Chapter-1

Geology and its relation to Forestry

1.1 Meaning of Geology:

The word geology comes from the Greek word "geo" meaning the "earth" and "logos" a discourse or science.

Geology defined as the science concerned with the description and understanding of the earth from its creation to the present day (or)

It is the study of the Earth as a whole, its origin, structure, composition, and history, and the nature of the processes which have been gives rise to its present state.

1.2 Branches of Geology:

Geology comprises the following main branches viz.

1. Mineralogy
2. Petrology
3. Palaeontology
4. Physical Geology
5. Stratigraphy (or) Historical Geology
6. Economic Geology
7. Applied Geology
8. Geophysics and
9. Geochemistry

1.2.1 Mineralogy: Studies the minerals which form the rocks. It also studies its composition, characteristics, modes of occurrence and origin. A specialized aspect of mineralogy is crystallography, which studies the external forms and internal atomic structure of the crystalline minerals.

1.2.2. Petrology: Studies the origin, occurrence and classification of rocks.

1.2.3. Palaeontology: The study of ancient life i.e. fossils.

1.2.4. Physical Geology: It deals with the endogenous (internal) and exogenous (external) agencies and the processes that bring about changes on the earth's surface.

The main divisions of physical geology are:

a) Structural Geology: It deals with the configuration of the rocks in the earth's crust produced due to a number of forces generated both exogenously and endogenously.

b) Geomorphology: Deals with the shapes of landforms and the processes which act upon them.

1.2.5. Stratigraphy: The study of earth history (or) it is the study of strata as a record of geological history

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1.2.6. Economic Geology: It deals with the study of mineral deposits, their modes of formation, modes of occurrence, distribution etc.

1.2.7. Applied Geology: It is the practical applications of geological knowledge in various areas such as mining, petroleum, Hydrology, Engineering and Environment.

a) Mining Geology: It deals with the applications of geology in the mining and extraction of minerals.

b) Petroleum Geology: It deals with the problems of locating and extracting petroleum and natural gas.

b) Hydrology: It deals with the hydrological properties of rocks and the occurrences of ground water, its movement and action

c) Engineering Geology: It deals with the application of geological knowledge in the field of engineering for the construction of dams, bridges, tunnels, buildings, roads along hill slopes etc.

d) Environmental Geology: Evaluation of man's interactions with his environment.

1.2.8. Geophysics: It is a branch of geology with the application of physics which includes geodesy, seismology, meteorology, oceanography etc.

1.2.9. Geochemistry: It deals with the chemical constitution of earth, the distribution and migration of various elements in various parts of the earth.

1.3) The importance of Geology: The study of Geology is important for numerous reasons: a few of them are:

i) It helps to understand the origin, nature and structure of the earth.

ii) It helps to explain the varied character of the landscape ad how the many different landforms have come into being.

iii) It is important in the study of soils.

iv) It is important in connection with water resources because the rocks, through their character and structure influence run-off and the percolation of water underground; rocks may also affect the quality as well as the quantity of water made available to man.

v) Rocks provide us with our mineral wealth and the expert geologist is often able to locate precise areas where minerals

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are likely to be found. Prospecting is very closely bound up with knowledge of rocks and rock structures.

vi) The availability of building materials is dependent upon the geology of an area to a very considerable extent.

vii) Knowledge of geology can the engineer, enabling him to anticipate and avoid the danger and calamities.

viii) Knowledge of geology helps us to be aware of and to forecast, though not with any precise accuracy, certain natural calamities such as earthquakes and volcanic activity.

ix) The study of geology, more particularly through its fossil record, helps us to understand the processes of natural evolution.

1.4) Geology and its relationship with other sciences:

Geology is only some 200 years old science but with in the past couple of centuries tremendous advances have been made. The geologists call supon the help of many other sciences to aid him in his work of detection and in providing answers to many of the problems which faced by him. Not only he barrowed from other sciences but there is often, overlap with other sciences: for example, Geophysics, which combines Geology and Physics, while Palaeontology, which studies fossil life, is clearly linked with Biology.

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All the above sciences viz., Cosmology, Physiography, Hydrology, Meteorology, Physics, Biology, Economics etc make some contribution to geology.

1.5. Relationship of Geology to Forestry:

In order to manage forests effectively and sustainably, we need an understanding of the underlying geology.

Forestry is affected by factors such as the composition of bed rock and soils, and the water retention capacity, nutrient content, acid susceptibility etc. of soils. Information about bed rock can be used in forestry to study growth conditions, for example by locating rocks such as limestone, shales and basic rocks, which favour forest growth. E.g. pine trees prefer acidic soils and Red sanders prefer quartzitic soils.

The distribution and the characteristics of plant species was determined by the environment, which include rock, soil and topography.

Soils provide anchorage to plants, acts as storehouse from which plants obtain necessary supplies of food materials and water. Soil influences the character and different types of vegetation patters i.e., "Forest types" and their distribution, rate of growth, quality of wood, vigour, resistance to diseases and wind damage etc. By studying the type of vegetation and its growth also, the type of soil, its fertility, depth, composition etc. may be determined.

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Principles of silviculture and Forest Management, also involves study of edaphic, climatological and other associated locality factors that are responsible for different types of forest vegetation and their distribution. The relation that vegetation bears to the soil and turn its relation to the rock and climate, is a subject ogf great importance to foresters, and is useful in the ecological approach to the problems of regeneration and for successful raising of forest crops, ehich means no only survival but establishing healthy and vigorous growing plantations.

Thus the study of Geology has too much utilization significance in the present day forestry.

CHAPTER - 2
GENERAL IDEAS REGARDING THE EARTH'S CRUST

Before passing on to the study of the Earth's Crust, it is necessary to know, in brief, the salient features concerning the position, the origin and the age of the earth, as also its internal constitution.

Image

The Real Image of our Milky Way Galaxy

←——————— 100,000 LIGHT YEARS ———————→

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SOME FACTS ABOUT OUR GALAXY

- **Milky Way galaxy -** a spiral galaxy of at least two hundred billion star.
- Our Sun is buried deep within the Orion Arm about 26,000 light years from the centre.
- Towards the centre of the Galaxy the stars are packed together much closer than they are where we live.
- Notice also the presence of small globular clusters of stars which lie well outside the plane of the Galaxy, and notice too the presence of a nearby dwarf galaxy - the Sagittarius dwarf - which is slowly being swallowed up by our own galaxy.
- Like all galaxies, the Milky Way is held together by gravity.
- This gravity also holds the stars, gas, and dust in orbit around the center of the galaxy.
- Just as the planets orbit around the sun, the sun orbits around the center of the Milky Way.
- The Sun completes one lap of the Galaxy about every 220 million years

2.1.2. THE SOLAR SYSTEM

- The Solar System consists of a central star (the Sun) and the bodies that orbit it. These bodies include nine (9) planets and their 61 known moons; asteroids; comets; and meteoroids. The Solar System also contains inter- planetary gas and dust. Most of the planets fall into two (2) groups. Four small rocky planets near the Sun (Mercury, Venus, Earth and Mars). Four gas giants furtherout (Jupiter, Saturn, Uranus and Neptune). Pluto belongs to neither group but is very small, solid and icy. Pluto is the outer most planet.

Between the rocky planets and gas giants is the asteroid belt, which contains thousands of chunks of rock orbiting the Sun. Most of the bodies in the Solar System move around the Sun in elliptical orbits located in a thin disc around the Sun's equator. All the planets orbit the Sun in the same direction (anti-clock wise when viewed from above). The entire Solar System orbits the centre of our Galaxy, the Milky Way.

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Image

2.1.4. THE EARTH – ITS POSITION IN SPACE:

The Earth is a member of the planetary system of the Sun. Besides the Sun, the Solar System includes nine (9) planets, their satellites, asteroids and comets. The planets are located in the order, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto from the Sun. The Earth is situated approx. 150 million Kms. from the Sun.

There are two theories about the position of the Earth in space. They are 1. Geocentric Theory and 2. Heliocentric Theory.

2.1.4.1. Geocentric Theory:

The Earth was the unmoving centre of the Universe, round which the Sun and the Stars and all other heavenly bodies revolved.

2.1.4.2. Heliocentric Theory:

The Sun was the centre of the universe and that the Earth and other planets revolved round it. The belief that the Sun was the centre of the universe was corrected by the German astronomer Johan Kepler in 1609. Galileo, the Italian astronomer and Sir Isaac Newton, the German scientist, had conclusively established that the Sun is at the centre of the Solar system.

Modern theories on the Earth are based on the Copernican theory.

The Earth, the planet on which we live has the highest density among Terrestrial group of planets. It has one satellite, the Moon. The Earth is unique amongst the planets of the Solar system in possessing a complex variety of living forms and an atmosphere of a nitrogen composition.

The EARTH – Some important Facts

- The shape of the Earth is that of a spheroid.
- Its equatorial radius is 6378.3 Km.
- Its polar radius is 6356.9 Km.
- Average density is 5.5 gm / cc.

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- Average density of surface rocks is approx. 2.8 gm / cc.
- Age of the earth is 4.5 billion years
- Area of the Earth's surface is 510.08 million square Km.
- Total land surface is 148.63 million square Km.
- Total water surface is 361.45 million square Km.
- The Earth completes one full rotation around its axis in 23 hours and 56 seconds.
- The Earth completes a full revolution around the Sun in 365.26 days.

2.2. ORIGIN OF THE EARTH

The Earth is a member of the planetary system of the Sun. It is commonly believed that the origin of the Earth is connected with that of the Solar System. The principal theories which have been advanced to explain the origin of the Earth, can be divided into two groups.

2.2.1.1. Catastrophic theories: In this, material is pulled out of the Sun by an external force such as gravitational pull resulting from the dynamic encounter or near – collision of the Sun with another star.

2.2.1.2. Natural or evolutionary theories: The planets became isolated masses of matter as the material of the solar-system condensed into the Sun.

All these theories have in common the idea that the planets evolved from the Sun. They differ as to the manner in which it occurred.

2.2.2. Important theories explaining the origin of the Earth are:

The various theories regarding the origin of the earth and other planets of the solar system, are as follows.

- Georges Buffon's Hypothesis (1745)
- Nebular Hypothesis (Kant 1755 & Laplace 1796)
- Planetesimal Hypothesis (Chamberlin & Mounton 1904)
- Tidal Hypothesis (Jeans 1919 & Jeffreys 1929)
- Weizsacker's Hypothesis (1944)
- Meteorite Hypothesis (Otto Schmidt 1944)

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- ❖ Big Bang Theory

2.2.2.1. Georges Buffon's Hypothesis (1745):

Some material was pulled out of the Sun by an external force such as gravitational pull resulting from the near collision of the Sun with another star. The cooling of the blobs of solar matter ejected from the Sun during the cataclysmic collision gave rise to the planets of which the Earth is a member.

2.2.2.2. Nebular Hypothesis:

The first Nebular Hypothesis was advanced by the German Philosopher Kant (1755) and then by the French mathematician Laplace (1796). According to this hypothesis, the planetary system is believed to have been evolved from a large, hot, gaseous nebula rotating in space.

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The rotating nebula, according to the law of universal gravitation, became more compressed and compact with an increase in the speed of rotation. Gradual cooling with contraction in size and increasing concentration of mass towards the centre of the nebula led to an increase in the rate of rotation and a growth of centrifugal force. As a result a ring of material was left while contraction of the remaining material continued. When the centrifugal force exceeded the force of gravity in the equatorial zone of the nebula a ring of matter began to spin off along the whole periphery of the rotating disc. Thus successive rings of matter were formed and left behind the contracting mass. Further cooling and coalescence of the rings led to the formation of Planets and their satellites. The remnant of the pre-existing nebula formed the central incandescent mass of the solar system i.e. Sun.

2.2.2.3. Planetesimal Hypothesis

According to Chamberlin & Moulton (1904), American Scientists, tremendous tides were set up on the surface of the Sun due to the near approach of a much larger star. This, in conjunction with the eruptive force prevalent in the Sun brought about a large scale disruption of the Sun and thus a large quantity of gaseous solar material was ejected in Space.

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These gaseous matter with gradual cooling condensed into small solid particles known as Planetesimals. These planetesimals revolved around the Sun in different orbits, during which many of them collided with one another, thereby the small planetesimals aggregated to form planets.

2.2.2.4. Tidal Hypothesis:

According to Jeans (1919), a British astronomer and Jeffreys (1929), the planets were formed from a gaseous filament that was torn out from the Sun due to the gravitational pull of a huge star which happened to approach very close to the Sun. This large filament of gas thus ejected in space was extremely unstable which immediately got splitted up into a number of fragments.

pic

These fragments with gradual cooling and condensation gave rise to the planets and thus the solar system came into existence.

2.2.2.5. Weizsacker's Hypothesis:

In 1944, a German physicist, Weizsacker proposed a modification of the Nebular Hypothesis. According to him, the Sun was surrounded by a thin, flat, rapidly rotating cloud of matter that encircled its equator.

This cloud was having a much larger quantity of hydrogen and helium which had escaped into space in course of time because of their being extremely light in weight. The materials that formed the planets were carried as floating dust particles in the rotating gaseous envelope round the Sun and by gradual accretion of these matters the planets were formed.

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2.2.2.6. Meteorite Hypothesis:

This hypothesis was suggested by the Soviet scientist Otto Schmidt in 1944. The Earth and the other planets of the solar system were formed from the cluster of interstellar matter captured by the Sun during its passage near the centre of gravity of the galaxy.

These are proto-planetary bodies with their own angular momentum. Through accretion of these matters, they began to grow in size and mass and exerted gravitational pull on one another and ultimately gave rise to planets and satellites.

2.2.2.7. The Big Bang theory:

The Big Bang theory is the current favoured hypothesis of the formation of the universe according to astronomy. This asserts that some 12 – 15 billion years ago there was a suddenly expansion and explosion of all matter and energy out of an original point – out of literally nothing – and that not only space but even time began at this moment.

pic

(So we cannot speak of an explosion in space - because there was no space before, or no time at which this could be measured – space and time being properties of the universe rather than something outside of it).

