### GEOLOGY AND SOIL SCIENCE (2+1)

**Class:- B.Sc (Forestry) Ist year**

**Course Teacher :- Dr Kundan Singh**

Theory

Geology – Relation to other sciences – Earth as a planet – Age – Interior – Surface features – Geological history of India – Geobotany – Rocks and minerals – Soil – definition – Pedology – Edaphology – Weathering of rocks and minerals –- Soil forming processes – Eluviation and illuviation – Soil texture-structure – Specific gravity – Porosity – Consistency – Soil moisture – Soil air – Soil temperature – Soil reaction and electrical conductivity – Colloids – Soil organic matter – Ion exchange.

### Practical

Identification of soil forming rocks and minerals – Collection and processing of soil samples – Estimation of pH and EC – Soil physical properties – Total nutrient analysis – CEC estimations.

### Lecture Schedule

1. Introduction to geology – its relation to other sciences- theories about the origin of earth
2. Earth as planet – geological history of India –age –interior-surface features
3. Geo-botany-distribution of forest types with respect to geology
4. Rocks –petrology- definition –classification-structure.
5. Minerals –mineralogy- definition-physical properties- economic minerals of India
6. Soil – definition – soil as a natural body – three dimensional – major components by volume
7. Pedology vs edaphology -weathering of rocks and minerals -
8. Factors influencing weathering – physical.
9. Weathering – factors – chemical; oxidation, reduction, hydrolysis, hydration, carbonation, solution
10. Biological factors of weathering –action of microorganisms, animals and plants.
11. Factors of soil formation – parent material – climate
12. Factors of soil formation – organism, relief and time
13. Soil forming process - eluviation, illuviation–horizon differentiation
14. Soil forming process - Podzolization, laterization
15. Soil forming process – Calcification, decalcification, salinisation, alkalization
16. Soil structure – definition and classification
17. Mid Semester Examination
18. Factors influencing soil structure
19. Soil texture – definition – methods of texture analysis, feel method
20. International pipette method -Stoke’s law – assumptions, limitations
21. Textural class-identification using textural triangle
22. Physical properties – absolute specific gravity, apparent specific gravity Pore space – definition – capillary and non-capillary porosity.
23. Factors influencing physical properties - soil compaction, organic matter and particle size.
24. Soil consistency – plasticity- Upper and lower plastic limits - Atterberg’s constant
25. Soil colour – definition – significance – color variables - Munsell color chart-factors influencing colour.
26. Soil moisture – definition-significance-moisture constant – hygroscopic co-efficient, Wilting point, field capacity, moisture equivalent – maximum water holding capacity
27. Energy concepts – pF scale – Measurement – Gravimetric – Electric and tensiometer methods – Pressure plate – Pressure membrane apparatus – Neutron probe – Soil water movement – Infiltration and percolation
28. Soil Air – composition- factors influencing –soil air renewal; Soil temperature – sources of heat, factors influencing- measurement
29. Soil reaction – definition – classification – factors influencing – nutrient availability at different pH – buffering capacity and its importance
30. Electrical conductivity – definition – classification – factors – influencing – measurement of electrical conductivity.
31. Colloids – definition- properties – nature of colloidal solutions-soil as a colloid
32. Soil colloids-inorganic and organic-silicate clays-structure- classification-properties
33. Soil organic matter-sources-composition-influence of organic matter on soil-C:N ratio- Organic matter decomposition
34. Ion exchange – cation and anion exchange – effect on soil properties

**Reference Books**

Botely, E.P. Rocks and Minerals. Weidenfold and Trcolsoo Publishers

Brady, N.C 1984. Nature and Properties of Soil. The Mac Millan Company, New York.

Hille, D. 1982. Introduction to Soil Physics. Academic Press, Inc. New York.

La, R. and D.I. Greenland 1979. Soil Physical Properties and Crop Production in the Tropics. John Wiley & Sons, New York.

Negi,S.S.Forest Geology and Soils.periodical Export Agency ,New Delhi.

Zum Berge, James, H and Nelson, A. 1972. Elements of Geology. John Wiley and Sons Publishers.

# LECTURE – 1

# Introduction to Geology – its relation to other sciences and Theories about the Origin of Earth

From academic point of view, Geology is fascinating since, it is a branch of science that deals with all aspects of the earth on which we live. Only a geologist can state conclusively that the location of the present Himalayan ranges was the site of a shallow sea some 60 million years back. The Indogangetic alluvial plains, on which the most prosperous states of the Indian Union are located, are geologically of very recent origin while the Deccan plateau forms the remnant of the original crust of the earth. All these are outcomes of the study of geology.

Geological evidences alone have conclusively established that though, at present there are no active volcanoes in India, Certain Portions of Western, Central and Eastern India were the locations of extreme volcanicity some 50 to 100 million years back. Studies of Fossils have shown conclusively that though the earth surface is dominated by mammals, there are records to establish that the earth was dominated by reptiles during the Mesozoic period (i.e. about 60 to 170 million years back) and by certain forms of invertebrate animals during the paleozoic age (171 to 500 million years back). The Flowering varieties came into existence only about 60 million years back. From the point of applied interest, geology is important as the discovery and exploration of economic mineral deposits demand a thorough knowledge of the science of the earth.

Studies of rocks and minerals have shown that petroleum deposits in India are to be found essentially within the rocks of tertiary era (1 to 60 million years). Important coal deposits are located in the rocks of upper Paleozoic age (170 to 300 million years). Ores of Fe, Mn, Cu, Pb, Zn, Ag, Cr, metallic deposits of mica, asbestos, graphite etc are located with in the extents of the oldest rocks of archaen age (i.e. rocks of 1500 to 4500 million years). In the quest of petroleum, coal and metallic minerals, therefore the rocks of the respective geological ages need be investigated and this needs through knowledge of Geology.

Geology is important to engineering students since they may have to undertake mining operation to recover suitable mineral deposits to be utilized by the nation, while others may need it for making roads and bridges, buildings, tunnels, dams and reservoirs, also for the recovery of metals and alloys from suitable mineral deposits. The science of Geology is very wide and to systematize this work, it has been focused to subdivide the subject into a number of branches.

**Physical or Dynamic Geology**

Aims at the proper understanding of the physical forces and processes, which mould the surface of the world through the physical action through ages. Thus the work done by flowing wind, running and underground water, oceans and seas, lakes and swamps, glaciers etc. as also the activities of living organisms form the subject matter of physical Geology.

**Structural Geology**

Study and interpret the structures found in rock masses. It includes the investigation of the structural features like folds, faults, joints etc, in the rocks forming the crust and interpretation of their possible mode and mechanism at formation. The crust of the earth has never been stationary and there are continuous movements of smaller magnitude taking place along rapid and forceful movements associated with the formation of mountains.

**Mineralogy**

It is that branch of Geology, which deals with the study of minerals. Minerals are inorganic substances and are integral parts of the rocks, which form the crust of the earth. In this branch of geology, the physical, chemical and optical properties of minerals are studied. This includes the understanding of their mode of occurrence and mutual association as well as the description of individual and distinguishing characteristics of mineral species.

**Petrology**

Is the science of rocks, investigates on the nature of the rocks, their mode of formation and evolution, their characteristic form, structures, texture etc. and their bearing upon the genesis of rocks.

**Stratigraphy or Historical Geology**

Branch of science that traces the evolution of the earth and also of its inhabitants through the records left in the rock sequences in different parts of the globe.

**Paleontology**

Branch of geology that deals with the mode of preservation of remains of plants and animals in the form of fossils, within rock beds and their proper utilization in elucidating the geological history of the earth. This science is of use to the geologists in their quest for new deposits of coal and petroleum.

**Economic geology**

This branch aims at the investigations on the mode of formation and occurrence of deposits of rocks and minerals of economic importance and means by which such deposits can be conveniently exposed for the benefit of the society.

**Engineering Geology**

Studies undertaken at dam, bridge, tunnel sites and along hill slopes to indicate clearly the geological conditions that must exist there. In addition, investigation concerning materials for construction and nature and availability of groundwater in rocks of different types may be included within the scope of this branch.

In addition to the above branches of geology, in conjunction with other allied branches of science, it has been further utilized in the study of earth as follows:

1. **Geophysics** - Involving Geology, Physics and Mathematics, has taken recourse in recent years, in exposing the sub-surface Geology in many parts of the Globe.
2. **Geochemistry** – Involves Geology and chemistry and finds widespread application in the field of mineral investigation.

**Theories about the Origin of Earth**

The earth is a member of the solar system or the sun’s family. The sun is an average sized star with 9 planets revolving around it. These are Mercury, Venus Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. Thus the earth is the third nearest planet to the Sun. It is a huge sphere with a radius of about 6400 kms. However, it is relatively small as compared to other planetary members of the solar system.

**Origin of the Earth**

The earth is a unique member of the solar family. It is busting with life and has a thick envelope of air around it. The earth’s origin has continued to baffle philosophers, thinkers and scientists since times immemorial. Various theories and hypothesis have been put forward to explain the origin of the earth. The main theories and hypothesis are discussed below.

**1.Nebular hypothesis (Kant and Laplace, 1755)**

During the past, the entire solar systems existed as a hot gaseous mass called nebula rotating in space. With time, the gaseous mass (nebula) cooled and contracted. Due to contraction, there developed a bulge at the equatorial region. This bulge subsequently separated into several rings. The ring coalesces in the form of a globe and continues to revolve around the nebula. In similar manner, ten rings were formed of which nine of them gave rise to nine planets.

One broke down into smaller fragments to form the group of planetoids, while the remnant of the pre-existing nebula formed the central incandescent mass of the solar system and is known as the **Sun**. The planets were originally gaseous but were subsequently cooled down into liquid and ultimately to the solid state.

There is a definite conclusion that this hypothesis cannot adequately explain the origin of the solar system.

**2.Planetismal hypothesis (Chamberlain and Moulton, 1904)**

Planets were formed as a result of mutual interaction between the sun and another star of suitable size. This is the theory of **biparental** origin of the solar system.

This theory postulates that due to the near approach of a larger star, tidal distortions were raised upon the surface of the sun and these in conjunction with the eruptive force prevalent in the sun (known as the solar prominence) brought about a description of the mass of the sun and a number of gaseous bulbs were shot forth, in space, to great distances.

These gaseous solar materials thus ejected in space were subjected to immediate chilling, resulting in the formation of a number of minute solid particles known as *planetisimals.*

These planetisimals continued to rotate round the sun in highly elliptical orbits. The orbits must have happened to intersect one another and at points of intersection, they must have collided whereby the small planetisimals continued to coalesce gradually giving rise to the planets. During collision and coalescence of the planetisimals, large quantities of heat must have been generated and were dissipated in space before the next collision could occur and accordingly the planets must have been solid all the time during the growth.

**3.Gaseous tidal hypothesis (Jeans and Jeffreys, 1925):**This also accepts the idea of biparental origin like that of planetisimal hypothesis but refuses to consider the disruptive forces in the sun (i.e. the solar prominence) had anything to do with the formation of the planets.

According to Jeans and Jeffreys, during the ancient past, an extremely large star, while moving in space chanced to approach the sun. Due to progressive and nearer approach of the star, a tidal pull was raised on the surface of the sun and this increased in size with the nearer approach of the passing star. At the stage, where the passing star began to recede, the tidal pull on the surface of the sun, thus formed, was detached from the body of the sun in the shape of a spindle bulging near the centre and tapering at both ends. This very large mass of gas, thus ejected in space, was naturally extremely unstable and was immediately broken down into a number of small fragments. In all, ten such pieces were formed, nine giving rise to the planets and one, which was broken down into pieces, to the group of planetoid. These fragments formed into globular masses revolving round the sun along definite orbits and cooled down gradually from the gaseous to the liquid and ultimately to the solid state.

This hypothesis is the most popular one due to do simplicity and capability of explaining the co-planar placement of the planets and the features relating to the distribution of mass and density in them and the density stratification that exists within the earth.

# LECTURES – 2 & 3

**Earth as planet – geological history of India –age –interior-surface features**

**Geo-botany-distribution of forest types with respect to geology**

**Present Condition of the Earth**

The earth may be considered as consisting of an inner globe, lithosphere surrounded by two layers viz., hydrosphere and atmosphere. The gaseous envelope or the atmosphere extends up to 200 miles from the surface of the earth. The hydrosphere is about 6 miles deep at its greater depth and occupies 139,440,000 sq. miles or nearly 70 per cent of the surface of the earth. The exposed surface of the lithosphere occupies the remaining 30 percent and covers about 57,510,000 sq. miles.

The earth’s crust is 20 to 40 miles thick and consists of many different kinds of rocks of which the granitic and basaltic layer form the inner most strata of solid rock. Below this crust lies the mantle, which extends to a depth of about 1800 miles. The upper portion of the mantle is believed to be plastic to a depth of about 150 miles. There after it is believed to be a solid rigid mass of rocks. The outer core that lies below the mantle is composed of some heavy metals such as Iron and Nickel and is nearly 1300 miles thick. The material is believed to be in a molten or semi fluid condition. The pressure at the outer core is about 1.5 million atmospheres. The inner core is about 850 miles thick, consists of the same minerals as outer core and is under a pressure of 3.5 million atmospheres at the centre. In spite of its extremely high temperature (about 4000oC) the inner core is believed to be in a solid state on account of the enormous pressure. The density of the different layers gradually increases from the outer crust to the inner core.

The atmosphere is the outermost layer and exists in the form of a gaseous envelope around the planet. Next to it is the hydrosphere or the layer of water. The lithosphere is the innermost globe, which is most completely surrounded by the hydrosphere.

**Atmosphere**

It extends from the surface of the earth to a distance of about 200 miles. It is lighter than hydrosphere and exerts a pressure of 14.6 lb./sq.inch at sea level. It consists of a mixture of gases, chief of them being N2, O2, CO2 and water vapor. Besides it also contains small quantities of other gases like H2, NH3, sulphuretted hydrogen, sulphurous acid gas, ozone and nitrogen oxides. It also contains inert gases like helium, argon neon, krypton and xenon.

**Composition of Atmospheric Air**

By volume (%) By weight (%)

N2 78.0 76.5

O2 21.0 23.1

CO2 0.03 0.04

Other gases 0.97 1.36

**Hydrosphere**

It is the layer of water surrounding the lithosphere. It is present in the form of seas and oceans. It covers 70% of the earth leaving only about 30% above sea level. The surface of the waters of the various seas is in one level in contrast with the surface of the land. This surface is known as the sea level. The depth of water in the various oceans varies considerably. The average depth is 2 ½ miles and maximum depth is 6 miles. The total volume of water is about 15 times the volume of land above sea level. If all the land on the earth is leveled, the water will stand to a height of about 2 miles.

**Lithosphere**

It is the inner most body within the gaseous and watery envelops. That portion of the lithosphere, which rises above the seawater, is visible to us and is known as land. The land is only about ¼th of the total surface of the earth. It is on this crust that life, both animal and plant sustains.

The inner mass, which forms the interior of the earth, is in molten condition. According to one belief, the whole of the inner core is a molten mass of materials, upto the centre. According to another view, the interior of the earth consists of a molten magma, about 50 to 100 miles thick, surrounding a gaseous centre. A gradation exists from the central gaseous nucleus, through the intermediate molten mass, to the outer solid crust. The interior of the earth is intensely hot and is at the same time under enormous pressure. There is progressive increase in temperature with depth. Though, the increase is not uniform at all depths and all places, there is a rise of 1oF for every 64 feet on an average. Assuming the temperature to increase at this rate, at a depth of 25 to 50 miles, it should be sufficiently high to melt all substances known to us. This indicates that the interior of the earth is in molten condition.

## Composition of the earth’s crust

The Earth’s crust is principally compassed of mineral matter. This mineral matter is made up of various elements combined together to form compounds. Some elements exist as such without forming compounds. Almost all the elements known to us at present, except the inert gases, are present in the earth’s crust. The elements do not exist in the earth’s crust as such. Each element is in combination with one or more other elements to form definite chemical compounds known as **minerals**. Many of these minerals in turn combine together to form aggregates, which we know as **rocks**. Almost all the mineral mater is present in the form of rocks in the earth’s crust.

**Possible Constitution of the Earth**

Geophysical studies of the earth have indicated that it consists of a number of nearly concentric layers of different properties. Velocity of earthquake waves suddenly changes whenever they meet a discontinuity. Mohorovich has discovered a seismic discontinuity called Moho which has been recognized by sudden increase of the velocity of the compressional shock waves from 6.5 to 8 kms/sec. Moho has been considered as the base of the earth’s crust.

The earth’s crust approximately 50 kms in thickness is the outer portion of the lithosphere between the ground surface and the moho. The crust has been divided into two sub-zones called Sial and Sima. The Sial is a heterogeneous mixture of rocks. The Sima is a homogenous plastic or semi-plastic concentric layers that behaves like a solid. The Sial floats on the Sima, which in turn floats on the lower concentric layer called the Mantle.

Sial contains about 65-75 % silica. Aluminium is the next important element in the Sial, represented by the most common rocks like granite, and rhyolite. Silica decreases to about 50-60 percent in the Sima where aluminium has largely been replaced by magnesium with minor quantities of iron.

Sima is represented by the most common rocks like basalt and gabbro at the upper level and by olivine rich rocks at the lower level.

These two layers of the earth are called as Sial and Sima respectively because their chief constituents are silica and aluminium and silica and magnesia respectively with an average density of 2.7 and 2.9 g/cc respectively.

Besides oxygen (approximately 47 %), Silicon is the most important element (28 %) found in Sial which also contains about 8 % A1, 5 % Fe, 3.5 % Ca and 2.6 % each of Na, Mg and K. P (0.09 %) and S (0.07 %) are the important non-metals that occur in the earth’s crust. Ninety elements have been detected in the earth’s crust, mostly in the combined forms.

**STRATIGRAPHY OF INDIA or GEOLOGICAL HISTORY OF INDIA**

The subject of **stratigraphy** or **historical geology** aims at understanding of the correct chronological order in which the rock beds were actually formed on the surface of the globe.

