INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad -500 043

CIVIL ENGINEERING DEPARTMENT

COURSE LECTURE NOTES

Course Name	**ENGINEERING GEOLOGY**
Course Code	ACEB05
Programme	B.Tech
Semester	IV
Course Coordinator	Mr K Tarunkumar, Assistant Professor, CE
Course Faculty	Mr K Tarunkumar, Assistant Professor, CE Ms. H Apurva Rama, Assistant Professor, CE
Lecture Numbers	1-60
Topic Covered	All

COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Access engineering properties of rock and unconsolidated materials in the characterization of geologic sites for civil work projects and the quantification of processes such as rock slides, soil-slope stability, settlement, and liquefaction.
II	Involves the collection, analysis, and interpretation of geological data and information required for the safe development of civil works.
III	Assessment and mitigation of geologic hazards such earthquakes, landslides, flooding; the assessment of timber harvesting impacts; and groundwater remediation and resource evaluation.

COURSE LEARNING OUTCOMES (CLOs):

Students, who complete the course, will have demonstrated the ability to do the following:

ACEB05.01	Know the importance of geology in civilEngineering.
ACEB05.02	Distinguish weathered rocks from fresh rocks
ACEB05.03	Understand the effects of weathering on dams,Reservoirs and tunnels.
ACEB05.04	Understand the case histories of failure of someCivil Engineering constructions due to Geological draw backs.
ACEB05.05	Identify and classify rock using basic geologicclassification systems
ACEB05.06	Study the minerals by their physical properties, chemical composition, optical properties and X- ray properties.
ACEB05.07	Study the rocks by their physical properties, chemical composition, optical properties and X-ray properties.
ACEB05.08	Understand the geological classification of rocks into Igneous, Sedimentary and Metamorphic rocks, their identification based on structure and texture.
ACEB05.09	Identify the major types of rock-forming minerals and rock under both field and laboratory conditions.

ACEB05.10	Understand the importance of various associated geological structures like folds, faults, joints and unconformities present at site for foundations.
ACEB05.11	Identify subsurface information and groundwater potential sites through geophysical investigations.
ACEB05.12	Understand to select a suitable site for dams and reservoirs to avoid seepage, silting and Tilting.
ACEB05.13	Understand internal geological processes (e.g. faults, earthquakes, volcanoes) and how they affect engineering studies.
ACEB05.14	Locate various subsurface mines and rock bodies by applying geophysical investigations such as Gravity methods, magnetic methods, Electrical methods, seismic methods, radio metric methods and geothermal methods.
ACEB05.15	Understand the structural and lithological considerations for tunnel construction to avoid leakage and falling of rock parts.
ACEB05.16	Understanding of impact of engineering solutions on the society and also will be aware of contemporary issues.
ACEB05.17	Apply geological principles for mitigation of natural hazards and select sites for dams and tunnels.
ACEB05.18	Possess the knowledge and skills for employability.
ACEB05.19	Understanding of impact of engineering solutions on the society and also will be aware of Contemporary issues.
ACEB05.20	Apply geological principles for mitigation of natural hazards and select sites for dams and tunnels.
ACEB05.21	Possess the Knowledge and Skills for employability and to succeed in national and international level competitive examinations.
ACEB05.22	Determination of shear strength of soil using direct shear test and tri-axial test in various drainage conditions.
ACEB05.23	Recognize the behavior of soil in normal, over and under consolidated soil. Understand the concept of dilatancy in sandy soil.

SYLLABUS

MODULE-I	INTRODUCTION
Branches of geology useful to civil engineering, scope of geological studies in various civil engineering projects. Department dealing with this subject in India and their scope of work- GSI, Granite Dimension Stone Cell, NIRM. Mineralogy-Mineral, Origin and composition. Physical properties of minerals, susceptibility of minerals to alteration, basic of optical mineralogy, SEM, XRD., Rock forming minerals, megascopic identification of common primary & secondary minerals.	
MODULE-II	**PETROLOGY**
Rock forming processes. Specific gravity of rocks. Ternary diagram. Igneous petrology- Volcanic Phenomenon and different materials ejected by volcanoes. Types of volcanic eruption. Concept of Hot spring and Geysers. Characteristics of different types of magma. Division of rock on the basis of depth of formation, and their characteristics. Chemical and Mineralogical Composition. Texture and its types. Various forms of rocks. IUGS Classification of phaneritic and volcanic rock. Field Classification chart. Structures. Classification of Igneous rocks on the basis of Chemical composition. Detailed study of Acidic Igneous rocks like Granite, Rhyolite or Tuff, Felsite, Pegmatite, Hornfels. Metamorphic Aureole, Kaolinization. Landform as Tors. Engineering aspect to granite. Basic Igneous rocks Like Gabbro, Dolerite and Basalt. Engineering aspect to Basalt. Sedimentary petrology- mode of formation, Mineralogical Composition. Texture and its types, Structures, Gradation of Clastic rocks. Classification of sedimentary rocks and their characteristics. Detailed study of Conglomerate, Breccia, Sandstone, Mudstone and Shale, Limestone Metamorphic petrology Agents and types of metamorphism, metamorphic grades, Mineralogical composition, structures & textures in metamorphic rocks. Important Distinguishing features of rocks as Rock cleavage, Schistosity, Foliation. Classification. Detailed study of Gneiss, Schist, Slate with engineering consideration.	
MODULE-III	**PHYSICAL GEOLOGY AND ROCK MECHANICS**

Weathering. Erosion and Denudation. Factors affecting weathering and product of weathering. Engineering consideration. Superficial deposits and its geotechnical importance: Water fall and Gorges, River meandering, Alluvium, Glacial deposits, Laterite (engineering aspects), Desert Landform, Loess, Residual deposits of Clay with flints. Solifluction deposits, mudflows, Coastal deposits. Sub surface investigations in rocks and engineering characteristics or rocks masses; Structural geology of rocks. Classification of rocks, Field & laboratory tests on rocks, Stress deformation of rocks, Failure theories and sheer strength of rocks, Bearing capacity of rocks.	
MODULE-IV	**GEOLOGICAL HAZARDS**
Rock Instability and Slope movement: Concept of sliding blocks. Different controlling factors. Instability in vertical rock structures and measures to prevent collapse. Types of landslide. Prevention by surface drainage, slope reinforcement by Rock bolting and Rock anchoring, retaining wall, Slope treatment. Case study on black clay. Ground water: Factors controlling water bearing capacity of rock. Pervious & impervious rocks and ground water. Lowering of water table and Subsidence. Earthquake: Magnitude and intensity of earthquake. Seismic sea waves. Revelation from Seismic Records of structure of earth. Case Study on Elevation and Subsidence in Himalayan region in India. Seismic Zone in India.	
MODULE-V	**GEOLOGY OF DAM AND RESERVOIR SITE**
Required geological consideration for selecting dam and reservoir site. Failure of Reservoir. favorable&unfavorable conditions in different types of rocks in presence of various structural features, precautions to be taken to counteract unsuitable conditions, significance of discontinuities on the dam site and treatment giving to such structures.	
Text Books:	
1. Parbin Singh, "Engineering and General Geology, 8th Edition,2010, S K Kataria& Sons. 2. Text Book of Engineering Geology, N. ChennaKesavulu, 2nd Edition 2009, Macmillan Publishers India.	
Reference Books:	
1. J. C. Harvey, "Geology for Geotechnical Engineers", Cambridge University Press 1982.	

MODULE-I

INTRODUCTION ON ENGINEERING GEOLOGY

Definition:-

a. The science which deals with the physical structure and substance of the earth, their history, and the processes which act onthem.
b. The geological features of adistrict.
c. The geological features of a planetarybody.

The importance of geology in civil engineering may briefly asfollows:

a. Geology provides a systematic knowledge of construction material, its occurrence, composition, durability and other properties. Example of such construction materials is building stones, road metal, clay, limestones andlaterite.

b. The knowledge of the 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 soil conservation.

c. Ground water is the water which occurs in the subsurface rocks. The knowledge about its quantity and depth of occurrence is required in connection with water supply, irrigation, excavation and many other civil engineeringworks.

d. 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 drillingdata.

e. In tunneling, constructing roads, canals, docks and in determining the stability of cuts and slopes, the knowledge about the nature and structure of rocks is verynecessary.

f. Before staring a major engineering project at a place, a detailed geological report which is accompanied by geological maps and sections, is prepared. Such a report helps in planning and constructing theprojects.

Physical Geology:

a. Physical Geology uses the scientific method to explain natural aspects of the Earth - for example, how mountains form or why oil resources are concentrated in some rocks and not in others.
b. This chapter briefly explains how and why Earth's surface, and its interior, is constantly changing. It relates this constant change to the major geological topics of interaction of the atmosphere, water androck.

Petrology:-

a. Petrology is the branch of geology that studies the origin, composition, distribution and structure ofrocks.

(from the Greek language : petra-"rock" and logos- "study")

b. "Lithology" was once approximately synonymous with petrography, but in current usage, lithology focuses on macroscopic hand-sample or outcrop-scale description of rocks while petrography is the specialty that deals with microscopicdetails.

Branches:

There are three branches of petrology, corresponding to the three types of rocks:

a. Igneous, metamorphic, andsedimentary.

1. Igneous petrology focuses on the composition and texture of igneous rocks (rocks such as granite or basalt which have crystallized from Molten rock ormagma).
   Igneous rocks include volcanic and plutonic rocks.

2. Sedimentary petrology focuses on thecomposition and texture of sedimentary rocks (rocks such as sandstone,shale.

3. Metamorphic petrology focuses on the composition and textureof metamorphic rocks such as slate, marble, gneiss, or schist which started out as sedimentary or igneous rocks but which have undergone chemical, mineralogical or textural changes due to extremes of pressure, temperature orboth).

4. Metamorphic rocks arise from the transformation of existing rock types, in a process called metamorphism, which means "change in form". The original rock (protolith) is subjected to heat (temperatures greater than 150 to 200 °C) causing profound physical and/or chemical change.

Structural geology:

a. Structuralgeology is the study of the three-dimensional distribution of rock units with respect to their deformationalhistories.

b. The primary goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately, to understand the stress field that resulted in the observed strain andgeometries.

Weathering of Rocks:

a. Weathering breaks down and loosens the surface minerals of rock so they can be transported away by agents of erosion such as water, wind and ice.

b. There are two types of weathering: mechanical andchemical.

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

2. The second classification, chemical weathering involves the direct effect of atmospheric chemicals or biologically produced chemicals also known as biological weathering in the breakdown of rocks, soils andminerals.

Introduction:

- A mineral is a naturally occurring substance that is solid and inorganic represent able by a chemical formula, and has an ordered atomicstructure.

- Minerals are broadly groupedinto

  a) The rock forming mineralsand

  b) Ore-formingminerals

  In civil engineering practice, it is important to have knowledge of the important rock- forming types.

  The ore-forming minerals are to be understood in detail by the mining, Metallurgical and Mineral Engineering professionals.

- The study of minerals is calledmineralogy.

- There are over 4,900 known mineral species; over 4,660 of these have been approved by theInternational Mineralogical Association(IMA).

- The silicate minerals compose over 90% of the Earth'scrust.

- Minerals are distinguished by various chemical and physicalproperties.

Formation of minerals:

- Minerals are crystalline solid substances, meaning the atoms making up a mineral are arranged in an ordered, three-dimensional,structure.

- The distances and angles between an individual atom and the neighbors it is bonded to are constant.

- The process of mineral formation is known as crystallization. In order for a mineral to crystallize, ions from the nearby environment must be broughttogether.

A second process of mineral formation occurs during cooling of a melt.

- When crystallization of this type takes place in water, we call itfreezing.

- Through a very similar mechanism, molten rock-forming liquids, known as magmas and lavas, cool and crystallize to form minerals and thusrocks.

Study of minerals:

- **Mineralogy** is a subject of geology specializing in the scientific study of chemistry, crystal structure, and physical (including optical) properties ofminerals.

- Specific studies within mineralogy include the processes of mineral origin and formation, classification of minerals, their geographical distribution, as well as theirutilization.

- As of 2004 there are over 4,000 species of minerals recognized by the IMA. Of these, perhaps 150 can be called "common," another 50 are "occasional," and the rest are "rare" to "extremely rare."