Recent discoveries indicate that the universe is not only expanding but it's its rate of expansion is increasing. The strongest evidence for the Big Bang hypothesis is the existence of the microwave background radiation. This is thought to be **the "echo" of the Big Bang, all that remains of the original fireball.**

Massive amounts of matter and antimatter were created and although much of it was similarly cancelled out with a huge release of energy, matter won the day and spawned the universe. A still more recent theory has the universe evolving from a previous universe, which in turn developed from a previous universe, and so on. Similarly our universe may be giving birth to countless further universes, of which we can know nothing.

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2.3. AGE OF THE EARTH:

The age of the Earth was a matter of speculation till very recent times and as such there was divergence of opinions about the antiquity of the Earth. Until recently geology relied extensively on the concept of the relative age of rocks.

With the discovery of radioactivity that a new method giving an approx. age, with comparatively less chances of errors was found. The determination of the age of the earth was attempted through two distinct processes:

1. **Indirect methods**

2. **Direct methods**

1. Indirect methods:

a) Sedimentation clock
b) Salinity clock – 100 m.y.
c) Evolutionary changes of Animals -
d) Rate of cooling of the Earth

2. Direct Method: HLP

a) Uranium – Lead
b) Thorium – Lead method
c) Potassium – Argon method
d) Rubidium – Strontium method
e) Radio – Carbon method

Half Life Period of some radio active elements.

U 238 $\longrightarrow$ Pb 206 + 8 He4
The Half – life of U-238 is 4500 m.y.

U 235 $\longrightarrow$ Pb 207 + 7 He4

Th 232 $\longrightarrow$ Pb 208 + 6 He4
The Half – life of Th-232 is 13,900 m.y.

K 40 $\longrightarrow$ Ar 40
The Half – life of K-40 is 1470 m.y.

Rb 87 $\longrightarrow$ Sr 87 + 7 He4

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The Half – life of Rb-87 is 50,000 m.y.

The Half – life of C-14 is 5730 m.y.

Best means of estimation of age of the earth are:

a) Uranium - Lead method

b) Rubidium – Strontium method and

c) Potassium – Argon method

On the basis of the data provided by the radio-active methods, the age of the earth has been estimated to be of 4500 million years i.e., 4.5 billion years.

2.4. INTERNAL STRUCTURE OF THE EARTH

Major parts of the Earth's Interior

1. The Crust (0 to 35 - 70 Km)
2. The Mantle (35-70 Km to 2900 Km) &
3. The Core (2900 Km to 6371 Km)

The Crust, mantle and core are separated by two sharp breaks, usually known as Major discontinuities

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2.4.1. **The Crust**

The Crust is the upper most shell of the earth that covers the rocks of the interior thinly. Its thickness over the oceanic areas is generally 5 – 10 Kms; it is called as Oceanic crust. On the continental areas it is about 35 Kms; it is called Continental crust. The thickness ranges from 55 – 70 Kms in orogenic belts. It consists of very low density rocks.

Sial layer

The Mohorovicic discontinuity marks its lower boundary. From the study of Shallow focus earth- quakes & artificial seismic explosions, it has been inferred that there are two zones of crustal rocks beneath the continents; In the continental regions the crust can be divided into two layers, the upper layer is called "Sial" and the lower one "Sima". The Conrad Discontinuity, which is located at 11 Kms separates the Sial layer from the Sima layer.

Sima layer

The Sima layer is also known as Lower continental Crust. This layer is rich in Silica and Magnesium and is basaltic in composition. Its thickness is about 22 Kms. It extends from the Conrad Discontinuity up to the Mohorovicic discontinuity. It includes two parts:

a) Outer Sima: extends upto a depth of 19 Kms and consists of rocks of intermediate composition.

b) Inner Sima: located from 19 kms depth to 33 Kms and consists of rocks of basic to ultra basic composition.

2.4.2. **The Mantle**

The second major part of the earth interior is the Mantle. It is the source – region of most of the earth's internal energy and of forces responsible for ocean floor spreading,

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continental drift, orogeny and major earth quakes. It extends from the Mohorovicic discontinuity up to a depth of 2900 Kms i.e. core boundary or Gutenberg discontinuity.

The material is denser than that of the overlying crustal rocks. The material is olivine-pyroxene complex.

2.4.3. The Core

It is the inner most part of the Earth's interior. It is separated from the mantle by the Gutenberg discontinuity and extends up to the very centre of the earth. The core consists of three parts:

a) Outer - core
b) Middle – core and
c) Inner - core

The Outer – core

It extends from 2900 Kms to 4982 Kms. It is considered to be in a state of homogeneous fluid.

The Middle - core

It extends from 4982 Kms to 5121 Kms. The material is in a fluid to semi-fluid state.

The Inner - core

It extends from 5121 Kms up to the centre of the Earth i.e. 6371 Kms. It is assumed to be in a solid state with a density of about 13. It is believed to contain metallic Nickel and Iron and is called "NiFe".

2.5. GEOLOGICAL PROCESSES

Throughout the life time of the Earth changes of all kinds have been going on in the Earth's crust and on its surface, in its materials, their structures, distribution of land and

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sea, mountains and plains and even climate and weather. The processes responsible for these changes are called "Geological Processes".

2.5.1.DIVISIONS OF GEOLOGICAL PROCESSES

The divisions of geological processes are 1. External such as weathering, erosion & deposition and 2. Internal such as Diastrophism & igneous activity etc.

EXTERNAL PROCESSES

The external processes operate on the surface of the Earth tending to reduce its many irregularities to a common level and hence are referred to as the processes of gradation or denudation. They derive their energy from external sources ultimately from Sun.

Weathering refers to the natural processes of disintegration and decomposition of rocks. Erosion is the natural removal and transportation of rock material. It is the process of degradation. Deposition is the natural filling and raising of the lower portions of the Earth's surface. So it is called the process of aggradation.

The process of gradation is in constant operation and produces changes in our landscape. The principal agents of gradation, also called the geological agents are

1. Running water
2. Ground water
3. Moving ice (Glaciers)
4. Oceans
5. Lakes
6. Wind
7. Gravity and
8. Organisms (small extent)

The configuration of the land surface is the outcome of the joint actions of some geological agents having both constructive as well as destructive effects on the existing superficial features.

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INTERNAL PROCESSES

Though of internal origin, show their effect on the surface as well. Diastrophism includes all movements of the Earth's solid crust – slow movements– which cause elevation or subsidence of large or small portions of the Earth's crust without compression of the rocks or those which cause compression and crumpling of rocks and their upraising into mountain ranges and sudden movements such as Earth quakes.

Igneous activity includes phenomena associated with the movements of hot molten rock material (Magma or lava) within and upon the Earth's crust. These phenomena should be intrusive (confined to interior of the earth) or extrusive (operating upon the earth's surface – volcanic eruptions).

2.6. WEATHERING & AGENCIES AFFECTING ROCKS:

ROCK WEATHERING

The total effect of various subaerial - processes that bring about the disintegration and decay of rocks exposed on the surface of the earth is called "Weathering".

It is the process of alteration of rock materials, during long exposure to air, moisture and organic matter. The prime elements of weather are temperature, pressure and moisture. Warmth and moisture favour chemical action which brings about decomposition of the earlier complex minerals into altered minerals of simple composition. The changes of temperature and pressure bring about physical or mechanical disintegration of rocks.

Water and moisture soaks into the cracks and joints of rocks, dissolves and alters minerals, expand by freezing and enlarges joints and fractures. This process begins in cracks or fractures and ultimately the entire rock is affected.

Factors influencing weathering

- Climate
- Topography
- Hardness of the rocks
- Presence of Faults & Joints in rocks
- Vegetation

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Types of Weathering

The weathering is of two types.

1. Physical or Mechanical weathering:

Materials are disintegrated by Atmospheric changes, frost action and organisms.

2. Chemical weathering

Minerals are decomposed, dissolved and loosened by water, oxygen, carbon-dioxide of the atmosphere and by organisms and products of their decay.

2.6.1. Mechanical Weathering

When the forces of weathering break rocks into smaller pieces, each containing the characteristics of the original matter, without change in the chemical makeup of the rocks, the process is called mechanical weathering. During mechanical weathering, rocks are broken into different shapes and smaller pieces. At the beginning the edges are jagged, as weathering continues, they become round. It takes place mostly in high temperatures areas.

In nature the following factors of physical processes lead to fragmentation of rocks. They are

1. Frost action
2. Temperature effects
3. Mechanical effects of Plants & Animals
4. Gravity and
5. Abrasion

Frost Action

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Unlike most liquids, water expands when it freezes. The repeated freezing and melting of water, called frost action, is another cause of mechanical weathering. When water

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freezes in cracks & joints in the rocks, it expands, making the crack / joint larger. As freezing continues size increases, ice exerts pressure on the surrounding rocks and causes damage.

Rocks can be broken apart by changes in temperature. As rocks are heated up in the sun during the day, the outside of the rock expands. The inside of the rocks remain cool and do not expand. When the air temperature drops at night, the outside of the rock cools and contracts. This continuing cycle causes particles to break off. This is called exfoliation. The process of exfoliation results in the formation of rounded masses of rocks. Such a sort of weathering is called Spheroidal weathering.

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GRAVITY

Gravity is another agent of mechanical weathering. Sometimes gravity pulls loosened rocks down mountain cliffs in a landslide. A landslide is a large movement of loose rocks and soil. As the rocks fall, they collide with one another and break into smaller pieces. Falling rocks usually occur in areas where a road has been cut through, leaving cliffs on both sides.

ABRASION

Wind-blown sand causes mechanical weathering. Abrasion is the wearing away of rocks by solid particles carried by wind, water or other forces. In desert regions, the wind easily picks up and moves sand. The sharp edges of the sand particles scrape off pieces of exposed rocks. Running water also carries loose rocks which scrape against each other and break.

2.6.2. CHEMICAL WEATHERING

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Because of change in chemical makeup of rocks, the weathering process takes place. This is called chemical weathering. During chemical weathering, changes occur in the mineral composition of rocks. Minerals can be added, removed or broken down (decomposed). Many substances react chemically with rocks to break them down. Water is the most important agent of chemical weathering.

converted to ferric iron or to various other hydroxides, with accompanying color changes from green black to yellow, red or brown.

HYDRATION

This process involves chemical addition of water to certain minerals of rock to form new minerals chiefly hydrous oxides & hydrous silicates. The orthoclase feldspar is decomposed and converted largely to Kaolin, the principal mineral in the clay.

$2KAlSi_3O_8 + 2(H_2CO_3) + H_2O \qquad AlSi_2O_5(OH)_4 + 2KHCO_3 + 4SiO_2$

CARBONATION

In this CO_2 added to certain bases particularly to oxides of calcium, magnesium, sodium and potassium to form either carbonates or bicarbonates of these metals.

$FeS_2 + H_2O + CO_2 \qquad H_2SO_4 + FeCO_3$

RATE OF WEATHERING

The rate of weathering depends on several factors:

- The composition of the rock
- The amount of time that the rock is exposed on the Earth's surface
- The amount of exposed surface on a rock

COMPOSITION OF ROCKS

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Two different types of rocks in the same climate can weather differently, depending on the minerals that make up each rock type. If the minerals in a rock resist chemical weathering, the rock is called a stable rock.

The stability of a rock can vary depending on the climate in which the rock is found. Limestone is stable in a dry climate but not in a wet climate.

AMOUNT OF TIME OF EXPOSURE

The amount of time that rock is exposed on the Earth's surface also affects its rate of weathering. A very old rock that has not been exposed to the forces of weathering can remain almost unchanged. If a newly formed rock is exposed to the forces of weathering can change quickly.

THE AMOUNT OF EXPOSED SURFACE

The amount of exposed surface area on a rock also affects its rate of weathering. As rocks are broken down into many small pieces, more rock surfaces are exposed and more weathering takes place. In rocks that contain many joints or cracks, various chemicals easily come into contact with the rock surfaces and break them down.

INFLUENCE OF CLIMATE ON WEATHERING

Weather is not uniform all over the world. In the hot, most moist climate of the equatorial belt, in the hot and dry desert climate, in the cool and moist climate of the temperate zones and in the cool and dry Arctic regions, rock weathering is going on continually but each region represents peculiarities of its own.

In the equatorial regions owing to high temperature and excessive rainfall, chemical weathering is very active, its characteristic end product is the Laterite, which consists largely of red hydrated oxides of Iron and Alumina. In desert regions due to dry climate water is constantly rising up towards the surface by capillary action and depositing their dissolved contents, the surface materials become cemented resulting in the formation of "Hard-Pan"

In Temperate regions in winter frost action is dominant, whereas in summer water plays a major part. In general solution and chemical decomposition are the dominant types of weathering. In the Arctic regions, frost action and the wedge work of ice are the dominant agents of mechanical weathering. This results in the formation of sharp ridges & peaks.

PRODUCTS OF WEATHERING – SOILS

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The weathering of rocks on the Earth's surface results in the formation of soil. Soil is formed when rocks are continuously broken down by weathering. As rocks weather, they break into smaller pieces. These pieces are broken down into even smaller pieces to form soil.

Soils are the most useful products of weathering and they are a complex mixture of inorganic mineral matter and decomposed organic residues. They differ greatly from area to area, not only in quantity but in quality as well.

Soil is the surface layer of the earth restricted to land, consisting of a layer of broken-down, fine and loose rock material, produced by the weathering processes, mixed with decayed vegetation and other organic matter. Soil may be found on top of the parent rock or at some distance from it after transport and supports vegetation. The science which deals with the study of the soil is known as Pedology and the process of soil formation is called Pedogenesis.

The chief factors in the soil formation are

1. Parent rock material,
2. Climate,
3. Action of living organisms,
4. Slope of the land surface and
5. Time.

1. PARENT ROCK MATERIAL

The type of rock in an area also affects soil formation. Some rocks do not weather as rapidly as other do. Rocks that do not break down easily do not form soil rapidly. In some climates it takes along time for granite to break down. So soil formation from granite is slow. But sandstone breaks easily and forms soil quickly.

2. CLIMATE

Climate is another important factor in the formation of soil. In areas with heavy rainfall and warm temperatures, weathering takes place more rapidly. Heavy rainfall may wash much of the topsoil away. Since Organisms are more plentiful in these areas, the soil is quickly replaced. They speed up the chemical and mechanical weathering of rocks.

