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Geology

Weathering – Soil formation factors and processes – Components of soils

Weathering

A process of disintegration and decomposition of rocks and minerals which are brought about by physical agents and chemical processes, leading to the formation of Regolith (unconsolidated residues of the weathering rock on the earth's surface or above the solid rocks).

(OR)

The process by which the earth's crust or lithosphere is broken down by the activities of the atmosphere, with the aid of the hydrosphere and biosphere.

(OR)

The process of transformation of solid rocks into parent material or Regolith.

Parent material

It is the regolith or at least it's upper portion. May be defined as the unconsolidated and more or less chemically weathered mineral material from which soil are developed.

Weathering

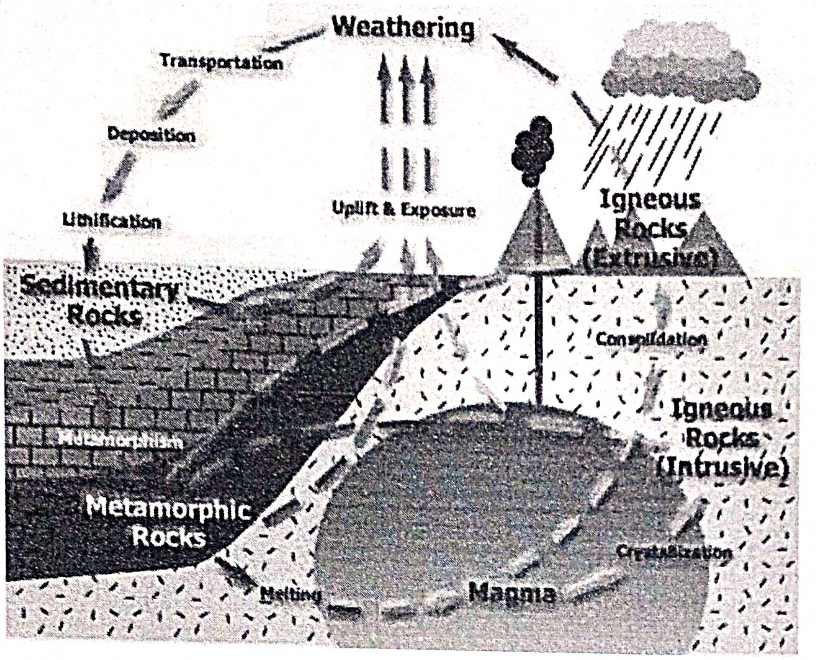
Two basic processes

Physical /mechanical **(disintegration)**

Chemical **(decomposition)**

In addition, another process: **Biological** and all these processes are work hand in hand. Depending up on the agents taking part in weathering processes, it is classified into three types.

Weathering of Rocks



Different agents of weathering

Physical/ Mechanical (disintegration)	Chemical (decomposition)	Biological (disint + decomp)
1.Physical condition of rock	1.Hydration	1.Man & animals
2.Change in temperature	2.Hydrolysis	2. higher plants & their roots
3.Action of H_2O	3.Solution	3.Micro organisms
-fragment&transport	4.Carbonation	
- action of freezing	5.Oxidation	
- alter. Wet & drying	6.Reduction	
- action of glaciers		
4.Action of wind		
5.Atmosp.electric pheno		

Physical weathering

The rocks are disintegrated and are broken down to comparatively smaller pieces, without producing any new substances

1. Physical condition of rocks

The permeability of rocks is the most important single factor. Coarse textured (porous) sand stone weather more readily than a fine textured (almost solid) basalt. Unconsolidated volcanic ash weather quickly as compared to unconsolidated coarse deposits such as gravels.

2. Action of Temperature

The variations in temperature exert great influence on the disintegration of rocks.

- During day time, the rocks get heated up by the sun and expand. At night, the temperature falls and the rocks get cooled and contract.
- This alternate expansion and contraction weakens the surface of the rock and crumbles it because the rocks do not conduct heat easily.
- The minerals within the rock also vary in their rate of expansion and contraction
    - The cubical expansion of quartz is twice as feldspar
    - Dark coloured rocks are subjected to fast changes in temperature as compared to light coloured rocks
- The differential expansion of minerals in a rock surface generates stress between the heated surface and cooled un expanded parts resulting in fragmentation of rocks.
- This process causes the surface layer to peel off from the parent mass and the rock ultimately disintegrates. This process is called Exfoliation

3. Action of Water

Water acts as a disintegrating, transporting and depositing agent.

i) Fragmentation and transport

Water beats over the surface of the rock when the rain occurs and starts flowing towards the ocean

- Moving water has the great cutting and carrying force.
- It forms gullies and ravines and carries with the suspended soil material of variable sizes.
- Transporting power of water varies. It is estimated that the transporting power of stream varies as the sixth power of its velocity i.e the greater the speed of water, more is the transporting power and carrying capacity.

Speed/Sec	Carrying capacity
15 cm	Fine sand
30 cm	Gravel
1.2 m	Stones (1kg)
9.0 m	Boulders (several tons)

The disintegration is greater near the source of river than its mouth

ii) Action of freezing

Frost is much more effective than heat in producing physical weathering

- ➢ In cold regions, the water in the cracks and crevices freezes into ice and the volume increases to one tenth
- ➢ As the freezing starts from the top there is no possibility of its upward expansion. Hence, the increase in volume creates enormous out ward pressure which breaks apart the rocks

iii) Alternate wetting and Drying

Some natural substances increase considerably in volume on wetting and shrink on drying. (e.g.) smectite, montmorilonite

- ➢ During dry summer/ dry weather – these clays shrink considerably forming deep cracks or wide cracks.
- ➢ On subsequent wetting, it swells.
- ➢ This alternate swelling and shrinking/ wetting or drying of clay enriched rocks make them loose and eventually breaks

iv). Action of glaciers

- ➢ In cold regions, when snow falls, it accumulates and change into a ice sheet.
- ➢ These big glaciers start moving owing to the change in temperature and/or gradient.
- ➢ On moving, these exert tremendous pressure over the rock on which they pass and carry the loose materials
- ➢ These materials get deposited on reaching the warmer regions, where its movement stops with the melting of ice

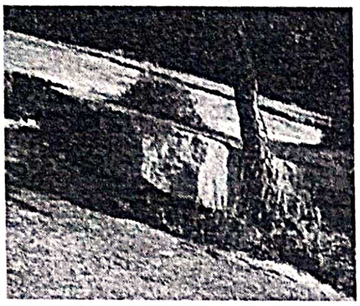
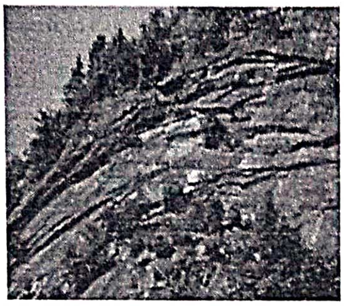
4. Action of wind

- ➢ Wind has an erosive and transporting effect. Often when the wind is laden with fine material viz., fine sand, silt or clay particles, it has a serious abrasive effect and the sand laden winds itch the rocks and ultimately breaks down under its force

- The dust storm may transport tons of material from one place to another. The shifting of soil causes serious wind erosion problem and may render cultivated land as degraded (e.g) Rajasthan deserts

5. Atmospheric electrical phenomenon

It is an important factor causing break down during rainy season and lightning breaks up rocks and or widens cracks


Chemical Weathering

Decomposition of rocks and minerals by various chemical processes is called chemical weathering. It is the most important process for soil formation.

Chemical weathering takes place mainly at the surface of rocks and minerals with disappearance of certain minerals and the formation of secondary products (new materials). This is called chemical transformation.

Feldspar + water ⟶ clay mineral + soluble cations and anions

Chemical weathering becomes more effective as the surface area of the rock increases.

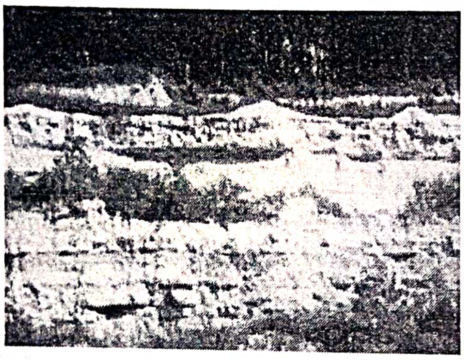
Since the chemical reactions occur largely on the surface of the rocks, therefore the smaller the fragments, the greater the surface area per unit volume available for reaction.

The effectiveness of chemical weathering is closely related to the mineral composition of rocks. (e.g) quartz responds far slowly to the chemical attack than olivine or pyroxene.

Average mineralogical composition (%)

Composition	Granite	Basalt	Shale	S. Stone	L.Stone
Feldspar	52.4	46.2	30.0	11.5	-
Quartz	31.3	-	2.3	66.8	-
Pyrox-amphi	-	44.5	-	-	-

FeO mineral	2.0	9.3	10.5	2.0	-
Clay mineral	14.3	-	25.0	6.6	24.0
Carbonates	-	-	5.7	11.1	76.0



Chemical Processes of weathering:

1. Hydration

Chemical combination of water molecules with a particular substance or mineral leading to a change in structure. Soil forming minerals in rocks do not contain any water and they under go hydration when exposed to humid conditions. Up on hydration there is swelling and increase in volume of minerals. The minerals loose their luster and become soft. It is one of the most common processes in nature and works with secondary minerals, such as aluminium oxide and iron oxide minerals and gypsum.