From the study of fossils contained within the rock beds, a stratigrapher may be in a position to comment on the nature of organisms, which happen to exist during the geologic past. A study of the lithological characteristics of the rock beds may lead him further to infer the climate and environment under which the beds were deposited.

In short, a stratigrapher ventures to read the detailed geological history of the earth from a study of the rock beds, which lie here and there on the surface of the globe.

**Stratigraphic Units**

A through study of the geological formations has led the stratigraphers to classify them into six major groups known as:

1. Archaeon or Azoic – most ancient
2. Pre-cambrian or Algon – mesozoic
3. Primary or palaeozoic
4. Secondary or mesozoic
5. Tertiary or cainozoic
6. Quartenary or recent – the youngest

For convenience, each major group is classified into several **systems** as follows:

**Paleozoic group** - 1. Cambrian

2. Ordovician

3. Silurian

4. Devonian

5. Carboniferous

6. Permian

Each system is in turn divided into two or more series. eg. Mississippian and Pennsylvanian are the two series that constitute the carboniferous system. Each series is divided into several stages, eg. Pennsylvanian is divided into two stages viz., westphalian and stephanian. The smallest recognizable unit in any stratigraphic sequence is however known as a zone and each zone may be made up of one or more beds. A few zones together form a stage. Thus the carnic stage of the upper Triassic series in Himalayan mountains is made up of three zones viz., a) Halobia beds, b) Grey beds and c) Tropites beds.

A series of rocks includes those rocks developed in a particular epoch. Rocks that were formed during a particular age have been put in the stage of rocks, which in turn may be divided into zone of rocks.

Every kind of living organism requires certain specific conditions favorable for their growth and this may be found within a particular geological period, epoch or age. Whenever any geological period ended, environments, which were favorable for the growth of specific groups of living organisms, i.e. plants and or animals, changed. So they died and remained buried in the sedimentary rocks on which they lived. These preserved bodies of animals and plants or their impressions on sedimentary rocks, are known as **fossils**. So every system of sedimentary rocks contains specific fossils that enable us to identify that particular system of rocks. Similarly certain living organisms lived during certain epochs and ages, remaining buried in the series and the stages of sedimentary rocks are identified on the basis of those specific fossils possessed by them.

A stage of sedimentary rock may contain different fossils in different levels. So, a set of sedimentary beds of stages of sedimentary rocks have been divided into ‘**zones**’ of sedimentary rocks.

Rocks of the proteozoic and Azoic eras have been classified, basically on field evidences viz., the order of super imposition of rocks, intensities of metamorphism of rocks, marked unconformities and changes in lithological appearances, although sedimentary rocks that were formed during later eras have also been classified on the basis of these criteria.

European geologists have classified rocks into groups and systems on the basis of unconformities and fossil content of rocks as found in Europe. This classification is used as a scale more or less for the entire world and is called as the **standard stratigraphical scale**, as below:

|  |  |  |
| --- | --- | --- |
| **Group of rocks** | **System of rocks** | **Time of formation in million of year** |
| Quartenary | Recent  Pleistocene  Unconformity | 0.025  1  - |
| Tertiary or kainozoic or Cenozoic | Pliocene  Miocene  Oligocene  Eocene  Unconformity | 8  25  40  65  - |
| Secondary or mesozoic | Cretaceous  Jurassic  Triassic  Unconformity | 130  170  230  - |
| Primary or paleozoic | Permain  Carboniferous  Devonian  Silurian  Ordovician  Cambrian  Unconformity | 280  320  390  420  490  550  - |
| Proteozoic | Precambrian  Eparchaean  Unconformity | 2225  - |
|  | Archaean  Earth’s crust | 3600 |

**Geological classification of rocks in India**

|  |  |  |
| --- | --- | --- |
| **Group of rocks** | **System of rocks** | **Time of formation (million of years)** |
| Aryan | Recent  Pleistocene  Pliocene  Miocene  Oligocene  Eocene  Cretaceous  Jurassic  Triassic  Permian  Upper carboniferous  Unconformity | 0.025  1  8  25  40  65  130  175  230  280  310  - |
| Dravidian | Lower canboniferous  Devonian  Ordovician  Cambrian  Unconformity | 330  390  490  550  - |
| Purana | Vindhyan  Cuddapah  Eparchaean  Unconformity | 1500  -  -  - |
| Archaean | Dharwar  Archaean  Earth’s crust | -  3600  - |

**Dharwar System**

In south India, they are well developed in Mysore and Southern Bombay and commonly described as Dharwar system. The Archaean rocks in India constitute a storehouse of important economic mineral deposits except coal, petroleum, sulphur. All other metallic and non-metallic minerals are found in archaean rocks. These rocks also contain gemstones like Sapphire, Zircon, Garnet, Emerald and Topaz. Archaean rocks are used as decorative stones in buildings.

**Precambrian / Algonkian Group (PCR)**

Archaean rocks were subjected to diastrophism, erosion and denudation, which led ultimately to the development of Eparchaean unconformity. The Precambrian lie above this unconformity and are well represented is different parts of the peninsula.

In India, PCR has given rise to two distinct formations viz., (1) Cuddapah system – older in age and (2) Vindhyan system – younger in age. Cuddapah is structurally complicated. Both are devoid of fossils.

**­Archaen**

The Archaen group of rocks refers to very ancient gneisses, schists, granites on which all sedimentary formations were formed. Schist and gneisses were formed due to metamorphism of igneous and sedimentary rocks. The rocks belonging to this group are devoid of fossils. When Archaean rocks were formed, there was no life in existence in the surface of the globe.

**Dharwarian rocks**

In some regions, the archaean rocks are made up of only sedimentary metamorphites or mixture of para and ortho-schists. Such rocks are called as Dharwarian rocks in India. Archaean and Dharwarian rocks are closely associated and of the same age. Archaean rocks are very complex in structure and composition; hence they are called as gneissic complex or basement complex or fundamental gneiss.

**Occurrence and Distribution**

Two third of the peninsula is covered by the archaean and associated Dharwarian rocks well developed in South India, Rajasthan, Madhya Pradesh and in the Singhbhum – Gangpur area of Bihar and Orissa. The rocks of this group belong to the eastern ghat ranges as well. In the extra peninsula, the Archaean occur along the whole length of the Himalayan mountains.

There are different series in this rock, as follows.

Place Series

Kashmir – Hazara Salkhala series

Kumaon and spiti Vaikrita series

Schistose rocks of Simla and Garhwal Jutoh and Chail

Schistose rocks of Nepal and Sikkim Daling

Gneissose rocks of Nepal and Sikkim Darjeeling

**Cuddapah System**

Occur in the Cuddapah basin of Andhra State. It lies unconformably above the gneisses and schists of archaean age. Cuddapah is made up of alternating layers of quartizites and shales and these exist on unconformity between any two successive series of this system. There are 4 series in cuddapah system.

1. **Papaghni series**: It is the oldest, 4500 ft. thick and lie unconformably on the Archaean rocks. In this the quartzitic sandstones, grits and conglomerates of the Gulcheru stage form the basement. This is overlain by grayish micaceous limestones and shales of the vempalle stage.
2. **Cheyair series :** More than 10,000 ft. in thickness. It’s lower part viz., Nagari or Pulivendla stage has quartzitic sandstone and conglomerate. It’s upper part viz., Tadpatri or Pullampet stage has shale beds.
3. **Nallamalai series:** More than 3,000 ft. in thickness and forms the Nallamalai hills. This has *Bairenkonda quartzites* and Cumbum shales and slates.
4. **Krishna series:** Younger and overlaps all series and lies right over the Archaean rocks. It has three stages, totaling to a thickness of 2000 ft.

The rocks of cuddapah also belong to the different parts of peninsula and extra – peninsula. Towards southern Bombay it is described as Kaladgi series and has quartzites, sandstone, conglomerates, limestones, shales etc.

The Delhi system of Rajasthan is considered equivalent to the cuddapah system of Rajasthan. The Delhi system is divided into two series viz., Alwar series and Ajabgarh series; the latter is the younger one.

The rocks of cuddapah age contain a number of important mineral deposits. In Andhra, deposits of talc and asbestos occur at the contact of vempalli limestone and the intrusive sills. The quartzites, slates, and limestones of the Delhi and the cuddapah system are utilised commonly as bulding and decorative stones.

**Vindhyan System**

This system is named after the vindhyan range of mountains. It constitutes unmetamorphised column of calcareous, arenaceous, argillaceous sedimentary rocks. This system covers 40,000 sq. km. The lower part of vindhyan system is made up of calcareous and argilaceous of sediments deposited under a marine environment, while the upper part of system is made up of arenaceous rocks. The rocks of vindhyan range are devoid of fossils. The upper vindhyan range is divided into Kaimur, Rewa and Bhander series, which are separated from one another by intervening horizons of diamond bearing conglomerates. The lower vindhyan rocks form the Semri series.

The rocks of this age are economically important. They contain useful deposits of building and decorative limestones, glass sand and diamond. The vindhyan sandstones are good quality buildings stones used in construction of palaces, forts, buildings. The vindhyan limestones of Rewa, are used for lime burning and in the cement industry.

**­**

**Paleozoic Group**

The geological formations developed during the paleozic era are found to contain fossils. They differ from the unfossiliferous formations of precambrian and Archaen age. They are found mostly in regions of extra-peninsular areas and have been studied in spiti, Kashmir, salt range and adjacent areas and in certain parts of Burma.

In the peninsula, the paleozoic group is represented by

1. The Talchir and Damuda series of permo carboniferous age,
2. Marine lower permian rocks near umaria in Madhya Bharat and
3. A portion of the upper Vindhyan sequence, which is possibly of cambrian age.

This age of rocks contain shales calcareous sand stones, conglomerates, quartzite’s, dolomites and slates.

**Salt Range**

The marine paleozoic rocks of cambrian, upper-carboniferous and permian age occur in the salt range in Pakistan. The geological successions in the salt range are pernian, Upper Carboniferous to lower permian, and cambrian. These rocks contain gypsum, dolomite, oil shales, salt marls, magnesium sandstone, purple sand stone etc.

**Mesozoic Group**

The mesozoic group of rocks occur in extra peninsular and peninsular region. The group is divided into three systems viz., Triassic, Jurassic and Cretaceous. The Triassic are well developed in Kumaon, Spiti, Kashmir and salt range.

Jurassic rocks are devloped characteristically is Cutch, Rajasthan, Kumaon, Spiti, Baluchistan, Kashmir, Hazara and Salt range. Characteristic rocks of the cretaceous age occur along the eastern coast of south India in the Narmada valley, salt range and in spiti and Kumaon, Tibet, Sind and Baluchistan. The upper part of Gondwana system of the peninsula is also of mesozoic age.

**Gondwana Group**

This group is named after the Gond kingdom in Madhya pradesh. The gondwana sediments contain enough remains of plant and animals with large number of coal seams. The Gondwana rocks occurs in India in Damodhar, sone, Narmada, Godavari, mahanadi valleys and occur in Himalayas, Kashmir and Baluchistan. Isolated patches of Gondwana are seen in Madras, Gundur, Vijayawada, Rajmundiry, Trichy and Ramnad. The upper Gondwana group is a age of cretaceous, Jurassic and Triassic. Lower Gondwana group contains Triassic, Permian and carboniferous. Goudwana group of rocks contain mostly shales, sandstones, conglomerates etc.

**Deccan Traps**

In the peninsula, the end of the mesozoic era was characterized by the pouring out of extensive – lava – flows, which were erupted mostly through fissures and occupy a major portion of the Deccan plateau. These lava flows have given rise to flat – topped mountains and plateaus with step-like terraces, described as the **trap rocks** and the formation are known as **Deccaon traps.**  Deccan traps occur in Bombay, Cutch, M.P and in some parts of South India. They are made up principally of basic vocalic rocks of basaltic composition. These are used commonly as excellent road metals. There of lighter colour are utilized as building stones. The black soil of the Deccan (known as Regur ) is most suitable for the cultivation of cotton and appears to have been derived mainly from the trap-rocks.

**Tertiary Group**

The tertiary group of rocks is well developed in extra peninsular region and Himalayan range. In peninsular region, tertiary rocks occur in Rajasthan, coastal tracts of Orissa, Madras, Travancore, Cutch, Gujarat. The Himalayan Mountains appear to have attained the configuration after remarkable phases of upliftment, which takes place during the mesozoic age. The tertiary rocks are seen in Sind and Baluchistan. The geological age of this region is from Paleocene to Pliocene. The tertiary rocks were formed under marinec environment. The lowest part of the tertiary group in this region contains limestones, shales, and sandstones. The upper part of the tertiary rocks in this area is made up to limestones.

**Himalayan Arc**

The Himalayan ranges are arranged in the form of an arc, the convex side of which lies towards the Indian sub-continent. The foothills of the himalayan arc exhibit a perfect development of the tertiary rocks. In the eastern and central parts of the himalayan arc, the belt is rather narrow and is composed of only younger tertiary rocks formed under estuarine and fresh water environment.

**Lecture 4**

**Rocks –petrology- definition –classification-structure**

# ROCKS

Rocks are aggregate of minerals. They are the basic units, which constitute the earth’s crust.

**Petrology**: is that branch of geology that deals with the study of rocks.

**Primary rocks**: were the first to have formed on the earth’s crust e.g.. Igneous rocks.

**Secondary rocks**: are formed due to the weathering and deposition or metamorphism of existing primary or secondary rocks viz. sedimentary and metamorphic rocks.

**Definition:** A rock may be defined as a mass of mineral water. It is composed of one or more minerals. Some rocks are hard and compact e.g.: granite and basalt, some are loose and feebly aggregated e.g.: sandstone and loose sand. Each rock possesses certain characters like structure, colour, specific gravity, cleavage, fracture and mineralogical make up, which help to distinguish one from the other.

There are three main categories of rocks based on their origin or mode of formation.

**1. Igneous rocks**: Formed by action of heat. These are the first to be formed when molten magma cooled and consolidated into solid rock. The other rocks were formed subsequently. Igneous rocks constitutes 95% of the earth’s crust. They are crystalline and known as **Crystalline rocks**. Also called as massive rocks as they occur in masses. Igneous rocks mainly consist of primary minerals of which quartz, feldspar, amphiboles, pyroxenes and micas are the most common. Igneous rocks are formed in different ways depending on the manner and conditions under which molten mass consolidated. They are

**a) Extrusive:** Formed when the molten mass was poured out on the surface of the earth where it consolidated on cooling. Among this includes the rocks of volcanic origins, which consolidated at the surface as lavo-flows or were forced between rocks near to surface. Rhyolite, obsidian, trachyte, dolerite and basalt – e.g. of extrusive rocks if volcanic origin.

**b) Intrusive rocks:** Sometimes the molten mass cooled and consolidated beneath the surface. Those that consolidated at much greater depth than others are **Plutonic rocks**. e.g. Granite, syenite, dolerite and gabbio.

Some intrusive rocks consolidated in vertical cracks and formed wall like masses called as **dykes**. Others consolidated into horizontal cracks called as **sills**. In some cases the molten material is forced in irregular and narrow cracks or fissures. This is called as **vein**.

Many igneous rocks, especially those of volcanic origin contain water under great pressure even in molten condition. As the molten magma comes to the surface, the pressure is released and water is turned into steam. As steam cannot escape, it forms a globular cavity known as **vesicle** and the rock container; this is called as v**esicular rock**. There are minerals embedded in these vesicles and such rocks are **amygdaloidal rock**. The minerals embedded in this are quartz, calcite, zeolite, glauconite, etc.

Based on chemical composition igneous rocks are divided into four classes.

1. Those that contain large amount of basic components – Basic rocks.
2. Those that contain more of acidic components – acidic rocks.
3. Those intermediate between the two – sub acid or
4. Sub-basic rocks according to the silica acid content.

1. Acidic rocks - >65 % silica. eg. granite, rhyolite, obsidian,

pitchstone

2. Sub-acidic rocks - 60.65 % silica eg. syenite and trachyte

3. Sub-basic rocks - 55.-60 % silica. eg. diorite and andesite

4. Basic rocks - 45-55 % silica. eg. gabbro, dolerite, bassalt

5. Ultra basic rocks - < 45 % silica

**Sedimentary rocks:** Formed through the agency of water. Also called as **aqueous rocks**. Formed from sediments brought by water. The sediment may contain various types of substances and sizes of particles. The particles are cemented by silica, iron oxide or lime to give a consolidated form. The rocks are mostly deposited in layers or strata – so called as **stratified rocks**. Sometimes they are formed by cooling, evaporation or by direct chemical precipitation. Anyway they are of secondary origin.

Sedimentary rocks divided into six groups as follows:

1. **Arenaceous**: Formed of the deposits of coarse grained particles. They are composed of siliceous material derived from the disintegration of older rocks. The fragmental material so derived is deposited in beds of varying thickness through the agency of water. Depending upon the nature of cementing material present, some arenaceous rocks are hard and refractory, but most are loose and fall away very easily. E.g. Sandstone, grit, conglomerate and breccia.
2. **Argillaceous rocks**: Consist of small sized particles known as clay. They are composed of hydrated silica of alumina in admixture with sand, various other silicates and calcareous matter. When clay is deposited mainly of silicate of alumina, it is known as kaolin or China clay. E.g. clay, mudstone, shale and fuller’s earth.
3. **Calcareous rocks**: Consists of carbonate of lime or lime and magnesia. They may be of sedimentary origin or formed by chemical precipitation or by organic agency. When, they are of organic agency, they are composed mainly of debris from plant and animal life. They are formed either by growth and decay of organisms in situ or by the transport and subsequent accumulation of their remains. The rocks so formed are found in layers, which vary considerably in depth of thickness. When formed by chemical precipitation, the calcareous material is deposited in the form of layers/sheets from waters containing calcium carbonate in solution. The important calcareous rocks of aqueous origin are limestone, chalk, magnesian, ferruginous limestones, dolomite, marks of various varieties and coral.
4. **Carbonaceous rocks**: Formed from decomposing vegetation under anaerobic conditions. When plants undergo decomposition under restricted air supply, is greater portion of the carbonaceous matter is retained and the material is slowly converted into coal. E.g. peat, lignite, coal, anthracite.
5. **Siliceous rocks**: Siliceous rocks of organic origin formed from parts of minute plants and animals like diatoms, radiolaria etc, Some are soft and friable and crumble to powder very easily. Others like flint and chert are hard and compact.
6. **Precipitated salts**: Consist mainly of deposits formed as rock masses either by cooling, evaporation or by chemical precipitation. Water charged with acid or alkaline material, acting under pressure as it does under subterranean regions, dissolves various mineral substances from rocks with which it comes in contact. The salts thus formed deposit as rocks and such rocks vary in composition. They are
7. Oxides: e.g. hematite, limonite, bauxite and quartz.
8. Carbonates: e.g. stalactite, stalagmite, magnetite and limestone.
9. Sulphates: e.g. gypsum and anhydrite
10. Phosphates: e.g. phosphorite
11. Chlorides: e.g. rock salt.

