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RCE 071 : Geology and Soil Mechanics

UNIT-1 : MINERALS AND ROCKS (1–1 C to 1–26 C)

Minerals : Their physical and detailed study of certain rock forming minerals. Rocks structure of earth and formation of rocks. Texture and classification of rocks. Engineering properties, weathering and suitability of rocks as engineering materials.

UNIT-2 : STRUCTURAL FEATURES OF ROCKS (2–1 C to 2–26 C)

Stratification and Lamination bedding of rocks. Dip and strike of bed. Rock deformation : Folds, Faults, joints unconformity and their classification, causes and relation to engg. behaviour of rock masses.

UNIT-3 : EARTHQUAKE AND LANDSLIDES (3–1 C to 3–19 C)

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UNIT 1

Minerals and Rocks

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Importance :
1. material.
2. Work of natural agencies.
3. foundation problem.
4. geological feature.
5. Study of Soil mechanism.
6. geological Survey.

PART-1

Minerals : Their Physical and Detailed Study of Certain Rock Forming Minerals.

Questions-Answers

Long Answer Type and Medium Answer Type Question

Que 1.1. **Give a brief account of the importance of geology in Civil Engineering. Explain the answer by giving suitable examples.**

AKTU 2013-14, Marks 3.5

OR

Write a brief note on geological studies in civil engineering.

AKTU 2015-16, Marks 10

OR

Write a note on the importance of geology in civil engineering.

AKTU 2016-17, Marks 10

Answer

Importance of Geology in Civil Engineering : The value of geology in mining has long been known but its use in civil engineering has been recognized only in comparatively recent years. The importance of geology in civil engineering may briefly be outlines as follows :

1. Geology provides a systematic knowledge of construction material, its occurrence, composition, durability and other properties. Examples of such construction materials are building stones, road metal clay, limestone and laterite.
2. The knowledge of geological work of natural agencies such as water, wind, ice and earthquakes helps in planning and carrying out major civil engineering works. For example–the knowledge of erosion, transportation and deposition helps greatly in solving the expensive problems of river control, coastal and harbour work and soil conservation.
3. The foundation problems of dams, bridges and buildings are directly concerned with the geology of the area where they are to be built. In these works drilling is commonly undertaken to explore the ground conditions. Geology helps greatly in interpreting the drilling data.
4. The stability of civil engineering structure is considerably increased if the geological feature like faults, joints, bedding planes, folding solution channel etc., in the rock beds are properly located and suitably treated.

5. In the study of soil mechanics, it is necessary to know how the soil materials are formed in nature.
6. The cost of engineering work will considerably reduced if the geological survey of the area concerned is done before hand.

Que 1.2. **Define minerals. Also classify it.**

OR

What are different rock forming minerals ?

AKTU 2014-15, Marks 03

Answer

Minerals :

1. A mineral is a naturally occurring substance that is solid and inorganic representable by a chemical formula, usually abiogenic (not produced by living organisms), and has an ordered atomic structure.
2. It is different from a rock, which can be an aggregate of minerals or non-minerals and does not have a specific chemical composition.

Types of Rock Forming Minerals : Following are the various types of rock forming minerals :

1. **Silicates :** It is very most important mineral group and rock forming minerals. It is very abundant due to large amount of silicon and oxygen in the Earth's crust.

Common silicate minerals :

i. **Olivine :**
   a. High temperature Fe-Mg silicate called ferromagnesian (typical mantle mineral-formed 100's km in earth).
   b. Individual tetrahedral linked together by iron and magnesium ions.
   c. Forms small rounded crystals with no cleavage.

ii. **Pyroxene Group :** $(Mg.Fe)SiO_3$
   a. Single chain structures involving iron and magnesium chains weakly paired.
   b. Two distinctive cleavages at nearly 90 degrees.
   c. Augite is the most common mineral in the pyroxene group.

iii. **Amphibole Group :** $Ca_2 (Mg.Fe)_5 Si_8 O_{22} (OH)_2$
   a. Double chain structure involving a variety of ions.
   b. Two perfect cleavages exhibiting angels of 124 and 56 degrees.
   c. Hornblende is most common mineral in the amphibole group.

iv. **Mica Group :**
   a. Sheet structure that result in one direction of perfect cleavage.

b. Biotite is the common dark colored mica mineral.

c. Muscovite is the common light mica mineral.

v. **Felspar Group :**

a. Most common mineral group.

b. 3-D framework of tetrahedra exhibit two directions of cleavage at 90 degrees.

c. Orthoclase (potassium feldspar) and plagioclase (sodium and feldspar) are the two most common members.

vi. **Clay Minerals :**

a. Clay is a general term used to describe a variety of complex minerals

b. Clay minerals all have a sheet or layered structure.

c. Most originate as product of chemical weathering.

2. **Important Non-Silicate Minerals :**

i. Calcite (Carbonate).

ii. Haematite (Oxide).

iii. Galena (Sulphide).

iv. Gypsum (Sulphate).

v. Halite (Halide).

vi. Pyrite (Sulphide).

Que 1.3. **Explain the various properties of rocks for minerals.**

OR

Define minerals. Define following physical properties of mine

i. **Fracture.**

ii. **Cleavage.**

iii. **Streak.**

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vi. **Hardness.**

AKTU 2014-15, Mark

Answer

A. **Minerals :** Refer Q. 1.2, Page 1–3C, Unit-1.

B. **Physical Properties of Minerals :**

1. **Color :**

i. Most minerals have a distinctive color that can be used for identification

ii. In opaque minerals, the color tends to be more consistent, so lea the colors associated with these minerals can be very helpful identification.

2. **Streak :**

i. Streak is the color of the mineral in powdered form. Streak show true color of the mineral.

ii. In large solid form, trace minerals can change the color appearance of a mineral by reflecting the light in a certain way.

Example : Black : Graphite, pyrite, magnetite, etc.

Gray : Gelena etc.

3. **Hardness :**

i. Hardness is one of the better properties of minerals to use for identifying a mineral.

ii. Hardness is a measure of the mineral's resistance to scratching.

iii. The Mohs scale is a set of 10 minerals whose hardness is known.

Mineral :	Talc	Gypsum	Calcite	Fluorite	Apatite
Hardness :	1	2	3	4	5
Mineral :	Orthoclase	Quartz	Topaz	Corundum	Diamond
Hardness :	6	7	8	9	10

4. **Cleavage :**

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i. Cleavage refers to the splitting of a crystal along a smooth plane.

ii. A cleavage plane is a plane of structural weakness along which a mineral is likely to split.

iii. The quality of a mineral's cleavage refers both to the ease with which the mineral cleaves and to the character of the exposed surface.

5. **Fracture :**

i. Fracture describes the quality of the cleavage surface.

ii. Most minerals display either uneven or grainy fracture, conchoidal (curved, shell-like lines) fracture, or hackly (rough, jagged) fracture.

6. **Crystalline Structure :**

i. Mineral crystals occur in various shapes and sizes.

ii. The particular shape is determined by the arrangement of the atoms, molecules or ions that make up the crystal and how they are joined. This is called the crystal lattice.

iii. There are degrees of crystalline structure, in which the fibers of the crystal become increasingly difficult or impossible to see with the naked eye or the use of a hand lens

7. **Luster :** Luster is the property of minerals that indicates how much the surface of a mineral reflects light.

8. **Odour :** Most minerals have no odour unless they are acted upon in one of the following ways: moistened, heated, breathed upon, or rubbed.

9. **Taste :** Only soluble minerals have a taste, but it is very important that minerals not be placed in the mouth or on the tongue.

10. Specific Gravity :

i. Specific gravity of a mineral is a ratio of the weight of the mineral to weight of an equal amount of water.

ii. The weight of the equal amount of water is found by finding the differe between the weight of the mineral in air and the weight of the min in water.

Que 1.4. **Discuss the process of formation of minerals in natu Which group of minerals is most common in occurrence ? Disc their salient features.** **AKTU 2014-15, Marks 8**

Answer

A. **Process :** Following are the process of formation of minerals in natu

1. **Precipitation, Evaporation and Weathering from a Fluid l H_2O or CO_2:**

i. This can take place within the Earth by hydrothermal process diagenesis and metamorphism, and at or near the Earth's surface result of evaporation, weathering or biological activity.

a. Anhydrite and Gypsum are formed from solutions by the proce evaporation.

b. Calcite is formed by precipitate from carbonated solution du Hing loss of carbon dioxide from limestone.

c. Clay minerals are an important group of minerals because t are among the most common products of chemical weather and thus are the main constituents of the fine-grai sedimentary rocks called mudrocks (including mudstones, stone, and shale).

2. **Sublimation from a Vapour :**

i. This process is somewhat more rare but can take place at a volc - anic vent, or deep in space where the pressure is near vacuum.

ii. For example, Salvite minerals.

3. **Crystallization from a Liquid :**

i. This takes place during crystallization of molten rock (magma) ei - ther below or at the Earth's surface.

ii. For example, Diamond.

4. **Solid - Solid Reactions :**

i. This process involves minerals reacting with other minerals in the Solid state to produce one or more new minerals. Such processes take p place during metamorphism and diagenesis due to changing temperature change pressure conditions.

ii. For example, Kyanite

B. Common Minerals and their Salient Features :

1. Felspar Group :

i. These minerals are mostly found in igneous rocks, sedimentary rocks and metamorphic rocks.

ii. Chemically, feldspar are classified into two types : alkali felspar and plagioclase felspar.

iii. In alkali feldspar, chemical compounds are K and Na. For example, the Orthoclase ($KAl\ SiO_3\ O_8$), Anorthite ($Ca\ Al_2\ Si_2\ O_8$). These are also called as Soda – Lime felspars.

iv. These can be used as ceramic materials.

2. Felspathoids Group :

i. These minerals are mostly found in igneous rocks only.

ii. Chemically, felspathoids are similar to feldspar but differs in their crystallization and also these contain less silica than feldspar.

iii. The nepheline ($(Na, K)\ Al\ SiO_4$), Leucite ($K\ Al\ Si_2\ O_6$) are the examples of felspathoids minerals.

iv. These can be used as ceramic materials.

3. Pyroxene group :

i. These minerals are mostly found in igneous rocks and metamorphic rocks.

ii. The chemical formula is $R\ SiO_3$ in which R is usually, Ca, Al, Na, Mg, Li and Fe.

iii. Pyroxenes are classified into two types based on their crystallization :

a. Orthorhombic pyroxenes.

b. Monoclinic pyroxenes.

4. Amphibole Group :

i. These minerals are mostly found in metamorphic rocks.

ii. The chemical formula is $R\ Ca_2\ Si_8\ O_{22}\ (OH)_2$ in which R is usually, Ca, Al, Na, Mg and Fe.

iii. Amphiboles are classified into two types based on their crystallization :

a. Orthorhombic amphibole.

b. Monoclinic amphibole.

5. Mica Group :

i. These minerals are mostly found in igneous rocks, sedimentary rocks and metamorphic rocks. These occur in foliated form and these can be split into very thin sheets.

ii. The chemical formula is $R\ K\ (Al\ Si_3\ O_{10})\ (OH)_2$ in which R is usually, Ca, Al, Na, Mg, Li and Fe.

iii. Micas are classified into two types based on their chemical composition and color.

a. **Light Mica :** For example, Muscovite $K\ Al_2\ (Al\ Si_3\ O_{10})\ (OH)_2$

b. **Dark Mica :** For example, Biotite $K\ (Mg, Fe)_3\ (Al\ Si_3\ O_{10})\ (OH)_2$

Que 1.5. **Explain the difference by giving examples :**

1. **Cleavage and fracture.**
2. Color and luster.
3. Density and specific gravity.
4. **Hardness and Tenacity.**

AKTU 2013-14, M

Answer

1. **Cleavage and fracture :**

S. No.	Cleavage	Fracture
1.	Cleavage is the manner in which a mineral break along its plane of weakness.	Fracture is a break mineral when atomic b perfect and there is no v
2.	Regular.	Irregular.
3.	A mineral breaks along its plane of weakness.	There is no plane of weak -ness
4.	**Example :** Halite, calcite, gypsum, etc.	**Example :** Quartz, gla

2. **Color and luster :**

S. No.	Color	Luster
1.	It is the appearance of the particular mineral in light.	It is intensity of reflection from the mineral surface
2.	Color of any mineral is a light dependent property.	It depends on refractive absorption and nature of surface.
3.	**Example :** Lazurite (deep blue), Pyrite (brass yellow), Cinnabar (carmine red), etc.	**Example :** Gypsum Labradorite (Pearly), (Vitreous), etc.

3. **Density and specific gravity :**

S. No.	Density	Specific gravity
1.	It is defined as the mass per unit volume of material.	It is define as the ratio of weight of mineral to the of water at 4 °C.
2.	**Example :** For water, $\rho_w = 1000$ kg/m^3 For mercury, $\rho_{Hg} = 13600$ kg/m^3.	**Example :** For water, For mercury, $G_{Hg} = 13$.

4. Hardness and Tenacity :

S. No.	Hardness	Tenacity
1.	Hardness is the ability of a mineral to resist scratching, rubbing or abrasion.	Tenacity is the resistance of a mineral breaking, tearing and bending.
2.	It is a fairly constant and diagnostic property of minerals.	In this term minerals may be sectile, brittle, flexible, plastic and elastic, the last two qualities being of diagnostic importance.
3.	**Example :** Talc ($H = 1$), Quartz ($H = 7$), fluorite ($H = 4$), apatite ($H = 5$), etc. where, H = Hardness value.	**Example :** Chlorites-flexible, Micas- elastic, Asbestos- flexible and elastic, etc.

Que 1.6. **Explain the following physical properties of mineral with its various types :**

1. **Habit.**
2. **Fracture.**
3. **Tenacity.**
4. **Luster.**

Answer

1. **Habit :** Habits are the distinctive form that mineral crystals may lake in different geologic settings. It refers to the difference in form when they grow in a free space compared to growing in a particular environment.

Types : Following are the various types of habits :

i. **Individual Crystals :**

a. **Cubic :** Cube shapes.

b. **Octahedral :** Shaped like octahedrons.

c. **Tabular :** Rectangular shapes. Example - feldspar.

d. **Equant :** A term used to describe minerals that have all of their boundaries of approximately equal length.

e. **Acicular :** Long, slender needle like crystals. Example - natrolite.

f. **Prismatic :** Abundance of prism faces.

g. **Bladed :** Like a wedge or knife blade. Example - kyanite.

ii. **Groups of Distinct Crystals :**

a. **Dendritic :** Tree-like growths.

b. **Reticulated :** Lattice-like groups of slender crystals.

c. **Radiated :** Radiating groups of crystals.

d. **Fibrous :** Elongated clusters of fibers. Example - asbest

e. **Botryoidal :** Smooth bulbous or globular shapes like grapes. Example - chalcedony.

f. **Globular :** Radiating individual crystals that form spheric

g. **Drusy :** Small crystals that cover a surface.

h. **Stellated :** Radiating individuals that form a star-like sh

2. **Fracture :** Refer Q. 1.3, Page 1–4C, Unit-1.

Types : Several different kinds of fracture patterns are obser

i. **Conchoidal Fracture :** Breaks along smooth curved surf example : Quartz.

ii. **Fibrous and Splintery :** Similar to the way wood breaks, for e Serpentine.

iii. **Hackly :** Jagged fractures with sharp edges, for example : Nativ

iv. **Even or Regular :** Rough regular surfaces, for example : Fli

v. **Uneven or Irregular :** Rough irregular surfaces, for example

3. **Tenacity :** Refer Q. 1.5(4), Page 1–8C, Unit-1.

Types : Tenacity can be described by the following terms :

i. **Brittle :** Breaks or powders easily.

ii. **Malleable :** Can be hammered into thin sheets.

iii. **Sectile :** Can be cut into thin sheeting with a knife.

iv. **Ductile :** Bends easily and does not return to its original shap

v. **Flexible :** Bends somewhat and does not return to its original

vi. **Elastic :** Bends but does return to its original shape.

4. **Luster :** Refer Q. 1.3, Page 1–4C, Unit-1.

Types : Following are the various types of luster :

i. **Metallic :**

a. Mineral looks shiny like a metal. Usually opaque and gives dark colored streak, for example : pyrite, galena.

ii. **Non-Metallic :**

a. **Vitreous :** Looks glassy, for examples : clear quartz, tour

b. **Resinous :** Looks resinous, for examples : sphalerite, sul

c. **Pearly :** Iridescent pearl-like, for example : apophyllite.

d. **Greasy :** Appears to be covered with a thin layer of oil for e nepheline, talc.

e. **Silky :** Looks fibrous, for examples : some gypsum, ser malachite.

f. **Adamantine :** Brilliant luster, for examples : diamond.

g. **Dull :** No light is reflected, for examples : chalk, clay, bauxite,

Que 1.7. **Explain various structure exhibited by minerals in their natural habits.**

Answer

Following are a few common structural forms (habits) observed in minerals.

1. **Tabular :** The mineral occurs in the form of a flattened, square, rectangular or rhombohedral shape. In other words, flattening is conspicuous compared to lengthwise elongation (Fig. 1.7.1). Examples : Calcite, orthoclase, barite etc.

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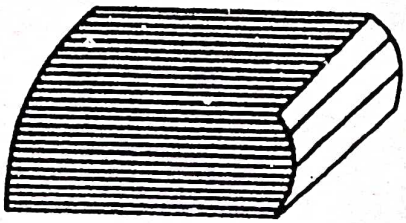


Fig. 1.7.1. Tabular (Barite)

2. **Elongated :** When the mineral is in the form of a thin or thick elongated, column-like crystals (Fig. 1.7.2). It is also commonly referred as a columnar structure.

Examples : Beryl, quartz, hornblende.

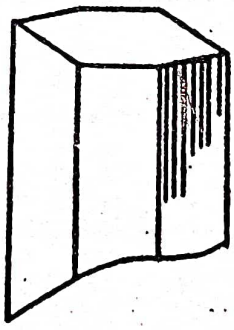


Fig. 1.7.2. Elongated (Beryl)

Bladed : The mineral appears as if composed of thin, flat, blade-like overlapping or juxtaposed parts (Fig. 1.7.3).

Example : Kyanite

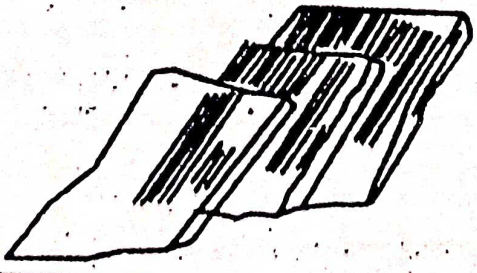


Fig. 1.7.3. Bladed (Kyanite)

Lamellar : The mineral is made up of relatively thick, flexible, leaf-like sheets (Fig. 1.7.4). Example : Vermiculite.

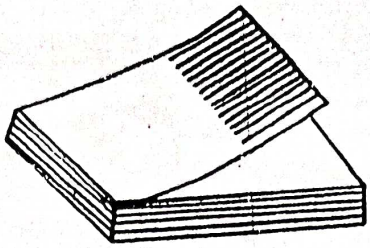


Fig. 1.7.4. Lamellar (Vermiculite).

5. **Foliated :** The structure is similar to lamellar in broader sens this case the individual sheets are paper thin, even thinner anc easily separated. Example : Muscovite (mica).
6. **Fibrous :** When the mineral is composed of fibres, generally sep either quite easily (example : asbestos) or with some difficulty (ex gypsum) (Fig. 1.7.5).

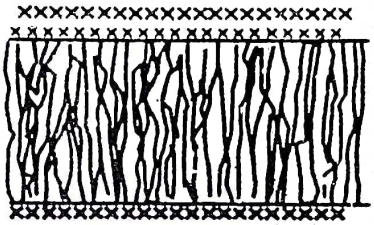


Fig. 1.7.5. Fibrous (Asbestos).

7. **Radiating :** The mineral is made up of needle like or fibrous cı which appear originating from a common point, thereby giving a rac appearance. Example : Iron pyrites (Fig. 1.7.6).

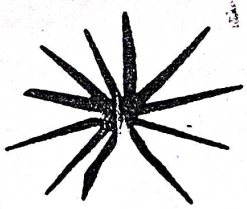


Fig. 1.7.6. Radiating (Pyrites).

When needles are pointed and not necessarily radiating, the stru is called acicular.

8. **Granular :** The mineral occurs in the form of densely packed mı small grain-like crystals. Example : Chromite (Fig. 1.7.7).

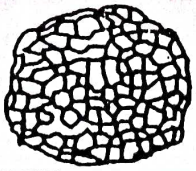


Fig. 1.7.7. Granular (Magnetite).

9. **Globular or Botryoidal :** When the mineral surface is in the for rounded, bulb-like overlapping globules or projections. Exam Haematite (Fig. 1.7.8).

Fig. 1.7.8. Globular (Haematite).

10. **Reniform :** It is similar to globular but the shape of the bulbs or projections resembles to human kidneys. Example : Haematite. (Fig. 1.7.9).

Fig. 1.7.9. Reniform (Haematite).

11. **Mammillary :** It is similar to globular but the projections are conspicuous in size, overlapping in arrangement and rounded in shape. Example : Malachite. (Fig. 1.7.10).

Fig. 1.7.10. Mammillary (Malachite).

Que 1.8. **What do you mean by minerals ? Explain the physical and chemical properties of all rock forming minerals.**

AKTU 2016-17, Marks 15

OR

What do you mean by minerals ? Explain the physical and detailed study of all rock forming minerals. **AKTU 2015-16, Marks 15**

OR

Define minerals. Explain the detailed study of all rock forming minerals. **AKTU 2017-18, Marks 10**

Answer

Minerals : Refer Q. 1.2, Page 1–3C, Unit-1.

Detailed study of rock forming minerals is given in the tabular from :

Properties → Mineral ↓	Origin	Chemical Composition	Crystal system	Color	Luster	Streak	Cleavage	Hardness	Specific Gravity	Fracture	Uses	Occurrence
Kaolinite	Igneous rock	$Al_2Si_2O_5(OH)_4$	Monoclinic	White, gray, yellowish	Dull	Color less	Uneven	2—2.5	2.6	Conchoidal	For making porcelain	Maharashtra
Orthoclase	Igneous rock	$KAl\ SiO_3O_8$	Monoclinic	Gray, pink, red	Vitreous	White	Perfect	6—6.5	2.5—2.6	Conchoidal	For making ceramic mat.	Madras, AP
Leucite	Volcanic Igneous rock	$KAl\ Si_2O_6$	Isometric, cubic	White, gray	Vitreous	Color less	Poor	5—6	2.47—2.5	Uneven	For making ceramic mat.	
Biotite	Igneous, metamorphic rock	$K(Mg, Fe)_3(Al\ Si_3\ O_{10})(OH)_2$	Monoclinic	Dark brown, black, green	Vitreous	Color less	Perfect	2—3	2.8—3	Uneven to hackly	In light weight concrete, insulating mat.	AP
Corundum	Igneous, metamorphic rock	$Al_2\ O_3$	Hexagonal	Yellow, red brown, blue	Vitreous to dull	Color less	Absent	9	3—4.1	Uneven to conchoidal	As gem stone, for making abrasive mat.	MP, AP, Tamilnadu, Karnataka, Maharashtra
Serpentine	Formed by alternation of $MgSO_4$	$Mg_6\ Si_4\ O_{10}(OH)_8$	Monoclinic	Green, yellow, brown	Waxy, Greasy, silky, fibrous	White	Basal in planty variety	4—6	2.5—2.6	Conchoidal, splintery	For making asbestos, as ornamental stone, insulating and fire proofing mat.	Orissa, AP, Chhatisgarh, Maharashtra, Anadaman & Nicobar
Dolomite	Sedimentary rock	$Ca\ Mg\ (CO_3)_2$	Hexagoanl	Green, black, white, brown	Vitreous	White	Perfect	3.5—4	2.85	Conchoidal	As flux in metallurgy, refactory mat., cement	Orissa, MP, Bihar, UP, Gujrat, WB
Olivine	Igneous rock such as gabbro, basalt,	$(Mg\ Fe)_2\ SiO_4$	Orthorhombic	Green, Pale yellow, olive green	Vitreous	White	Poor, more distinct in fayalite	6.5—7	3.27—4.37	Conchoidal	In aluminum industry to cast objects	AP, Assam, Haryana, MP, Orissa, Maharashtra, Rajasthan

Properties Mineral	Origin	Chemical Composition	Crystal system	Color	Luster	Streak	Cleavage	Hardness	Specific Gravity	Fracture	Uses	Occurrence
Gypsum	Sedimentary rock	$CaSO_4.2H_2O$	Monoclinic	White, red, yellow, dark gray	Vitreous	White	Perfect	1.5—2	2.3	Conchoidal	For making cement, sulphuric acid, fertilizer	HP, Gujrat, Tamilnadu, Rajasthan, J&K
Graphite	Metamorphic rock-gneiss, schist	Pure carbon	Hexagonal	Deep gray	Metallic	Black, shining	Perfect	1—2	2—2.3	Uneven	For making paints, pencil, lubricants	MP, Orissa, Madras, Bihar, Mysore
Hornblende	Acidic Igneous rock, metamorphic rock	$Ca_2 Na (Mg,Fe)_4 (Al, Fe) (Si_8 Al_8 O_{22}) (OH)_2$	Monoclinic	Black, dark green	Vitreous	White with greenish tint	Perfect	5.5—6	2.9—3.5	Uneven	For making cement	AP, WB, Rajasthan, Karnataka, Tamilnadu
Muscovite	Igneous, sedimentary, metamorphic rock	$(H,K) AlSiO_4$	Monoclinic	White transparent	Pearly	Color less	Perfect basal	2—2.5	2.9	Uneven	For making insulating material	Bihar, AP, Madras, Rajasthan, Kerala
Quartz	Igneous, sedimentary, metamorphic rock	SiO_2	Hexagonal	Red, green blue, color less	Vitreous	White	Nil	7	2.65	Conchoidal	For making glass, optical instruments	AP, HP, Gujrat, Haryana
Topaz	Igneous, rock	$Al(Al_2 F SiO_4)$	Orthorhombic	Yellow, white, greyish	Vitreous	Color less	Perfect	8	3.5—3.6	Conchoidal	As gen stone	Bihar, AP, Mysore

PART-2

The Origin, Structure, Texture and Classification of Igneous Ro

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.9. **What are rocks ? Write the appropriate classificatio rocks.**

Answer

A. **Rock :** In geology, rock is naturally occurring solid aggregate of one more minerals or mineraloids. For example, the common rock granite a combination of the quartz, felspar and biotite minerals. Most rock consist of polyminerals.

B. **Classification of Rocks :** On the basis of their origin, rocks are broad classified into three major groups :

1. **Igneous Rock :**

i. It is formed though the cooling and solidification of magma or lava. may form with or without crystallization.

ii. Generally, these rocks are massive in form and it is supposed that the rocks are the oldest. Ones formed on the Earth's crust, also known primary rocks.

iii. **Example :** Granite, gabbro, are formed by the consolidation of magm Basalt is formed due to solidification of lava.