Example:

a) $2Fe_2O_3 + 3HOH \longrightarrow 2Fe_2O_3.3H_2O$

(Haematite) (red) **(Limonite) (yellow)**

b) $Al_2O_3 + 3HOH \longrightarrow Al_2O_3.3H_2O$

(Bauxite) **(Hyd. aluminium Oxide)**

c) $CaSO_4 + 2H_2O \longrightarrow CaSO_4.2H_2O$

(Anhydrite) **(Gypsum)**

d) $3(MgO.FeO.SiO_2) + 2H_2O \longrightarrow 3MgO.2SiO_2.2H_2O + SiO_2 + 3H_2O$

(Olivine) (Serpentine)

2. Hydrolysis

Most important process in chemical weathering. It is due to the dissociation of H_2O into H^+ and OH^- ions which chemically combine with minerals and bring about changes, such as exchange, decomposition of crystalline structure and formation of new compounds. Water acts as a weak acid on silicate minerals.

$$KAlSi_3O_8 + H_2O \longrightarrow HAlSi_3O_8 + KOH$$

(Orthoclase) (Acid silt clay)

$$HAlSi_3O_8 + 8\ HOH \longrightarrow Al_2O_3.3H_2O + 6\ H_2SiO_3$$

(recombination) (Hyd. Alum.oxide) (Silicic acid)

This reaction is important because of two reasons

- clay, bases and silicic acid - the substances formed in these reactions - are available to plants
- water often containing CO_2 (absorbed from atmosphere), reacts with the minerals directly to produce insoluble clay minerals, positively charged metal ions (Ca^{++}, Mg^{++}, Na^+, K^+) and negatively charged ions (OH^-, HCO_3^-) and some soluble silica – all these ions are made available for plant growth.

3. Solution

Some substances present in the rocks are directly soluble in water. The soluble substances are removed by the continuous action of water and the rock no longer remains solid and form holes, rills or rough surface and ultimately falls into pieces or decomposes. The action is considerably increased when the water is acidified by the dissolution of organic and inorganic acids. (e.g) halites, NaCl

$NaCl + H_2O \longrightarrow Na^+, Cl^-, H_2O$ (dissolved ions with water)

4. Carbonation: Carbon di oxide when dissolved in water it forms carbonic acid.

$$2H_2O + CO_2 \longrightarrow H_2CO_3$$

This carbonic acid attacks many rocks and minerals and brings them into solution. The carbonated water has an etching effect up on some rocks, especially lime stone. The removal of cement that holds sand particles together leads to their disintegration.

$$CaCO_3 + H_2CO_3 \longrightarrow Ca(HCO_3)_2$$

(Calcite) (Ca bi carbonate)

slightly soluble readily soluble

5. Oxidation

The process of addition and combination of oxygen to minerals. The absorption is usually from O_2 dissolved in soil water and that present in atmosphere. The oxidation is more active in the presence of moisture and results in hydrated oxides. (e.g) minerals containing Fe and Mg.

$$4FeO \text{ (Ferrous oxide)} + O_2 \longrightarrow 2Fe_2O_3 \text{ (Ferric oxide)}$$

$$4Fe_3O_4 \text{ (Magnetite)} + O_2 \longrightarrow 6Fe_2O_3 \text{ (Haematite)}$$

$$2Fe_2O_3 \text{ (Haematite)} + 3H_2O \longrightarrow 2Fe_2O_3.3H_2O \text{(Limonite)}$$

6. Reduction

The process of removal of oxygen and is the reverse of oxidation and is equally important in changing soil colour to grey, blue or green as ferric iron is converted to ferrous iron compounds. Under the conditions of excess water or water logged condition (less or no oxygen), reduction takes place.

$$2Fe_2O_3 \text{ (Haematite)} - O_2 \longrightarrow 4FeO \text{ (Ferrous oxide) - reduced form}$$

In conclusion, during chemical weathering igneous and metamorphic rocks can be regarded as involving destruction of primary minerals and the production of secondary minerals.

In sedimentary rocks, which is made up of primary and secondary minerals, weathering acts initially to destroy any relatively weak bonding agents (FeO) and the particles are freed and can be individually subjected to weathering.

Biological Weathering

Unlike physical and chemical weathering, the biological or living agents are responsible for both decomposition and disintegration of rocks and minerals. The biological life is mainly controlled largely by the prevailing environment.

1. Man and Animals

- The action of man in disintegration of rocks is well known as he cuts rocks to build dams, channels and construct roads and buildings. All these activities result in increasing the surface area of the rocks for attack of chemical agents and accelerate the process of rock decomposition.
- A large number of animals, birds, insects and worms, by their activities they make holes in them and thus aid for weathering.
- In tropical and sub tropical regions, ants and termites build galleries and passages and carry materials from lower to upper surface and excrete acids. The oxygen and water with many dissolved substances, reach every part of the rock through the cracks, holes and galleries, and thus brings about speedy disintegration.
- Rabbits, by burrowing in to the ground, destroy soft rocks. Moles, ants and bodies of the dead animals, provides substances which react with minerals and aid in decaying process.
- The earthworms pass the soil through the alimentary canal and thus brings about physical and chemical changes in soil material.

2. Higher Plants and Roots

The roots of trees and other plants penetrates into the joints and crevices of the rocks. As they grew, they exert a great disruptive force and the hard rock may broken apart. (e.g) pipal tree growing on walls/ rocks.

The grass roots form a sponge like mass, prevents erosion and conserve moisture and thus allowing moisture and air to enter in to the rock for further action.

Some roots penetrate deep into the soil and may open some sort of drainage channel. The roots running in crevices in lime stone and marble produces acids . These acids have a solvent action on carbonates.

The dead roots and plant residues decompose and produce carbon dioxide which is of great importance in weathering.

3. Micro- organisms

In early stages of mineral decomposition and soil formation, the lower forms of plants and animals like, mosses, bacteria and fungi and actinomycetes play an important role. They extract nutrients from the rock and N from air and live with a small quantity of water. In due course of time, the soil develops under the cluster of these micro-organisms.

These organisms closely associated with the decay of plant and animal remains and thus liberate nutrients for the use of next generation plants and also produces CO_2 and organic compounds which aid in mineral decomposition.

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Soil formation factors and processes

The soil formation is the process of **two consecutive stages.**

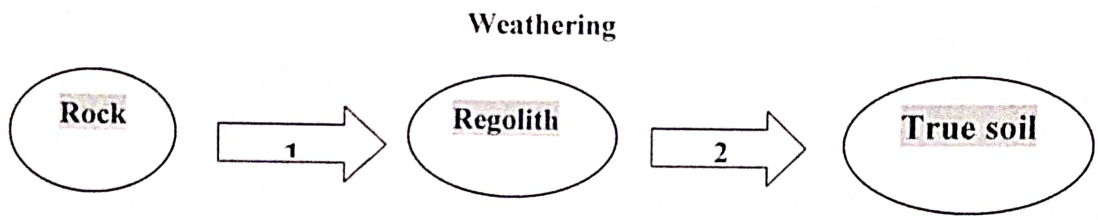
1. The weathering of rock (R) into Regolith

2. The formation of true soil from Regolith

The evolution of true soil from regolith takes place by the combined action of soil forming factors and processes.

- The first step is accomplished by weathering (disintegration & decomposition)

- The second step is associated with the action of Soil Forming Factors



Factors

Dokuchaiev (1889) established that the soils develop as a result of the action of soil forming factors

$$S = f(P, Cl, O)$$

Further, Jenny (1941) formulated the following equation

$$S = f(Cl, O, R, P, T, \ldots)$$

Where,

Cl – environmental climate
O – Organisms and vegetation (biosphere)
R – Relief or topography
P – Parent material
T- Time
... - additional unspecified factors

The five soil forming factors, acting simultaneously at any point on the surface of the earth, to produce soil.

Two groups

Passive : i) Parent material, ii) Relief, iii) Time

Active : iv) Climate, v) Vegetation & organism

Passive Soil forming factors

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

Parent Material

It is that mass (consolidated material) from which the soil has formed.

Two groups of parent material

- **Sedentary**

  Formed in original place. It is the residual parent material. The parent material differ as widely as the rocks

- **Transported**

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

a) by gravity - Colluvial
b) by water - Alluvial , Marine , Locustrine
c) by ice - Glacial
d) by wind - Eolian

Colluvium

It is the poorly sorted materials near the base of strong slopes transported by the action of gravity.

Alluvium

The material transported and deposited by water is, found along major stream courses at the bottom of slopes of mountains and along small streams flowing out of drainage basins.

Lacustrine

Consists of materials that have settled out of the quiet water of lakes.

Moraine

Consists of all the materials picked up, mixed, disintegrated, transported and deposited through the action of glacial ice or of water resulting primarily from melting of glaciers.

Loess or Aeolian

These are the wind blown materials. When the texture is silty - loss; when it is sand.

