M. A. M. COLLEGE OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

AG2211 APPLIED GEOLOGY

UNIT I : GENERAL GEOLOGY – PART A

1. **What is the importance of geology in civil engineering?**
   The importance of Geology knowledge in civil engineering
   - Nature of soil materials can be found out.
   - Provides knowledge about materials used in construction
   - Required for foundations faults.
   - Design of highways and roads.
   - Helpful for river control and shipping work.
   - Helpful for constructing dams.
   - Constructing tunnels.
2. **Write any four branches of geology.**
   Petrology, Mineralogy, Crystallography, Stratigraphy, Paleontology
3. **Distinguish between continental crust and oceanic crust.**
   Continental crust - Sial (Si = Silicon and Al= Aluminium) having density 2.75 to 2.90. It has been estimated that the Sial rocks are 70 per cent of the Earth's crust, which include chiefly Granite. These rocks are generally on the upper regions of the crust. The thickness varies between mountain ranges (70-100 km) and plain areas (around 65 km).

   Oceanic crust - Sima (Si=silicon and Ma= Magnesium) having density 2.90 to 4.75. Sima rocks include heavy and dark coloured rocks like Basalts. In these rocks, the percentage of Silica is reduced and Magnesium attains the next importance in place of Aluminium of Sial rocks. These rocks are generally found on the floors of the Oceans and beneath sial rocks. The thickness is around 5 km.
4. **What are seismic waves? List the types of seismic waves**
   Waves generated by an earthquake are termed as seismic waves. There are three main types of wave-motion.
   - P-waves or primary waves or push-pull waves or longitudinal waves.
   - S-waves or secondary waves or shear waves or transverse waves.
   - L-waves or Love waves or Rayleigh waves or surface waves.
5. **What are the discontinuities found in the earth?**
   The propagation of these seismic waves (P-waves and S- waves) inside the earth demarcates different zones, by two major and three minor discontinuities. These discontinuities are due to differential composition and nature of the earth.

   The major discontinuities are

   a. Mohorovicic discontinuity (crust-mantle discontinuity) and
   b. Gutenberg discontinuity (crust-mantle discontinuity).

   The minor discontinuities are

   a. Conrad discontinuity (sial - sima) in crust
   b. Repetiti discontinuity (outer mantle - inner mantle) and
   c. Lehmann discontinuity (outer core- inner core)
6. **What are seismograph and seismogram?**
   The instrument used for recording of seismic shocks is known as '*Seismograph'* and the records of science shocks prepared and presented as report by seismographs are known as *'Seismograms'.*
7. **Name the scales used for the estimation of earthquakes**
   Rosi-Forrel scale, Mercalli scale, Richter scale
8. **What are the seven major plates in platetectonics?**
   Pacific, North American, South American, African, Eurasian, Antarctic, Indo-Australian

9. What are the evidences for plate tectonics?

- Ring of fire - volcanoes that encircle most of the Pacific Ocean
- Distribution of earthquakes along plate margins
- Sea floor spreading
- Paleo magnetism
- Location of earthquake foci along steeply-dipping subduction zones
- Age dating sediments on either side of the mid-ocean ridge indicates the sediments get progressively older away from the mid-ocean ridge axis
- Thickness of sediments also increases away from ridge

10. What is an asthenosphere?

The asthenospher**e** (from Greek *asthenēs* *'weak'* + sphere) is the highly viscous, mechanically weak and ductilely-deforming region of the upper mantle of the Earth. It lies below the lithosphere, at depths between 100 and 200 km below the surface, but perhaps extending as deep as 700 km. It is considered the source region of mid-ocean ridge basalt.

11. Explain the subduction zone.

In geology, subduction is the process that takes place at convergent boundaries by which one tectonic plate moves under another tectonic plate and sinks into the mantle as the plates converge. Regions where this process occurs are known as *subduction zones*. Rates of subduction are typically measured in centimeters per year, with the average rate of convergence being approximately 2 to 8 cm per year.

12. Define weathering.

Weathering is defined as the natural processes of mechanical disintegration and chemical decomposition of rocks, brought about by the agents of atmosphere and temperature.

13. What are the types of weathering?

There are two types: During mechanical (or physical) weathering rocks break up or crumble with no change in the composition of the parent rock. In chemical weathering, the minerals present in the rocks undergo chemical alteration or decay. Some times due to the activity of living organisms the rock may be weathered, can be termed as biological weathering.

14. Distinguish Exfoliation and spheriodal weathering.

<u>Exfoliation</u> is the process of peeled away of the rock layers one after the other. This type of mechanical weathering is brought about by temperature changes on massive rocks. In desert regions, rocks expand during day time and contract at nights. This causes stresses in the outer parts of rock masses and results in their mechanical separation.

<u>Spheroidal Weathering</u> is a kind of chemical weathering. When water containing dissolved gasses enters a rock mass divided by rectangular joints, the rock surfaces are attacked chemically. Since the corners and edges have greater surface area, they will be rapidly weathered. As a result, the rectangular rock bodies will have their edges and corners rounded off. In course of time, there will be a spherical mass with a fresh innermost core surrounded by layers of more altered material. The weathered rock is comparable to an onion. The spheroidal weathering is characteristic of rocks called Basalts and Charnockites.

15. What is Seafloor Spreading?

In 1947- Harry Hess suggested a new hypothesis, While mapping the Mid-Atlantic Ridge (an undersea mountain chain), Scientists discovered that rock samples from the ocean floor were much younger (150my) than the continental crust. The center of the ridge is actually a break in the crust and magma wells up pushing crust apart, magma solidifies to new rock. Robert Dietz named this seafloor spreading, if the ocean is moving, then the continents must be moving too.

16. Give any four erosion features of river.

Hog back, Cuesta, Mesa, Butte

17. What are the types of fluvial erosion?

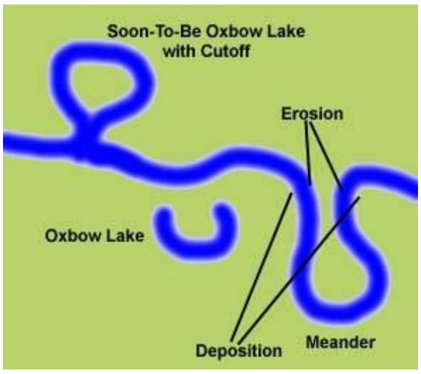
Hydraulic action, Attrition, Abrasion and cavitation

18. What is a delta?

Deltas are depositional features of Δ shape, which are formed in older stages of rivers. These are submerged equivalents of alluvial fans. These are the fertile regions of rivers.

19. Explain stream meanders and oxbow lake?

Mature rivers flow across wide river valleys and meander or snake across the flat plains. These meandering streams create large loop meanders that develop into oxbow lakes adjacent to the stream.



20. Define Aquiclude

A rock body or formation which may be porous enough to hold enough quantity of water but which by virtue of its other properties does not allow an easy and quick flow through it, is called an aquiclude.

21. Define Deflation

The process of removal of particles of dust and sand by strong winds created big depression in desert regions. Sometimes with its base touching the water table create OASIS.

22. Give the earthquake belts in India.

a. Zone of maximum intensity : Assam, all the north-eastern states, northern Bihar, upper strips of Uttar Pradesh, Uttaranchal, Delhi, Harayana, Punjab, full regions of Himachal Pradesh and Jammu and Kashmir including Leh, Ladakh
b. Zone of intermediate intensity: Southern flat lands of Harayana, Punjab, Uttar Pradesh, Rajastan, Madhya Pradesh, Bihar, Bengal, Orissa, Northern parts of Gujarat and Maharashtra.
c. Zone of minimum intensity: Triangular part of India surrounded on the sides by Arabian sea, Bay of Bengal and the Indian ocean.

23. Define Aquifer

An underground rock which contains lot of pore spaces which are interconnected can give a good supply of groundwater. Such a rock is called **aquifer**. Sand is an excellent aquifer.

24 Distinguish between confined and unconfined aquifer.

Confined aquifers are those in which an impermeable dirt/rock layer exists on both sides that prevent water from seeping into the aquifer from the ground surface located directly above. Instead, water seeps into confined aquifers from farther away where the impermeable layer doesn't exist.

Unconfined aquifers are those into which water seeps from the ground surface directly above the aquifer.

25. What is Wave Cut platform?

The undercutting sea erosion of sea cliff and sea stacks continues and eventually the overhanging cliff or stacks collapses downwards - this process continues and the cliff gradually retreats and becomes steeper. As the cliff retreats, a gently-sloping rocky platform is left at the base, this is known as a **wave-cut platform** which is exposed at low tide.

26. What is tombolo?

Tombolo is a beach that extends between a headland, or other part of the mainland, and an island

27. Distinguish between Dunes and Loess.

Sand dunes are hills of wind borne sand. They are formed whenever there is some obstruction in the course of wind. Sand dunes are layered. They show ripple marks and false bleeding.

Loess is an Aeolian deposit of silt size. It is yellow in colour and highly porous. The deposit is unstratified. (Not layered) They are able to stand as vertical cliffs.

28. What is Zone of saturation?

The lower zone in the vertical distribution of groundwater is called **zone of saturation**. Here all the openings in rocks are completely filled with water. The uppermost level of this zone is called **water-table**.

29. What do you mean by Perched Water?

Perched aquifer will occur when low-permeability materials interbed with higher permeability units, causing downward percolating water to form a perched saturated lense in the zone of saturation. The water present in this aquifer is **perched water**.

PART B

DISCUSS THE IMPORTANCE OF GEOLOGY IN CIVIL ENGINEERING

- The success or failure of an onshore or offshore civil engineering structure depends largely on the physical conditions which fall within the province of Geology. The work of an engineer should be based on his implicit faith in geology and the findings of the geologist.
- An engineering geologist's has to observe and record geological information and translate this data to practical engineering design, construction and maintenance of civil engineering projects.
- The engineering projects are built on rocks and soil. Rocks and soil are the basic sources of construction materials. The civil engineer and the engineering geologist have to work together in the field in the initial planning stage. They work together are separately in some stage based on field and project work requirements.
- Civil engineer requires field training in geology to understand the natural geological condition and their influence on civil engineering projects. A civil engineer must be in a position to understand the geological map of the projects area with due practical knowledge for assessing the data.
- Civil engineers must take field training in geology to understand geological settings particularly in the identification of litho logical units. Outcrop pattern, attitudes of geological formations, field recognition of faulted displaced zones, assessment of weather ability pattern of the region etc.,
- The application of geology – preliminary exploration, design, construction operation etc., in the construction of engineering projects. Such as dams, tunnels, highways, canals and buildings results in better and economical engineering structures.
- Engineering geology is the branch of earth science studying the geological conditions for the constructions and utilization of engineering structures. The main purpose of engineering geology is to provide a solution for the safe construction of civil engineering structures.
- Engineering geology is a multidisciplinary subject having interrelation with other disciplines, such as hydrology, rock mechanics, soil mechanics, geophysics, remote sensing, photogrammety, exploration geology, geochemistry, drilling etc.,

1. DESCRIBE THE EARTH STRUCTURE & COMPOSITION WITH NEAT SKETCH.

EARTH STRUCTURES AND COMPOSITION

The Atmosphere

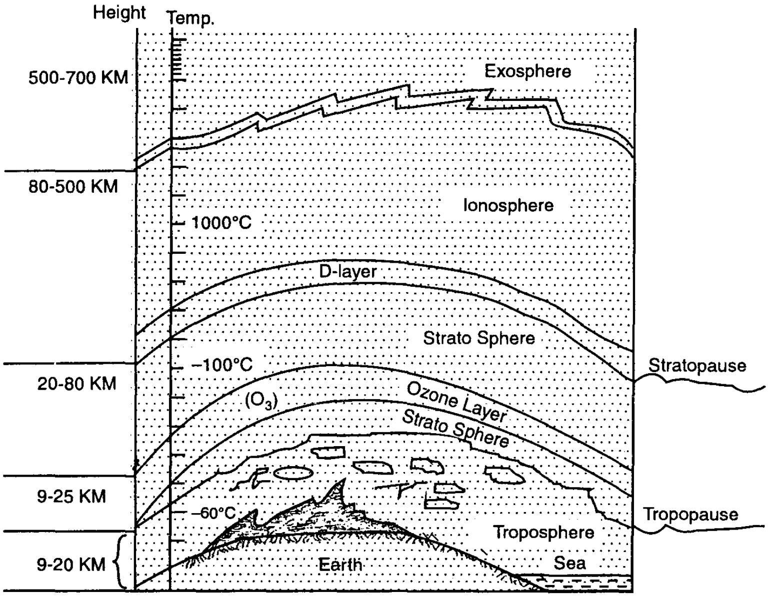
- The outer gaseous part of the Earth starting from the surface and extending as far as 700 km and even beyond is termed atmosphere.
- It makes only about one-millionth part of the total mass of the Earth. The gaseous envelope, like the other matter, is held around the planet due to gravitational pull of the body of the Earth.

Based on thermal characters the atmosphere is divided into the following layers:

(a) The Troposphere:

- It is the lowermost zone of the atmosphere rising from the surface of the earth extending, on an average to a height of 11 km.
- Its upper boundary called tropopause about 9km above the poles and at 18 km above the equator.
- The troposphere contains almost nine-tenths of the total mass of the atmosphere this layer of gases that is responsible for most of the weather forming or 1 processes on the earth.
- In the troposphere there is recorded a regular fall in tem a lapse rate of 6.3 up to tropopause resulting to as low temperatures as —40 C to -60 degree at those heights.

Structure of the atmosphere



(b) The stratosphere

- It is the second layer of the atmosphere starting from the tropopause and extending upto an average height of 50 km
- The temperature becomes constant for a height of 20km (above tropopause) and then starts increasing.
- It contains almost the entire concentration of OZONE GAS that occurs above the Earth in the form of a well-defined envelope distinguished as the Ozone layer
- The stratosphere itself has a layered structure and there is no significant mixing or turbulence of gases in this layer.
- The Ozone Layer starts at a height of 9 km above the surface and continues up to 35 km. The maximum concentration of ozone in this layer is estimated at a height of 20-25km.
- The importance of ozone layer for the life on the planet Earth lies in its capacity to absorb a good proportion of the solar radiation including the entire content of most dangerous ultraviolet rays coming from the Sun.
- In this process, the gas gets itself heated up and hence becomes the cause of higher temperature in the upper regions of the atmosphere.
- The upper boundary of the stratosphere is called stratopause.

(c) The Mesosphere

- This is the third thermal zone of atmosphere which begins at stratopause at about 50km above the surface and continues up to a height of about 80 km.
- It is characterized with a steep fall in temperature that may go to as low levels as —100 °C at the upper limit of mesosphere.

(d) The Thermosphere

- The fourth and the last zone of the atmosphere starts at about 80 km and extends up to 500 km and beyond.
- In this zone, temperature starts rising once again and reaches 1000°C and above.

- The IONOSPHER is a special zone recognized within the atmosphere. It starts from 80 km and extends upwards to variable heights.
- Atmospheric gases at these heights absorb a great part of solar radiation coming to the Earth.
- In this process, these gases break up into ions or electrically charged particles. As a result, this part of the is made up entirely ions and hence is designated as ionosphere.

(e) The Lithosphere

- Together the crust and upper mantle are called **Lithosphere** and they extend to about 80 km**.** This is flow on the asthenosphere, highly viscous layer.
- The **asthenosphere** (from Greek *asthenēs* *'weak'* + sphere) is the highly viscous, mechanically weak and ductilely-deforming region of the upper mantle of the Earth. It lies below the lithosphere, at depths between 100 and 200 km below the surface, but perhaps extending as deep as 700 km. It is considered the source region of mid-ocean ridge basalt
- Three specific layers or zones in the interior of the earth are
    - The crust,
    - The mantle and
    - The core.
- The term lithosphere is now understood to include only the uppermost shell of the earth, the crust and a part of the second layer, the mantle, up to which the material exists in a definite solid state.
- The interior of earth can be studied indirectly through geophysics principles. The seismic waves, produced during an earthquake give the idea of interior of the earth. The propagation of these seismic waves (P-waves and S- waves) inside the earth demarcates different zones, by two major and three minor discontinuities. These discontinuities are due to differential composition and nature of the earth.
- The major discontinuities are

    c. Mohorovicic discontinuity (crust-mantle discontinuity) and

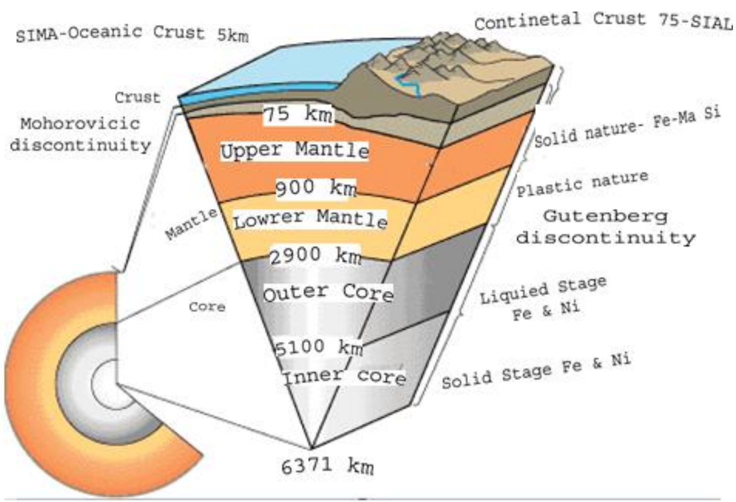
    d. Gutenberg discontinuity (crust-mantle discontinuity).