Physical properties:

- The physical characteristics of minerals include traits which are used to identify and describe mineral species. These traits include color, streak, luster, density, hardness, cleavage, fracture, tenacity, andcrystal

- Color .Cleavage
- Streak .Fracture
- Luster .Tenacity
- Density .Habit
- Hardness

MODULE-II

PETROLOGY

Definition of rock:

a. In geology, **rock** is a naturally occurring solid aggregate of one or more minerals or mineraloids.
b. For example, the common rock granite is a combinationof

    I. the quartz, feldspar and biotite minerals. The Earth's outer solid layer, the lithosphere, is made ofrock.

c. Rocks have been used by mankind throughout history. From the Stone Age, rocks have been used for tools. The minerals and metals found in rocks have been essential to humancivilization.
d. Three major groups of rocks are defined: Igneous, Sedimentary, and Metamorphic. The scientific study of rocks is called**petrology**.

Crystallization:

a. **Crystallization** is also a chemical solid–liquid separation technique, in which mass transfer of a solute from the liquid solution to a pure solid crystalline phaseoccurs.
b. In chemical engineering **crystallization** occurs in acrystallizer.

Dykes and sills:

- Dyke" and "sill" are geological terms used to describe an intrusion; usually a mass of igneous or volcanic rocks that forcibly entered, penetrated, and embedded into layers of another rock or land form. Dykes and sills areoften.

A **dike** or **dyke** in geological usage is a sheet of rock that formed in a fracture in a pre-existing rockbody.

- However, when the new rock forms within and parallel to the bedding of a layers rock, it is called a**sill**.
- It is a type of tabular or sheet intrusion, that either cuts across layers in a planar wall rock structures, or into a layer or unlayered mass ofrock.

Structure and texture of igneous rocks:

- The texture of igneous rocks depends on the composition of the magma and the conditions surrounding the magma'scooling.
- The textures are different in intrusive, vein, and extrusive rocks. Intrusive rocks are characterizedby

  aholocrystalline texture, in which all the rock material is crystallized.

- Also depends on the shape of the crystals of the componentminerals.

Structure and texture of Sedimenatry rocks:

- The relationship between rock structure and texture and rock genesis is more pronounced insedimentary rocks than in igneousrocks.
- Clastic rocks consist of detrital (clastic) grains of various sizes andshapes.
- The grains, which canbe angular, subrounded, or rounded, sometimes liefreely without attachment.
- The structure of clastic rock, which depends on the mutual arrangement of the grains, can be random, laminar, or fluidal. With a random structure, the particles do not have an ordered arrangement.

Properties of rocks and Minerals:

Physical Properties of Calcite	
Chemical Classification	carbonate
Color	usually white but also colorless, gray, red, green, blue, yellow, brown, orange
Streak	white
Luster	vitreous
Diaphaneity	transparent to translucent
Cleavage	perfect, rhombohedral, three directions
Mohs Hardness	3
Specific Gravity	2.7
Diagnostic Properties	rhombohedral cleavage, powdered form effervesces weakly in dilute HCl, curved crystal faces and frequent twinning
Chemical	

Composition	$CaCO_3$
Crystal System	hexagonal
Uses	acid neutralization, a low hardness abrasive, soil conditioner, heated for the production of lime

Physical Properties of Hematite	
Color	black to steel-gray to silver; red to reddish brown to black
Streak	red to reddish brown
Luster	metallic, submetallic, earthy
Diaphaneity	Opaque
Cleavage	None
Mohs Hardness	5 to 6 ½
Specific Gravity	5.0 to 5.3
Diagnostic Properties	red streak, specific gravity
Chemical	

Composition	$Fe2O3$
Crystal System	trigonal
Uses	the most important ore of iron, pigment, heavy media separation, radiation shielding, ballast, polishing compounds, a minor gemstone
Chemical Classification	silicate
Color	Quartzoccursinvirtuallyeverycolor.Commoncolorsareclear,white,gray,purple, yellow, brown, black, pink, green,red.
Streak	colorless (harder than the streak plate)
Luster	vitreous
Diaphaneity	transparent to translucent
Cleavage	none - typically breaks with a conchoidal fracture

FIGURE -1

Physical Properties of Chromite	
Chemical Classification	oxide
Color	dark gray to black, rarely brownish black
Streak	dark brown
Luster	metallic to submetallic
Diaphaneity	opaque
Cleavage	none
Mohs Hardness	5.5 to 6
Specific Gravity	4.0 to 5.1 (variable)
Diagnostic Properties	luster, streak
Chemical Composition	FeCr2O4 with magnesium substituting for iron in significant amounts
Crystal System	isometric
Uses	an ore of chromium

Physical Properties of Fluorite	
Chemical Classification	halide
Color	typically purple, green and yellow. Also colorless, blue, red and black.
Streak	white
Luster	vitreous
Diaphaneity	transparent to translucent
Cleavage	four directions of perfect cleavage
Mohs Hardness	4

Specific Gravity	3.2
Diagnostic Properties	cleavage, hardness, specific gravity, color
Chemical Composition	CaF_2
Crystal System	isometric
Uses	Numerous uses in the metallurgical, ceramics and chemical industries. A source of fluorine, hydrofluoric acid, metallurgical flux. High clarity pieces are used to make lenses for microscopes, telescopes and cameras.

Physical Properties of Pyrite	
Chemical Classification	sulfide
Color	brass yellow - often tarnished to dull brass
Streak	greenish black to brownish black
Luster	metallic
Diaphaneity	opaque
Cleavage	breaks with a conchoidal fracture
Mohs Hardness	6 to 6.5
Specific Gravity	4.9 to 5.2
Diagnostic Properties	color, hardness, brittle, greenish black streak
Chemical Composition	iron sulfide, FeS_2
Crystal System	isometric

Texture and structure of metamorphic rocks:

- The structures and textures of metamorphic rocks arise during the recrystallization in thesolid state of primary sedimentary and magmaticrocks.
- The recrystallization occurs under the action of lithostatic pressure, temperature.
- Which leads to an ordered arrangement of the mineralGrains?

FIGURE-2

DEFINITION:

- **Groundwater** (or **ground water**) is the water present beneath Earth's surface in soil pore spaces and in the fractures of rockformations.

- A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity ofwater.

- The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the watertable.

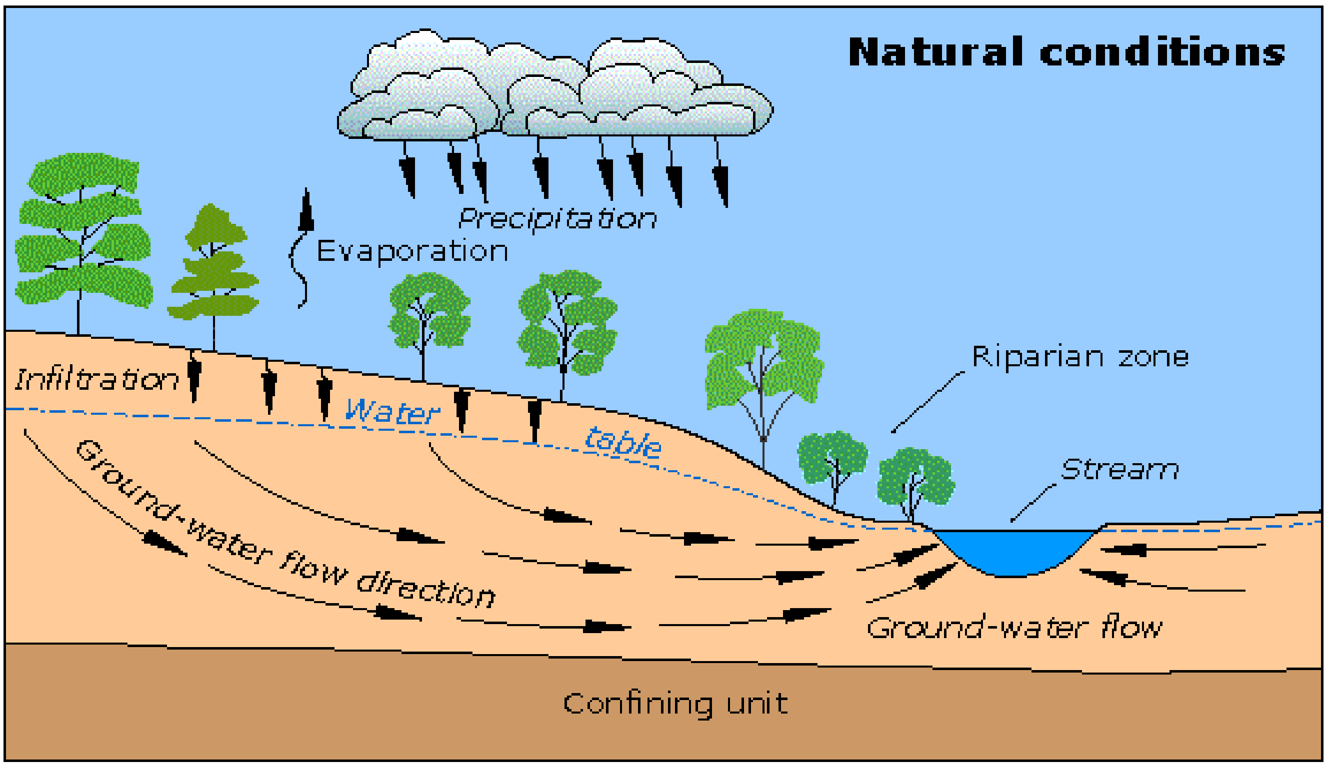

FIGURE-3

USES:

- Groundwater is alsooften withdrawn for agricultural, municipal, and industrial use by constructing and operating extractionwells.
- Thestudy of the distribution andmovement of groundwater is hydrogeology, also called **GROUNDWATER HYDROLOGY**.
- Groundwater is often cheaper, more convenientand less vulnerable to pollution than surface water.

SPRINGS:

- A **spring** is the result of an aquifer being filled to the point that the **water** overflows onto the land surface.

- They range in size from intermittent seeps, which flow only after much rain, to huge pools flowing hundreds of millions of gallonsdaily.

Types of springs:

- Seepage or filtration spring. The term seep refers to springs with small flow rates in which the source water has filtered through permeableearth.
- Fracture springs, discharge from faults, joints, or fissures in the earth, in which springs have followed a natural course of voids or weaknesses in thebedrock.

CONE OF DEPRESSION:

- A **cone of depression** occurs in from a an aquifer when groundwater is pumpedaquifer well. In an unconfined depression of the (water table), this is an actual water levels.
- In confined aquifers (artesian), the cone of depression is a reduction in the pressure head surrounding the pumpedwell.

DIFFERENCE:

- The size and shape (slope) of the cone of depression depends on many factors. The pumping rate in the well will affect the size of thecone.
- Also, the type of aquifer material, such as whether the aquifer is sand, silt, fractured rocks etc., also will affect how far the coneextends.
- The amount of water in storage and the thickness of the aquifer also will determine the size and shape of the cone of depression.
- As a well is pumped, the cone of depression will extend out and will continue to expand in a radial fashion until a point of equilibriumoccurs.
- This usually is when the amount of water released from storage equals the rate of pumping. This also can occur when recharge to the aquifer equals the amount of water beingpumped.