**Metamorphic rocks**: The igneous and sedementary rocks after they were first formed sometimes undergo a change. When the change is considerable, the rock is said to have undergone metamorphosis and the new rock is known as a metamorphic rock. The metamorphism is brought about by the action of water, heat or pressure or by the combined action of any one of these or all . The change brought about by water is hydro-metamorphism. The change brought about by heat is thermo-metamorphism. The change brought about by pressure is dynamo- metamorphism. The changes that are brought about are both physical and chemical in character. In some cases the metamorphism is so pronounced that the new rock looks quite different from the original.

The action of water tends to remove some material or introduce new materials. By the introduction of a cementing material like silica, lime or iron oxide, loose sand may be turned into a sandstone or a sandstone into a quartzite. By the removal of certain constituents by percolating waters, basalt or granite may be converted into a laterite.

The action of heat hardens the rock and develops new crystals in it. Crystalline marble is produced this way from amorphous limestone by the action of heat and pressure. Due to pressure, the crystals of the original rock get pressed or flattened and the new rock is foliated. When foliation is slight, the layers are inseparable and it is called as gneiss. It foliation is complete with distinct and separable layers it is called as schist.

# Lecture 5

# Minerals –mineralogy- definition-physical properties-economic minerals of India

### MINERALS

A mineral is a naturally occurring inorganic substance having a definite chemical composition and distinct physical characters. It usually contains two or more elements in chemical combination in certain definite proportions. A mineral that forms the original component of a rock is **primary minerals** e.g. Feldspar, hornblende, mica.

That which has been formed, or deposited or introduced as a result of subsequent changes is secondary mineral. e.g. limonite, gibbsite, clay minerals like kaolinite, montmorillonite.

A mineral may occur as both primary and secondary. e.g. quartz. As a primary mineral it is a component of granite. As a secondary mineral, it is deposited in the form of veins, amygdolates etc. Those minerals, which are regarded as the chief component of a rock, are known as **essential minerals**. While those which occur in small quantities and whose presence/absence is of no consequence for the character of the rock is known as accessory minerals.

Essential : Felspar, amphiboles, pyroxenes, mica

Accessory : Tourmaline, ilmenite, and magnetite.

Each mineral possesses in addition to a definite chemical composition, certain physical characteristics, which enable it to be differentiated from others. The important physical properties that characterize the minerals are Crystal form, specific gravity, colour, cleavage, streak, fracture, luster, opacity and hardness,

Chalcedony (white), agate (banded), flint and chert (massive) and moss agate belong to the crypto-crystalline varieties. Quartz is an important constituent of granite, rhyolite, conglomerate and sandstone. Among metamorphic rocks, gneiss and quartzite contains appreciable quantities of this mineral. It is present in almost all soils of which sand and coarse silt fractions contain the largest amount.

Feldspars may be divided into two groups: orthoclase and plagioclase. Orthoclase feldspars are mainly potash feldspars. Plagioclase feldspars are either soda-feldspar e.g. albite, calcium-feldspar e.g. anorthite or soda-lime feldspars, e.g. oligoclase, labrodonite.

Potash feldspars are present in granite, syenite. Plagioclase feldspars form important constituents of basic igneous rocks like basalt, gabbro etc. Feldspars are present in sand and silt fractions.

Pyroxenes: e.g. augite and enstatite

Amphibole: e.g. hornblende and actinolite. They are also known as ferromagnesian minerals. In addition to Ca, Mg, and Fe, these minerals content a number of other bases e.g. iron, Mn, Titanium, Na, and K.

Mica group is next important group to which muscovite and biotite belongs. They have a characteristic plate-like structure. They are present in all three classes. Biotite, which is usually double in coloured and is rich in Fe and Mg than muscovite. They are found mainly in the fine sand fraction. These along with orthoclase feldspars are the source of potassium in soil. Other primary minerals are apatite, magnetite and ilmenite. They are more resistant to weathering and are usually found in the sand fraction of soils. Clay minerals are the most important secondary minerals.

#### Physical Properties of Minerals

**Colour:** is due to transmission or reflection of light and its selective absorption within the body of the mineral or upon its surface. The true colour is initiated to a great extent due to the presence of minute quantities of impurities. Quartz should be absolutely colourless but occurs in shades of pink, yellow, or grey due to impurities.

**Streak:** defined as the colour of its own powder. This is determined by producing a mark with the mineral on an unglazed surface such as white porcelain plates. The streak may be the same as its colour or different. Hematite is steel grey in colour, but a cherry red streak. Corundum, as it is harder than porcelain cannot produce the streak. Streak is a very distinct feature for identification.

**Hardness:** Property by which it offers resistance to any force which might tend to cause abrasion on its surface. Diamond is the hardest and Talc is the softest.

#### Moh’s Scale of Hardness

Talc Orthoclase

Gypsum Quartz

Calcite Topoz

Fluorite Corundum

Apatite Diamond

**Specific gravity:** is the ratio of the weight of the mineral to that of an equal volume of water. Weight of the mineral is W1, its weight in water is W2. The weight of an equal volume of water is W1-W2 and specific gravity is

W1

W1-W2

**Cleavage:** Property of a mineral, by virtue of which it develops a tendency to break down, along a particular direction, offering plane and smooth surfaces. The resulting cracks, which are formed due to this tendency, are known as Cleavage – cracks. Quartz has no cleavage, while galena and calcite have well developed cleavage.

**Fracture:** defined as the nature of surface produced due to fracturing of the mineral mass. Quartz produces a fractured surface made up of a number of curvatures, both concave and convex. This smooth surfaced curvature is called as **conchoidal** **fracture**. The fracture that is uneven and irregular is called as irregular surface.

**Lustre:** Virtue of which it is capable of reflecting light. It is a nature and amount of shine that a mineral can offer due to reflection of light upon its surface.

**Metallic lustre:** If the shining is similar to that of broken pieces of metals. Non-metallic lustre may be vitreous (glass), adamantine (diamond), resinous, pearly, silky and greasy.

**The form and structure**: Mineral may be crystalline/amorphous. If crystalline it may occur in the form of a well developed crystals or alternatively it may be massive without crystals.

##### **Chemical Property**

Phenomenon of crystallization is **polymorphism**. e.g. CaCO3 crystallizes in two form. **Calcite**: in the trigonal division of hexagonal system. **Aragonite**: crystallizes in orthorhombic system.

2. **Isomorphism:** Substances of different but at the same time of allied chemical composition are capable of crystallizing in exactly related forms. Albite (Na2AlSl3O8) and anorthite (CaAl2Sl2O8) are isomorphism.

The other important chemical property is solubility and fusibility.

#### LECTURE – 6

#### SOIL AS A NATURAL BODY- Pedology & Edaphology

Soil is composed of partly weathered, unweathered and transformed product of rocks and rocks minerals and organic matter. The soil particles are present partly as individuals and partly as aggregates or ‘peds’. The organic matter is often firmly combined with mineral particles forming aggregates which are of various sizes and shapes, just as the inter particle pores.

#### Soil – A Porous Body

In a moisture free soil, the pores are filled up with air, which can be easily replaced with water. The quantity of water varies with the size of the pores that is determined by individual particles and of the aggregates. The pores in the surface and sub-surface decide whether all or part of rainwater will soak the soil and go down to the water table or not, water enters the pores through capillary force and ultimately can wet a dry soil. Unless, this water is removed by suction or air pressure, air cannot get in to the soil. It is possible to determine the quantities of soil particles having different sizes as well the total magnitude of pores.

This soil is described as the three phase system: solid, liquid and gaseous phase. When completely dry or frozen, soil becomes a two-phase system, liquid phase being either absent or part of the solid phase.

#### Solid Phase

Soil material less than 2 mm size constitutes, according to international convention, the soil sample. The solid phase thus obtained is broadly composed of inorganic and organic constituents. Soils having more than 20 per cent of organic constituents are arbitrarily designated as organic soil. When inorganic constituents dominate, they are called as mineral soils. Majority of Indian soils are mineral soils.

#### Inorganic Constituents

The inorganic constituents which form the bulk of the solid phase of soil consists of silicates of both primary and secondary origin, having a definite chemical composition and well defined crystalline structure. Soil may also contain a certain proportion of carbonates, soluble salts and free oxides of iron, aluminium and silicon, in addition to amorphous silicates.

#### Primary Minerals

Rocks are the original source of primary minerals in soils. The most abundant are quartz, feldspars with small proportion of pyroxenes, amphiboles, olivines, micas etc. The primary minerals in soil are mostly concentrated in coarse fraction.

#### Secondary Minerals

On weathering, primary minerals are broken down to small fragments such as silica, alumina, iron oxide etc. These are capable of being synthesised into structurally different silicates called secondary minerals, which are the most active ingredients of the soils with respect to chemical, physical and mineralogical properties. Particles of size <2 microns (0.002 mm) is the clay fraction with colloidal properties.

The clay fraction may be composed of clay minerals, hydrated iron and aluminium oxide minerals and amorphous minerals. The secondary minerals are dominant in soil clays. The clay minerals are alumino silicate in chemical composition and crystalline in structure. The oxide and hydroxide minerals constitute a sizeable fraction of soils of humid tropical and subtropical regions and account for variable iron and aluminium (Fe & Al) in those soils.

The principal forms of amorphous minerals in soils are oxides and hydroxides of Fe, Al and silicon. Allophane is a prominent amorphous mineral and is found in soils of volcanic origin.

#### Calcium Carbonate

Carbonates of soil are mostly of calcium with occasionally dolomite. Carbonates may be formed from parent rock or interaction of calcium released during weathering with CO2 of biological origin. Due to low solubility, carbonates of Ca & Mg persist even in the soils of humid region. Calcium carbonate is sparingly soluble and their presence in soil is detected through effervescence when treated with HCl. The CaCO3 is normally absent in soils having a pH less than 7.0. Soils with high CaCO3 are Calcareous. The CaCO3 may be in pulverized form or as concretions. The pH of such soils is 8.0 – 8.5.

#### Soluble Salts

These are released from rocks during weathering. In high Rainfall areas, these are leached down to lower depths.

In low rainfall, low lying and poor drainage areas, soluble salt content may gradually rise so as to limit plant growth. At a range of 0.1 to 0.2 per cent on a dry soil basis, the soluble salt content will cause damage to plants. Salinity is measured conductometrically and expressed as dSm-1 (equivalent to mmho cm-1). Salinty above 4 dSm-1 is harmful. Cations in soluble salt are Ca, Mg, Na and K and anions are chlorides, sulphates, carbonates and bicarbonates. At times, in specific situations nitrates and borates are also present.

#### Free Oxides of Silicon, Iron and Aluminium

During weathering and soil formation, oxides of iron and aluminium and silicon are formed which remain in soil as such or get coated over soil particles.

#### Organic Constituents

Only a fraction of solid phase is of organic origin. The sources are plants and animals. In the process of microbial decomposition of organic materials, most of them are fully decomposed but a small part is transformed into new products which get thoroughly mixed up with soil and become an ingredient – soil humus. This is a continuous process and hence there is the possibility of existence of undecomposed or partially decomposed material along with fully transformed soil humus.

#### Soil Organic Matter

Constitutes humus, humus like fractions and other metabolic organic compounds of the solid phase. The soil organic matter content in most Indian soils is 1 to 2 per cent. Also thee is as low as 0.2 and as high as 10.0 per cent.

#### Living Organisms

Soil is the habitat for enormous number of living organisms. Some are visible to naked eye and many are of microscopic dimensions. Root of higher plants and soil macroflora belong to the first group while microbes like bacteria, fungi and actinomycetes belong to the other group. The live weight of microorganisms may be 4000 kg/ha and it constitutes about 0.01 – 04% of the total soil mass.

#### Liquid Phase

40-50% of the bulk volume of the soil body is occupied by voids or soil pores. This may be completely or partially filled with water. The considerable portion of rain/irrigation water is absorbed by soil and stored in it and later released to the atmosphere through evaporation or transpiration by plants. Soil is a reservoir for supplying water and keeps salts in solution and used as plant nutrients. Thus the liquid phase is an aqueous solution. When all pores are filled with water or solution, it is saturated soil. This stage is transient under field conditions. Water starts draining immediately from bigger pores first. After a few hours (24 hours of saturation) the downward flow is almost negligible and water is retained in soil.

#### Gaseous Phase

The air filled pores constitutes the gaseous phase of the soil system. Volume of gaseous phase is thus dependent on that of liquid phase. At any stage, the sum of volumes of the liquid and gaseous phase remains constant for a particular soil. The nitrogen and oxygen of soil air are almost same as that of the atmospheric air. But the concentration of carbon-di-oxide is much higher.

The three phases of the soil system have definite roles to play. The solid phase provides mechanical support and nutrients to the plants. The liquid phase supply water and along with it dissolved nutrients to plant roots. The aeration need of plants is satisfied by gaseous phase. The soil’s function to sustain plant growth is thus shared complementarily by its three phases.

#### Pedological and Edaphological Approach

These are two different concepts of which one treats soil as natural entity, a bioichemically weathered and synthesized product of nature. The other treats soil as a natural habitat for plants and justifies soil studies primarily on that basis. There are two approaches, viz.,

#### Pedology

Deals with origin of soil, its classification and its description. Derived from the Greek word Pedon which means soil or earth. Pedology in the study of soil as a natural body and does not focus primarily on the soil’s immediate practical use. Pedologist studies, examines and classifies soil as they occur in their natural environment. Highway engineers use this concept of soil.

#### Edaphology

Derived from Greek word edaphos – meaning soil or ground. It is the study of soil from the standpoint of higher plants. Edaphologist consider the various properties of the soil in relation to plant production.

#### Definition

“**Soil is a natural body developed by natural forces acting on natural materials. It is usually differentiated into horizons from mineral and organic constituents of variable depth which differ from the parent material below in morphology, physical properties and constitutions, chemical properties and composition and biological characteristics” - Joffee.**

**LECTURES 7 - 10**

**WEATHERING OF ROCKS AND MINERALS AND SOIL DEVELOPMENT**

Weathering is the disintegration and decomposition of rocks and rock minerals by physical, chemical and biological agents, singly or in combination. Weathering and soil development proceed almost simultaneously in case of soft rocks, while in case of hard rocks, weathering precedes soil development. In these processes, two types of weathering can be recognized viz., **Geochemical** and **Pedochemical**. Geochemical weathering takes place before soil development and continues somewhat unperceptibly beneath the soil cover. This is also termed as **geogenesis**.

Pedochemical weathering or **pedogenesis** is the result of disintegration and transformation of minerals that take place within the soil. The principle agents of weathering are

1. Temperature (mainly mechanical / physical)
2. Water (mechanical and chemical)
3. Plant and animals (physical and chemical)
4. Air (partly mechanical and partly chemical)

**PHYSICAL WEATHERING**

**Temperature**

It results in the comminution of rocks and rock minerals. Granite, for example, subjected to physical weathering retains its original chemical and mineral composition. Changes in atmospheric temperature during day and night and also its seasonal variation cause surface expansion and contraction and break down of the big mass of rocks into smaller fragments. This is common in arid regions. Similarly alternate freezing and thawing in cold regions is a chief agent of physical weathering.

Other agents of physical weathering are

1. Moving water or ice
2. Mutual rubbing of rock fragments
3. Air blast of sand grains.

Physical weathering is predominant in soil formation in the desert and arctic regions, where the soils are characterized by the presence of layer proportions of coarse particles.

**Chemical Weathering**

It gives rise to drastic alteration in the constituent minerals, partially or wholly, with the formation of secondary minerals, which differ markedly from the primary minerals. The secondary products may be formed by alteration in site or by precipitation from solutions under conditions favorable for it.

The principal reactions involved in chemical weathering are one or more of the following depending on the prevailing conditions viz., Oxidation, hydrolysis, reduction, solution, hydration and carbonation.

**Oxidation**

Oxygen is the most energetic oxidizing agent and brings about oxidation of elements such as Fe2+ to Fe3+ e.g.

2 Fe Si03 + 3H2O+ O 2 Fe (OH)3 + 2 SiO2

2 Fe S+ 5 H2O + 9O 2 Fe (OH)3 + 2 H2SO4

The above reaction indicates the possibility of formation of hydrated ferric oxide, silica and sulfuric acid as products of chemical weathering if ‘S’ containing minerals are present.

**Reduction**

Takes place under anaerobic condition. Here Iron and polyvalent elements are reduced to more soluble or mobile forms and are likely to be lost by leaching. Soil environment may change so that oxidation and reduction processes may alternate. Iron and manganese are particularly susceptible to changes

Some oxides are reduced to their lower oxides.

2 Fe2 O3 O2 = 4 Fe O

**Hydration**

Is possible either by the bonding of water molecule to mineral lattices or to cations present in such minerals. Hydration may even alter the crystal structure. e.g.(i.) Formation of serpentine from olivine. (ii). Gypsum from calcium sulphate.

