CHAPTER – I : SOIL AS A NATURAL BODY

Man is dependent on soil and to a certain extent good soil is dependent upon the man. Soils on which plants grow is considered as the natural body because of its separate identity. Like other living bodies it also develops slowly and slowly from the parent material which is also a product of weathering of rocks and minerals. It them reaches to maturity and provides well developed profile. Soil is a natural resource. It exists on the earth even before the existence of mankind on earth. So to study soil from various dynamics and its relation with other entities whether living or non-living things, a branch of science was designated called as soil science. So, soil science is the branch of science that studies soil formation, its mapping and classification, physical, chemical and biological of soil and management of soil for various purposes.

Soil Science : "The science dealing with soil as a natural resource on the surface of the earth, including Pedology (soil genesis, classification and mapping), physical, chemical, biological and fertility properties of soil and these properties in relation to their management for crop production."

Soil :- The soil is derived from the Latin Word "SOLUM" Means FLOOR or GROUND

- For a Layman soil is dirt or debris
- For an Agriculturist soil is a habitat for plant growth (to grow crops)
- For a Mining Engineer soil is a debris covering the Rocks
- For a Civil Engineer soil is a material on which road bed or house bed is formed
- For a Home Owner soil is a mellow or loamy or hard material

Definitions

Generally, soil refers to the loose surface of the earth as identified from the original rocks and minerals from which it is derived through weathering process. From time to time soil scientists thought about the soil and coined the definitions such definitions are given as under :

Whitney (1892): Soil is a nutrient bin which supplies all the nutrients required for plant growth

Hilgard (1892): Soil is more or less a loose and friable material in which plants, by means of their roots, find a foothold for nourishment as well as for other conditions of growth".

Dokuchaiev (1900): Russian scientist - Father of soil science - Soil is a natural body composed of mineral and organic constituents, having a definite genesis and a distinct nature of its own.

Ramann (1917) : Soil is the upper most weathered layer of the solid earth crust. It consists of rocks that have been reduced to small fragments and have been changed chemically together with the remains of plants and animals that live on it and in it.

Marbut (1928) : Soil is the outer layer of the earth crust usually unconsolidated, ranging in thickness from merely in film to a maximum of somewhat more than ten feet which differs from the material beneath it, also usually unconsolidated in colour structure, texture, physical constitution, chemical composition, biological characteristics, probably chemical processes in reaction and morphology.

Joffe (1936): "Soil is a natural body of mineral and organic constituents differentiated into horizons - usually unconsolidated - of variable depth which differs among themselves as well as from the underlying parent material in morphology, physical makeup, chemical properties and composition and biological characteristics".

Jenny (1941): Soil is a naturally occurring body that has been formed due to combined influence of climate and living organisms acting on parent material as conditioned by relief over a period of time.

Ruffin and Simonson (1968): Soil is a mixture of Earth's uppermost mantle of weathered rock and organic matter.

Buckman and Brady (1969): Soil is a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms

Soil Science Society of America (1970)

1. Soil is the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro and microorganisms and topography, all affecting over a period of time and producing a product, that is "SOIL" that differs from the material from which it is derived in many, physical, chemical, biological and morphological properties and characteristics.
2. The unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Modern definitions of soils : Soil is a natural body, synthesized in profile from a variable mixture of broken and weathered minerals and decaying organic matter which covers the earth in a thin layer and which supplies, when containing the proper amounts of air and water, mechanical support and in part, substance for plants. (OR) Soil is a natural body and formed under various ecosystems with the help of various factors. It is the end product of the combined influence of natural processes controlled by climate, topography, organisms, parent material and climate.

Dr. W.E.H. Blum : Soils not only serve for agriculture and forestry, but also for filtering, buffering and transformation activities between the atmosphere and the ground water, protecting the food chain and drinking water against pollution and biodiversity

As soil provides nutrients, water, air and anchorage and supports life on Earth, it can be called as **Soul Of Infinite Life (SOIL)**

Soil as a three dimensional body :- Soil is a three dimensional body having length, breadth and depth. They form a continuation over the land surface and differ in properties from place to place. Its upper boundary is air or water and lower boundary is the rock lithosphere.

Soils, might be described as border-like phenomenon of the earth's surface. They belong to the pedosphere, in which lithosphere, atmosphere, hydrosphere and biosphere overlap and interact. Soil is in the interface between atmosphere including biosphere, hydrosphere and pedosphere. Soil is the ultimate result of interaction of various factors such as climate (atmosphere, hydrosphere), relief (biosphere), organisms (biosphere), parent material (pedosphere) and time.

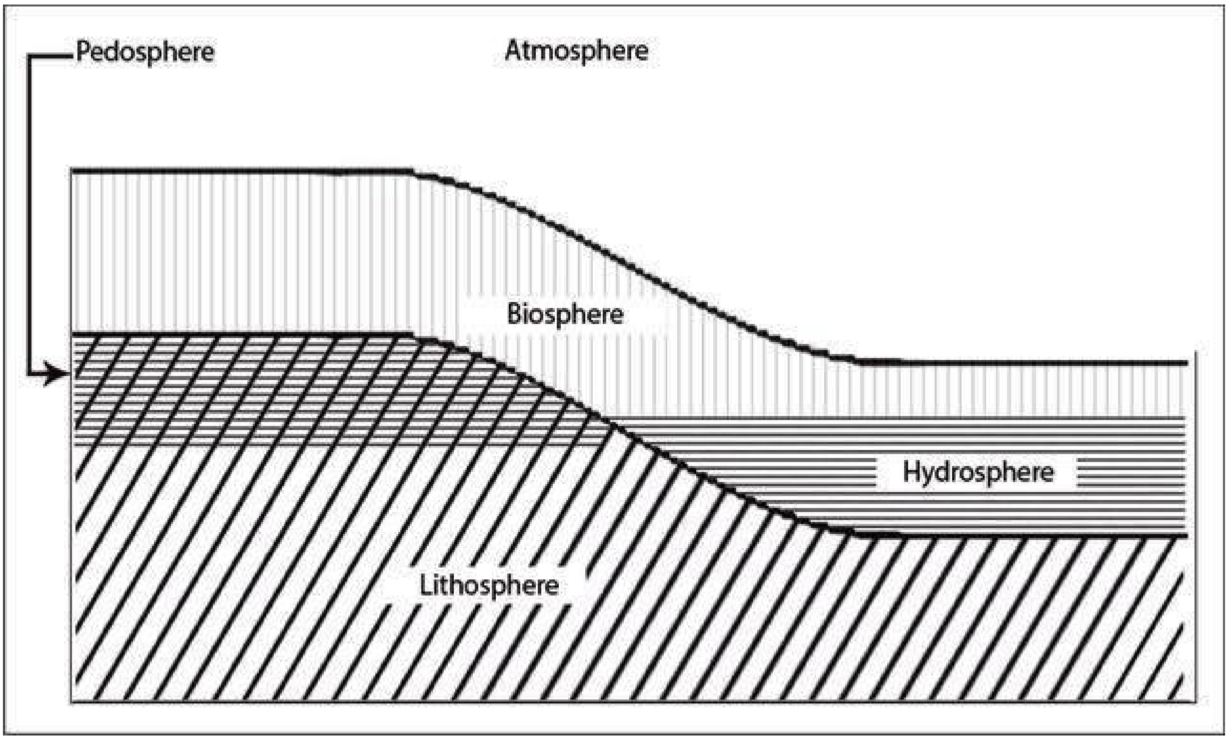


Fig. : Soil as interface between different spheres of environment

The pedosphere (from Greek work pedon "soil" or "earth" and sphaira "sphere") is the outermost layer of the Earth that is composed of soil and subject to soil formation processes. It exists at the interface of the lithosphere, atmosphere, hydrosphere and biosphere. The pedosphere is the skin of the Earth and only develops when there is a dynamic interaction between the atmosphere (air in and above the soil), biosphere (living organisms), lithosphere (unconsolidated regolith and consolidated bedrock) and the hydrosphere (water in, on and below the soil). The pedosphere is the foundation of terrestrial life on Earth.

Branches of Soil Science :-

Soil Physics	:	Soil has a mechanical behavior, it means soil has physical properties and through which it controls physical process in and through the soil. Involves the study of physical properties of soil.
Soil Chemistry	:	This branch of soil science deals with the study of chemical properties and composition of soil. It also studies the chemical processes that takes place in soil. Chemical constituents, chemical properties and the chemical reactions.
Soil Biology	:	It refers to the soil inhabiting organisms and their biology, functions and activities. In this scientist study the role of living organisms in biological transformations that take place in soil. For examples, insects and nematodes.
Soil Microbiology	:	This important field, deals with the microbial communities in the soil, their roles and characteristics with respect to soil fertility and land reclamation and especially it concerns with the nutrition of plant through root nodulation or diseases caused by plant pathogenic microbes in the soil. Deals with microorganisms, its population, classification, its role in transformations
Soil Pedology	:	Dealing with the genesis, survey and classification. Soil genesis deals with the weathering of rocks and minerals and factors and processes of soil formation whereas, soil classification is the systematic rearrangements of soils into groups or categories on the basis of their characteristics.
Soil Fertility	:	It concerns the ability of a soil to supply the essential plant nutrients for plant growth. Nutrient supplying properties of soil
Soil Conservation	:	It deals with the protection of soil from the physical loss by erosion (by wind and water) or chemical deterioration. Thus, soil conservation is concerned with a combination of all management and land use method that safeguard the soil against deterioration by natural or human induced factors. Dealing with protection of soil against physical loss by erosion or against chemical deterioration i.e excessive loss of nutrients either natural or artificial means
Soil Mineralogy	:	This branch deals with the primary and secondary soil minerals and their contribution to the chemistry, physics, fertility and biology of the soils and their relation to soil genesis.
Soil Survey	:	The systematic analysis and examination of the soils in the field and laboratories, their description, classification, mapping and interpretation according to their suitability for different management systems is deal with in soil surveys.
Soil Technology	:	It is an applied side of the soil science. It deals with the study of principles and the practices of soil erosion and conservation. It also deals with the soil health or soil problems that include salinity, sodic, acidic, degradation, water logging etc.

Some important definitions :-

(A.) Soil, A Soil and The Soil :

- Soil :- It is the collective term for all soils just like vegetation which is used to designate plants.
- A Soil :- Any soil which shows some well defined characteristics and properties.
- The soil :- Specific soils which show definite locations and also the characteristics like Jabalpur clay, Gwalior sandy clay loam.

(B.) Surface soil and Sub soil :

Surface soils :-

- Surface soil is a medium for plant growth.
- It is a major zone of root development.
- It carries higher amounts of water, organic matter and available plant nutrients.
- It has high permeability and dark colouration.
- It is ploughed and cultivated and is subject to manipulation and management.

Sub soils :-

- Sub soil is less subjected to field alteration (human interference) except by drainage.
- Root do not penetrate deeply hence are less.
- Permeability and chemical nature of sub soil influence the surface layer.
- Organic matter is less and hence colour of the soil is light.

By proper cultivation and incorporation of organic residues, chemical fertilizers and some amendments, physical and chemical conditions may be modified. In short its fertility and to a little degree its productivity may be raised, lowered or stabilized for economic crop production.

(C.) Soil fertility and soil productivity :

Soil Fertility :- Fertility refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportion.

Productivity :- Productivity refers to the ability of soil to yield crops. It is a broader term since fertility is only one of a number of factors that determinates the magnitude of crop yields.

(D.) Mineral and Organic soils :

Mineral Soil :- Mineral soil are these which contain organic matter less than 20% if clay is zero per cent (0%) or less than 30% if clay is 50%.

