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SOIL FORMING PROCESSES

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Objectives:

Soils are the products of weathering from some parent rocks. All soils initially come from some pre-existing rocks. They are called as 'parent materials'. The Parent Material may be directly below the soil, or at great distances away from it. It is necessary to understand the factors and processes that are responsible for the formation of soils. The major objective of studying this lesson is to understand the various factors of soil formation and the host of processes that result in the formation of various kinds of soils.

1. Introduction

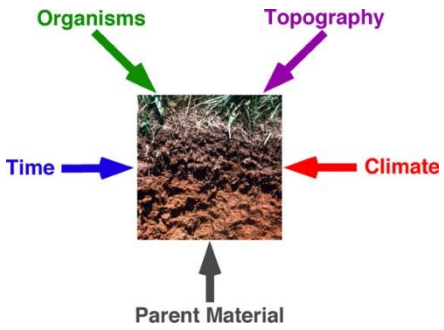
Soil formation is a long term process. It takes several million years to form a thin layer of soil. As soil is a complex mixture of various components, its formation is also more complex. The Formation of a particular type of soil depends upon the physico-chemical properties of the parent rock, intensity and duration of weathering, climatic and other parameters.

Pedogenesis or **soil evolution (formation)** is the process by which soil is formed.

2. Origin of soils:

The force of wind, water or glaciers might have transported the soil to some other place. In addition to the soil parent material, origin of soil is also dependent upon other prevailing processes affecting soil formation. Climatic conditions are important factors affecting both the form and rate of physical and chemical weathering of the parent material. The formation of soils can be seen as a combination of the products of weathering, of structural development of the soil, of differentiation of that structure into horizons or layers, and lastly of its movement or translocation.

3. Factors of Soil Formation



4. Factors affecting the formation of soil

The Jenny equation
Soil scientist, Hans Jenny has suggested that type of soil found on any site is dependent upon the interaction of five factors.
Jenny's state factor equation for soil genesis:
S = f (C, O, R, P, T, . . .)
C = Climate

O = Organisms
R = Relief (topography)
P = Parent Material
T = Time
...= Other unspecified factors
Any of the physical, chemical or biological processes taking place in the soil as a result of these factors are called pedogenic processes

State Factor Analysis

Folger's concept of sediment genesis
Se = f (G, H, B) (G, H, B) ?
Se = sediment characteristics ?
G = source geology
H = hydrology (flow regime)
B = bathymetry

5. Time :

Soil formation takes several hundreds to thousands of years to undergo significant changes. Soils can take many years to form. Younger soils have some characteristics from their parent material, but as they age, the addition of organic matter, exposure to moisture and other environmental factors may change its features. With time, they settle and are buried deeper below the surface, taking time to transform. Eventually they may change from one soil type to another. Most of the soils of the world have taken more than 10,000 years to form the current state of soils.

6. Parental Material (PM)

The parental material determines the mineralogical composition and widely contributes to the chemical and physical characteristics of the soil. The type of parental material also determines the rate at which soil forming processes occurs. Different places have different soils based on the parent materials such as marine area peaty soils due to the marine organic deposits and flood plain clay soils due to alluvial deposits.
Accordingly, the complexity of soil patterns, texture, composition, and color in different areas highly depends on the physical and chemical compositions of the parent materials. Majority of loamy soil, for instance, forms as a result of thin deposits of fine grained materials that have been mixed with organic materials and other underlying materials through natural process.
Most soil parent materials were rocks at some time in their history.
The minerals in rocks contribute to soil fertility and other soil properties long after the original rock is gone.
Consequently, it is a valuable skill to be able to identify a few broad categories of rock.
Geologists classify rocks into igneous, sedimentary and metamorphic rocks, according to their origins.
In this lesson you will learn how to identify these major rock types and about some common rock forming minerals.
Weathering breaks up rock and minerals, changes their chemical composition and characteristics, and also synthesizes a soil from the upper part of the regolith.
This unconsolidated material is acted on by the five soil forming factors and soil is formed.
For this reason the upper part of the regolith is called parent material.