2.Unconfinedaquifer

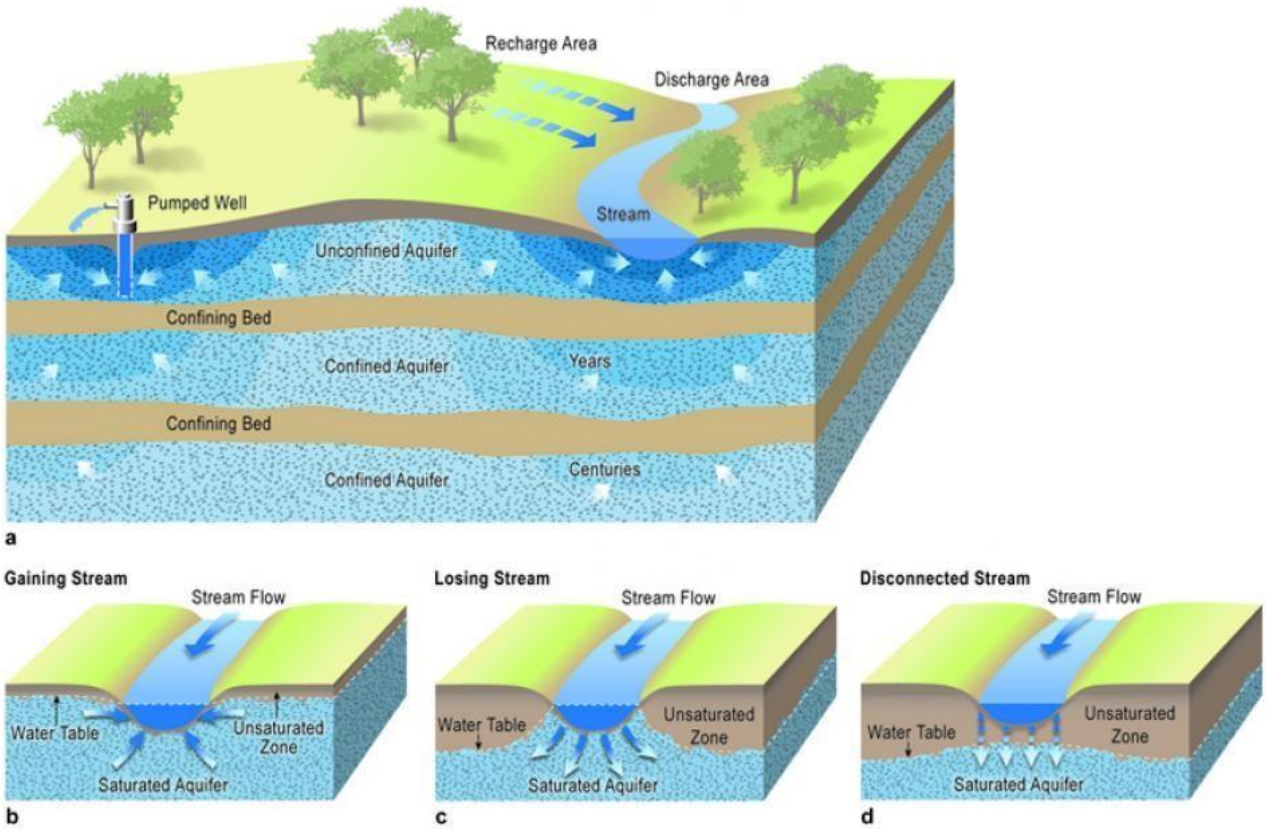

FIGURE-5

- An **aquifer** is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a waterwell.
- The study of water flow in **aquifers** and the characterization of **aquifers** is calledhydrogeology.
- What is confining layer(aquitard)?
- Geological material through which significant quantities of water can notmove, located below unconfined aquifers, above and below confined aquifers. Also known as a confiningbed.

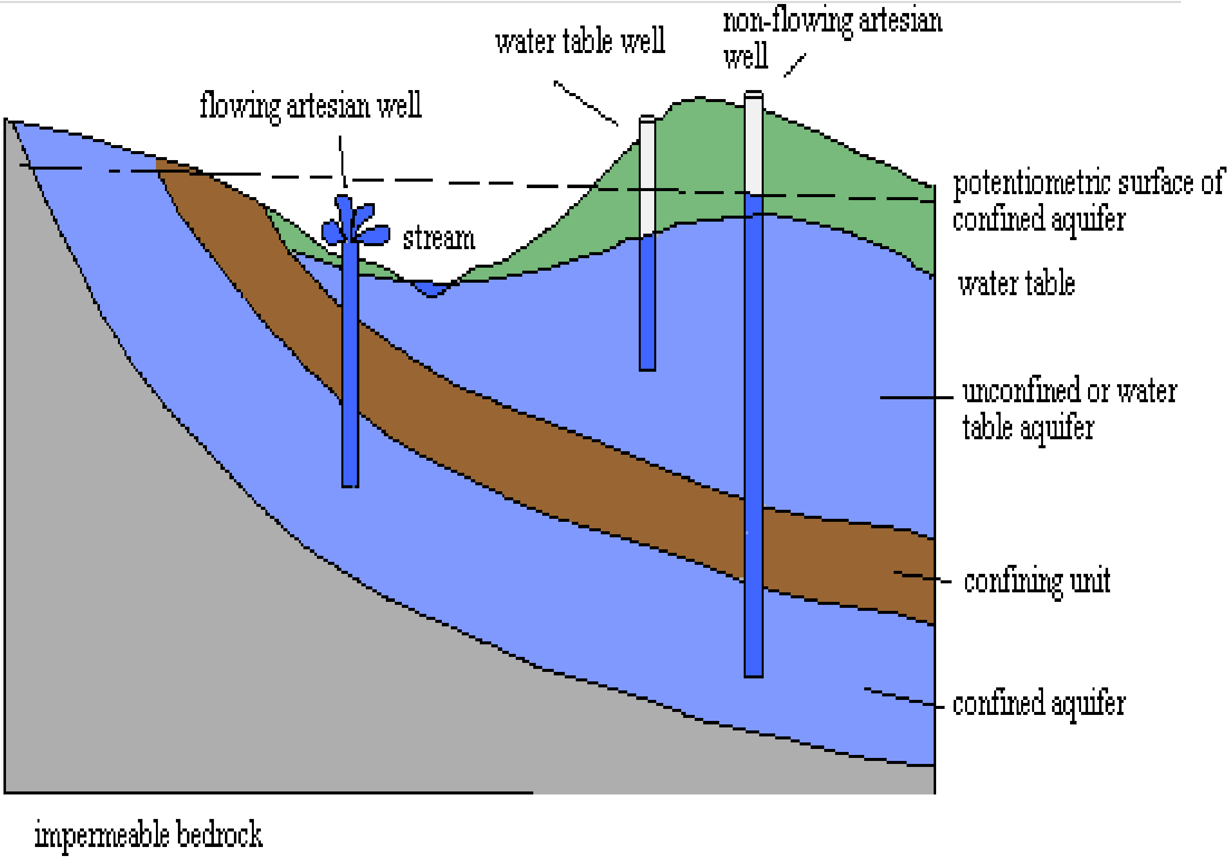

FIGURE-6

Confined aquifer(artesian) :-

- Confined aquifers are those in which an impermeable dirt/rock layer exists that preventswater from seeping into the aquifer from the ground surface located directlyabove.

Unconfined aquifer (water table aquifer):-

- **Unconfined aquifers** are those into which water seeps from the ground surface directly abovethe **aquifer**.

Unconfined aquifers:

- Natural recharge of the unconfined aquifers is mainly due to the downward seepage (or percolation) through the unsaturated zone of the excess water over passing the field capacity of the soil. Recharge can also occur through upward seepage (leakage) from underlyingaquifers.

Confined aquifers:

- A regional confined aquifer is directly recharged by precipitation in the area where the aquifer crops out, having the same characteristics as an unconfinedaquifer.

INFILTRATION GALLERIES:

- Infiltration galleries is aconduit,
- Built in permeable earth, for collecting groundwater.
- We have seen earlier that ground water travels towards lakes, rivers or streams. This water which is travelling can be intercepted by digging a trench or by constructing a tunnel with holes on sides at right angle to the direction offlow.
- These underground tunnel used for tapping underground water near rivers, lakes or streams are called "INFILTRATIONGALLERIES".
- These are also known as Horizontalwalls.

Example:-

- Infiltration galleries can be used to collect sub-surface flow from rivers. Water is taken to a collective well, or sump, and then pumped to a storagetank.
- Infiltration galleries vary in size, from a few meters feeding into spring box, to many kilometers forming an integral part of unban watersupply.

Construction of galleries:

- To ensure a continuous supply of water, infiltration galleries should be built in the end of dry season and should be at least one meter under the dry season watertable.
- Excavate a trench to at least 1 m below the watertable,
- Lay graded gravel on the base of thetrench.
- Lay the pipe or drain blocks on top of the gravel. Cover the top and sides with more graded gravel.
- Cap the gravel with an impermeable layer of clay to prevent surface water entering the gallery.

Stratigraphy is a branch of geology which studies rock layers (strata) and layering (stratification).

It is primarily used in the study of sedimentary and layered volcanic rocks.
Stratigraphy includes two related subfields:

1. Lithologic stratigraphy orlithostratigraphy,

2. Biologic stratigraphy orbiostratigraphy.

Application of stratigraphy was by William Smith in the 1790s and early 1800s. Smith, known as the "Father of English geology".

Created the first geologic map of England and first recognized the significance of strata or rock layering and the importance of fossil markers for correlating strata.

1) Lithostratigraphy:

Lithostratigraphy, or lithologic stratigraphy, provides the most obvious visible layering. It deals with the physical contrasts in lithology, or rock type. Such layers

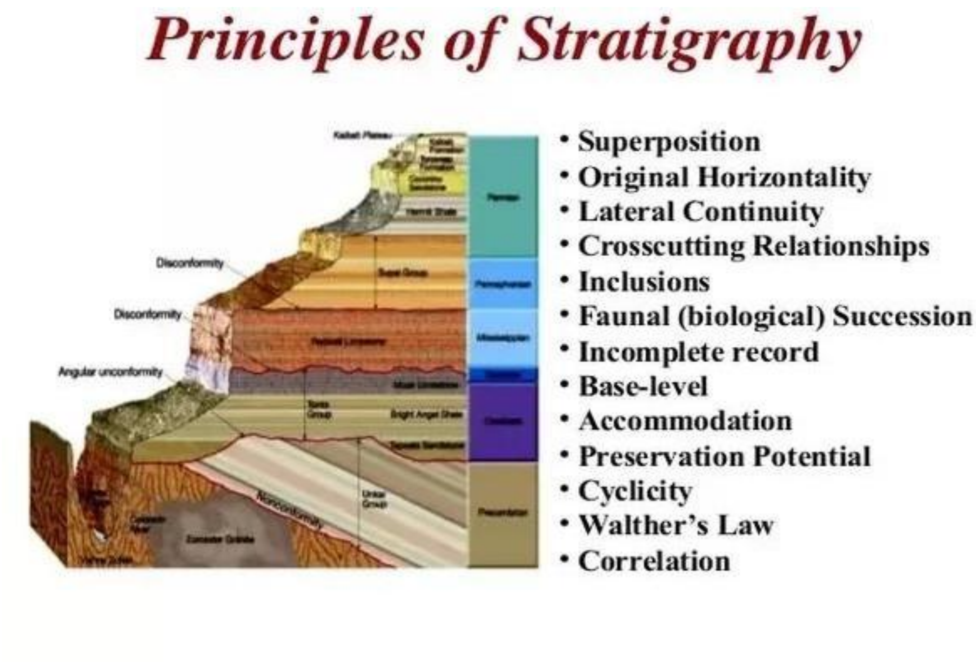

FIGURE-7.

Lithology:

The **lithology** of a rock unit is a description of its physical characteristics visible at outcrop, in hand or core samples or with low magnification microscopy, such as colour, texture, grain size, or composition.

2) Biostratigraphy:

Biostratigraphy is the branch of stratigraphy which focuses on correlating and assigning relative ages of rock strata by using the fossil assemblages contained within them.

Biologic stratigraphy was based on William Smith's principle of faunal succession, which predated, and was one of the first and most powerful lines of evidence for, biological evolution.

Out crop:

- An **outcrop** or **rocky outcrop** is a visible exposure of bedrock or ancient superficial deposits on the surface of theEarth.
- Outcrops do not cover everywhere on the surface of the earth, these are mostly covered with a thick and thin layer called alluvium or most common language assoil.
- However, in places where the overlying cover is removed through erosion or tectonic uplift, the rock may be exposed, or *cropout*.
- In fact in some areas the soil may spread over for thousands of square km and the bed block may not be visibleanywhere.

- As in the mountains and sub- mountains tracts, exposure of rocks may be easily seen forming sides of valley or caps ofhills.
- Hence outcrop is simply defined as "An exposure of solid rock on the surface of the rock".

Strike :

- Strike is a geographic direction given by the line of intersection of a horizontal plane with a bedding plane of a layer ofrock.
- It is measured in field with the help of acompass.

Dip:

- It is defined as the max angle of inclination with the horizontal. It is expressed both in terms of degree of inclination and direction ofinclination.
- The amount of dip is called angle of inclination, which a bedding plane makes with a horizontalplane.

True Dip:

- when the dip of the layer is measured in a direction that is essentially at right angles to the strike of the particular layer, then It is called TRUEDIP.

Apparent Dip:

- When the dip of the layer is measured in any other direction which is not a right angles to the strike direction is called APPARENTDIP.

