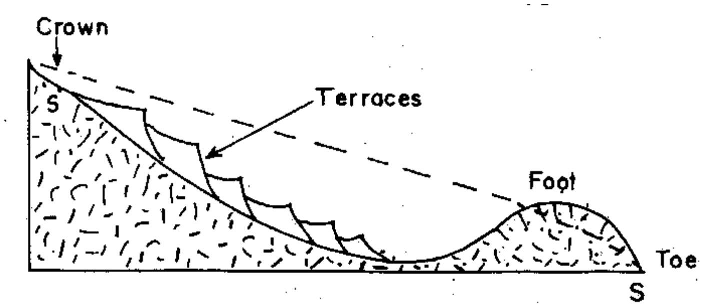
Rotational lip plane in is spoon shaped, concave upwards, character materials

Rock Slide These are typical translational slides common in slopes with stratified and jointed rocks and involve sudden or rapid movement of un deformed strata or blocks of rocks separated along joints or down slope dipping bedding planes at critical angles where the gradient of the slope is steeper than the dip of the beds. One or several of the water lubricated bedding planes form potential slip planes. The beds hold only so long as there is cohesion between them. When the dip approaches at the angle of limiting friction, the whole sequence of top strata above the slip plane slides down.



SLUMP: - These are typical rotational slides common in unconsolidated materials especially mud and clay. These occur when the foot or toe of a slope is cut away either by natural erosion or by human activity. These are also called slip outs.

The slip plane is highly spoon shaped curved upward. The failed mass characteristically gets slumped at the toe area of the original slope, when a slope suffers multiple slides a terrace like features results.



FALLS (Rock Falls): - Sudden and very rapid free fall leaping, rolling and or bouncing of detached blocks and boulders of rocks along joints and bedding planes of barren outcrops and solid bed rock materials in very steep slopes especially cliffs, overhanging cliffs and in steep hillsides, road and railway cuts following the laws of free falling bodies

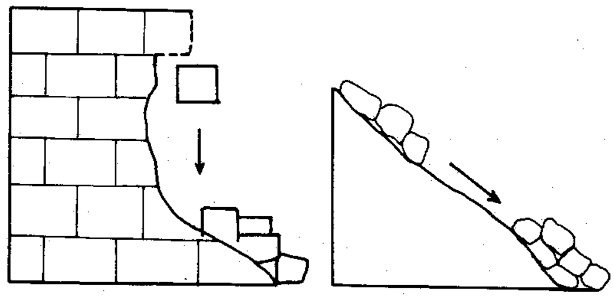
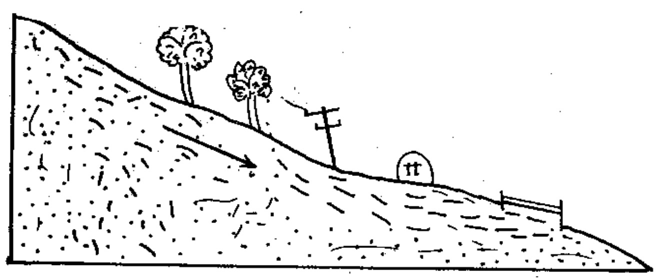


Fig. 7.5 Rock Falls

FLOWS: - Slow to fast downhill movement of unconsolidated materials, earth sand and rock debris, dry or wet with water or ice and snow and in some cases bedrock itself. Flows are characterized by the absence of a recognizable slip plane. The movement resembles those of viscous fluids. Flows are of two types according to the materials and rate of movement slow or fast.

Slow Flows: - These are of two types

(a). Soil Creep: - A very slow almost imperceptible down slope plastic movement of wet or dry surface materials following the laws of viscous flows of fluids and semi fluids. Curved tree trunks recognize soil creep, tilted lampposts telegraph as well as displacement or destruction of foundations, buildings, and retaning walls, fences etc on sloping grounds



If water saturated materials are involved soil creep is called solifluxion and when it its a wet mud without vegetation mud flow. Mudflows are common in areas effected by wild forest fires and on slopes of volcanic cones.

Fast Flows(Rapids Flows

): -
Fast flows are sudden and very fast-to-fast downhill slide of soil, rock debris and boulders with large masses of ice and snow on steep slopes of Snow Mountains. It includes disruption of highways, railroads, recreation facilities heavy damage to buildings and loss of life.

CAUSES OF LANDSLIDES

Many factors are causing a mass of material to slide or flow. Some of them play a direct role and are easily understand whereas others are indirectly responsible for the instability of the landmass. All such factors that facilities land sliding in one way or another is generally grouped in tow headings.

1) Internal Factors
2) External Factors

Internal Factors: - These include such causes, which tend to reduce the shearing of the rock, further it is classified into, 1) the nature of slope, 2) water content, 3) composition and compaction of the mass, 4) geological structures

1) **the nature of slope: -** Some slopes are very stable even when very steep whereas other are unstable, even at very gentle slope. But a great majority of failure are confined to slopes only, indicating that slopes are directly responsible for mass failure.
2) **Water content: -** Much importance is attached to the role of water is causing mass movements. It may act in a number of ways to reduce the shearing strength of the rock or soil mass. Even presence of water in the pore spaces of rocks has been found to affect all the strength properties adversely. When water within the mass is also capable of flow around the grains. Similarly, when water happens to move along a plane of weakness within the mass, that plane gets lubricated and may turn into an effective plane of shear failure. In sliding type of failure this lubricating action is of great importance.
3) **Composition and compaction of the mass:** - Some materials are stable in a given set of conditions of slopes and water content whereas others may be practically unstable under those very conditions. This clearly suggests that compaction plays an important part in defining the stability of the masses. Sandstone exhibits a great variation in chemical composition. Siliceous Sandstones would be highly stable even during intensive rains and at steep slopes whereas clayey or calcareous may suffer repeated failure under same conditions.

Along with composition, the texture of rocks plays an important part-It indicates the degree and manner of packing of grains or crystals. Porosity and permeability of are the two important factors influencing the percolation of water through the mass.

4) **geological structures: -** Of all the geological structure the inclination(dip), joints, faults zones of the strata, presence or deposition of shear, fault zone, joints and other

planes of weakness are important in defining their stability.

External Factors: - Earthquakes and blasting around mines due to this vibration is librated from this mass failure may take place.

Preventative measures of Landslides

Many methods for controlling the slides are available and choice of many methods will depend of factors like nature of slide, the underlying cause for it, the nature and amount of material involved and the economical consideration, of such method most important are.

1) Providing adequate drainage
2) Construction of retaining walls
3) Stabilizing the slopes

Providing adequate drainage: - It involves the removal of moisture form within the rocks as well as preventing any further moisture to approach the material to sliding. This may be achieved either by surface drainage or by subsurface drainage; construction of interpretation ditches, waterways, trenches and drainage tunnels may become necessary. Grouting the joints and other fractures may also prove helpful.

Retaining structure: - Al such devices like construction of retaining wall etc. are aimed at stopping the moving mass by force and their success is always doubtful. Construction of retaining wall requires an accurate assessment of the forces, which the wall has to withstand. Retaining walls may prove exceptionally, successful where,

A) the ground is neither too fine or too plastic
B) the sliding mass is likely t remain dry
C) the movement is of shallow nature

Slope treatment: - When the material is soil and situation is a slope the failure is attributed to a loss of stability. In such cases the treatment involves stability for the particular type of soil and slope and if such computation indicate that a given slope of soil will not be stable then the solution lies in either,

A) Flattening the slope
B) Decreasing the load
C) Increasing the shearing resistant of the soil by decreasing its water content with help of drains and evaporation
D) A forestation that is growth of vegetation cover with intricate and interwoven root system has also been found useful in stabilizing the barren slopes.

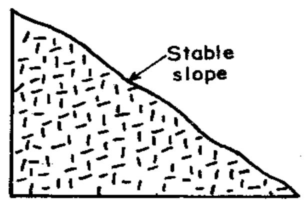
Effects on Hillside Homes and Structures, Landslide Damages:

STABLE AND UNSTABLE SLOPE: -

Slopes thus may be classifies into stable and unstable slopes governed by critical geological parameters.

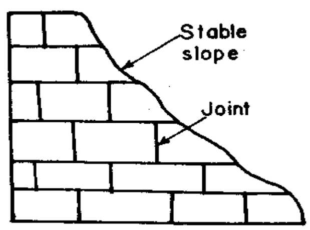
Stable Slopes ***Geological Parameters***

1.



Massive granite basalt gneiss quartzite massive sandstone, massive limestone gentle or steep slope

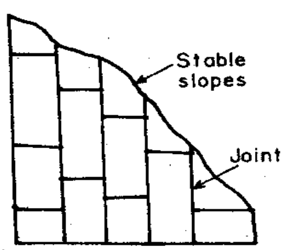
2.



Horizontal beds. Vertical joints, Gentle or steep slopes.

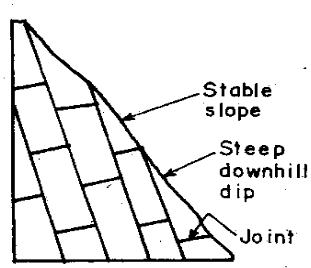
Y

3.



Vertical beds. Horizontal joints.

4.

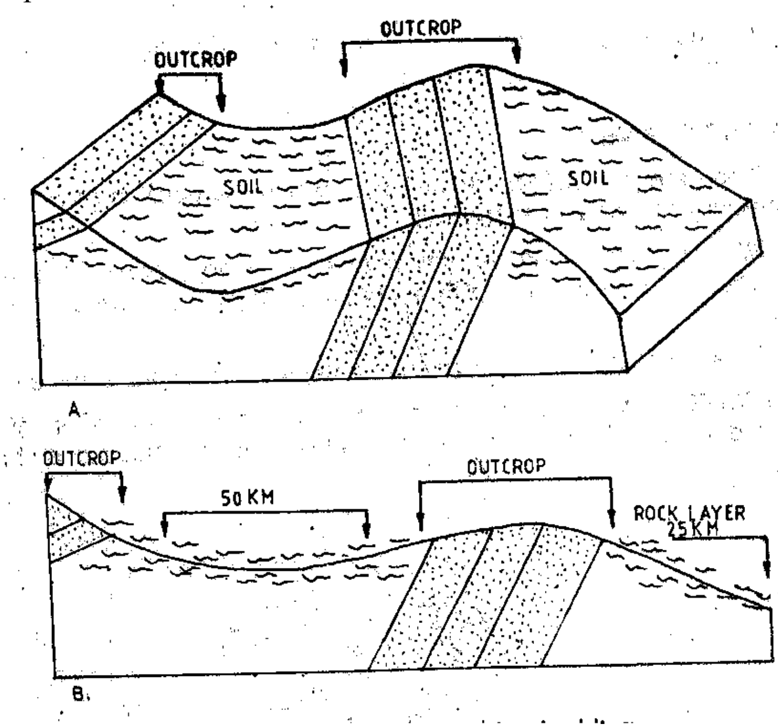


Steeply inclined beds dipping in the direction of natural slope dip of the beds > slope gradient joints dip.

- **Folds**
- **Faults**
- **Un-conformites**

OUTCROP

everywhere on the surface; a thin or thick layer of alluvium or soil often covers it. In certain regions alluvium or soil may be spread for thousands of square kilometer and the bed may not be visible anywhere. In other areas, however, exposures of rocks may be easily seen forming sides of valleys or caps of the hills or even flatlands in fields. An outcrop is the exposure of a solid rock on the surface of the earth.

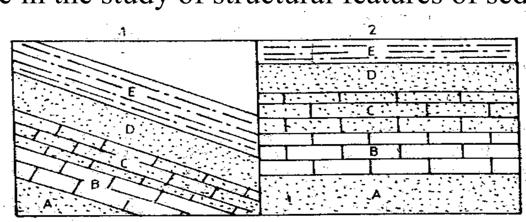


Rock outcrop-showing bedding

A= in block diagram B= In Cross section

BEDDING

Most sedimentary rocks are deposited under conditions, which favor development of distinct layers form bottom to top. These layers are often easily distinguished on the basis of variation in color, composition and grain size. As it is sedimentary rocks are the most widespread on the surface of the earth, forming more than 75 percent of all the rocks exposed. This layered character; called Stratification or Bedding is, therefore, of fundamental significance in the study of structural features of sedimentary rocks.



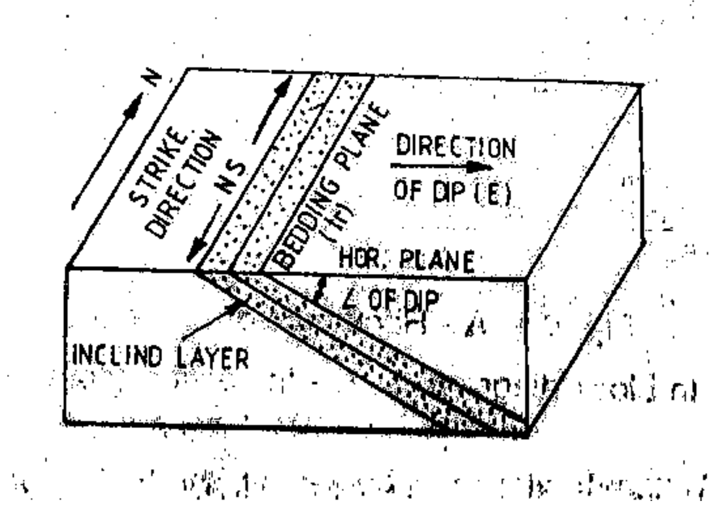
1=Inclined layers, 2= Horizontal layers

DIP and STRIKE

These are two definite quantities by which the position or attitude of a body of rock, especially stratified, is expressed.

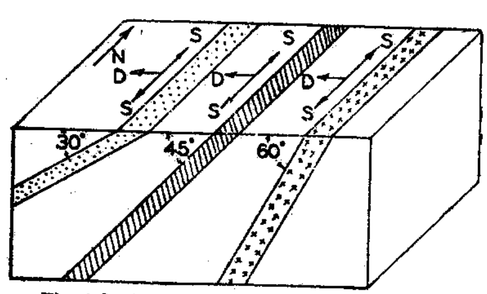
DIP: - It is defined as the maximum angle of slope of a bed or layer of rock with the horizontal. It is expressed both in terms of degree of inclination and direction of inclination.
The amount of dip is the angle between the bedding plane and a horizontal plane.

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 a horizontal plane.

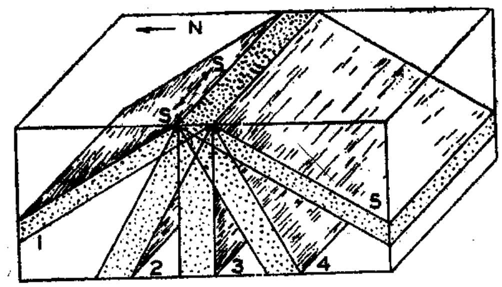


Dip and Strike explained

Two layers inclined towards east make an angle 30o with the horizontal plane, hence, dip = 30o, the layers extend in north south direction, hence strike is NS.



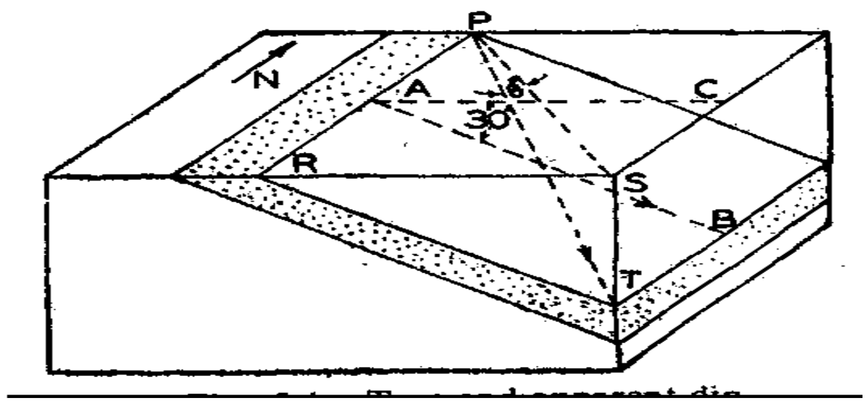
Dip & Strike of beds, all the beds strike North-South but their dips are different.
The different beds dip towards west at different angles but all of them strike North-South. By knowing only the strike of a bed it not possible, therefore, to say anything about its amount or direction of dip. Thus, if a bed strikes East-West, it may have any dip either towards North or towards South, or it may even be a vertical bed running East – West.



Dip & Strike of bed, SS is the strike of the bed but the bed may have any dip towards North or South or it may be vertical.

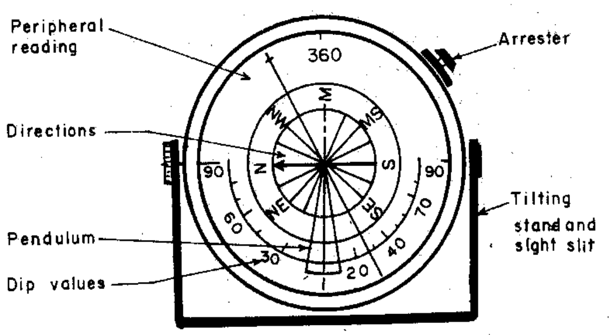
In specifying the attitude of any inclined bed, therefore, its amount and direction of dip should both be mentioned clearly. Unless this is done, its position in space cannot be properly defined. It is well known that upon the surface of a dipping be, the amount of slope is maximum along a line perpendicular to the strike and this is, therefore, the True Dip or the maximum slope of the bed, with respect to the horizon. The geographical direction, in which the line of quickest descent slopes down, is the direction of true dip. In the given diagram, the true dip of the bed, measured along the line of quickest descent, is 30o. The direction of true dip is obviously east. Along any direction other than that of the true dip, the gradient is scheduled to be much less and this may,

APPARENT AND TRUE DIP



The amount of slope is maximum along a line perpendicular to the strike and this is, therefore the true dip or the maximum slope of the bed, with respect to the horizon. The geographical direction, in which the line of quickest descent slopes down, is the direction of true dip. In the given diagram, measured true dip of the bed, measured along the line of quickest descent, is 30^o. The direction of true dip is obviously east. Along any direction other than that of the true dip, the gradient is scheduled to be much less and this may, therefore, be defined as the apparent dip of the bed of the bed along any given direction. Therefore, the apparent dip of any bed towards any direction must always be less that its true dip. In the given diagram, the gradient of the bed along any line PT (i.e., the angle ø) is obviously much less than that along the line AB (i.e., 30^o). The apparent dip of the bed, along any direction PT is, therefore, ø, which is always less that 30^o, unless PT runs parallel to AB. Along PR (which runs North-South and represents the strike of the bed, there exists no slope and the apparent dip is, therefore, 0^o. From the foregoing discussion, it may be summarized that that an inclined bed has the maximum or the true dip along the line of quickest descent and, if followed along its strike appears to be horizontal. In any other direction, however, it exhibits an apparent dip, which is less than the true dip of the bed.

