RAJIV GANDHI PROUDYOGIKI VISHWAVIDYALAYA, BHOPAL

New Scheme Based On AICTE Flexible Curricula

Civil Engineering, IV-Semester

CE405 ENGINEERING GEOLOGY & REMOTE SENSING

Unit 1: Introduction and physical geology: branches application and scope of geology, age and parts of the earth, weathering or rocks, geological action of river, ground water, sea and oceans, Concept and causes of earthquakes and volcanoes.

Unit 2: Mineralogy and crystallography: fundamentals of mineralogy, physical properties, study of common rock forming minerals and ore minerals, importance to civil engineering, and element of crystals and introduction to crystal systems.

Unit 3: Petrology: rock cycle, composition, classification and structures of igneous, sedimentary and metamorphic rocks of civil engineering importance, study of common rock types, brief geological history of India.

Unit 4: Structural geology: dip, strike, outcrops, classification and detailed studies of geological structures i.e. Folds, Faults, Joints, Unconformity and their importance in civil engineering.

Unit 5: Applied geology and remote sensing, engineering properties of rocks, selection of sites for Dam, Tunnel, Reservoirs and Canals, uses of remote sensing technique. Types, components and elements of remote sensing, EMS and MSS, Visual interpretation technique, application of GIS in civil engineering and resource mapping (site selection, water resources, rocks and soil)

List of Experiment's (Expandable)

1. Identification of simple rock forming minerals and important ores.
2. Identification of rocks
3. Simple map Exercises.
4. Field Visit/Geological Excursion

Reference:

1. Prabin Singh -"Engineering and General Geology"
2. P. K. Mukherjee -"A test Book of Geology"
3. S. K. Garg --"A text Book of Physical and Engineering Geology"

UNIT I

Introduction and physical geology: branches application and scope of geology, age and parts of the earth, weathering or rocks, geological action of river, ground water, sea and oceans, Concept and causes of earthquakes and volcanoes.

Concept of geology in civil engineering: The standards and techniques of geology are adopted for the purpose of civil engineering operations. Extensively Engineering Geology has divisions:

(1) The study of raw materials

(2) The study of the geological characteristics of the area where engineering operations are to be carried out such as Groundwater characteristics; the load bearing capacity of rocks; the stability of slopes; excavation; rock mechanics etc for civil engineer.

Scope of Geology In Civil Engineering

1. **Geology offers vital statistics approximately the development substances on the website online used inside the construction of homes, dams, tunnels, tanks, reservoirs, highways and bridges.**
2. **Geological records are most vital in starting stage, layout segment and creation segment of an engineering venture.**
3. **Geology is beneficial to recognize the technique of mining of rock and mineral deposits on this planet's floor and subsurface.**
4. **Geology is beneficial for supply, garage and filling up of reservoirs with water.**
5. **Earlier than building roads, bridges, tunnels, tanks, reservoirs and buildings, selection of web page is vital from the point of stability of basis.**
6. **Geology gives a scientific expertise of creation materials and their properties.**
7. **The knowledge approximately the character of the rocks in tunneling and production of roads.**
8. **The foundation problems of dams, bridges and homes are directly associated with geology of the area in which they are to be built.**
9. **The information of floor water is essential in reference to excavation works, water deliver, irrigation and plenty of other purposes.**
10. **Geological maps and sections help extensively in planning many engineering projects.**
11. **If the geological capabilities like faults, joints, beds, folds are located, they should be definitely dealt with. For this reason, the stableness of the rock systems is essential.**
12. **Pre-geological survey of the place concerned reduces the fee of planning paintings.**

Minerals, Rocks and soils constitute earth materials. They play a vital role in the website evaluation and operations in civil engineering practice, whether it's miles tunneling, hydro-electric powered projects, ground water development, foundation for structures, look at of slope balance and so on. A fundamental expertise of the earth substances is essential.

Accordingly, examine of minerals, rocks and soils bureaucracy the first step in civil engineering factor of view. Consequently, a civil engineer should recognize the introduction of Geology and its branches and importance of a few branches which includes physical Geology, Petrology; Structural Geology and so on.

GEOLOGY (in Greek, Geo manner Earth) is a branch of science dealing with the have a look at of the Earth. It's also referred to as earth technology. The study of the earth as an entire, its origin, structure, composition and the character of the strategies that have given rise to its present role is called as geology.

Geology contains the following branches:

1. Crystallography

2. Mineralogy

3. Petrology

4. Geophysics

5. Geochemistry

6. Structural Geology

7. Stratigraphy

8. Physical Geology

9. Geomorphology

10. Paleontology

11. Hydrogeology

12. Engineering Geology

13. Remote sensing

14. Economic Geology

15. Mining Geology

Crystallography: The look at of the characters of crystals is called crystallography. Crystals are our bodies bounded through flat faces (surfaces), organized on an exact plane due to inner arrangements of atoms.

Mineralogy: The study of the characters of minerals (example: quartz, pyroxene, amphibole, mica, chlorite, garnet) is called Mineralogy. A mineral is a certainly happening homogeneous substance, inorganically formed with a definite chemical composition, with a certain physical properties and crystalline structures.

Note: Coal, oil etc. are considered as minerals THOUGH they arise by organic matter under exceptional condition.

Petrology: The study of rocks in all their elements which include their mineralogist, textures, structures (systematic description of rocks in hand specimen and thin sections); beginning and their relationships to other rocks.

Geophysics: The segment of the earth which encompass the structure, bodily situations and evolutionary history of the earth as a whole.

Geochemistry: The have a look at of chemical composition of minerals and rocks of the earth.

Structural Geology: The study of rock systems consisting of folds that have resulted from moves and deformation of the earth's crust.

Stratigraphy: The take a look at of the stratified rocks in particular their sequence in time, the person of the rocks and correlation of beds at special localities.

Physical Geology: It deals with the geological procedures which result in adjustments inside the crust and upon the surface of the earth. It also offers with the floor functions of the earth (land bureaucracy) or its topography

Geomorphology: The description and interpretation of land bureaucracy.

Paleontology: The look at of historic lifestyles, willpower of environment, evolution of organism and so on.

Internal Structure of Earth -:

The internal structure of the Earth is layered in spherical shells: an outer silicate solid crust, a highly viscous asthenosphere and mantle, a liquid outer core that is much less viscous than the mantle, and a solid inner core.

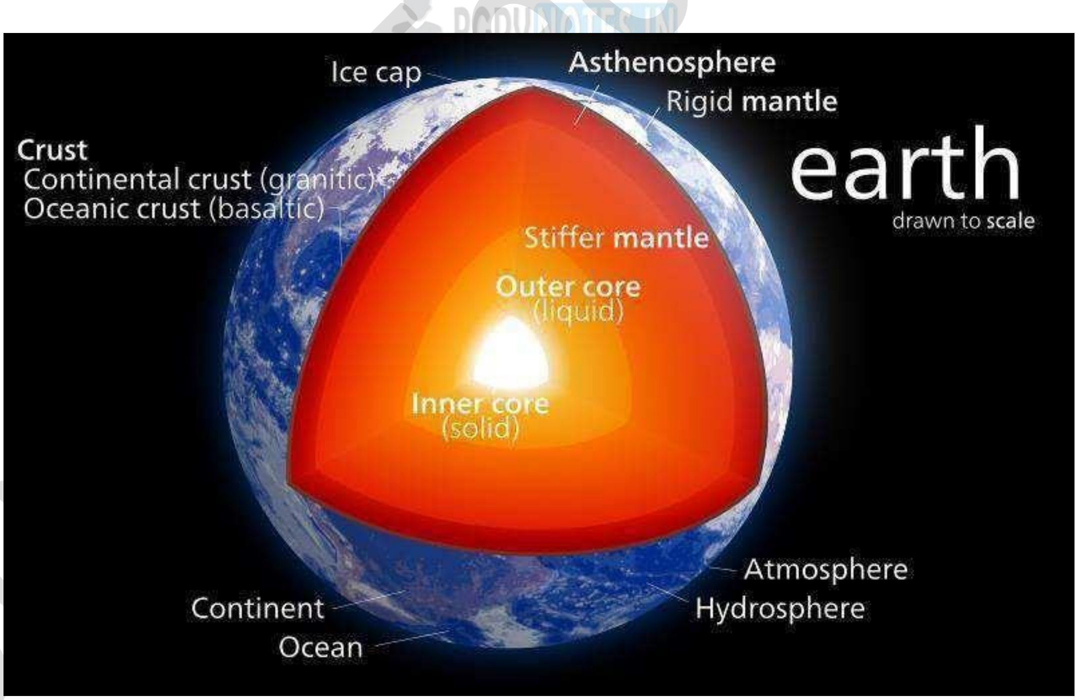


Fig. 1 Internal Structure of Earth

The structure of Earth can be defined in two ways: by mechanical properties such as rheology (Is the study of the flow of matter, primarily in a liquid state, but also as "soft solids" or solids under conditions in which they respond with plastic flow rather than deforming elastically in response to an applied force. It is a branch of physics which deals with the deformation and flow of materials, both solids and liquids), or chemically.

Mechanically, it can be divided into lithosphere, asthenosphere, mesospheric mantle, outer core, and the inner core. Chemically, Earth can be divided into the crust, upper mantle, lower mantle, outer core, and inner core.

Earth's interior is made of a sequence of layers that sit down below the floor crust. in order of depth, those layers encompass the stable, however flowing mantle, the liquid outer middle and the solid iron outer middle, which allows create Earth's shielding magnetic field.

1. Crust

2. Mantle

3. Core

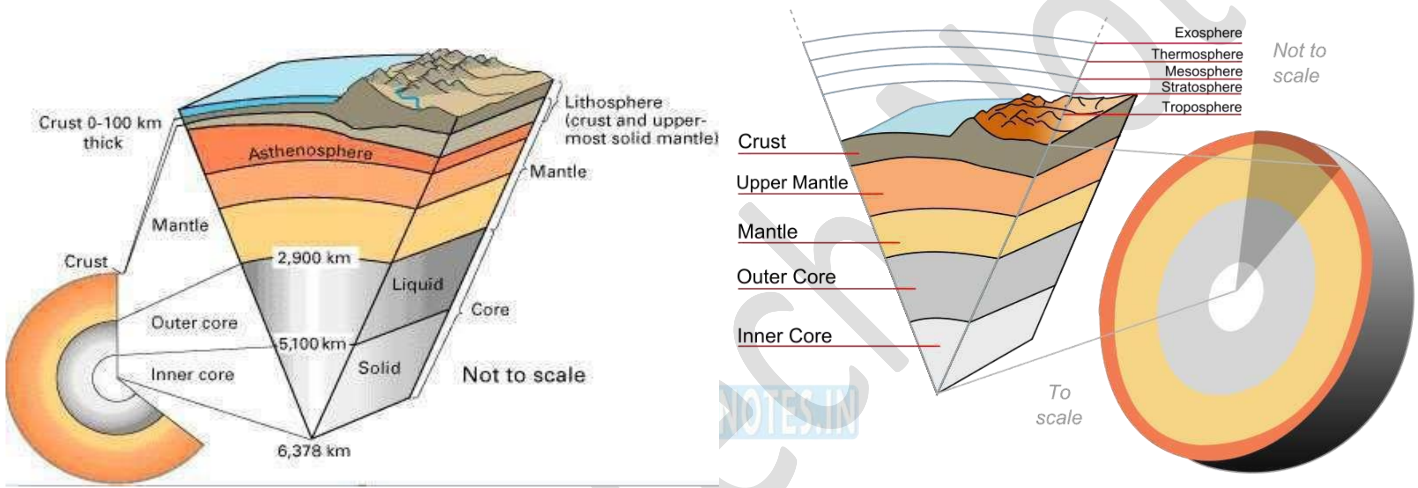


Fig. 2 Internal Structure of Earth

1. Crust-: The crust stages from 5–70 km (~3–44 miles) intensive and is the outermost layer. The skinny components are the oceanic crust, which underlie the sea basins (5–10 km) and are composed of dense (mafic) iron magnesium silicate igneous rocks, like basalt. The thicker crust is continental crust that is much less dense and composed of (felsic) sodium potassium aluminum silicate rocks, like granite. The rocks of the crust fall into two essential classes – SIAL and SIMA (Sues, 1831–1914). Its miles predicted that SIMA starts off evolved about 11 km under the Conrad discontinuity (a 2nd order discontinuity). The uppermost mantle together with the crust constitutes the lithosphere. The crust-mantle boundary takes place as bodily exclusive activities. First, there is a discontinuity within the seismic speed, that's maximum commonly referred to as the Mohorovic discontinuity or Moho.

2. Mantle -: Earth's mantle extends to a depth of two, 890 km, making it the thickest layer of Earth. The mantle is divided into higher and lower mantle. The upper and decrease mantle are separated with the aid of the transition region. The bottom part of the mantle subsequent to the center is referred to as the D" (D high prime) layer. The stress at the bottom of the mantle is a hundred and forty GPA. The mantle consists of silicate rocks that are wealthy in iron and magnesium relative to the overlying crust. Even though solid, the high temperatures within the mantle cause the silicate fabric to be sufficiently ductile that it could drift on very long timescales. Convection of the mantle is expressed at the floor via the motions of tectonic plates.

The two most important things about the mantle are: (1) It is made of solid rock, and (2) It is hot. Scientists know that the mantle is made of rock based on evidence from seismic waves, heat flow, and meteorites. The properties fit the ultramafic rock peridotite, which is made of the iron- and magnesium-rich silicate minerals. Peridotite is rarely found at Earth's surface due to high heat in mantle heat flows in two different ways within the Earth: conduction and convection. Conduction is defined as the heat transfer that occurs through rapid collisions of atoms, which can only happen if the material is solid. Heat flows from warmer to cooler places until all are the same temperature. The mantle is hot mostly because of heat conducted from the core. Convection is the process of a material that can move and flow may develop convection currents.

3. Core-: The average density of Earth is 5,515 kg/m^3 due to the fact the average density of floor material is most effective around 3,000 kg/m^3, we have to conclude that denser materials exist inside Earth's center. Seismic measurements show that the center is divided into two components, a "stable" inner middle with a radius of ~1,220 km and a liquid outer core extending past it to a radius of ~3, 400 km. The densities are among 9,900 and 12,200 kg/m^3 within the outer core and 12,600–13,000 kg/m^3 inside the internal middle.

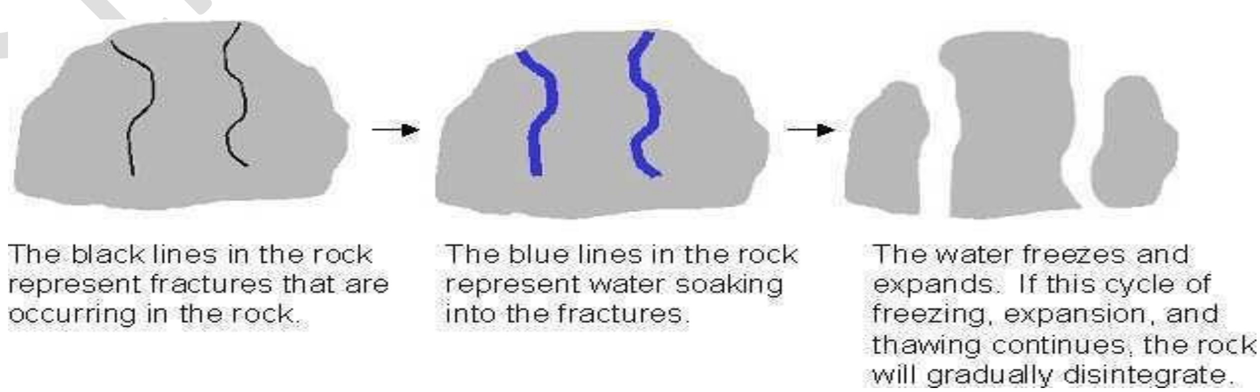
Weathering

Weathering is the technique with the aid of which rocks are broken down and decomposed by the movement of external businesses which include wind, rain, temperature adjustments. Weathering is the preliminary level in the system of denudation.

Types of Weathering

1. **Physical Weathering**
2. **Chemical Weathering**
3. **Biological Weathering**

Physical weathering is the weakening and subsequent disintegration of rock by bodily forces. These physical forces consist of temperature fluctuation, abrasion, frost motion (freezing and thawing), and salt crystal growth. Temperature fluctuation can motive expansion or contraction of rock. While the temperature of rock increases, the rock expands. Whilst the temperature of rock decreases, the rock contracts. This technique of growth and contraction is a bodily pressure and may crack or wreck rock. Abrasion of rock is as a result of the friction of water, wind, or ice upon the rock. The continuous publicity to these elements slowly breaks down the uncovered surface of the rock.



Frost motion is the repeated cycle of ice formation and ice soften within the pore areas and fractures of rocks causing disintegration of the rock. whilst water in rock pores freezes, its extent increases by using about 10% this will create a huge amount of strain on rocks. The significance and volume of frost movement is depending on the frequency, duration and depth of the freezing and thawing cycles.

Salt crystal increase can cause the wreck-up of rock materials. Crystal increase frequently takes place when groundwater moves into empty pores or spaces of rock by means of capillary action as the water evaporates, salt crystals develop and gather, setting strain at the rock and inflicting it to interrupt aside. Salt crystallization is not unusual in drier climates.

Chemical weathering

Chemical weathering is the weakening and subsequent disintegration of rock by means of chemical reactions these reactions consist of oxidation, hydrolysis, and carbonation those techniques both shape or break minerals, hence altering the nature of the rock's mineral composition. Temperature and, specially, moisture are essential for chemical weathering; chemical weathering of rock minerals generally happens extra fast in warm, humid climatic regions.

Oxidation is the response of rock minerals with oxygen, accordingly converting the mineral composition of the rock whilst minerals in rock oxidize, they turn out to be much less proof against weathering. Iron, a commonly known mineral, turns into crimson or rust colored whilst oxidized.

Chemical weathering is the weakening and subsequent disintegration of rock with the aid of chemical reactions these reactions encompass oxidation, hydrolysis, and carbonation those strategies both form or break minerals, for this reason altering the nature of the rock's mineral composition. Temperature and, particularly, moisture are critical for chemical weathering; chemical weathering of rock minerals commonly happens greater fast in hot, humid climatic regions.

Oxidation is the reaction of rock minerals with oxygen, accordingly changing the mineral composition of the rock whilst minerals in rock oxidize; they grow to be much less proof against weathering. Iron, a usually regarded mineral, will become crimson or rust colored while oxidized. Carbonation is the process of rock minerals reacting with carbonic acid. Carbonic acid is formed whilst water combines with carbon dioxide. Carbonic acid dissolves or breaks down minerals inside the rock.

$CO_2 + H_2O \rightarrow H_2CO_3$

(Carbon dioxide + water → carbonic acid)

$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^-$

(Calcite + carbonic acid → calcium + bicarbonate)

Hydrolysis is a chemical response as a result of water. Water modifications the chemical composition and size of minerals in rock, making them less proof against weathering.

Biological weathering

It is the weakening and subsequent disintegration of rock with the aid of plants, animals and microbes. Growing plant roots can exert stress or strain on rock although the system is bodily, the stress is exerted via a organic technique (i.e., growing roots) biological methods can also produce chemical weathering, for example wherein plant roots or microorganisms produce natural acids which help to dissolve minerals. Microbial activity breaks down rock minerals by changing the rock's chemical composition, therefore making it extra vulnerable to weathering. One instance of microbial interest is lichen; lichen is fungi and algae, residing together in a symbiotic relationship. Fungi release chemical substances that wreck down rock minerals; the minerals as a consequence launched from rock are consumed by using the algae. As this process maintains, holes and gaps preserve to broaden on the rock, exposing the rock similarly to bodily and chemical weathering. Burrowing animals can pass rock fragments to the surface, exposing the rock to extra excessive chemical, bodily, and organic methods and so not directly enhancing the procedure of rock weathering.

Geological work of Rivers

A river is one of the major geological agent which carries out its work. The work is mainly divided into three stages, namely

1. River Erosion
2. River Transportation
3. River Deposition

River Erosion: Erosion means mechanical disintegration or chemical decomposition of rocks are transported from the site with the help of natural agencies like wind and running water (or) subsequent displacement. River is a powerful eroding agent and carries out its work in different ways such as hydraulic action, solution and abrasion / attrition etc.

- Hydraulic action: The physical breakdown of rocks take place naturally and greater the movement greater will be the erosion. In the initial and youth stages, the rivers acquire more considerable kinetic energy. When such water dashes against rock forcefully, it will break and this will be more effective if

1. The rocks are already weathered.
2. They are porous and are not well cemented.
3. Those possess fractures cracks etc.

- Solution: This process is a part of hydraulic action which involves only chemical decay of rocks. This is an invisible process and very effective under favorable conditions.

- Attrition: This is a mechanical weathering process. When the rock fragments hit the rocks which are already exposed, abrasion take place. Thus the rock fragments during abrasion undergo wear and tear which is called attrition.

During transportation, heavier and larger materials move slowly while finer and lighter material move fast when attrition take place the angular edges disappear and spherical, ellipsoidal stones etc are formed after a long journey.

River Transportation: A river transports its material physically as well as in a solution form. The transport system is divided into three groups.

1. Bed load -: comprises heavier particles of sand, pebbles, gravels etc. which are transported mainly by their rolling, and skipping, along the bottom of stream.

2. Suspended load consists of silt, fine sands, clay and such load is carried by river in its body of water in suspension. As the river is moved, the load is also carried along with it. Thus load is transported continuously without break till conditions are favorable. This type of natural suspension and separation of sediments account to their size is called Sorting.

3. Dissolved load: Material is transported in a solution condition. The ability to transport the sediments is influenced by river velocity, density etc.

River Deposition is the last phase of geological work of a river. Among the different kinds of river deposits, a few are listed below:

Alluvial cones and fans: River sediment is known as alluvium. If the deposit is spread over a small area but has a relatively steep slope, it is called an alluvial cone. On the other hand, if the deposit is spread over a large area and has a gentle slope, it is called an alluvial fan.

Placer deposits: The placer deposits are characteristically composed of heavier metals such as Gold, Platinum, Chromite, magnetite, Rutile, Ilmenite, Monazite etc. which are commonly economic minerals.

Example Rand placer deposit of South Africa is famous for gold.

Delta deposits: Most of the rivers reach this stage just before they merge with the sea. Rivers Ganga and Brahmaputra have built up the best deltaic regions of the world. Deltas are very fertile and valuable for agriculture.

Natural levees: During the time of floods, the river carries a very large scale of river dumps along its course on either side which are known as natural levees example silt, clay .

Meander Development

A meander in general is a bend in a (moving with smooth twists & turns) water coarse. A meander bend is formed when the moving water in a stream erodes the out banks and widens its valley. If the river encounters any obstacle, it shall not have the capacity to uproot it and therefore it takes a diversion and continues its downward coarse. This is responsible for the formation of deposits known as placer deposits.

By virtue of its relatively weak condition the river compulsorily undergoes a number of curves or bends which makes its path zigzag. These bends are called meanders and the phenomenon is known as Meandering. Meandering is therefore a characteristic feature of the mature stage.

In due course of time these bends become more and more acute due to deposition of sediments along the inner curve and erosion along the outer curve. Ultimately under favorable conditions such as floods, these loops are cut off from the main course of the river. Such cut off bodies of water which are curved in plan are called cut off lakes or horse shoe lakes or ox bow lakes.

Delta: A delta is a land-form that is formed at the mouth of a river where the river flows into an ocean, or sea. Deltas are formed from the deposition of the sediment carried by the river as the flow leaves the mouth of the river. Over long periods of time, this deposition builds the characteristic geographic pattern of river delta.

Development of delta: The favorable conditions for the formation of delta are:

1. **The river should have large amount of load.**
2. **The river should have totally exhausted its energy at the time of its merger with the sea.**
3. **The oceans at the mouth of the river should not be turbulent otherwise as & when loose sediments are deposited they are washed away by the waves and currents of the sea.**

During delta formation the prevailing conditions will be such that the river will be shallow and will change its direction and velocity frequently. Under such conditions deltas develop a typical structure known as cross bedding.

The delta will have gently incline bottom layers of fine sediments known as bottom set beds. These are overlain by steeply inclined middle layers of coarse sediments known as forest beds. Above these again gently dipping layers of the mixture of finer and coarser sediments occur. They are known as top set beds. Though all these three sets of beds are inclined towards the sea, they differ in the amount of inclination and hence they are not parallel. Such a peculiar bedding phenomenon is known as cross bedding.

Valleys: In geology, a valley is a depression with predominant extent in one direction. A very deep river valley may be called a canyon or gorge. The terms U-shaped and V-shaped are descriptive terms of geography to characterize the form of valley. Most valleys belong to one of these two main types or a mixture of them, at least with respect of the cross section of the slopes or hills.

Formation and Development: A valley is an extended depression in the Earth's surface that is usually bounded by hills or mountains and is normally occupied by a river or stream. Valleys are one of the most common landforms on the Earth and they are formed through erosion or the gradual wearing down of the land by wind and water. In river valleys for example, the river acts as an erosional agent by grinding down the rock or soil and creating a valley. The shape of valleys varies but they are typically steep-sided canyons or broad plains, however their form depends on what is eroding it, the slope of the land, the type of rock or soil and the amount of time the land has been eroded. There are three common types of valleys which include V-shaped valleys, U-shaped valleys and flat floored valleys. V-SHAPED VALLEYS/ RIVER VALLEYS: A V-shaped valley, sometimes called a river valley, is a narrow valley with steeply sloped sides that appear similar to the letter "V" from a cross-section. They are formed by strong streams, which over time have cut down into the rock through a process called down cutting. These valleys form in mountainous and/or highland areas with streams in their "youthful" stage. At this stage, streams flow rapidly down.

- **An example of a V-shaped valley is the Grand Canyon in the Southwestern United States. After millions of years of erosion, the Colorado River cut through rock of the Colorado Plateau and formed a steep sided canyon V-shaped canyon known today as the Grand Canyon.**
- **The original natural large river valleys of the world such as Nile, Ganges, Amazon, Mississippi etc.**

Fig. 3 Youth Stage of River

U-Shaped Valleys/ Glacial Valleys: A U-shaped valley is a valley with a profile similar to the letter "U." They are characterized by steep sides that curve in at the base of the valley wall. They also have broad, flat valley floors. U-shaped valleys are formed by glacial erosion. U-shaped valleys are found in areas with high elevation and in high latitudes, where the most glaciations has occurred. Large glaciers that have formed in high latitudes are called continental glaciers or ice sheets, while those forming in mountain ranges are called alpine or mountain glaciers.

Due to their large size and weight, glaciers are able to completely alter topography. This is because they flowed down pre-existing river or V-shaped valleys during the last glaciations and caused the bottom of the "V" to level out into a "U" shape as the ice erode the valley walls, resulting in a wider, deeper valley. For this reason, U-shaped valleys are sometimes referred to as glacial troughs.