2. **Sedimentary Rocks :**

i. These are the types of rock which are formed by the deposition of material at the Earth's surface and within bodies of water.

ii. Sedimentation is the collective name for processes that cause miner and/or organic particles (detritus) to settle and accumulate or mineral to precipitate from a solution.

3. **Metamorphic Rocks :** These arise from the transformation of existin rock types, in a process called metamorphism, which means "change i form". The original rock (protolith) is subjected to heat (temperature greater than 150 to 200 °C) and pressure (1500 bar), causing profoun physical and/or chemical change.

I.R&S.R. Compressed करते है तो Physical & chemical property change होती है जिससे M.R. बनती है

Que 1.10. **Give a critical account of classification of igneous rocks. Which is the suitable classification for a field engineer and why ?**

Solified

3 main type of st^n
① flow st^n
② Pillow st^n (water)
③. Vesicular st^n (gases)

AKTU 2013-14, Marks 3.5

Answer

Classification : Following are the classification of igneous rocks :

A. Classification based on Depth of Formation :

Following are the two types :

1. Extrusive Rock :

i. An extrusive igneous rock forms when magma erupts and solidifies on the Earth's surface.

ii. Because of extrusive rocks are so commonly associated with volcanoes, they are also called volcanic rocks.

iii. The texture of these rocks is fine grained texture, e.g., Basalts.

2. Intrusive Rocks :

i. An intrusive igneous rock forms when magma crystallized within the crust.

ii. Depending upon the depth of formation, the intrusive rocks are classified into plutonic rocks and hypabyssal rocks.

Plutonic Rocks :

a. The rocks formed at greater depth are called as plutonic rocks. The texture of these rocks is coarse grained texture.

b. For examples : Granites, Gabbros rocks.

Hypabyssal Rocks :

a. The rocks formed at depth close to the crust are called as hypabyssal rocks.

b. Hypabyssal igneous rocks are formed at a depth in between the plutonic and volcanic rocks. These are less common than plutonic or volcanic rocks and do often form dikes, sills, laccoliths, dolerites rocks.

c. The texture of these rocks is finer than plutonic and coarse grained than volcanic rock.

B. Classification Based on Silica (SiO_2) Content :

Following are the types of rocks on the basis of the percentage of silica present in the rock :

1.	Acid (or Felsic)	Silica > 66 wt %	Example : Granites, Quartz, Rhyolite
2.	Intermediate	Silica 52-66 wt %	Example : Diorite
3.	Basic (or mafic)	Silica 45-52 wt %	Example : Basalt
4.	Ultrabasic (or Ultramafic)	Silica < 45 wt %	Example : Peridotite

3. S .table Classification for Field Engineering :

Table 1. Tabular classification of igneous rocks.

Dom. Min. → / Rock divisions	I Quartz	II Quartz + Felspars: Orthoclase dominant	II Quartz + Felspars: Plagioclase dominant	II Quartz + Felspars: Alkali fel. dominant	III Felspars: Soda-lime fel. dominant	III Felspars: Lime-soda fel. dominant	IV Felspars + Felspathoids	V Felspathoids	V Ferromagnetic minerals
Phanerites [P] and Microphanerites [M] — Felsic	Vein quartz	Granite	Tonalite	Syenite	Diorite,	Gabbro & anorthosite	Nepheline syenite	Ijolite	Peridotite
Phanerites [P] and Microphanerites [M] — Mefelsic							Theralite teschenite		
Phanerites [P] and Microphanerites [M] — Mafic		Micro granite	Micro tonalite	Micro syenite	Micro diorite	Micro gabbro			Picrites pyrozenite
Porphyries [PO] Microporphyrics [MO] Glasses [G] — [PO]	—	Granite porphyry	Tonalite porphyry	Syenite porphyry	Diorite porphyry	Gabbro porphyry	Nepheline syenite porphyry	—	—
Porphyries [PO] Microporphyrics [MO] Glasses [G] — [M]		GRANO PHYRE			← LAMPROPHYRES →				Limburgi
Porphyries [PO] Microporphyrics [MO] Glasses [G] — [G]		← PITCH STONE →			TACHYLITE				
Aphanites [A] Glasses [G] — [A]		Rhyolite	Dacatie	Trachyte	Andesite	Basalt	Phonolite	Leuctiophyres	Olivine basalt
Aphanites [A] Glasses [G] — [G]		← PITCH STONES →			TACHYLITE				
		← OBBIDIAN →							
Silica saturation	Oversaturated (> 66%)			↓	Saturated (48–65%)		↓ Unsaturated (<48%)		

← Volcanic group hypabyssal group plutonic group

Que 1.11. Discuss Bowen's reaction series. What is its significa in the process of crystallization of magma ?

AKTU 2013-14, Marks

Answer

A. Bowen's Reaction Series :

1. Bowen found by experiment that the order in which minerals cryst from a basaltic magma depends on temperature.
2. As a basaltic magma is cooled Olivine and Ca-rich plagioclase cryst first.
3. Upon further cooling, Olivine reacts with the liquid to produce pyro and Ca-rich plagioclase react with the liquid to produce less Ca plagioclase.
4. But, if the Olivine and Ca-rich plagioclase are removed from the l by crystal fractionation, then the remaining liquid will be more rich.

5. If the process continues, an original basaltic magma can change to first and andesite magma then a rhyolite magma with falling temperature.
6. Bowen's reaction series is shown as a chart.

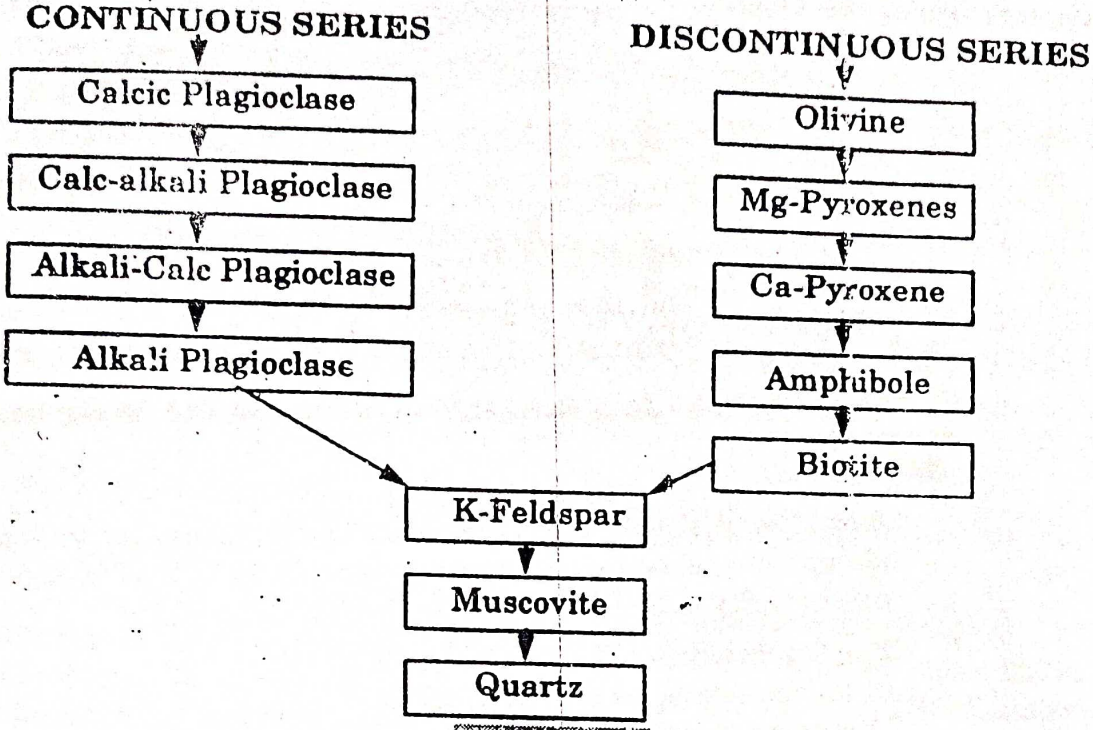


Fig. 1.11.1.

7. The three minerals shown at the end of chart indicate the fact that from a melt these three minerals will form towards the last stages of crystallization and they do not react with the remaining melt, if any.

B. Significance :

1. Bowen's reaction series is able to explain why certain types of minerals tend to be found together while others are almost never associated with one another.
2. The Bowen's reaction series shows the stability of minerals with the ones at bottom being most stable and the ones at top being quickest to weather. This is because minerals are most stable in the conditions closest to those under which they had formed.

Que 1.12. Explain various forms in which igneous rocks occur in nature with the help of neat sketches. **AKTU 2014-15, Marks 03**

Answer

Following are the forms in which igneous rocks occur in nature :

1. Dykes :

i. It may be defined as columnar bodies of igneous rocks that cut across the bedding plane or unconformities or cleavage planes and similar structures.

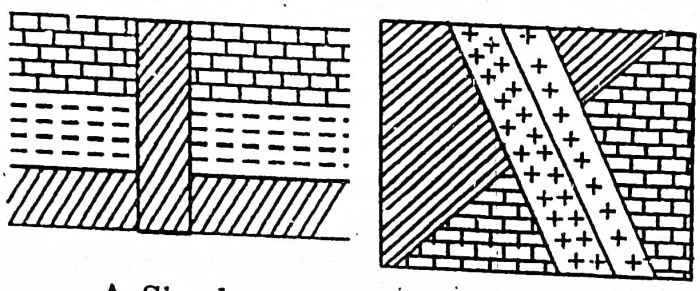
ii. Generally the dykes are formed by the intrusion of magma i pre-existing fractures.

iii. It depends on the nature of magma and the character of the invac rock whether the walls of the fracture are pushed apart, that is, i widened or not.

iv. Dykes show great variations in their thickness, length, texture a composition.

v. They may be only few centimeters or many hundreds of meters thi Similarly, in length they may be anything between a few meters many kilometers.

vi. In composition, dykes are generally made up of hypabyssal rocks li dolerites, porphyries and lamprophyres, showing all textures betwe glassy and phaneritic types.



A. Simple B. Multiple

Fig. 1.12.1.

2. **Sills :**

i. Those igneous intrusions that have been injected along or between t bedding planes or sedimentary sequence are known as sills.

ii. It is typical of sills that their thickness is much small than their wid and length.

iii. Moreover, this body commonly thins out or tapers alone its outer margi

iv. The upper and lower margins of sills commonly show a comparative finer grain size than their interior portions.

v. This is explained by relatively faster cooling of magmatic injection these positions.

vi. In length, sills may vary from a few centimeters to hundreds of mete

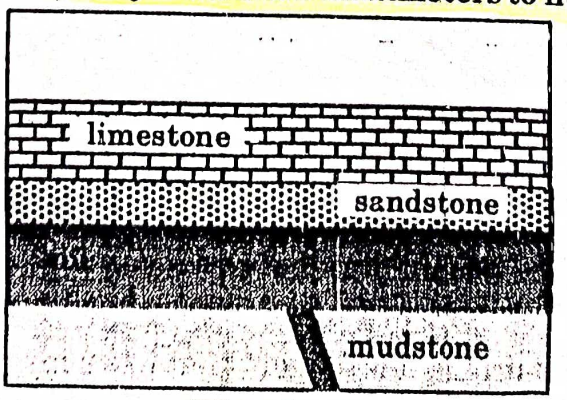


Fig. 1.12.2.

3. Laccoliths :

i. It is a concordant body, with flat bottom and convex upward. It is dome shaped.

ii. When viscous magma is injected rapidly along the bedding, as it cannot spreads it pushes up the overlying layers and keep on piling up.

iii. It causes folding of the overlying rock layers.

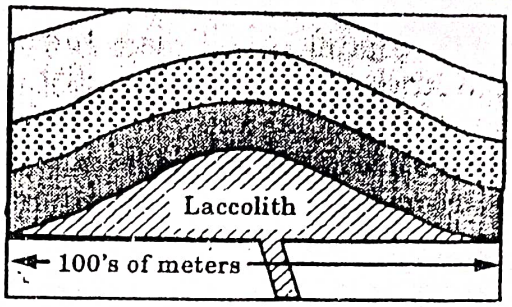


Fig. 1.12.3.

4. Lopoliths :

i. Those igneous intrusions, which are associated with structural basins. that are sedimentary beds inclined towards a common centre, are termed as lopoliths.

ii. They may form huge bodies of consolidated magma, often many kilometers long and thousands of meters thick.

iii. It is believed that in the origin of the lopoliths, the formation of structural basin and the injection of magma are contemporaneous, that is, broadly simultaneous.

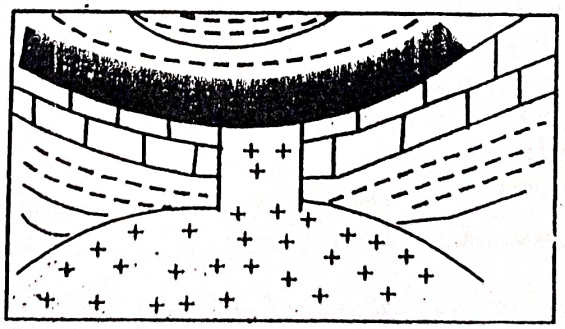


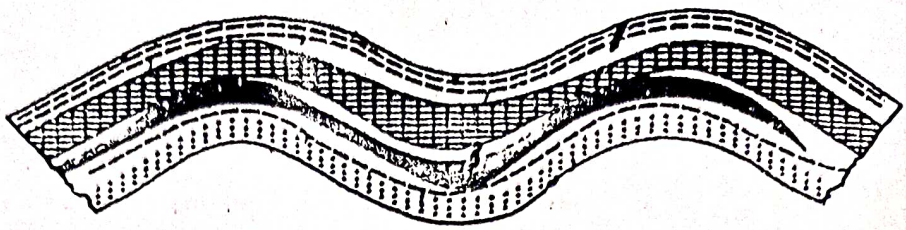
Fig. 1.12.4. Lopoliths.

5. Phacoliths :

i. These are concordant, small sized intrusive that occupy positions in the troughs and crests of bends called folds.

ii. In outline, these bodies are doubly convex and appear crescents or half-moon shaped in cross-section.

iii. As regards their origin, it is thought that when magma is injected into a folded sequence of rocks, it passes in the crests and troughs almost passively *i.e.*, without exerting much pressure, as shown in Fig. 1.12.5.



Phacoliths (Dark shaded)

Fig. 1.12.5.

Q.e 1.13. Explain with the help of neat sketches important te of igneous rocks and also possible cause for their formation.

Answer

A study of the textural character of rocks provides valuable inform about mineral composition, cooling and solidification conditions. Te are broadly classified into five types. These are :

1. **Equigranular :** Those textures in which majority of constituent c of a rock are broadly equal in size. In igneous rock, these textur shown by granite and felsites and hence are also often name as gr and felsitic texture as shown in Fig. 1.13.1.

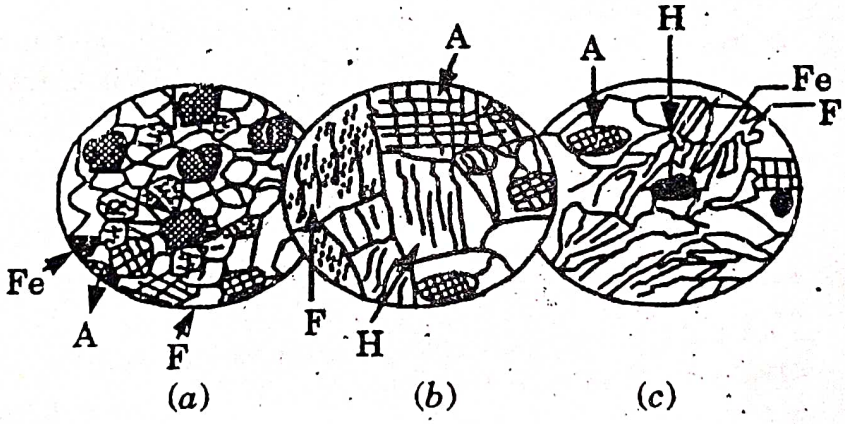


Fig. 1.13.1. Equigranular texture.

2. **Inequigranular :** In which the majority of constituent mineral marked difference in their relative grain size are group inequigranular texture as shown in Fig. 1.13.2.

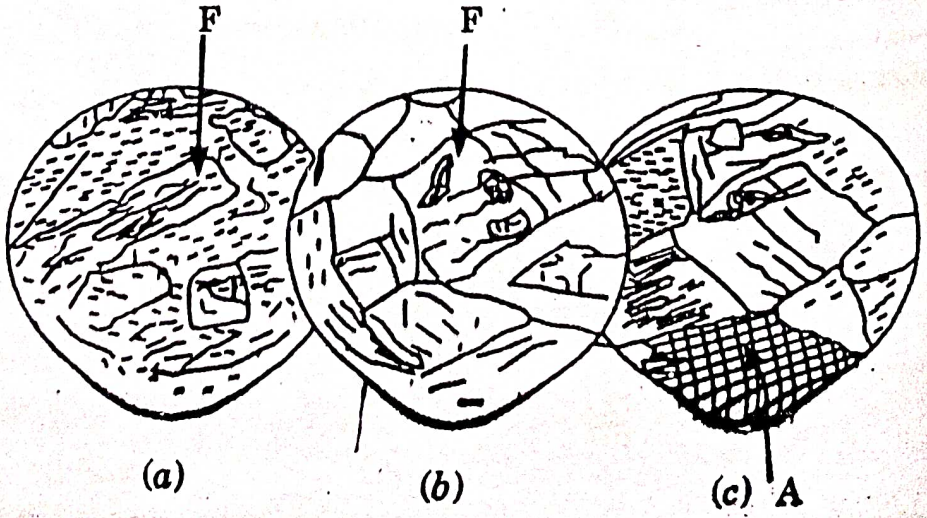


Fig. 1.13.2. Inequigranular texture.

3. **Directive Texture :** Those textures which indicate the result of flow of magma during the formation of rock are known as directive texture.

4. **Intergrowth Texture :** Sometimes two or more mineral may crystallize out simultaneously in a limited space so that the resulting crystals are mixed up or intergrown. This type of mutual arrangement is expressed by the term intergrowth texture as shown in Fig. 1.13.3.

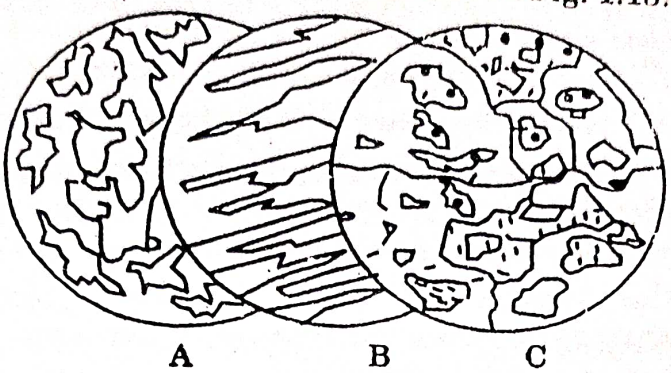


Fig. 1.13.3. Intergrowth texture.

5. **Intergranular Texture :**

i. In certain igneous rocks, crystal formed at earlier stages may get so arranged that polygonal or trigonal spaces are left in between them.

ii. These spaces get filled by crystalline or glassy masses of other material. The texture so produced is called an intergranular texture as shown in Fig. 1.13.4.

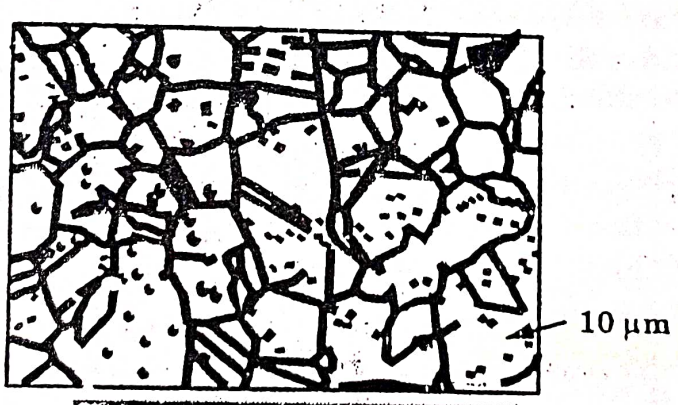


Fig. 1.13.4. Intergranular texture.

PART-3

The Origin, Structure, Texture, and Classification of Sedimentary Rocks.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

classifica

Clastic

Sedimen

(28)

Nonclastic Sediment
- chemically formed rock. mineral matter in Sol^n of percipitation. (change in water temp)
- organically f. r.

- Bio-chemical rock → plant & living animal
- Organic rock → Rock Containing organic m

Que 1.14. **What are sedimentary rocks ? How are they cla**
Give a brief description of each class with examples.

AKTU 2016-17, M

Answer

A. **Sedimentary Rocks :** Sedimentary rocks are types of rock formed by the accumulation or deposition of small parti subsequent cementation of mineral or organic particles on th oceans or other bodies of water at the Earth's surface.

B. **Classification :** Following are the classification of sedimenta

1. **Based on the Presence of the Sediment of Particular Gra**

i. **Rudaceous Rocks :** The rocks which include all the coarsed g more than 2 mm size heterogeneous composition are called as r rocks. These are also called as rudites or phephites. Bre conglomerates are the important rocks.

ii. **Arenaceous Rocks :** The rocks which include all the sedime between 1/16 – 2 mm are called as arenaceous rocks. These called as arenites or psammites. Sandstone, greywacke and ark the important rocks.

iii. **Argillaceous Rocks :** The rocks which include all the finest s of size less than 1/16 mm are called as argillaceous rocks. These called as lutites or pelites. Silt, clay, shale, and mudstones important rocks.

2. **On the Basis of the Chemical Composition of Sedim Rocks :**

i. **Siliceous Rocks :** These sedimentary rocks contain silica constituent.

Example : Flint, chert, jasper.

ii. **Carbonate Rocks :** These sedimentary rocks are precipitate carbonate rich water under different condition, controlled concentration of carbon dioxide.

Example : Carbonate deposits of iron, limestone, dolomite.

iii. **Ferruginous Rocks :** These sedimentary rocks are form precipitation of iron oxides.

Example : Haematite, pyrite, iron stone.

iv. **Evaporites :** These sedimentary rocks are formed by evapora saline lakes.

Example : Gypsum, anhydrite, rock salt, borates.

tion -

→ Rudaceous Rock. bigger rock (gravel, pebble, boulder)
→ Arenaceous Rock. Sandgrains,
→ Argillaceous Rock. fine-grained sediment. (mix sand & silt)

3. **On the Basis of Organically Formed Sedimentary Rocks :**

i. **Biochemical Rocks :** The biochemical sediments are produced when plants, and animals living under water, extrude from it dissolved mineral matter, usually calcite, to form shells or other hard parts. These shells accumulate on the ocean floor in great quantities to form sedimentary rocks.

Example : Shell limestone.

ii. **Organic Rocks :** The sedimentary rocks formed due to accumulation and decomposition of vegetation matter is known as organic rocks.

Example : Peat, lignite, coal.

Que 1.15. **Explain how sedimentary rocks are formed. Describe various structures present in the rocks.** **AKTU 2014-15, Marks 3.5**

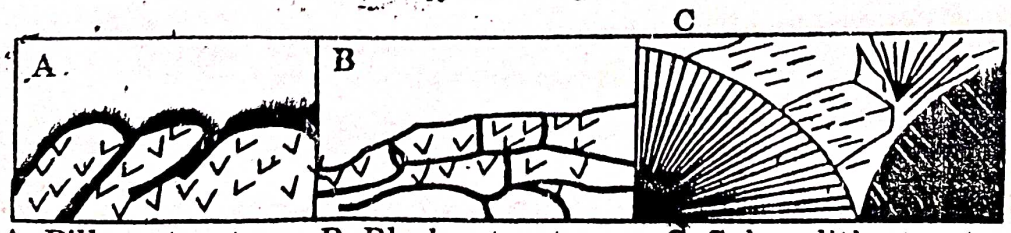
Answer

A. **Formation of Sedimentary Rocks :**

1. The process of formation of sedimentary rocks is ever prevailing. Even at present, millions of tonnes of existing rocks are broken every year in different areas of the Earth by natural process.
2. The sediments so produced are transported to the settling basins such as sea floors where they are deposited, get compacted and consolidated and finally transformed into a cohesive solid mass. That is a sedimentary rock.
3. Similarly, millions of sea and oceanic organisms perish every month and their hard parts are accumulating at the floors of these water bodies.
4. These hard parts gradually get compacted and converted into sedimentary rocks of a different origin.
5. Some chemical processes especially evaporation and precipitation regularly operate on surface of water bodies containing dissolved salts and produce solids that settle down in those bodies.
6. Similarly processes are believed to have operated right from the beginning of the Earth as a distinguished planet of the solar system.
7. Hence, at present, formation of sedimentary rocks has to be explained with specific reference to the type of the source of the sediments/particles and the environment in which these materials have been deposited.

B. **Structure of Igneous Rock :**

1. **Structure due to Mobility of Magma or Lava**



A. Pillow structure B. Blocky structure C. Spherulitic structure

Fig. 1.15.1.

i. **The Flow Structures :** These are defined by the development of paralle or nearly parallel layers or bands or streaks in the body of an igneou rock. The parallelism is caused by the flow of magma or lave during t process of crystallization.

ii. **The Pillow Structure :**

a. This characterized by the development of bulbous, overlappin pillow like surfaces in the body of igneous mass.

b. It is typical structure or rocks formed from mobile basaltic lava.

c. In such a lava flow, its upper surface gets solidified while the la beneath remains hot and capable of flowing. But further flow possible only when the crust formed at the top ruptures.

d. The ruptures occur at the margins of previously congealed ov marks; from such ruptures lava flows out and cools down aga forming fresh bulbous tops.

iii. **The Ropy and Blocky Structure :**

a. These are structural variations developed in the volcanic rocks d to different mobility. Highly viscous "dry" lavas undergo very lit movement after their eruption and before cooling. Their surfac show broken and fragmented appearance. These are called t blocky lava.

b. On the other hand, very mobile lava flows for considerable distar and cooling during flow process so that its upper surface is smootl wrinkled rather than actually broken. The surface structure then referred as ropy lava.

iv. **The Spherulitic Structure :** It is distinguished by the presence of t mineral fibers of various sizes arranged in perfect or semi perfect rad manner about a common centre.

v. **The Orbicular Structure :** In this, a rock mass appears as if compo of ball like aggregation. Each ball is in turn composed of concent shells of different minerals. This structure is shown by some granit

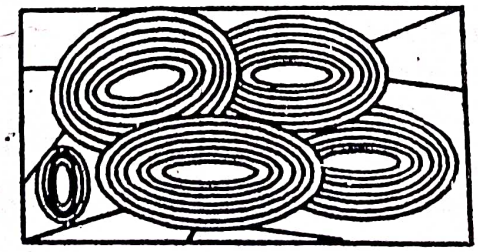


Fig. 1.15.2. Orbicular structure.