Eolian

The soils developed on such transported parent materials bear the name of the parent material; viz. Alluvial soils from alluvium, colluvial soils from colluvium etc. In the initial stages, however, the soil properties are mainly determined by the kind of parent material.

Endodynamomorphic soils

With advanced development and excessive leaching, the influence of parent material on soil characteristics gradually diminishes. There are soils wherein the composition of parent material subdues the effects of climate and vegetation. These soils are temporary and persist only until the chemical decomposition becomes active under the influence of climate and vegetation.

Ectodynamomorphic soils

Development of normal profile under the influence of climate and vegetation.

Soil properties as influenced by parent material: Different parent materials affect profile development and produce different soils, especially in the initial stages.

- Acid igneous rocks (like granite, rhyolite) produce light-textured soils (Alfisols).
- Basic igneous rocks (basalt), alluvium or colluvium derived from limestone or basalt, produce fine-textured cracking-clay soils (Vertisols).
- Basic alluvium or aeolian materials produce fine to coarse-textured soils (Entisols or Inceptisols).
- The nature of the elements released during the decaying of rocks has a specific role in soil formation. (e.g.) Si and Al forms the skeleton for the production of secondary clay minerals.
- Iron and manganese are important for imparting red colour to soils and for oxidation and reduction phenomena.
- Sodium and potassium are important dispersing agents for day and humus colloids.

- Calcium and magnesium have a flocculating effect and result in favorable and stable soil structure for plant growth.

2. Relief or Topography

The relief and topography sometimes are used as synonymous terms. They denote the configuration of the land surface. The topography refers to the differences in elevation of the land surface on a broad scale.

The prominent types of topography designations, as given in FAO Guidelines (1990) are:

Land surface	with slopes of
1 Flat to Almost flat	0 – 2 %
2 Gently undulating	2 - 5 %
3 Undulating	5 – 10 %
4 Rolling	10 – 15 %
5 Hilly	15 –3 0 %
6 Steeply dissect	> 30 % with moderate range of elevation (<300 m)
7 Mountainous	> 30% with great range of elevation (>300 m)

Soil formation on flat to almost flat position

On level topographic positions, almost the entire water received through rain percolates through the soil. Under such conditions, the soils formed may be considered as representative of the regional climate. They have normal solum with distinct horizons. But vast and monotonous level land with little gradient often has impaired drainage conditions.

Soil formation on undulating topography

The soils on steep slopes are generally shallow, stony and have weakly- developed profiles with less distinct horizonation. It is due to accelerated erosion, which removes surface material before it has the time to develop. Reduced percolation of water through soil is because of surface runoff, and lack of water for the growth of plants, which are responsible for checking of erosion and promote soil formation.

Soil formation in depression

The depression areas in semi-arid and sub humid regions reflect more moist conditions than actually observed on level topographic positions due to the additional water received as runoff. Such conditions (as in the Tarai region of the Uttar Pradesh) favour more vegetative growth and slower rate of decay of organic remains. This results in the formation of comparatively dark- coloured soils rich in organic matter (Mollisols).

Soil formation and Exposure/ Aspect

Topography affects soil formation by affecting temperature and vegetative growth through slope exposures (aspect}. The southern exposures (facing the sun) are warmer and subject to marked fluctuations in temperature and moisture. The northern exposures, on the other hand are cooler and more humid. The eastern and western exposures occupy intermediate position in this respect.

3. Time

Soil formation is a very slow process requiring thousands of years to develop a mature pedon. The period taken by a given soil from the stage of weathered rock (i.e. regolith) up to the stage of maturity is considered as time. The matured soils mean the soils with fully developed horizons (A, B, C). It takes hundreds of years to develop an inch of soil. The time that nature devotes to the formation of soils is termed as Pedologic Time.

It has been observed that rocks and minerals disintegrate and/or decompose at different rates; the coarse particles of limestone are more resistant to disintegration than those of sandstone. However, in general, limestone decomposes more readily than sandstone (by chemical weathering).

Weathering stages in soil formation

Stages	**Characteristic**
1 Initial	Un weathered parent material
2 Juvenile	Weathering started but much of the original material still un weathered
3 Virile	Easily weatherable minerals fairly decomposed; clay content increased, slowly weatherable minerals still appreciable
4 Senile	Decomposition reaches at a final stage; only most resistant minerals survive
5 Final	Soil development completed under prevailing environments

- The soil properties also change with time, for instance nitrogen and organic matter contents increase with time provided the soil temperature is not high.

- $CaCO_3$ content may decrease or even lost with time provided the climatic conditions are not arid
- In humid regions, the H^+ concentration increases with time because of chemical weathering.

B. Active Soil Forming Factors

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

1. Climate

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

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

Climate affects the soil formation directly and indirectly.

Directly, climate affects the soil formation by supplying water and heat to react with parent material.

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

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

Precipitation

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

Temperature

- Temperature is another climatic agent influencing the process of soil formation.
- High temperature hinders the process of leaching and causes an upward movement of soluble salts.
- High temperature favors rapid decomposition of organic matter and increase microbial activities in soil while low temperatures induce leaching by reducing evaporation and there by favour the accumulation of organic matter by slowing down the process of decomposition. Temperature thus controls the rate of chemical and biological reactions taking place in the parent material.

Jenney (1941} computed that in the tropical regions the rate of weathering proceeds three times faster than in temperate regions and nine times faster than in arctic .

2. Organism & Vegetation

Organism

- The active components of soil ecosystem are plants, animals, microorganisms and man.
- The role of microorganisms in soil formation is related to the humification and mineralization of vegetation
- The action of animals especially burrowing animals to dig and mix-up the soil mass and thus disturb the parent material
- Man influences the soil formation through his manipulation of natural vegetation, agricultural practices etc.

- Compaction by traffic of man and animals decrease the rate of water infiltration into the soil and thereby increase the rate of runoff and erosion.

Vegetation

- The roots of the plants penetrate into the parent material and act both mechanically and chemically.
- They facilitate percolation and drainage and bring about greater dissolution of minerals through the action of CO_2 and acidic substances secreted by them.
- The decomposition and humification of the materials further adds to the solubilization of minerals
- Forests – reduces temperature, increases humidity, reduce evaporation and increases precipitation.
- Grasses reduce runoff and result greater penetration of water in to the parent material.

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

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.

Eluviation

It is the mobilization and translocation of certain constituent's viz. Clay, Fe_2O_3, Al_2O_3, SiO_2, humus, $CaCO_3$, 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 (A_2 or E horizon).

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

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.

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

Calcification

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

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 + Ca \rightarrow Ca\,(HCO_3)_2 \text{ (soluble)}$$

$$Ca\,(HCO_3)_2 \xrightarrow[CO_2]{\text{Temp.}} CaCO_3 + H_2O + CO_2 \text{ (precipitates)}$$

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).

Decalcification

It is the reverse of calcification that is the process of removal of CaCO3 or calcium ions from the soil by leaching

$$CaCO_3 + CO_2 + H_2O \xrightarrow{\text{Temp.}} Ca(HCO_3)_2 \text{ (soluble)}$$

(insoluble) CO_2

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. In fact, the process is essentially one of acid leaching.

The process operates under favorable combination of the following environments.

i) **Climate:** A cold and humid climate is most favorable for podzolization.

ii) **Parent material:** Siliceous (Sandy) material, having poor reserves of weatherable minerals, favor the operation of podzolization as it helps in easy percolation of water.

iii) **Vegetation:** Acid producing vegetation such as coniferous pines is essential

iv) **Leaching and Translocation of Sesquioxide:** In the process of decomposition of organic matter various organic acids are produced. The organic acids thus formed act with Sesquioxide and the remaining clay minerals, forming organic- Sesquioxide and organic clay complexes, which are soluble and move with the percolating water to the lower horizons (Bh, Bs).

Aluminium ions in a water solution hydrolyze and make the soil solution very acidic.

$$2Al + 6H_2O \longrightarrow 2\,Al(OH)_3 + 6H^+$$

As iron and aluminium move about, the A horizon gives a bleached grey or ashy appearance. The Russians used the term Podzols (pod means under, the zola means ash like i.e. ash-like horizon appearing beneath the surface horizon) for such soils.

To conclude, the Podzolization is a soil forming process which prevails in a cold and humid climate where coniferous and acid forming vegetations dominate. The humus and Sesquioxide become mobile and leached out from the upper horizon s and deposited in the lower horizon.

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.

i) **Climate**

Unlike podzolization, the process of laterization operates most favorable in warm and humid (tropical) climate with 2000 to 2500 mm rainfall and continuous high temperature (25°C) throughout the year.

ii) **Natural vegetation**

The rain forests of tropical areas are favorable for the process.

iii) **Parent Material**

Basic parent materials, having sufficient iron bearing ferromagnesian minerals (Pyroxene, amphiboles, biotite and chlorite), which on weathering release iron, are congenial for the development of laterites.

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 hydro orphic soils.

The process is not particularly dependent on climate (high rainfall as in humid regions) but often on drainage conditions.

The poor drainage conditions result from:

- Lower topographic position, such as depression land, where water stands continuously at or close to the surface.

- Impervious soil parent material, and.
- Lack of aeration.

