

CHAPTER10

Rock and Soil Formation

OBJECTIVES

At the end of this chapter, students should be able to:

- â describe processes of rock formation.
- â identify types of rocks.
- â list factors of soil formation.
- â make a sketch of a soil profile.
- â discuss the basic principles of soil classification.

10.1 Introduction

The earthâ€™s surface consists of four interconnected geological layers (geospheres), namely, the lithosphere, the hydrosphere, the biosphere and the atmosphere. The lithosphere is the solid rocky crust covering the entire surface of the earth, the hydrosphere is made up of all the water on or near the surface of the earth and the biosphere is composed of all the living organisms: plants, animals and micro organisms while the atmosphere is the gaseous envelop that surrounds the earth. By weathering the solid crust otherwise called rock break down to form the soil upon which plants grow.

10.2 Processes of Rock Formation

Rock is the hard solid material that forms part of the surface of the earth. Rock contains primary and secondary minerals. The primary minerals that exist in their natural form consist of quartz, biotite, olivine, muscovite and feldspar. The secondary minerals are those that have worn out and combine with other elements such as oxides of magnesium, iron, and aluminium; sulphate and carbonate of iron, magnesium and calcium; clay minerals such as the silicate and the hydrous oxide.

10.3 Types of Rock

There are three major types of rock based on their mode of formation as follows:

- (i) Igneous Rock**
- (ii) Sedimentary Rock**
- (iii) Metamorphic Rock**

10.3.1 Igneous rock

This is formed as a result of high temperature and pressure beneath the earthâ€™s crust which causes the liquid material (molten magma) lying below the earth surface to solidify or erupt in the form of a volcano.



FIGURE 10.1 Igneous rock

There are two types of igneous rocks :

(a) Intrusive or plutonic

(b) Extrusive or volcanic

Intrusive or plutonic igneous rock : These are formed when the molten magma fails to push out of the surface of the earth before cooling and solidifying. The molten magma at this point in time has enough time to cool and harden into rock. They are coarsely crystalline and deeply formed. Examples are granite, diorite and gabbro. They contain minerals like quartz, feldspar and mica. In Nigeria, these rocks can be found in Benue, Bauchi, Zaria, Plateau, Ilorin, Ondo, Ado Ekiti, Abakiliki and Ogoja areas.

Extrusive or volcanic igneous rock : This is formed when the molten magma is pushed out of the surface of the earth, cools and hardens rapidly. The rocks formed in this way are rather glassy in appearance and have small grains. Examples are basalt and andesite.

Characteristics of igneous rock

- â They are coarsely crystalline in texture.
- â They are glassy in appearance.
- â They are usually hard and impervious.
- â They are resistant to erosion.
- â They do not contain fossil.
- â Their colours vary from pink, green, grey or black.
- â They usually contain fine grains.
- â They do not form layers.

10.3.2 Sedimentary rock

They are formed when weathered particles are transported from their place of origin and deposited in another area as solid particles. They are aided by natural agents such as wind, rains, river, flood, ice and stream. These materials accumulate in layers and are cemented together with time, forming sedimentary rocks.



FIGURE 10.2 Sedimentary rock

Types of sedimentary rocks are:

- (i) Mechanically formed sedimentary rocks.
- (ii) Organically formed sedimentary rocks.
- (iii) Chemically formed sedimentary rocks.

Mechanically formed sedimentary rocks :

Mechanically formed sedimentary rocks are known as ‘secondary rocks’. They are formed as a result of accumulation and cementation of weathered materials over a period of time. Examples are dolomite, conglomerates, sandstone, limestone and quartzites.

Organically formed sedimentary rocks :

They are formed as a result of deposition and hardening of shells and skeletons of aquatic organisms such as fish, oyster shells and snails. When these organisms were alive, they derived calcium carbonate from the water. When they died and decomposed, they compressed for some time to form chalk or limestone. When plants are depressed and submerged they decompose to form rocks. Examples are coal, peat, graphite and lignite. The remains of plants and animals found in sedimentary rocks are known as fossils.

Chemically formed sedimentary rocks :

During chemical reaction of minerals in the rocks, precipitates are formed and deposited in layers over time. Examples are sodium chloride, gypsum and nitrate.

Characteristics of sedimentary rocks

- â They occur in layers (stratified).
- â They contain fossils (dead plants and animals).
- â They are prone to erosion.
- â They form precipitates.
- â They react with weak acids.
- â They are soft.

10.3.3 Metamorphic rocks

They are formed by the alteration of sedimentary or igneous rocks from their original form by heat, pressure or chemical change. The rock undergoes transformation and hence the name ‘metamorphic’ rock. In the case of sedimentary rocks, any fossils contained in them are destroyed during the process.