    The minor discontinuities are

    d. Conrad discontinuity (sial - sima) in crust

    e. Repetiti discontinuity (outer mantle - inner mantle) and

    f. Lehmann discontinuity (outer core- inner core)



The Crust (0-60 Km) The earth is composed of different rocks. In an ordinary sense the term rock means something hard and resistant but the meaning of the word has been extended so as to include all natural substances of the Earth's crust, which may be hard like granite or soft like clay and sand. It has been estimated that 95 percent of the earth crust is made of primary i.e., first formed (Igneous) rocks which is mostly composed of Granite having Quartz, Feldspar, Biotite mica and Homblende in varying proportions the remaining 5 percent of the crust is made up of secondary (Sedimentary or Metamorphic) rock.

The Earth's crust is in the form of a very thin layer of solidified rocks and is heterogeneous in nature. These rocks may be classified on the basis of their density into the following two groups.

- **Continental crust** - Sial (Si = Silicon and Al= Aluminium) having density 2.75 to 2.90. It has been estimated that the Sial rocks are 70 per cent of the Earth's crust, which include chiefly Granite and Silica. These rocks are generally on the upper regions of the crust. The thickness varies between mountain ranges (70-100 km) and plain areas (around65 km).
- **Oceanic crust** - Sima (Si=silicon and Ma= Magnesium) having density 2.90 to 4.75. Sima rocks include heavy and dark coloured rocks like Basalts. In these rocks, the percentage of Silica is reduced and Magnesium attains the next importance in place of Aluminium of Sial rocks. These rocks are generally found on the floors of the Oceans and beneath sial rocks. The thickness is around 5 km.

Mantle (60-2900 Km): It is the part of the earth below the crust and surrounding the core. The imaginary line that separates the lithosphere from the mantle is known as 'Moho' (Mohorovicic discontinuity). Because of high temperature and great pressure, the mineral matter in this part is the molten condition. The mantle can be distinguished into upper mantle and lower mantle due to the Repetiti discontinuity due to the low velocity zone in mantle.

Core: (2900-6378 Km) It is the innermost layer of the earth; it extends from below the mantle (Gutenberg discontinuity) to the central part of the earth. The density of the core is found to be 13.6. On the basis of earthquake waves, the core has been further divided into two by Lehmann discontinuity, as follows

- **Outer core:** (2900-5150 km) The outer core is 2,250 km thick and surrounds the core. It is believed that it is still in molten condition. S-waves
- **Inner core:** (5150-6371 km) The inner core is also called 'Nife' because it consists of Nickel and iron. Its thickness is about 1,221 km. It is very hard in nature.

(f) The Hydrosphere

- It is a collective name for all the natural water bodies occurring on or below the surface. Although hydrosphere makes only 0.03 percent of mass of the earth as a planet, its relevance to the existence of life on this planet can hardly be overstated
- More than 98 percent of the hydrosphere is made up of huge surface bodies of saline water called seas and oceans.
- Rivers and lakes spread over hundreds of thousands square kilometers are other constituents of the hydrosphere.
- Huge bodies of frozen water, the ice and snow, together making up the glaciers are the third major component of hydrosphere.
- Lastly, but not the least, water occurring in pores, cavities and cracks of the rocks of the crust of the earth, called the ground water, is another important part of the hydrosphere.

(g) The Biosphere

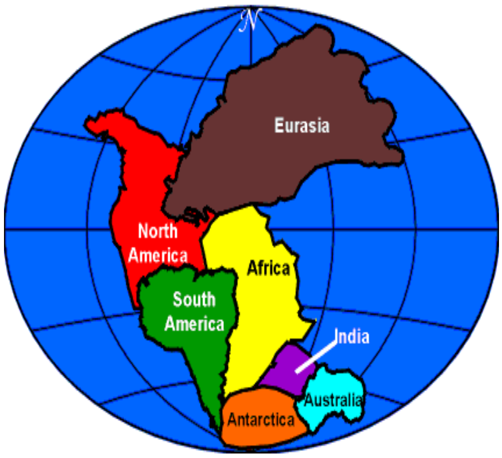
- This term is sometimes used to express the collective life form, as it exists on the surface and under water.
- The biosphere depends for its existence on the other three zones of the planet already described: the lithosphere, the atmosphere and the hydrosphere.
- This zone has also been responsible for many geological processes that have been going on the planet since the evolution of life.

2. DESCRIBE IN DETAIL ABOUT THE CONTINENTAL DRIFT AND THE PLATE TECTONICS.

CONTINENTAL DRIFT

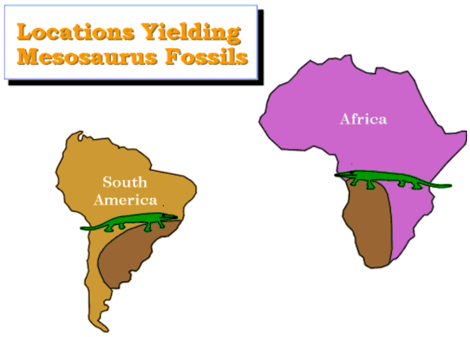
1912- Alfred Wegener proposed this hypothesis

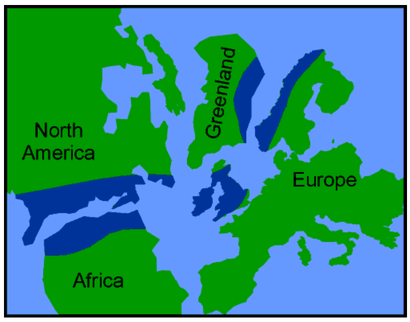
- Continental drift- stated that continents had moved
- Continents once formed a single land mass called Pangaea
- There was once a huge sea called Panthalassa
- About 200 mya Pangaea broke up into smaller pieces and drifted to current locations over time.
- Movements of crust may have formed Mountain ranges
- Wegener's ideas met with strong opposition. He died in 1930 without finding an explanation for why continents move.



Evidence for continental drift

- Similarities in coastlines- parts of the continents seemed to fit together like a puzzle
- Fossil remains of Mesosaurus- a small extinct reptile of 270 mya has been found on both E. coast of South America and W. coast of Africa





- Climate- coal deposits indicate that continents were once in a tropical area.
- Glacial deposits in areas that are now too warm for glaciers.
- Rock formations- Mountains such as the Appalachians seem to extend to Scotland, Greenland and Europe
- Termination of Mountain chains

PLATE TECTONICS

In the last century we have gathered much evidence to support the idea that Earth's surface is broken up into "lithospheric" plates that slowly move over the top of the mantle. **Plate** is a rigid piece of lithosphere floating on a partially plastic substrate (asthenosphere). There are seven major plates and around 30 plates in total.

Seven Major Plates

1. Pacific
2. North American
3. South American
4. African
5. Eurasian
6. Antarctic
7. Indo-Australian

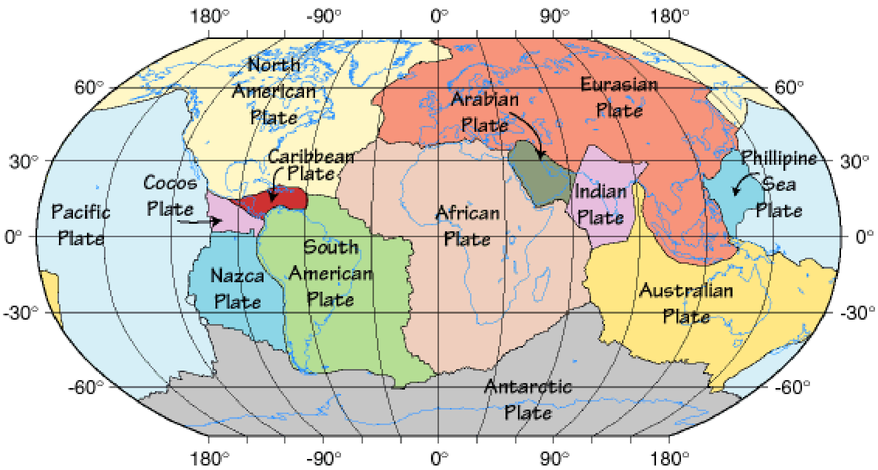


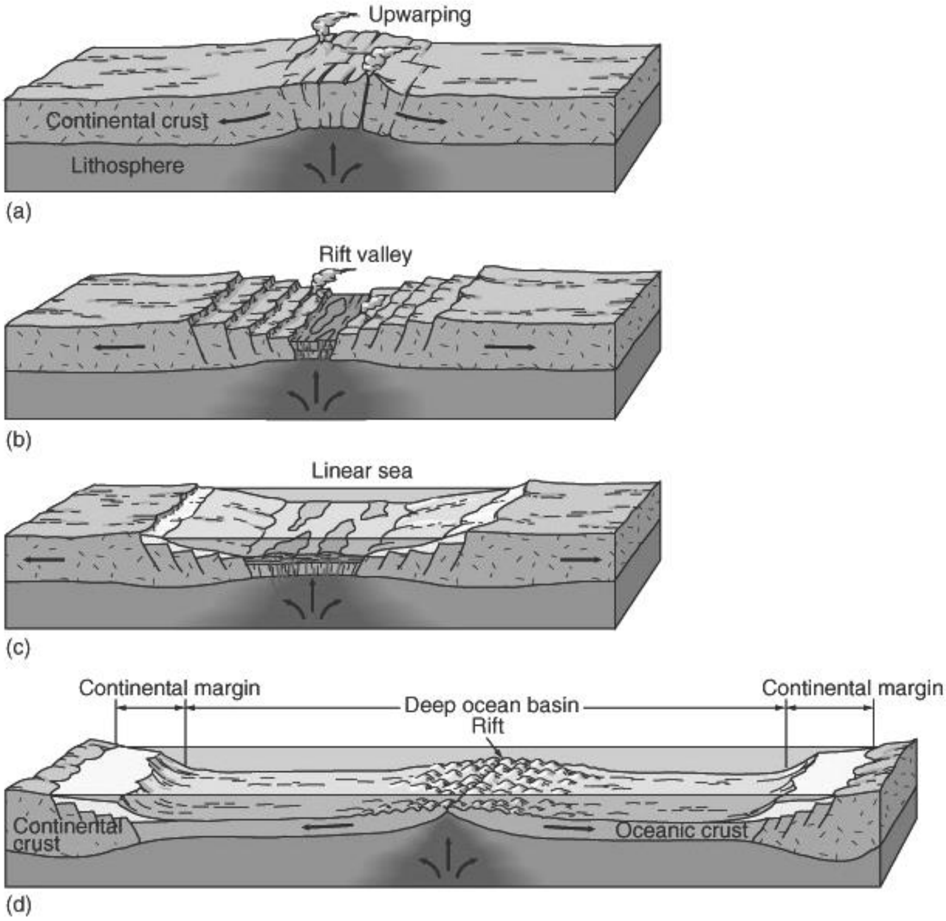
Plate Margins

- Active margins- occur along plate boundaries and result in earthquakes, volcanoes and mountain building ex. West coast of South America
- Passive margins- do not occur at plate boundaries. Ex. East coast of North America

Plate Boundaries

Three Main types of plate boundaries

- Divergent- where new crust is generated as the plates pull away from each other
- Convergent- where crust is destroyed as one plate dives under another
- Transform boundaries- where crust is neither produced nor destroyed as the plates slide horizontally past each other



Diverging Boundaries

- Also called spreading centers, found mostly on the sea floor
- Best known mid-Atlantic Ridge
- ~2.5 cm a year spreading rate
- Molten rock from asthenosphere rises and fills the space between plates
- Rock on either side of the rift is the same age and polarity
- Rift valley- narrow valley formed as plates separate ex. Mid ocean ridge and East coast of Africa
- Other rift valleys form where continents are separated by plate movement ex. Red sea formed by the separation of the African and Arabian Plate
- Iceland, Straddles Mid-Atlantic ridge, Splitting along a spreading center between the North Americana and Eurasian Plates

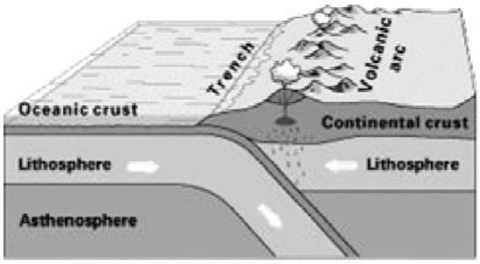
Convergent Boundaries

- Two plates coming together or converging

Three main types of collisions

1) Oceanic- Continental Collision

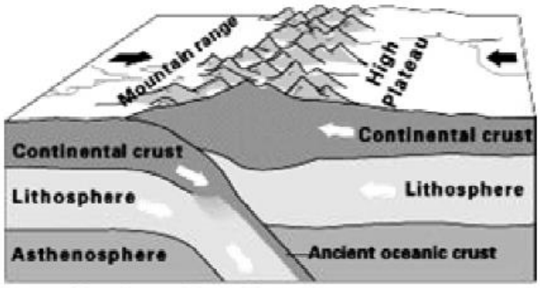
- Oceanic is denser- it subducts or plunges under continental crust
- Subduction- where one plate moves under another.
- Forms deep ocean trench ex. Peru-Chile trench, Mariana Trench
- Oceanic plate melts, magma rises the continental crust to form volcanic mountains
- Features- earthquakes, volcanic mountains, trenches, subduction



Oceanic-continental convergence

2) Continental-Continental Collision

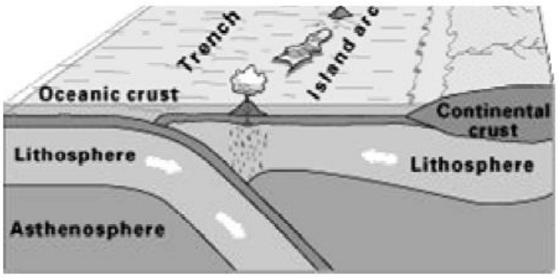
- Neither plate is subducted because they are the same density
- Colliding edges are crumpled and uplifted producing mountain ranges ex. Himalayas
- Features- Mountains and earthquakes only Current location of hot spot



Continental-continental convergence

3) Oceanic-Oceanic Collision

- Forms from the collision of two oceanic plates
- Forms deep Ocean trench
- Island Arc- part of the subducted material melts, resulting magma rises to the surface along the trench to form a chain of volcanic islands
- Features- subduction, earthquakes, volcanic islands, trenches



Oceanic-oceanic convergence

Transform Fault Boundaries

- Two plates grinding past each other
- Do not slide smoothly, scrape together and move in sudden spurts of activity ex. San Andreas fault,
- Breaking of the rock (faults) cause earthquakes but NOT volcanic activity
- Areas that have not moved are the areas likely for strong earthquakes
- Plate-boundary Zones
- Usually include two large plates and one or more micro plates
- Have complicated geologic structures and earthquake patterns

Rates of Motion

- Rates vary greatly
- Average rate of spreading is 2.5 cm per year, 15 cm/yr.

Plate movement

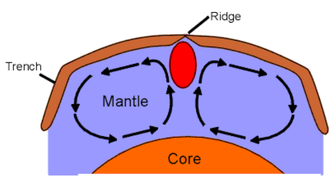
- The earth's crust consists of two parts oceanic and continental crust
- Oceanic crust is made of basalt
- Continental crust is composed of granite and is less dense than basalt
- The oceanic crust and continental crust and the ridged upper mantle make up the lithosphere. It is broken up into 30 identified plates

Driving Force for plates

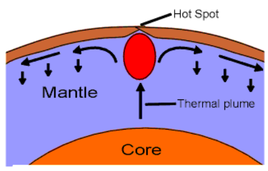
Convection Cells and Hot Spots

Convection Cells

- Asthenosphere, found beneath the lithosphere,Partially molten and flowing, form convection currents
- Hot rising currents push the plates apart and form divergent boundaries
- Cool sinking currents push the crust together and form convergent boundaries



Convection Model



Hot Spot Model

Hot Spots

- Not a plate boundary
- Magma works it way up through lithosphere
- Hot spot remains stationary, but plate drifts
- Volcano on the surface is carried away from the hot spot
- A new volcano forms where new crust has moved over it
- ex. Hawaiian islands and Yellowstone National Park

Evidences for plate tectonics

Seafloor Spreading

- 1947- Harry Hess suggested a new hypothesis
- While mapping the Mid-Atlantic Ridge (an undersea mountain chain), Scientists discovered that rock samples from the ocean floor were much younger (150my) than the continental crust.
- The center of the ridge is actually a break in the crust and magma wells up pushing crust apart, magma solidifies to new rock.
- Robert Dietz named this seafloor spreading, if the ocean is moving, then the continents must be moving too.