Under such conditions, iron compounds are reduced to soluble ferrous forms. The reduction of iron is primarily biological and requires both organic matter and microorganisms capable of respiring anaerobically. The solubility of Ca, Mg, Fe, and Mn is increased and most of the iron exists as Fe^{++} organo - complexes in solution or as mixed precipitate of ferric and ferrous hydroxides.

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

$$Ca.Mg.2NaX \longrightarrow Ca^{++} + Mg^{++} + 2Na^{+} + x^{-6} + 3CO_3^{2-} \longrightarrow Na_2CO_3 + MgCO_3 + CaCO_3$$

(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 :

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

(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.

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Soil profile

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

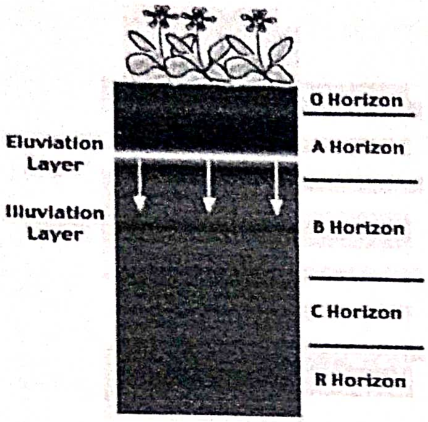
O horizon - It is called as organic horizon. It is formed in the upper part of the mineral soil, dominated by fresh or partly decomposed organic materials.

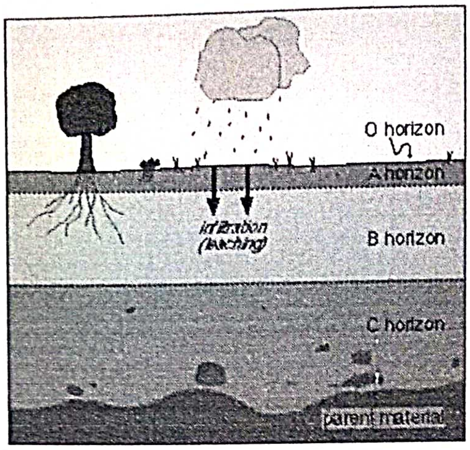
- This horizon contains more than 30% organic matter if mineral fraction has more than 50 % clay (or) more than 20 % organic matter if mineral fraction has less clay.
- The organic horizons are commonly seen in forest areas and generally absent in grassland, cultivated soils.
- O1 - Organic horizon in 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.

Besides, lower case letters are used to indicate the special features of master horizons. This case letters follow the subdivisions of master horizons. eg. Ap - ploughed layer eg. B2t - illuvial clay

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.





Special Features

Soil Individual or Polypedon: The Soil Survey Staff (1960) defined the soil individual or polypedon (Pedon, Ground) as a natural unit of soil that differs from its adjoining unit on the landscape in one or more properties.

The term pedon has been proposed for small basic soil entities that are part of the continuum mantling the land.

A **pedon** is the smallest volume that can be called "a soil". The set of pedons must fit within the range of one series and occur in a contiguous group to form a polypedon.

A **polypedon** is therefore, defined as a contiguous similar pedons bounded on all sides by "not-soil or by pedons of unlike characters. It is a real physical soils body which has a minimum area of more than 1 sq. km and an unspecified maximum area.

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Soil physical properties

Physical properties (mechanical behaviour) of a soil greatly influence its use and behaviour towards plant growth. The plant support, root penetration, drainage, aeration, retention of moisture, and plant nutrients are linked with the physical condition of the soil. Physical properties also influence the chemical and biological behaviour of soil. The physical properties of a soil depend on the amount, size, shape, arrangement and mineral composition of its particles. These properties also depend on organic matter content and pore spaces.

Important physical properties of soils.

1. Soil texture, 2. Soil structure, 3. Surface area, 4. Soil density,

5. Soil porosity, 6.Soil colour, 7.Soil consistence

Soil texture- Textural classes- Particle size distribution

Definition

Soil texture refers to the relative proportion of particles or it is the relative percentage by weight of the three soil separates viz., sand, silt and clay or simply refers to the size of soil particles. The proportion of each size group in a given soil (the texture) cannot be easily altered and it is considered as a basic property of a soil. The soil separates are defined in terms of diameter in millimeters of the particles Soil particles less than 2 mm in diameter are excluded from soil textural determinations.

Stones and gravels may influence the use and management of land because of tillage difficulties but these larger particles make little or no contribution to soil properties such as WHC and capacity to store plant nutrients and their supply.

Gravels : 2 – 4 mm

Pebbles : 4 – 64 mm

Cobbles : 64 – 256 mm

Boulders : > 256 mm

Particles less than 2 mm is called fine earth, normally considered in chemical and mechanical analysis.

The components of fine earth: Sand, Silt and Clay (Soil separates. The size limits of these fractions have been established by various organizations. There are a number of systems of naming soil separates.

(a) The American system developed by USDA

(b) The English system or British system (BSI)

(c) The International system (ISSS)

(d) European system

i) USDA

Soil separates	Diameter (mm)
Clay	< 0.002 mm
Silt	0.002 – 0.05
Very Fine Sand	0.05 – 0.10
Fine Sand	0.10 – 0.25
Medium Sand	0.25 - 0.50
Coarse Sand	0.50 - 1.00
Very Coarse Sand	1.00 – 2.00

ii) BSI

Soil separates	Diameter (mm)
Clay	< 0.002 mm
Fine Silt	0.002 – 0.01
Medium Silt	0.01 – 0.04
Coarse Silt	0.04 – 0.06
Fine Sand	0.06 - 0.20
Medium Sand	0.20 - 1.00
Coarse Sand	1.00 – 2.00

iii) ISSS

Soil separates	Diameter (mm)
1. Clay	< 0.002 mm
2. Silt	0.002 – 0.02 mm
3. Fine sand	0.02 – 0.2 mm
4. Coarse sand	0.2 – 2.0 mm

iv) European System

S.No	Soil separates	Diameter (mm)
1	Fine clay	< 0.0002 mm
2	Medium clay	0.0002 – 0.0006
3	Coarse clay	0.0006 – 0.002
4	Fine silt	0.002 - 0.006

5	Medium silt	0.006 - 0.02
6	Coarse silt	0.02 - 0.06
7	Fine sand	0.06 - 0.20
8	Medium sand	0.20 - 0.60
9	Coarse sand	0. 60 - 2.00

Sand

- Usually consists of quartz but may also contain fragments of feldspar, mica and occasionally heavy minerals viz., zircon, Tourmaline and hornblende.
- Has uniform dimensions
- Can be represented as spherical
- Not necessarily smooth and has jagged surface

Silt

- Particle size intermediate between sand and clay
- Since the size is smaller, the surface area is more
- Coated with clay
- Has the physico- chemical properties as that of clay to a limited extent
- Sand and Silt forms the SKELETON

Clay

- Particle size less than 0.002 mm
- Plate like or needle like in shape
- Belong to alumino silicate group of minerals
- Sometimes considerable concentration of fine particles which does not belong to alumino silicates. (eg). iron oxide and $CaCO_3$
- These are secondary minerals derived from primary minerals in the rock
- Flesh of the soil

Knowledge on Texture is important. It is a guide to the value of the land .Land use capability and methods of soil management depends on Texture

Particle size distribution/ determination

The determination of relative distribution of the ultimate or individual soil particles below 2 mm diameter is called as Particle size analysis or Mechanical analysis

Two steps are involved

i) Separation of all the particles from each other i.e. Complete dispersion into ultimate particles

ii) Measuring the amount of each group

Separation

S.No	Aggregating agents	Dispersion method
1	Lime and Oxides of Fe & Al	Dissolving in HCl
2	Organic matter	Oxidises with H_2O_2
3	High concn. of electrolytes (soluble salts)	Precipitate and decant or filter with suction
4	Surface tension	Elimination of air by stirring with water or boiling

After removing the cementing agents , disperse by adding NaOH

Measurement

Once the soil particles are dispersed into ultimate particles, measurement can be done

i) Coarser fractions – sieving – sieves used in the mechanical analysis corresponds to the desired particle size separation

For 2 mm, 1 mm and 0.5 mm – sieves with circular holes

For smaller sizes, wire mesh screens are used (screening)

ii) Finer fractions – by settling in a medium

The settling or the velocity of the fall of particles is influenced by

Viscosity of the medium

Difference in density between the medium and falling particles

Size and shape of object

Stokes' Law

Particle size analysis is based on a simple principle i.e. "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 particles.

Thus $V = kr^2$, where k is a constant. This equation is referred to as Stokes' law.

Stokes (1851) was the first to suggest the relationship between the radius of the particles and its rate of fall in a liquid. He stated that "the velocity of a falling particle is proportional to the square of the radius and not to its surface. The relation between the diameter of a particle and its settling velocity is governed by Stokes' Law:

$$V = \frac{2gr^2(ds - dw)}{9n}$$

Where ,

V - velocity of settling particle (cm/sec.)

g - acceleration due to gravity cm/ sec^2 (981)

ds - density of soil particle (2.65)

dw - density of water (1)

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

r - radius of spherical particles (cm).