One of the world's most famous U-shaped valleys is Yosemite Valley in California. It has a broad plain that now consists of the Merced River along with granite walls that were eroded by glaciers during the last glaciations.

Geological work of wind

Wind is the moving air. Wind blowing over the solid surface of the lands is also an active agent of landform development. Its activity is particularly intensive in the deserts and semi deserts which constitute about 20% of the surface of continents.

The geological action of wind is particularly effective in areas that lack plant cover, have a considerable diurnal and seasonal temperature variation, and low precipitation. The geological action of wind can conveniently be divided in to three stages viz. Erosion, Transportation and Deposition. As a whole, the geological action of wind is largely governed by its velocity. But wind alone has little influence on shaping the surface of the ground, because it is only able to move small dry particles. In humid climatic regions, the

surface of the earth is protected by a solid cover of vegetation and also by the cohesive effects of moisture in the soil from sharp temperature fluctuations causing physical weathering and the deflation work of the wind.

Erosion Wind erosion manifests itself in three forms viz. (I) deflation, (ii) abrasion or corrosion and (iii) attrition. Wind uses sand as the agent of erosion. Wind and running water are in much respect similar in the ways in which they erode and transport sediment particles.

1. Deflation: A strong wind can transport very coarse sand, lifting it from the ground and carry it for great distances. This process of removal of loose soil of rock particles, along the course of the blowing wind is known as 'deflation' (from the Latin de flare=to blow off).

The wind picks up and removes loose particles from the earth's surface, and thus helps to lower the general level. This process operates well in dry regions with little or no rainfall. The rate of deflation depends on the force of the wind, the nature of the rock and the degree of weathering it has suffered etc.

Features Produced by Deflation

(I) Hamada: When the loose particles are swept away the hard mantle left behind is known as 'hamada'. The term has been applied to the stone-strewn surface in the Sahara desert, left after the finer materials are removed by wind. This is a form of lag-deposits.

(ii) Blow-outs or deflation-hollows: Deflation sometimes leads to the formation of depression or hollows on the land surface. At few places, deflation may continue to deepen a blow-out in fine-grained sediment until it reaches the water-table. These depressions may range from a few meters to a kilometer or more in diameter, but it is usually only a few meters deep. Such depressions, when deepen until '.he water-table and gets filled with water, create shallow ponds or lakes known as 'Oases'. The position of the oasis is quickly stabilized by the growth of vegetation-commonly palm trees. Some oases are very small with only a few trees, whilst others are large enough to support moderate-sized townships surrounded by gardens and date palms. The pans of South Africa, the so-called lakes of west and central Australia etc. are probably the results of long-continued deflation.

(iii) Lag deposits: Sometimes a layer of residual pebbles and cobbles are strewn upon the surface while intervening finer particles have been removed as a result of deflation. These accumulations of pebbles and boulders have been designated by the general term lag-deposits.

By rolling or jostling about, as the finer particles are removed, the pebbles become closely fitted together forming what is known as a desert pavement. This layer protects the underlying sediment from further deflation. Its widespread occurrence is emphasized by the variety of names applied to it Reg in Algeria; rig in Iran, serer in Libya; the gibbers in Australia.

2. Abrasion

The loose particles that are blown away by the wind serve as tools of destruction, wearing away the surface with which it comes in contact. This process is also known as corrosion. Abrasion is mainly effective as part of saltation (a mode of wind transport) and can operate only near the ground because of the inability of wind to lift sand more than a few feet. Its main effect is mostly seen in under cutting and fluting at the base of upstanding rock masses. Depending on the hardness of the rock and the character of the material bomb by the wind, the surface of rocks is polished, covered with striations, furrows or grooves.

Features Produced by Abrasion

(I) Yardang: It is a grooved or furrowed topographic form produced by wind abrasion. The grooves are elongated in the direction of prevailing winds and are separated by sharp ridges. The yardangs commonly develop, where the exposed rocks have vertical layers, consisting of alternations of hard and soft strata, and when the winds are steady and blow in one direction, the softer strata are scoured away more rapidly than the hard and resistant strata. Thus, there develops a topographic feature consisting of elongated ridges and furrows, depending on the original rock characteristics. These are also usually under-cut. These are common in parts of the Asiatic deserts.

(I) Ventifacts: These are the pebbles faceted by the abrasive effects of wind-blown sand. These are developed when sand has been blown over pebbles for a longtime, so that they become worn from the repeated abrasion and smooth polished surfaces result. Ventifacts with one smooth surface are called Einkanters, with two abraded surfaces as Zweikanter and with three smooth faces as Dreikanters.

(II) Pedestal rock: It is a wide rock-cap standing on a slender rock column, produced because of wind abrasion. As we know, the sand-blast action is most effective just above the surface of the ground where the drift is thickest and it decreases rapidly upwards as a result of which rocks which projects upwards are under-cut. When soft rocks capped with harder and resistant rocks are exposed to wind abrasion, the softer rocks being more deeply worn, produce a mushroom-shaped form in which the upper widened part of the rock rests upon a relatively thin and short rock-column.

(IV) Zeugen These are tabular masses of more resistant rock resting on under-cut pillars of softer material and are very often elongated in the direction of prevailing wind; besides the strata are horizontal.

3. Attrition: While on transit, wind born particles often collide with one another and such mutual collision brings about some degree of grinding of the particles. Thus rounding of grains become perfect to a great extent and the grains are reduced to smaller dimensions. The more the length of transit and velocity, the greater is the degree of rounding

Depositional features

Soil formation and soil profile-: The development of a soil from inorganic and organic materials is a complex process. Intimate interactions of the rock and hydrologic cycles produce the weathered rock materials that are basic ingredients of soils. Weathering is the physical and chemical breakdown of rocks and the first step in soil development. Weathered rock is further modified by the activity of soil organisms into soil, which is called either residual or transported, depending on where and when it has been modified. A soil can be considered an open system that interacts with other components of the geologic cycle. The characteristics of a particular soil are a function of climate, topography, parent material (the rock or alluvium from which the soil is formed), time (age of the soil), and organic processes (activity of soil organisms). Vertical and horizontal movements of the materials in a soil system create a distinct layering, parallel to the surface, collectively called a soil profile. The layers are called zones or soil horizons. Our discussion of soil profiles will mention only the horizons most commonly present in soils Soil generally consists of visually and texturally distinct layers, also called profiles, which can be summarized as follows from top to bottom:

A) Surface soil: Organics mixed with mineral matter. This layer of mineral soil contains the most organic matter accumulation and soil life. This layer eluviates (is depleted of) iron, clay, aluminum, organic compounds, and other soluble constituents. When eluviations are pronounced, a lighter colored "E" subsurface soil horizon is apparent at the base of the "A" horizon. A-horizons may also be the result of a combination of soil bioturbation and surface processes that winnow fine particles from biologically mounded topsoil. In this case, the A-horizon is regarded as a "bio mantle".

B) Subsoil: Subsurface layer reflecting chemical or physical alteration of parent material. This layer accumulates iron, clay, aluminum and organic compounds, a process referred to as illuviation.

C) Parent rock, also known as substratum: The parent material in sedimentary deposits. Layer of large unbroken rocks. This layer may accumulate the more soluble compounds.

R) Bedrock: The parent material in bedrock landscapes. This layer denotes the layer of partially weathered bedrock at the base of the soil profile. Unlike the above layers, R horizons largely comprise continuous masses of hard rock that cannot be excavated by hand. Soils formed in situ will exhibit strong similarities to this bedrock layer. These areas of bedrock are less than 50 feet of the other profiles.

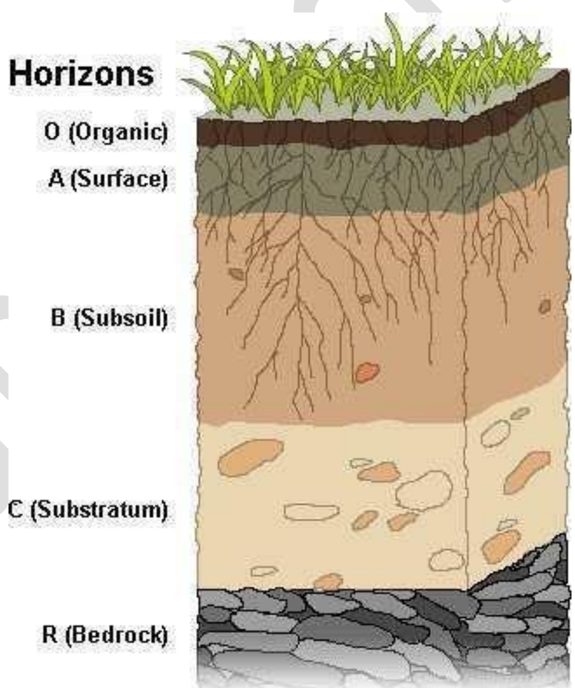


Fig. 4 Soil Profile

Volcano -: A volcano is a rupture in the crust of a planetary-mass object, such as Earth, that allows hot lava, volcanic ash, and gases to escape from a magma chamber below the surface. The word volcano is derived from the name of Volcano, a volcanic island in the Aeolian Islands of Italy whose name in turn comes from Vulcan, the god of fire in Roman mythology.[3] The study of volcanoes is called volcanology, sometimes spelled Volcanology.

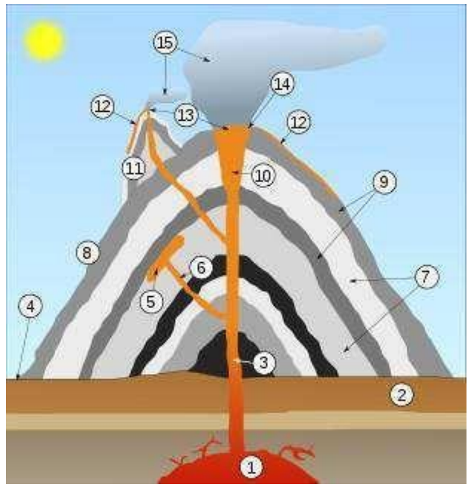


Fig. 5 Volcano

1. Large magma chamber
2. Bedrock
3. Conduit (pipe)
4. Base
5. Sill
6. Dike
7. Layers of ash emitted by the volcano
8. Flank 9. Layers of lava emitted by the volcano
9. Throat
10. Parasitic cone
11. Lava flow
12. Vent
13. Crater
14. Ash cloud

Volcanic features

The most common perception of a volcano is of a conical mountain, spewing lava and poisonous gases from a crater at its summit; however, this describes just one of the many types of volcano. The features of volcanoes are much more complicated and their structure and behavior depends on a number of factors. Some volcanoes have rugged peaks formed by lava domes rather than a summit crater while others have landscape features such as massive plateaus. Vents that issue volcanic material (including lava and ash) and gases (mainly steam and magmatic gases) can develop anywhere on the landform

Volcanic cones (cinder cones).

Volcanic cones or cinder cones result from eruptions of mostly small pieces of scoria and pyroclastic (both resemble cinders, hence the name of this volcano type) that build up around the vent. These can be relatively short-lived eruptions that produce a cone-shaped hill perhaps 30 to 400 meters high. Most cinder cones erupt only once. Cinder cones may form as flank vents on larger volcanoes, or occur on their own.

Paricutin in Mexico and Sunset Crater in Arizona are examples of cinder cones. In New Mexico, Ceja Del Rio is a volcanic field of over 60 cinder cones.

Stratovolcanoes or composite volcanoes are tall conical mountains composed of lava flows and other eject in alternate layers, the strata that gives rise to the name. Stratovolcanoes are also known as composite volcanoes because they are created from multiple structures during different kinds of eruptions. Strato/composite volcanoes are made of cinders, ash, and lava. Cinders and ash pile on top of each other, lava flows on top of the ash, where it cools and hardens, and then the process repeats. Classic examples include Mount Fuji in Japan, Mayon Volcano in the Philippines, and Mount Vesuvius and Stromboli in Italy. Throughout recorded history, ash produced by the explosive eruption of Stratovolcanoes has posed the greatest volcanic hazard to civilizations.

Supervolcanoe: A Supervolcanoe usually has a large caldera and can produce devastation on an enormous, sometimes continental, scale. Such volcanoes are able to severely cool global temperatures for many years after the eruption due to the huge volumes of sulfur and ash released into the atmosphere. They are the most dangerous type of volcano. Examples include: Yellowstone Caldera in Yellowstone National Park and Valles Caldera in New Mexico (both western United States); Lake Taupe in New Zealand; Lake Toba in Sumatra, Indonesia; and Ngoro Crater in Tanzania. Because of the enormous area they may cover, super volcanoes are hard to identify centuries after an eruption. Similarly, large igneous provinces are also considered super volcanoes because of the vast amount of basalt lava erupted (even though the lava flow is non-explosive).

Types of volcano

A popular way of classifying magmatic volcanoes is by their frequency of eruption, with those that erupt regularly called active, those that have erupted in historical times but are now quiet called dormant or inactive, and those that have not erupted in historical times called extinct. However, these popular classifications—extinct in particular—are practically meaningless to scientists. They use classifications which refer to a particular volcano's formative and eruptive processes and resulting shapes, which was explained above.

1. Active: There is no consensus among volcanologists on how to define an "active" volcano. The lifespan of a volcano can vary from months to several million years, making such a distinction sometimes meaningless when compared to the life spans of humans or even civilizations. For example, many of Earth's volcanoes have erupted dozens of times in the past few thousand years but are not currently showing signs of eruption. Given the long lifespan of such volcanoes, they are very active.

Mount Etna and nearby Stromboli, two Mediterranean volcanoes in "almost continuous eruption" since antiquity

2. Extinct: Four peaked volcano, Alaska, in September 2006 after being thought extinct for over 10,000 years Mount Rinjani eruption in 1994, in Lombok, Indonesia Extinct volcanoes are those that scientists consider unlikely to erupt again because the volcano no longer has a magma supply. Examples of extinct volcanoes are many volcanoes on the Hawaiian – Emperor Seamount chain in the Pacific Ocean,

3. Dormant: It is difficult to distinguish an extinct volcano from a dormant (inactive) one. Volcanoes are often considered to be extinct if there are no written records of its activity. Nevertheless, volcanoes may remain dormant for a long period of time. For example, Yellowstone has a repose/recharge period of around 700,000 years, and Toba of around 380,000 years.

Volcanic products

Volcanoes usually produce three types of materials viz. solid, liquid and gaseous.

(a) Solid products: Enormous quantities of solid materials are thrown out by volcanoes during an eruption. They consist of fragments of rocks or pieces of already cooled lava. The ejection of the solid materials is usually accompanied by violent explosions. The solid materials, during the initial stages of volcanism, mostly contain the fragments of the crustal rocks through which the pipe of the volcano passes; but at later stages they consist mostly the fragments of solidified lava, resulted from the partial solidification in the molten reservoir beneath the surface as well as the solidified lava of earlier eruptions. The rock fragments ejected during volcanic-eruptions are called pyroclasts or tephra. Generally, larger fragments fall at the edge of the crater and slide down its inner and outer slopes, while smaller ones are thrown into the surrounding plains or pile up at the foot of the cone.

According to their size and shape the pyroclastic materials are classified as follows:

(I) Volcanic blocks: These are the largest masses of rock blown out. These are either the masses of the solidified lava of earlier eruptions or those of the pre-existing rocks. They are usually angular and the diameter of the fragments is always above 32 millimeter. Thus they are the huge solid fragments ejected during a volcanic activity.

(I) Volcanic bombs: These are rounded or spindle-shaped masses of hardened lava, which may develop when clots of lava are blown into the air and get solidified before reaching the ground.

Their ends are twisted, indicating rapid rotation in the air while the material was plastic. Because of their somewhat rounded appearance, they are known as volcanic bombs. The diameter of these fragments is always above 32 millimeter. Bread-crust bombs are those volcanic bombs which present a cracked surface, may be due to the approximately solid state of the material from which they have been formed, which gives the appearance of the crust of bread.

(II) Cinders or lapilli: The size of the fragments is between 4 mm to 32 mm, and is shaped very much like bombs. The term 'lapilli' is used when the fragments are not conspicuously vesicular; and in case of vesicular fragments they are known as cinders. Still smaller fragments are called volcanic-sand.

(IV) Ash: These particles range in size from 0.25 mm to 4mm and as such, are the fine particles of lava.

(v) Fine-ash or volcanic dust: These are the minute pyroclastic- tic materials, and their diameter is always less than 0.25 mm. In many instances volcanic dust was carried by wind to enormous distances and scattered over a vast territory forming volcanic dust layers.

Pyroclastic materials accumulating on the slopes and adjoining areas of a volcano with gradual compaction and cementation gives rise to rocks called Volcanic-tuffs. These tuffs when consist of angular fragmental

materials, they are known as Volcanic- breccias; when volcanic bombs are predominant in the tuffs, they are referred to as Volcanic-agglomerates. The diameter of these fragments is always larger than 20 mm. The welded tuffs are commonly known as Ignimbrites. In certain instances, a great cloud of superheated vapors and incandescent rock material and volcanic ash are violently emitted during the eruption. These are called Nueces andantes and are sometimes referred to as glowing avalanches.

(b) Liquid products: Lava's are the major and the most important liquid product of a volcano. As we know, the magma that has flowed out on to the surface is called lava. All lava's contain gases, but because of the high pressure that prevails in the interior of the earth the content of gases and vapors in the magma is more.

According to the composition and the gas content, the temperature of lava's during eruptions usually ranges between 900°C to 1200°C. Like magma, lava is also divided in to three types viz. acidic, medium and basic, depending on the silica content

Acid lavas contain a high proportion of silica, have a high melting point and are usually very viscous and therefore their mobility is low. They cool very slowly and contain many gases in a dissolved state.

They congeal at relatively short distances from the crater. Rhyolite, composed of orthoclase feldspar and quartz are the examples of acid lavas.

The lavas of intermediate or medium composition have the silica content between 55 to 60%. Andesite lavas are the best examples of the lavas of intermediate nature and they mostly characterize extrusions around the margins of the Pacific.

The basic lavas contain low percentage of silica, which is usually 50% or less. These lavas melt at lower temperature, and have a high density as well as liquid consistency. They cool quickly and contain little gas.

These lavas are highly mobile and spread over large distances, forming flows or sheets. Basalts are the best examples of the basic lava.

Since the lava behaves differently depending on their chemical composition they give rise to different configurations when consolidated, as described below:

(I) Lava tunnels: Sometimes the outer surface of the lava flows; cools and solidifies first forming a crust while the lava is still in a liquid state inside. This enclosed liquid may drain out through some weak spots of the solidified flow forming a tunnel called a lava-tunnel.

(II) Block lava: It is also known as aa-lava. In this case, the gases escape explosively from the partly crystallized flows thus breaks the congealing crust in to an assemblage of rough and uneven blocks. The escape of gases increases the viscosity of the lava and helps in rapid cooling, giving rise to a solidified lava flow with spiny, rubble surface. It is therefore the Hawaiian name, aa (pronounced ah-ah meaning rough or spiny) is applied to this type of lavas.

(III) Ropy-lava: Lavas with low-viscosity remain mobile for a longer period. These lavas usually contain much entrapped gas and cool very slowly. The lava spreads out in thin sheets and congeals with a smooth surface which wrinkles or twisted into ropy form like that of a stream of flowing pitch. It is also called Pahoehoe-structure.

(IV)Pillow lava: Lava erupted under water-logged sediments in sea-water, beneath ice-sheets, or in to rain soaked air, characteristically emerges as a pile of rounded bulbous blobs or pillows. Basic lava of spilitic type often presents pillow structure.

(V) Vesicular or Scoriaceous structure : When lavas heavily charged with gases and other volatiles are erupted on the surface, the gaseous constituents escape from the lava, due to the decrease of pressure, giving rise to a large number of empty cavities of variable dimensions on the surface of the lava-flows.

Due to the presence of vesicles or cavities, the resulting structure is known as vesicular- structure. These cavities when filled up subsequently with secondary minerals, the structure is called amygdaloidal structure and the infillings as amygdales.

A highly vesicular rock, which contains more gas space than rock, is known as 'Scoria'. In more viscous lavas, when the gases cannot escape easily and the lava quickly congeals, it forms Pumice or 'Rock -froth', which contains so much void space that it can float in water.

(VI) Jointing

As a consequence of contraction due to cooling joints are developed in the lava flows, which may be manifested in the form of sheet, platy or columnar structures,

(c) Gaseous Products-: Volcanic activity is invariably associated with emanation of steam and various gases from the volcanoes.

Water vapor constitutes about 60 to 90% of the total content of the volcanic gases. Second in abundance to steam among volcanic gases is CO_2.

Amongst other gases which have been detected in considerable quantities, hydrochloric acid, Sulphurdioxide, hydrogen, nitrogen, boric-acid pours, phosphorous, arsenic vapor, argon, hydrofluoric acid etc. are the most important

Earthquake:-

An earthquake is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is called the hypo center, and the location directly above it on the surface of the earth is called the epicenter.

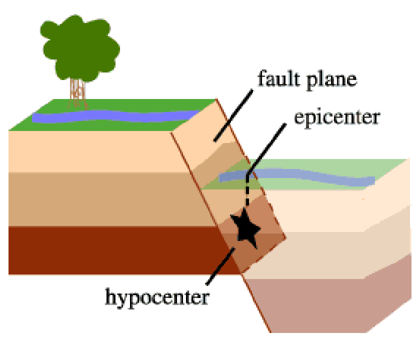


Fig. 6 Basic Structure for Earthquake

Sometimes an earthquake has fore shocks. These are smaller earthquakes that happen in the same place as the larger earthquake that follows. Scientists can't tell that an earthquake is a fore shock until the larger earthquake happens. The largest, main earthquake is called the main shock. Main shocks always have aftershocks that follow. These are smaller earthquakes that occur afterwards in the same place as the main shock. Depending on the size of the main shock, aftershocks can continue for weeks, months, and even years after the main shock.

Causes of Earthquake

An earthquake basically is an outcome of the movements of tectonic plates beneath the Earth's surface. However, these are also caused due to certain other reasons. These are mostly natural reasons however sometimes these can even be man-made. Given below are the various causes of earthquakes:

Volcanic Eruptions

Volcanic eruptions are a common cause of earthquake. Areas that are faced with frequent volcanic activities are more prone to earthquakes.

Geological Fault

It occurs because of the displacement of plates from their original position. As the rocks move alongside these planes, it brings about tectonic earthquakes.

Human Activities

Man is known to influence various natural activities and earthquakes are no exception. Nuclear bombing, building of dams and mining are few such human activities that can cause earthquake.

Effects of Earthquake

The effects of an earthquake are terrible and devastating. Many building, hospitals, schools, etc are destroyed due to it. A lot of people get killed and injured. Many people lose their money and property. It affects the mental health and emotional health of people.

The environmental effects of it are that including surface faulting, tectonic uplift and subsidence, tsunamis, soil liquefaction, ground resonance, landslides and ground failure, either directly linked to a quake source or provoked by the ground shaking.

Types of Earthquake

There are different types of earthquakes that have been experienced on our planet. Here is a look at the main types of earthquakes:

Tectonic Earthquake

A tectonic earthquake is an outcome of the breakage of Earth's crust because of exertion of pressure on rocks and tectonic plates.

Aftershock

This is often a mild earthquake that takes place in the same area that has been hit by a severe earthquake few hours, days or weeks before.

Foreshock

A small earthquake that takes place before a severe earthquake is referred to as a foreshock.

Explosion Earthquake

This type of earthquake occurs because of explosion of a chemical and nuclear device.

Volcanic Earthquake

It is an earthquake that occurs due to the combination of tectonic forces and volcanic activities.

Collapse Earthquake

This type of earthquake is caused due to the explosion of rocks. These are generally mild earthquakes that occur due to mining activities.

Submarine Earthquake

It is an earthquake that takes place underwater particularly at the bottom of an ocean. It is commonly referred to as Tsunami.

Volcano

Volcano, vent in the crust of the Earth or another planet or satellite, from which issue eruptions of molten rock, hot rock fragments, and hot gases. A volcanic eruption is an awesome display of the Earth's power. Yet while eruptions are spectacular to watch, they can cause disastrous loss of life and property, especially in densely populated regions of the world. Sometimes beginning with an accumulation of gas-rich magma (molten underground rock) in reservoirs near the surface of the Earth, they can be preceded by emissions of steam and gas from small vents in the ground.

Volcanoes are closely associated with plate tectonic activity. Most volcanoes, such as those of Japan and Iceland, occur on the margins of the enormous solid rocky plates that make up the Earth's surface. Other volcanoes, such as those of the Hawaiian Islands, occur in the middle of a plate, providing important evidence as to the direction and rate of plate motion.

****

UNIT II Mineralogy & Crystallography

Mineralogy and crystallography: fundamentals of mineralogy, physical properties, study of common rock forming minerals and ore minerals, importance to civil engineering, and element of crystals and introduction to crystal systems.

Definition of a Mineral

A mineral is a naturally-occurring, homogeneous solid with a definite, but generally not fixed, chemical composition and an ordered atomic arrangement. It is usually formed by inorganic processes.

1.) "Naturally occurring" means that synthetic compounds not known to occur in nature cannot have a mineral name. However, it may occur anywhere.

2.) "Homogeneous solid" means that it must be chemically and physically homogeneous down to the basic repeat unit of the atoms. It will then have absolutely predictable physical properties (density, compressibility, index of refraction, etc.). This means that rocks such as granite or basalt are not minerals because they contain more than one compound.

3.) "Definite, but generally not fixed, composition" means that atoms, or groups of atoms must occur in specific ratios. For ionic crystals (i.e. most minerals) ratios of cat-ions to anions will be constrained by charge balance, however, atoms of similar charge and ionic radius may substitute freely for one another; hence definite, but not fixed.

4.) "Ordered atomic arrangement" means crystalline. Crystalline materials are three-dimensional periodic arrays of precise geometric arrangement of atoms. Glasses such as obsidian, which are disordered solids, liquids (e.g., water, mercury), and gases (e.g., air) are not minerals.

5.) "Inorganic processes" means that crystalline organic compounds formed by organisms are generally not considered minerals. However, carbonate shells are minerals because they are identical to compounds formed by purely inorganic processes.

Physical Properties of Minerals:-

Physical properties can be determined in inspection or by simple test it can be determined by hand specimen. The chief physical properties are color, streak, luster, hardness, habit, cleavage, fracture, odor, and tenacity; specific gravity and crystal forms. Correct identification are made of with polarizing microscope

1. Crystal form and habit (shape).
2. Luster and transparency
3. Color and streak.
4. Cleavage, fracture
5. Specific gravity
6. Habit

7. Tenacity

8. Density

9. Hardness

Crystal form and habit.