There are 5 general categories of parent material:

Residual Rocks and Minerals

1. Glacial Deposits
2. Loess Deposits
3. Alluvial and Marine Deposits
4. Organic Deposits

1. Two types of minerals are found in natural systems: ***primary*** and ***secondary.***
    - Whether the mineral is primary or secondary depends on the mode of formation and not on the mineral composition.
    - minerals that crystallize from cooling magma are called primary.
    - minerals that crystallize during the weathering of primary minerals are called secondary minerals.

7. Climate :

Climate especially precipitation, temperature and frost action have a fundamental influence on the soil formation process that takes place within any given location. The prevailing climatic conditions highly determine the nature of weathering process that will take place and the rates of physical and chemical processes.

Climate directly has an effect on the kind of vegetation in an area which in turn will affect the soil formation processes related to root penetration and vegetation cover**.**
The availability of moisture also has an influence on soil pH and the decomposition of organic matter. The accumulation and decay of organic matter also depends on humidity and temperature.

Rainfall leaches away soluble materials and iron-rich minerals from the upper soil horizons into the lower ones and evaporation brings about the accumulation of salt compounds in the surface horizons.

Cold winter temperatures give room for frost action which physically disintegrates the rocks into fragments.

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.

8. 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.

9. 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.

10. Topography and relief

Topography is the configuration of a land surface and the relations among its man-made and natural features. Typically, it is the shape of the land surface and its position as well as slope on the landscape. So, these characteristics all together highly determine the types of soils formed within a region. In most regions, soils formed from similar parent materials under the same climatic conditions present differences due to their position on the landscape.

The differences are primarily because of varying drainage conditions owed to the depth of the water table or surface runoff. Soils formed on sloping areas and higher elevations are by and large excessively drained.

11. Soil formation on flat to almost flat position

On level topographic conditions, almost the entire water received through rainfall 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.

12. 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.

13. 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.

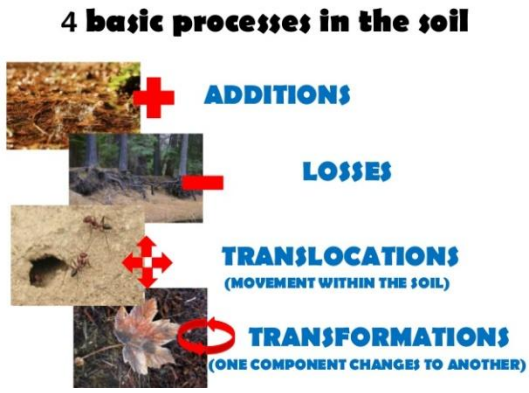
14. Organisms (living things including man, plants and animals)

All living organisms play an active role in the soil formation processes. Organisms including fungi, bacteria, animals, humans, and vegetations are the major determinants and they impact on the physical and chemical environments of the soils.

Micro-organisms encourage acidic conditions which change the soils chemistry and eventually determine the kind of soil formation process that occur.

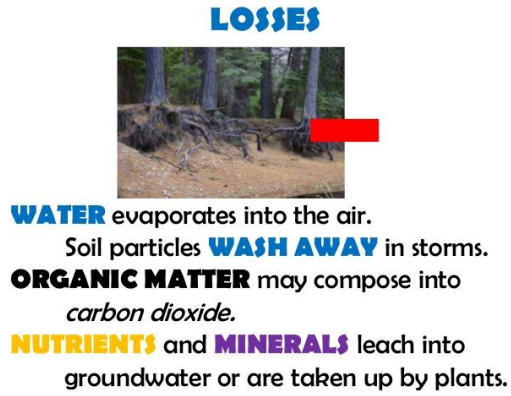
Microbial activities also decompose organic matter and recycle them in the soil. Larger animals including burrowing animals and earthworms mix the soil and alter its physical characteristics. Man's activates have as well made tremendous changes to the natural soils. Through cultivation, construction, and addition of fertilizer and lime has altered the physical and chemical properties of the soil. Filling, mining, and artificial drainage have altered the natural soil environments thereby negatively and positively affecting the process of soil formation.

