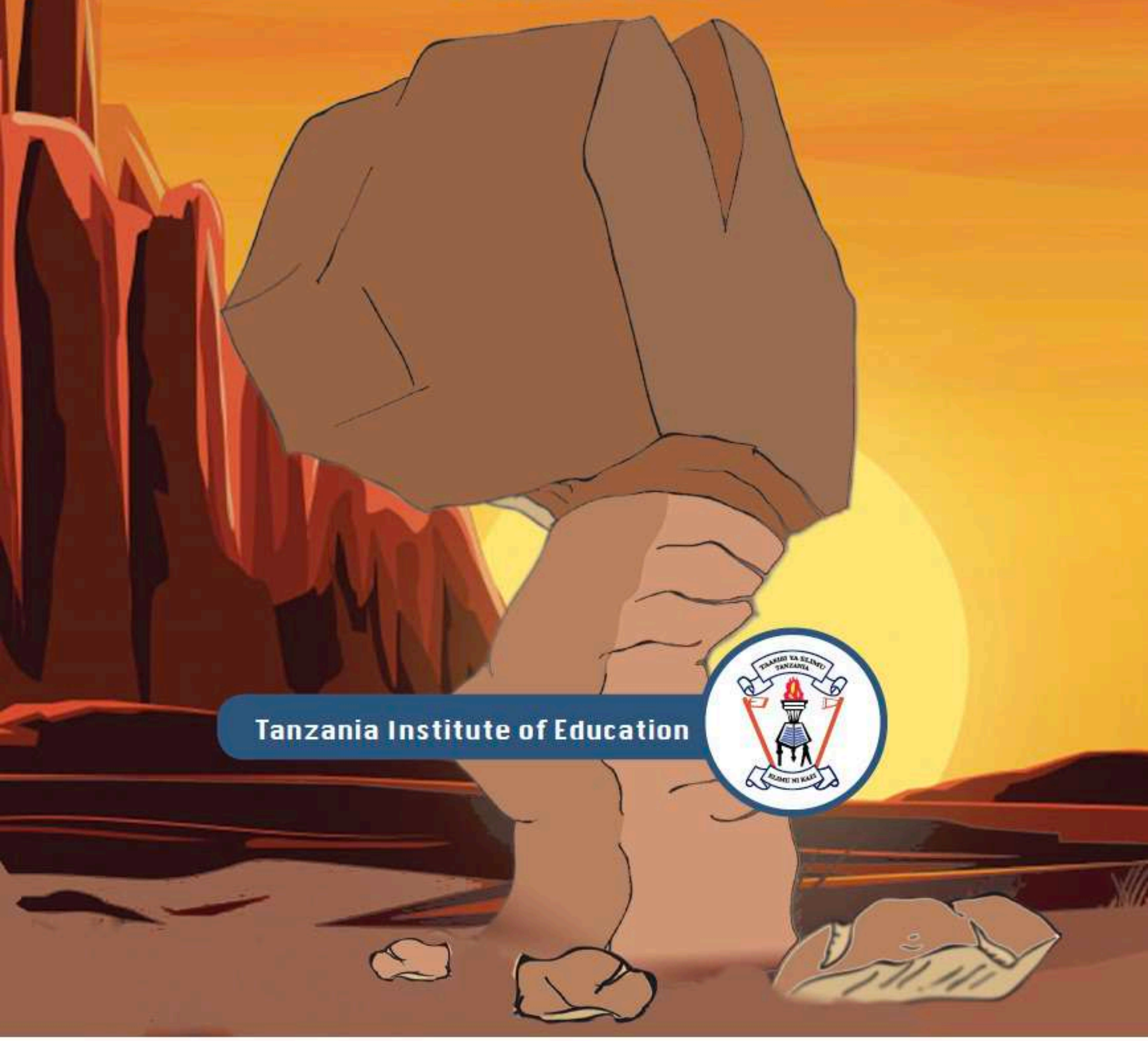
Geography

for Secondary Schools

Student's Book
Form Three



Tanzania Institute of Education

Geography

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Student's Book

Form Three

THE UNITED REPUBLIC OF TANZANIA
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Preface

This textbook, *Geography for Secondary Schools* is written specifically for Form Three students in the United Republic of Tanzania. The book is prepared in accordance with the 2005 Geography Syllabus for Secondary Education, Form I-IV issued by the then Ministry of Education and Vocational Training (MoEVT).

The book is divided into ten chapters, namely; Structure of the Earth, Forces that affect the Earth, Weathering and mass wasting, The action of running water and ice on the Earth's surface, The action of wind and waves on the Earth's surface, Soil, Elementary survey, Map reading and interpretation, Photograph reading and interpretation and Application of simple statistics.

Each chapter contains illustrations, activities, and exercises. You are encouraged to do all activities and exercises. Doing so will enhance your understanding and promote the development of the intended competencies.

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Chapter One

Structure of the Earth

Introduction

The Earth is the third planet in the solar system after Mercury and Venus. It is the only planet where life exists. In this chapter you will learn about the internal and external structure of the Earth, rocks of the earth's crust and the geological time scale. The competencies developed from this chapter, will enable you to utilize rocks and atmosphere sustainably for individual and national development.

The concept of the structure of the Earth

The Earth's structure is composed of two parts namely, internal structure and external structure. The internal structure is composed of three concentric zones called core (barysphere), mantle (mesosphere), and crust. The external structure consists of atmosphere and hydrosphere. The atmosphere is made up of a mixture of gases which surround it. The gases act as an envelope around the earth. The hydrosphere is the water part of the earth.

Internal structure of the Earth

The internal structure of the earth is sometimes referred to as the inner zone of the earth. It consists of three concentric layers, namely the crust, mantle and core as shown in Figure 1.1. These layers are classified on the basis of the density of their rock. The less dense rocks float on the top of the denser zones which are further down. The heavier elements like iron and nickel are settled at the core of the earth.

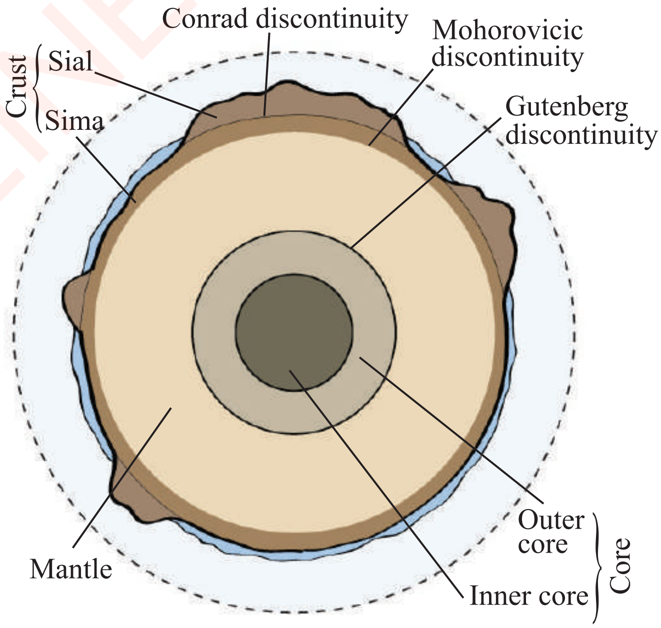


Figure 1.1: *Cross sectional view of the internal structure of the Earth*

The crust

The crust is the outermost and the thinnest zone of all zones of the internal structure of the earth. The crust has a thickness of about 8 kilometres to 50 kilometres and an average density of 2.7 gm/cc. It consists of two sub-layers laying over one another, namely the SIAL and SIMA. SIAL is the continental part of the crust which is composed of granite rocks. The rocks are composed of silica and alminium (SIAL). The SIMA is the layer beneath the SIAL. It is made up of basaltic rocks rich in silica and magnesium. This layer makes up the ocean floor. The SIMA and SIAL are separated by a layer known as Conrad discontinuity.

The structure of the Earth's crust is on continuous changes caused by internal and external forces operating on and within it. Continental drift theory states that before the formation of the present continents, the earth was one SIALIC land mass called Pangaea. The super continent, Pangaea, was surrounded by a SIMA-floored ocean called Panthalasa. Pangaea, which covered one-third of the surface, existed millions of years ago. Studies show that the super continent (Pangaea) began to develop over 300 million years ago and became fully formed about 270 million years ago. Pangaea started to break up into the present continents around 200 million years ago.

Pangaea began to break up into Gondwanaland in the South and Laurasia in the North during the late pre-Cambrian era about 200 million years ago. The Gondwanaland and Laurasia were separated by a long narrow sea called Tethys. The two masses continued breaking into the continents that exist today. Scientists call this movement "continental drift".

The mantle

The mantle is also referred to as mesosphere. It lies between the core and the crust. It is made of very dense igneous rocks of iron, silicon, oxygen, aluminum and magnesium. It extends downwards to about 2 900 kilometres. It consists of rocks with a density of about 3.0 gm/cc to 3.4 gm/cc. The mantle is divided into two parts: upper mantle and lower mantle. The upper mantle combines with the crust to form a larger layer called lithosphere. The top thin portion of the upper mantle below the crust is in a semi-molten state which forms a layer known as asthenosphere. The remaining part of the mantle is rigid. The convection currents generated in the lower mantle due to high temperature, trigger various internal movements. A layer separating the mantle from the crust is called Mohorovicic discontinuity.

The core

The core is the inner most part of the earth. It is also called barysphere. It consists of nickel and iron. The core is under great pressure and heat with average density of about 10.5 gm/cc. The core is divided into two parts, namely outer and inner cores. It is demarcated from the mantle by a layer called Gutenberg discontinuity.

The outer core

The outer core is about 2 300 kilometres thick. It is made up of very hot molten rock materials that are composed of mainly iron and nickel. The density and temperature constantly increase along the border between mantle and core and that the outer core is in liquid-like state. The temperature in the rock along the border is about 3 700ºC.

The inner core

The inner core is solid due to great pressure exerted by other layers towards the centre. It has a temperature of about 5 500ºC and a density of about 16 - 17 gm/cc. The inner core has a diameter of about 2 600 - 2 700 kms.

Activity 1.1

1. Visit your school library and find physical geography books, or use Internet sources to search and read on the internal structure of the earth. Then;
   (a) write down the information you have obtained about the internal structure of the earth.
   (b) share and discuss with your fellow students information about the internal structure of the earth.

2. Use the knowledge you have developed and in groups of 5 students, take a boiled egg then cut it into two halves without peeling its outer layer and then, do the following questions:
   (a) identify the layers.
   (b) compare the three layers of the boiled egg with the crust, mantle and the core.
   (c) draw a diagram of the internal structure of the earth and locate the following: crust, mantle and core.

Exercise 1.1

Answer all questions.

1. With the aid of a well labeled diagram explain the internal structure of the earth.
2. Explain why the outer core is in a molten state while the inner core is in a solid state?
3. Name the layer which separates:
   (a) Mantle from crust
   (b) Core from mantle

The external structure of the Earth

The external structure of the Earth is composed of atmosphere and hydrosphere. The atmosphere is a mixture of gases which forms an envelope-like cover which surrounds the earth. The hydrosphere is the water masses part of the external structure of the earth. It forms a region that includes all the earth's water bodies, frozen and floating ice, water in the upper layer of the soil, and the small amounts of water vapour in the earth's atmosphere. The external part of the earth also includes the biosphere which is composed of all living organisms like human beings, plants, animals and micro organisms like bacteria.

The Earth's atmosphere

The Earth's atmosphere refers to the thin layer of gases held by gravitational force around the Earth. These gases in percentage volume include nitrogen 78.09%, oxygen 20.95%, carbon dioxide 0.03%, argon and water vapour, which all together occupy 0.93%. The atmosphere is divided into different layers based on temperature change with altitude. The layers are troposphere, stratosphere, mesosphere, and thermosphere (Figure 1.2).

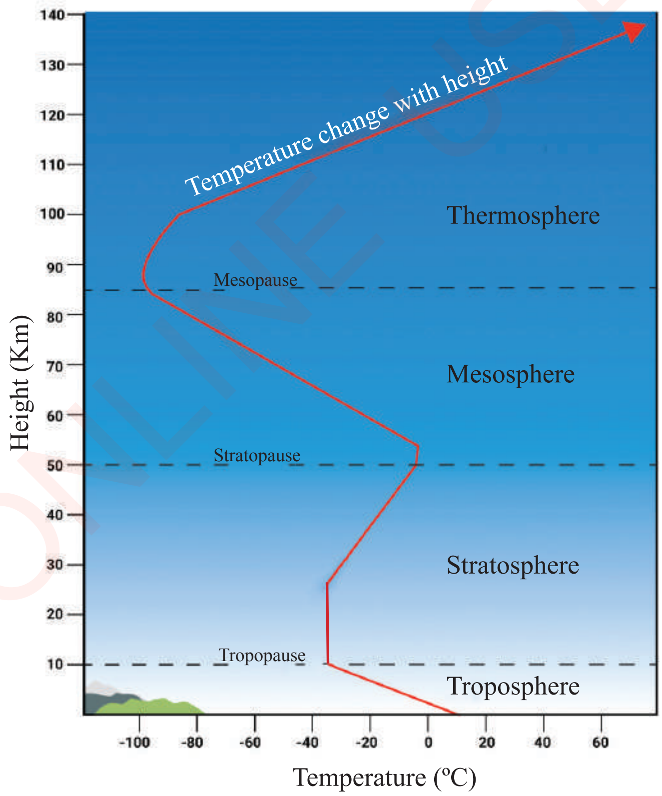


Figure 1.2: *Layers of the Earth's atmosphere*

The troposphere

This is the lower part which makes the first layer of the atmosphere which contains about 75% of all air masses. It has a height that ranges from 0 to 10 kilometres from the earth's surface. This is the layer that supports life to humans and other living organism. Elements of weather occur in this part and it has enough water vapour for cloud formation. In this layer, temperature decreases by 0.6ºC at every 100 meters increase in height (altitude). The troposphere is separated from the stratosphere by a thin shield zone called tropopause.

The stratosphere

This is the second layer of the atmosphere which is above the troposphere. It extends between 10 to 50 kilometres from the earth's surface. Airplanes fly in the lower part of this layer. Within this layer there is a thin layer called ozone (O_3) which is responsible for absorbing ultraviolet rays from the Sun. In the stratosphere, temperature increases as height increases. This is because of the ultraviolet radiation absorbed by the ozone layer. The ultraviolet radiation can be harmful to living organisms if it reaches the Earth's surface. The layer which separates the stratosphere from the mesosphere is called stratopause.

The mesosphere

This is a thin layer which is above the stratosphere. Its height is estimated to be between 50 and 85 kilometres from the earth's surface. It is the coldest layer of the atmosphere because temperature decreases rapidly to -90ºC as the altitude increase due to absence of water vapour, clouds and dust that could absorb solar radiation. Also temperature decreases because the layer experiences strongest winds (nearly 3 000 km/hr). In this layer, meteors burn up due to the friction of gases before they reach the earth's surface. It is separated from the thermosphere by a layer called mesopause.

The thermosphere

This is the highest atmospheric layer where temperature increases to 1 500ºC due to absorption of ultraviolet and x-rays radiations by atoms and molecules. It is estimated to have a height ranging between 85 and 1 000 kilometres from the earth's surface. In this layer, radio waves are reflected, so it is very important for communication.

Activity 1.2

In a group, do the following:

(a) use the Internet, reference books and text books to read about the external structure of the earth.

(b) draw a diagram to show layers of the atmosphere, then describe the characteristics of each layer.

(c) with assistance of your subject teacher, present your work in class and allow your fellow students to discuss what you have presented.

(d) take note of all important contributions they give.

Exercise 1.2

Answer the following questions.

*Match each item in **Column A** with its correct description from **Column B**.*

Column A	Column B
1. The layer with high temperature due to radiation	(a) the atmosphere
2. It is the air mass surrounding the earth's surface	(b) troposphere
3. The layer where airplanes fly	(c) lithosphere
4. The sphere where human activities are performed and rain formation takes place	(d) thermosphere
5. The cold layer due to decrease in temperature as the altitude increases	(e) asthenosphere
	(f) mesosphere
	(g) stratosphere

6. Explain why temperature in the stratosphere increases with the increase in height, while the mesosphere experiences a decrease in temperature as height increases.

7. What is the importance of troposphere for the living organisms and human development?

Rocks of the Earth's crust

Rocks are natural solid materials made up of various minerals in different ratios. Rocks differ in colour, texture, density, mode of formation and ability to resist erosion. They differ also in chemical composition, age, permeability and hardness. There are three main types of rocks on the basis of their mode of formation, namely; *igneous*, *sedimentary* and *metamorphic* rocks.

Igneous rocks

The term 'igneous' comes from the Latin word "ignis" which means fire. These are rocks formed by the process of cooling and solidification of molten materials (magma or lava). Igneous rocks are associated with volcanic activity and their distribution is controlled by plate tectonics. The molten materials can be derived from partial melting of pre-existing rocks which can be caused by one or more of the following processes: increase in temperature, decrease in pressure and change in composition. Magma cools and solidifies within the crust while lava cools and solidifies on the earth's crust. Igneous rocks formed when solidification takes place within the earth's crust are called intrusive igneous rocks or plutonic rocks and those which cool and solidify outside the earth's surface are called extrusive igneous rocks or volcanic rocks.

Intrusive igneous rocks

These are rocks formed when magma flows through vents or cracks then cools very slowly and solidifies before reaching the earth's surface. The slow cooling process of magma within the earth's crust forms a large crystal. Examples of such rocks are granite, gabbros and diorite. The intrusive rocks are divided in two types, namely hypabyssal intrusive igneous rocks and plutonic igneous rocks.

Hypabyssal intrusive igneous rocks

These are types of igneous rocks formed when magma cools and solidifies within but near the earth's surface. These rocks can be exposed by prolonged erosion on the earth's surface. They are medium in size including rocks like granophyre (Figure 1.3), polyphones and dolerite.

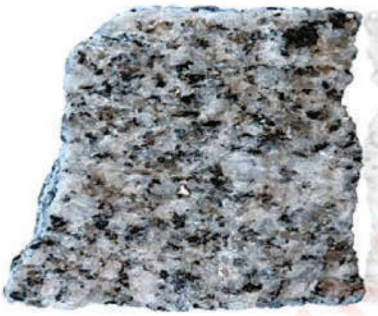
Figure 1.3: *Granophyre*

Source: https://www.akindjourney.com/read/big-rocks

Plutonic intrusive igneous rocks

These are rocks formed when magma cools and solidifies deep in the earth's crust. The rock has large particles due to slow rate of cooling. Examples of these rocks are granite, diorite, gabbro and peridotite (Figure 1.4).

Gabbro



Granite

Diorite

Figure 1.4: *Examples of plutonic intrusive igneous rocks*

Source: https://www.google.comsearch?q=igneous+rocks+pdf&rlz

Extrusive igneous rocks

These are rocks formed on the surface of the earth. They are formed when magma erupts and reaches the earth's surface as lava or fragmental ejecta then cools and solidifies relatively quickly. Examples of these rocks are basalt, pumice and rhyolite. In Tanzania, basalt, pumice and rhyolite are found in Kilimanjaro and Rungwe.

Characteristics of igneous rocks

(a) They are hard rocks;
(b) They are crystalline as they do not occur in layers;
(c) They do not contain fossils;
(d) They can undergo metamorphism to form metamorphic rock or weathered to form sedimentary rocks; and
(e) They contain minerals like iron and magnesium.