COMPASS CLINOMETER



The amount of dip and the direction of dip are measured by using the instrument called Compass Clinometers. It is a simple instrument made up of a graduated circular dial. At the center of this dial, there exists a suitable pivot, on which a magnetic needle can rotate freely. From the base of pivot a pendulum hang freely ad is provided with a pointer against which readings are graduated from 0-90^o scale can be taken conveniently. The pendulum is used to the determination of dip of rock beds, of joints, fault plane. The free movement the magnetic needle and the pendulum can be stopped with the help of an arresting key on the body of the instrument. The instrument is provided with bridge, which can be rotated about North-South axis of the dial and kept vertical when the equipment is in used as a compass.

It is also used as clinometers (i.e. to determine the amount of dip of an inclined surface) the bridge lies in contact with the instrument rests on the inclined surface obviously at this position, the dial lies in a vertical plane if base lies parallel o the direction of maximum slope of the inclined surface. At this position pendulum oscillate freely and its pointer reads the amount of slope of the plane.

The amount of dip is expressed in degrees like 30^o, 40^o etc

The direction of dips expressed also in degree with two geographic directions like $N30^oW$, $S60^oE$

JOINTS

Joints: Definition

Joints are natural divisional planes or fractures dissecting rock masses in patterns along which there has been no parallel movement of blocks of rocks. The joints are rupture deformation, but differ from fault in not accompanied by dislocation of blocks of rocks fig 1 however, there may be slight displacement at right angles producing an open fracture. Tensional forces due to drying shrinkage or contraction, or compressive forces due to earth movement produce joints in rocks.

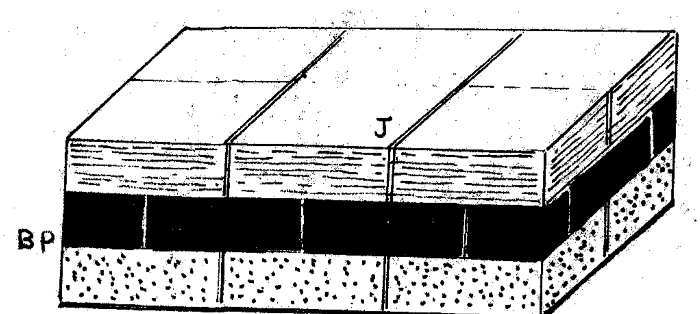


Fig. 10.1 Typical Joints
J = Joint plane BP = Bedding plane

fig.1

Characteristics of joints:

Joints are planar discontinuities, i.e. parallel open cracks, characterized by size, spacing and orientation. Joints surfaces may be straight curved smooth or jagged or striated. They are universal and mostly are open at the surface and die out at depths; however, joints may be filled up with mineral mater like quartz, calcite, dolomite or clay. When open joints below the surface may contain water under pressure. Joints may be of any attitude, vertical, inclined or horizontal. Joints spacing varies widely from a few centimeters to several meters.

Joint systems:

Joints do not occur alone. They commonly occur in groups running parallel to each other. A group of parallel joints of common origin in called a joint set. Two or more joints sets usually intersect in characteristic patterns, perpendicularly or obliquely at constant angle, producing joint system. Joint sets or systems give rock masses a fragmental appearance when closely spaced and a block by appearance when widely spaced.

Classification of joints

Joints are classified according to there

1). Mode of origin and forces responsible called genetic types

2). The trend (strike) of joints trace relative to the attitude (dip & Strike) of rock beds called geometric types.

GENETIC TYPES

Basically two types of joints are recognized:

(a). **Tension joints** and (b) **Shear joints**

(a) **Tension joints**: There are joints produced by tensional forces developed by increase or decrease of volume of rocks due to drying shrinkage while cooling or dehydration and stretching of the limbs of folded strata.

Tension joints are large and wide. Their rough irregular, slickensides or jagged surfaces, recognizes them. These are related to various types or rocks and their modes of formation and are affected by the litho logical nature of rocks. Rocks yield easily to tensional forces and most joints are tension joints.

TENSION JOINTS IN IGNEOUS ROCKS

As cooling and solidification progress magma or lava become increasingly rigid and ultimately rupture or crack producing tension joints.

A. **MURAL JOINTS**:

This system is typical of granites and related massive plutonic and certain hypabyssal rocks. Mural joints consist of three almost equally spaced mutually perpendicular joint sets dissecting the rock mass into cubical blocks. These points are typical tension joints produced in the rock mass during cooling and solidification of magma die to contraction in three directions

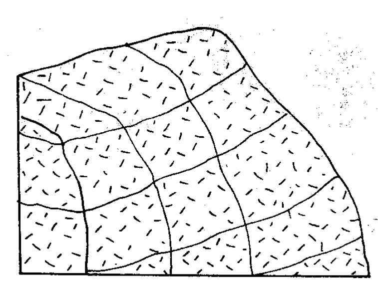


Fig. 10.2 Mural joints in granite

Mural joint system helps obtain easily intact cubical blocks of rock in quarries. However, the joint planes allow natural weathering agents to attack blocks of rock around whereby they become rounded or irregularly cubical boulders gradually as those of granite hills.

B. **SHEET JOINTS**:

This system, also typical of granite and other plutonic rocks, consists of one set of prominent joints parallel to the ground surface with varying spacing usually increasing with depth, and the other less marked at right angles. Sheet joints dissect the rock mass into sheet like blocks. In some cases the main joint planes instead of straight and parallel may be a bit curved or undulating producing g lens like blocks of the rock due to pinching and swelling, sheet joints occur fairly close together, frequently undulating or pinching and selling near the surface but become wider downwards and disappear altogether at depth. Therefore layers of rocks generally are thinner near the surface and thicker at depth. Sheeted rocks often appear as sedimentary strata and help obtaining slabs of rocks. These joints are produced by tensional forces due to relief from confining pressures and consequent unimpeded vertical expansion of the rock. Example: - Chamundi granite.

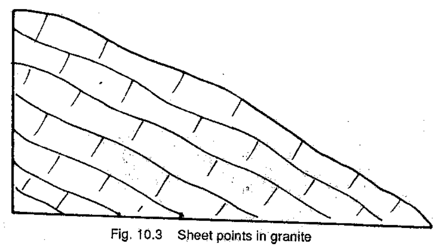


Fig. 10.3 Sheet points in granite

C. **COLUMNAR JOINT**S:

This system is typical and certain other volcanic igneous rocks, and consists of vertical and horizontal cross joints dissect the rock mass into a number of vertical polygonal, usually hexagonal prismatic columns. These joints are produced during the cooling of horizontal flows of lava due to the development of weak planes by radial contraction around spaced centers in the cooling mass of lava. The lines joining these centers are directions of great tensile stress

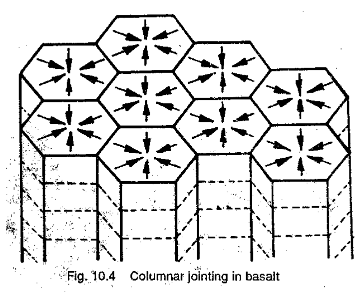


Fig. 10.4 Columnar jointing in basalt

When molten lava cools and solidifies enormous thermal contraction take place and the stress which accompanies the contraction develops a strain beyond the elastic limit of the solidified rock, its rigidity is overcome and series of more or less regularly space vertical cracks develop perpendicular to these directions. As the cracks advance they bound in between beautiful hexagonal prismatic columns of rock.

Example: Santa Marina Groups of Islands

Tension joints in Sedimentary Rocks:

As the sediment become more and more consolidated under pressure it gets compressed and occupy smaller volume and finally ruptures. Thus joint sets develop at right angles to each other more or less at regular intervals. These joints are found prominently developed in massive as well as bedded sedimentary rocks of uniform composition and grain size. The most common tension joint system sedimentary rocks called Master Joints.

MASTER JOINTS:

This system is typical of sandstones and limestone's and consists of three sets of mutually perpendicular joints of which one set parallel or coincides with the bedding planes. The other two sets, which traverse across the bed, are staggered in respect of successive beds. These joints persist for long distance with remarkable regularity in spacing and width and thus are called master joints. Master joints dissect the rock mass into rectangular blocks. In shale these joints are generally very closely spaced.

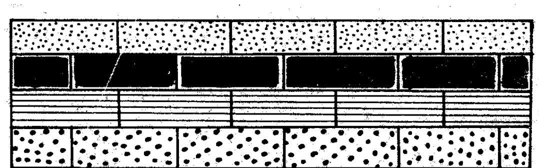


Fig. 10.5 Master joints in sedimentary rocks

Extension and release joints;

In case of folded strata tension joints are produced in the crustal region and extend either parallel to or at right angles to the axial plane or in both the directions. Those that are parallel to the axial plane are called release joints (strike joints) and those at right angles are called extension joints (dip joints)

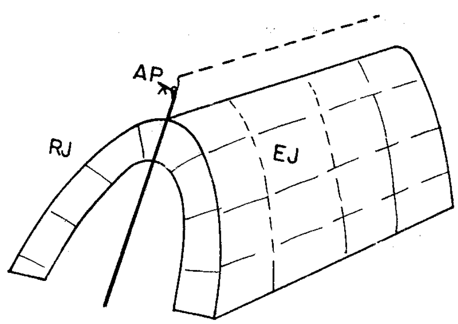


Fig. 10.6 Extention (EJ) and Release joints (RJ) AP : Axial Plane

Tension joints in metamorphic rocks:

As metamorphic rocks are derived from igneous or sedimentary rocks, depending upon the nature and intensity of metamorphic changes the joint pattern of the parent rock may be preserved wholly or partially or deformed or completely change over or destroyed. Thus more massive rocks like gneiss show mural and sheet joints. Bedded and foliated rocks like marble and quartzite show master joints.

SHEAR JOINTS:
These are associated with deformed rocks, especially folded ones. Shear joints consist of intersecting or criss-cross sets at a high angle. These are called conjugate joint-system.

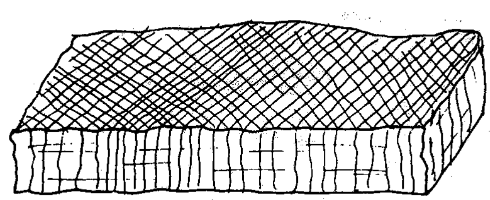


Fig. 10.7 Shear joints (Conjugate joint system)

Conjugate joint systems:
Shear joints are produced mostly shearing stresses commonly involved in folding and faulting. These are generally very narrowly spaced and can be recognized by clean-cut smooth surfaces, as the joint blocks are not drawn apart.

In case of certain deformed and metamorphosed pegmatite's, quartzite's, schist's ad amphibolites closely spaced criss-cross joint system consisting of two or three obliquely intersecting sets are observed dissecting the rock mass into small, irregular blocks, and fragments. Thus when weathered or excavated or blasted most metamorphic rocks other than gneiss disintegrates into small fragments. Fig 10.7.

GEOMETRIC TYPES

These are classified, specified, and described according to the trend (strikes) of joint trace relative to the attitude of rocks masses (dip and strike)

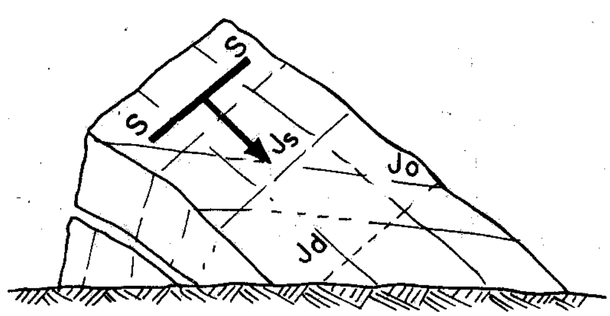


Fig. 10.8 Dip joints (Jd) Strike Joints (Js) and oblique joints (Jo)

(a). Dip Joints: joints that strike parallel to the direction of the dip of rock bed eg extension joints
(b). Strike Joints: Joints that strike parallel to the direction of the strike of rock beds. eg. Release joints
©. Oblique joints: joints that strike at an angle to the directions of dip and strike of rock beds. These are also called diagonal joints eg conjugate joints

IMPORTANCE OF JOINTS

Joints in rocks form advantages as well as potential weak and dangerous features. They are t be very carefully studied and assessed of their pattern, intensity, depth and continuity. Joints break the continuity of the rocks and reduce their strength greatly. Joint concentration is best studied on the basis of statistical data obtained from rose diagram and point contour diagram.

Joints influence quarrying and blasting pattern
Joints spacing determine the size and shape of the blocks to be obtained in a quarry, mural and master joints help quarrying intact cuboidal or rectangular dimension stones. Sheet jointing helps obtaining crushed stone for concrete aggregate, road metal, rail road ballasting.

Joints provide passages for the percolation of water and help weathering and formation f soil.

Joints control the natural groundwater drainage system in rocks underground.

Joints often provide passages for the groundwater to rise to the surface or issue out to the surface or issue out to the surface and form springs.

Joints planes provide potential depositional channels of mineralizing solutions.

Joints are helpful in exploration of water and locating well sites.

Joints render rocks weak and unstable.

Joints planes form slop planes in inclined and folded beds and therefore induced landslides and rock falls.

Joints render rocky banks of rivers unfit for bridge and dam abutments.

Joints planes are responsible for leakage of water in tunnels, leakage from reservoirs and dam abutments and beneath dams in rocky gorges.

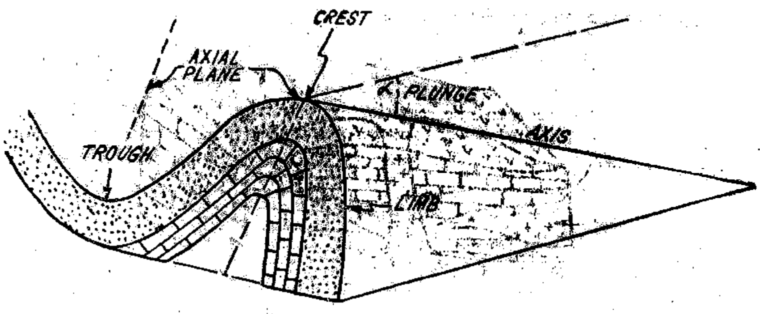
Difference between faults and joints

	FAULTS	JOINTS
1	Fracture or fracture zone with Displacement of the sides Relative to one another parallel to the fracture	Fracture that divides A rock and along which There has been no Movement parallel to The fracture
2	Occur generally single or in groups, parallel vertical inclined radial or intersecting	Occur in numbers parallel to each other and intersecting perpendicularly or obliquely
3	Comparatively widely spaced	Relatively closely spaced
4	Fault fissure open clean cut irregular filled with gouge	Joint planes open at surface may close down at depth filled with gouge, mineral matter.
5	Fault plane surface rough silken sided grooved scratched	Rough or smooth, never slicken sided
6	Fault blocks forced to override other	No movement
7	Contact of beds of different composition thickness and age	Same rock
8	Cut rock strata with displacement of the contiguous parts	Divide the rock mass into regular cuboidal, rectangular. Columnar or prismatic blocks
9	May be subjected intermittent movement (activated)	Nil
10	Forms potential hazard causes earthquakes	Responsible for landslides and rock falls
11	Result from tensional as well as compressive forces	Result from tensional as well as compressive forces
12	Continued application of stress following rupture lead to dislocation (fault movement)	Operation of stress stops with rupture

FOLDS

An undulation is obtained in rock strata produced by compressive forces in plastic strata similar to buckling of an overload column.

PARTS OF FOLD: -



Axial line or Axis: - The median line about which folding has taken place. The axis may be horizontal, inclined or vertical

Axial plane: - An imaginary plane that divides a fold into two more or less symmetrical halves. The axial plane may be vertical inclined or horizontal

Limbs: - The two sides of a folds the left limb and right limb
Crest: - Highest position of fold, it is always curving or angular
Crest line: - The two sides of crest point are referred as crest line
If the fold axis is inclined then it referred as Plunge of fold

CLASSIFICATION OF FOLDS: -

It is classified and described according to the attitude of the limbs, axis, axial plane and the nature of beds. The important types are

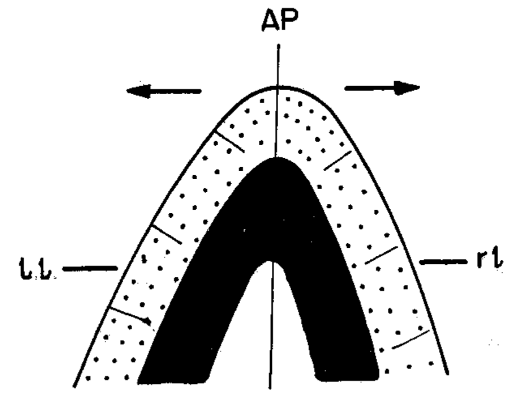


Fig. 8.4 Typical anticline (vertical)
AP: Axial plane rl : Right Limb LL : Left limb

ANTICLINE: - A simple up fold in which older beds lie inside and the limbs dip away from each other equally or unequally like the sides of a gable roof of a house. When the limbs dip equally the fold is called a symmetrical anticline when dip unequally, it is called asymmetrical anticline.

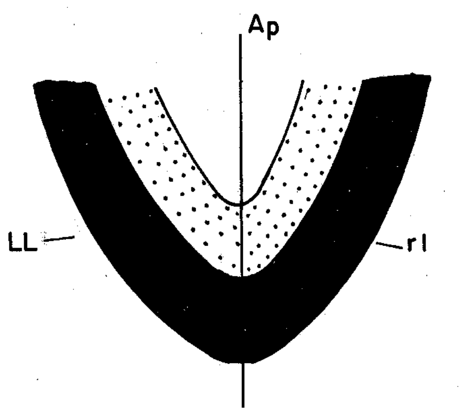
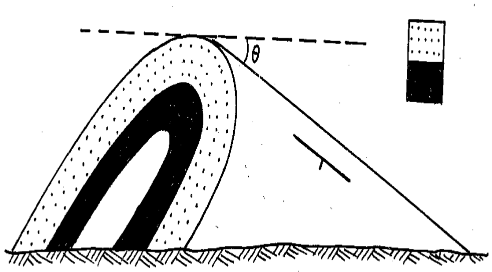
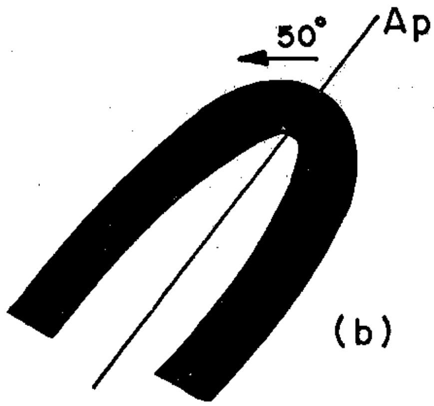


Fig. 8.5 A Typical Syncline AP : Axial Plane LL : Left Limb RL : Right Limt

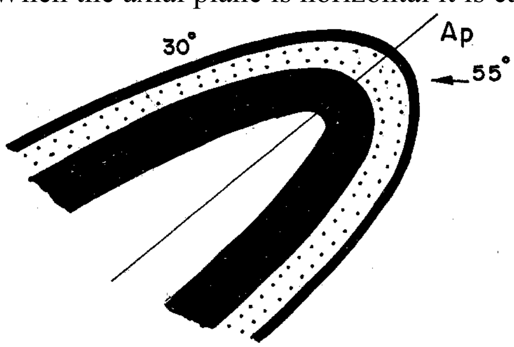
SYNCLINE: - a Simple down fold in which younger beds lie inside and the limbs dip towards each other. When the limb dip equally the fold is called symmetrical synclines, when dip unequally an asymmetrical syncline.