Assumptions and Limitations of Stokes' Law

Particles are rigid and spherical / smooth. This requirement is very difficult to fulfill, because the particles are not completely smooth over the surface and spherical. It is established that the particles are not spherical and irregularly shaped such as plate and other shapes.

The particles are large in comparison with the molecules of the liquid so that in comparison with the particle the medium can be considered as homogenous. Ie the particles must be big enough to avoid Brownian movement. The particles less than 0.0002 mm exhibit this movement so that the rate of falling is varied.

The fall of the particles is not hindered or affected by the proximity (very near) of the wall of the vessel or of the adjacent particles. Many fast falling particles may drag finer particles down along with them.

The density of the particles and water and as well as the viscosity of the medium remain constant. But this is usually not so because of their different chemical and mineralogical composition.

The suspension must be still. Any movement in the suspension will alter the velocity of fall and such movement is brought by the sedimentation of larger particles (> 0.08 mm). They settle so fast and create turbulence in the medium.

The temperature should be kept constant so that convection currents are not set up.

Methods of Textural determination

Numerous methods for lab and field use have been developed

i) Elutriation method – Water & Air ; ii)Pipette method

iii) Decantation/ beaker method ; iv) Test tube shaking method

v) Feel method – Applicable to the field – quick method – by feeling the soil between thumb and fingers

Feel Method

Evaluated by attempting to squeeze the moistened soil into a thin ribbon as it is pressed with rolling motion between thumb and pre finger or alternately to roll the soil into a thin wire.

η Four aspects to be seen – i) Feel by fingers, ii)Ball formation , iii) Stickiness and iv) Ribbon formation

Soil Textural Classes

To convey an idea of the textural make up of soils and to give an indication of their physical properties, soil textural class names are used. These are grouped into three main fractions viz., Sand, Silt and Clay.

According to the proportion of these three fractions a soil is given a name to indicate its textural composition. Such a name gives an idea not only of the textural composition of a soil but also of its various properties in general.

On this basis soils are classified into various textural classes like sands clays, silts, loams etc

Sands

The sand group includes all soils in which the sand separates make up at least 70% and the clay separate 15% or less of the material by weight. The properties of such soils are therefore characteristically those of sand in contrast to the stickier nature of clays. Two specific textural classes are recognized in this group sandy and loamy sand although in practice two subclasses are also used Loamy fine sand and loamy very fine sand.

Silt

The silt group includes soils with at least 80% silt and 12% or less clay. Naturally the properties of this group are dominated by those of silt. Only one textural class - Silt is included in this group.

Clays

To be designated a clay a soil must contain at least 35% of the clay separate and in most cases not less than 40%. In such soils the characteristics of the clay separates are distinctly dominant, and the class names are clay, sandy clay and silty clay. Sandy clays may contain more sand than clay. Likewise, the silt content of silty clays usually exceeds clay fraction.

Loams

The loam group, which contains many subdivisions, is a more complicated soil textural class. An ideal loam may be defined as a mixture of sand, silt and day particles that exhibits the properties of those separates in about equal proportions. Loam soils do not exhibit dominant physical properties of sand, silt or clay. Loam does not contain equal percentage of sand, silt and clay. However, exhibit approximately equal properties of sand, silt and clay.

Determination of Textural Class

In the American system as developed by the United State Department of Agriculture twelve textural classes are proposed.

The textural triangle

It is used to determine the soil textural name after the percentages of sand, silt, and clay are determined from a laboratory analysis. Since the soil's textural classification includes only mineral particles and those of less than 2mm diameter, the sand plus silt plus clay percentages equal 100 percent. (note that organic matter is not included.) Knowing the amount of any two fractions automatically fixes the percentage of the third one.

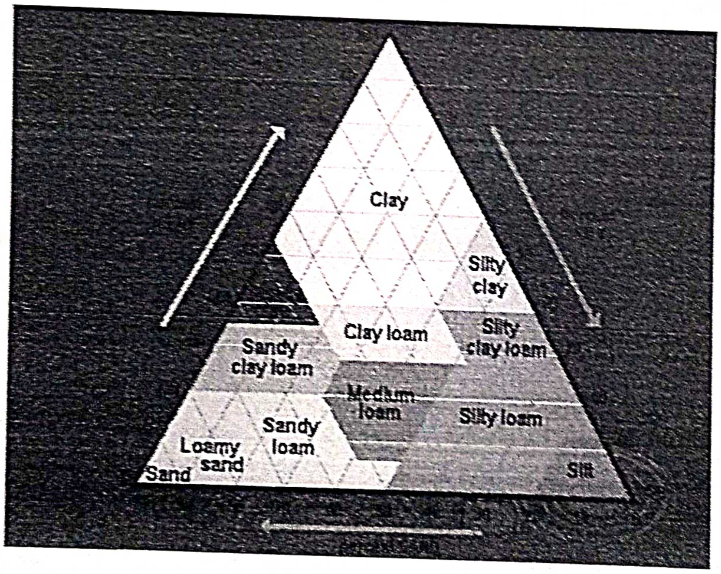
To use the diagram, locate the percentage of clay first and project inward parallel to sand line. Do likewise for the per cent silt and project inward parallel to clay line and for sand, project inward parallel to silt. The point at which the projections cross or intersect will identify the class name Some times, the intersecting point exactly fall on the line between the textural classes. Then it is customary to use the name of the finer fraction when it happens. (eg). Soil containing 40% clay, 30% sand.

Importance of Soil Texture

Presence of each type of soil particles makes its contribution to the nature and properties of soil as a whole

- Texture has good effect on management and productivity of soil. Sandy soils are of open character usually loose and friable.
- Such type of the texture is easy to handle in tillage operations.
- Sand facilitates drainage and aeration. It allows rapid evaporation and percolation.
- Sandy soils have very little water holding capacity. Such soils can not stand drought and unsuitable for dry farming.
- Sandy soils are poor store house of plant nutrients

- Contain low organic matter
- Leaching of applied nutrients is very high.
- In sandy soil, few crops can be grown such as potato, groundnut and cucumbers.
- Clay particles play a very important role in soil fertility.
- Clayey soils are difficult to till and require much skill in handling. When moist clayey soils are exceedingly sticky and when dry, become very hard and difficult to break.
- They have fine pores, and are poor in drainage and aeration.
- They have a high water holding capacity and poor percolation, which usually results in water logging.
- They are generally very fertile soils, in respect of plant nutrient content. Rice, jute, sugarcane can be grown very successfully in these soils.
- Loam and Silt loam soils are highly desirable for cultivation
- Generally, the best agriculture soils are those contain 10 – 20 per cent clay, 5 – 10 per cent organic matter and the rest equally shared by silt and sand and 30% silt - called as clay rather than clay loam.



Soil structure – Classification

Soil conditions and characteristics such as water movement, heat transfer, aeration, and porosity are much influenced by structure. In fact, the important physical changes imposed by the farmer in ploughing, cultivating, draining, liming, and manuring his land are structural rather than textural.

Definition

The arrangement and organization of primary and secondary particles in a soil mass is known as soil structure. Soil structure controls the amount of water and air present in soil. Plant roots and germinating seeds require sufficient air and oxygen for respiration. Bacterial activities also depend upon the supply of water and air in the soil.

Formation of soil structure

Soil particles may be present either as single individual grains or as aggregate i.e. group of particles bound together into granules or compound particles. These granules or compound particles are known as secondary particles. A majority of particles in a sandy or silty soil are present as single individual grains while in clayey soil they are present in granulated condition. The individual particles are usually solid, while the aggregates are not solid but they possess a porous or spongy character. Most soils are mixture of single grain and compound particle. Soils, which predominate with single grains are said to be structureless, while those possess majority of secondary particles are said to be aggregate, granulated or crumb structure.

Mechanism of Aggregate Formation

The bonding of the soil particles into structural unit is the genesis of soil structure. The bonding between individual particles in the structural units is generally considered to be stronger than the structural units themselves.

In aggregate formation, a number of primary particles such as sand, silt and clay are brought together by the cementing or binding effect of soil colloids. The cementing materials taking part in aggregate formation are colloidal clay, iron and aluminium hydroxides and decomposing organic matter. Whatever may be the cementing material, it is ultimately the dehydration of colloidal matter accompanied with pressure that completes the process of aggregation.

Colloidal clay

By virtue of high surface area and surface charge, clay particles play a key role in the formation of soil aggregates. Sand and silt particles can not form aggregates as they do not possess the power of adhesion and cohesion. These particles usually carry a coating of clay particles; they are enmeshed in the aggregates formed by the adhering clay particles. Colloidal particles form aggregates only when they are flocculated. There is vast difference between flocculation and aggregation. Flocculation is brought about by coalescence of colloidal particles and is the first step in aggregation.

Aggregation is something more than flocculation involving a combination of different factors such as hydration, pressure, dehydration etc. and required cementation of flocculated particles. The cementation may be caused by cations, oxides of Fe and Al, humus substances and products of microbial excretion and synthesis. Clay particles form aggregates only if they are wetted by a liquid like water whose molecules possess an appreciable dipole moment.

$$Clay^{-} - {}^{+}Water^{-} - {}^{+}Cation^{+} - {}^{-}Clay^{-} - {}^{+}Water^{-} - {}^{+}Cation^{+} - {}^{-}Clay^{-}$$

The aggregation also depends upon the nature of clay particles, size and amount of clay particles, dehydration of clay particles, cations like calcium and anions like phosphate.