Paleo magnetism

- The earth acts like a giant magnet
- When magma cools and solidifies iron bearing rock becomes magnetized and the orientation becomes permanent
- It was once thought that the orientation was always north
- In the mid 1900's rocks were found that oriented south
- Scientist concluded that the magnetic fields had reversed
- All the rocks with magnetic fields pointing north fell within a given time frame called normal polarity
- At many times the polarity has reversed which show up as patterns of alt. Bands

Additional Evidence in Support of Plate Tectonics

- Distribution of earthquakes along plate margins
- Location of earthquake foci along steeply-dipping subduction zones
- Age dating sediments on either side of the ridge indicates the sediments get progressively older away from the mid-ocean ridge axis
- Thickness of sediments also increases away from ridge
- Ring of fire- volcanoes that encircle most of the Pacific Ocean

3. EXPLAIN SEISMIC WAVES? GIVE A DETAILED ACCOUNT ON THE RECORDING OF EARTH QUAKE AND THE EARTHQUAKE BELTS IN INDIA.

EARTHQUAKES

Seismic Waves: Waves generated by an earthquake are termed as seismic waves. There are three main types of wave-motion.

1. Primary or 'P' waves: These are longitudinal waves similar to sound waves and travel in solid, liquid and gaseous media. They have short wavelength and high-frequency.
2. Secondary or 'S' waves: These are transverse waves, also known as sheer waves, travel only in solid media. In comparison to primary waves, they are slow in motion. They travel at varying velocities through the solid parts, proportional to the density of the materials. They are also having short wave length and high frequency.
3. 'L' waves: These are transverse vibrations and are confined to the outer skin of the crust. They are also known as surface waves (or) Rayleigh (R) waves. They have low velocity, low frequency and long wavelength. These are responsible for most of the destructive force of the earthquake.

Scale of Intensity

Various scales have been proposed to estimate the intensity of earthquake from the amount of damage causes. These scales are

1. Rosi-Forrel scale,

   In the Rosi Forrel scale, the intensity has been classified into severe, catastrophic and disastrous.
2. Mercalli scale,

   The Mercalli intensity scale has devised twelve numbers with the increase of intensity. In this case – number 1 detected only by seismographs. Gradually the number increases when the earthquake intensity becomes feeble, slight, moderate, strong etc. At number '8' it is "destructive". Similarly it becomes "disastrous" at number and at number "12", the effect is totally catastrophic, where there is total destruction and objects thrown into air.
3. Richter scale of earthquake magnitude etc.

   In the Richter-scale, the scale number ranges from '0' to '9'. Here it is particularly important to notice that a magnitude earthquake is 10 times larger than magnitude 7 earthquakes, 100 times larger than a magnitude 5 earthquake.

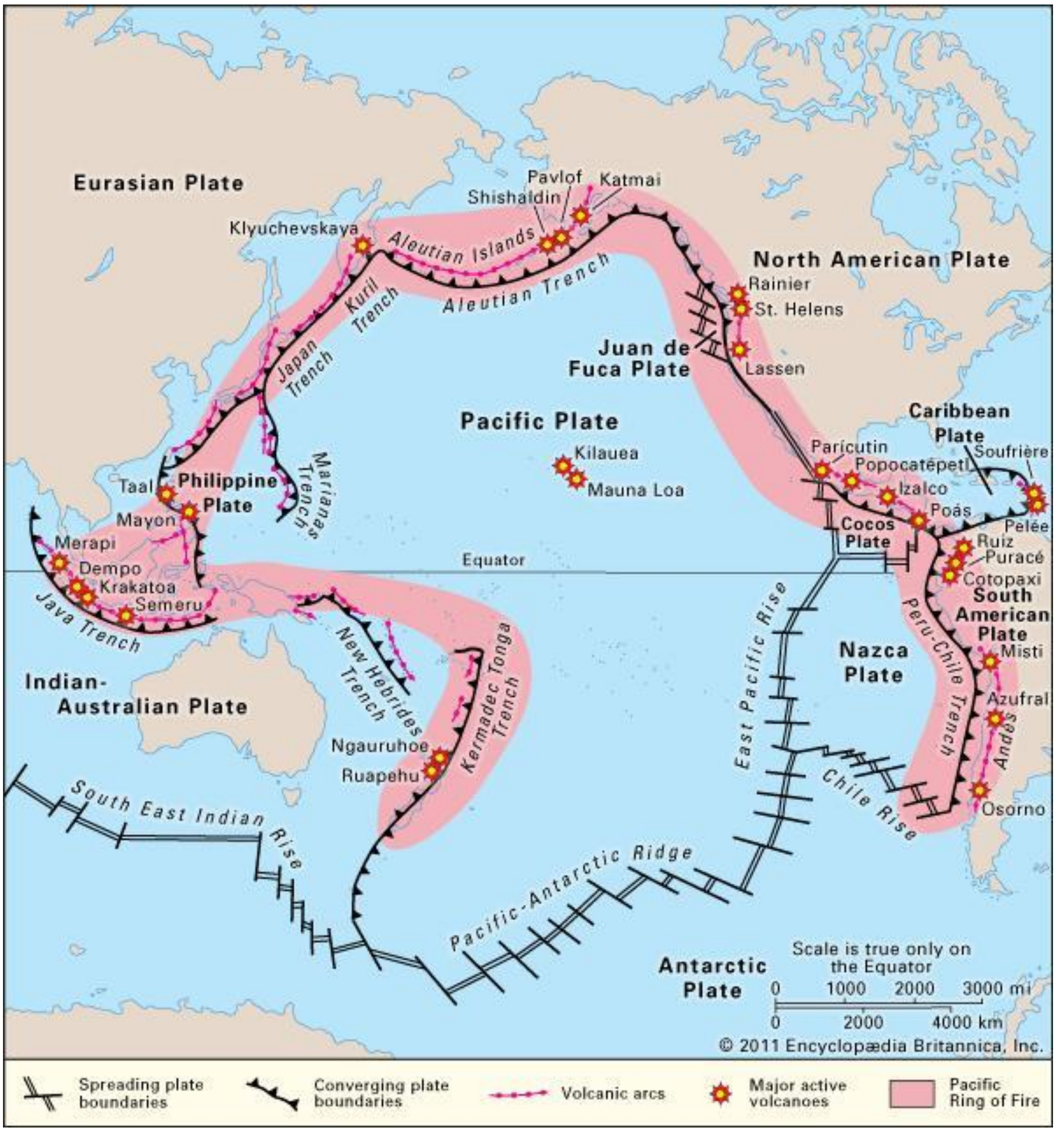
Recordings of Earthquakes

The instrument used for recording of seismic shocks is known as '*Seismograph'* and the records of science shocks prepared and presented by seismographs are known as *'Seismograms'.*

Distribution of Earthquakes in Earth

- The destructive earthquakes are concentrated in a ring surrounding the Pacific Ocean. About 75% of world earthquakes are from this region. The ring coincides with the Circum Pacific Ring of Fire.
- The second chain is termed as East-Indian, which extends over Indonesia, Andaman-Nicobar, Islands and Burma.
- The third belt extends over Himalayas, Kun-Lun, Tien Shan and Altai Range up to the Lake Baikal.
- Another belt extends from the Pamir Knot to Afghanistan, Iran, Turkey, Greece, Rumania, Atlas Mountains, Gibralatar and the Azores Islands.

- A belt also extends from the Gulf of Aden, between Seychelles and Maladive Islands, turns to the West-South of Africa and goes up to the Falkland Islands.
- Another belt also runs along the Great Rift Valley of East Africa.
- It is noticed that the present earthquake regions are associated with the younger fold-mountain regions, and the present earthquake activity is a phase of the end of the Alpine-Orogeny.



Distribution of Earthquakes in India

On the basis of the intensities or the destructiveness of the earthquakes a map of India has been published by the Meteorological Department in collaboration of the Indian Standard Institution. The map shows the five seismic zones based on modified Mercalli Scale.

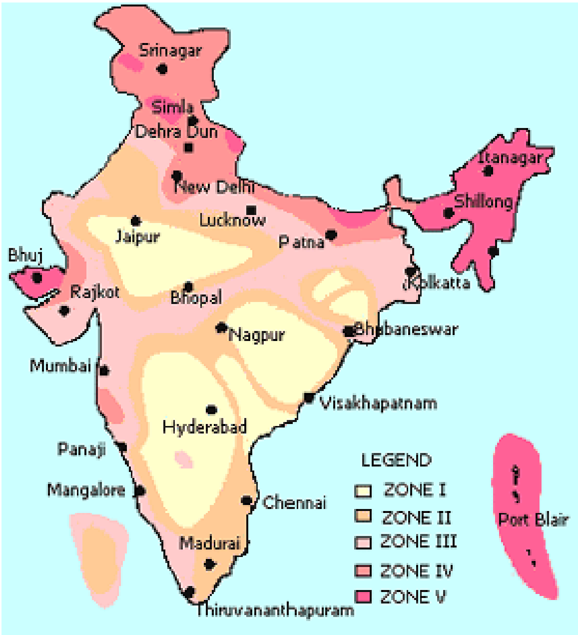
Zone I - Intensity V or below (instrumental, feeble, slight, moderate rather strong)

Zone II - Intensity VI (Strong)

Zone III - Intensity VII (Very Strong)

Zone IV - Intensity VIII (destructive) Zone

Zone V-Intensity more than VIII (disastrous, catastrophic)



Zone V:

Represents areas of the most destructive and catastrophic earthquakes where there is extremely high damage risk. The following areas fall into this zone: certain parts of Jammu and Kashmir, parts of Himachal Pradesh, Uttaranchal, Monghyr and Darbhanga districts of Bihar, northern part of India and Kutch region of Gujarat.

Zone IV:

Represents areas where there is high damage risk by destructive earthquakes. This zone comprises the State of Jarnmu and Kashmir, Himachal Pradesh, northern part of Punjab and Haryana, Delhi, eastern Uttar Pradesh, tarai and bhabar regions, the Himalayan areas of Uttaranchal, Bihar and Sikkim.

Zone III:

Covers southern and Southeastern parts of Rajasthan, larger parts of Madhya Pradesh, Maharashtra, Karnataka, Jharkhand and northern and northwestern part of Orissa.

Zone II and I: Combined to form a Single zone

Rest of the above mentioned areas. These are the low damage risk zone.

4. EXPLAIN IN DETAIL THE PROCESS OF PHYSICAL AND CHEMICAL WEATHERING OF ROCKS AND MINERALS.

WEATHERING

The term weathering refers to natural processes of mechanical disintegration and chemical decomposition of rocks. Weathering is brought about by the agents of atmosphere. It is very slow process and its effects on rocks are noticeable only over a period of countless centuries. Weathering will loosen the rocks and prepare them for erosion.

Agents of Weathering

The elements of atmosphere are the active agents of weathering. The atmospheric gases and temperature changes are the outstanding agents. Additional help comes from water and its dissolved substances. Organisms and lighting also play major roles in the process of weathering.

Kinds of weathering

There are two types: During mechanical (or physical) weathering rocks break up or crumble with no change in the composition of the parent rock. In chemical weathering, the minerals present in the rocks undergo chemical alteration or decay.

Mechanisms of physical weathering:

The different methods by which physical weathering can be brought about in rocks are illustrated below:

Frost Wedging

The rain water fills up the cracks present in rocks. When this water freezes during winter it expands considerably. The expansive force will wedge the rocks apart. By repeated freezing and thawing to rocks are fragmented to pieces. The frost wedging takes place in jointed rocks situated in mountain peaks and Polar Regions.

Insolation:

The alternating higher and lower temperature of a region gives rise to expansion and contraction of solid rocks which results in weathering. This weathering due to thermal effect can be described as insolation.

Exfoliation

By this process, the rock layers are peeled away one after the other. This type of mechanical weathering is brought about by temperature changes on massive rocks. In desert regions, rocks expand during day time and contract at nights. This causes stresses in the outer parts of rock masses and results in their mechanical separation.

Root wedging

Roots and trunks of plants and trees insert themselves into the rock crevices. When they grow, they exert powerful force on the adjoining blocks of rocks and dislodge them. This process of disintegration of rocks is called Root wedging and is typical of hill slopes.

Mechanisms of Chemical Weathering:

The different processes of chemical weathering are explained below:

Solution: Rocks like lime stones are dissolved and destroyed by rain water.

Carbonation: By addition of carbon-di-oxide water produces carbonic acid in nature. This will react with certain elements (like calcium or Magnesium) in rocks and produce soluble carbonate compounds.

Oxidation: The addition of Oxygen into certain constituents is called as Oxidation. Oxygen is available in the atmosphere. For example Iron present in rocks will combine with oxygen and produce Iron Oxide.

Hydration: The addition of water into certain elements in rocks is called as hydration. For example, the Aluminium, Iron or Manganese present in rocks will be converted into the respective Hydroxides by the addition of water.

Spheroidal Weathering: This is a kind of chemical weathering. When water containing dissolved gasses enters a rock mass divided by rectangular joints, the rock surfaces are attacked chemically. Since the corners and edges have greater surface area, they will be rapidly weathered. As a result, the rectangular rock bodies will have their edges and corners rounded off. In course of time, there will be a spherical mass with a fresh innermost core surrounded by layers of more altered material. The weathered rock is comparable to an onion. The spheroidal weathering is characteristic of rocks called Basalts and Charnockites.

Products and Economic Importance of Weathering:

1. Weathering results in the formulation of soil. The soil is essential for life.
2. By weathering useful minerals like clay and bauxite are formed from parent rocks.
3. By mechanical weathering hard useful and heavy minerals like gold and diamond are liberated from parent rocks and concentrated as placer deposits.
4. Weathered zones in massive rocks are favourable for storage of ground water.

Civil Engineering problems related to weathering:

1. Weathering includes weakness in the rocks. Hence hard rocks are becoming weak rocks. Such weak rocks are unsuitable for foundations to construct heavy structures.
2. Clay and silt are produced along the weak planes of a rock, thus de-stabilizing the rock strengths.
3. The rocks which can undergo chemical weathering will have weak planes and solution holes within them. They are unsuitable for Civil Engineering works.

5. EXPLAIN THE WORK OF A RIVER AND DESCRIBE THE VARIOUS EROSIONAL AND DEPOSITIONAL LANDFORMS CREATED BY A RIVER.

RIVER AS A GEOLOGICAL AGENT

Geological action of river:

The phenomenon, which is associated with the geological action of river, is usually known as the fluvial cycle erosion. The geological work of river is composed of three stages, erosion, transportation and deposition.

Erosion:

The erosion caused by the running water is of two types: Mechanical erosion or Chemical erosion. Mechanical erosion is associated with the running water takes place in four distinct manners like:

Hydraulic action: Erosion of the bank and the bed-rock of the river by the forces inherent in the flow of running water, due to surface relief i.e., gradient.

Abrasion: The materials which are being carried away by the running water acts as tools of destruction, and during their transportation, because of their rubbing against the surface of the bed rock, they bring about a scraping of the surface. This process of erosion is also known as '***Corrosion***'.

Attrition: Materials during their transit often collide among themselves and in turn get themselves teared and this is the process, through which big boulders are gradually reduced in size and finally reach the size-grade of sand and silt.

Cavitation: This is because of the presence of the air bubbles which create a whirling action at the time of penetration of water through the existing pores and fissures, and the small sand particles along with the air bubbles play a major role in widening the cavities.

Transportation:

Eroded products are carried by traction, suspension and solution. Streams move their load by (1) Pushing and dragging of angular pieces: (2) Rolling rounded and sub-angular pebbles along their floors: (3) Carrying in suspension fine grains of sand, silt and clay and (4) Dissolving the soluble constituents.

Deposition:

Deposition is brought about by the diminished velocity of streams and a decrease in the volume of water. The velocity may be checked by a decrease in slope, obstruction by resistant rocks in the course of streams, freezing of the water and the flowing of a stream into a body of quiet water. Volume of water will vary according to seasons.

Features and Landforms formed by River

Stream valley: The erosive power of streams produce valleys which exhibit a V shaped cross section in youthful stage and U shaped in cross section in mature stages. They will be straight in youth stage and meanders in old stage.