3. LOCAL TOPOGRAPHY

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The surface features of the region also determine the speed at which soil is formed. On very steep slopes, rainwater running off the land erodes the soil and exposes rock to weathering.

4. TIME

Time is one of the most important factors in soil formation. The longer a rock is exposed to the forces of weathering, the more it is broken down. Mature soil is formed if all three layers have had time to develop.

5. ACTION OF LIVING ORGANISMS

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Hence the character of the ultimate soil derived from a given rock will to a great extent depend upon other factors of soil formation. Soils which rest upon the bed rock from which they are derived are called residual soils. Residual soil has a composition similar to that of the parent rock it covers. Transported soils are those soils that have been carried to their present position from their original places. They owe their present location and position to agents of transportation like wind, running water, moving ice or simply gravity.

Since these agents accomplish different degrees of sorting transported soils naturally vary in texture from fine silts to coarse gravel. They also vary in chemical composition.

CHAPTER - 3. MINERALOGY

Mineralogy is the science of minerals or is the scientific study (physical & optical properties) of minerals.

Why to study mineralogy because, the solid earth crust of the earth is made up of rocks, which are aggregates of minerals.

Mineral is a structurally homogeneous solid of definite chemical composition, formed by the inorganic processes of nature.

Ex: Diamond, Quartz, Feldspar, Galena, Graphite etc.

3.1. CLASSIFICATION

3.1.1. Minerals are classified into two groups.

a) Rock forming minerals and

b) Economic minerals

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a) **Rock forming minerals:** These are very important constituents of rocks such orthoclase, augite, biotite, hornblende etc.

b) **Economic minerals:** These are important and very useful to the society. Ex: Hematite, bauxite, galena etc.

Metals can be extracted from the economic minerals.

3.1.2. Minerals can also be classified as:

a) Primary minerals and b) Secondary minerals

a) Primary minerals: These are formed as products of magmatic consolidation. Ex: Quartz

b) Secondary minerals: These are formed due to the operation of certain processes, on the early formed magmatic bodies. Ex: Malachite (An ore of Copper).

3.1.3. From petrological angle minerals can be classified as:

a) Essential minerals and

b) Accessory minerals

a) Essential minerals are those which are dominant and also decided the name of the rock.

b) Accessory minerals are of least proportion and are not significant in the naming of rock.

Ex: Potash feldspar is an essential mineral & biotite is an accessory in granite.

3.1.4. Scientific classification of minerals: It is based on the chemical composition. Classification was done by J.D. Dana, an American Mineralogist.

1. Native elements like Gold, copper, manganese etc.
2. Sulphides like Galena, Pyrite
3. Sulpho-salts
4. Halides like rocksalt, fluorite etc.
5. Oxides like Quartz
6. Oxygen-salts like calcite, feldspar, barite etc.
7. Organic salts and

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8. Hydro-carbon compounds

3.2. GROUPS

Various minerals have been grouped into certain families based on their structural

3. Feldspathoid group
4. Zeolite group
5. Pyroxene group
6. Amphibole group
7. Garnet group
8. Epidote group
9. Mica group and
10. Other miscellaneous minerals

From the chemical analysis of various rocks from different geographical locations, it was found that only eight (8) elements namely O, Si, Al, Fe, Ca, Na, K and Mg nearly make up 99% of the earth crust. The earth crust is made up of over 80 elements (except radioactive elements) and contains nearly 2000 minerals. Out of these many are of rare occurrence.

3.3. CRYSTAL FORMS

Most of the minerals are crystalline, while a few are amorphous (non-crystalline). When minerals crystallise under favourable condition, they take the form of crystals.

A crystal is a homogenous anisotropic solid and is characterized by definite chemical composition and orderly arrangement of atoms. A study of crystals is known as Crystallography. The process by which crystals are formed is called crystallization.

The important parts of crystals are faces of crystal, edges of the crystal, corners of the crystal, centre of the crystal, planes of the crystal, zones of the crystal and interfacial angles of the crystal.

Crystals must show the external symmetry due to orderly arrangement of faces, corners and edges. The three main elements of symmetry are planes of symmetry, axes of symmetry and centre of symmetry.

The crystallographic axes are imaginary lines which connect the centres of opposite faces, opposite corners, or opposite edges, and which intersect in a common origin within a crystal. All crystals of the same mineral possess the same degree of symmetry, and the same fixed angles between corresponding faces.

3.4. CRYSTAL SYSTEMS:

On the basis of the relations of the crystallographic axes, all the crystals may be grouped into six (6) "systems of crystallization". They are

1) Isometric System
2) Tetragonal System
3) Hexagonal System
4) Orthorhombic System
5) Monoclinc System and
6) Triclinic System

3.4.1. ISOMETRIC (OR) CUBIC SYSTEM:

Three equal axes, at right angles to one another.

Eg. Garnet, Leucite, Fluorite, Pyrite and Halite etc.

3.4.2. TETRAGONAL SYSTEM:

Eg. Zircon, Cassiterite

3.4.3. HEXAGONAL SYSTEM:

Four axes. Three equal horizontal axes which intersect at 60°. Vertical axis is longer or shorter. Eg. Quartz, Apatite, Calcite, Tourmaline and Beryl.

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3.4.4. ORTHORHOMBIC SYSTEM:

Three axes of different length, but they intersect at right angles.

Eg. Olivine, Barytes and Topaz.

3.4.5. MONOCLINIC SYSTEM

Three unequal axes. The vertical axis & one horizontal axis are at right angles. The third axis is inclined.

Eg. Orthoclase, Micas, Hornblende, Augite, Gypsum.

Pic

3.4.6. TRICLINIC SYSTEM:

Three unequal axes. None at right angle. Eg. Plagioclase and Axinite.

3.5. CRYSTALS HABITS & TWINNING:

HABITS: The crystal habit of a mineral is a term used to denote the relative development of faces and forms in its crystals; (or) it refers to the form or combination of forms commonly occurring in crystals of that mineral.

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Prismatic habit: When the external form of a crystal is column-like, bounded by a group of vertical faces, it is said to be have a Prismatic habit.
Pyramidal habit: When a crystal displays maximum development of pyramidal faces, it is said to possess Pyramidal habit.

Tabular habit: Whenever a crystal shows prominent flat surfaces the habit of the crystal becomes tabular.

3.6. TWINNING:

Two or more crystals of the same or related mineral species may sometimes inter grow in such a way that the individual parts are in reverse position to each other. Such crystals are called "Twinned-crystals". Sometimes it also appears as if one-half of the twinned crystal is produced by rotation of 180°, about some crystal axis is common to both.

Twin-plane: It is an imaginary plane which divides a twin crystal into two halves such that one-half is a reflection of the other.
Twin - axis: It is an imaginary line about which rotation is necessary to bring the twin to its un-twinned state.

Twinning-centre: When twinning is defined with respect to symmetry about a point, the referred point is called the twin-centre.
Composition plane: The plane by which the component crystals of a twin are joined is called the composition plane.
Diagram of twinned crystals of Albite. On the more perfect cleavage, which is parallel to the basal plane (P), is a system of fine striations, parallel to the second cleavage (M).

2) **Penetration twin:** When the twin appears as if the individuals are crossing each other.
   Eg. Staurolite, Pyrite, Fluorite etc.
3) **Repeated twin:**
   a) Polysynthetic or lamellar twin: In this the twin planes are parallel to each other.
      Eg. Plagioclase, Calcite etc.
   b) Symmetrical or Cyclic twin: Here the twin plane does not remain parallel but tends to produce circular forms.
   Eg. Spinel, Rutile etc.

3.6.2. IMPORTANT MINERALS & THEIR CHARACTERISTIC TWINS:

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1. Carlsbad twin, twin plane (010). Eg. Orthoclase & Plagioclase.
2. Baveno twin , twin plane (021). Eg. Orthoclase & Plagioclase.
3. Manebach twin, twin plane (001). Eg. Orthoclase & Plagioclase.
4. Swallo- tails, twin plane (100). Eg. Gypsum.
5. Pericline twin, composition plane (010) and b-axis is the twin axis. Eg. Plagioclase.
6. Albite-twin, twin plane (010). Eg. Plagioclase.
7. Cyclic twin, twin plane (110). Eg. Aragonite.
8. Skew twin, twin plane (hkl). Eg. Staurolite.

Colour,	Odor
Streak,	Feel
Lustre,	Fluorescence
Hardness,	Phosphorescence
Cleavage,	Magnetism
Fracture,	Crystal form
Form,	
Specific gravity.	

It is observed that each mineral has a set of outward signs or physical properties. Some of them are very characteristic and differentiate the mineral from each other. These properties can be determined either by inspection or simple tests. These properties are of great practical significance as they can be readily determined for the identification of minerals.

3.7.1. COLOUR

Minerals show a great variety of colours. The colour of a mineral is usually not a dependable or distinguishing character. It is produced due to reflection or transmission of light and its selective absorption within the body of a material or on its surface as the case may be.

The causes of colours in minerals are varied. In some it is a fundamental property, directly related to the chemical composition of the mineral. In some it is related to composition but depends on crystal structure. In others it is due to impurities. Minerals which exhibit constant and characteristic colour are known as idiochromatic.

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Those with variable colour are termed allochromatic. Metallic minerals generally exhibit consistency in colours than the non-metallic minerals. Some minerals show distinctive colours as follows;

a) White: Calcite, barite, Opal, Talc, Chalk etc'
b) Blue: Azurite, Sodalite & Apatite etc.
c) Green: Fluorite, Beryl, Malachite, Olivine, Serpentine etc.
d) Yellow: Sulphur, Chalcopyrite, Citrine, Siderite etc.
e) Red: Jasper, Orthoclase, Zircon etc.
f) Lead grey: Galena, Graphite etc.
g) Steel grey: Hematite
h) Brass yellow: Pyrite
i) Colourless: Halite, Quartz, Calcite etc.

pic

3.7.2. STREAK

The streak of a mineral is the colour of its powder. Generally it can be observed by scratching the mineral upon the surface of a white unglazed porcelain (Streak plate) plate or by scratching a mineral with a file. Streak is more reliable diagnostic property than the colour, as it is more constant. Streak of transparent and translucent minerals is white.

The streak of dark coloured minerals with non-metallic lustre is lighter than their colour, but minerals which exhibit metallic lustre have streak darker than their colour. Certain minerals exhibit a different colour in powdered form from the mineral in mass.

Minera	Color	Streak
Pyrite	Brass yellow	Dark green / greenish black
Hematite	Steel grey / iron Black	Cherry red
Limonite	Black	Yellowish - brown3
Chalcopyrite	Golden yellow	Greenish black

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Magnetite Iron black Black

3.7.3.

It is the appearance of a mineral surface in a reflected light. It varies with the composition and the reflecting capacity of the mineral surface. Fundamentally lustre is of two types. They are a). Metallic and b). Non-metallic

a) **Metallic lustre:** It is the brilliant appearance of a metal and is silvery or brassy. Eg. Gold, Galena, Graphite, Pyrites etc. When feebly displayed it is termed as sub-metallic. Eg. Chromite, cuprite.

pic

b) Non-metallic lustre: Minerals with non-metallic lustre are generally light coloured. Several varieties of non-metallic lustre are recognised. They are

i). Vitreous: It is the lustre of glass. Eg. Quartz, Halite etc.

ii). Adamantine: A mineral possessing the clear, brilliant lustre of a diamond. Eg. Diamond, Zirco and Rutile.

iii). Resinous: It is the lustre exhibited by resin. Eg. Serpentine, Opal etc.

iv). Pearly: When a mineral possess a lustre of a pearl. Eg. Talc, mica etc.

v). Silky: It is the lustre exhibited by silk fibres.

Eg. Asbestos, Gypsum etc.

vi). Greasy: It is the lustre like that of a grease. Eg. Nepheline

vii). Dull

or Earthy: Appearance of dry earth or minerals which have no lustre. Eg. Kaolin.

3.7.4. HARDNESS

It is the degree of resistance of a mineral offers to scratching or abrasion on it's surface. It is an important criterion for the recognition of minerals. Hardness must be determined only from the fresh surface of the mineral but not from an altered or weathered surface. Diamond is the hardest of all minerals as it can scratch all others. Talc is the softest as any other mineral can scratch upon it's surface.

MOH's SCALE: Practical purposes a generally adopted scale recognisesten degrees of hardness, this is known as Moh's Scale of hardness.

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1	**Talc**		Soft, greasy feel and easily scratched by the finger nail.
2	**Gypsum**		Just capable ofbeing scratched by the finger nail.
3	**Calcite**		Capable of being scratched by a pin or copper coin.
4	**Fluorite**		Not scratched by a pin but scratched by a steel knife blade, the mineral will not scratch glass.
	Apatite		The mineral is just scratches common glass and is scratched by a knife.
	Orthoclase		Barely marked by a well tempered steel knife,the mineral scratches common glass easily.
	Quartz		Harder than most ordinary common substances and represented in order of hardness by Quartz, Topaz, Corundum & Diamond
	Topaz		
	Corundum		
	Diamond		

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Any mineral of this scale can only scratch those lower in the scale. Any mineral will be scratched by the higher in the scale. Minerals of equal hardness may scratch each other.

3.7.5. CLEAVAGE

It is the tendency of a mineral to break or split along certain planes or directions of weakness giving more or less smooth surfaces. It is very useful diagnostic property. The splitting may takes place with varying degrees of ease and perfection. A mineral may or may not possess any cleavage. If present, it may occur in one or more directions. Only crystalline minerals are capable of possessing cleavage and amorphous substances are necessarily devoid of this characteristic.

5. Conchoidal: When the fractured surface has a no. of curvatures both concave & convex in a concentric form as in the case of a broken glass.   Eg. Quartz, Opal etc.

6. Earthy: When the broken surface is very smooth and soft, it is called Earthy. Eg. Chalk.

Pic

3.7.7. FORM & STRUCTURE

Form: The external geometrical shape is the reflection of the internal arrangements of the atoms. Such shape is also called as "Form".