PLUNGE FOLD: - A folds whose axis is inclined from the horizontal. It is also called a pitching fold. The angle of inclination of the axis from the horizontal in called the plunge or the pitch. It is expressed in degree.



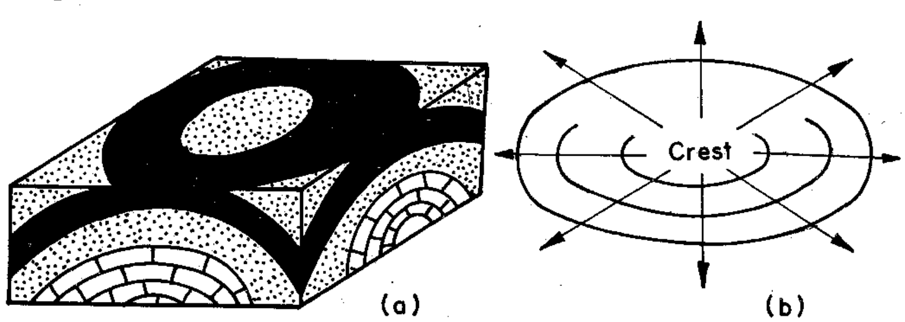


ISOCLINAL FOLD: - A fold in which the limbs dip at equal angle in the same direction i.e limbs are parallel to each other. The axial plane may be vertical inclined or horizontal. When the axial plane is horizontal it is called as recumbent fold.



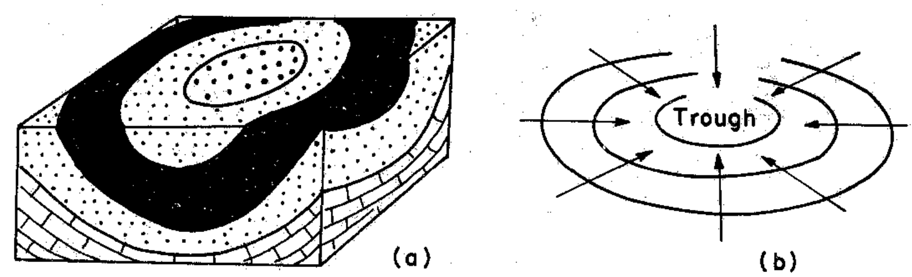
OVERFOLD OR OVERTURN FOLD: -

A fold in which the axial plane is inclined form the vertical and the limb dip in the same direction but unequally i.e the limbs are not parallel to each other. The limb below the axial plane is the overturned limb.



DOME OR PERICLINE FOLD: -

An up fold with older beds inside in which the beds dip outward from all crest on all directions like an open umbrella. A dome fold or periclinal may be symmetrical and circular, elliptical or irregular in plan.



BASIN FOLD OR CENTRO CLINE FOLD: -

Down folds with younger beds inside in which the beds dip inward towards the trough like a bowl or inverted umbrella.

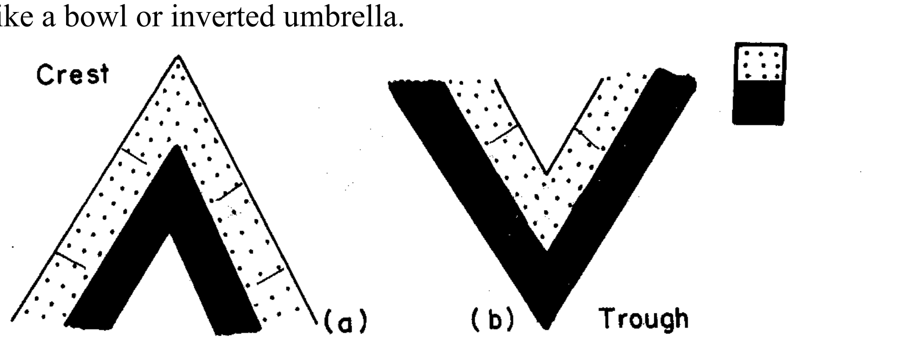
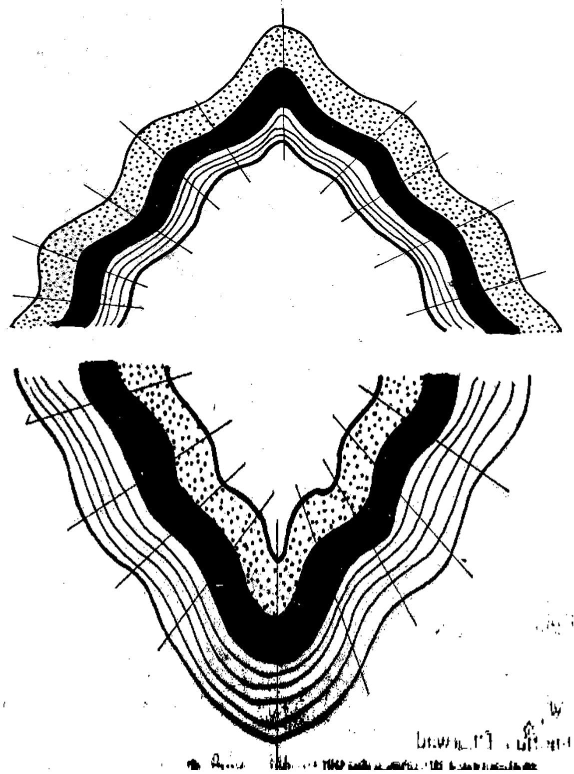


Fig. 8.14 Chevron foldswigh sharp and angular crest and trauglar (a) Chevron anticline (b) Chevron Syncline

CHEVRON FOLD: -

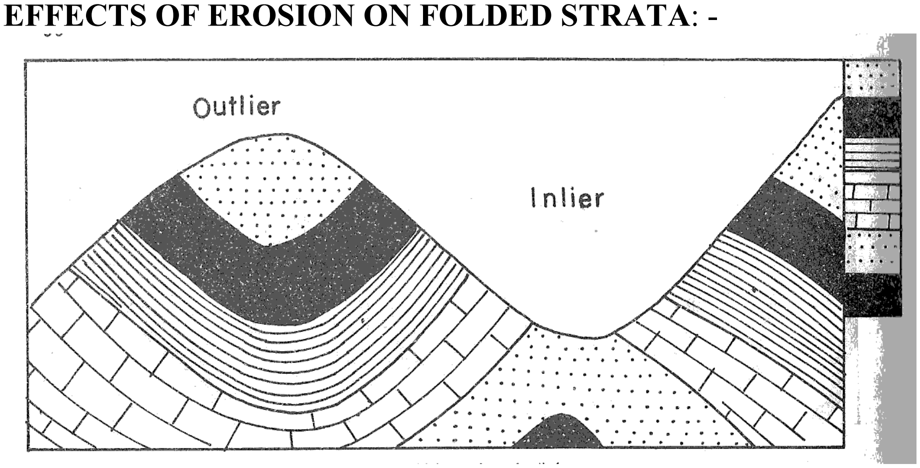
If the crest point is acute then it is referred as Chevron fold. This is due to very much of magnitude of force is acted on either side.

ANTICLORIUM(a) & SYNCLORIUM(b): -



(a) (b)

EFFECTS OF EROSION ON FOLDED STRATA: -



Normally anticlines form ridges and synclines trough. But on erosion anticlines are eroded down along with crest, which will be in strata of tension and form long channels called **anticline valley or Inliers**.

In case of synclines the limbs are easily eroded and the trough region being compressed tightly standing ridges resisting erosion called **synclinal hills or outlier**.

IMPORTANCE OF FOLDS: -
Folded strata is greatly strained broken and incompetent, therefore form weak and unsafe zones in construction areas especially excavation tunneling, hillside, cutting and dam, bridge site.

Anticline and other up folds form potential oil traps while synclines and other down fold form potential aquifer for groundwater. In some instances down folds like synclines when filled with groundwater artesian conditions undergoing pressure affecting the stability of the ground above and therefore the stability of structure constructed in such ground.

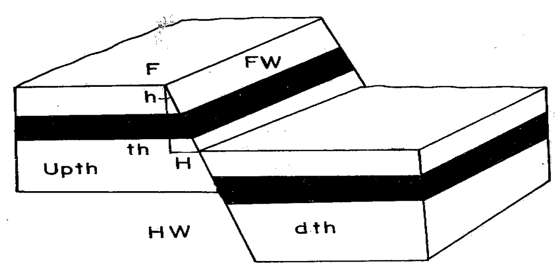
RECOGNITION HAVE FOLDS IN THE FOLDS: -
1). Folds re seen clearly on mountain regions, seacoasts, cliff, riverbanks, quarries deep cutting, trenches.
2). Successions of similar beds regular intervals met with in vertical shafts and bore wells indicate recumbent folds.
3). In geological maps standard sign and symbols indicate folds.
4). ---- Pointing towards syncline
------- Opposing dip arrows indicate anticline

FAULTS

A fault is a fracture or fracture zone in rocks along which there has been displacement of the two sides relative to one another parallel to the fracture.

A fault is a rupture deformation produced either by tensional or compressive force and may be local or regional like famous San Andreas system of faults of North America.

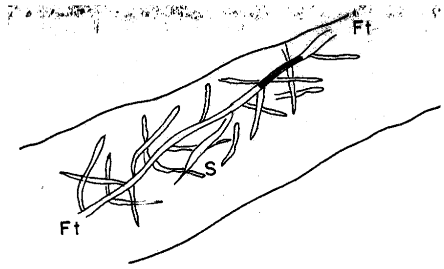
PARTS OF FAULT: -



1).Fault plane (FF): - The planar fracture surface along which the break and dislocation of rock beds have taken place.

In elevation and plan, ie the vertical and horizontal sections the fault plane appears as a line along which the dislocated beds remain almost in contact with each other.

The fault plane may be simple, clean cut smooth or slickensided open fracture or a an irregular zone of a number or smaller intersection fracture making a small angle with the main fault called a shear zone often filled with crushed rock and flour.



Shear zones range in width from less than a meter to several meters.

Fault plane may be vertical, but commonly it is steeply inclined. The attitude of the fault plane is specified by its dip and strike parameters. The intersection of fault plane with the surface is called the fault outcrop, fault line, fault strike or commonly fault trace. The fault trace in most cases of high angle faults is straight or slightly sinuous. When the dip of the fault plane is low and the ground relief high it may be very irregular.

The direction of the trend of the fault trace with reference to the north-south line is the strike of the fault.
The lower wall of an inclined fault plane is called the **footwall** and the upper wall the **hanging wall.**

<u>2). Throw</u>: - The vertical component of fault movement

The side of fault plane or trace, which appears to have moved down, ie the fault block above an inclined fault plane is called down, throw side.

The side that appears to have moved up relative to the down throw side is called the up throw side.

The amount of throw varies from a few centimeters to thousand of meters.

<u>3). Heave</u>: - The horizontal component of the fault movement, t he shift in measured at right angles to the strike movement.

<u>4). Hade</u>: - The angle between the inclined fault plane and the vertical. Hade is the compliment of the dip of the fault plane. Hade is measured from the vertical and is expressed in degrees.

<u>5). Slip</u>: - The displacement of the formerly adjacent points. The slip may be-

(a). <u>Translational:</u> - the direct down dip or upside movement of rocks blocks on the fault plane in the direction of its true dip called dip-slip or sideward movement called strike slip or a combination of these called oblique-slip (b). <u>Rotational</u>: - the fault blocks rotated relative to each other.

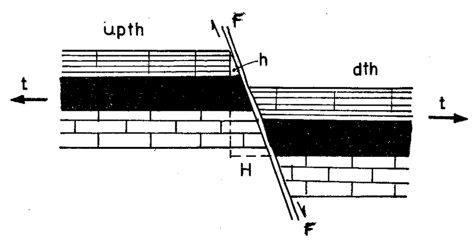
Classification and Types of Faults

Faults are classified and types described on the basis of
(a). The direction of slip of beds, ie the apparent displacement of fault blocks relative to each other and the causative forces called the genetic types.

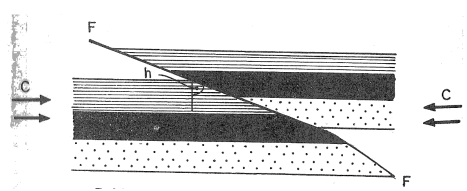
(b). The attitude of fault plane relative to the attitude of rocks beds called the geometric types.

GENETIC TYPES

Of the various types of faults the normal, reverse and lateral faults are the basic types.



NORMAL FAULT: - A normal fault is a high angle dip-slip fault in which the fault plane is inclined steeply with hade10o-20o or less. The vertical component of the movement ie the throw is generally large. The fault traces of normal faults commonly run straight or slightly sinuous, but may be very irregular due to slumping of the sides later. Normal faults may small, local or regional features and area also called gravity faults.



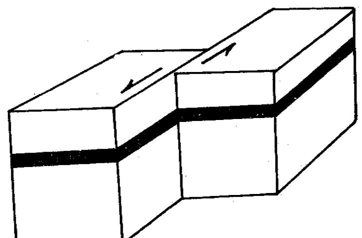
REVERSE FAULT: - A reverse fault is a low –angle dip-slip fault in which the fault plane is inclined less steeply towards the up throw side i.e the hade is pointing towards the up throw side and the hanging wall has moved up relative to the foot wall.

Reverse faults are produced by severe compressive forces and the fault planes commonly area gently dipping with large hade over45o. The heave or the horizontal of the movement is very large, often many kilometers in case of larger faults. The up throw side is actually thrust over the down throw side due to great tangential forces. As such a reverse fault is also called thrust fault especially when the strata is gently inclined and the fault plane is dipping at less than 45o. When the topography is high the fault trace of a reverse fault will be very irregular. Reverse fault may be small, local or regional.

LATERAL FAULT: - A lateral fault is a strike slip fault i.e in which the dislocation is essentially horizontal in the direction of the strike of the fault plane without any dip-slip component.

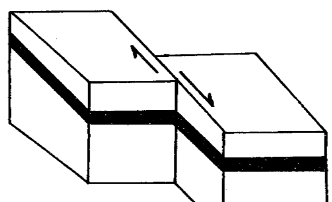
Lateral faults are also called faults, transverse, transcurrent or wrench faults.

The fault plane is vertical of near vertical.



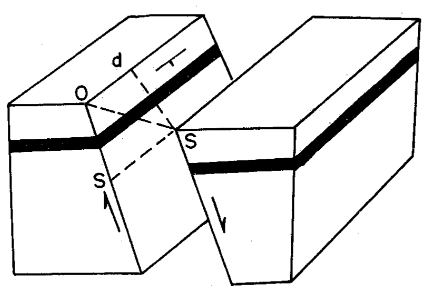
(a)

(a). Left-lateral or Sinistral Fault: - in which the left block appears to have moved towards the observer.

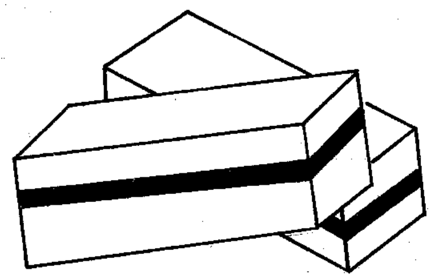


(b)

(b). Right-Lateral or Dextral Fault: - in which the right side block appears to have moved towards the observer.



©. Diagonal-slip Fault: - This is an oblique –slip fault in which the dislocation is diagonal i.e at an angle to the directions of true-dip and strike of the fault plane, up or down both dip-slip and strike-slip components.



(d). Hinge-Fault: - A fault with an angular or rotational displacement in which the wall rocks of one side have rotated along an axis normal to the fault plane with respect to the rocks of the other wall.

GEOMETRIC TYPES

In regions of inclined and folded beds faults are described according to the trend of the fault trace relative to the attitude of rock bodies.

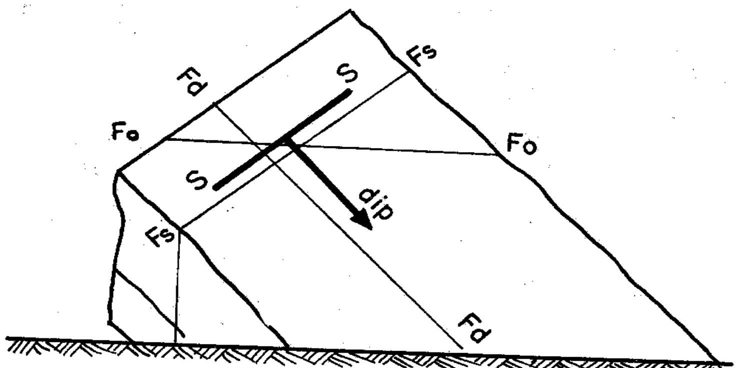


Fig. 9.8 Fault trace and directions of dip and strike of strata
Fd-Fd = dip fault. Fs-Fs = strike fault Fo-Fo = oblique fault.

<u>(a). Dip Fault</u>: - In which the fault plane trends in the direction of the dip of strata, i.e the fault strikes parallel to the dip of the strata.

<u>(b). Strike Fault</u>: - In which the fault trace trends in the direction of the strike of the strata i.e the fault strikes parallel to the strike of the beds.

<u>©. Oblique Fault</u>: - When the fault trace trends at an angle to the dip and strike directions of the strata i.e the fault strikes diagonally across the beds. Oblique fault is also called a diagonal fault.

SPECIAL KINDS OF FAULTS

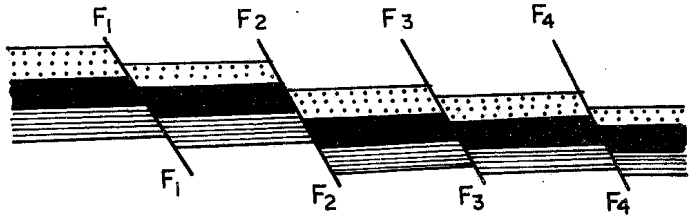
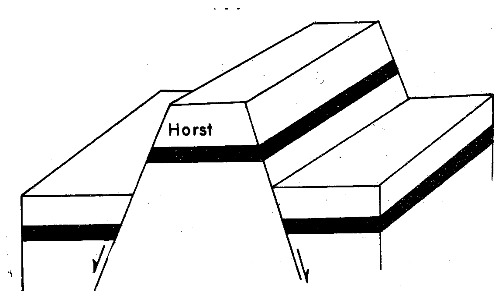
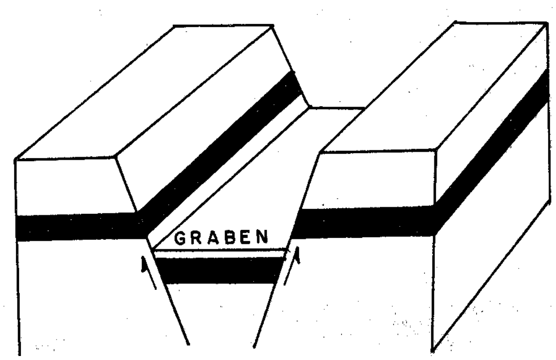


Fig. 9.12 A Step fault system

STEP FAULT: - a fault system consisting of a number of faults all parallel to each other vertical or inclined in the same direction with repeated down throw sides also systematically in the same side resulting in the dislocated strata resembling steps of a **stair case**. Each step is a fault block and its top may be horizontal or tilted. **Step fault** is also called a **fault terrace.**



RIDGE FAULT: - A fault system consisting of a pair of normal faults whose fault planes are inclined away from each other with a common up throw side in between. The up throw side of a ridge fault system forms a conspicuous inverted wedge shaped ridge parallel to the fault planes, generally long compared to its width called **ridge or a horst.**



TROUGH FAULT: - A fault system consisting of a pair of normal faults whose fault planes are inclined towards each other with a common down throw side in between. The down throw side of a troughs fault system forms a long trench or depression parallel to the fault planes, general long compared to its width called **fault basin or graben of a rift valley.**

CAUSES AND MECHANISM OF FAULTING

Faults are produced from several causes

1). Tectonic Process: - involving forces operating within the crust of the earth.