Organic soils :- Organic soils are these which contain organic matter more than 20% if clay is zero per cent (0%) or more than 30% if clay is 50%.

Organic matter (%)

	20	21	22	23	24	25	26	27	28	29	30	
Mineral soils	0	5	10	15	20	25	30	35	40	45	50	**Organic soils**

Per cent clay

Functions of soil :-

1. It provides the mechanical support for crops and these to stand erect.
2. It acts as a natural store house of the plant nutrients. Plant foods are released from soil due to

   (a.) Chemical reactions taking place in presence of air and water.

   (b.) Action of micro-organisms.
3. It works as a medium through which plants take up their important requirements like air and water.

CHAPTER – II

PEDOLOGICAL AND EDAPHOLOGICAL CONCEPTS OF SOIL

Soil is considered as a **(i)** Soil as a natural body – A biochemically weathered and synthesized product of nature (Pedology) and **(ii)** Soil as a natural habitat for plants and other living organisms (Edaphology). These two conceptions illustrate the two approaches viz. pedological and edaphological approaches respectively.

Historical Developments in Pedology

Pedology is a branch of soil science which has been evolved through the creation of ideas in due course of time. It has also been identified as the heart, soul and artistry of soil science. Generally, pedology has been subdivided into soil morphology, soil forming factors, soil forming processes, soil survey, soil characterization and analysis, soil classification, soil geomorphology, soil mapping, and soil interpretation. A brief history of temporal development in key concepts of pedology is presented as under :

Period	**Key concepts**
Pre-1880	Concept of soil as a medium for plant growth and as a weathered rock layer.
1880-1900	Initiation in developments of fundamental concepts in *pedology*; soil as a natural body; soil horizons/profile; soil forming factors; early ideas of soil geography.
1900-1940	Global acceptance of concepts of soil as a natural body and soil forming factors; development of first regional soil classification system; initiation of soil surveys; identification of key soil-forming processes.
1940-1960	Factors of soil formation and genesis of soils clarified; efforts to develop globally acceptable soil classification systems; intensified soil mapping.
1960-1990	Refinement of global soil taxonomic system; identification of pedon concept; development of early soil models and soil cover pattern concept; recognition of coevolution of soils and landforms.
1990-present	Increased understanding of soil processes; refinement of global soil models; further refinement of global soil taxonomic systems; development of statistical and computerbased soil formation systems; development of geo-informatics for land resource management, environmental pedology, and hydropedology.

Pedological Research in India

Pedological research in India had made a modest beginning in the later part of 20^{th} century which was mainly focused on soil genesis, classification and mineralogy. Work on soil survey started in 1950 in most states as a part of their agricultural development programmes. With the establishment of the *National Bureau of Soil Survey and Land Use Planning (NBSS&LUP)* in the year 1976, a premier institute of pedology working under the aegis of Indian Council of Agricultural Research (ICAR), pedological research received an impetus in the country. During the last four decades, NBSS&LUP had made outstanding research contributions through developing soil resource inventory at different scales, undertaking studies on their genesis, revising existing theories and concepts, soil correlations, soil mineralogy, paleo-pedology, carbon sequestration, modeling climate change and related research in edaphology and pedology education in some State Agricultural Universities.

Pedological Approach:

The origin of the soil, its classification and its description are examined in Pedology. (From Greek word *pedon*, means soil or earth). Pedology is the study of soil as a natural body as they occur in their natural envionrment. In this approach, we consider about origin of soil which includes the study of rocks, rock forming minerals, pedogenic factors and processes involved in soil genesis, soil survey, soil description and soil classification. The pedological information are is useful to engineers and town planner as to farmers.

History of Edaphology

Edaphologists are people who study edaphology. The earliest edaphologists were Cato (234–149 BC) and Xenophon (431–355 BC). Cato was the first person to devise soil capability classification for specific crops. Cato also has some writing which recommends the use of legumes, crop rotation, and tillage to enhance nitrogen content in the soil. On the other hand, Jan Van Helmot (1577-1644) carried out various experiments which re-energized the interest in edaphology. In his experiment, growing a willow tree in a pot of soil and supplying only rainwater for five years. The weight gained by the tree was greater than the weight loss of the soil.

Edaphological Approach:

Edophology (from Greek word *edaphos*, means soil or ground) is the study of soil from the stand point of higher plants. This is an applied branch of soil science which is important for agricultural production and involves study on properties of the soil which affect plant growth, nutrition and yield of crops. Edaphological approach includes study of fertility, chemistry, physics, microbiology and technology of soils. This helps to suggest appropriate soil management for plant growth.

Areas of Study in Edaphology and Pedology

Edaphology	**Pedology**
Physical edaphology is mostly concerned with the drainage and irrigation of crops. Soil husbandry is part of edaphology that involves studying how to prevent the degradation and soil erosion in croplands. The study consists of looking for ways in which soil resources are	Pedology, on the other hand, focuses on the pedosphere which is the environment that pedologist interacts with, in the environment. Pedosphere looks beyond just the production of crops and looks at other areas such as restoration of wetlands, land treatment of

sustainable by means such as the use of cover crops and soil conditioners.	wastewater, and management of environmental nutrients. Pedology assesses other factors such as acid rain and global warming.
Edaphology focuses on the formation of soil which is a weathered layer from the crust of the earth. The study of edaphology focuses on processes such as chemical and physical weathering, decomposition of materials, and the texture of the soil. The structure of soil and water composition in the soil are two other branches that fall under edaphology.	Pedology, on the other hand, focuses majorly on the environment that the soil is. This environment, pedosphere, entails the interaction of soil life and the climate. Pedosphere also looks at the dependence of soil profile on characteristic layers. The five major external concepts in pedology about soil patterns are time, organisms, climate, parent material, and relief. Pedologists currently have shifted most of their energy to pedogenesis processes. Pedogenesis processes are how functioning and evolution of soil occur. Sustainable use of soil is majorly understood when there is a vast knowledge of the history of soil which would enable in creating a balance with the environment.

CHAPTER – III

Major Component of Soil and Elemental Composition of Earth Crust

Major components of soil :-

Soil composition is an important aspect of nutrient management. While soil minerals and organic matter hold and store nutrients, soil water is what readily provides nutrients for plant uptake. Soil air, too, plays an integral role since many of the microorganisms that live in the soil need air to undergo the biological processes that release additional nutrients into the soil.

Soil is one of the most important natural resources of the earth. It is basically made up of two components *viz* organic and inorganic. Most of the mineral soils are poor in organic components. As a matter of fact in tropical soils of India, the SOC content rarely exceeds 1.5%; logically therefore the entire composition of soil is inorganic on weight basis. On volume basis as discussed earlier soil is composed of three phases *viz* solid, gas and liquid with a general ratio of 2:1:1. The typical soil consists of approximately 45% mineral matter, 5% organic matter, 20-30% water, and 20-30% air. These percentages are only generalizations at best. In reality, the soil is very complex and dynamic. The composition of the soil can fluctuate on a daily basis, depending on numerous factors such as water supply, cultivation practices, and/or soil type.

Mineral soils consist of four major components (Fig 1)

Major components	State	Per cent by volume	Per cent by weight	Example
1. Mineral matter	Solid	45	95	• Primary and secondary minerals
2. Organic matter	Solid	05	05	• Dead – Decaying organic debris and colloidal humus. • Living – bacteria, fungi, protozoa, worms, insects, plants.
3. Water	Liquid	20 – 30	–	• Variable solution of salts & gases
4. Air	Gas	20 – 30	–	• Variable N_2, O_2, CO_2 in different proportions and saturated with water vapour.

1. Mineral matter in soil (A real solid part of soil) :- Inorganic portion of the soil is composed of small rock fragments and minerals of various kinds and composition.

(A.) Rock fragments, which produce regolith are formed due to weathering of massive rocks. They are coarser in size.

(B.) Minerals vary in size from as large as rock fragments to as small as colloidal clay particles which can only be seen with the aid of electron microscope.

(i) Some primary minerals like quartz persist in the profile with a little change in composition from the original rocks (ii) However minerals like silicate clays and iron oxides are formed by weathering of less resistant minerals. They are called secondary minerals.

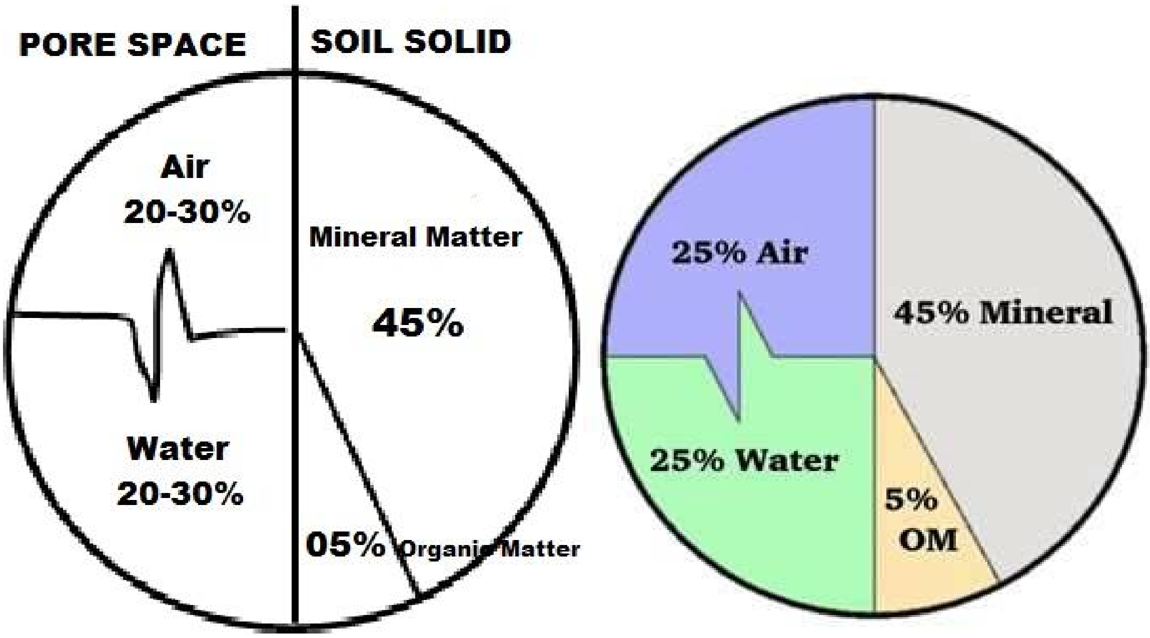


Fig 1 :Major components of soil

(a.) Forms of minerals constituents in the Earth's crust and soil

Minerals	Earth's crust	Soil
Feldspars	58	2.5
Hornblende group	15	3.0
Quartz	13	44.5
Micas	04	0.5
Clays	01	21.5
Other minerals	09	28.0
Total :-	**100**	**100**

(b.) Size of mineral constituents (Inorganic particles)

Size	Name	Visibility through	Dominants composition
Very coarse	Stone, Gravels	Naked eye	Rock fragments
Coarse	Sand	Naked eye	Primary minerals
Fine	Silt	Microscope	Primary & Secondary minerals
Very fine	Clay	Electronic microscope	Secondary minerals

Soils are dominantly inorganic and contain mineral matters. These mineral matters may be grouped into a) crystalline and b) non-crystalline/amorphous components.