Recognizing crystal forms (a crystal face plus its symmetry equivalents) in the various crystal systems is one of the reasons we spend some time in lab studying block models. The crystal faces developed on a specimen may arise either as a result of growth or of cleavage. In either case, they reflect the internal symmetry of the crystal structure that makes the mineral unique. The crystal faces commonly seen on quartz are growth faces and represent the slow rest growing directions in the structure. Quartz grows rapidly along its c-axis (three-fold or trigonal symmetry axis) direction and so never shows faces perpendicular to this direction. On the other hand, calcite rhomb faces and mica plates are cleavages and represent the weakest chemical bonds in the structure. There is a complex terminology for crystal faces, but some obvious names for faces are prisms and pyramids. A prism is a face that is perpendicular to a major axis of the crystal, whereas a pyramid is one that is not perpendicular to any major axis.

Crystals that commonly develop prism faces are said to have a prismatic or columnar habit. Crystals that grow in fine needles are acicular; crystals growing flat plates are tabular. Crystals forming radiating sprays of needles or fibers are satellite. Crystals forming parallel fibers are fibrous, and crystals forming branching, tree-like growths are dendritic.

Luster and transparency

The way a mineral transmits or reflects light is a diagnostic property. The transparency may be opaque, translucent, or transparent. This reflectance property is called luster. Native metals and many sulfides are opaque and reflect most of the light hitting their surfaces and have a metallic luster. Other opaque or nearly opaque oxides may appear dull, or resinous. Transparent minerals with a high index of refraction such as diamond appear brilliant and are said to have an adamantine luster, whereas those with a lower index of refraction such as quartz or calcite appear glassy and are said to have a vitreous luster.

Color and streak

Occur due to certain wavelength of light by atoms making of crystals. Color is fairly self-explanatory property describing the reflectance. Metallic minerals are white, gray, or yellow. The presence of transition metals with unfilled electron shells (e.g. V, Cr, Mn, Fe, Co, Ni, and Cu) in oxide and silicate minerals causes them to be opaque or strongly colored so that the streak, the mark that they leave when scratched on a white ceramic tile, will also be strongly colored.

On the basic of color of a mineral; may belong to anyone of three types

Idiochromatic: show a constant color appear metallic crystal ex. Copper

Allochromatic: Show variable colors, appear non-metallic ex. Quartz

Pseudochromatic: Shows false color

Some minerals viewed in different directions shows irregular changes in color

1. Play of color: Change in rapid succession on rotation ex. Diamond
2. Change of color: Rate of change of colors on rotation and intensity is low ex. Labrodorite
3. Iridescence: Shows rainbow colors in interior or exterior surface ex. Limonite, hematite
4. Tarnish: Change of original color due to oxidation ex. Bornite
5. Greasy luster: Luster exhibited by grease ex. Talc
6. Dull or earthy: No luster said to earthy luster ex. Kaolin

Cleavage, fracture

Cleavage: It is defined as a tendency of mineral to break more easily with smooth surface along plane of weak bonding. The cleavage can be classified as perfect, good, poor, and indistinct PERFECT CLEAVAGE: Mica, Galena, and Calcite

NO CLEAVAGE: Quartz

Fracture: The nature of the surface of a mineral is called as fracture. The common types of fracture are

1. Even fracture: Surface almost flat ex. Flint, Chert
2. Uneven fracture: Surface is irregular and rough ex. Fluorite
3. Conchoidal fracture: Curved surface showing concentric line like shell ex. Quartz
4. Hacky fracture: ʻough surface with sharp and jagged point's ex. Asbestos
5. Earthy fracture: Smooth, soft and porous ex. Chalk, kaolin

Specific gravity:

It is the number which represents the ratio of weight of the mineral to the weight of an equal volume of water.

Habit (Form): The chief habits of minerals are shown as follows,

1. Accicular: Needle like crystal ex. Natrolite
2. Fibrous: Aggregate of long thin fibre ex. Asbestos
3. Foliated: Thin separate sheet ex. Mica
4. Bladed: Occur as small knife blade ex. Kyanite
5. Tabular: Broad flat surface ex. Gypsum, feldspar
6. Columnar: Columnar crystal ex. Tourmaline
7. Granular: Aggregate of equidimensional grains ex. Magnetite
8. Reinform: Kidney shaped form ex. Hematite.
9. Oolitic: Aggregate bodies resembling fish roe ex. Bauxite
10. Massive: Structural less mass ex. Flint

Tenacity

It is the ability of a mineral to deform plastically under stress. Minerals may be brittle, that is, they do not deform, but rather fracture, under stress as do most silicates and oxides. They may be sectile, or be able to deform so that they can be cut with a knife. Or, they may be ductile and deform readily under stress as does gold.

Density

It is a well-defined physical property measured in g/cm3.a Most silicates of light element have densities in the range 2.6 to 3.5. Sulfides are typically 5 to 6. Iron metal about 8, lead about 13, gold about 19, and osmium, the densest substance, and a native element mineral, is 22. Density may be measured by measuring the volume, usually by displacing water in a graduated cylinder, and the mass. Specific gravity is very similar to density, but is a dimensionless quantity and is measured in a slightly different way. Specific gravity is measured by determining the weight in air (Wa) and the weight in water (Ww) and computing specific gravity from SG = Wa / (Wa-Ww). In practice this is done using a Jolly balance as we will see in lab.

Hardness

HARDNESS: Hardness of mineral depends on chemical composition determined by rubbing or scratching a mineral of unknown hardness against one of known hardness. It is usually tested by seeing if some standard minerals are able to scratch others. A standard scale was developed by Friedrich Moh's in 1812 the standard minerals making up the Moh's scale of hardness are:

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond

This scale is approximately linear up to corundum, but diamond is approximately 5 times harder than corundum.

Unique Properties

A few minerals may have easily tested unique properties that may greatly aid identification. For example, halite (NaCl) (common table salt) and sylvite (KCl) are very similar in most of their physical properties, but have a distinctly different taste on the tongue, with sylvite having a more bitter taste. Whereas it is not recommended that students routinely taste mineral specimens (some are toxic), taste can be used to distinguish between these two common minerals.

Another unique property that can be used to distinguish between otherwise similar back opaque minerals is magnetism. For example, magnetite (Fe_3O_4), Ilmenite ($FeTiO_3$), and pyrolusite (MnO_2) are all dense, black, opaque minerals which can easily be distinguished by testing the magnetism with a magnet. Magnetite is strongly magnetic and can be permanently magnetized to form a lodestone; Ilmenite is weakly magnetic; and pyrolusite is not magnetic at all.

Classification of Minerals

It has constant physical property which are used in the identification of mineral in the field, it can be divided into 2 groups

Rock forming mineral: Found in abundance of earth crust

Ore forming minerals: Economic valuable mineral.

Minerals are classified on their chemistry, particularly on the anionic element or polyanionic group of elements that occur in the mineral. An anion is a negatively charge atom, and a polyanion is a strongly bound group of atoms consisting of a cat-ion plus several anions (typically oxygen) that has a net negative charge. For example carbonate, $(Co_3)^2$-, silicate, $(Sio_4)^4$- are common poly anions. This classification has been successful because minerals rarely contain more than one anion or polyanion, whereas they typically contain several different cat-ions.

Native elements: The first group of minerals is the native elements, and as pure elements, these minerals contain no anion or polyanion. Native elements such as gold (Au), silver (Ag), copper (Cu), and platinum (Pt) are metals, graphite is a semi-metal, and diamond (C) is an insulator.

Sulfides: The sulfides contain sulfur (S) as the major "anion". Although sulfides should not be considered ionic, the sulfide minerals rarely contain oxygen, so these minerals form a chemically distinct group. Examples are pyrite (FeS_2), Sphalerite (ZnS), and galena.

Halides: The halides contain the halogen elements (F, Cl, Br, and I) as the dominant anion. These minerals are ionically bonded and typically contain cat-ions of alkali and alkaline earth elements (Na, K, and Ca). Familiar examples are halite (NaCl) (rock salt) and fluorite (CaF_2).

Oxides: The oxide minerals contain various cat-ions (not associated with a polyanion) and oxygen. Examples are hematite (Fe2O3) and magnetite (Fe3O4).

Hydroxides: These minerals contain the polyanion OH- as the dominant anionic species. Examples include brucite (Mg $(OH)_2$) and gibbsite ($Al(OH)_3$).

Carbonates: The carbonates contain Co_3^{2-} as the dominant polyanion in which C^{4+} is surrounded by $_3O^{2-}$ anions in a planar triangular arrangement. A familiar example is calcite (CaCO3). Because NO3- shares this geometry, the nitrate minerals such as soda niter (nitratite) ($NaNO_3$) are included in this group.

Sulfates: These minerals contain SO_4^2- as the major polyanion in which S6+ is surrounded by four oxygen atoms in a tetrahedron. Note that this group is distinct from sulfides which contain no O. A familiar example is gypsum ($CaSO_4\ 2H_2O$).

Phosphates: The phosphates contain tetrahedral PO43- groups as the dominant polyanion. A common example is apatite ($Ca_5\ (PO_4)_3(OH)$) a principal component of bones and teeth. The other trivalent tetrahedral polyanion, arsenate AsO43-, and vanadate VO43- are structurally and chemically similar and are included in this group.

Borates: The borates contain triangular BO33- or tetrahedral BO45-, and commonly both coordination's may occur in the same mineral. A common example is borax.

Silicates: This group of minerals contains SiO44- as the dominant polyanion. In these minerals the Si^{4+} cat-ion is always surrounded by 4 oxygen's in the form of a tetrahedron. Because Si and O are the most abundant elements in the Earth, this is the largest group of minerals and is divided into subgroups based on the degree of polymerization of the SiO_4 tetrahedral.

Mineral Groups:

Mineral Group	Examples
1. Oxides 2. Silicates 3. Carbonates 4. Sulphides 5. Sulphates 6. Chlorite	1. Quartz, magnetite, hematite 2. Feldspar, mica, hornblende, augite, olivine 3. Calcite, dolomite 4. Pyrites, galena, Sphalerite 5. Gypsum 6. Rock salt

Table 1. Mineral Groups

Rock forming minerals:

1. Silicate minerals: Constitute 90% of earth crust
2. Non- silicate minerals: There are 2 groups,
   A. Stable (quartz group, feldspar group)
   B. Unstable (pyroxene group, amphibole group, mica group, olivine)

Quartz Group

Quartz is found in almost every geological environment. It is a common constituent in most of the rock types and soil groups. Granite, sandstone, limestone, and most of the igneous, sedimentary, and metamorphic rocks contain quartz. Quartz contains mainly oxygen and silicon. These two constituents make upto 75 % of the earth's crust. An alternate name for the Quartz Group is the Silica Group. It is chemically inert in contact with most substances. Quartz occurs in hydrothermal veins and pegmatite. Well-formed crystals may reach several meters in length and weigh hundreds of kilograms. It has electrical properties and heat resistance that make it valuable in electronic products. Its luster, color and diaphaneity make it useful as a gemstone and also in the making of glass. It has a hexagonal crystal structure and is made of trigonal crystallized silica. Some quartz crystal structures are piezoelectric and are used as oscillators in electronic devices such as quartz clocks and radios. An amorphous (glass) SiO2, called Lechatelierite, is caused by lightning strikes in sand, distinct from typical window glass that is impure. The structure of quartz is built from SiO_4 tetrahedra which are linked by sharing each corner with another tetrahedron. In a three dimensional framework, every Si has four oxygen (O) and every ‘O’ has 2 Si as nearest neighbor. The chemical composition of quartz is nearly 100% SiO_2.

Varieties of quartz group of minerals are divided into two varieties namely

1. Crystalline varieties
2. Crypto crystalline varieties

The Crystalline varieties includes:-

1) Amethyst
2) Milky quartz
3) Rose quartz
4) Rock crystal
5) Aventurine quartz
6) Citrine
7) Smoky quartz
8) Blue quartz

Amethyst is the beautiful Violet colored quartz crystal. The color is due to the presence of the trace element of Ferric iron, which turns white when heated to 300°C (571°F), then to yellow (citrine) at 500°C (932°F), but becomes violet again if exposed to x-rays or bombarded with particles.

The Cryptocrystalline varieties includes:-

Cryptocrystalline quartz is those, which by nature, having a microscopic crystalline structure. They are: 1) Agate 2) Chalcedony 3) Carnelian 4) Jasper 5) Onyx 6) Tiger’s eye 7) ‘utilated quartz 8) Chrysoprase 9) Heliotrope 10) Flint or chert Agate is a concentric, banded, fibrous variety of quartz formed by precipitation from watery solutions in rounded cavities of volcanic rocks (geodes) . It occurs with beautiful clusters of rock crystal or amethyst at the centre.

Physical Properties of Quartz:

1. Crystal system: Hexagonal
2. Habit: Crystalline or amorphous
3. Fracture: Conchoidal
4. Hardness: 7
5. Specific gravity: 2.65-2.66(low)
6. Streak: No

Transparency: Transparent/semi-transparent/opaque

Uses:

1. Used as semi precious stone
2. Form of sand in construction

3. Used as abrasive in industries
4. Used for making watches
5. Piezoelectric crystal for frequency state

Feldspar Group

This group of minerals consists of framework tecto silicates Feldspar is the most common rock-forming mineral (~ 60% of the earth's crust). The mineral name feldspar is derived from the German words feld + spar. The word "feld" is "field" in German and "spar" is a term for light colored minerals that break with a smooth surface. The feldspars are by far the most abundant group of minerals and are found in igneous, metamorphic and many sedimentary rocks and thus can be found throughout different geological environment. It is more commonly found in igneous and metamorphic rocks. Feldspar minerals are essential components in igneous, metamorphic and sedimentary rocks, to such an extent that the classification of a number of rocks is based upon feldspar content. Feldspars are tectosilicates with every oxygen atom shared by adjacent silicon or aluminum tetrahedra.

Chemical Composition:

1) Potash feldspar $KAlSi_3O_8$
   a. Orthoclase
   b. Sanidine
   c. Microcline
2) Soda-lime feldspar $NaAlSi_3O_8$ (OR) $CaAl_2Si_2O_8$
   a. Albite
   b. Oligoclase
   c. Andesine
   d. Amarthitite
   e. Labrodorite

Physical properties of Feldspar Group

1. Potash Feldspar
a) Crystal system: Monoclinic, Triclinic
b) Habit: Tabular (crystalline)
c) Cleavage: Perfect (2- directional)
d) Fracture: Conchoidal or uneven
e) Color: White, grey, pink, green, red
f) Luster: Vitreous
g) Hardness: 6-6.5
h) Specific gravity; 2.56-2.58(low)
i) Streak: No
j) Occurrence: Igneous rock
k) Uses: Ceramics, glass, tableware, enamels, electric porcelain, false teeth

2. Orthoclase Feldspar
a) Crystal system: monoclinic
b) Color: red
c) Chemical composition: kalsi3o8
d) Microcline:
e) Crystal system: triclinic
f) Color: flesh red
g) Chemical composition: $KAlSi_8o_8$
h) Uses: ceramic semiprecious

Pyroxenes Group:

It is important group of rock forming minerals. They are commonly occur in dark colors, igneous and metamorphic rocks, they are rich in calcium, magnesium, iron, silicates It show single chain structure of silicate It is classified into orthopyroxene and clinopyroxene. It is based on internal atomic structure

Augite is a common rock-forming pyroxene mineral with formula (Ca, Na) (Mg, Fe, Al, Ti) (Si, Al) $2O^6$. The crystals are monoclinic and prismatic. Augite has two prominent cleavages, meeting at angles near 90 degrees.

Physical properties of Augite

1. Crystal system: Monoclinic
2. Habit: Crystalline
3. Cleavage: Good (Prismatic cleavage)
4. Fracture: Conchoidal
5. Color: Shades of grayish green and black
6. Luster: Vitreous
7. Hardness: 5-6
8. Specific gravity: Medium
9. Streak: White
10. Occurrence: Ferro magnesium mineral of igneous rock (dolerite)
11. Uses: Rock forming mineral
12. Composition: [(Ca, Na) (Mg, Fe, Al) (Al, Si) $2o^6$
13. Transparency: Translucent/opaque

Hypersthene is a common rock-forming ino silicate mineral belonging to the group of orthorhombic pyroxenes. Its chemical formula is (Mg, Fe)SiO3. It is found in igneous and some metamorphic rocks as well as in stony and iron meteorites. Many references have formally abandoned this term, preferring to categories this mineral as enstatite or ferrosilite.

1. Color: Gray, brown or green.
2. Luster: Vitreous to pearly. Weathered specimens can have a sub-metallic luster ("bronzite").
3. Transparency: Crystals are generally translucent and rarely transparent.
4. Crystal System: Orthorhombic

5. Crystal Habits include rare individual crystals that have a stubby prismatic habit typically massive or in coarse lamellar or fibrous aggregates.
6. Cleavage is perfect in two directions at nearly 90 degrees.
7. Fracture is uneven.
8. Hardness is 5 - 6.
9. Specific Gravity is approximately 3.4 - 3.9+ (above average for non-metallic minerals)
10. Streak is white.
11. Other Characteristics: Index of refraction is approximately 1.69 - 1.77.
12. Associated Minerals include iron and stony meteorites, olivine, biotite, quartz, feldspars such as Labrodorite and certain types of garnets such as almandine.
13. Notable Occurrences include the North Creek, New York, USA and Labrador, Canada.
14. Best Field Indicators are color, crystal habit, hardness, cleavage, index of refraction and luster.

Amphibole Group:

Amphibole is an important group of ino silicate minerals, forming prism or needlelike crystals, composed of double chain Sio_4 tetrahedra, linked at the vertices and generally containing ions of iron and/or magnesium in their structures. Amphiboles can be green, black, colorless, white, yellow, blue, or brown. These are closely related to pyroxene group It shows double chain silicate structure Rich in calcium, magnesium, iron oxide and Mn, Na, K and H.

Hornblende is a group name used to describe Ferro-hornblende and Magnesio-hornblende, but the term is generally more inclusive for all calcium aluminum amphiboles. (Hornblende is frequently also used to describe any dark, opaque amphibole mineral without individual analysis.) The individual Hornblende minerals appear very similar and can be virtually indistinguishable without complex analysis, and are often just grouped under a Hornblende label without further distinguishing.

Physical Properties of Hornblende: (Compound-Complex Silicate)

1. Crystal system: Monoclinic
2. Habit: Crystalline
3. Cleavage: Good (prismatic)
4. Fracture: Conchoidal
5. Color: Dark green, dark brown black
6. Luster: Vitreous
7. Hardness: 5 to 6
8. Specific gravity: 3 to 3.5 (medium)
9. Streak: Colorless or white
10. Composition: Hydrous silicates of Ca, Na, Mg, Al
11. Transparency: Translucent/opaque
12. Occurrence: Found in igneous rocks
13. Uses: Road material

Mica Group:

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

Classification of Mica

1. Light Mica:
   a) Muscovite-KAl_2 $(AlSi_2O_{10})(OH)_2$-Potash mica
   b) Paragonite-$NaAl_2$ $(AlSi_3O_{10})$ $(OH)_2$-Sodamica
   c) Lepidolite-KLiAl (Si_4O_{10}) $(OH)_2$ –Lithiummica
2. Dark Mica:
   a) Biotite-K $(Mg, Fe)_3(AlSi3O10)(OH)_2$.(Fe Mg mica)
   b) Phogopite-KMg_3 (Al3Si3O10)(OH)2-(Mg mica)
   c) Zinwaldite-Complex Li-Fe mica

Physical Properties of Mica

1. Crystal system: Monoclinic
2. Hardness: 2-3
3. Luster: Vitreous
4. Habit: Foliated
5. Cleavage: Perfect (basal)

Physical Properties of Muscovite Mica:

1. Crystal system: Monoclinic
2. Hardness: 2-3
3. Luster: Vitreous
4. Habit: Foliated
5. Cleavage: Perfect
6. Specific gravity: 2.7-
7. Streak: Colorless
8. Composition: kal_2 $(Alsi_2o_{10})(OH)_2$
9. Occurrence: In igneous rock (granite and pegmatite) and accessory mineral in sedimentary rock
10. Uses: Electrical industry
11. Transparency: Transparent
12. Fracture: Even
13. Color: Colorless

Physical Properties of Biotite:

1. Crystal System: Monoclinic
2. Habit: Foliated
3. Cleavage: Perfect
4. Fracture: Even

5. Color: Black, deep green
6. Luster: Vitreous
7. Hardness: 2.5-3
8. Sp.Gravity: 2.7-3
9. Streak: Colorless
10. Composition: $(Mg\ Fe)_3(Al\ Si3O_{10})(OH)_2$
11. Occurrence: Commonly found in igneous rocks, sedimentary rocks
12. Transparency: Translucent
13. Uses: Electrical industries

Carbonate Mineral:

Calcite:

1. Crystal system: Hexagonal
2. Habit: Tabular
3. Cleavage: Perfect
4. Fracture: Even
5. Color: Milky white, grey, green, yellow, colorless etc
6. Luster: Vitreous
7. Hardness: 3
8. Sp. Gravity: 2.71(low)
9. Streak: Colorless
10. Composition: $CaCO3$
11. Transparency: Transparent
12. Uses: Used for manufacture of cement and lime it is also used as fertilizer
13. Occurrence: Rocking forming mineral in sedimentary rocks.

Clay Mineral Group:

Clay is a finely-grained natural rock or soil material that combines one or more clay minerals with possible traces of quartz ($SiO2$), metal oxides (Al_2O_3, MgO etc.) and organic matter. Clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure. Clays are plastic due to particle size and geometry as well as water content, and become hard, brittle and non–plastic upon drying or firing

Clay minerals include the following groups:

Kaolin group which includes the minerals kaolinite, dickite, halloysite, and nacrite (polymorphs of $Al_2Si_2O_5(OH)_4$).

Smectite group which includes dioctahedral smectites such as montmorillonite, nontronite and beidellite and trioctahedral smectites for example saponite.

Illite group which includes the clay-micas. Illite is the only common mineral Chlorite group includes a wide variety of similar minerals with considerable chemical variation.

Physical Properties of Kaolin Group:

Kaolinite:

1. It is formed by weathering of Aluminate- silicate minerals. The feldspar rick rocks are commonly weathered to kaolinite.
2. Crystal system: Triclinic
3. Habit: Massive
4. Color: White sometimes brown
5. Cleavage: Perfect
6. Fracture: Even
7. Streak: White
8. Luster: Dull earthy
9. Hardness: 2
10. Specific gravity: 2.6(low)
11. Transparency: Translucent
12. Composition: $Al_2Si_2O_5(OH)_4$
13. Occurrence: secondary mineral formed by alternation of alkali feldspar
14. Uses: ceramic industries, medicine, cosmetics and main components in porcelain

Physical Properties of Smectite Groups:

Montmorillonite:

1. It is derived from weathering of volcanic ash In contact with water it expands several times its original volumes act as drilling mud and it is main constituents as patronize
2. Crystal system: Monoclinic
3. Habit: Lamellar/ Globular
4. Color: White, blue or yellow
5. Streak:
6. Luster: Dull Earthy
7. Fracture: Uneven
8. Cleavage: Perfect
9. Hardness: 1-2
10. Sp. Gravity: 1.7-2(low)
11. Transparency: Translucent
12. Composition: $(Na, Ca)\ 0.33(Al\ Mg)_2 Si_4O_{10}(OH)_{2.nH2O}$
13. Occurrence: derived from volcanic ash also weathering of muscovite, illite, kaolinite
14. Uses: Mainly used for oil industry (drilling mud)

Physical Properties of illite:

The illite clay has a structure similar to that of muscovite. They form by alternate minerals like muscovite and feldspar.

9) Chemical composition: $(K, H)\ Al_2(Si\ Al)_4O_{10}(OH)_2 XH_2O$

10) Uses: in oil industry
11) Crystal system: Foliated Monoclinic
12) Habit: Foliated
13) Color: Grey, Green
14) Streak: White
15) Cleavage: Good
16) Fracture: Even
17) Luster: Vitreous
18) Sp. Gravity: Low
19) Hardness: 2-3

Crystallography: - Crystallography is the experimental science of determining the arrangement of atoms in crystalline solids.

Crystal: A crystal is defined as a solid body bounded by plane natural surfaces, which are the external expression of a regular arrangement of its constituent atoms or ions (Berry, Mason and Dietrich 1983).

Unit Cell – This is a pattern that yields the entire pattern when translated repeatedly without rotation in space. The repetition yields infinite number of identical unit cells and the pattern is regular. In order to fill space without gaps, the unit cell must at least be a parallelogram in 2D (2-dimensional) space.

Symmetry Elements: Symmetry is the most important of all properties in the identification of crystalline substances. In this section we shall be concerned with the symmetrical arrangement of crystal faces, an arrangement which reflects the internal symmetry of the lattice. Symmetry may be described by reference to symmetry planes, axes, and the centre of symmetry as discussed here below.

1. Plane of Symmetry – This is defined as a plane along which the crystal may be cut into exactly similar halves each of which is a mirror image of the other. A crystal can have one or more planes of symmetry. A sphere for example has infinite planes of symmetry.

2. Axis of Symmetry – This is a line about which the crystal may be rotated so as to show the same view of the crystal more than once per revolution, e.g. a cube. Alternatively it can be defined as a line along which the crystal may be rotated such that the crystal assumes a position of congruence i.e. the crystal presents the same appearance to a fixed observer.

3. Center of Symmetry – Center of symmetry is the point from which all similar faces are equidistant. It is a point inside the crystal such that when a line passes through it, you'll have similar parts of the crystal on either side at same distances. A cube possesses a centre of symmetry.

Crystal system: - In crystallography, the terms crystal system, crystal family, and lattice system each refer to one of several classes of space groups, lattices, point groups, or crystals. Informally, two crystals are in the same crystal system if they have similar symmetries, although there are many exceptions to this.

Crystal systems, crystal families and lattice systems are similar but slightly different, and there is widespread confusion between them: in particular the trigonal crystal system is often confused with the Rhombohedral lattice system, and the term "crystal system" is sometimes used to mean "lattice system" or "crystal family".

1. Triclinic, also known as anorthic, is a crystal system with the lowest symmetry. In this system there are no restrictions on angles or sides.

1. $a \neq b \neq c$
2. $\alpha \neq \beta \neq \gamma$

2. Monoclinic crystal system introduces a restriction on two of the angles. Now α and γ must equal to 90°. This makes the b side the symmetry unique axis.

1. $a \neq b \neq c$
2. $\alpha = \gamma = 90°$ and $\beta \neq 90°$

3. In the Orthorhombic crystal system, all the angles must be 90°. The sides, on the other hand, can change independently of each other.

1. $a \neq b \neq c$
2. $\alpha = \beta = \gamma = 90°$

4. In the Tetragonal crystal system we introduce yet another restriction. Now, not only do all the angles have to equal 90°, but the two sides a and b have to be the same length too. This makes the c side a symmetry unique axis.

1. $a = b \neq c$
2. $\alpha = \beta = \gamma = 90°$

5. For the Trigonal, also known as Rhombohedral, crystal system, the length of the sides and the angles are equal, but the shape of the cell is harder to visualize.