2). Non-Tectonic process: - involving gravity

Tectonic Process: -

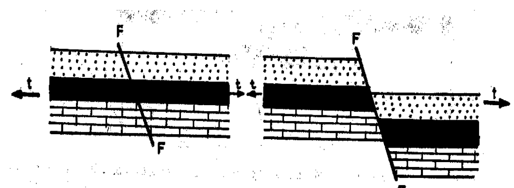


Fig. 9.16 Normal faulting
FF= Steep fault plane. tt = tensional forces

1). Horizontal tension- rocks fail under tension along near vertical fracture or along shear fracture dipping over 60^o.

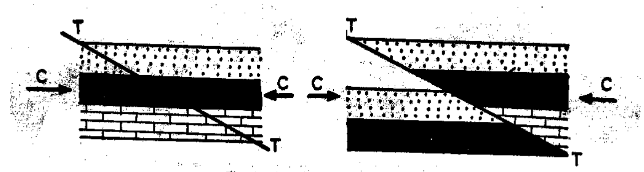


Fig. 9.17 Reverse faulting
T.T = Thrust plane (Low angle fault plane) CC : Compressive force

2). Horizontal compression: - Rocks fail under compression along low angle fractures

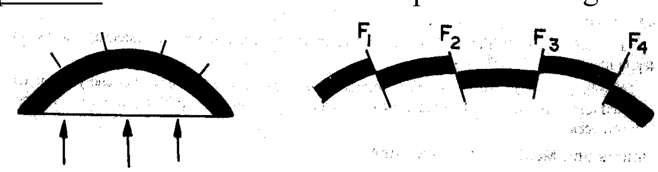


Fig. 9.18 Faults resulting from vertical movements
F_1F_2 : Step faults F_2F_3. graben F_3F_4 = horst

3). Vertical movements: - associated with folding like arching or depressing the rock strata developing tensional forces by which the rocks fail by rupture with differential movements.

Non-Tectonic process: -

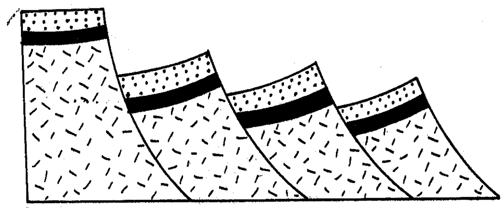


Fig. 9.19 Faulting due to landslides – A step fault system

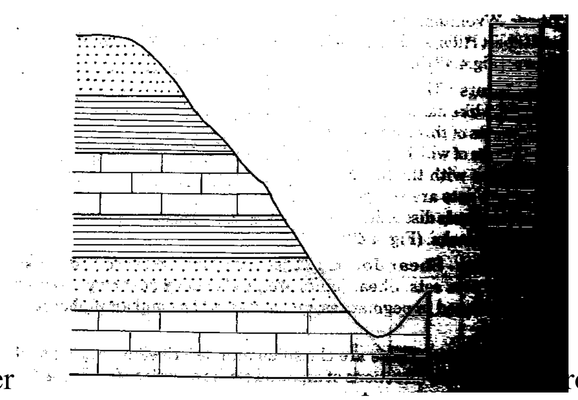
Of the various non-tectonic processes that cause rock deformation, landslide are more effective, a succession of slightly curved parallel fractures with characteristic displacement occur in rock bodies under certain conditions due to landslide slumping.

IMPORTANCE OF FAULT: -

- Faults form a major defect in rocks and therefore a potential hazard in engineering and mining works.
- Fault movement trigger earthquake and landslides.
- Fault zones are most undesirable features in dam and reservoir sites.
- Faults provide passages for percolation of water and mineralizing solutions
- Fault zones form sites of mineralization
- Fault are responsible for lakes, swamps and spring heads
- Fault zones often form potential oil traps

UNCONFORMITIES

When stratified rock formations are deposited regularly and continuously one above the other without any disturbance or break in the succession presenting a series of parallel beds, the sequence is called conformable beds or series and the structure is called conformity.

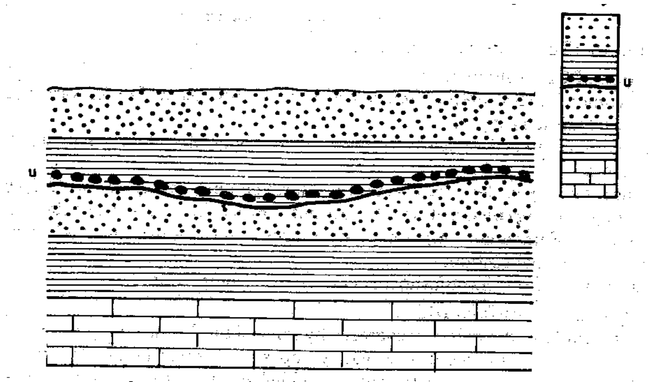


If, on the other roded surface of an older series that is not the next in the succession the two series are said to be unconformable and the erosion surface is between that separate the tow series is called unconformity. Unconformity indicates discontinuity, disruption or breaks the deposition and therefore a time gap. The relief of he erosion surface between the older and the new or younger series may be smooth or irregular.

KINDS OF UNCONFORMITIES

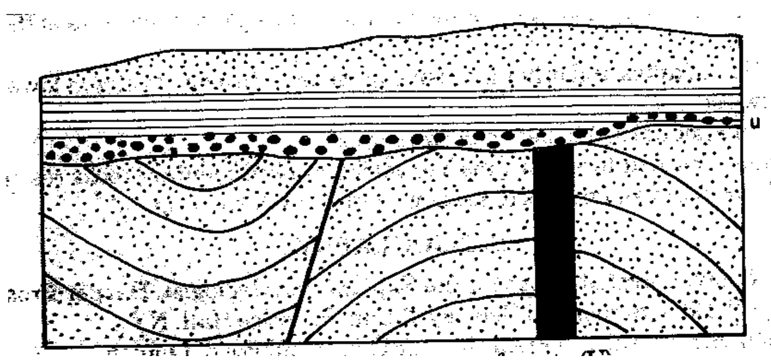
Unconformity is of three kinds.

1). PARALLEL UNCONFORMITY OR DISCONFORMITY



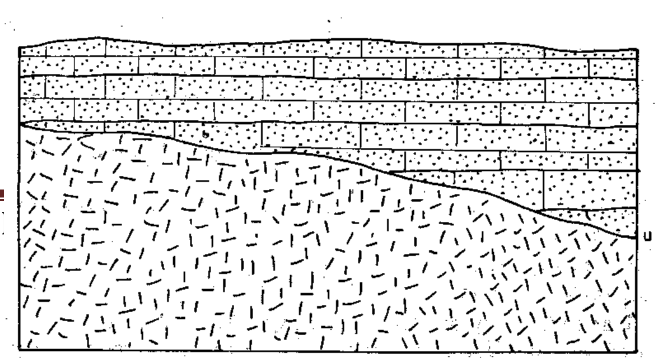
An erosion surface with an uneven relief between two parallel (conformable) series.

2). ANGULAR UNCONFORMITY



An unconformity in which a younger parallel series deposited on an erosion surface of a lower deformed (tilted, folded and or faulted) older series with an angular discordance.

3). NON-CONFORMITY



An unconformity between two series of rock of different origins like an upper younger stratified formation and an older non-stratified or massive igneous or metamorphic rock.

IMPORTANCE OF UNCONFORMITY

1. Unconformity represents a gap or break in the succession of rock strata and a time gap of thousands of millions of years.
2. Unconformity is the basic criterion for the division of geologic time into era, periods and epoch etc.
3. Unconformity under certain conditions form potential aquifers and oil traps
4. In engineering construction sites unconformities form potential defects as two series of rock formations of unequal competence, structure and types are involved with deformed and strained beds deeper sections

Thus in most cases unconformity renders sites incompetent.

RECOGNITION OF UNCONFORMITIES

Unconformity in the field is recognized by some of the following criteria:

1. Direct observation in hill sides, valleys slopes, cliff, quarries and excavations
2. One formation resting on the tilted or folded and eroded edges of several beds
3. Presence of a bed of conglomerate called basal conglomerate consisting of pebbles of underlying older beds on an erosion surface.
4. Contrast in the trends dip, strike and folding, faulting fossils etc of the two adjacent or successive series.
5. Termination of dikes and other intrusive igneous bodies and fault in lower series at the junction at the two series
6. Presence of residual soil in between tow series
7. Rock formations of different origin like volcanic or sedimentary rock resting upon the eroded surface of a igneous or metamorphic rock formation

APPLIED ENGINEERING GEOLOGY

UNIT - 06

Content :

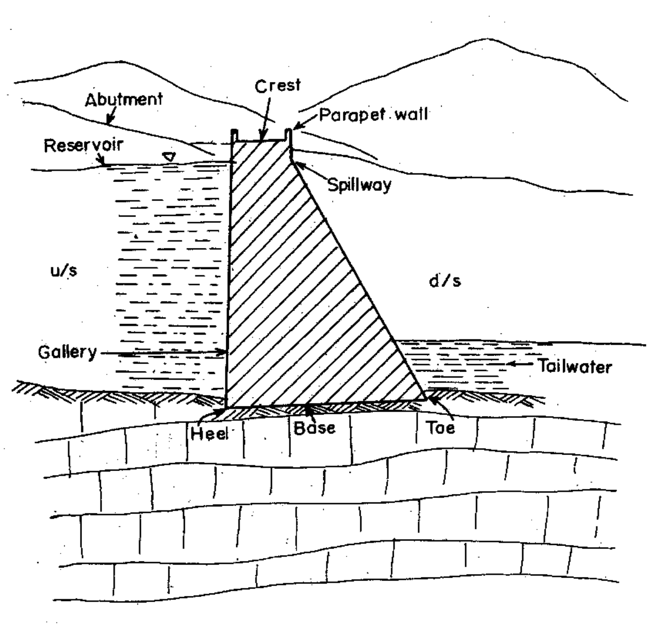
ENGINEERING GEOLOGY

- **Geological Maps**
- **Selection of site for Dams & Reservoirs**
- **Selection of site for Tunnels**
- **Selection of site for Bridges & Highways**

DAMS

A dam may be defined as a solid barrier constructed at a suitable location across a river valley. The principle uses are to provide stream regulation and storage for communities or industrial water supply, power, irrigation, flood control, water traffic. A dam that serves more than one such purpose is known as multipurpose dam.

SCHEMATIC CROSS SECTION OF DAM



ABUTMENT: - These are the sloping side of the river valley, upon which the dam is built

RIVER CHANNEL SECTION: - It is the central portion of the dam that directly overlies river channel or that portion of the valley.

HELL OF THE DAM: - Heel is the upstream portion of dam where it contacts the bearing surface of supporting the dam.

TOE OF THE DAM: - Toe is the downstream portion of dam where it contacts the bearing surface.

CREST OF THE DAM: - It is the top most part of the dam

PARAPET WALL: - Wall that are placed along top of the dam to afford safety to the road.

FREE BOARD: - It is the distance between highest level of water in the reservoir and the top of the dam.

AXIS OF DAM: - It is an arbitrary line drawn along center of the plan of he crest.

CROSS SECTION: - It is drawn on a vertical; cross section is perpendicular to the axis of the dam.

GALLERY: - Formed openings within the dam. They may run either transversely or longitudinally and may be level or have a sloping grade. They provide for drainage water seeping through the face or the foundation. It provides access equipment within the dam for observing performance.

DEAD STORAGE WATER LEVEL: - It is the elevation f the reservoir below that water stays permanently in reservoir and cannot be with draw through out lets

TAIL WATER: - It is the water level at the downstream base of dam.

MAXIMUM WATER LEVEL: - It is the highest elevation at which water can be stored in the reservoir without overtapping the dam.

MINIMUM WATER LEVEL: - Lowest elevation, which the reservoir can be lowered, and still water withdrawn though the outlet.

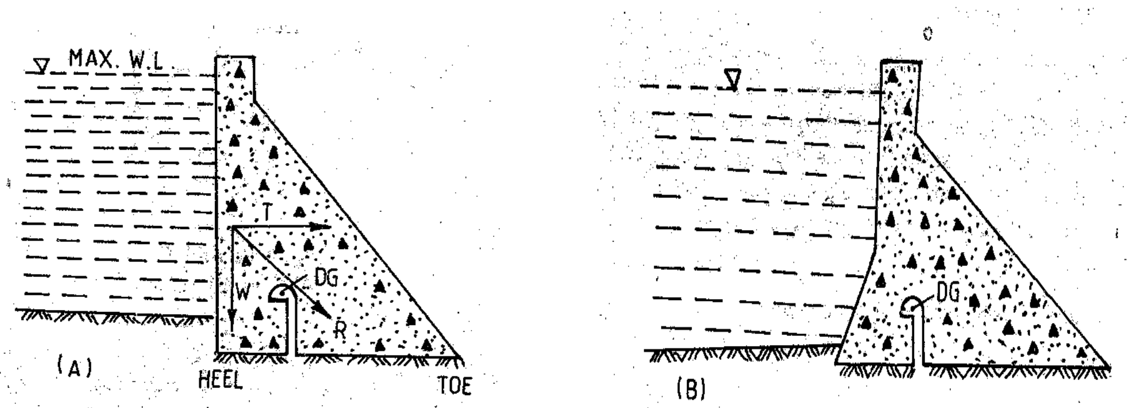
The principal classes of dams: -

A). Concrete dams: - a). Gravity dam
b). Buttress dam
c). Arch dam
B). Embarkement dam: - a). Earth fill dam
b). Rock fill dam
C). Composite dam

Other type includes dam in plains, hydrostatic fill dam, semi-hydrostatic fill dm, and barrages. These dams are the rare structure.

CONCRETE DAMS: - These assume one of the three main designs Gravity, Buttress and Arch dam all require strong foundation that will deform little when loaded by the dam.

GRAVITY DAM: - A gravity dam is a solid masonry or concrete structure generally of a triangular in cross-section. Solid gravity dam drive their stability form weight of the materials comprising the structure. Axis may be straight line; it is designed that it can withhold a percolated volume of water by its weight. All the applied forces on such a dam as due to water and weight of the dam itself are assumed to be directly transmitted to the foundation rock.



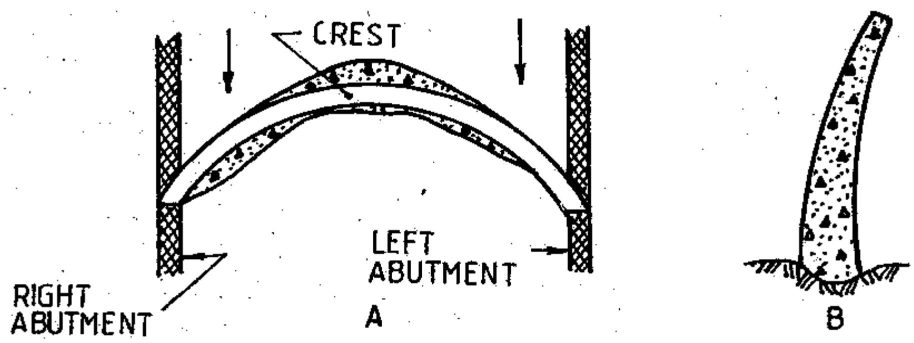
Typical Cross Section of Concrete Dam, Upstream Face

A=Vertical B=Partly inclined
Example: - Tunga Badhara dam. K.R.S.Dam

BUTTRESS DAM: -
This may be regard as, modified gravity dam with the volume of concreted reduced by taking advantage of the structural strength of reinforced concrete. Buttress dm is composed principally
--- A sloping upstream deck of RCC that takes upon water load.
--------Buttress vertical walls with their axis normal to the plane of the slab that support the slab and transmit the water load to the foundation

ARCH DAM: -

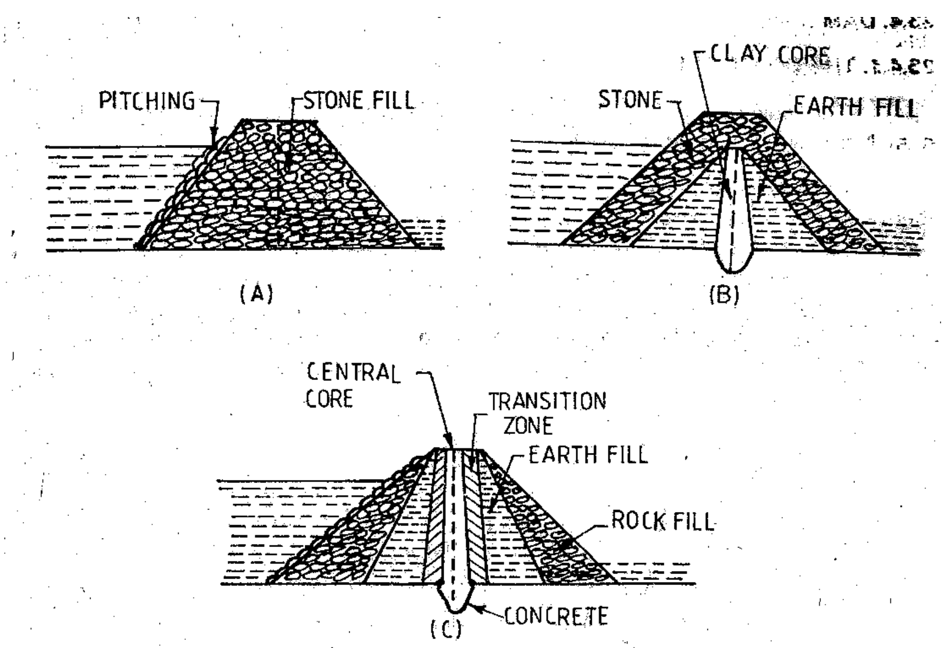
An arch dam is an impermeable concrete shell shaped s an arch in plan when curved in vertical section it forms a dome shape. Many gravity dams are arched in plan. But he characteristic of an arch dam is that it's cross section. Arch dam are thin, they require the least volume of construction materials of all designs yet their shape makes them the strongest of all types.