Forms are of three types:

1. **Crystallised:** If a mineral develops well defined shape and occurs like a perfect crystal.   Eg. Quartz.
2. **Crystalline:** If a mineral does not bear a regular shape but indications of crystallization are visible by the presence of small crystals.
3. **Amorphous:** Amorphous crystals have no crystalline structure. Eg. Opal.

Structure: Many a times minerals exhibit a definite shape externally which is termed as "Structure". Structures are very characteristic in some minerals. The following are the important types of structures of minerals.

I) Acicular: When a mineral is made up of very sharp and slender needles. Ex. Natrolilte.

II) Capillary: If a mineral is hair like.   Ex. Millerite.

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III) Bladed: When aggregate of thin blade like parts are seen. Eg. Kyaninte.

VI) Reticulated: If groups of slender x'ls are in lattice shape. Eg. Rutile x'ls in some micas.

v) Radiated or divergent: When fibres or needles diverge from a central point. Eg. Celestites.

vi) Dendrite: It occurs plant or tree like. Eg. Manganese oxide.

vii) Drusy: When a surface is covered with a layer of mixture of x'ls. Eg. Quartz.

viii) Columnar: Occurs an aggregate of thin or stout parallel columns. Eg. Tourmaline

ix) Lamellar or tabular: When a mineral is made up of an aggregate of plates one over the other. The plates are seperable. Eg. Chlorite.

x) Fibrous: When a mineral is made up of fibres, which may be parallel or radiating.

Eg. Asbestos, Gypsum.

xi) Granular: If a mineral is composed of large number of grains of more or less same size. Eg. Chromite.

xii) Foliated: If a mineral is made up of leaves that can be easily seperated. Eg. Mica

xiii) Mamillary: The mineral is composed of large rounded masses. Eg. Chlorite.

xiv) Globular: When there are spherical or hemispherical over lapping projections in mineral. Eg. Hematite.
xv) Batryoidal: If a structure is an aggregate of spherical masses of the size peas.
Eg. Psilomalene.
xvi) Oolitic: When the aggregate is of small spheres (fish roe) Eg. Silicious Oolite.
xvii) Reniform: When the aggregate is in the shape of a kidney. Eg.Hematite.
xviii) Banded: If the mineral bears bands of various colour and differing texture. Eg. Banded hematite.
xix) Amygdaoidal: When a rock contains almond shaped nodules. Eg. Zeolites as in filings in cavities of Lavas.
xx) Stellate: When fibres are arranged in a radial fashion. Eg. Wavelite.
Wiry: As in a rope when the slender wires are twisted. Eg. Copper.

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3.7.8. SPECIFIC GRAVITY

The specific Gravity of a mineral is the ratio of the weight of the mineral to that of an equal volume of water at 4°C.

Weight of the mineral in air = $W_{1,}$

It's weight in water = W_2
Lost in weight of the mineral in water =Weight of an equal volume of water= W_1-W_2
Specific Gravity = $W_{1,}$/ W_1-W_2

The specific gravity of a mineral forms an important and distinguishing character only when the mineral is either too heavy or too light.

In case of minerals of moderate specific gravity, this character is not of much importance.

3.7.9. FEEL

Feel is the sensation upon touching or handling minerals. The different types of feel are: greasy, soapy, rough and harsh.

3.7.10. ODOR

Some minerals give a characteristic smell when rubbed, breathed upon, or heated. The chief types of odor are:

1. Arsenical: Like the odor of garlic. Eg. Orpiment
2. Sulphurous: Like the odor of burning sulphur. Eg. Pyrite
3. Argillaceous: Like the odor of clay.

3.7.11. FLUORESCENCE

Some minerals when exposed in sunlight or UV light, produce a colour, quite different from their own, and from that of the exiting light. Eg. Green colour Fluorite shows a blue or purple colour in sunlight. This property of minerals is called Fluorescence.

Some minerals glow and emit light when they are placed in UV light, or certain other electrical radiation. The glow induced in the mineral may continue for a few seconds or minutes after the removal of the cause. This property of mineral is called "Phosphorescence".

Eg. Diamond and Fluorite.

3.8. COMMON ROCKFORMING MINERALS:

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The minerals which chiefly occur in the rocks of the earth's crust are:

i. Feldspars
ii. Quartz
iii. Pyroxenes
iv. Amphiboles
v. Micas and
vi. Olivine

3.8.1. Feldspars: The Feldspars are the most abundant minerals. They constitute about 2/3rd of the igneous rocks. They are divided into two major divisions –

(i) Potash Feldspars. Eg. Orthoclase, microcline and
(ii) Soda-lime Feldspars. Eg. Plagioclase, albite & anorthite

pIC

- Atomic structure: Tectosilicates
- Chemical composition: They are alumino-silicates of Potassium, sodium, calcium and barium.

Physical properties:

1. Crystal form: Orthoclase is Monoclinic. Microcline & other plagioclases are Triclinic.

2. Colour: Orthoclase is Flesh-red. Microcline is green & Plagioclases ranges from white to grey

. 3. Lustre: Vitreous or Pearly.

4. Cleavage: Good (2 – sets).

5. Streak: White

7. Hardness: 6 (six)

6. Sp. Gravity: 2.5 to 3.0

i. Occurrence of K- Feldspars:

Potash feldspars are found in acid igneous rocks such as Granites, Pegmatites, Syenites etc, in sandstones and in gneisses. They occur associated with quartz and micas.

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ii. Occurrence of Soda- lime Feldspars

The soda-lime feldspars are called "Plagioclase". Plagioclase feldspars are found in the basic igneous rocks. They are found associated with Hornblende, Augite, or Olivine.

Both types of feldspars are also found in metamorphic rocks. In the course of weathering the feldspars are decomposed and "Sericite" (very fine grained micaceous material), "Kaolin", or "Bauxite" may be formed.

3.8.2. QUARTZ:

Quartz is a member of the silica group of minerals, which have tekto-silicate structure and the chemical composition is SiO_2.

Pic

There are three crystalline polymorphs of silica. White quartz is a low temperature polymorph formed below 870°C, Trydimite is formed between 870°C to 1470°C and Cristobalite is formed at a temperature above 1470°C.

The non-crystalline variety of silica occurs as (i) Lechatelierite (ii) Opal and (iii) Chalcedony.

Physical characters:

a) Form: White quartz is a member of the Hexagonal system, Tridymite belongs to Orthorhombic system and Cristobalite belongs to Isometric system. Opal is an amorphous variety of Quartz.

b) Colour: Generally colourless or white but some varieties may have light shades of colour due to presence of impurities.

Rock crystal:	Colourless, transparent
Amethyst:	Purple / Violet
Rose quartz:	Pink
Smoky quartz:	Dark grey
Jasper:	Brick red
Flint:	Grey

Plants and animals can cause mechanical weathering. The roots of plants sometimes loosen rock material. A plant growing in a crack can make the crack larger as the root spread out. This is known as root-pry. It is organic since this activity is caused by living things.

Chert: Waxy white

Citrine: Pale yellow

C) Streak: White

d) Fracture: Conchoidal

e) Lustre: Vitreous to Sub-vitreous

f) Hardness: 7 (Seven)

g) Cleavage: No cleavage

h) Sp. Gravity: Low (2.65)

Occurrence: It is present in silica rich igneous rock such as Granites, Pegmatites. It is the basic material of sandstone and is found in metamorphic rocks like gneisses, schists.

3.8.3. PYROXENES:

These rock forming silicates contain the Si_2O_6 single chain structure (Inosilicates). These are anhydrous silicates of Mg and Fe and thus are predominantly found in Ferro-magnesian rocks i.e., in basic and ultrabasic rocks. The important minerals in pyroxene group "Diopside" [$CaMg(SiO_3)_2$], "Hypersthene" [$(MgFe)(SiO_3)_2$] and "Augite" [Ca,Mg,Fe, Al] $AlSi_2O_6$.

h) Sp. Gravity: Low (2.65)

Occurrence: It is present in silica rich igneous rock such as Granites, Pegmatites. It is the basic material of sandstone and is found in metamorphic rocks like gneisses, schists.

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e) Cleavage: 2 sets

f) Sp. Gravity: Low to moderate

g) Twinning: Contact twinning in case of monoclinic members.

Pic

Occurrence:

Mostly found in basic rocks like Gabbro, Peridotite & Pyroxenite etc. Hypersthene is characteristic of norites and charnockites. Augite occurs commonly in basic igneous rocks like Basalts and Gabbros.

3.8.4. AMPHIBOLES:

These are hydrous ferro-magnesian silicate minerals and along with pyroxene constitutes about $1/5^{th}$ of all the known rocks. Atomic structure: Inosilicates characterised by double chain structure. Chemical composition: Hydrous silicates of Magnesium, Iron, Calcium, Aluminium as well as Alkali metals.

Physical properties:

1. Crystal form: Anthophyllite is Orthorhombic. Hornblende, Glaucophane are Monoclinic and Cossyrite is Triclinic.
2. Colour: Most of the members are greenish-black in colour.
3. Lustre: Vitreous

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4. Cleavage: Perfect (2 – sets).
5. Hardness: 5 – 66. Sp. Gravity: 2.5 to 3.5
7. Twinning: Contact twins

Occurrence: Mostly occur in metamorphic rocks, derived from basic or ultra-basic igneous rocks and also in igneous rocks.

3.8.5. MICAS

Micas constitute an important group of rock forming minerals. They form a link between feldspar and felspathoids. Atomic structure: Phyllosilicates which possess the Si_4O_{10} sheet structure. Chemical composition: These are hydrated alumino silicates of K, Na or Li, with Mg or Fe in darker members.

Classification of Micas:

Micas may be classified as 1. Muscovite group Eg. Muscovite – K-alumino silicate with (OH) and 2. Biotite group Eg. Biotite – K, Mg, Fe, Al silicate with (OH).

Physical properties:

1. Crystal form: Crystallise in Monoclinic system but the forms are pseudo-hexagonal.
2. Colour: Muscovite - Colourless, Biotite - Dark coloured.
3. Lustre: Pearly, Splendant
4. Cleavage: Perfect basal cleavage.
5. Hardness: 2 – 3.
6. Sp. Gravity: Low
7. Twinning: Rarely seen.
8. **Special characteristics**: They possess unique combination of properties of elasticity, toughness, flexibility, transparency, resistance to heat and property of splittings into thin films.

Occurrence:

Muscovite occurs in acid igneous rocks. Biotite occurs in all igneous rocks, particularly the acid and intermediate ones. In sedimentary rocks also they are present. In Schist's and gneisses micas are the usual constituents.

3.8.6. OLIVINE:

This is also a group of rock forming minerals. Atomic structure: Nesosilicates which essentially consists of series of isolated SiO_4 tetrahedra which are linked by means of

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metal cations. Chemical composition: This group includes minerals which may be represented by the formula R_2SiO_4, where R = Mg or Fe.

Important minerals of Olivine: 1. Forsterite - Mg_2SiO_4 & 2. Fayalite - Fe_2SiO_4

Physical properties:

1. Crystal form: Crystallises in Ortho- rhombic system.
2. Colour: Olive green or brown.
3. Lustre: Vitreous
4. Cleavage: Absent
5. Fracture: Conchoidal
6. Hardness: 6.5 to 7.0
7. Sp. Gravity: 3.2 - 4.3
8. Twinning: Rare.
9. Alterations: Olivine commonly alters to serpentine.

Occurrence:

It characterises the ultra-basic igneous rocks as dunites, peridotites, serpentines and basic rocks like Gabbro, dolerite, basalt etc. The common associates are chromite, spinel, pyrope etc. Olivine and quartz never occur together.

3.9 ESSENTIAL MINERALS

Minerals whose presence or absence decides the name (i.e. the position in a classification) of a rock are called Essential minerals. (or) Essential minerals are those which are dominant and also decided the name of the rock.

An essential mineral need not be present in large quantities, e.g. a trace of nepheline or a trace of quartz is sufficient to place a Syenite in the unsaturated or oversaturated class respectively.

- **In the same way, the presence or absence of plagioclase feldspar will determine whether the rock is called a Pecrite or a peridotite.**

Accessory minerals

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Minerals present in a rock in such small amounts that their presence or absence is not significant when considering the mineral composition for classification purposes are called Accessory minerals.

Ex: Potash feldspar is an essential mineral & biotite is an accessory in granite.

3.9.1. MICA GROUP OF MINERALS

- Atomic structure: Phyllosilicates which possess the Si4O10 sheet structure.

pic

- Chemical composition: These are hydrated alumino silicates of K, Na or Li, with Mg or Fe in darker members.

Classification of Micas

Micas may be classified as

1. Muscovite group Eg. Muscovite –
   [KAl2 (AlSi3O10) (OH)2]

2. Biotite group Eg. Biotite –
   [K (MgFe) $(AlSi_3O_{10})$ $(OH)_2$]

Muscovite –

Physical properties

1. Crystal form:

Crystallises in Monoclinic system but the forms are pseudo-hexagonal.

5. Hardness: 2.0 - 2.5

6. Sp. Gravity: 2.7 – 2.9

7. Fracture: Even - the fracture surfaces are mostly even and flat.

8. Special characteristics: They possess unique combination of properties of elasticity, toughness, flexibility, transparency, resistance to heat and property of splittings into thin films.

Occurrence

- Muscovite occurs in acid igneous rocks like Granite and Pegmatites and also in metamorphic rocks like Schists.

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- ❖ Many sedimentary rocks also contain Muscovite.

Distribution

- ❖ Muscovite occurs in India in Bihar, Rajasthan, Andhra Pradesh in Pegmatitic rocks.
- ❖ In AP it occurs in Guduru, Anantamadugu, Sidapuram, Nagaram, Kalichedu, Tatipatri etc. places of Nellore district.

USES

- ❖ Muscovite is the most useful mica.
- ❖ Muscovite chiefly used as insulating material in electrical, electronic instruments.
- ❖ It is also used in the manufacture of paper, roofing material, lubricants & rubber tyres.