Examples are slate, marble, gneiss schist, hornfel, quartzite and pumice. Due to metamorphism of these rocks sandstone changes to marble, shale changes to slate.

Characteristics of metamorphic rocks

- â They exist in different textures and colours.
- â Some may occur in layers or strata.
- â Some may be hard or soft.
- â They are non-crystalline in texture.

10.4 Importance of Rock in Agriculture

- â **Soil formation:** Soil is formed from weathered rocks. Soil is the bedrock of all agricultural activities.
- â **Plant nutrient:** Nutrients which are utilized by plants and animals are derived from the rocks. Examples are magnesium, calcium and potassium.
- â **Construction purposes:** Granite and sandstone when quarried are used in building and road constructions.
- â **Erosion control:** Rocks are used in building embankment to control erosion. At times rocks are used to fill potholes to prevent formation of ditches.
- â **Domestic use:** Some rocks are used in constructing grinding stones, which are used in our homes.
- â **Exportation:** Some rocks that are rich in certain minerals, such as gold, tin, coal and diamond, are exported to earn foreign exchange.
- â **Sources of minerals:** (Food) Rock salt such as sodium chloride (table salt) is a source of minerals.
- â **Raw materials:** Some rocks are sources of raw materials, such as cement, limestone, dolomite-marble, glasses and paint, for our industries.
- â **Sources of fuel:** Petroleum and coal are minerals sourced from underground and they are used as fuel.
- â **Ornamentals:** Some beautiful rocks are polished and used in-house decorations.

10.5 Factors of Soil formation

Soil is the natural body of material occupying the upper portion of the solid globe of the earth on which agricultural activities are carried out. Soil is the loose weathered material that covers the earth surface which supports the growth of plants and sustains human and animal life.

Soil formation is influenced by five major factors, namely :

- â Parent material
- â Climate
- â Topography
- â Living organisms
- â Time

(a) Parent material : The type of soil formed is determined by the physical nature of the parent material as well as the chemical and minerals present in it. Parent material of predominantly quartz minerals will give rise to sandy soil. Similarly, parent material that is dominated by mica and feldspars mineral will give rise to clay soil. The chemical composition of the parent material to a large extent determines the natural vegetation that will grow on

the soil. It also contains different minerals which account for differences in soil colour, texture and structures.

(b) Climate: This is the average weather condition of a place over a long period of time. The components of the climate are temperature, rainfall, sunshine, relative humidity, wind and pressure. These are very important in soil formation.

(i) Temperature : The measurement of the degree of hotness and coldness of a place. The heating and cooling of rocks result in continual expansion and contraction which creates cracks on the rock, resulting in the disintegration of the rock forming soil. When the weather is cool, the water in holes in the rock freezes up at night and when there is sunlight during the day, they melt leading to disintegration of the rocks.

(ii) Rainfall : The presence of rainfall leads to physical and chemical breakdown of parent material to form soil. It enhances vegetative growth of plants, whose roots help to break down rocks into small particles.

(iii) Sunshine : The sunshine provides radiant energy which increases the temperature of a place. Sunshine helps in the expansion of rocks which helps them to disintegrate.

(iv) Relative humidity: This helps to increase the moisture content of a place. The moisture helps in the chemical reaction of some minerals in the rock causing them to breakdown into smaller particles.

(v) Wind: The wind helps to carry and transport rock particles which collide with one another, resulting in the disintegration of rock to form soil.

(vi) Pressure : When forces are exerted physically or mechanically on rock, they break into pieces to form soil.

(c) Topography : This relates to the physical features of an area of land, especially the position of its mountains, rivers and valleys. The slope of the land or its inclination determines the extent of water run-off. On flat lands or areas with gentle slope the rate of run-off of excess water is low and the soil is well drained. Topography, therefore determines the formation of shallow or deep soils depending on the degree of slope and extent of erosion.

(d) Living organisms : This involves the activities of the plant and other living organisms that help to accelerate the rate of soil formation in the following ways:

- â Plants and animals living in the soil help to break down rock into soil.
- â The cracks and openings created by plants and animals allow water and air which after considerable reactions break down the rock.
- â Micro-organisms like fungi, protozoa and bacteria help in the decomposition of organic matters which aids soil formation.
- â Animals like millipedes, rodents and crickets burrow into the soil. This facilitates the formation of soil.
- â The activities of man during farming help to break down rock into soil.
- â Animals like sheep, cattle, goat and elephants use their hooves to trample on the rock thus breaking it into particles.
- â Plant leaves and parts yield organic matter when dead; this mixes with minerals of the rock to form soil.
- â The roots of plants equally send out chemical substances which gradually dissolve the parent rock to form soil.
- â Human activities like quarrying helps to break down rocks.