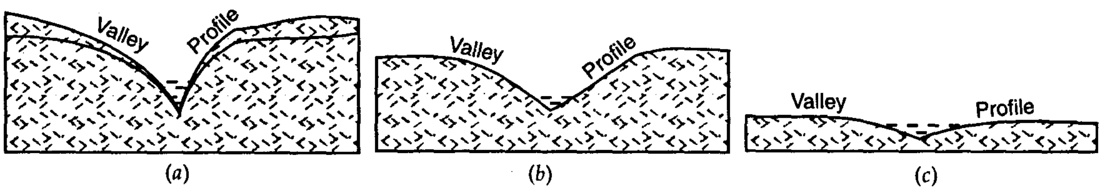
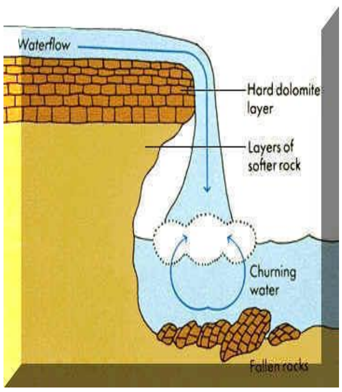
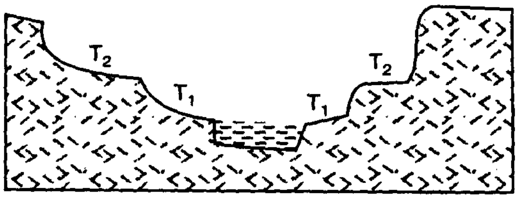


Fig. 4.7. Transverse Profile of a River Valley.
A = Mountainous tract; B = Semi Mountainous tract; C = Plain tract

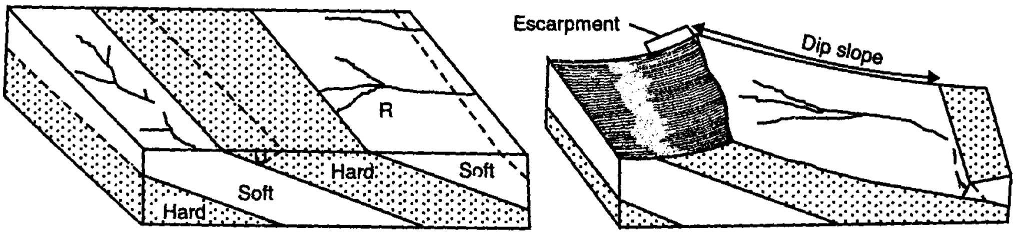
Water fall: When a stream crosses the boundary between hard and soft rocks, hard rocks stand out unaffected whereas soft rocks on downstream are more eroded. This give a steep gradient in stream course and a water fall is produced.



Stream Terraces: These are bench like ledges or flat surfaces that occur on the sides of many river valleys. From a distance, they may appear as succession of several steps of a big natural staircase rising up from the riverbank. They may be made up of hard rock or of soft rock, but the essential thing is that they look like steps. Some of them are clearly features of river erosion indicating that the stream has cut down its own channel not continuously but in a series of stages.



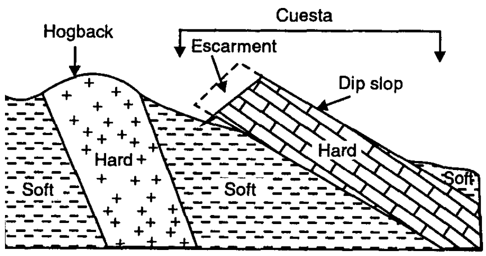
Escarpment: It is a steep slope resulted from differential weathering of rocks.



(*a*) Favourable conditions (*b*) Escarpment and dipslope developed due to undercutting (*u*) and removal (*R*) of upper layer respectively.

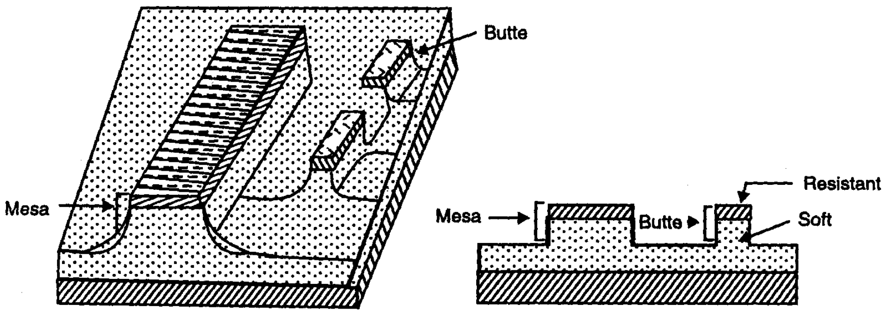
Cuesta: In a region of sub-horizontal beds, a gentle slope is developed along the gentle dips of strata, such a landscape is known as cuesta.

Hog-back: it is a cuesta, in which the dip slope and scrap slope are both approximately 45°.



Mesa: An isolated table land area with steep sides

Butte: With continued erosion of the sides a mesa reduced to a smaller flat topped hill, known as 'butte'.



(*a*) Mesa (*b*) Butte

Pediment: It is a plain of eroded bed rock in an arid region developed between mountain and basin areas. Pediments converge to from pediplains

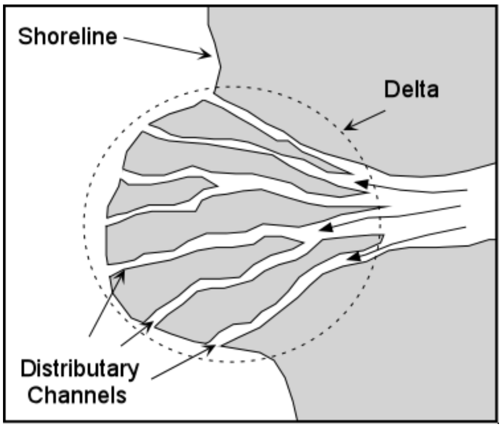
Peneplains: The peneplains are formed in the old stages of rivers and are the plain lands produced by the river.

Monadnock: sometimes some mounds or small hillocks of hard rock persists on the peneplains and are known as monadnocks.

Natural levee: On the flood-plains, long depositional ridges extending parallel to the river are found, which are known as Natural levee.

Alluvial fans and cones: On descending to the plains from the hills the velocity of a river and the carrying capacity are reduced. At this point the river sheds a large amount of load which assumes a fan or conical shape.

Deltas: These are depositional features of Δ shape, which are formed in older stages of rivers. These are submerged equivalents of alluvial fans. These are the fertile regions of rivers.



Sloughs: Depressions on the flood-plains of meandering rivers, which are excavated during floods due to the tendency of the overflowing water to follow a short-course.

6. EXPLAIN THE WORK OF WINDS AND THEIR ENGINEERING IMPORTANCE.

WIND AS A GEOLOGICAL AGENT

INTRODUCTION

Wind can operate only in dry climates. There should be no vegetation also. Hence wind is an effective geological agent only in deserts

MECHANISM OF WIND EROSION

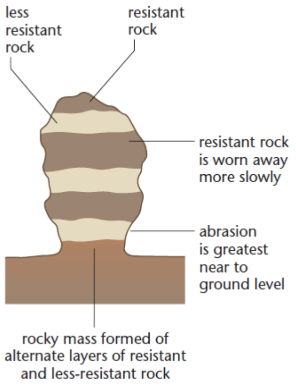
- Loose sediments can be lifted by wind. This is called **deflation** (Deflare – blow away)
- The sediments carried by wind will strike against the rock and bring about wear and tear on them. This is called **abrasion** or sand blasting action.
- The particles carried by wind will collide among themselves. They will be reduced and powdered. Their edges and corners will be rounded. This is called **attrition.**

Erosional landforms

- A broad shallow valley is produced by the blowing away of wind. Such a valley is called **deflation basin**.
- When deflation basin is filled by rain water it is called a **playa lake**.
- During deflation bigger sized fragments are left behind, as they cannot be lifted by wind. They are called **lagstones.**
- When lagstones are cemented like a mosaic floor, it is called **desert pavement**.
- Sandy particles carried by wind attack the rocks on the way. This is called abrasion or sand blasting action. By this action the soft minerals (mica) are removed very easily.

Hard minerals (Quartz) survive and resist sand blasting action. The resulting rock will have many pore spaces. Such a rock is called a **Honey comb rock**.

- By sand blasting action, the rocks on the way are eroded. The top portion of a standing rock mass will be affected by fine materials. Therefore top part is eroded to smaller extent. But the bottom portions are attacked by bigger particles. Hence there is a larger amount of wear and tear at the bottom. The resulting rock body will have a narrow bottom and a wide top. It is called a **Mushroom rock or Pedastal Rock**
- There are many pebbles on the floor of a desert. They are subjected to sand blasting action. As a result their sides will be leveled. The resulting wind faceted pebbles are called **ventifacts**.

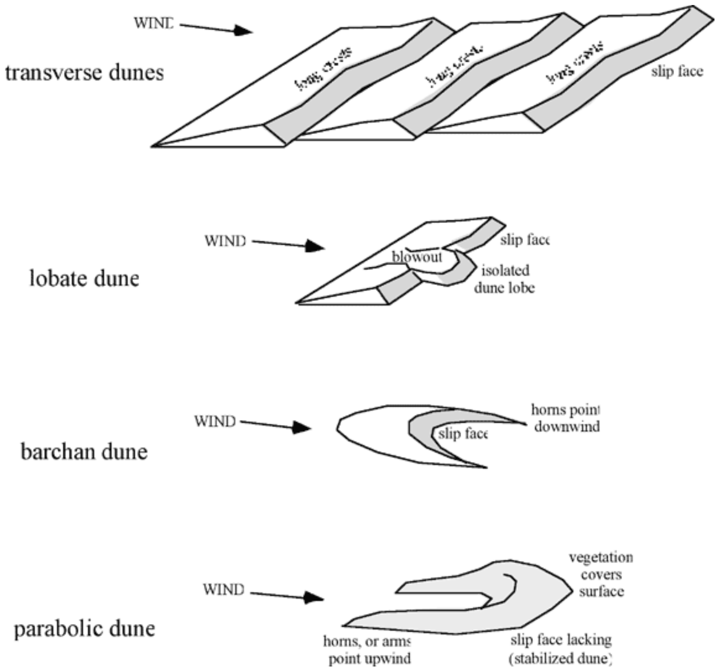



Depositional feature

There are two depositional features namely, sand dunes and loess.

Sand dunes

- Sand dunes are hills of wind borne sand.
- They are formed whenever there is some obstruction in the course of wind.
- Sand dunes are layered. They show ripple marks and false bleeding.
- The dune has a gentle slope on the windward side and a steep slope on the leeward side.
- Dunes commonly migrate. Their movement can be arrested by growing vegetation.
- There are certain important types of dunes.
    a. Barchans: crescent shaped. Horns pointing in the direction of blowing wind.
    b. Parabolic Dune: Parabolic shaped. Horns pointing against the direction of wind.
    c. Transverse Dune: dune is elongated normal to the direction of blowing wind.
    d. Longitudinal dune : large (kms in length, ~ one km wide) linear forms parallel to the strong persistent winds, form in dry subtropical deserts with irregular sand supply.
    e. whaleback: a ridge of coarse sand left in the path of a migrating longitudinal dune



Loess deposits:

- This is an Aeolian deposit of silt size.
- It is yellow in colour and highly porous.
- The deposit is unstratified. (Not layered)
- They are able to stand as vertical cliffs.
- They contain lot of unaltered minerals.
- They are very fertile.
- E.g. Loess deposits occur in China.

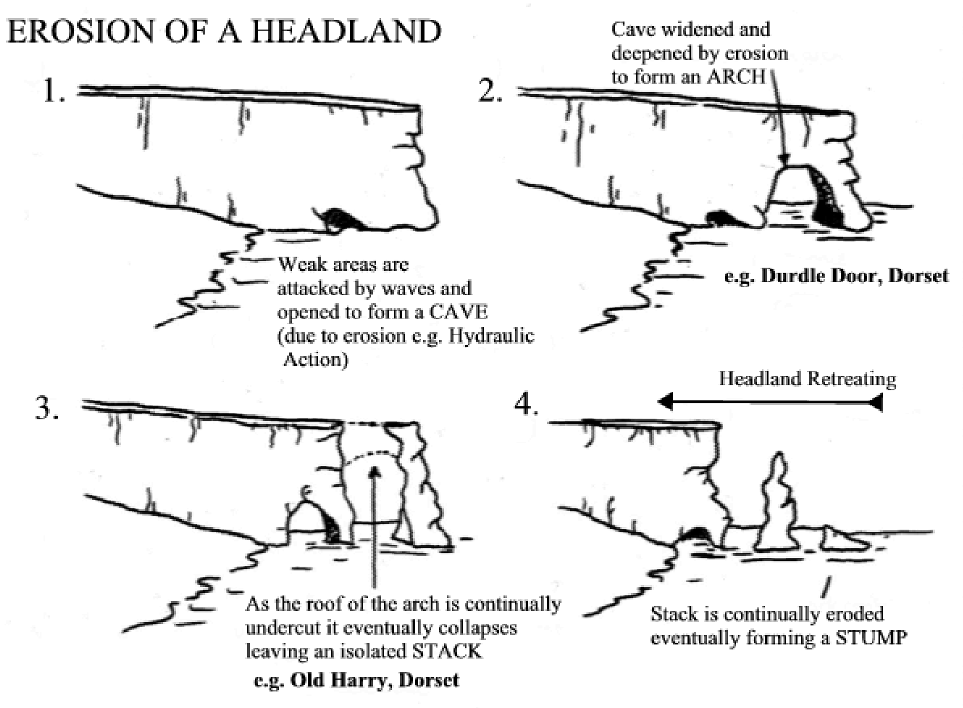
7. EXPLAIN THE WORK OF SEA AND THEIR ENGINEERING IMPORTANCE.

SEA AS A GEOLOGICAL AGENT

Erosional Landforms

- As sea erosion works against the shore, beaches are not the only resulting landforms. Headlands and bays are also created. A **bay** is where the rock material comprising the shoreline is softer and more susceptible to erosion, while **headlands** refer to the harder rocks that do not wear away as easily
- Landforms of coastal erosion include cliffs, wave-cut platforms, arches, stacks, headlands and caves (amongst others). The existence of many of these features depends upon the maintenance of a vertical cliff-face through an on-going cycle of **undercutting, collapse and retreat**.
- When waves break at the foot of a rock face of headlands, a **wave-cut notch** is created by marine erosion processes.
- The continued erosion of sea notch results in **sea cave**
- The erosion of a cave(s) in a sea stack creates a **sea arch**
- Over time, a section of rock is removed from the top of the sea arch, leading ultimately to the collapse of the un-supported section above.
- The subaerial remnants of headlands that project above the sea, and is isolated from headland is described as **sea stacks**

- Every time this process is repeated, a new near-vertical cliff-face is created, **sea cliff,** the remnant of erosion of headlands, because erosion occurs at and above the water level
- The erosion of a cliff is greatest at its base where large waves break - here hydraulic action, scouring and wave pounding actively undercut the foot of the cliff forming an indent called a wave-cut notch whilst the cliff face is also affected by abrasion as rock fragments are hurled against the cliff by the breaking waves. This undercutting continues and eventually the overhanging cliff collapses downwards - this process continues and the cliff gradually retreats and becomes steeper. As the cliff retreats, a gently-sloping rocky platform is left at the base, this is known as a **wave-cut platform** which is exposed at low tide.



Depositional Landforms

Landforms in the sediment (mostly sand) delivered by rivers and, to a much lesser extent, generated by headland erosion

Beach

- average wave energy is sufficient to transport sand from the shallow sea bed and move it onshore
- higher gradient gravel, boulder or shingle beaches occur at the base of headlands and behind sandy beaches, that is, where there is higher wave energy capable of removing sand
- sand is carried onshore in the swash; the backwash seeps into the beach and flows seaward with has sufficient energy to suspend and remove only the finer sediments (silt and clay)
- thus beaches are a lag deposit of sand drifting along the shore, as the swash commonly is oblique to the shoreline whereas the backwash is always directly seaward (down the beach)
- beaches adjust quickly to changes in wave and tidal energy resulting in a change in beach mass balance = sediment inputs (fluvial + from offshore + eolian + mass wasting sea cliffs) - sediment outputs (eolian + to offshore)

Barrier bars or islands

- Ridges of sand up to a km wide and 100 m high that lie parallel to about 13% of the world's coasts
- consist of sand blow seaward onto tidal flats during low tide and sand in the backwash which comes out as suppension as the rip current meet the incoming surf
- interupted by tidal inlets so that logoons behind the bars are subject to tides

Beach ridges

- a berm (beach crest) usually exist just above high tide
- other beach ridges represent storm deposits or emerged off shore bars

Spit

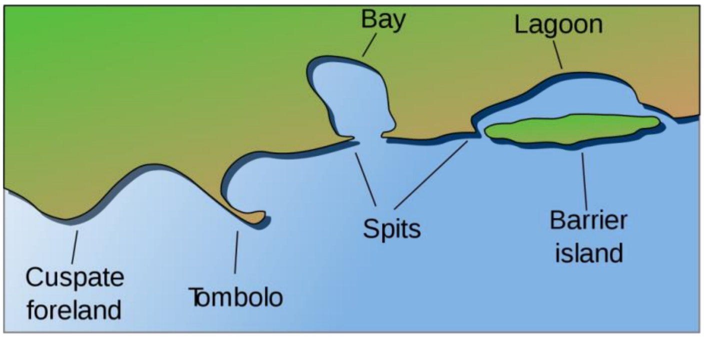
- extension of a beach from a headland in lower energy environment (bay or lagoon) in the direction of the longshore drift

Baymouth bar

- spits merge to create bars that extend across the mouths of bays
- waves energy is dissipated on the bar and the bay becomes a logoon
- logoons fill with sediment, supporting salt marshes
- thereby, sediment progrades towards retreating headlands and coastlines become less irregular

Tombolo

- a beach that extends between a headland, or other part of the mainland, and an island



8. GIVE A DETAILED ACCOUNT OF THE ORIGIN, MODE OF OCCURRENCE AND PROSPECTING OF GROUNDWATER.

GROUNDWATER

Hydrologic cycle

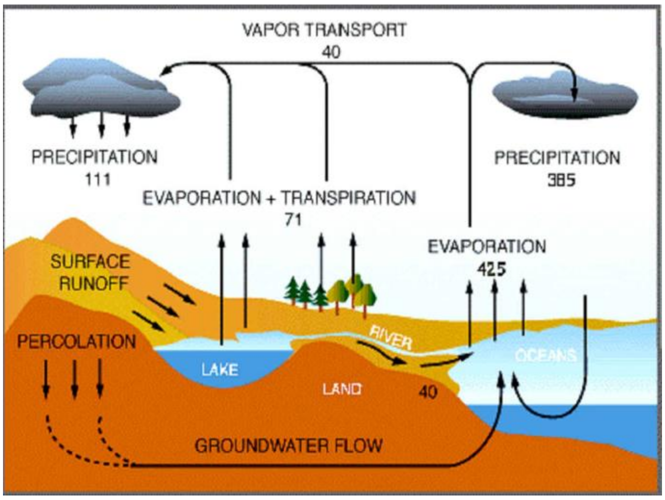
There is a natural cycle of water on the surface of the earth. This is called Hydrologic cycle.