1. $a = b = c$
2. $\alpha = \beta = \gamma \neq 90°$

6. The Hexagonal crystal system can be visualized as a prism with hexagons as the bases. In order to describe it in terms of a, b, c and the three angles, we introduce restrictions such as γ must equal 120°.

1. $a = b \neq c$
2. $\alpha = \beta = 90°$ and $\gamma = 120°$

****

Unit 3

Petrology: rock cycle, composition, classification and structures of igneous, sedimentary and metamorphic rocks of civil engineering importance, study of common rock types, brief geological history of India.

Petrology is the branch of geology that studies rocks and the conditions under which they form. Petrology has three subdivisions: igneous, metamorphic, and sedimentary petrology.

Rock cycle

The rock cycle is a basic concept in geology that describes the time-consuming transitions through geologic time among the three main rock types: sedimentary, metamorphic, and igneous.

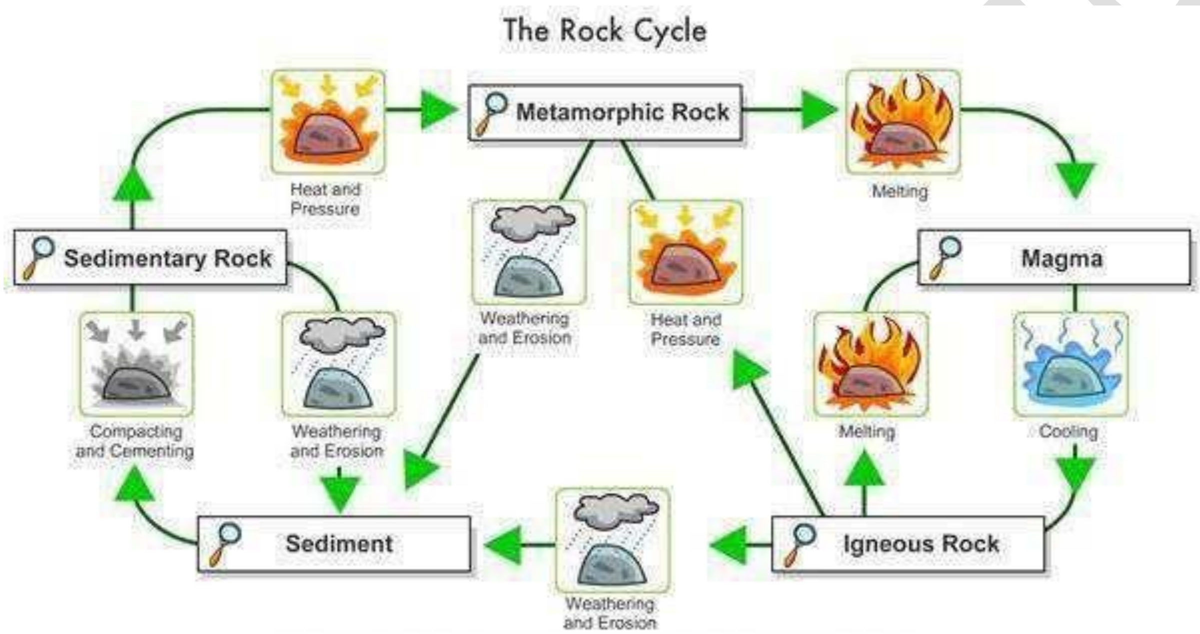


Fig. 6 Rock Cycle

The Rock Cycle is a group of changes. Igneous rock can change into sedimentary rock or into metamorphic rock. Sedimentary rock can change into metamorphic rock or into igneous rock. Metamorphic rock can change into igneous or sedimentary rock.

Igneous rock forms when magma cools and makes crystals. Magma is a hot liquid made of melted minerals. The minerals can form crystals when they cool. Igneous rock can form underground, where the magma cools slowly. Or, igneous rock can form above ground, where the magma cools quickly.

When it pours out on Earth's surface, magma is called lava. Yes, the same liquid rock matter that you see coming out of volcanoes.

On Earth's surface, wind and water can break rock into pieces. They can also carry rock pieces to another place. Usually, the rock pieces, called sediments, drop from the wind or water to make a layer. The layer can be buried under other layers of sediments. After a long time the sediments can be cemented together to make sedimentary rock. In this way, igneous rock can become sedimentary rock.

All rock can be heated. But where does the heat come from? Inside Earth there is heat from pressure (push your hands together very hard and feel the heat). There is heat from friction (rub your hands together and feel the heat). There is also heat from radioactive decay (the process that gives us nuclear power plants that make electricity).

Baked rock does not melt, but it does change. It forms crystals. If it has crystals already, it forms larger crystals. Because this rock changes, it is called metamorphic. Remember that a caterpillar changes to become a butterfly. That change is called metamorphosis. Metamorphosis can occur in rock when they are heated to 300 to 700 degrees Celsius.

When Earth's tectonic plates move around, they produce heat. When they collide, they build mountains and metamorphose (met-ah-MORE-foes) the rock.

The rock cycle continues. Mountains made of metamorphic rocks can be broken up and washed away by streams. New sediments from these mountains can make new sedimentary rock.

Classification of Rocks

This classification is based on the mode or process of formation of a rock. Thus, some rocks may be formed from natural hot molten materials. Others may be formed at ordinary temperatures from compaction of particles or sediments, and still. Therefore, in the geological classification of rocks following three types of rocks are recognized.

(I) Igneous Rocks:

All those rocks that have been formed by cooling and crystallization from an originally hot and molten material are grouped as Igneous Rocks. They are the most abundant rocks of the crust depth-wise. The hot molten material occurs below the surface of the earth and is known as Magma. Quite Often, it erupts out at the surface as Lava from cracks in the crust called volcanoes. Magma may cool and crystallize below the surface and change it into solid rocks. Similarly, lava flowing over the surface (even underwater in oceans) may also change it into rocks.

Three different types of igneous rocks are thus formed:

1) Plutonic: Formed at great depths, generally from 210 km below the surface. These have coarse crystals.

Examples: Granites, Syenite', Gabbros.

2) Hyppabyssal: Formed at the intermediate depth below the surface generally up to 2 km. These have mixed characters.

Examples: Porphyries of various types.

Note: The platonic and Hyppabyssal are sometimes grouped as intrusive rocks

3) Volcanic: These are formed on the surface of the earth, even underwater in oceans from the cooling of lava from volcanoes. They are also called extrusive rocks and are commonly made up of very fine crystals.

Examples: Basalts and Traps.

(II) Sedimentary Rocks:

These Types of Rocks are also called secondary rocks. The existing rocks on the surface of the earth are being broken into smaller particles by the natural process of decay and decomposition called weathering and erosion. Atmospheric gases, temperature variation, wind, water, and ice are some natural agencies which break the existing rocks into small fragments and sediments. These particles are then carried away and deposited at other places such as at sea-bed, lake-bed, and river-bed and so on. Gradually, the accumulated particles get compressed and compacted under their own load and are thereby transformed into rock-solid cohesive masses of particles.

In some cases, the particles may be bound together by some natural cementing material; with or without any pressure. These are also sedimentary rocks. In seas and oceans, a large number of sea-organisms live and die. Their hard parts also accumulate at the sea-bed and are gradually transformed into rocks. Since the particles in such rocks are derived from organisms, they are called organically formed sedimentary rocks in comparison to the mechanically formed sedimentary rocks of the first type. The third category of sedimentary rocks is formed due to chemical processes like evaporation and precipitation. Naturally, they are designated as chemically formed sedimentary rocks. The sedimentary rocks are very widespread, area wise, on the surface of the earth. Depth-wise, however, they form only a small proportion of the crust. Common sedimentary rocks are Sandstones, Quartzite, Limestone's, Dolomites, and Shale's.

(III) Metamorphic Rocks:

This rock type is originally either igneous rocks or sedimentary rocks which have undergone some change in their structure, shape or composition. The change might have been due to an increase in temperature or pressure or both. Sometimes, the change is due to some chemically active fluids that act on the pre-existing rocks.

The nature of change in the rock will depend on;

- **(i) The nature of existing rock.**
- **(ii) The type of factors operating on the rock (temperature, pressure, fluids).**
- **(iii) The intensity of factors.**
- **(iv) The duration of action.**

Very interesting new rock type may be formed from pre-existing igneous or sedimentary rocks depending upon the above conditions.

1. **Thus limestone, a sedimentary rock, may change to a variety of Marbles.**
2. **Similarly, sandstone, again a sedimentary rock, may change into a very hard Quartzite.**
3. **Granite (igneous rock) changes to Gneiss and shale, a sedimentary rock, into the so well known metamorphic rock Slate.**
4. **Another very important fundamental fact about these metamorphic changes in rocks is that they all take place essentially in a solid state.**
5. **The original rocks are heated and compressed but seldom melted. (Once melted and recrystallized, they form igneous and not metamorphic rocks).**
6. **Distinction between Igneous, Sedimentary and Metamorphic rocks.**

1- Formation

Igneous rock is formed through the cooling and solidification of magma or lava. Igneous rock may form with or without crystallization, either below the surface as intrusive (plutonic) rocks or on the surface as extrusive (volcanic) rocks.

Sedimentary Rocks formed by the deposition of material at the Earth's surface and within bodies of water. Sedimentation is the collective name for processes that cause mineral and/or organic particles (detritus) to settle and accumulate or minerals to precipitate from a solution.

2- Abundance on the earth crust

The sedimentary rock cover of the continents of the Earth's crust is extensive, but the total contribution of sedimentary rocks is estimated to be only 8% of the total volume of the crust.

Igneous and metamorphic rocks make up 90–95% of the top 16 km of the Earth's crust by volume.

3-Mineralogical contents

Felsic Igneous rock, highest content of silicon, with predominance of quartz, alkali feldspar and/or feldspathoids the felsic minerals; these rocks (e.g., granite, rhyolite) are usually light colored, and have low density. While mafic Igneous rock, lesser content of silicon relative to felsic rocks, with predominance of mafic minerals pyroxenes, olivines and calcic plagioclase; these rocks (example, basalt, gabbro) are usually dark colored, and have a higher density than felsic rocks, ultramafic rock, lowest content of silicon, with more than 90% of mafic minerals.

Most sedimentary rocks contain either quartz (especially Siliciclastic rocks) or calcite (especially carbonate rocks). In contrast with igneous and metamorphic rocks, a sedimentary rock usually contains very few different major minerals. However, the origin of the minerals in a sedimentary rock is often more complex than those in an igneous rock. Minerals in a sedimentary rock can have formed by precipitation during sedimentation or digenesis. In the second case, the mineral precipitate can have grown over an older generation of cement.

4- fossils

Among the three major types of rock, fossils are most commonly found in sedimentary rock. Unlike most igneous and metamorphic rocks, sedimentary rocks form at temperatures and pressures that do not destroy fossil remnants. Often these fossils may only be visible when studied under a microscope (microfossils).

5- Structures

Structures in sedimentary rocks can be divided into 'primary' structures (formed during deposition) and 'secondary' structures (formed after deposition). Structures are always large-scale features that can easily be studied in the field.

The structures of igneous rocks are large scale features, which are dependent on several factors like: (a) Composition of magma. (b) Viscosity of magma. (c) Temperature and pressure at which cooling and consolidation takes place. (d) Presence of gases and other volatiles.

6- Classification

Igneous rocks are classified according to mode of occurrence, texture, mineralogy, chemical composition, and the geometry of the igneous body.

Based on the processes responsible for their formation, sedimentary rocks can be subdivided into four groups: Clastic sedimentary rocks, biochemical (or biogenic) sedimentary rocks, chemical sedimentary rocks and a fourth category for "other" sedimentary rocks formed by impacts, volcanism, and other minor processes.

7- Importance

Sedimentary rocks host large deposits of SEDEX ore deposits of lead-zinc-silver, large deposits of copper, deposits of gold, tungsten, Uranium, and many other precious minerals, gemstones and industrial minerals including heavy mineral sands ore deposits. Petroleum geology relies on the capacity of sedimentary rocks to generate deposits of petroleum oils. Coal and oil shale are found in sedimentary rocks. A large proportion of the world's uranium energy resources are hosted within sedimentary successions. Sedimentary rocks contain a large proportion of the Earth's groundwater aquifers. Our understanding of the extent of these aquifers and how much water can be withdrawn from them depends critically on our knowledge of the rocks that hold them (the reservoir).

Many types of igneous rocks are used as building stone, facing stone and decorative material, such as that used for tabletops, cutting boards, and carved figures. Pumice is used as an abrasive material in hand soaps, emery boards, etc.

Description, occurrence, engineering properties, distribution and uses

1. Granit: It’s a common type of felsic intrusive igneous rock that is granular and phaneritic in texture. Granites can be predominantly white, pink, or gray in color, depending on their mineralogy.

Occurrence: Granite containing rock is widely distributed throughout the continental crust. Much of it was intruded during the Precambrian age; it is the most abundant basement rock that underlies the relatively thin sedimentary veneer of the continents. Outcrops of granite tend to form rounded massifs. Granites sometimes occur in circular depressions surrounded by a range of hills, formed by the metamorphic aureole or hornfels. Granite often occurs as relatively small, less than 100 km2 stock masses (stocks) and in batholiths that are often associated with orogenic mountain ranges. Small dikes of granitic composition called aplites are often associated with the margins of granitic intrusions. In some locations, very coarse-grained pegmatite masses occur with granite.

Uses: Engineers have traditionally used polished granite surface plates to establish a plane of reference, since they are relatively impervious and inflexible. Sandblasted concrete with a heavy aggregate content has an appearance similar to rough granite, and is often used as a substitute when use of real granite is impractical.

2. Diabase (/ˈdaɪ.əbeɪs/) or dolerite or microgabbrois: A mafic, holocrystalline, sub volcanic rock equivalent to volcanic basalt or plutonic gabbro. Diabase dikes and sills are typically shallow intrusive bodies and often exhibit fine grained to aphanites chilled margins which may contain tachylite (dark mafic glass).

Diabase is the preferred name in North America, yet dolerite is the preferred name in most of the rest of the world, where sometimes the name dia base is applied to altered dolerites and basalts. Many petrologists prefer the name micro gabbro to avoid this confusion.

Uses: These are used as construction stone, or polished and used as architectural stone. Diorite was used as a structural stone by the Inca and Mayan civilizations of South America and by many ancient civilizations in the Middle East.

3. Sandstone is a Clastic sedimentary rock composed mainly of sand-sized (0.0625 to 2 mm) mineral particles or rock fragments. Most sandstone is composed of quartz or feldspar (both silicates) because they are the most resistant minerals to weathering processes at the Earth's surface, as seen in Bowen's reaction series. Like un-cemented sand, sandstone may be any color due to impurities within the minerals, but the most common colors are tan, brown, yellow, red, grey, pink, white, and black. Since sandstone beds often form highly visible cliffs and other topographic features, certain colors of sandstone have been strongly identified with certain regions. Rock formations that are primarily composed of sandstone usually allow the percolation of water and other fluids and are porous enough to store large quantities, making them valuable aquifers and petroleum reservoirs. Fine-grained aquifers, such as sandstones, are better able to filter out pollutants from the surface than are rocks with cracks and crevices, such as limestone or other rocks fractured by seismic activity.

Uses: Sandstone was a popular building material from ancient times. It is relatively soft, making it easy to carve. It has been widely used around the world in constructing temples, homes, and other buildings. It has also been used for artistic purposes to create ornamental fountains and statues.

Origin: Sandstones are Clastic in origin (as opposed to either organic, like chalk and coal, or chemical, like gypsum and jasper). They are formed from cemented grains that may either be fragments of a pre-existing rock or be mono-minerallic crystals. The cements binding these grains together are typically calcite, clays, and silica. Grain sizes in sands are defined (in geology) within the range of 0.0625 mm to 2 mm (0.0025–0.08 inches). Clays and sediments with smaller grain sizes not visible with the naked eye, including siltstones and shales, are typically called argillaceous sediments; rocks with larger grain sizes, including breccias and conglomerates, are termed rudaceous sediments.

4. Limestone is a sedimentary rock, composed mainly of skeletal fragments of marine organisms such as coral, and molluscs. Its major materials are the minerals calcite and aragonite, which are different crystal forms of calcium carbonate ($CaCO_3$).About 10% of sedimentary rocks are limestone's. The solubility of limestone in water and weak acid solutions leads to karst landscapes, in which water erodes the limestone over thousands to millions of years. Most cave systems are through limestone bedrock.Limestone has numerous uses: as a building material, an essential component of concrete (Portland cement), as aggregate for the base of roads, as white pigment or filler in products such as toothpaste or paints, as a chemical feedstock for the production of lime, as a soil conditioner, or as a popular decorative addition to rock gardens.

Uses: Limestone is very common in architecture, especially in Europe and North America. Many landmarks across the world, including the Great Pyramid and its associated complex in Giza, Egypt, were made of limestone. So many buildings in Kingston, Ontario, Canada were, and continue to be, constructed from it that it is nicknamed the 'Limestone City'. On the island of Malta, a variety of limestone called Globigerina limestone was, for a long time, the only building material available, and is still very frequently used on all types of buildings and sculptures. Limestone is readily available and relatively easy to cut into blocks or more elaborate carving. Ancient American sculptors valued limestone because it was easy to work and good for fine detail. Going back to the Late Pre-classic period (by 200–100 BCE), the Maya civilization (Ancient Mexico) created refined sculpture using limestone because of these excellent carving properties.

5. Laterite: Soil layer that is rich in iron oxide and derived from a wide variety of rocks weathering under strongly oxidizing and leaching conditions. It forms in tropical and subtropical regions where the climate is humid. Lateritic soils may contain clay minerals; but they tend to be silica-poor, for silica is leached out by waters passing through the soil. Typical laterite is porous and claylike. It contains the iron oxide minerals goethite, $HFeO_2$; lepidocrocite, FeO (OH); and hematite, Fe2O3. It also contains titanium oxides and hydrated oxides of aluminum, the most common and abundant of which is gibbsite, Al2O3•3H2O. The aluminum-rich representative of laterite is bauxite.

6. Gneiss: Gneiss is a foliated metamorphic rock made up of granular mineral grains. It contains a lot of feldspar minerals and bands of quartz and sometimes mica. It normally has a banded appearance and is sort of laminated. It appears similar to granite.

7. Marble: Marble is among the non-foliated metamorphic rocks produced from the metamorphism of dolostone or limestone. It takes high polish and is often used for sculpture and as building material. Marble is mainly composed of calcium carbonate.

Uses: Slabs and blocks of marble are used for stair treads, floor tiles, facing stone, cemetery stones, window sills, ashlars, sculptures, benches, paving stones and many other uses some marble is heated in a kiln to drive off the carbon dioxide that is contained within the calcite.

8. Schist: Schist is a foliated metamorphic rock that is well developed and contains substantial amounts of mica. Because of the high concentrations of mica, schist can readily split into thin layers. Geologists say it represents the intermediate metamorphic grade between gneiss and Phyllite. Sometimes schist might contain high amounts of chlorite.

9. Slate: Slate is a low-grade and fine-grained metamorphic rock that can be separated into thin pieces. It is a type of foliated metamorphic rock that is produced by the metamorphism of shale. Slates are predominantly realigned clay minerals.

10. Quartzite: Quartzite is a hard metamorphic rock consisting essentially of interlocking quartz crystals. It is a non-foliated metamorphic rock formed during the metamorphism of sandstone.

Uses: Because of its hardness and angular shape, crushed quartzite is often used as railway ballast. Quartzite is a decorative stone and may be used to cover walls, as roofing tiles, as flooring, and stair steps. Its use for countertops in kitchens is expanding rapidly. It is harder and more resistant to stains than granite. Crushed quartzite is sometimes used in road construction. High purity quartzite is used to produce ferrosilicon, industrial silica sand, silicon and silicon carbide. During the Paleolithic quartzite was used, in addition to flint, quartz, and other lithic raw materials, for making stone tools.

Brief geological history of India

Theories related to the origin of the Earth have put forth various intuitions such as one that said the earth originated from the sun. It was earlier a hot gaseous mass which on cooling first turned into a liquid and then a solid. This was the gaseous hypothesis put

A more popular theory was proposed by Laplace known as the Nebular hypothesis. This proposed that the Earth was formed from the solidification of a ring thrown away by a cooling and rotating Sun. This ring was one of the several ones that condensed to form the various planets.

Another theory known as the Tidal hypothesis put forth by Jenny and Jeffrey's assumes the presence of two nebulas instead of one as assumed by Laplace. According to this theory a large nebula wandering in space came close to a smaller nebula. As the larger nebula wandered away from the smaller one, the matter rising in the form of a tidal wave from the smaller nebula was pulled towards it. This matter was pulled so much away from the smaller nebula that it could not go back to the parent nebula.

However it could not follow the larger nebula also and as the larger nebula pulled away, the matter was detached from the smaller nebula. On cooling the matter condensed to form the planets and they started revolving around the sun. This hypothesis is more closer to reality due to the structure of our solar systems with smallest planets located far away from the sun and larger ones located at intermediate positions.

200 million years ago India was a part of Gondwana. Indian peninsular block is a fusion of three blocks Aravali, Singbhum and Dharwad.

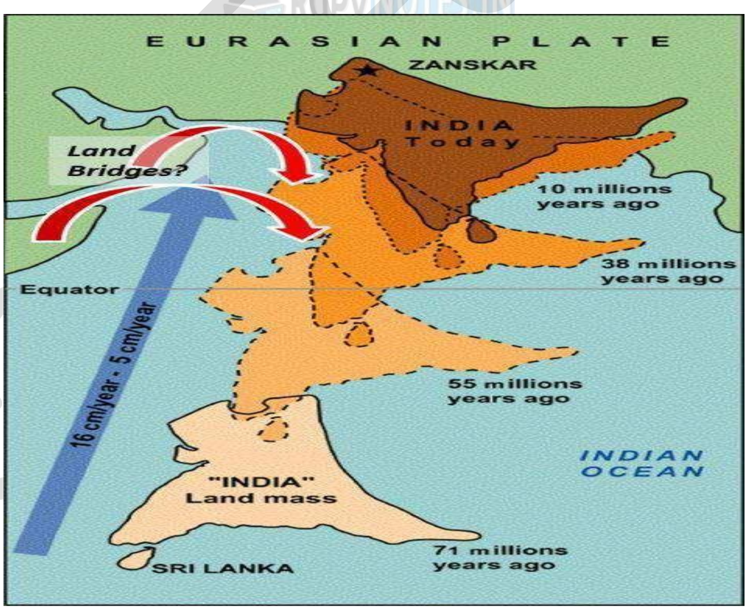


Fig 7: Gondwanaland and India

Indian plate tectonics

The Aravallis, Satpudas, Eastern Ghats, Vindhyans and Bijjawals are remnants of it. Rift valleys which are formed are Godavari, Mahanadi, and Damodar towards the Bay of Bengal. The Narmada and son rift valleys are towards the Arabian Sea. Rift valley and peninsular blocks

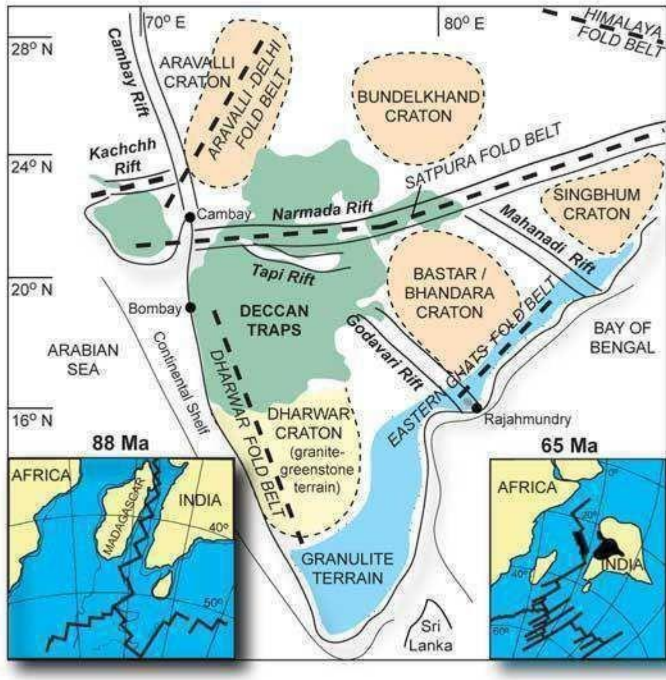


Fig 8: Rift valleys and Peninsular block

The Indian plate separated from Gondwana and then Madagascar. It moved over Reunion Island and due to hotspot volcanism developed the Deccan lava plateau. The collision between Indian plate and Eurasian plate led to formation of Himalayas.

Archaen Formation (Pre Cambrian)

Geologically, the subcontinent of India was a part of the Gondwanaland (the Southern Continent). The geological history of India is described in the below sections:

Archaen Formation (Pre Cambrian)

87% of the Earth's history is of this period (4.6 billion years ago till 570 million years ago). Archean means "oldest rocks of the Earth's crust". This period saw the development of the Earth's atmosphere, the first photosynthesis, first chemosynthesis and formation of the life supporting atmosphere. Throughout the world the rocks of this period are called as "Fundamental Geinesses" OR "Basement complex". They are devoid of any form of life or sediment and form the core of all great fold mountain ranges of the world. The In the Peninsular region, the archaean rocks are known to be of three well-defined types:

The Bengal Gneiss

The Bengal gneiss is highly foliated. It occurs mostly in the Eastern Ghats. The Bundelkhand Gneiss it is coarse grained in structure and found mostly in southern India. It occurs mostly in Bundelkhand (UP), Baghelkhand (MP), Maharashtra, and Rajasthan.

The Nilgiri Gneiss

It is criss crossed and has quartz veins and is mostly like granite.

Dharwar System

This geologic time extends from 2500 million years ago to 1800 million years ago. These are the first metamorphosed sedimentary rock systems in Indian geological time scale.

The Dharwar rocks are highly metaliferous. They are rich in iron ore, manganese, lead, zinc, gold, silver, dolomite, mica, copper, tungsten, nickel, precious stones and building materials. Some of the important series of the Dharwar System are:

Champion Series:-

Its gold mines are one of the deepest in the world.

Champaner Series:-

It is an outlier of the Aravallis system in the vicinity of Vadodra. An attractive green variety of marble is obtained from this series

Chlipi Series:-

It occupies parts of Balaghat, Jabalpur and Chhindwara districts of Madhya Pradesh. Close pet Series, Iron-Ore Series, Khondolite Series, Rialo Series, Sakoli Series, and Sausar Series.

The Cuddapah System (The Purana Group)

The Cuddapah system is made of shales, slates, limestone and quartzite. The rocks are generally without fossils. The Cuddapah formations, named after the district of Cuddapah in Andhra Pradesh, are sedimentary-metamorphic formations.