Fe and Al oxides

The colloidal Fe oxides act as cementing agent in aggregation. Al oxides bind the sand and silt particles. These act in two ways. A part of the hydroxides acts as a flocculating agent and the rest as a cementing agent.

Organic matter: It also plays an important role in forming soil aggregates.

- During decomposition, cellulosic substances produce a sticky material very much resembling mucus or mucilage. The sticky properly may be due to the presence of humic or humic acid or related compounds produced.
- Certain polysaccharides formed during decomposition.
- Some fungi and bacteria have cementing effect probably due to the presence of slimes and gums on the surface of the living organisms produced as a result of the microbial activity

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Classification

The primary particles –sand, silt and clay - usually occur grouped together in the form of aggregates.

Natural aggregates are called peds where as clod is an artificially formed soil mass. Structure is studied in the field under natural conditions and it is described under three categories

1 Type - Shape or form and arrangement pattern of peds

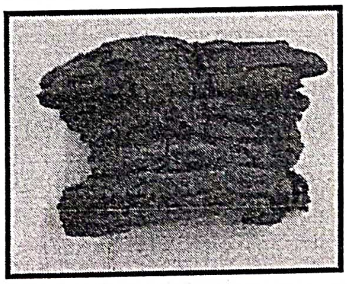
2 Class - Size of Peds

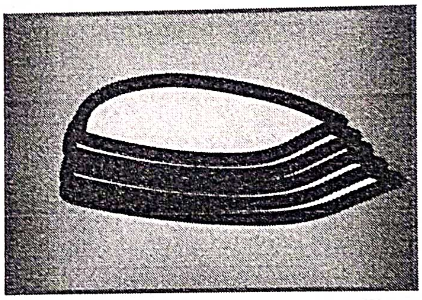
3 Grade - Degree of distinctness of peds

Types of Structure: There are four principal forms of soil structure

Plate-like (Platy)

In this type, the aggregates are arranged in relatively thin horizontal plates or leaflets. The horizontal axis or dimensions are larger than the vertical axis. When the units/ layers are thick they are called platy. When they are thin then it is laminar. Platy structure is most noticeable in the surface layers of virgin soils but may be present in the subsoil. This type is inherited from the parent material, especially by the action of water or ice.

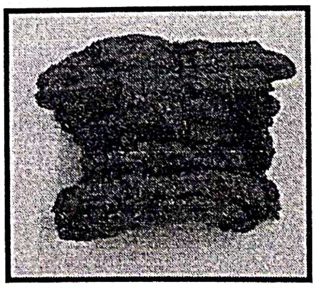




Prism-like

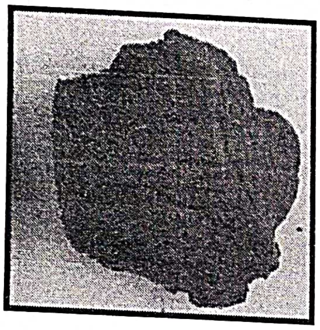
The vertical axis is more developed than horizontal, giving a pillar like shape.

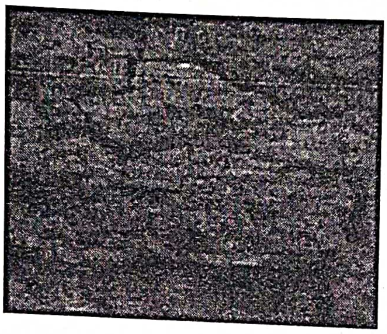
Vary in length from 1- 10 cm. Commonly occur in sub soil horizons of Arid and Semi arid regions. When the tops are rounded, the structure is termed as columnar when the tops are flat / plane, level and clear cut - prismatic.

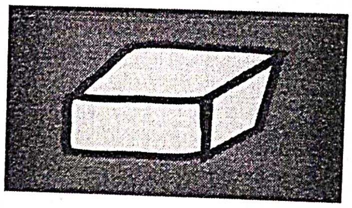


Block like

All three dimensions are about the same size. The aggregates have been reduced to blocks .Irregularly six faced with their three dimensions more or less equal. When the faces are flat and distinct and the edges are sharp angular, the structure is named as angular blocky. When the faces and edges are mainly rounded it is called sub angular blocky. These types usually are confined to the sub soil and characteristics have much to do with soil drainage, aeration and root penetration.



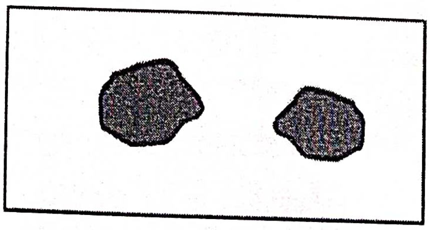




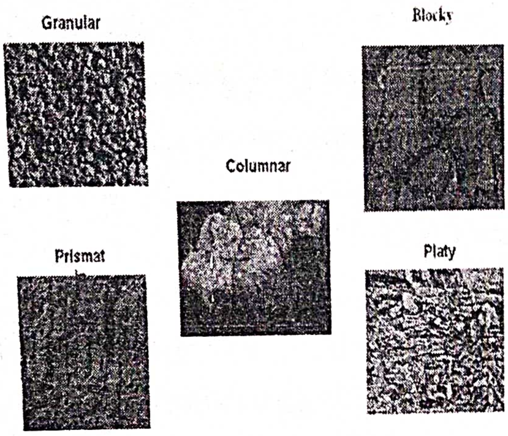
Spheroidal (Sphere like)

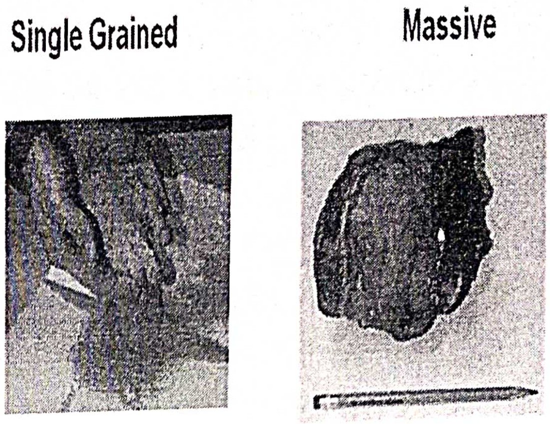
All rounded aggregates (peds) may be placed in this category. Not exceeding an inch in diameter. These rounded complexes usually loosely arranged and readily separated. When wetted, the intervening spaces generally are not closed so readily by swelling as may be the case with a blocky structural condition. Therefore in sphere-like structure, infiltration, percolation and aeration are not affected by wetting of soil. The aggregates of this group are usually termed as granular which are relatively less porous. When the granules are very porous, it is termed as crumb. This is specific to surface soil particularly high in organic matter/ grass land soils.

Classes of Structure: Each primary structural type of soil is differentiated into 5 size classes depending upon the size of the individual peds.



Soil structure –with structure **Soil structure –without structure**





The terms commonly used for the size classes are

1. Very fine or very thin
2. Fine or thin
3. Medium
4. Coarse or thick
5. Very Coarse or very thick

The terms thin and thick are used for platy types, while the terms fine and coarse are used for other structural types.

Grades of Structure

Grades indicate the degree of distinctness of the individual peds. It is determined by the stability of the aggregates. Grade of structure is influenced by the moisture content of the soil. Grade also depends on organic matter, texture etc. Four terms commonly used to describe the grade of soil structure are:

1. **Structureless:** There is no noticeable aggregation, such as conditions exhibited by loose sand.
2. **Weak Structure:** Poorly formed, indistinct formation of peds, which are not durable and much un aggregated material.

3. **Moderate structure:** Moderately well developed peds, which are fairly durable and distinct.

4. **Strong structure:** Very well formed peds, which are quite durable and distinct.

Structure naming

For naming a soil structure the sequence followed is grade, class and type; for example strong coarse angular blocky, moderate thin platy, weak fine prismatic.

Factors Affecting Soil Structure

The development of structure in arable soil depends on the following factors:

1. Climate

Climate has considerable influence on the degree of aggregation as well as on the type of structure. In arid regions there is very little aggregation of primary particles. In semi arid regions, the degree of aggregation is greater.

2. Organic matter

Organic matter improves the structure of a sandy soil as well as of a clay soil. In case of a sandy soil, the sticky and slimy material produced by the decomposing organic matter and the associated microorganism cement the sand particles together to form aggregates. In case of clayey soil, it modifies the properties of clay by reducing its cohesiveness. This helps making clay more crumby.

3. Tillage

Cultivation implements break down the large clods into smaller fragments and aggregates. For obtaining good granular and crumby structure, optimum moisture content in the soil is necessary. If the moisture content is too high it will form large clods on drying. If it is too low some of the existing aggregates will be broken down.

4. Plants, Roots and Residues

Excretion of gelatinous organic compounds and exudates from roots serve as a link

Root hairs make soil particles to cling together. – Grass and cereal roots Vs other roots

Pressure exerted by the roots also held the particles together

Dehydration of soil - strains the soil due to shrinkage ⊕ result in cracks ⊕ lead to aggregation

Plant tops and residues – shade the soil – prevent it from extreme and sudden temperature and moisture changes and also from rain drop impedance.