The cycle consists of the following parts:

- **EVAPORATION:** Evaporation occurs when the physical state of water is changed from a liquid state to a gaseous state.
- **CONDENSATION:** Condensation is the process by which water vapor changes it's physical state from a vapor, most commonly, to a liquid. Water vapor condenses onto small airborne particles to form dew, fog, or clouds.
- **PRECIPITATION:** The clouds are condensed on the mountains producing rain.
- **SURFACE RUN OFF:** Part of rain water flows on the surface in the form of rivers and reaches back the sea.
- **INFILTRATION:** Part of the rain water penetrates into the ground and is stored up in the open spaces of rocks. This is called groundwater.

- **TRANSPIRATION:** The groundwater is absorbed by the roots of plants and is again let off in to the atmosphere as vapour through the leaves.

This natural cycle is show in figure.



OCCURRENCE OF GROUND WATER

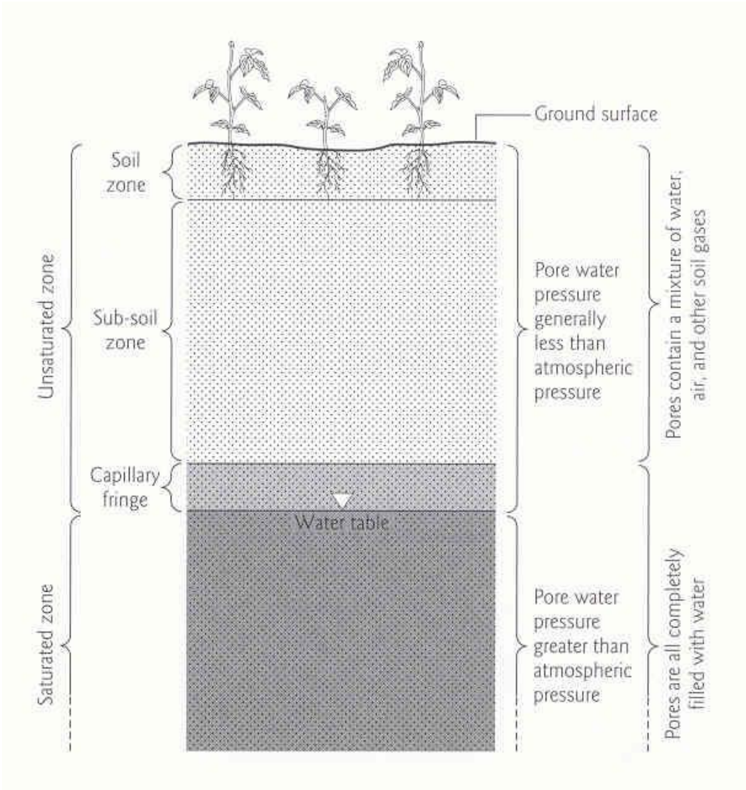
Ground water

- A part of rain water penetrates into the ground. The rocks immediately below the ground surface contain openings and cracks. They are filled up by this water. This is called groundwater or sub-surface water.

Sources of groundwater

- Rain water (**metronic water**) is the chief source of groundwater. Sometimes, hot water may be contributed by deeper magmatic sources. It is called **juvenile water**. The pores in sedimentary rocks contain water trapped during deposition. This is called **connate water.**

The occurrence of water under the ground is shown by a sketch



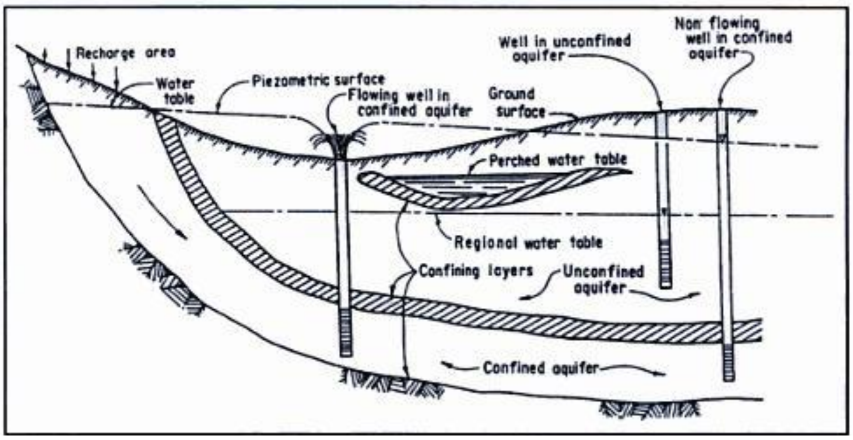
- There are two zones of groundwater.
- The lower zone is called **zone of saturation**. Here all the openings in rocks are completely filled with water. The uppermost level of this zone is called **water-table**.
- The upper zone is called **zone of aeration**. Here, the openings are filled partly with water and partly with air. This is also called **Vadose Zone**.
- An underground rock which contains lot of pore spaces which are interconnected can give a good supply of groundwater. Such a rock is called **aquifer**. Sand is an excellent aquifer.

Aquifer

- Aquifer has two properties namely, good porosity and permeability.
- Volume percentage of pore spaces in rock is called **porosity**. When pores are numerous and occupy more spaces a large quantity of water can be stored.
- The speed of passage of water through the rock is called **permeability**. A high permeability will help in recharging of the well after pumping.
- On the basis of porosity and permeability, aquifer can be classified as follows
- **Aquifer** - a saturated geologic unit that can store enough water and transmit it fast enough under ordinary to be hydrologically significant
- **Aquifuge -** a rock that neither transmits nor stores water
- **Aquiclude** - a geologic unit that only stores water but does not transmit enough water
- **Aquitard** - a unit that stores and transmits water fast enough to be hydrologically significant but insufficient for well production

Types of aquifer

- Aquifers come in two types which are shown below: unconfined and confined.
- **Unconfined aquifers** are those into which water seeps from the ground surface directly above the aquifer.
- **Confined aquifers** are those in which an impermeable dirt/rock layer exists that prevents water from seeping into the aquifer from the ground surface located directly above. Instead, water seeps into confined aquifers from farther away where the impermeable layer doesn't exist.



- **Perched aquifer** will occur when low-permeability materials interbed with higher permeability units, causing downward percolating water to form a perched saturated lense in the zone of saturation. The water present in this aquifer is perched water. The water table of this aquifer is perched water table.

Spring

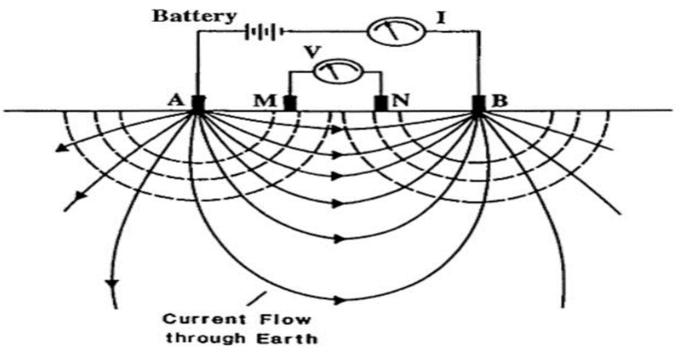
- When groundwater issues out on the land surface on its own accord, it is called a **spring.** A spring is formed whenever water-table cuts the land surface. An example is shown in the following figure, a stream valley is slowly deepened it touches the water table and a spring is formed.

Artesian Well

- When groundwater flows out of a well with very great pressure it is called "Artesian Well". The natural conditions needed for the development of artesian well are shown at the following figure. The conditions are
    - Inclined sand layer called aquifer
    - Clay caps above and below
    - A good catchment area of water supply
- There are Artesian wells in Neyveli Lignite field in Tamil Nadu. Infact the artesian pressure poses a hazard for lignite mining.

PROSPECTING FOR GROUNDWATER

- Searching for groundwater is called Groundwater prospecting. Some people claim that they have super natural powers of finding groundwater with a wooden fork. They are called water diviners. This water diving method has no scientific basis.
- Nowadays, good quality groundwater can be located with the help of electrical and seismic instruments. These are called geophysical methods of prospecting
- In the modern days with the advent of scientific knowledge and sophisticated technology, investigations are being carried out to locate water bearing formations in hard rocks. Among the various geophysical techniques, electrical principles are used widely for targeting the underground water resources.
- In the electrical resistivity method four electrodes are driven down into the flat ground in a collinear manner. The outer electrodes are designated as current electrodes, since they are connected to the current measuring system. The inner electrodes are called potential electrodes and are connected to voltage measuring units. By measuring current and potential it is possible to estimate the true resistivity of buried rock layers by applying Ohm's law.



Common Resistivities (ohm-m)

Material Value	Resistivity range	Typical
Igneous & Metamporphic rocks	10^2 - 10^8	10^4 10^3
Sedimentary rocks	10 - 10^8	10^3
Unconsolidated	10^{-1} - 10^4	10^3
Groundwater	1 - 10	5
Pure water		10^3

UNIT 2: MINERALOGY – PART A

1. **List out the different crystal system.**
   Isometric or cubic systems:
   Tetraogonal system.
   Hexagonal system.
   Orthorhombic System.
   Monoclinic system
   Triclinic system.
2. **Give the axial character of orthorhombic system.**
   Orthorhombic system consists of three axes of unequal length and are mutually perpendicular.
3. **What is double refraction?**
   Due to the inequality of **RI**'s, the light ray entering into a anisotropic mineral is split into two rays with different velocities and directions. This is known as **double refraction**.
4. **Explain polymorphism.**
   Minerals having same chemical composition may show different crystal structure (as a function of changes in **P & T** or both). So, being crystallized in different Symmetry Systems they exhibit different physical properties, this is called polymorphism.
5. **Name the different types of feldspar.**
   Alkali feldspar (Plagioclase) K- Feldspar
   orthoclase (monoclinic) — $KAlSi_3O_8$
   sanidine (monoclinic) —$(K,Na)AlSi_3O_8$
   microcline (triclinic) — $KAlSi_3O_8$
   anorthoclase (triclinic) — $(Na,K)AlSi_3O_8$
6. **Write the uses of Clay minerals.**
   China clay (kaolin):-Is used in the manufacture of potteries, earthenware, rubber, paint etc.
   Kaolinite:- Is used in the manufacture of porcelain.
   Kayanite:- Is used in he manufacture of high grade porcelain and refractory's. A few lustrous varietie are also used as gemstones.
   Sillimanite:- Is used in the manufacture of porcelain, refractory's, potteries, etc.,
7. **List the important properties and uses of Calcite.**
   (1) Chemical composition – Calcium carbonate ($Ca\ Co_3$)
   (2) Structure – Crystalline
   (3) Crystal system – Hexagonal
   (4) Colour – White, pale, red or brown
   (5) Lustre – Vitreous
   (6) Streak – White
   (7) Hardness – 3.0
   (8) Specific gravity – 2.6 - 2.8
   (9) Fracture - Conchoidal
   (10) Cleavage – Perfect in three directions.
8. **Define Isometric system of crystals.**
   All those crystals that can be referred to three crystallographic axes, which are essentially equal in length at right angles to each other, and mutually interchangeable, are said to belong to the isometric or cubic system
9. **Give the physical properties of Mica.**
   (1) Chemical composition – Silicate of aluminium and potassium
   (2) Structure – Crystalline
   (3) Crystal system – Monoclinic
   (4) Colour – Colourless, yellow or red

(5) Lustre – Pearly
(6) Streak – Colourless
(7) Hardness – 2.5 to 4.3
(8) Specific gravity – 2.7 to 2.9
(9) Fracture - even
(10) Cleavage – Perfect
(11) other properties – it can Split up into thin sheets in one direction

10. How are minerals are identified and what are the symmetry elements of crystal?

Their Colour, Streak, Hardness, Cleavage, Crystal form, Specific gravity and Lustre generally identify minerals.

The symmetry elements are (i) Plane of symmetry (ii) Axis of symmetry (iii) Centre of symmetry.

11. Define. Bituminous Coal (Common coal)

The original vegetable matter has been fully transformed into carbonaceous material so that it forms a hard, brittle and compact mass. It burns with a yellow flame.

12. What is meant by coking capacity of Bituminous?

Its ability to change into a plastic mass when subjected to heating at very high temperature in the absence of air.

13. Define Mineralogy.

It is defined as naturally occurring inorganic solid substance that is characterized with a definite chemical composition and very often with a definite atomic structure. It is a branch of geology, which deals with the various aspects related to minerals such as their individual properties their mode of formation and mode of occurrence.

14. What are the physical properties of minerals?

(1) Chemical composition (2) Structure (3) Crystal system (4) Colour (5) Lustre (6) Streak (7) Hardness (8) Specific gravity (9) Cleavage (10) Fracture (11) Other properties

15. Define. Streak

Streak is the colour of the finely powdered mineral as obtained by scratching or rubbing the mineral over a rough unglazed porcelain plate. The plate often named as streak plate. It is important and diagnostic property of many coloured minerals.

16. What is meant by fracture and types of fracture?

The appearance of the broken surface of a mineral in a direction other than that of cleavage is generally expressed by the term fracture. The types are:

1. Even 2. Uneven 3. Conchoidal 4. Splintery 5. Hackly 6. Earthy

17. Define the formula for calculated in specific gravity.

$$\text{Specific gravity} = \frac{\text{Weight of the mineral in air}}{\text{Loss of weight in liquid}} \times d$$

18. Define Planes of symmetry.

Plane of symmetry: It divides a crystal into similar and similarly placed halves. This plane provides crystal so that one half is the mirror image of the other.

19. Define axis of symmetry.

Axis of symmetry: If a crystal one being rotated, come to occupy the same position in space more than one in a complete turn, the axis about which rotation taken place is called an axis of symmetry.

20. Define centre of symmetry

Centre of symmetry: A crystal has a centre of symmetry when like faces, edges are arranged in pairs in corresponding positions on opposite sides of a central point. The cube and bricks obviously have centre of symmetry.

PART B

1. EXPLAIN IN DETAIL THE AXIAL RELATION, SYMMETRY ELEMENTS OF ALL THE CRYSTALS SYSTEMS.

CRYSTAL SYSTEMS AND CLASSES

Crystallographic – Axes

- "Crystallographic – Axes" are the imaginary lines passing through the centre of the crystal, but not lying in the same plane, and used as axes of reference for denoting the position of faces.
- They are usually axes of symmetry, normal to planes of symmetry or lines parallel to prominent edges of crystals.
- These crystallographic axes are of paramount significance in the classification of all the crystals into six major subdivisions, known as 'crystal system'.
- The divisions of the crystals into systems are made on the basis of
  - (i) Number of crystallographic axes,
  - (ii) Relative length of the crystallographic, and
  - (iii) Angular relationship existing between crystallographic axes.
- Accordingly, crystals which may be referred to the same set of crystallographic axes, belong to the same crystal system.

CRYSTAL SYSTEMS

1. **Isometric or cubic systems**: $a_1=a_2=a_3$; $a\Delta c=90^0$.

Here, there are three axes which are of equal length and mutually perpendicular therefore interconvertible. Two axes are horizontal and the third is vertical.

2. **Tetraogonal system**. $a_1=a_2\neq c$; $a\wedge c=90^0$.