At places the Cuddapah formations are 6000 m in thickness. The enormous thickness of these rocks indicates the Sinking of beds of the basin with growing sedimentation.

The metallic contents in the ores of Cuddapah rocks are, however, low and at places uneconomical for extraction.

The Vindhyans System

The Vindhyans System derives its name from the Vindhyans Mountain. This mountain forms a dividing line between the Ganga Plain and the Deccan Plateau.

It has enormous sedimentary deposits and at places their depth is more than 4000m. In some tracts, the Vindhyans rocks are buried under Deccan lava. The Great Boundary Fault (GBF) separates the Vindhyans System from the Aravallis for a distance of about eight hundred km

The Vindhyans system is well known for red-sandstone, sandstone, building material and raw materials for cement, chemical industries.

The historical buildings of Qutab Minar, Humayun's Tomb, Fatehpur Sikri, Agra Fort, Red Fort, Jama-Masjid, Birla Mandir, the Buddhist Stupa of Sanchi, etc. have been constructed from the red-sandstone obtained from the Vindhyans Ranges.

The Palaeozoic Group (Cambrian To Carboniferous Period)

This is known as the Dravidian Era in the Indian Geological Time Scale.

The Palaeozoic Era extends from 570 million years ago to 24.5 million years ago. It marks the beginning of life on the Earth's surface.

The formations of this period are almost absent in the Peninsular India except near Umaria in Rewa.

It was during this period that the Pangaea was broken and the Tethys Sea came into existence.

The Mesozoic Era (The Gondwana System)

The term is used for a period of geologic time in which the presence of fossil invertebrates dominated the rocks.

In the Indian Geological Time Scale, these periods extend from the Upper Carboniferous up to the beginning of the Cenozoic Era or the Aryan Era.

Most of the good quality coal deposits (bituminous and anthracite) of India are found in Gondwana formations.

The Gondwana System of rocks provides over 95% of the coal of India.

India's best and largest coal deposits are found in the Gondwana System mainly in the Damodar Valley of West Bengal, Jharkhand, the Mahanadi valley of Odisha and Chhattisgarh, the Godavari valley of Andhra Pradesh and the Satpura basin of Madhya Pradesh.

Aryan period (Beginning of the Upper Carboniferous Period)

The Upper continent of Gondwanaland developed fissures and its broken parts started drifting away from each other. The Subcontinent of India drifted towards north and north-east to collide with the Asian land mass

The Tertiary mountain building gave birth to Himalayas.

The Subcontinent of India assumed its present shape.

Evolution and spread of man in different parts of the world. The development and expansion of the Arabian Sea and the Bay of Bengal.

The Cretaceous System (The Deccan Trap)

This period is marked by the transgression of the sea (Coromandal coast, Narmada valley) and outpouring of huge quantity of lava (basalt) so as to form the Deccan Trap.

During this period, enormous quantity of basaltic lava was poured out to the surface assuming a great thickness of over 3000 m. The Lava Plateau (the Deccan Trap) is the result of that lava eruption.

The lava plateau of India (Deccan Trap) has a maximum thickness of about 3000 m along the coast of Mumbai from where it decreases towards south and east.

The Tertiary System (The Cenozoic Era)

Cenozoic means recent life. The beginning of the Tertiary Period is about 65 million years ago. Fossils in these rocks include many types, closely related to modern forms, including mammals, plants and invertebrates.

During this Period, as India collided with Tibet, the sediments which had been accumulating in the Tethys basin had begun to rise by a slow rise of ocean bottom. The upheaval of the Himalayas altered the old topography of the subcontinent.

There is enough evidence to prove that the Himalayas are still rising.

The Quaternary Period (The Pleistocene and Recent Formations)

The Northern Plains of India came into existence during the Pleistocene Period

The Pleistocene period is marked by Ice Age and glaciations on a large scale in the Northern Hemisphere. The moraine deposits and the karewa formations of Kashmir Valley are of the Pleistocene period. The river terraces of the Narmada, Tapi, Godavari, Krishna, and Kaveri, etc. are also of the Pleistocene Period.

****

Unit 4

Structural geology: dip, strike, outcrops, classification and detailed studies of geological structures i.e. Folds, Faults, Joints, Unconformity and their importance in civil engineering.

Structural Geology

As a branch of geology, it deals with 'the study of systems located in rocks'. it's also referred to as tectonic geology or simply tectonics. Structural geology is an arrangement of rocks and performs an critical position in civil engineering in the selection of appropriate sites for all forms of initiatives consisting of dams, tunnels, multistoried homes, etc. Structural geology is the look at of the three dimensional distribution of rock units with respect to their deformational histories. The number one intention of structural geology is to use measurements of gift-day rock geometries to find information approximately the history of deformation (strain) inside the rocks, and ultimately, to recognize the strain area that resulted inside the determined strain and geometries.

Structural Functions/ Attitude of beds:

a) Out crop -: The rock exposure at the floor of the earth. Outcrops permit direct remark and sampling of the bedrock in situ for geologic analysis and developing geologic maps. In situ measurements are important for correct evaluation of geological records and outcrops are therefore extremely vital for know-how the geologic time scale of earth history.

b) Contour:- a contour line (often just called a "contour") joins points of equal elevation (height) above a given level, such as mean sea level. A contour map is a map illustrated with contour lines, for example a topographic map, which thus shows valleys and hills, and the steepness or gentleness of slopes.

Types of contour lines:-

1. Index Contour Lines:- Index contour lines are accented with a heavier mark, so that these lines will be the first thing to catch your eye when you look at a topographical map. Like all contour lines, they form in concentric circles or shapes and each index contour line is evenly spaced from one line to the next. Typical intervals between contour lines might be 100 or 200 feet although greater or lesser numbers are possible. Index contour lines are marked with the elevation above sea level and they are usually figured in intervals, such as every 100 or 200 feet.

2. Intermediate Contour Lines:- Between each pair of contour lines, there exists a set of intermediate contour lines. The intermediate contour lines usually come in sets and each intermediate contour line represents an equal amount of elevation change between each line. Also important is the fact that the elevation change between one index contour line and an adjacent intermediate contour line will also be the same value as the change between two intermediate contour lines that are located next to each other.

For example, if on a map, you have your index lines placed 100 feet apart, the likely scenario is that there will be four intermediate contour lines placed between each pair of index lines. Four lines would create five spaces and to make the change equal, the gap between each line would have to represent 20 feet of elevation change. It is important to remember that intermediate and supplementary contour lines are not marked with their elevation above sea level.

3. Supplementary Contour Lines:- Supplementary contour lines are expressed as a dashed line. These lines are drawn at all one elevation, but they differ from the previous two types of lines in that their spacing or change in elevation that they represent is different. They almost always represent half the elevation change that is found between intermediate and index contour lines. Therefore, these lines are only used on topographic maps where the overall change in elevation is very gradual or slight.

c) Strike-: The fashion of the rock bed on the floor surface is strike. Strike, in geology, direction of the line formed by the intersection of a fault, mattress, or different planar function and a horizontal plane. Strike indicates the mind-set or function of linear structural features consisting of faults, beds, joints, and folds.

d) Dip-: The attitude of inclination of a rock mattress with the horizontal aircraft is called dip. It measured in a aircraft perpendicular to the stripe line.

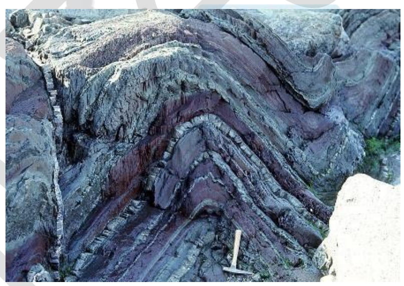
There are kinds of dip.

1. True dip: it's far a perpendicular aircraft to the strike line.

2. Apparent dip: it's far a dip measured in some other course than the true dip is known as apparent dip.

Fold

Fold may be described because the curve or zigzag shape proven via rock beds. In other wordsWavy undulation in rock beds are called folds.



Or

A geological fold occurs whilst one or a stack of originally flat and planar surfaces, together with sedimentary strata, are bent or curved because of permanent deformation. Synsedimentary folds are the ones due to slumping of sedimentary fabric before it's miles lithified.

Terms associated with FOLDING:

a) Limbs
b) Axial line
c) Axis of folds
d) Crest
e) Trough

1. Limbs:-

The sloping facets of folds from crest to trough are known as the limbs. An character fold could have no less than two limbs.

2. Axial Line:-

It's miles an imaginary plane or a floor which divides a fold into two equal halves.

3. Axis of Folds:-

An axis of fold is described as the line of intersection among the axial aircraft and the surface of any of the constituent rocks mattress.

4. Hinge Line:-

Crest is the area in which the curvature is greatest, and the limbs are the edges of the fold that dip faraway from the hinge.

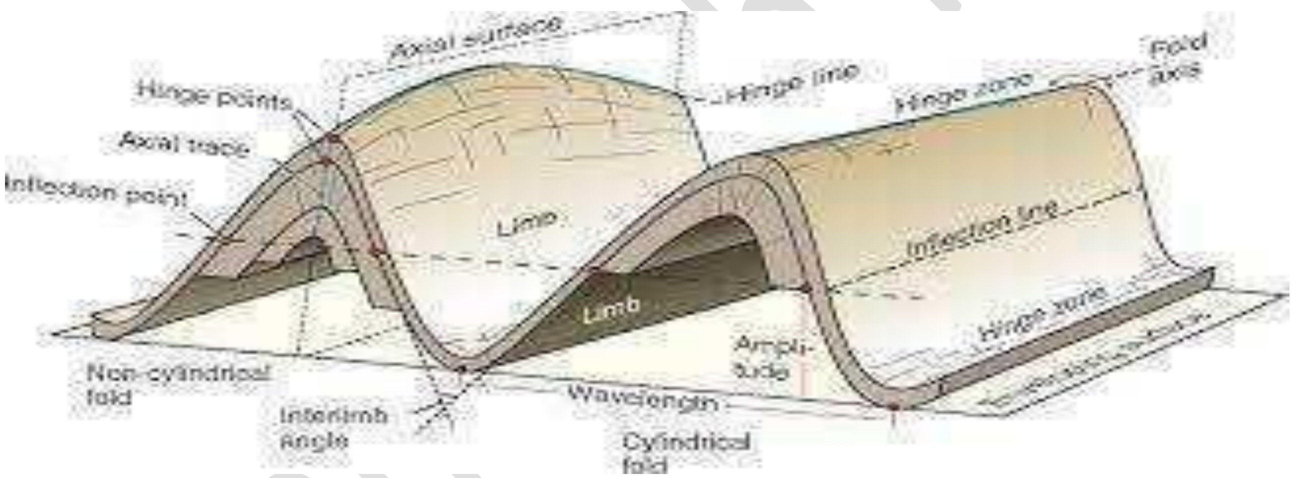
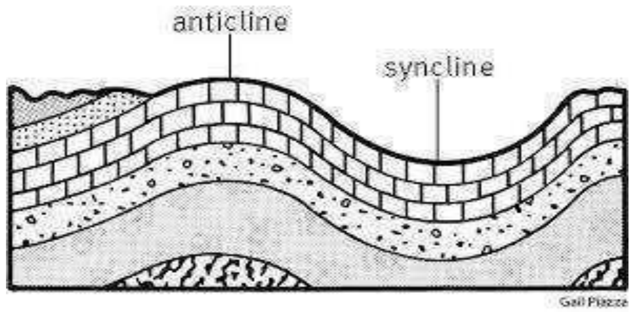


Fig. 9 Structure of Fold

Classification of Folds

1. **Fundamental category**
2. **Unique classification**
3. **Fundamental category**
   a) **Syncline: - Anticlines are folds in which every 1/2 of the fold dips away from the crest.**
   b) **Anticline: - Synclines are folds wherein every half of the fold dips towards the trough of the fold.**



Unique classification

1. **Based On The Position Of Axial Plane:**
   - a) **Symmetrical fold**
   - b) **Asymmetrical fold**
   - c) **Overturned fold**
   - d) **Recumbent fold**
   - e) **Isoclinal fold**
2. **Primarily Based On Degree Of Compression:**
   - a) **Open folds**
   - b) **Closed folds**
3. **Based Totally On Mode Of Foundation:**
   - a) **Basin**
   - b) **Dome**
   - c) **Anticlinorium**
   - d) **Synclinorium**
   - e) **Geosyncinorium**
   - f) **Geoanticlinorium**

Folds are created in rock once they enjoy compression pressure this is when the rock is being driven inward from each facet that is like in case you placed a spring among your fingers and push them together. As you push, you're compressing the spring, and rock can be compressed inside the equal manner over long periods of time. There are exceptional types of folds created via compression pressure relying on which way the rock bends.

a) A monocline is a fold in which the rock layers shape an S-form as the perimeters of the rock are compressed. you can don't forget this sort of fold because all of the layers of rock are nonetheless horizontal, entering into one direction in preference to bending vertically upward or downward like anticlines and synclines. And seeing that 'mono' method 'one,' monoclines are layers in simplest 'one course.'

b) Domes, which can be like anticlines however instead of an arch, the fold is in a dome form, like an inverted bowl. Similarly, there also are basins, which can be like synclines but once more, as opposed to a sinking arch, the fold is within the form of a bowl sinking down into the ground.

c) Symmetrical folds are folds with the same angle. This makes sense on account that symmetry approaches the identical on each facet. We can also have the opposite of symmetrical, which takes place in asymmetrical folds, or folds with one of kind angles.

d) Isoclinal folds are just like symmetrical folds; however those folds each have the identical attitude and are parallel to every other. 'Iso' means 'the identical' (symmetrical), and 'cline' way 'angle,' so this calls literally method 'same angle.' So, Isoclinal folds are both symmetrical and aligned in a parallel style.

e) Overturned folds occur when the folding is so severe that the fold appears to have turned over on itself. Further, we can have recumbent folds, which might be even more intense than overturned folds these are folds which might be almost horizontal. 'Recumbent' way 'mendacity down,' so you could think about this fold as mendacity down sideways.

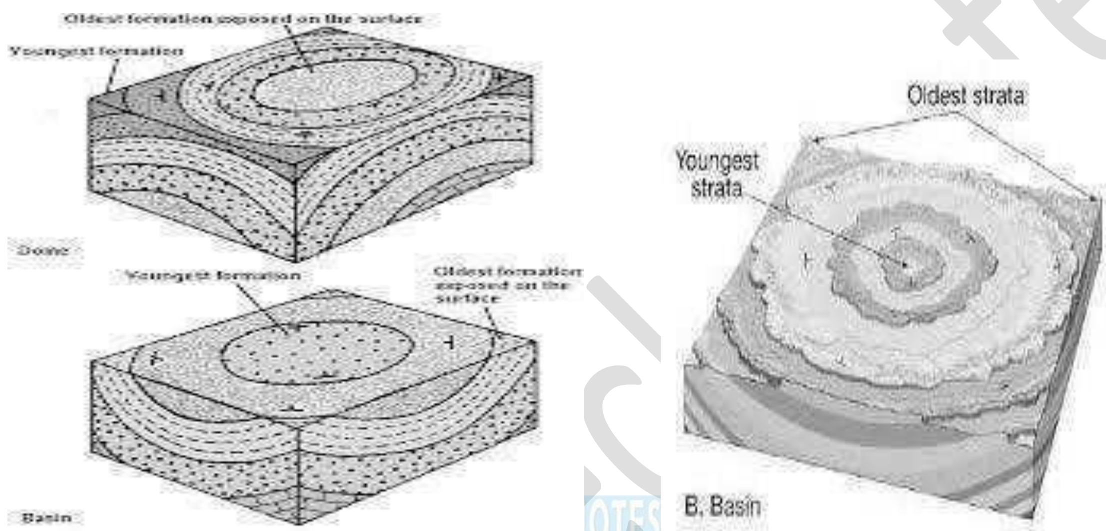


Fig. 10 Dome and Basin

Causes of Folding:

The folds arise as a result of the tectonic pressure and stress in the rocks and rather than fracture, they fold. They are easily visualized by the loss of horizontality of the strata. When tectonic forces acting on sedimentary rocks are a number of characteristic forms. Sedimentary rocks are more flexible than the metamorphic, and when the thrust is not intense enough to move them fold as if they were a piece of paper.

A fold is a bending of the rocks of the earth's crust. It is structured in the form of waves, successive. As such some of the features of the folds correspond to a wave either.

Rock layers in Folds

The rock layers in folds can be folded in two ways: as a result of transverse bending and by longitudinal bending.

Transversal flexure

The layer is bent under the action of forces applied perpendicular to the layer plane direction. For this slouch, various forces must exist. The folds that arise in this case are caused by the transverse bending folds. The most characteristic among them arise as a result of the action of vertical forces applied to the horizontal layers.

For example, the bending folds transversal firm layers that cover the crystalline basement, elevated above the block bounded by the fractures. The forces that form pairs are directed from the bottom up to meet the latter and are caused by the gravitational force, which holds the layers in its original level outside the boundaries of the block that rises.

Longitudinal flexure

It arises under the action of the compressive force parallel to the direction layers. The latter, during the longitudinal compression, loses its stability and deforms rather than uniformly thickening, they are curved. The role of the layered structure of the rocks during the transverse and longitudinal deflections is not the same.

During transverse bending, even if there is no mechanical dividing determined by stratification, the deformation end with the formation of a fold. For example, if the layers are drawn simply in the side wall of a plastic test tube and, therefore, they cannot play any mechanical role. A result of the first deformation will turn out to be in a curved fold transverse bending.

The longitudinal bending plays different stratification geological folds in principle without the latter in any way that may form folds, since one of the conditions for their formation necessary during bending is longitudinal slip between possible layers. The slouching packet divided by folds of strata slips relieved surfaces, all sliding layer to the underlying, towards the dome and anticline respect to the overlying, towards the hook syncline. Due to friction, to bend the strata, all inside layer is under the action of a pair of forces, one of which (on the roof of the layer) is directed towards the anticline dome. The other (in the wall layer) is directed to the hook of the syncline. This torque tends to cause a deformation in the displacement layer.

Faults

In geology, a fault is a planar fracture or discontinuity in a quantity of rock, throughout which there has been substantial displacement due to rock-mass motion. large faults within the Earth's crust end result from the movement of plate tectonic forces, with the largest forming the boundaries between the plates, including subduction zones or remodel faults energy release associated with fast motion on energetic faults is the reason of most earthquakes.

Types of Faults

On the basis of slip

1. Dip slip fault
2. Strike slip fault
3. Oblique slip fault

a) Dip slip fault:- The faults in which the slip takes area along the direction of the slip is referred to as dip slip fault inside the dip slip fault net slip is parallel to the dip of fault
b) Strike slip fault:- The faults wherein the slip takes vicinity alongside the path of the strike is called dip slip fault .inside the dip slip fault net slip is parallel to the strike fault
c) Oblique strike fault:- while the net slip is neither parallel to strike nor parallel to the dip of fault is known as oblique strike fault.

On the basis of movement:

1. Normal fault
2. Reverse fault

a) Normal fault: - A dip-slip fault in which the block above the fault has moved downward relative to the block below. This type of faulting occurs in response to extension. "Occurs when the "hanging wall" moves down relative to the "foot wall"

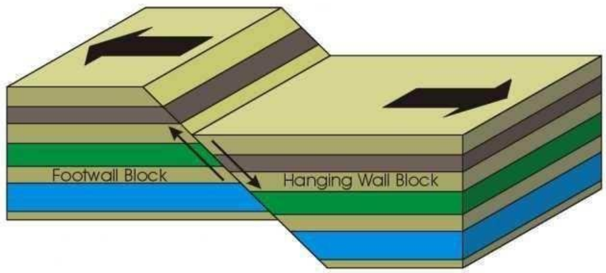


Fig. 11 Normal Fault

b) Reverse fault

A dip-slip fault in which the upper block, above the fault plane, moves up and over the lower block. This type of faulting is common in areas of compression, when the dip angle is shallow, a reverse fault is often described as a thrust fault. "Occurs where the "hanging wall" moves up or is thrust over the "foot wall"

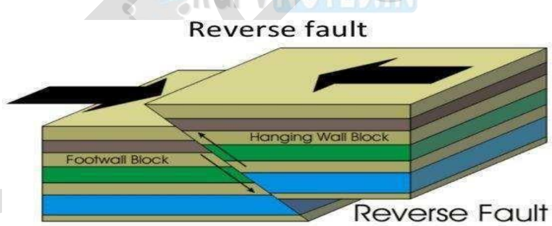


Fig. 11 Reverse Fault

On the basis of angle:-

1. High angle fault :- A high attitude fault is one that dips at angle more than 45°
2. Low angle fault:- A low perspective fault is one which dips at angle smaller than 45°

On the basis of formation:-

1. Parallel faults
2. Step faults
3. Graben or rift fault
4. Horst
5. Radial fault

6. Peripheral faults
7. Enechelon faults

a) Parallel fault

A chain of faults strolling greater or less parallel to one another and all handing in the same route, are called "parallel faults"

b) Step fault

It's far consists of those parallel faults in which down throw of all are in the same course and it offers a step like association

c) Graben or Rift fault

Whilst regular faults fade in the direction of every other and the beds between them are thrown down within the form of a wedge, the shape is known as graben or rift fault

d) Horst

A horst includes a important block on the both aspects of which adjacent beds seem to were faulted down

e) Radial faults

Some of faults exhibiting a radial pattern are described as radial faults

f) Peripheral faults

Curved faults of extra or much less round, or are like outcrops on stage surface are referred to as peripheral faults

g) Enechelon Faults

Enechelon fault are relatively quick faults which overlap each different

On the basis of altitude:-

1. Dip fault
2. Strike fault
3. Bedding fault
4. Oblique fault
5. Tear fault or transcurrent fault

a) Dip fault

A dip fault is one shore strike is parallel to the dip of strata and also referred to as transverse faults whilst it runs across the overall shape of the region

b) Strike Fault

A strike fault is one shore strike is parallel to the strike of strata and also called longitudinal faults while it runs throughout the general structure o the area

c) Bedding fault

When strike of the fault aircraft is oblique to the strike of dip of strata, its miles called an oblique fault

e) Oblique fault

While the strike of the fault plane is oblique to the strike and dip of strata, it's far referred to as an indirect Fault.

f) Tear fault or transcurrent fault

It generally moves transverse to the strike of united states rocks .the fault aircraft is more or less vertical and often enlarge from an extended distances it's also referred to as a wrench fault.

Causes of faults:-

Geological faults happen when stress occurs and determines the fault's type after the event. There are three main categories of stress:

a) Compression stress:- Occurs at convergent plate boundaries. The plates move and crash toward each other. This is what like when two cars crash into each other.

b) Tension stress: - Occurs at divergent plate boundaries. The plates are drifting away from each other.

c) Shear stress:- Occurs majorly at transform boundaries. The plates slide past each other horizontally in opposite directions.

Joints:-

A brittle-fracture surface in rocks along which little or no displacement has occurred

Types of Joints:

Joints are classified based on (a) forces causing the joints and (b) the position of the joint relative to the dip and strike of the rock bed.

Joints of the former type are said to be of Genetic type and the latter of Geometric type.

1. Genetic Types of Joints:- These joints are of two types, namely tension joints and shear joints. Tension joints are large as well as wide. These joints are formed by tensile forces which are induced due to change in volume of rocks due to drying shrinkage in the process of cooling or dehydration and stretching of the fold limbs of strata. The tension joints appear rough, irregular with jagged surfaces. Rocks easily yield to tensile forces and the rock joints are mostly tension joints.

Tension Joints in Igneous Rocks: - As magma undergoes cooling and solidifies or as lava gradually cools and becomes rigid, cracks or ruptures occur forming tension joints.

These joints may be mural joints or sheet joints or columnar joints.

Mural Joints:- These joints are common in granites and related plutonic rocks and some hypabyssal rocks. These joints appear in a three dimensional network, the joint sets being mutually perpendicular to each other. The joints break the rock into separate somewhat cubical blocks. Such block separation permits easy quarrying of the rock. The joints may be attacked by weathering agents due to whose actions the separated cubical blocks may get rounded.

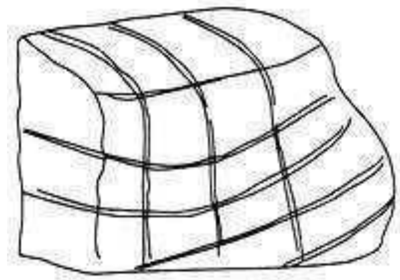


Fig. 17.46 Mural joints in granite

(b) Sheet Joints:- These joints also are seen in granites and other plutonic rocks. In this case there is one set of prominent joints parallel to the ground surface whose spacings generally increase with depth and a second set running at right angles. The joints in this case separate the rock body into sheet like blocks.

Fig. 17.47 Sheet joints in granite

(c) Columnar Joints:- These joints are seen in basalts and some other volcanic igneous rocks. They consist of vertical and horizontal joints separating the rock body into a number of vertical polygonal (quite often hexagonal prismatic columns). When the horizontal lavas cool weak planes are developed by radial contraction causing these joints.

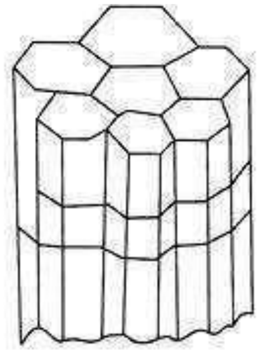


Fig. 17.48 Columnar joints in basalt

Tension Joints in Sedimentary Rocks:- When many layers of sediments are deposited, during their consolidation under high pressure ruptures occur breaking them into smaller volumes. These joints appear at right angles to each other in more or less regular intervals. These are common in massive and also the bedded sedimentary rocks. The most common tension joints of sedimentary rocks are called master joints.

Master Joints:- These joints are mostly seen in sandstones and limestone's. These joints consist of three sets of mutually perpendicular joints. One set of joints is parallel to the bedding planes. The other two sets are perpendicular to the bedding planes and occur in staggered pattern. These joints continue for long distance maintaining regularity in spacing and width and are therefore named as master joints.

Extension and Release Joints:- These joints are seen in folded rock strata. These joints are formed in the crustal region of the fold and they extend parallel or at right angles to the axial plane or in both these directions. The joints running parallel are called release joints (they run along the strike of the folds) and the joints running at right angles to these are called extension joints.

Shear Joints:- These are joints associated with deformed rocks especially folded rocks. These joints occur as intersecting or crisscrossing sets at a high angle. These joints are referred to as conjugate joint system. These joints are produced by the action of shear stresses occurring in folding and faulting stages. They are narrowly spaced intersection joints.

Geometric Joints:- In this case the joints are classified based on their attitude relative to the dip and strike of the rock strata. In this case the joints are classified into dip joints, strike joints and oblique joints. Dip joints run in the direction of the dip of the strata. (Ex: Extension joints). Strike joints run in the direction of the strike of the strata (Ex: Release joints). Oblique joints are at some inclination to the dip and strike directions of the strata. These joints are also called diagonal joints. (Ex: Conjugate joints).