2. **Structure due to cooling of magma :** Following are the structure rock due to cooling of magma :

i. Jointing structure.

ii. Rift and grain.

iii. Vesicular structure.

iv. Miarolitic structure.

3. **Miscellaneous Structure :** Following are the miscellaneous structure of rocks :

i. Reaction structure.

ii. Xenolithic structure.

Que 1.16. **Explain the various types of texture of sedimentary rocks.**

Answer

Texture of Sedimentary Rocks : Sedimentary rocks show considerable variation in their texture (or mutual relationship of the constituent minerals). Their texture is determined by at least six contributing factors :

1. **Origin of Grains :**

i. A sedimentary rock may be partially or wholly composed of clastic (or allogenic) grains, or of chemically formed or organically contributed parts.

ii. Thus the rock may show a clastic texture or a non-clastic texture.

2. **Size of Grains :** Three textures recognized on the basis of grain size are :

i. Coarse-grained rocks; average grain size > 5 mm

ii. Medium-grained rocks; average grain size between 5 and 1 mm.

iii. Fine-grained rocks; average grain size < 1 mm

3. **Shapes of Grains :**

i. The sediments making the rocks may be of various shapes: rounded, subrounded, angular and sub-angular. They may show sphericity to various degrees.

ii. Roundness and sphericity are the indications of varying degree of transport and abrasion suffered during that process.

iii. Breccias are made up mostly of rough and angular fragments indicating least transport and abrasion.

iv. Conglomerates are full of rounded and smooth-surfaced pebbles and gravels indicating lot of transport and rubbing action during their transport before getting deposited and consolidated into a rock mass.

4. **Packing of Grains :**

i. Sedimentary rocks may be open-packed or porous in textures or densely packed depending upon their environment of formation.

ii. The degree of packing is generally related to the load of the overlying sediments during the process of deposition.

5. Fabric of Grains :

i. A given sedimentary rock may contain many elongated particl orientation is studied and described in terms of orientation longer axes.

ii. If-all or most of the elongated particles are arranged in such a their longer axes lie in the same general direction, the rock i show a high degree of preferred orientation.

iii. This direction is generally indicative of the direction of flow of th during the period of deposition.

6. Crystallization Trend :

i. In sedimentary rocks of chemical origin, the texture is generall by the degree and nature of crystallized grains.

ii. Rocks may show perfectly interlocking grains giving rise to cr granular texture or they may be made up of non-crystalline, particles when they are termed as amorphous.

PART-4

The Origin, Structure, Texture and Classification of Metamorphic Rocks.

Questions-Answers

Long Answer Type and Medium Answer Type Questio

Que 1.17. **What are metamorphic rocks ? Discuss the agents of metamorphism.** **AKTU 2013-14, 2014-15; Ma**

Answer

A. Metamorphic Rocks :

1. Metamorphic rocks are created by the physical or chemical although by heat and pressure of an existing igneous or sedimentary into a denser form.

2. Metamorphic rocks are always more dense than their original r and also much less susceptible to erosional breakdown.

B. Agents of Metamorphism : Following are the ag metamorphism :

1. Chemical Activity as a Metamorphic Agent :

i. Chemically active fluids also enhance the metamorphic proces

ii. Most commonly, the fluid is water containing ions in solution.

iii. Water is plentiful, because some water is contained in the pore spaces of virtually every rock.

iv. In addition, many minerals are hydrated (have water bound chemically), and thus contain water within their crystalline structures.

2. **Heat as a Metamorphic Agent :** The most important agent of metamorphism is heat because it provides the energy to drive the chemical changes that result in the recrystallization of minerals.

3. **Pressure and Stress as Metamorphic Agents :**

i. Pressure, like temperatures, also increases with depth.

ii. Buried rocks are subjected to the force, or stress by the load above.

iii. This confining pressure is analogous to water pressure where the force is applied equally in all directions.

Que 1.18. **Describe sedimentation and metamorphism. List of various types of textures and structures evolved due to metamorphic process.**

AKTU 2017-18, Marks 10

Answer

A. Sedimentation :

1. The sediments as produced through weathering and erosion are transported to settling basins.

2. These basins may be located in different environments such as on the continents, along the sea-shores or in deep-sea environments. As such sedimentary rocks formed in different environments will show different inherent characters.

3. In the continental environments may be included the glacial deposits, the fluvial deposits, the glacio-fluvial deposits and the eolian deposits, each type giving rise to a definite type of sediment accumulation.

4. In the marine deposits, some sediment may be dropped just along the sea-shore, or at some shallow depth within the sea or miles away in the deep-sea environment.

B. Metamorphism :

1. It is the term used to express the process responsible for all the changes that take place in an original rock under the influence of changes in the surrounding conditions of temperature, pressure and chemically active fluids.

2. Metamorphism occurs at temperatures and pressures higher than 200 °C and 300 MPa.

C. **Texture of Metamorphic Rocks :** Following are the type of textu of metamorphic rocks :

1. **Crystalloblastic Texture :**

i. In describing metamorphic textures the terms 'blastic' or 'blast' a commonly used as a suffix to represent the metamorphic equivalents igneous textures of similar look.

ii. Recrystallization of the minerals produces a crystalloblastic texture whi is similar to the holocrystalline texture of igneous rocks. These textur are the products of metamorphism process.

2. **Porphyroblastic Texture :** If during metamorphism a texture simil to that of porphyritic comes into existence the same is described a porphyroblastic texture.

3. **Palimpsest Texture :** The textures which were present in the paren rock are retained by the rock despite metamorphic changes in the rock in other aspects.

4. **Blasto-Porphyritic Texture :** The porphyritic texture retained b the igneous rock after it has undergone the process of metamorphism may be named as blasto-porphyritic.

5. **Blastophitic Texture :** It is also an example of palimpsest texture, in which the ophitic texture of the original igneous mass is found to continue to exist in the final metamorphosed rock.

6. **Xenoblastic Texture :** If the minerals of crystalloblastic metamorphic rocks do not possess perfect crystal outline, they are defined as xenoblastic texture crystals, and if the mineral grains might have developed perfect crystal outline during recrystallization and such grains are described as idioblastic.

7. **Granoblastic Texture :** In this texture the recrystallined mineral grains are commonly found to be equidimensional.

D. **Structures of Metamorphic Rocks :** Following are the structures of metamorphic rocks :

1. **Cataclastic Structure :** It is characterized by the development of extremely fine rock mass under the influence of severe crushing and shearing effects of stresses operating during metamorphism.

Example : Mylonite, breccia.

2. **Schistose Structure :**

i. These rocks show more or less parallel bands.

ii. Flaky minerals, such as biotite, hornblende, chlorite and talc are influenced by the temperature and pressure conditions and form parallel layered arrangements resulting in a schistose structure.

iii. However, if the bands are unequidimensional, this is termed as foliation. These are exhibited by rocks such as hornblende schist, chlorite schist, and biotite schist.

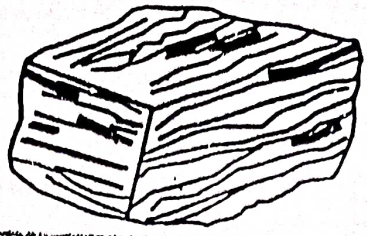


Fig. 1.18.1. Schistose structure (Mica Schist).

2. **Gneissose Structure :** In this structure, bands of platy and flaky minerals alternate with those of equidimensional and granular minerals. These bands are generally contrasting colors, composition and textures as shown in Fig. 1.18.2.

Example : Hornblende gneiss and biotite gneiss.

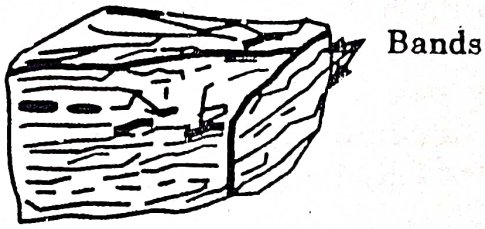


Fig. 1.18.2. Gneissose structure (Banded Gneiss).

3. **Maculose Structure :** It is characterized by a spotted appearance of the rock that may be caused due to the formation of large sized crystals within the fine grained rock mass as shown in Fig. 1.18.3.

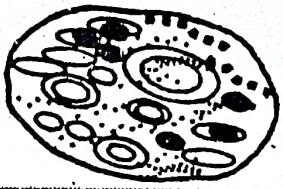


Fig. 1.18.3. Maculose structure (Hornfels).

4. **Granulose Structure :** It is a typical structure of metamorphic rocks like marble and quartzite and is characterized by an essential granular character of the constituent materials. The individual grain may be irregular in outline but are interlocking as shown in Fig. 1.18.4.

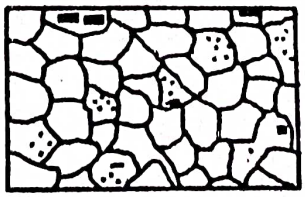


Fig. 1.18.4. Granulose structure (Marble).

Que 1.19. Explain the terms metamorphic facies, metamorphic grade and metamorphic zone. Give example to each case.

Answer

A. Metamorphic Grades :

1. The approximate extent or degree to which an original rock has be changed due to metamorphism is expressed by the term metamorp grade.
2. Three terms are used to express the grades : low grade, medium gra and high grade.
3. These grades are indicated by the presence of a set of minerals that a called the index minerals.

i. **Low Grade :** It prevails within a temperature range of 200-400 °C a a large pressure range. Important index minerals are: laumonti prehnite, and lawsonite.

ii. **Medium Grade :**

a. This grade prevails up to a temperature range of 650 °C and indicated by the index minerals like staurolite and cordierite.

b. Pressure variations play an important role in determining the stabili of various minerals formed in this grade.

iii. **High Grade :**

a. It is believed to begin at temperatures around 580 °C under pressu of 3.5 lb and continues up to temperature of 800 °C and above.

b. Hypersthene is a typical index mineral of high grade metamorphis and granulites are the common resulting metamorphic rocks.

B. Metamorphic Zones :

1. The grade of metamorphism generally increases with depth for tl simple reason that both temperature and pressure factors become stroı and stronger at deeper levels within the crust of the earth. This fact hı given birth to the concept of metamorphic zones that signify the rang of metamorphic effects at different depths below the surface. In othe words, zones indicate depth wise extension of particular grades metamorphism in a general way.
2. The three metamorphic zones are : epizone, mesozone and ketazone.

i. **The Epizone :**

a. It is the near surface zone and is characterised by a low temperatur (generally less than 300 °C) and strong shear stress.

b. Rocks in this zone are, therefore, metamorphosed chiefly unde the influence of dynamic metamorphism.

c. The common rocks resulting in this zone are slates and mica schist

ii. **The Mesozone :**

a. It is the middle zone in which the temperature factor become rather moderate (300-500 °C) and the pressure factor is of both th types : shear as well as hydrostatic type.

b. Dynamothermal metamorphism is the typical process of this zone and high grade schist like biotite-garnet schist are chief rocks formed.

iii. The Ketazone :

a. It is the high temperature and great depth type metamorphic zone where hydrostatic stresses are quite dominant.

b. Plutonic metamorphism is the representative kind and rocks formed in this zone include great variety of gneisses.

C. Metamorphic Facies :

1. Metamorphic rocks can be classified on the basis of metamorphic environment through which these rocks have passed. An association of metamorphic rocks that have formed under a closely related metamorphic environment (that is within a range of temperature-pressure-chemically-active fluid conditions) is termed as a metamorphic facies.
2. A metamorphic facies may be characterized by a set of minerals or typical rocks.
3. The concept of metamorphic facies simplifies the classification of metamorphic rocks in that it eliminates the necessity of knowing the nature of the parent rocks and their original characters.
4. At present ten metamorphic facies are considered.

PART-5

Suitability of Igneous, Sedimentary and Metamorphic Rocks as Engineering Material.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.20. **Discuss the suitability of igneous, sedimentary and metamorphic rocks as an engineering material.**

Answer

Use of Rocks :

1. Rock is widely used as building material available to man from prehistoric times.
2. Stones have been used for construction and architectural purposes since the beginning of the civilization.
3. Rock is a natural aggregate of minerals formed under the inorganic process of nature.

1. **Suitability of Igneous Rock as Engineering Material :**

i. **Granite :** It is a most important building stone. Use for decor purpose. It can take a fine polish and is the strongest stone amon the varieties of building stone.

ii. **Basalt :** This is mainly used for the construction of bridge and o engineering work. They are basic in character.

iii. **Dolerites :** It is widely used for the road construction work.

iv. **Diorite :** It is widely used for rubble masonry and for road work.

v. **Syenite :** It is used for decorative purpose.

2. **Suitability of Sedimentary Rock as Engineering Material :**

i. **Breccias :** Some of the compacted varieties of breccias which susceptible to polish, can be used as ornamental work.

ii. **Conglomerates :** The harder and longer varieties of conglomera are used in foundation concrete and railway ballast.

iii. **Shale :** Shale is usually soft and brittle rocks which are used for br and tile manufacture.

iv. **Limestone :** It is used in cement industry and road metal.

3. **Suitability of Metamorphic Rocks as Engineering Materials**

i. **Slate :** It is foliated rock and is seldom used as building stone, becaus its low crushing strength and perfect cleavage.

ii. **Marble :** It is non-foliated rocks. It is sufficiently hard and can ta polish. It is extensively used as a building stone specially for decorati purpose.

iii. **Quartzite :** The rock is generally very hard, strong, dense and uniform grained. It finds extensive use in building and road construction.

iv. **Gneiss :** It is a foliated rock. Harder varieties of Gneiss are used as ro material and concrete aggregate.

v. **Schist :** It is also foliated rocks. It is used as roofing material, staircas etc.

Que 1.21. **Discuss the rock cycle with neat sketch.**

Answer

Rock Cycle :

1. The rock cycle is a basic concept is geology that describes transitior through geologic time among the three main rock types. Sedimentar metamorphic and igneous. Each rock type is altered when it is force out of its equilibrium conditions.

2. The rock cycle explain that how the three rock types are related to eac other and how process change from one type to another over times.

3. The process of transformation :

i. Igneous rocks, as a consequence of weathering, give rise to sedimentar rocks. Further, under the influence of metamorphism they also giv rise to orthometamorphic rocks.

ii. Sedimentary rocks, when buried to great depths (due to tectonic activity), form magma on melting and subsequently solidify to form igneous rocks

and under the influence of metamorphism change over to parametamorphic rocks.

iii. The metamorphic rocks, like the igneous rocks, on weathering, give rise to sediments which form sedimentary rocks later.

iv. The metamorphic rocks, like the sedimentary rocks, when buried to great depths due to tectonic activity will melt and give rise to magma, from which igneous rocks are formed.

v. Thus one group of rocks gives rise to another in nature due to geological reasons.

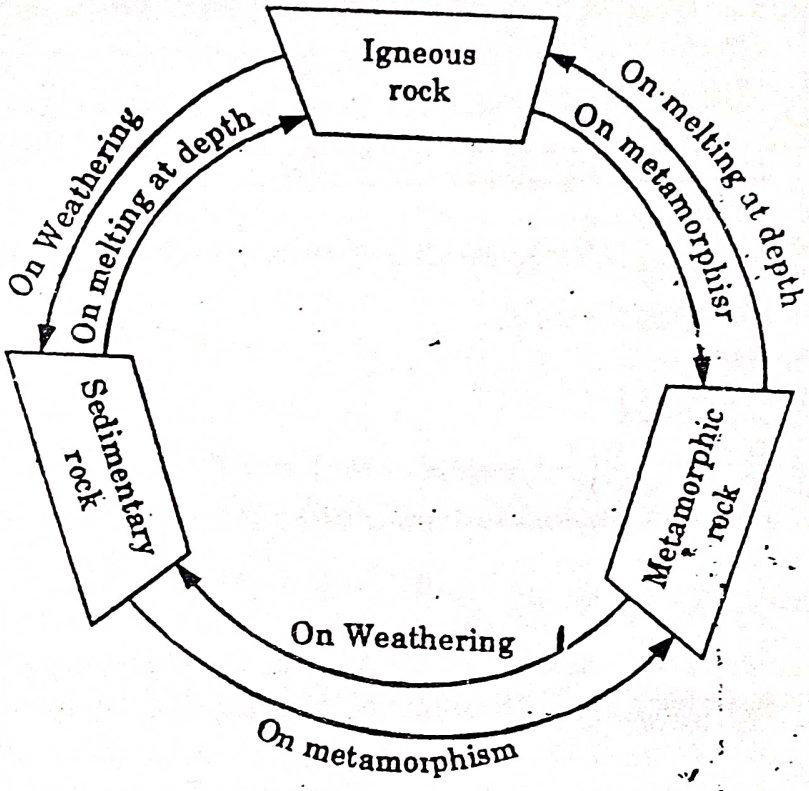


Fig. 1.21.1. Rock cycle.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Give a brief account of the importance of geology in Civil Engineering. Explain the answer by giving suitable examples.

Ans. Refer Q. 1.1, Unit-1.

Q. 2. Explain the various properties of rocks forming minerals.

Ans. Refer Q. 1.3, Unit-1.

Q. 3. Discuss the process of formation of minerals in nature Which group of minerals is most common in occurren Discuss their salient features.

Ans. Refer Q. 1.4, Unit-1.

Q. 4. What do you mean by minerals ? Explain the physical chemical properties of all rock forming minerals.

Ans. Refer Q. 1.8, Unit-1.

Q. 5. Give a critical account of classification of igneous ro Which is the suitable classification for a field engineer why ?

Ans. Refer Q. 1.10, Unit-1.

Q. 6. Discuss Bowen's reaction series. What is its significanc the process of crystallization of magma ?

Ans. Refer Q. 1.11, Unit-1.

Q. 7. Explain various forms in which igneous rocks occu nature with the help of neat sketches.

Ans. Refer Q. 1.12, Unit-1.

Q. 8. What are sedimentary rocks ? How are they classifie Give a brief description of each class with examples.

Ans. Refer Q. 1.14, Unit-1.

Q. 9. What are metamorphic rocks ? Discuss the various age of metamorphism.

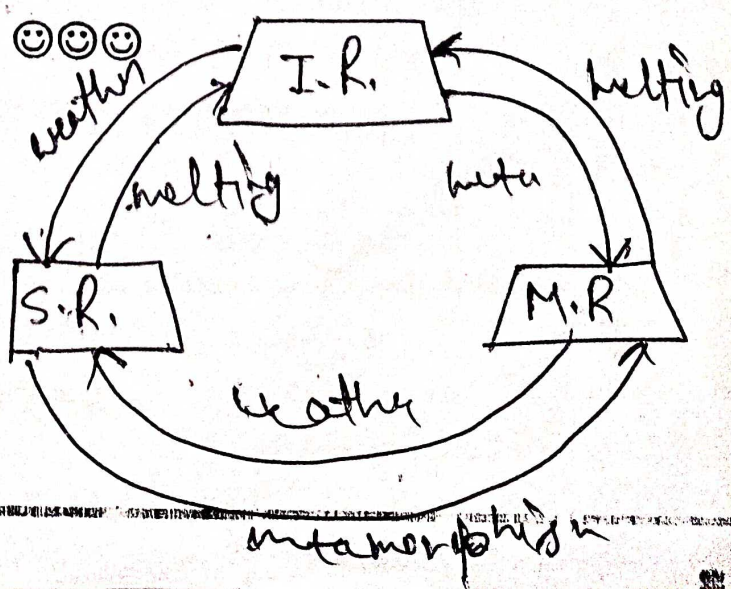
Ans. Refer Q. 1.17, Unit-1.

Q. 10. Describe sedimentation and metamorphism. List of vari types of textures and structures evolved due to metamorp process.

Ans. Refer Q. 1.18, Unit-1.

Q. 11. Discuss the suitability of igneous, sedimentary a metamorphic rocks as an engineering material.

Ans. Refer Q. 1.20, Unit-1.



2 UNIT

Structural Features of Rocks

CONTENTS

Part-1	:	Stratification and Lamination, Bedding of Rocks, Dip and Strike of Bed	**2–2C to 2–10C**
Part-2	:	Rock Deformation : Folds, Faults	**2–10C to 2–19C**
Part-3	:	Joint, Unconformity and Classification	**2–19C to 2–25C**

Igneous rock $\xrightarrow{\text{erosion}}$ Transport करके $\longrightarrow$ Deposit होता है

PART-1

Stratification and Lamination, Bedding of Rocks Dip and Strike of Bed.

Questions-Answers

Long Answer Type and Medium Answer Type Question

Que 2.1. **Define the term rocks. Describe the formati sedimentary rocks.**

Answer

A. **Rocks :** Refer Q. 1.9, Page 1–16C, Unit-1.

B. **Formation of Sedimentary Rocks :** The sedimentary rocks are f from the pre-existing rocks through the following stages :

1. **Erosion of the Existing Rocks :** Rocks existing on the surface earth are exposed to decay and the disintegration by the action of n agencies like atmosphere, water, and ice on them. So, the massive are converted into fine sediment. This process is known a weathering as erosion of the existing rocks.

2. **Transportation of the Eroded Material :**

i. The detritus produced from the decay and disintegration of th existing rocks forms the source of the sedimentary rocks but it ha transported to a suitable place for transformation again into mass.

ii. The wind, running water and ice in the form of glacier are th strong and common agents of transport for carrying millions of t of sediments and particle from one place to another.

3. **Deposition of the Material :** The eroded material which is trans by transporting agent is deposited sooner or later depending up circumstances. These sediments continue to accumulate in suitable of sedimentation.

4. **Transformation of the Deposited Material into Thick Massive Rocks :**

i. When the accumulation is sufficient, the loose rock particle are sub to compaction and finally converted into sedimentary rocks favourable circumstances.

ii. The process of transformation of loose rock particles into har massive sedimentary rock is achieved through the following two (a) Welding (b) Cementation.

iii. Welding :

a. Welding is the process of compaction of the sediments accumulated in lower layer of a basin due to the pressure exerted by the land of the overlying sediments.

b. This result in squeezing out most of the water from in between the sediments, thus bringing them closer and consolidating them virtually in solid rock mass.

iv. Cementation :

a. The sediments are held together by a foreign binding or cementing material.

b. This cementing material is generally supplied by the percolating waters.

c. The most common cementing material are carbonates of calcium and magnesium as well as oxides of iron and silicon.

Que 2.2. **Explain how sedimentary rocks are formed. Describe various structures present in the rocks.**

AKTU 2014-15, Marks 3.5

OR

Define stratification. Briefly describe the lamination bedding.

AKTU 2015-16, Marks 10

OR

Explain lamination, stratification, cross and graded beddings and where do they occur.

AKTU 2017-18, Marks 10

OR

Explain the following :

i. Strike. **ii. Graded bedding.**

iii. Current bedding. **iv. Stratification.**

AKTU 2014-15, Marks 03

Answer

A. Formation of Sedimentary Rocks : Refer Q. 2.1, Page 2–2C, Unit-2.

B. Structure of Igneous Rocks : Refer Q. 1.15, Page 1–25C, Unit-1.

C. Various Types of Structure Developed in Sedimentary Rocks :

1. Strike :

i. It is defined as the direction of a line formed by the intersection of the bedding and horizontal plane.

i. It is geographic direction given by a line of intersection of a horizontal plane of a layer of rock.

iii. Simply stated, if one walks along a horizontal line drawn on a bedding plane, one would be walking along the strike of the layer.

iv. It is also measured in field with the help of a compass.

2. Graded Bedding :

i. In geology, a graded bed is one characterized by a systematic change in grain or clast size from the base of the bed to the top.

ii. Most commonly this takes the formal grading, with coarser sediments at the base, which grade upward into progressively finer ones.

iii. Normally, graded beds generally represent depositional environmental which decrease in transport energy as time passes but also form during rapid depositional events.

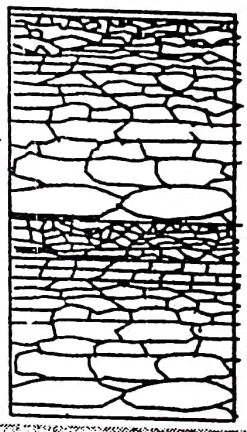


Fig. 2.2.1. Graded bedding.

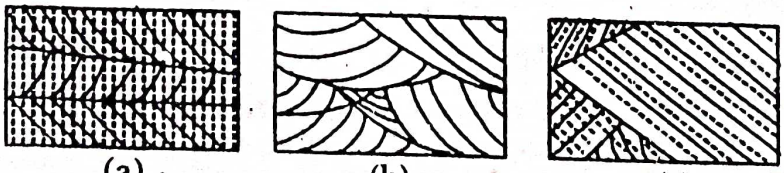
3. **Current Bedding :**

i. In this structure, minor beds or lamination lies at an angle to the plain of general stratification.

ii. These minor beds commonly terminate abruptly at the top where they are overlain by the next current bedded deposit.

iii. Current bedding is commonly found in shallow water.

iv. In current bedding, the minor beds are inclined and stacked up in the form of a wedge in the direction of water current or prevailing wind as shown in Fig. 2.2.2.



(a) (b) (c)

Fig. 2.2.2. Current bedding flase bedding.

4. **Stratification or Bedding :**

i. Most sedimentary rocks are deposited under conditions which favour development of distinct layers piled up one above another, from bottom to top.

ii. These layers are also called beds, or strata are quite often be distinguishable on the basis of variation in their color, composition and grain size.

iii. This layered character is bedding and stratification and is one of the most fundamental structures of the sedimentary rocks.

iv. Since sedimentary rocks are superficially the most widespread rocks, forming more than 75 % of the exposed surface of the earth, it can be clearly observed, stratification in all of its splendor in hills, mountains and steep valleys, in any part of the world.

v. The layers may be horizontal, inclined, vertical or even bent or warped or broken presenting every where some new and interesting structure or geological feature of study.

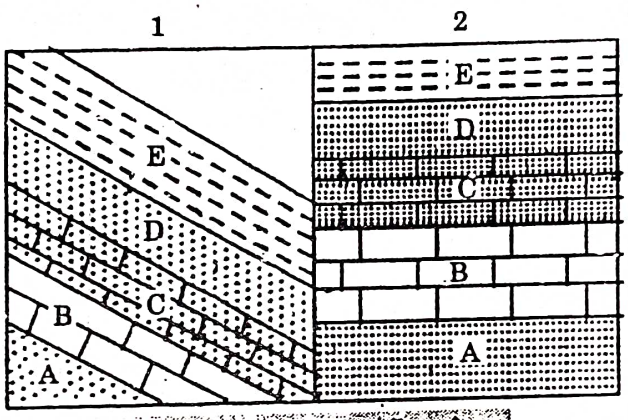
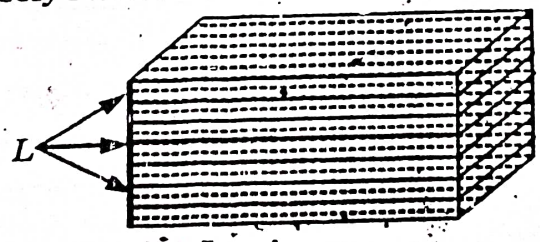


Fig. 2.2.3. Stratification.