Water itself combines with some minerals / compounds of rocks to form hydrates:

1) 2 Fe2O3 + 3 H2O --🡪 2 Fe2 O3 + 3 H2O

Haematile --🡪 Limonite

2) Olivine to serpentine, (a hydrated Mg silicate)

3 (MgO, FeO S1O2) + 2H2O ---🡪 3 MgO 2 S1O2 .2 H2O

(serpentine) + S1O2 + 3FeO

Fe O (ferrous) oxidized to ferric oxide(Fe2O3) Fe2O3 3H2O (Ferric hydroxide)

**Carbonation**

Combination of cations with carbonic acid brings about a breakdown of mineral lattice. Although the atmosphere contains 0.03 percent CO2, rainwater may contain as high as 0.45 percent CO2.

In regions of high rainfall, the action of CO2 on the decomposition of rocks may be quite considerable. High concentration of CO2 in rainwater is capable of reacting with sparingly soluble carbon forming bicarbonates which are rarely soluble.

e.g Dissolution of limestone in rain water.

H2 O + CO2 = H2CO3 (CO2 of atmosphere in rain water)

Limestone, which is inoculation water, is readily soluble in carbonated water.

Ca CO3 + H2 CO3  Ca (HCO3)2

It also attacks insoluble silicate minerals i.e Felspar, mica, hornblende and convert them to simple silicates liberating carbonates of alkali and alkali earths.

i) K2OAl2O3 6S1O2 + 2H2O+ CO2 Al2O3 2S1O2 2H2O + K2CO3 + 4 S1O2

(Felspar ) (Kaolin)

ii) K2O3Al2O3 6S1O2 . 2H2O+ CO2 + 4H2O 3(Al2O3 2S1O2 .2H2O) + K2CO3

( Muscovite) (Kaolin)

**Hydroysis**

It is a very important process of chemical weathering. By hydrolysis, alkali and alkaline earth ions are replaced in the alumino or ferrosilicate lattice by hydrogen ions with the formation of aluminosilicic or ferrosilicic acid and liberation of alkali and alkaline – earth hydroxides.

The silicic acids are either converted into secondary minerals, i.e. new products or are further decomposed into iron oxide, alumina and silica. E.g. Transformation of orthoclase Feldspar

(KAlSi3 O8) + H2O (HAl Si3 O8) + KOH

unit lattice of kaolinite

**Solution**

Some substances in rock are directly soluble in water and when these soluble substances are removed by continuous action of flowing water, the rock so longer remains solid and breaks to pieces. The solvent action of water is increased when it is acidulated by dissolution of organic and inorganic acids. Such water dissolves alkali, alkaline earths and silica also.

**Biological Weathering**

Physical and chemical weathering brought about by biological agents is biological weathering. Plant roots are one such potent agent. The growing roots of plants exert tremendous pressure in widening cracks and crevices in rocks and their penetration causes disruption of rocks. Minor forms of plant life thrive in such crevices and help further disintegration of rocks. The other important contribution of plant roots is generation of carbon dioxide after their decay.

The CO2 thus formed favors carbonation. This CO2 is the result of activity of soil microorganisms, which convert roots and other organic substances present in soil into humus. Autotrophic organisms derive carbon from atmospheric carbon – di-oxide and energy from inorganic constituents and in the process bring about mineral transformation. It has been reported that the rhizosphere activity of forest seedlings, grown in sand culture containing biotite as their sole source of potassium and magnesium, leads to tram formation of biotite to kaolinite.

**Weathering and stability of minerals:**

The weathered products of rocks and rock minerals are called parent material for soil development. The various complex physical and chemical reactions lead to the break down of the minerals and formation of a number of secondary minerals and / or clay minerals. The smaller the particle sizes of the parent material and higher the temperature, the more rapid is the rate of chemical weathering. The particle sizes of the products vary according to environment from those of the finest clay to coarse sand.

**Weathering and formation of secondary minerals**

The nature of weathering products, some of which may be stable and some partially stable depends upon the nature of the reactants and pH of the weathering environment. Some of the products may be lost by leaching.

* Some of the soluble cations may get exchanged with those of the primary minerals or secondary minerals
* Ultimate products of weathering are silica, alumina and soluble cations – some of these are lost by leaching or combine to form secondary minerals.
* Some secondary minerals like mica and biotite may act as primary mineral and further transforms themselves in situ into other secondary clay minerals. Thus other secondary clays are formed from mica depending on the environment.

E.g.

Mica vermiculite montmorillonite

The nature and type of transformation depend on the prevailing condition.

E.g. presence of calcium and magnesium and a general condition of base saturation are conducive to the formation of montmorilonite or smectite minerals.

Clay minerals in hot dry or cold dry climates where chemical weathering is minimum are the result of largely in situ reactions. Thus kaolinite, a common product of exhaustive hydrolysis and leaching is observed in desert soils owing to in situ decomposition.

The minerals vary in their stability to weathering. The relative stability of minerals is viz., i) Easily weathered – Olivine, Hornblende, Augite, Biotite, Apatite, Anorthite, Andesine, Oligoclase, Albite, Garnet; ii) Moderately stable – Orthoclase, Muscovte, Titanite, Ilmentite, Magnetite, Tourmaline, Zircon and iii) Very stable – Quartz.

#### LECTURES : 11-12

#### FACTORS OF SOIL FORMATION

To increase our understanding of soils as they occur in the field, three phases must be considered:

1. Soil genesis – evolution of soil from its parent materials,
2. Soil classification – grouping of soils having common properties; and
3. Soil survey – the depiction of geographic distribution of soils and their relationship to landscapes.

#### Factors Affecting Soil Formation

1. Climate (temperature and precipitation)
2. Living organisms (native vegetation, microbes, soil animals and human beings: biosphere)
3. Nature of parent material
4. Topography of the site
5. Time that parent materials are subjected to soil formation.

Based on this, the soils is defined as “dynamic natural bodies having properties derived from the combined effect of climate and biotic activities as modified by topography, acting on parent materials over a period of time” – Jenny.

Joffee has defined soil as “ Though weathering is a destructive process, soil formation and weathering go on simultaneously and soil body or **solum** is the final product of both these processes. The soil development or formation is called **soil genesis**. Parent material, topography and time are passive while climate and biosphere are active soil factors.

#### Climate

This is the most influential of the factors because it determines the nature of weathering that occurs. Temperature and precipitation affect the rates of chemical, physical and biological processes responsible for profile development. For every 10oC rise in temperature, the rates of biochemical reaction double. Climate also influences the natural vegetation. Temperature and effective moisture influence the organic matter content of the soil.

#### Rainfall

As rain water percolates and moves from one part of the parent material to another, it carries with it substances in solution as well as in suspension. These are either deposited in another part of the parent material or leached out and removed from the soil body. The movement may be upwards, downwards or even horizontal. So part of the soil body is deprived of some constituents and another is enriched. Indirectly, rainfall influences soil formation through the activities of plant and animal life. The nature, type and amount of vegetation, which it supports in turn affects rainfall.

#### Temperature

Temperature is another climatic agent that influences the process of soil formation. High temperatures hinder the process of leaching and cause an upward movement of soluble salts. Wherever moisture conditions are favourable high temperature favours the growth of luxurious vegetation and at the same time bring about a rapid decomposition of organic matter due to the increased activities of the micro organisms. Low temperatures induce leaching by reducing evaporation. They favour the accumulation of organic matter by slowing down the process of decomposition.

## Vegetation

Biosphere is another important active soil forming agent. It includes elements like vegetation, micro organisms and animals both big and small like rodents, insects, worms etc., that inhabitat soil body. Of these, vegetation is the most pronounced. The roots of plants penetrate deep into the parent material and act both mechanically and chemically. They facilitate percolation, drainage, dissolution of minerals through the action of carbon-di-oxide and other acidic substances. The decomposition and humification of the material adds to the solubilization of minerals. The indirect effect of vegetation is on climate. E.g. Forests lower the temperature of air and increase humidity, reduce evaporation and increase precipitation. Grasses reduce run-off and as a result, greater quantities of rain water penetrate into the parent material.

#### Living Organisms

Soil organisms play a major role in profile differentiation. Organic matter accumulation, profile mixing, nutrient cycling and structural stability are all enhanced by the activities of organisms in the soil. In addition, an interaction develops among the natural vegetation, soil organisms and the characteristics of the soil. As soils develop under native grasslands, bacteria can fix atmospheric nitrogen in to the compounds usable by plants. Other microorganisms attack plant and animal residues, producing slimy organic materials. These along with an abundance of plant roots help bind soil particles to aggregates.

Human activities also can significantly influence soil formation. Destroying natural vegetation (trees, grass) and subsequently tilling the soil modifies the soil forming factors. Similarly, irrigation, fertilization and liming all have significant influences on soil forming processes in some areas.

#### Parent Material

Geological processes have brought to earth numerous parent materials. The nature of parent materials profoundly influences soil characteristics. For e.g., soil texture is influenced by parent material and in turn, soil texture helps control the downward movement of water, thereby affecting the translocation of fine soil particles and plant nutrients. The chemical and mineralogical compositions can also influence weathering directly. E.g., limestone in parent material will delay the development of acidity, a process that moist climate encourage. In addition, leaves of trees found on limestone materials are relatively high in calcium and other base forming metallic cations. As these high base leaves are incorporated into the soil and are decomposed, they further delay the process of acidification, or the progress of soil development in humid temperate areas.

Parent material also influences the quantity and type of clay minerals present in the soil profile. Parent material itself may contain varying amounts and types of clay minerals. Also they greatly influence the kinds of clays that can develop as the soil evolves. Though parent material is a passive factor, at times the effect of climate is subdued or masked by parent material. Soils formed under such conditions are **endodynamomorphic** soils (e.g. Young soils formed on mountain slopes). A soil where the influence of climate is predominate is **ectodynamomorphic** soil. Different rocks or parent materials under similar conditions give rise to soils similar to one another. On the other hand, similar rock or parent material under dissimilar conditions gives rise to different soils.

#### Topography

This relates to the configuration of the land surface and is described in terms of difference in elevation, slope and so on. The topography of the land can hasten or delay the work of climatic forces. Rolling to hilly topography encourages natural soil erosion of the surface layers, which reduces the possibility of a deep soil.

There is a definite interaction among topography, vegetation and soil formation. In the grassland and forest transition zones, trees commonly occupy the slight depression. This is apparently a moisture effect and the nature of the soil in the depression is quite different from that of the uplands. In mountainous regions, slope exposure is unusually warmer than the northern exposure.

#### Time

The length of time that materials have been subjected to weathering influences soil formation. Time or age controls the degree of maturity of a soil body. When the soil body has been acted upon by the soil formers for a longer period of time and when the process of soil formation are more or less complete, it is a mature soil. These soils are well developed. But young or immature soil is still undergoing pedogenic processes and horizon differentiation is not well marked. In course of time, young soil may become mature and mature soils are sometimes degraded. It should be emphasized that two or more of the factors influencing soil formation are usually active simultaneously and interdepent. Thus climate and parent material influence vegetation, which in turn over a period of time has helped influence the nature of parent material available.

### Lectures 13-15

**Soil Forming Processes**

* The pedogenic processes, although slow in terms of human life, yet work faster

than the geological processes in changing lifeless parent material into true soil full of life.

* The pedogenic processes are extremely complex and dynamic involving many

chemical and biological reactions, and usually operate simultaneously in a given

area.

One process may counteract another, or two different processes may work

simultaneously to achieve the same result. Different processes or combination of processes operate under varying natural environment. The collective interaction of various soil forming factors under different environmental conditions set a course to certain recognized soil forming processes.

The basic process involved in soil formation (Simonson, 1959) includes the following.

* Gains or Additions of water, mostly as rainfall, organic and mineral matter to the

soil.

* Losses of the above materials from the soil.
* Transformation of mineral and organic substances within the soil.
* Translocation or the movement of soil materials from one point to another within

the soil. It is usually divided into

* movement of solution (leaching) and
* movement in suspension (eluviation) of clay, organic matter and hydrous oxides

**A. Fundamental Soil forming Processes**

**1.Humification:** Humification is the process of transformation of raw organic matter into

humus. It is extremely a complex process involving various organisms.

First, simple compounds such as sugars and starches are attacked followed by proteins

and cellulose and finally very resistant compounds, such as tannins, are decomposed and the dark coloured substance, known as humus, is formed.

**2.Eluviation:** It is the mobilization and translocation of certain constituent’s viz. Clay,

Fe2O3, Al2O3, SiO2, humus, CaCO3, other salts etc. from one point of soil body to

another. Eluviation means washing out. It is the process of removal of constituents in

suspension or solution by the percolating water from the upper to lower layers. The

eluviation encompasses mobilization and translocation of mobile constituents resulting in

textural differences. The horizon formed by the process of eluviation is termed as eluvial

horizon (A2 or E horizon).

Translocation depends upon relative mobility of elements and depth of percolation.

**3.Illuviation:** The process of deposition of soil materials (removed from the eluvial

horizon) in the lower layer (or horizon of gains having the property of stabilizing

translocated clay materials) is termed as Illuviation. The horizons formed by this process

are termed as illuvial horizons (B-horizons, especially Bt) The process leads to textural

contrast between E and Bt horizons, and higher fine: total clay ratio in the Bt horizon.

**4.Horizonation:** It is the process of differentiation of soil in different horizons along the depth of the soil body. The differentiation is due to the fundamental processes,

humification, eluviation and illuviation.

**B. Specific Soil Forming Processes**

The basic pedologic processes provide a framework for later operation of more specific

processes

**1.Calcification:** It is the process of precipitation and accumulation of calcium carbonate (CaCO3) in some part of the profile. The accumulation of CaCO3 may result in the development of a calcic horizon.

Calcium is readily soluble in acid soil water and/or when CO2 concentration is

high in root zone as:

CO2 + H2O →H2CO3

H2CO3 + Ca → Ca (HCO3)2 (soluble)

Temp.

Ca (HCO3)2 → CaCO3 + H2O + CO2 (precipitates)

CO2

The process of precipitation after mobilization under these conditions is called calcification and the resulting illuviated horizon of carbonates is designated as Bk horizon (Bca).

**2.Decalcification**: It is the reverse of calcification that isthe process of removal of CaCO3 or calcium ions from the soil by leaching

Temp.

CaCO3 + CO2 + H2O → Ca (HCO3)2 (soluble)

(insoluble) CO2

**3.Podzolization:** It is a process of soil formation resulting in the formation of Podzols and Podzolic soils.In many respects, podzolization is the negative of calcification. The calcification process tends to concentrate calcium in the lower part of the B horizon,

whereas podzolization leaches the entire solum of calcium carbonates. Apart from calcium, the other bases are also removed and the whole soil becomes distinctly acidic.

**4. Laterization**: The term laterite is derived from the word later meaning brick or tile and was originally applied to a group of high clay Indian soils found in Malabar hills of

Kerala, Tamil Nadu, Karnataka and Maharashtra.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 extent of 70 to 80 per cent of the total mass, are called laterites or latosols (Oxisols). The soil forming process is called Laterization or Latozation.

Laterization is the process that removes silica, instead of sesquioxides from the upper layers and thereby leaving sesquioxides to concentrate in the solum. The process

operates under the following conditions.

**5. Gleization:** The term *glei* is of Russian origin 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 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 (high rainfall as in humid regions) but often on drainage conditions.This is responsible for the production of typical bluish to grayish horizon with mottling of yellow and or reddish brown colors.

**6. Salinization**: It is the process of accumulation of salts, such as sulphates and chlorides of calcium, magnesium, sodium and potassium, in soils in the form of a salty (salic) horizon. It is quite common in arid and semi arid regions. It may also take place through capillary rise of saline ground water and by inundation with seawater in marine and coastal soils. Salt accumulation may also result from irrigation or seepage in areas of impeded drainage.

**7. Desalinization**: It is the removal by leaching of excess soluble salts from horizons or

soil profile (that contained enough soluble salts to impair the plant growth) by ponding

water and improving the drainage conditions by installing artificial drainage network.

**8. Solonization or Alkalization:** The process involves the accumulation of sodium ions on the exchange complex of the clay, resulting in the formation of sodic soils (Solonetz). All cations in solution are engaged in a reversible reaction with the exchange sites on the clay and organic matter particles.The reaction can be represented as:

Ca.Mg.2 NaX → Ca++ + Mg++ + 2 Na+ + x-6 + 3CO3 2- → Na2CO3 + MgCO3 + CaCO3

(Where X represents clay or organic matter exchange sites)

**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.Much of the dispersion can be eliminated if Ca++ and or Mg++ ions are concentrated in the water, which is used to leach the soonest. These Ca and Mg ion can replace the Na on exchange complex, and the salts of sodium are leached out as

2NaX + CaSO4→ Na2SO4 + CaX

(leachable)

**10. Pedoturbation:** Another process that may be operative in soils is pedoturbation. It is the process of mixing of the soil.Mixing to a certain extent takes place in all soils. The most common types of pedoturbation are:

**Faunal pedoturbation**: It is the mixing of soil by animals such as ants,

earthworms, moles, rodents, and man himself

**Floral pedoturbation** : It is the mixing of soil by plants as in tree tipping that

forms pits and mounds

**Argillic pedoturbation:** It is the mixing of materials in the solum by the churning

process caused by swell shrink clays as observed in deep Black Cotton Soils.

**Development of Soil Profile**

The development of soil profile is a constructive process where in disintegrated material resulted from weathering of rocks and minerals gets converted into a soil body.

Definition of soil profile: The vertical section of the soil showing the various layers from

the surface to the unaffected parent material is known as a soil profile.

The various layers are known as horizons. A soil profile contains three main horizons.They are named as horizon A, horizon B and horizon C. The surface soil or that layer of soil at the top which is liable to leaching and from which some soil constituents have been removed is known as horizon A or the horizon of eluviation.

The intermediate layer in which the materials leached from horizon A have been

re-deposited is known as horizon B or the horizon of illuviation. The parent material from which the soil is formed is known as horizon C. A Study of soil profile is important as it is historic record of all the soil forming processes and it forms the basis for the study in pedagogical investigations.

Soil profile is the key for the soil classification and also forms the basis for the practical utility of soils. A hypothetical mineral soil profile will include O, A, B, C and R master horizons and all the possible sub-horizons.

**Master horizons and sub horizons:**

**O horizon** - It is called as organic horizon. It is formed in the upper part of the mineral

soil, dominated by fresh or partly decomposed organic materials.