Crystalline components

The crystalline minerals are naturally-occurring, inorganically formed and show definite, ordered atomic arrangements and chemical composition. Minerals present in clay (< 2 µm) fractions are called clay minerals. The minerals vary in size. Some are as large as rock fragments and a few are so small that we need electron microscope to see those particles. Minerals are generally grouped into primary (which are formed at the time of rock formation; example, quartz) and secondary (formed from the primary minerals by weathering process; example, alumino-silicate minerals). By and large, primary minerals are more frequently found in the coarser fragments of soils such as sand (> 50 µm) and silts (50-2 µm) fractions, whereas clays (< 2 µm) are usually dominated by the secondary minerals.

Non-crystalline/amorphous components

These are also known as allophanes (*Gk. Allo* = otherwise; foreign) which are amorphous or para-crystalline clay minerals whose structure and composition is still uncertain. They occur frequently in soils formed from volcanic ash. Non-crystalline and amorphous components are also found in soils which are highly weathered especially the red soils from high rainfall areas. These are found as the oxides of iron and aluminium.

2. Soil organic matter (A transitory soil constituents) :-

It forms 1-5% of the solid part of soil. Although it occupies less but has a large role to play in controlling morphological, physical and chemical properties of soils. Soil organic matter (SOM) is the sole source of native nitrogen in soil, and contains other important nutrients mainly sulphur and phosphorus. The SOM is important for soil structure. It influences water, air and temperature of the soil which indirectly influence various soil plant processes. It is made up of living organisms of the soil flora and fauna (*Figure 3*), living and dead plant roots, which may be partly decomposed and modified with the newly synthesized organic substances of plant or animal origin. Organic matter may be grouped broadly into two different groups, namely i) original tissues of plants/animals/ debris and the partially decomposed product, and ii) humus. The humus includes highly decomposed soil organic matter including dead materials and is the decomposition product of small plant roots, shed aerial parts of higher plants (litter, straw) and organisms of soil flora and fauna. Organic matter is the important source of energy for soil microorganisms.

Functions :-

i. It influences the soil properties and consequently the plant growth.
ii. It acts as granulator of the mineral particles.

iii. It is a major source of N, P and S, the important plant nutrients.
iv. It is the main source of energy for soil micro organisms.
v. It improve water holding capacity for plants.

3. Soil water (A dynamic solution) :- Dynamic nature of water can be shown by the two concepts.

(A.) Firstly the soil water is held with varying degree of tenacity with the soil pores depending upon the amount of water present.

i. Moisture present in the soil pores of medium sizes is considered optimum. It is easily taken up by plants. It is greatly reduced by root absorption and evaporation.
ii. The remaining moisture present in tiny pores and as thin films is subject to great attraction by soil solids as well as plant roots where former competes the latter.
iii. Such moisture present in small amounts cannot be absorbed by plant roots.

(B.) Secondly due to dissolve salts, soil water makes up the soil solution which is an important medium for supplying nutrients to the growing plants. There is an exchange of nutrients between soil solids and soil solution and then between soil solution and plants. These exchanges are influenced by the degree of concentration of salts in the soil solution.

4. Soil Air (A changeable constituents) :- Air located in the network of soil pores is known as soil airs. It differs from atmospheric air in several ways.

i. It is not continuous hence varies from place to place.
ii. It contains higher amount of moisture.
iii. It contains about 0.45% of CO_2 gas when atmospheric air contains only 0.03%. Decrease of CO_2 in soil airs favours in the increase of O_2 gas.
iv. Its content and composition is governed by the degree of soil – water relationship.
    (a.) At the early stage of water supply all the soil pores are filled up by water and air is removed. As the water decreases either by transpiration evaporation or leaching, soil pores are again occupied by air.
    (b.) Some of the gases like CH_4, CO_2, CO, NH_3 etc. are produced by micro-organisms, which change the composition of soil air. These gases are also soluble in water.

Composition of Soil air and atmospheric air :-

Gases	**Soil air**	**Atmosphere air**
Oxygen (O_2)	20.00	21.00
Nitrogen (N_2)	78.60	78.03
Carbon dioxide (CO_2)	0.30	0.03
Inert gas – Argon (Ar)	0.90	0.94

Composition of soil air in different soils :-

Air	Nitrogen	Oxygen	Carbon dioxide
Atmospheric air	79	20.95	0.03
Soil air	79 – 80	18 – 20	0.15 – 2.00
Sandy soil air	79 – 80	19.95	0.30
Loamy soil air	79 – 80	19.20	0.62
Clayey soil air	79 – 80	19.69	0.66
Manured soil air	79 – 80	18.23	1.85
Compost heap	79 – 80	13.98	6.72

Soil as a tremendous biological laboratory :-

(a.) Representative mineral soil harbers a number of living organisms including animal and plants which comprise the life of soil.

(b.) Total weight of living matter (including plants roots, in an acre –furrow slice) varies from 02 to 10 which may be sufficient to influence physical and chemical nature of soil.

(c.) Approximately number of different type of organisms found in one gram of soil are :

S. No.	Organisms name	Number of organisms (one gram of soil)
1.	Bacteria	10^9
2.	Actinomycetes	10^7
3.	Fungi	10^6
4.	Algae	10^5
5.	Protozoa	10^6
6.	Earthworm	10^6 (per acre per inch of soil)

(d.) Soil organisms like insects and earthworms disintegrate plant residues physically while smaller organisms like bacteria, fungi and Actinomycetes complete the decomposition process. These decay processes release the plant nutrients like N, P and S.

(e.) Humus, the most useful biochemical product, is the result of microbial activity.

Clay and Humus as the seats of soil activity :-

(a.) Clay and Humus exist in colloidal state.

(b.) They have larger surface area per unit weight and hence

- Cations and anions are highly adsorbed.
- Leaching losses are reduced.
- Chemical and physical properties are controlled.

(c.) Humus colloids have greater nutrients and water holding capacity than clay.

(d.) Clay present in larger amounts in soil contributes equally or more to humus in relation to physical and chemical properties of soil.

- **Geology :** Geology was coined from the Greek words "Ge" meaning the earth and "logos" meaning a discourse of reasoning. It is the science which tells about the history of earth from the records of associated rocky materials and their imbedded remnants of plants and animals.

Importance of Geology in agriculture : Geology is important to agriculture because it studies about the –

i. Formation and composition of rocks and minerals from which soils are formed.
ii. Agencies responsible for the decomposition of rocks and minerals and formation of soil.

- **Composition of earth as a whole :** The earth is compared of three spheres

1. Atmosphere :

- Contributes about 0.03% by weight of earth and extends from 75 to 325 kiolmeters surrounding the planet.
- It exerts the pressure of 14.75 lbs/square inch at the sea level.
- It comprises a mixture of large number of gases, the dominant ones being nitrogen (N) and oxygen (O_2).

2. Hydrosphere : Refers to oceans which cover nearly ¾ of the earth surface. It contributes about 6.9% by weight of earth.

3. Lithosphere :

- **Outer surface or land –** Outer surface or the land consists of various continents and islands of the world. It comprises of mountains, valleys and plains.
- **Earth crust –** Upper solid layer of the earth's mass is known as earth crust. It is considered as the chief materials for geological investigation.
- **Nucleus or inner part –** It is extremely hot and more or less in liquid stage. It is supposed to be heavier than the earth crust.

- **Elemental composition of earth's crust (per cent by weight):- (**Fig 2)

The earth's crust is principally composed of mineral matter. This mineral matter is made up of various elements either single or combined together to form compounds. Almost all the elements known to us, except the inert gases, are present in the earth's crust. Each element is in combination with one or more elements to form a definite chemical compound known as mineral. Many of these minerals in turn combine together to form aggregates, which we know as rocks. Almost all the mineral matter is present in the form of rocks in the earth's crust. Thus, rocks are composed of elements, which in turn are made up of atoms. Out of 115 elements known, 8 are sufficiently abundant as to constitute about 99% by weight of the Earth's Crust (up to 16 km).

Elemental composition of Earth's crust (% by weight) is as under:

Element	Ionic form	Atomic weight	% by weight	
Oxygen (O)	O_2^-	16.00	46.60	**Non – metallic 74.32% (¾th)**
Silicon (Si)	Si^{4+}	28.06	27.72	
Aluminium (Al)	Al^{3+}	26.97	8.13	**Metallic 25.68% (¼th)**
Iron (Fe)	Fe^{2+}	55.85	5.00	
Calcium (Ca)	Ca^{2+}	40.08	3.63	
Sodium (Na)	Na^+	22.99	2.83	
Potassium (K)	K^+	39.09	2.59	
Magnesium (Mg)	Mg^{2+}	24.32	2.09	
Other metallic ions	-	-	1.41	
		Total :-	**100.00**	

Elemental composition of other metallic ions in the Earth's crust (% by weight) is as under:

Element	Ionic form	Atomic weight	% by weight	
Titanium (Ti)	Ti^+	47.90	0.62	**Other Metallic ions 1.41%**
Hydrogen (H)	H^+	1.00	0.14	
Phosphorus (P)	PO_4^{3-}	30.98	0.12	
Carbon (C)	$C^{4\pm}$	12.01	0.09	
Manganese (Mn)	Mn^{2+}	54.93	0.09	
Sulphur (S)	SO_4^{2-}	32.06	0.06	
Chlorine (Cl)	Cl^-	35.45	0.05	
Barium (Ba)	Ba^{2+}	137.36	0.04	
Fluorine (F)	F^-	19.00	0.03	
Strontium (Sr)	Sr^{2+}	87.63	0.02	
Bromine (Br)	Br^-	79.91	Traces	
Nitrogen (N)	NO_3^-	14.00	Traces	