In this system, there are three axes, of which two equal length are horizontal, but both are at right angles to each other. The third one is vertical and it may be shorter or longer than that of the horizontal axes.

3. **Hexagonal system**. $a_1=a_2\neq a_3$; $a\wedge c=90^0$.

Here, there are four axes of which three are in the horizontal plane, which are mutually inclined at 60^0 but the angle between their positive ends is 120^o. these horizontal axes are equal in length. The fourth axis is vertical and may be shorter or longer in length than that of the horizontal ones.

4. **Orthorhombic System**. $a\neq b\neq c$; $a\wedge b\wedge c=90^0$.

It consists of three axes of unequal length and are mutually perpendicular.

5. **Monoclinic system**. $a\neq b\neq c$; $a \wedge c\neq 90^o$, $b\wedge c=90^0$

In this system, there are three unequal axes, which are designated as a,b and . the axes 'a' and 'b' are lateral axes and the axes 'a' and 'b' and 'b' and 'c' makes 90^o with each other but the axes 'a' and 'c' make an oblique angle with each other.

6. **Triclinic system**. $a\neq b\neq c$; $a\wedge b\wedge c\neq 90^0$

Here there are three unequal axes, which are inclined to each other at an oblique angle.

Symmetry Elements of the crystal system

ISOMETRIC SYSTEM (Normal Class)

a. Axes of Symmetry: 13 in all
   3 are axes of four-fold symmetry;
   4 are axes of three-fold symmetry

6 are axes of two fold symmetry

b. Planes of symmetry: 9 in all

   3 planes of symmetry are at right angles to each other and are termed the principal (axial) planes;

   6 planes of symmetry are diagonal in position and bisect the angles between the principal planes.

c. It has a Centre of symmetry.

TETRAGONAL SYSTEM

a. Axis of symmetry: 5 in all; of these 2 axes are horizontal and of two fold symmetry, 2 axes are horizontal bisecting the angles made by first set of horizontal axis; they are also of two fold symmetry. 1 axis is vertical and of four fold symmetry (hence tetragonal forms).
b. Planes of symmetry: 5 in all; of these 1 plane is horizontal, 2 planes are vertical, 2 planes are vertical diagonal.
c. There is centre of symmetry.

HEXAGONAL SYSTEMS

a. Axis of symmetry: 7 in all; 1 axis, vertical, of six fold symmetry,; 6 axes, horizontal of two fold symmetry.
b. Planes of symmetry; 7 in all; 1 plane horizontal containing 6 axes of symmetry, 6 planes, vertical and vertical diagonal,
c. There is a Centre of Symmetry.

RHOMBOHEDRAL SYSTEMS

a. Axis of Symmetry: 4 in all, 1 vertical axis of three fold symmetry. 3 horizontal axes of fold symmetry.
b. Planes of symmetry: 3 in all. All the planes are vertical diagonal in position.
c. A center of symmetry.

ORTHORHOMBIC SYSTEM

a. Axis of Symmetry: 3 in all, of two fold symmetry.
b. Planes of symmetry: 3 in all. Axial in position.
c. A center of symmetry.

MONOCLINIC SYSTEMS

a. Axis of Symmetry: 1 axes of two fold symmetry only.
b. Planes of symmetry: 1plane of symmetry only. The plane of symmetry is that plane which contains the crystallographic axes ‘a’ and ‘b’.
c. A center of symmetry

TRICLINIC SYSTEM

a. Axis of Symmetry: none
b. Planes of symmetry: none
c. Center of symmentry is present

This class if characterized by only a centre of symmetry which is the point of intersection of the three crystallographic axes.

2. DESCRIBE THE PHYSICAL PROPERTIES STUDIED IN THE IDENTIFICATION OF MINERALS IN HAND SPECIMEN.

INTRODUCTION

Physical properties of minerals are important and useful diagnostic parameters. They are used to identify minerals macroscopically. These properties are also important for the identification of minerals.

(1) COLOUR

The colour of any object is a light dependent property: it is the appearance of the particular object in light (darkness destroys colour). On the basis of colour, a mineral may belong to any one of the three types:

Idiochromatic having a characteristic, fairly constant colour related primarily to the composition of mineral. **Metallic minerals (e.g. of copper group) belong to this category.**

Allochromatic having a variable colour; the variety colour is generally due to minute quantities of colouring impurities thoroughly dispersed in the mineral composition. **non-metallic minerals like quartz, calcite, fluorite and tourmaline etc.**

Pseudochromatic showing a false colour. Such an effect generally happens when a mineral is rotated in hand; it is then seen to show a set of colours in succession.

Some of the peculiar phenomena connected with colour in minerals are briefly explained below.

- **Play of Colours**
  - It is the development of a series of prismatic colours shown by some minerals on turning about light.
  - The colours change in rapid succession on rotation and their effect is quite brilliant and appealing to the eye.
  - These are caused by the interference of light reflected from numerous cleavage surfaces of the mineral. Example: diamond.
- **Change of Colours**.
  - It is similar to play of colours except that the rate of change of colours on rotation and their intensity is rather low. Example: labradorite.
- **Iridescence**
  - Some minerals show rainbow colours (similar to those appearing in drops of oil spilled over water) either in their interior or on the exterior surface. This is called iridescence.
- **Tarnish**
  - This may be described as a phenomenon of change of original colours of a mineral to some secondary colours at its surface due to its oxidation at the surface. Example: Bornite and Chalcopyrite.

(2) LUSTRE

It is the shine of a mineral. Technically speaking, it is intensity of reflection of light from the mineral surface and depends on three factors:

(1) The refractive index of the mineral.

(2) The absorption (of light) capacity of the mineral.

(3) The nature of reflecting surface.

Classification of lusture

Metallic lusture

- Metallic lusture are characteristic of high density, high refractive index and opaque minerals like galena, pyrite and chalcopyrite.

Non-Metallic Luster

- The reflection may vary from very brilliant shine as that of diamonds to very feeble greasy luster of olivine and nepheline.

(3) STREAK

- It is an important and diagnostic property of many colored minerals. Simply defined, streak is the colour of the finely powdered mineral as obtained by scratching or rubbing the mineral over a rough unglazed porcelain plate.
- Colourless and transparent minerals will always give a colourless streak that has no significance.

(4)HARDNESS

- Hardness may be defined as the resistance, which a mineral offers to an external deformation action such as scratching, abrasion, rubbing or indentation. Hardness of a mineral depends on its chemical composition and atomic constitution.
- F. Mohs proposed a relative, broadly quantitative **"scale of hardness**" of minerals assigning values between 1 and 10.

1. **Talc,**
2. **Gypsum,**

    Finger nail >2

3. **Calcite,**
4. **Fluorite,**
5. **Apatite,**

    Knife >5

    Window glass 5½

6. **Orthoclase,**

    File 6½

7. **Quartz,**
8. **Topaz,**
9. **Corundum,**
10. **Diamond.**

(5) CLEAVAGE

- It is defined as the tendency of a crystallized mineral to break along certain definite directions yielding mote or less smooth, plane surfaces. mineral.
- A mineral may have cleavage in one, two or three directions.
- Since cleavage directions are always parallel to certain crystal faces in a mineral, these may be described as such.
- For instance, cubic cleavage (galena and haylite), rhombohedral cleavage (calcite) and prismatic cleavage, basal cleavage and octahedral cleavage.

(6) FRACTURE

- The appearance of the broken surface of a mineral in a direction other than that of cleavage is generally expressed by the term fracture.
- Common types of fractures are:
    - **Even** When the broken surface is smooth and flat. Example: chert.
    - **Uneven** When the mineral breaks with an irregular surface which is full of minute ridges and depressions. It is a common fracture of many minerals. Example: Fluorite.
    - **Conchoidal** The broken surface of the mineral shows broadly concentric rings or concavities which may be deep or faint in outline. In the latter case, the fracture may be termed as subconchoidal. Example: Quartz.
    - **Splintry** When the mineral breaks with a rough woody fracture resulting in rough projection at the surface. Example: kyanite.
    - **Hackly** The broken surface is highly irregular with numerous sharp, fine, pinching projections. Example: Native Copper.
    - **Earthy**. The surface is smooth, soft and porous. Example Chalk.

(7) TENACITY

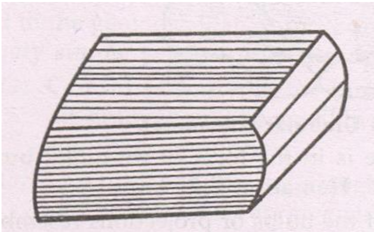
- The behaviour of a mineral towards the forces that tend to break, bend, cut or crush it is described by the term tenacity.
    - **Sectile** When a mineral can be cut with a knife, it is described as sectile.
    - **Malleable** If the slices cut out of it can be flattened under a hammer, it is said to be malleable.

- **Brittleness** Most minerals exhibit the property of brittleness, by virtue of which they change into fine grains or powder when scratched with a knife or when brought wider the hammer.
- **Flexible** A mineral is said to be flexible when it can be bent, especially in thin sheets. Chlorites are flexible.
- **Elastic** Some minerals are not only flexible but elastic, that is, they regain their shape when the force applied on them is removed. Micas are best example. The flexible and elastic fibres of asbestos can be woven into fire-proof fabric.
- As such, in terms of tenacity mineral may be sectile, brittle, flexible, plastic and elastic, the last two qualities being of diagnostic importance.

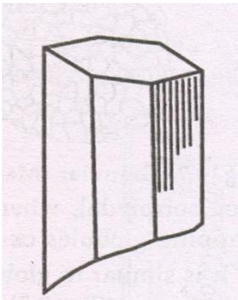
(8) <u>STRUCTURE</u> (Form)

The physical make up of a mineral is expressed by the term structure and is often helpful in identifying a particular mineral. Following are a few common structural forms (habits) observed in minerals

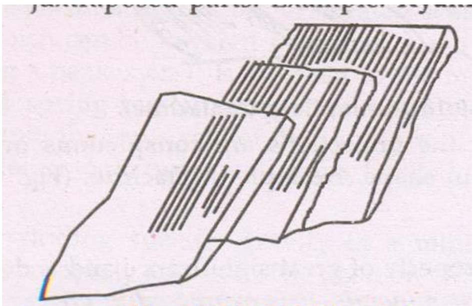
<u>Tabular</u> The mineral occurs in the form of a flattened, square, rectangular or rhombohedral shape. In other words, flattening is conspicuous compared to lengthwise elongation. Examples: Calcite, orthoclase, barite etc.



<u>Elongated</u> When the mineral is in the form of a thin or thick elongated, column-like crystals. Examples: Beryl, quartz, hornblende.



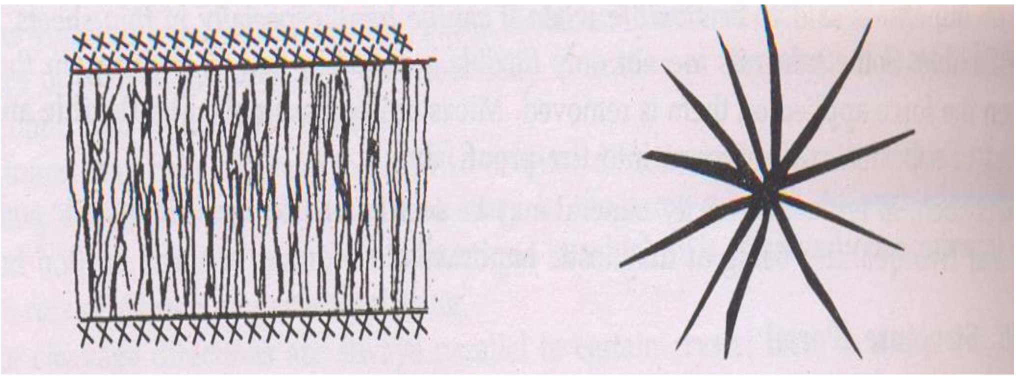
<u>Bladed</u> The mineral appears as if composed of thin, flat, blade-like overlapping a parts. Example: Kyanite.



<u>Lamellar</u>. The mineral is made up of relatively thick, flexible, leaf-like sheets. Example: Vermiculite.

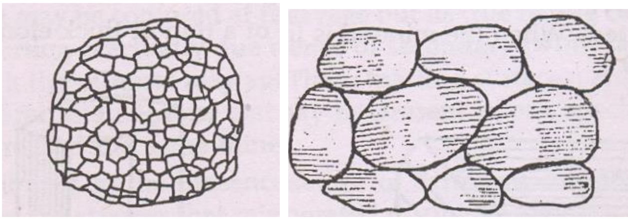
<u>Foliated</u>. The structure is similar to lamellar in broader sense but in this case the individual sheets are paper thin, even thinner and can be easily separated. Example: Muscovite (mica)

<u>Fibrous.</u> When the mineral is composed of fibres, generally separable, either quite easily (example: asbestos) or with some difficulty (example: gypsum)



Radiating. The mineral is made up of needle like or fibrous crystals which appear originating from a common point thereby giving a radiating appearance. Example:
Iron pyrites

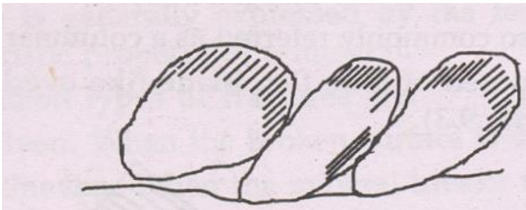
Granular The mineral occurs in the form of densely packed mass of small grain-like crystals. Example: Chromite



GRANULAR GLOBULAR

Globular or botroiydal, when the mineral surface is in the form of rounded, bulb- like overlapping globules or projections. Example: Hematite

Reniform It is similar to globular but the shape of the bulbs or projections resembles to human kidneys. Example: Hematite.



Reniform(Hematite)

Mammillary (Malachite).

Mammillary It is similar to globular but the projections are conspicuous in size, overlapping in arrangement and rounded in shape. Example: Malachite.

(9) SPECİFİC GRAVİTY

Specific gravity (SG) or relative density is a unitless number that expresses the ratio between

the weight of a substance and the weight of an equal volume of water at 4° (Max. ρ).
Density (ρ) is the weight of a substance per volume= g/cm³. It is different than **SG,** and varies from one locality to another (max. at poles, min. at equator).

Examples

Mineral	Composition	Atomic Wt.	SG
Aragonite	$CaCO_3$	40.08	2.94
Strontianite	$SrCO_3$	87.62	3.78
Witherite	$BaCO_3$	137.34	4.31
Cerussite	$PbCO_3$	207.19	6.58

(10) ODOUR:

Most minerals have no odour.

- **Garlic**: Minerals with As.
- **Horseradish** (kara turp) :when heated, minerals with Se,
- **Bituminous**: asfaltite, petroleum products.
- **Sulphurous**: when heated, minerals with S.
- **Fetid**: minerals with S. When heated H_2S (rotten eggs) evolves.
- **Argillaceous**: Moistened clay minerals.

3. BRIEFLY EXPLAIN THE PHYSICAL PROPERTIES, CHEMICAL COMPOSITION AND USES OF QUARTZ GROUP OF MINERALS.

QUARTZ GROUP OF MINERALS

Color	Quartz occurs in virtually every color. Common colors are clear, white, gray, purple, yellow, brown, black, pink, green, red.
Streak	Colorless (harder than the streak plate)
Luster	Vitreous.
Diaphaneity	Transparent to translucent.
Cleavage	None - typically breaks with a conchoidal fracture.
Mohs Hardness	7
Specific Gravity	2.6 - 2.7
Distinguishing Characteristics	Conchoidal fracture, glassy luster, hardness.
Chemical Composition	SiO_2
Crystal System	Hexagonal
Melting Point	1705°C
Boiling Point	2477°C

- **Amethyst** is the purple gemstone variety.
- **Citrine** is a yellow to orange gemstone variety that is rare in nature
- **Milky Quartz** is the cloudy white variety.
- **Rock crystal** is the clear variety that is also used as a gemstone.
- **Rose quartz** is a pink to reddish pink variety.
- **Smoky quartz** is the brown to gray variety.
- **Agate** is a banded variety (sometimes with translucent bands)
- **Flint** is generally black with a fibrous microscopic structure
- **Jasper** is any colorful agate

4. BRIEFLY EXPLAIN THE PHYSICAL PROPERTIES, CHEMICAL COMPOSITION AND USES OF FELDSPAR GROUP OF MINERALS.

FELSPAR GROUP

- The felspar are the most prominent group of minerals making more than fifty percent, by weight, crust of the Earth up to a depth of 30km.
- The group comprises about a dozen or so minerals of which 3-4 may be easily described as the most common minerals in rocks.

Chemical Composition

- In chemical constition, felspars are chiefly alumino silicates of Na, K and Ca with following general formula:

$$WZ_4O_8$$

in which W = Na, K, Ca and Ba and Z = Si and Al. The Si : Al shows a variation from 3:1 to 1:1.