Biotite Physical properties

1. Crystal form: Crystallises in Monoclinic system but the forms are pseudo-hexagonal.
2. Colour: Deep brown - Black
3. 3. Lustre: Vitreous - Pearly
4. 4. Cleavage: Perfect cleavage.
5. 5. Hardness: 2.5 - 3.0
6. 6. Sp. Gravity: 2.8 – 3.0
7. 7. Fracture: No
8. 8. Special characteristics: They possess unique combination of properties of elasticity, toughness, flexibility, transparency, resistance to head and property of splittings into thin films.

   Occurrence.

   ❖ It is a constituent of most igneous rocks (such as granite) and many metamorphic rocks (such as schist and gneiss).

- ❖ It is seldom found in sedimentary rocks.

Distribution

- ❖ Muscovite occurs in India in Bihar, Rajasthan, Andhra Pradesh in Pegmatitic rocks.

❖ In AP it occurs in Guduru, Anantamadugu, Sidapuram, Nagaram, Kalichedu, Tatipatri etc. places of Nellore district.

USES

❖Biotite is used in light weight concrete.

❖Biotite particles are sometimes used as a surface treatment in decorative concrete, plaster and other construction materials.

❖ It is also used in the potassium-argon method of dating igneous rocks.

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3.9.2. Asbestos

- ❖ Asbestos is a set of six naturally occurring silicate minerals used commercially for their desirable physical properties. They all have in common their asbestiform habit: long, thin fibrous crystals.
- ❖ Mineralogically it is divided into two divisions.
- ❖ They are Chrysotile Asbestos E.g. Fibrous serpentine & Amphibole Asbestos E.g. Trimolite, Actinolite, Anthophyllite etc.
- ❖ Out of these two, Chrosotile Asbestos is very important and useful.

Composition of Serpentine

- ❖ The fibrous variety of serpentine is often called Chrysotyle Asbestos. Serpentine is a hydrous magnesium silicate with its chemical formula as [Mg6 (Si4O10) (OH)8]

Serpentine

Physical properties

1. Crystal form: Crystallises in Monoclinic system
2. Colour: Green (Various shades of green)
3. Lustre: Greasy or waxy
4. Cleavage: No
5. Hardness: 2.0 - 5.0 (Generally 4)
6. Sp. Gravity: 2.2
7. Fracture: Splintery
8. Special characteristics: Its fibres are fine, silky and very strong. 22000 m. of thread can be span from one kg of serpentine. It can withstand a temperature of 5000°F or 2760°C

Occurrence

- ❖ It is found in both igneous and metamorphic rocks and may make up the entire rock mass.
- ❖ Serpentine minerals commonly occur as alterations of magnesium silicates, especially olivine, pyroxene, and amphibole. Associated with magnesite, chromite, and magnetite.

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- It is usually found in the shape of large rock masses, known as Serpentine rocks.

Distribution

- The best quality Chrysotile asbestos is found in Andhra Pradesh.
- The most important occurrences are in the districts of Kurnool and Kadapa and the less important ones in Anantpur district.
- In the Pulivendla taluk of Kadapa district, between Brahmanapalle and Lopalanutola, asbestos was formed in Vempalli limestones and shales by a dolerite body.

  The asbestos is cross fibred Chrysotile variety with an average thickness of 0.9m. Numerous veins of Chrysotile asbestos also occur in Rajupalam area of Cuddapah district.
- In Kurnool district asbestos occurs in Dhone taluk in Vempalli limestones associated with trap rocks.
- The present level of production in A.P. is around 2000 tonnes per annum.

USES

Serpentine uses include: Mainly used in asbestos, and also in thermal conductivity, as industrial mineral & ornamental stone.

3.9.3.Talc

- Talc is a metamorphic mineral resulting from the metamorphism of magnesian minerals such as serpentine, pyroxene, amphibole, olivine, in the presence of carbon dioxide and water.
- Talc is a hydrous magnesium silicate, much like that of Serpentine.
- Composition: $[Mg_3(Si_4O_{10})(OH)_2]$

Physical properties

Lustre: Wax like or Pearly

Cleavage: Excellent basal cleavage

5. Streak: White to pearly green

6. Hardness: 1.0

7. Sp. Gravity: 2.8

8. Fracture: uneven

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9. Special characteristics: It is the softest known mineral and listed as *1* on the Mohs hardness scale. It can be easily scratched by a finger nail. It has a distinctly greasy feel.

The massive variety often called Soap stone / Steatite.

Occurrence

Talc is a common metamorphic mineral in metamorphic belts which contain ultramafic rocks, such as soapstone (a high-talc rock), and within white schist and blue schist.

Distribution

❖ Best grade Steatite/Talc/Soap stone occurs at various places in Kurnool, Ananthapur, Kadapa and low grade occurs in Chittoor and Khammam Districts.

USES

❖ Talc is used as an ingredient in ceramics, paper, paint, roofing, plastics, cosmetics, talcum and baby powders, pharmaceuticals, cosmetics and a variety of other assorted uses such as making rubber and plastics.

❖ Talc is also used as food additive.

3.10. Economic minerals

❖ **These are important and very useful to the society (or) Minerals which are of economic value are called economic minerals.**

❖ **Ex: Hematite, bauxite, galena etc.**

❖ **The economic mineral has chemical composition and certain physical properties.**

❖ The utility value of the economic mineral matter depends upon the physical properties rather than the chemical composition.

❖ **Eg. Both Diamond & Graphite constitute Carbon chemically, differ in their physical properties, making diamond most precious gem and graphite as heat and chemical resistance substance.**

❖ **Economic minerals are broadly classified into metals & non-metals.**

❖ **Gold, Copper, Iron, Nickel etc fall under metallic group, where as**

❖ **Coal, Clay, Petroleum, Gem stones etc fall under nonmetallic group.**

❖ **About 2000 mineral species are known. Out of which 50 are rock forming minerals and 200 are regarded as economic minerals.**

Ore minerals

❖ An ore mineral is defined as a substance from which one or two metals can be extracted.

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- **A single metal can be extracted from different ore minerals. Chalcopyrite, Bornite, Chalcocite, Cuprite are all ore minerals from which Copper alone can be extracted. Therefore Chalcopyrite, Chalcocite, Cuprite and bornite are ore minerals of Copper.**
- **Some ore minerals occur as Native metals Ex. Gold & Platinum.**
- **But many ore minerals are found in combination with elements like Silicon, Oxygen and Sulphur etc.**
- **Sometimes a single ore mineral provide more than one metal.**

  Eg. Stannite ore mineral on extraction yields Copper & Tin.

Gangue minerals

- **Sometimes ore minerals occur in association with other minerals of uneconomic importance. Minerals of uneconomic importance associated with ore minerals in an ore deposit are called Gangue minerals.**
- **In short, gangue minerals are waste products, non economical materials found in ore deposits.**
- Ore
- Ore is a mixture of ore mineral and gangue mineral and from which one or two metals can be extracted profitably.

- **Normally the proportion of ore minerals and gangue minerals varies and always gangue minerals will be more in proportions than the ore minerals**
- **The ore will be more profitable when the part of the gangue mineral is less.**
- Ore
- **The metal content of an ore is called the Tenor. Tenor is always expressed in terms of percentage for metals like Copper, Iron, Manganese, Lead etc, for precious metals like Gold and Platinum it is always expressed in ounces per ton.**
- **Higher the tenor better the ore will be.**
- Economic minerals
- **Andhra Pradesh is a Mineral rich State ranking 2nd in the Country containing a vast and variety of Mineral Wealth particularly Industrial Minerals. Andhra Pradesh engaged in mining of 42 Industrial Minerals to name a few Limestone, Mica, Barytes, Bauxite, Beach Sands, Steatite, Quartz, Feldspar, Manganese, Dolomite, Iron ore etc.**
- Economic minerals

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- **The state accounts for considerable reserves of important minerals, viz,**
- **Barytes (97%),**
- **Dolomite, Asbestos (96%),**
- **Calcite (75%),**
- **Fire clay, Ball clay (55)%, **
- **Limestone (44%),**
- **Vermiculite (27%),**
- **Garnet (23%),**
- **Fuller's Earth (6%),**
- **Feldspar (5%).**

3.10.1.IRON

- **Iron, Manganese and Chromium are the important ferrous and ferroalloy minerals.**
- **Iron is the back bone of the modern industry.**
- Iron is most widely distributed and abundant metal in rocks of the earth crust.

Process of formation

- **The ores of iron are formed with magmatic segregation,by contact metamorphism,by sedimentary process, by residual concentration processes.**
- **Some ores the products of two or more processes.**

IRON

The chief ores of iron, their composition and tenor % are as follows.

Ore	Composition	Tenor %
Magnetite	Fe_3O_4	72.4
Haematite	Fe_2O_3	70.0
Limonite	$2Fe_2O_3.3H_2O$	60.0
Siderite	$FeCO_3$	48.2
Pyrite	FeS_2	46.2

IRON

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- **Iron ore occurs in Kurnool, Ananthapur, Chittoor, Khammam, Warangal, Karimnagar, Adilabad and Prakasham districts. The total estimated reserves are around 265 Million Tonnes of various grades of Iron ore.**
- **High grade Hematite Iron ore from Ananthapur and Kurnool is being exploited and catering the needs of Sponge & Pig Iron Plants in the State.**
- **The low grade Magnetite Iron ore deposits with 22 to 35% Fe are found over a length of 52 KM near the Port in Ongole- Prakasam district.**

IMPORTANT ORES:

1. Magnetite:

It's chemical composition is Fe_3O_4 . Iron black in colour, cherry red colour streak, metallic lustre, hexagonal crystal system, sub-conchoidal fracture, hardness 5.5-6.5, High specific gravity. Useful in the manufacture of steelzzzs and in the heavy media coal washers. Some magnetite varieties are using as natural magnets.

2. Hematite:

It's chemical composition is Fe_2O_3 . Steel grey or Iron black in colour, cherry red colour streak, metallic lustre, hexagonal crystal system, sub-conchoidal fracture, hardness 5.5-6.5, High specific gravity. Useful in the manufacture of metallic iron and steel and soft variety is used in the paint industry.

3. Pyrite:

It's chemical composition is FeS_2. Bronze yellow in colour, greenish black streak, metallic lustre, Cubic crystal system, conchoidal or uneven fracture,hardness 6.0 -6.5. It is useful in the manufacture of H_2SO_4.

3.10.2. MANGANESE

- **It is one of the most important ferro alloy metals. Manganese is alloyed with iron to produce special steels with specific properties. It is also essential for making all carbon steels.**
- **Manganese ore of high purity is used in glass industry, paints, pigments, dyes and in fertilizer industries.**

Process of formation

- **Manganese deposits are formed either by hydrothermal solution or by the process of sedimentation or residual concentration processes.**

MANGANESE

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The chief ores of Manganese, their composition and tenor % are as follows.

Ore	Composition	Tenor %
Hausmanite	Mn_3O_4	72.4
Braunite	Mn_2O_3	64.3
Manganite	MnO(OH)	62.5
Pyrolusite	MnO_2	63.0
Psilomalene	MnO_3 $2H_2O$	
Dialogite	$MnCO_2$	47.8
Rhodonite	$MnSiO_3$	41.86

MANGANESE

- **India is one of the largest producers of manganese in the world.**
- **Rich manganese deposits are present in Srikakulam district of Andhra Pradesh.**
- **There are number of deposits in Viziayanagaram, Adilabad and Prakasham Districts.**
- The estimated reserves are about 7.5 Million Tonnes of low grade manganese with 30 to 40% Mn in the state.

IMPORTANT ORE:

1. Psilomalene:

It's chemical composition is MnO3 2H2O. Dark steel grey in colour, brownish black streak, sub-metallic lustre, Monoclinic crystal system, hardness 5 - 6, specific gravity is medium to high.

- It is one of the chief ores of Manganese. High grade varieties are used in the manufacture of batteries. It is the chief raw material for the preparation of chemicals like KMnO4.
- The Manganese ore can be used for the manufacture of Electrolytic Manganese Dioxide, Manganese Chloride.

3.10.3. GOLD

- **Gold is one of the precious metals like platinum and silver. Gold occurs in nature as native gold with a purity of nearly 99.8%, when it is pure.**
- **It is more soft, ductile, malleable. The specific gravity is 19.3.**
- **Gold is known to man since antiquity.**
- **Mostly used in the preparation of ornaments. Its purity is expressed in terms of carats. One carat means 1 part of gold in 24 parts.**

Process of formation

Plants and animals can cause mechanical weathering. The roots of plants sometimes loosen rock material. A plant growing in a crack can make the crack larger as the root spread out. This is known as root-pry. It is organic since this activity is caused by living things.

■ **Gold deposits are formed by various processes such as Magmatic concentration, contact metamorphism, replacement and cavity fillings types by hydrothermal solutions.**

GOLD

■ **The chief ores of Gold, their composition and tenor % are as follows.**

Ore	Composition	Tenor %
Native gold	Au	99.8
Elements with other metallic elements	Gold amalgum (Au, Ag, Mg) GOLD	40.0

- **Gold occurs in India both as native gold associated with quartz-veins or reefs. It occurs in alluvial sands of large no. of rivers.**
- **The main source of gold in India is in Quartz reefs traversing Dharwar rocks in Kolar district of Karnataka. Next to Kolar, we get gold in Hutti area of Raichur district of Karnataka.**
- It also occur at Ramagiri in Anantapur district of AP in Dharwarian age Chloride schist.
- High grade varieties are used in the manufacture of batteries. It is the chief raw material for the preparation of chemicals like $KMnO_4$.
- **The Manganese ore can be used for the manufacture of Electrolytic Manganese Dioxide, Manganese Chloride.**

COPPER

- **Copper is one of the most important non-ferrous metals. Copper is widely distributed and abundant element in combination and also in native state.**
- **It is comparatively soft, but it is tough, malleable and ductile with specific gravity of 8.9.**
- **Copper is used extensively for the manufacture of alloys such as Bronze, Gun metal, Bell metal.**

Process of formation

- **Copper salts are used in various industries such as disinfectant, in printing and dying of textiles, for preserving timber as fungicide.**
- **These deposits are formed by Magmatic concentration, by contact metasomatic process, by hydrothermal solution filling the cavities or by hydrothermal solutions replacing minerals of rocks through which it is passing. Supergene sulphide enrichment process has also yielded valuable deposits.**

COPPER

■ The chief ores of COPPER, their composition and tenor % are as follows.