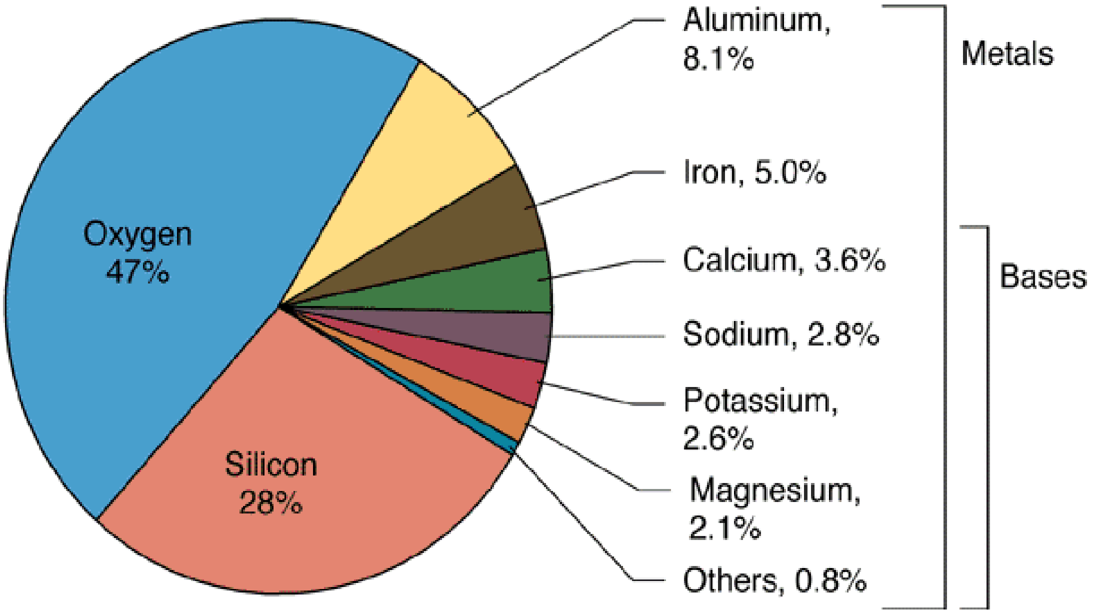
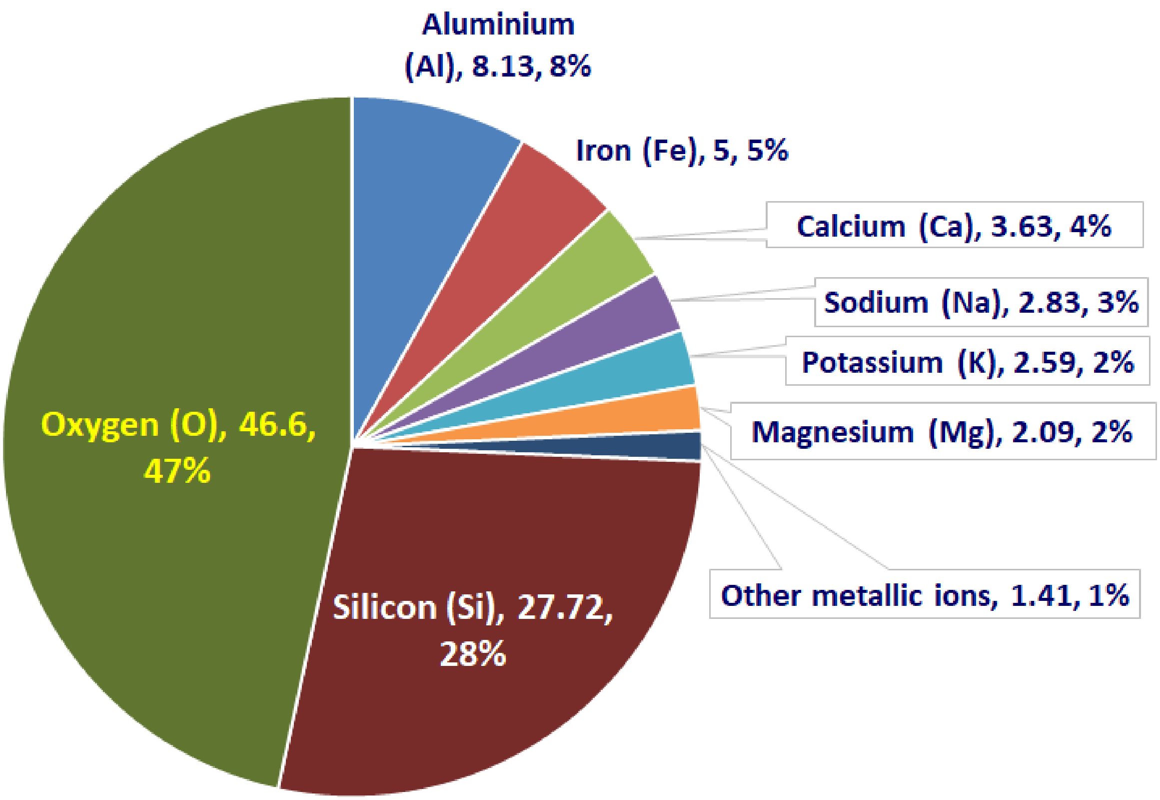


Fig 2 :Elemental composition of earth crust



CHAPTER – IV

SOIL GENESIS: SOIL FORMING ROCKS AND MINERALS

Soil Genesis :-

This is the phase of soil science includes the study of soil forming factor and soil forming process.

Or

"It studies about development of soil from the geological material eg. Rocks, mineral, granite, basalt".

The materials of the earth's crust consists mainly two categories :

1. Rocks
2. Minerals

Rocks

Rocks are the mixture of two or more minerals and hence vary in their physical and chemical properties.

Definition of rock*:* A naturally occurring hard mass of mineral matter formed after the solidification of molten magma comprising of two or more rock forming minerals *e.g.* granite, basalt, and gneiss. But some may be monomineralic *e.g.* olivine, and dunite.

Petrology – It is the branch of science which study about rocks.

Petrography – which gives information about the description of rocks.

Petrogenesis – which deals with study of the origin of rocks.

Classification of rocks :- Rocks are mainly three types.

1. Igneous rocks
2. Sedimentary rocks
3. Metamorphic rocks

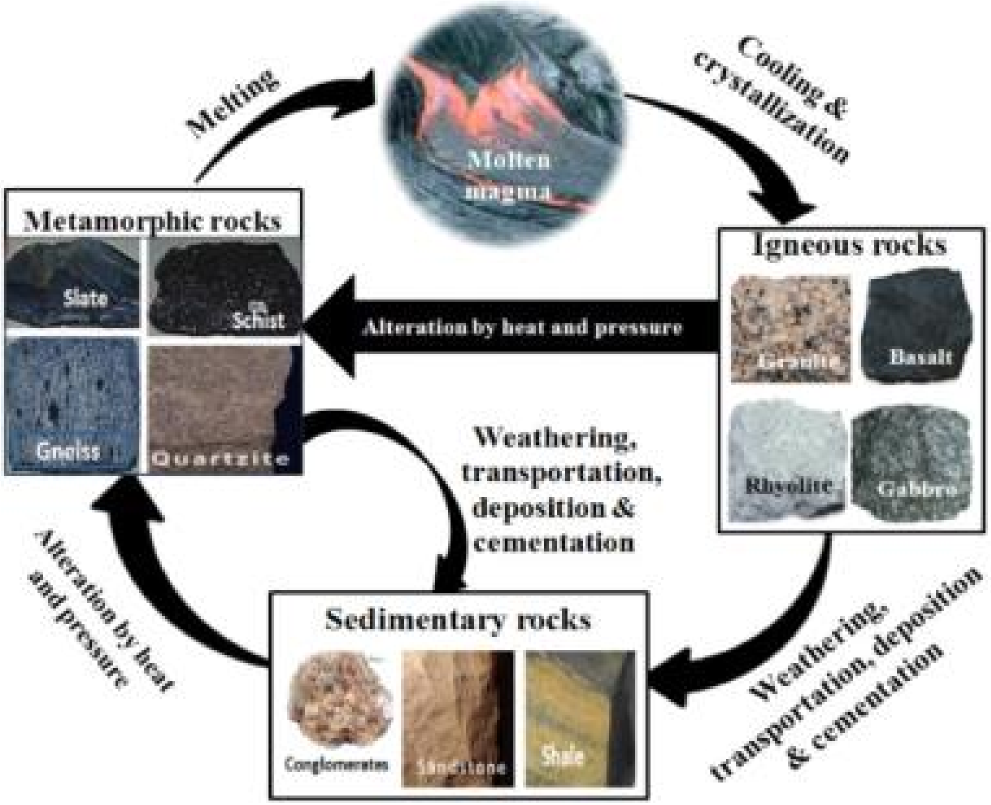
Composition of rocks :- The composition of the upper five kilo meter (5 km) of earth's crust is as follows –

A. Sedimentary Rocks (74%) :-	1. Shales	:	52%
	2. Sand Stones	:	15%
	3. Lime Stone & Dolomite	:	07%
B. Igneous Rocks (18%):-	1. Granite	:	15%
	2. Basalt	:	03%
C. Other Rocks (08%) :-	Other	:	08%

Earth crust as whole :- The composition of earth's crust as a whole differs significantly from the one described above and comprised of the following:

1. Igneous rocks : 95%
2. Sedimentary rocks*: 05% (Shales – 4%, Sandstone – 0.75% & Lime stone – 0.5%)

*Although sedimentary rocks form only 5% of the total earth crust, yet they are important as they occur to the extent of 74% (almost 3/4th) at or near the surface of the earth (upper 5 km). Igneous rocks are dominant in deeper layers.



(I.) Igneous rocks :- Igneous rocks are formed by the cooling and crystallization (solidification) of molten material, magma (beneath) from the interior of the earth. They are characterized by non-foliated or non-flattened, massive and crystalline structure. They are a source of parent material for other rocks and for soils.

Classification of igneous rocks –

A. Based on the origin (considering depth) :-

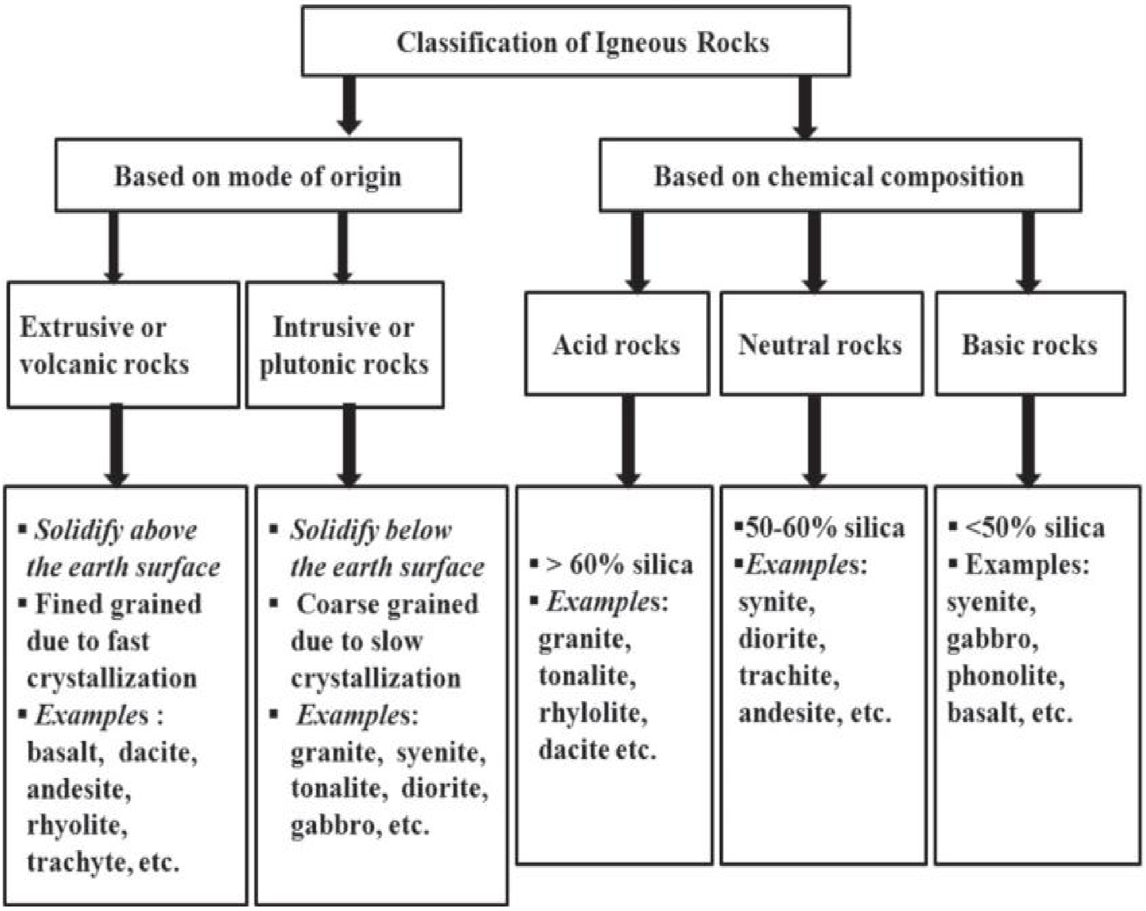
(i.) Plutonic – When magma solidifies at a greater depth

(ii.) Intrusive – When magma solidifies at a moderate depth

(iii.) Extrusive – When magma solidifies at the earth surface

B. Based on chemical composition (considering silica content) :-

Nature	**Per cent of silica (SiO_2)**	**Example**
Basic rocks	40 – 55%	Gabbro, Basalt, Lime stone, Marble & Diabase
Neutral rocks (intermediate)	55 – 60%	Diorite (Sub basic)
	60 – 65%	Syenite (Sub acid)
Acid rocks	> 65%	Granite, Rhyolite, Sandstone, Gneiss etc.