5. **Lamination :**

i. It is a term closely related to stratification.



L = Lamina

Fig. 2.2.4. Lamination bedding.

ii. It is layered structure developed in extremely fine grained sedimentary rocks made up of clay and silt so that different layers are very thin, paper thin, (lamina = leaf). It is typical form of sedimentary rocks as shown in Fig. 2.2.4.

Que 2.3. **What is lamination bedding ? Explain its effect on topography.**

AKTU 2015-16; 2017-18, Marks 10

Answer

A. **Lamination Bedding :** Refer Q. 2.2, Page 2–3C, Unit-2.

B. **Effects :** Following are the effects of lamination bedding on topography

1. If the sedimentary rocks are flat-lying, then it is mostly the effect of the topography on the geological boundaries which controls the nature of the outcrop pattern.
2. However, if the sedimentary rocks have been folded, it is more the geological structure which controls the outcrop of the stratigraphic formations, unless the topographic relief is very marked.
3. Under these circumstances, the outcrop pattern of the sedimentary formations shows how the bedding varies in strike as it is traced across the area under consideration.
4. The dip of the bedding can be found by studying the effect of the topography on the geological boundaries, wherever this can be determined.

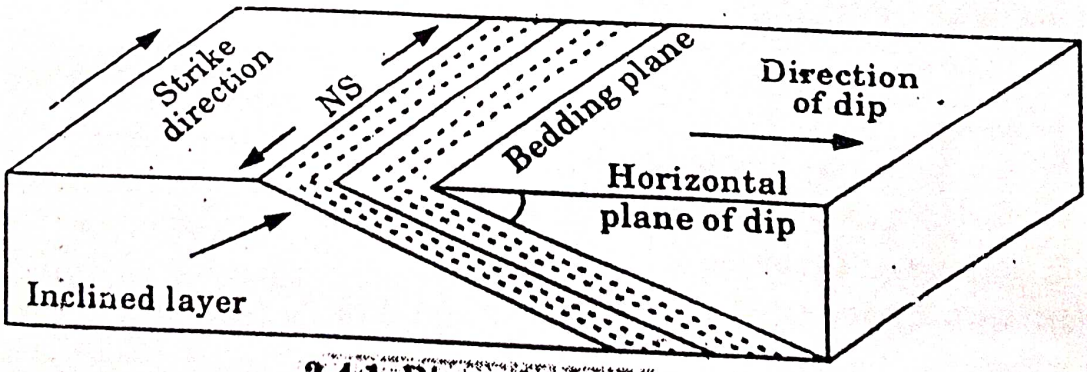
Que 2.4. Describe the dip and strike in rocks.

OR

Explain true dip and apparent dip. **AKTU 2014-15, Marks 03**

Answer

1. **Dip :** It is defined as the maximum angle of inclination with the horizontal It is expressed both in terms of degree of inclination and direction of inclination Fig. 2.4.1.



2.4.1. Dip and strike

i. **Angle of Inclination :** The amount of dip is called angle of inclination which a bedding plane makes with a horizontal plane. It may vary from 0° (horizontal) to 90° (vertical). The layers may be inclined in any geographic direction *i.e.*, east, west, north or south or in between.

ii. **Direction of Inclination :** The direction is determined with a simple compass where as the angle of dip is determined with an instrument called clinometer.

2. **Strike :** It is a geographic direction given by the line of intersection of a horizontal plane with a bedding plane of a layer of rock. It is measured in field with the help of a compass.

3. **True Dip :** When the dip of a layer is measured in a direction that is essentially at right angles to the strike of the particular layer, then and only then it is called true dip.

4. **Apparent Dip :** When the dip of a layer is measured in any other direction, which is not at right angles to its direction. It is called an apparent dip.

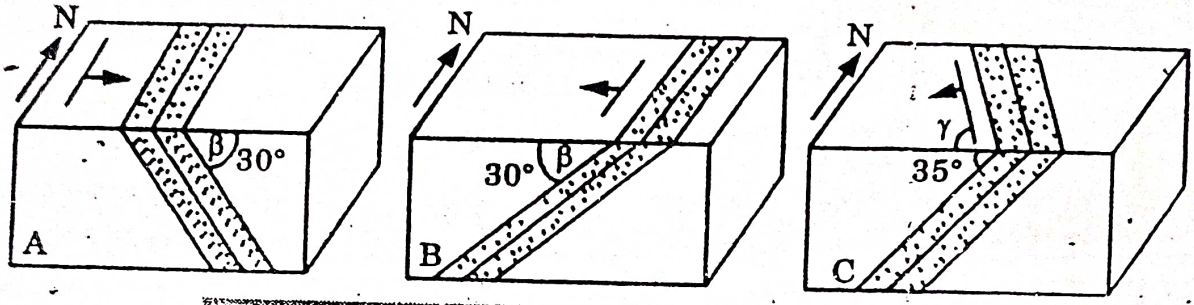


Fig. 2.4.2. True (A and B) and apparent dip (C).

Que 2.5. **Write short notes on :**

1. **Outcrop.**
2. **Overlap.**

Answer

1. **Outcrop :**

i. An outcrop or rocky outcrop is a visible exposure of bed rock or ancient superficial deposits on the surface of the earth.

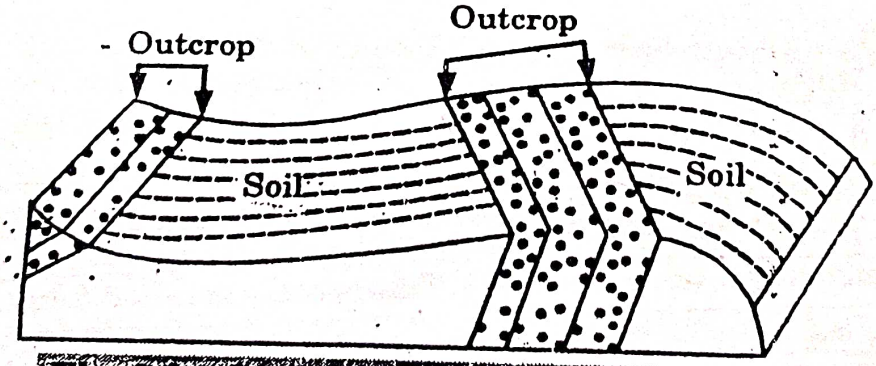


Fig. 2.5.1. Rock outcrop showing bedding.

ii. Solid rocks are not exposed everywhere on the surface of the earth; these are mostly covered with a thick layer of loose deposit, called alluvium of soil.

iii. In fact, in some areas, the soil spread over for thousands of kilometers and the bedrock may not be visible anywhere.

iv. An outcrop is simply defined as an exposure of a solid rock on the surface of the earth.

2. Overlap :

i. Overlap or onlap is the geologic phenomenon of successively younger rock strata extending progressively further across an erosion surface cut in older rocks. It is generally associated with a marine transgression.

ii. It is a more general term than over-step, in which the youngest bed overlap onto successively older beds. The opposite is off lap.

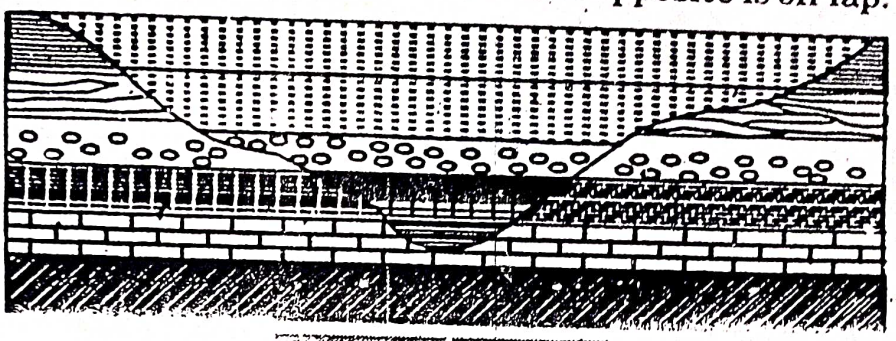


Fig. 2.5.2. Overlap.

Que 2.6. **Write short note with neat sketch :**

1. Inlier.

2. Outlier.

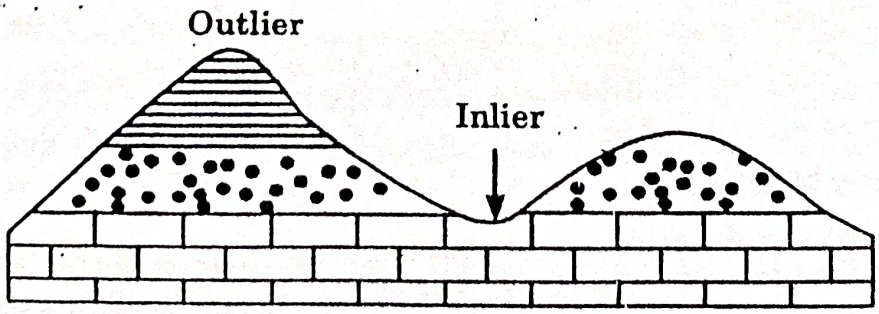
Answer

1. Inlier :

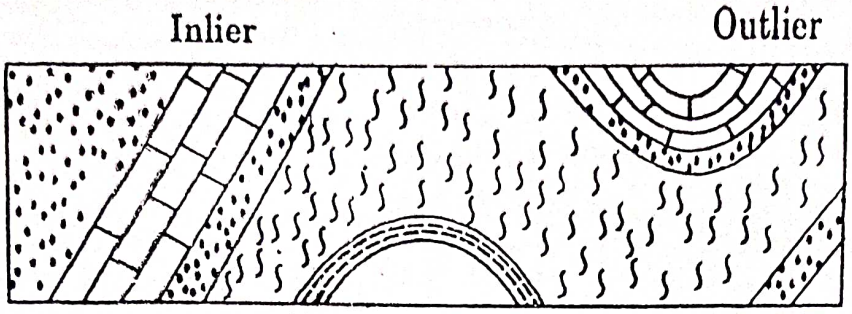
i. It is an outcrop of old rocks surrounded by the outcrop of the younger rocks. Its presence on a map indicates either an eroded anticline or a valley.

ii. In other words, an inlier is an area of older rocks surrounded by younger rocks, inliers are typically formed by the erosion of overlying younger rocks to reveal a limited exposure of the older under laying rock

2. Outlier : It is an outcrop of younger rocks surrounded by the outcrop of the old rocks. Its presence on a map indicates either an eroded Syncline or a hill.



(*a*) Formed in horizontal rocks.



(*b*) Formed in folded rocks.

Fig. 2.6.1. Inlier and outlier.

Que 2.7. **Explain the following :**

1. **Vesicular structure.**
2. **Ripple marks.**

Answer

1. **Vesicular Structure :**

. In most of the cases, lava is rich in gases at the time of eruption.

i. But these gases tend to escape during the process of cooling and crystallization of lava, which results in the formation of cavities of various sizes and shapes in the cooled mass, rendering the mass of the rock spongy.

ii. Such structure of a volcanic rock, in which this spongy character has been developed due to existence of empty cavities, has been defined as vesicular structure.

v. In some cases, liquids may seep into these cavities and cool down forming secondary minerals.

. These are called amygdaloids and structure of the rock is amygdaloidal.

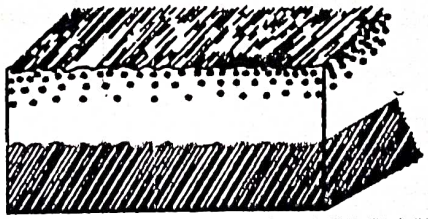


Fig. 2.7.1. Vesicular structure.

. **Ripple Marks :**

The wavy undulations are formed on the surface of the bedding planes due to the mechanical action of wind in loose and soft sediments.

. These are occurred under shallow water Fig. 2.7.2.

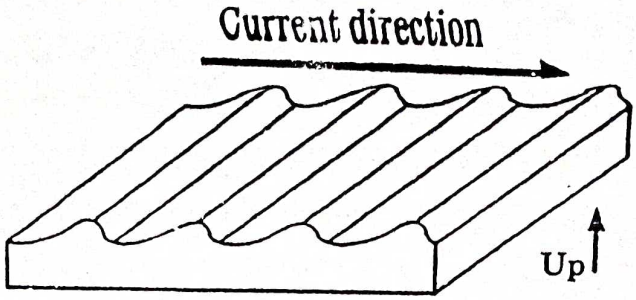


Fig. 2.7.2. Ripple marks.

PART-2

Rock Deformation : Folds, Faults

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.8. **Describe folding with the help of its parts.**

OR

Explain the following parts of a fold with a neat sketch.

1. **Limbs.**
2. **Crest.**
3. **Trough.**
4. **Axis of fold.**

Answer

A. **Folding :** When rocks deform in a ductile manner, instead of fracturing to form faults, they may bend or fold and the resulting undulating shaped structures are called folds. This process is called folding of rocks.

B. **Parts of a Fold :** Following are the parts of fold :

1. **Hinge :** The hinge of a fold is the line of maximum curvature in folded bed. There is a hinge for each folded bed. Hinges are characterised by their position and orientation.
2. **Limb :** The sloping sides of the fold are called the limb.
3. **Crest :** The curved portion of the fold at the top are called the crest.
4. **Trough :** The curved portion of the fold at the bottom are called trough.
5. **Axial Plane :** An imaginary plane which divides the folds into two equal halves is called the axial plane.
6. **Axis of Fold :** The line of intersection between the axial plane and the surface of any of the constituent rock bed is called the axis of fold.

7. **Plunge of Fold :** The inclination of the fold axis with the horizontal is called the plunge of fold are shown in Fig. 2.8.1.

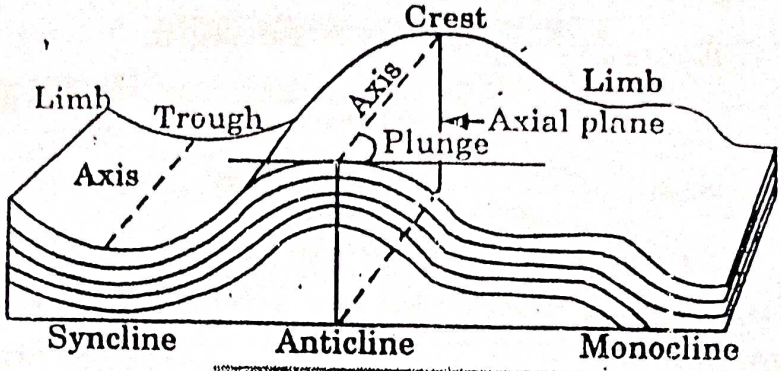


Fig. 2.8.1. Parts of fold.

Que 2.9. **What are folds ? Describe various types of folds.**

AKTU 2014-15, Marks 3.5

OR

Define a fold. How folds are classified ? Explain with the help of neat sketches, important types of folds. **AKTU 2013-14, Marks 04**

Answer

A. **Folds :** It may be defined as undulations or curvatures developed in the rocks of the crust as a result of stresses to which these rocks have been subjected from time to time in past history of the Earth.

B. **Classification of Folds :** Following are the classification of folds :

1. **Based on Appearance in Cross Section :**

i. **Anticline :**

a. The fold which is convex upwards and the limbs commonly dip away from the axial plane on either side of the axis, is called as anticline.

b. In this case, the older rocks are occurred towards the centre of curvature of the fold as shown in Fig. 2.9.1(*a*).

ii. **Syncline :**

a. The fold which is concave upwards and the limbs commonly dip towards the axial plane on either side of the axis, is called as syncline.

b. In this case, the younger rocks occurred towards the centre of curvature of the fold as shown in Fig. 2.9.1(*b*).

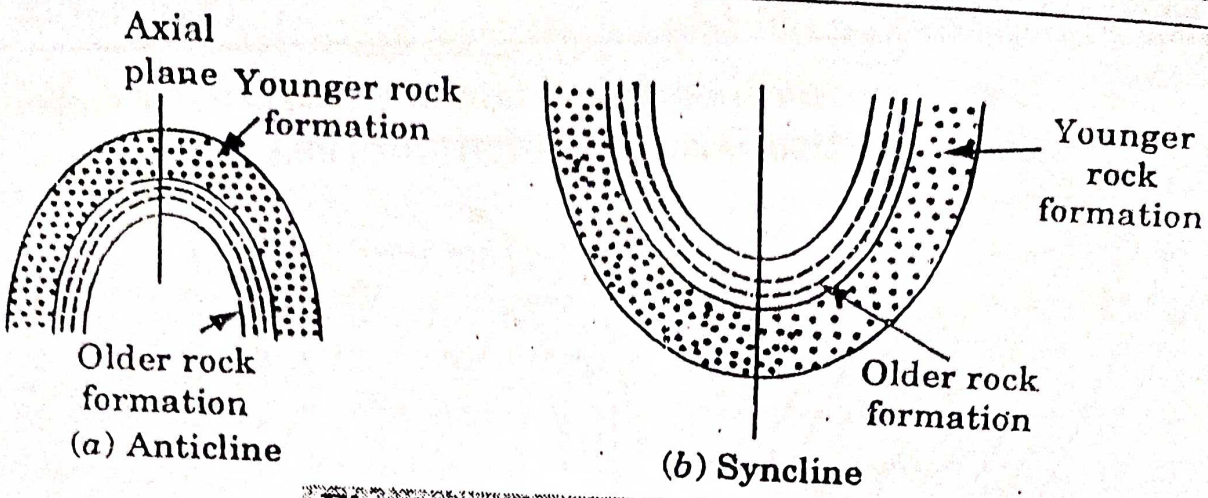


Fig. 2.9.1. Anticline and syncline.

2. Based on Position of Axial Plane :

i. Symmetrical Fold :

a. The fold in which axial plane divides the fold equally in two parts called as symmetric fold.

b. The fold may be anticline or syncline as shown in Fig. 2.9.2.

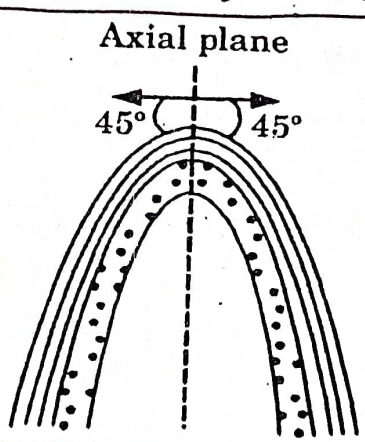


Fig. 2.9.2. Symmetrical fold.

ii. Asymmetrical Fold :

a. The fold in which axial plane divides the fold unequally in two parts is called as asymmetric fold.

b. The fold may be anticline or syncline as shown in Fig. 2.9.3.

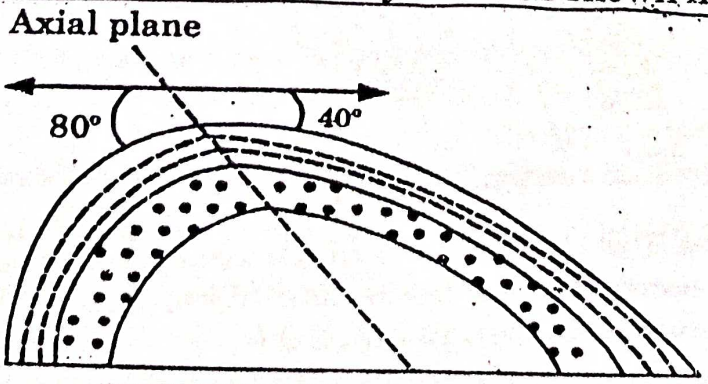


Fig. 2.9.3. Asymmetrical fold.

iii. Overturned Fold :

a. The fold in which axial plane is inclined and both the limbs dip in the same direction, is called as overturned fold.

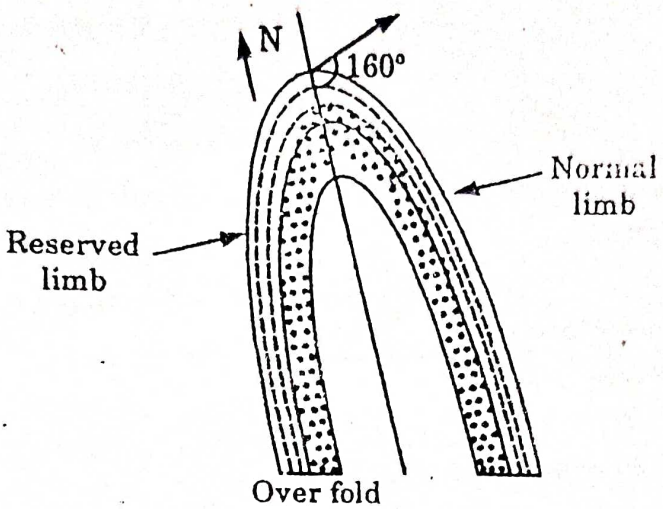


Fig. 2.9.4. Overturned fold.

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

c. It may be anticline or syncline as shown in Fig. 2.9.4.

iv. **Isoclinal Fold :**

a. The group of fold in which axial plane is essentially parallel and the limbs are dipping in the same directions at equal angles are called as isoclinal fold.

b. The axial plane may either be horizontal, vertical or inclined as shown in Fig. 2.9.5.

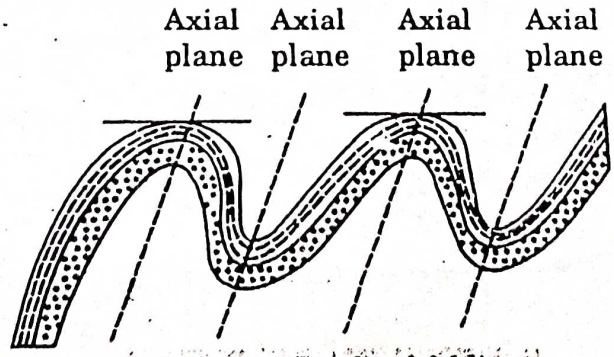


Fig. 2.9.5. Isoclinal folding.

v. **Recumbent Fold :** The fold in which axial plane is essentially horizontal and the limbs are dipping in the same directions horizontally is called as recumbent fold as shown in Fig. 2.9.6.

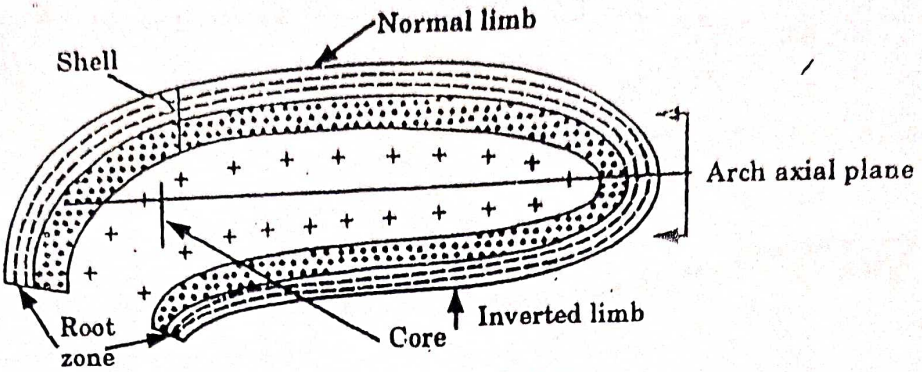


Fig. 2.9.6. Recumbent fold.

3. **Based on Mode of Occurrence :**

i. Anticlinorium fold.

ii. Synclinorium fold.

iii. Dome fold.

iv. Basin fold.

4. **Based on Degree of Compression :**

i. Open fold.

ii. Closed fold.

5. **Based on Position of Axis :**

i. Non-plunging fold.

ii. Plunging fold.

6. **Other types of Fold :**

i. Fan fold.

ii. Monocline fold.

iii. Chevron fold.

iv. Drag fold.

Que 2.10. Write a brief note on the causes of folding.

Answer

Causes of Folding : Folds are formed mainly due to :

1. **Tectonic Process :**

i. Horizontal compression folds are formed due to compressive force acting parallel to the surface of the earth, the intensity of compressive force decreases gradually below the crystal layers of the earth as shown in Fig. 2.10.1.

ii. According to the contraction theory, folds may be formed due to :

a. Cooling of the earth materials.

b. Formation of denser materials within the earth.

c. Intrusion of magma.

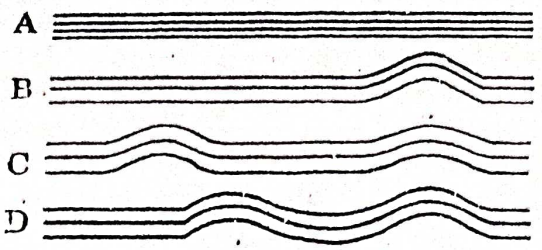


Fig. 2.10.1. Fold produced due to horizontal compression.

2. **Non-tectonic Process :**

i. Folds resulting from a non-tectonic process are formed mainly due to the geological process operating on the exposed lithological formation, resulting in erosion, transportation and deposition of sediments.

ii. For instance, weathered strata liberated from hill slopes accumulate as hillside wastage, creeping of the strata results in the formation of a folded structure of rock materials.

Que 2.11. **What are faults ? Give their terminology and their classification with suitable diagrams.** **AKTU 2016-17, Marks 10**

OR

Describe faults and classify faults on the basis of apparent movement of disrupted blocks. **AKTU 2017-18, Marks 10**

Answer

A. **Fault :** A fault is a planar fracture or discontinuity in a volume of rock across which there has been significant displacement as a result of rock-mass movement.

B. **Fault Terminology :** Following are the fault terminology :

1. **Fault Plane :** The surface at which the fracture occurs in the rock mass and along which the movement of rock blocks take place is called a fault plane.

2. **Dip :** It is the angle between the horizontal surface and the plane of the fault.

3. **Hade :** It is define as the angle between the fault plane and the vertical that strikes parallel.

4. **Foot Wall :** The lower wall of an inclined fault is called the foot wall.

5. **Hanging Wall :** The upper wall of an inclined fault is called the hanging wall.

6. **Fault Zone :** Fault zone is a region, from metres to kilometres in width, which is bounded by major fault within which sub-ordinate fault may be arranged variably or systematically.