Sedimentary rocks

Sedimentary rocks are found in strata. These rocks are formed by the deposition of eroded materials transported by moving water, wind, ice, ocean currents, waves and drifts. They are a result of continued weathering and erosion, transportation, deposition and lithification (compaction and cementation) of sediments. Most sedimentary rocks are in horizontal layers called strata (Figure 1.5). The strata are separated from each other by a surface known as a bedding plane. They exist in various views as shown in Figure 1.6. Sedimentary rocks are not crystalline. They often contain fossils of dead living things collected by winds, water, ice, ocean currents and drifts.

Figure 1.5: *Sedimentary rocks*

Source: http://pages.geo.wvu.edu/~kammer/g100/SedimentaryRocks.pdf

Figure 1.6: *Different views of sedimentary rocks*

Source: https://www.sandatlas.org/collage-of-sedimentary-rocks/

There are three types of sedimentary rocks according to their mode of formation. These are mechanically formed sedimentary rocks, organically formed sedimentary rocks and chemically formed sedimentary rocks.

Mechanically formed sedimentary rocks

Mechanically formed sedimentary rocks are formed by deposition of sediments from eroded materials of existing rocks. Examples of mechanically formed sedimentary rocks are sandstone, mudstone, shale, and boulder clays. The alluviums are deposited by water, moraines, boulder clays are deposited by ice and loess is deposited by wind. These types of rocks have different economic uses. For example, sandstones are used in making building blocks.

Organically formed sedimentary rocks

These are rocks formed from deposition of plants and animals remains. Examples of such rocks are limestone, chalk and coral from animals and peat; and coal and lignite from plants. These rocks have various uses. For example, chalk is used in cement and paint factories while coal is a source of energy for industrial and domestic uses.

Chemically formed sedimentary rocks

Chemically formed sedimentary rocks are formed by deposition of solid substances from solution, for example rock salt, gypsum dolomite, potash and nitrate gypsum. They also form part of the ingredients in inorganic fertilizer manufacturing as well as in building material industries.

Characteristics of sedimentary rocks

(a) They are stratified;
(b) They contain fossils;
(c) They can undergo metamorphism to form metamorphic rocks;
(d) They are soft and well-jointed; and
(e) They are non-crystalline.

Metamorphic rocks

When igneous and sedimentary rocks are subjected to great heat and pressure, they change their physical and chemical properties and form new types of rocks called metamorphic rocks. The word "metamorphic" is derived from two Greek words 'meta' and 'morph'. Meta means change and morph means form. So, metamorphic means to change form. Examples of metamorphic rocks include marble, which is derived from limestone, slate derived from clay, graphite from coal, quartz from sandstone and gneiss from granite (Figure 1.7).

Figure 1.7: *Examples of metamorphic rocks*

Source:https://courses.lumenlearning.com/wmopen-geology/chapter/outcome-metamorphic-rocks/

Types of metamorphic rocks

There are three main types of metamorphic rocks based on their mode of formation. These are defined below:

Thermal metamorphic rocks

These are formed by intense heat. Formation of these types of rocks occurs when the existing rocks come into contact with magma or lava. These rocks change their form and character. Examples are limestone to marble and sandstone to quartzite.

Dynamic metamorphic rocks

These are formed by the influence of pressure exerted by the earth's horizontal and vertical movements which also cause mountain formation. Examples are shale to schist and clay to slate.

Thermal-dynamic metamorphic rocks

These rocks are formed by the process that takes place as a result of the combination of intensive temperature and pressure. An example is when coal changes to graphite.

Characteristics of metamorphic rocks

(a) They are hard compared to all other types of rocks;

(b) These rocks are sometimes found in strata, but in a crystalline form;

(c) They are formed from other types of rocks due to the influence of intense heat and pressure;

(d) The rocks can change into other types of rocks through melting, weathering and deposition.

A rock cycle

A rock cycle is the process where a rock changes from one type of rock to another (Figure 1.8). This process is endless as no rock can remain unchanged forever. For example, an igneous rock can change to a sedimentary rock or to a metamorphic rock and then back to an igneous rock. At first, the igneous rock may be formed due to cooling and solidification of magma or lava. Then the igneous rock can be attacked by agents of weathering to form sediments which through deposition and compaction a sedimentary rock will be formed.

Also, an igneous rock or sedimentary rock can undergo metamorphism due to the influence of either pressure or temperature or both to form a metamorphic rock. A metamorphic rock can also undergo weathering and sedimentation to form a sedimentary rock. Likewise, a metamorphic rock can undergo further metamorphism to form another metamorphic rock like the change of slate to schist.

Lastly, when any rock that is either sedimentary or metamorphic is subjected under very high temperature, it can melt and on cooling form an igneous rock.

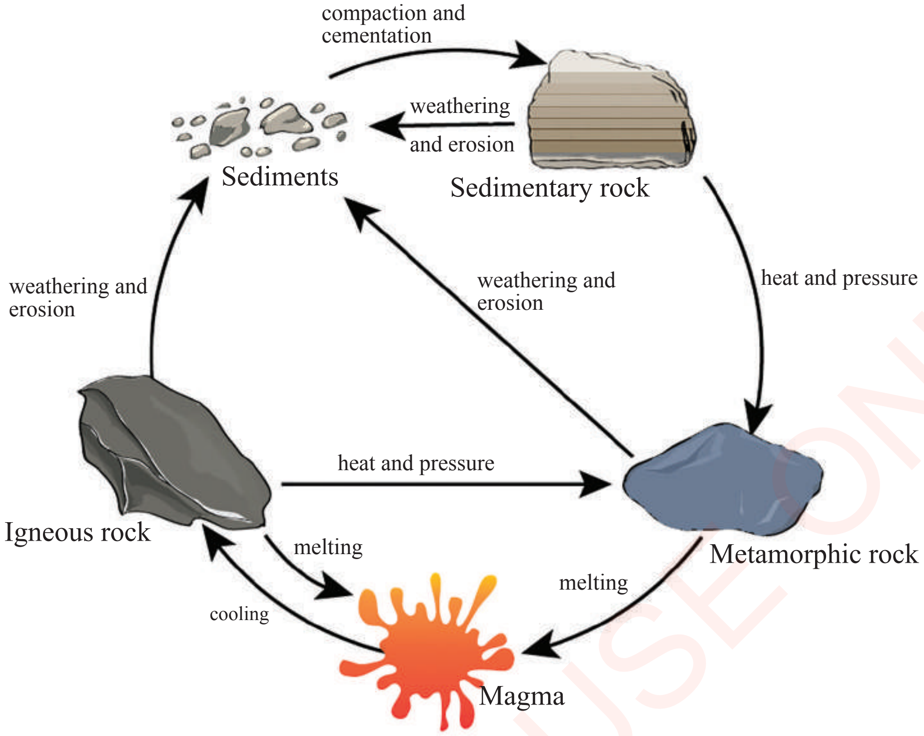
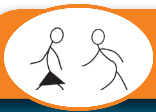


Figure 1.8: *Rock cycle*



Activity 1.3

1. Visit a nearby area that has different types of rocks, then:

   (a) identify types and characteristics of rocks found in the area.

   (b) elaborate how each of the identified rock is formed.

2. Visit your school library, and find physical geography books or use Internet sources to:

   (a) read and write how one type of rock can change into another type.

   (b) present your work in the class with an assistance of your subject teacher, and accommodate all inputs or respond to questions asked by students about your presentation.

Exercise 1.3

Answer all questions.

1. Distinguish a metamorphic rock from an igneous rock.
2. Elaborate the steps for the formation of sedimentary rocks.
3. With examples, describe types of sedimentary rocks.
4. Mention the conditions necessary for the formation of metamorphic rocks.
5. With the aid of well labeled diagrams and examples, elaborate how:
   (a) sedimentary rocks can change into metamorphic rocks.
   (b) igneous rocks can change into sedimentary rocks.
   (c) metamorphic rocks can change into igneous rocks.
6. Distinguish between volcanic rocks and plutonic rocks.

Simplified geological time scale

Different types of rocks of the earth's crust did not form at the same time. Moreover, they are not a result of a single geologic event. They are a result of different geologic processes which took place at different geologic periods in the history of the earth. In determining the type of a rock according to its age, a geological time scale is used.

A geological time scale is a chart used for dating the history of the earth, including its rocks. It attempts to show the age of rocks as far back as 600 million years before the present. The scale is divided into eras, periods and years. Table 1.1 shows a simplified geological time scale divided into the following four main eras.

(a) The ancient or Pre-Cambrian era
(b) The Paleozoic era
(c) The middle or Mesozoic era
(d) The recent or Cenozoic era

The eras are further subdivided into periods and years, each reflecting the major geological events, which occurred as well as the history of the evolution of mankind and other mammals. The time before the Paleozoic era is referred to as the Proterozoic or Precambrian era.

Table 1.1: *Simplified geological time scale*

Era	Period	Years in millions before present	Major geological events in Africa	Major biological events
Cenozoic	Quaternary	1	Glaciation of East Africa mountains, formation of river terraces and raised beaches	Age of man
	Tertiary	163	Formation of the Atlas Mountains Lava flows in Ethiopia	Age of mammals
Mesozoic	Cretaceous	63	Deposition of marine sediments in Sahara and Southern Nigeria Formation of Enugu coal field	Age of man
	Jurassic	135	Break-up of Gondwana land Marine invasion of east Africa coast, land separation	Age of man
	Triassic	180	Drakensberg lavas, formation of upper Karroo, volcanic activity in West Africa	Age of large animals (Dinosaurs)
Paleozoic	Permian	230	Formation of lower Karroo beds, formation of rich coal deposits in Tanzania and South Africa, ice age in Central and South Africa	Age of amphibia

Table 1.1: *Simplified geological time scale (continues)*

Era	Period	Years in millions before present	Major geological events in Africa	Major biological events
	Carboniferous	280	Cape fold formed	Age of insect and large trees
	Devonian	345	Marine invasion of Libya, the Sahara and Western Sudan. Continental basins formed by crustal warping	Age of fish
	Silurian	405	Continental sedimentation in Congo Basin, Tanzania and South Africa, followed by intensive folding	First and plant animals
	Ordovician	500	Marine invasion of western Sahara and Kalahari	First abundant fossils record of marine life
Pre-Cambrian	Protorozoic or Archean	6000 to 500	Glaciations of Africa south of the Equator. Extensive metamorphism of oldest known fossil, unicellular algae formed in Swaziland (eSwatini) and Mali	Algae

Importance of the geological time scale

The geological time scale reflects the ages of rocks by showing the time of their formation. It also helps in understanding how different features were formed and it enables prediction of crustal changes over time by observing the evolvement of old and young rocks.

Activity 1.4

In a group, discuss geological events which occurred in East Africa during:

(a) Jurassic period
(b) Permian period
(c) Silurian period

Exercise 1.4

Answer all questions

1. With examples, discuss the major eras of the geological time scale
2. Why is the geological time scale important in the study of rocks development?

Economic importance of rocks

Rocks contain various valuable minerals which occur in the veins of igneous rocks. These minerals include gold, copper, iron, diamond and tin. Some of these minerals are found in Tanzania. For example, gold is found in the Lake Zone, diamond in Shinyanga and copper in Kigoma and Mpanda. Tanzanite is another type of mineral found in igneous rocks in Mererani, Manyara region. Tanzania is the only country in the world in which Tanzanite is found. The impermeability of some rocks are beneficial in retaining underground water which can be harvested and utilized for various purposes. For example, Dodoma and Singida regions have a lot of underground water due to the type of underlying rocks. Also, rocks account for the formation of soils of different types as a result of weathering. Rocks are also used in building and construction works, while some of the rocks, for example marble, are used in decorating buildings. Other rocks are used as a source of tourist attraction, for example Bismak rocks in Mwanza. Some rocks are used in the manufacturing of chemicals and cement, for example potassium, gypsum and limestone.

Revision exercise 1

Section A

Choose the correct answer.

1. Rocks rich in silica and aluminium form a layer of the earth's crust called _____.
   (a) sima
   (b) sial
   (c) mantle
   (d) core

2. The envelope of air surrounding the earth's surface is called ______.
   (a) lithosphere
   (b) atmosphere
   (c) biosphere
   (d) hydrosphere

3. Continents and their respective mountains are formed on the _____.
   (a) sial
   (b) mantle
   (c) mohorovicic
   (d) magma

4. The core is rich in _____.
   (a) silica and sima
   (b) iron and nickel
   (c) alminium and oxygen
   (d) silica and magnesium

5. Igneous rocks are_____.
   (a) crystalline
   (b) not very hard
   (c) formed in layers
   (d) metamorphic

6. The outer layer of the internal structure of the earth is called ______.
   (a) the mantle
   (b) the crust
   (c) the hydrosphere
   (d) the atmosphere

7. The action of high temperature and great pressure on some rocks can change their physical and chemical properties to form _____.
   (a) plutonic rocks
   (b) metamorphic rocks
   (c) granite rocks
   (d) hypabyssal rocks

8. Organically formed sedimentary rocks occur _____.
   (a) from animal and plant remains
   (b) when other rocks undergo chemical precipitation
   (c) by heat and pressure
   (d) by sediments from eroded rock materials of the existing rocks

Section B

*Write **TRUE** for a correct statement and **FALSE** for an incorrect statement.*

9. All rocks can change into metamorphic rocks if subjected to high temperatures and pressure for a long period of time.
10. The Geological Time Scale describes how rocks were formed.
11. Agents of erosion play an important role in the formation of sedimentary rocks.
12. Limestone and chalks are sedimentary rocks formed mechanically.
13. Rocks are the parent materials from which different types of soils are formed.
14. Metamorphic rocks are not as hard as igneous rocks.
15. All rocks contain economically valuable minerals.

Section C

Answer the following questions:

16. Describe the internal layers of the earth from the centre to the surface.
17. Describe three types of rocks according to their mode of formation.
18. Explain why an igneous rock is referred to as the mother rock?
19. What is the economic importance of rocks?

20. Why are metamorphic rocks often very hard and resistant to weathering?

21. Describe the rock cycle.

22. What is the importance of geological time scale in learning about rocks formation?

23. Using the geological time scale, complete the table below.

Events	Period
A. Formation of upper Karroo	…………………..
B. ……………………	Tertiary
C. Glaciation of East African mountains	……………………
D. ……………………..	Cambrian
E. Formation of Atlas Mountains	……………….….....

Chapter Two

Forces that affect the Earth

Introduction

The earth's surface is undergoing continuous morphological changes. The changes are a result of both internal and external forces. In this chapter you will learn about internal forces and how these forces are generated and distributed within the earth's crust. You will also learn on the effects of those forces and features formed within or on the earth's crust. The competencies developed in this chapter will enable you to utilize resources resulting from geological processes. The competencies will also enable you to interpret different geographical phenomena that occur in your surroundings, hence help you to anticipate, mitigate and recover from the effects resulting from the impacts of hazardous conditions.

Internal forces

Internal forces originate and operate within the earth's crust. They are also called endogenic forces. These forces are the result of energy produced by internal heat, chemical reactions taking place within the earth, and the transfer of rock materials to the earth's surface. Internal forces which shape the earth's surface begin underneath the lithosphere and cause vertical and horizontal earth movements.

Internal Earth's movements

These are movements of the solid parts of the Earth away from one another, towards each other as well as upward and downward the earth's crust. The forces working from inside the Earth, in turn, cause movements of rocks. These movements are called Earth movements, and the forces which produce these structural features are known as diastrophic forces. The Earth movements bring enormous changes on the earth's surface. Since these movements arise from the movements of the actual structure of the earth's crust, they are also called tectonic movements. The word tectonic is derived from a Greek word, *tekton* which means builders. Therefore, the earth movements are constructional forces responsible for building of different types of land forms such as fracture, bends, subsidence or warping the earth's crust to create different features such as depressions and mountains.

There are two types of earth movements, namely vertical or radial movements and horizontal or lateral movements. The two movements exert great tensional and compressional forces which become a basis for analysing the resulting landforms.

Compressional and tensional forces

Compressional forces are those which cause crustal rocks to move towards each other. On the other hand, tensional forces are forces that pull crustal rocks in the opposite direction causing the rocks to move apart and rocks between faults to subside. While compressional forces produce reverse faults and folding, tensional forces produce normal faults (Figures 2.1 and 2.2). These forces result to the movements that lead to the formation of different features as explained in the sections that follow.

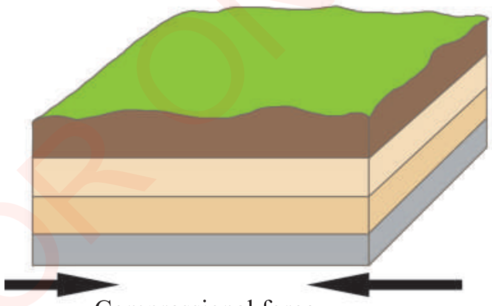


Figure 2.1: *Compressional forces*

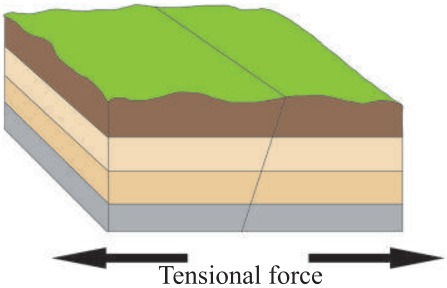


Figure 2.2: *Tensional forces*

(a) Vertical movements

These are either upward or downward movements occurring within the earth's crust. Vertical movements are also known as radial movements. They are also referred to as epeirogenic movements because they are usually on a large scale. Vertical movements cause uplift or subsidence of wide-ranging areas of the crust. They are responsible for the formation of extensive features of the landscape like plateaus, basins, block mountains (horsts), rift valleys and some types of escarpment called fault line scarps. Vertical movements may also result to emerged or submerged coasts. The following section describes in detail features resulting from vertical movements.

Block mountain

A block mountain refers to a table-like mountain formed as a result of vertical movements of the blocks of the crust that lead to rising of a fault-bordered block. Uplifted blocks may either be tilted when they form tilt blocks or horizontal when they form *horsts*. A block mountain can be formed by either tensional or compressional forces. This is when the earth movements cause parallel faults which result into uplifting of some parts as shown in Figure 2.3. Examples of block mountains are Usambara, Pare and Uluguru in Tanzania, Ruwenzori in Uganda, Sinai in Asia and Vosges and Black Forest in Europe.

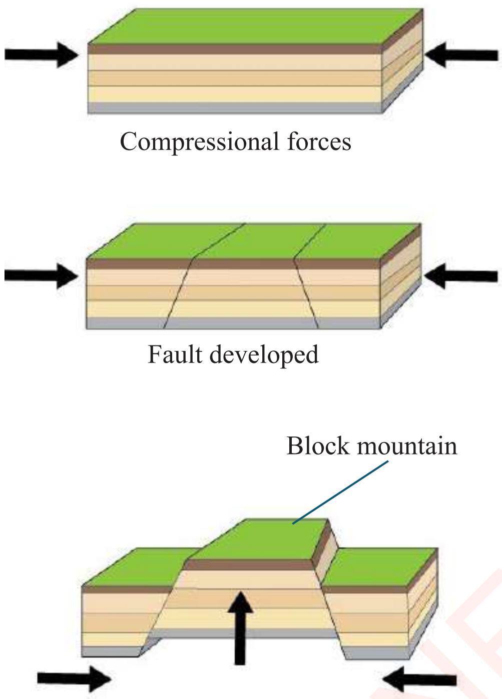


Figure 2.3: *Formation of block mountains*

Plateau

A plateau is a large, extensive uplifted part of the earth's crust, which is almost flat at the top. The formation of plateaus, dates back to Mesozoic and Jurassic eras. Such landforms include those of East Africa and Brazil plateaus. High plateaus especially in tropical latitudes are utilized in various ways including agriculture and settlements.