Atomic Structure

- At atomic level, the felspars show a continuous three-dimensional network type of structure in which the Sio4 tetrahedra are linked at all the comets, each oxygen ion being shared by two adjacent tetrahedra.
- The Si04 tetrahedra is accompanied in this network by AIO4 tetrahedra so that felspars are complex three dimensional framework of the above two types of tetrahedra.
- The resulting network is negatively charged and these negative charges are satisfied by the presence of positively charged K, Na, Ca and also Ba.

Crystallization

- The felspar group of minerals crystallise only in two crystallographic systems:
  - Monoclinic and Triclinic.

Classification

- Felspars are classified both on the basis of their chemical composition and also on their mode of crystallization.
- Chemically, felspar fall into two main groups:
  - The potash felspars and
  - The soda time felspars.

Potash Felspars

Orthoclase (K AL Si_3O_8), Sanidine (K AL Si_3O_8) and Microtine (K AL Si_3O_8)

Soda-Lime Felspars

- These are also called the plagioclase felspar and consist of an isomorphous series of six feispars with two components: Na Al Si_3O_8 and Ca Al_2 Si_2 0_8 as the end members.
- The series is also known as Albite-Anorthite series.
  - Albite
  - Labradoirte
  - Oligoclase
  - Bytwonite
  - Artdesine
  - Anorthite

	Albite	**Anorthite**	**Oligoclase**
Chemical Composition	(Na,Ca)AlSi3O8, Sodium, calcium (0 to 10%) aluminum silicate.	CaAl2Si2O8, Calcium aluminum silicate.	(Na,Ca)AlSi3O8, Sodium, calcium (10 to 30%) aluminum silicate.
Class	Silicate	Silicate	Silicate
Crystallography	Triclinic; pinacoidal	Triclinic; pinacoidal	Triclinic; pinacoidal
Habit	Crystals commonly tabular. Usually massive, granular, lamellar. Twinning very common.	Usually massive, cleavable, granular, or compact.	Crystals commonly tabular, uncommon. Usually massive, cleavable, granular, or compact. Twinning common.

Physical properties	Cleavage {001} perfect, {010} nearly perfect, {110} imperfect. Fracture uneven to conchoidal. Brittle. H. 6-6.5. S.G. 2.6-2.63. Luster vitreous, sometimes pearly. Color white to colorless; occasionally bluish, gray, reddish, greenish depending on impurities. May have play of opalescent colors (moonstone). Streak white. Transparent to sub-transparent.	Cleavage two perfect {010,001} at 86°. Fracture uneven to conchoidal. Brittle. H. 6. S.G. 2.74-2.76. Luster vitreous. Color white-gray, reddish. Transparent to translucent.	Cleavage {001} perfect, {010} nearly perfect, {110} imperfect. Fracture conchoidal to uneven. Brittle. H. 6-6.5. S.G. 2.63-2.67. Luster vitreous. Colorless, white, gray, greenish, yellowish, brown, reddish, depending on impurities; occasionally shows brilliant reflections from inclusions of hematite giving it a golden shimmer (sunstone). Streak white. Transparent to translucent.

	Microcline	**Orthoclase**
Chemical Composition	KAlSi3O8, Potassium aluminum silicate	KAlSi3O8, Potassium aluminum silicate.
Class	Silicate	Silicate
Crystallography	Triclinic; pinacoidal	Monoclinic; prismatic
Habit	Crystals often short prismatic. Twinning may be present. Often massive, coarsely cleavable to granular.	Crystals often short prismatic. Twinning may be present. Often massive, coarsely cleavable to granular.
Physical properties	Cleavage {001}, {010} perfect at nearly right angles (89.5°). Fracture uneven. Brittle. H. 6-6.5. S.G. 2.56-2.63. Luster vitreous, sometimes pearly on cleavage surfaces. Color white, gray, pale cream-yellow, flesh-pink, various shades of red, green (amazonstone). Streak uncolored to white. Transparent to translucent	Cleavage {001}, {010} perfect at right angles (90°). Fracture uneven to conchoidal. Brittle. H. 6-6.5. S.G. 2.55-2.63. Luster vitreous. Colorless, white, gray, pale yellow, pink, flesh-red. Streak colorless to white. Transparent to translucent.

5. DESCRIBE THE PHYSICAL PROPERTIES AND USES OF THE FOLLOWING MINERALS.

(a) Augite
(b) Hornblende
(c) Biotite
(d) Muscovite
(e) Calcite

AUGITE Ca (Mg, Fe, Al) (Al, Si)$_2$O$_6$

Crystal System

- Monoclinic; occurs usually in short prismatic crystals and as a granular mass.

Cleavage

Prismatic [and good. Commonly shows parting parallel to base (001).

Colour

Variable, depending on chemical composition; occurs in shades of grayish, green and black.

Hardness

5 — 6

Sp. Gravity

3.25 — 3.55 (Depending primarily, on iron content).

Lustre

Commonly vitreous.

Composition

A complex Fe-Mg silicate.

Optical

Optically (+); strongly pleochroic when rich in iron and titanium.

Occurrence

A very common ferro-magnesian mineral of igneous rocks. The basic and ultra basic rocks are specially rich in augite.

HORNBLENDE Ca$_2$Na (Mg, Fe) (Al, Fe) [SiAl)$_4$ O 11]$_2$ [OH]$_2$

Crystal System

Monoclinic, crystals long, slender and prismatic.

Cleavage

Perfect, prismatic, parallel to [110]; Prismatic.

Colour

Dark green, dark brown, black.

Hardness

5.5 to 6

Sp. Gravity

3.0 to 3.47 (variable, depending on composition).

Lustre

Vitreous.

Streak

White, with greenish tint.

Composition

Highly variable and complex; broadly an aluminous amphibole.

Optical

Under microscope hornblende crystals generally appear in six-sized outline. The mineral section shows strong pleochroism, an oblique extinction and is commonly optically (-)

Occurrence

Hornblende is a common rock-forming mineral in igneous and metamorphic rocks. Amphibolite, a metamorphic group of rock may be made up chiefly of hornblende. Because of their widespread occurrence, hornblende and augite are taken as representative minerals from the amphibole and pyroxene groups respectively.

Varieties

About half a dozen varieties of hornblende have been differentiated on the basis of variation in its chemical composition

BIOTITE

Crystal System

Monoclinic; commonly occurs in tabular sheets or short prismatic plates.

Cleavage

Highly perfect and basal

Colour

Black, deep green variety is also found.

Hardness

2.5 — 3.1

Sp. Gravity

2.7 to 3.1, increases with iron content.

Streak

Colourless

Optical

Optically (.-), strongly pleochroic in thin sections under microscope.

Occurrence

Commonly found in igneous rocks and metamorphic rocks like gneisses. It is rare in sedimentary rocks compared with muscovite.

MUSCOVITE

Crystal System

Monoclinic; commonly occurs in platy form with pseudo symmetry of hexagonal or orthorhombic type.

Cleavage

Eminent, basal (001)

Colour

Colourless in thin sheets; as a mass may appear pale yellow.

Hardness

2.5—3.0

Sp. Gravity

2.7 to 3.1

Lustre

Pearly on cleavage faces; Vitreous.

Streak

Colourless

Optical

Optically (—)

Occurrence

It is the most common variety of all the micas and occurs in abundance in acidic igneous rocks such as granites and pegmatities and also in metamorphic rocks (mica schists). It is a common accessory mineral of sedimentary rocks.

Varieties

Muscovite is a good electrical insulator and finds extensive use in electrical industry and for making fire proof material.

CALCITE

Crystal System

Hexagonal-Rhombohedral.The mineral occurs in great variety of crystals: tabular, rhombohedral, prismatic, thin and elongated.

Cleavage

Highly perfect, rhombohrdral. Parting is also common.

Colour

Pure calcite is white and transparent. Milky-white, opaque varieties are also common. Small proportions of impurities give various tints to calcite: pink, red, violet, blue, green and black.

Hardness: 3

Specific Gravity

2.71.

Lustre

Vitreous. Earthy in massive varieties.

Optical

Under microscope calcite appears as shapeless patches showing one or more sets of cleavages and interference colours of high order

Occurrence

Calcite is one of the most common rock forming minerals in sedimentary rock. Limestones are almost entirely made up of calcite and the dolomites contain this mineral to a good proportion. The recrystallized variety of calcite makes the well-known metamorphic rocks marbles. Calcite is principally a secondary mineral formed from the carbonate rich water of sea and oceans.

Varieties

Calcite occurs in numerous varieties including Aragonite, Iceland spar, Satin spar and chalk The Iceland spar is a transparent crystalline variety valued as a source material for optical instruments.

6. EXPLAIN THE COMPOSITION AND CLASSIFICATION OF COAL

COAL

- The term coal is generally applied to a sedimentary formation of highly carbonaceous matter that is derived from vegetable matter involving set of processes such as burial, compaction and biochemical transformation.

Chemical Composition

- Coal is composed of carbon, oxygen, hydrogen, nitrogen, traces of sulphur and phosphorous, Carbon being the major component.
- Coals may contain varying properties of mineral matter which may be residues of the mineral constituents of the plants from which coals are derived.
- The chemical composition of coal may be in the following range.
    - Carbon (60-90 percent),
    - Oxygen (2 - 20 percent).
    - Hydrogen (1-12 percent)
    - Nitrogen (1-3 percent).

Classification

- Coal is divided into four major classes on the basis of carbon content and burial period. As the burial period is more, more carbon is present.
    - Peat – 50-60% carbon
    - Lignite - 60-70% carbon
    - Bituminous coals - 70-90% carbon and
    - Anthracite 90-95% carbon.
- Vegetal matter contains carbon less than 50%.
- Graphite contains 98% of carbon.

Peat

- It is essentially a partly changed vegetable matter in the first stage of transformation to coal.
- The vegetable structure is easily visible and the evidence of its being in the process of transformation is also clearly seen.
- Peat is generally composed of remains of moss-like plants but occasionally may contain reeds and partially altered portions of trees of higher order.
- Chemically, it is very rich in moisture and consists of carbon, hydrogen, sulphur and nitrogen as important constituents.
- Two types of peat are commonly recognized
    - Bog Peat, which is evolved out of lower type of vegetation, like mosses.
    - Mountain Peat, that is decomposed and partially altered form of higher types of trees.
- Peat is a low value fuel in its application. It finds uses where available in abundance as *(i)* domestic fuel, *(ii)* gas purifier, *(iii)* for steam raising, *(iv)* in thermal power stations and also as a soil treatment material.

Lignite

- It is a variously coloured (brown, black or light grey, earthy) variety of coal of lowest rank.
- In lignite, transformation of vegetable matter to coal-like material is almost complete.
- It is compact and earthy in texture and has a brown streak. Fibrous texture is also shown by some lignites.
- A typical lignite has following composition:
    - Fixed carbon: 60 percent;

- oxygen: 20-25 percent.
- Hydrogen: 05 percent;
- nitrogen: 02-05 percent, and
- Sulphur 01-02 percent.

- Lignites are used as domestic fuels and also in industry for distillation and gasification.
- This variety of coal has also been used in steam locomotives and for producing gas.

Bituminous coals

- It is also known as the common coal, sometimes as coking coal and is, in fact, the most common and important variety of commercial coals.
- In this, the original vegetable matter has been fully transformed into carbonaceous material so that it forms a hard, brittle and compact mass.
- It burns with a yellow flame.
- The common bituminous coal is sometimes distinguished into three different types on the basis of its carbon content: sub-bituminous, bituminous and semi-bituminous coals.
- In the sub-bituminous coals, the volatile constituents and moisture make the bulk of the coal matter. They possess no caking power (see below). Carbon is generally between 63-75 per cent and oxygen between 10-20 per cent.
- The proper bituminous coals often show a typically banded structure and are quite rich *in* carbon and poor in moisture content.
- Their carbon content ranges between 70-90 per cent and the volatile matter is also quite high: 20 to 45 percent.

Anthracite coal

- It is a coal of highest rank in which original organic source has been completely transformed into carbonaceous substance.
- Anthracite is very hard, jet black in colour, compact in structure and showing an almost metallic (steel grey) luster.
- It is difficult to ignite and burns with a typically blue flame without emitting any smoke.

7. EXPLAIN THE ORIGIN AND OCCURRENCES OF COAL

Origin of coal

- Coal is formed by the accumulation of vegetal matter which undergoes geological processes bringing changes in the physical and chemical composition.
- Origin of Coal can be explained by in-situ and drift theories.
- *In-situ theory:* This theory states that the coal vegetation was fossilized practically on the site of growth, either due to tectonic movement or due to some other reasons.
- *Drift theory:* The drift theory is however strongly held by some geologists, which states that the coal-seams have been formed as a result of drifting and subsequent accumulation of the plant bodies away from their place of growth.

Formation of Coal

- The process of formation of coal depends on the source material, places and condition of accumulation and the climatic condition.

Source material:

- Two types of sources yielded vegetable material for the formation of the coal:
- the higher vegetation including herbs, shrubs and trees, growing on the plains, plateaus, sub-mountainous and mountainous areas and characterized with wood

tissue rich in cellulose and lignin (50-70%) and protein (10-15%); this type of source has been named as the humic sediment;

- the lower vegetation, comprising chiefly planktonic algae, as is often found at the bottom of lakes and seas, submerged under water. This source has been named as sapropelic sediments.

Stages of formation

- Formation of coal can be explained by the following two stages
- *Humification process:* The changes brought about in the plant debris during this process are due to the decay and decomposition of the substances like resins, lignins, proteins, cellulose etc. present in plants. These changes are brought about by the activity of bacteria and other micro-organisms which ideally thrive in swampy conditions. This process is also called fermentation and the result is the formation of a porus, fibrous and friable mass called 'Peat'.
- *Coalification:* Peat once formed, under the prevailing conditions at depth in the earth's crust and due to various geological factors, is transformed through various stages to coal. Thus bituminous coal into anthracite. This series of peat-lignite-bituminous-anthracite is called coalification. The rank of the coal increases at a place with depth.

Indian Occurrences of coal

- India is one of five major producers of coal in the world.
- It is endowed with huge reserves of common or bituminous coal, chiefly of non-coking types.
- Fairly good but localized deposits of peat, lignite and anthracite have also been mined at different places.
- On the basis of their occurrence relative to geological age, coal deposits of India are often classified into two groups: Lower Gondwana Coals and Tertiary Coals, the former being of great economic importance.

(A) The Gondwana

- About 98 percent of coal annually produced in India comes from formations of Lower Gondwana age
- The Gondwana coal are derived from coal seams that occur interbedded commonly with sandstones and shales and sometimes with limestones.
- It is believed that these coals have been formed from Glossopteris types of vegetation deposited in shallow type of basins where they were transported by streams of fluvio-glacial and fluvial origin.
- Their occurrence in coal-bearing formations separated by totally barren (with respect to coal) formations are indicative of repeated climate changes during the Permian times- the geological period of their formation.
- The lower Gondwana coals are mainly of bituminous type, Major coalfields belonging to this class occur in Bihar, West Bengal, Orissa and Madhya Pradesh.

(B) The Tertiary Coals

- These coals are found in the states of Assam, Arunachal Pradesh, Himachal Pradesh, Nagaland and Jammu and Kashmir.
- The Makum coalfield of Assam, spread over an area of 150 sq.km, is an important example, in which reserves of 235 million tones are estimated to occur.
- The coal is high in volatile matter (38-51%) and low in moisture content (2 to 9 percent). It is regarded as an ideal type for chemical industry.
- The Jangalgali and Kalakote coalfield of Jammu (Jammu and Kashmir state) are of semi anthracitic type and low in moisture content 'and sulphur.

(C) The Lignite Deposits

- India has only scarce occurrence of lignite type of coal. Important deposits reported so far occur in Tamil Nadu, Pondichery, Kutch, Kerala and Uttar Pradesh.

- Of these, the Neyveli lignite field in Arcot district of Tamil Nadu is the most important which holds about 2600 million tones of the estimated total of 2900 million tones of lignite deposits in the country.

8. EXPLAIN THE ORIGIN AND OCCURRENCES OF PETROLEUM

PETROLEUM

- Petroleum is a general term applied to a complex mixture of hydrocarbons and some other compounds that occur in a liquid form entrapped within the rocks of the surface of the earth.
- It is also termed as mineral oil and crude oil.

Chemical Composition

- Crude oil is chiefly a complex mixture of hydrocarbons which occur in an isomeric combination.
- The main hydrocarbons that constitute crude belong to
  - Paraffins (methane, ethane, propane and butane).
  - Napthanes series and aromatic hydrocarbon.
- Besides hydrocarbons, small quantities of compounds of sulphur, nitrogen and oxygen are also present in varying properties.
- The natural gas which is often associated with petroleum deposits is made up of gaseous hydrocarbons of the paraffin group besides with an admixture of low boiling liquid hydrocarbons like pentane and hexane.

Origin of Petroleum

The origin of petroleum depends on

- The nature of the source material
- The process that resulted into the transformation of source material to the crude oil,
- The environment that controlled such a transformation,
- The migration of the oil from the place of actual (likely) formation to the present occurrence and also the complex chemical composition.