DEFINITION:

- Folds are one of the most common geological structures found in rocks. When a set of horizontal layers are subjected to compressive forces, they bend either upwards or downwards.
- The bends noticed in rocks are calledfolds.
- Folds are described variously as wavy or arch or curvy types founds inrocks.
- In terms of nature too, folds may occur as single local bends or may occur repeatedly and intricately folded according to the tectonic history of theregion.

Types of FOLDS:

Based on different principles, the folds are variously classified on:

1. Symmetricalcharacter.
2. Upward or downwardbend.
3. Occurrence ofplunge.
4. Bedthickness
5. Behaviour of the foldpattern.

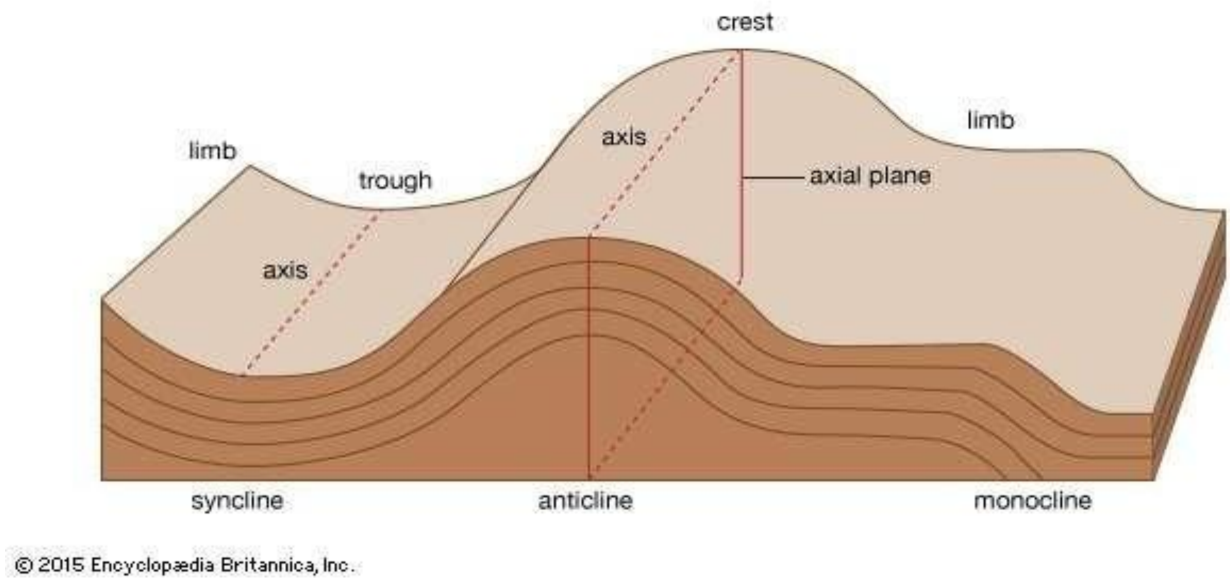

FIGURE-8

Anticline and Syncline:

- When beds are bent upwards, the resulting fold is called Anticline. This fold is convexupwards.
- (*Anti*= Opposite, *Cline*=Inclination)
- Syncline is just opposite to anticline on its nature, when the beds are bent downwards the resulting fold is calledSyncline.

Symmetrical and Asymmetrical folds:

- When the axial plane divides a fold into two equal halves in such a way that one half is the mirror image of another, then such fold is called Symmetricalfold.
- If the two halves are not mirror images, then the fold is called Asymmetrical fold. IF the compressive forces responsible for folding are not of the same magnitude, asymmetrical folds areformed.
- Open and ClosedFolds
- Similar and ParallelFolds

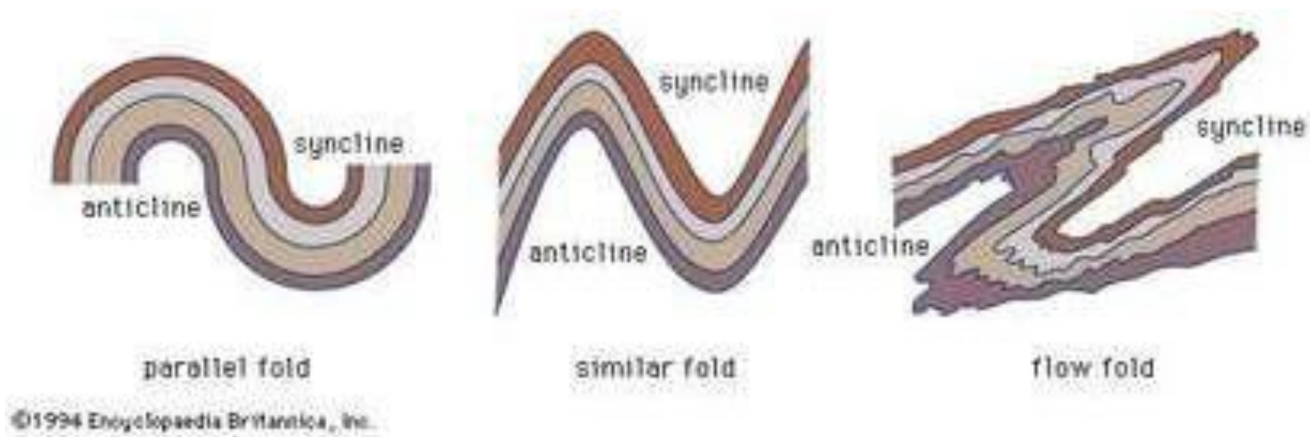

FIGURE-9

MODULE-III

STRUCTURAL GEOLOGY

STRATIGRAPHY:

Stratigraphy is a branch of geology which studies rock layers (strata) and layering (stratification).

It is primarily used in the study of sedimentary and layered volcanic rocks.
Stratigraphy includes two related subfields:

1. Lithologic stratigraphy orlithostratigraphy,

2. Biologic stratigraphy orbiostratigraphy.

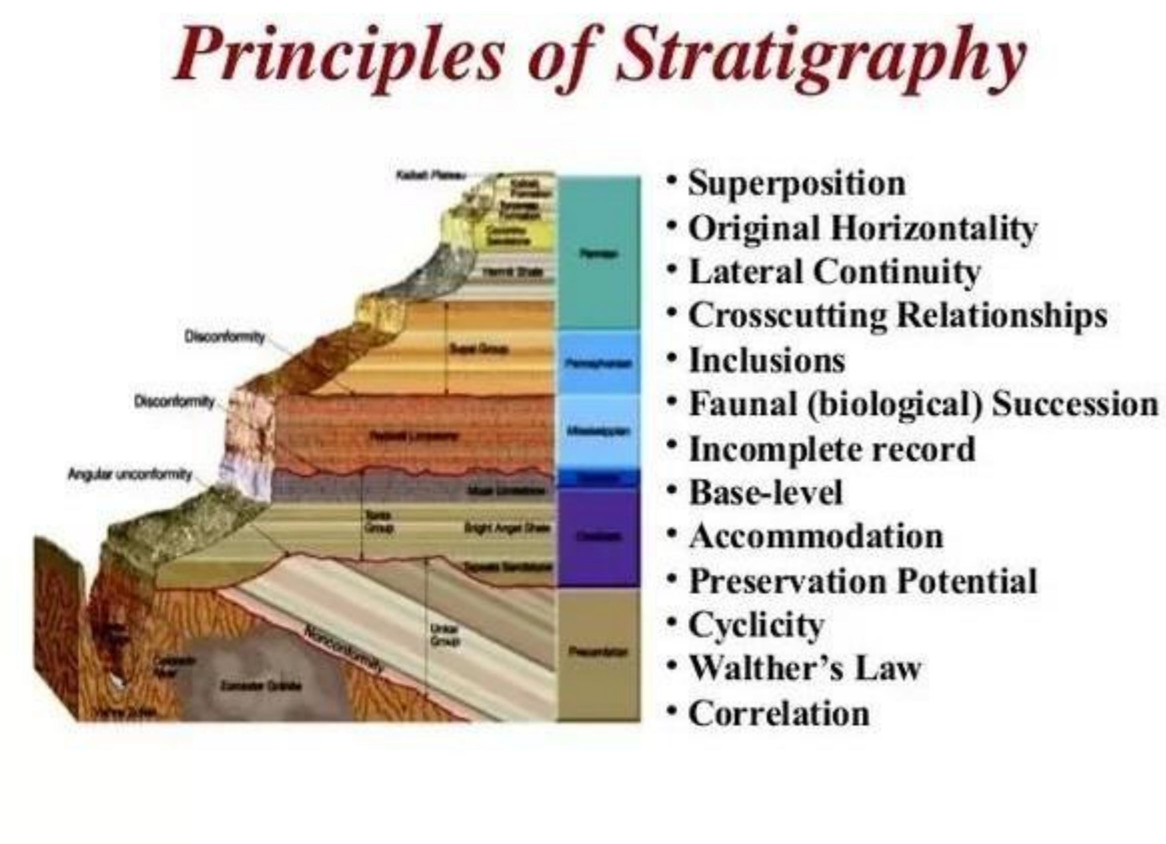

FIGURE-10

Application of stratigraphy was by William Smith in the 1790s and early 1800s.
Smith, known as the "Father of English geology“.

Created the first geologic map of England and first recognized the significance of strata or rock layering and the importance of fossil markers for correlating strata.

1) Lithostratigraphy:

Lithostratigraphy, or lithologic stratigraphy, provides the most obvious visible layering. It deals with the physical contrasts in lithology, or rock type. Such layers can occur both vertically– in layering or bedding of varying rocktypes.

Lithology:

The **lithology** of a rock unit is a description of its physical characteristics visible at outcrop, in hand or core samples or with low magnification microscopy, such as color, texture, grain size, or composition.

2) Biostratigraphy:

Biostratigraphy is the branch of stratigraphy which focuses on correlating and assigning relative ages of rock strata by using the fossil assemblages contained within them.

Biologic stratigraphy was based on William Smith's principle of faunal succession, which predated, and was one of the first and most powerful lines of evidence for, biological evolution.

Out crop:

- An **outcrop** or **rocky outcrop** is a visible exposure of bedrock or ancient superficial deposits on the surface of theEarth.

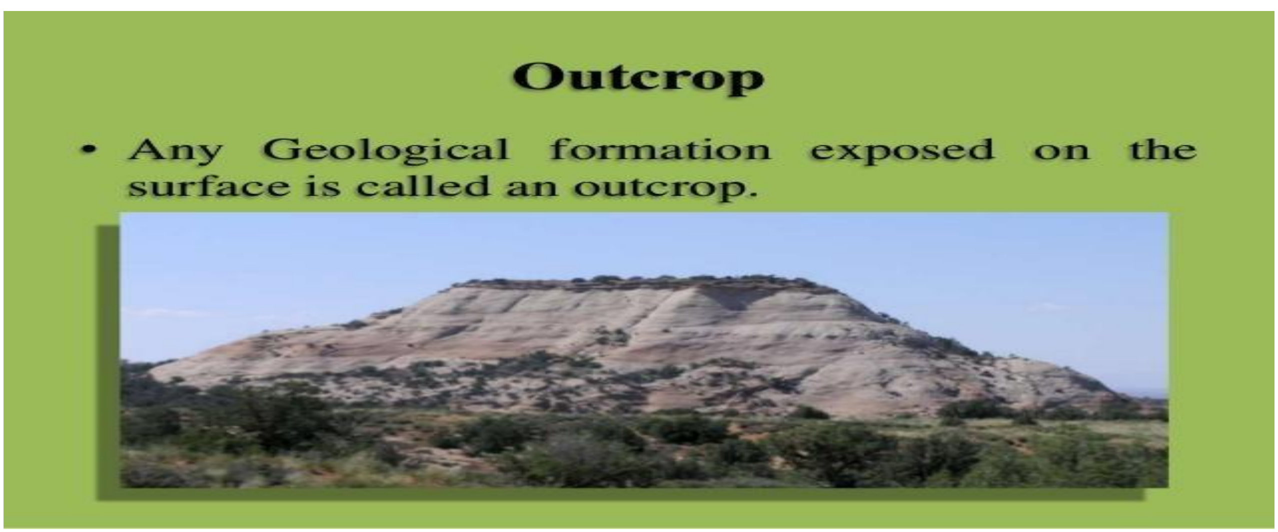

FIGURE-11

- Outcrops do not cover everywhere on the surface of the earth, these are mostly covered with a thick and thin layer called alluvium or most common language assoil.
- However, in places where the overlying cover is removed through erosion or tectonic uplift, the rock may be exposed, or *cropout*.
- In fact in some areas the soil may spread over for thousands of square km and the bed block may not be visibleanywhere.
- As in the mountains and sub- mountains tracts, exposure of rocks may be easily seen forming sides of valley or caps ofhills.
- Hence outcrop is simply defined as "An exposure of solid rock on the surface of the rock".