Basin

A basin is a large, extensive depression formed by the sinking or downwarping of the earth's surface. Examples of basins formed in this way are Lake Victoria basin in Tanzania, Lake Chad basin in central Africa and Amazon basin in South America. Some basins are formed by river deposition like the Congo Basin in the Democratic Republic of Congo.

Submerged and emerged coasts

When coastal areas are subjected to vertical earth's movements, changes in land and sea levels may occur resulting into either submerged or emerged coasts. Features produced through coast submergence include ria coasts, fiord coasts, Dalmatian coastline and estuaries. Coasts that emerge produce features such as raised beaches.

A ria coast

When a highland coast is submerged, the lower parts of its river valley become flooded to form long narrow branching inlets separated by narrow headlands. Such inlets are called rias as shown in Figure 2.4. Examples of ria coasts are found on the coast of Sierra Leone, Guinea and Guinea Bissau.

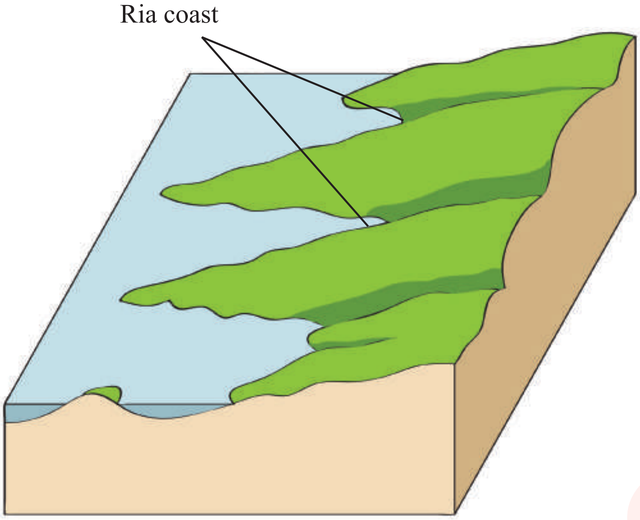


Figure 2.4: *Ria coast*

Dalmatian coast

When a highland coast whose valleys are parallel to the coast is submerged, some of the valleys are flooded and the separating mountain ranges become chains of islands. The flooded valleys are sometimes called narrow inlets and the coast is known as a longitudinal or dalmatian coast (Figure 2.5). Examples of dalmatian coastlines are found in Croatia.

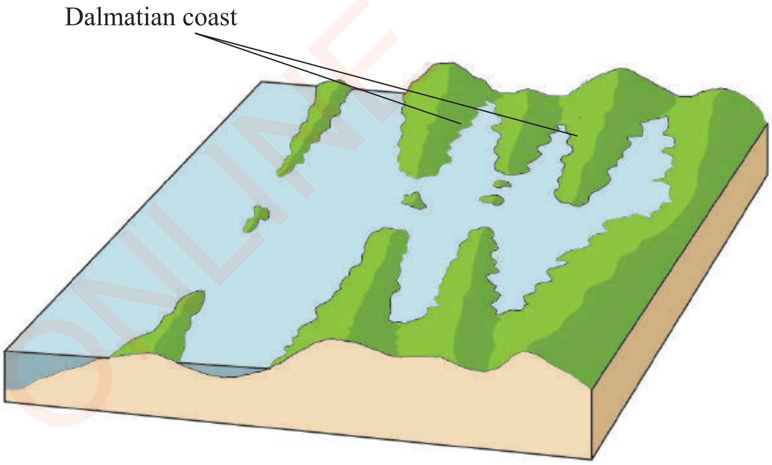


Figure 2.5: *Dalmatian coast*

Estuaries

A rise of the sea level along a lowland coast causes the sea to penetrate inland along river valleys, often to a considerable distance. The flooded parts of the valleys are called estuaries as shown in Figure 2.6. The estuaries often make excellent sites for ports. An example of an estuary in Africa is the Gabon Estuary in West Africa.

Figure 2.6: *Estuaries*

A fiord coast

When a glaciated highland coast becomes submerged, the flooded lower parts of the valleys get filled with sea water, and the resulting features are called fiords as shown in Figure 2.7. During glaciation, the river valleys become widened and deepened. When the glaciers melt and the sea level rises, the steep-sided valleys are exposed. The water inside the fiord is much deeper than it is at the entrance. In other words, a fiord is a feature formed when the lower end of the U-shaped valley is occupied by the sea.

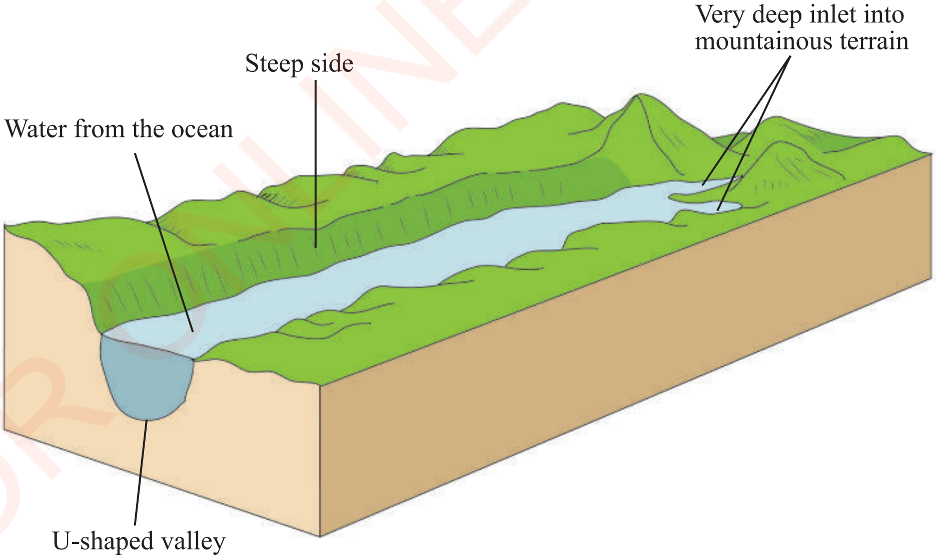


Figure 2.7: *Fiords coast*

Raised beaches

Raised beaches are also a result of faulting and vertical earth movements. They are beaches which have been exposed after the coast was forced to rise due to uplift. Raised beaches are common in African coast, for example, Bagamoyo area in Tanzania, Accra area in Ghana and Mossel Bay in South Africa.

Activity 2.1

In a group, take a plastic bucket and cover it with its plastic lid then do the following;

(a) put a heavy stone on it
(b) press the stone towards the plastic lid
(c) observe the results and write down what happened
(d) from the results, in groups, discuss the vertical movement of the earth's crust and its effects.

Exercise 2.1

Answer all questions.

1. The Earth's surface is undergoing continuous morphological changes. Explain.
2. A block mountain is a result of both vertical and horizontal movements. Explain.

(b) Horizontal movements

These are sideways movements of the earth's interior that cause the crustal rocks either to fold, fault or form joints. Horizontal movements are also known as lateral movements. These movements are a result of compressional or tensional forces. These forces cause folding and faulting which may later cause formation of different features. Features formed by lateral movements include fold mountains, rift valleys, faults and block mountains.

Folding

This refers to the bending of the earth's crust caused by compressional forces. The folds are formed when the crustal rock is subjected to both weak and intense compressional forces. As a result, upfolds (anticlines) and downfolds (synclines) emerge as shown in Figure 2.8. The sides of the fold are called limbs. The nature of the fold depends on the intensity of the forces involved.

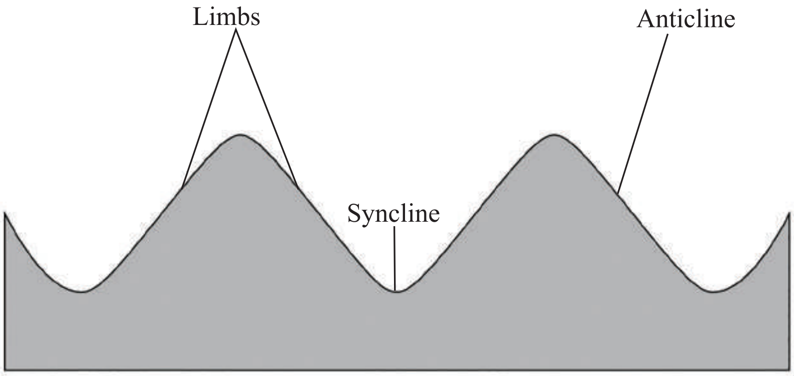


Figure 2.8: *Anticline and Syncline*

The continuous process of folding results into a series of complex and extensive anticlines and synclines on the earth's crustal rocks, thus forming a range of mountains called fold mountains as shown in Figure 2.9. Most of the highest mountain ranges in the world fall under the category of fold mountains. Examples of fold mountains include the Andes in Latin America, the Rockies in North America, the Himalayas in Asia and the Alps in Europe. In Africa, Atlas and the Drakensberg mountains are vivid examples of fold mountains.

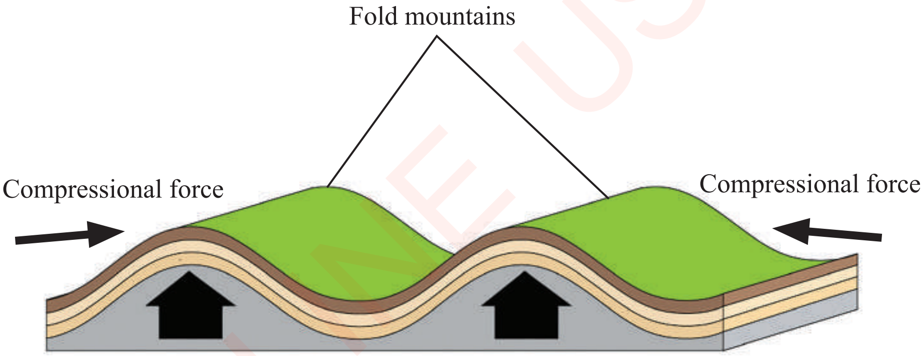


Figure 2.9: *Fold mountain*

Types of folds

Folding which is the result of a compressional process may cause the formation of different types of folds, namely; simple folds, asymmetrical folds, overfolds and overthrust folds.

Simple fold

This is a type of fold in which the limbs incline in the same angle as shown in Figure 2.10. It occurs when forces on both sides are of equal strength. When the angles of anticline and syncline are almost equal, the fold is referred to as simple fold. It is also known as symmetrical fold. This means that the slopes on both sides of the fold (anticline or syncline) are almost uniform.

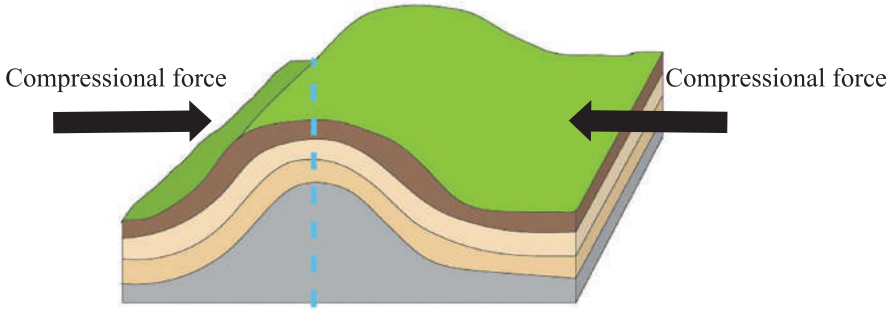


Figure 2.10: *Simple/Symmetrical fold*

Asymmetrical fold

This is a type of fold in which one side of the limb is steeper than the other side. This occurs when one side is subjected to greater force than the other side. The side subjected to greater force becomes steeper than the other (Figure 2.11).

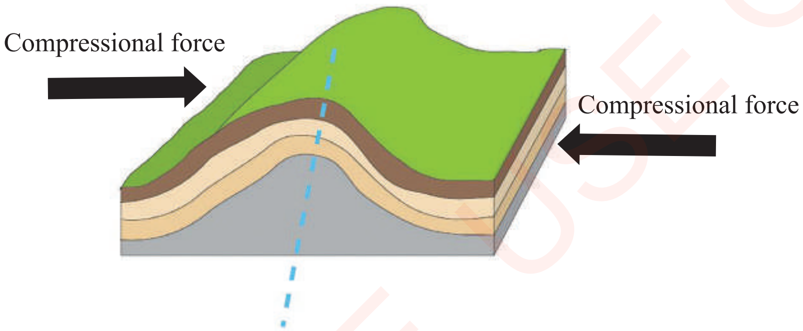


Figure 2.11: *Asymmetrical fold*

Overfold

This type of fold is also called *recumbent fold*. It is a type of folding in which one anticline limb is pushed over the other due to intensive folding movements by compressional forces on one side, as shown in Figure 2.12. Overfold or recumbent folding happens when a high compressional force is exerted on an asymmetrical fold.

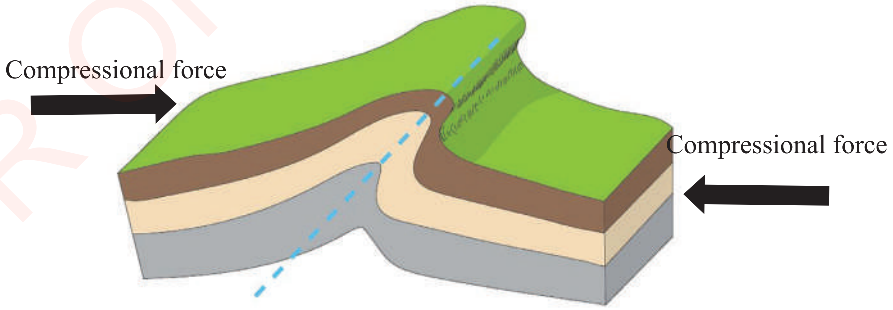


Figure 2.12: *Overfold*

Overthrust fold

This is a fold formed when one limb is pushed further over another limb due to compressional forces (Figure 2.13). It is a type of fold which occurs when there is great pressure on an overfold, enough for the rocks to fracture and a mass to thrust forward several kilometres along the plane of the fracture.

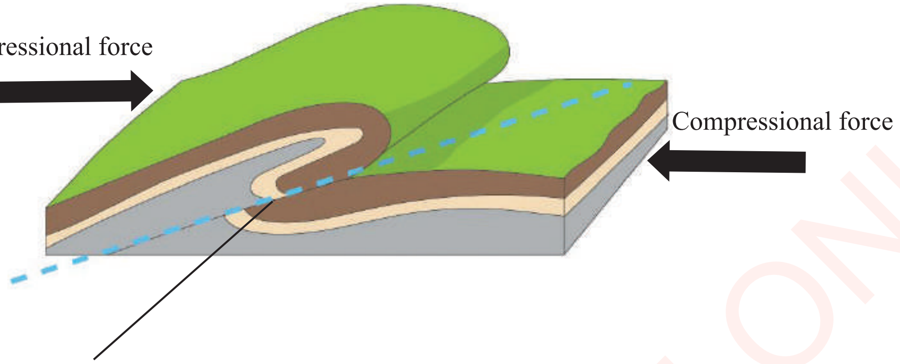


Figure 2.13: *Overthrust fold*

Faulting

A fault is a fracture or rupture on the crustal rock which causes the displacement of its sides relative to each other. It is normally caused by lateral forces of either compressional or tensional forces accompanied by vertical movements. Tensional forces cause normal faults while compressional forces cause reverse faults. Features produced through faulting include rift valleys and block mountains (horsts).

Types of faults

Faults are normally formed due to lateral or vertical movements. The forces which are responsible for the formation of faults can be either compressional or tensional. There are five types of faults, namely; normal, reverse, tear, overthrust and monocline as described below:

Normal fault

This is a type of fault resulting from tensional forces. It occurs when the inclination of the fault-plane and the direction of the down-throw are on the left or to the right, as shown in Figure 2.14.

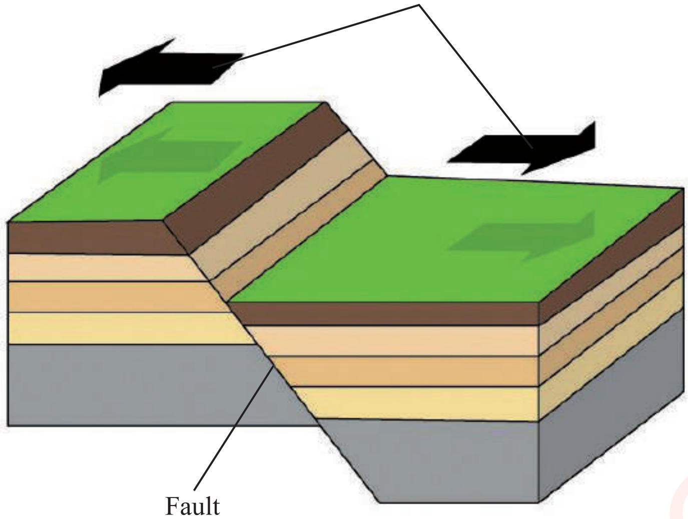


Figure 2.14: *Normal fault*

Reverse fault

This is a type of fault which results from compressional forces. It occurs when the beds of rocks on one side of the fault plane are thrust over the other side as shown in Figure 2.15.

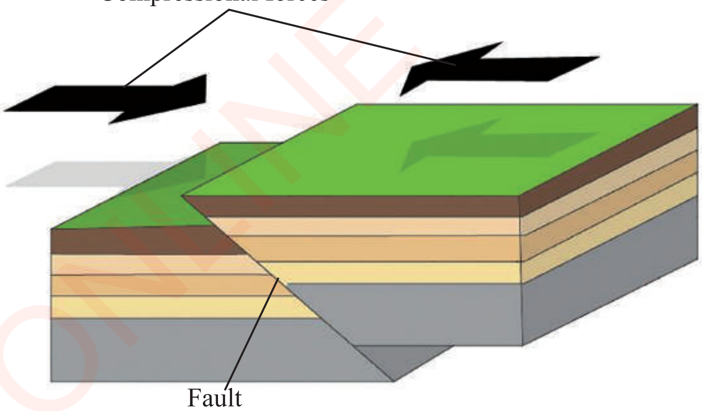


Figure 2.15: *Reverse fault*

Transform fault

Transform fault is also called a strike or tear fault. It usually leads to the occurrence of earthquakes. It is a vertical fracture produced when two rock blocks slide against one another resulting into horizontal displacement along the line of the fault, as shown in Figure 2.16.

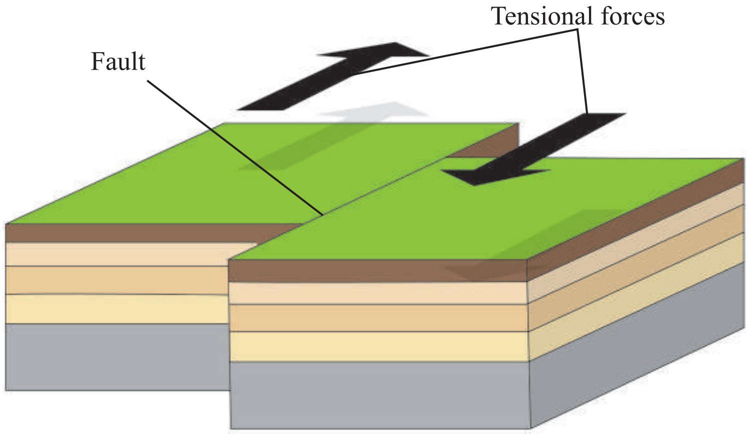


Figure 2.16: *Transform (Tear) faults*

Overthrust fault

This is a fault within the overthrust fold along which one limb slides over the other limb due to intensive compressional forces, as it is shown in Figure 2.17.