Plants and animals can cause mechanical weathering. The roots of plants sometimes loosen rock material. A plant growing in a crack can make the crack larger as the root spread out. This is known as root-pry. It is organic since this activity is caused by living things.

Ore	Composition	Tenor %
Native copper	Cu	
Cuprite	Cu_2O	88.8
Chalcopyrite	$CuFeS_2$	84.5
Chalcocite	Cu_2S	79.8
Covellite	CuS	66.4
Malachite	$CuCO_3\ Cu(OH)_2$	57.3
Azurite	$2CuCO_3\ Cu(OH)_2$	55.1

COPPER

Copper deposits are found in Nellore and Krishna districts of AP. Agnigundala of Guntur district in AP, Mylaram of Khammam district have yielded good deposits of copper.

IMPORTANT ORE:

1. Chalcopyrite: **It's chemical composition is $CuFeS_2$, brass yellow in colour, greenish black streak, Hexagonal crystal system, Uneven fracture, hardness 3.5 - 4, occurs mainly in hydrothermal deposits.**
2. **Malachite:** It's chemical composition is CuCO3Cu(OH)2, bright green in colour, light green streak, Monoclinic crystal system, silky lustre, cleavage present, hardness 3.5 - 4, occurs in the zone of weathering of oxidation.
3. **Azurite:** It's chemical composition is 2CuCO3Cu(OH)2, deep azure blue in colour, blue streak, Monoclinic crystal system, vitreous lustre, conchoidal fracture, hardness 3.5 – 3.8; occurs on the surface of copper deposits in the zones of oxidation and weathering.

3.10.5 ALUMINIUM

Plants and animals can cause mechanical weathering. The roots of plants sometimes loosen rock material. A plant growing in a crack can make the crack larger as the root spread out. This is known as root-pry. It is organic since this activity is caused by living things.

- **Aluminium is not found in a free state but found in combination.**
- **It constitutes nearly 8% of the earth's crust.**
- **Most abundant of all metals.**
- **Chief industrial sources of Aluminium is Bauxite.**
- **The chief ore of Aluminium is Bauxite. Its chemical composition is Al_2O_3 $2H_2O$.**

Ore	Composition	Tenor %
Native copper	Cu	
Cuprite	Cu_2O	88.8
Chalcopyrite	$CuFeS_2$	84.5
Chalcocite	Cu_2S	79.8
Covellite	CuS	66.4
Malachite	$CuCO_3$ $Cu(OH)_2$	57.3
Azurite	$2CuCO_3$ $Cu(OH)_2$	55.1

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3.10.5 ALUMINIUM

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- **Chief industrial sources of Aluminium is Bauxite.**
- The chief ore of Aluminium is Bauxite. Its chemical composition is Al_2O_3 $2H_2O$.

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- **It was caught up in swamps, preserved by burrial and subsequently altered due to heat, pressure and complicated chemical and biochemical processes.**
- **It is found in the form of beds sandwiched between layers of sediments deposited from time to time.**
- **The process of conversion of plant material intocarbonaceous matter is called coalification.**

Character and rank Coal

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- **The character of coal naturally depends upon the original plant, degree of its decay, besides heat, pressure and degree of alteration.**
- **The process may be complete or may be arrested at any one stage, thus giving rise to coal of varying ranks.**
- **Coal is ranked as peat, lignite, sub-bituminous coal, bituminous coal, anthracite in the order of progressive maturity.**
- **Depth of burial plays a significant part in getting different ranks in coal.**
- **The percentage of carbon, hydrogen, volatiles and moisture content determine the rank of coal.**

Peat**: Represents the first stage of formation. It contains**

about 90% moisture and 10% of combustible matter. It has

low heating value. Easily we can recognise the plant remains

in it.

Lignite**: It is low rank coal, it gives brown streak with fair**

percentage of combustible matter.

Bituminous coal: **It is medium to high rank coal, usually black**

containing 90% of combustible matter.

Anthracite: **Hgh rank coal, hard, sense with glassy lustre**

and conchoidal fracture. Burns without smoke containing

highest percentage of combustive matter of these different types of coal, bituminous coal and anthracite are of special interest. They are the main source of a special type of coaking or metallurgical coal suitable for use in the steel industry.

Age of Coal:

Workable coal beds throughout the world are all of post Devonian period in general and Carboniferous period in particular. Good variety of coal is from Carboniferous period. Lignite deposits are from tertiary period.

Distribution of Coal in India

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In India workable coal occurs only in two horizons of geological time scle

(1) Lower Gondwana Period (180 M.Y. old)

(2) Tertiary Period (60 M.Y. old)

The coal bed in Gondwana period is principally confined to About 98% of Indias coal is from Lower Gondwanas. These coal fields occur in the states of West Bengal, Bihar, MP, Orissa, AP & Maharastra.

The most important group from the point of reserves, quality and development is the coal fields of Damuda series in West Bengal and Bihar.

Important coal mining centres are Ranigunj, Jharia, Giridih, Bokaro, Ramgarh and Karanpura. Of these again Ranigunj and Jharia coal fields produce best coal and are responsible for 80% of country's total output of best coal.

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(2) Tertiary coal seams occur in widely separated regions. Assam in the East; Jammu & Kashmir in the North, Rajasthan in the West and Tamilnadu in South. The tertiary coal seams in general are of Lignites.

3.10.7. PETROLEUM

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- **Petroleum is the natural fuel preferred to any other fuel. It means rock oil.**
- **Modern industry, warfare, transportation depends now-a- days mostly on petroleum.**
- **Primarily petroleum oil and petroleum gas is used to produce energy for power or heat and for lubricants.**
- **Petroleum is composed of many hydrocarbons i.e., compounds of carbon and hydrogen with minor oxygen, nitrogen and sulphur.**
- **Geologic and Geographic distribution of petroleum:**
- **Petroleum occurs in sedimentary rocks, very rarely it moves into adjacent rocks of igneous and metamorphic rock types.**
- **The most common rock types of petroleum bearing are sands; sand stone, conglomerate, porous lime stones, dolomites etc.**

Geologic and Geographic distribution of petroleum:

- **Geological age ranges from Cambrian to Pliocene.**
- **Of all rocks, rocks belonging to sedimentary group of tertiary age are prolific petroleum yielding rocks.**

Formation of oil pool

- **Organic material buried in marine sediments underwent changes to produce natural hydrocarbons, such hydrocarbons subsequently moved into porous sedimentary rocks known as reservoir rocks and got accumulated to form commercial oil pools.**
- **Oil pools are accumulation of oil in large quantities in porous sedimentary rocks.**

For the formation of oil pool certain conditions are necessary.

They are Migration and accumulation

Suitable reservoir rocks

Suitable traps

Retention

Formation of oil pool

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1. **Migration and accumulation of drops of oil formed in the source mud by the bacterial action slowly gets migrated into the adjacent sands. The forces viz., compaction of muds, capillary action, gravity, currents and buoyancy etc help in migration of oil drop.**
2. **Accumulation take place only in porous and permeable rocks. A rock like clay has high porosity but low permeability and hence it is not a reservoir rock but only a cap rock. The most suitable reservoir rocks are loose, unconsolidated sands and porous sand stones.**
3. **There are two types of traps which hold the oil from getting away from the place of accumulation. They are**

i. Structural traps

ii. Stratigraphic traps

i. Structural traps: **Some of the most important structural traps are Anticline, Dome, monocline, faults, fissures and salt domes.**

ii. Stratigraphic traps: **Unconformities, sand stones lenses, buried coral reefs; over laps etc.**

Important oil bearing rocks in India

- **In India important oil occurring places are in ASSAM, PUNJAB, GUJARAT & AP.**
- **The petroleum bearing rocks are confined to narrow belt of tertiary strata.**
- **There are only three areas where petroleum been found on a commercial scale. They are**
- **Punjab Sind Gujarat Gulf (Cutch Cambay area)**
- **Assam Gulf (Digboi, Naharkatia)**
- **Bombay High: In Miocene rocks having Anticlinal structure has proved to be of great commercial importance.**
- **Apart from these prominent areas ONGC has carried out exploration work in Godavari, Krishna & Cauvery basins.**
- **Oil & Natural Gas occurs in an area of 20,000 Sq.KM on-shore and 21,000 Sq.KM off-shore in East and West Godavari and Krishna Districts. The present availability of Gas from Krishna, Godavari Basins is of the order of 3 to 4 Million Cu. Mt / day.**

3.10.8. RADIO – ACTIVE MINERALS

- Radio active minerals usually decay and emit alpha, beta and gamma rays.
- The decay of radio active minerals results in its transformation into another element.
- The radio active isotope of radium is the most useful radio, isotype used for therapeutical purpose.
- It is also used as a tracer in bio-chemical reactions and in the study of hydrology.

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- Uranium and plutonium are the sources of energy.

SOME RADIO – ACTIVE MINERALS

Pitch blend – UO_2 and UO_3

Uraninite – UO_2

Monozite – (Ce, Y, La, Th) PO_4.

FORMATION PROCESSES

Radio active minerals mainly the uranium and thorium minerals are deposited under three categories Pegmatitic, Hydrothermal, secondary.

DISTRIBUTION IN INDIA

1. Uranium with thorium bearing minerals were first reported in a mica – Pegmatitic rock of Gaya district, Bihar.
2. Uranium bearing rocks are scattered all over the peninsular India and in the extra peninsular India.
3. The important locations are Singhbhum mineral belt.
4. Bihar mica belt of Hazaribagh, Rajasthan mica belt of Bhilwara and Bunas, Nellore mica belt of Andhra Pradesh.
5. Also occurs in beach sands of Kerala, Tamilnadu, A. P., and Orissa.

4.1. Introduction: The earth is made up with different types of rocks. The study of these rocks as well as rocks on the moon is known as Petrology.

Rocks are aggregates of minerals. They are made up of different assemblages of minerals. They form a major part of the earth's crust. Out of 2000 known minerals, about 50 are rock forming minerals and of these again only some 30 are common in rocks.

4.2. MAJOR TYPES OF ROCKS:

a) **Based on the formation**, rocks are divided into three basic types. They are 1. Igneous rocks, 2. Sedimentary rocks and 3. Metamorphic rocks.

b) **On the basis of their origin**, all rocks are grouped into primary rocks & secondary rocks. Primary rocks are first formed on the surface of the earth. Eg. Igneous.

Secondary rocks formed from pre-existing rocks. Eg. Metamorphic & Sedimentary.

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4.2.1. Rock Cycle: All rocks are connected in a cycle of creation, change, and destruction called the Rock cycle. This cycle of changes leading to the formation of the three groups of rocks from each other is referred to as the "Rock cycle".

The rock cycle begins with molten rock (Magma below ground, lava above ground) which cools and hardens to form igneous rock. Exposure to weathering and erosional forces, break the original rock into smaller pieces. The smaller material (now called sediment) is carried away by rivers, wind, glaciers, and other means and is eventually deposited elsewhere.

These sediments can then be buried and lithified (hardened), forming sedimentary rock. Sedimentary rock can be deeply buried, subjected to heat and pressure, which over time, cause it to change its structure into a new rock, a metamorphic rock. Eventually these metamorphic rocks may be heated to the point where they again melt into magma.

Sometimes igneous rocks can be buried and metamorphosed, skipping the sedimentary rock phase. Sometimes sedimentary and metamorphic rocks can be uplifted and eroded to form new sedimentary rocks. It is also possible for rocks to remain unchanged in stable regions for long periods of time.

4.3.1. IGNEOUS ROCKS:

These are the rocks formed by solidification of magma and lava. Igneous rocks constitute about 95% of the crustal rocks. They show great variations in their chemical composition, mineralogical and textural characters. So, in order to know these differences and to name each rock, classification is necessary.

There are three basic concepts for classification. They are based on Chemical composition, Mineralogical assemblage and Geological occurrence & texture.

4.3.1.1. Based on Chemical composition igneous rocks are divided as following:

Acidic (or) Silicic: In which silica is more than 66%.

Intermediate: In which silica ranges between 52% to 66%.

Basic: In which silica ranges between 45% to 52%.

Ultra basic: In which silica less than 45%.

4.3.1.1.1. Based on Chemical composition & Saturation principle igneous rocks are divided as following:

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Oversaturated: Containing saturated minerals and free silica of magmatic origin.

Saturated: Containing only saturated minerals.

Unsaturated: Containing unsaturated minerals.

4.3.1.1.2. Chemical composition (Standard minerals) or CIPW classification:

This is based on the set of standard minerals called the NORM. The NORM is divided into two groups the Salic and the Femic.

Salic	Femic
Quartz	Diopside
Orthoclase	Hypersthene
Albite	Olivine
Anorthite	Acmite
Leucite	Magnetite
Nepheline	Ilmenite
Corundum	Hematite
Zircon	Apatite

4.3.1.2. Based on Mineralogical assemblage and Geological occurrence & texture.

Igneous rocks are classified into two main categories: **Intrusive and Extrusive.**

Intrusive (inside) igneous rocks: These are formed from magma that cools and solidifies deep beneath the Earth's surface. The insulating effect of the surrounding rock allows the magma to solidify very slowly. Intrusive rocks have large crystals that can be seen with the naked eye. A common example of an intrusive igneous rock is Granite.

Extrusive (exit) igneous rocks: These are formed from lava that cools and solidifies at or near the Earth's surface. Lava, at the surface, is exposed to air and water, which causes the molten rock to cool rapidly. Molecules in lava do not have

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time to arrange themselves to form large crystals. Extrusive rocks have crystals that are too small or fine-grained. A common example of an extrusive igneous rock is Basalt.

Sometimes extrusive rocks, cool so rapidly that they completely lack crystal structure and are considered a volcanic glass. Eg. Obsidian & Pumice.

4.3.1.3.Based on Geological occurrence & Texture:

On the basis of the depth at which the igneous rocks form, the igneous rocks have been grouped into Volcanic rocks, Hypabyssal rocks and Plutonic rocks.