Strike :

- Strike is a geographic direction given by the line of intersection of a horizontal plane with a bedding plane of a layer ofrock.
- It is measured in field with the help of acompass.

Dip:

- It is defined as the max angle of inclination with the horizontal. It is expressed both in terms of degree of inclination and direction ofinclination.
- The amount of dip is called angle of inclination, which a bedding plane makes with a horizontalplane.

True Dip:

- when the dip of the layer is measured in a direction that is essentially at right angles to the strike of the particular layer, then It is called TRUEDIP.

Apparent Dip:

- When the dip of the layer is measured in any other direction which is not a right angles to the strike direction is called APPARENTDIP.

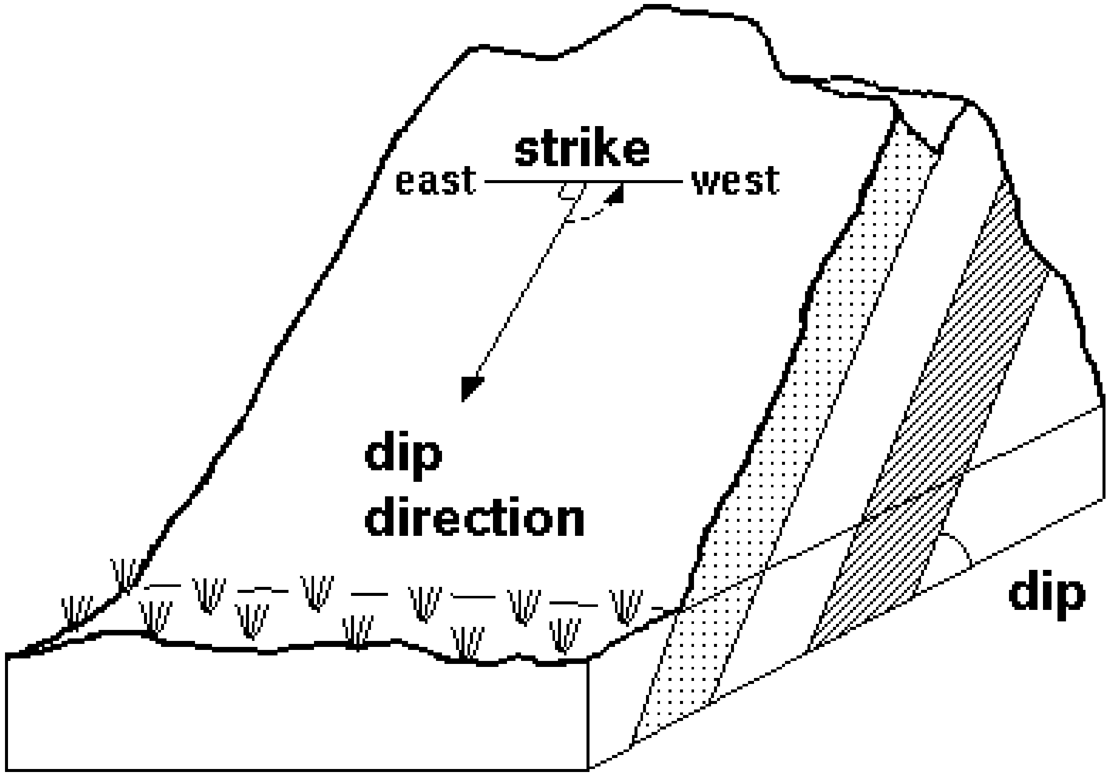

FIGURE-12

MODULE-IV
GEOLOGICAL HAZARDS

DEFINITION:

- A sudden violent shaking of the ground, typically causing great destruction, as a result of movements within the earth's crust or volcanicaction.

- A sudden release of energy in the earth's crust or upper mantle, usually caused by movement along a fault plane or by volcanic activity and resulting in the generation of seismic waves which can bedestructive.

Seismic Waves

- **Seismic waves** are **waves** of energy that travel through the Earth's layers, and are a result of an **earthquake**, explosion, or a volcano that gives out low-frequency acousticenergy.
- Seismic waves are studied by geophysicists called **seismologists**. Seismic wave fields are recorded by a seismometer, hydrophone (in water), or accelerometer.
- The propagation velocity of the waves depends on density and elasticity of themedium.
- Velocity tends to increase with depth and ranges from approximately 2 to 8 km/s in the Earth's crust, up to 13 km/s in the deepmantle.

CLASSIFICATION AND CAUSES OF EARTHQUAKE:

Based on depth of their origin, earthquake is described as shallow or intermediate or Deep.

- Earthquake with a focus depth less than 60km are called shallowearthquake.
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- The **Non Tectonic earthquake** on the other hand, is generally due to external or surfacial causes. This type of earthquake is very frequent, but minor in intensity and generaly not destructive innature.

Types:

Among the many types of seismic waves, one can make a broad distinction between *body waves* and *surfacewaves*.

- Body waves travel through the interior of theEarth.
- Surface waves travel across the surface. Surface waves decay more slowly with distance than do body waves, which travel in threedimensions.

Includes ***Primary*** and ***Secondary*** waves:

Primary waves (P-wave):

- Primary waves are compressional waves that are longitudinal in nature. P waves are pressure waves that travel faster than other waves through the earth to arrive at seismograph stations first, hence the name"Primary".

- These waves can travel through any type of material, including fluids, and can travel at nearly twice the speed of S waves. In air, they take the form of sound waves, hence they travel at the speed of sound. Typical speeds are 330 m/s in air, 1450 m/s in water and about 5000 m/s in granite.

Secondary waves(S-Waves):

- Secondary waves (S-waves) are shear waves that are transverse in nature. Following an earthquake event, S-waves arrive at seismograph stations after the faster-movingP-waves.
- S-waves can travel only through solids, as fluids (liquids and gases) do not support shear stresses. S-waves are slower than P-waves, and speeds are typically around 60% of that of P-waves in any givenmaterial.

SEISMIC BELTS AND SHIELD AREAS:

- Seismic belts are those places where earthquakes occur frequently. Shield areas are those places where earthquakes occur either rarely or verymildly.
- Occurrence of an earthquake in a place is an indication of underground instabilitythere.
- Statistics have revealed that nearly 50% of earthquakes have occurred along mountain ridges and 40% of earthquakes along steepcoasts.
- The study of recorded earthquakes shows that they take place on land most frequently along two well-defined seismicbelts.

1. *Circum Pacific Belt* which accounts for 68% of earthquakeoccurrence.
2. *Mediterranean belt* accounts 21% of earthquake which extends east-west from Portugal, Himalayas and Burma with a branch through Tibet andChina.

RICHETER SCALE:

- The **Richter magnitude scale** (also **Richter scale**) assigns a magnitude number to quantify the energy released by anearthquake.
- The Richter scale, developed in the 1930s, is a base-10 logarithmic scale, which defines magnitude as the logarithm of the ratio of the amplitude of the seismic waves to an arbitrary, minoramplitude.
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- An Earthquake of magnitude 5 may cause damage within radius of 8km, but that of magnitude 7 may cause damage in a radius of 80km, and that of 8 over a radius of250km.

CONSTRUCTION OF BUILDINGS IN SEISMIC AREAS-

PRECAUTIONARY MEASURES:

- Buildings should be Founded on hard bedrock only and never on loose soils or Fractured rocks, this is because lose ground settles due to earthquakevibrations.
- Buildings situated in cuttings on hill slides, near sheet slopes always suffer more when an earthquakeoccurs.
- For large Buildings, raft types of foundations are desirable. Square foundations are morestable.
- Different parts of a building should be well tied together so that the whole structure behaves like a single unit to theVibrations.
- Only rich cement mortar and reinforced concrete should beused.
- Buildings with irregular shapes with wings, Verandas, Porches and all structures should beavoided.
- Buildings should have RCC roofs and they should be designed not to yield to lateralstress.
- Resonance is the important factor, If the period of vibration of a structure is the same as that of the foundation rock it will collapse because of the resonanceeffect.

CIVIL ENGINEERING CONSIDERATIONS IN SEISMIC AREAS:

- Seismic areas are the places which experience earthquakesfrequently.
- Therefore constructions in seismic and a seismic areas differ in terms of theirdesign.
- So a civil engineer should only think of making his constructions immune toearthquakes. It is possible to find the difficulties by predicting some crucialfactors:

a. The exact place of earthquakeoccurrence.
b. The duration of theearthquake.
c. The direction of movement of the ground at the time ofearthquake.

BASICS OF A DAM:

a. In a way ,the success of dam is not only related to its own safety and stability but also depends on the success of associatedreservoirs.
b. If in a dam construction the dam stands firmly and the reservoir leaks , then the dam is to be treated as a failure because the purpose for which it has been constructed has not beenserved.
c. Therefore care is needed in construction of dam andreservoir.

The important geological considerations in the selection of dam site are asfollows:
The geological considerations are:

1. Narrow rivervalley
2. Occurrence of bed rock at a shallowdepth
3. Competent rocks to offer a stable foundations

BEDROCK AT SHALLOW DEPTH

a. To ensure the stability and safety of a dam, the dam has to rest on very strong and very stable rocks(i.ebedrock).
b. If the bedrock is available at shallow depth then the cost for the foundation of dam isless.
c. If in any case the bedrock is at greater depth thenthe cost is high as it needs lot of excavation and concretefilling.
d. Therefore to ensure the bedrock has actually reached bores should be drilled for 20’ or more through therocks.
e. Competent rocks for safefoundation.
f. If igneous rocks occur at the site selected for dam, then they will offer a safefoundation.
g. If sedimentary rocks occur like shale, poorly cemented sandstones and limestone then they shall naturally be undesirable to serve as foundationrocks.
h. In metamorphic rocks the rocks like marbles, like quartzites can bear a granulose structure and they are not porous and permeable, therefore metamorphic rocks are unsuitable for damsites.

DAMS AND RESERVOIRS :

ENVIRONMENTAL IMPACTS

DAMS

- A dam is a barrier that impounds water or undergroundstreams.
- Generate electricpower.
- Manage or prevent water flow into specific landregions.
- Evenly distributed betweenlocations.

BENEFITS OF DAMS

1. Powergeneration
2. Watersupply
3. Stabilize water flow /irrigation
4. Floodprevention
5. Landreclamation
6. Recreation and aquaticbeauty
7. Navigation

DISADVANTAGES OF DAMS

1. Seepage andevaporation
2. Groundwater tableeffects
3. Sedimentation behinddams
4. Erosion downstream by sediment-starvedwaters
5. Clogging of rivers by side-canyonfloods

RESERVOIR

The dams constructed across the rivers create artificial lakes which are known as reservoirs.

ENVIRONMENTAL IMPACTS OF DAMS

1. Biological, chemical and physical properties ofrivers
2. Blocks fishmigrations
3. Trapssediments
4. Changes in temperature, chemical composition, dissolved oxygen levels and the physical properties of a reservoir are often not suitable to the aquatic plants andanimals.
5. Reservoirs often host non-native and invasive species (e.g. snails, algae, predatoryfish)

6. Species in thearea
7. Waterquality
8. Fertility of theland
9. Problems ofpollution
10. Socialimpacts
11. SoilErosion
12. SpeciesExtinction
13. Spread of Disease

CHANGES TO EARTH'S ROTATION

Nasa geophysicist Dr. Benjamin Fong Chao found evidence that large dams cause changes to the earth's rotation, because of the shift of water weight from oceans to reservoirs. Because of the number of dams which have been built, the Earth's daily rotation has apparently sped up by eight-millionths of a second since the 1950s. Chao said it is the first time human activity has been shown to have a measurable effect on the Earth's motion.

EXAMPLES OF GEO HAZARDS

Geo hazard includes :

1. Earthquakes
2. Landslides
3. Tsunamis
4. Avalanches
5. Floods
6. Volcanoes

EARTHQUAKES

a. Earthquake is a sudden vibration that occurs on the surface of the earth with a release of large amount ofenergy.

b. The point of originating of earthquake is known as focus orhypocenter
c. The point on the earth's surface which lies vertically above the focus is known as epicentre.

