

# AGS 2110

## Lecture 4

### SOIL FORMATION

#### 4.1 *Factors of Soil Formation*

A factor of soil formation is an agent or force which influences parent material with the potential of changing it. The major factors of soil formation are: parent material, climate, relief, organisms and time. These factors are theoretically independent variables in that field sites can be found in which they vary independently of each other.

##### 4.1.1 Parent material

The state of a weatherable material at time zero of soil formation is called *parent material*. The present soil owes its properties to composition of the parent material and modifications resulting from the effect of environmental factors. In general, the younger the soil the greater the influence of parent material. Following is a discussion of the common types of parent materials:

- **Sedimentary rocks**

- i. *Limestone and dolomites*

Limestone and dolomites by definition contain more than 50% carbonates and the rest of the rock is composed of silt and clay and/or quartz and/or iron and other contaminants. Soil forms in the residuum left from dissolution of the carbonates during weathering. Thus, the kind of soil formed is related to the dominant kind of impurities in the limestone. If the limestone is rich in clay the clay and permeable soils develop. Due to low rate of leaching through these dense soils, they ordinarily are not highly leached and are high in pH and base saturation. If the limestone is rich in sand, the soils tend to be coarse loamy, gravelly or acid and low in base saturation. If it is rich in iron impurities such as hematite, a red soil results, generally acid in reaction if in a humid climate.

- ii. *Sandstones*

Sandstones by definition contain more than 50% sand-size particles predominantly quartz. The cementing agents are variously silica, iron, and *carbonates* which together with the impurities (feldspars or mica) have great influence on the kind of soil formed from sandstones. In general, soils from

these rocks are coarse textured and highly permeable. They tend to be of low base status, nutrient reserve and pH especially if formed in humid climates in which the high permeability promotes acid leaching. The soils tend to be deep, unless they are forming in residuum from sandstones cemented with silica, in which case they are shallow because of the slow rate of dissolution of this type of cementing agent. The soils formed from sandstones with some iron cement tend to be reddish in color. If the feldspar content is greater than 25%, the rock is described as arkosic sandstone or arkose if the feldspar content is very high. Soils formed in residuum from rocks such as these tend to be clayey because of the feldspar weathering into clay and have high nutrient reserve because of nutrient release from the feldspars.

### *iii. Shales*

Shales are layered rocks called clay shales, clay stones or mudstones if comprised of predominantly clay, or siltstone if predominantly comprised of silt-size particles. In general, their mineral composition is of layer silicates, feldspars, quartz, small amounts of mica and sometimes calcium carbonate. Soils formed in residuum from clay shales are generally fine textured, relatively impermeable and consequently little leached and with shallow depth. They are high in base status and pH. Illite and montmorillonite generally are the main clay minerals.

### ▪ **Igneous rocks**

Granites and gneiss are the principle igneous rocks. They contain about 25% quartz, 65% K-feldspar with lesser amounts of mica and hornblende. These rocks may show slight differences in weathering pattern due to differences in structure-the gneiss being banded with mineral segregation in bands. But they produce by and large same kind of soils which are coarse-loamy, acidic and low in base status because of the high quartz content of the parent rock. Mineral nutrients tend to be low in these soils, except in cool climates. The soils tend to be yellow or yellowish brown because of low iron content of the parent rock. Clayey mineralogy is kaolinitic in warm climates while in cool climates it comprises a combination of vermiculite, illite and montmorillonite.

- **Matamorphic rocks**

The common metamorphic rocks are schists which are thinly plated rich in mica, with varying amounts of quartz and with very small amounts of other weatherable minerals. The soils from these rocks tend to be silty with high potassium reserve Illite and vermiculite are the main clay minerals.

- **Dark-coloured ferromagnesian (mafic or basic) rocks**

This group includes andesites, diorites, basalt and hornblende gneiss. All are rich in iron and magnesium bearing minerals and calcic plagioclase feldspars that weather rapidly yielding a good deal of clay and free iron. These minerals also keep the base status high. The soils are rich in clay. The colours are dark red or dark brown due to the high-free iron content. Base status and pH are Kaolinite and halloysite predominate under good drainage, while montmorillonite predominates under poor drainage.