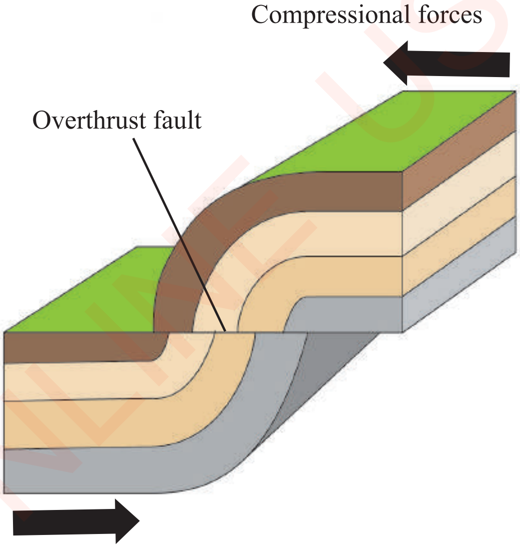


Figure 2.17: *Overthrust faults*

Monocline fault

This fault involves a tensional fracture in which the strata are bent. It is closely related to the normal fault but the normal fault has horizontal strata. A monocline is closely related to a normal fault and may turn into one at depth or further along the line of movement.

Joints

All rocks develop joints. Joints are small cracks revealing lines of weaknesses. Joints are caused by tensional stresses set up by bending or folding in sedimentary rocks. Joints differ from faults in the sense that faulting takes place across several layers of the crust accompanied by displacement, whereas joints occur in a single layer or rock usually not accompanied by displacement. However, on the earth's surface, an igneous rock can develop joints due to continued expansion and contraction. Joints greatly increase the available surface for weathering. Important features resulting from jointing are called *tors*. Tors are hill-like structures, as shown in Figure 2.18.

Figure 2.18: *Tor*

Rift valley

A rift valley is a narrow trough laying down between parallel faults, with throws in opposite directions forming a long steep-sided valley. Such a valley is long proportional to its width. It is formed from both vertical and lateral movements of the earth's crust when two faults develop parallel to each other. It can develop either by tensional or compressional forces.

Formation of a rift valley by tensional forces

A rift valley is formed when tensional forces pull the two sides of parallel faults apart, leaving the centre to subside. The act of extreme tensional forces, breaks up rocks along the stratum leading to the formation of cracks and fractures on the earth's crust. A block between the two parallel faults subsides to form a valley (Figure 2.19).

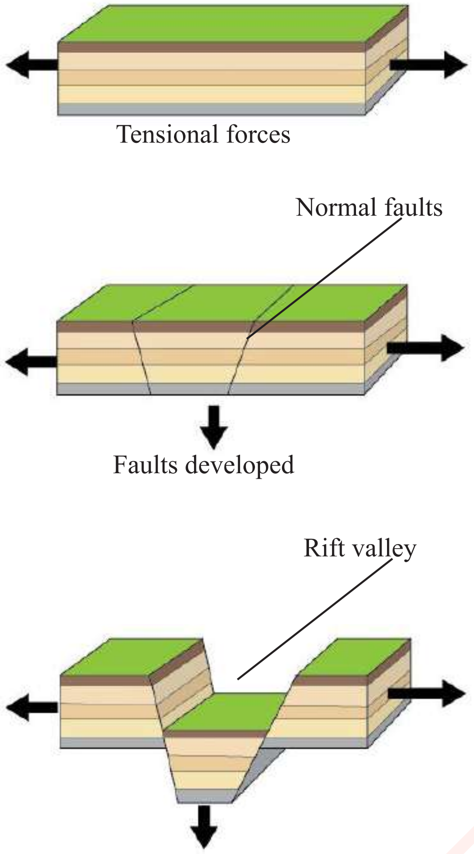


Figure 2.19: *Formation of a rift valley by tensional forces*

Formation of a rift valley by compressional forces

The valley is formed in such a way that the masses on either side of the faults thrust up higher than the central block which is forced down between the two to form the valley. Otherwise, these forces of compression cause two reversed faults and the pieces of land on either side lift up above the general level of the ground to form a rift valley as shown in Figure 2.20. Examples of rift valleys are the East African Rift Valley, the Jordan Rift valley in Asia and the Rhine Rift Valley in Europe.

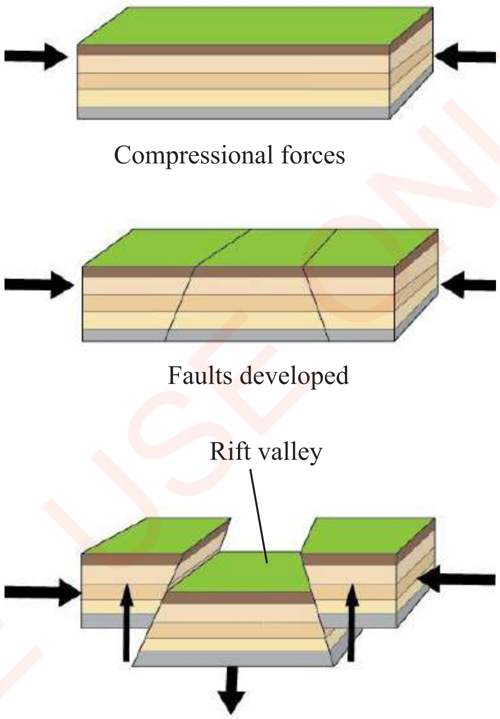


Figure 2.20: *Formation of a rift valley by compressional forces*

A rift valley may form a lake when filled with water. Examples of rift valley lakes include Tanganyika, Nyasa, Rukwa, Magadi, Baringo, Naivasha, Eyas, Natron, Turkana, Edward and Albert in East Africa.

Activity 2.2

1. In a group, take a piece of paper then hold it on the opposing sides.
   (a) pull the piece of paper towards you
   (b) write what happens after pulling the paper.
   (c) relate the results with the effects of tensional forces
2. Take any piece of paper which is hard like a manila sheet, then hold the two sides.
   (a) slowly compress the paper
   (b) observe the results and write what you observe
   (c) share what you experienced with your fellow students in relation to the occurrence of fold mountains.

Exercise 2.2

1. With the aid of diagrams, explain how a rift valley is formed.
2. Explain how fold mountains are formed.

Vulcanicity

Vulcanicity is the whole process through which molten materials and gases are forced into the earth's crust and onto the surface to form intrusive rocks within the earth's crust or extrusive rocks on the earth's surface. Vulcanicity is usually associated with earth movements.

Vulcanicity is a wider term which comprises both intrusive and extrusive igneous activity while volcanicity refers to the extrusive rocks formed when molten materials from the earth's interior are forced out and cool on the earth's surface. When the molten materials are still inside the crust they are referred to as magma but on reaching the surface they lose their gases and thus they are referred to as lava. Therefore, features formed by extrusive vulcanicity are known as volcanoes. Volcanoes are the cones formed due to the accumulation of lava.

Rocks formed below the earth's crust are under high temperatures and great pressure hence, they are in the molten state. When a crack or fault (fissure) or a hole (vent) is formed, magma is forced out through them, pile up and solidify beneath to form intrusive features such as batholiths, dykes, sills and laccoliths. On the other hand, when magma reaches the surface quietly or violently they form extrusive features. The nature of the formed intrusive or extrusive vulcanic features depends on the degree of fluidity of the magma where less viscous magma flows rapidly and spreads further, while more viscous magma flows slowly and solidifies rapidly near the vent and forms a dome shape. The nature of the rock weakness such as joints, faults, cracks or fissures also determines the speed and position of volcanic features.

Causes of vulcanicity

Vulcanicity may occur due to the exertion of excessive weight of overlying rocks on the mantle. The exerted force of rocks over the mantle increases pressure and temperature of the rocks and keeps them in a molten state. Vulcanicity can also result from the friction along rock surfaces at the boundaries of tectonic plates. The friction raises temperature and reduces pressure, hence eruption of magma through the cracks. Furthermore, surface water infiltrates into the ground where it comes across the super-heated rocks, and due to increase in heat and pressure, it flows out of the earth's crust as hot spring or geysers.

Types of vulcanicity

Vulcanicity is divided into two main parts, namely intrusive vulcanicity and extrusive vulcanicity (volcanicity). Both intrusive and extrusive vulcanicity result into the formation of various landforms as described in the following sub-section.

Intrusive vulcanic features

Intrusive features are formed when magma fails to reach the earth's surface and therefore cools and solidifies within the earth's crust. In this case, the magma may spread, accumulate or remain in the passage within the crustal rocks where it cools and solidifies to form intrusive igneous features. The intrusive igneous features are categorised into hypabyssal and plutonic features. Hypabyssal features are volcanoes formed beneath the earth but near the surface while plutonic features are formed deeper beneath the earth. Intrusive vulcanic features include dykes, sills, laccoliths, lapoliths, phacoliths and batholiths.

Dyke

It is a wall-like feature formed when a mass of magma cuts across the bedding planes of the rocks. It is formed after magma cools and solidifies along the bedding planes (Figure 2.21). Since it does not follow the nature of the bedding plane of the rock, it is a discordant feature. Examples of dykes are found in the Jos Plateau in Nigeria, and West and South of Blantyre along the Tyolo Scarp in Malawi.

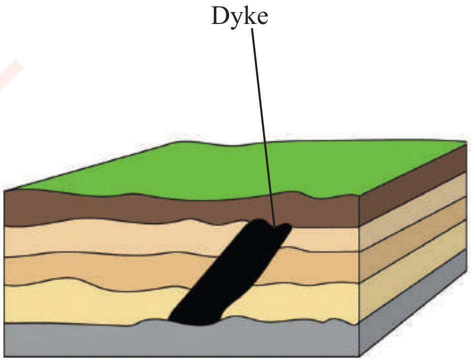


Figure 2.21: *Dyke*

Sill

This is a sheet of igneous rock which forms when magma solidifies horizontally along the bedding plane as shown in Figure 2.22. It is concordant to structure of rock strata. It takes thickness of different sizes and can cover many kilometres. When exposed to erosion, a sill may form a ridge-like escarpment or waterfall. The natural bridge in Kiwira, Mbeya in Southern Tanzania is an example of a sill. Other examples are found in South Africa along the railway line from Kimberly to Cape town and Kinkon Falls in Guinea.

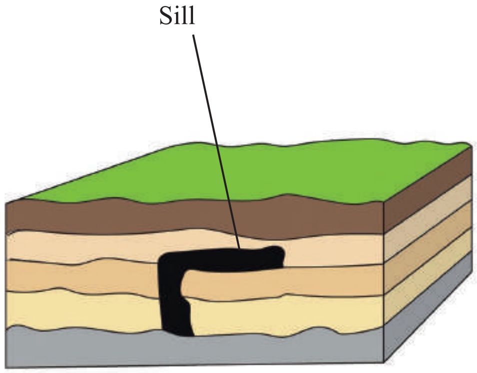


Figure 2.22: *Sill*

Laccolith

This is a dome-shaped intrusive feature that has been formed within or between layers of sedimentary rocks as shown in Figure 2.23. It is formed when the pressure of the viscous magma becomes high enough to force the overlying strata to fold and push up making a dome or mushroom like structure.

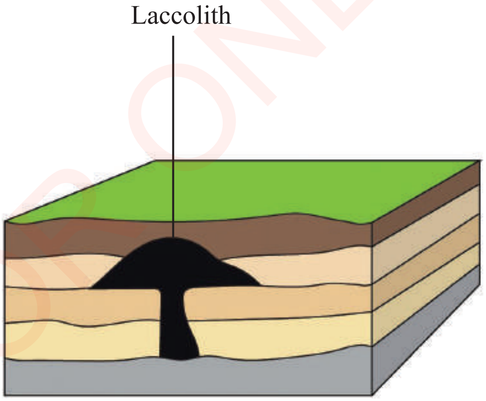


Figure 2.23: *Laccolith*

Lopolith

A lopolith is a large saucer-like intrusive igneous rock lying concordant to the rock strata forming a shallow basin, as shown in Figure 2.24. The lopolith is formed as a result of greater weight of the overlying strata and deposits. An example of a lopolith is that which found in Bushveld Basin in the Transvaal, in South Africa.

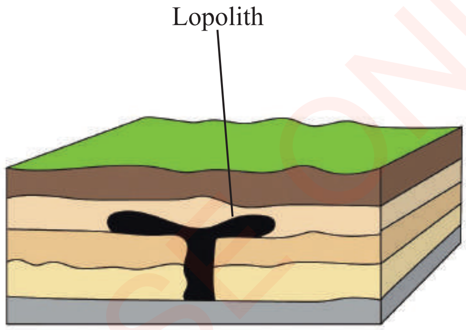


Figure 2.24: *Lopolith*

Phacolith

This is the concordant intrusion of igneous rock, formed after cooling and solidification of magma near the crest of an anticline or the base of a syncline (Figure 2.25). A phacolith can form along the sedimentary bed rock which is concordant thereby exerting great thickness along the synclines or anticlines.

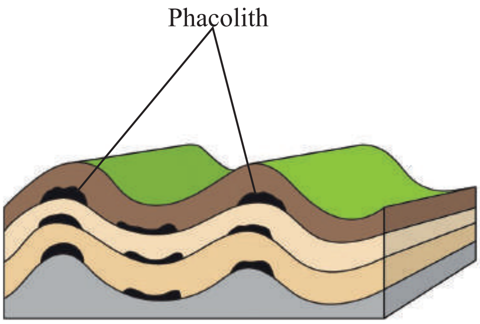


Figure 2.25: *Phacolith*

Batholith

This is a large body of an igneous rock formed at the base of the earth's crust. It is formed by the intrusion and solidification of magma very deep in the crust, as shown in Figure 2.26. It is commonly composed of coarse-grained rocks. Most batholiths intrude across mountain folds and are elongated along the dominant axis of range. A batholith forms the root of a mountain.

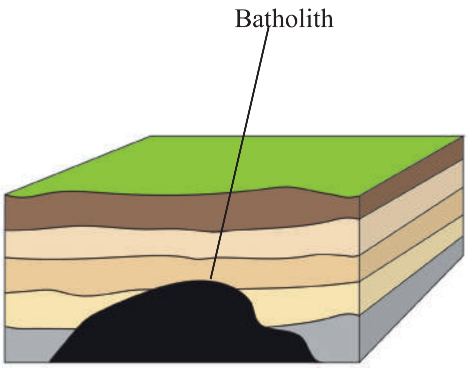


Figure 2.26: *Batholith*

Extrusive volcanic features

These features are formed when molten materials reach the earth's surface through vents or fissures. The molten materials that are ejected onto the surface are called lava. Silent eruption is an ejection of magma which takes place without involving much force. Some extrusive volcanic features take place through fissures, therefore they are called fissure eruptions. Violent eruptions usually occur through a vent, and take place with great force. Lava emerging through a vent can build up a volcano.

Volcanoes

A volcano is formed from the accumulation of molten rock which flows out through a vent onto the earth's crust. The mountain's funnel-like depression or vent around which the erupted materials accumulate is called a crater.

Types of volcanoes

Volcanoes are categorized as *active, dormant* or *extinct*.

Active volcano

An active volcano is one known to have regular eruptions. Active volcanoes include Mount Oldonyo Lengai in Tanzania, Mount Longonoti in Kenya, Mount Nyiragongo in the Democratic Republic of Congo and Mount Pinatubo in the Philippines.

Dormant volcano

A dormant volcano is one that erupts rarely but still shows signs of eruption. Such signs include rumbling, gaseous emission and lava flow which indicate the likelihood of a volcano to erupt again. Mount Kilimanjaro and Meru in Tanzania, and Mount Menengai in Kenya are good examples of dormant volcanoes.

Extinct volcano

An extinct volcano is one which shows no signs of erupting again, although it was formed through volcanic activity many years ago. This type of volcano is no longer characterised with signs as rumbling, emission of smoke, lava flow or ash. Much of its original structures may have been destroyed by denudation. Examples of extinct volcanoes include

Mpoli in Tanzania, Kulod in Kenya as well as Mikeno, Karisimbi and Sabinyo in Uganda.

Volcanic activities may form several features which are described in the following sub-sections.

Ash and cinder cones

These are cone shaped accumulation of rock fragments (pyroclasts) around the vent. They are formed when lava is blown and ejected violently to great height and fall back to the earth and builds up a cone-like feature (Figure 2.27). The slopes of the cone are always concave due to the spreading tendency of lava at the base of the cone. Examples of ash and cinder cones are Sarabwe Fileko in Rungwe (Southern Tanzania), Busoka and Bitale in (South West Uganda), South of Lake Turkana (Kenya) and Jos Plateau of Nigeria.

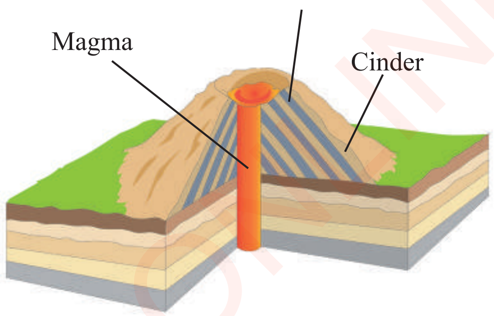


Figure 2.27: *Ash and cinder cone*

Composite cone (strata-volcano)

It is a large cone with alternative layers of lava and ash. Lava often escapes from the sides of the cone where it builds up small conelets, as shown in Figure 2.28. The cone has steep sided slopes and it is the most common volcano. Examples of composite cones are Kilimanjaro and Meru mountains in Tanzania, Nyiragongo Mountain in the Democratic Republic of Congo and Muhavura Composite in the East of Virunga Ranges lying in the south-west of Uganda.

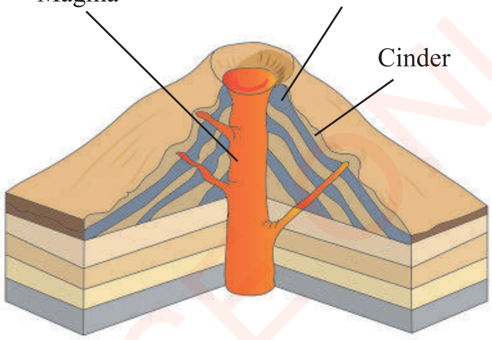


Figure 2.28: *Composite cone*

Volcanic plug

A volcanic plug is also referred to as a plug dome or spine volcano. It is formed when a mass of very viscous acid magma is forced out through a vent from the ground (Figure 2.29). The plug is extruded amid clouds of hot blowing ash and cinders. An example of a plug dome is Mount Hoggar in Algeria.

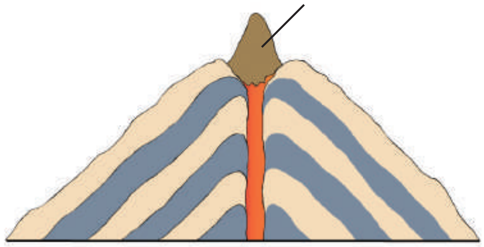


Figure 2.29: *Volcanic plug*

Crater

A crater is a depression on top of a volcanic cone. It is formed by violent volcanic eruption when the upper part of a volcanic plug is blown off. The depression may turn into a crater lake when filled with water from either rainfall or melting ice, as shown in Figure 2.30. Examples of craters are Embakai, Olmoti and Ngozi in Tanzania.