Unconformities

Unconformities are gaps in the geologic record that may indicate episodes of crustal deformation, erosion, and sea level variations. They are a feature of stratified rocks, and are therefore usually found in sediments (but may also occur in stratified volcanic). They are surfaces between two rock bodies that constitute a substantial break (hiatus) in the geologic record (sometimes people say inaccurately that "time" is missing). Unconformities represent times when deposition stopped, an interval of erosion removed some of the previously deposited rock, and finally deposition was resumed.

Commonly three types of unconformities are distinguished by geologists:

Angular Unconformities:- Angular Unconformities are those where an older package of sediments has been tilted, truncated by erosion, and then a younger package of sediments was deposited on this erosion surface. The sequence of events is summarized in the pictures at left. First: subsidence and sediment deposition occurs; Second: rocks are uplifted and tilted (deformation); Third: erosion removes the uplifted mountain range; Fourth: subsidence occurs, the sea covers the land surface, and new sediments deposition occurs on top the previous land surface. Then the cycle may repeat.

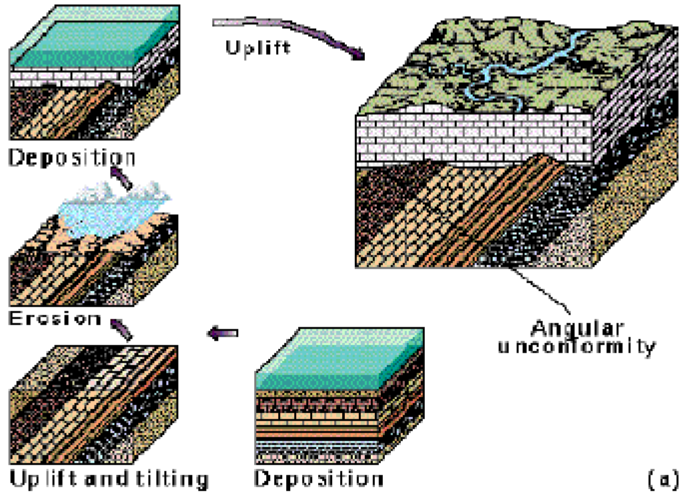


Fig 14 Process of Unconformity

Disconformities: - Disconformities are also an erosion surface between two packages of sediment, but the lower package of sediments was not tilted prior to deposition of the upper sediment package. The sequence of events is as follows: First: subsidence and sediment deposition; Second: uplift and erosion; Third: renewed subsidence and deposition. Because the beds below and above the disconformity are parallel, disconformities are more difficult to recognize in the sedimentary record. In the diagram at left, the disconformity is indicated by an irregular black line between the 3rd and 4th rock unit from the bottom.

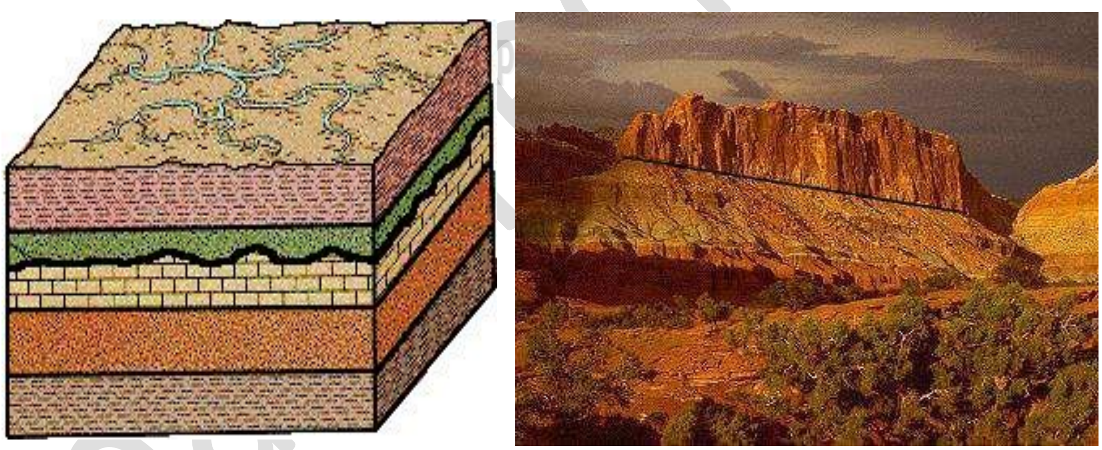


Fig. 15 Disconformities

Nonconformities:- Nonconformities are unconformities that separate igneous or metamorphic rocks from overlying sedimentary rocks. They usually indicate that a long period of erosion occurred prior to deposition of the sediments (several km of erosion necessary). In the diagram at left, the igneous/metamorphic rocks below the nonconformity are colored in red.

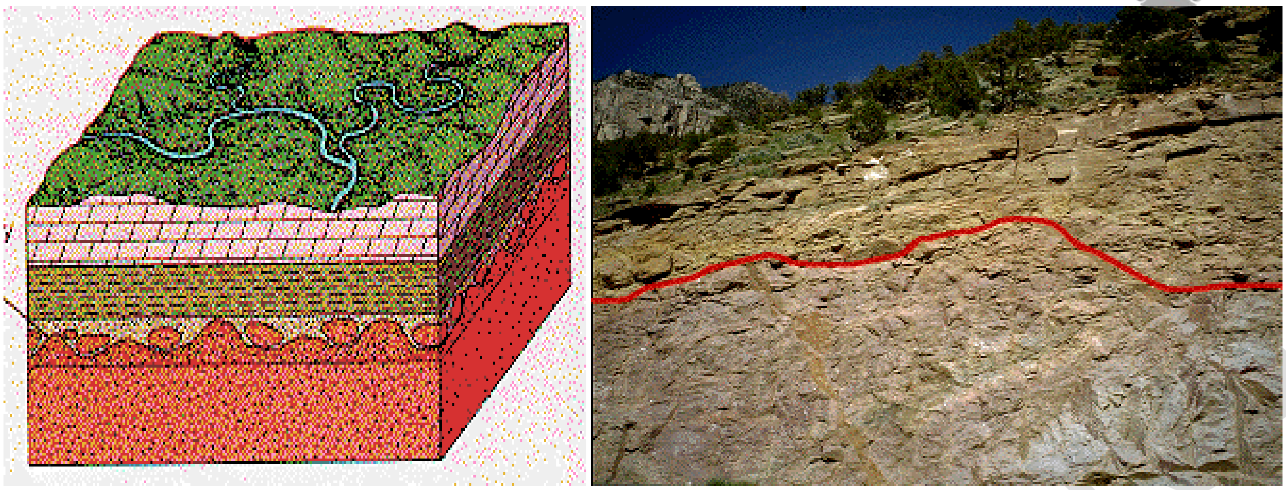


Fig. 16 nonconformities

****

Unit 5

Applied geology and remote sensing, engineering properties of rocks, selection of sites for Dam, Tunnel, Reservoirs and Canals, uses of remote sensing technique. Types, components and elements of remote sensing, EMS and MSS, Visual interpretation technique, application of GIS in civil engineering and resource mapping (site selection, water resources, rocks and soil).

Applied Geology

The application of various fields of geology to economic, engineering, water-supply, or environmental problems; geology related to the human activity.

Use of Applied geology in civil engineering

Civil engineering projects involve some excavation of soils and rocks, or involve loading the Earth by building on it. In some cases, the excavated rocks may be used as constructional material, and in others, rocks may form a major part of the finished product, such as a motorway cutting of the site or a reservoir. The feasibility, the planning and design, the construction and costing, and the safety of a project may depend critically on the geological conditions where the construction will take place.

Remote Sensing

Remote sensing (RS), also called earth observation, refers to obtaining information about objects or areas at the Earth's surface without being in direct contact with the object or area. Humans accomplish this task with aid of eyes or by the sense of smell or hearing; so, remote sensing is day-today business for people. Reading the newspaper, watching cars driving in front of you are all remote sensing activities. Most sensing devices record information about an object by measuring an object's transmission of electromagnetic energy from reflecting and radiating surfaces.

Basic principle of Remote Sensing

Detection and discrimination of objects or surface features means detecting and recording of radiant energy reflected or emitted by objects or surface material. Different objects return different amount of energy in different bands of the electromagnetic spectrum, incident upon it. This depends on the property of material (structural, chemical, and physical), surface roughness, angle of incidence, intensity, and wavelength of radiant energy.

The Remote Sensing is basically a multi-disciplinary science which includes a combination of various disciplines such as optics, spectroscopy, photography, computer, electronics and telecommunication, satellite launching etc. All these technologies are integrated to act as one complete system in itself, known as Remote Sensing System. There are a number of stages in a Remote Sensing process, and each of them is important for successful operation.

Stages in Remote Sensing

1. **Emission of electromagnetic radiation, or EMR (sun/self- emission)**
2. **Transmission of energy from the source to the surface of the earth, as well as absorption and scattering**

3. Interaction of EM´ with the earth's surface: reflection and emission
4. Transmission of energy from the surface to the remote sensor
5. Sensor data output
6. Data transmission, processing and analysis

All objects radiate electromagnetic energy by virtue of their atomic and molecular oscillations. The total amount of emitted radiation increases with the body's absolute temperature and peaks at progressively shorter wavelengths. The sun, being a major source of energy, radiation and illumination, allows capturing reflected light with conventional (and some not-so-conventional) cameras and films.

The basic strategy for sensing electromagnetic radiation is clear. Everything in nature has its own unique distribution of reflected, emitted and absorbed radiation. These spectral characteristics, if ingeniously exploited, can be used to distinguish one thing from another or to obtain information about shape, size and other physical and chemical properties.

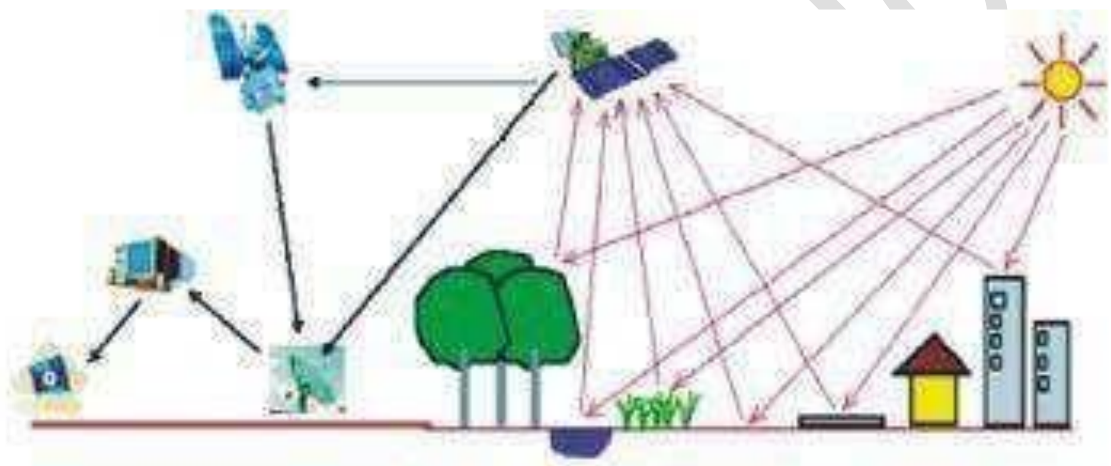


Fig.18 Basics of Remote Sensing

Electromagnetic Radiation and the Electromagnetic Spectrum

EMR is a dynamic form of energy that propagates as wave motion at a velocity of c = 3 x 1010 cm/sec. The parameters that characterize a wave motion are wavelength (λ), frequency (ν) and velocity (c)

The relationship between the above is c = λ ν

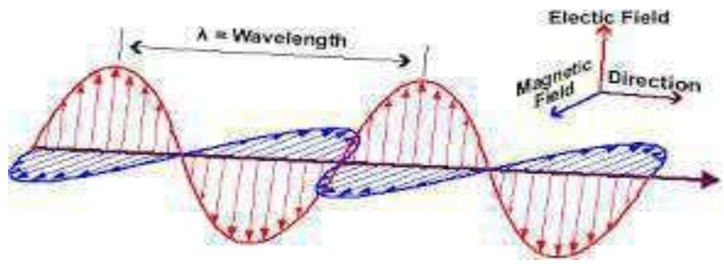


Fig. 19 Electromagnetic Radiations

Electromagnetic energy radiates in accordance with the basic wave theory. This theory describes the EM energy as travelling in a harmonic sinusoidal fashion at the velocity of light. Although many characteristics of EM energy are easily described by wave theory, another theory known as particle theory offers insight into how electromagnetic energy interacts with matter. It suggests that EMR is composed of many discrete units called photons/quanta. The energy of photon is

$Q = hc / \lambda = h\nu$

Where

Q is the energy of quantum,

h = Planck's constant

The geology of an area dictates the location and nature of any civil engineering structures.

Roads and Railways Problems for a road or railway project may be caused by any of the following geological features:

i. Faults
ii. Junctions between hard and soft formations
iii. Boundaries between porous and impermeable formations
iv. Spring-lines
v. Fractured granites
vi. weathered schists2
vii. Landslip areas
viii. Areas where beds dip towards the road or railway, as shown in the adjacent diagram.

Fig. 20 Road and vehicle relationship

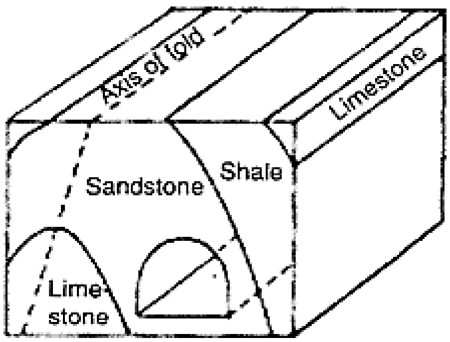
1 - A passage for surplus water from a dam. 2 - A coarse-grained metamorphic rock that consists of layers of different minerals and can be split into thin irregular plates.

If the terrain and proposed route are such that these features cannot be avoided, construction of suitable safety features is required. Earthwork construction must include an embankment to stabilize areas of landslip. Lightweight material on a concrete raft may be needed where the road traverses deep, compressible deposits.

Drainage holes can be drilled into rock to ensure that water is drained from potential slip surfaces, such as bedding planes. Unless water is properly drained from a rock embankment, pressures will build-up within and behind the rock, eventually causing it to fracture and collapse.

Effects of geological structures in tunneling Case of Folds

For tunneling purposes, folded rocks are in general unsuitable because the affected rocks are under great strain and the subsurface removal of material, i.e., creation of tunnels in such rocks may cause the release of the contained strain which may appear as collapse of the roof, or as caving or bulging of sides, or floor etc. If the tunneling work is taken up along the thick beds of limbs, parallel to the axis of the fold, because the disadvantages associated with crests and troughs do not occur. This is because, along the crests of folds, the beds contain numerous tensions and other factures and if the tunnel is made through them, frequent falling of rocks from the roof may occur.



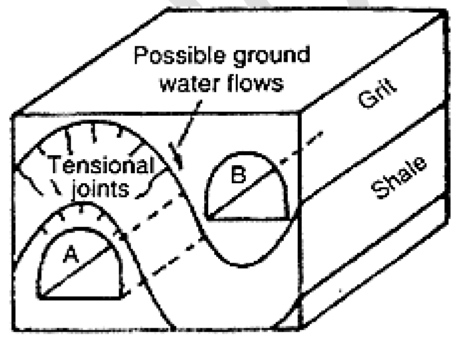


Fig. 21 Tunnel

At certain situations, where folds occur with wedge-shaped rocks tapering downwards may provide a desirable situation for tunneling. This is because the wedge-shaped shapes will lie perpendicular to the curved bedding and prevent rocks from falling as they act as key rocks in arches. In spite of this, as the fractured rock is not cohesive, it cannot be strong and competent. Its competence becomes lesser when its openings get saturated with water. Hence, tunneling by excavation in such ground is unsafe and unstable. Over break also occurs there considerably which means lining work will be costlier.

Along the troughs, rocks will be highly compressed. Therefore they will be tough and offer greater resistance for excavation. This means tunneling work will be difficult and progress less. Further, by virtue of dip of limbs, water will be percolated along the bedding planes and accumulate along troughs. If the accumulation of water is of artesian1 type then tunneling along troughs may encounter sever ground water problems and shall be disastrous also.

1-An artesian aquifer is a confined aquifer containing groundwater under positive pressure. This causes the water level in a well to rise to a point where hydrostatic equilibrium has been reached. This type of well is called an artesian well. Water may even reach the ground surface if the natural pressure is high enough, in which case the well is called a flowing artesian well.

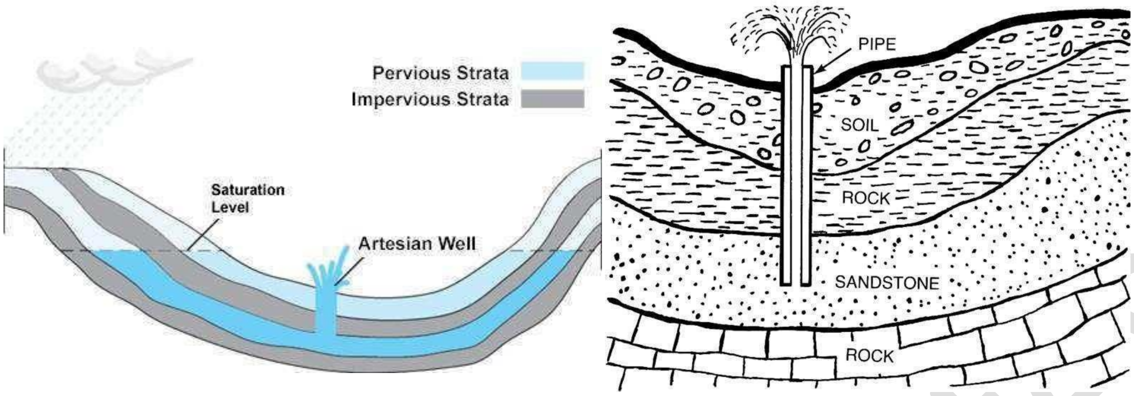


Fig. 22 Artesian wells

Fig. 22.1 Artesian wells

When the tunnel alignment is perpendicular to the axis of the fold, this situation is also undesirable because, under such a condition, different rock formation are encountered from place to place along the length of the tunnel and also the tunnel has to pass through a series of anticlines and synclines. These two factors bring heterogeneity in the physical properties of rocks and also in physical conditions in anticlinal parts. In synclinal folds, the conditions are exactly reversed.

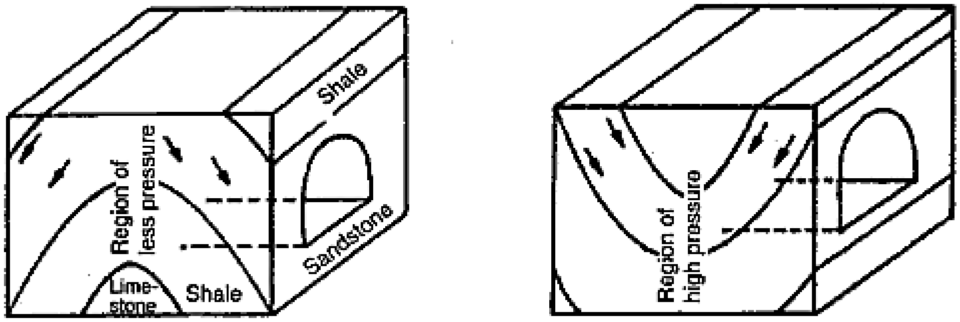


Fig. 23 Tunnel position

Effect of faults at Tunnel site:

Normally faults are harmful and undesirable as they create a variety of problems. The problems with faults occurring at tunnel site can be described as followed.

1. Active fault zone: These are the places where there is scope for further recurrence of faulting which will be accompanied by the physical displacement of litho logical units. Such faults will lead to dislocation and discontinuity in the tunnel alignment. So occurrence of any active fault in tunnels is very undesirable.

2. Inactive fault zone: These are the places where there is no scope of further occurrence of faulting, yet these prone to intense fractures due to earlier faults. This means that these zones are of great physical weakness. So if such zones occur along the course of a tunnel, it is necessary to provide lining.

3. Highly permeable zones (with or without faulting): Zones that are highly porous, permeable and decomposed may occur at tunnel sites these also require heavy concrete lining.

Effect of Joints on Tunneling:

Joints interfere with tunneling work as follows:

1. **It causes serious ground water problems, unless the water table position is reasonably below the level of the tunnel floor.**
2. **If the joints are too many, they may severely hamper the competence even inherently strong rocks and render them unsuitable for tunneling.**
3. **The openings of joint planes enable the ground to be saturated with water and thereby decrease the strength of the rocks considerably. So, joints become responsible indirectly also for reduction in strength of rocks at the tunnel site.**
4. **If joints occur unfavorably, they may cause fall of rocks from the roof of the tunnel. This means tunneling will be unsafe and needs lining.**
5. **Joints may act as sites for the development of solution cavities and solution channels in lime stone terrain. This is due to the action of percolating carbon dioxide-bearing waters.**

Joints, being oriented cracks, their attitude with reference to the tunnel alignment are also very important. Such of these joints which strike parallel to the tunnel axis naturally persist for long distances and hence are undesirable for tunneling. On the other hand, joints which strike oblique or perpendicular to the tunnel axis will obviously have a limited effect on them.

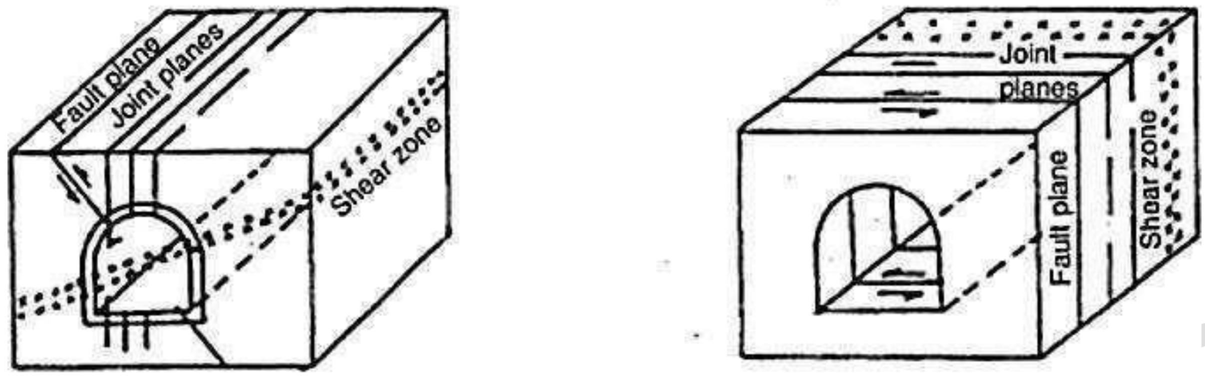


Fig. 24 Tunnel position

In sedimentary rocks, the occurrence of joints is undesirable because these rocks, which are originally weak and incompetent, and become weaker.

In metamorphic rocks also, joints are not characteristic, but are frequently present. Granite gneisses and quartzite's, being very competent, can remain suitable for tunneling even if some joints occur in them. But schist and slates with joints will become very incompetent and necessarily require lining.

Dams:

Geological investigations of a site proposed for construction of a dam must be complete and detailed. Features such as rock-types, geological structures, weathering, fractures and fissures must all be considered. The main considerations are that the material on which the dam rests must be able to carry the weight of the structure without failing. The geology upon which the dam is built must also be impervious1 to water. The abutments2, (the rock faces to which the dam wall is attached) must also be impervious and strong enough to support the dam wall, especially in the case of an arch dam (where more force is transmitted to the abutments).

Left: Cross-section through an arch dam.

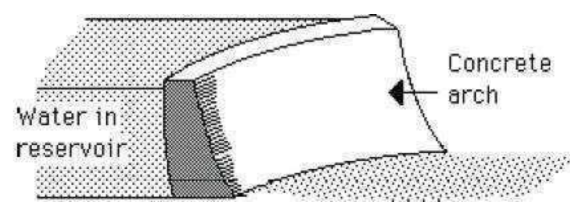


Fig. 25 Cross section of Dam

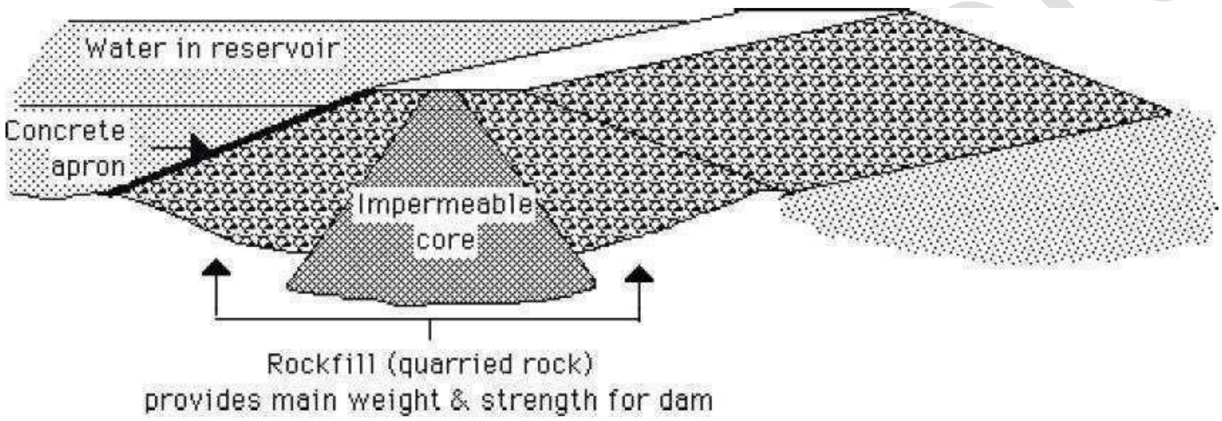
Failure of a dam can be due to many factors including:

i. **Earthquakes**
ii. **A sudden drop in water level**
iii. **Inadequate protection of the reservoir side of the dam from wave action**
iv. **Insufficient spillway capacity, so that water flows over the whole of the dam surface, with consequent erosion**

1 - Not allowing something to pass through; not penetrable. 2 - A structure built to support the lateral pressure of an arch or span, e.g., at the ends of a bridge.

The type of dam selected depends largely on the nature of the surrounding rocks. If they are strong and stable, an arch dam, such as the one shown below can be constructed. This type of dam requires a minimum of construction materials, but the concrete must be of high quality. The Barossa Reservoir Dam (the Whispering Wall), The Roosevelt Dam are examples of an arch dams.

An earth and rock fill embankment dam, as shown in the diagram below must be constructed where the surrounding rocks are not strong enough to support an arch dam. This type of dam is more expensive to build, requiring much more material. The main weight and strength of the dam is provided by compacted quarried rock. The core is made of impermeable material, such as clay, bitumen1 or concrete.