(II.) Sedimentary rocks :- It is derived from the igneous rocks. Sedimentary rocks have been formed by the consolidation of sediments. The sediments are transported to new places through the action of wind or water and deposited in new arrangements and cemented to form secondary rocks. Also known as stratified rock. They are formed through four stages i.e. 1. Weathering, 2. Transportation, 3. Deposition and 4. Digenesis

a) Weathering: Physical, chemical and biological weathering of primary rocks give rise to quartz, secondary minerals and soluble substances (Ca, Mg, Fe, and salts)

b) Transportation: Transportation of weathered material by water, wind, glaciers and runoff.

c) Deposition or sedimentation: Transported sediments settled to form graded bedding**.** The coarse particles settle first followed by finer particles down the stream.

d) Diagenesis: Transformation of unconsolidated sediments to rock with compaction and cementation processes.

- Mechanical sediments are known as clastic.
- Sedimentary rocks formed through chemical reactions.

S. No.	Sedimentary rocks	Dominant minerals	Properties
1.	Lime stone	Calcite ($CaCO_3$)	Light to grey, flour like, fine grained effervesance readily.
2.	Dolomite	Dolomite Ca Mg $(CO_3)_2$	Effervesance only with hot HCl
3.	Conglomerate*	Varies	-
4.	Calcareous sandstone	-	-
5.	Arenaceous sandstone	-	-
6.	Sandstone	Quartz (SiO_2)	Light coloured & porous structure
7.	Siltstone	-	-
8.	Shale	Clay	Light to dark, laminated.

* **Conglomerate –** Small sized stones or various mineralogical make up adhered to one structure are known as Conglomerate.

Classification of sedimentary rocks

- Transported and Fragmented (Mechanically) deposited
  - Arenaceous or sandy
    - Loose (Sand & Gravel)
    - Consolidated (Sandstone)
  - Argillanceous or clayey
    - Loose (Kaoline, Pipe clay, Fire clay)
    - Consolidated (Madstone, Shales, Laterites)
- Transported in solution & precipitated (Chemically formed)
  - Inorganically
    - Loss of CO_2 or insoluble in sea water (Calcareous rocks, Lime stones, Stalactites, Stalagmite, Chalk, Dolomite)
    - Evaporation (Rock salt, Gypsum, Halite)
  - Organically
    - Formed due to accumulation and partial decomposition of organic remains under anaerobic conditions Ex. Lignite and Anthracite

(III.) Metamorphic rocks :- Metamorphic rocks have been formed due to subsequent transformation of igneous and sedimentary rocks under the influence of heat, pressure and chemically active liquids and gases. Change may occur in mineral composition or texture or both. The structure and mineral composition of metamorphic rocks depend upon the composition of the original rock and the kind of metamorphism There are three broad classes of metamorphic rocks :-

- Thermal : Changes bring about by the dominant factor heat.
- Dynamo thermal : Changes by the combined effect of pressure and heat.
- Hydro metamorphosis : Changes due to water.

S. No.	Rock	Mineral composition	Description
1.	Gneiss	Formed from granite (Igneous)	A crystalline rock, with a banded appearance. Alternating light and dark colours, banded and foliated. Feldspar, quartz, mica, biotite and muscovite are dominant minerals
2.	Schist	Formed from basalt or shale (Sedimentary)	As original rock, A finely-foliated or laminated rock. Mica and chlorite are dominant minerals.
3.	Quartzite	Formed from sand stone (Sedimentary)	Light or brown, compact and uniform texture, foliated structure. It is resistance to disintegration and decomposition and hence stony in unfertile soils are development.
4.	Slate	Formed from shale (Sedimentary)	Grey to black, compact and uniform texture. A very finely-foliated rocks with mineral particles too small to be seen. It splits into thin smooth sheets. Mica, quartz and chlorite are the dominant minerals in it.
5.	Marble	Formed from lime stone (Sedimentary)	Light red, green, black, compact fine to coarse texture Non foliated, crystalline rock. Calcite and dolomite are dominant minerals.

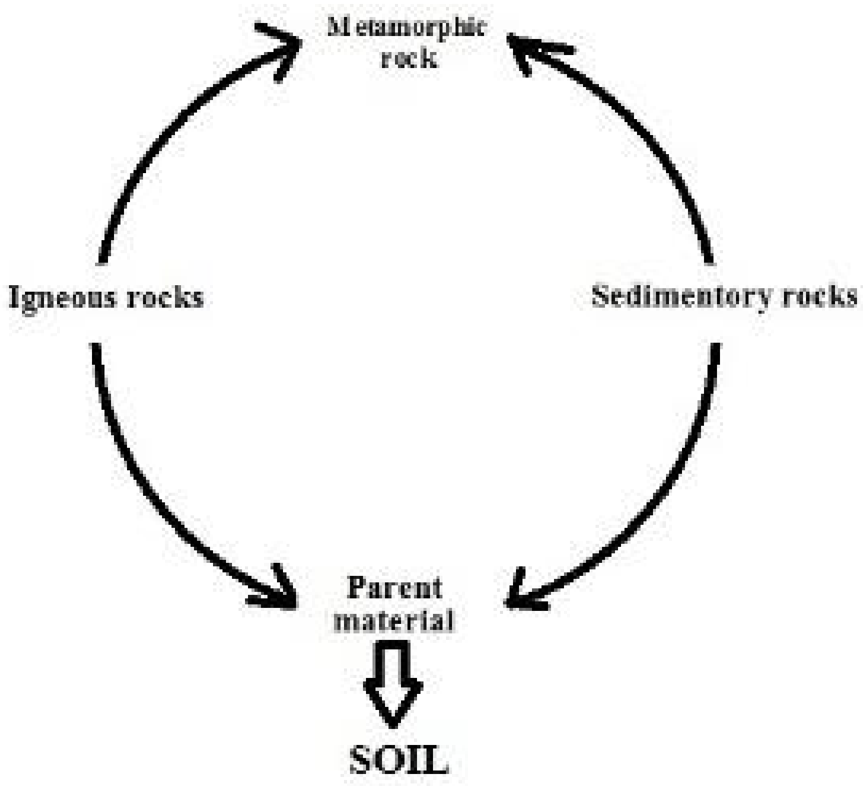
Pre-existing rocks and their equivalent metamorphic rocks :-

Original /Pre-existing rocks	Metamorphic rocks
Conglomerate, granite, syenite, gabbro, rhyolite, andesite	Gneiss
Basalt	Schist
Sandstone	Quartzite
Limestone and dolomite	Marble
Iron ores	Haematite- schist
Coal	Graphite
Shale	Slate

Average chemical composition (%) of important rocks :-

Rocks	**Igneous**	**Shales (Metamorphic)**	**Sand stones (Sedimentary)**	**Lime stones (Sedimentary)**
SiO_2	59.1	58.1	78.3	5.2
Al_2O_3	15.3	15.4	4.8	0.8
FeO & Fe_2O_3	6.9	6.5	1.5	0.5
MgO	3.5	2.4	1.2	7.9
CaO	5.1	3.1	5.2	42.3
Na_2O	3.8	1.3	0.5	0.1
K_2O	3.1	3.2	1.3	0.5
H_2O	1.2	5.8	1.6	0.8
TiO_2	1.1	0.7	0.3	0.1
CO_2	0.1	2.6	5.0	41.5
Others	0.8	0.9	0.3	0.5

❖ **Conversion of rocks to soil :-** The illustration figure shows the conversion of one type of rocks to other and also to the parent materials. Then the parent material gets converted ultimately to the soil.



Minerals

Minerals are naturally occurring solids with a definite chemical composition and physical features (crystal structure). OR "Solid substances composed of atoms having an orderly and regular arrangement". It is crystalline or non-crystalline. Minerals are transparent or non-transparent.

The study of minerals is called mineralogy. There are over 4,900 known mineral species; over 4,660 of these have been approved by the International Mineralogical Association (IMA). The minerals influence the release of structural ions and the chemical activity of exchangeable ions. Therefore, the mineralogical composition of soils has a strong relevance to soil fertility.

Minerals that are original components of rocks are called primary minerals. (feldspar, mica, etc.). Minerals that are formed from changes in primary minerals and rocks are called secondary minerals (clay minerals). Those minerals that are chief constituents of rocks are called as essential minerals (Feldspars, pyroxenes micas etc) and those which are present in small quantities, whose presence or absence will not alter the properties of rocks are called accessory minerals (tourmaline, magnetite etc).

S. No.	**Dominant group of minerals**	**%**	**Example**
1.	Feldspars	58	Orthoclase (K predominant), Plagioclase
2.	Amphiboles and Pyroxene	16	Ambhiboles (acidic) – hornblende, Olivine Pyroxenes (Basic) - Augite
3.	Quarts	13	Serpentine (most common) Garnet
4.	Mica	04	Muscovite (White mica) Biotite (Black mica)
5.	Accessory minerals	09	Zircon, Ilmenite, Apatite, Titanite, Pyrite, Magnetite, Rutile.

Formation of minerals :- Formation of minerals takes place due to the combination of elements. Such elemental combinations are governed by four basic principles.

1. Metals and non-metals combine with oxygen to form their oxides. It happens because

(i.) Oxygen in abundance and

(ii.) Metals and non-metals have greater affinity with oxygen.

$$2\,Ca + O_2 = 2CaO \text{ (Calcium oxide)}$$
(Calcium – Metal) = Base former

$$C + O_2 = CO_2$$
(Carbon – non-metal) = Acid former

2. In contact with water metallic oxides react with H_2O to form bases.

$$CaO + H_2O = Ca(OH)_2 \quad \text{(Calcium hydroxide – base)}$$

3. Non-metallic oxides combine with H_2O to form acid

$$CO_2 + H_2O = H_2CO_3 \quad \text{(Carbonic acid)}$$

4. Bases and acids came into contact and react with each other to form salts

$$\underset{\text{(Calcium hydroxide)}}{Ca(OH)_2} + \underset{\text{(Carbonic acid)}}{H_2CO_3} = \underset{\text{(Calcite)}}{CaCO_3} + 2H_2O$$

Base Acid = Salt + Water

Characteristics of minerals :-

Minerals are the natural substances which have definite chemical composition and exist as salts and oxides. Minerals can be described by various physical properties which relate to their chemical structure and composition. Minerals bear some physical properties also by which they can be identified in the field and always in the laboratory. Physical properties are Hardness, Specific gravity, Shape of crystal, Cleavage, Colour, Lustre, Streak, Tenacity, and Fracture. More specific tests for minerals include reaction to acid, magnetism, taste or smell, and radioactivity.

Out of these, hardness is one of the most fundamental physical property which is used to identify the mineral even in the field. Hardness is referred to the numbers from 01 to 10 for different minerals showing relative hardness :-

Minerals	**Relative / Hardness scale**	**Specificity of hardness**
Talk	1	Easily scratched with thumb nail.
Gypsum	2	Can be scratched with thumb nail.
Calcite	3	Not scratched by thumb nail but easily scratched with knife.
Fluorite	4	Can be scratched with a knife but less easily than calcite.
Apatite	5	Can be scratched with a knife but only with difficulties.
Feldspars	6	Cannot be scratched with a knife but can be scratched with quartz.
Quartz	7	Can scratch feldspars.
Topaz	8	Can scratch quartz.
Corundum	9	Can scratch topaz.
Diamond	10	Can scratch corundum.