#### **4.1.2 Relief**

Relief refers to the landscape pattern in an area. It affects the following soil properties:

- Depth of solum
- Soil depth
- Colour of the soil profile
- Degree of horizon differentiation
- Soil reaction
- Soluble salt content
- Temperature, and
- Character of initial material

- **Relief and climate**

Relief influences the distribution of climatic forces and agencies on soil material. Variation in slope and elevation influences the distribution of energy, meteoric water, plant nutrients and vegetation by varying:

- Conditions of organic activity

- Exposure of soil to precipitation
- Exposure of soil to wind
- Conditions of natural drainage including depth to water table

- **Relief and organisms**

cool highlands there is high accumulation of organic matter resulting into high microbial activity. In warm low lands there is low organic matter accumulation due to high decomposition rates caused by high temperatures.

- **Relief and parent material**

In broad river deltas, crests of natural levees near the stream channels course material than the areas beyond the levees.

- **Relief and time**

Relief changes with time. The age of a soil is determined by the stability of the surface.

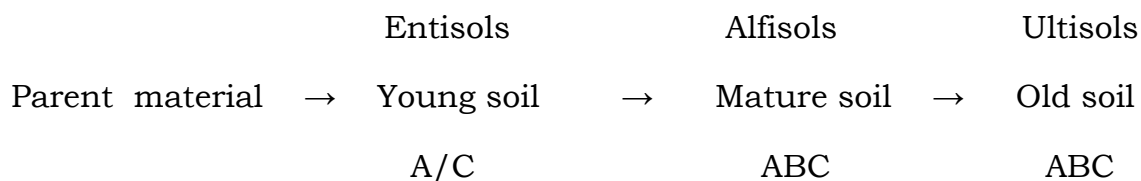
### 4.1.3 Vegetation

Vegetation is a dominant factor of soil formation as it is the primary source of organic matter and because of its major role in the nutrient cycling and hydrology of the soil.

### 4.1.4 Organisms

Leaf litter accumulates on the ground surface, roots contribute organic material below the surface. Coatings of organic matter occur on ped surfaces together with clay (organo-clay cutans). Mineralization of organic matter releases nutrients to plants. Microbial activity influences shaping of peds and pores, concentration of organic and mineral matter.

### 4.1.5 Time



The main soil forming processes in Entisols are:

- Accumulation of organic matter
- Weathering
- Leaching
- Translocation of colloids

The main soil forming processes in Alfisols is development of the B-horizon (Argillic).

In Ultisols, the main soil forming processes are high weathering resulting into a well developed Argillic horizon.

#### **4.1.6 Climate**

Climate controls some of the chemical and physical reactions taking place in the soil. Rainfall provides the water necessary for soil formation processes:

- It dissolves soluble material ( $\text{CaCO}_3$ )
- It is necessary for growth of plants and organisms
- It transports material from one part of soil to another
- It physically raptures material when it freezes

- **Effect of rainfall on soil properties**

pH decreases with increase in rainfall. The hydrogen ion activity increases with increase in rainfall.

Depth to carbonates increases with increase in rainfall due to solubility of carbonates in the leachate.

N content increases with increase in rainfall due to decomposition of organic matter.

Clay content increases with increase in rainfall due to increase in weathering reactions resulting into increase in formation of clay-size particles.

Base saturation decreases with increase in rainfall due to leaching.

Al content increases with increase in rainfall due to dissolution of clay minerals.

### ▪ **Effect of temperature on soil properties**

Temperature influences the reactions involved in the processes of soil formation, the type and amount of vegetation and hence the kind of organic matter.

Soil nitrogen and organic matter decreases with increase in temperature due to increase in decomposition reactions.

Clay content increases with increase in temperature due to increase in weathering reactions which produce finer particles.

Development of red colours increases with increase in temperature due to increase in weathering reactions which produce hematite.

#### **4.1.7 Land use**

Land use applies to the current use of land, whether agricultural or non-agricultural. It has a major influence on the direction and rate of soil formation.

#### **4.1.8 Human influence**

Human activity is another major influence on soil formation. Human activity may affect the landscape or the physical and chemical properties of the soil.

### **4.2 Processes of Soil Formation**

A process of soil formation is a reaction or re-arrangement of soil matter. It is a complex of or sequence of events, including both complicated reactions and comparatively simple re-arrangements of matter which ultimately affects the soil in which it operates. Numerous events may take place at the same time or in sequence to mutually reinforce or contradict each other; e.g. calcification and podzolization operate concurrently in certain Boralfs in very cold parts of the world.