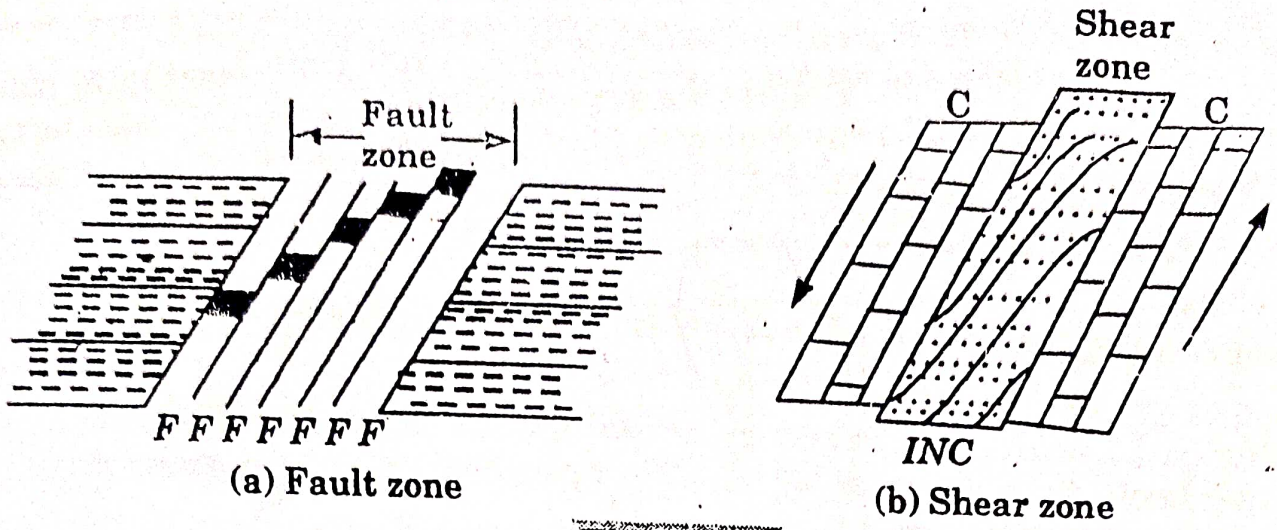


Fig. 2.11.1.

7. **Shear Zone :** The fault plane may be single slickenside or rough open fracture or an irregular zone of a number of smaller intersecting fracture called a shear zone.

8. **Slip :** The term slip is used for measuring relative displacement of formerly adjacent point on opposite side of the fault and is measured in the fault surface.

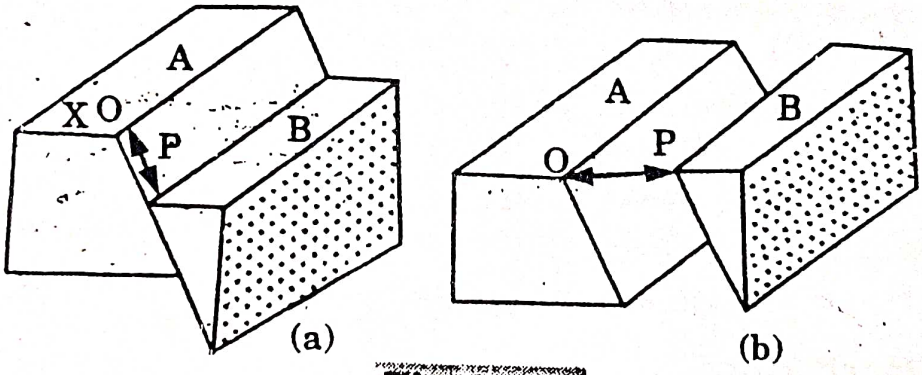


Fig. 2.11.2.

9. **Net Slip :** It is the total displacement of the fault surface between two formerly adjacent points located on opposite wall of the fault as shown in Fig. 2.11.2(a).

10. **Dip Slip :** It is the component of the net slip measured parallel to the dip of the fault plane as shown in Fig. 2.11.2(b).

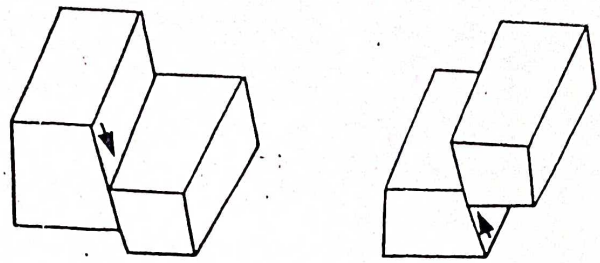
11. **Heave:** It is the horizontal component of dip separation measured in a direction perpendicular to the strike of the fault in a vertical plane.

C. **Classification of Faults :** Following are the classification of faults :

1. **Classification on the basis of Genetic / Apparent Movement of Disrupted Rocks :**

i. **Normal Fault :** The fault that result from horizontal tensional stresses in brittle rocks and where the hanging wall block has moved down relative to the foot wall block, is called as normal fault as shown in Fig. 2.11.3(a).

ii. **Reverse Fault :** The fault that result from horizontal compression stresses in brittle rocks and where the hanging wall block has moved up relative to the foot wall block, is called as reverse fault as shown in Fig. 2.11.3(b).



(a) Normal fault (b) Reverse fault

Fig. 2.11.3. Normal and reverse fault.

iii. **Hinge Faults :** The fault in which one block rotates with respect to other block, is called as hinge fault as shown in Fig. 2.11.4.

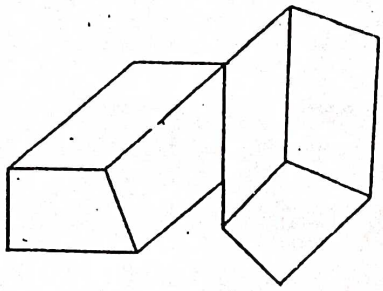


Fig. 2.11.4. Hinge fault.

2. **Classification on the basis of Attitude of Fault :**

i. **Strike Faults :** These faults are those which run parallel, or nearly so, to the strike of the beds.

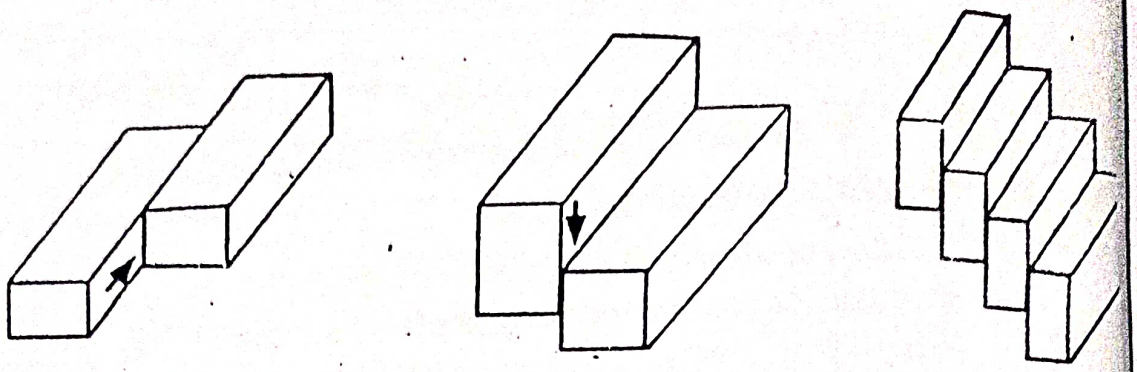
ii. **Dip Faults :** The fault in which the fault plane is parallel to the dip of the beds is called as dip fault.

iii. **Oblique Faults :** These are sometimes called diagonal faults oblique angle with the strike of the rocks in which it has caused the displacement.

3. **Classification on the basis of Slip :**

i. **Strike Slip Faults :** The fault in which the net slip is parallel to the strike of the fault is called as strike slip fault as shown in Fig. 2.11.5(a). It is also called as wrench fault.

ii. **Dip Slip Faults :** The fault in which the slip occurs is parallel to the dip of the beds is called as dip slip fault as shown in Fig. 2.11.5(b).



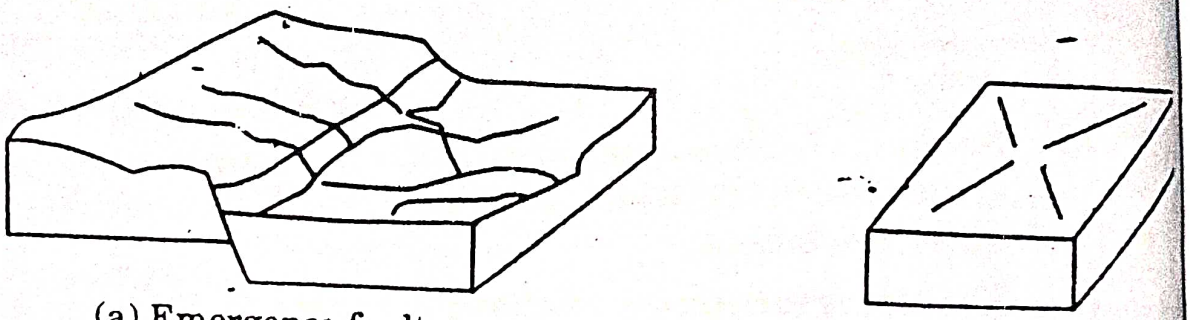
(a) Strike slip fault (b) Dip slip fault (c) Step fau

Fig. 2.11.5.

iii. **Step Faults :** A series of parallel faults, in which the succe movement of each block takes the stair like appearance and all in the same direction, are called step faults as show Fig. 2.11.5(c).

4. **Classification on the basis of Mode of Occurrence :**

i. **Parallel Faults :** A series of faults, in which the successive move of each block takes in the same direction having the same strike are called parallel faults.



(a) Emergence fault. (b) Radial fault.

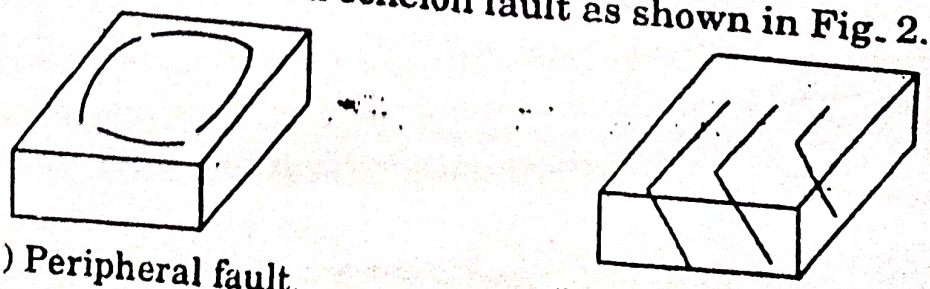
Fig. 2.11.6.

ii. **Emergent Faults :** The fault which cuts the surface of the ear called as emergent fault as shown in Fig. 2.11.6(a).

iii. **Radial Faults :** The fault which shows the radial pattern fractur the surface of the earth is called as radial fault as shown in Fig. 2.11.

iv. **Peripheral Faults :** The faults that are concentrated along the bo or the margin of they are called as peripheral fault as show Fig. 2.11.7(a).

v. **En echelon Faults :** The group of small sized faults that are overlap each other are called as en echelon fault as shown in Fig. 2.11.7(b)



(a) Peripheral fault. (b) En echelon fault.

Fig. 2.11.7.

Que 2.12. **Write a short note on causes of faulting.**

Answer

Causes of Faulting : Following are the causes of faulting :

1. Faults are generally caused under the influence of stresses acting upon the rocks of the crust of the earth from within any rock on or below the crust may withstand all the operating stresses up to a limit, which depends upon its cohesive strength and internal friction, but, when that limit is crossed by the operating stresses, the rock yields by fracturing or breaking along certain directions.
2. Immediately (or even gradually) after the development of these fractures, the blocks created along the fractures suffer sudden (or gradual) displacement along those fractures under the influence of the same (or different) stresses that caused the fracturing of the rocks at the first place.
3. The displacement may take place essentially along the fracture surface or in different directions and for different distances depending upon the magnitude of the operating stresses thus, giving rise to different types of faults.

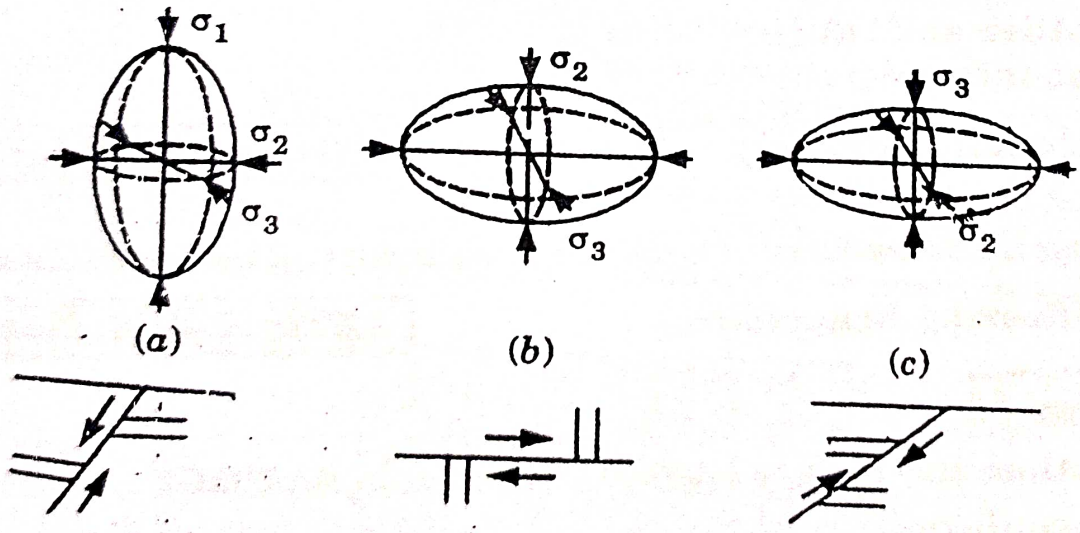


Fig. 2.12.1. Relationship between principal stresses and type of faulting.

σ_1 = Maximum principal stress in vertical.

σ_2 = Intermediate principal stress in vertical.

σ_3 = Least principal stress in vertical.

PART-3

Joint, Unconformity and Classification.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.13. **Define the joint. Describe the different types of joir**

OR

How will you differentiate between faults and joints ? Describe characteristics of different types of joints with neat sketches.

AKTU 2013-14, Marks

OR

Distinguish between joints and faults.

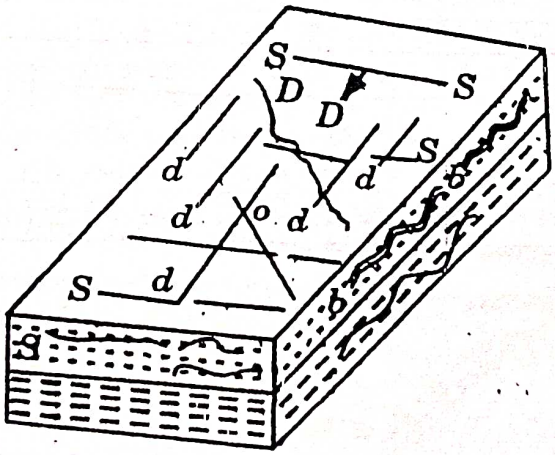
AKTU 2014-15, Marks

Answer

A. **Joint :** Joints are defined as divisional planes or fractures along which has been no relative displacement.

B. **Classification :** Following are the types of joints :

1. **On the Basis of Geometry :** On the basis of geometry the joints are classified according to the trend of joint planes (trace) relative to the directions of dips and strike of rock beds as shown in Fig. 2.13.1.



Geometrical classification
S = Strike joints; d = Dip joints;
o = Oblique joints; b = Bedding joints

Fig. 2.13.1.

i. **Dip Joints :** Dip joints are those that strike parallel to the direction of dip.

ii. **Strike Joints :** Strike joints are those that strike in the same direction of the rock.

iii. **Oblique Joints :** Oblique or diagonal joints are those in which the strike of the joint makes an inclined angle with the strike of the formation.

Characteristics :

1. These are simply referred as bedding joints.
2. In the folded regions, joint orientation is conveniently described with reference to the hinge of the fold.

2. **On the Basis of Genesis (Origin) :** On the basis of genesis the joints are classified as :

i. **Tension Joints :**

a. Tension joints are those, which have developed due to the tensile forces acting on the rocks.

b. The most common location of such joints in folded sequence is on the outer margins of crests and troughs.

c. They are also produced in igneous rocks during their cooling.

d. Joints produced in many rocks during the weathering of overlying strata and subsequent release of stresses by expansion are also thought to be due to the tensile forces as shown in Fig. 2.13.2.

iii. **Compression Joints :** Rocks may be compressed to crushing and numerous joints may result due to the compressive forces in this case. In the core regions of folds where compressive forces are dominant, joints may be related to the compressive forces.

iv. **Shear Joints :** These are commonly observed in the vicinity of fault planes and shear zones where the relationship with shearing forces is clearly established. In folded rocks, these are located in axial regions.

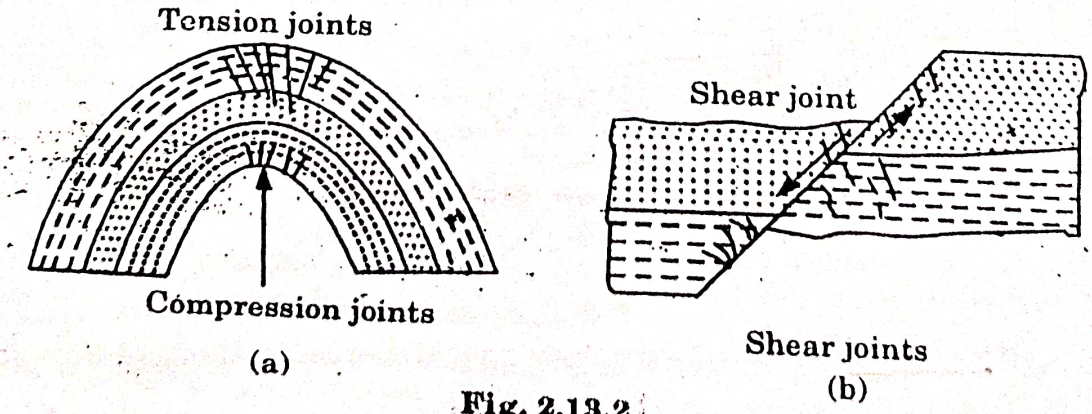


Fig. 2.13.2.

C. Difference between Joint and Faults :

S. No.	Joints	Faults
1.	It is defined as divisional planes or fractures along which there has been no relative displacement.	It is a fracture in rocks along which there has been a displacement of the two sides parallel to the fracture.
2.	These are small in size.	These are big in size.
3.	It has no movement therefore cause none or very little displacement.	It has lateral movement that causes displacement.
4.	It is formed when rocks are stretched to their breaking point.	It is formed because of constant tectonic movement.

Que 2.14. Define unconformity and its classification.

OR

Define the following :

A. Outlier and Inliers.

B. Unconformity.

C. Columnar jointing. **AKTU 2014-15, Marks 3.5**

OR

Explain the behaviour of rocks unconformity. Classify them relate to engineering behaviour. **AKTU 2015-16, Marks 10**

Answer

A. Outlier and Inliers : Refer Q. 2.6, Page 2–8C, Unit-2.

B. Unconformity :

1. It is a contact between two rock units in which the upper limit is usually much younger than the lower unit.
2. Unconformities are typically buried erosional surfaces that can resort a break in the geologic record of hundreds of millions of years or more.
3. It is also defined as a surface of erosion or non-deposition that separates the younger rock formations from the older rocks.

C. Classification of Unconformities :

1. Angular Unconformity :

i. Angular unconformities develop due to the deposition of younger rock sedimentary on the older rock formations. Older rock formations are steeply inclined.

ii. In some conditions, these beds are folded and faulted.

iii. The surface which separates the two groups of rocks is called the angular unconformity as shown in Fig. 2.14.1.

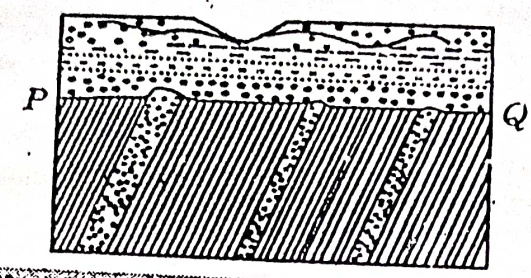


Fig. 2.14.1 Angular unconformity.

2. **Parallel or Disconformity :** In this type, rock formation unconformity of beds which lie below and above the unconformity are parallel. However, older rock formations will show neither folding nor faulting as shown in Fig. 2.14.2

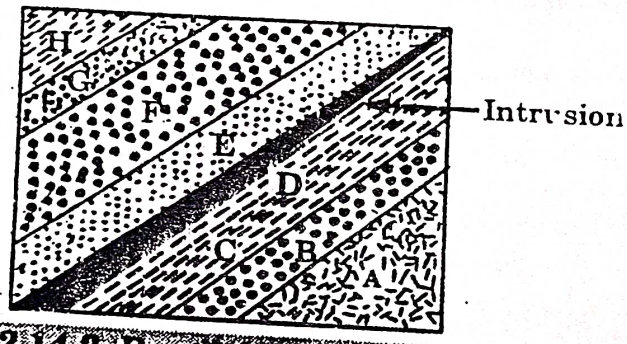


Fig. 2.14.2. Parallel or disconformity.

3. **Non-Conformity :** There are unconformities which are formed due to the geologic origin, particularly rock formations underlying older rocks of plutonic origin, overlying sedimentary or volcanic rocks as shown in Fig. 2.14.3.

Fig. 2.14.3. Non-conformity.

4. **Local Unconfomity :** This is similar to disconformity but its extent is local in nature. This type of unconformity is also termed as regional unconformity.

C. Columnar Jointing :

i. These types of joints are typical of volcanic igneous rocks although they may also be observed in other rocks. These are also called prismetic joints.

ii. The joints divide the rock mass into polygonal blocks each block being bounded by three to eight sides. Five and six sided blocks are common

iii. Normally, the main joints are vertical or perpendicular to the surface and may extend to varying depths ranging from a few cent to many meters. In surface area also, the blocks may vary fror centimeters to a couple of meters.

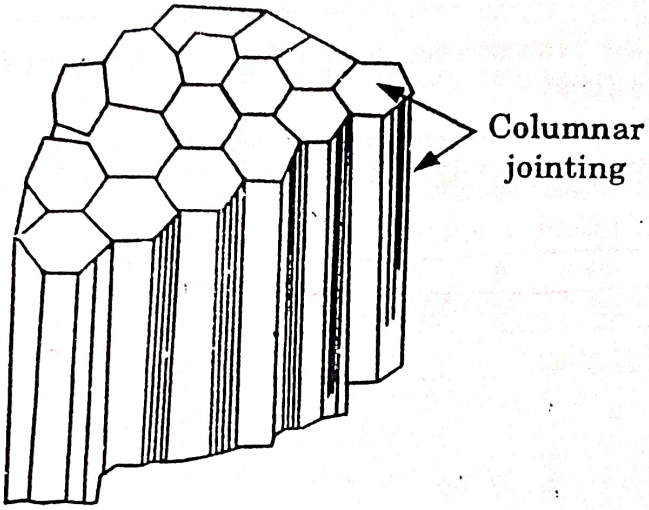


Fig. 2.14.4. Columnar joints.

Que 2.15. Differentiate between the following :

1. **Normal and reverse fault.**
2. **Dip slip and strike slip fault.**
3. **Angular unconformity and parallel unconformity.**
4. **Disconformity and non-conformity.** **AKTU 2013-14, Marl**

Answer

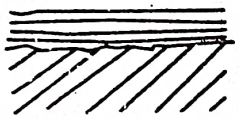
1. **Difference between Normal and Reverse Fault :**

S. No.	Normal Fault	Reverse Fault
i.	It is formed when tension forces cause movement within Earth's crust.	It is formed when compression forces cause movement within Earth's crust.
ii.	The hanging wall moves down with respect to the foot wall.	The hanging wall moves up with respect to the foot wall.

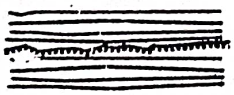
2. Difference between Dip Slip and Strike Slip Fault :

S. No.	Dip Slip Fault	Strike Slip Fault
i.	Faults which move along the direction of the dip plane are called dip slip fault.	Faults on which the two blocks slide past one another are called strike slip fault.
ii.	It occurs due to tension or compression.	It occurs due to shearing.

3. Difference between Angular Unconformity and Parallel Unconformity :

S. No.	Angular Unconformity	Parallel Unconformity
i.	Sedimentary rocks form and then are eroded; new sedimentary rocks are laid down on top.	Sedimentary rocks form with invisible gap in time between them due to erosion of older unit or non-deposition.
ii.	Diagram 	Diagram

4. Difference between Disconformity and Nonconformity :

S. No.	Disconformity	Nonconformity
i.	Sedimentary rocks form and then are eroded; new sedimentary rocks are laid down on top of eroded surface.	Non-sedimentary rocks form with may or may not be eroded, then sedimentary rocks are laid down on top.
ii.	Diagram 	Diagram

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION

Q. 1. Explain how sedimentary rocks are formed. Describe various structures present in the rocks.

Ans. Refer Q. 2.2, Unit-2.

Q. 2. What is lamination bedding ? Explain its effect on topography.

Ans. Refer Q. 2.3, Unit-2.

Q. 3. Describe the dip and strike in rocks.

Ans. Refer Q. 2.4, Unit-2.

Q. 4. What are folds ? Describe various types of folds.

Ans. Refer Q. 2.9, Unit-2.

Q. 5. What are faults ? Give their terminology and their classification with suitable diagrams.

Ans. Refer Q. 2.11, Unit-2.

Q. 6. How will you differentiate between faults and joints ? Describe the characteristics of different types of joints with neat sketches.

Ans. Refer Q. 2.13, Unit-2.

Q. 7. Explain the behaviour of rocks unconformity. Classify them related to engineering behaviour.

Ans. Refer Q. 2.14, Unit-2.

Q. 8. Differentiate between the following :

1. **Normal and reverse fault.**
2. **Dip slip and strike slip fault.**
3. **Angular unconformity and parallel unconformity.**
4. **Disconformity and non conformity.**

Ans. Refer Q. 2.15, Unit-2.

☺☺☺

3

UNIT

Earthquake and Landslides

CONTENTS

Part-1 :	Earthquake, Its Causes and Classification	3–2C to 3–10C
Part-2 :	Seismic Zones of India and Geological Consideration for Construction of Building, Projects in Seismic Areas	3–10C to 3–14C
Part-3 :	Landslides : Causes, Classification and Preventive Measures	3–14C to 3–18C

PART-1

Earthquake, its Causes and Classification.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. **Explain the term earthquake. What are the effect earthquake ?**

Answer

Earthquake :

1. An earthquake is the result from the sudden release of stored energy due to sudden vibrations of the Earth's crust that creates seismic wave At the Earth's surface, earthquakes may manifest themselves l shaking or displacement of the ground and sometimes cause tsunami which may lead to loss of life and destruction of property.
2. An earthquake is causes by tectonic plates getting stuck and putting strain on the ground. The strain becomes so great that rocks give by fault planes breaking. Smaller earthquakes can also be cause volcanic activity.
3. Earthquakes may occur naturally or as a result of human activities its most generic sense, the word earthquake is used to describe seismic event whether a natural phenomenon or an event caused humans that generates seismic waves.
4. Earthquakes happen every day around the world, but most of them unnoticed and cause no damage. Large earthquakes, however, can ca serious destruction. They may be caused by the ground shaking, a ti wave or tsunami, fire or by gas or petrol leaks.