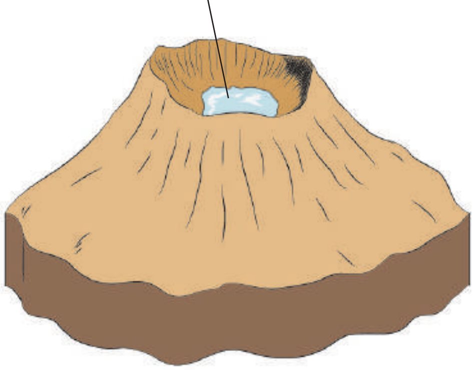


Figure 2.30: *Crater*

Caldera

It is a large rounded depression formed when the upper part of a volcano is either blown away by violent eruptions or subsides into the crust or in the volcanic cone, as shown in Figure 2.31. Caldera is a broadened crater. Examples are Ngorongoro Caldera in Tanzania, Eboga Caldera in Cameroon and Katmei Caldera in Alaska.

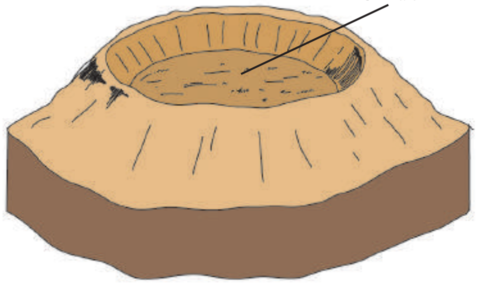


Figure 2.31: *Caldera*

Acid lava cone (Cumulo dome volcano)

It is a dome shaped volcano with (convex) steeply- sloping sides formed when acidic lava cools and solidifies around the vent, as shown in Figure 2.32. Lava does not flow away, rather it piles up near the vent due to its viscocity. The viscosity of the lava that forms a cumulo dome is a result of high content of silica and its high melting point. An example of cumulo dome is Ntumbi dome found 30 km East of Mbeya Region, in Tanzania.

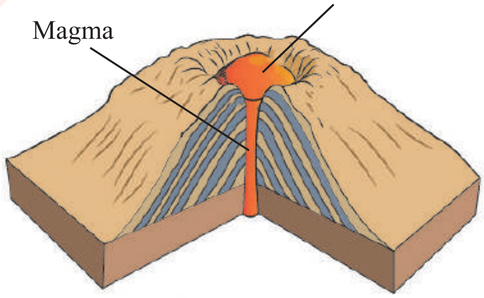


Figure 2.32: *Acid lava cone*

Shield volcano

A shield volcano is an extensive cone with gentle slope sides formed when basic (basalt) lava is poured onto the surface and spreads to occupy a large area, as shown in Figure 2.33. Lava from the earth's interior flows out through a vent. A basic or shield volcano can also form when lava flows out through a single or many fissures.

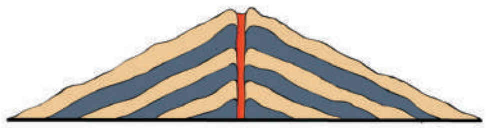


Figure 2.33: *Shield volcano*

Other associated volcanic features

These features are associated with vulcanicity as described in the following sub-sections.

Solfatara

It is a volcanic hole emitting sulphurous gases as dominant and water vapour. Other materials emitted by solfatara are hot muds. Solfataras are generally found in places with young volcanic activities. An example of solfatara is Naple Solfatara emissions in Italy.

Fumarole

It is a volcano which emits steam, mud and gases like sulphur. Examples of fumarole are found in the valley of Thousand Smokes in Alaska. Also, Kibo in Kilimanjaro can be put under this category, though it emits only gasses.

Mofette

It is a volcano which emits carbon dioxide gas. Examples of mofette are Kyejo in Rungwe, Southern Tanzania, Auverge in France and Java in Indonesia.

Hot spring

It is a quiet outflow of superheated water from the ground. The outflowing hot water contains some mineral substances in solution or in suspension. Hot springs are common in Iceland as well as in some African countries such as Tanzania, Kenya and Ethiopia. Hot springs may be used to provide geothermal energy for different purposes especially for electricity generation. Examples of hot springs are Amboni in Tanga and Nanyala in Songwe region, Tanzania.

Geyser

This is a hot spring that throws out water into the air with great force and sometimes accompanied by steam. It occurs when heated water in the crustal rock is ejected explosively through a plumb-like narrow channel higher above surface. (Figure 2.34). Examples of geysers are Allalobed and Dallol found in Afar region in Ethiopia.

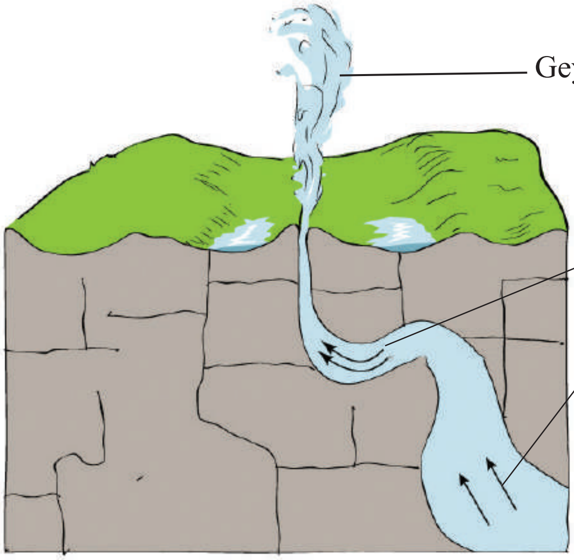


Figure 2.34: *Geyser*

Mud volcano

Mud volcano is also known as mud dome. It is a landform formed from accumulated mud or slurries, water and gases erupted from the earth's interior. Mud volcanoes do not produce lava and are not necessarily triggered by magmatic activity.

The world distribution of major volcanic zones

Volcanoes are related to earth movements. They occur in the following zones as shown in Figure 2.35.

(a) Zones of recent mountain building such as the fold mountain zones of South East Asia;

(b) Along divergent boundaries where volcanic materials outflows through the boundaries to form such features as mid-Atlantic ridge in Atlantic ocean;

(c) Continental coastlines such as the Western coast of North and South America;

(d) Convergent boundaries such as the Island of Japan; and

(e) Faulting regions such as those within the zone of the Great Rift Valley in Tanzania, Kenya, Uganda, Ethiopia and Malawi.

Figure 2.35: *World map showing major volcanic zones*

The economic importance of volcanic activities

Volcanoes have enormous economic importance. Volcanic materials produce fertile soil that supports agriculture activities both cash and food crop production. Volcanic activities result in the formation of precious stones and minerals, like gold from Geita in Tanzania and silver from Kakamega, Kenya. Minerals bring foreign currency used for the development of country's economy. Consistently, volcanic activities facilitate geothermal energy production because when magma rises close to the earth's surface, it heats the groundwater to boiling point. When a well is drilled in these regions, hot water is pumped out as steam due to the extreme heat. The steam can then be used to drive turbines and produce electricity useful for different domestic, industrial and office activities. A good example is in Iceland where over 90% of homes are heated through geothermal energy. Also, it is a source of hydroelectric power generation through geysers and hot springs. Tanzania extracts carbon gas from Kyejo and other parts of Rungwe District.

Moreover, volcanic activities contribute towards provision of building materials, for instance, igneous rocks are used for building and construction of roads. Basalt, diabase and pumice are good examples. Features that result from volcanic activities attract tourists. For example, the snow-capped Mount Kilimanjaro, Mount Oldonyo Lengai and the Ngorongoro caldera in Arusha attract tourists who bring in foreign currency and create employment opportunities among the citizens. Apart from that, volcanic mountains influence the formation of orographic rainfall. For example, the windward side of Mount Kilimanjaro receives adequate rainfall that supports agriculture activities; and some volcanic features are sources of rivers which can be harnessed through dams to produce electricity or for irrigation purposes. For example, the source of River Pangani is Mount Kilimanjaro whose water is used to generate hydro-electric energy at Hale and Nyumba ya Mungu Electrical Power Stations. Volcanic soils are fertile and suitable for agricultural production.

Negative effects of volcanic eruptions

Large volcanic eruptions can cause deaths as well as destruction of properties. Lava and mudflows caused by volcanic eruption kill people and destroy properties as it erupts and flows rapidly down the volcano sides. The lava flow can also destroy agricultural land since the solidified lava hardens and makes it difficult for farmers to cultivate the land. Moreover, volcanic eruptions may release poisonous gases such as sulphur dioxide and carbon dioxide which may have adverse impacts to human beings as well as the atmosphere.

Activity 2.3

In a group, do the following:

(a) discuss the necessary conditions for the occurrence of violent and silent volcanoes;
(b) write the necessary conditions you have discussed;
(c) present these conditions to your fellow students in the classroom for more discussion;
(d) improve your work, then write it in your exercise book; and
(e) submit your work to your subject teacher for marking.

Exercise 2.3

Answer all questions.

1. Differentiate between:
   (a) geysers and hot springs
   (b) caldera and crater
   (c) fissures and vents
2. "Volcanic eruptions are always destructive". With examples discuss this statement.
3. Use illustrations to account for the necessary conditions for the occurrence of hot springs and geysers.

Earthquakes

An earthquake is a sudden vibration or shaking of part of the earth's crust caused by natural forces operating beneath the earth's crust. Sometimes the shaking can be caused by artificial forces caused by human activities like drilling, bombing and quarrying. Such shaking can cause movement of the earth's crust horizontally or vertically and sometimes a combination of the two. The shaking can be minor or major but short lived and cover small area. Earthquakes usually occur in faulted and volcanic areas. Sometimes earthquakes occur in zones where tectonic plates converge or diverge one another or slide over or past one another. The intensity of an earthquake can be detected and measured by using an instrument called *seismograph*. The instrument is also known as *seismometre*.

Focus

This is a point in the earth's crust where an earthquake originates. Sometimes it is several kilometres below the surface as shown in Figure 2.36. When there is an earthquake, wave energy originates from the focus. The waves produced by the earthquake are known as seismic waves and are of two types, namely: body waves and surface waves. The waves which travel within the earth crust are known as body waves. There are of two types, namely; primary waves which cause the crustal rock to move back and forth in the direction of wave and secondary waves which cause crustal rock to move from side to side (at right angles) to the direction of wave.

The waves which travel on the surface are known as surface waves. There are two types of surface waves, namely love waves which cause the surface rock to move from side to side and Rayleigh (R) waves which cause the surface rocks to have a vertical circular movement. Surface waves are the most destructive on the surface.

An epicentre

Refers to the point on the earth's surface that is vertically and immediately above the point of origin (focus) of an earthquake (Figure 2.36). It is a point on the earth's surface the earthquake vibrations first hit, and then spread outwards.

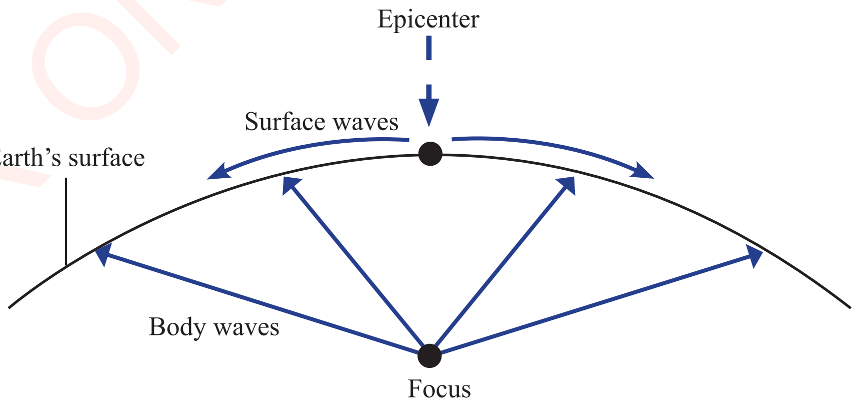


Figure 2.36: *Earthquake focus and epicentre*

The ground motions generated by the earthquakes, also known as seisimic waves, are measured by using seismograph. A seismograph plots the intensity in form of seismogram. A seismogram is a graph which shows the intensity of the earth's vibration. A measure of the severity of an earthquake by its magnitude is called Richter scale. The scale reading ranges from 0 to 9. The Mercall scale is used to show the intensity of the earthquake which varies from place to place. The term magnitude refers to the energy released by the vibration, while intensity refers to the damage caused by the vibration.

Causes of earthquakes

One of the causes of earthquakes is isostatical adjustment of the earth's crust. This happens as the crust adjusts itself to changing pressure caused by weight exerted on the earth's crust. The crust may move downwards or upwards. The movements then trigger the upper mantle which leads to earthquakes. These movements may also make the earth adjust along faults. Faulting of the crust is caused by plate tectonic movements where one plate slides over the other plate. Such movements cause disturbances which in turn generate shock waves that end up shaking the earth's crust. Similarly, volcanism can also cause the occurrence of earthquakes. This is due to the fact that magma moving under the influence of internal pressure of the earth's interior erupts leading to shaking of the earth's surface. Moreover, mass movements like landslides and rock fall can also cause minor tremors. Falling of heavy objects from the atmosphere such as meteorites can lead to the shaking of the earth's crust.

Furthermore, tremors can be influenced by human activities like the use of bombs and other explosives in quarrying and mining that use dynamite.

Effects of Earthquakes

Earthquakes are associated with occurrence of faulting, folding or even vulcanicity. When an earthquake occurs, it causes shaking of the ground which might rapture due to tensional and compressional forces and vigorous movement of magma and gases in the interior of the earth. Moreover, when earthquakes occur in the ocean, they result in ocean waves called Tsunamis. These waves are very high and when they reach the coast, they cause flooding. The Indian Ocean Tsunami of 26th December, 2004 caused over 200 000 deaths of people in Banda Aceh, Indonesia and other different countries along the Indian ocean including Tanzania. Similarly, lateral and vertical displacement of parts of land can occur. For instance in San Francisco, in 1906, an earthquake caused horizontal displacement of rocks by 7 metres.

Earthquakes can also damage transport and communication lines like gas and oil pipelines, telephone lines and roads. They can raise or lower coastal rocks. For example, in the Alaskan, earthquake of 1899 caused some coastal areas to raise by 16 metres. Destruction of houses and other structures as well as loss of human life are significant impacts associated with earthquakes. For example, in 1906, an earthquake killed 700 people and caused substantial loss of property in San-Francisco. In Tanzania, the earthquake which occurred in Bukoba District, in Kagera Region on 10^{th} September, 2016, caused deaths of more than 20 people and destruction of properties. About 1264 buildings were destroyed. Earthquakes can also cause part of the sea floor to rise or subside. For example, the depth of the sea in some areas of the coast of Morocco decreased from 40m to 15m after the 1960 earthquake. Earthquakes can also cause fire outbreaks due to the falling of electric poles, and volcanism. Ground shaking caused by earthquakes triggers off landslides and avalanches which destroy human settlements and can also cause human and animal deaths.

World distribution of earthquakes

Earthquakes are found in areas associated with lines of weakness in the crust. Such areas include boundaries or margins of tectonic plates and lines of riffs, as shown in Figure 2.37. Areas hit by earthquakes are associated with the following features:

(a) Mid-oceanic ridge like the entire of the mid Atlantic Ocean;

(b) The ocean deep trenches and volcanic islands of the Pacific Ocean;

(c) The region of crustal compression (Young fold mountains) stretching across southern Europe and Asia linking the Atlantic and Pacific Oceans;

(d) Rift valley areas such as the Great East African Rift Valley and areas which are vulnerable to earthquakes in Tanzania (Examples are Kagera Region in North-Western Tanzania and Rungwe in Southern Tanzania highlands);

(e) The circum-pacific belt, which includes the West Coast of North and South America, Japan, the Philippines and East Indies;

(f) The belt from Atlas in North West Africa, the Alpines in Southern Europe to the Himalayas; and

(g) Along all the boundaries of the tectonic plates.

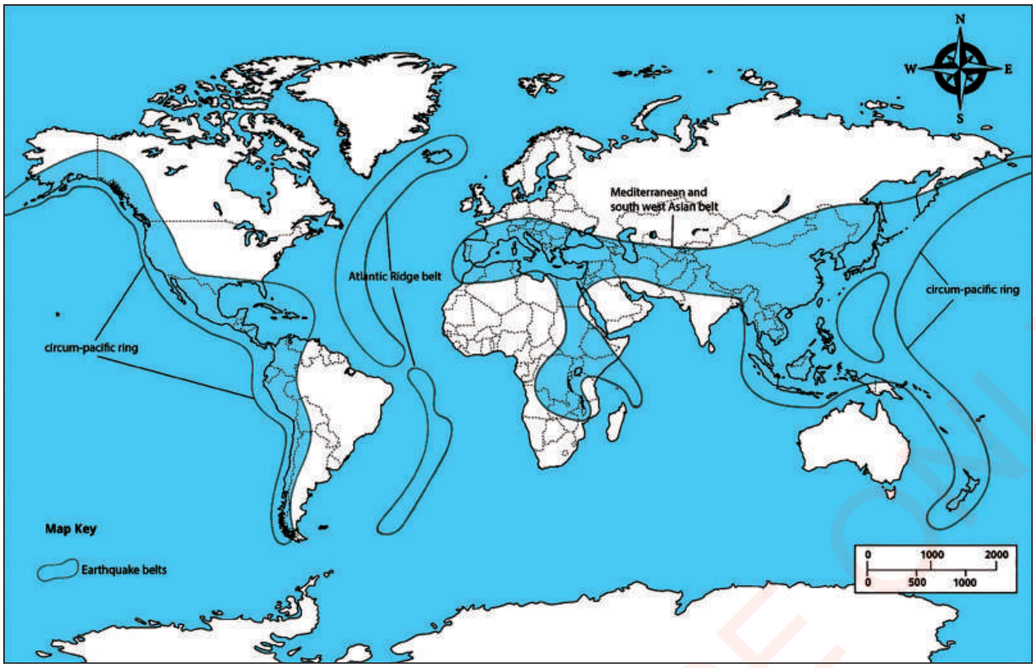


Figure 2.37: *World distribution of earthquakes*

Every person living in areas susceptible to earthquakes should be educated on precautions that they should take to minimize risk before, during and after an earthquake.

Precautions to be taken prior to earthquake incident

It is very important to take precautions before earthquakes strike in order to avoid possible dangers. First and foremost, people should be advised to stay away from high risk areas. People should not construct buildings in fault line zones. People should be advised to construct buildings and roads that can withstand earthquakes. Training and preparedness services should be available. For example, fire brigade units, ambulance and helicopter services should always be available. People should be advised on what to do in the event of an earthquake. Emergency services should be organised to provide first aid, water, power and food to the victims. In addition, emergency communication plans should be put in place. Remember telephone communication may not work.

What to do during an earthquake incident

Some earthquakes can be very violent. If you are inside a house, move out and stay in an open place or slide under a table or bed and cover your head and body with heavy clothing to protect yourself from heavy and sharp objects such as glass. If you are outside, ensure that you stay away from buildings, trees, electric poles and electrical cables or anything else that might fall on you. Also, if you are in a moving vehicle, stop as quickly as safety permits and stay in the vehicle. Avoid stopping near or under tall buildings, trees and electrical poles since they may fall over you. Proceed cautiously once the earthquake has stopped. Avoid using roads, bridges or humps that might have been damaged by the earthquake. If trapped in rubble, do not light a match, but cover your mouth with a handkerchief or clothing. Tap on a pipe or wall so that rescuers can locate you or use a whistle if available. Also shout only as a last resort as shouting can cause you to inhale dangerous particles of dust.