Four (4) categories of soil forming processes can be distinguished:

- **Additions**-of organic matter and mineral material to the soil as solids, liquids or gases
- **Transformations**-of mineral and organic material within the soil
- **Translocations**-of organic and mineral material from one point to another within the soil profile

- **Losses**-of organic and mineral material from the soil profile

#### 4.2.1 Additions

This is the addition of organic and mineral material to the soil body; examples include the following:

- **Enrichment:** General term for addition of organic and mineral material to a soil body eg. From surrounding pedons, depressions, by air from remote areas.
- **Cumulization:** Aolian, hydrologic and man-made additions of organic and mineral material to the surface of a soil solum. Effects most evident in depressional areas where material eroded from soils upslope.
- **Melanization:** The darkening of light coloured mineral initial unconsolidated materials by admixture of organic matter (as in dark mollic or umbric horizons).
- **Littering:** The accumulation on the mineral soil surface of organic litter and associated humus to a depth of less than 30cm.
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#### 4.2.2 Transformation

This involves the transformation of material within the soil body. This involves the changing of material from one form to another within the soil body. Following is a description of various forms of transformation processes:

- **Podzolization:** The concentration of silica (silication) in the layer eluviated as a result of chemical migration of aluminium and iron and/or organic matter.
- **Desilication (Ferrallitization, Ferritization, Allitization):** The chemical migration of silica out of the solum and thus the relative concentration of sesquioxides in the solum (goethite, gibbsite, etc) with or without formation of ironstone (laterite, hardened plinthite) and concentrations.
- **Decomposition:** The breakdown of mineral and organic materials
- **Synthesis:** The formation of new particles of mineral and organic species.
- **Humification:** The transformation of raw organic material into humus.

- **Paludization:** The accumulation of deep (>30cm) deposits of organic matter as in mucks and peats (Vertisols), poorly drained soils.
- **Ripening:** Chemical, biological and physical changes in organic soil after air penetrates previously waterlogged material.
- **Mineralization:** The release of mineral components of organic matter through decomposition which become available as plant nutrients.
- **Braunification:** The release of iron from primary minerals and the dispersion of particles of iron oxides in increasing amounts; their progressive oxidation or hydration giving the soil mass ranging from brown to reddish brown and red colours. The reddening of subsoils of uplands is attributed to the process of brownification.
- **Gleyzation:** The reduction of iron under anaerobic waterlogged soil conditions with the production of bluish to greenish grey matrix colours with or without yellowish brown, brown and black mottles and ferric and manganiferous concentrations.
- **Loosening:** Increase in volume of voids by activity of plants, animals and humus and by freeze-thaw or other physical processes and by removal by removal of material by leaching.
- **Hardening:** Decrease in volumes of voids by collapse and compaction and by filling of some voids with fine earth, carbonates, silica and other materials.

#### 4.2.3 Translocation

This is the movement of matter from one part to another within a soil body. Examples include the following:

- **Eluviation:** Movement of material out of a portion of a soil profile as in an Albic horizon.
- **Illuviation:** Movement of material into a portion of the soil profile as in an Argillic horizon or Spodic horizon.
- **Calcification:** Accumulation of calcium carbonate from one part of the profile into another to form a Calcic horizon.
- **Decalcification:** The removal or leaching of calcium carbonate from a Calcic horizon.

- **Salinization:** The accumulation of soluble salts such as sulphates and chlorides of calcium, magnesium, sodium and potassium in salty (salic) horizons; common in sub-humid and arid regions.
- **Desalinization:** The removal or leaching of soluble salts from a salic soil horizon.
- **Alkalinization (Solonization):** The accumulation of sodium ions on the exchange sites in a soil.
- **Dealkalinization (Solodization):** The leaching of sodium ions and salts from nitric horizons. This process involves a lot of dispersion of clay caused by hydration of sodium ions which have high dispersion power.
- **Lessivage:** The mechanical migration of small mineral particles from the A to the B horizons of a soil producing in the B horizon relative enrichment of clay (Argillic horizon).
- **Pedoturbation:** Biologic, physical (freeze/thaw and wet-dry cycles churning and cycling of soil material thereby homogenizing the soil to varying degrees).
- **Leucinization:** The paling of soil horizons by disappearance of dark organic materials either through transformation to lighter coloured ones or through removal from the horizons.

#### 4.2.4 Losses (Subtractions)

This refers to complete loss of a soil material from the soil profile. Examples include the following:

- **Leaching (Depletion):** Washing out of materials from the soil profile.
- **Erosion:** Removal of material from the surface layer of a soil mainly by runoff water or wind action