Effects of Earthquake : Following are the effects of earthquake :

1. **Shaking and Ground Rupture :**

i. Shaking and ground rupture are the main effects created by earthquake principally resulting in more or less severe damage to buildings or ot rigid structures.

ii. The severity of the local effects depends on the complex combination the earthquake magnitude, the distance from epicenter, and the lo geological and geomorphological conditions, which may amplify or red wave propagation.

iii. The ground-shaking is measured by ground acceleration.

2. **Landslides and Avalanches :** Earthquakes can cause landslides and avalanches, which may cause damage in hilly and mountainous areas.

3. **Fires :** Following an earthquake, fires can be generated by break of the electrical power or gas lines.

4. Soil Liquefaction :

i. Soil liquefaction occurs when, because of the shaking, water-saturated granular material temporally loses their strength and transforms from a solid to a liquid.

ii. Soil liquefaction may cause rigid structures, as buildings or bridges, to tilt or sink into the liquefied deposits.

5. **Tsunamis :** A tsunami is a series of waves created when a body of water, such as an ocean, is rapidly displaced on a massive scale. Earthquakes, mass movements above or below water, volcanic eruptions and other underwater explosions, landslides, large meteorite impacts and testing with nuclear weapons at sea all have the potential to generate a tsunami. The effects of a tsunami can range from unnoticeable to devastating.

6. **Human Impacts :** Earthquakes may result in disease, lack of basic necessities, loss of life, higher insurance premiums, general property damage, road and bridge damage and collapse of buildings or destabilization of the base of buildings which may lead to collapse in future earthquakes.

7. **River Water :** Due to vibrations of earthquakes, river changes its course results in formation of springs.

Que 3.2. **What are the causes of earthquake ? Classify the earthquake ?** **AKTU 2017-18, Marks 10**

Answer

A. **Causes of Earthquake :** Following are the causes of earthquake :

1. **Movements of Tectonic Plates :**

i. Most naturally occurring earthquakes are related to the tectonic nature of the earth. Such earthquakes are called tectonic earthquakes.

ii. In this type, the failure occurs at the fault plane, result in a violent displacement of the Earth's crust.

iii. The elastic strain energy is released and seismic waves are radiated, thus causing an earthquake.

2. **Volcanic Eruptions :** Earthquake may also occur in volcanic regions and are caused by the movement of magma in volcanoes. Such earthquakes can be an earth warning of volcanic eruptions.

3. **Anthropogenic Sources :** Some earthquakes have anthropogenic मानवजनित sources, such as extraction of minerals and fossil fuels from the Earth's

crust, the removal or injection of fluids into the crust, reservoir induced seismicity, massive explosions, and collapse of large buildings.

4. Dams :

i. A rare few earthquake have been associated with the buildup of large masses of water behind dams, such as the Kariba Dam in Zambia Africa.

ii. World's largest reservoir induced earthquake occurred on December 10, 1967 in the Koyna region of Western Maharastra in India. It had a magnitude of 6.3 on the Richter scale.

5. Use of Explosives :

i. The detonation of powerful explosives, such as nuclear explosions, can cause low magnitude ground shaking.

ii. Thus, the 50-megaton nuclear bomb code-named Ivan denoted by the Soviet Union in 1961 created a seismic event comparable to a magnitude 7 earthquake, producing the seismic shock so powerful that it was measurable even on its third passage around the Earth.

vi. Removal to Natural Gases : Earthquakes have been also known to be caused by the removal of natural gas from sub-surface deposits, for instance in the northern Netherlands.

B. Classification : The earthquakes fall into two broad categories :

based of depth

1. Natural Earthquakes : It is caused by natural forces. Following are the various types of natural earthquakes :

① Shallow - Shock is originated upto 5c depth from E.S

② Intermediate (50-300 Km) from Earth Surface

③ Deep 300 onwards

i. Tectonic Earthquakes :

a. The term 'tectonic' refers to any structural change in rocks caused due to their deformation or displacement. The word "tectonic" has been derived from the Greek word taken meaning "a builder".

b. The main cause of tectonic earthquakes is the building up stresses in rocks until they are strained to breaking point.

c. These are caused by the sudden earth movements, generally along faults, usually at depths varying from about 4.5 km to 24 km below the earth surface.

d. Majority of natural earthquakes including the most powerful and damaging ones belong to this category.

ii. Plutonic Earthquakes :

a. These are deep focus earthquakes, the depth of disturbances being between 250 km and about 700 km.

b. Gutenberg and Richter made a critical analysis of plutonic earthquakes and concluded that the mechanism of origin of shocks seems to be the same at all depths.

iii. Volcanic Earthquakes :

a. These are associated with explosive eruption of volcanoes. Naturally, they occur in volcanic zones of the world.

b. The circum pacific belt is a typical example where volcanic earthquakes are common hazards. Their intensity and magnitude depends on the explosive power of volcanic eruption.

c. The earthquakes of volcanic origin are less severe and more limited in extent than those caused by the fracturing of the Earth's crust.

2. **Artificial Earthquakes :** Artificial earthquake, which occur due to human activities causes disturbance in the Earth's crust producing vibrations of various magnitudes.

Que 3.3. **Define earthquake and tsunamis. Give a detailed account of tectonic earthquake.** **AKTU 2014-15, Marks 06**

Answer

A. **Earthquake :** Refer Q. 3.1, Page 3–2C, Unit-3.

B. **Tsunamis :**

1. Tsunami or tidal wave is a series of waves in a water body caused by the displacement of a large volume of water, generally in an ocean or a large lake.

2. Earthquakes, volcanic eruptions and other underwater explosions above or below water all have the potential to generate a Tsunami.

C. **Tectonic Earthquake :**

1. A tectonic earthquake occurs when strains in rock masses have accumulated to a point where the resulting stresses exceed the strength of the rocks, and sudden fracturing results.

2. The fractures propagate rapidly through the rock, usually tending in the same direction and sometimes extending many kilometres along a local zone of weakness.

3. As a fault rupture progresses along or up the fault, rock masses are flung in opposite directions and thus spring back to a position where there is less strain.

4. At any one point this movement may take place not at once but rather in irregular steps these sudden slowing and restarting give rise to the vibrations that propagate as seismic waves.

5. Such irregular properties of fault rupture are now included in the modeling of earthquake sources, both physically and mathematically.

6. Roughness along the fault are referred to as asperities, and places where the rupture slows or stops are said to be fault barriers.

7. Fault rupture starts at the earthquake focus, a spot that in many cases is close to 5-15 km under the surface.

8. The rupture propagates in one or both directions over the fault plane until stopped or slowed at a barrier. Sometimes, instead of being stopped

at the barrier, the fault rupture recommences on the far side; at other times the stresses in the rocks break the barrier, and the rupture continues.

Que 3.4. What are the terminology of the earthquake ?

Answer

Terminology used in earthquake :

1. **Focus :** The focus of an earthquake, also called its "hypocentre", is the point below ground level where the earthquake originates and generates shock waves which generates in all direction.
2. **Epicenter :** The epicenter is the point at the ground level, immediately above the focus.
3. **Focal Depth :** It is the depth of focus from the epicenter. It is important parameters in determining the damaging potential of an earthquake Most of the damaging earthquakes have shallow focus with focal depth less than about 70 kms.

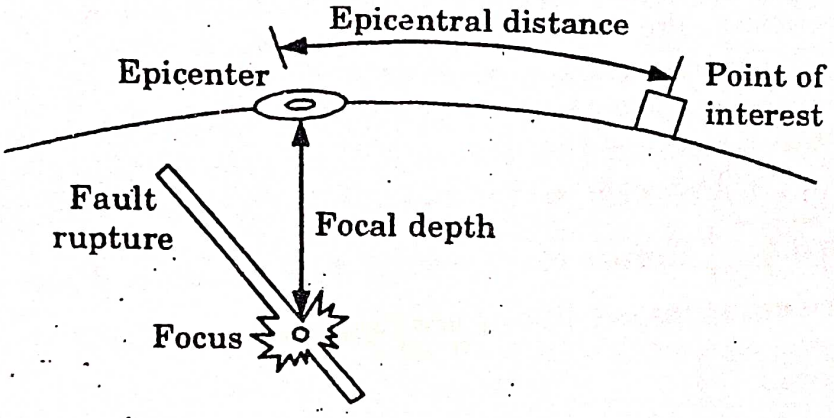


Fig. 3.4.1. Basic terminology.

4. **Epicentral Distance :** It is the distance between the epicenter and the point of interest.
5. **Seismic Noise :** Many faults give rise to numerous very small and, t human senses, imperceptible earthquakes which may be described a "seismic noise".
6. **Isoseismal Lines :**

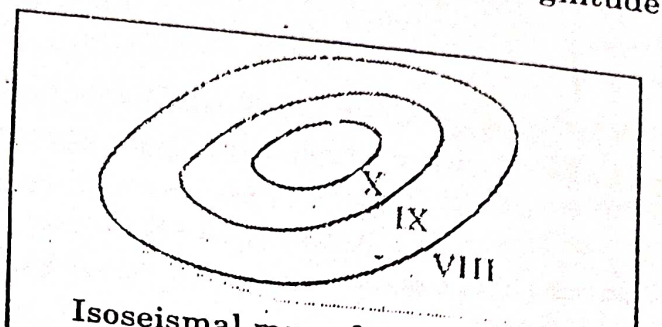
i. It is the line joining the places with equal seismic intensity *i.e.*, line joining points where similar ground motions were experienced; the are assessed by examining the damage done.

ii. It is observed that isoseismal lines are circles if the focus is the centre a in case of homogeneous ground and theses are elliptical if the focus the line in case of heterogeneous ground. It is shown in Fig. 3.4.2.

7. Magnitude of Earthquake :

i. Magnitude is a quantitative measure of the actual size of the earthquak

ii. The magnitude of earthquake is measured with the help of Richter scale, body wave magnitude, surface wave magnitude and wave energy magnitude.



Isoseismal map of the 2001 Bhuj (India) Earthquake

Fig. 3.4.2.

8. **Intensity of Earthquake :**

i. It is a qualitative measure of the actual shaking at the location during an earthquake and is assigned as Roman Capital Numerical.

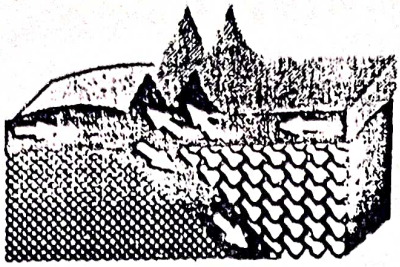
ii. The intensity of earthquake is measured with the help of intensity scales namely Modified Mercalli Intensity (MMI), the Rossi-Forel scale, the European Macroseismic Scale, the Shindo scale and the MSK-64 scale. The scale uses in India, Israel, Russia is the MSK-64 scale.

Que 3.5. **Define the term plate tectonics. What are the effects of plate tectonics on Earth surface ?**

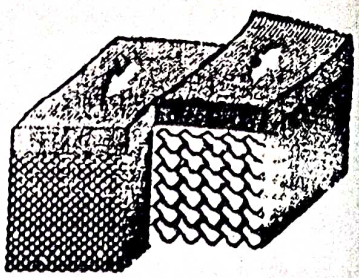
Answer

Plate Tectonics :

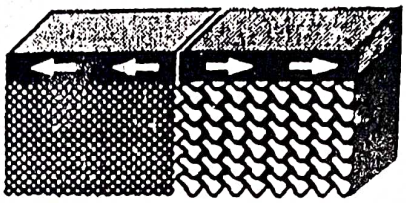
1. The lithosphere is not one solid rock. It is broken up into large plates. Scientists believe these huge plates of crust and upper mantle move about on the lower mantle. The theory that the lithosphere is made up of moving plates *i.e.*, sliding of Earth's mass takes place in pieces called tectonic plates.
2. The upper part of surface of the Earth upto a depth of 100 km consists of seven major tectonic plates and many smaller ones. These plates slowly move in different directions and at different speeds from those of the neighboring ones.
3. Sometimes, the plate in the front is slower; then, the plate behind it comes and collides and mountains are formed. On the other hand, sometimes two plates move away from one another (and rifts are created). In another case, two plates move side-by-side, along the same direction or in opposite directions.
4. There are three types of inter-plate interactions are the convergent, divergent, and transform boundaries (Fig. 3.5.1), respectively. The convergent boundary has a peculiarity (like at the Himalayas) that sometimes neither of the colliding plates wants to sink.



Convergent boundary



Transform boundary



Divergent boundary

Fig. 3.5.1.

Effect of Plate Tectonics : Following are the effects of plate tec on Earth's surface :

1. Mountains are formed due to the movement of plates towards other and colloids.
2. Volcanic eruption would occur due to movement of plates away each other thereby generating a gap which becomes the likely pla upward movement of magma.
3. Rift valleys are formed due to the sinking of medial block along parallel faults.
4. Tectonic valley also develops when a trough like depression is cre by synclinal folding of the strata.
5. Tectonic earthquakes are produced due to the folding or faulting.

Que 3.6. **How will you differentiate between Richter magni and Mercalli intensity scale of earthquake ?**

AKTU 2016-17, Marks

OR

Give an account of Richter magnitude and Mercalli intensity s of earthquake. How will you compare between them ?

AKTU 2013-14, Marks

Answer

A. Richter Scale :

1. It is a quantitative logarithmic (base-10) scale. It is also called as magnitude scale.
2. The Richter magnitude of an earthquake is determined from logarithm of the amplitude of waves recorded by seismogra (adjustments are included to compensate for the variation in the dista between the various seismographs and the epicenter of the earthqua

3. Because of the logarithmic (basis-10) scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude, in terms of energy, each whole number increase corresponds to an increase of about 31 times the amount of energy released.
4. Measurements have no limits and can be either positive or negative.

B. Mercalli Intensity Scale :

1. This scale is used for measuring the intensity of an earthquake.
2. The scale quantifies the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale of 1 through 12, with 1 denoting a weak earthquake and 12 one that causes almost complete destruction.
3. The terms Mercalli intensity scale should not be used unless one really means the original ten degree scale of 1902.
4. In 1902, the ten degree Mercalli scale was expanded to twelve degrees by Italian physicist Adolfo Cancani.

C. Difference between Richter Magnitude and Mercalli Scale :

Parameter	Richter Scale	Mercalli Scale
Measures	The energy released by the earthquake.	The effects caused by earthquake.
Measuring tool	Seismograph.	Observation.
Calculation	Logarithmic (base-10) scale obtained by calculating logarithm of the amplitude of waves.	Quantified from observation of effect on Earth's surface, human, objects and man-made structures.
Scale	From 2.0 to 10.0.	I (not felt) to XII (total destruction).
Consistency	Varies at different distances from the epicenter, but one value is given for the earthquake as a whole.	Varies depending on distance from epicenter.

Que 3.7. **What is an earthquake ? Discuss briefly their causes. What precautions are to be taken for the construction works in seismic areas ?**

AKTU 2013-14, Marks 04

Answer

A. Earthquake : Refer Q. 3.1, Page 3–2C, Unit-3.

B. Causes of Earthquake : Refer Q. 3.2, Page 3–3C, Unit-3.

C. **Precautions :** Following are the precautions taken for the construct works in seismic areas :

1. The foundation of the building should be rest on a solid or firm rockb Grillage foundations should preferably be provided.
2. The masonry should be erected simultaneously in cross walls and l walls and no joint should take place in the masonry.
3. All the masonry should be done with cement mortar of not less tl 1 : 4 mix.
4. Flat RCC slab should be provided.
5. All the parts of building should be tied firmly with each other.
6. The building should be uniform of height.
7. Cantilever, projections, parapets, domes etc. should be avoided.
8. Doors and windows should be provided in the walls diagonally oppo to each other, and wide windows should be avoided.

PART-2

Seismic Zones of India and Geological Consideration for Construction of Building, Projects in Seismic Areas.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.8. **Name the different seismic zones in which Indi divided.**

AKTU 2015-16, Marks

OR

Define Seismic Zones ? Briefly describe the different Seismic Zo of India.

AKTU 2016-17, Marks

OR

Write a note on different seismic zones of India.

AKTU 2017-18, Marks

Answer

A. **Seismic Zones :**

1. A seismic zone is a region in which the rate of seismic activity rema fairly consistent.
2. India is divided into four seismic zones *i.e.*, zone II, III, IV and V. The zones are divided on the basis of maximum considered earthquake service life of structure in each seismic zone.

B. **Types of Zone :** Following are the types of seismic zones :

1. **Zone V :**
i. The areas of this zone have the highest risk of effects by an earthquake.
ii. The earthquake intensity for this zone is MSK-IX or greater.
iii. The zone factor for this zone is 0.36, which is indicative of effective (zero period) level earthquake in this zone.
iv. This zone is called as very high damage risk zone.
v. Some of the regions which fall under this zone are Rann of Kutch, eastern regions etc.

2. **Zone VI :**
i. The areas of this zone have the lesser risk to effects by an earthquake as compared to zone V.
ii. The earthquake intensity for this zone is between MSK-VIII to MSK-IX.
iii. The zone factor for this zone is 0.24.
iv. This zone is called as high damage risk zone.
v. Some of the regions which fall under this zone are Northern regions, North Eastern Regions, Delhi etc.

3. **Zone III :**
i. The areas of this zone have the lesser risk by an earthquake.
ii. The earthquake intensity for this zone is MSK-VII.
iii. The zone factor for this zone is 0.16.
iv. This zone is called as moderate damage risk zone.
v. Some of the regions which fall under this zone are some parts of Gujarat and Maharashtra, Andaman & Nicobar Islands etc.

4. **Zone II :**
i. The areas of this zone have the least risk of an earthquake.
ii. The earthquake intensity for this zone is MSK-VI.
iii. The zone factor for this zone is 0.10.
iv. This zone is called as low damage risk zone.
v. Larger parts of India come under this zone.

Que 3.9. **What are seismic waves? Describe the origin and characteristics of seismic waves.** **AKTU 2017-18, Marks 10**

OR

Define seismic waves and explain the types of seismic waves.

Answer

Earthquake or Seismic Waves :

1. The strain energy released by an earthquake sets up several types of pulses (wave motion) at the focus. These called seismic or earth quake waves.
2. These waves are vibrations originate from the focus and are propagated in all directions.
3. These vibration travels through the rocks in the form of elastic waves.

Types of Seismic Waves : There are mainly three types of seismic waves :

1. ***P*-waves :** [The particle vibrate in the direction of propagation]

i. These are primary waves (longitudinal or pressure waves).

ii. These are the fastest among the seismic waves.

iii. They travel as the fast as 8-13 km/sec depending upon the density elasticity of the medium. Therefore, when an earthquake occurs, are the first wave.

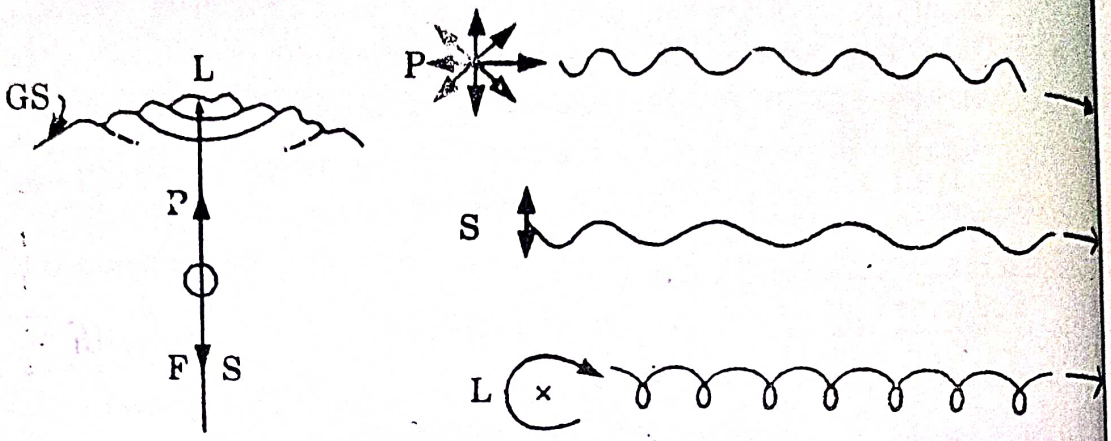


Fig. 3.9.1. Earthquake or seismic wave propagation.

2. ***S*-waves :** [P.V. at right angle to direction of propagation]

i. Secondary waves (*S*-waves) are shear waves that are transvers nature.

ii. In earthquake event, *S*-waves arrive at seismograph stations after faster moving *P*-waves and displace the ground perpendicular to direction of propagation.

iii. Depending on the propagation direction, the waves can take on diffe surface characteristics.

iv. For example : In the case of horizontally polarized *S*-waves, the gro moves alternately to one side and then the other *S*-waves are slo than *P*-waves and speeds are typically around 60 % of that of *P*-wave any given material.

3. ***L*-waves :**

i. Love waves are horizontally polarized shear waves (SH waves), exist only in the presence of a semi-infinite medium overlain by an up layer of finite thickness.

ii. They usually travel slightly faster than the Rayleigh waves, about 9 of the *S*-wave velocity and have largest amplitude.

Que 3.10. Write a note on :

A. Tectonic movement.

B. Reservoir induced seismicity. **AKTU 2017-18, Marks 1**

Answer

A. Tectonic Movement : Refer Q. 3.3, Page 3–5C, Unit-3.

B. Reservoir Induced Seismicity (RIS) :

1. It is a very complicated phenomenon, a result of complex, not entire known mechanisms that are very different in various cases.

2. RIS covers a wide interval of earthquake magnitudes, from micro earthquakes to very strong ones with magnitudes of upto $M = 6.5$.

3. There are two major factors for induced seismicity due to reservoir :

i. When a dam is built and the reservoir filled with water, the amount of pressure exerted on the earth in that area changes dramatically. When the water level of a reservoir is raised, pressure on the underlying ground increases; when the water level is lowered, the pressure decreases. This fluctuation can stress the delicate balance between tectonic plates beneath the surface, possibly causing them to shift.

ii. Another factor is the water itself. When the water pressure increases, more of it is forced into the ground, filling cracks and crevices. All of this water pressure can expand those cracks and even create new, tiny ones in the rock, causing greater instability below ground. What's more, as the water sinks deeper, it can act as sort of a lubricant for rock plates that are being held in place by friction alone. The lubrication can cause those plates to slip.

Que 3.11. **Describe the mode of propagation of seismic waves and describe the elastic rebound theory regarding origin of earthquake.**

Answer

A. Mode of Propagation of Seismic Waves : Refer Q. 3.9, Page 3–11C, Unit-3.

B. Elastic Rebound Theory :

1. The mechanism of tectonic earthquake can be explained by this theory.

2. Rocks are made of elastic material, and so elastic strain energy is stored in them during the deformations that occur due to the gigantic tectonic plate actions that occur in the Earth. But, the material contained in rocks is also very brittle.

3. Thus, when the rocks along a weak region in the Earth's crust reach their strength, a sudden movement takes place there, as shown in Fig. 3.11.1; opposite sides of the fault suddenly slip and release the large elastic strain energy stored in the interface rocks.

4. The sudden slip at the fault causes the earthquake, a violent shaking of the Earth when large elastic strain energy released spreads out through seismic waves that travel through the body and along the surface of the Earth. And, after the earthquake is over, the process of strain build-up at this modified interface between the rocks starts all over again. Earth scientists know this as the elastic rebound theory.

5. The material points at the fault over which slip occurs usually constitute an oblong three-dimensional volume, with its long dimension often running into tens of kilometers.

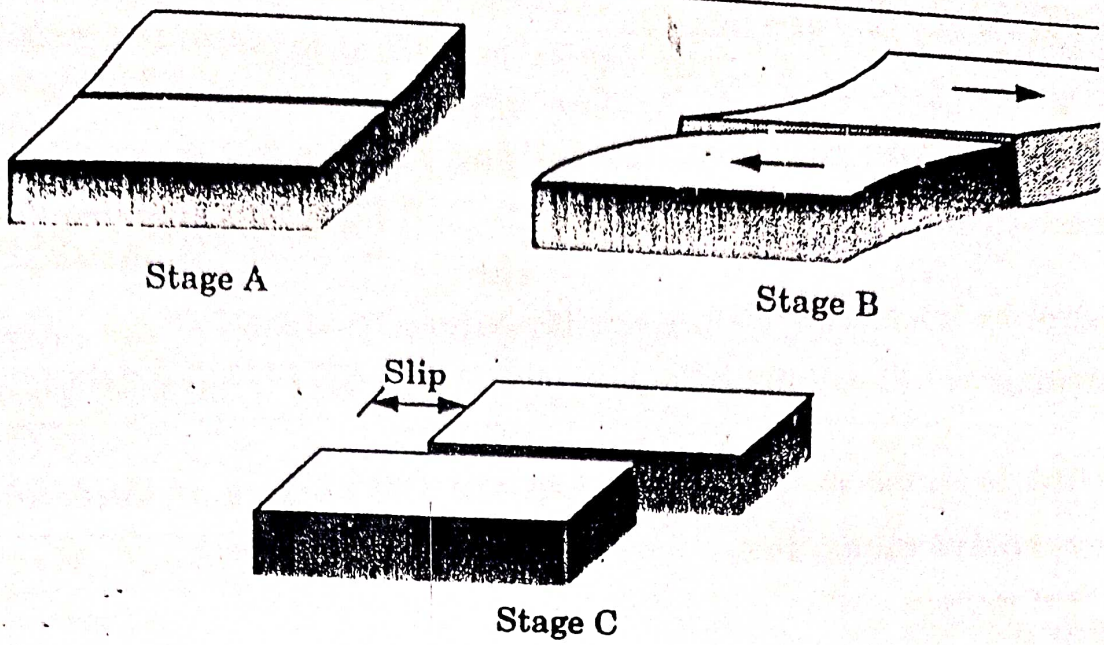


Fig. 3.11.1. Elastic strain build-up and brittle rupture.

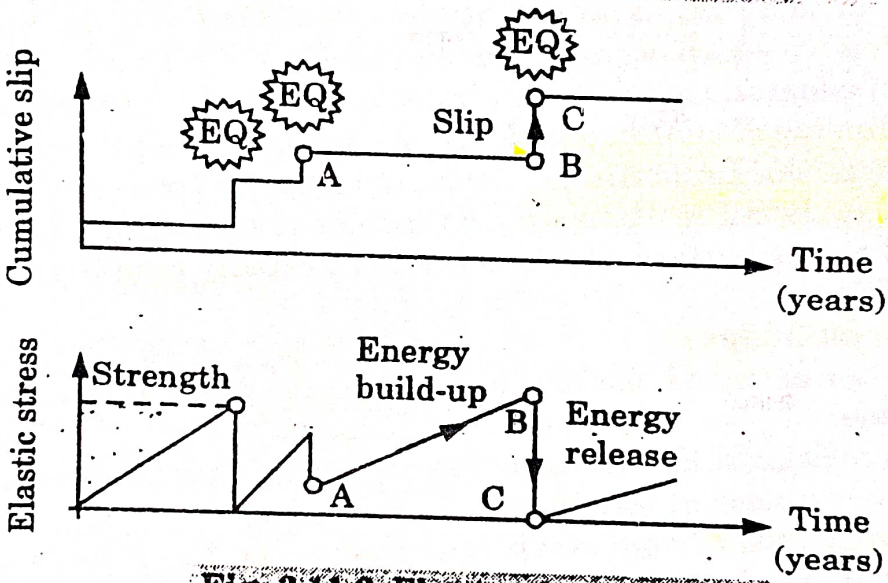


Fig. 3.11.2. Elastic rebound theory.