Plant residues – serve as a food to microbes – which are the prime aggregate builders.

5. Animals

Among the soil fauna small animals like earthworms, moles and insects etc., that burrow in the soil are the chief agents that take part in the aggregation of finer particles.

6. Microbes

Algae, fungi, actinomycetes and fungi keep the soil particles together. Fungi and actinomycetes exert mechanical binding by mycelia, Cementation by the products of decomposition and materials synthesized by bacteria.

7. Fertilizers

Fertilizer like Sodium Nitrate destroys granulation by reducing the stability of aggregates. Few fertilizers for example, CAN help in development of good structures.

8. Wetting and drying

When a dry soil is wetted, the soil colloids swell on absorbing water. On drying, shrinkage produces strains in the soil mass gives rise to cracks, which break it up into clods and granules of various sizes.

9. Exchangeable cations

Ca, Mg ------------ H, Na

Flocculating Deflocculating

Good structure Poor structure

10. Inorganic cements: $CaCO3$ and Sesquioxides

11. Clay, 12. Water

Effect of Soil Structure on other Physical Properties

Porosity

Porosity of a soil is easily changed. In plate like structure, pore spaces are less where as in crumby structure pore spaces are more.

Temperature

Crumby structure provides good aeration and percolation of water in the soil. Thus these characteristics help in keeping optimum temperature in comparison to plate like structure.

Density: Bulk density varies with the total pore space present in the soil. Structure chiefly influences pore spaces Platy structure with less total pore spaces has high bulk density where as crumby structure with more total pore spaces has low bulk density

Consistence

Consistence of soil also depends on structure. Plate-like structure exhibits strong plasticity.

Colour

Bluish and greenish colors of soil are generally due to poor drainage of soil. Platy structure normally hinders free drainage.

Importance of Structure: Soil structure influences rather indirectly by the formation of an array of pores of various shapes and sizes. These pores are controlling factors governing water, air and temperature in soil.

The role of soil structure in relation to plant growth

- Soil structure influences the amount and nature of porosity.
- Structure controls the amount of water and air present in the soil. Not only the amount of water and air dependent on soil structure, but 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 infiltration, water holding capacity, aeration and drainage. It also provides good habitat for microorganisms and supply of nutrients.

Class of Soil Structure as differentiated by size of soil peds

Class	Platy	Prismatic	Columnar	Blocky	S.A.Blocky	Granular	Crumb
V.Fine or V.Thin	<1	<10	<10	<5	<5	<1	<1
Fine or Thin	1-2	10-20	10-20	5-10	5-10	1-2	1-2
Medium	2-5	20-50	20-50	10-20	10-20	2-5	2-5
Coarseor Thick	5-10	50-100	50-100	20-50	20-50	5-10	-

V.C or V.Thic	>10	>100	>100	>50	>50	>10	-

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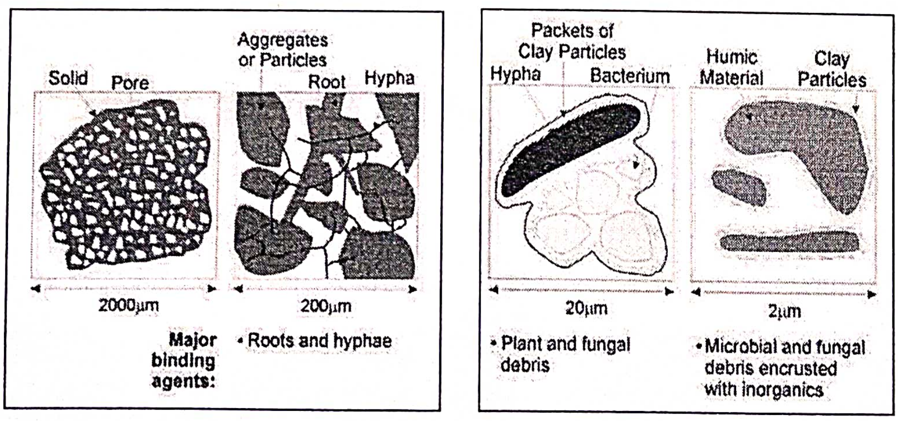
Soil aggregates-significance-soil consistency-soil crusting

Soil aggregates

Soil aggregates are 'clumps' of soil particles that are held together by moist clay, organic matter (such as roots), by organic compounds (from bacteria and fungi) and by fungal hyphae (*pronounced "highfee"*). Aggregates vary in size from about 2 thousandths of a millimetre across up to about 2 millimetres across, and are made up of particles of varying sizes. Some of these particles fit closely together and some do not and this creates spaces of many different sizes in the soil. These spaces, or pores, within and between soil aggregates are essential for storing air and water, microbes, nutrients and organic matter. Soils with many aggregates are called "well-aggregated". Such soils are more stable and less susceptible to erosion.

There are two ways that bacteria could be involved in soil aggregation. One way is by producing organic compounds called polysaccharides. Bacterial polysaccharides are more stable than plant polysaccharides, resisting decomposition long enough to be involved in holding soil particles together in aggregates. The other way bacteria are involved in soil aggregation is by developing a small electrostatic charge that attracts the electrostatic charge on clay surfaces, bringing together small aggregates of soil.



Fungi grow in long, threadlike structures, called hyphae. The amount of aggregation in the soil has been found to relate to the length of fungal hyphae in the soil. Fungi help to form aggregates in the soil by enmeshing soil particles with their hyphae and forming cross-links between soil particles. Mycorrhizal fungi and fungi that colonise fresh organic matter are believed to be the most important for assisting with stabilisation of soil particles into aggregates.

Significance of soil aggregation

Crop growth is often constrained by poor root development, by slow water infiltration and water movement through the soil, and by poor soil aeration. These constraints are often associated with poor soil porosity. Soil aggregation is important to developing and maintaining good soil porosity and hence to good root growth and to movement of soil water and gases. With more soil in water stable aggregates, it is expected that:

- The rate of water infiltration and percolation will increase
- Soil crusting will be less – which improved root penetration and access to soil moisture and nutrients and emergence of seedlings
- Resistance to the splash effect of raindrops will increase and soil erodibility will decrease; and
- Runoff will decrease, making more water available to the crop.

The importance of soil physical properties to crop growth, including soil aggregation properties, is often under-estimated by producers, and practical exercises can be useful in conveying information on the importance of these properties.

Soil Consistence

Soil consistence is defined as "the resistance of a soil at various moisture contents to mechanical stresses or manipulations".

It combines both the '**cohesive**' and '**adhesive**' forces, which determine the ease with which a soil can be reshaped or ruptures.

Adhesion	Cohesion
Molecular attraction that holds the surfaces of two substances (eg. Water and soil particles) in contact	Holding together: force holding a solid or liquid together, owing to attraction between like molecules. Decreases with rise in temperature

Soil consistence is described at three moisture levels namely 'wet', 'moist' and 'dry'.

1. **Wet soils:** Consistency is denoted by terms stickiness and plasticity

Stickiness is grouped into four categories namely i) non sticky, ii) slightly sticky, iii) sticky and iv) very sticky

Plasticity of a soil is its capacity to be moulded (to change its shape depending on stress) and to retain the shape even when the stress is removed. Soils containing more than about 15% clay exhibit plasticity – pliability and the capacity of being molded. There are four degrees in plasticity namely i) non plastic, ii) slightly plastic, iii) plastic and iv) very plastic.

2. **Moist soil:** Moist soil with least coherence adheres very strongly and resists crushing between the thumb and forefinger. The different categories are

i. Loose-non coherent

ii. Very friable - coherent, but very easily crushed

iii. Friable - easily crushed

iv. Firm - crushable with moderate pressure

v. Very firm - crushable only under strong pressure

vi. Extremely firm - completely resistant to crushing. (type and amount of clay and humus influence this consistency)

3. **Dry soil:** In the absence of moisture, the degree of resistance is related to the attraction of particles for each other. The different categories are

i) Loose - non coherent

ii) Soft - breaks with slight pressure and becomes powder

iii) Slightly hard - break under moderate pressure

iv) Hard - breaks with difficulty with pressure

v) Very hard - very resistant to pressure

vi) Extremely hard - extreme resistance and cannot be broken

Soil crusting

Formation mechanism:

Soil crusts usually are formed as a result of compaction at the immediate surface due to an externally applied force. This force is supplied primarily by the impact of raindrops as the soil is wetted and the radiant energy of the sun as the soil dries. When the rain drops fall on dry soil.

Bulk density and particle density of soils & porosity

Particle Density

The weight per unit volume of the solid portion of soil is called particle density. Generally particle density of normal soils is 2.65 grams per cubic centimeter. The particle density is higher if large amount of heavy minerals such as magnetite, limonite and hematite are present in the soil. With increase in organic matter of the soil the particle density decreases. Particle density is also termed as true density.