(e) Time : It is the period passed since the factors of soil formation act on the parent material. Time plays an important role in soil formation thus:

- â It takes a very long time for soil to develop.
- â It takes time for plants and animals to decay and form soil.
- â Climatic factors influence the time soil takes to disintegrate.
- â Time determines the type of soil to be formed.
- â It takes a long time for small pieces of rock to disintegrate into grains of soil.
- â It takes time for rainfall to leach certain chemicals like chlorides, carbonates and sulphate to form soil.

10.6 Processes of Soil Formation

Soil is formed due to combined action of factors of soil formation on the parent material. The process of soil formation is known as weathering. Weathering is a complex process of change which results in the disintegration of rock into tiny particles. The process of rock formation includes:

- (i) physical processes.
- (ii) chemical processes.
- (iii) biological processes.

Physical Processes : These are the breaking down of rocks into smaller particles without altering their chemical composition.

The agents of physical weathering are temperature, ice, water, wind and pressure.

â **Temperature :** Temperature varies with day and night. Due to this variation the rock expands and contracts resulting in the disintegration of rock to smaller particles over a period of time.

â **Ice :** Water that collects in crevices and holes on rocks cools down and freezes to ice during the cold hours of the night. During the day, the ice melts and cools again during the night. Repeated freezing and melting of the ice in the holes and crevices causes the rock to break into pieces.

â **Water :** Flowing water in the form of river, rain, floods, sea and lakes, due to its corrosive nature wears the rock surfaces away. The rock particles are carried by the running water where they break down further, as they run against each other and are deposited as soil.

â **Wind :** Wind is air in motion. The rock particles that are formed as a result of weathering are carried by wind and used forcefully to break down rocks. Wind also removes already deposited soil particles, thereby exposing the inner rocks to further weathering.

â **Pressure :** Pressure can cause rocks to crack. When roots of trees exert their pressure on the rocks, it leads to breaking down of rocks into tiny particles.

Chemical Processes : These involve the action of water on rocks which results in a series of reactions as follows:

â **Hydrolysis :** This is a chemical reaction in which the hydrogen ion of water changes position with the ion of another element of the rocks, leading to alteration of the element and formation of hydroxide. Such alteration weakens the rocks or minerals which are then weathered and deposited as soil particles.



(Orthoclase) water Acid Potassium

(Dissociated) (Silicate clay) (hydroxide)

â **Hydration :** This is the rigid combination of water molecules with rock minerals to form the hydrated mineral. The newly formed rock will

disintegrate due to instability. For example, conversion of iron (II) rocks (hematite) to hydrated rocks (limonite).



(Hematite) Yellow

(Limonite)

â **Solution** : This is a process by which a solvent (water) dissolves a rock mineral or salt (solute) to form a solution of acid or alkali. These solutions of acid or alkali, in turn, accelerate the wearing of rocks depending on their ionic constituents. The weathered minerals are deposited as soil particles.

â **Oxidation** : This involves the addition of oxygen to rock mineral or removal of hydrogen from a rock mineral. For example, conversion of iron (ii) to iron (iii).



â **Carbonation** : The carbon in the atmosphere combines with rainwater to form carbonic acid. This acid dissolves the rock, thus forming soil particles.



Biological Processes : These involve the influence of plant, animal and man's activities which disintegrates rocks. They include :

â The roots of plants growing and exerting pressure on the rocks.

â The action of burrowing soil organisms (earthworm, termite, crickets and rodents). They disintegrate the rock, forming soil particles.

â The activities of man in quarrying and cultivation of farm land in which rocks are broken down.

â The action of bigger animals whose hooves help to break down rocks (sheep, cattle, goat and elephant).

â Plant leaves and parts influence the organic matter content of the soil when they die and decay.

10.7 Soil Profile Development

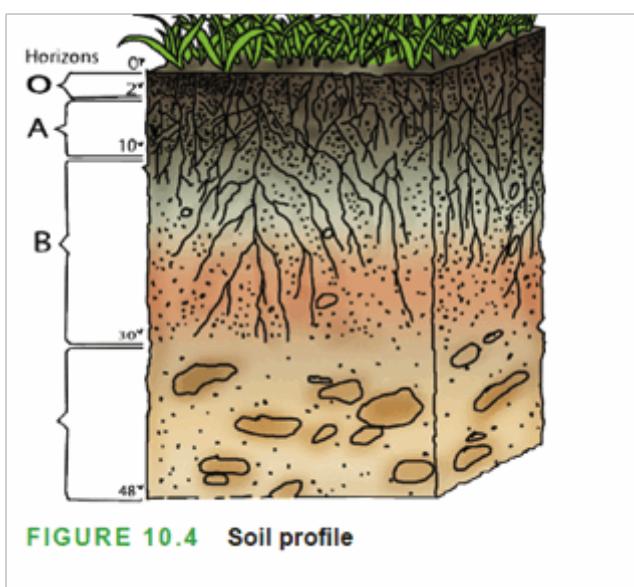
Soil profile refers to the vertical cross section of the soil from the surface into the underlying unweathered materials. An ideal soil profile consists of four main layers or horizons. There are four distinct layers or horizons in any soil profile. These are as follows:

â **A-horizon:** This consists of two layers: The organic matter layer and the top soil. The organic matter layer contains dead plant/animal materials, decayed and decaying organic matter. This is usually dark in colour. The top soil is the uppermost layer of soil immediately after organic matter layer. It contains sandy loam particles and harbours soil organisms like bacteria, fungi and worms. It is rich in soil nutrients.

â **B-horizon:** This is the sub-soil. It is greyish or brownish in colour. It contains sandy loam and little humus. Minerals available in this layer can only be reached by deep-rooted crops like rubber, cocoa, citrus, oil palm and mango.

â **C-horizon:** This is also called the parent material layer. It is reddish orange in colour and is made up of gravel and clay particles.

â **D-horizon:** This is also referred to as the bedrock. It consists of unweathered rocks.



Importance of Soil Profile

- â It helps to determine the level of soil fertility.
- â It determines easy penetration of roots of crops.
- â It determines the types of crop to be grown in a particular area.
- â The level of parent material determines the type of mineral salt available to plants.
- â It determines the level of drainage and irrigation of the soil.

Activity 1: The students should collect different types of rocks found in their locality. Group them into two and identify the rocks based on their mode of formation. List the different characteristics of each rock and in tabular form enumerate the differences among the three types of rocks collected.

Activity 2: Collect 50 g soil sample, put the soil into a 500 cm³ measuring cylinder. Add

300 cm³ of water and 10 ml of hydrogen peroxide and shake vigorously. Leave to stand for 30 minutes. Record your observation. Draw and label a typical soil profile.

Summary

- ◆ The earth surface consists of four interconnected geographical layers consisting of lithosphere, hydrosphere, biosphere and atmosphere.
- ◆ Rock is the hard solid material that forms part of the surface of the earth and some other plants.
- ◆ There are three types of rocks, namely igneous, sedimentary and metamorphic rock.
- ◆ Weathering occurs when rocks disintegrate.
- ◆ There are three types of weathering: physical, chemical and biological.
- ◆ When rocks weather they form soils.
- ◆ The vertical section of soil shows the soil profile which is made up four horizons – A-horizon, B-horizon, C-horizon and D-horizon.

Revision Questions

Essay Questions

1. (a) What is rock weathering?
 (b) State two factors of agricultural importance of weathering.
 (c) List four factors of soil formation. (NECO/SSCE 2007)

2. (a) Explain briefly the processes of formation of
 (i) Igneous rocks.
 (ii) Sedimentary rocks.

(iii) Metamorphic rocks.

(b) Give two examples each of igneous and metamorphic rocks and three examples of sedimentary rocks. (WASSCE June 2001)

3. (a) Enumerate three processes involved in rock weathering.

(b) List and discuss briefly the agents of two processes of weathering.

(WASSCE 1989) **4.** List and discuss the processes of soil formation. (WASSCE 1992)

Objective Questions

1. Ice causes rock weathering

- (a) through the processes of expansion and contraction.
- (b) through movement of large rock fragments.
- (c) by dissolving some minerals in the disintegrated rock fragments.
- (d) by exerting an abrasive action on rock fragments.

2. The factors which affect the number of activities of soil micro-organisms include the following except

- (a) topography.
- (b) soil moisture.
- (c) soil aeration.
- (d) degree of soil acidity.

3. Gneiss is a metamorphic rock formed from

- (a) sandy stone.
- (b) slate.
- (c) shale.
- (d) clay.

4. Which of the following does not influence rock weathering?

- (a) Water
- (b) Carbonation
- (c) Amonification
- (d) Temperature

5. The alternate heating and cooling of rocks will result in

- (a) molten magma.
- (b) fragmentation.
- (c) solidifi cation.
- (d) sedimentation.

6. Which of the following is an example of igneous rock?

- (a) Gneiss
- (b) Limestone
- (c) Sandstone
- (d) Granite
- (e) Quartzite

Answers to Objective Questions

1. (a) 2. (a) 3. (c) 4. (c) 5. (b) 6. (d)