Cross-section through an embankment dam.

Fig. 26 Cross-section embankment

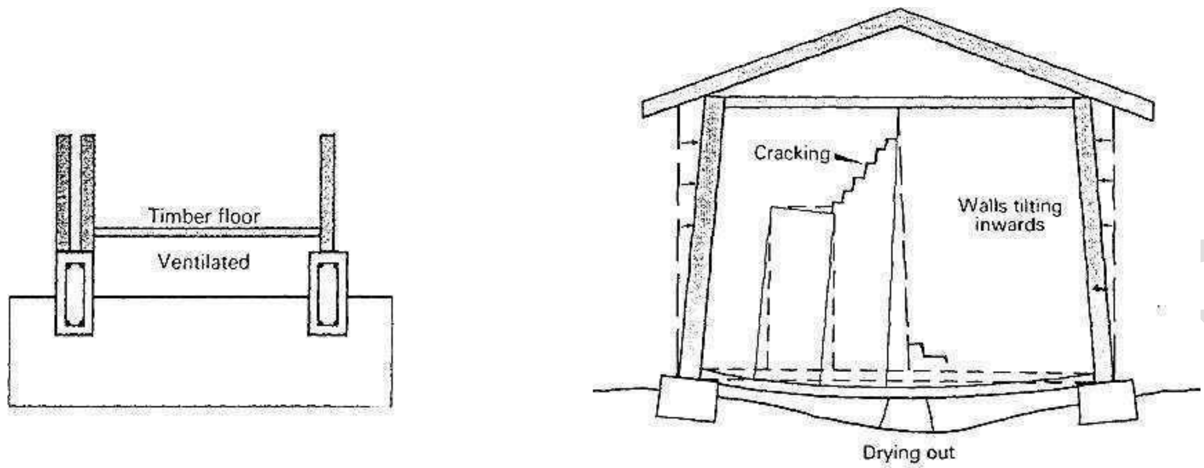
Rock and soil tests are taken before homes are built. For larger buildings, deep holes may be drilled to test the strength and stability of the rocks under the proposed building. The type and strength of foundations required are determined from the results of these tests. People who build houses in areas of clay soil are likely to find that windows and doors stick and that cracks appear in brick walls. Piers under the house move and concrete slabs may crack. This is because clays swell when wet and shrink after drying. Adelaide's 'Bay of Biscay' soils, which underlie some of the north-eastern suburbs, contain a type of clay called montmorillonite which swells to almost twice its dry volume when wet. This is responsible for many cracks in older buildings. These soils are said to be expansive.

1 - A metamorphic rock with a banded or foliated structure, typically coarse-grained and consisting mainly of feldspar, quartz, and mica.

Two other types of problem soils are collapsing soils, which settle rapidly on wetting, and compressible soils that consolidate and settle slowly over several years.

The footing is that part of a house that is in direct contact with the soil or rock forming the foundation. Strip footings were the earliest type used. These consisted of concrete strips beneath the walls of the house.

Strip footings proved to be unsuitable in areas of expansive soil, as the soil under the house dried out and shrank (shrink), causing the problems shown in the diagram below.



Cross-section through strip footings

Fig. 27 Strip Footing

Slope Failure

The term slope failure covers a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows.

Causes of Slope Failure

Gravity

Although gravity acting on an over-steepened slope is the primary cause of a landslide, other contributing factors include:

i. Earthquakes that create stress causing weak slopes to fail.
ii. Volcanic eruptions that produce loose ash deposits and debris flows.
iii. Vibrations from machinery, traffic, blasting, and even atmospheric thunder that may trigger failure of very weak slopes.
iv. Excess weight from accumulation of rain, snow, the stockpiling of rock or ore, or from built structures that may stress weak slopes to failure.

Relief

Slope failure occurs in hilly or mountainous regions all over the world — essentially wherever there is any significant topographic relief. In Australia, significant landslides coincide with mountainous areas.

Water

Rock and soil slopes are weakened through saturation by melting snow or heavy rain. Water filling the pores of permeable materials allows the grains to slide past each other with little friction. Water acts as a lubricant increasing the ease of movement of rock and soil particles (and therefore slope failure). Slope material that becomes saturated with water may develop a debris flow or mudflow. The resulting slurry of rock and mud

can pick up trees, houses, and cars, causing the blocking of bridges and tributaries and increasing the likelihood of flooding.

Undercutting

Undercutting is erosion of material at the foot of a cliff or steep bank — E.g. on the outside of a meander. Ultimately the overhang collapses and the process is repeated. Undercutting caused by rivers, glaciers, or ocean waves creates over-steepened slopes, which are prone to failure. Human activities, such as quarrying and road construction also result in undercutting.

Rock Types

In unconsolidated material, that is material not held together by cement or by a strong interlocking crystal structure, landslides start after a significant part of the whole rock mass is saturated with water and therefore lubricated. A single shock or vibration can trigger the down-slope movement of an entire unstable hillside. Any area of very weak or fractured materials resting on a steep slope will be likely to experience landslides.

Slope Angle

A pile of sand always assumes the same angle of slope, whether it is a few centimetres high, or a huge sand dune. The angle that the sand makes with the horizontal is called the angle of repose. It is about 37° for fine sand, and steeper for coarse sand and angular pebbles, as shown in the diagrams below.

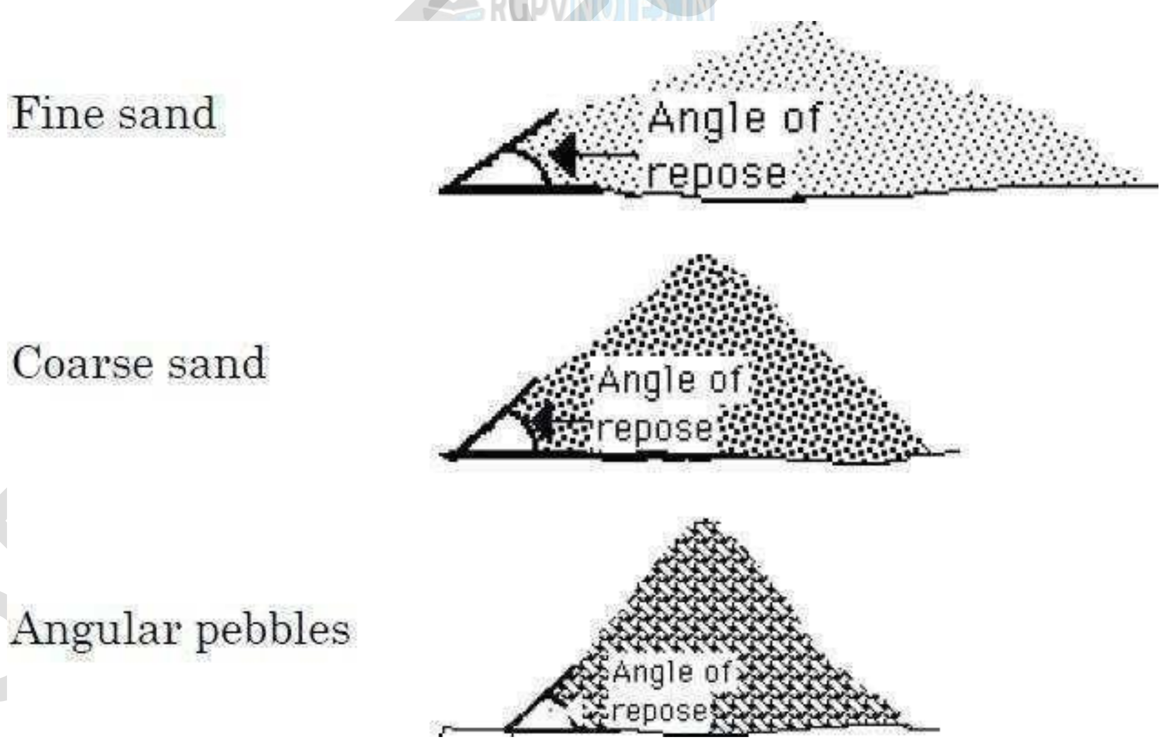


Fig. 28 Slope action

If a slope is steepened beyond this natural angle, for example for a road cutting, it then becomes unstable and the slightest vibration may lead to slope failure. The angle of repose is reduced if the sand or unconsolidated rock material becomes water-saturated. Moreover, the angle of repose is significantly reduced underwater.

Effect of Geological Structures on location of Reservoirs:

If any of the following geological settings occur at the reservoir site, there will be significant difference in terms of leakage of reservoir water.

1. **The case wherein beds of the limb dip in the upstream direction, there will not be any effective leakage of water from the reservoir. This is so because all percolated water will be directed in the upstream direction only, along the bedding planes.**

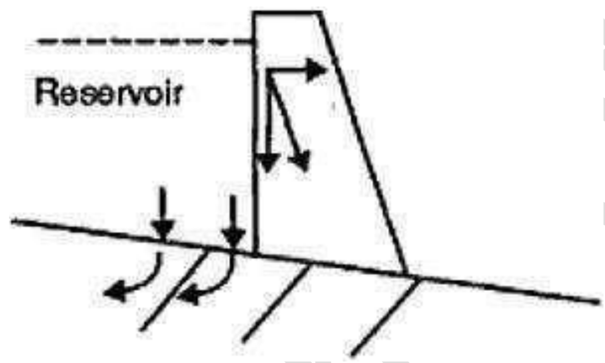


Fig. 29 Cross section for reservoir

2. **The case wherein if strata at the reservoir site are horizontal, there may baa little seepage of water of the reservoir in the downstream side along the horizontal bedding planes.**

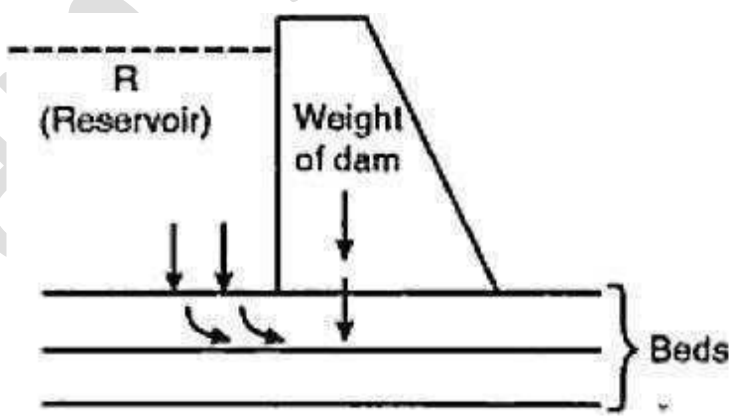


Fig. 30 Cross section for reservoir

3. **The case wherein strata dip in the downstream direction, there shall be considerable leakage of reservoir water along the bedding planes which are dipping in the downstream direction.**

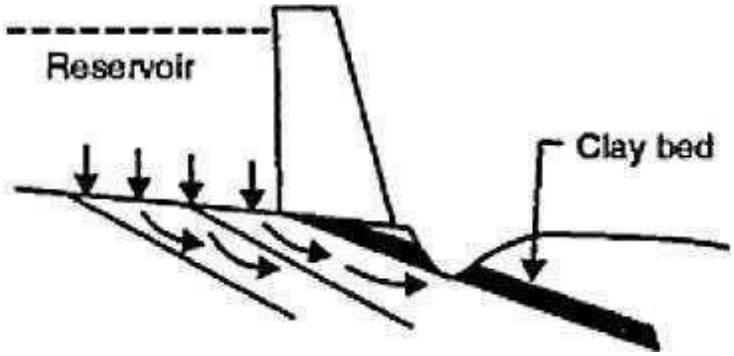


Fig. 31 Cross section for reservoir

3. **In the case of strata containing faults, the faults which dip in the downstream direction are more harmful. This is so because they not only cause effective and significant loss of water but also endanger the safety of the dam by creating, uplift pressure over it. However, if the water table occurs at or near the surface of the reservoir site, faults do not contribute to loss of water. If server fault or shear zone occurs as outcrops along the upstream course of the river, they get eroded quickly and contribute heavily to the load of the river. This means sever silting problems in the concerned reservoirs.**
4. **In the case of joints present in the reservoir site or basin, they act as avenues for serious leakage of water. The prevailing water table position will affect the influence of leakage.**
5. **If the ground water is contributing to the surface water (effluent conditions), the resultant effect will nullify the effect of presence of joints and cause no leakage. If the ground water is fed by surface water (influent conditions), this will permit the joints to play their role in leakage of water as expected. But a matter of consolation is that even if joints are contributing to the leakage of water, in course of time, this adverse effect partly disappears slowly, because the fine silt and clay settle in the openings of joints and seal them off.**

b. The other adverse effect of joints is similar to faulting when it occurs in the upstream side. If jointing has occurred in the valley in the upstream side, such disintegrated rocks under quick erosion and contribute to the river load heavily. This means that rate of silting will be very heavy in the reservoir. This, in turn, reduces the life of the reservoir. So, as a precaution, such places have to be grouted or covered suitably.

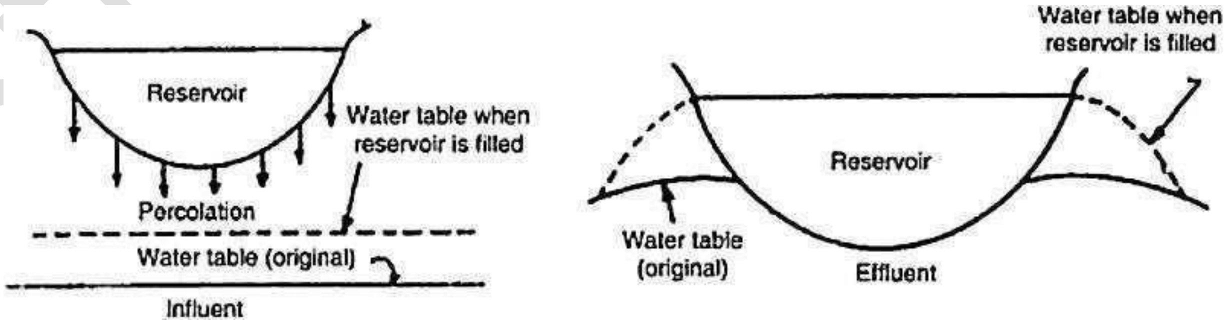
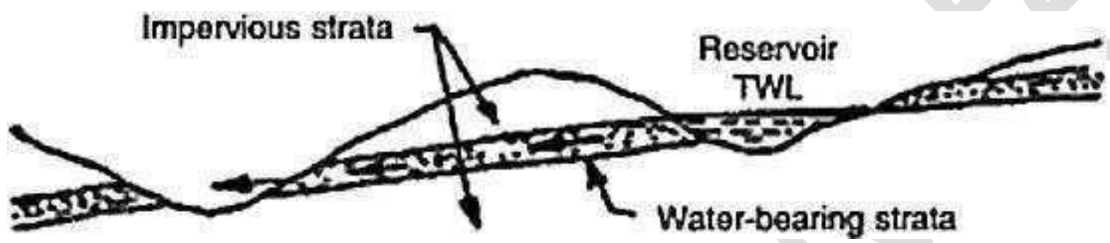


Fig. 32 Cross section for reservoir

6. In the case where beds strike parallel to the length of the valley, topography and the position of occurrence of different beds at the reservoir site are taken granted for the same as, topographically, another parallel valley occurs at the lower level and adjacent to the valley containing the reservoir. In this situation, litho logical, a permeable bed (say, sandstone or cavernous lime stone) occurs in between the impermeable beds (like shales). When all the beds are conformable and striking parallel to the length of the valley, with respect to the relative position of the beds, the permeable bed occurs at the rim of the reservoir and all beds are dipping towards the same side. Under these conditions,

a. When tilted permeable bed is exposed in the adjacent valley, there will be leakage of the reservoir water into the adjacent valley lying at the lower level.



b. If the folding occurs in such an area, the leakage won't occur.

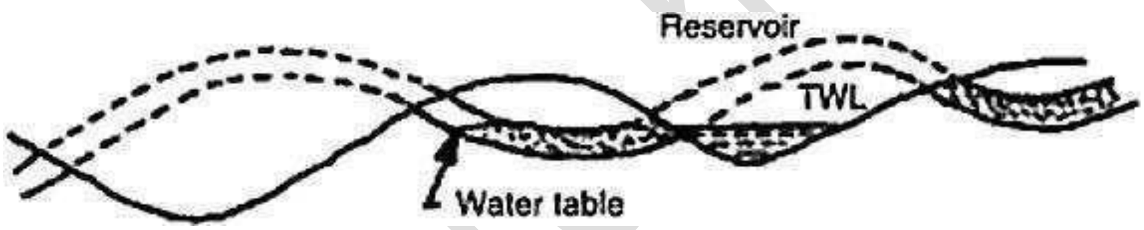


Fig. 32 Water Table

c. If a fault occurs in the reservoir area, and if the permeable bed through which reservoir water percolates gets terminated against an impermeable bed along the fault plane, the leakage is prevented.

Basic components of Remote Sensing:

The sun is the major source of energy, radiation and illumination. At any given moment our sun is bombarding the earth with a variety of wavelengths of EMR, including visible light, infrared, radio and microwaves. Detection and discrimination of surface features means detecting and recording of radiant energy reflected or emitted by surface (Joseph, 2004; Lille sand and Kiefer, 1987; 2000). Different features return different amount and kind of energy in different bands of the electromagnetic spectrum, incident upon it. This unique property depends on the property of material (structural, chemical and physical), surface roughness, angle of incidence, intensity and wavelength of radiant energy (Elachi, 1987). Everything in nature has its own unique distribution of reflected, emitted and absorbed radiation. These spectral characteristics, if ingeniously exploited, can be used to distinguish one thing from another or to obtain information about shape, size and other physical and chemical properties. Because the emission and reflection of many different types of EMR can be detected by instruments, they can also be used for remote sensing. Thus, to understand remote sensing, it is important to first understand the basics of EMR.

History of Remote Sensing:

The technology of modern remote sensing has a very long history, dating back to the end of the 19th century with the invention of the camera.

Initially cameras were used to take photographs on the ground, which provided (and still does) a fascinating and exciting way to capture moments in time and keep a record of something that happened, which looked more realistic than a drawing or painting, and which could be captured much quicker than by drawing or painting.

The idea and practice of remote sensing first developed in the 1840s, when it was realized that a different and perhaps more revealing view of a particular landscape could be obtained by taking a photograph from a vantage point, such as an incline or building, and efforts were made to look down at the Earth's surface by taking pictures with the aid of cameras secured to tethered balloons, for purposes of topographic mapping.

It was realized that the airborne perspective gave a completely different view than to what was available from the ground. The most novel platform at the end of the last century is perhaps the famed pigeon fleet that operated as a novelty in Europe.

By the first World War, cameras were mounted on airplanes, which provided aerial views of fairly large surface areas and was used as a method of data and information acquisition, that proved invaluable in military reconnaissance. Thus, aerial photography remained the single standard tool for depicting the surface from a vertical or oblique perspective till the early 1960s.

The history of Satellite remote sensing can be traced back to the early days of the space age of both Russian and American programs. It actually began as a dual approach of imaging surfaces, from spacecraft, using several types of sensors. After World War II, in 1946, V-2 rockets acquired from Germany, containing automated still or movie camera, were launched to high altitudes from White Sands, New Mexico.

These rockets, however never attained orbit, but took pictures of the earth's surface as the vehicle ascended. In the 1960s, with the emergence of the space program, cosmonauts and astronauts started taking photographs out of the window of their spacecraft in which they were orbiting the earth.

Today, remote sensing is carried out using airborne and satellite technology, not only utilizing film photography, but also digital camera, scanner and video, as well as radar and thermal sensors.

Unlike in the past, when remote sensing was restricted to only the visual part of the electromagnetic spectrum i.e., what could be seen with naked eye, today through the use of special filters, photographic films and other types of sensors, the parts of the spectrum which cannot be seen with the naked human eye can also be utilized.

Thus, today remote sensing is largely utilized in environmental management, which frequently requires rapid, accurate and up-to-date data collection.

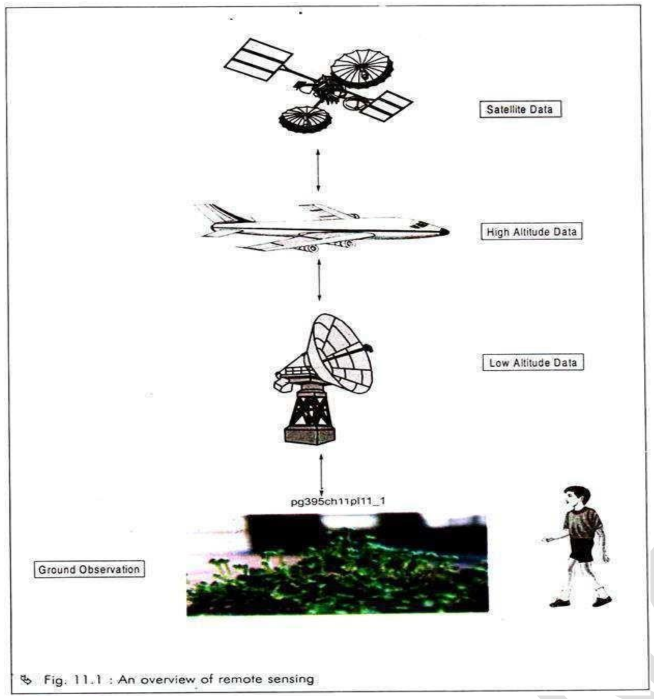


Fig. 33 Overview of Remote Sensing

2. Principles of Remote Sensing:

Remote sensing involves the detection and measurement of the radiations of different wavelengths reflected or emitted from distant objects or materials, which helps in their identification and categorization.

It offers four basic components to measure, which include:

- **(i) The energy source**
- **(ii) The transmission path**
- **(iii) The target**
- **(iv) The satellite sensor**

Among these, the energy source or electromagnetic energy, is very important, as it serves as the crucial medium for transmitting information from the target to the sensor. It is described as an electromagnetic spectrum, on which, many forms exist that describe energy in a specific region of the spectrum .

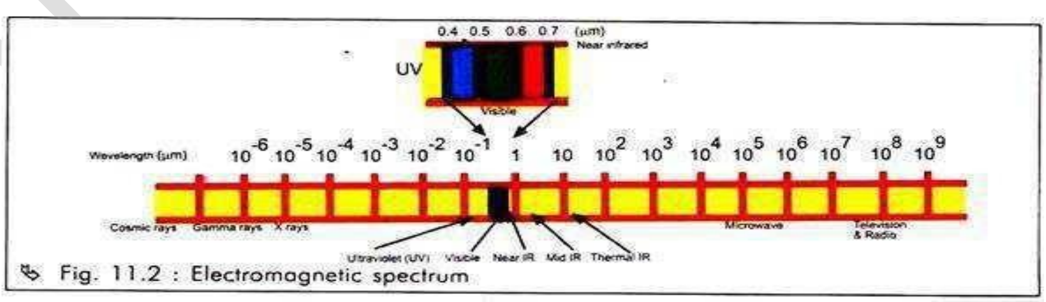


Fig. 34 Electromagnetic spectrum

Electromagnetic spectrum

These are visible light, radio waves, microwaves, heat, UV rays, X-rays and gamma rays. This spectrum is an overview of the continuum of electromagnetic energy from extremely short wavelengths (cosmic gamma rays) to extremely long wavelengths (radio and television waves). These divisions are not absolute and definite as overlapping may occur.

The basic unit of wavelength is measured in meters (m). Most energy in the visible (including U.V., visible, and near infrared) and infrared portions of the electromagnetic spectrum is measured in micrometers (10-6m) [1 micrometer = 10,000 angstroms]. Millimeters may be used for longer wavelengths (blue – 0.4 – 0.5 mm).

Regions of Electromagnetic Spectrum

Regions of Electromagnetic Spectrum		
1.	Gamma Ray	<0.03 nanometers
2.	X - Ray	0.03 - 3.0 nanometers
3.	Ultraviolet	3.0 nanometers - 0.4 micrometers
4.	Visible	0.4 - 0.7 micrometers
5.	Near Infrared	0.7 - 1.3 micrometers
6.	Mid-Infrared	1.3 - 3.0 micrometers
7.	Thermal Infrared	3.0 - 5.0 mm + 8.0 - 14.0 mm
8.	Microwave	0.3 - 300.0 cm

Fig. 35 Regions of ES

Depending on the wavelength and the nominal spectral location, principal applications can be matched with suitable satellite bands for classification.

Band, Wavelength, Nominal Spectral Location and Principal Applications

Band	Wavelength	Nominal Spectral Location	Principal Applications
1	0.45-0.52	Blue	Useful for coastal water mapping as it is designed for water body penetration. Also useful for forest type mapping, soil/ vegetation discrimination, and cultural feature identification.
2	0.52-0.60	Green	Useful for vegetation discrimination and vigor assessment as designed to measure green reflectance peak of vegetation. Also useful for identification of cultural feature.
3	0.63-0.69	Red	Aiding in plant species differentiation, as it is designed to sense in a chlorophyll absorption region. Also useful for identification of cultural feature.
4	0.76-0.90	Near infrared	Useful for determination of vegetation types, vigor, and biomass content, for soil moisture discrimination and for delineating water bodies.
5	15.5-1.75	Mid-infrared	Useful for determination of vegetation moisture content, soil moisture discriminations, and thermal mapping applications.
6	10.4-12.5	Thermal infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08-2.35	Mid-infrared	Useful for discrimination of types of mineral and rock and determination of vegetation moisture content.

Fig. 36 Wavelength range

3. Types of Remote Sensing:

Satellite remote sensing involves gathering information about features on the Earth's surface from orbiting satellites, which may carry either of the following two types of sensor systems:

(i) Passive System:

It generally consists of an array of small sensors or detectors, which records the amount of electro-magnetic radiation reflected and/or emitted from the Earth's surface. Thus, passive remote sensing relies on naturally reflected or emitted energy of the imaged surface.

Most remote sensing instruments fail into this category, obtaining pictures of visible, near-infrared and thermal infrared energy. A multi-spectral scanner is an example of a passive system. Passive visible and near-infrared data are used in a variety of GIS applications, for example in the classification of vegetation and land-use, and may be performed at a variety of temporal and spatial scales.

Common Remote Sensing Systems

(ii) Active System:

This type of a system propagates its own electro-magnetic radiation and measures the intensity of the return signal. Thus, active remote sensing means that the sensor provides its own illumination and measures what comes back. Remote sensing technologies that use this type of system include lidar (laser) and radar.

Synthetic Aperture Radar (SAR) is an example of an active system. Active remote sensing (radar and lidar) systems are rapidly increasing in use since the launch of the ERS-1 Synthetic Aperture Radar (SAR) satellite in 1991. In comparison to visible/near-infrared imagery, radars are sensitive to very different surface properties.