Table Particle density of different soil textural classes

Textural class	Particle density (g/ cm^3)
Coarse sand	2.655
Fine sand	2.659
Silt	2.798
Clay	2.837

Bulk Density

The oven dry weight of a unit volume of soil inclusive of pore spaces is called bulk density. The bulk density of a soil is always smaller than its particle density. The bulk density of sandy soil is about 1.6 g / cm^3, whereas that of organic matter is about 0.5. Bulk density normally decreases, as mineral soils become finer in texture. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil. Generally soils with low bulk densities have favorable physical conditions.

Bulk density of different textural classes

Textural class	Bulk density (g/cc)	Pore space (%)
Sandy soil	1.6	40
Loam	1.4	47
Silt loam	1.3	50
Clay	1.1	58

Factors affecting bulk density

1. **Pore space**

   Since bulk density relates to the combined volume of the solids and pore spaces, soils with high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. Consequently, any factor that influences soil pore space will affect bulk density.

2. **Texture**

   Fine textured surface soils such as silt loams, clays and clay loams generally have lower bulk densities than sandy soils. This is because the fine textured soils tend to organize in porous grains especially because of adequate organic matter content. This results in high pore space and low bulk density. However, in sandy soils, organic matter content is generally low, the solid particles lie close together and the bulk density is commonly higher than in fine textured soils.

3. **Organic matter content**

   More the organic matter content in soil results in high pore space there by shows lower bulk density of soil and vice-versa.

Porosity

Soil porosity refers to that part of a soil volume that is not occupied by soil particles or organic matter.

The pore space of a soil is the space occupied by air and water. The amount or ratio of pore space in a soil is determined by the arrangement of soil particles like sand, silt and clay. In sandy soils, the particles are arranged closely and the pore space is low. In clay soils, the particles are arranged in popous aggregates and the pore space is high. Presence of organic matter increases the pore space.

Factors influencing pore space

Soil texture

Sandy surface soil	: 35 to 50 %
Medium to fine textured soils	: 50 to 60 %
Compact sub soils	: 25 to 30%

Crops / vegetation

Some crops like blue grass increases the porosity to 57.2% from the original 50%

Cropping reduces the porosity as cultivation reduces the organic matter content and hence decrease in granulation. Virgin soils have more pore space.

Continuous cropping reduces pore space than intermittent cropping. More the number of crops per year, lesser will be the pore space particularly macro pores.

Conservation tillage and no tillage reduces porosity than conventional tillage

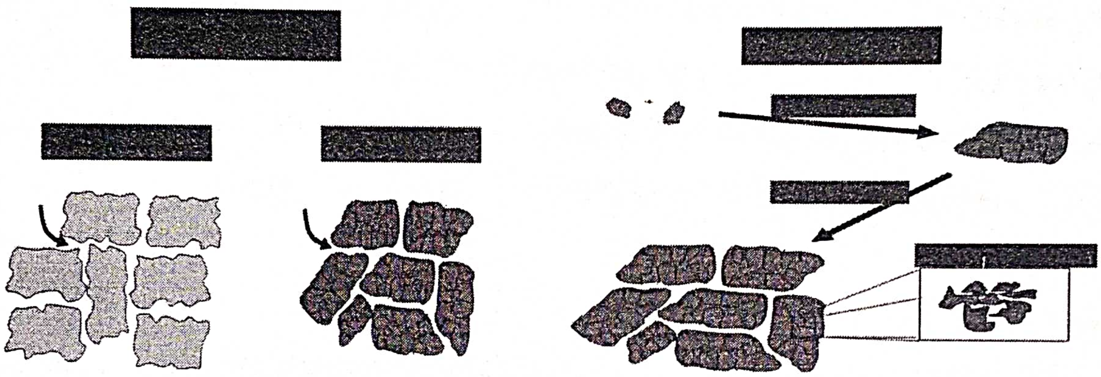
Size of pores

1. Macro pores (non-capillary pores) : diameter >0.05 mm
2. Micro pores (capillary pores) : diameter < 0.05 mm

In macro pores, air and water moves freely due to gravitation and mass flow. In micro pores, the movement of air and water is very slow and restricted to capillary movement and diffusion.

Sandy soil have more macro pores and clay soils have more micro pores. So in sandy soils, water and air movement is rapid due to macro pores though the pore space is higher and in clay soils the air and water is slower due to micro pores though the total pore space is higher.

Loamy soils will have 50% porosity and have equal portion of macro and micro pores.



Significance and manipulation of soil porosity

The bulk density and pore space are inter related. Development of low bulk density values also means the development of large amount of pore spaces. In nature, low bulk density values are usually found in soilswith high organic matter contents. High biological activities are necessary for formation and large accumulation of organic matter. Together with the effect of soil organisms, the high humus content will encourage aggregation, increasing in this way soil porosity, and thereby decreasing bulk density values. The cultivation effect of the soil macro and micro fauna produces an intricate system of macropores, which is a major factor for lowering the bulk density of soil. Continous cropping is noted to decrease the amount of organic matter in soils, and is expected to decrease soil aggregation. Tillage by ploughing is designed to increase the pore space in soils, but is infact decrasing organic matter. To alleviate these problems conservation tillage and no tillage have been introduced. Though many claimed that this increased the organic matter, the later have not always increased the total pore space.

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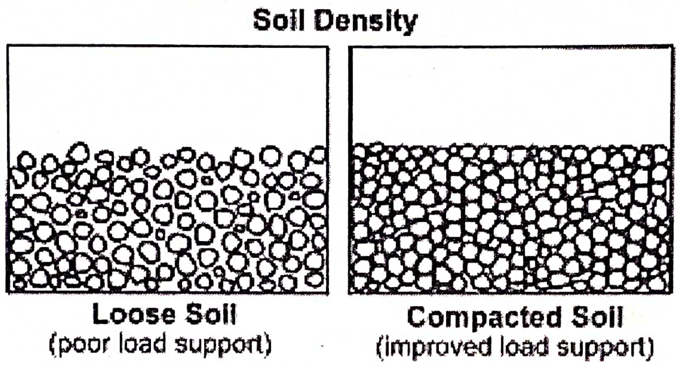
Soil compaction

Soil compaction is defined as the method of mechanically increasing the density of soil. In construction, this is a significant part of the building process. If performed improperly, settlement of the soil could occur and result in unnecessary maintenance costs or structure failure. Almost all types of building sites and construction projects utilize mechanical compaction techniques.



Soil Colour

Soil colour indicates many soil features. A change in soil colour from the adjacent soils indicates a difference in the soil`s mineral origin (parent material) or in the soil development. Soil colour varies among different kinds as well as within the soil profile of the same kind of soil. It is an important soil properties through which its description and classification can be made.

Kinds of soil colour

Soil colour is inherited from its parent material and that is referred to as lithochromic, e.g. red soils developed from red sandstone. Besides soil colour also develops during soil formation through different soil forming processes and that is referred to as acquired or pedochromic colour, e.g. red soils developed from granite or schist.

Factors affecting soil colour

There are various factors or soil constituents that influence the soil colour which are as follows:

- **Organic matter:** soils containing high amount of organic matter show the colour variation from black to dark brown.
- **Iron compounds:** soil containing higher amount of iron compounds generally impart red, brown and yellow tinge colour.
- **Silica, lime and other salts:** Sometimes soils contain either large amounts of silica and lime or both.

Due to presence of such materials in the soil the colour of the soil appears like white or light coloured.

- **Mixture of organic matter and iron oxides:** Very often soils contain a certain amount of organic matter and iron oxides. As a result of their existence in soil, the most common soil colour is found and known as brown.
- **Alternate wetting and drying condition:** During monsoon period due to heavy rain the reduction of soil occurs and during dry period the oxidation of soil also takes place.due to development of such alternating oxidation and reduction condition,the colour of soil in different horizons of the soil profile is variegated or mottled. This mottled colour is due to residual products of this process especially iron and manganese compounds.
- **Oxidation-reduction conditions:** when soils are waterlogged for a longer period, the permanent reduced condition will develop. The presence of ferrous compounds resulting from the reducing condition in waterlogged soils impart bluish and greenish colour.

Therefore, it may be concluded that soil colour indirectly indicative of many other important soil properties.besides soil colour directly modify the soil temperature e.g.dark coloured soils absorb more heat than light coloured soils.

Determination of soil colour

The soil colours are best determined by the comparison with the Munsell colour.

This colour chart is commonly used for this purpose.the colour of the soil is a result of the light reflected from the soil.soil colour rotation is divided into three parts:

Hue - it denotes the dominant spectral colour (red,yellow ,blue and green).

Value - it denotes the lightness or darkness of a colour (the amount of reflected light).

Chroma - it represents the purity of the colour (strength of the colour).

The Munsell colour notations are systematic numerical and letter designations of each of these three variables (Hue,Value and Chroma).For example ,the numerical notation 2.5 YR6/6 suggests a hue of 2.5 YR,value of 5 and chroma of 6. The equivalent or parallel soil colour name for this Munsell notation is `red`.

Soil water

Water, an excellent solvent for most of the plant nutrients,is a primary requisite for plant growth,

Importance of Soil Water

- Soil water serves as a solvent and carrier of food nutrients for plant growth
- Yield of crop is more often determined by the amount of water available rather than the deficiency of other food nutrients
- Soil water acts as a nutrient itself
- Soil water regulates soil temperature