Classification of minerals :-

Minerals are usually classified as primary or secondary. Such classification is made with reference to the origin or mode of formation only. It does not consider their compositions. Some minerals like quartz or mica either by primary or secondary. A brief classification of minerals along with their characteristics and examples are as under :

Primary minerals :-

- When the mineral is formed from the cooling and solidification/crystallization of molten magma / lava.
- These mineral are also known as original minerals.
- Their chemical composition is not changeable.
- Inherited from igneous and metamorphic rocks
- Formed at elevated temperature
- Percentage in soil depends on its sand and silt content.
- Oxygen and silicon together or with one or more cations are combined to form silicate minerals which are more than 90% in the earth crust.
- These are silicate minerals

S. No.	Primary Minerals	Chemical Formula
1.	Quartz	SiO_2
2.	Harnblende	$Ca_2Al_2Mg_2Fe_2Si_6O_{22}(OH)_2$
3.	Muscovite	$KAl_3Si_3O_{10}(OH)_2$
4.	Biotite	$K(Mg.Fe)_3Si_3O_{10}(OH)_2$
5.	Augite	$Ca_2(AlFe)_4(MgFe)_4Si_6O_{24}$
6.	Orthoclase (K-Feldspar)	$KAlSi_3O_8$
7.	Pyroxene	(NaCa)(Mg,Fe,Al)
8.	Amphiboles (Hornblende)	$Ca_2Mg_5H_2(SiO_3)_8$+ Fe,Al&Na
9.	Olivine	$(Mg, Fe)_2SiO_4$
10.	Microcline	$KAlSi_3O_3$
11.	Na plagioclase	Na $AlSi_3O_8$
12.	Ca plagioclase	Ca $Al_2Si_2O_8$

Secondary minerals :-

- They are obtaining from primary minerals due to chemical changes.
- Formed by weathering of primary minerals or inherited by soils from some sedimentary rocks.
- Most common is clay minerals.
- Other secondary minerals found in soils or arid and semi-arid (dry) regions are gypsum, calcite, apatite etc.

S. No.	Secondary Minerals	Chemical Formula
A.	**Silicate clay minerals :-**	
1.	Kaolinite	$Si_4Al_4O_{10}(OH)_8$
2.	Smectite (Vermiculite) Smectite (Montmorillonite)	$(Mg,Fe^{2+},Fe^{3+})_3[(Al,Si)_4O_{10}](OH)_2\cdot 4H_2O$
3.	Illite	$K_2Si_6Al_6O_{20}(OH)_4$
4.	Chlorite	$Si_8Mg_5(OH)_4O_{20}(OH)_2\ 4H_2O$
B.	**Non-silicate clay minerals :-**	
5.	Hematite	Fe_2O_3
6.	Gibbsite	$Al_2O_3\ 3H_2O$
7.	Goethite	$(FeO(OH)_nH_2O)$
8.	Calcite	$CaCO_3$
9.	Dolomite	$CaMg\ (CO_3)_2$
10.	Apatite	$Ca_5(PO_4)_3$ (Cl, F, OH)
11.	Gypsum	$(CaSO_4.2H_2O)$
12.	Limonite	$Fe_2O_3\ 3H_2O$
13.	Magnesite	$MgCO_3$
14.	Siderite	$FeCO_3$

Accessory minerals :-

- Occur only in small quantities in rocks but not essential.
- Form a group of heavy minerals due to their high specific gravity
- These are non-silicate minerals

S. No.	Accessory Minerals	Chemical Formula
1.	Zircon	$Zr(SiO_4)$
2.	Zeolite	Ca, Na and K silicates
3.	Pyrite	FeS_2
4.	Magnetite	Fe_3O_4
5.	Illemenite	$FeTiO_3$
6.	Barytes	$BaSO_4$
7.	Serpentine	$Mg_6(Si_4O_{10})(OH)_8$

Important rock forming minerals and their relative abundance in earth's crust are as under:

A. Primary Minerals

Ferromagnesian minerals :

i) Olivine, pyroxene, and amphiboles : 16.8 %

ii) Biotite and muscovite : 3.6 %

Non–ferromagnesian minerals :

iii) Feldspar (albite, anorthite, oligoclase) : 61.0 %

iv) Quartz : 11.6 %

B. Secondary clay minerals and others : 7.0 %

Mineral sources for plant nutrients :-

Nutrients	**Sources**
Nitrogen (N)	Organic matter
Phosphorus (P)	Apatite, Fe/Al phosphate
Potassium (K)	Micas, Feldspar, Orthoclase, Microcline
Calcium (Ca)	Anorthite (Primary mineral), Calcite
Magnesium (Mg)	Dolomite, Muscovite, Biotite, Olivine, Vermiculite, Glauconite, Brucite
Sulphur (S)	Gypsum, Pyrite
Zinc (Zn)	Sphalerite, Olivine, Hornblende
Manganese (Mn)	Pyrosulite
Iron (Fe)	Limonite, Hematite
Copper (Cu)	Chalcopyrite, Olivine, Augite, Biotite
Molybdenum (Mo)	Olivine
Boron (B)	Tourmaline
Chloride (Cl)	Apatite

CHAPTER – VI

Weathering : Definition and its Classification

Weathering may be defined as physical disintegration and chemical decomposition of rocks and minerals resulting in the formation of parent material under natural conditions. It is basically a combination of transformation and synthesis *or* the process of disintegration and decomposition of rocks and minerals which are brought by physical, chemical and biological weathering, leading to formation of parent material or regolith.

Weathering is influenced by the (a) climate (b) type of vegetation (c) slope (d) structure and (e) composition of rocks.

Weathering is considered as of three types :-

A. Physical weathering (Disintegration)

B. Chemical weathering (Decomposition)

C. Biological weathering

A. Physical weathering (Disintegration)

Physical weathering is a mechanical process which causes disintegration of consolidated rocks without any chemical changes. It is reduction of a large size rocks to number of smaller size particle. The agents responsible for physical weathering are :

1. **Temperature :-** Variation in temperature greatly effects the rocks and minerals. As a result of diurnal temperature changes the rocks get heated during the day and cooled during the night. Heating and cooling of rocks results in differential expansion and contraction of minerals.

   As the temperature rises during summer and down during the winter. These changes in temperature in day and night causes physical disintegration particularly in tropical areas. As the rocks are poor conduction of heat the differential heating and cooling tends to set up a lateral stress which may causes the surface layer to soil known as Exfoliation (Breaking of rocks due to alternate heating and cooling is termed as Exfoliation). Heterogeneous rocks are easily disintegrated due to temperature.

2. **Water (Action of running water) :-** The rain water falls on the land and travels towards the low lying areas such as rivers, lakes and oceans, continuously detaching, and shifting, sorting and reworking the sediments that it carries. When loaded with sediments (sand, silt, clay, gravels and even the bolder) flowing water has a tremendous cutting power, resulting in the formation of gorges, ravines and valleys.

3. **Ice (Action of freezing water) :-** The moving ice is an detachment and transporting agency of tremendous capacity. Snow received at higher elevations or polar regions accumulates and starts moving in the form of glaciers. During their movement, glaciers cause great deal of cutting and crushing of the bedrocks. Although glaciers are not so extensive in the present day environments in the recent geological past, they had transported and deposited parent materials over millions of hectares on this planet. At present, glacier are active in upper parts of the Himalayas.
4. **Wind :-** Wind, an important agent of transportation of suspended particles, also exerts an abrasive action. Generally, the effect of wind is more pronounced during arid climate. Wind removes the small broken pieces of rocks from the tap and exposes the unmeasured for further physical weathering or disintegration.

B. Chemical weathering (Decomposition)

Chemical weathering (Decomposition) is a process of decomposition of rocks and minerals where some new products are formed. The process of chemical weathering may be defined as the transformation of original rocks and minerals into new compound having different chemical composition and physical properties. It is greatly influenced by the presence of water and exposed surface area, the greater the surface area per unit volume of soil available for reaction. It is the most important process so for as soil formation is concerned.

Feldspar + Water = Clay mineral + Soluble Cations & Anions

According to Jackson and Sherman (1953) :- Chemical weathering is two types.

1. Geochemical weathering – Which take place below the soil solum (in 'C' horizon)
2. Pedochemical weathering – in A+B horizons

1. **Geochemical weathering –** Which take place below the soil solum (in 'C' horizon). It is affected by following agents.
   (i.) Solution :- Water is universal solvent and hence influence chemical weathering. Solubility of some salts present in soil as follows –

Salts	**Highly soluble**	**Slightly to moderately soluble**	**Extremely lass soluble**
Nitrate	All	–	–
Chloride	All	–	–
Sulphate	Some	Some	–
Carbonate	K & Na	Ca, Mg, Mn, Fe	–
Bicarbonate	K & Na	Ca, Mg, Mn, Fe	–
Silicate	–	Natural silicates	–
Hydroxide	K & Na	Mg	Fe, Al, Ti

$$2KAl_2Si_3O_8 + 3H_2O = Al_2(OH)_4\,Si_2O_5 + 4SiO_2 + 2\,KOH$$
(Orthoclase) = (Kaolinite) + (Quartz)

(ii.) Carbonation :- Addition of CO_2, When CO_2 added in H_2O, it makes carbonic acid and it is a weak acid. Carbonic acid is very important agent of chemical weathering water charged with carbonic acid becomes strong solubilizer of rocks and minerals.

$$2KAl_2Si_3O_8 + H_2CO_3 + H_2O = Al_2(OH)_4\,Si_2O_5 + 4SiO_2 + K_2CO_3$$
(Orthoclase) = (Kaolinite) + (Quartz)

$$H_2O + CO_2 = H_2CO_3$$
$$CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$$
Calcite Carbonic acid Calcium bi carbonate
(Slightly soluble) (Readily soluble)

(iii.) Hydration (Addition of water into compound):- Hydration refers to the chemical weathering of water molecules with a particular mineral (large number of minerals like feldspar, amphiboles, mica and pyroxenes become hydrated forming hydrous compounds).

$$Fe_2O_3 + 3HOH = Fe_2O_3 * 3H_2O$$
(Hematite – Red) (Limonite – Yellow)
$$CaSO_4 + 2HOH = CaSO_4 * 2H_2O$$

(iv.) Hydrolysis (Decomposition of water molecules) ;- Hydrolysis depends upon the dissociation of water into H^+ and OH^-. It is a double decomposition process.

$$KAl_2Si_3O_8 + H+ OH- = HAlSi_3O_8 + KOH$$
(Orthoclase) (Acid silicate clay)

(v.) Oxidation :- Oxidation is the process of addition of O_2 to various minerals. It is more active in presence of water. Minerals containing Fe, Mn and S are easily oxidized.

$$4FeO + O_2 = 2Fe_2O_3$$
(Ferrous oxide) (Ferric oxide – Hematite)

(vi.) Reduction (Addition of hydrogen) :- Reduction is the process of removal of oxygen from minerals. Under condition of water logging (Anaerobic), the reduction process takes place.

$$4FeO + O_2 = 2Fe_2O_3$$
$$2Fe_2O_3 + 4H_2S = 4FeS + 4H_2O + O_2$$
(Hematite) (Hydrogen sulphide) (Ferrous sulphide)

2. **Pedochemical weathering –** It is the disintegration of and chemical modification of minerals taking place within the soil solum (A+B horizons).

(i.) Oxidation – Reduction cycle :- Alternation between reducing and oxidizing conditions is responsible for the release of Fe and Mn from primary minerals localization into mottles and concretions in the soil solum. Alternation between strong reducing and oxidizing conditions in poorly drained soils, especially those of costal low land areas. (this process consist of replacement of exchangeable Al^{3+} by exchangeable Fe^{2+} on reducing conditions and return oxidation condition this exchangeable Fe^{2+} ion is displaced and Al^{3+} appear in exchange sites.