PART-3

Landslides : Causes, Classification and Preventive Meas

Questions-Answers

Long Answer Type and Medium Answer Type Questio

Que 3.12. **What are landslides ? Describe their types, cau preventive measures.**

AKTU 2014-15, Ma

OR

What do you mean by landslides ? Describe their preventive measures.

AKTU 2015-16, Marks 10

OR

What is landslide? What are its causes ? Also give the preventive measures of landslides.

AKTU 2017-18, Marks 10

OR

What is mass movement ? Explain the causes of landslide and preventive measures.

AKTU 2016-17, Marks 10

Answer

A. Landslides :

1. Landslide refers to the downward sliding of huge quantities of land masses which occurs along steep slopes of hills or mountains.
2. In general, landslides are viewed as slope failures resulting in sudden slipping of enormous volumes of material along downward slopes.

B. Types of Landslides : Following are the types of landslides :

1. **Debris Slide / Slump :** Failure of unconsolidated material along a shearing surface which slides down rapidly is called a slump or debris slide.
2. **Rock Slides :**
   i. When detached blocks of bed rock moves down the hill, it is called a rock slide.
   ii. In rock slide, the movement takes place on bedding planes, joints or any other planes of weakness.
3. **Rock Fall :** From steep rock slopes, blocks of rocks of varying size which are loosened by weathering, suddenly fall downward under the influence of gravity. This is called rock fall.

C. Causes of Landslides : Following are the factors which promote landslides :

1. **Water :** Water is an important factor in causing landslides. It acts in three ways :
   i. Water diminishes the strength of rock soil and thus helps in their movement.
   ii. The water that seeps into the rock or soil not only produces lubrication but also exerts additional force on the grains tending to displace them along the direction of water movement.
   iii. It adds weight to the material, hence many landslide occurs after rains. On freezing, it exerts an expensive force.
2. **Slope :**
   i. It has been observed that majority of the earth or rock failure are continental slopes.
   ii. This indicates that slopes are directly responsible for slides. As a rule, steeper the slopes, greater is the instability of such rock mass.

3. **Nature of Rocks/Lithology :**

i. Unconsolidated sediments, such as clay, sand gravel etc., cannot stand permanently along steeper slopes greater than their angle of repose (about 35°) and are likely to be affected by landslides.

ii. Where weak and slipper rocks like shale, volcanic tuff, phyllite are present, they are not likely to remain stable on steep slopes, for a considerable period of time.

4. **Structure of Rocks :** Joints, fractures, shear zones, and bedding planes usually become the slip surface in case of landslides, landslide is particularly common on hill slopes where dip of rock bed is also in the same direction.

5. **Anthropogenic Causes (Man-Made Causes) :**

i. Excavation of slope. ii. Loading of slope.

iii. Deforestation. iv. Irrigation.

v. Artificial vibration.

D. **Preventive Measures for Landslides :** Following are the preventive measures for landslides :

1. **To Counter the Effect of Slope :** Retaining walls may be constructed against slopes. Terracing of the slope is another effective measure.

2. **To Counter the Effect of Water :** A proper drainage system is the suitable measure. This involves the quick removal of percolated moisture by means of surface and sub-surface drainage.

3. **To Counter Structural Defect :** The different structural defects such as weak planes and zones may be either covered or grouted suitably so that they are effectively sealed off.

4. Growing vegetation, plants and shrubs on loose ground helps in keeping the loose soil together.

5. Avoiding heavy traffic and blasting operations near the vulnerable places helps in preventing the occurrence of landslides.

Que 3.13. **What are different types of mass failures ? Explain salient features in each case.**

AKTU 2013-14, Marks 06

Answer

A. **Types of Mass Failure :** Following are the types of mass failure :

1. **Flowage :**

i. The flowage is a downgrade movement of mass along no definite surface of failure.

ii. Mass involved in this type of failure is primarily unconsolidated or loosely packed or rendered so by natural processes of decay and disintegration.

iii. In flowage of unconsolidated or poorly consolidated mass, each grain or unit of grains behaves as if it has its own surface of shear failure.

iv. The result is that the movement is distributed throughout the mass and in a highly irregular manner as shown in Fig. 3.13.1.

v. Flowage is further distinguished into slow and rapid flowage :

a. In the slow flowage, failure is not easily perceptible. The ground may be moving downslope at as such low rates as few centimeters a year or even less.

b. In rapid flowage, the movement of failing mass may be easily visible and the mass may travel a few metres or more in a day.

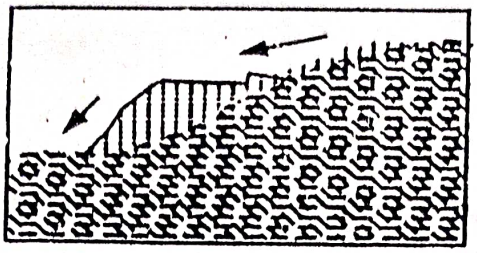


Fig. 3.13.1. Flowage.

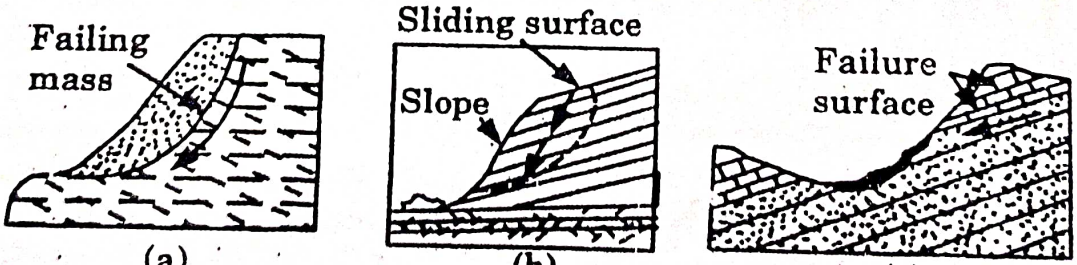
2. Sliding :

i A true landslide is a type of mass failure in which a superficial mass fails by moving as a whole along a definite surface of failure. The surface of failure may be planar or semicircular in outline.

ii. It is often characteristic of a landslide that the mass above the failure surface is unstable whereas the material lying below the surface is generally stable.

iii. Moreover, sliding may involve material of any composition, shape and of varying degree of consolidation : loose soil, rock fragments and whole blocks or slabs of rock.

iv. In unconsolidated deposits, loose, inherently weak rock masses and weathered top surface sliding commonly takes place along curved shear surfaces as shown in Fig. 3.13.2.



(a) Sliding in a mass along a circular failure surface.

(b)

(c) Side along a planar.

Fig. 3.13.2.

v. But when the mass involved is hard, brittle and coherent, such as massive igneous, sedimentary and metamorphic rocks, shear surfaces are broadly planar in character.

vi. In such cases, a set of joint planes or bedding planes or fault planes may be the most convenient natural planes of failure under specific circumstances favouring sliding.

vii. Landslides are further distinguished into translational slides, rotational slides and rock falls on the basis of the type of movement involved in the failure.

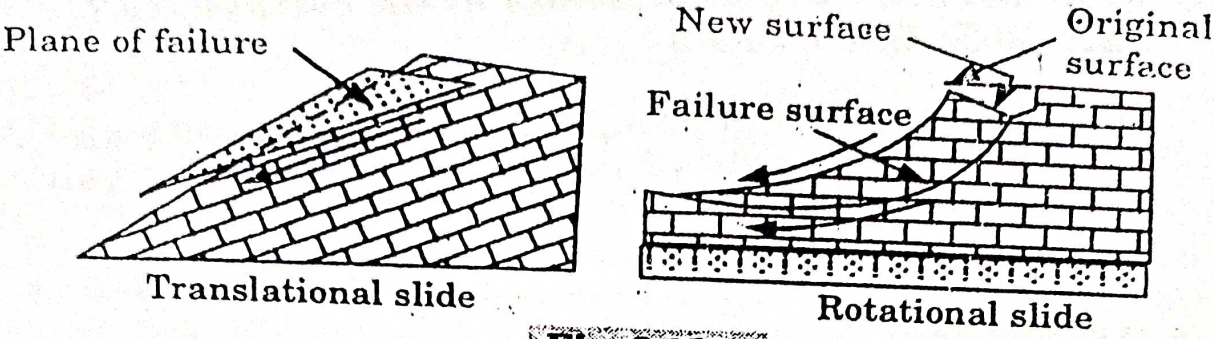


Fig. 3.13.3.

3. Subsidence :

i. It is defined as sinking or settling of the ground in almost vertically downward direction which may occur because of removal of natural support from the underground or due to compaction of the weaker rocks under the load from overlying mass.

ii. The net result in each case is that the surface material, natural ground or artificial fill suffers a sinking downward movement as shown in Fig. 3.13.4.

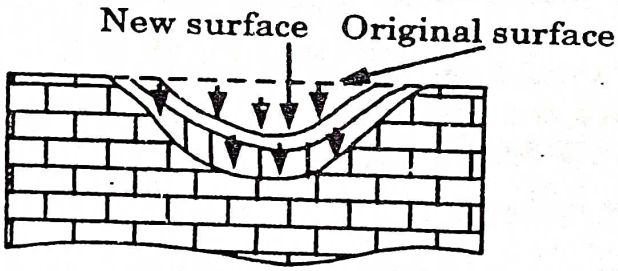


Fig. 3.13.4. Subsidence.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. What are the causes of earthquake ? Classify the earthquake ?

Ans. Refer Q. 3.2, Unit-3.

Q. 2. Define earthquake and tsunamis. Give a detailed account of tectonic earthquake.

Ans. Refer Q. 3.3, Unit-3.

Q. 3. What are the terminology of the earthquake ?

Ans. Refer Q. 3.4, Unit-3.

Q. 4. Give an account of Richter magnitude and Merc intensity scale of earthquake. How will you comp. between them ?

Ans. Refer Q. 3.6, Unit-3.

Q. 5. What is an earthquake ? Discuss briefly their causes. What precautions are to be taken for the construction works in seismic areas ?

Ans. Refer Q. 3.7, Unit-3.

Q. 6. Name the different seismic zones in which India is divided.

Ans. Refer Q. 3.8, Unit-3.

Q. 7. What are seismic waves? Describe the origin and characteristics of seismic waves.

Ans. Refer Q. 3.9, Unit-3.

Q. 8. Write a note on :

i. Tectonic movement.

ii. Reservoir induced seismicity.

Ans. Refer Q. 3.10, Unit-3.

Q. 9. What are landslides ? Describe their types, causes and preventive measures.

Ans. Refer Q. 3.12, Unit-3.

Q. 10. What are different types of mass failures ? Explain salient features in each case.

Ans. Refer Q. 3.13, Unit-3.

☺☺☺

4

UNIT

Geological and Geophysical Investigations

CONTENTS

Part-1 : Geological Investigation for Site Selection of Dams, Reservoirs, Tunnels, Bridges and Highways ..... 4–2C to 4–15C

Part-2 : Principles of Geophysical Explorations, Methods for Sub-Surface Structures ..... 4–15C to 4–20C

PART-1

Geological Investigation for Site Selection of Dams, Reservoirs, Tunnels, Bridges and Highways.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. **What do you mean by objective of Geological Investigation ?**

Answer

Objective of Geological Investigation : The main objective of geological investigations for most engineering projects is to determine :

1. The geological structure of the area :

i. Surface investigation.

ii. Sub-surface investigations.

2. The lithology of the area.
3. The ground water conditions in the region.
4. The seismicity of the region.
5. The geological structure of the area, which also includes topography and geomorphology, is determined by conducting extensive and intensive geological surveys.
6. The lithological details are revealed by those investigation would include the type of rocks that make up different parts of the area, on the surface as also up to and even beyond a desired depth, their textures, major structures and physical and engineering properties like hardness, strength, modulus of elasticity, rigidity, porosity and permeability.
7. The ground water conditions are of great significance in all major engineering structures.
8. The seismic factor has become a parameter of great concern during last sixty years or so. Hence, for any type of civil engineering construction in a region its seismicity has also to be studied critically.

Que 4.2. **Describe the geology investigation for site selection of dam and reservoir.**

AKTU 2016-17, Marks 15

OR

Give an account of geological investigations of dams and reservoirs.

AKTU 2014-15, Marks 06

Answer

A. Geological Investigations for Dams :

1. Suitable foundations must be available.
2. For economy, the length of the dam should be as small as possible, and for given height it should store the maximum volume of water. It, therefore, follows that the river valley at the dam site should be narrow but should open out stream to provide a large basin for a reservoir. A general configuration of contours of a suitable site is shown in Fig. 4.2.1.

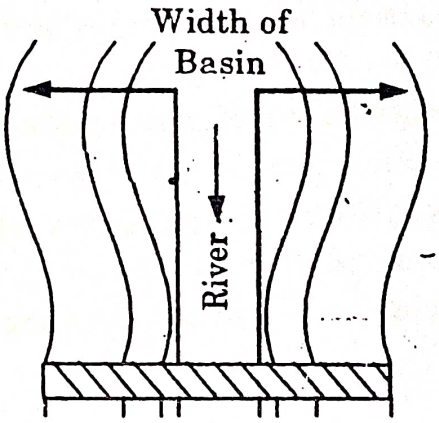
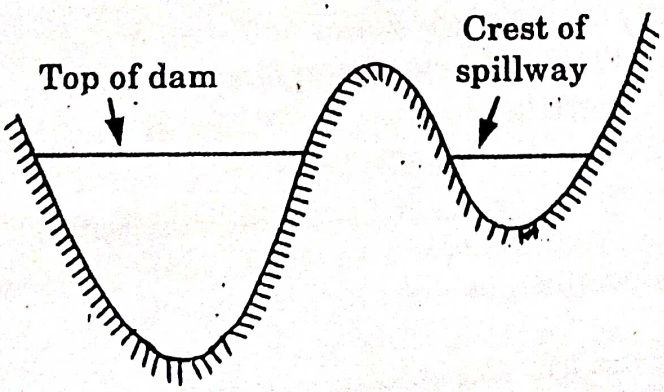


Fig. 4.2.1. Contour map of a suitable site for a dam.

① Type of rock.
② Property of rock.
③ Str feature of " .
④ Crushing & shearing strength of rock.
⑤ Space of joint in rock area
⑥ Watertable of bed pl
⑦ Thickness of - are
⑧ Weathering of rock.

3. The general bed level at dam site should preferably by higher than that of the river basin. This will reduce the height of the dam and will facilitate the drainage problem.
4. A suitable site for the spillway should be available in the near vicinity. If the spillway is to be combined with the dam, the width of the gorge should be such as to accommodate both.
5. The best dam site is the one, in which a narrow deep gorge is separated from the flank by a hillock with its surface above the dam, as shown in Fig. 4.2.2.



If such a site is available, the spillway can be located separately in the flank, and the main valley is spanned by an earthen or a similar dam.

6. Materials required for the construction should be easily available, either locally or in the near vicinity, so that the cost of transporting them is as low as possible.
7. The reservoir-basin should be reasonably water-tight. The stored water should not escape out through its side walls and bed.
8. The value of land and property submerged by the proposed dam should be as low as possible.
9. The dam site should be easily accessible, so that it can be economically connected to important towns and cities by rails, roads etc.
10. Site for establishing labour colonies and a healthy environment should be available in the near vicinity.
11. Minimum construction and maintenance cost.

B. Geological Investigation for Reservoir :

1. Good runoff from the catchment area with minimum percolation losses.
2. Runoff free from excessive silt load.
3. Soil in the catchment area does not contain harmful soluble salts and minerals.
4. Water tight reservoir perimeter, there should be no serious leakage from the reservoir basin.
5. High and steep side hills to ensure deep reservoir with maximum storage, but minimum surface area and hence minimum evaporation losses and lesser possibility of weed growth, steep sided reservoirs are, therefore ideal but are rarely available.
6. Geology of the region *i.e.*, type of rock and soil besides climate suitable to ensure minimum erosion of the soil. Impervious rock formation is the best.
7. Rock formation having dip in the upstream direction is preferable. Storage water is led out of the basin if the rock is dipping downstream.
8. Ideal dam site *i.e.*, narrow gorge with sound foundations to locate dam and rapid widening of the valley above dam site to afford greater average volume per meter of height and length of the dam.
9. Reservoir basin barren, so that cost of land acquisition and forest clearance is the minimum.
10. Minimum submergence of forest and cultivated lands and habitations, so that the uprooted population is the least and the land acquisition and compensation charges are bare minimum.

Que 4.3. Describe the geological investigation for site selection of dams and reservoirs, tunnels, bridges and highways.

AKTU 2015-16, Marks 15

Answer

A. **Dam and Reservoir :** Refer Q. 4.2, Page 4–2C, Unit-4.

B. **Geological Investigation for Site Selection of Tunnels :**

1. The alignment of tunnelling project should be least.

2. Tunnelling is complicated process and involves huge costs. Excav -ation methods are intimately linked with the type of rocks excavated. C choice of the right method is one of the most important aim and obje geological investigation.

3. The general topography of the area marking highest and lowest po point depressions, slide area, cold climate etc., to be surveyed.

4. Lithology of area such as composition, altitude and thickness of rock formation is surveyed for site selection.

5. The hydrological conditions such as depth of water table, possibili -lity aquifer are examined.

6. Assessment of environmental hazard is examine because tunne lling method might involve vibrations induced through blasting and gro gravel cutting and drilling producing dust and sound affect the nearby are

7. Assessment of cost and stability is the important consideration for site selection for tunnels.

C. **Geological Investigation for Site Selection of Bridge :**

Following are the geological investigations for site selection of brid

1. **The Depth to the Bed Rock :** The river bed below the water is cove by varying thickness of consolidated natural deposits of sand, grav and boulder such lose material are not safe as foundation for brid piers for at least two reason :

i. Piers placed directly on them would be unstable.

ii. The cover material is liable to be removed due to coming by river wa

2. **The Nature of the Bed Rock :** The bed rock selected as foundation the pier must be strong enough to bear the total of the following lo

i. The compressive vertical load due to the weight of the bridge span that of pier material.

ii. The horizontal load due to the thrust of the water flowing above transmitted directly and through the pier.

iii. The dynamic, complex load, often inclined and shearing in charac due to heavy traffic on the bridge.

3. **The Structural Disposition of Rock :** When the bridges sites are located in the zones of seismic activity, the foundations are required to be designed for additional seismic load as specified in the codes of respective areas.

D. **Geological Investigation for Site Selection of Highways :** Following are the various details to be collected for site selection of highways :

1. Population and its distribution in each area.
2. Industrial and agricultural development and future trends.
3. Existing facilities with regard to communication, recreation and education etc.
4. Sources of income and estimated revenue.
5. Traffic volume in vehicles per day.
6. Accidents and their cost analysis.
7. Topography survey and soil survey.
8. Location and classification of existing roads.
9. Growth of passenger trips.
10. Mass transportation facilities.

Stability of roads

(a) Topography
(b) Geological Str
(c) Road in hilly area
(d) Road in Marshy region
(e) Road in water logged area

Que 4.4. **Describe the geological considerations and problems encountered for a selection of dam site.**

साधना

AKTU 2017-18, Marks 10

Answer

A. **Geological Considerations of Dam Sites :** Following are the geological considerations for a selection of dam site :

1. The site along the river valley which has the least area cross-section shall be selected.
2. The site should be free from severe leakage otherwise safety of the dam is affected.
3. The site should have very strong and stable rocks.
4. The site having igneous rocks is safer for dam as comparing with sedimentary rock particularly shale, poorly cemented sandstones and cavernous limestone.
5. Occurrence of metamorphic rocks like genesis is also suitable as dam site and schist are undesirable.
6. The site should be free from intrusions.
7. A dam site with fault zones should be treated careful if there is fault at site.

B. **Geological Problem :** Following are the geological problems encountered for a selection of dam site :

1. **Dams on Shale :**

i. The cementation shale is stronger and do not disintegrate when subjected to wetting and drying.

ii. The compaction shale on the other hand is soft and they slake when subjected to alternate wetting and drying. Their bearing strength is low and they become plastic when wetted.

2. Dams on Soluble Rocks :

i. The soluble rocks include limestone and dolomites and marbles.

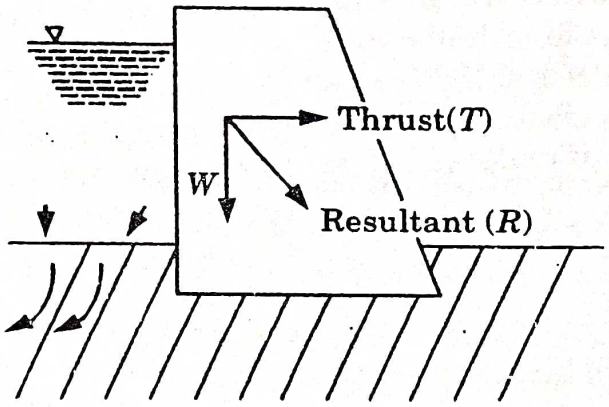
ii. These rocks are generally sufficiently strong to support the weight of the dam, they may contain underground solution channels and caverns.

iii. If such solution channels are present at a dam site, the leakage through them may be on such a large scale that the reservoir may not hold water for long.

3. Dams on Strata Dipping Upstream :

i. The dams located on rocks dipping upstream represent ideal foundation conditions.

ii. These strata are most capable of supporting the weight of dams and the pressure of the reservoir because the resultant of these two force act nearly at right angles to the bedding planes of rocks as shown in Fig. 4.4.1.



where, W = Weight of dam

Fig. 4.4.1. Dam on rocks dipping upstream.

iii. The water in the reservoir does not percolate below the dam to the upstream dip of rocks. As result the leakage of water and the development of uplift pressure will be minimum.

4. Dams on Strata Dipping Downstream : The dams constructed on rocks dipping downstream (Fig. 4.4.2) may not be safe due to the following reasons :

i. The percolation of water may lubricate the junctions of rock bed which may facilitate sliding of dam.

ii. The water percolating through the strata dissolves the cementing materials of rocks and enlarges the openings by mechanical erosion.

iii. The water which enters into the openings of rocks below the dam causes the development of uplift pressure, which tends to decrease the stability of the structure.

iv. In Fig. 4.4.2, *R* is the resultant of the weight of the dam and pressure of the reservoir water. In this case, this resultant acts nearly parallel to the bedding planes and endangers the stability of the dam.

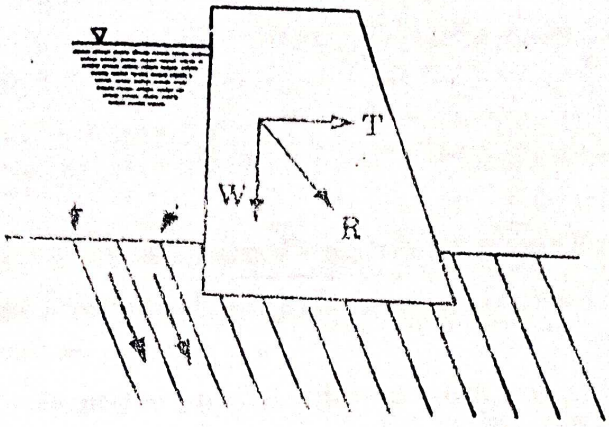


Fig. 4.4.2. Dam on strata on dam's upstream dipping downstream.

5. **Dams Built Across Strike of Rocks :**

i. The best foundation condition is when only one uniform rock is present along the length of a dam.

ii. If a dam is aligned across the strike of strata, its foundation will be on different rock types of varying properties. In such a case there are changes of unequal settlement of the dam.

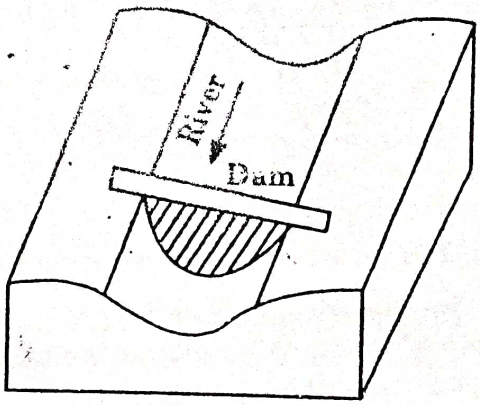


Fig. 4.4.3. Dam aligned across the strike of rocks.

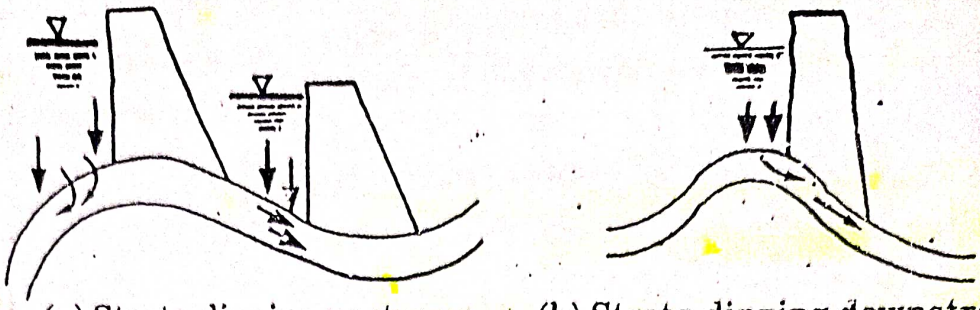
6. **Dams on Jointed and Permeable Rocks :** Where highly fissured, jointed and permeable rocks exist below the dam, they will not only leakage of water, but also build uplift pressure at the base of the dam.

7. **Dams on Faulted Rocks :** The faulted rocks are weak and undesirable along the faulted plane. The dam structure that is to be constructed on faulted rocks required great caution in calculating the design strength in various sections of the dam.

8. **Dams on Folded Rocks :**

i. The rock site with folding of beds on a relatively large scale is less dangerous than faulting unless the folds are of a complex nature.

ii. If the fold is occurred along the upstream dipping of beds then it advantageous than the fold occurred along the downstream dipping of beds. It is shown in Fig. 4.4.4(a) and Fig. 4.4.4(b).



(a) Strata dipping upstream (b) Strata dipping downstream

Fig. 4.4.4.