Post earthquake incident

Expect aftershocks which can cause more damage and injury. After an earthquake, you are advised to listen to media for latest emergency information; stay away from damaged areas; return home only when authorities declare it is safe; be aware of possible tsunami if you live in coastal areas; clean up spilled chemicals, bleaches, gasoline, or other flammable liquids immediately; leave the area if it smells gas or fumes from other chemicals; and inspect utilities. Check for gas leakages, damage to electrical systems and plumbing.

Minimising risks caused by earthquake incidences

For the purpose of reducing the risks associated with earthquake incidences, houses should be constructed using light materials; tall buildings should be constructed on a strong and reinforced foundation made of steel and concrete; the height of buildings should depend on the recommendation of land survey authorities; education and preparedness plans should be in place to help to reduce deaths and injuries caused by earthquakes; and civil engineers should erect buildings right from basement rocks. In case of vibrations, the rocks and the buildings will vibrate at the same frequency hence reduce damage. It is also recommended to build tall houses resting on rollers. In case of an earthquakes, the rollers tend to protect the buildings.

Activity 2.4

In a group, discuss and suggest five possible areas where an earthquake can occur in Tanzania.

(a) For each suggested area, give reasons why an earthquake can occur.

(b) Present your work in the class and invite discussion for improvement.

Exercise 2.4

Answer all questions

1. Explain the precautions you will have to take to protect yourself during the occurrence of an earthquake.
2. Briefly explain possible environmental effects associated with the occurrence of earthquakes.
3. Explain two reasons why earthquakes differ from other tremors.
4. Explain the factors which determine the intensity of earthquakes.

Revision exercise 2

Section A

Choose the correct answer.

1. Downward or upward movements of the earth's crust are called _____.
   (a) internal earth movements
   (b) radial movements
   (c) lateral movements
   (d) rotational movements

2. Radial movements within the earth's crust are associated with the formation of _____.
   (a) basins, rift valleys and volcanos
   (b) joints, faults and fissures
   (c) horsts, grabens and basins
   (d) joints, basins and faults

3. Lateral movements within the earth's crust usually cause _____.
   (a) folding, faulting and joints

(b) basins, horsts and rift valleys

(c) synclines and anticlines

(d) earthquakes and grabens

4. Earthquakes may be caused by the following, except _____.

(a) tensional forces

(b) lateral movement

(c) soil erosion

(d) vertical movement

5. All forces operating within the earth's crust are _____.

(a) responsible for the formation of landforms

(b) destructing to the features of the earth's surface

(c) caused mainly by human activities

(d) initiated by volcanic activity

Section B

Answer the following questions:

6. Use a diagram to explain the formation of:

(a) Rift valleys

(b) Block mountains

(c) Fold mountains

7. With the aid of diagrams, describe internal volcanic features.

8. With examples, explain five effects of earthquakes.

Section C

Match each item in ***Column A*** *with its corresponding item from* ***Column B***.

Column A	Column B
9. Atlas and the Drakensberg	(a) composite cone
10. A dome-shaped intrusive feature	(b) magma
11. Large cone with alternative layers of lava and ash	(c) phacolith
	(d) batholith
12. Rocks in molten state within the earth's crust	(e) lava
	(f) fold mountain
13. The point from which the earthquake originates	(g) laccolith
	(h) focus
14. A large body of an igneous rock formed when magma solidifies at the base of the earth's crust	

Chapter Three

Weathering and mass wasting

Introduction

Weathering and mass wasting are processes of denudation on the earth's surface caused by external forces. Denudation processes wears away earth's surface. In this chapter, you will learn about weathering and mass wasting as external forces which act on the earth's surface. You will also examine different forms of both weathering and mass wasting and the factors which influence weathering and mass wasting. The competencies developed in this chapter will enable you to avoid activities that can accelerate the occurrence of weathering and mass wasting and opt for means to minimize their effects in the environment. Likewise, the competencies developed will help you utilize benefits resulting from weathering and mass wasting.

Weathering

Weathering is a process of gradual weakening, decomposition and disintegration of rocks into smaller particles on the earth's surface as exposed to weather changes. Weathering is caused and accelerated by physical actions, chemical processes and biological actions. Weathering occurs without movement and thus is not synonymous to erosion. The process of weathering prepares the rock materials for movement, either by gravity or transportation through the agents of erosion. Weathering is important in soil formation since smaller particles of the broken rocks form the structure and texture of soils. Also, these particles determine components of soil, its colour and chemical composition.

Types of weathering

There are three major types of weathering, namely; mechanical or physical weathering, chemical weathering and biological weathering.

Mechanical weathering

Mechanical or physical weathering is the process whereby exposed rocks disintegrate without any change in their chemical composition. The process is caused mainly by changes in temperature, frost and rainfall. Mechanical weathering is common in arid and semi-arid regions since the differences between day and night temperature are very high. Mechanical weathering has four ways of occurrence, as described below.

(a) Mechanical weathering due to temperature change

During the day, rocks of different mineral properties exposed to the atmosphere get heated and expand at different rates due to high temperature and contract at different rates at night due to low temperature. The process of alternate change in temperature leads to *exfoliation*, *salt crystalisation* and *granular disintegration*.

(i) *Exfoliation*

The difference in expansion and contraction causes the outer layers of the rocks to crack and peel off, thus reducing the size of the rocks. This process is called exfoliation and the features resulting thereafter are isolated masses of round-shaped rocks called exfoliation domes. The peeled off rock fragments fall to the bottom of the standing rocks and are subjected to further alternate expansion and contraction. Finally, they disintegrate into even smaller fragments to form a hill of steep sloping rock fragments called talus or sometimes screes. The fragments often collect at the base of exfoliation domes. Figure 3.1 is an example of an exfoliation dome. There are many exfoliation domes in Egypt and Kalahari, Sahara and Sinai deserts.

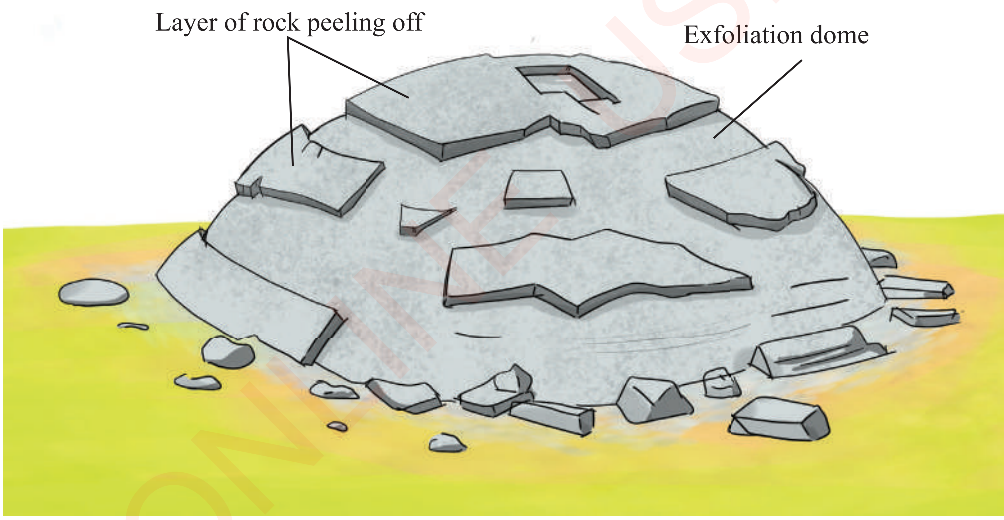


Figure 3.1: *Exfoliation dome*

(ii) *Salt crystalisation*

This occurs when water in the rock cracks evaporates due to high temperature, leaving behind salt crystals in the cracks, that cause the entire rock to expand and break up.

(iii) *Granular disintegration*

As the temperature increases, some of rocks disintegrate by releasing rock grains or particles as they have different capacities of withstanding heat.

(b) Mechanical weathering due to frost action

This occurs in mid-latitudes and high mountain areas where water accumulates in rock fissures (cracks) and freezes during winter. Usually, it involves the freezing of water in the cracks during the night and thawing (melting) during the day. Since frozen water increases in volume, the cracks widen and deepen, ultimately causing the rocks to disintegrate into angular fragments of rocks to form screes or talus. Figure 3.2 shows block disintergration.

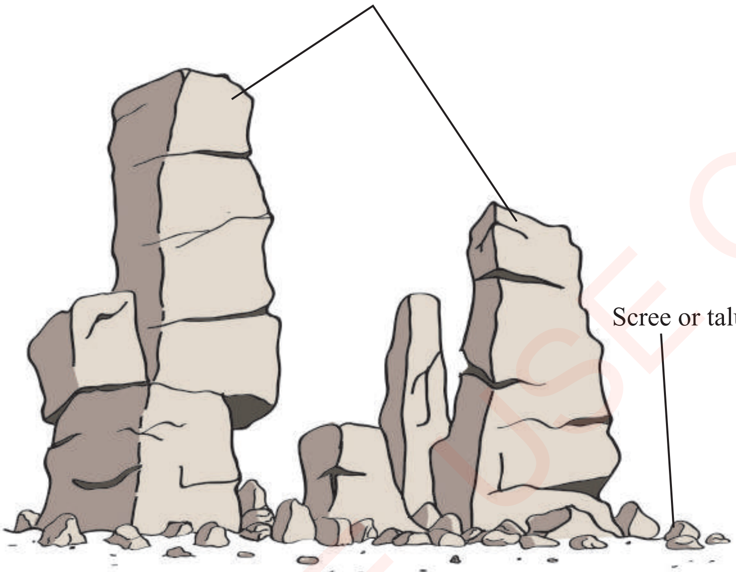


Figure 3.2: *Block disintegration*

(c) Mechanical weathering due to alternate wetting and drying

Rain has minor effects on mechanical weathering except as a source of water for frost action. However, when a drought succeeds a rainy period, rocks give up moisture previously absorbed and as a result some rocks such as shale may crumble into small elongated fragments.

(d) Mechanical weathering due to pressure release

If overlying layers of rocks are removed by denudation, the release of pressure may allow the exposed rock to expand and crack to form joints, thus causing curved rock shells. Granite is particularly liable to this process of weathering.

Chemical weathering

Chemical weathering refers to the decomposition of some or all of mineral constituents in a rock resulting in the collapse of the rock through chemical processes. Normally, two or more chemical weathering processes take place at the same time. Chemical weathering is more noticeable in hot wet regions than in cold dry regions. Chemical weathering involves processes of *carbonation*, *solution*, *hydrolysis*, *oxidation*, and *hydration*.

(a) Carbonation

Carbonation refers to a process where carbonic acid reacts with carbonates contained in other substances to form a new substance. Carbon dioxide in the atmosphere dissolves in rain water to form weak carbonic acid which acts on calcareous rocks such as limestone and chalk. Calcareous rocks are kept in their rock state by insoluble carbonate. However, the weak carbonic acid in rain water turns the insoluble carbonate into soluble bicarbonates. The calcareous rock loses its rock state as the formed soluble bicarbonates are washed down through the soil. This process produces features like grikes and clints. Figure 3.3 shows an example of clints and grikes. The carbonation process is illustrated by a chemical equation as follows;

(i) $H_2O + CO_2 \longrightarrow H_2CO_3$ (Weak Carbonic acid)

(ii) $CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$

Calcium carbonate, water, Carbon dioxide → Calcium bicarbonate (soluble)

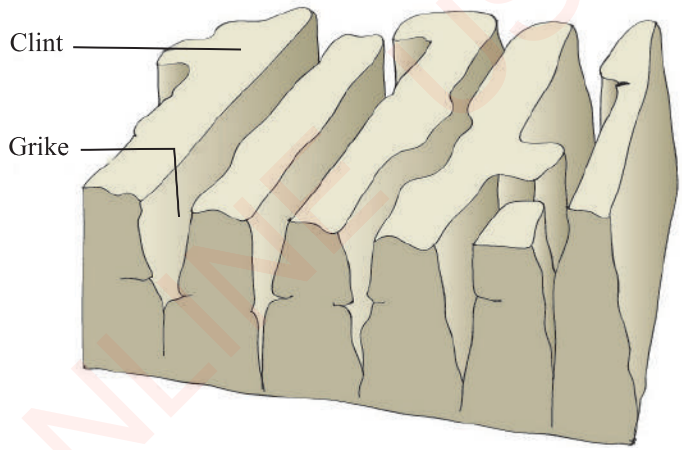


Figure 3.3: *Clint and Grikes*

(b) Solution

Rock minerals dissolve directly in water without being changed into another mineral compound, to form a solution. For example, calcium bicarbonate rocks tend to dissolve in water and get washed away.

(c) Hydrolysis

Hydrolysis is a process whereby hydrogen ions from water combine with mineral ions from rocks to form new chemical compounds. These compounds formed can easily be weathered through other weathering processes. For example, when feldspar reacts with water and carbon dioxide it results into a clay mineral and silica residual, whereby potassium carbonate is removed in solution.

$$\underset{\text{Feldspar}}{2KA1Si_3O_8} + 2H_2O + CO_2 \longrightarrow \underset{\text{Clay mineral}}{A1_2Si_2O_5H_4} + K_2CO_3 + \underset{\text{Silica}}{4SiO_2}$$

(d) Hydration

Hydration is a process whereby some mineral rocks absorb water and bulge, thereafter becoming loose and breaking easily. A good example is absorption of water by calcium sulphate to form gypsum.

(e) Oxidation

It is a process whereby oxygen combines with other elements or substances of the rock to form new compounds. Some rocks containing iron react with oxygen in the presence of water to form new minerals. The new minerals formed by oxidation are often easily attacked by other weathering processes. The ferrous state of rocks changes into ferric state forming a yellow or brown easily crumbled substance. However, the magnitude of chemical weathering depends on climatic conditions. In equatorial regions where humidity and temperature are permanently high, the rate of chemical weathering is higher than in other regions like desert areas where humidity is low. Hence, in areas with low humidity, the rate of chemical weathering is low.

$$\text{Oxidation:} \quad 4Fe + 3O_2 \longrightarrow 2Fe_2O_3$$

Biological weathering

Biological weathering is the disintegration of rocks due to the action of living organisms such as plants and animals. Sometimes it involves both chemical and physical weathering, particularly when biological disintegration is accompanied with secretion of chemicals from plants or animals. This process is also known as biotic weathering. There are different actions by plants and animals that contribute to weathering. These are explained in the sections that follow.

(a) The action of plants

Plant roots, especially those of trees, can grow into rock joints and cracks. As the roots increase in size overtime, they force the rocks to break apart (Figure 3.4). This is called weathering by wedging action or wedging mechanism. If rain water enters the cracks caused by the roots, or if the roots rot and decay in the cracks, they produce chemicals which may react with minerals in the rock and decompose it.

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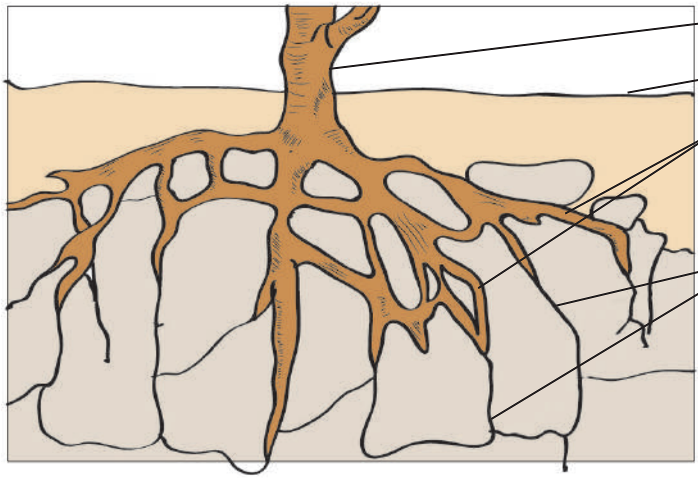


Figure 3.4: *Action of plant roots in disintegration of rocks*

(b) The action of animals

Animals cause biological weathering through chemical and physical processes. Movement of large animals causes mechanical weathering. Burrowing animals such as rodents, rats, rabbits and earthworms weaken and break up the rocks. When animals and birds excrete on the rocks or when they die and decay, they release chemical substances on the rocks known as humic acid, which later on cause chemical weathering as they alter the chemical composition of the rocks.

(c) Action of human beings

Human beings perform various activities that contribute to weathering. Human activities are the fastest cause of weathering compared to all other processes. People break down rocks both mechanically and chemically in various ways. Rocks are broken down mechanically through activities such as blasting with explosives, quarrying, farming, mining and construction of roads and buildings. Movements of trucks and other heavy machinery on the ground are among other factors which may cause mechanical break up of rocks.

Human beings also weather rocks chemically by polluting the environment in different ways. For example, chemical substances are discharged into rivers, making the water corrosive and in turn, rocks that come into contact with this water are corroded and weakened. Some chemicals are dumped directly on the exposed rocks. This too can be corrosive as the chemicals react with some minerals in the rocks and cause rock disintegration.

During agricultural activities, fertilizers , pesticides and other chemical substances added in the soil increase chemical reaction that may lead to chemical weathering of rocks.

Significance of weathering

The weathering process has the following social economic benefits to the life on earth:

(a) It leads to soil formation. Weathering breaks rocks into small particles which after being mixed with organic matter lead to the formation and development of soil;

(b) It provides materials for pottery and bricks making. The weathering process produces new substances such as clay, which is used in pottery and brick making;

(c) It offers opportunity for tourism. The weathering process results in some attractive features like granite tors. These are tourist attractions that bring local income and foreign currency to a country. A good example is Bismarck rock in Mwanza Region, in Tanzania on the shore of Lake Victoria;

(d) It provides building materials. Weathering is a source of building materials. For example, scree and rock blocks can be used in the construction of houses, bridges and dams; and

(e) It can contribute to the modification of landforms. Weathering is significant because it weakens the surface rocks and in so doing it facilitates the agents of erosion and transportation hence modifying landforms. Most of the depositional features either by water or wind benefit from weathering processes. For example, deltas and estuarine features are formed as a result of deposition of weathered materials.

Activity 3. 1

1. In a group, discuss and differentiate between the following concepts;
   (a) weathering and denudation
   (b) oxidation and carbonation
   (c) hydration and hydrolysis
2. Read textbooks concerning weathering, and
   (a) with examples, explain the economic importance of weathering
   (b) make a presentation in the class for discussion.
3. Walk around your environment and observe the effects of roots on rocks. Write what you have observed.

Mass wasting

Mass wasting refers to the downward movement of weathered materials on a slope under the influence of gravity. This movement does not necessarily involve the agents of erosion and transportation such as running water, ice, wind and sea waves. Mass wasting also refers to the creeping, flowing, sliding or falling of rocks and weathered mass materials downhill. The angle of slope and gravity are the major determinants of mass wasting. The movement ranges from very slow and unobservable movement to very fast and catastrophic movement.

Types of mass wasting

Mass wasting can be categorized into two types: slow and rapid mass wasting.

Slow mass wasting

This is a slow but steady movement of material down a slope. It can be so slow such that it may not be noticeable. Types of slow mass wasting are *soil creep*, *talus creep* and *solifluction*.

Soil creep

It is the slowest and unobservable movement of weathered materials, mainly fine soil, down a gentle slope. Water acts as a lubricant in this movement. The movement can also be triggered off by grazing animals, heating and cooling of soil and alternate wetting and drying of the ground. Soil creep can be manifested through mounds of soil behind the walls, tilting and cracking of walls bending of trees, fences and electrical poles as well as cracking of the road. Figure 3.5 is an example of soil creep.