Volcanic rocks: Volcanic rocks are formed when the magma erupts at the earth's surface and cools rapidly. The volatiles present in the magma escape into the atmosphere. Volcanic rocks often contain gas cavities called Vesicles. These rocks sometimes show flow structure. It is seen as lines or streaks of different colour in a rock. The texture of rocks are fine grained or glassy.

Eg. Rhyolite, Obsidian, Trachyte, Andesite, Basalt.

Hypabyssal rocks: Hypabyssal rocks are formed when consolidation of magma takes place very close to the earth's surface. Examples of such igneous bodies are dykes and sills. Hypabyssal rocks may be fine grained or even partly glassy.

Eg. Pegmatite, Dolerite.

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Pic

4.3.2. Common Igneous Rocks:

Some common examples of Igneous rocks are **Granite**, Syenite, Gabbro, Rhyolite, Trachyte, Dolerite, Basalt etc.

GRANITE:

Granites are coarse grained, light coloured igneous rocks of plutonic origin. Their colours are grey, pink, black or red. They are acidic in nature.

It is composed of quartz, alkali feldspars (orthoclase and microcline) and small amount of biotite or hornblende or both. The average granite contains 60% feldspars, 30% quartz and 10% ferromagnesian minerals.

These occur extensively in the Batholiths of eroded fold mountain ranges and in continental shield regions of the earth's crust. These are the most abundant of all the plutonic rocks.

The varieties of granites are named according to the major mineral present, as Muscovite granite, Hornblende granite etc. Some granites are named according to the typical texture they show, as graphic granite etc.

Granites are formed due to the crystallization of magma. In Andhra Pradesh these rocks are found mainly around Hyderabad and in Khammam, Guntur, Nellore and Prakasam districts.

Uses: Granites are extensively used as building stones for structural as well as decorative, monumental and architectural purposes.

SYENITE:

It is a coarse grained, intermediate, plutonic igneous rock. Mainly composed of orthoclase, soda-plagioclase and one or more mafic minerals such as biotite and

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hornblende. It contains 80 to 85% feldspars. It has little or no quartz. Syenites are generally light in colour.

These rocks occur relatively small intrusive like small stocks, volcanic rocks or plugs, sills and dykes. Nepheline syenite is found near Paloncha in Khammam district.

Uses: Because of the rarity of the Syenite, it is of little commercial use as structural material.

DIORITE:

Diorites are light coloured, coarse grained igneous rocks with plutonic origin. Mineralogically they are intermediate rocks. Silica content may vary between 52 – 66%. Mainly composed of plagioclase feldspar and hornblende. However, in some varieties augite and biotite may occur. Most diorites contain little or no quartz.

Uses: Used for crushed stone and for monumental and decorative purposes.

pic

BASALT:

Basalts are the most important volcanic rocks. They are dark coloured such as grey or black fine grained rock to glassy rocks. They are basic to ultra basic in nature. Calcic plagioclase feldspars and ferro-magnesian minerals are essential constituents of Basalts. Quartz may sometimes present in smaller amounts. It makes up most of the ocean floors. Deccan lavas are typical example for Basalts.

Uses: Basalts are very tough stones, used as road metals and as crushed stones.

4.3.2. SEDIMENTARY ROCKS:

These rocks have been derived from the pre-existing rocks. Sedimentary rocks are formed by the deposition and consolidation of "new sediments", in layers, over the pre-existing rocks. The "new sediments" are, in fact, eroded away from old rocks by weathering, and are then transported by agents like wind, water, ice etc. These eroded sediments, after travelling some distance, may get deposited, which on consolidation, will result in the formation of "Sedimentary rocks".

The unconsolidated or semi-consolidated sediments are called "Regoliths". These rocks are also called as Stratified rocks or secondary rocks.

Sedimentary rocks are generally found to occur at or near the surface of the earth. In fact, they are covering as high the Earth's surface area as 75% or so. But,

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the total volume or quantities of these rocks are only about 5% of the volume of the Earth's crust.

4.3.2.1. Classification of Sedimentary Rocks:

i. Based on the way of transportation of sediments:

Based on the way of transportation of sediments the sedimentary rocks are classified as Marine, Lacustrine, Glacial, Eolian and Fluvial rocks.

ii. Based on mode of origin:

Based on the mode of origin the sedimentary rocks are classified as a) clastic, b) organic and c) chemical sedimentary rocks.

a) Clastic Sedimentary Rocks: These are mechanically formed rocks, derived from fragments or individual minerals of other rocks. These are of three types.

i) **Rudaceous rocks:** Bouldery deposits. Eg. Conglomerate

ii) **Arenaceous rocks**: Sandy rocks Eg. Sandstone

iii) **Argillaceous rocks**: Clayey rocks Eg. Shale

b) Organic: Consisting of accumulated animal or plants remains. These are of two types.

i) **Calcareous rocks:** Limestone rocks

ii) **Carbonaceous rocks:** Coal seams

c) Chemical: These are formed due to precipitation and accumulation of soluble constituents. These are of three types.

i) **Carbonate rocks:** Limestones & Dolomite

ii) **Sulphate rocks**: Gypsum

iii) **Chloride rocks:** Rock salt

4.3.2.2. Some Common Sedimentary rocks:

SANDSTONE:

Sandstone is one of the most common sedimentary rocks. These are mechanically formed clastic sedimentary rocks which result from compaction and consolidation of sand particles. The sand stones are medium grained with wide variation in colour, shape, size and compaction. They show a variety of colours like grey, red, brown, white depending on upon the nature of cementing material. The grains may be rounded or irregular, fine or coarse and loosely or densely packed. Quartz is the common constituent of sand stone. The other minerals present in considerable amount are Feldspars, Garnet, Magnetite and Mica.

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Depending upon the cementing material, the sandstones are classified into (i) Siliceous sandstone: Cementing material is silica, (ii) Calcarious sand stone: Cementing material is Calcium carbonate, (iii) Ferruginous sand stone: Cementing material is iron-oxide and (iv) Argillaceous sandstone: Cementing material is clay.

CONGLOMERATE:

It is a clastic rudaceous sedimentary rock. Conglomerates consist only of the more durable fragments which, by reason of their hardness and toughness have been enabled. Loose rudaceous deposits with

rounded fragments are described as Gravel, Pebble beds. The pebbles and gravels on consolidation and cementation produce a rock known as Conglomerate. Gravels consist of more or less rounded fragments of diameter between 2 to 10 mm. Pebble beds consist of larger fragments ranging up to 50mm diameter. The pores of rock are may be filled up with a matrix which is composed of Argillaceous or Calcareous or Ferruginous.

LIMESTONE:

This is an organic sedimentary rock. Limestones are very fine grained. Limestones are identified by their softness, their fossil content. Therocks are formed due to gradual accumulation of shells or skeletons of sea animals like corals, crinoids etc. The organic limestone is deposited mainly due to bio-mechanical process. These limestones are frequently heterogeneous in composition consists of chiefly $CaCO_3$ and hard parts of organisms such as shells and calcareous skeletons or their broken fragments. These are known as fossiliferous limestones. These limestones are further named depending upon the organisms involved.

Eg. Shelly limestone, Coral limestone, Algal limestone and Crinoidal limestone.

SHALE:

It is an Argillaceous sedimentary rock. The grain size in these rocks is less than 0.01mm. When loose and dry, these material forms dust, with varying amount of moisture it forms mud and clay. When welded into a compact rock is called Shale and these are well bedded and splits easily along the bedding plane. If it lacks fissibility they are called mud stones.

Fine grained texture, thin layered structure and lamination are the main characters of a shale. Shales are often soft and can be scratched by a knife. In majority of shales, quartz, clay minerals and other minerals are available. Red shale, Ferruginous shale, green shale are the various terms used for the description of shales. Based on the characteristic minerals shales are divided into four types. They are Siliceous shale, Arkoses shale, Micaceous shale and Chloritic shale.

4.3.3. METAMORPHIC ROCKS:

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Earth movements can push all types of rock deeper into the Earth. When the pre-existing rocks are subjected to increased temperature, pressure and action of chemically active fluids, metamorphic rocks are formed. During metamorphism re-crystallization of the mineral constituents takes place, as a result new minerals and new textures are produced.

Heat, pressure and chemically active liquids or gases are the three factors responsible for metamorphism.

4.3.3.1. Kinds of metamorphism:

1. **Thermal metamorphism**: All types of transformations in which heat is the dominating factor.
2. **Cataclastic or Kinetic metamorphism:** The metamorphism which is due to the dominant action of stress.
3. **Dynamo-thermal metamorphism:** Changes produced by the combination of directed pressure and heat.

4.3.3.2. Some Common Sedimentary rocks:

SLATE:

Slates are produced by the metamorphism of shale and are the most common kind of metamorphic rock. They are fine grained rocks having slaty structure due to which they split into thin smooth plates. They are composed of very fine grained mixture of quartz,chlorite,sericite and feldspar.

Marble

Maeble are produced by the metamorphism of limestone & dolomites. They contain interlocking grains of calcite or dolomites minerals and hence their name is said to be granulose. Marble is chemically the same as limestone but it is much harder and far more expensive. Some of the finest marble comes from Italy and it is used for sculptures and as a fine building material.

SCHIST:

A rock having well developed schistose structure is known as a schist. Schist is largely composed of flaky minerals such as muscovite, biotite, hornblende, chlorite, talc etc. Depending upon the flaky mineral present, the schists are described as muscovite-schist, biotite-schist, hornblende-schist, chlorite-schist, talc-schist etc.

GNEISS:

A rock having gneissose structure is known as a Gneiss. It is composed of feldspars, quartz, and some mafic minerals. Gneisses are distinguished by the minerals that

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are present in comparatively large amount, such as biotite-gneiss, hornblende-gneiss etc.

QUARTZITE:

Metamorphosed sandstones having granulose structures are called quartzites. They are mainly composed of quartz with small amount of mica, tourmaline, graphite or iron-minerals.

CHAPTER-5. SOIL SCIENCE

5.1. INTRODUCTION:

Soil science is the study of soil as a natural resource on the surface of the earth includig soil formation, classification and mapping; physical,chemical, biological, and fertility properties of soils; and these properties in relation to the use and management of soils.

The study of soils as naturally occurring phenomena is called pedology. (from the Greek word *pedon, meaning soil* or earth).

5.2. DEFINITION OF SOIL:

Soil' is the thin layer on the surface of the Earth on which the living beings survive. Soil is the layer which is composed with many substances, in this layer various plants have their roots. Soil is made up of many substances like weathered rock particles, and decayed plant and animal matter. Soil is formed over a long period of time. It can take 500 - 1000 years or more.

5.3. SOIL FORMING FACTORS

Soils develop as a result of the interplay of 5 factors;

- Parent material
- Organisms: vegetation, fauna and soil biota
- Relief (landforms and topography)
- Time
- Climate
- Soil is formed from the weathering of rocks and minerals.

5.4. SOIL PROFILE

A vertical section made through a soil reveals a series of more or less distinct layers. These layers from the surface down to the unchanged parent material is called the soil-profile. This is a characteristics of residual soil i.e the soil developed on top of the parent rock, where there is a transitiom from the top soils to the partially decayed rocks and finally

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to the unaltered rock. A transported soil does not show any such characteristic.

A simple soil profile shows three distinct layers designated as A,B,C – layer.

- The upper layer containing most of the organic material is called the A-Layer or horizon, which is commonly known as the topsoil. This is the horizon of maximum biological activity.
- The layer below the A-horizon is the B-horizon, which is poor in organic content and rich in clay. This layer is commonly regarded as sub-soil. Mineral matter removed from the A-horizon through solution are precipitated in the B-horizon.
- The C-horizon lies below the B-horizon.
- This horizon contains remnants of the parent material and is little affected by biological activity. However, it is affected by physical and chemical processes.
- This horizon grades downward into the unaltered parent rock.
- Bed rock underlying the C-horizon is designated as R-horizon.

Pic

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5.5. **TYPES OF SOILS FOUND IN A.P.**

The types of soil, which are usually found in the Andhra Pradesh State are:

- Red soil
- Alluvial soil
- Laterite soil
- Black soil
- Saline & Alkaline soil
- Peaty & Marshy soils

1) Red Soil: They are quite wide in their spread. The red colour is due to diffusion of iron in the profile. These are charactarised by light texture, porous and friable structured abundance of lime, kankar and free carbonates. They are distributed throughout Peninsular India excluding the Deccan traps region and narrow strip of costal alluvium.

They are deficient in Nitrogen & Phosphoric acid.

2) Alluvial soils: This is the largest and agriculturally most important group of soils. This is found in coastal and delataic areas in A.P. The fresh alluvial deposits carry valuable forests.

3) Lateritic soil: These are composed of a mixture of hydrated oxides of aluminium and iron with small amounts of manganese oxide. Laterites are of two kinds namely primary or high level and secondary or low level form.

The primary laterites are usually found as a cap on the top of the Deccan traps and gneissic rocks in Andhra Pradesh. This is poor in nutrients especially potash, phosphorous and lime

5) Saline & Alkaline soils: The characteristic of these soils are (i) Presence of injurious salts of Na, Mg and Ca which are carried to the top layer by capillary action from lower layers.

6) Peaty & Marshy soils:

These are relatively unimportant soils and occur only locally. The origin is due to accumulation of organic matter under anerobic conditions. They are blue coloured on account of the presence of ferrous compounds.

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5.6. HUMUS

It is a product of the decomposition of plant and animal residues. It is a valuable constituent of soil.

Pic

It covers a wide variety of substances derived from the dead and decomposing bodies of all kinds of animals and plants. Humus has a characteristic black or dark brown color, due to an accumulation of organic carbon. It contains on an average 58% carbon which is somewhat greater than the carbon content of plant tissues (45-50%) from which it is derived. Its nitrogen content varies from 3 to 6. It possesses a definite C:N ratio which varies from 10:1 to 12:1 for most soils.

Properties:

1. It is a light bulky amorphous material of dark brown to black colour.
2. It has a great water holding capacity & water absorbing capacity
3. It has high ion adsorbing capacity, nearly four to six times that of clay.
4. It is insoluble in water. It dissolves readily in dilute alkali giving a dark coloured liquid.
5. It behaves like a weak acid and forms salts with bases.
6. It serves as a source of energy and food for the development of various micro-organisms.
7. Humus is an important source of nutrients for higher plants.
8. Humus is transitional and doesn't remain in the soil for ever, it has a certain permanency and disappears from the soil only slowly.