Classification ofearthquakes

- Based on their mode of origin:
- Earthquakes occurring due to surface causes due to volcanic causes due to tectonic causes.

Based on depth of focus:

a. Shallow focusearthquakes(<55km)
b. Intermediate focusearthquakes(55-300km)
c. Deep focusearthquakes(300-650km)

CAUSES OF EARTHQUAKES

Earthquakes occur due to:

1. Tsunamis
2. Occurrence oflandslides
3. Avalanches
4. Volcaniceruptions
5. Man-madeexplosions
6. Meteorites

LANDSLIDES

- If a mass of earth or rock moves along a definite zone or surface the failure is called asLandslide.
- The foremost force responsible for the occurrence of landslide is due to the action of gravity.

CAUSES OF LANDSLIDES

1. Due to ground waterpressure
2. Due to melting of glaciers and heavyrainfall
3. Due to volcaniceruptions.
4. Due to heavy machinery equipments and trafficflow.

TSUNAMI

1. A Tsunami is a giant wave (or series of waves) created by an undersea earthquake, volcanic eruption andlandslide.

2. Tsunamis are often called as tidal waves but this is not accurate description because tides have little effect on giant tsunami waves.

VOLCANOES

A Volcano is a vent (hole) in the earth's crust through which lava, steam, ashes and etc., are expelled.

AVALANCHES

1. An Avalanche is any amount of snow sliding down amountainside.
2. Another term for avalanche is snowslide.

FLOODS

A Flood is an overflow of water that submerges the land which is usually dry.

EFFECTS OF GEOHAZARDS

1. A great loss of plant, human and animallife.

2. Destruction and damage to thebuildings.

3. Disruption of civic facilities like electricity, water,telephones.

4. Loss of communication such as road, rail, water and airtransportation.

5. Increase in infectious diseases due to the pollution created by thishazards.

WATER TIGHTNESS AND INFLUENCING FACTORS WATER-TIGHTNESS:

It is the process which is implemented after the effect of weathering in order to preventing the leakage of water through fractured rock and bed rocks which are located below the surface and covered with loose soil.

a. If the dam is constructed without proper water-tightening, the impounded water in the reservoir covers large area and percolates overit.

b. Due to higher level of the water in reservoir, hydrostatic pressure is formed, which makes the leakage of water more effective on sides and floor of thereservoir.

INFLUENCING FACTORS:

1. Buried riverchannels
2. Influence of rocktype
3. Influence of geologicalstructures
4. Scope of preventingleakage
5. Influence of water table.

GEOLOGICAL FACTORS EFFECTING WATERTIGHTNESS CONTENTS:

1. Water tightnessintroduction
2. Factors affecting watertightness
3. Factors affecting life of areservoir

WATERTIGHTNESS:

Water at the site of reservoir and dam tends to percolate to underground through fractures and voids, this leakage may results in decrease in water level at reservoir so a reservoir must be made with sufficient watertightness.

- Factors effecting watertightness
- Buried riverchannel
- Types ofrocks
- Geologicalstructures
- Watertable
- Presence of impermeable of permeable layer on thesurface

BURIED RIVER CHANNEL:

This is generally present as a glaciers below the surfaces it may not decrease the water tightness.

ROCK TYPE:

- Generally faults and fractures present in igneous and metamorphic rocks so rock used in construction of reservoir should have lessfractures

- Geological structures, water table and some other factors may not have much effect as above.

ELECTRICAL METHODS

INDEX :

- Electro resistivitymethod.
- Electromagneticmethod.
- Self-potentialmethod.

ELECTRO RESISTIVITY METHOD:

- The formation of electrical resistivites of sub-surface differ from one another if they are homogenous.
- These resistivitiesare studied by means of resistivitymethod.
- They are two types of resistivityinvestigations

1) Profiling
2) Sounding

ELECTRO MAGNETIC METHOD :

In the principles of electromagnetic field an alternating magnetic field is formed in ground with help of an appropriate source. The formed electromagnetic field induces eddy currents in conductive ore bodies in sub-surface and these produces secondary electromagnetic fields. The magnetic element of secondary electromagnetic field is examined at surface to find underground ore deposits.

Important electromagnetic methods are

1) Dip anglemethod
2) Enslinmethod
3) Sling rammethod
4) Sandburgmethod.
5) Turrammethod.

SELF POTENTIAL METHOD :

Self potential method is also known as spontaneous polarization method which is based on electrical potentials naturally present in earth. Pyrite ,Pyrhotieanssulphideores which indicates spontaneous polarization. Apart from these graphite produces strong SP method.

ADVANTAGES OF ELECTRO RESSISTIVITY METHODS :

- In the exploration of groundwater.
- Exploration ofpetroleum.
- Finding highly conductive bodies such as sulphide ore bodies andgraphite.

ADVANTAGES OF ELECTRO MAGNETIC METHOD :

- Finding oredeposits.
- Exploration ofsoil.
- Ground water studies where overburden is of highresistivity.

GROUND SUBSIDENCE

INTRODUCTION:

- Small scale verticalmovements
- Causing substantial economic losses and societaldisruption
- Human induced andnatural
- Occurring on time-scales of a fewdecades

SUBSIDENCE AND UPLIFT:

- Subsidence: The lowering of the land surface dueto
    - Creation of cavities in solid rock by mining, combustion of coal or dissolution of solublematerial
    - The removal of fluids (water or oil) from the pore spaces of unconsolidated or poorly consolidatedsediments
- Uplift: changed land conditions due to expansivesoils

SUBSIDENCE:

- Underground mining is the most widespread cause of subsidence by directremoval
- Removal causing changes in local or regional groundwater system either by natural or anthropogeniccauses

ADVANTAGE SOF SELF POTENTIAL METHOD:

- Exploration of economic mineraldeposits.

- Finding areas ofcorrosion.
- In bore holes ofinvestigation.

DAMS

Dam is a solid barrier constructed at a suitable location across a river valley to store flowing water and used for

- Hydropower
- Irrigation
- Water for domesticconsumption
- For drought and floodcontrol
- Other additional utilization is to developfisheries

TYPES OF DAMS

There are four types of dams. They are

- Archdam
- Gravitydam
- Buttressdam
- Earthdam

ARCH DAM:

- This type of dams are concrete dams which are curved or convex upstream in plan. It is dependent upon the arch action for itsstrength.
- Arch dam is thinner and requires less material for construction compared to other dams.
- Arch dams are built across narrow deep river gorges.

GRAVITY DAM

- Gravity dams are the dams which resist the horizontal thrust of water entirely by their ownweight
- they use their weight to hold back the water in thereservoir
- Made of earth or rock fill orconcrete

BUTTRESS DAM

- Buttress dams are dams in which the face is held up by a series ofsupports.
- Buttress dams can take many forms – the face may be flat or curved.
- Usually buttress dams are made of concrete and may be reinforced with steelbars.

EARTH DAMS

- Earth dams are trapezoidal inshape
- Earth dams are constructed where the foundation rocks are weak tosupport

- Earth dams are relatively smaller in height and broad at thebase
- They are mainly built with clay, sand and gravel. Hence they are also known as Earth fill dam or Rock filldam

DEFINITION:

- A sudden violent shaking of the ground, typically causing great destruction, as a result of movements within the earth's crust or volcanicaction.
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CONSTRUCTION OF BUILDINGS IN SEISMIC AREAS-

PRECAUTIONARY MEASURES:

- Buildings should be Founded on hard bedrock only and never on loose soils or Fractured rocks, this is because lose ground settles due to earthquakevibrations.
- Buildings situated in cuttings on hill slides, near sheet slopes always suffer more when an earthquakeoccurs.
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DAMS AND RESERVOIRS AND THEIR

ENVIRONMENTAL IMPACTS

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6. Recreation and aquaticbeauty
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DISADVANTAGES OF DAMS:

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II. Groundwater tableeffects
III. Sedimentation behinddams
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7. Waterquality
8. Fertility of theland
9. Problems ofpollution
10. Socialimpacts
11. SoilErosion
12. SpeciesExtinction
13. Spread of Disease

EXAMPLES OF GEO HAZARDS

Geo hazard includes :

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8. Landslides
9. Tsunamis
10. Avalanches
11. Floods
12. Volcanoes

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- The foremost force responsible for the occurrence of landslide is due to the action of gravity.

CAUSES OF LANDSLIDES

Natural causes

a. Due to ground waterpressure
b. Due to melting of glaciers and heavyrainfall
c. Due to volcaniceruptions.

WATER TIGHTNESS AND INFLUENCING FACTORS
WATER- TIGHTNESS:

a. It is the process which is implemented after the effect of weathering in order to preventing the leakage of water through fractured rock and bed rocks which are located below the surface andcovered with loose soil.
b. If the dam is constructed without proper water-tightening, the impounded water in the reservoir covers large area and percolates overit.

c. Due to higher level of the water in reservoir, hydrostatic pressure is formed, which makes the leakage of water more effective on sides and floor of thereservoir.

GEOLOGICAL FACTORS EFFECTING WATERTIGHTNESS CONTENTS:

1. Water tightnessintroduction
2. Factors affecting watertightness
3. Factors affecting life of areservoir

WATERTIGHTNESS:

Water at the site of reservoir and dam tends to percolate to underground through fractures and voids, this leakage may results in decrease in water level at reservoir so a reservoir must be made with sufficient watertightness.

- Factors effecting watertightness
- Buried riverchannel
- Types ofrocks
- Geologicalstructures
- Watertable
- Presence of impermeable of permeable layer on thesurface

BURIED RIVER CHANNEL:

This is generally present as a glaciers below the surfaces it may not decrease the water tightness.

ROCK TYPE:

- Generally faults and fractures present in igneous and metamorphic rocks so rock used in construction of reservoir should have lessfractures
- Geological structures, water table and some other factors may not have much effect as above.

SELF POTENTIAL METHOD :

Self potential method is also known as spontaneous polarization method which is based on electrical potentials naturally present in earth. Pyrite ,Pyrhotieanssulphideores which indicates spontaneous polarization. Apart from these graphite produces strong SP method.

ADVANTAGES OF ELECTRO RESSISTIVITY METHODS :

- In the exploration of groundwater.
- Exploration ofpetroleum.
- Finding highly conductive bodies such as sulphide ore bodies andgraphite.

ADVANTAGES OF ELECTRO MAGNETIC METHOD :

- Finding oredeposits.
- Exploration ofsoil.
- Ground water studies where overburden is of highresistivity.

GROUND SUBSIDENCE

INTRODUCTION:

- Small scale verticalmovements
- Causing substantial economic losses and societaldisruption
- Human induced andnatural
- Occurring on time-scales of a fewdecades

SUBSIDENCE AND UPLIFT:

- Subsidence: The lowering of the land surface dueto
  - Creation of cavities in solid rock by mining, combustion of coal or dissolution of solublematerial
  - The removal of fluids (water or oil) from the pore spaces of unconsolidated or poorly consolidatedsediments
- Uplift: changed land conditions due to expansivesoils

SUBSIDENCE:

- Underground mining is the most widespread cause of subsidence by directremoval
- Removal causing changes in local or regional groundwater system either by natural or anthropogeniccauses

ADVANTAGE SOF SELF POTENTIAL METHOD:

- Exploration of economic mineraldeposits.
- Finding areas ofcorrosion.
- In bore holes ofinvestigation.

FOLDS DEFINITION:

- Folds are one of the most common geological structures found in rocks. When a set of horizontal layers are subjected to compressive forces, they bend either upwards or downwards.
- The bends noticed in rocks are calledfolds.
- Folds are described variously as wavy or arch or curvy types founds in rocks.
- In terms of nature too, folds may occur as single local bends or may occur repeatedly and intricately folded according to the tectonic history of theregion.

Types of FOLDS:

Based on different principles, the folds are variously classified on:

1. Symmetricalcharacter.
2. Upward or downwardbend.
3. Occurrence ofplunge.
4. Bedthickness
5. Behaviour of the foldpattern.