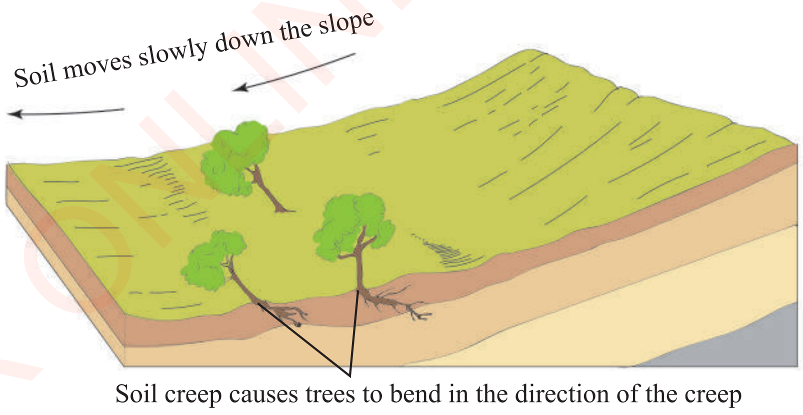


Figure 3.5: *Bending of trees due to soil creep*

Talus creep

Talus creep (scree) is a slow movement of angular waste rock of all sizes (talus or scree) down a slope. It is common on the sides of mountains, hills and scarps.

It takes place where free thaw action is common especially in the highlands and in high latitude regions. It also results in scars where the talus moves. Figure 3.6 is an example of talus creep.

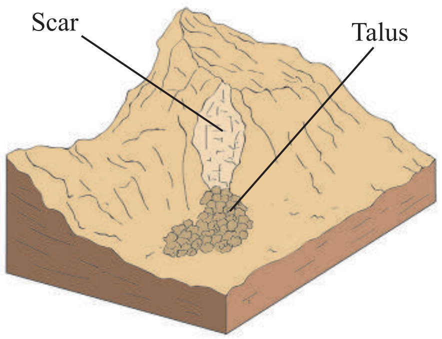


Figure 3.6: *Talus creep*

Solifluction (slugging)

This is a gravitational movement of gravel mixed with soil saturated with water, down a slope. It is limited to mountains and cold climate areas where thawing causes a saturated surface layer to flow over underlying frozen ground. This results into deposits of frozen materials known as solifluction lobes and saturated materials. Figure 3.7 is an example of solifluction.

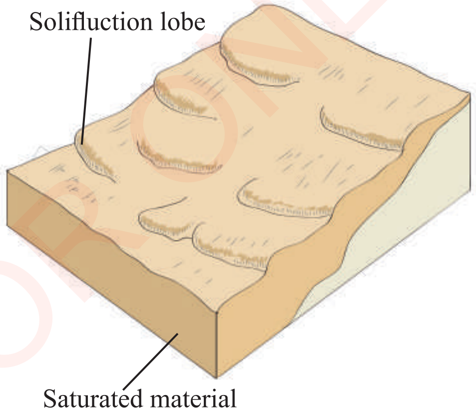


Figure 3.7: *Solifluction*

Rapid mass wasting

This is a fast and sudden movement of rock materials. It occurs in the form of landslides, which involves the slumping, sliding and falling of rocks from moderate to steep slopes. Types of rapid mass wasting include *mudflow*, *earthflow*, *landslide*, *rockslide*, *rockfall* and *avalanche*.

Mudflows

A mudflow is a rapid movement of saturated soil containing gravels and boulders, down a slope. The materials flow as semi-liquid mud with boulders and gravels embedded in the mud. Mudflows are common in arid and semi-arid areas, especially after spells of sporadic downpours. Mudflows move faster than earthflows because they contain more water while earthflows are relatively drier as shown in Figure 3.8.

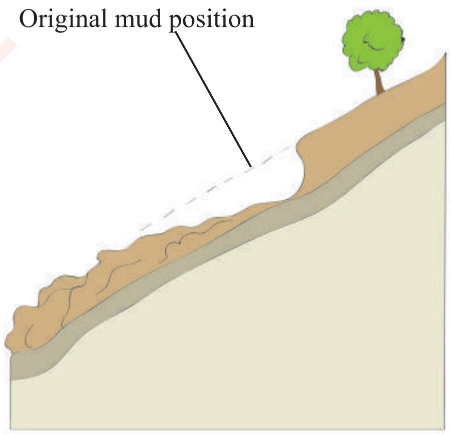


Figure 3.8: *Mudflow*

The following are some specific conditions that influence mudflows:

(a) Presence of loose materials on the surface, which become slippery when wet;

(b) Presence of a steep slope which facilitate movement of the materials; and

(c) Lack of vegetation on steep slopes which facilitates the movement of materials with high speed since the soil is not consolidated by plant roots.

Earthflows

This is a flow of relatively less saturated unconsolidated rock materials down a steep slope. It takes place after heavy rainfall where soil and other weathered materials mix with water and break away from the slope in a short time, as shown in Figure 3.9.

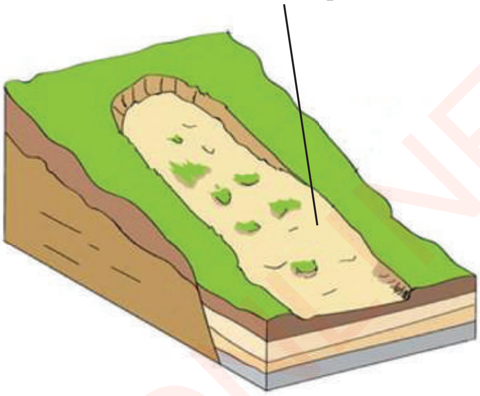


Figure 3.9: *Earth flow*

Landslides

A landslide involves slipping or slumping of the land or rock. It is a rapid movement of a large mass of debris, rocks or earth down a hill or mountain side as shown in Figure 3.10(a) and 3.10(b). Landslides are caused by the lubricating action of water, the pull of gravity and deep undercutting of the base of a steep slope by earthquake or movements. Prolonged heavy rainfall may accelerate a landslide.

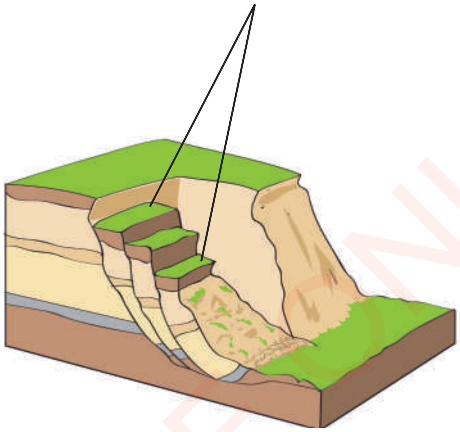


Figure 3.10(a): *Landslide*

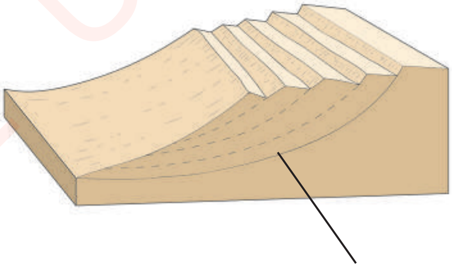


Figure 3.10(b): *Landslide*

Rockslide

This is a sliding movement of a slab or rock down a steep slope. No rotation is involved. It has a slower average speed compared to a rock fall. It can be triggered off by an earthquake or human activities like mining or cultivation, as shown in Figure 3.11.

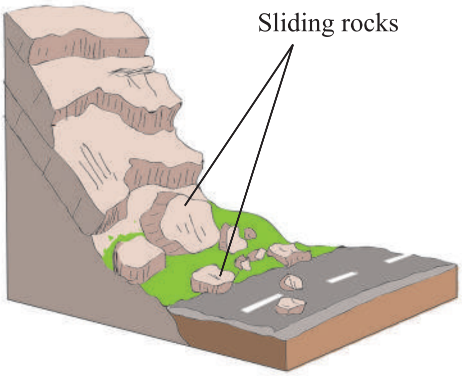


Figure 3.11: *Rockslide*

Rockfall

This is a free fall of rock masses from the top to the foot of a cliff, as shown in Figure 3.12. The prolonged falling of rocks results to collection of talus at the bottom. This is one of the fastest fall of rocks in a steep slope. It takes place after a rock has been weakened. It is caused by alternate expansion and contraction resulting from temperature variations and by ice action which excavate joints or cracks in the rock.

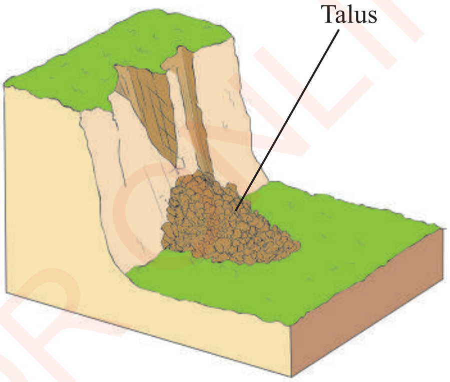


Figure 3.12: *Rockfall*

Avalanche

An avalanche is a sudden sliding or falling of a large mass of snow, ice and loose rock materials down a mountain side. It is common in temperate mountainous regions where snow accumulates to great thicknesses, as shown in Figure 3.13. Avalanches occur mostly during winter and spring. They can be caused by earthquakes, accumulated quantities of snow to great thicknesses that might create higher pressure and heat at the bottom of snow, eventually leading to sliding. Avalanches are characterised by occurrence of faults, accumulated snow, ice and rock material.

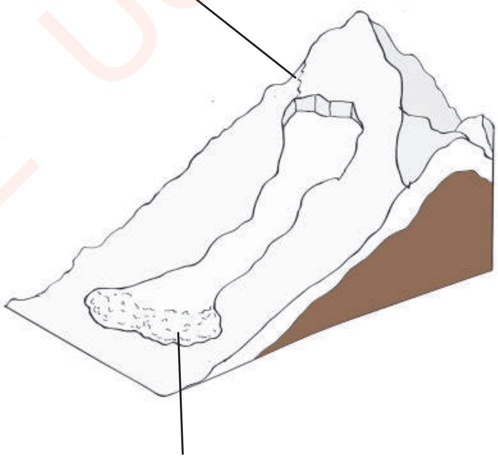


Figure 3.13: *Avalanche*

Activity 3.2

In a group;

(a) discuss the factors that trigger mass wasting.

(b) write in your exercise book, the factors that trigger mass wasting.

(c) make a presentation to your fellow students in the classroom for discussion.

Factors affecting the nature and speed of mass wasting

(a) *The nature of the materials and the extent of saturation*: In a situation where the weathered layer is very deep or where rocks are weak, thin bedded or steeply dipping mass wasting tends to be rapid.

(b) *The angle of slope*: The steeper the slope the faster the rate of movement.

(c) *Climate*: This includes the amount and nature of rainfall, annual and daily temperature ranges. Heavy rain or alternate freezing and thawing encourages movement.

(d) *The influence of vegetation*: Absence of vegetation to hold the soil material encourages movement.

(e) *Human activities*: Mining, building and herding of animals are among the ways in which human beings have affected the stability of the earth's surface. The areas which are affected by human activities tend to encourage movement of material.

(f) Earthquakes and volcanic eruptions often cause large and widespread movements.

Effects of mass wasting on the environment

Mass wasting has both positive and negative impacts on the environment as described in the following sections:

(a) *Formation of fertile soil*: The materials which are transported down slope tend to accumulate at the foot of the hills or mountains. Thereafter, they form fertile soils which did not exist before. The accumulated fertile soils can support agricultural activities.

(b) *Land degradation*: Mass wasting erodes the land on steep slopes thus making it unsuitable for agriculture.

(c) *Tourist attraction*: Features resulting from mass wasting such as rockfall and avalanches attract tourists. For example, the avalanches of Switzerland attract a large number of tourists which in turn boost the economy of the country.

(d) *Formation of lakes*: Landslide materials often end up in valleys where they accumulate and form barriers to flowing rivers. Water of the blocked rivers accumulates on the upstream side of the barriers and eventually forms a lake.

(e) *Damage of property and loss of life*: Mass wasting can destroy buildings, means of transport, and lines of communication and can even cause loss of life.

Activity 3. 3

Think on the relationship between weathering and mass wasting, then do the following:

(a) write in your exercise book the relationship between weathering and mass wasting.

(b) with the assistance of your teacher share this with your fellow students in the classroom for more discussion.

Revision exercise 3

Section A

*Match each item in **Column A** with its corresponding item from **Column B**.*

Column A	Column B
1. Peeling-off of outer layers of rock due to alternate expansion and contraction caused by temperature changes.	(a) Mechanical weathering
2. Rock disintegration caused by actions of plants and animals.	(b) Biological weathering
3. Rock disintegration which does not involve chemical processes.	(c) Denudation
4. A process resulting to formation of new types of rocks when water combines with minerals of an existing rock.	(d) Erosion
5. Removal of rock debris from one area to another, caused by wind, water or waves.	(e) Mass wasting
6. Movement of weathered material due to gravity.	(f) Oxidation
	(g) Exfoliation
	(h) Hydrolysis

Section B

Write TRUE for a correct statement and FALSE for an incorrect statement.

(a) Clearing of natural vegetation enhances the possibility of mass wasting.

(b) Scree is normally found in cold deserts due to low temperatures.

(c) Human activities like setting fire on rock boulders can cause exfoliation.

(d) Hydration and hydrolysis are basically similar processes of chemical weathering.

(e) Weathering is economically important to humans.

Section C

Fill in the blanks by choosing one of the most correct answer from the box;

hydrolysis, erosion, deposition, weathering, mass wasting, grikes, oxidation, chemical weathering

(a) The process which prepares rocks materials for movement either by gravity or by agents of erosion is _____.

(b) Landslides, soil creep and soil flow are forms of_____.

(c) _____ involves carbonation, hydration and oxidation.

(d) A process whereby oxygen combines with any substance to form a new substance is known as _____.

(e) The grooved sides of clint are called _____.

Section D

Answer the following questions:

1. Differentiate between:
   (a) chemical weathering and biological weathering
   (b) hydration and oxidation
   (c) soil flow and soil creep
2. List five processes of chemical weathering.
3. How do animals cause biological weathering?
4. Account for the role of humans in the weathering process.
5. How can the risks associated with mass wasting be minimised?
6. How can we make use of the features resulted from weathering?

Chapter Four

The action of running water and ice on the Earth's surface

Introduction

Erosion, transportation and deposition of weathered materials by running water and ice result into formation of different physical features. In this chapter, you will learn about action of running water and ice on the landscape. You will also learn about features formed by the process of erosion and deposition and importance of those features to human beings. The competencies developed from this chapter will enable you to use the formed landscape features profitably.

The work of running water

Running water refers to water that flows on the surface of the earth. This can be in the form of surface runoff, streams or rivers. Rain water or snowmelt which does not infiltrate into the ground flows on the surface as runoff. It can flow as a sheet of water, or collect into small channels to form rills and streams. When rills are enlarged, they form gullies. Water flowing by force of gravity through a defined channel is referred to as a river.

Running water in the form of runoff or rivers, plays a significant role in shaping the earth's surface through erosion, transportation and deposition. There are three types of erosion formed by runoff, namely sheet erosion, rill erosion and gully erosion.

Sheet erosion

This type of erosion occurs on slightly gentle slopes where rain water that does not infiltrate into the ground flows on the surface resulting into uniform removal of a thin layer of the top soil on large areas as shown in Figure 4.1. Where land is steep and runoff is heavy, sheet erosion progresses into rill erosion.

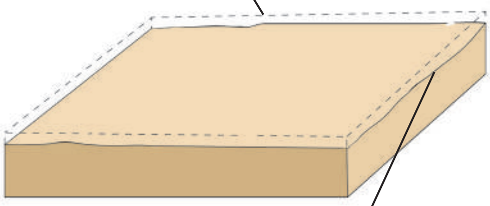


Figure 4.1: *Sheet erosion*

Rill erosion

This occurs when the surface soil is washed unevenly by running water through small channels or rills, as shown in Figure 4.2.

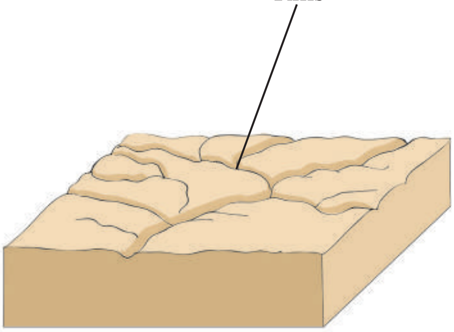


Figure 4.2: *Rill erosion*

Gully erosion

This occurs when the surface soil is washed away as heavy rainfall opens wide the rills into larger grooves known as gullies as shown in Figure 4.3.

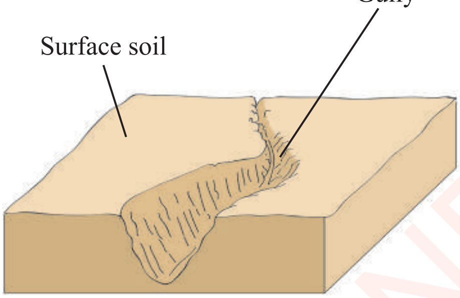


Figure 4.3: *Gully erosion*

The work of a river

A river is a large amount of water flowing in a defined channel from a source. A river performs triple functions, namely erosion, transportation and deposition of eroded materials.

(a) Erosion by a river

River erosion can occur through four related processes, namely hydraulic action, corrasion or abrasion, attrition and corrosion or solvent action

Hydraulic action

Hydraulic action is an erosive process caused by the force of moving water against river banks and river floor. When water is compressed with air, sweeps away loose materials into the river and rolls large boulders away. This process causes caving and slumping of river banks.

Corrasion

Corrasion, also known as *abrasion* is an erosive process responsible for wearing away of the bed and banks of a river, using the load carried by the river. This load comprises of gravels, pebbles and boulders which are used by the river water as grinding, scratching or cutting tools. Where pebbles are whirled by eddy currents, they excavate a river bed and form hollows called *pot-holes*.

Attrition

Attrition involves disintegration of the load itself due to constant collision of fragments with each other and colliding with river banks or the river bed. The fragments are reduced to particles of different sizes as the load moves downstream.

Corrosion

Corrosion, also known as *solution* is a process by which rock is weathered through chemical reaction and solution. It is the process by which water dissolves some rock elements and minerals resulting into rock erosion. Consequently, this process leads to the removal and transportation of rock materials in solution downstream.

Thus, causing the river to erode materials vertically, laterally and headward.

Vertical erosion. This involves the down-cutting of the river bed which consequently deepens the river channel.

Lateral erosion. This involves the side-cutting of the river banks and as a result, the river channel is widened.

Headward erosion. This involves upward erosion that lengthens the river, stream at its head.

(b) Transportation by a river

Transportation is one of the functions of a river. The eroded materials by the river actions are referred to as load. The load can be transported from one point to another. There are three types of transported load, namely bed load, suspended load, and dissolved load. These types of load are transported into four major ways: solution, saltation, traction and suspension.

Solution

Solution is a type of river transportation where the dissolved load is transported downstream through solution. Limestone can be transported in this form.

Saltation

Saltation is the type of river transportation process which involves small pebbles and stones being dragged, slid or bounced along the river bed. This kind of transportation is common near the source of a river.

Traction

Traction is a way in which a river transports its load where large boulders and rocks are rolled along the river bed.

Suspension

Suspension is a river transportation method where a suspended lighter load, is carried along in the water. This is common near the mouth of a river.