This horizon contains more than 30% organic matter if mineral fraction has more

than 50 % clay (or) more than 20 % organic matter if mineral fraction has less clay.

The organic horizons are commonly seen in forest areas and generally absent in

grassland, cultivated soils.

**O1** - Organic horizon in which the original forms of the plant and animal residues

can be recognized through naked eye.

**O2** - Organic horizon in which the original plant or animal matter can not be

recognized through naked eye.

**A horizon** - Horizon of organic matter accumulation adjacent to surface and that

has lost clay, iron and aluminium.

**A1** - Top most mineral horizon formed adjacent to the surface. There will be

accumulation of humified organic matter associated with mineral fraction and

darker in Colour than that of lower horizons due to organic matter.

**A2** - Horizon of maximum eluviation of clay, iron and aluminium oxides and

organic matter. Loss of these constituents generally results in accumulation of

quartz and other sand and silt size resistant minerals. Generally lighter in Colour

than horizons above and below.

**A3** - A transitional layer between A and B horizons with more dominated

properties of A1 or A2 above than the underlying B horizon. This horizon is

sometimes absent. Solum.

**B horizon** - Horizon in which the dominant features are accumulation of clay,

iron, aluminium or humus alone or in combination. Coating of sesquioxides will

impart darker, stronger of red Colour than overlying or underlying horizons.

**B1** - A transitional layer between A and B. More like A than B.

**B2** - Zone of maximum accumulation of clay, iron and aluminium oxide that may

have moved down from upper horizons or may have formed in situ. The organic

matter content is generally higher and Colour darker than that of A2 horizon

above.

**B3** - Transitional horizon between B and C and with properties more similar to

that of overlying B2 than underlying C.

**C horizon** - It is the horizon below the solum (A + B), relatively less affected by

soil forming processes. It is outside the zone of major biological activity. It may

contain accumulation of carbonates or sulphates, calcium and magnesium

**R** - Underlying consolidated bed rock and it may or may not be like the parent

rock from which the solum is formed.

When two or more genetically unrelated (contrasting) materials are present in a profile as in the case of alluvial or colluvial soils then the phenomenon is known as lithological discontinuity. This is indicated by the use of Roman letters as prefixes to the master horizons. eg. Ap, B2, II B22, IIIC

### LECTURES : 16 – 18

**Soil Structure**

It refers to the arrangement of various soil particles. It describes the gross, overall combination or arrangement of the primary soil separates into secondary groupings called aggregates or peds.

**I.Types** : Four principal types

i. Spheroidal (granular and crumb) ii. Platy iii. Prism like iv. Block like

1. **Spheroidal** (granular and crumb)

* rounded peds or aggregates
* usually lie loosely and are separated from each other
* relatively non-porous aggregates are called **granular**
* when the granules are especially porous, the term **crumb** is used.

2. **Plate-like (platy):** aggregates (peds) are arranged in relatively thin horizontal plates, leaflets or lenses.

* found in surface layers of some virgin soils
* but may characterize the lower horizons
* Often inherited from the parent materials, especially those laid down by water or ice.

i) When the units are thick – **platy**

ii)When the units are thin – **laminar**

* + 1. **Prism-like** (Columnar and Priomatic subtypes)
* Vertically oriented aggregates or pillars
* Found in arid and semi arid regions

1. **Block like:** (Blocky and sub-angular blocky)

* aggregates have been reduced to blocks
* when the edges of the cubes are sharp and when the
  1. rectangular faces distinct blocky - **angular**
  2. when sub-rounding has occurred, **sub-angular blocky**

usually confine to subsoil.

Two or more of the structural types listed usually occur in the same soil profile.

**Classification of soil structure**

Based on

**Type** – determined by the shape, & arrangement of the peds

**Class** – differentiated by the size of peds

**Grade** - as determined by the distinctiveness and durability of the peds with which the peds are observed.

**II) Class**: Very fine, fine, medium, coarse and very coarse

For ex - Crumb structures having peds <1 mm size are very fine

2-5 mm size are medium

**III) Grade**: Weak, moderate and srong

Soil is structureless: When there is no observable aggregates, there is no line of cleavage indicating the presence of peds eg. Single grain – Sand dune areas

Massive – puddled soil from a rice field.

**Importance of structure**

* Role of soil structure in relation to plant growth is as below:
* Soil structure influences the amount and nature of porosity
* Structure controls the amount of water and air present in the soil, also their movement and circulation are also controlled by soil structure.
* It affects tillage practices
* Structure controls runoff and erosion
* Platy structure normally hinders free drainage whereas sphere like structure (granular and crumby) helps in drainage.
* crumby and granular structure provides optimum filtration, WHC, aeration and drainage.
* It also provides good habitat for microorganisms and supply of nutrients.

### Lectures 19 - 21

### SOIL TEXTURE

Soil texture and soil structure are major physical properties of soil. **Soil texture** is defined as the relative proportions of various sized particles in a given soil. This involves the size of individual mineral particles. **Soil structure** is the arrangement of soil particles into groups or aggregates. These together help determine not only nutrient supplying ability of soil solids but also the supply of water and air necessary for plant root activity.

Classification of Soil Particles (Soil Separates) According to Size

**I) British Standards Institution**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sl.**  **No.** | **Soil separates** | **Size in mm** | **Sl.No.** | **Soil separates** | **Size in mm** |
| 1. | Clay | < 0.002 | 5. | Fine sand | 0.06 – 0.2 |
| 2. | Fine silt | 0.002 – 0.006 | 6. | Medium sand | 0.2-0.6 |
| 3. | Medium silt | 0.006 - 0.02 | 7. | Coarse sand | 0.6-2.0 |
| 4. | Coarse silt | 0.02 – 0.06 | 8. | Gravel | >2.0 |

**II) International society of soil science**

|  |  |  |
| --- | --- | --- |
| **Sl.**  **No.** | **Soil separates** | **Size in mm** |
| 1. | Clay | < 0.002 |
| 2. | Silt | 0.002 – 0.02 |
| 3. | Fine sand | 0.02 – 0.2 |
| 4. | Coarse sand | 0.2 – 2.0 |
| 5. | Gravel | > 2.0 |

**III) United States Departments of Agriculture (This is the commonly used classification)**

|  |  |  |
| --- | --- | --- |
| **Sl.**  **No.** | **Soil separates** | **Size in mm** |
| 1. | Clay | < 0.002 |
| 2. | Silt | 0.002 – 0.05 |
| 3. | Very fine sand | 0.05 – 0.10 |
| 4. | Fine sand | 0.10 – 0.25 |
| 5. | Medium Sand | 0.25 – 0.50 |
| 6. | Coarse Sand | 0.50 – 1.00 |
| 7. | Very Coarse Sand | 1.00 – 2.00 |
| 8. | Gravel | > 2.0 |

**IV) United States of Public Roads Administration**

|  |  |  |
| --- | --- | --- |
| **Sl.**  **No.** | **Soil separates** | **Size in mm** |
| 1. | Clay | < 0.005 |
| 2. | Silt | 0.005 – 0.05 |
| 3. | Find sand | 0.05 – 0.25 |
| 4. | Coarse sand | 0.25 – 2.00 |
| 5. | Gravel | > 2.00 |

#### Particles Size Analysis- International Pipette method

The principle involved is as follows :When soil particles are suspended in water, they tend to sink. Because there is little variation in the density of most soil particles, their velocity (v) of settling is proportional to the square of the radius (r) of each particle. Thus v = kr2, where ‘k’ is a constant. This is **Stoke’s law**. With the knowledge of velocity of settling, Stoke’s law can be used to calculate the radius of the particles as they settle and the percentage of each size fraction in the sample. These percentages are used to identify the soil textural class as sand, silt or loam.

Particles which are heavy or big in size sink first, followed by those that are smaller. Extremely small particles do not sink, but remain in suspension almost indefinitely. The rate of settling depends on the size or diameter of the particle, assuming the density to be the same. Stoke’s law governs the relationship between the diameter of a particle and its settling velocity.

2 d1 – d2

v = g r2

9 n

where,

v = velocity of settling particle (cm/sec)

g = acceleration due to gravity (981)

d1 = density of soil particles (2.65)

d2 = density of water (1)

n = coefficient of viscosity of water (0.0015 at 4oC)

r = radius of the spherical particles (cm).

#### Assumption to Use Stoke’s Law

1. It holds good for spherical bodies that sink at uniform speed.
2. The diameter of the soil particle that sink is assumed to be the same as that of the sphere. The imaginary diameter of the soil particle is known as **effective diameter** or **equivalent diameter**.
3. The speed of fall is assumed to be uniform in a 10 cm column or depth of water.
4. The falling particles should not touch the sides of the beaker or vessel.

This method of particle size analysis or mechanical analysis is **sedimentation method**. Based on the difference in preliminary treatment and procedure for fractionation, they are

1. Decantation method / beaker method
2. Centrifugal method
3. Pipette method (The most commonly followed method)

#### Textural Composition / Textural Classes

The soil texture class names are used to indicate the various textural make up of soil and its physical properties. Three broad groups of these classes are recognized. They are Sands, Loams and clays. This grouping is based on three main fractions viz., sand, silt and clay.

**Sand**: Includes all soils in which the sand separates make up atleast 70% and clay separate is 15% or less. The properties are those of sand. This includes sand and loamy sand.

**Silt**: Includes soils with atleast 80% silt and 12% less of clay. Properties are those of silt. Only one class prevails, viz., Silt.

**Clay**: Soil must contain 35% clay separate and atleast not less than 40%. The character of clay is dominant. The classes are clay, sandy clay, and silty clay. Sandy clays may contain more sand than clay. The silt content of silty clays exceeds that of clay.

**Loam**: An ideal loam may be defined as a mixture of sand, silt and clay that exhibits the properties of those separates in about equal proportion. Soils of agricultural importance are mostly a type of loam. Based on the varying quantities of sand and clay in the soil,loam has different textural classes. Sandy loam when sand is dominant, similarly silt loams, silty clay loams, sandy clay loams and clay loams.

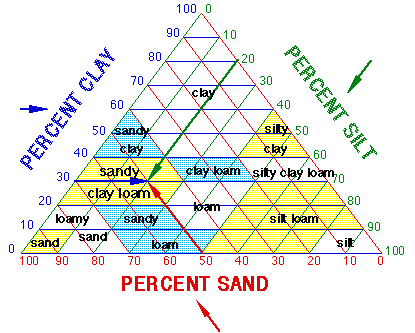
General terms used to describe soil texture in relation to the basic soil textural class names

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl.**  **No.** | **Common Name** | **Texture** | **Basic soil textural class names** |
| 1. | Sandy soils | Coarse | Sands, Loamy sand |
| 2. | Loamy soils | Moderately coarse  Medium  Moderately fine | Sandy loam, Fine sandy loam  Very fine sand loam, Loam, Silt loam, Silt  Sandy clay loam, Silty clay loam, Clay loam |
| 2. | Loamy soils | Moderately coarse  Medium  Moderately fine | Sandy loam, Fine sandy loam  Very fine sand loam, Loam, Silt loam, Silt  Sandy clay loam, Silty clay loam, Clay loam |
| 3. | Clayey soils | Fine | Sandy clay, Silty clay, Clay |

#### Criteria used with the field method of determining soil texture classes

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl.****No.** | **Criteria** | **Sand** | **Sandy loam** | **Loam** | **Silt loam** | **Clay loam** | **Clay** |
| 1. | Individual grains visible to eye | Yes | Yes | Some | Few | No | No |
| 2. | Stability of dry clods | Do not form | Do not form | Easily broken | Moderately easily less than | Hard & stable | Very hard & stable |
| 3. | Stability of wet clods | Unstable | Slightly stable | Moderately stable | Stable | Very Stable | Very stable |
| 4. | Stability of ribbon when wet soil rubbed between thumb & finger | Does not form | Does not form | Does not form | Broken appearance | Thin, will break | Very long & flexible |

Textural Triangle

****

**Textural Triangle (USDA)**

### LECTURE – 22 - 23

### SPECIFIC GRAVITY

# Specific gravity is the ratio of the substance to the weight of an equal volume of water. In other words, it represents the weight of a unit volume o f the substance in the C.G.S system. The true specific gravity, also known as particledensity, of soils varies between 2.5 and 2.7 with an average of 2.65. It is constant for almost all soils that are free of or contain very little organic matter. It is neither affected y soil texture nor by soil structure. Whether the soil particles are big or small it has no appreciable effect on absolute specific gravity.

#### Particle Density

Density is defined as the mass of a unit volume of soil solids. This is called as Particle Density (DP) or absolute specific gravity. In metric system, particle density is expressed as mega grams per cubic meter (Mg/m3). Thus if 1 m3 of soil solids weigh 2.6 Mg, the DP is 2.6 Mg/m3.

The size of the particles of a mineral and the arrangement of soil solids has nothing to do with particle density. It depends on the chemical composition and crystal structure of the mineral particles and is not affected by pore space.

The range for most mineral soils varies between 2.60 and 2.75 Mg/m3. This narrow range occurs because quartz, feldspar, micas and colloidal silicates with densities within this range usually make up the major portion of mineral soils. When minerals with high particle density e.g., magnetite, garnet, epidote etc. are present, particle density may exceed 2.75 Mg/m3.

Organic matter weighs much less than an equal volume of mineral solids and it’s particle density is 1.1 – 1.4 Mg/m3. Hence mineral surface soils with high organic matter have lower particle densities than sub soils. E.g. some mineral soils high in organic matter (15-20%) have particle density as low as 2.4 Mg/m3. Thus organic matter in a soil markedly affect the particle density of a soil. For calculation, the average arable mineral surface soil (3.5% organic matter) is considered to have a particle density of 2.65 Mg/m3.

#### Bulk Density – Apparent Specific Gravity/Volume Weight

This is the second weight measurement defined as the mass (weight) of unit volume of dry soil. This includes soil solids and pores (Db).

#### Calculation of Bulk Density and Particle Density

a) Consider a cubic meter of certain soil in a field

1.33

* This weighs 1.33 Mg.

1. If all the solids are compressed, it will be like

* ½ Pore space

1.33

* ½ solids

c) To calculate B.D. Volume of 1 m3 (solids + pores)

Weight = 1.33 Mg (solids only)

The factors that affect pore space will affect bulk density also

1) Fine textured soils such as silt loam, clay, clay loam, have lower bulk density than sandy soils. The solid particles of fine textured soils are organized in porous grains or granules especially if adequate organic matter is present. Hence they have high pore space and low bulk density. In sandy soils, organic matter is generally low, particles are together and bulk density is high. In fine textured soils, bulk density ranges from 1.00 – 1.60 Mg/m3. In coarse textured soils (sand), it ranges from 1.20 – 1.80 Mg/m3. In very compact soils – bulk density is 2.0 Mg/m3 or even greater. In such soils there are no macro pores and root growth is impaired, the constraint becomes most noticeable above bulk density of 1.6.

2. Bulk Density is higher in lower profile. This is apparently due to lower organic matter content, less aggregation, and root penetration and compaction due to overlying layers.

3. System of crop and soil management also influences bulk density.

Weight of oven dry soil

BD =

Volume of soils

(Solids + Pores)

Bulk density in this case is one half of Particle density and per cent pore space is 50. Bulk density is the weight of solid particles in standard volume of field soil (Solid plus pore space). Particle density is weight of solid particles in a standard volume of those solid particles.

## PORE SPACE

The volume of soil mass that is not occupied by soil particles is known as pore space. Thus is occupied by air and water. The plant roots grow and exist in this pore space. It directly controls the amount of water and air in soil, and indirectly controls plant growth and production.

**Soil Porosity**: Soil porosity is the percentage of pore space by volume in a soil. It can be calculated from the absolute and apparent specific gravity.

Bulk density

% Pore space = 100 - x 100

Particle density

### Lecture 24 Soil Consistency

The manifestation of the physical forces of cohesion and adhesion acting within the soil at various moisture contents are designated by the term called consistency. It includes such properties of the soil as resistance to compression, friability, plasticity, stickiness etc.

### Plasticity:

Defined as the property which enables a clay / soil to take up water, to form a mass that can be deformed into any desirable shape and to maintain the shape after the deformation pressure is removed. Atterberg has putforth three values to describe the plastic behaviour of any soil. These are known as **Atterberg Constants.**

1. **Lower plastic limit:** Shows the moisture content at which the soil begins to show plasticity.
2. **Upper plastic Limit:** The moisture content at which the soil loses its plasticity and begins to flow.
3. **The Plasticity number:** The difference in the moisture per centage between lower plastic limit and upper plastic limit.

### LECTURE – 25

### SOIL COLOUR

Colour is produced by the spectral reflectance of light by the soil. It is an indirect measure of many important properties of soils. Soil colour are measured by using Munsell colour chart. This chart consists of 175 different coloured chips, systematically arranged according to the mean soil notations, on cards in a loose leaf note book. The Munsell notations consists of three variables viz., hue, value and chroma.

**Hue** is the dominant spectral colour. It is related to dominant wavelength of light. The symbol in the letter abbreviation of the colour of rainbow (R for red, YR for yellow red, Y for yellow etc.) preceded by numbers from o to 10. In the colour chart, hue is arranged radially from one card to next.

**Value** refers the relative lightness of colour and is a function (approximately the square root) of the total amount of light. The notation for value consists of numbers from 0 for absolute black to 10 for absolute white. Value is vertically arranged in the colour chart.

**Chroma** is the relative purity or strength of the spectral colour. The notation for chroma consists of numbers beginning at 0 for grey and increases with decreasing greyness. In writing the Munsell notation, the order is hue, value and chroma with a space between the hue letter and the succeeding value number and a virgule between the two numbers for value and chroma, e.g. 5 YR 5/6 (5YR is hue, 5 is values and six is chroma).

The colour of the soil is determined by holding the soil sample below the colour chip being compared. The colour is determined under dry and moist conditions. If the soil sample has more than one distinct colour, then both the colours are recorded. If the soil sample has too many colours, the subbed colour is recorded.

The nomenclature for the soil colour consists of two complementary system viz., colour name and Munsell notation of the colour. Both of them are essential. The colour names are used in description of soils. The munsell notation is useful for international soil correlation.