This appearance of Al^{3+} causes some destruction and disintegration of silicate clay structure.

$$\boxed{\text{Clay}}\ Al^{+++} \underset{\textbf{Reduction}}{\overset{\textbf{Oxidation}}{\rightleftharpoons}} Fe^{++}\ \boxed{\text{Clay}}$$

(ii.) Shuttling of Al from clay lattices to hydrous oxides (on exchangeable site) :- Pedochemical weathering is responsible for destruction of clay (eg. Montmorillonite) in the solum. Under some conditions i.e. if soil clays are initially saturated with exchangeable Ca^{++} and Mg^{++} and these are displaced by H^{+} in acid weathering. The H^{+} causes in stability brining out Al^{+++} from the clay lattice, with subsequent disintegration of part of the lattice. Hydrolysis of this Al^{3+} results in additional H^{+} ions which cause further weathering of the clay. This process is apparently responsible for the decomposition of montmorillonite.

(iii.) Potassium removal from micas :- Removal of a small to moderate amount of K^{+} from the interlayer of the mica does not cause or great distortion of the silica – alumina packets. Removal of > 50% of the interlayer K, sheet alignment is lost and strain and distortion of the lattice takes place. Therefore, added K is not easily fixed and the remaining interlayer K become available with complete removal of K from interlayer – vermiculite, montmorillonite clay minerals types are produced.

(iv.) Aluminium interlayering of 2:1 clay minerals :- As important pedogenic mineral modification in acid soils is the precipitation of islands of hydroxy – Al in interlayer space of vermiculite and to a layer extant in montmorillonite clay. The Al-interlayered clay is referred to as "2:1 – 2:2 integrade". As a result the CEC of the clay is partially blocked and neutralized. This interlayer Al^{3+} contributes to acidity.

3. Biological weathering

Biological weathering is a change brought by living agents (humans and animals, higher plants and their roots and micro-organisms) which is mainly controlled by prevailing environment and are responsible for both physical and chemical changes. Soil is natural body could not formed by products of physical and chemical weathering, it was important to act on this material by biological agents like microbes, earthworm etc to change its morphological features. Biological factors work along with chemical and physical factors in braking down the rocks and minerals.

(i) **Microorganisms:** – At the very initial stage of mineral decomposition and soil formation, the lower forms of plant and animals like bacteria, fungi, actinomycetes etc play an important role. These organisms act upon the decay of plants and animal remains and produce appreciable amounts of sulphuric, nitric and some organic acids. These acids increase the chemical weathering by solution. Higher plants excrete carbonic acid through their roots which also aid in the decomposition of rocks and minerals.

(ii) **Man and animals :-** The action of human being in the disintegration of rocks is well recognized as he cuts the rocks to build dams, channels, roads and buildings etc. Due to such activities of man, the bigger size rocks are converted into smaller ones and thereby increased the surface area of rocks which favours the chemical weathering process leading to decomposition of rocks and minerals. The role of animals is somewhat similar to man, large number of birds, insects and worms etc live in the rocks and by their activities, they make holes into rocks and thus help in weathering.

(iii) **Higher plants and their roots :-** The roots of trees and other plants penetrate into the joints and crevices of rocks. Due to growth and development of those trees, the roots exert a tremendous pressure because of its development and the massive and hard rock may be broken into smaller ones. During roots respiration CO_2 produce and that also take part in weathering process.

CHAPTER – VII

FACTOR OF SOIL FORMATION

Introduction :-

Soil is a product of combined interaction of soil forming factors and soil forming processes. Soil forming factors influence the properties of soil but direct relation between them are very difficult to derive as all factors act simultaneously to form a soil. Dokuchaev (1889) was the first to show that soil forms a definite pattern on the landscape and establish that they develop distinct horizons under the influence of parent material, climate and organism which he put as: S=f (p,cl,o). Later on Jenny (1941) added two more factors i.e. relief and time. He stated that all five soil forming factors act simultaneously at one point on the surface to produce soil are: climate, biosphere, relief or topography, parent material and time. These are further classified into two groups i.e. active and passive soil forming factors by J.S. Joffe (1949).

According to Dokuchaiev (1889) :- Soils develop as a result of the action of soil forming factors.

S = f (cl, o, p)

Where : S	-	Soil formation
cl	-	Climate
o	-	Organisms
p	-	Parent Material

According to Janny (1941) :- Soil properties is determined by the relative influence by the following factors.

S = f (cl, o, r, p, t)

Where : S	-	Soil formation
cl	-	Climate
o	-	Organisms or b – biosphere
r	-	Relief / Topography
p	-	Parent Material
t	-	Time / Age of land

Janny (1941) gave soil sequences or equation :-

1. Climo sequence - S = f (cl) (o, r, p, t)
2. Bio sequence - S = f (o) (cl, r, p, t)
3. Topo sequence - S = f (r) (cl, o, p, t)
4. Litho sequence - S = f (p) (cl, o, r, t)
5. Chromo sequence - S = f (t) (cl, o, r, p)

According to Joffee (1949) :- Transformation of parent material or weathered rocks and material into soil by different pedogenic factor is known as ***soil formation***. It is a continuous process. Joffe divided the factors of soil formation into mass and energy.

Pedogenic factor : 1. Active 2. Passive

A. Active factor (Energy) :

1. Climate (cl)	–	i.	Rainfall
		ii.	Temperature
		iii.	Wind
		iv.	Haridity or Evaporation
2. Biosphere or Organism & Vegetation (o)	–	i.	Flora - Plant
		ii.	Fauna - Animal

B. Passive factor (Mass) :

3. Parent material (p)	–	i.	Physical aspect
		ii.	Chemical aspect
4. Relief / Topography (r)	–	i.	Elevation
		ii.	Slope
		iii.	Topography
5. Time / Age of land (t)	–	i.	Recent : 10^1 year
		ii.	Mature : 10^3 year
		iii.	Senite : 10^5 year

A. Active Soil Forming Factors

The active soil forming factors are those which supply energy that acts on the mass for the purpose of soil formation. These factors are climate and vegetation (biosphere).

1. Climate :- Climate is the most significant factor controlling the type and rate of soil formation. The dominant climates recognized are:

- **Arid climate:** The precipitation here is far less than the water-need. Hence the soils remain dry for most of the time in a year.
- **Humid climate:** The precipitation here is much more than the water need. The excess water results in leaching of salt and bases followed by translocation of clay colloids.
- **Oceanic climate:** Moderate seasonal variation of rainfall and temperature.
- **Mediterranean climate:** The moderate precipitation. Winters and summers are dry and hot.
- **Continental climate:** Warm summers and extremely cool or cold winters.
- **Temperate climate:** Cold humid conditions with warm summers.
- **Tropical and subtropical climate:** Warm to hot humid with isothermal conditions in the tropical zone.

Climate affects the soil formation directly and indirectly.

Directly, climate affects the soil formation by supplying water and heat to react with parent material. Indirectly, it determines the fauna and flora activities which furnish a source of energy in the form of organic matter. This energy acts on the rocks and minerals in the form of acids, and salts are released. The indirect effects of climate on soil formation are most clearly seen in the relationship of soils to vegetation.

Precipitation and temperature are the two major climatic elements which contribute most to soil formation.

Precipitation

Precipitation is the most important among the climatic factors. As it percolates and moves from one part of the parent material to another. It carries with it substances in solution as well as in suspension. The substances so carried are re deposited in another part or completely removed from the material through percolation when the soil moisture at the surface evaporates causing an upward movement of water. The soluble substances move with it and are translocated to the upper layer. Thus rainfall brings about a redistribution of substances both soluble as well as in suspension in soil body.

Temperature

- Temperature is second important factor of climate as it influences the chemical reactions involved in soil formation.
- High temperature hinders the process of leaching and causes an upward movement of soluble salts.
- High temperature favors rapid decomposition of organic matter and increase microbial activities in soil while low temperatures induce leaching by reducing evaporation and there by favour the accumulation of organic matter by slowing down the process of decomposition. Temperature thus controls the rate of chemical and biological reactions taking place in the parent material.
- According to van't Hoff law "with every 10 °C rise in temperature, the speed of chemical reaction increases by a factor of two or three. This process applies to weathering of minerals which release soluble components and thus help in soil development. For example,
    - Warm and humid climate of tropical regions – weathering of rocks from few metres to 30-40 m
    - Cold temperate region –weathering of rocks from few cm to 1 m.
    - Cold and humid region – rate of organic matter decay is very slow.
    - Arid region – low content of organic matter, nitrogen and clay in soils

2. Biosphere or Organism and Vegetation
Organism

- The active components of soil ecosystem are plants, animals, microorganisms and man.
- The role of microorganisms in soil formation is related to the humification and mineralization of vegetation.
- Macro-organisms such as rodents, moles, snails, earthworms, termites, millipedes, centipedes etc., owing to their burrowing habit, cause mixing of soil material. By doing so they retard the differentiation of soil horizons and as a consequence retard the process of soil development.
- Microorganisms such as bacteria, fungi, actinomycetes, protozoa and nematodes inhabit in large numbers in soil and play an important role in the decomposition of organic matter and indirectly it also helps in decomposition of mineral matters through production of organic acids. Rapid decomposition of soil materials (mineral and organic) helps in movement and deposition of these constituents in different layers, leading to the development of soil.
- The action of animals especially burrowing animals to dig and mix-up the soil mass and thus disturb the parent material
- Man influences the soil formation through his manipulation of natural vegetation, agricultural practices etc.
- Compaction by traffic of man and animals decrease the rate of water infiltration into the soil and thereby increase the rate of runoff and erosion.

Vegetation

- The roots of the plants penetrate into the parent material and act both mechanically and chemically.
- They facilitate percolation and drainage and bring about greater dissolution of minerals through the action of CO_2 and acidic substances secreted by them.
- Forests – reduces temperature, increases humidity, reduce evaporation and increases precipitation.
- Grasses reduce runoff and result greater penetration of water in to the parent material.
- Vegetation is an active factor of soil formation which constitutes second component of soil solid *i.e.* organic matter. It is a source of food for soil organisms and is one of the most important indicator of soil health.
- Decomposition of organic matter produces soluble organic acids which help in breakdown of the minerals present in parent rock, resulting in the release of essential plant nutrients. It also influences soil properties by way of improving water and nutrient holding capacity, colloidal properties of soil and reducing tendency of crust formation and soil erosion by wind & water.

Passive Soil forming factors

The passive soil forming factors are those which represent the source of soil forming mass and conditions affecting it. These provide a base on which the active soil forming factors work or act for the development of soil.

3. Parent Material :- It is that mass (consolidated material) from which the soil has formed. It is the unconsolidated material and more or less chemically weathered mineral material from which the soils are formed. It is initial portion of soil. It may be defined as a loose unconsolidated mass of mineral matter formed upon the weathering of rocks which serves as the raw material of soil formation.

Rocks & minerals $\xrightarrow{\text{Weathering}}$ Parent Material $\xrightarrow{\text{Soil forming factor}}$ Soil profile

There are three groups of parent material -

I. Transported :- The parent material transported from their place of origin. They are named according to the main force responsible for the transport and redeposition.