A=Plan B=Section

Example: - **IDDUK**I dam is the highest arch dam in Asia.

EMBANKMENTS: - These consists essentially core of impermeable material, such as clay or concreted, supported by permeable boulders of earth and rock fill, when a clay are used it is normally flanked by filters of permeable material such as sand to protect the core from erosion by the seepage of reservoir water through dam. Embankment dams, by virtue of the slopes required for their stability. Earth fill and rock fill dam are terms used to described suitable sedimentary materials such a clay, sand and rock blocks that cam be placed to forming safe embankment.



(Some types of Embankment Dams)

COMPOSITE DAM: -

Dam site which geological unsuitable which broad valleys and strong rocks on one side and weak ones on the other side. By combined gravity dam and earth dam.

SELECTION OF DAM SITES AND SELECTION CRITERIA: -

To construct a dam many important factors were borne in mind by the geologist and engineers. Among them safety and stability of the dam is most important. The stability and safety depends on three important factors

1). Choice of site for foundation

2). Material used in construction

3). Method of construction

Selection of site for dam is of maximum importance. Dams are constructed to preserve water for longer use. Reservoir must hold water and should not leak, therefore before the project is under taken the physiography, geologic sequence and structure of the rock formation in the river basin must be studied in great detail. The major is the foundation upon which the structure is built and the relation of foundation materials to the new and different condition of geologic environment such a stress and strain must be determined.

The following criteria's are very important while selection of sites for dam.

- ☞ The rock should be sound and resistant o the expected static and dynamic forces.
- ☞ The river valley slopes should be stable when the reservoir in full and also the abutment must be strong.
- ☞ The dam foundation should be safe from sliding especially in the place of gravity dam,
- ☞ The foundation and the reservoir walls should be watertight.
- ☞ The rocks of the dam site should be resistant to solution activity, erosion, decomposition and other detrimental effects of wetting and drying.
- ☞ The location of construction materials mainly concrete aggregate should be within and economically justified distance forms the project.

SELECTION OF DAM SITES IN IGNEOUS AND METAMORPHIC ROCKS (hard rock areas)

Safety and stability of any dam is largely depending on the nature, strength and structure of the rock formation. They must be sufficiently strong and impervious to offer a safe foundation and abutments. In such cases igneous and metamorphic rock are capable of supporting enormous load and are impervious to a greater extent, on the basis of mode of occurrence, igneous rocks are sub-divided into plutonic and volcanic rocks. In general, the plutonic rocks and volcanic rocks differ widely on their suitably for dam sites. Plutonic roks are strong and have adequate bearing and sharing strength for any engineering requirements.

Granite, Syenite, Diorite, gabbros, Genesis, Schist, Quartzite and other varieties of massive igneous and metamorphic rocks are capable of supporting enormous load and are impervious to the desired extent, provided they do not contain much of joints, shear-zones and such planes of weakness. Among metamorphic rocks, the schist's are generally of variable strength, while quart and hornblende schist's are rather strong, the mica schist's are relatively weak.

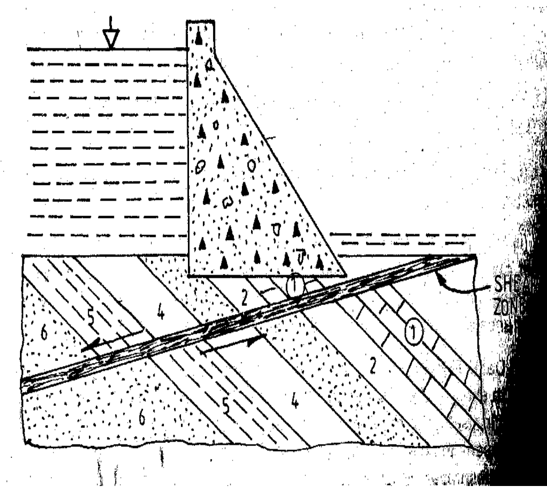
SELECTION FO DAM SITES IN SEDIMENTARY ROCKS

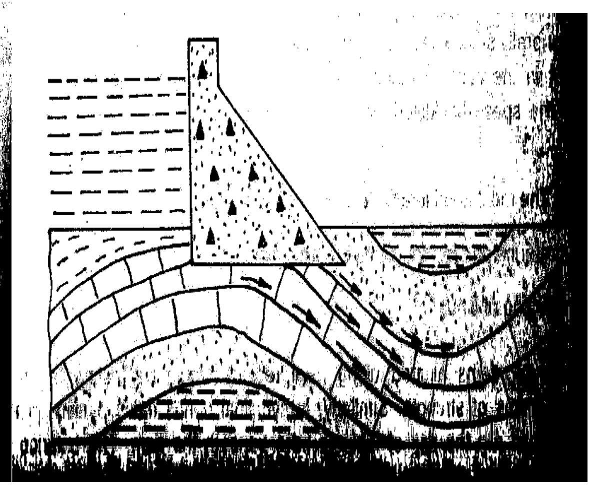
Thick and well-cemented beds of sandstones, grit, conglomerate and breccias are generally strong and impervious. However, the weak zones in such rocks may allow excessive percolation under the dam and these openings should therefore, be properly sealed by means of grouting. Massive and strong sedimentary rocks with calcareous matrix may become weak in course of time, due to removal of a portion of the cementing material in solution such foundation and abutment rocks, at dam sites should be studied and carefully protected. Limestone's, Dolomite marbles and other carbonate rocks are usually strong enough to support the weight of the dam. These soluble rocks, however contain enough of joints and solution cavities of variable dimensions, which act as suitable avenues for percolation f too much of water below the dam. A t dam sites therefore the exposures of carbonate rocks should examined carefully to ascertain the extent to which they are likely to allow leakage of water underneath rocks like shale, clay stone, mudstone etc., are rather weak in nature especially when they are moist.

Sandstones are frequently interred bedded with shale. These layers of shale may constitute potential sliding surfaces. Sometimes such inter bedding causes the undesirable properties of shale by permitting excess of water to shale, sandstone. Contact seepage may weaker shale surfaces and cause slider, which dip away from abutments and spillways cuts.

Unlike the massive igneous and metamorphic rocks the sedimentary rocks are characterized by the presence of bedding planes. In case of dams lying in sedimentary rocks, therefore, the bearing capacity and water tightness of he foundation are dependent to some extent, on the orientation of the bedding planes in space. Horizontal beds are most capable of supporting he weight of a dm since, in such cases; the load acts at right angles to the bedding planes. The weight of the dam, however, is not the only force acting on the foundation. The other forces in play are the thrust of the water in the reservoir and this tends to push the dam horizontally towards the downstream side of he reservoir. The resultant of these too mutually perpendicular forces is obviously inclined downstream. The exact amount of inclination of this resultant is however, dependent on the magnitude of forces.

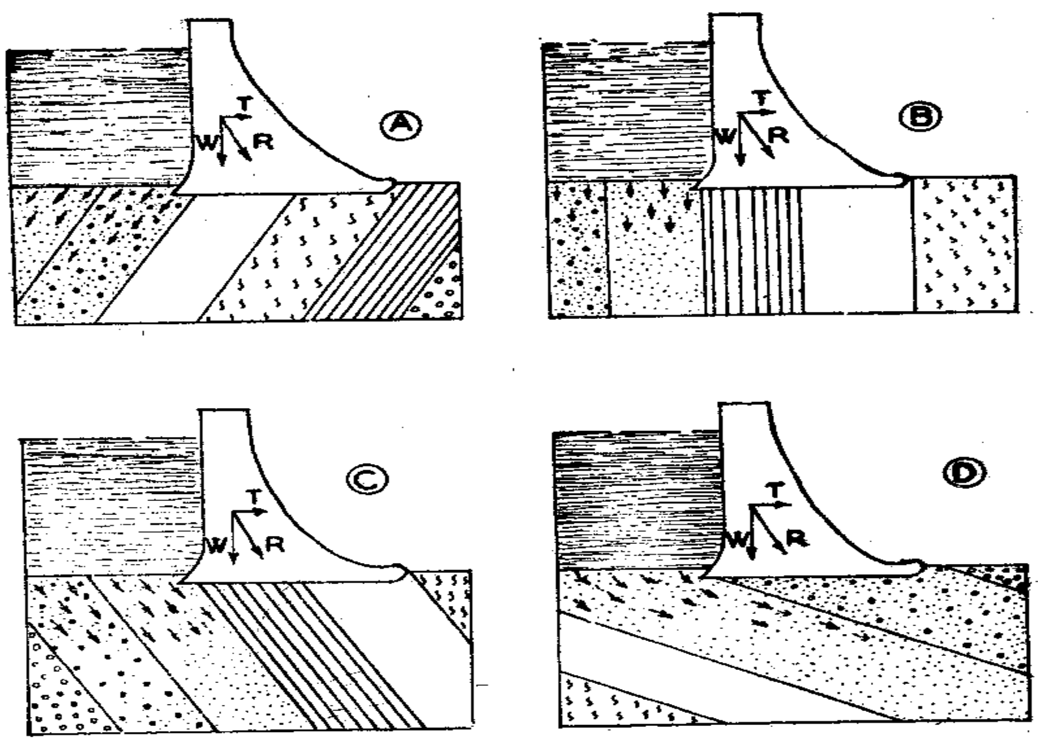
Leaving aside the aforesaid ideal condition sedimentary beds at dam sites may have any other orientation.





A B

A= SHEAR ZONE UNDER A DAM - UNFAVORABLE
B= EFFECT OF FOLDING ON DAM SITE



(T=Trust of water in Reservoir, R=Resultant force, W= Weight of the dam)

☞ Beds with steep upstream slope do not cause any problem at dam site **Fig. A.**

☞ The vertical beds are not likely to be dangerous as foundation for dams **Fig. B**.

☞ A steep downstream slope of the beds is likely to allow the water in the reservoir to more underneath the dam and exert uplift pressure on the structure **Fig. C**

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☞ If the beds exhibit a gentle downstream slope. The condition is worse, there is a great chance of seepage of much of water form to reservoir **Fig. D** .

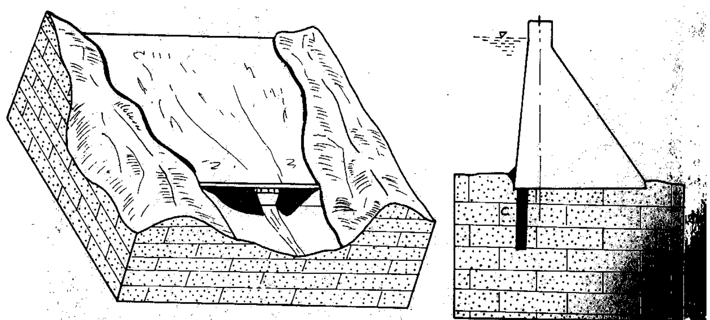
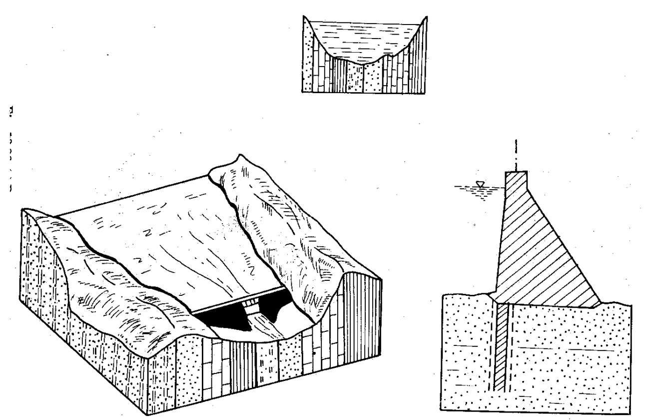


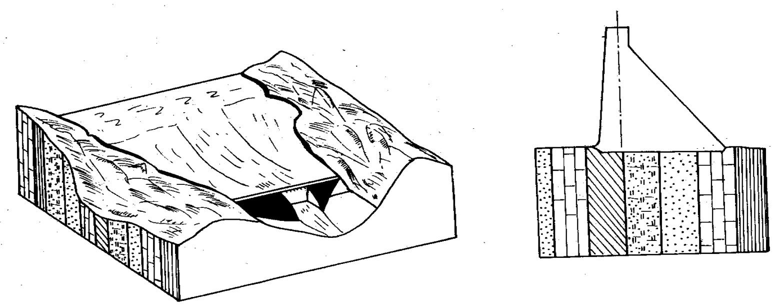
Fig. 13.27. Dam on horizontal beds. C—Impermeable concrete cut-off wall below the

Marshal For Dam, Guntersville Dam Tenn.

Dams on Horizontal Beds: - Horizontal beds provide good and safe foundations offering best support for the dam wall taking the load safely as bedded rocks are stronger in compression. But the presence of open bedding planes, seams and joints complicates the conditions and pose problems by providing passages for percolation of water beneath the dam.



Dams on Vertical Beds: -Vertical beds in dam sites either parallel to or across the dam axis act as vertical sheet piles and take weight of the dam safely. Jointed vertical beds, however allow leakage through bedding and joint plains, from the reservoir beneath the dam when they are parallel to the river course with detrimental effects on dm stability. In case of sites with a series of vertical beds, the dam structure would be safe if it is positioned with its heel resting on a thick intact impermeable bed as this acts as natural cut off wall.



Dam across anticline dip valley: - In this case there is a choice between a site on upstream dipping limb and a site on downstream dipping limb (Site A) and a site on downstream dipping limb (site B).

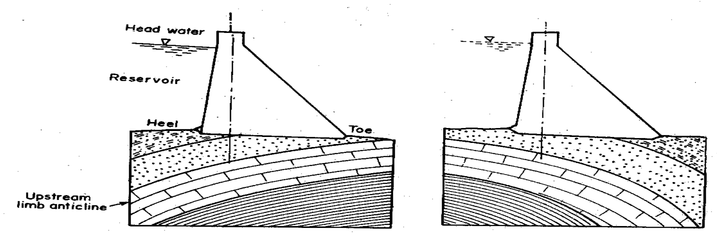


Fig. 13.35. Dam across anticlinal dip valleys.
Sita A : Dam on upstream dipping limb.
Site B : Dam on downstream dipping limb

Dam across synclinal dip valley: -In this case there is a choice between a site on downstream dipping (Site A) and another on upstream dipping limb (Site B). In case of site A on downstream dipping limb any permeable bed or open bedding below the dam wall allow percolation of water which may develop dangerous uplift pressures. In case of site B on upstream dipping limb, the situation develops typical artesian condition. When water leaks through artesian aquifer beneath, the dam is subjected to the dangerous artesian pressure, affecting its stability. Thus folded beds at the dam site therefore must be carefully studied in relation to the dam alignment for stability.

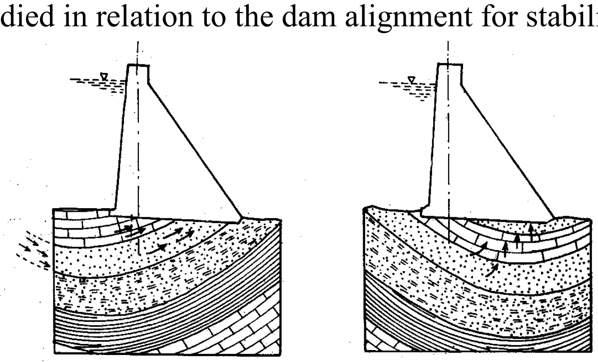
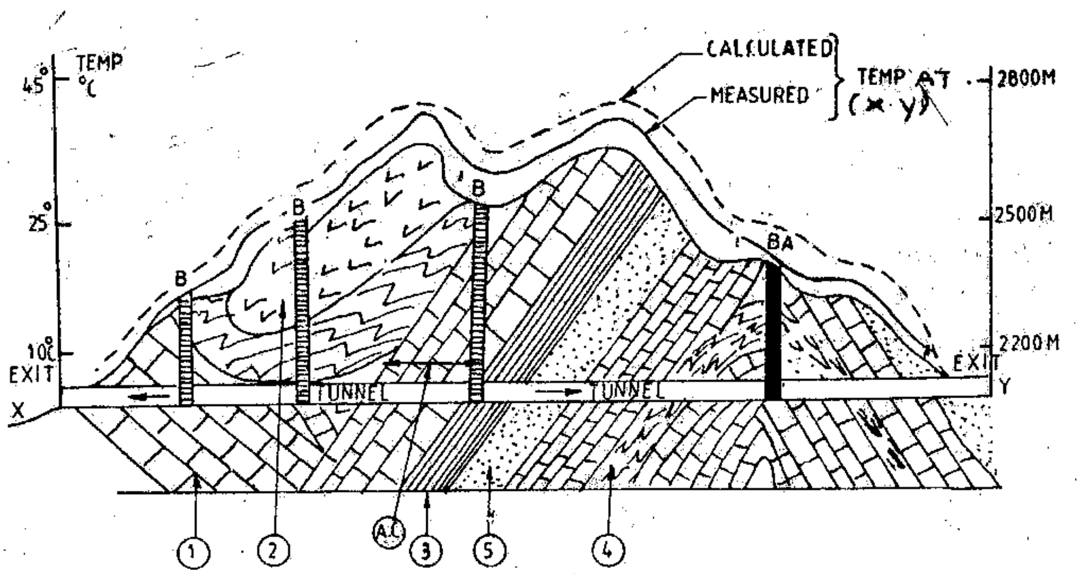


Fig. 13.37. Dam site across synclinal dip valleys.
AP—Artesian Pressure; UP—Uplift Presure C—Cut off; L—Leakage.

TUNNELS

Tunnels are passages underneath the earth's surface, which are always constructed with some specific purpose. Along roads and railways, tunnels are driven through hills with a view to providing a short t and convenient route across the natural obstacle. Tunnels can be driven through a rock or earth mass by methods used in mining including blasting. Either in normal air or using compressed air can do this. In rare cases, mining operations in soft ground such as quick sand may be carried on by applying artificial freezing or chemical stabilization of the ground.



A Typical Geological Profile

1= **Limestone**, 2= **Volcanic**, 3= **Clay**, 4= **Quartzite**, 5= **Sandstone**, BA= **Dyke**, AC= **Artesian Condition**, B= **Boreholes**

TUNNEL TERMINOLOGY

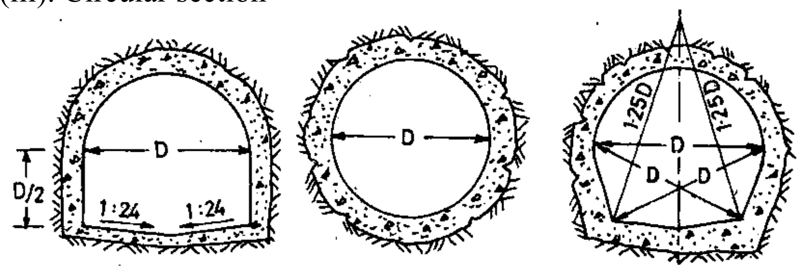
A tunnel is horizontal excavation that is open to the ground surface at each end. When an excavation proceeds in a vertical or near-vertical direction and is open to the surface only at the top, is called SHAFT. A drift is similar to a tunnel, except that a drift is open to the surface at one end only. The term rise indicating an inclined excavation driven form the main tunnel. Stope also used as a descriptive term to indicate that during tunnel excavation, the rock in the tunnel roof keeps dropping out thus the roof of the tunnel is did to be stopping upwards.