15. Four Soil Forming Processes



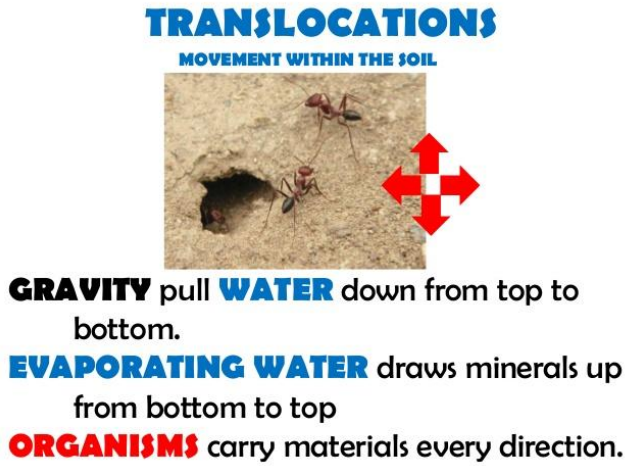
A. **Additions:** Materials added to the soil, such as decomposing vegetation and organisms (organic matter--OM), or new mineral materials deposited by wind or water.

B. **Losses:** Through the movement of wind or water, or uptake by plants, soil particles (sand, silt, clay, and OM) or chemical compounds can be eroded, leached, or harvested from the soil, altering the chemical and physical makeup of the soil.



C. **Transformations:** The chemical weathering of sand and formation of clay minerals, transformation of coarse OM into decay resistant organic compounds (humus).

D. **Translocations:** Movement of soil constituents (organic or mineral) within the profile and/or between horizons. Over time, this process is one of the more visibly noticeable as alterations in color, texture, and structure become apparent.



16. Seven Mechanisms of Soil Formation

A. Accumulation of materials

Materials are added to the soil such as organic matter and decomposing materials or new mineral materials deposited by the forces of ice, water or wind and they accumulate over time. This happens in the top layer of the soil. In poorly drained soils, the organic materials accumulate since water-logging prevents it from being oxidized or broken down by soil organisms.
In well drained soils, the materials accumulate when they are held up by the root systems. Depositions by the forces of wind, water or ice equally contribute to the accumulation of new materials. Some plants with the help of bacteria fix atmospheric nitrogen and ammonia compounds into the soil as nitrates.

B. **Leaching and losses**

Leaching - leaching is the removal of soluable components of the soil column. As water washes down through the soil it can carry away bases such as calcium, held as exchangeable ions in clay-humus complexes, as well as acidification through the substitution of hydrogen ions. Through the movement of water, wind, ice or the uptake of the accumulated materials by plants, the new particles including clay, organic matter, clay, silt or other chemical compounds are leached and eroded away or taken up from the soil by plants. As a result, the physical and chemical compositions of the new accumulated materials together with the soil parent material are altered. A prime example is the leaching out of some carbonates, magnesium and other minerals.

C. **Transformation and illluviation**

Here the soil particles held in the suspension after the leaching such as clay are transformed after which they accumulate. Transformation is the chemical weathering of silt, sand, and the formation of clay minerals as well as the change of organic materials into decay resistant organic matter. After, the clay and other accumulated materials are washed from the upper horizons and deposited in the lower horizons. The plants and animals are also responsible for transformation of the soil by physically and chemically breaking down the materials. The soil begins to take shape on its own through transformation, which improves natural drainage and nutrient composition.

Illuviation - here soil particles held in suspension, such as clay, are accumulated (eg. deposited).

Eluviation - here soil particles held in suspension, such as clay, are removed (eg. washed away).

D. **Podsolisation and translocations**

Podsolisation -
Podsolisation occurs when strongly acid soil solutions cause the breakdown of clay minerals. As a result silica, aluminium and iron form complexes with organic substances in the soil.
These minerals are removed from the surface zone of the soil and can accumulate in distinct dark sub-surface layers - very evident on inspection.

Upland heaths and moors often contain podsols.
Podsolisation takes place when strong acidic solutions breakdown the clay minerals.