Que 4.5. **What are tunnels ? Explain with neat sketches tunnels located in :**

1. **Anticline and syncline.**
2. **Foot wall and hanging wall.**
3. **Fissured and fractured zone.**

AKTU 2013-14, Marks

Answer

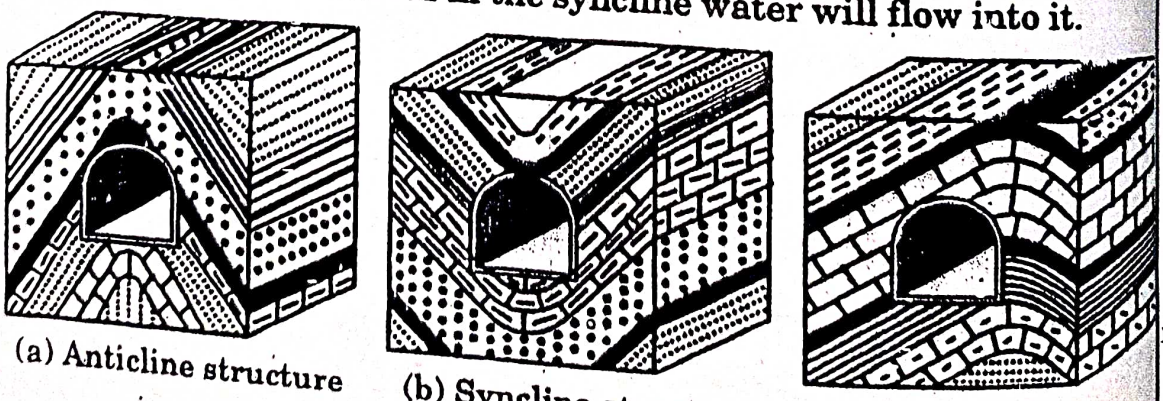
Tunnels :

1. These are underground routes or passages driven through the grou without disturbing the overlying soils or rock cover.
2. They are open at both ends to the ground surface.
3. They are driven for a variety of purposes and are classified according public utility tunnels.
4. The main classes of tunnels are traffic tunnels, hydropower tunnels a

1. **Tunnels Located in Anticline and Syncline :**

i. Location of a tunnel in an anticline tends to relieve the vertical pressu on the lining whereas in a tunnel location in a syncline, there will be increase in pressure.

ii. If located in water bearing strata anticlinal portion will have wa flowing from it, whereas in the syncline water will flow into it.



(a) Anticline structure (b) Syncline structure (c) Anticline structure

Fig. 4.5.1.

2. **Tunnel Located in Foot Wall and Hanging Wall :**

i. If the tunnel is driven from the hanging wall, the fault first appears the invert (floor), and it generally is possible to provide adequate suppo or reinforcement when driving through the rest of the zone.

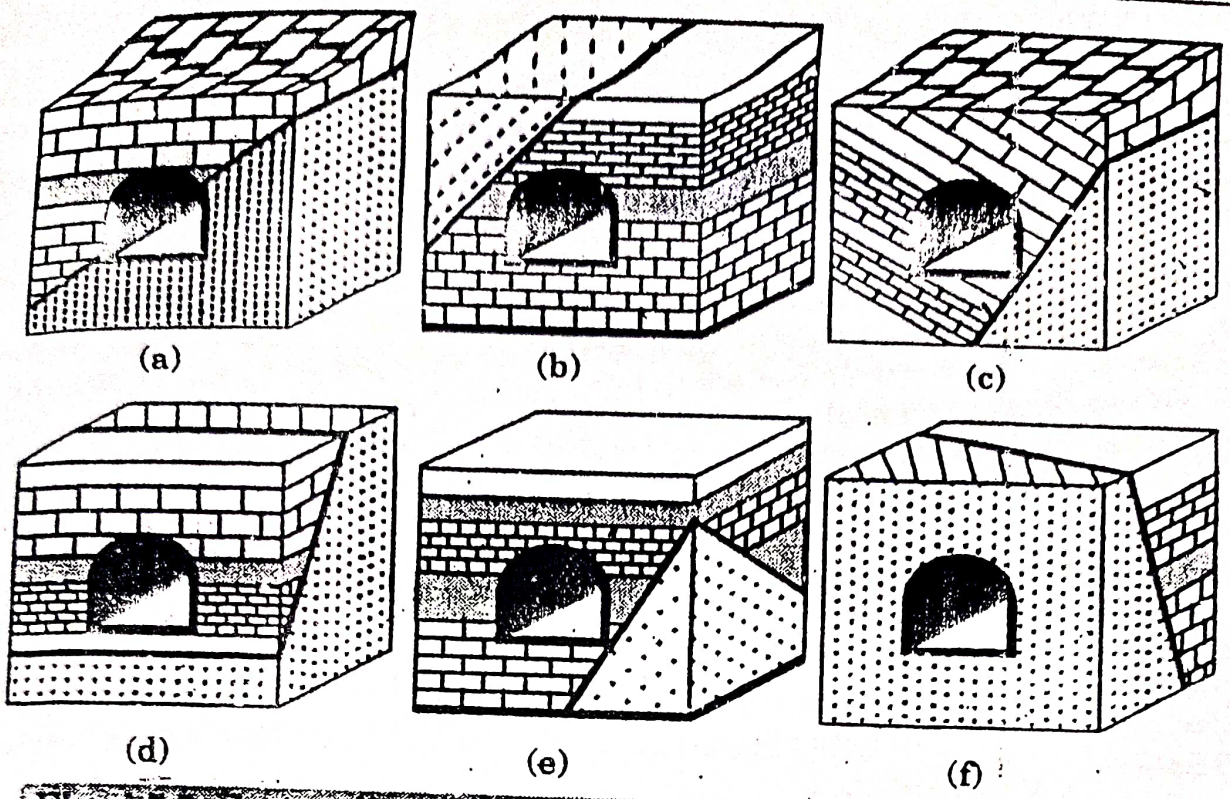


Fig. 4.5.2. Foot wall and hanging wall located on tunnel site.

ii. Conversely, when a tunnel is driven from the foot wall side, the fault first appears in the crown (roof), and there is a possibility that a wedge-shaped block, formed by the fault and the tunnel, will fall from the roof without warning.

3. **Tunnel Located in Fissured and Fractured Zone :**

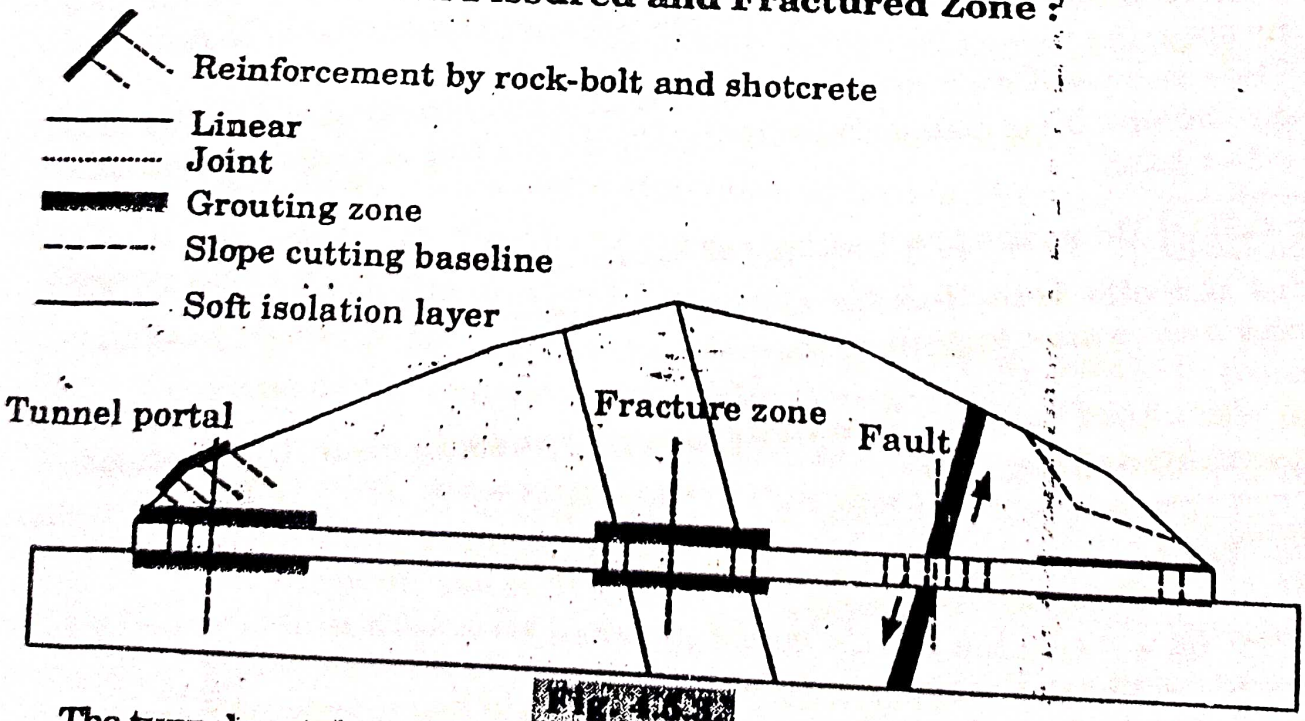


Fig. 4.5.3.

i. The tunnel portal and the inner part passing through the fault and fracture zone always suffered serious damage, and it is very important to reduce the risk and damage from strong earthquake and its secondary disasters.

ii. The sections of the tunnel in which the antidamping design must be concentrated are shown in Fig. 4.5.3.

Que 4.6. **What are the geological investigations necessary the alignment of hill roads ?** **AKTU 2013-14, Marks**

Answer

Geological Investigation for the Alignment of Hill Roa

Following geological investigations are necessary for the alignme hill roads :

1. **Meandering :**

i. Construction of roads in hilly regions is always a job full of n complications. Thus, the most important principle for road alignment based on connecting two visible points by the shortest route is the i difficult to be followed in hilly regions.

ii. The topographic and the permissible factors necessitate, more often a meandering, zig-zag course.

2. **Aerial Survey :**

i. Another very important complication is the area that has to be survey in the specified time.

ii. This will require, obviously, use of some quicker methods of survey

iii. Hence, aerial surveying may become necessary for successful complete of the project in specified time.

3. **Rock Consideration :** If some solid and stratified rocks are encounter along the alignment, special investigations should be carried o determine :

i. Dip and strike of the bed.

ii. Lithological composition of the rocks.

iii. Presence and nature of faulting, jointing and permeability due to t secondary planes of weakness.

Que 4.7. **Enumerate the geological factors which influence choice of site for a reservoir.**

OR

What are the standard guidelines suggested by the expert investigation selection the site for dam or reservoir ?

Answer

Selection of site for reservoirs : The following criteria sha considered for the suitability of site for reservoirs :

1. A good reservoir site would be a valley section constricted by a na gorge at its outfall with steep banks.
2. A reservoir site should cover a small area but has a great dep provide the adequate capacity so as evaporation losses are minim
3. A site should have very low rate of silting.
4. A site should be free from anticlinal strike valley or faults valley.
5. A site should not have buried river channel which is source of lea
6. A site should not have the porous and permeable rocks (*i.e.*, aqui

Que 4.8. **Describe role of geological conditions that influence the design and stability of a traffic tunnel.**

Answer

1. Tunnels are passages, underneath the earth's surface (or passages through hills or mountains) used for different purpose.
2. Unlike other civil engineering construction which lies on the surface, tunnels lie within the rocks.
3. For the reason, the need for their safety and stability is much more important.
4. The construction of the tunnels involves penetration through rocks of various types, it is apparent that the convenience.
5. Cost and safety of tunnelling operation is dependent primarily on the geological characteristics of the country rocks along the alignment of the proposed tunnel.
6. Following are the role of geological conditions that influence the design and stability of traffic tunnel :

i. **Nature of Rock Type :** It is very important for the safety and stability of the tunnel. Competent rocks will lead to safe but slow tunnelling and the incompetent rocks, through amenable for easy tunnelling will be unstable and hence requires living.

ii. **Geological Structures :** The bearing of geological structure in tunnels is very important because :
   a. They modify the competency and suitability of rocks for tunnelling.
   b. This may create or prevent ground water conditions. Folds, faults, joints are most common structural features associated with rocks.

iii. **Groundwater Condition :**
   a. Sub-surface water percolates through the pore spaces, joints fault planes, shear zones, solution cavities and other opening with in the country rocks.
   b. The nature extent and mutual relation of these opening determine the porosity and permeability of the country rock and govern the ground water condition along the course of any tunnel.
   c. The ground water problem is the most serious, because under adverse conditions longer quantities of ground water may gush out and inundate the tunnels.

Que 4.9. **Give an account of the structural disposition of the foundation rock for bridges.**

Answer

Structural Disposition of the Foundation Rock for Bridges :

1. Ideally, the horizontal attitude and uniformly massive structure with depth are desirable characters in the foundation rock as these after inherent resistance against failure.

2. However even inclined rocks in a confined situation under the bridge piers are considered.
3. Quite safe if these possess normal strength values. Folding and faulting might cause some uncertainty in establishing a perfect geological profile out are not otherwise negative factors.
4. Acute fracturing and profuse jointing is, however, undesirable at the foundation levels as these might cause settlement beyond the allowable limits.
5. When the bridge sites are located in the zones of seismic activity, the foundations are required to be designed for additional seismic loads as specified in the codes of respective areas.
6. In the glaciated area, special care must be taken to establish the existence of drowned or buried valleys that might be filled by secondary material of most heterogeneous characters.
7. In such cases a bed rock may be encountered only at great depth and it may be desirable to reach it through piles.
8. In fact occurrence of drowned valleys is considered one of the major complications in bridge foundation that limits the options of a design engineer.
9. Similarly the factor of scour must never be overlooked. River bed materials and rocks under them at shallow depths are liable to removed by scouring.
10. The scour itself is a function of river velocity and direction of the currents on the one hand and nature of the consolidation of the rocks on the other hand.

Que 4.10. **Describe the geological investigation that you will carry out for the site selection for the construction of a road in marshy regions and water logged area.**

OR

Write the short note on construction of roads in marshy regions and permafrost regions.

Answer

A. Roads in Marshy Regions :

i. Subsidence :

i. In some regions, the apparently strong soil might be underlain by weak, saturated or semi dry or dry and loose material like mud, peat, muck and compressible clay in good thickness.

ii. In such regions, the road thickness is of considerable importance and if it transfers all or greater part of the load to the underlying weaker zones, failure due to subsidence; might be the major threat to the stability of the road.

iii. It (subsidence) has to be predicted and controlled before it takes place.

iv. Geological investigations are especially important and should reveal the presence of unstable material at critical depths. Such unstable areas include swamps, marshes, peat bogs, saturated clays and the like.

v. In areas, where such layers or deposits are encountered, their geological character and geometric dimensions should be thoroughly investigated and the cuts and road foundations designed accordingly. Of great importance to know is the nature of the soft deposits and their thickness. These could be obtained by test drill holes.

2. Treatment :

i. In all such regions, the most satisfactory method for ensuring stability is to excavate the weak soil or peat or other such material and replace it with sound material.

ii. This is, obviously, possible when the area involved is quite small and the deposit is shallow in character.

iii. In other cases, methods aimed at inducing strength by artificial means may be adopted.

iv. Drainage may also contribute effectively in stabilizing such regions.

3. **Roads in Water Logged Areas :**

i. It has been observed that roads situated in water-logged areas get deformed and damaged due to reasons connected with water-logging.

ii. A simple explanation is that due to rise of water table in such regions, the capillary moisture wets the sub grade soil to varying degrees depending upon its textures.

iii. This leads to unequal reduction in bearing capacity of the soils which manifests itself in the road deformation.

iv. The deformation becomes more serious when such roads continue to be under heavy traffic.

v. There are two possible ways to treat this trouble :

a. Lower down the water-table to the safe limits.

b. Increase the thickness of the road crust.

B. Roads in Permafrost Regions :

1. In permafrost regions the ground remains permanently frozen below some depth. During the summer, thawing may set up in the top layers.

2. When roads are constructed in such regions ignoring such facts regarding the ground, these might fail within short span of time.

3. The reason is simple, when a road is constructed over a frozen ground, the warm fill material acts as a blanket over the intergranular ice below and thus causes its melting, which causes subsidence because the soil below becomes temporarily saturated.

4. Necessary precautions aimed at stopping development of such a situation are required to be taken.

5. Vegetation, if any, should not be disturbed and a well-planned 'insulating layer' should be given in between the warm fill of the road surface and the ice below.

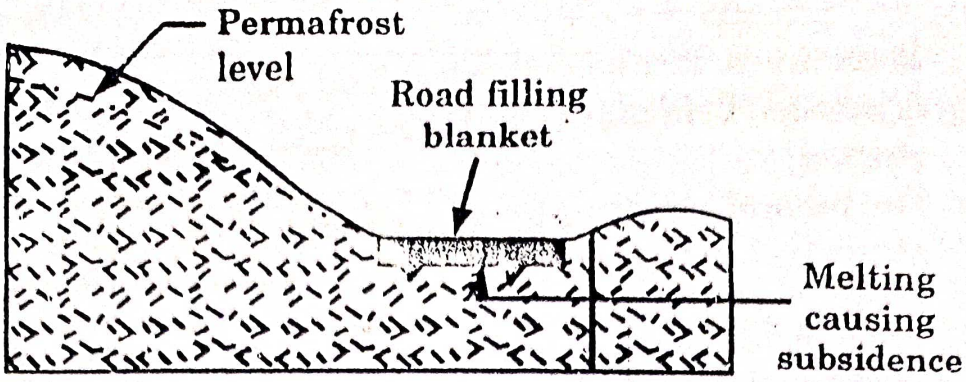


Fig. 4.10.1. Road in permafrost area.

6. Ice crystals should be allowed to remain in their original state.

PART-2

Principles of Geophysical Explorations, Methods for Sub-Surface Structures.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.11. **What do you mean by geophysical exploration ? Bri describe its principles for sub-surface structures.**

AKTU 2015-16, Marks 15 **AKTU 2017-18, Marks**

Answer

A. Geophysical Exploration :

1. It is a method to get the position of all minerals, hydrocarbon, geothe reservoir, groundwater reservoir and other geological structure.
2. Geophysical exploration represents a primary tool for investigati the subsurface and is applicable to a very wide range of problems.
3. The importance of geophysical exploration as a mean of deriving surface geological information is so great that the basic principle scope of the methods and their main fields of application shoul appreciated by any practicing earth scientist.

B. Principles of Geophysical Exploration :

1. The rocks or ore bodies have different physical parameter/prope like density, magnetic susceptibility, elasticity, radioactivity and the or electrical conductivity.
2. This means that the Earth's upper layer by virtue of geolo inhomogeneities exhibit differences in their physical properties.
3. In geophysical exploration, a particular natural field like gra magnetism or natural field, is measured on the surface.

4. Sometimes, artificial physical field like an electrical or electromagnetic or seismic field is created in the earth and its distribution in the area is studied.
5. The inhomogeneities in physical properties of sub-surface rocks, ores, geological structures produce deviation in the measured physical parameters.
6. These deviations of the measured quantities from the normal distribution expected due to the homogeneous sub-surface conditions are termed as geophysical anomalies, and they form diagnostic measures to the inhomogeneities in the subsurface of this investigated area.
7. By careful study to the intensity, character and distribution of the geophysical anomalies, it is possible to locate the geological objects or structures.

Que 4.12. Name the various geophysical explorations. Describe the seismic refraction method for determination of depth of the bed rock. Explain its importance in civil engineering.

AKTU 2013-14, Marks 06

Answer

A. **Geophysical Explorations :** Following are the two types of geophysical explorations :

1. **Surface Investigations :** These include preparation of topographic maps using the normal mapping techniques. In fact, all field surveys begin with the preparation (or availability) of topographic maps showing elevation contours relative to some datum.
2. **Sub-Surface Explorations :** Following are the two types of sub-surface explorations :

i. **Direct Sub-Surface Explorations :** The direct methods involve examination of rocks or materials of the underground by digging of drill holes, trial pits, aditus, shafts, galleries and exploratory tunnels.

ii. **Indirect Sub-Surface Investigations :** The indirect methods of sub-surface explorations are used extensively and involve application of geophysical techniques for obtaining fairly accurate idea of sub-surface geology.

B. **Seismic Refraction Method :**

Principle : Seismic methods of study are based on the principle that sub-surface rock formations bear different elastic properties because of this, the velocities of propagation of seismic waves through them, change with changes in lithology measurement of the seismic wave velocities of rock formation. Therefore, provides a scope to distinguish subsurface lithological units.

Process : In seismic methods, artificial explosions are made in the ground. The seismic waves, thus produced travel through the sub-surface layers of the earth, suffer reflection or critical refraction and arrive at the surface of the earth where they are detected by geophones.

C. Importance : Following are the importance of geophysical explora in civil engineering :

1. It is important to map the sub-surface structure of a region an elucidate the underlying structures.
2. It is also important for the spatial distribution of rock units and to de structures such as faults, folds and intrusive rocks.
3. This is an indirect method for assessing the likelihood of ore deposit hydrocarbon accumulations.
4. It is used within civil construction and engineering for a variety of us including detection of buried water, gas, sewerage, mapping of soft so etc.

Que 4.13. **Describe electrical resistivity method of si inves gation.** **AKTU 2014-15, Marks 0**

Answer

Electrical Resistivity Method :

1. The electrical resistivity method is an active geophysical method.
2. It employs an artificial source which is introduced into the ground throu a pair of electrodes.
3. The procedure involves measurement of potential difference betwe other two electrodes in the vicinity of current flow.
4. The measure of resistivity is presumed to be a measure of the flu content and porosity of rocks.
5. Therefore, the resistivity measurements help in making distinctio between saturated and unsaturated rocks, and also between rocks differing porosity.
6. As shown in Fig. 4.13.1, the current is introduced into the ground by tw current electrodes C_1 and C_2 and the potential difference between th inner electrodes P_1 and P_2 is measured.
7. All the four electrodes are placed in a line at the same distance apart.

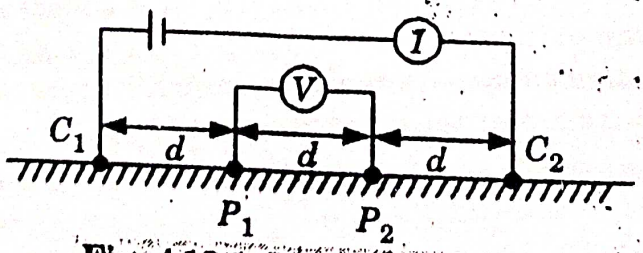


Fig. 4.13.1. Resistivity method.

8. The resistivity of the ground is determined by the following equation

$$R = 2\pi d \frac{V}{I}$$

where, R = Resistivity.
d = Distance between electrodes.
V = Potential difference between the inner electrode.
I = Current.

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velocities of the underlying materials. Bedrock may be defined by compressional wave velocities.

6. The information obtained from a seismic refraction survey is used to compute the depths to various subsurface layers and the configurations of these layers. The thickness of the layers and the velocity contrasts between the layers govern the effectiveness and the accuracy of the survey.
7. Seismic refraction surveys do not provide all compressional wave velocities or delineate all sub-surface layers. Seismic refraction interpretation assumes that layer velocities increase with depth.
8. Following are the various methods includes in it :

i. Seismic refraction surveys.
ii. Seismic reflection surveys.
iii. Surface wave surveys.

Que 4.15. **Discuss the objects and general methods of geologica investigation for major engineering projects.**

Answer

Objects : The main object of geological investigations for mos engineering projects is to determine :

i. Tne geological structure of the area.
ii. The lithology of the area.
iii. The groundwater conditions in the region.
iv. The seismicity of the region.

2. The geological structure of the area, which also includes topograph and geomorphology, is determined by conducting extensive and intensiv geological surveys.
3. These surveys would reveal the entire topographic details (*i.e.* existenc of hills, slopes, valleys, plains, plateaus), occurrence of folds, faults anc major unconformities and joint systems and geomorphic details of wate bodies like rivers, lakes, springs.
4. The lithological details as revealed by these investigations would includ the type of rocks that make up different parts of the area, on the surfac as also upto and even beyond a desired depth, their textures, majo structures and physical and engineering properties like hardnes strength, modulus of elasticity, rigidity, porosity and permeability.

Geological Investigations : Following are the two types of geologic investigation :

A. **Surface Investigations :**

1. These include preparation of topographic maps (if these are not alread available) using the normal mapping techniques. In fact all field surve begin with the preparation (or availability) of topographic maps showir elevation contours relative to some datum.
2. Aerial surveys and preparation of photogeological maps are the late methods of surface investigations. The entire area involving a

engineering study is photographed using sophisticated cameras and controls from low flying aeroplanes.

3. Hydrogeological surveys to obtain hydrogeological details of the area are also conducted partly on the surface with a view of recording following details that are of immense help in the later studies :

i. Drainage pattern of the area and discharge.

ii. Location and discharge details of springs and other leakage points.

iii. Location of wells and measurements of water levels after intervals to note aberrations in behaviour with time.

iv. Precipitation and evaporation details.

4. All surface surveys, however, carefully carried out, can give only superficial details. These could broadly be classed as preliminary surveys and have necessarily to be followed by well planned subsurface investigations which would provide fairly accurate idea about the sub-surface geological conditions at the most critical locations.

B. Sub-Surface Explorations :

1. These are accomplished by following two broad methods: direct sub-surface explorations and indirect sub-surface investigations.

2. The direct methods involve examination of rocks or materials of the underground by digging of drill holes, trial pits, adits, shafts, galleries and exploratory tunnels.

3. In such explorations either the underground areas are reached for direct examination & testing or samples are obtained which are examined and tested in the laboratory.

4. The indirect methods of subsurface explorations are used extensively and involve application of geophysical techniques for obtaining fairly accurate idea of sub-surface geology.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Describe the geology investigation for site selection of dam and reservoir.

Ans. Refer Q. 4.2, Unit-4.

Q. 2. Describe the geological investigation for site selection of dams and reservoirs, tunnels, bridges and highways.

Ans. Refer Q. 4.3, Unit-4.

Q. 3. Describe the geological considerations and problems encountered for a selection of dam site.

Ans. Refer Q. 4.4, Unit-4.

Q. 4. What are tunnels ? Explain with neat sketches the located in :

1. **Anticline and syncline.**
2. **Foot wall and hanging wall.**
3. **Fissured and fractured zone.**

Ans. Refer Q. 4.5, Unit-4.

Q. 5. What are the geological investigations necessary alignment of hill roads ?

Ans. Refer Q. 4.6, Unit-4.

Q. 6. What do you mean by geophysical exploration ? describe its principles for sub-surface structures.

Ans. Refer Q. 4.11, Unit-4.

Q. 7. Name the various geophysical explorations. Descri seismic refraction method for determination of de the bed rock. Explain its importance in civil enginee

Ans. Refer Q. 4.12, Unit-4.

Q. 8. Describe electrical resistivity method of site investig

Ans. Refer Q. 4.13, Unit-4.

Q. 9. Give a comparative account of electrical and se methods of geological investigations.

Ans. Refer Q. 4.14, Unit-4.

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