There are four terms commonly used to describe the location of parts of the tunnel cross section. There is the floor or invert, at the bottom of cross section; the flat strut that sometimes is used instead on an arch is called an invert strut. The top of the cross section is the roof, also referred as the back or crown. The sides of the tunnel section are referred to as the tunnel walls and spring line is the pint where the curved portion of the roof intersects the top of the wall.

SHAPE AND SIZE OF THE TUNNEL CROSS-SECTION

The tunnels may be constructed in different shapes, depending on the nature of the soil/rock and other practical considerations. The three types of sections, which are commonly adopted, are:

(i). D-Shape
(ii). Horse-shoe shape; and
(iii). Circular section



(a) D-shape (b) Circular shape (c) Horse-shoe shape

(i). D-Shape: - is usually adopted in rocks, where unlined tunnels are proposed to be constructed. Such a section has an arch roof and straight vertical sides. The arch roof can easily take vertical loads and transfer them to the sides. The sides may be constructed in RCC, in case of soft soils. This section is suitable for subways and for navigation tunnels. These are the principals; advantages for this section, and make it the usually adopted section for highway and railway tunnels (Fig. a).

(ii). Horse-shoe shape: - is usually lined, and offers strong resistance to external pressures from water bearing soils or soft grounds: as well as the internal pressures of fluids, if passing through the tunnels. It is therefore, most suitable for sewers, water conduits, etc. Circular section, however, is not suitable for roads and railways, as more filling will be required for obtaining a flat base (Fig. b).

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(iii). Circular section: - having a semi-circular roof together with arched sides and a curved invert. When lined, this c/s offers good resistance to external ground pressure, and serves to combine the advantages of both the D-shaped and circular sections. It is the best shape suited for traffic tunnels, as the floor if the tunnel is nearly flat, which also provides working space to the contractor for storing materials during construction and is also suitable for carrying water or sewage. This shape is a very commonly used ofr highway and raiway tunnel in all countries of the world (Fig. c).

In view of the fact that the construction of a tunnel involves penetration through rocks of various types, it is apparent that the convenience, cost and stability of tunneling operation is dependent primarily on the geological characteristics of the country rocks along the alignment of the proposed tunnel. The geologic factors, which govern the extent to which tunneling conditions may be favorable or adverse and thus determine the cost and stability of tunnels.

☞ The nature of he country-rocks occurring along the alignment of the tunnel.

☞ The geological structure of the region.

☞ The position of the water table within the country-rocks and the Prevailing ground water condition along the length of the Tunnel.

The convenience and cost of tunneling operation as well as the safety and stability of a tunnel depend, to a considerable extent, on the nature of the rocks, which occur along the course of the tunnel. Crystalline rocks of igneous origin (like granite, syenite, diorite) can be excavated with great difficulty, particularly if they are massive and devoid of planes of weakness. The cost of tunneling through rocks of this type is naturally high, but this extra cost is compensated in another form, since such tunnels normally require no protective inner lining for their safety and stability. Presence of joints, shear zones and other planes of weakness, on the other hand reduces the strength of these rocks and under such conditions the cost of excavation likely to be reduced. But regarding safety t is very dangerous, we have to give proper protection to the lining of the tunnel. Rocks like basalt (volcanic rocks) are had and tough and at the same time it contains joints and vesicles filled up with water, tunneling through such rocks re generally hazardous.

In so far as sedimentary rocks are concern, tunneling through thick and compact beds of sandstone like shale, limestone, marl, and clay are likely offer no trouble. Unconsolidated sediments like gravel and boulder beds and loose soil and alluvium can be excavated easily, but such tunnels always require a strong inner lining for their safety and stability. For the same e reason, tunnels through crushed and fragmented rocks must be protected by means of suitable lining. Roof load in tunnels through unconsolidated or fragmentary materials is rather insignificant provided the thickness of the roof exceeds three times the diameter of the tunnel.

Among metamorphic rocks, the compact and massive gneisses and granulites can be excavated with great difficulty, while the softer verities like schist’s, Phyllis’s, slates and marbles are not likely to offer much of resistance.

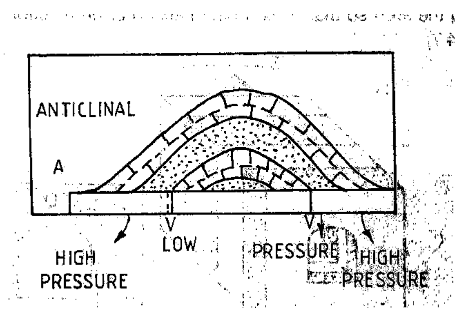
At any tunnel site, the geological structure of the surrounding rocks determines not only the prevalent tunneling condition but also the stability of the tunnel. The common structural features present in the different rock-types are joints, fault- planes, shear-zones etc., which impart some amount or weakness to the rocks affected by them

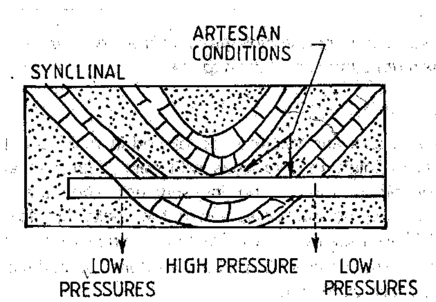
TUNNEL LOCATED IN ANTICLINE AND SYNSLINE

Folds signify beds and curvatures and a lot of strain energy stored in the rocks. Their influence on design and construction of tunnels is important from at least three angles.

Folding of rocks introduces considerable variation and uncertainty in a sequence of rocks, so that entirely unexpected rocks might be encountered along any given direction. This situation becomes especially serious when folding is not recognized properly in preliminary or detailed surveys due either to its being localized or to misinterpretation.

Folding of rock introduces peculiar rock pressures. In anticline folds, loads of rocks at the crest are transferred by arch action to a great extent on to the limbs, which may be highly strained,





A. Anticlinal – low pressure in middle region **B.Synclinal- high pressure in middle region**

These conditions are reversed when the folds are of synclinal types. In such cases, rocks of core regions are greatly strained. Again, the axial regions of folds, anticline or syncline, having suffered the maximum bending are more often heavily fractured. The alignment of a tunnel passing through a folded region has to take these aspects in full consideration. When excavations are made in folded rocks, the strain energy is likely to be released immediately, soon after or quite late to tunneling operations; very often causing the dreaded rock bursts. Very slow release of small amounts of strain energy might cause bulging of walls or caving in of roofs.

Folded rocks are often best storehouses for artesian water and also ideal places of aquifers. When encountered during tunneling unexpectedly, these could create uncontrollable situations. The shattered axial regions being full of secondary joint systems are highly permeable. As such very effective drainage measures are often required to be in readiness when excavations are to cross-folded zones.

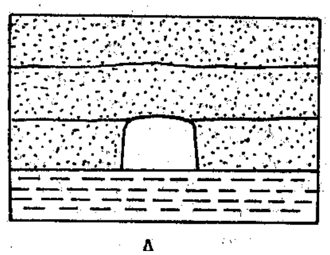
TUNNELING ALONG DIP AND STRIKE JOINTS SYSTEMS

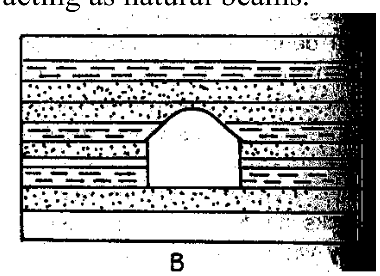
The design, stability and cost of tunnel depend not only on the type of rock but also on the structures developed in these rocks.

DIP AND STRIKE: -

These two quantitative properties of rocks determine the attitude of the rocks and hence influence the design of excavation to a great extent. Three general cases may be considered.

Horizontal strata occur for longer tunnels, when encountered for small tunnels or for short lengths of long tunnels, horizontally layered rocks might be considered quite favorable. In massive rocks, that is, when individual layers are very thick, and the tunnels diameter not very large, the situation is especially favorable because the layers would then over bridge flat excavations by acting as natural beams.



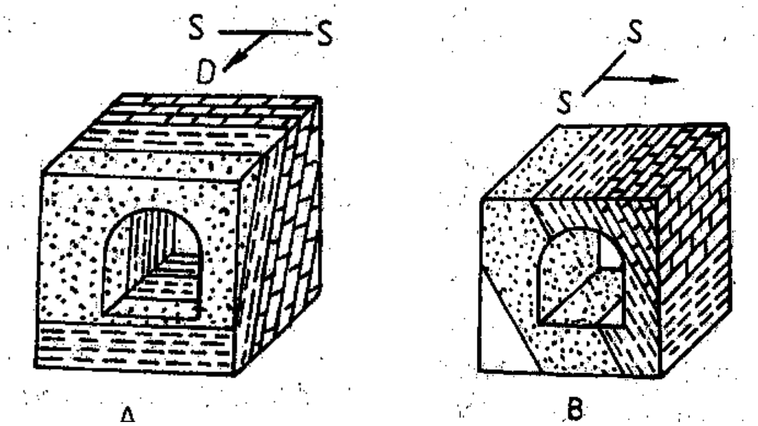


A= Safe situation **B=Unsafe at Top**

But when the layers are thin or fractured, they cannot be depended upon as beams, in such cases either the roof has to be modified to an arch type or has to be protected by giving a lining.

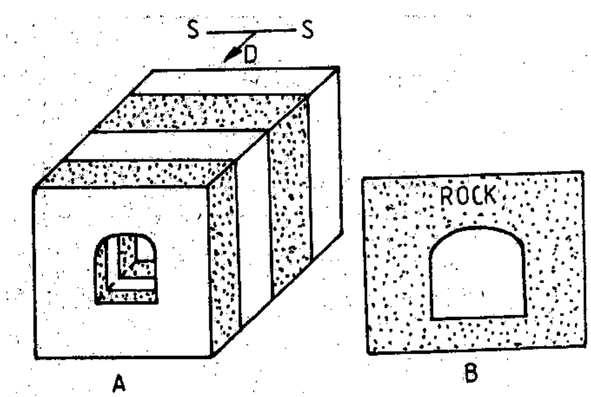
Moderately inclined strata, such layers that are dipping at angle upto 45^{o} may be said as moderately inclined. The tunnel axis may be running parallel to the dip direction, at right angles to the dip direction or inclined to both dip and strike directions. Each condition would offer a different set of problems.

In the first situation that is, when the tunnel axis is parallel to the dip direction the layer offer a uniformly distributed load on the excavation.



A= Dip of layers B=Strike of layers

When the tunnel axis is parallel to dip or parallel to strike or inclined to both dip and strike directions. In vertical rocks for examples, when the tunnel axis is parallel to dip direction, the formations stand along the sides and on the roof of the tunnel as massive girders. An apparently favorable condition, of course, provided all the formations are inherently sound and strong when considered individually also.



Tunneling in steeply inclined strata

A= General View B= Part shown in enlarged section

In tunnels running parallel to strike of vertical beds, it is more than likely that a number of bedding planes are intersected at the roof and along the arch so that natural beam or arch action gets considerably weakened.

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RESERVOIRS

An extensive storage facility for a pre-determined quantity of water behind a dam constructed across a river.

Functions of reservoir: A year round supply of a calculated quantity of water through controls and regulations for irrigation, power generation, drinking, recreation, navigation & flood control.

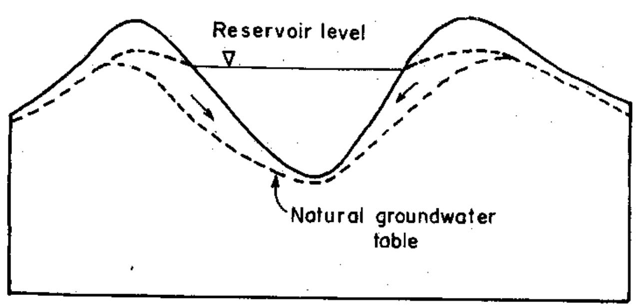
The important criteria for the selection of favorable sites for reservoirs are
#An effective storage
#Water tightness
#Do not silt up soon
A good reservoir site would be a valley section constructed be a narrow gorge at its outfall with steep banks. The competence of the selected span of a river valley depends upon the geology of the area, rock types, their conditions and permeability governed by defects like joints, cracks and fissure system, faults their orientation and relation to bedding, solubility dissolution and erosion.

Reservoir problem
No reservoir site is practically watertight. Reservoirs fail due to excessive leakage or rapid silting. Thus the chief problems associated with reservoirs are seepage & leakage problem and sediment problem

Water tightness: - The water tightness of reservoir can fairly be determined by the nature of the river and ground water conditions.

Nature of rivers: - Effluent rivers do not allow leakage through porous beds provided the reservoir level does not overtop the groundwater divide. Occurrence of seeps and springs above the reservoir level indicates the effluent nature of river. The will be large-scale leakage through permeable formation in case of influent river.

Water table: - The most important factor controlling leakage is the position of water table in the area.



A steep w

Fig. 13.38. (a) Steep water table indicating tight ground.

suggests large opening in rocks or their little holding capacity.

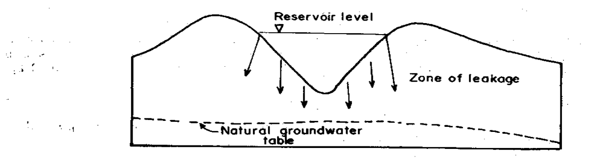


Fig. 13.38. (b) Flat water table indicating large openings in the ground.
Example : McMillan and Hondo Reservoirs, New Mexico, USA.

Sediment Problem: -When a dam is constructed across a river and a reservoir is created, the transporting capacity of the river in the backwater area gets reduced and the rivers borne sediment got by erosion of rock formations, landslides and forest fires in the catchments area is dropped in the still water of the reservoir behind the dam. These accumulate on the reservoir floor over a considerable area and thickness analogous to a delta deposits. This reduces the capacity of the reservoir and impair many of its functions like power generation, flood control, navigation etc.

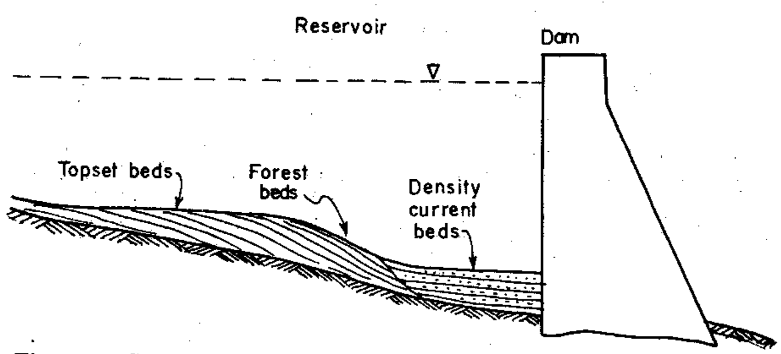


Fig. 13.39. Sediment deposition on the reservior floor behind the dam.

Silt control: - Silting in reservoirs, however is reduced to some extent by control of sediment production is soil erosion, landslides, and forest fires in the catchments area by

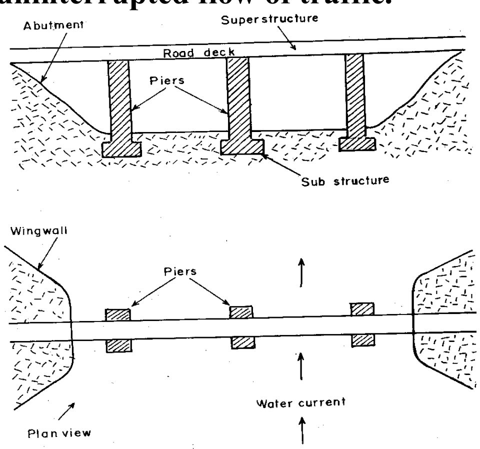
Water shed treatment (soil conservation measure): Reforestation range seeding, strip cropping and contour farming

Structural measures: - Construction of farm ponds, flood-retarding structures. Silt ejectors, check dams, silt barriers grade stabilization and channel improvement.

BRIDGE SITES

Bridge is a structure spanning a river or a depression providing communication across it. Bridges are integral parts of roads and railways. They are constructed across river valleys, gorges, canals and other depressions in order to connect places separated by them for an

uninterrupted flow of traffic.



Parts of Bridge

Bed: - **Surface of firm ledge or bedrock providing a stable foundation for bridge piers.**

Abutment: - **The end supports of a bridge to withstand thrust**

Bridge: - **Load bearing masonry or concrete surface of a bridge carrying and distributing the traffic load to the main beam.**

Wing wall: - **A masonry or concrete wall that guides a river into a bridge.**

Pier: **- A rectangular, oval or circular masonry or RCC column that supports the superstructures of abridge erected from a firm bearing bed for stability.**

A bridge structure consists of two components a). A Substructure

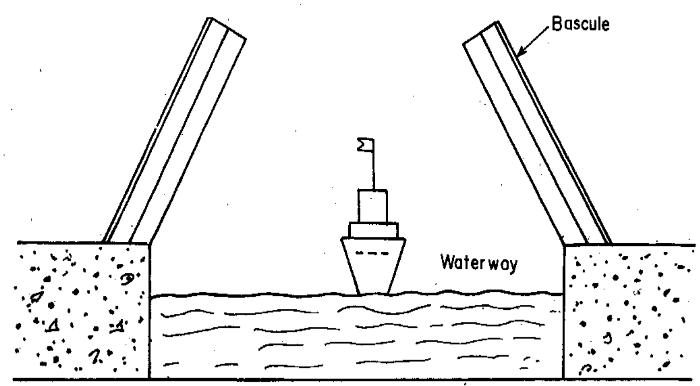
b). A Superstructure

Substructure: - **This consists of constructions on the banks, piers, wing walls and foundation.**

Superstructure: -**This comprises of construction that rest on the piers and the abutments include girders or beams.**

BRIDGE TYPES: - It is classified into I). Stationary bridges
II). Movable bridges

Stationary bridges: - **These are common bridges constructed across valleys and depressions built of masonry or concrete accommodating roads or railways. Masonry is used for arch bridges. Reinforced or priestesses concrete is used for medium to long bridges, in some cases steel is used. Suspension bridges are the best example.**



Movable bridges

Movable bridges: - **These are adopted across waterways that accommodate shipping. These are consists of one or two movable steel sections or spans- single or double bascules. These are lifted up at either end to allow ships to pass through and then lowered back to position providing normal road or railway.**

Bridge problem and geologic parameters

Bridges are subjected to sudden loading due to traffic. The weight of the bridge structure and the traffic loads are o be safely transmitted to the foundations and

abutments. Thus the stability, safety and economy of bridges depend largely on the geologic parameters such as conditions of the foundation and abutment rock formation and materials.