Accordingly, aluminum, silica and iron form complex materials together with organic compounds in the soil. These materials and the other accumulations are translocated within the profile and/or between the horizons. After a relatively extended time, the movements of the accumulated mineral precipitate such as iron oxides minerals are responsible for the reddish and brownish color of the different soil horizons.

E. Laterization is a pedogenic process common to soils found in tropical and subtropical environments. High temperatures and heavy precipitation result in the rapid **weathering** of rocks and minerals.
Movements of large amounts of water through the soil cause **eluviation** and **leaching** to occur.

F. Calcification occurs when evapotranspiration exceeds precipitation causing the upward movement of dissolved alkaline salts from the groundwater.
At the same time, the movement of rain water causes a downward movement of the salts. The net result is the deposition of the translocated cations in the **B horizon**. In some cases, these deposits can form a hard layer called **caliche**.

G. Gleying - gleying occurs in waterlogged, anaerobic conditions when iron compounds are reduced and either removed from the soil, or segregated out as mottles or concretions in the soil. Marshy wetlands often contain gleyed soils.

17 . Weathering Processes

Weathering is the breakdown and alteration of rocks and minerals at or near the Earth's surface into products that are more in equilibrium with the conditions found in this environment.
The products of weathering are a major source of sediments for erosion and deposition.
The residue of weathering consists of chemically altered and unaltered materials. The most common unaltered residue is quartz. Many of the chemically altered products of weathering become very simple small compounds or nutrient ions. Some of the products of weathering, less resistant alumino-silicate minerals, become clay particles.
There are three broad categories of mechanisms for weathering: chemical, physical and biological

18. Chemical Weathering

Chemical weathering involves the alteration of the chemical and mineralogical composition of the weathered material. A number of different processes can result in chemical weathering. The most common chemical weathering processes are hydrolysis, oxidation, reduction, hydration, carbonation, and solution.

Hydrolysis is the weathering reaction that occurs when the two surfaces of water and compound meet.

Oxidation is the reaction that occurs between compounds and oxygen. The net result of this reaction is the removal of one or more electrons from a compound, which causes the structure to be less rigid and increasingly unstable.

Hydration is simply the reverse of oxidation, and is thus caused by the addition of one or more electrons producing a more stable compound.

Carbonation is the reaction of carbonate and bicarbonate ions with minerals. The formation of carbonates usually takes place as a result of other chemical processes.

The most important factor affecting all of the above mentioned chemical weathering processes is climate. Climatic conditions control the rate of weathering that takes place by regulating the catalysts of moisture and temperature.

19. Physical Weathering

Physical weathering is the breakdown of mineral or rock material by entirely mechanical methods brought about by a variety of causes. Upon freezing the volumetric change of water from liquid to solid is 9 %. This relatively large volumetric change upon freezing has potentially a great rupturing effect. Abrasion occurs when some force causes two rock surfaces to come together causing

mechanical wearing or grinding of their surfaces. Collision between rock surfaces normally occurs through the erosional transport of material by wind, water, or ice. Alternate wetting and drying of rocks, sometimes known as slaking, can be a very important factor in weathering.

20. Biological Weathering

Biological weathering involves the disintegration of rock and mineral due to the chemical and/or physical agents of an organism. The types of organisms that can cause weathering range from bacteria to plants to animals.
Biological weathering involves processes that can be either chemical or physical in character.

21. Role of 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.

22. Role of 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 CO2 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.

23. The pedogenic 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.

24. 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.

25. The human factor of soil formation

Of the classical factors of soil formation, climate, relief, parent material, time and organisms, it is the latter factor which discretely includes human impact. However, soils modified by human activities were often labeled as ‘disturbed’, ‘artefacts’, ‘manipulated’ or ‘artificial’ and were considered to be ‘deviations’ rather than a part of the soil continuum. It is not appropriate that human impact be integrated in the soil forming factor ‘organisms’.

26. Conclusion:

A soil is composed primarily of minerals which are produced from parent material that is weathered or broken into small pieces. There are thousands of different soils throughout the world. Weakly developed, moderately developed, and well developed soils are formed through a combination of five important factors, Parent rocks, climate, living organism, topography, temperature and water. 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.

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