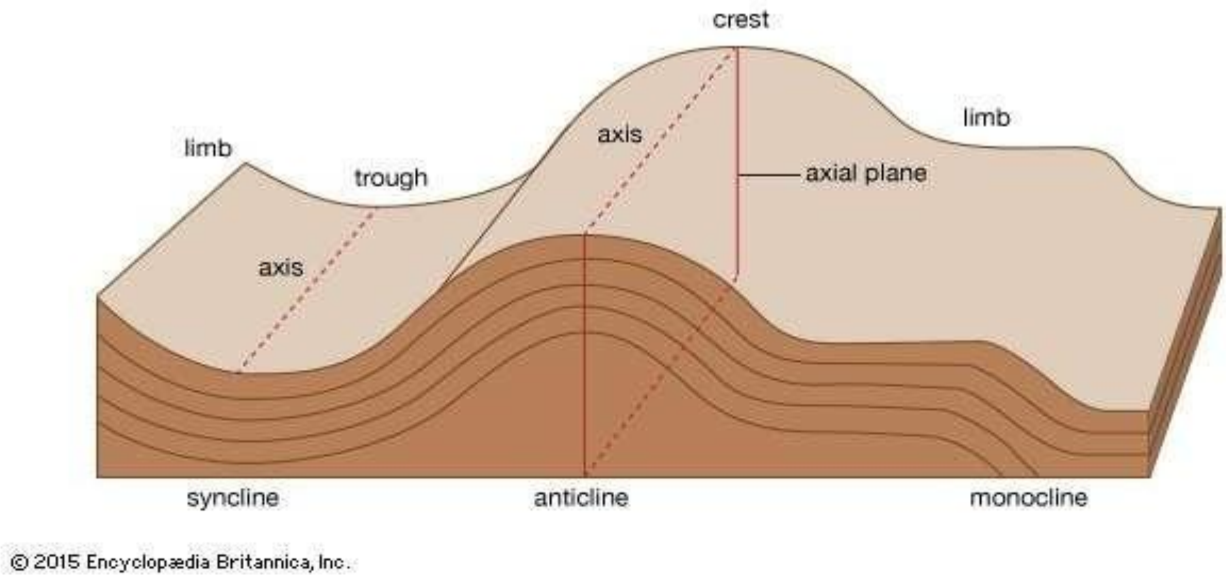

FIGURE-13

Anticline and Syncline:

- When beds are bent upwards, the resulting fold is called Anticline. This fold is convexupwards.
  (*Anti*= Opposite, *Cline*=Inclination)
- Syncline is just opposite to anticline on its nature, when the beds are bent downwards the resulting fold is calledSyncline.

Symmetrical and Asymmetrical folds:

- When the axial plane divides a fold into two equal halves in such a way that one half is the mirror image of another, then such fold is called Symmetricalfold.
- If the two halves are not mirror images, then the fold is called Asymmetrical fold. IF the compressive forces responsible for folding are not of the same magnitude, asymmetrical folds areformed.
- Open and ClosedFolds
- Similar and ParallelFolds

FIGURE-14

MODULE-V

GEOLOGY OF DAM AND RESERVOIR SITE

DEFINITION:

- A sudden violent shaking of the ground, typically causing great destruction, as a result of movements within the earth's crust or volcanicaction.
- A sudden release of energy in the earth's crust or upper mantle, usually caused by movement along a fault plane or by volcanic activity and resulting in the generation of seismic waves which can bedestructive.

Seismic Waves

- **Seismic waves** are **waves** of energy that travel through the Earth's layers, and are a result of an **earthquake**, explosion, or a volcano that gives out low-frequency acousticenergy.
- Seismic waves are studied by geophysicists called **seismologists**. Seismic wave fields are recorded by a seismometer, hydrophone (in water), or accelerometer.ncy acousticenergy.
- The propagation velocity of the waves depends on density and elasticity of themedium.
- Velocity tends to increase with depth and ranges from approximately 2 to 8 km/s in the Earth's crust, up to 13 km/s in the deepmantle.

CLASSIFICATION AND CAUSES OF EARTHQUAKE:

Based on depth of their origin, earthquake is described as shallow or intermediate or Deep.

- Earthquake with a focus depth less than 60km are called shallowearthquake.
- If the depth more than 60km but less than 300km, they are called Intermediate earthquake.
- Which have focus depth more than 300km, they are called Deepearthquake. Based on the causes responsible for their occurrence, earthquakes are described as Tectonic or non Tectonic.
- **Tectonic earthquake** are exclusively due to internal causes, due to disturbances or adjustments of geological formations taking place in the earth's interior, they are less frequent, but more intensive and hence more destructive innature.
-
- The **Non Tectonic earthquake** on the other hand, is generally due to external or surfacial causes. This type of earthquake is very frequent, but minor in intensity and generaly not destructive innature.

BASICS OF A DAM:

A. In a way ,the success of dam is not only related to its own safety and stability but also depends on the success of associatedreservoirs.

B. If in a dam construction the dam stands firmly and the reservoir leaks , then the dam is to be treated as a failure because the purpose for which it has been constructed has not beenserved.

C. Therefore care is needed in construction of dam andreservoir.

The important geological considerations in the selection of dam site are as follows: The geological considerations are :

- Narrow river valley
- Occurrence of bed rock at a shallowdepth
- Competent rocks to offer a stablefoundations

BEDROCK AT SHALLOW DEPTH

a) To ensure the stability and safety of a dam, the dam has to rest on very strong and very stable rocks(i.ebedrock).
b) If the bedrock is available at shallow depth then the cost for the foundation of dam isless.
c) If in any case the bedrock is at greater depth then the cost is high as it needs lot of excavation and concretefilling.
d) Therefore to ensure the bedrock has actually reached bores should be drilled for 20’ or more through therocks.
e) Competent rocks for safefoundation.
f) If igneous rocks occur at the site selected for dam, then they will offer a safefoundation.
g) If sedimentary rocks occur like shale, poorly cemented sandstones and limestone then they shall naturally be undesirable to serve as foundationrocks.
h) In metamorphic rocks the rocks like marbles, like quartzites can bear a granulose structure and they are not porous and permeable, therefore metamorphic rocks are unsuitable for damsites.

DAMS AND RESERVOIRS AND THEIR

DAMS

- A dam is a barrier that impounds water or undergroundstreams.
- Generate electricpower.
- Manage or prevent water flow into specific landregions.
- Evenly distributed betweenlocations.

BENEFITS OF DAMS

1. Powergeneration
2. Watersupply
3. Stabilize water flow /irrigation
4. Floodprevention
5. Landreclamation
6. Recreation and aquaticbeauty
7. Navigation

DISADVANTAGES OF DAMS

1. Seepage andevaporation
2. Groundwater tableeffects
3. Sedimentation behinddams
4. Erosion downstream by sediment-starvedwaters
5. Clogging of rivers by side-canyonfloods

RESERVOIR

The dams constructed across the rivers create artificial lakes which are known as reservoirs.

ENVIRONMENTAL IMPACTS OF DAMS

1. Biological, chemical and physical properties ofrivers
2. Blocks fishmigrations
3. Trapssediments
4. Changes in temperature, chemical composition, dissolved oxygen levels and the physical properties of a reservoir are often not suitable to the aquatic plants andanimals.
5. Reservoirs often host non-native and invasive species (e.g. snails, algae, predatoryfish)
6. Species in thearea
7. Waterquality
8. Fertility of theland
9. Problems ofpollution
10. Socialimpacts
11. SoilErosion
12. SpeciesExtinction
13. Spread of Disease

Earthquakes occur due to:

- Tsunamis
- Occurrence oflandslides
- Avalanches
- Volcaniceruptions
- Man-madeexplosions
- Meteorites

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ELECTRICAL METHODS

- Electro resistivitymethod.
- Electromagneticmethod.
- Self potentialmethod.

ELECTRO RESISTIVITY METHOD:

- The formation of electrical resistivites of sub-surface differ from one another if they are homogenous.
- These resistivities are studied by means of resistivitymethod.
- They are two types of resistivityinvestigations

1) Profiling
2) Sounding

ELECTRO MAGNETIC METHOD :

In the principles of electromagnetic field an alternating magnetic field is formed in ground with help of an appropriate source. The formed electromagnetic field induces eddy currents in conductive ore bodies in sub-surface and these produces secondary electromagnetic fields. The magnetic element of secondary electromagnetic field is examined at surface to find underground ore deposits.

1) Important electromagnetic methods
2) Enslinmethod
3) Sling rammethod
4) Sandburgmethod.
5) Turrammethod.

SELF POTENTIAL METHOD :

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DAMS

Dam is a solid barrier constructed at a suitable location across a river valley to store flowing water and used for

- Hydropower
- Irrigation
- Water for domesticconsumption
- For drought and floodcontrol
- Other additional utilization is to developfisheries

TYPES OF DAMS

There are four types of dams. They are

- Archdam
- Gravitydam
- Buttressdam
- Earthdam

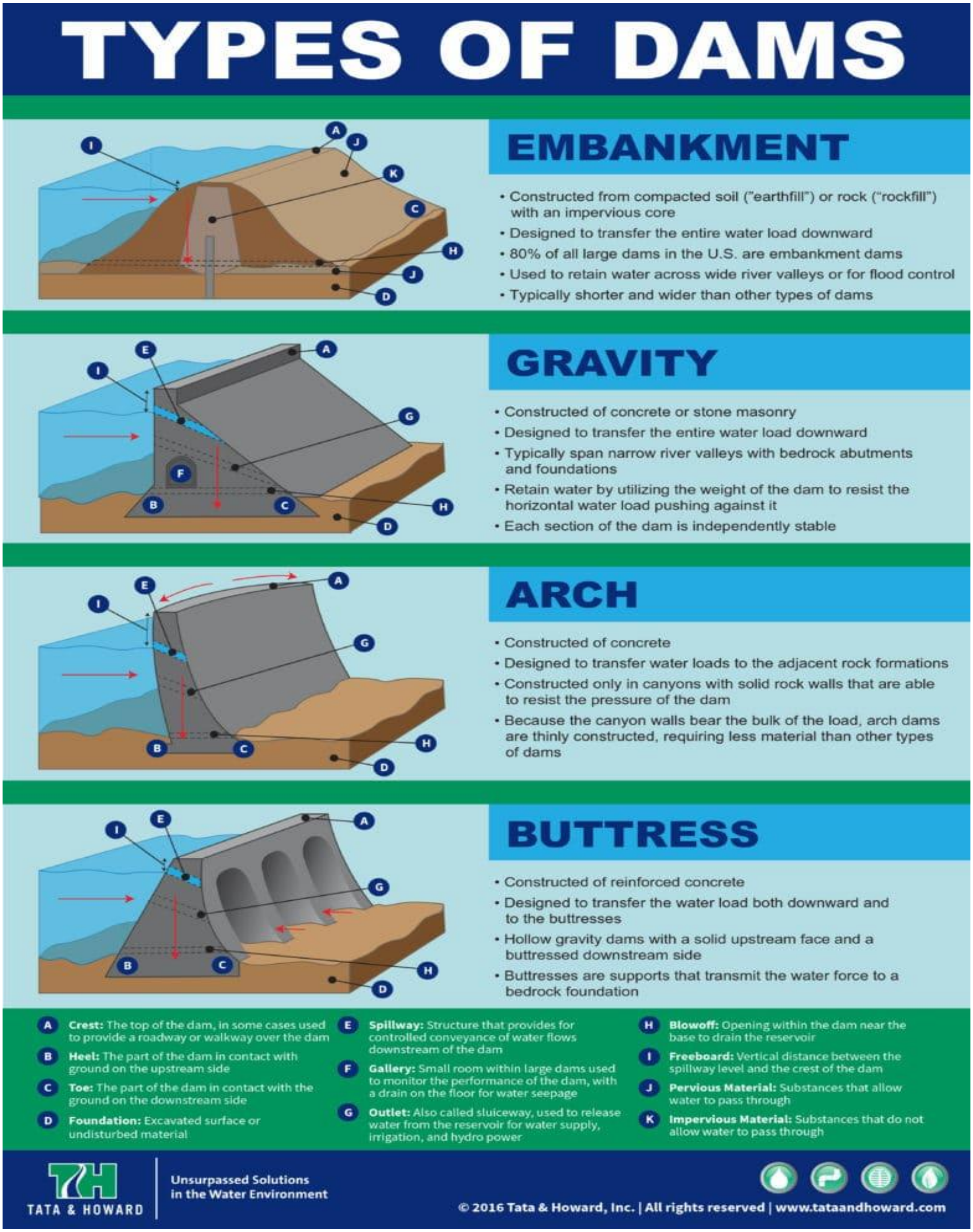
TYPES OF DAMS
EMBANKMENT
• Constructed from compacted soil ("earthfill") or rock ("rockfill") with an impervious core
• Designed to transfer the entire water load downward
• 80% of all large dams in the U.S. are embankment dams
• Used to retain water across wide river valleys or for flood control
• Typically shorter and wider than other types of dams
GRAVITY
• Constructed of concrete or stone masonry
• Designed to transfer the entire water load downward
• Typically span narrow river valleys with bedrock abutments and foundations
• Retain water by utilizing the weight of the dam to resist the horizontal water load pushing against it
• Each section of the dam is independently stable
ARCH
• Constructed of concrete
• Designed to transfer water loads to the adjacent rock formations
• Constructed only in canyons with solid rock walls that are able to resist the pressure of the dam
• Because the canyon walls bear the bulk of the load, arch dams are thinly constructed, requiring less material than other types of dams
BUTTRESS
• Constructed of reinforced concrete
• Designed to transfer the water load both downward and to the buttresses
• Hollow gravity dams with a solid upstream face and a buttressed downstream side
• Buttresses are supports that transmit the water force to a bedrock foundation
A Crest: The top of the dam, in some cases used to provide a roadway or walkway over the dam
B Heel: The part of the dam in contact with ground on the upstream side
C Toe: The part of the dam in contact with the ground on the downstream side
D Foundation: Excavated surface or undisturbed material
E Spillway: Structure that provides for controlled conveyance of water flows downstream of the dam
F Gallery: Small room within large dams used to monitor the performance of the dam, with a drain on the floor for water seepage
G Outlet: Also called sluiceway, used to release water from the reservoir for water supply, irrigation, and hydro power
H Blowoff: Opening within the dam near the base to drain the reservoir
I Freeboard: Vertical distance between the spillway level and the crest of the dam
J Pervious Material: Substances that allow water to pass through
K Impervious Material: Substances that do not allow water to pass through
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FIGURE-15