- by gravity – Colluvium (It is the poorly sorted materials near the base of strong slopes transported by the action of gravity).
- by water – Alluvium (River/Stream deposits) – The material transported and deposited by water is, found along major stream courses at the bottom of slopes of mountains and along small streams flowing out of drainage basins. Ocean (marine deposits), Lacustrine (Consists of materials that have settled out of the quiet water of lakes) and Delta (deposits at mouth of sea).
- by ice – Moaine (Glacial lake) – Consists of all the materials picked up, mixed, disintegrated, transported and deposited through the action of glacial ice or of water resulting primarily from melting of glaciers. Till plan & Outwash plain
- by wind – Aeolian (deposition of sand size) and Loess (deposition of silt size)

II. Residual parent material (Sedentary) :- Formed in original place. It is the residual parent material. The parent material differ as widely as the rocks.

- Igneous – Granite, Basalt & Rhyolite.
- Sedimentory – Lime stone, sand stone and shales.
- Metamorphic – Gneiss, Schist, Marble, Slate.

III. Biological parent material (Cumulose) :-

- Fibric (mass peats) – Least decomposed leaves
- Folic (shrub/leaf mould) – Partially decomposed leaves.
- Sepric (mixed mucks) – Highly decomposed leaves.

4. **Relief or Topography :-** The relief and topography sometimes are used as synonymous terms. They denote the configuration of the land surface. The topography refers to the differences in elevation of the land surface on a broad scale. The prominent types of topography designations, as given in FAO Guidelines (1990) are :

Land surface with slopes of

• Flat to Almost flat	:	0 – 2 %
• Gently undulating	:	2 - 5 %
• Undulating	:	5 – 10 %
• Rolling	:	10 – 15 %
• Hilly	:	15 –3 0 %
• Steeply dissect	:	> 30 % with moderate range of elevation (<300 m)
• Mountainous	:	> 30% with great range of elevation (>300 m)

Soil organic matter and clay move in the form of suspension with flowing water from uplands and get deposited in the low lends, thus affecting the soil formation. Generally low lend soils are darker in colour, higher in pH, EC, clay and organic matter content. Soil formation is very poor on steep slopes due to erosion and the gently sloping flat land is ideal for soil development. Due to higher rate of water percolation and leaching of soil constituents on flat lands, horizon differentiation is rapid and depth of soil is more as compared to upland and lowland positions. In lowland depressions, water is available but percolation is very poor due to deposition of clay and organic matter particles which clog the soil pores. Thus, soil development is very poor.

The term 'Catena' was introduced by G. Miline (1935), for a sequence of topographically related soils which have comparable parent material, climate and age but show different soil characteristics because of the variation in relief.

5. **Time :-** Soil formation is a very slow process requiring thousands of years to develop a mature pedon. The period taken by a given soil from the stage of weathered rock (i.e. regolith) up to the stage of maturity is considered as time. The matured soils mean the soils with fully developed horizons (A, B, C). It takes hundreds of years to develop an inch of soil. The time that nature devotes to the formation of soils is termed as Pedologic Time. It has been observed that rocks and minerals disintegrate and/or decompose at different rates; the coarse particles of limestone are more resistant to disintegration than those of sandstone. However, in general, limestone decomposes more readily than sandstone (by chemical weathering).

Rate of soil development (aging) varies among the soils. The warm humid climate, flat to gently sloping topography, sandy parent materials are favourable for soil formation, whereas, cold and arid climate, clayey parent material, steep slope, flood plains and activities of burrowing animals retard the pace of soil profile development.

Chapter VIII
Soil Forming Process

Soil forming process is distinct by the way it works and not by the kind of soil farm. The meaning is the activity of the soil forming factor. The pedogenic processes are extremely complex and dynamic, involving many chemical and biological reactions and different processes or combination of processes operate under the influence of soil forming factors.

According to R.W. Simonson (1959) :- He gave a criteria about the soil forming process have two steps involves i.e. (a) accumulation of parent materials and (b) Differentiation or alteration of horizons. According to him the four basic pedogenic processes are involved in soil formation.

Basic pedogenic processes :-

1. **Addition or gains :** Addition of water, organic and mineral matter to the soil through enrichment, cumulization, melanisation and littering etc.
2. **Removal or losses :** Losses of water, organic and mineral matter from the soil trough leaching, uptake and erosion etc.
3. **Transformation :** Transformation of mineral and organic substances within the soil.
4. **Translocation :** Translocation or the movement of soil materials from one point to another within the soil. It is usually divided into : (i) Movement of solution (leaching) and, (ii) Movement in suspension (eluviations) of materials, such as clay, organic matter and hydrous oxides.

Fundamental pedogenic processes :-

1. **Humification :** It is the process of transformation (that is decomposition) of raw organic matter into humus. During the process, the soluble organic substances regroup themselves into large molecules by polymerization. Humification helps in the formation of surface humus layer.
2. **Eluviation/Emigration :** Eluviation means washing out. It is the process of removal of constituents, in suspension or solution form, by the percolating water from the upper to the lower soil layers, resulting textural differences which leads to horizon differentiation or development of soil. It refers to movement and removal of material in solution from entire solum.
3. **Illuviation//Immigration :** Illuviation means washing in. The process of deposition or accumulation of soil materials (removed from the eluvial horizon) in the lower layer or horizon of gains, is termed as Illuviation. The horizons formed by this process is termed as illuvial horizon (B horizon, especially Bt).

4. **Horizonation :** The development of all the horizons in soil is Horizonation. In the favourable conditions development of different horizons in soil takes about 250 years but it adverse condition, it takes even more than 1000 years.

Specific pedogenic processes :-

1. **Calcification** : This process occurs in arid and semi-arid climates. It is the process of precipitation and accumulation of calcium carbonate ($CaCO_3$) in some part of the profile. The accumulation of $CaCO_3$ may result in the development of a calcic horizon. Calcium is readily soluble in acid soil water and /or when CO_2 concentration is high in root zone as :

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$H_2CO_3 + CaCO_3 \longrightarrow Ca(HCO_3)_2 \text{ (Soluble)}$$

$$Ca(HCO_3)_2 \xrightarrow[CO_2 \downarrow]{\text{Temperature} \uparrow} CaCO_3 + H_2O + CO_2$$

2. **Decalcification :** It is the reverse of calcification, that is the process of removal of $CaCO_3$ or calcium ions from the soil by leaching. The process operates in humid climate where leaching becomes more pronounced and removes calcium bicarbonates in solution to deeper layers, and the soils are termed as decalcified.

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2 \text{ (Soluble)}$$

3. **Podzolization :** The term podzolization is derived from the Russian term Podzol (Pod, means under and zola means ash-like), that is ash like appearance below the surface horizon. Podzolization is a process of acid hydrolysis. The process of soil formation, resulting in the formation of Podzols (Spodosols) and Podzolic soils, is termed as Podzolization. Calcification tends to concentrate $CaCO_3$ in the lower part of the B-horizon, whereas Podzolization leaches the entire solum. A part from Ca, the other bases are also removed and the whole soil becomes distinctly acidic. As the sesquioxide (Al_2O_3 and Fe_2O_3 – Red colour) move out, the A-horizon gives a bleached gray or ashy appearance hence the term podzol and sesquioxide may accumulate in B-horizon. It takes place in those areas where temperature is very –very low and precipitation is very high.

   Ex. Fungi is more here which create acidity in soil and under in acidic condition silica present remain insoluble (silication process) and Fe & Al soluble in such condition move to lower horizons.

4. **Laterization :** The term laterite is derived from the Latin word later, meaning brick or tile, and was originally applied to a group of high clay soil observed in the Malabar hills of Kerala, India. It refers specifically to a particular cemented horizon in certain soils which, when dried, become very hard, like a brick. Such soils (in tropics), when massively-impregnated with

sesquioxides (iron and aluminium oxides) to the extent of 70 to 80% of the total mass are called laterites or latosols (presently Oxisols). The soil forming process is called 'Laterization or Lotozation'. It takes place in those areas where temperature is high and precipitation is also high. Bacteria is main organisms in such soils. The *laterite (Oxisols)* and *lateritic (Ultisols)* are mainly used for shifting agriculture, low intensity grazing and growing plantation crops with adequate nutrient supply.

5. **Gleization :** The term 'glei' is of Russian origin which means blue, grey or green clay. The gleization is a process of soil formation resulting in the development of a glei (or gley horizon) in the lower part of the soil profile, but above the parent material, due to poor drainage condition (lack of oxygen) and where waterlogged conditions prevail. Such soils are called Hydromorphic Soils. The process is not particularly dependent on climate but often on drainage conditions.
6. **Salinization :** Salinization is the process of accumulation of salts, such as sulphates, chlorides of calcium, magnesium, sodium and potassium, in a soil in the form of salty (salic) horizon (z) leading to development of saline soil. A soil is considered as saline, if ECe (salinity of saturation extract) 4.0 dS m^{-1}, pH <8.5 and ESP <15. These soils are also called ***white alkali soils*** and contain mostly Cl and SO_4 of Ca and Mg with less amounts of CO_3 and HCO_3 of Na. Such soils develop under conditions of high and brackish groundwater, where evaporation losses far exceed the precipitation. There the groundwater containing high salts moves upward by capillary action. The water, on evaporation, leaves the salts behind which accumulate at the surface or at some depth depending upon the capillary fringe. The factor responsible for the accumulation of salts in the development of salt affected soils are :
   - Arid and semi arid climatic conditions associated with shallow and brackish groundwater.
   - Lower / poor drainage condition of soils, from where the accumulated salts may not be drained because of inhibiting cost.
   - Lower topographic positions, where the salts are washed in by surface runoff and end to accumulate on evaporation.
   - Old lake bottom, which on drying, leaves salts at its surface.
   - Alluvial deposits along with the sea coasts or coastal regions, such as that of Gujrat, India, which are influenced by the ingress of highly saline sea water.
   - Saline irrigation and / or groundwater.

7. **Desalinization :** It is the removal by leaching of excess soluble salts from the soil (that contained enough soluble salts to impair the plant growth) by pounding water and improving the drainage conditions b installing artificial drainage network.
8. **Solonization or Alkalization :** It is accumulation of high exchangeable Na^+ ions on the exchange complex of the clay, resulting in the formation of Sodic soils (Soloetz). These soils are also called black alkali soils and contain mostly CO_3 and HCO_3 of Na and less amounts of Cl and SO_4 of Ca and Mg. The dominance of Na on exchange sites causes dispersion of clay leading to poor physical condition for plant growth and increase in soil pH (>8.5). High pH adversely affects nutrients' availability to plants and bring about the dissolution of soil organic matter which forms thin friable layer on soil surface. Soil colloids are dispersed and tend to remove downward results in poor physical condition. The organic matter forms black organo-clay coatings and hence called black alkali soil.
9. **Solodization or Dealkalization :** The process refers to the removal of Na^+ from the exchange sites. This process involves dispersion of clay. Dispersion occurs when Na^+ ions become hydrated. The gypsum is used and the added calcium helps to knock out sodium from the exchange sites without causing dispersion in soil as :

$$2NaX + CaSO_4.2H_2O \longrightarrow Na_2SO_4 + CaX$$

10. **Pedoturbation :** It is the process of mixing of soil. Mixing to a certain extent takes place in all soils. The most common types of pedoturbation are :
    - **(a.)** Argilli pedoturbation (Fr. Argille, meaning clay) – It is the mixing of materials in the solum by the churning process caused by swell –shrink clays, as is observed in deep black cotton soils (Vertisols) of central India.
    - **(b.)** Faunal pedoturbation – It is the mixing of soil by animals, such as ants, earthworms, moles, rodents and man himself.
    - **(c.)** Floral pedoturbation – It is the mixing of soil by plants, such as tree tipping, that forms pits and mounds.
    - **(d.)** Cryo (means – Ice) pedoturbation – It is the mixing of soil due to freezing water or ice. It is only in *Gelisol* soil order.

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