The important bridge problems that lead to the failure are

 # Erosion of the piers and wing walls

 # Deep scouring and collapse of bridges

 # Washout due to flood currents

 # Settlement of piers

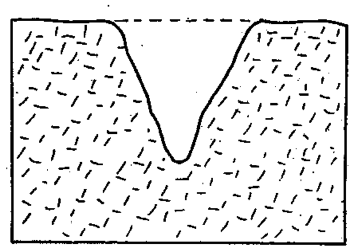
 # Earthquake effects

GEOLOGY OF BRIDGE SITES

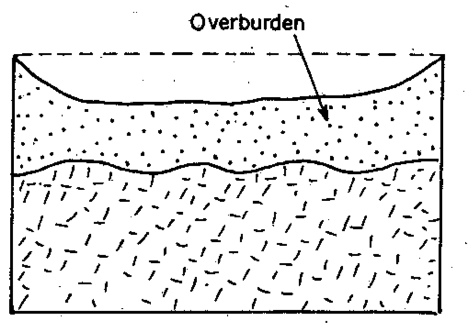
An ideal site for the construction of a bridge is the one across a valley cut in sound rock and where the stream flow is free from scour, provoking currents due to bends and other causes. A high stable bank, narrow stretches of water accommodating a bridge of minimum length with little or no effect.

The important geological aspects and conditions are

 # Bed rock at round surface i.e. sound hard rock profile of the bed and banks of valleys, canals and depressions.



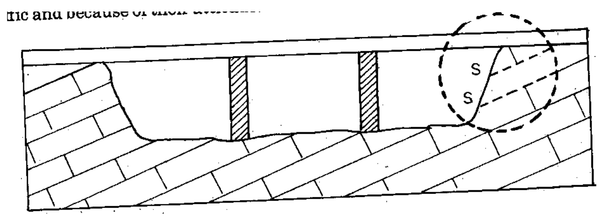
 # The piers and abutments of bridges should be constructed on hard intact rocks only and not on overburden such as fill, rock debris sand etc.



 # Rock formation should be intact, strong and tough without defects and weak planes.

 # Intact intrusive igneous rocks like granite, compact basalt, Sedimentary like hard Sandstone free from excessive joints and metamorphic like massive gneiss, quartzite provide excellent foundation abutment and bearing materials.

 # Bedded and Jointed formations especially those dipping into the river at lesser angle than the slope of the natural banks always dangerous as they tend to slide at any movement it is shown in figure.



 # Faulting brings rocks of diverse characters ad strength together along the fault line. Any further displacement at the fault contact may adversely affect the piers like displacement, tilting are took place abridge structure. Therefore it is very essential to treat the fault one well and substructure suitability designed.

 # Soluble formations like Limestone, Gypsum rocks are enlarged with elongated joints solution channels networks of excessive cracks create serious problems like understanding of banks.

APPLIED ENGINEERING GEOLOGY

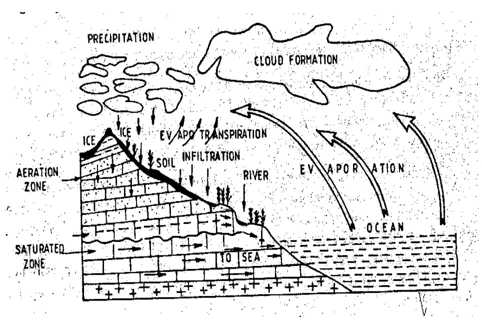
UNIT - 07

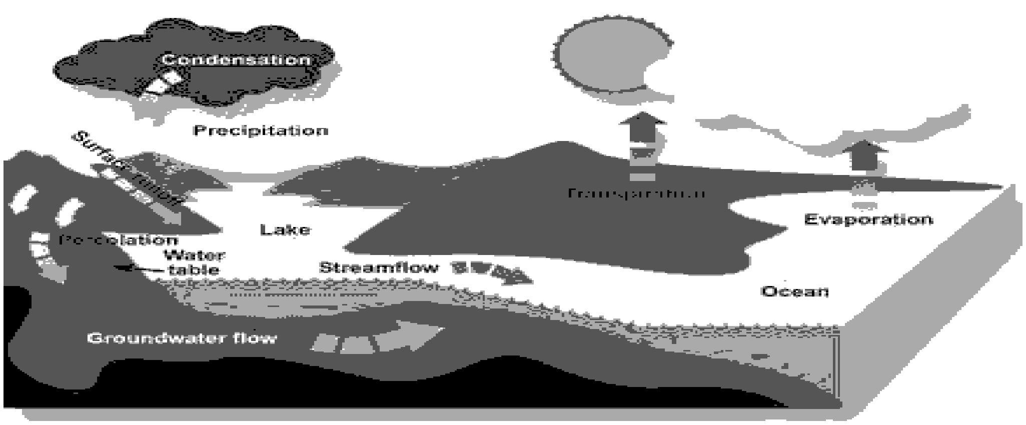
Content :

HYDROLOGY

- **Hydrological cycle**
- **Aquifers and its types**
- **Geological & Geophysical investigation of ground water**
- **Re- charge of ground water**

HYDROLOGICAL CYCLE





HYDROLOGICAL CYCLE

In one form or another, water occurs practically everywhere, varying in quantity from an almost unlimited supply in the oceans to nearly none in desert regions. It occurs in the atmosphere as water vapors, clouds and precipitation. On the earth's surface it is found principally in streams, in lakes and in the oceans. Beneath the ground surface it occurs under various classifications.

The hydrosphere, atmosphere and upper part of the lithosphere constitute the three media in which the water of the earth circulates. The circulation of water from the oceans to the atmosphere to the lithosphere and the lithosphere to the oceans, through complex and interdependent process including precipitation, runoff, groundwater flow, evaporation and transpiration is called the Hydrological Cycle.

The oceans, comprising the largest single body of water, having 78% of the earth's surface area and store 98% of the earth's water resources. The water evaporated from the sea and land forms a part of the atmospheric moisture which when it moves into low temperature regions, is condensed and precipitated as rain and snow. When humidity is high, moisture condenses on the soil surface as dew. Before reaching ground, apart or all of the precipitated water may get intercepted by plants in the atmosphere itself. In dense forest a substantial part of the precipitated water may be returned to the atmosphere by evaporation. The part of the water reaching the ground is dissipated in several ways.

It may be absorbed in the ground, evaporated, transpired by plants, or may flow over ground as runoff into streams to reach the oceans or inlands basins. Runoff occurs when the ground surface is situated with water. The water absorbed in the ground infiltrates down through interstices of rocks till it reaches the ground water body and completes the hydrologic cycle.

OCCURRENCE OF GROUND WATER

The rainfall that percolates below the ground surface passes through the voids of the rocks and joints the water table. These voids are generally interred connected permitting the movements of the groundwater. Some of the rocks are not permitting the water inside, hence the mode of occurrence of ground water depends largely upon the type of formation, and hence upon the geology of the area.

In fact all the materials of variable porosity near the upper portion of the earth's crust can be considered as a potential storage place for the groundwater and are called as ground water reservoir. The volume of water contained in the found water reservoir in any localized is. The water storage capacity of the ground water is depend on

1). The porosity of the rocks
2). The rate at which water is added to it by infiltration
3). The rate at which water is lost from by evaporation, transpiration, seepage and with drawl by man.

POROSITY: - the porosity of the rocks, which is the major geological criteria for occurrence of gorund water, is a quantities measurement of voids present in the rock. It is generally defined as the percentage of the voids present in a given volume of aggregate.

$$\text{Porosity } (n) = \frac{\text{Total volume of voids in the aggregate } (V_v)}{\text{Total volume of the aggregate } (V)} \qquad n = \frac{V_v}{V} \times 100$$

Porosity depends upon the shape, packing and degree of sorting of the component grains in a given material uniform and well-sorted grains given rise to higher porosity, whereas heterogeneous grains with irregular arrangement decrease the porosity.

Porosity of few rocks

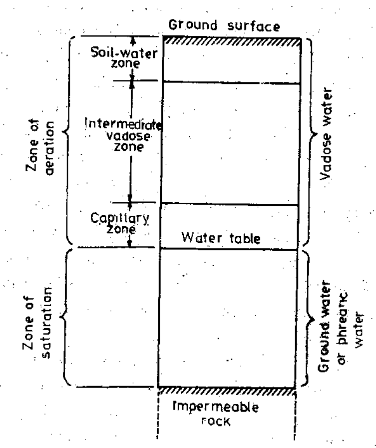
Granite	---- 1.5%	only gravel	--- 25%
Slate, Shale	---- 4%	only sand	--- 35%
Limestone	---- 5-10%	only Clay & Soil	--- 45%
Sand and Gravel	---- 20-30%		

PERMEABILITY: - The ground water is stored in the pores of a rock, and will available in the underground rocks, only if they are sufficiently porous. The permeability is defined as the ability of rock or unconsolidated formation to transmit or pass water through itself.

FORMS OF SUBSURFACE WATER

In general the tern groundwater or subsurface water refers to the water that occurs below the surface of earth. The main source of groundwater is infiltration. The infiltrated water after meeting the soil moisture deficiency percolates deeply and becomes groundwater. The groundwater is free from pollution and is very useful for domestic use in small towns and isolated forms. The subsurface is considered into two zones

Zone of saturation
Zone of aeration



ZONE OF SATURATION: - This zone, also known, as groundwater zone is the space in which all the pores of the soil are filled with water. The water table forms its upper limit and marks a free surface.

ZONE OF AERATION: - In this zone the soil pores are only partially saturated with water. The space between the land surface and the water table marks the extent of this zone. Further the zone of aeration has three sub zones—SOIL WATER ZONE, CAPILLARY FRINGE, INTERMEDIATE ZONE

SOIL WATER ZONE: - This lies close to the ground surface in the major root band of the vegetation from which the water is lost to the atmosphere by evaporanspiration. The lithological character of the belt is most important from the groundwater pint of view, as this is the zone, which largely controls the infiltration of rainwater.

CAPILLARY FRINGE: - The belt overlying the water table in which water is drawn up from the zone of saturation and held against the force of gravity. The water is held by capillary fringe is determined by the texture of the rock pore space above the zone of saturation. The capillary rise in sediments ranging from clay to coarse sand varies roughly as follows. The capillary fringe moves up and down depending on the fluctuation of the water table.

INTERMEDIATE ZONE: - The intermediate zone, as the name indicates lies between capillary fringe and the belt of soil moisture. In areas where the water table lies close to the land surface, the intermediate zone mat absent. In areas of deep water tables the intermediate zones may attain a thickness of hundred of meters.

All earth materials; from soil to rocks have pore spaces. Although these pores are completely saturated with water below the water table from the groundwater utilization aspect only such material through which water moves easily and hence can be extracted with these are significant. On this basis the saturated formations are classified into four categories.

A). AQUIFERS: - An aquifer is a saturated formation of earth material, which not only stores water but yield it in sufficient quantity. Thus on aquifer transmits water relatively easily due to its high permeability. Unconsolidated deposits of sand and gravel form good aquifers.

B). AQUITARD: - It is a formation through which only seepage is possible and thus the yield is significant compared to an aquifer. It is partly permeable.

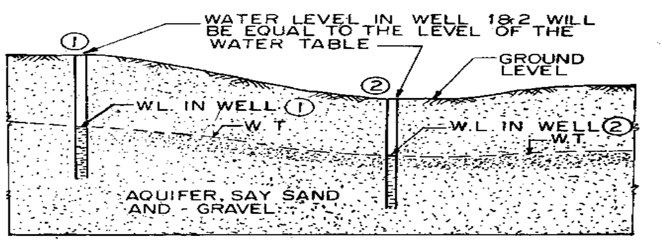
C). AQUICLUDE: - It is a geological formation, which are porous but not permeable. Such rocks may bear water but do not yield the same as they are impermeable. Argillaceous rocks like shale and clay are typical examples.

D). AQUIFUGES: - It is a geological formation, which are neither porous nor permeable. Naturally, these are not, suitable for ground water occurrence. Massive granites and quartzite are typical examples.

TYPES OF AQUIFERS

Aquifers vary in depth, lateral extent and thickness, but in general all aquifers fall into two categories.

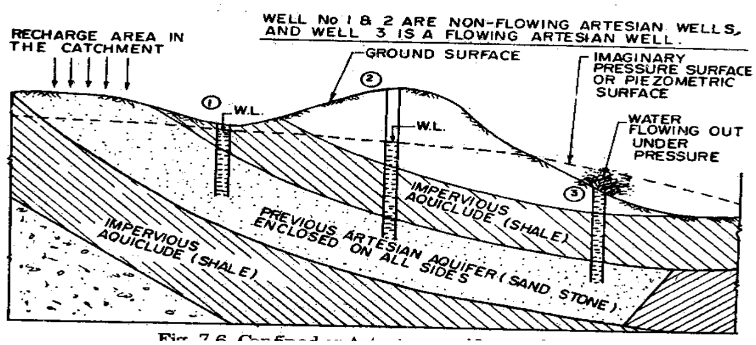
1). UNCONFINED AQUIFERS
2). CONFINED AQUIFERS



UNCONFINED AQUIFERS

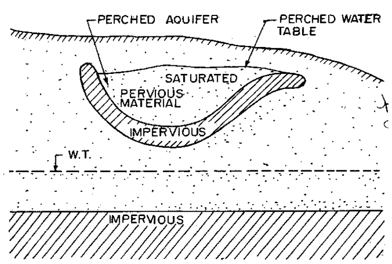
1). UNCONFINED AQUIFERS: - Unconfined aquifers also called non-artesian aquifers, are the top most

Water bearing strata having no confined impermeable over burden lying over them. The ordinary gravity wells of 2-5 mts diameters, which are excavated through such top most aquifers are known as unconfined wells. The water level in these wells will stand equal to the level of the water table as shown in figure. Such wells are, therefore also known as water-table wells or gravity wells.



CONFINED AQUIFERS (Artesian well

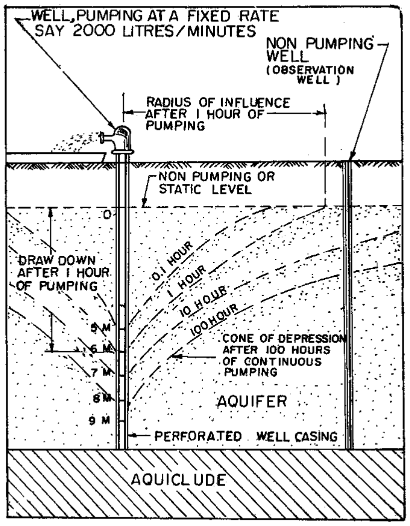
2). CONFINED AQUIFERS (Artesian well): - When an aquifer is encased on its upper and under surface by impervious rock formation and is also broadly inclined so as to exposed the aquifer somewhere to the catchment's area at a higher level for the creation of sufficient hydraulic head, it is called a confined aquifer or an Artesian aquifer. A well excavated through such an aquifer yields water that often flows out automatically, under the hydrostatic pressure, and even rises or gushes out of surface for a reasonable height. However, the ground profile is high, the water may remain well below the ground level. Where water is gushing out automatically is known as flowing wells.



PERCHED AQUIFERS

PERCHED AQUIFERS: -Perched aquifer is a special case, which is sometimes found to occur within an unconfined aquifer. If within the zone of saturation, an impervious deposit below a pervious deposit is found to support a body of saturated material, then this body of saturated material that is a kind of an aquifer is known as the perched aquifer. The top surface of the water held in the perched aquifer is known as the perched water table.

Pumping of wells and cone depression



When water is drawn from a well by a pump etc, the water level in the well will immediately decline, so that hydraulic gradient is established towards the well, forming a cone of depression. The development of this hydraulic gradient enables the flow of water into the well from the surrounding aquifer.

The difference between the original non-pumping level of water in the well, and the pumping level is called the draw down and the maximum distance from the pumped well is known as radius of influence. As the pumping continues the drawn down increases, and the radius of influence of the well expands, until the equilibrium conditions are established. This is so happening, only when the outflow becomes equal to the yield and in such an equilibrium condition, the draw down will become constant.

If several closely spaced wells are drawing water from the same aquifer, then their respective cone of depressions overlap, so that they interfere with one another. This results in greater draw down in each well condition that could result in a general lowering of the water table in this heavily pumped area.

GROUNDWATER PROSPECTING

The term groundwater prospecting means searching for the ground water. It not only includes to find out the places where ground water is available, but also to find out its approximate quantity and quality as well. Carrying out can do this job, what are called ground-water survey.

These groundwater surveys or investigations are extremely important in arid regions, where ground water is scarcely available. In such regions, if such surveys are not carried out in advance, and the excavation of wells is undertaken, then everything may come out to be futile, as no sufficient and good quality water may become available for obtaining the required water supplies.

Besides this problem of conducting such surveys for obtaining water supplies, another problem, which an engineer may face, is to detect whether any ground water would be encountered in underground construction operations, and the likely problems that it may create in those operations. The engineer will also have to find out the means and ways to check and control that ground water, and the problems created by it.

For both these purposes, investigations would have to be conducted to detect the presence of water at the given region or at the particular site, and to fairly estimate its quality or quantity, or both.
The very first indicator of the presence of groundwater in an arid region is the presence of plants and vegetations, especially the plants that habitually grow in arid regions only when they can send their roots down to the water table. The type of grown plants will also, to certain extent, indicate the depth of the water table. The plants may also to some extent indicate the quality of the groundwater.

The other important type of geophysical investigation, which may be performed for groundwater exploration, is called the Resistivity surveys.

Resistivity surveys make use of the fact that water increases the conductivity of rocks, and thereby decreasing their resistivity. Hence, if it can be established geologically, that the same rock formation exists for a certain depth, say 100m, and by electrical testing it is found that the resistivity is decreasing below say 60m depths, then it can be easily concluded that water is present below 60m depths.

ELECTRICAL RESTIVITY METHODS

These methods are based on the principle that electrical resistivity of loose unconsolidated or partially consolidated surficial materials like the products of rock weathering and erosion such as soil loss, alluvium sand and clay is different from that of bed rock over which they are deposited. The more porous or jointed and fissured the rock lower is its electrical resistance. Thus intact igneous and metamorphic rocks in general greater resistance than sedimentary rock.

Geologic Bodies	Resistivity
Clays	200-500ohms/cm
Sedimentary Rocks	5000-10,000 Ohms/cm
Igneous Rocks	Above 10,000 Ohm/cm
Metamorphic Rocks	………do………

Equipment: - The receptivity equipment consists essentially

1). Power pack of a high voltage battery 200v as a source of current and a measuring assembly consisting of a voltmeter or potentiometer for measuring small potential difference accurately and a multi range milliammeter for measuring current.

2). Four Stainless Steel metallic spikes (electrodes) about 800mm long 20m dia prod vided with heads for easy driving into the ground and clamps for cable connection.

3). Abundant stranded insulated single conductor cable of 0.5m2 conducting area. The cable is wound on portable reels.