### LECTURES: 26&27

### SOIL Moisture

#### Importance of Soil Water

1. Large quantities of water should be supplied to satisfy the requirements of growing plants because water is continually lost by evaporation. Thus water should be available when plants need it. This water mostly comes from soil.
2. Water is a universal solvent, which along with dissolved nutrients make up the soil solution from which plants absorb essential nutrients.
3. Soil moisture controls soil air and soil temperature.
4. The force with which water strikes the soil controls soil erosion.

#### Structure and Properties of Soil Water

It is a simple compound, individual molecules contain one oxygen atom and two smaller hydrogen atoms. The elements are bonded covalently, each hydrogen sharing its single electron with oxygen. They are arranged in a V-shape at 104.5o. There is an asymmetrical arrangement and shared electrons are closer to oxygen atoms and in a water molecule, the side on which hydrogen atoms are located are electropositive and the opposite side is electronegative, leading to polarity.

**1. Polarity**

The property of polarity explains how water molecules interact with each other. They are not completely independent, but coupled with neighbouring molecules. The hydrogen of one molecule attracts the oxygen end of the other resulting in a chain like (polymer) grouping.

Due to polarity, the water molecules are attracted to electrostatically charged ions. Cations viz., H+, Na+, K+ and Ca2+ get hydrated through their attraction to oxygen end of water molecule and negatively charged substances get hydrated through their attraction to hydrogen end of water molecules.

Polarity of water is the cause for dissolution of salts in water. When water molecules are attracted to electrostatically charged ions, they are more closely packed than in pore water and their energy level is lower and thus when ions or clay particles are hydrated energy must be released. The released energy is heat of solution if ions are hydrated and it is heat of wetting when clays are hydrated.

**2. Hydrogen Bonding**

The phenomenon by which hydrogen atoms act as a links between water molecules is called as hydrogen bonding. This leads to high electronegativity and is the cause for polymerization of water. H bonding also accounts for high boiling point, specific heat, and viscosity of water compared to other hydrogen containing compounds e.g. H2O.

**3. Cohesion and Adhesion**

H bonding accounts for two basic forces responsible for water retention and movement in soils: (i) the attraction of water molecules for each other – cohesion. Attraction of water molecules for solid surfaces – adhesion or called also as adsorption. By adhesion some water molecules are held together rigidly at soil solid surfaces. In turn, these tightly bound water molecules hold other water molecules by cohesion. Thus adhesion and cohesion together control the movement of water retention.

**4. Surface Tension**

This is evidenced at liquid – air interfaces and results from greater attraction of water molecules for each other (cohesion) than for the air above. The net effect is an inward force at the surface causing the water surface to be a stretched elastic membrane. This is surface tension. Due to greater cohesion, water has high surface tension than other liquids. Surface tension is an important factor in capillarity and determines how water moves.

## Forms of Soil Water

Soil particles possess the power to adsorb moisture from atmosphere. The water adsorbed is known as **hygroscopic water**. Soil water is subject to certain physical forces as a result of which it is retained in soil. There are two forces acting (i) force of attraction/adsorption exerted by the surface of soil particles, (ii) force of gravity. Surface force is greater than gravity. Depending on the magnitude of the resultant force acting on it at any one time, water remains attached or is move downwards to lower layers. These are three types of water based on the force.

**Hygroscopic Water:** Water held on the surface of colloidal particles by dipole orientation of water molecules is hygroscopic water. The layer is very thin and force with which it is held is 10,000 atm. Due to great force it is held so tenaciously that it is incapable of any movement and plants cannot use it. To remove this water, soil is heated at a temperature of 105oC to 110oC for 8-12 hours.

**Hygroscopic Coefficient**: Hygroscopic coefficient is the maximum amount of hygroscopic water adsorbed by 100 g of dry soil at standard conditions of temperature and humidity.

**Capillary Water:** If water is supplied to a soil that has reached its maximum hygroscopic capacity, it begins to adhere to the surface of soil particles as a thin film of liquid water. This is capillary water. As moisture content increases, the thickness of the film increases and finally adjacent particles join and become continuous. It is not as firm as hygroscopic water. It evaporates easily, plant roots easily absorb capillary water. This is otherwise known as available water.

The capacity of the soil the hold maximum amount of capillary water is its **maximum capillary capacity**. At this stage major portion of porespace is filled with water leaving only the interstices. The capillary of the soil to hold the maximum amount of total water is known as its **water holding capacity**. It indicates the maximum amount of water, a soil can hold against gravity. Fine textural soils have high WHC than coarse textured soils.

If hygroscopic coefficient is deducted from WHC it gives maximum capillary capacity. Capillary potential is defined as the energy required to move a unit mass of water in a column of soil against capillary forces from a free water surface to a given point above this surface.

#### Soil Water Characteristics

**Soil Water Energy:** Based on the force with which the soil water is held in the soil it is grouped into three.

1. **Gravitational water**: Drains away under the force of gravity through the large soil pore spaces.
2. **Capillary water**: C.W. is retained in the capillary pores and around soil particles by forces of cohesion and adhesion after gravitational water has moved out.
3. **Hygroscopic water**: Retained very firmly as a thin film around individual soil particles after capillary water has been drained. It is essentially non liquid and moves primarily in the vapor form and it is not available to higher plants.

**Moisture Constants**: For describing soil moisture. They are

**1. Field Capacity (FC)**: This is to describe the amount of water held in the soil after gravitational water has drained away and for all purposes, the downward movement has stopped. This is the concept of expressing the upper limit of plant available soil moisture.

**2. Hygroscopic Coefficient**: used to describe the amount of hygroscopically bound water in soils. Used to mark the lower limit of available H2O. It is the moisture content of the soil that has been absorbed on the soil particles, particularly soil colloids, as a non-liquid and can move only in the vapour phase.

**3.Permanent Wilting Point (PWP)**: The moisture content at which plants remain permanently wilted even when water is added to soil is called as PWP. This is used to define the lower limit of available water. To determine this constant, sunflower is the most widely used test plant.

These moisture constants are used to describe the plant available water-holding capacity of soils. The readily available soil water is considered to be the amount of moisture retained in the soil between field capacity and PWP. It is obtained by calculating the different moisture content of a soil when it is subjected 0.01 or 0.03 Mpa and then to 1.5 Mpa of pressure. However, the capacity of deep rooted trees to use water from capillary fringe above a water table reduces the values of these moisture constants for some forest soils.

**Soil Water movement**

Three types of water movements are observed in soil

These are 1. Saturated flow 2. Unsaturated flow 3. Vapour movement

1. **Saturated Flow:** When the pores are completely filled with water

Moves at water potentials larger ( less negative) than –33kPa. It is water flow caused by gravity pull. It begins with water infiltration-which is water movement into soil when rain or irrigation water is on the soil surface.

When the soil profile is wetted, the movement of more water flowing through the wetted soil is termed **percolation.** The direction of flow is from a zone of higher moisture potential to lower moisture potential.

**Vertical water flow:**

The most common mathematical expression for the vertical water flow rate through soil is called **Darcy’s Law**.

The law states that the rate of flow of liquid or flux through a porous medium is proportional to the Hg in the direction of flow of the liquid.

Qw = --K (dw) At / ds

Where, Qw = quantity of water in cm3

K= Rate constant cm/s

dw=Water height (head),cm

A= soil area cm2

t= Time (any time-units may be used as long as units are given)

ds = soil depth used, cm.

**B. Unsaturated flow:**

In unsaturated soils, the relatively rapid water movement is through the large and continuous pores. But in unsaturated soils, ( soil pores contain some air as well as water), these macro pores are filled with air, leaving only the finer pores to accommodate water movement, which, as would be expected is low. Unsaturated flow is the flow of water held with water potentials lower (more negative) than about –20 to –33 kPa. Water will move towards the region of lower potential and the rate of flow is greater as the water potential gradient ( the difference in potential between wet and dry) increases and as the size of the water filled pores also increases. The water movement under these conditions is very slow compared to that occurring when the soil is saturated.

**C. Water Vapour movement:**

There are two types of water movement.

a). Internal movement: The change from the liquid to the vapour state takes place within the soil that is in the soil pores.

b). External movement:

The phenomenon occurs at the land surface and resulting vapour is lost to the atmosphere by diffusion and convection (surface evaporation). The diffusion of water vapour from one area to another in soil does occur. Water vapour moves from high Vp (generally in moist soil) to low pressure (generally in dry soil).

### LECTURE – 28

### SOIL AIR & SOIL TEMPERATURE

Soil air – composition – air capacity – factors influencing – soil temperature – amount of air space – microbial activity – season – moisture, effect of soil aeration on biological activity and higher plants – soil air renewal – mass flow and diffusion.

Soil air is one of the five components of soil (mineral matter, organic matter, air, water organisms). Part of the soil volume not occupied by soil particles is porespace and this is occupied by both water and air. The volume of air varies inversely with water. The liquid and gaseous phase contribute to 50 per cent under optimum conditions of water supply, the air content is 25 per cent.

In an alluvial soil at Pusa, solid particles occupy 48 to 49 per cent of total volume. At air-dry moisture content, air occupies 73-84 per cent.

#### Composition of Soil Air

Of the number of gases in soil air, nitrogen, oxygen, CO2 and water vapour are the most important constituents. If differs from atmospheric air in three aspects

1. Greater proportion of CO2
2. Lesser amount of Oxygen and
3. Greater amount of water vapour in soil air. Nitrogen is almost of same concentration in both.

|  |  |  |  |
| --- | --- | --- | --- |
| **Gases** | **Soil Air (%)** | | **Atmospheric Air** |
| **Temperature** | **Tropical** |
| Nitrogen | 79.2-81.4 | 85.9-91.4 | 78.0 |
| Oxygen | 15.1-20.6 | 7.6-18.6 | 21.0 |
| Carbon dioxide | 0.2-4.5 | 1.0-5.00 | 0.03 |

#### Effects of Soil Aeration / Importance of Soil Aeration

**a) On soil reactions and properties**

Soil aeration influences many soil reactions and in turn, soil properties. These reactions are associated with microbial breakdown of organic residues. Poor aeration slows down the rate of decay. The decay is determined by O2 gas of the soil. Where oxygen is present, aerobic organisms are active and oxidation reaction takes place.

C6H12O6 + 6O2 6CO2 + 6H2O

(Sugar)

In the above of oxygen, anaerobic organisms domination and oxidation is slowered.

C6H12O6 3CO2 + 3CH4 (Methane)

Poorly aerated soils are significant sources of methane gas, a pollutant of the upper atmosphere and responsible for global warming.

Less complete decomposition than the above will lead to production of organic acids and ethylene gas (C2H4) which is toxic to higher plants.

Thus presence/absence of oxygen will modify the nature of decay process and its effect on plant growth.

**b) Oxidation – Reduction of Inorganic Elements**

The level of oxygen determines the forms of several inorganic elements. Oxidised states of nitrogen and sulfur are readily utilized by plants. Generally oxidised forms of most elements are more desirable especially in acid soils of humid region, because reduced forms of Iron and Mn are in toxic levels in moist acid soils.

In drier areas, the reduced forms of Fe and Mn are preferred. In neutral to alkaline soils of drier areas. Oxidised forms of Fe and Mn are present as insoluble compounds leading to their deficiencies. Colours such as red, yellow and reddish brown indicate well oxidised states grays blues predominant if insufficient oxygen is present. Imperfectly drained soils are characterised by alternate streaks of oxidised and reduced materials. The mottled condition includes a zone of alternate good and poor aeration, which is not conducive to proper plant growth.

**c) Effects on Higher Plants**

Higher plants are affected in three ways due to poor aeration.

**(i) Growth of Plants:** The tolerance of a given plant to low porosity is different for seedlings rather than rapidly growing plants. In adequate supply of oxygen either retards growth or ceases completely. The oxygen demand varies with species. If soils air is below 10-12% plants are likely suffer.

**(ii) Nutrient and Water:** Absorption of nutrient and water is affected in reduced oxygen in soil. Because low oxygen constrain root respiration, the process which provides energy for nutrient and water absorption. Over supply of water will reduce water absorption by plants. Poorly drained soils show nutrient deficiency symptoms even though they are fairly well supplied with available nutrients.

(iii) Formation of inorganic compound toxic and plant growth

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl.**  **No.** | **Element** | **Normal form in well-oxidized soils** | **Reduced form in waterlogged soils** |
| 1. | Carbon | CO2 | CH4 |
| 2. | Nitrogen | NO3- | NH4+, N2 |
| 3. | Sulfur | SO42- | H2S, S2- |
| 4. | Iron | Fe3+ (Ferric oxides) | Fe2+ (Ferrous) |
| 5. | Manganese | Mn4+ (Manganic oxides) | Mn2+ (Manganous oxides) |

**d) On Microbial Activity**

Microbes in soil need oxygen for respiration and metabolism. Nitrification, sulfur oxidation, decomposition of organic matter requires oxygen. Oxygen deficiency slow down the rate of microbial activity in soil. It will alter the type of organisms functioning. Anaerobic organisms dominate under this condition. Accumulation of CO2 in soil air is also injurious to plant growth as it leads to a toxic condition. Excess CO2 retard germination. Insufficient aeration leads to diseases of plants. E.g. Dieback of fruit trees, citrus, peach. Poor aeration leads to development of toxins and reduced forms of Fe and Mn, accumulation of organic acids as butryic, acetic etc. in toxic quantities.

Another important aspect of aeration is the ease with which gas exchange takes place. In sandy soils and soils with large pores, exchange is rapid. In clayey and fine-textured soils, it is poor. Such soils may have sufficient pore space but will not allow rapid exchange. In such soils, crumb structures are to be maintained. Texture and structure thus control the air content of soil and air renewal.

**Mass flow:** The force for mass flow is the total pressure gradient of the gas, i.e. entire mass of air streaming from zone of high pressure to low pressure. The difference in pressure is due to changes in soil temperature, wind action, atmospheric pressure, rain water and irrigation. If there is a temperature difference between soil surface and atmosphere, exchange takes place.

### SOIL TEMPERATURE

Temperature of the soil greatly affects the physical, biological and chemical processes occurring in the soil. The main source of heat energy for soil is solar radiation. Which determines the thermal regime of the soil and growth of plants. The modes of heat transfer in soil are convection, conduction and latent heat transfer.

#### Importance of Soil Temperature

**Plant Processes:** Plants vary widely in soil temperature at which they grow best and there is variability in optimum temperature for plant processes. E.g. for corn, seed germination requires 7-10oC and root growth at 25oC. The life cycle of flowers and ornamentals also is influenced greatly by soil temperature. Tulip bulk requires “chilling” to develop flower development.

**Microbial Processes:** Microbial oxidation of ammonium ions x nitrates ions occurs readily at 27-32oC and negligible when lowered at 10oC. Thus anhydrous ammonia fertilizers can be injected into cold soils in the spring and the ammonium ions will not be readily oxidized to nitrate ions until the soil temperature rises. At high soil temperatures, certain plant diseases are controlled. In hot summers with daily temperature of 735oC, covering the ground with transparent plastic sheet can raise soil temperature to 50oC or even higher. This temperature will reduce certain with causing diseases. This heating process called as soil solarization is used to control pests and diseases. The speed of chemical reactor is doubled for every 10oC rise in temperature.

**Freezing and Thawing:** In addition to direct influence of temperature on plant and animal life, the effect of freezing and thawing must be considered. Alternate freezing and thawing subject the soil aggregates to pressure as ice crystals and expand and alter the physical structure of the soil. The alternate freezing and thawing dead to imperfect drainage and kill the plants. The temperature of soils in the field is dependent directly or indirectly on three factors viz., i) Net amount of heat the soil absorbs, ii) The heat energy required to bring about a given charge in the temperature of a soil and iii) Energy required for changes such as evaporation, which are constantly occurring at or near the surface of soils.

#### Sources of Heat

**1. Solar radiation** is the major source of heat to soils. The insulation or exposure of the earth to the heat of the sun warms the soil surface. Clouds and dust particles intercept the rays. Only 35-40% of solar radiation reaches the earth. Of this, primarily used to evaporate water and only about 10% is absorbed by soil.Part of the energy received is further lost to atmosphere by reflection from earth. The other factors that influence the amount of energy absorbed by soils, is soil colour, slope, vegetation etc. Depending on the colour, the amount of heat absorbed varies from 40 to 85 % of the incident radiation. Dark colour soils absorb more energy. Dark soils are usually high in organic matter content and hold large amount of water, which requires more energy.

The angle at which the sun’s rays strike the soil also influence soil temperature. If it is pependicular, it is greatest. Whether the soil is base or covered with vegetation or mulch also markedly influence the amount of solar radiation reaching the soil. Base soils warm up more quickly and cool off more rapidly than those covered with vegetation or plastic mulches. Frost penetration is greater in base non-insulated soil.

The chemical and biological processes in the soil also evolve heat, but the quantity is small and hence has no effect on soil temperature.

#### Factors Controlling Soil Temperature

**a) Nature of Soil:** Soil consists of mineral and organic matter. The specific heat of these two vary. The capacity of the soil to absorb heat varies with the proportion of the two. The specific heat of mineral matter is greater than the organic materials and their conductivity is also high. The specific heat of dry soil is 0.17 to 0.27. The mineral soils get more heated than organic soils.

The amount of energy required to raise the temperature of water by 1oC (heat capacity) is much greater than that required to warm soil solid by 1oC. When heat capacity is expressed per unit mass e.g. Calories/g (cal/g) it is specific heat. Pure water – 1.00 cal/g, dry soil is 0.2 cal/g.

Specific heat is an important property. It controls the degree to which soils warm up.

Consider a dry soil of 10 kg H2O/100 kg solids m 273 cal/kg

Wet soil of 30 kg H2O/100 kg solids 385 cal/kg.

The wet soil will warm up more slowly than dry one.

Soil texture also influences soil temperature. Sandy soils warm up quicker than fine grained clay as the latter has large amount of water. Soil structure controls the pore space or amount of air in soil. Soils with good structure warm up rapidly. Soil colour also influences soil temperature. Temperature is greater in dark soils. Black soils absorb more heat and are warmers. However if dark colour is due to humus, they are cooler, as the humus has low heat absorbing capacity.