Source Material

Inorganic theories:

1. Reaction of alkali-metals (which are common in the interior of the earth) with carbon dioxide forming acetylene that combine with water to form hydrocarbons.
2. Reaction of iron carbide with percolating waters at very high temperature and pressure that leads to the formation of hydrocarbons
3. Concentration of cosmic hydrocarbons that existed in the beginning of the earth, when it was still in astral state, followed by their absorption by substratum on cooling of the earth and subsequent concentration in the coolest layers of the lithosphere.
4. Decomposition of the terrestrial waters that percolated down into the body of the earth by radioactive and other sources into hydrogen and oxygen and combination of hydrogen so formed with carbon of magma rich in that gas.

Organic Theories

- These form the generally accepted view regarding the parent material of the oil. All such theories suggest an essentially organic nature for the source material of petroleum.
- Sufficient evidence exists to prove that there have been huge accumulations of organic matter - both of vegetable and animal kingdom - in geological times.

Transformation

- It is commonly accepted that the organic source material (of either type) is transformed into oil-like liquid through a set of stages.

- In the first stage, the carbon-rich organic remains collected over long geological times undergo biochemical decomposition through the agency of microorganisms.
- This change may result in conversion of original mass into thick, heavier, bituminous substance that subsides under its own weight to lower zones of higher temperature and higher pressure.
- The bituminous material undergoes activated degeneration in an oxygen free environment resulting in the liquid, gaseous and solid fractions of hydrocarbons.

Environment

- Various views have been expressed regarding this aspect of the problem also and the most important conclusion is that oils were evolved out of organic debris deposited in anaerobic environment (places free of oxygen).
- The most ideal site for such conditions to prevail would be the cut off gulfs or isolated branches of seas where lack of oxygen could have been easily caused by non-circulation and virtual stagnation of water. T
- To support a continuous supply of organic debris to ensure good accumulation, this anaerobic layer should be succeeded by an upper oxygenated surface zone where source organisms could thrive.

Migration

- The sedimentary formations in which the oil occurs at present are called reservoirs or pools.
- These are not always the same rocks in which the oil was originally formed. The reservoir rocks may be situated at exceedingly large distances from the original site of oil formation.
- The journey of oil from the source to a reservoir rock is termed as *migration* and has been explained in various ways.
- Compaction of the source material is thought to be chiefly responsible for oil migration and it is believed to take places by a method called interface capture operating somewhat in the following manner:
  - A clay bed with appropriate concentration of organic matter is deposited; it is loose and water-rich in the beginning.
  - Overburden increases due to continued sedimentation. This leads to expulsion of water by squeezing effect. Simultaneously, oil formed in the clay layer is also expelled alongwith the water.

Indian Occurrences of Petroleum

- India, like many other countries of the world, is oil-deficient and imports huge quantities annually to meet its demands. At present, oil is extracted mainly from oil reserves in Assam, Gujarat and Maharashtra.
- In Assam, oil is extracted from the oil fields of Digboi, Nahorkatiya, Badarpur and Makum.
- The oil formations belong to Tipam (sandstone) series in Digboi and to Barail series in the Nahorkatiya field.
- The well-known oilfields (and gas fields) Western India are the Ankleshwar oil field of Gujarat, the Cambay gas fields, the Nawagam oil field and the Bombay High oil and gas field.
- In Tamil Nadu, narimanam in nagapatinam districy belongs to Cauvery delta regions.

9. EXPLAIN THE PROPERTIES, BEHAVIOR AND ENGINEERING SIGNIFICANCE OF

CLAY MINERALS.

THE CLAY MINERALS

- The clay minerals are essentially hydrous aluminium silicates or occasionally hydrous magnesium or iron silicates. Clay minerals are crystalline with a very few exceptions.
- The lattice structure of clay minerals is essentially the basis for their classification into three groups namely, the kaolinites, the montmorillonites, and the illites. The range of specific gravity values in clay minerals is as follows: illites from 2.64 to 3.0, kaolinites from 2.60 to 2.68 and montmorillonites from 2.2 to 2.7.

The kaolinites:

- The chemical formula of the kaolinites in $Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O$ or $H_4Al_2Si_2O_9$.
- The latter formula is more correct, since it shows that the structural water is bound to the lattices in the form of a hydroxyl, OH, and not as H_2O.
- The minerals of this group are formed of a single tetrahedral silica sheet and a single octahedral alumina sheet, a combination that repeats it indefinitely.
- Particles forming the kaolinite minerals may be regarded generally as aggregates of small, sometimes approximately hexagonal flakes.
- The kaolinites form very stable clays because their tight inexpandible structure resists the introduction of water into the lattices and its consequent destabilizing effect.
- Furthermore, when wet, the kaolinites are but moderately plastic and tend to have a larger coefficient of internal friction than other clay minerals.
- Generally, unless they contain expandible impurities, the kaolinites themselves are not subject to expansion or heaving when saturated.
- It should be noted that the clay minerals are seldom found in "pure" form; usually more than one type are present, and the percentage and size of each type present will determine the ultimate characteristics of the combined mineral, Halloysite.
- One of the kaolinite minerals, occurs in round or flattened tubes.
- When this mineral is wet, the tube like structure apparently acts like a pile of roller bearings and the mass flows or creeps.
- As a material for embankments, the halloysites generally are regarded as unsuitable.

The Montmorillonites:

- The chemical formula of the montmorillonites is $(OH)_4\,Si_8\,Al_4\,O_{20}{\cdot}nH_2O$.
- The term nH_2O refers to the interlayer water which may be present between the sheets of a natural montmorillonite in the form of one, two, three, or more layers of water, each layer being one molecule thick.
- According to prevailing views, montmorillonite is composed of conjoining identical units made of an alumina octahedral sheet between two silica tetrahedral sheets.
- The sheets are bound together rather loosely and thus an unstable mineral results, especially in the presence of water.
- In fact, the attracted water molecules easily insert themselves between the sheets, causing swelling expansion.
- In such cases, individual montmorillonite flakes are enclosed (Wrapped) in water films thus wet motmorillonites have a high plasticity and a low coefficient of internal friction.
- When a saturated montmorillonite is drying out, it is subject to high shrinkage and cracking.
- The expansive properties of the montmorillonite clays are a matter of engineering concern.

- Heavy structures founded on such clays may be lifted and damaged, not to mention possible failures of pavements and building slabs placed directly on the ground.
- Slopes, both artificial and natural, made primarily of montmorillonite clays are subject to sliding and flowing in wet weather.
- The well known bentonites usually formed from volcanic ashes are a form of montmorillonite clay noted for their expansive properties.
- In engineering practice these properties can be put to beneficial use, however, particularly for preventing leakage from reservoirs and canals.
- In canals, the canal lining is made of a mixture of local soil and montmorillonite-type clay.
- When the canal is put into operation water makes the clay swell and thus seal the canal banks and bottom.

The Illites.

- The generalized chemical formula for illites is $(OH)_4\, K_y\, (Si_{8-y} \cdot Al_y)(Al_4 \cdot Fe_4 \cdot Mg_4 \cdot \text{-} Mg_6)O_{20}$.
- A structural unit of an illite is similar to that of montmorillonites with some change in chemical composition.
- Whereas the montmorillonites consist of exceedingly fine particles that appear like fog, even under the greatly enlarging electron microscope, the flakes composing the illites frequently form aggregates.
- The aggregate like structure, exposes less surface to attract water than the montmorillonites.
- Hence, in comparison with montmorillonites, the illites have a more limited hydration capacity.
- The expansive properties of illites also are less and their coefficients of internal friction higher than the montmorillonites.

Engineering significance of clay minerals

- In engineering practice, clays are described as consisting of particles, although actually the particles are minute flakes. As in all crystalline substances, the atoms in these flakes are arranged in units, in these case sheets.
- Whenever clay is encountered in the foundation, the engineer and the geologist are placed on guard as there is “unpredictable” phenomena takes place on clay minerals. A definite identification of clay minerals is required in major engineering works.
- In clay minerals sheets are of two varieties:
    - Silica sheets and alumina sheets. A silica sheet is made of tetrahedral each tetrahedron being bounded by four triangular plane surfaces with oxygen atoms at the vertices and a silicon atom in the interior of the tetrahedron. All oxygen atoms are equally spaced and all are distant from the silicon atom. The tetrahedral are combined into hexagonal units. In each unit oxygen atoms 1 are connected with oxygen atoms 2 and 3, by means of protruding atoms 4, are connected to six neighbouring units of identical size and shape. By repeating themselves indefinitely and still sharing oxygen atoms, these units form a lattice of the mineral.
    - An alumia sheet consists of two-row units shown in fig1.3a,b,c arranged in octahedrons with oxygen O, atoms or hydroxyl, OH, groups at the vertices of alternate rows, respectively and with an embedded aluminium atom at the middle.
- If a mineral contains a large number of bases (for instance, sodium cations, Na +) and is acted upon by a liquid containing a high number of bases of some other kind (for

instance, potassium cations, K^+), the mineral and the liquid may interchange their cations, sometimes in a rapid reaction.

- This is the Base Exchange or more accurately, cation exchange, which usually is more intense in the clay minerals than in other minerals. The commonly exchangeable cations in clay minerals are Na^+, K^+, Ca^{++}, Mg^{++}, H^+ and $(NH_4)^+$.
- The Base Exchange property varies considerably for different clay minerals. The kaolinites are the least susceptible and the montmorillonites the most susceptible to cation exchange. Also, when in an extremely fine state, all inorganic minerals reveal a weak cation exchange capacity. Some organic soils also have considerable cation-exchange capacity.

The Base Exchange properties of soil are the basis of stabilization of soils by certain chemicals or by electroosomotic phenomena. Water softeners depend upon the base-exchange capacity, and acid soils containing H^+ ions can be sweetened to improve their agricultural value by adding lime, which causes an exchange of H^+ and Ca^{++} ions.

Uses of Clay Minerals

Filtering: Clays are used to decolorize, filter, and purify animal, mineral, and vegetable oilsand greases due to their high absorbing properties.
Environmental Sealants: Bentonite is used to establish low permeability liners in landfills, sewage lagoons, water retention ponds, golf course ponds, and hazardous waste sites.
Pharmaceuticals/ Cosmetics:
Bentonite is used as a binder in tablet manufacturing and in diarrhea medications. Clays are used as thickeners in a wide variety of cosmetics including facial creams, lipsticks, shampoos and calamine lotion.
Pelletizing: Bentonite is used to bind tiny particles of iron ore, which are then formed into pellets for use as feed material for blast furnaces.

Paints: Finely ground clays are used in the paint industry to disperse pigment evenly throughout the paint. Without clays, it would be extremely difficult to evenly mix the paint base and color pigment.

10. BRIEFLY EXPLAIN THE VARIOUS PROCESS OF FORMATION OF ORE MINERALS.

IGNEOUS PROCESS

Magmatic concentration

The magmatic deposits are formed during different stages of magma crystallization. Certain metallic oxides, sulphides and native minerals, like chromite, magnetite, millerite, diamond etc., were formed in the early stages of magmatic crystallisation and became segregated by crystal separation to form early magmatic mineral deposits, while others crystallized later than the host rock and accumulated at the original site or injected elsewhere to give rise to late magmatic mineral deposits like pegmatitic deposits containing tin, beryllium, tentalum, niobium, lithium and other ores.

- **Early Magmatic Deposits**

The early formed ore minerals in the deposits may occur as below

  - **Disseminated** in the enclosing rock eg diamond in kimberlite.
  - **Segregated** due to crystallization differentiation. e.g. stratiform and banded graded deposits of chromite in Nausahi-sukinda area, Orissa.
  - **Injected** into the host rocks or the surrounding rocks e.g. canadiferous magnetite deposits of Dublabera, Singhbhum district in Bihar.

- **Late Magmatic Deposits**

The late magmatic deposits may be accounted for

  - **Residual liquid segregation** wherein the residual magma with crystallization becomes progressively richer in silica, alkali and water. It sometimes contains titanium and iron which on crystallization segregated to form titaniferous magnetite deposits e.g. titaniferous magnetite of Hassan district, Karnataka

- **Residual liquid injection** which takes place due to earth's disturbance like igneous intrusion. The residual liquids rich in form when injected crystallized to form magnetite deposits, e,g., magnetite dyke rock of Kasipatanam, Vishakapatanam district, Andhra Pradesh.
- **Immiscible liquid segregation** in which certain salts in magma under certain conditions separate out an unmixed solutions like oil and water and segregate to form important mineral deposit . it has been observed that sulphur and silica form two hot immiscible liquids wherein a molten mass consists of various metals.
- **Immiscible liquid injection** when the unmixed sulphide rich fraction accumulated in the magma chamber, as described above is squirted out before consolidation towards the places of less pressure, such as shear zones. They intrude the older rocks and enclose brecciated fragments of host and foreign rocks.

Sublimation

- Sublimation is a process of mineral deposits associated with volcanism, thermal springs and fumaroles wherefrom volatilized matter is redeposited at lower temperature and pressure. Sulphur and borax of Puga area, Ladakh are examples of such deposits. They are associated with thermal springs and fumaroles.

Hydrothermal processes

- The term hydrothermal means hot water with possible temperature if 500^{o} C to 50^{o}C. The fluid resulting as an end product of magmatic differentiation constitutes hydrothermal solution which carries metals originally present in the magma to the site of deposition. The process is responsible for formation of epigenetic mineral deposits i.e. those formed later than the rocks that enclose them. The hydrothermal solution in its journey through the rocks loses heat and metal contents with increased distance. The deposition may have taken place at high temperature (hypothermal deposit), intermediate temperature (mesothermal deposit), or low temperature (epithermal deposit).
- **Cavity filling:** The precipitation of minerals from mineralizing solution in the cavities or the open spaces in rock forms cavity filling deposit.
- **Metasomatic Replacement:** Metasomatic replacement is defined as a process of simultaneous solution and deposition by which earlier formed mineral is replaced by a new one. it takes place when the mineralizing solution comes in contact with mineral which is unstable in its presence.

SEDIMENTARY PROCESS

Residual concentration

- Residual concentration is the process of accumulation of valuable minerals after removal of undesired material by weathering.

Mechanical concentrations

- Mechanical concentration is a process by which heavy minerals are separated from light ones by moving water or air and concentrated in the form of placer deposits. It thus includes two steps.
    - Separation of heavy and stable minerals from mother rock by the process of weathering.
    - Their accumulation at suitable site.

- The placers are known as *eluvial placers* in case of their concentration on hill slope, *stream or alluvial placers* if concentrated in stream and *beach placers* when on beaches. They are known as *eolian placers* in case of their concentration by wind action.

Oxidation and supergene enrichment

- The process of oxidation and supergene enrichment give rise to many large and rich ore deposits. Both the processes, in general occur together. Oxidation is operative in the upper part of the ore-deposits above the ground water table, called zone of oxidation. Ore minerals are oxidized by the surface water and produce solvent that dissolves other minerals and carries them down the ground water table. The leaching solution as proceeds downward loses a part of their metallic content within the zone of oxidation as oxidized ore. The secondary or supergene enrichment takes place when the down trickling solution reaches below the water table and its metallic contents are precipitated as secondary sulphides. Below this zone is the primary or hypogene zone which remains altogether unaffected. The process in ideal situation gives rise to a zone of gossan in the topmost part of the oxidation zone, followed by a supergene enrichment zone and then a primary zone.

Evaporation

- Evaporation is one of the important agencies which brings about deposition of many valuable minerals, once in solution, like gypsum, common salt, potash, nitrates and many other non-metallic minerals. Warm and arid climate is essential to cause evaporation whether in ocean water, lake water or ground water.

Pegmatitic Deposits:

- Pegmatites are very coarse grained igneous rocks Economic ore deposits are associated with granitic pegmatites. Residual elements such as Li, Be Nb, Ta, Sn and U that are not readily accommodated in crystallizing silicate phases end up in the volatile fraction. When this fraction is injected into the country rock a pegmatite is formed. Temperatures of deposition vary from 250-750°C. Pegmatites are divided into simple and complex. Simple pegmatites consist of plagioclase, quartz and mica and are not zoned. Crystals in pegmatites can be large, exceeding several meters.
- Three hypotheses to explain their formation:
    - fractional crystallization
    - deposition along open channels from fluids of changing composition
    - crystallization of a simple pegmatite and partial to complete hydrothermal replacement

METAMORPHIC PROCESS

Metamorphism

- Metamorphism is an important process to give rise to many new mineral deposits by altering the earlier deposits/rocks. It is by recrystallization and reconstitution of pre-existing rock forming minerals that some valuable mineral deposits are formed. Heat, pressure and water play an important role in bringing about metamorphism.

Contact metasomatism

Contact metasomatism is a process of formation of new mineral by reaction between the contact rock and the escaping high temperature gaseous emanations with other important minerals from the magma chamber. E.g. limestone or dolomite converts to marble. The temperature for contact metasomatism may possibly be ranging from 400^o to 800^oC, or even higher.