FIELD PROCEDURE AND INTERPRETATION

In this method, four electrodes are driven into the ground in a straight line at equal distances and electric current is intruded through, two outer spikes called current electrodes, which are connected by insulated wire through a mill ammeter to a power pack. The current flows through the ground.

Theoretically the current flow extends to indefinite depths but the intensity diminishes with dept. For practical purposes the current is considered to be confined within a depth approxcipamately equal to one-third the distance between the current electrodes

The current impressed into the ground is recorded by the miliammeter.

In homogeneous ground the lines of current flow have a definite shape independent of the medium of the distance between electrodes. As such the current penetration can be varied by varying the electrode spacing.

Next, the voltage drop due to potential difference between two inner electrodes called potential electrodes is measured from the potentiometer. Restivity is then obtained by the expression

R=2P/I

R=Resistivity, P= Potential difference, I= Current applied between electrodes

The value of R so measured is only apparent resistivity of the ground as the ground is rarely homogeneous.

The underground configuration of rocks is deduced by variations in the apparent resistivity obtained as a function of depth.

The depth of penetration is controlled either by expanding electrode spacing or moving the electrode system as a whole. The depth determined would be over the central point of electrode determined would be over the central point of electrode system. This forms the station sounded.

Thus principally there are two distinct methods of resistivity determinations
a). Expanding electrodes separation techniques or Vertical Profiling
b). Lateral traversing techniques or Horizontal Profiling.

a). Expanding electrodes separation techniques or Vertical Profiling: - In this method electrode spacing is increased about a fixed central point thereby depth of current penetration is increased. If the ground is homogeneous resistivity is constant for all electrode spacing and equal to actual resistance of the geological formation. Therefore the graph of resistivity against electrode spacing would be a constant.

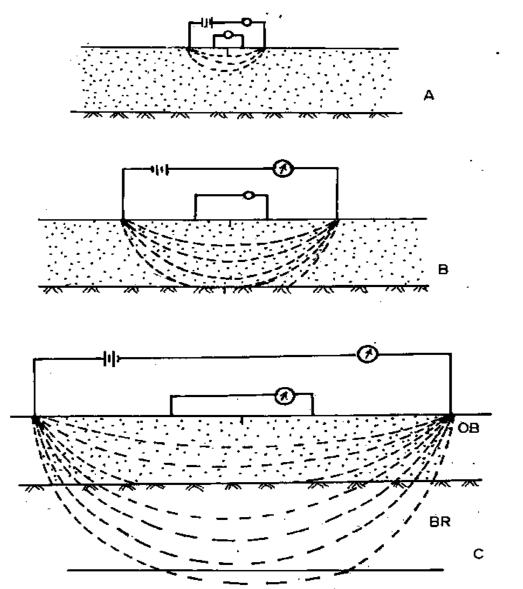
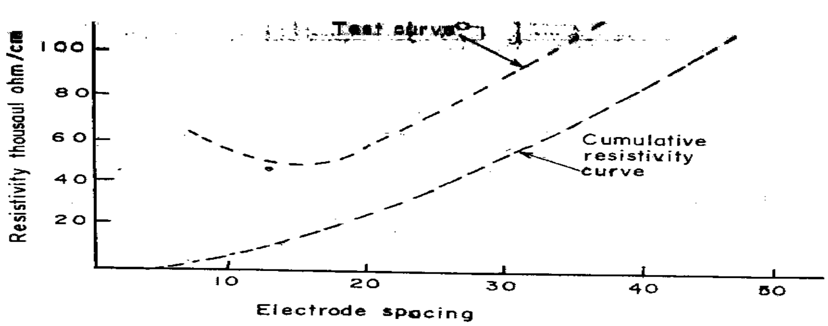


Fig. 16.28. Expanding electrode technique.
(a) Current flow confined to overburden, (b) in bedrock, (c) in deeper layer.

The resistivity curve is then compared with a series of master curves, computed for various values of depth and resistivity ratio like those of mastr curves and depth is obtained



Test value curve for electrical resistivity analysis

b). Lateral traversing techniques or Horizontal Profiling.: - In this method electrode system is moved along a traverse while the electrode spacing is kept constant, i.e. the depth of penetration is kept constant and the horizontal variations or variations in depth of a given geological formation is determined. The apparent resistivity is measured at measured at successive stations along the line of traverse and plotted as ordinates against distance to obtai

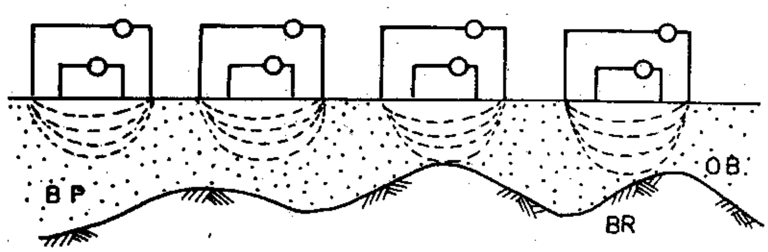


Fig. 16.30. Horizontal profiling - Lateral Traversing Technique. OB—Overburden, BR—Bedrock, BP—Bedrock Profile.

Electrical sounding methods are usually employed in engineering geology site investigations in conjunction with auger holes, trial pits, boring and core drilling in the determination of depth of bed rock, unconformity, location of construction materials (sand and Gravel) and water bearing formations.

In addition by other related techniques like using fine electrode configuration, the dip of strata concealed vertical dykes, faults etc, can be traced.

POTENTIALITY OF DIFFERENT ROCKS AS AQUIFERS

The various kinds of rocks posses' variable water-bearing properties, depending chiefly on their permeability and porosity. Of the three important types of rocks, the Sedimentary rocks, generally, constitute the best aquifers, the Metamorphic rocks and especially the foliated ones, making moderate to good aquifers; and the Igneous rocks generally behaving as the poor aquifers. The various kinds of rocks and their water-bearing potentials are briefly discussed below.

SEDIMENTARY ROCKS AS AQUIFERS: - Among the Sedimentary rocks, Gravels posses the highest water retaining as well as water yielding capacities. This is truer in case of loose and weakly cemented coarse gravels. In general, next to Gravel, the other Sedimentary rocks in their successive order of decreasing water bearing capacity are; loose sand, sandstone, limestone etc. Shale (Clay) is the poorest in absorbing water, being impermeable although porous, and hence classified as aquicludes.

Among sandstones, the water-bearing capacity depends much upon their texture and nature of cementing material. Coarse-grained sandstone may be good aquifers. Whereas fine grained sandstone may prove to be the poorest aquifers.

The water-bearing capacity of limestone depends much upon the presence of solution channels, crevices, fissures and other such opening in the rock. Hence, fissured and cracks limestones may prove to be excellent aquifers and other compacted limestones mat prove to be totally unproductive.

IGNEOUS ROCKS AS AQUIFERS: - The intrusive igneous rocks like granites, syenites etc., are generally very compact and dense and hence are non-porous. They are barren groundwater under normal conditions. However when they are traversed by fissures or cracks, they may be capable of holding some groundwater quantities. Even these cracks and fissures die out with depth, and as such, there is absolutely no possibility of getting any groundwater in these rocks at depths greater than 80-100mts.

The extrusive igneous rocks also exhibit great variations in their water-bearing properties. Basic igneous rocks like basalts are generally rich in cavities and contraction cracks; and as such may become permeable and sources of groundwater. Acidic igneous rocks like rhyolites may or may not contain groundwater, because such rocks although generally posses interstices, but may be filled up with ash and other material, and hence the uncertainty.

METAMORPHIC ROCKS AS AQUIFERS: - Non-foliated metamorphic rocks like Marble and Quartzite are generally impermeable, except along the original bedding, if the same is not completely destroyed during metamorphism. Foliated metamorphic rocks like Slates, Schist, Phyllites and sometimes even Gneiss may contain some good amount of groundwater due to their being highly fractured.

RECHARGE AND DISCHARGE AREAS

Water enters the groundwater system as precipitation falling on recharges areas, which are areas where water is added to the saturated zone.

It means through the system to discharge areas, which are areas where subsurface water is discharged to streams or to a bodies of surface water. The aerial extent of recharge areas is invariably larger than that of discharge area. In humid regions, recharge areas encompass nearly all areas except stream and their adjacent floodplains. In more arid regions, recharge occurs mainly in mountains and in the alluvial fans.

From the figure streams that flow from mountains having substantial rainfall into much drier regions in which the water table lies deep beneath the surface. Water from these rivers leaks downwards and recharges the groundwater below.

ARTIFICIAL RECHARGE

Although most recharge is supplied directly by rain fill, this intense demand for water in some areas has led to artificial recharge of the ground. One example is the practice of water spreading in dry parts of the American West. A common way to spread water for recharge is to build a low dam across a stream valley. This holds water bank that would otherwise flow away and allows it to seep downward and recharge aquifers beneath the stream be. The water thereby, stored underground is withdrawn through wells as needed.

In some regions an aquifers may be recharged with used water. This practice has increased as air-conditioning, which requires a large volume of water, has become commonplace in hot, dry regions. Some cities have laws requiring that water used for air conditioning be returned to the ground, where it successfully builds up the water table. This illustrates the basic principles of groundwater conservation. Where groundwater with drawl exceeds the rate of recharge, the lowering of the water table can lead to subsidence of the ground.

FLUCTUATIONS OF THE WATER TABLE

The water table is a subdued imitation of the ground surface above it. It is high beneath hills and low at valleys because water tends to move toward low points in the topography where the pressure on it is least. If all rainfall were to cease, the water table would slowly fallen and gradually approach the levels of the valleys. Percolation would diminish and cease, and the stream in the valley would dry up. In times of drought, when rain may not fall for several weeks or even months, we can sense the flattening of the water table in the drying up o wells. When that occurs we knew that the water table has fallen to a level below the bottoms of the wells.

APPLIED ENGINEERING GEOLOGY

UNIT - 08

Content :

ENVIRONMENTAL GEOLOGY

- **Remote Sensing**
- **G I S & G P S**
- **Land sate imageries**
- **Impact of Mining , Quarring**

REMOTE SENSING

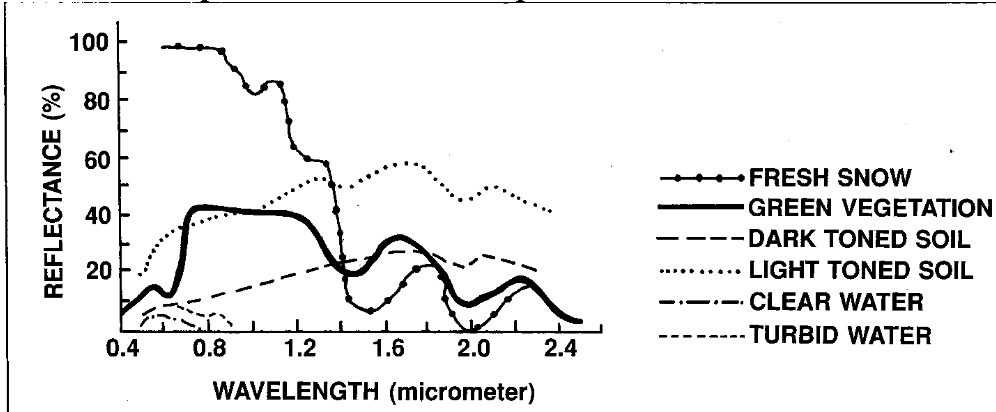
Generally, the identification and study of different objects on the earth's surface, without physically coming in contact with them is termed as Remote Sensing. This is done mainly with the help of aerial photographs and satellite Imagery. The basis for remote sensing is the electromagnetic energy emitting from the sun and reaching the earth's surface. Depending upon their physico-chemical characteristics, a different object respond differently in different wavelength regions of the electromagnetic spectrum and is called the spectral response of the objects. The sensors placed on board the aircrafts and satellites record the energy thus reflected or emitted by different objects. This information is converted into photographic prints or digital tapes, which are studied and interpreted for various objects and phenomena occurring on the earth's surface.

Depending on the source of energy which ultimate the object under study, the Remote Sensing techniques are classified into two types, namely
a). Active Remote Sensing
b). Passive Remote Sensing

a). Active Remote Sensing: - In passive remote sensing system, the naturally radiated or reflected energy from the earth's surface features is measured by the sensors operating in different selected spectral bands on board the air borne/space borne platforms (Similar to photography in day time without flash).

b). Passive Remote Sensing: - An active remote sensing system supplies its own source of energy to illuminate the objects and measure the reflected energy returned to the system (Similar to photography in night with flash).

Comparison of reflectance spectra of a few land covers



Comparison of reflectance spectra of a few land covers

Platforms for Remote Sensors

Operation needs some Platforms. Depending upon the purpose behind the use of sensor, the type of sensor, size, height and power requirements of the sensors, and the other a platform is chosen. Basically the platforms for earth observations can be divided in three categories.

- Ground based platforms
- Air borne platforms
- Satellite platforms

Ground based platforms: -

Such platforms can be stationary or mobile. In case of towers, roof or high-rise building etc., can be used to position sensors for collection of data. Sometime even tripod is used. In the case of mobile platforms, the vehicles with mounting sensors to collect data.

Air borne platforms: -

This category includes aircrafts (both low and high flying), drones (remotely piloted aircrafts) helicopters, balloons, rockets etc. Aircrafts have been the main platforms for remote sensing since the beginning of the century. Aircrafts; though expensive can be made use of whenever and wherever desired, provided landing and take off are available nearby.

Satellite platforms: -

With the launch of Sputnik in 1957, when the satellite showed a global coverage was possible a satellite promised to be an attractive proposition as a platform. The height at which a satellite can be flown is typically 300-1000km for earth observation satellites. It provides synoptic view over a larger area. A variety of sensors can be mounted on such a platform to acquired data for monitoring the earth environmental including it natural resources. A satellite once launched remains in orbit except for minor disturbances.

Microwave remote sensing: -
One of the major problems faced in the use of optical remote sensing data available from LANDSAT (NASA), IRS (INDIA), JERS (JAPAN) etc in coastal regions and north eastern region, are the persistent cloud cover. In this context remote sensing data collected in microwave region is found to have the following advantages,

- All weather capability, specifically it can collect data even in cloudy condition that is not possible to certain extent.
- Day and Night observing capability
- Soil depth penetration in ideal conditions is possible to certain extent

The Microwave satellite to carry microwave sensor was the SEASAT launched in 1078. The shuttle image radar flights (SIR-A and SIR- B) in 1981 and 1984 respectively, provided the additional data. Presently regular data is available from ERS-1 (Earth Resource Satellite) launched in 1991 and JERS-1 (Japan) launched in 1992 have led to the initiation of several R&D studies which include the use of data for the study of (application of remote sensing)

- Soil Moisture
- Mapping of agricultural irrigated/un- irrigated areas
- Determination of canal seepage
- National waste land mapping (to identify type and extent of wasteland at village level)
- National drinking water mission (hydro geomorphologic maps, helps in scientific source finding of drinking water)
- Agricultural drought monitoring (to assess and monitor agricultural drought at district level)
- Forest cover mapping, forest fire
- Urban studies (to study the urban land use / land cover and growth etc of all major cities
- Crop acreage and production estimation (to estimate the crop acreage and forecast prediction)
- Natural hazard study, flood mapping, landslides, earthquake
- Snow mapping
- Environmental impact of mining and thermal power complexes (to develop a suitable methodology for monitoring environmental parameters
- Oceanography – fishing, tsunamis, cyclones, movements of waves, currents, tides
- Coral reef mapping
- Natural resources
- Defense activity.
- Lithology, Landforms Structures & Recharge the rain water into the ground

IMPACT OF MINING ON ENVIRONMENT

For example the essential raw material for cement manufacture being Limestone, it has to be exploited from where it occurs. In India, only opencast mines are winning Limestone, a low cost material. To produce a tones of cement 1.5-1.6 tones of Limestone is required over 21,400 sq.m will come under mining operation every year depending upon the thickness of limestone to be exploited. Such huge operation will no doubt, leave its impact on relief and topography, hydrology, air forestry/agriculture wild life etc.

However the environmental impacts of operating the limestone mines may not be very serious as in the case of other such as chemical, fertilizer and metallurgical industries.

RELIEF AND LANDSCAPE ALTERATIONS: Mining operation and installation of various allied units will change the existing topography and will cause creation of huge pits or leveling of hills or creation of wastes heaps etc.

IMPACT ON HYDROLOGY: Mining activities in some cases may disturb the aquifer, the ground water flow and recharge capacity of the surrounding areas are affected due to change in topography.

CONTAMINATION OF WATER: Limestone mining by and large does not adversely contaminate the rain waters and ground water flowing through the exposed mine cuts but may carry fine particle of Limestone dust, which may cause silting problems, but they are non-toxic. Surface runoff from mine cuts may however be turbid during monsoons due to seepage of overburden soil etc.

AIR POLLUTION OR DUST POLLUTION: In mining air pollution is mainly caused by dust generation. Blasting is one of the pollutants as it creates fumes, dust, vibrations, air blaster, noise and fly rock fragments. The other activities such as drilling excavation, waste dumping will also cause dust nuisance. Crushing plant, conveyors and transfer points will be the other sources of dust generation.

NOISE POLLUTION: Noise may be defined as" Unwanted sound". This implies sounds, which interfere with human communication, comfort health etc. The noise pollution in the Limestone blasting and movement of heavy earth moving equipment cause mine.

IMPACT ON FORESTRY /VEGETATION: The mining operation if carried out on hills, which are usually associated with forests and vegetation causes. Impairment (spoil) and affects climate, rainfall, soil erosion and causes in equilibrium between biotic substance and macro/micro organisms. When carried out on plains affect agriculture and grazing lands.

IMPACT ON WILDLIFE: Noise and habitation may probably cause migration of the existing wild life.

IMPACT OF HUMAN ENVIRONMENT: The impact of mining on human environment can be both beneficial and detrimental as it may provide job opportunities and overall development of the region, can also deprive some of them of their agricultural land. Sometimes it can help in water resources for water irrigation and domestic use.

VIBRATION, AIR BLAST AND NOISE CONTROL: The noise in mines is caused by blasting, movement of heavy earth moving equipment which in terms causes vibration and air blast. The following can control these: -

a). Avoiding blasting during night and foggy weather which associated with temperature inversion

b). Stemming of the blast hole properly

c). Avoid blasting when wind velocity is more than 25km/hr

d). Large scale plantation or shade giving trees also reduce the noise and Vibration level,

e). Using rock breaking, the secondary blasting (which usually produces a huge noise) can be avoided

FUMES CONTROL: ensuring complete detonation with the use of proper primers and boosters can reduce Production of blast fumes containing toxic gases. By maintaining well the engines of mining machinery the fumes from them can be controlled well.

DUST CONTROL: During mining the dust can be controlled by the following

a). DRILLING: the using suitable dust can control Dust Collector, which is also a stationary requirement.

b). BLASTING: If the topsoil is completely removed before blasting, dust generation during the same can be minimized.

c). CRUSHING: Dust can be reduced by using dust Collectors or by spraying dust suppressants including water.

d). TRANSPORTATION: Dust is generated when loaded dumpers move over unconcerned roads. This can be overcome by concreting the roads or by sprinkling water over the roads regularly.