**b) Soil Moisture:** Moist soils have higher specific heat than dry soils. So moist soils are heated slowly. Greater moisture content, greater heat is required to the soil. Further water evaporation also lowers the temperature. Effect of rain on temperature is due to change in air temperature and the increase in evaporation. Once the soil is wet after the start of the monsoon, subsequent rains have as appreciable effect on soil temperature. The change in temperature is then controlled by rate of evaporation.

**c) Plant Cover:** Soils covered with vegetation absorb less heat than base soils. Vegetation absorbs most of the incident radiation. Soils with forest species are well protected than those with annual crops. Plant cover prevents the soil from getting cool also, as it retards loss of heat. So soils with dense cover are cooler. Base soils cooled more rapidly there is danger of frost injury in base soils in winter.

**d) Topography:** The slope, its direction and position affects soil temperature. In the northern hemisphere. Soil on the southern slope gets heated to a greater extent than that in the northern slope. This is due to a more perpendicular ray of sun on the southern slope. However the angle, greater the absorption of heat. That is why in temperate regions southern exposure is preferred for plantation and orchards.

**e) Climate:** In temperature and cool arctic region soils are cooler than in tropics and seals tropics. Towards equator, temperature is high. The variation in precipitation also controls soil temperature. If rainfall is high temperature of soil is low soil along sea coast or water bodies have lower temperature than that away. Water absorption heat and atmosphere is changed with water vapour. Therefore temperature is reduced.

**f) Season:** In temperate regions, temperature is lowest in winter and highest in summer. This is due to the amount of heat energy received from the sun. Also the angle of incidence on the earth. In winter, amount received is less and loss due to radiation is high. Seasonal variation in soil temperature is less in tropics and semi-tropics.

**Lecture 29 SOIL REACTION**

**Soil pH**

pH is defined as the negative logarithm of hydrogen ion concentration or simply the log of the reciprocal of the hydrogen ion concentration (Sorenson, 1906).

pH = -log (H+) = log 1 / (H+)

The acidity or alkalinity of a so1ution can be expressed on the scale of acidity and alkalinity. The scale of acidity or alkalinity is called pH scale. The unit of this scale is

called pH value. This scale runs from 0 to 14. The neutral point in this scale is at pH 7.

All the values above pH 7 represent alkalinity and below 7 denote acidity. The degree of

alkalinity increases as values go above pH 7 and the degree of acidity increases as the pH decreases below 7.

## Classification

|  |  |
| --- | --- |
| **pH values** | Classification |
| <6.5 | Acidic |
| 6.5-7.5 | Neutral |
| >7.5 | Alkaline |

**Sorenson (1969)** suggested that H ions concentration be generally expressed as

the numerical value of the negative power to which 10 must be raised in order to express

the required concentration and this value be designated by the symbol pH. Thus,

technically pH is the negative logarithm of the H ion concentration or the logarithm to the

base ten of the reciprocal of hydrogen ion concentration

i.e. H+ = 10 - pH

log [H+] = -pH log 10

- pH = log [H+] / log 10

pH = log [H+] / log 10

Since log 10 =1, therefore pH = -log [H+] OR pH = log 1/ [H+]

**Soil acidity**: There are three kinds of acidity. (i) Active acidity is due to the H+ ion in the

soil solution.

(ii) Salt replaceable acidity represented by the hydrogen and aluminum that are easily

exchangeable by other cations in a simple unbuffered salt solution such as KCl and

(iii) Residual acidity is that acidity which can be neutralized by limestone or other

alkaline materials but cannot be detected by the salt-replaceable technique. Obviously,

these types of acidity all add up to the total acidity of a soil.

i**. Active acidity**: The active acidity is a measure of the H+ ion activity in the soil solution

at any given time. However, the quantity of H+ ions owing to active acidity is very small

compared to the quantity in the exchange and residual acidity forms. For example, only

about 2 kg of calcium carbonate would be required to neutralize the active acidity in a

hectare-furrow slice of an average mineral soil at pH 4 and 200/0 moisture. Even though

the concentration of hydrogen ions owing to active acidity is extremely small, it is

important because this is the environment to which plants and microbes are exposed.

ii. **Salt replaceable (exchangeable) acidity**: This type of acidity is primarily associated

with the exchangeable aluminum and hydrogen ions that are present in largest quantities

in very acid soils. These ions can be released into the soil solution by an unbuffered salt

such as KCl.

Al3+ + 4KCI +AlCl3+HCI' L~~~ H + L~~~~ ~ (Soil Solid) (Soil Solution) (Soil Solid)

(Soil solution). In moderately acid soils, the quantity of easily exchangeable aluminum

and hydrogen is quite limited. Even in these soils, however, the limestone needed to

neutralize this type of acidity is commonly more than 100 times that needed for the soil

solution (active acidity). At a given pH value, exchangeable acidity is generally highest

for smectites, intermediate for vermiculites, and lowest for kaolinite.

**iii. Residual acidity:** Residual acidity is that which remains in the soil after

active and exchange acidity has been neutralized. Residual acidity is generally associated

with aluminum hydroxy ions and with hydrogen and aluminum atoms that are bound in

non exchangeable forms by organic matter and silicate clays. If lime is added to a soil,

the pH increases and the aluminum hydroxy ions are changed to uncharged gibbsite.

**Factors Controlling Soil Reactions**: Soil reaction varies due to following factors

1. Nature of soil colloids:

2. Soil solution:

3. Climate:

4. Soil management:

5 Parent materials:

6. Precipitation:

7. Decomposition of organic matter:

8. Native vegetation:

9. Soil depth

10 Nitrogen fertilization:

11. Flooding:

**Influence of Soil Reaction on Availability of Nutrients:**

The unproductiveness of acid andalkali soils is very often due to the lack of available plant nutrients. In highly acid soils(low pH), the availability of some of the nutrients such as aluminum, iron, manganese etc., is increased to a point to become toxic to the plant. At the same time the supplies ofavailable calcium, nitrogen, phosphorus etc., are reduced to starvation level (become unavailable). The same is the case at high pH (alkaline conditions), plant growth suffers due to the unavailability of nutrients like nitrogen, phosphorus and some minor elements (e.g., iron, manganese, boron etc). Another indirect effect occurs through the activity of microorganisms. Most microorganisms function at their best within a pH range 6.0 to 7.5. If soil reaction is changed beyond this range, the microorganisms become functionless. Consequently the supply of some of the essential plant nutrients like nitrogen is considerably reduced.

1**. Nitrogen**: Plant absorbs most of their nitrogen in the form of nitrate of which

availability depends on the activity of nitrifying bacteria. The micro- organisms

responsible for nitrification are most active when the pH is between 6.5 and 7.5. They are

adversely affected if the pH falls below 5.5 and rises above 9.0. Nitrogen fixing bacteria

(like Azotobactor) also fail to function below pH 6.0. The decomposition of organic

matter which is the primary source of nitrogen is also slowed down under acidic

condition.

2. **Phosphorus:** Its availability is at its highest when the reaction is between 6.5 and 7.5.

When the reaction is above or below this range, availability is reduced. In the strongly

acidic soil (pH 5.0 or less), iron, aluminum, manganese and other bases are present in a

soluble state and in more quantity. The phosphates of these elements are formed and

become unavailable.

3 **Potassium:** The availability of potassium does not influence by soil reaction to any

great extent. In acid soil potassium is lost through leaching. The unavailability of K is due to the conversion of exchangeable to non-exchangeable potassium in alkaline soil.

Particularly if the alkalinity is due to CaCO3 (brought about by over liming in acid soil),

the solubility of soil potassium is depressed.

4. **Calcium and magnesium**: Acid soils (base unsaturated) are poor in / available calcium and magnesium. In alkaline soil (pH not exceeding 8.5) the availability of Ca and Mg nutrients are always high. When the pH is above 8.5, the availability of these nutrients again decreases.

**5. Iron, aluminum and manganese**: When the pH is low the solubility of "iron, aluminum and manganese compounds are increased. and hence they are readily available in acid soils. At the pH range 5.5 to 7.0, iron and manganese are present in the soluble ferrous (Fe++) and manganous (Mn++) forms. At pH below 5.5. the solubility of these

compounds considerably increased with the result that they have a toxic influence on

plant growth. Under neutral and alkaline conditions, iron and manganese are usually

present in ferric (Fe3+ ) and manganese (Mn++++) states. Hence in soils with pH 7.5 and

above, they become unavailable and sometimes produce deficiency diseases like

chlorosis in plants.

**6. Sulphur:** The availability of sulphur is not affected by soil reaction as sulphur

compounds are soluble. in low pH range. However, it is more soluble in acid soil and lost

in leaching. Acid conditions, which retard the decomposition of organic matter, therefore,

retard the release of available sulphur. The availability of sulphur present in organic

matter depends upon the decomposition of organic matter.

**7. Micronutrients**: In general, the availability of boron, copper and zinc is reduced in

alkaline soils and that of molybdenum in acid soils. The availability of these nutrients

progressively decreases as the soil pH increases. Their availability also decreases under

highly acid condition when the pH is below 5.0. Zinc availability in alkaline soils from

insoluble zinc salts (calcium zincate) is reduced. Zinc and copper are adsorbed on the

clay colloids and not easily displaced and hence not available for plant growth. The

availability of molybdenum is reduced under acid soils. It is more available in neutral and

alkaline soils.

**Lecture 30 Soil Electrical Conductivity**

The electrical conductivity (E.C) measurement gives the total amount of soluble salts present in the soil and is expressed as millimhos / cm or dSm-1. As the amount of the soluble salts in a solution increases the electrical conductivity also increases. This electrical conductivity is measured in terms of the resistance offered to the flow of current using a conductivity bridge.

It is known that solutions offer some resistance to the passage of electric current through them, depending upon the concentration of salts present. Hence E.C is measured in terms of electrical resistance between parallel electrodes immersed in the soil suspension of water. In such a system, the solution between the electrodes becomes the electrical conductor to which the physical laws relating to resistance are applicable. The electrical resistance “R” is directly proportional to the distance “L” between the electrodes and inversely proportional to the cross sectional area “A” of the conductor.

Hence R = L / A or R= r x L / A

Where r = proportionality constant known as electrical resistivity

If L = 1 cm and A = 1 cm2 then R = r.

Where r is called specific resistivity. Hence specific resistance is the resistance of a conductor 1 cm in length and 1 cm2 in area.

Higher the salt content, higher the passage of current and lesser the resistance to the flow of the current. Hence the reciprocal of specific resistivity is called as specific conductivity. Therefore specific conductivity is defined as the conductivity of a solution enclosed in a cell whose electrodes are exactly 1 cm and possess a surface area of 1 cm2. The resistance is expressed as ohms / cm and the conductivity is expressed in reciprocal ohms or mhos per cm. It is not possible to make a conductivity bridge having electrodes 1 sq.cm. in area and place exactly 1 cm apart. Hence, the factor called the cell constant is determined for the given cell. Modern conductivity meters are calibrated to read directly the electrical conductance with given cell.

**Classification**

|  |  |  |
| --- | --- | --- |
| **EC (dSm-1)** at 25 °C | Salinity effect | **Interpretation** |
| 0.0-1.0 | Harmless | Salinity effect negligible |
| 1.1 – 3.0 | Critical | Limits yield of sensitive crops |
| >3.1 | Injurious | Limits yield of many crops |

**Lectures 31 & 32 SOIL COLLOIDS**

**SOIL COLLOIDS**

The colloidal state refers to a two-phase system in which one material in a very

finely divided state is dispersed through second phase. The examples are: Solid in liquid - Clay in water (dispersion of clay in water). Liquid in gas-Fog or clouds in atmosphere.The clay fraction of the soil contains particles less than 0.002 mm in size. Particles less than 0.001 mm size possess colloidal properties and are known as soil colloids.

**General Properties of Soil Colloids**

1.Size

2. Surface area

3. Surface charges

i) Ionizable hydrogen ions

ii) Isomorphous substitution

4. Adsorption of cations.

5. Adsorption of water

6. Cohesion:

7. Adhesion:

8. Swelling and shrinkage

9**.** Dispersion and flocculation:

10. Brownian movement:

11. Non permeability

**Types of Soil Colloids** : There are four major types of colloids present in soil

1. Layer silicate clays

2. Iron and aluminum oxide clays (sesquioxide clays)

3. Allophane and associated amorphous clays

4. Humus.

Layer silicate clays, iron and aluminum oxide clays, allophane and associated amorphous

clays are inorganic colloids while humus is an organic colloid.

1. Layer silicate clays: These are most important silicate clays and are known as

phyllosilicates (Phyllon - leaf) because of their leaf-like or plate like structure. - They are

comprised of two kinds of horizontal sheets. Qne dominated by silicon and other by

aluminum and/or magnesium.

Silica Tretrahedron: The basic building block for the silica-dominated sheet is a unit

composed of one silicon atom surrounded by four oxygen atoms. It is called the silica

tetrahedron because of its four-sided configuration. An interlocking array or a series of

these silica tetrahedra tied together horizontally by shared oxygen anions gives a

tetrahedral sheet.

Alumina Octahedron: Aluminium and/or magnesium ions are the key cations in the

second type of sheet. An aluminium (or magnesium) ion surrounded by six oxygen atoms

or hydroxyl group gives an eight sided building block termed octahedron. Numerous

Octahedra linked together horizontally comprise the octahedral sheet. An aluminumdominated sheet is known as a dioctahedral sheet, whereas one dominated by magnesium is called a trioctahedral sheet. The distinction is due to the fact that two aluminum ions in a dioctahedral sheet satisfy the same negative charge from surrounding oxygen and hydroxyls as three magnesium ions in a trioctahedral sheet.

The tetrahedral and octahedral sheets are the fundamental structural units of silicate clays. They, in turn, are bound together within the crystals by shared oxygen atoms into

different layers. The specific nature and combination of sheets in these layers vary from

one type of clay to another and largely control the physical and chemical properties of

each clay.

**Types of Silicate Clay Minerals:** On the basis of the number and arrangement of

tetrahedral (silica) and octahedral (alumina-magnesia) sheets contained in the crystal

units or layers, silicate clays are classified into three different groups

1 :1 Type clay minerals

2:1 Type clay minerals

2: 1: 1 Type clay minerals

1:1 Type Minerals: The layers of the 1:1-type minerals are made up of one tetrahedral

(silica) sheet combined with one octahedral (alumina) sheet-hence the terminoiogy. In

soils, kaolinite is the most prominent member of this group, which includes hallosite,

nacrite. and dickite. The tetrahedral and octahedral sheets in a layer of a kaolinite crystal are held together tightly by oxygen atoms, which are mutually shared by the silicon and aluminum cations in their respective sheets. These layers, in turn, are held together by hydrogen bonding. Consequently, the structure is fixed and no expansion ordinarily occurs between layers when the clay is wetted. Cations and water do not enter between the structural layers of a 1 : 1-type mineral particle. The effective surface of kaolinite is thus restricted to its outer faces or to its external surface area. Also, there is little isomorphous substitution in this 1: 1- type mineral. Along with the relatively low surface area of kaolinite, this accounts for its low capacity to adsorb cations.

**2:1-Type Minerals**: The crystal units (layers) of these minerals are characterized by an

octahedral sheet sandwiched between two tetrahedral sheets. Three general groups have

this basic crystal structure.

i) Expanding-type : smectite and vermiculite

ii) Non-expanding type : mica (illite)

**Expanding Minerals:** The smectite group is noted for interlayer expansion, which occurs by swelling when the minerals are wetted, the water entering the interlayer space and forcing the layers apart. Montmorillonite is the most prominent member of this group in soils, although beidellite, nontronite, and saponite are also found.

**The flake-like crystals of smectites (e.g., Montmorillonite**) are composed of an

expanding lattice 2:1-type clay mineral. Each layer is made up of an octahedral sheet

sandwiched between two tetrahedral (silica) sheets. There is little attraction between

oxygen atoms in the bottom tetrahedral sheet of one unit and those in the top tetrahedral

sheet of another. This permits a ready and variable space between layers, which is

occupied by water and exchangeable cations. This internal surface far exceeds the surface

around the outside of the crystal. In montmorillonite magnesium has replaced aluminum

in some sites of the octahedral sheet. Likewise, some silicon atoms in the tetrahedral

sheet may be replaced by aluminum. These substitutions give rise to a negative charge.

These minerals show high cation exchange capacity, marked swelling and

shrinkage properties. Wide cracks commonly form as smectite-dominated soils (e.g.,

Vertisols) are dried. The dry aggregates or clods are very hard, making such soils difficult

to till.

**Vermiculites** are also 2: 1-type minerals in that an octahedral sheet occurs between two

tetrahedral sheets. In most soils vermiculites, the octahedral sheet is aluminum-dominated

(dioctahedral), although magnesium dominated (trioctahedral) vermiculites are also

common. In the tetrahedral sheet of most vermiculites, considerable substitution of

aluminum for silicon has taken place. This accounts for most of the very high net

negative charge associated with these minerals. Water molecules, along with magnesium and other ions, are strongly adsorbed in the interlayer space of vermiculites.

They act primarily as bridges holding the units together rather than as wedges driving

them apart. The degree of swelling is, therefore considerable less for vermiculites than for smectites. For this reason, vermiculites are considered limited-expansion clay minerals, expanding more than kaolinite but much less than the smectites.

The cation exchange capacity of vermiculites usually exceeds that of all other silicate clays, including montmorillonite and other smectites, because of very high negative charge in the tetrahedral sheet. Vermiculite crystals are larger than those of the smectites but much smaller than those of kaolinite.

**Non-expanding minerals**: Micas are the type minerals in this group. (eg) Muscovite and

Biotite. Weathered minerals similar in structure to these micas are found in the clay fraction of soils. They are called fine-grained micas. Like srnectites, fine-grained micas have a 2:1-type crystal. The properties such as hydration, cation adsorption, swelling, shrinkage. and plasticity are much less intense in fine-grained micas than in smectites. The fine grained micas exceed kaolinite with respect to these characteristics, but this may be due in part to the presence of interstratified layers of smectite or vermiculite. In size, too, fine-grained mica crystals are intermediate between the smectities and kaolihites. Their specific surface area varies from 70 to 100 m2/g, about one eighth that for the smectites.