As for example, radar images are sensitive to the shape, orientation and size of leaves and their moisture content, rather than the vegetation color. Similarly, airborne lidars have been largely used for mapping surface topography in three dimensions. Existing and planned radar and lidar altimeters will also help in monitoring closely the elevation of the world's ice caps and sea level with centimeter precision.

4. Advantages of Remote Sensing:

Remotely sensed imaging systems have several advantages over camera photography, from which it differs significantly in the following two ways:

(i) It is not just restricted to the visible part of the electromagnetic spectrum (from about 0.4 to 0.7 micrometers in wavelength), but can also measure energy at wavelengths invisible to the eye, such as near-infrared, thermal infrared and radio wavelengths.

(ii) Most remote sensing instruments can record different wavelengths at the same time, yielding not one but numerous images of the same location on the ground, each corresponding to a different range of wavelengths called a band.

Thus, remotely sensed data acquired by the Earth observation satellites provides a number of benefits for studying the Earth's surface, which include:

(i) Good spectral (including infra-red bands) and spatial resolution.
(ii) Allows broad regional coverage.
(iii) Allows continuous acquisition of data.
(iv) Provides up-to-date information because of the capability of regular revisit.
(v) Provides cost effective and map-accurate data.
(vi) Provides large archive of historical data.
(vii) Enables to combine satellite digital data with other digital data.
(viii) Has the ability to manipulate or enhance digital data,
(ix) Allows the possibility of stereo viewing.

5. Limitations of Remote Sensing:

Although remote sensing has many advantages over ground-based survey, yet remote sensing has not totally replaced ground-based survey methods, largely because of some limitations with this technology, which still exist.

These include:

(i) Cost of data collection and data purchase.
(ii) Problems with data analysis and interpretation.
(iii) Potential limitations with spatial, spectral and temporal resolutions of the various sensors.
(iv) Problems with all weather capability as some sensors cannot 'see' through cloud.

In-spite of these limitations, remote sensing has however many advantages over ground- based survey in that large tracts of land can be surveyed at any one time, and areas of land (or sea) that are otherwise inaccessible can be monitored.

The advent of satellite technology and multi-spectral sensors has further enhanced this capability, with the ability to capture images of very large areas of land in one pass, and by collecting data about an environment that would normally not be visible to the human eye.

6. Applications of Remote Sensing:

Satellite data allows the proper management of our renewable and non-renewable resources as it provides timely and detailed information about the Earth's surface.

Following are a few examples of some of the important uses of satellite data:

(i) Assessment and monitoring of vegetation types and their status.
(ii) Agricultural property management planning and crop yield assessment.
(iii) Soil surveys including mineral and petroleum exploration.
(iv) Litho logic mapping.
(v) Monitoring and planning of water resources and groundwater exploration.
(vi) Geographic information
(vii) Map making and revision and production of thematic maps.
(viii) Weather and agricultural forecasts and assessment of environment and natural disasters.
(ix) Urban planning.
(x) Image processing.
(xi) Precision geo-referencing.
(xii) Laser film writing and printing.

Applications of Remote Sensing in Forest Resource Management:

(i) Satellite imagery can provide the visible boundaries of soil types, while remote sensing provide for a shallow penetration of soils. Additional physical data can be obtained from spectral signatures for the soil surfaces.

(ii) Remote sensing allows for classification of soils, which can be interpreted from the remote sensing images and the spectral signatures.

(iii) Remote sensing can provide information on the productivity of forests, meadows, wildlife habitat conditions, land-use and recreational suitability, which allows for future protection of the environment.

(iv) Multi temporal techniques can be used to map dynamical features, erosion and soil moisture.

(v) Remote sensing can also be used in combination with ground radar, to detect changes of diagnostic soil horizons such as albic, spodic and argillic horizons or soil/rock boundaries.

Elements of Visual Interpretation

Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of tone, shape, size, pattern, texture, shadow, and association. Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyze. The nature of each of these interpretation elements is described below:**

Fig. 37 Tone

Tone refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allow the elements of shape, texture, and pattern of objects to be distinguished.

Fig. 38 Shape

Shape refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by rotating sprinkler systems would appear as circular shapes.

Fig. 39 Size

Size of objects in an image is a function of scale. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use.

Fig. 40 Pattern

Pattern refers to the spatial arrangement of visibly discernible objects. Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees and urban streets with regularly spaced houses are good examples of pattern.

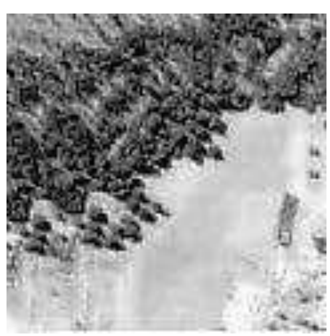


Fig. 41 Texture

Texture refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most important elements for distinguishing features in radar imagery.

Fig. 42 Shadow

Shadow is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery.

Fig. 43 Association

Association takes into account the relationship between other recognizable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds, and sports fields. In our example, a lake is associated with boats, a marina, and adjacent recreational land.

GIS

GIS can be defined as "An integrated system of computer hardware and software coupled with procedures and a human analyst which together support the capture, storage, management, manipulation, analysis, modeling and display of spatially referenced data "

In short geographical information system gives power to create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas and develop effective solutions like never before. It can be said as supporting tool for decision making process. Mapmaking and geographic analysis are not new, but a GIS performs these tasks better and faster than do the old manual methods.

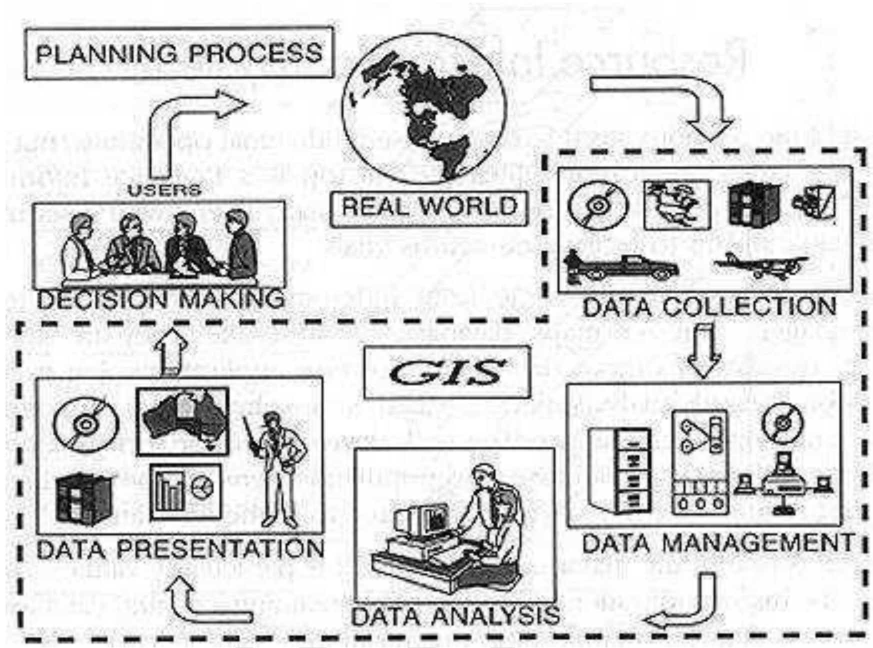


Fig. 44 Process of GIS

Data Models:

Conversion of real world geographical variation into discrete objects is done through data models. It represents the linkage between the real world domain of geographic data and computer representation of these features. Data models are of two types: Raster and Vector. There are three different geometric classes of data in both the models, viz. the point representing the position, line giving the length and polygon giving information about the perimeter or area.

Raster model: In raster type of representation of the geographic data, a set of cells located by coordinate is used; each cell is independently addressed with the value of an attribute. Each cell contains a single value and every location corresponds to a cell. One set of cell and associated value is a layer.

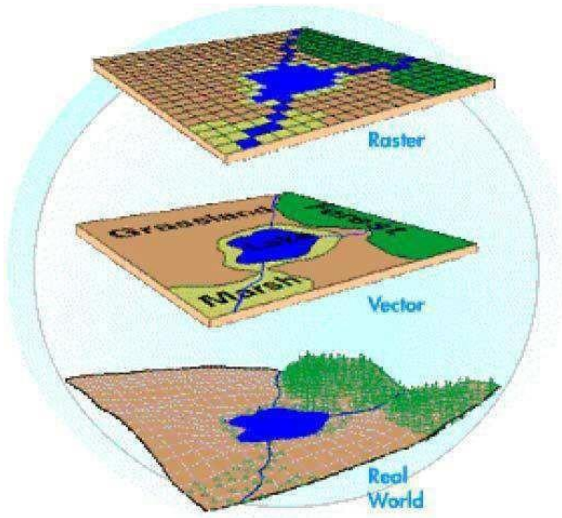


Fig. 45 Data models generated in GIS domain

Vector model: Vector data model uses line segments or points represented by their explicit 'x', 'y' coordinates to identify locations. Discrete objects are formed by connecting line segments which area is defined by set of line segments. Vector data models require less storage space, outputs are appreciable, estimation of are/perimeters is accurate and editing is faster and convenient as compared to raster model.

Layers and Coverage's:

The common requirement to access data on the basis of one or more classes has resulted in employing several schemes in which all data of a particular level of classification, such as roads, rivers or vegetation types are grouped into so called layers and more than one layer together form coverage. The concept of layers is to be found in both vector and raster models. The layers can be combined with each other in various ways to create new layers that are a function of the individual ones. The characteristic of each layer with in layer-based GIS is that all locations with each layer may be said to belong to a single arial region or cell, whether it be a polygon bounded by lines in vector system, or a grid cell in a raster system. But it is possible for each region to have multiple attributes. The following figure shows layers and coverage concept in GIS.

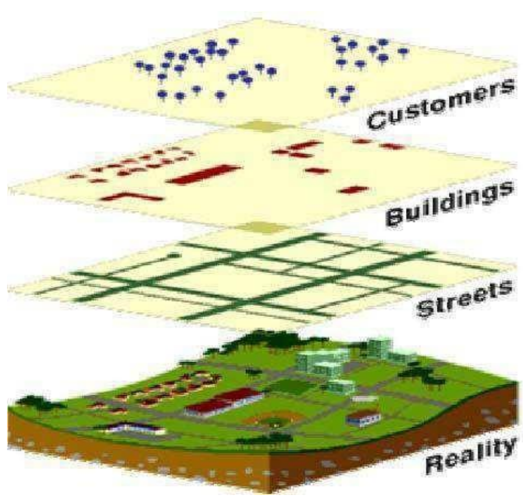


Fig. 46 Different layers and coverage's generated in GIS domain

Global Positioning System (GPS):

The Global Positioning System (GPS) is a burgeoning technology, which provides unequalled accuracy and flexibility of positioning for navigation, surveying and GIS data capture. The GPS provides continuous three-dimensional positioning 24 h/day throughout the world. The three dimentional nature of GPS measurements also allows us to determine horizontal as well as vertical displacement at the same time and place (Kalpan, 1996; Segall and Davis, 1997). The technology seems to be beneficiary to the GPS user community in terms of obtaining accurate data upto about100 meters for navigation, metre-level for mapping, and down to millimetre level for geodetic positioning. The GPS technology has tremendous amount of applications in GIS data collection, surveying, and mapping.

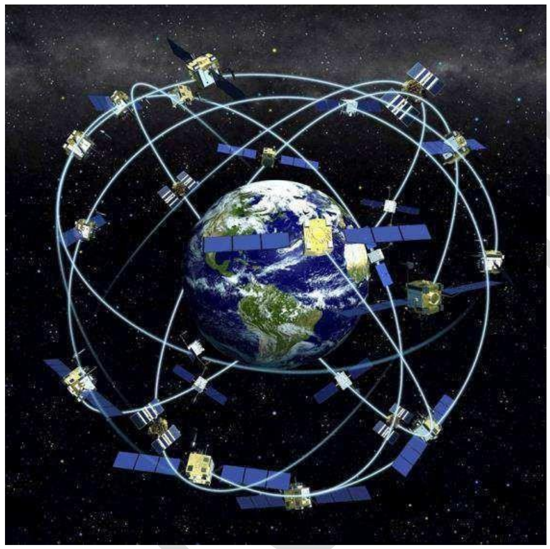


Fig. 47 Constellation of NAVSTAR satellites orbiting earth

GPS –Basics:

The GPS uses constellation of 24 satellites, continuously orbiting earth and computers to compute positions anywhere on earth (figure 3.14). The GPS is based on satellite ranging. That means the position on the earth is determined by measuring the distance from a group of satellites in space. In order to understand GPS basics, the system can be categorized into five logical steps:

(1) Triangulation from the satellite is the basis of the system
(2) To triangulate, the GPS measures the distance using the travel time of the radio message
(3) To measure travel time, the GPS need a very accurate clock
(4) Once the distance to a satellite is known, then we need to know where the satellite is in space
(5) As the GPS signal travels through the ionosphere and the earth's atmosphere, the signal is delayed. To compute a position in three dimensions we need to have four satellite measurements. The GPS uses a trigonometric approach to calculate the positions.
(6) The GPS satellites are so high up that their orbits are very predictable and each of the satellites is equipped with a very accurate atomic clock.

GPS – Components:

The GPS is divided into three major components as listed below:

(1) The Control Segment
(2) The Space Segments
(3) The User Segment

The Control Segment:

The Control Segment consists of five monitoring stations (Colorado Springs, Ascesion Island, Diego Garcia, Hawaii, and Kwajalein Island). Three of the stations (Ascension, Diego Garcia, and Kwajalein) serve as uplink installations, capable of transmitting data to the satellites, including new ephemerides (satellite positions as a function of time), clock corrections, and other broadcast message data, while Colorado Springs serves as the master control station. The monitoring stations track all GPS signals for use in controlling the satellites and predicting their orbits. Meteorological data also are collected at the monitoring stations, permitting the most accurate evaluation of tropospheric delays of GPS signals. Satellite tracking data from the monitoring stations are transmitted to the master control station for processing. This processing involves the computation of satellite ephemerides and satellite clock corrections. The master station controls orbital corrections, when any satellite strays too far from its assigned position, and necessary repositioning to compensate for unhealthy (not fully functioning) satellites.

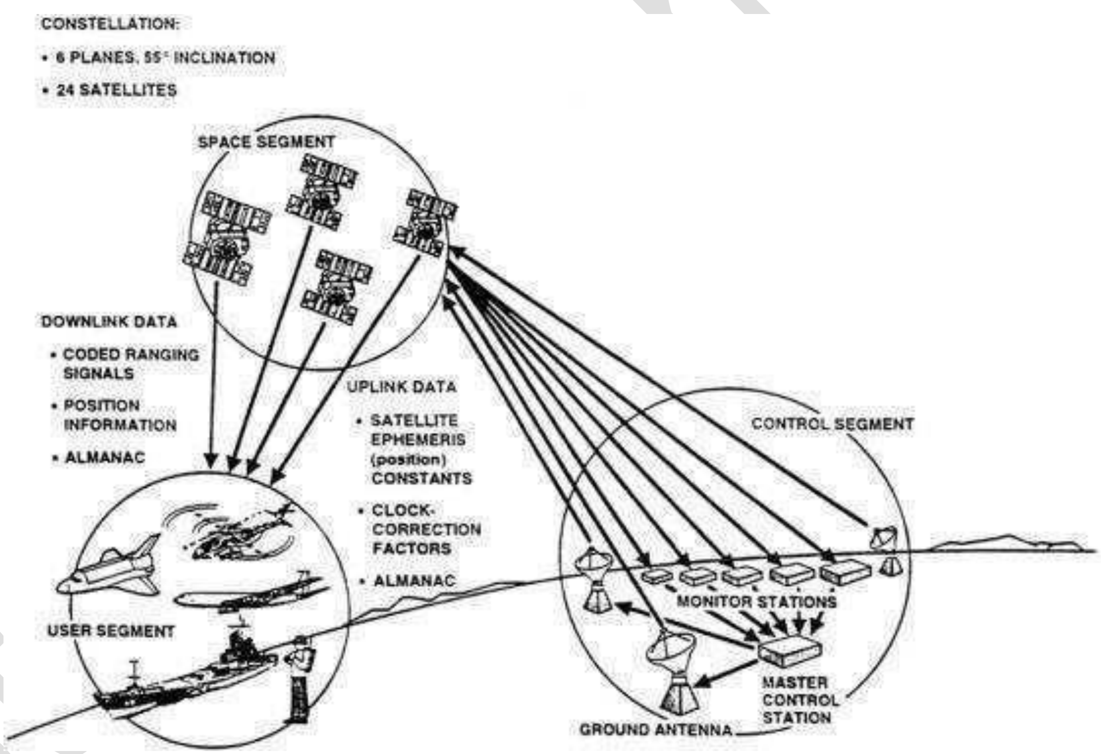


Fig. 48 Different components of GPS

The Space Segment:

The Space Segment consists of the constellation of 24 earth orbiting NAVASTAR satellites. The satellites are arrayed in 6 orbital planes with 4 satellites per plane, equally spaced 60◌ apart along the equator and inclined at 55 from the equatorial plane. They orbit at altitudes of about 12000, miles each, with orbital periods of 12 sidereal hours (i.e., determined by or from the stars), or approximately one half of the earth's periods, approximately 12 hours of 3-D position fixes. The next block of satellites is called Block IIR, and they will provide improved reliability and have a capacity of ranging between satellites, which will increase the orbital accuracy. Each satellite contains four precise atomic clocks (Rubidium and Cesium standards) and has a microprocessor on board for limited self-monitoring and data processing. The satellites are equipped with thrusters which can be used to maintain or modify their orbits.

The User Segment:

The user segment is a total user and supplier community, both civilian and military. The User Segment consists of all earth-based GPS receivers. Receivers vary greatly in size and complexity, though the basic design is rather simple. The typical receiver is composed of an antenna and preamplifier, radio signal microprocessor, control and display device, data recording unit, and power supply. The GPS receiver

decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation, and time. This is a continuous process and generally the position is updated on a second-by-second basis, output to the receiver display device and, if the receiver display device provides data capture capabilities, stored by the receiver-logging unit.

GIS helps to present information in a straightforward method to your project. With ArcGIS Server technology, it is easier to take the map of something you have created with ArcGIS Desktop software and post them on the Web so that your staff and partner in the field can view how a project is developing.

Critical Infrastructure Protection

The security and the safety of the building are in the hands of the engineers. Utilities, bridges and other crucial infrastructures require comprehensive decision-making equipment for preparation response, emergency assessment and recovery activities. GIS technology offers situational responsiveness tools for combining information from flood evacuation and elevation routes to inspection results and structural specifications.

With vital infrastructure information packed in a geo database, it is easier to display the information in actual time on a Web-based map. You can use GIS tools to analyze and combine specific data required to meet a required task. Add weather data and current traffic, draw barrier protection regions and share new changes in actual time.

Land Fill Site Assortment

GIS is a useful tool which can be utilized in the search for appropriate new landfill sites. It is also powerful technologies that permit correct spatial data processing covering a bigger number of themes. The arrival of highly sophisticated high-tech GIS systems, Landsat satellites and digitalized map data and other remote sensing devices that helps define land use patterns and infrastructural have dramatically improved the GIS potential to aid the progress of more organized approach to landfill site selection.

This kind of approach should preferably syndicate computerized GIS and geotechnical site analysis procedures. Also, there is a need for better transparency in the procedure of site selection to encourage public confidence in the nonbiased scientific foundation process.

Urban Development and Town Planning

The exceptional growth of urbanization in many countries such as India has caused problems of sanitation, power and waste supply, housing, environmental pollutions and disposal of effluents. For a maintainable development of urban agglomeration, ideal resources development model and urban land use plan need to be generated by integrating the information on demographics, natural resources and socio-economic statistics in a GIS domain with the presently available satellite records.

GIS quickly analyzes and incorporates various types of images and information for sites analysis. It's extremely accurate results presented geographically provide insights into interactions and connections as clients can relate easily to a simple map. The base map may include serial photos, environmental

protection areas, city and zoning designations soil and topographic maps. Overlays or pertinent data on commercial activity, traffic flow, and population growth combine to paint a significant picture of sites constraints and opportunities swiftly.

Civil engineers use GIS to uphold a track of numerous city and regional displays, predict future essentials of the public and plan accordingly to make sure everybody in the community has a functional life. And with the changing technology more so, local planning agencies, states, regional and federal have realized GIS power to identify the problems and react to them efficiently as they share the outcomes with others. A GIS solution offers tools to help touch their agency undertakings while spending less and doing more.

Watershed Management

GIS improves controls for flow statics, watershed features, and debris flow probabilities and enables the watershed allocation using Digital Elevation Models (DEMs). It offers a stable procedure for watershed analysis using scandalized datasets and DEMs such as land cover, climates variables, gauging station locations and soil properties. Arc Hydro with ArcGIS offers the flexibility to syndicate watershed datasets from a map source with river and stream networks.

Engineers who make use of GIS are able to save money because they no longer require owning expensive printers or properties for conscripting such as technical pens and papers. Equally, they don't require having a large control of drafters or sketching the same plot of land or a particular structure detail by hand. They only need to state a location on GIS mapping. This means improved communication among the team members as well as better record keeping when you make changes in the ground. The engineer can draw changes in the ground to the progress in the project to advance billing while the phases in the project are finalized.

ESRI, the firm that developed GIS, assures that GIS allows you to request any question about a particular place. GIS will assist you in accumulating and obtaining the date, help you in analyzing and examining the data and act on the information received by GIS. ESRI defines this as "acquire, ask, analyze, examine and analyze" sequence as the geographic approach since all that happens or has happened before or could happen in the future is connected to geography. GIS connects all this information to geography and permits you to access and analyze it as long as you are aware where something occurred.

Spatial Analysis

GIS offers tools for demonstrating information to support faster decisions, optimize network and resource allocation, characterizes and discover geographic patterns and systematize workflow through a graphical modeling environment.

Spatial Data Management

GIS manages and organizes geographic information to support efficient and fast visualization and logical applications, no matter the amount of data held in an organization. Organizations securely store and manage massive amounts of spatial information and promulgate data changes between several data sources.

Transportation Planning

GIS is used to manage transportation and logistical hitches. Once the transportation department is planning to construct a new road or a railway route, engineers can perform this by adding topographical and environmental data into the GIS platform. It easily points out the best direction for transportation grounded on criteria such as least harm to habitat, flattest route, and least disturbance to the local individuals.

Environmental Analysis

GIS provides exploration to support design including material consumption, hydrology analysis, soil load analysis, volume calculations, runoff and air emissions, slope stability, traffic capacity, and erosion control. Environmental analysis with GIS permits you to view trends, patterns, and relationships that weren't evident without visualization of data.

Provide Construction Requirements

GIS provides management and mechanics for constructing new infrastructure including earth movement, machine control takeoffs, payment calculations, schedules, logistics, materials tracking and traffic management.

Data Collection as Built Surveying

GIS provides tools to accumulate detailed data and document present settings. As-built surveying with GIS expertise allows the surveyor to provide data into operational GIS, eradicating costly data conversion and minimizing errors.

Designing

GIS permits the formation of innovative infrastructure data for diverse civil works including, classifying, cross sections, stipulations, quantity haul plans, design planning, equipment presentation, and environmental improvements plans. This includes incorporation with traditional design outfits such as database and CAD for new design capabilities.

Preparing Response and Retrieving Activities

GIS expertise provides situational awareness and equipment for linking information from flood depth and clearing paths for a bridge's mechanical provisions and inspection results.

CAD Integration

CAD interoperability is an essential part of ESRI's software solutions. Attainable files on national GIS uses Web locations and level CAD documents are adapted and managed from the main location, reducing duplicated datasets and giving a platform for all spatial data supply and functionality.

Results Interpretation

One of the most obvious and interesting features of GIS is the capability to offer analysis results in map form. The invention of cartographic quality maps or presentations can provide support in numerous pertinent decision processes. More advantages can be achieved using other graphic GIS features. Through interactive model visualization, reasonable predictions can be assessed. Visualization can be accompanied by spatial queries of model outcomes. Such queries help to identify possible correlations between model predictions and input parameters.

Data Handling

GIS in civil engineering software has a unique ability to capture manage and store spatially referenced data such as lines points and polygons or as continuous field. It is used as the spatial file; GIS helps in modeling presentations through handling a precise form of data that would else be compromised to store in a spatial database. This is one of the most compelling motives for using GIS and the most mentioned benefit.

Land Analysis

GIS software enhances the optimum land use, functional proficiency of a proposed design, its marketability and the general cost-effectiveness of a project. GIS may be used for hydrologic, terrain, visibility analysis, and land-use suitability. Also, it can be used to assess the environmental effect for defining the consequences of different regulatory requirements.

Model Application

GIS provides a framework to model spatially neighborhood engineering phenomena. Engineering explores that has been traditionally mapping founded such as flood predicting benefit from efficiency in performing spatial operations that were achieved manually in the past.

Visualization and Cartography

By using 2D and 3D, you can experience a more cooperative way of seeing data, picturing change over space and time to identify trends and patterns and disseminate knowledge to managers, engineer, regulators, clients, and field-based personnel.

Construction Management

GIS provides the mechanism and management for constructing new infrastructure including machine control, intermediate construction, earth movement, traffic management, logistics, material tracking and payment calculations.

Operating and Maintaining Infrastructure

GIS mapping models infrastructure network and utility and incorporates other related types of data such as CAD drawings and raster images. Display tools and spatial selection allow you to visualize ongoing activities, scheduled work, historical information and recurring maintenance problems.

3D Renderings

Environmental analysis with GIS mapping permits you to view trends, patterns, and relationships that were not visibly evident without data design visualization. It allows the formation of new infrastructure for innovative civil works including contouring, grading, mass haul plans, equipment staging, and environmental mitigation plan.

Providing Accuracy

GIS saves time and provides accuracy when producing a map for the project. It enables to have exceptional maps with various scales at low cost. The map acts as the project document, and it is used in the design stage at an estimated cost. The construction manager needs such in their job.

Regional Planning

Planners use GIS to research implement, develop research and the progress of their plans. It offers surveyors, engineers, and planners with the tools needed to map and design the cities and neighborhoods. Planners have the technical proficiency, political savvy and financial understanding to transform vision tomorrow into strategic action as they make use of GIS to facilitate the process of decision making.

Space Utilization

GIS helps engineers to arrange and spatially visualize small space and come up with the best way to use it. Operational costs can be minimized by using space more efficiently such as managing moves of assets and people.

Properties of rocks

Density, unit weight, specific gravity and water content Density of the rock is the mass of rock per unit volume whereas unit weight of the rock is the weight per unit volume. Highly porous rocks and relatively poor arrangement of grains (less packing) usually have relatively less densities and vice versa. The bulk unit weight considers the bulk (total) volume of rocks whereas the solid unit weight considers volume excluding the pores, fissures. Obviously, for porous rocks the unit weight of solid would be relatively higher than the bulk unit weight as the value in the denominator is relatively lower due to exclusion of pores and micro fractures.

****