ARCH DAM:

- This type of dams are concrete dams which are curved or convex upstream in plan. It is dependent upon the arch action for itsstrength.
- Arch dam is thinner and requires less material for construction compared to otherdams.
- Arch dams are built across narrow deep river gorges.

GRAVITY DAM

- Gravity dams are the dams which resist the horizontal thrust of water entirely by their ownweight
- they use their weight to hold back the water in thereservoir
- Made of earth or rock fill orconcrete

BUTTRESS DAM

- Buttress dams are dams in which the face is held up by a series ofsupports.
- Buttress dams can take many forms – the face may be flat or curved.
- Usually buttress dams are made of concrete and may be reinforced with steelbars.

EARTH DAMS

- Earth dams are trapezoidal inshape
- Earth dams are constructed where the foundation rocks are weak tosupport
- Earth dams are relatively smaller in height and broad at thebase
- They are mainly built with clay, sand and gravel. Hence they are also known as Earth fill dam or Rock filldam
-

Secondary waves(S-Waves):

- Secondary waves (S-waves) are shear waves that are transverse in nature. Following an earthquake event, S-waves arrive at seismograph stations after the faster-movingP-waves.
- S-waves can travel only through solids, as fluids (liquids and gases) do not support shear stresses. S-waves are slower than P-waves, and speeds are typically around 60% of that of P- waves in any givenmaterial.

SEISMIC BELTS AND SHIELD AREAS:

- Seismic belts are those places where earthquakes occur frequently. Shield areas are those places where earthquakes occur either rarely or verymildly.
- Occurrence of an earthquake in a place is an indication of underground instabilitythere.
- Statistics have revealed that nearly 50% of earthquakes have occurred along mountain ridges and 40% of earthquakes along steepcoasts.

- The study of recorded earthquakes shows that they take place on land most frequently along two well-defined seismicbelts.
- *Circum Pacific Belt* which accounts for 68% of earthquakeoccurrence.
- *Mediterranean belt* accounts 21% of earthquake which extends east-west from Portugal, Himalayas and Burma with a branch through Tibet and China.

RICHETER SCALE:

- The **Richter magnitude scale** (also **Richter scale**) assigns a magnitude number to quantify the energy released by anearthquake.
- The Richter scale, developed in the 1930s, is a base-10 logarithmic scale, which defines magnitude as the logarithm of the ratio of the amplitude of the seismic waves to an arbitrary, minoramplitude.
- In 1935, the seismologists *Charles Francis Richter* and *Beno Gutenberg*, of the California Institute of Technology, developed the (future) Richter magnitude scale, specifically for measuring earthquakes in a given area ofstudy.
- The Richter scale was succeeded in the 1970s by the Moment Magnitude Scale (MMS). This is now the scale used by the United States Geological Survey to estimate magnitudes for all modern largeearthquakes.
- An Earthquake of magnitude 5 may cause damage within radius of 8km, but that of magnitude 7 may cause damage in a radius of 80km, and that of 8 over a radius of250km.

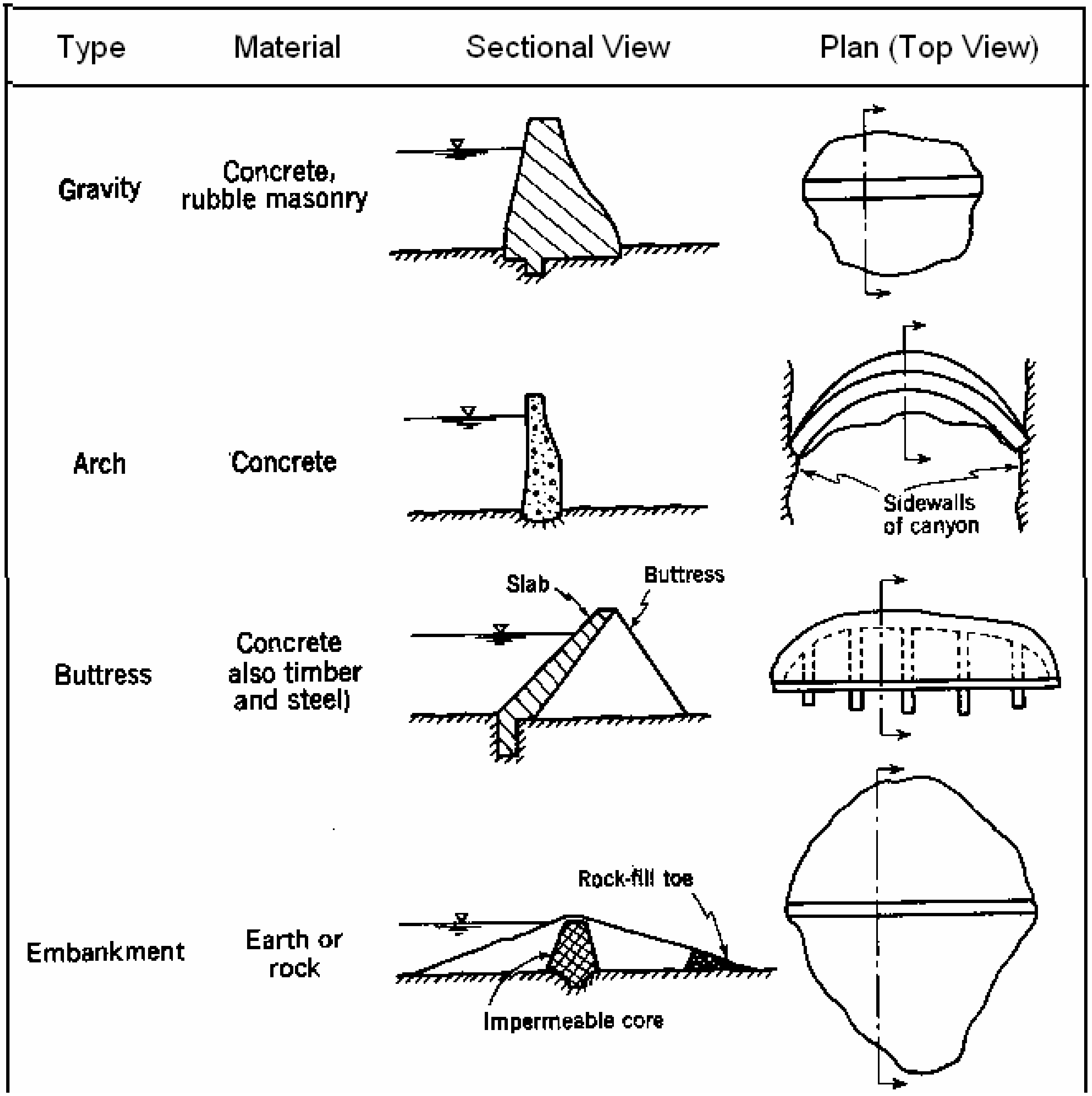

FIGURE-16

CONSTRUCTION OF BUILDINGS IN SEISMIC AREAS-

<u>PRECAUTIONARY MEASURES:</u>

- Buildings should be Founded on hard bedrock only and never on loose soils or Fractured rocks, this is because lose ground settles due to earthquakevibrations.
- Buildings situated in cuttings on hill slides, near sheet slopes always suffer more when an earthquakeoccurs.
- For large Buildings, raft types of foundations are desirable. Square foundations are morestable.
- Different parts of a building should be well tied together so that the whole structure behaves like a single unit to theVibrations.
- Only rich cement mortar and reinforced concrete should beused.
- Buildings with irregular shapes with wings, Verandas, Porches and all structures should beavoided.
- Buildings should have RCC roofs and they should be designed not to yield to lateralstress.
- Resonance is the important factor, If the period of vibration of a structure is the same as that of the foundation rock it will collapse because of the resonanceeffect.

CIVIL ENGINEERING CONSIDERATIONS IN SEISMIC AREAS:

- Seismic areas are the places which experience earthquakesfrequently.
- Therefore constructions in seismic and a seismic areas differ in terms of their design.
- So a civil engineer should only think of making his constructions immune toearthquakes. It is possible to find the difficulties by predicting some crucialfactors:

BASICS OF A DAM:

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DAMS AND RESERVOIRS

ENVIRONMENTAL IMPACTS

DAMS

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- Generate electricpower.
- Manage or prevent water flow into specific landregions.
- Evenly distributed betweenlocations.

BENEFITS OF DAMS

1. Powergeneration
2. Watersupply
3. Stabilize water flow /irrigation
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- Reservoirs often host non-native and invasive species (e.g. snails, algae, predatoryfish)
- Species in thearea
- Waterquality
- Fertility of theland
- Problems ofpollution
- Socialimpacts
- SoilErosion
- SpeciesExtinction
- Spread of Disease

EXAMPLES OF GEO HAZARDS

Geo hazard includes :

- Earthquakes
- Landslides
- Tsunamis
- Avalanches
- Floods
- Volcanoes

Common causes of dam failure include:

- Sub-standard construction materials/techniques (Gleno Dam).
- Spillway design error (South Fork Dam, near failure of Glen Canyon Dam).
- Geological instability caused by changes to water levels during filling or poor surveying...
- Sliding of a mountain into the reservoir (Vajont Dam – not exactly a dam failure
- Reservoir (from French réservoir – a "tank") is, most commonly, an enlarged natural or artificial lake, pond or impoundment created using a dam or lock to store water.
- Reservoirs can be created in a number of ways, including controlling a watercourse that drains an existing body of water, interrupting a watercourse to form an embayment within it, through excavation, or building any number of retaining walls or levees.
- Defined as a storage space for fluids, reservoirs may hold water or gasses, including hydrocarbons. Tank reservoirs store these in ground-level, elevated, or buried tanks. Tank reservoirs for water are also called cisterns. Most underground reservoirs are used to store liquids, principally either water or petroleum, below ground.

Features of rocks:

Important features to look for when writing descriptions and identifying rocks are:

Texture:

Refers to the shape, arrangement and distribution of minerals or grains / clasts within the rock - the texture in a geological sense does NOT refer to the roughness of the surface of the rock;

Structure:

Refers to broader features of a rock which may extend beyond the hand specimen into the outcrop; examples are bedding (in sedimentary rocks), foliation (in metamorphic rocks);

Note: Texture and structure, collectively referred to as fabric, are of primary importance in determining which major rock group a particular rock specimen belongs to.

Grain size:

Refers to the size of individual mineral crystals or clasts (pieces of pre-existing rock) in a rock. Grain size is useful for determining various rock types within the three major rock groups;

Mineralogy:

Refers to the minerals present within the rock, and also their relative proportions (especially important in the case of igneous rocks);

Other features:

Features such as colour, hardness / strength and specific gravity can also provide useful information, and should be included in a complete petrographic description. If a rock appears to be weathered this is an important feature to note as weathering can change physical characteristics markedly. The size of the sample should also be noted.