**2:1:1 Type Minerals**: This silicate group is represented by chlorites, which are common

in a variety of soils. **Chtorites** are basically iron-magnesium silicates with some

aluminum present. In a typical chlorite clay crystal, 2:1 layers, such as in vermiculites,

alternate with a magnesium-dominated trioctahedral sheet, giving a 2:1:1 ratio.

Magnesium also dominates the trioctahedral sheet in the 2:1 layer of chlorites. Thus, the

crystal unit contains two silica tetrahedral sheets and two magnesium-dominated

trioctahedral sheets giving rise to the term 2: 1 :1 or 2:2-type structure. The negative charge of chlorites is about the same as that of fine-grained micas and considerably less than that of the smectites or vermiculites. Like fine micas, chlorites may be interstratified with vermiculites or smectites in a single crystal. Particle size and surface area for chlorites are also about the same as for fine grained micas. There is no water adsorption between the chlorite crystal units, which accounts for the non expanding nature of this mineral.

**1.Mixed and interstratified layers**: Specific groups of clay minerals do not occur

independently of one another. In a given soil, it is common to find several clay minerals

in an intimate mixture. Furthermore, some mineral colloids have properties and

composition intermediate between those of any two of the well defined minerals

described. Such minerals are termed mixed layer or interstratified because the individual

layers within a given crystal may be of more than one type. Terms such as "chloritevermiculite"and "fine-grained mica- smectite" are used to describe mixed-layer minerals. In some soils, they are more common than single-structured minerals such as

montmorillonite.

2**. Iron and aluminum oxide clays (sesquioxide clays**) : Under conditions of extensive

leaching by rainfall and long time intensive weathering of minerals in humid warm

climates, most of the silica and much of the alumina in primary minerals are dissolved

and slowly leached away. The remnant materials, which have lower solubility, are

sesquioxides. Sesquioxides (metal oxides) are mixtures of aluminum hydroxide, Al

(OH)3, and iron oxide, Fe2O3, or iron hydroxide, Fe (OH)3. These clays do not swell, not sticky and have high phosphorus adsorption capacity.

3. **Allophane and other Amorphous Minerals** : These silicate clays are mixtures of silica and alumina. They are amorphous in nature. Even mixture of other weathered oxides (iron oxide) may be a part of the mixture. Typically, these clays occur where large

amount of weathered products existed. These clays are common in soils forming from

volcanic ash (e.g., Allophane). These clays have high anion exchange capacity or even

high cation exchange capacity. Almost all of their charge is from accessible hydroxyl

ions (OH-), which can attract a positive ion or lose the H+ attached. These clays have a

variable charge that depends on H+ in solution (the soil acidity).

4. **Humus (Organic Colloid) :** Humus is amorphous, dark brown to black, nearly insoluble in water, but mostly soluble in dilute alkali (NaOH or KOH) solutions. It is a temporary intermediate product left after considerable decomposition of plant and animal remains.They are temporary intermediate because the organic substances remain continue to decompose slowly. The humus is often referred to as an organic colloid and consists of various chains and loops of linked carbon atoms. The humus colloids are not crystalline. They are composed basically of carbon, hydrogen, and oxygen rather than of silicon, aluminum, iron, oxygen, and hydroxyl groups.

The organic colloidal particles vary in size, but they may be at least as small as the silicate clay particles. The negative charges of humus are associated with partially

dissociated enolic (-OH), carboxyl (-COOH), and phenolic groups; these groups in turn

are associated with central units of varying size and complexity.

**Lecture 33 Soil Organic Matter**

**ORGANIC COLLOIDS – SOIL ORGANIC MATTER**

Soil organic matter (SOM) comprises an accumulation of

i) Partially disintegrated and decomposed plant and animal residues

ii) Other organic compounds synthesized by the soil microbes upon decay.

OM content of a well drained mineral soil is LOW: 1 – 6 % by weight in the top soil

and even less in the subsoil.

Sources of SOM

The primary sources of SOM are plant tissues

• The tops and roots of trees

• Shrubs, grasses, remains of harvested crops and Soil organisms

Animals are secondary sources of OM.

• Waste products of animals

• Remains of animals after completion of life cycle.

Factors Affecting Soil Organic Matter

1. Climate 2.Natural vegetation 3.Texture 4.Drainage 5.Cropping and Tillage 6.

Rotations, residues and plant nutrients.

**Decomposition of SOM**

The organic materials (plant and animal residues) incorporated in the soil are

attacked by a variety of microbes, worms and insects in the soil if the soil is moist. Some

of the constituents are decomposed very rapidly, some less readily, and others very

slowly. The list of constituents in terms of ease of decomposition:

1. Sugars, starches and simple proteins Rapid Decomposition

2. Crude proteins

3. Hemicelluloses

4. Cellulose

5. Fats, waxes, resins

6. Lignins Very slow Decomposition

The OM is also classified on the basis of their rate of decomposition

Rapidly decomposed : Sugars, starches, proteins etc.

Less rapidly decomposed : Hemicelluloses, celluloses etc.

Very slowly decomposed : Fats, waxes, resins, lignins etc.

Simple decomposition products

Aerobic – CO2, H2O, NO3, SO4

When organic material is added to soil, three general reactions take place

a. The bulk of the material undergoes enzymatic oxidation with CO2, water,

energy and heat as the major products.

b. The essential elements such as N, P and S are released and / or

immobilized by a series of reactions.

Compounds very resistant to microbial action is formed either through modification of

compounds or by microbial synthesis.

A. Decomposition of soluble substances: When glucose is decomposed under aerobic

conditions the reaction is as under:

Sugar + Oxygen ---------------- CO2 + H2O

Under partially oxidized conditions,

Sugar + Oxygen ----------------- Aliphatic acids

(Acetic, formic etc.) or

Hydroxy acids

(Citric, lactic etc.) or

Alcohols (ethyl alcohol etc.)

Some of the reactions invoiced may be represented as under:

C6H12O6 + 2O2 --------------- 2 CH3. COOH + 2CO2 + 2H2O

2C6H12O6 + 3O2 --------------- 2 C6H8O7 + 4 H2O

C6H12O6 + 2O2 --------------- 2C2H5OH + 2 CO2

i) **Ammonification :** The transformation of organic nitrogenous compounds (amino

acids, amides, ammonium compounds, nitrates etc.) into ammonia is called

ammonification. This process occurs as a result of hydrolytic and oxidative enzymatic

reaction under aerobic conditions by heterotrophic microbes.

ii)**Nitrification:** The process of conversion of ammonia to nitrites (NO2) and then to

nitrate (NO3) is known as nitrification. It is an aerobic process by autotrophic

bacteria.

Nitrosomonas Nitrobacter

NH3 ---------------- NO2 ------------------------- NO3

Ammonia Nitrite Nitrate

The net reactions are as follows:

NH4 + O2 ------------------- NO2 + 2H+ + H2O + energy

NO2 + O2 ------------------- NO3 + energy

iii**) Denitrification**: The process, which involves conversion of soil nitrate into gaseous

nitrogen or nitrous oxide, is called Denitrification. Water logging and high pH will

increase N loss by Denitrification.

Pseudomonas / Bacillus

Nitrate -------------------------------- Nitrogen Gas

**B. Decomposition of Insoluble Substances**

i) Breakdown of Protein: During the course of decomposition of plant materials, the

proteins are first hydrolyzed to a number of intermediate products and may be

represented as under:

Hydrolysis Proteases Aas

Proteins ------------- Peptones ---------- Amides -------- Ammonia Peptides

Aminization Ammonification

Aminization : The process of conversion of proteins to aminoacids.

Ammonification: The process of conversion of aminoacids and amides to ammonia.

ii) Breakdown of cellulose: The decomposition of the most abundant carbohydrates is as

follows:

hydrolysis hydrolysis

Cellulose -------------- Cellobiose --------------------- Glucose

(cellulase) (cellobiase)

oxidation

----------------- Organic acids ------------- CO2 + H2O

This reaction proceeds more slowly in acid soils than in neutral and alkaline soils.

It is quite rapid in well aerated soils and comparatively slow in poorly aerated soils.

iii) Breakdown of Hemicellulose: Decompose faster than cellulose and are first

hydrolyzed to their components sugars and uronic acids. Sugars are attacked by microbes

and are converted to organic acids, alcohols, carbon dioxide and water. The uronic acids

are broken down to pentose and CO2. The newly synthesized hemicelluloses thus form a

part of the humus.

iv) Breakdown of Starch: It is chemically a glucose polymer and is first hydrolyzed to

maltose by the action of amylases. Maltose is next converted to glucose by maltase. The

process is represented as under:

(C6H10O5)n +nH2O ------------- n (C6H12O6)

C. Decomposition of ether soluble substances:

Fats------------------------- glycerol + fatty acids

Glycerol ------------------- CO2 + water

D. Decomposition of lignin: Lignin decomposes slowly, much slower than cellulose.

Complete oxidation gives rise to CO2 and H2O.

**Factors affecting decomposition**

1. Temperature 2. Soil moisture 3.Nutrients 4.Soil pH 5. Soil Texture 6. Other Factors.: Toxic levels of elements (Al, Mn, B, Se, Cl), excessive soluble salts,shade and organic phytotoxins in plant materials.

**Role of organic matter**

1. OM creates a granular condition of soil which maintains favorable condition of

aeration and permeability.

2. Water holding capacity of soil is increased and surface runoff, erosion etc., are reduced

as there is good infiltration due to the addition of OM.

3. Surface mulching with coarse OM lowers wind erosion and lowers soil temperatures in

the summer and keep the soil warmer in winter.

4. OM serves as a source of energy for the microbes and as a reservoir of nutrients that

are essential for plant growth and also hormones, antibiotics.

5. Fresh OM supplies food for earthworms, ants and rodents and makes soil P readily

available in acid soils.

6. Organic acids released from decomposing OM help to reduce alkalinity in soils;

organic acids along with released CO2 dissolve minerals and make them more available.

7. Humus (a highly decomposed OM) provides a storehouse for the exchangeable and

available cations.8. It acts as a buffering agent which checks rapid chemical changes in pH and soil reaction.

**HUMUS**

Humus is a complex and rather resistant mixture of brown or dark brown amorphous and colloidal organic substance that results from microbial decomposition and synthesis and has chemical and physical properties of great significance to soils and plants.

**Humus Formation**

The humus compounds have resulted from two general types of biochemical

reactions: Decomposition and Synthesis.

1. **Decomposition:** a) Chemicals in the plant residues are broken down by soil microbes

including lignin. b) Other simpler organic compounds that result from the breakdown

take part immediately in the second of the humus-forming processes, biochemical

synthesis. c) These simpler chemicals are metabolized into new compounds in the body

tissue of soil microbes. d) The new compounds are subject to further modification and

synthesis as the microbial tissue is subsequently attacked by other soil microbes.

2. **Synthesis**: Involve such breakdown products of lignin as the phenols and quinones. a)

These monomers undergo polymerization by which polyphenols and polyquinones are

formed. b) These high molecular weight compounds interact with N-containing amino

compounds and forms a significant component of resistant humus. c) Colloidal clays

encourage formation of these polymers. d) Generally two groups of compounds that

collectively make up humus, the humic group and the nonhumic group.

**Properties of Humus**

1. The tiny colloidal particles are composed of C,H, and O2. The colloidal particles are

negatively charged (-OH, -COOH or phenolic groups), has very high surface area, higher

CEC (150 – 300 cmol/kg), 4 - 5 times higher WHC than that of silicate clays. 3) Humus

has a very favorable effect on aggregate formation and stability. 4) Impart black colour to

soils. 5) Cation exchange reactions are similar to those occurring with silicate clays.

**Clay – Humus Complex**

Humus, the organic amorphous colloid supplies both basic and acidic ions which is transitory and ultimately disappears from soil. Clay, the inorganic crystalline colloid

supplies chiefly the basic nutrient ions is more or less stable. Both these colloids form the

soil colloidal complex and are extremely active and form important sources of plant

nutrients.

It is believed that humus and clay exist in the soil as clay – humus complex, the two

being held together by cations like Ca, Fe, etc. Depending upon the nature of binding

cation, two types of Clay – humus complex have been recognized. The colloidal complex

bound by Ca ions is more stable and is responsible for the favorable physical condition of

the soil, particularly its structure. The other type where Fe acts as the binding agent

creates a poor physical condition of the soils.

**Lecture 34 ION EXCHANGE**

Colloids are primarily responsible for the chemical reactivity in soils. Since soil colloids are derived from these clays, their reactivity is also influenced by parent material and weathering. Each colloid (inorganic and organic) has a net negative (-) charge developed during the formation process. This means it can attract and hold positively (+) charged particles. An element with an electrical charge is called an ion. Potassium, sodium (Na), hydrogen (H), Ca and Mg all has positive charges. They are called cations and ions with negative charges, such as nitrate and sulfate, are called anions. Negatively charged colloids attract cations and hold them like a magnet holds small pieces of metal.

**Mechanism of Cation Exchange:** The exchange of cations has been explained on the

basis of the electro-kinetic theory of ion exchange. According to this theory, the adsorbed

cations forming the outer shell of the ionic double layer are supposed to be in a state of

oscillation when suspended in water, forming a diffuse double layer. Due to these

oscillations, some of the cations move away from the surface of the clay micelle. In the

presence of the solution of an electrolyte a cation of the added electrolyte slips in between the inner negative layer and the outer oscillating positive ion. The electrolyte cation is now adsorbed on the micelle and the surface cation remains in solution as an exchanged ion. Thus the exchange of cations takes place. Cations are positively charged nutrient ions and molecules. While, clay particles are negatively charged constituents of soils. These negatively charged particles (clay) attract, hold and release positively charged nutrient ions (cations). Organic matter particles also have a negative charge to attract cations. Sand particles carry little or no charge and do not react. Cations held by soils can be replaced by other cations. This means they are exchangeable. For example, Ca++ can be exchanged for H+ and /or K+ and vice versa.

**Cation Exchange Capacity (CEC):** The CEC is the capacity of soil to hold and exchange cations. The cation exchange capacity is defined simply as the sum total of the

exchangeable cations that a soil can adsorb. The higher the CEC of soil the more cations

it can retain. Soils differ in their capacities to hold exchangeable K+ and other cations.

The CEC depends on amount and kinds of clay and organic matter present. A

high-clay soil can hold more exchangeable cations than a low-clay soil. CEC also

increases as organic matter increases. Clay minerals usually range from 10 to 150

meq/100 g in CEC values. Organic matter ranges from 200 to 400 meq/100 g. So, the

kind and amount of clay and organic matter content greatly influence the CEC of soils.

Clay soils with high CEC can retain large amounts of cations against potential loss by

leaching. Sandy soils, with low CEC, retain smaller quantities. This makes timing and application rates important in planning a fertilizer programme. For example, it may not be wise to apply K on very sandy soils in the middle of a monsoon, where rainfall can be high and intense. Fertilizer application should be split to prevent leaching and losses through erosion. Also, splitting N applications to meet peak crop demand are important to reduce the potential for nitrate leaching on sands as well as finer-textured soils.

**Means of Expression:** The cation exchange capacity is expressed in terms of equivalents

or more specifically, as milli equivalents per 100 gram and is written as meq /100g. For example, to write 12.5 meq/100 g in the newer metric system, it can be written as: 12.5 c mol (+) kg-1 of soil (centimoles) or 125 m mol (+) kg-1 of soil (millimoles). Replacing power of cations: The replacing power of cations varies with the type of ion, it’s size and degree of hydration, valence and concentration and the kind of clay mineral involved. As it is controlled by number of factors no single order of replacement can be given.

**Anion Exchange**

Anion adsorption: Adsorption of negative ion (anions) e.g. Cl-, NO3- SO42-

and H2PO4-on positively charged sites of clay and organic matter is known as anion adsorption.

**Sources of positive charge**

1. Isomorphous substitution: Low valency cations replaced by high valency cations.

2. Surface and exposed broken bonds of clay lattice: OH group in certain acid soils.

3. Complex aluminium and iron hydroxy ions in acid soils.

4. pH dependent charges are important for anion exchange of organic matter

**Anion exchange**: The basic principles of cation exchange apply as well to anion

exchange, except that the charges on the colloids are positive and the exchange is among

negatively charged anions.A simple example of an anion exchange reaction is

Micelle NO3- + Cl - ------------ Micelle Cl - + NO3

(Soil solid) (In soil solution) (Soil solid) (In soil solution)

**Importance of anion exchange:** The phenomenon of anion exchange assumes importance in relation to phosphate ions and their fixation. The exchange is brought about mainly by the replacement of OH ions of the clay mineral. The reaction is very similar to cation exchange.

OH - Clay + H2PO4 ----------- H2PO4 - Clay + OH-

The adsorption of phosphate ions by clay particles from soil solution reduces its

availability to plants. This is known as phosphate fixation. As the reaction is reversible,

the phosphate ions again become available when they are replaced by OH ions released

by substances like lime applied to soil to correct soil acidity. Hence the fixation is

temporary. The whole of the phosphate adsorbed by clay is, however, not exchangeable,

as even at pH, 7.0 and above. So, substantial quantities of phosphate ions are still retained

by clay particles. The OH ions originate not only from silicate clay minerals but also

from hydrous oxides of iron and aluminium present in the soil.

The phosphate ions, therefore, react with the hydrous oxides also and get fixed as in the

case of silicate clay, forming insoluble hydroxy - phosphates of iron and aluminium.

Al (OH) 3 + H2PO4 ---------------- Al (OH)2 . H2PO4 + OH -

(Soluble) (Insoluble)

If the reaction takes place under conditions of slight acidity it is reversible, and soluble

phosphate is again liberated when hydroxy phosphate comes in contact with ions. If the

reaction takes place at a low pH under strongly acid conditions, the phosphate (ions) are

irreversibly fixed and are totally unavailable for the use of plants.