5.7. MICRO NUTRIENTS

The nutrients which required in greater quantities are

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The nutrients which required in smaller quantities are

oron (B)

- Helps in the use of nutrients and regulates other nutrients.
- Aids production of sugar and carbohydrates.
- Essential for seed and fruit development.
- Sources of boron are organic matter and borax

Copper (Cu)

Important for reproductive growth.
Aids in root metabolism and helps in the utilization of proteins.

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- Important for reproductive growth.
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Chloride (Cl)

- Aids plant metabolism.
- Chloride is found in the soil.

Iron (Fe)

- Essential for formation of chlorophyll.
- Sources of iron are the soil, iron sulfate.

Manganese (Mn)

- Functions with enzyme systems involved in breakdown of carbohydrates, and nitrogen metabolism.
- Soil is a source of manganese.

Molybdenum (Mo) Macronutrients

Macronutrients can be broken into two more groups: **primary** and **secondary nutrients**.

The **primary nutrients** are **nitrogen (N)**, **phosphorus (P)**, and **potassium (K)**. These major nutrients usually are lacking from the soil first because plants use large amounts for their growth and survival.

The s**econdary nutrients** are **calcium (Ca)**, **magnesium (Mg)**, and **sulfur (S)**. There are usually enough of these nutrients in the soil so fertilization is not always needed. Also, large amounts of Calcium and Magnesium are added when lime is applied to acidic soils. Sulfur is usually found in sufficient amounts from the slow decomposition of soil organic matter, an important reason for not throwing out grass clippings and leaves.

Micronutrients are those elements essential for plant growth which are needed in only very small (micro) quantities. These elements are sometimes called minor

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elements or trace elements, but use of the term micronutrient is encouraged by the American Society of Agronomy and the Soil Science Society of America. The micronutrients are **boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo)** and **zinc (Zn)**. Recycling organic matter such as grass clippings and tree leaves is an excellent way of providing micronutrients (as well as macronutrients) to growing plants. **Zinc (Zn)**

- Essential for the transformation of carbohydrates.
- Regulates consumption of sugars.
- Part of the enzyme systems which regulate plant growth.
- Sources of zinc are soil, zinc oxide, zinc sulfate.

5.8. Soil Moisture

Soil moisture is the water that is held in the spaces between soil particles. Surface soil moisture is the water that is in the upper 10 cm of soil, whereas root zone soil moisture is the water that is available to plants, which is generally considered to be in the upper 200 cm of soil.

Compared to other components of the hydrologic cycle, the volume of soil moisture is small; nonetheless, it of fundamental importance to many hydrological, biological and biogeochemical processes. Soil moisture information is valuable to a wide range of government agencies and private companies concerned with weather and climate, runoff potential and flood control, soil erosion and slope failure, reservoir management, geotechnical engineering, and water quality. Soil moisture is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. As a result, soil moisture plays an important role in the development of weather patterns and the production of precipitation. Soil moisture also strongly affects the amount of precipitation that runs off into nearby streams and rivers.

. Soil micro-organisms

There are billions to hundreds of billions of soil microorganisms in a mere handful of a typical, garden soil. The various organisms that inhabit the soil, both macro and micro, form one of the important components of all soils. The soil contains several distinct groups of micro-organisms of which the algae, fungi, actinomycetes, bacteria

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and protozoa are the most important. Soil micro-organisms, like higher plants, depend almost entirely on soil for their nutrition and growth.

Microorganisms are found in large numbers in soil - usually between one and ten million microorganisms are present per gram of soil - with bacteria and fungi being the most prevalent. However, the availability of nutrients is often limiting for microbial growth in soil and most soil microorganisms may not be physiologically active in the soil at a given time.

Some examples:

Root nodules formed on the root system of a Leguminasae plant. Nitrogen-fixing root nodule bacteria *(Bradyrhizobium)* present inside the nodule provide valuable organic nitrogen to the host plant, which promotes plant growth.

Mycorrhizal fungi colonize the root systems of many plants and aid in the uptake of nutrients by the plant, thereby improving plant growth and overall health.

Ecological significance of soil micro-organisms.

Soil microorganisms are very important as almost every chemical transformation taking place in soil involves active contributions from soil microorganisms. In particular, they play an active role in soil fertility as a result of their involvement in the cycle of nutrients like carbon and nitrogen, which are required for plant growth. Certain soil microorganisms such as mycorrhizal fungi can also increase the availability of mineral nutrients (e.g. phosphorus) to plants. Other soil microorganisms can increase the amount of nutrients present in the soil. For instance, nitrogen-fixing bacteria can transform nitrogen gas present in the soil atmosphere into soluble nitrogenous compounds that plant roots can utilise for growth.

These microorganisms, which improve the fertility status of the soil and contribute to plant growth, have been termed 'biofertilizers'. In contrast to these beneficial soil microorganisms, other soil microorganisms are pathogenic to plants and may cause considerable damage to crops.Large numbers of pathogenic microorganisms are routinely found in the soil and many of them can infect the plant through the roots. However, certain native microorganisms present in the soil are antagonistic to these pathogens and can prevent the infection of crop plants. Other soil microorganisms produce compounds that stimulate the natural defence mechanisms of the plant and improve its resistance to pathogens. Collectively, these soil microorganisms have been termed 'biopesticides' and represent an emerging and important alternative (i.e. biological control) to the use of chemical pesticides for the protection of crops against certain pathogens and pests

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5.10. SOIL PHYSICAL PROPERTIES

Soil profile is not uniform throughout its depth. It contains two or more horizons, each possessing certain morphological features that distinguish one from the other. The same morphological features that differentiate the various horizons also characterise a soil profile and help to differentiate it from others.

The physical properties of soils include colour, texture, structure, density, porosity, temperature, water content, consistency etc. are dominant factors affecting the use of a soil.These properties determine the availability oxygen in soils, the mobility of water into or through soils, and the ease of root penetration. The same morphological features that differentiate the various horizons also characterise a soil profile and help to differentiate it from others.

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SOIL COLOUR

The colour of the soil is one of the most outstanding morphological features. Very often the various horizons are differently coloured. The variation in colour of the different horizons serves as one of the factors that leads to the recognition of different soil types. Soil colour varies considerably. There are a number of recognised soil colours. Some of the more important soil colours are black, red, yellow, brown, grey and white. The soil colour is due to the colour of the predominant soil particles.

The black colour of a number of soils is mainly due to the accumulation of humus or decaying organic matter. The colour of red soils is mainly due to the presence of iron oxide in the form of ferric oxide. Yellow soils also owe their colour due to iron oxide. The colour of grey is due to the removal of bases like iron from the soil mass by leaching. White colour usually indicates a sand or sandy soil. Colour serves as an indicator of the geological and pedological origin of the soil.

SOIL TEXTURE

TEXTURE denotes the size of the individual soil particle. The soil particle –size groups, called soil separates, are sands (the coarsest), silts, and clays (the smallest). The relative proportions of soil separates in a particular soil determine its soil texture.

Texture will determine water intake rates (absorption), water storage in the soil, the ease of tilling the soil, the amount of aeration (vital to root growth), and will influence soil fertility. The mechanical removal of finer particles from the surface layer tends to make the horizon of eluviation more coarse.The texture becomes more and Plants and animals can cause mechanical weathering. The roots of plants sometimes loosen rock material. A plant growing in a crack can make the crack larger as the root spread out. This is known as root-pry. It is organic since this activity is caused by living things.

more heavy with depth, and it reaches max, heaviness in the horizon of illuviation. According to the relative proportion of big and small sized particles present in it, the soil may be termed COARSE or FINE.

Textural names are given to soils based upon the relative proportions of each of the three soil separates – sand, silt and clay. Soils that are predominantly clay are called Clay textural class; those with high silt content are Silt textural class; those with a high sand percentage are Sand textural class.A soil that does not exhibit the dominant physical properties of any of these three groups is called loam.

In the estimation of soil texture, particles below 2mm diameter are separately determined which constitute sand, silt and clay. Each one of them is characterized as below:

Coarse sand:	2.0 – 0.2 mm diameter
Fine sand:	0.2 – 0.02 mm diameter
Silt:	0.02 – 0.002 mm diameter
Clay:	< 0.002 mm diameter

The textural triangle is used to determine the soil textural name after the percentage of sand, silt, and clay are determined from a laboratory analysis.

SOIL STRUCTURE

The arrangement of soil particles in a soil mass or aggregates is known as soil structure.Natural aggregates are called Peds. Structure controls the amount of water and air present in the soil. Soil structural units (peds) are described by three characteristics: type (shape), class (size), and grade (strength of cohesion together). Types of structure describe the ped shape with the terms granular, crumb, platy, blocky, subangular blocky, prismatic and columnar.

Structure classes are the ped sizes such as very fine, fine, medium, coarse and very coarse.

- Very coarse: >10 mm
- Coarse: 5-10 mm
- Medium: 2-5 mm
- Fine: 1-2 mm
- Very fine: <1 mm

Structure grades are evaluated by the distinctness, stability or strength of the peds.

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Structureless: Soils have no noticeable peds. It might be an unconsolidated mass, is called single grain, or it might be a cohesive mass, is called massive.

Structured: Three structural grades are used

a)Weak: Peds are barely distinguishable; only a few distinct peds can be seperated from the soil mass.
b) Moderate: Peds are visible in place; many can be handled without their breaking.
c)Strong: Most of the soil mass is visible as peds, most of which can be handled with ease without their breaking.

Soil structure influences many important properties of the soil such as the rate of infiltration of water. Both granular and single-grain soils have rapid infiltration rates, blocky and prismatic soils have moderate rates, and platy and massive soil conditions have slow infiltration rates.

PARTICLE DENSITY & BULK DENSITY

Density is the weight (or more correctly, the mass) of an object per unit volume.

Two density measurements – particle density and bulk density are common for soils. Particle density is the density of the solid soil particles only; the measurement does not include water weight or pore (air) space.

Bulk density, is the density for a volume of soil as it exists naturally, includes any air space and organic materials in the soil volume.

Bulk density = Soil mass (dry) / Soil volume

SOIL POROSITY

The amount of pore space in soil, sediments, and rock is called porosity**.** It can also be defined as the percentage of a material's total volume that is taken up by pores.

$$\% \text{ Porosity} = \frac{\text{Volume of pore space}}{\text{Total volume of sediment}} \times 100$$

Porosity depends on the size, shape, and mixture of grains and particles that compose soil and rock.

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Small particles such as clays are able to compact more closely together, reducing the amount of porosity. However, larger particles such as sand and gravel will have more spaces available between them. Round particles compacted together will have more spaces than elongated grains that stack more tightly. Particles of uniform size (well sorted) will also have more pore space available than grains of varying sizes (poorly sorted) because small particles can fill in the spaces between the larger grains.

SOIL PERMEABILITY

Permeability is the measure of how easily water flows through soil or rocks. So it depends on the size of the pore space and how well connected they are to one another. It is often defined as pore interconnectedness and the unit of measurement is usually distance (cm, m, or ft.) per time (second, minute, day).

Permeability depends on several factors – grains size of particles and the amount of cracks and fractures. If the sediments or rock particles are composed of very small grains, such as in clays and silts, the space through which water can flow is limited. If sediments are comprised of coarser grains like sand and gravel, pore space is more available.

Porosity and Permeability Ranges for Sediments

	Porosity	Permeability
Well-sorted sand or gravel	25-50%	High
Sand and gravel, mixed, poor sort	20-35%	Medium
Glacial till	10-20%	Medium
Silt	35-50%	Low
Clay	33-60%	Low

SOIL CONSISTENCY

Soil consistency describes how well a soil sticks together or resists fragmentation. Consistency is the soil's behaviour under stress. It is measured at three moisture conditions: air-dry, moist and wet. Soil consistency is of value to predict cultivation problems and adaptation to engineering qualifications, such as the ability to bear building weight.

IDEAL SOIL FEATURES

An ideal soil is well aerated to ensure that oxygen is not limiting to the growth and function of roots and soil inhabiting organisms. Its pH is slightly acid to neutral to limit the availability of toxic elements and to promote the availability of essential

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nutrient elements. And it contains an ample supply of plant-available water and nutrients.

Organic Matter (OM)	4% — 10%	Ideally, as humus.
pH	6.0 - 6.5	

Bases (cations) as % of exchange capacity

Calcium (Ca)++	60% — 70%	Ca & Mg together should add to 80% of exchange capacity
Magnesium (Mg)++	10% — 20%	— do —
Potassium (K)+	3% — 5%	Needs a highly bio-active soil to keep it available
Sodium (Na)+	1% — 4%	NaCl, table salt.
Hydrogen (H)+	8% — 10%	

Other major nutrients (anions)

Phosphorus (P)-	3% — 5%	Needs a highly bio-active soil to keep it available
Sulfur (S)-	1/2 of Phosphorus (up to 200 ppm.)	Needed for synthesis of essential amino acids.
Chlorine (Cl)-	1x to 2x Sodium	NaCl, table salt.

Minor elements (of Major importance)

Iron(Fe)	Fe: 100-200ppm	Iron and Manganese are twins/opposites/ synergists, as are Copper and Zinc.
Manganese(Mn)	Mn: 1/2 x Fe (up to 50 ppm)	—Do—
Zinc (Zn)	Zn: 1/10 x P (up to 50ppm)	
Copper (Cu)	Cu:1/2 x Zn	
Boron (B)	1/1000 of Calcium	Essential for Calcium utilization

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(up to 4 ppm)

Trace elements (also of Major importance)

Chromium (Cr)+	1 - 2ppm is enough.
Cobalt (Co)+	2-10ppm
Iodine (I)-	1 - 2ppm is enough.
Molybdenum (Mo)+}	1 - 2ppm is enough.
Selenium (Se)-	1 - 2ppm is enough.
Tin (Sn)+	1 - 2ppm is enough.
Vanadium (V) +	1 - 2ppm is enough.
Nickel	1 - 2ppm is enough.

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