(c) Deposition by a river

This is a geographical process in which sediments, soil and rocks are accumulated on the river bed, oftenly at the lower stage of the river. Transported load can be deposited to create layers of sediments which form different features. Deposition occurs when there is a decrease in the speed of water, reduction of the gradient of the river, and an increase of the load carried at this stage. Deposition may take place where the volume of water declines due to excessive evaporation and soaking. Furthermore, deposition takes place when the river water spreads into a wide plain as it no longer has energy to carry more load or when there is an obstacle across the river channel such as vegetation or damming.

Progressive deposition forms an outward and seaward alluvium accumulation resulting in the formation of a delta. Sometimes the river is forced to divide into several channels of water outlets. These channels are called distributaries.

The long profile of a river

The stretch of a river course from its source to its mouth is called the long profile of a river. The river profile is divided into three main sections, namely the upper, the middle and the lower courses as presented in Figure 4.4(a) and 4.4(b).

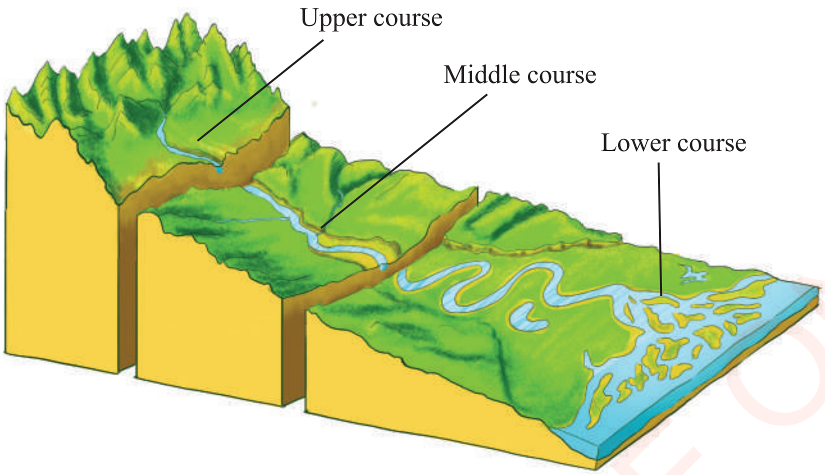


Figure 4.4(a): *Long profile of a river*

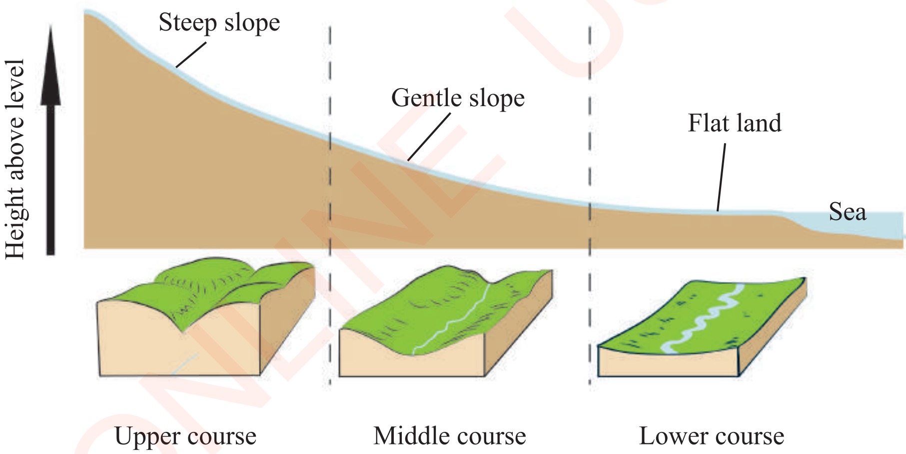


Figure 4.4(b): *Cross section view of a long profile of a river*

The upper course of a river

This course is also known as the young stage of a river. At this stage, a river is characterised with a very steep slope. Water flows with high speed resulting into vertical erosion. Vertical erosion leads to the development of a steep-sided V-shaped valley. The angle of the sides of a V-shaped valley depends on the resistance of rocks both to erosion and to the weathering process. In its upper course, the river follows a winding course due to interlocking spurs.

Features produced in the upper course of a river

At this stage the river is characterized by the following features: V-shaped valleys, pot holes, interlocking spurs, plunge pools, waterfalls, gorges, canyons and rapids. These are described below.

V-shaped valley

In the upper stage the river flows with high speed due to the steep slope of the river bed. As the river flows, it performs vertical erosion which results into a steep sided V-shaped valley, as seen in Figure 4.5.

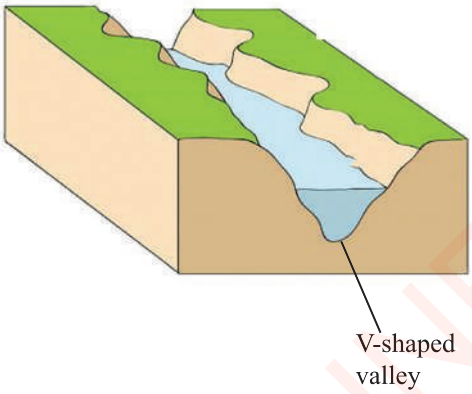


Figure 4.5: *V-shaped valley*

Interlocking spurs

As the river flows, it erodes the landscape in the upper course, winds and bends to avoid the areas of hard rock. This creates interlocking spurs which resemble interlocking parts of a zip. This often results into alternating projections of high land called spurs (Figure 4.6). Sometimes spurs are referred to as overlapping, intermediate or interlocking spurs.

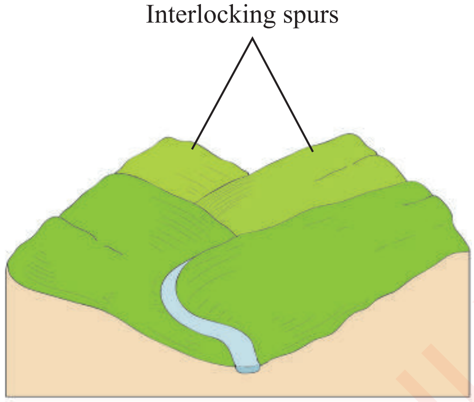


Figure 4.6: *Interlocking spurs*

Rapids

Rapids are formed by a sudden steepening of the slope because of unequal resistance in the successive rocks in the river profile. It is where the river flows faster than its normal speed (Figure 4.7).

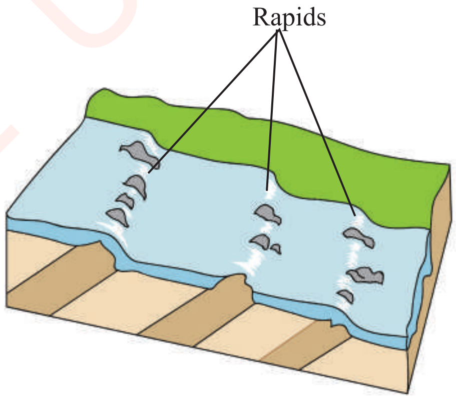


Figure 4.7: *Rapids*

Waterfalls

Waterfalls occur when there is a sharp break in a river bed. This is a result of erosion of soft rock which lies horizontally under hard rock. Waterfalls can also occur when a hard rock stands vertically along the edge of the steep sides of the river bed. The continuing process of erosion causes the hard rock to hang and as a result, water drops down suddenly (Figure 4.8).

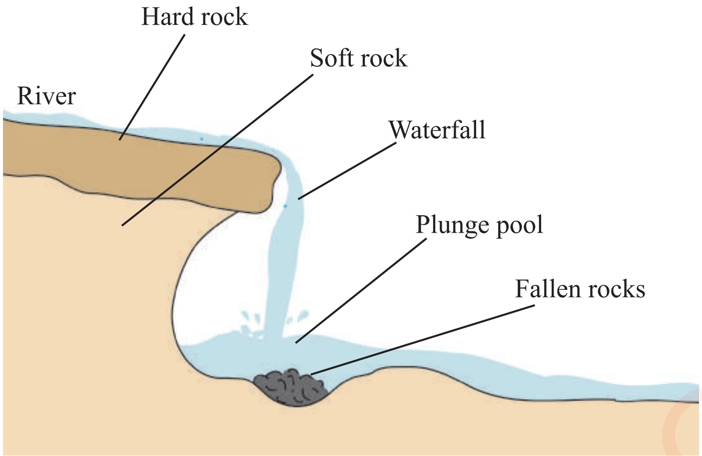


Figure 4.8: *Waterfalls and plunge pool*

Plunge-pool

These are big pot holes formed at the base of waterfalls. These are formed due high velocity of falling water into the river bed (Figure 4.8). This is a result of hydraulic action.

Pot holes

These are circular depressions on the river bed formed by the swirling action of a river where pebbles carried in the water form a circular depression on the river bed and leave holes on it (Figure 4.9).

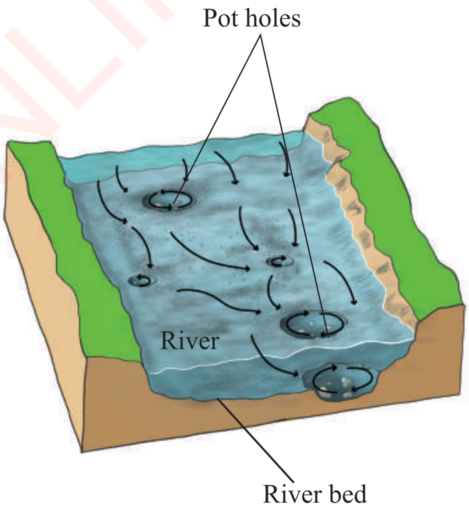


Figure 4.9: *Pot holes*

River gorges and canyons

Gorges are deep and narrow elongated steep sided valleys or troughs formed as a result of vertical erosion of a river. A canyon is a widened deep gorge. Conditions for formation of gorges include the following:

(a) It is formed where river erosion cuts down more rapidly than the forces of weathering. For example, the Indus and Brahmaputra gorges were formed by powerful rivers cutting down at the same rate in the Himalaya ranges. Other gorges include the Grand Canyon of the Colorado River in U.S.A which is nearly 500km long and has a depth of 1.9 km.

(b) It is formed when a river cuts through limestone rocks in arid regions. An example is the Grand Canyon of the Colorado River in the U.S.A, the largest and best-known canyon in the world.

(c) When a waterfall is formed on a resistant rock layer that is horizontal or is gently dipping upstream. Stiegler's Gorge found in Rufiji river in Tanzania is an example for this condition.

(d) When the river flows in a faulted river bed which makes it erode more vertically than laterally.

The middle course of a river

This is also known as the mature stage of a river. It is characterised by a gentle slope which decreases water velocity. The major function of a river at this stage is transportation of the load and lateral erosion that opens up the valley to attain a U-shaped valley. Boulders and pebbles are deposited at this stage. The river valley attains almost a straight course. At this stage, the river may be joined by tributaries, hence increase in river volume. The increase of the river volume leads to the increase of energy to carry large river load. At this stage the main activity of the river is transportation. Besides, the deposition function of the river starts. Features formed at this stage are meanders and bluffs on the outside bank and slip off slope on the inside meander.

Meanders

Meanders are formed when a river performs lateral erosion, which leads to the development of curves as a result of deposition of the river load on the concave side, as shown in Figure 4.10. Examples of river meanders are found along river Ruaha in Iringa, Tanzania.

Bluffs

Bluffs are raised steep banks bordering the river, formed after the interlocking spurs have been cut back through lateral erosion, thus the river valley becomes wide. Figure 4.10 is an illustration of bluffs.

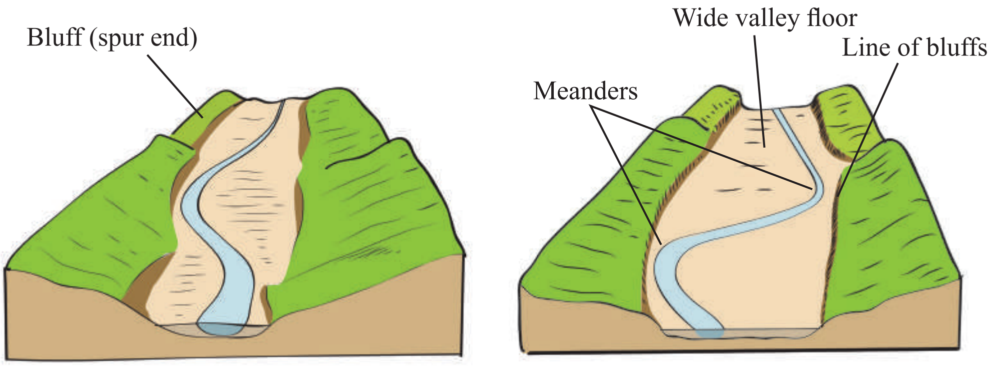


Figure 4.10: *Meanders and bluffs*

The lower course of a river

This is the lowest section of a river course. It is also known as old stage of the river. At this stage, the river meanders over a broad flood plain. In this section, deposition on the river course is the main function. The gradient of the river is very low and so deposition occurs due to insufficient energy of the river to carry its load. The load carried becomes heavier and deposition takes place both on the river floor and on the river banks. The heavy load such as gravel is deposited vertically on the bed while the finer and less heavy load is deposited laterally on the river banks. Features associated with the lower course of the river include *flood plains*, *natural levees*, *ox-bow lakes* and *delta*.

The flood plain

A flood plain refers to an area of gentle or flat land bordering a river with deposited sediments. Beyond this lower stage, lie wetlands and ox-bow lakes. When the natural levees break, the river invades the adjacent plains (flooding) and deposits a large quantity of silt which turns into alluvial soil. Alluvial soils are fertile and therefore suitable for agriculture. The flood plain is characterised by deposition of a load of sand and silt carried by the river. It is also characterized by meanders which are prominent and cut-off develops and produces ox-bow lakes.

An ox-bow lake

An ox-bow lake is a crescent-shaped lake that is formed from river meanders cut off from main stream in the flood plain. Ox-bow lakes are typical features of meandering rivers, and result from river erosion on concave banks and deposition on convex banks. Erosion on concave banks enables the river to make a new way while deposition on the convex slopes helps to silt up the former course. Stages in the development of an ox-bow lake are described below:

(a) Development of river meanders. The river keeps on twisting and turning in the flood plain. Concave and convex banks develop. A neck of land separates two concave banks where erosion is active

(Figure 4.11). The narrow neck of land between the two concave banks is narrowed by erosion.

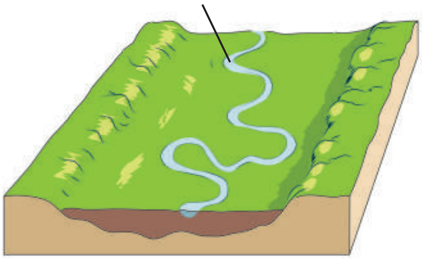


Figure 4.11: *Meander*

The neck is finally cut off to a new way. At this stage, deposition begins to seal up the ends of the meander (Figure 4.12 a and b).

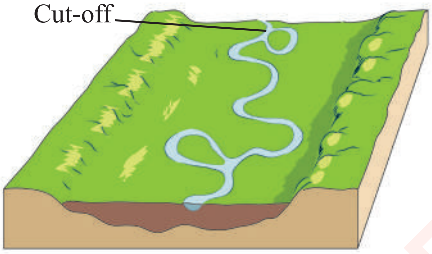


Figure 4.12(a): *Meander cut-off*

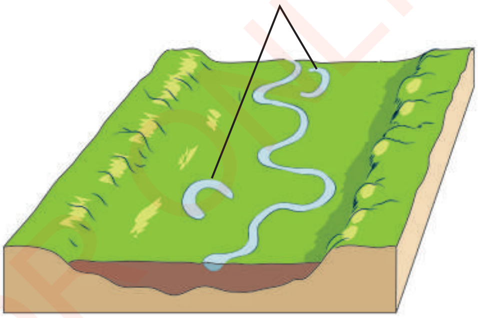


Figure 4.12(b): *Ox-bow lake*

(b) Deposition takes place along the two ends of the cut-off and it is eventually sealed off to form an ox-bow lake. After the formation of an ox-bow lake, the river lies above the level of the ox-bow lake due to the raising of the river bed and banks. Examples of ox-bow lakes are found in the flood plains of Rufiji river in Tanzania and Mississippi river in the U.S.A. Sometimes due to decline in gradient, a flood plain may be formed at the middle stage of a river. Example in Ruaha river in Tanzania.

A natural levee

A natural levee protects a river from flooding. When a river flows over its banks at flooding season, deposition takes place on the river banks. Repeated flooding causes the banks to be raised to form levees. Levees are formed as a result of lateral deposition of sand and silt (Figure 4.13). They protect the river from evading the adjacent plains.

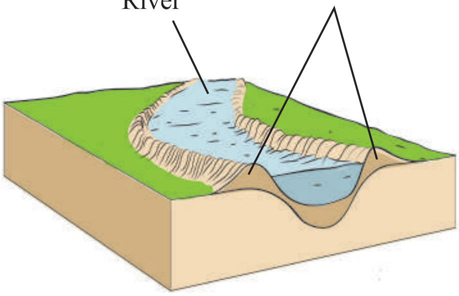


Figure 4.13: *Natural levees*

Deferred junction and deferred stream

After a long period of deposition, the bed of a river is also raised. In some occasions a river flows above the level of its flood plain. When this happens, the tributaries find it difficult to join the main river. As a result they flow parallel to the main river for a considerable distance. This delayed junction with the main stream is called a deferred junction and the tributary in the flood plain is called a deferred stream, as shown in Figure 4.14.

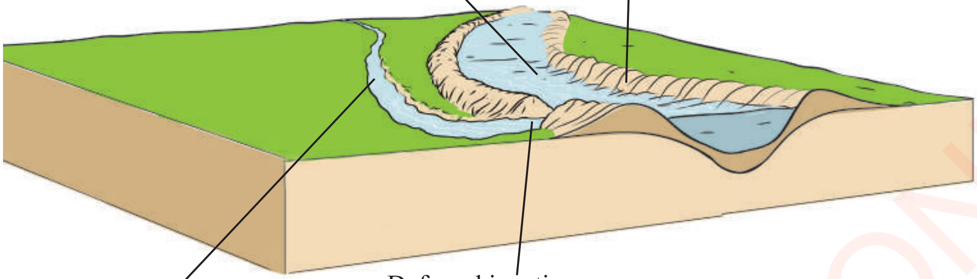


Figure 4.14: *Deferred junction and deferred stream*

Delta

Progressive deposition of a load at the old stage of a river leads to the formation of a delta. A delta is a low-lying swampy plain which slowly becomes colonized by various types of plants. The growth of a delta interferes with the flow of a river causing the river to split up into several separate channels in the same way as river braids. A river flowing over its delta divides into branches called distributaries. Rivers that flow into the open ocean with strong waves do not form deltas. This is because running water carries all the sediments away as fast as they get deposited. The following are the necessary conditions for the development of a delta:

(a) There should be active erosion in the upper and middle courses of the river to obtain enough load.

(b) The gradient of the river should be very low.

(c) There should be no large lakes in the upper and middle courses of the river. The presence of lakes and reservoirs in the upper course reduces the river speed and allows deposition before reaching the flood plain.

(d) The coast where the river enters a lake or ocean should be tideless and sheltered from strong currents, to avoid washing away of the load.

(e) There should be a shallow adjoining sea or continental shelf to allow deposition. However, it should be an area with weak back wash waves.

Types of deltas

There are four types of deltas, namely arcuate delta, bird's foot or digitate delta, estuarine delta and cuspate delta.

An arcuate delta

Refers to a type of delta which is triangular in shape. It is composed mainly of coarse sediments such as gravels and sand. Arcuate deltas have a large number of distributaries. Examples of arcuate deltas are the Nile delta in Egypt and the Rufiji delta in Tanzania (Figure 4.15).

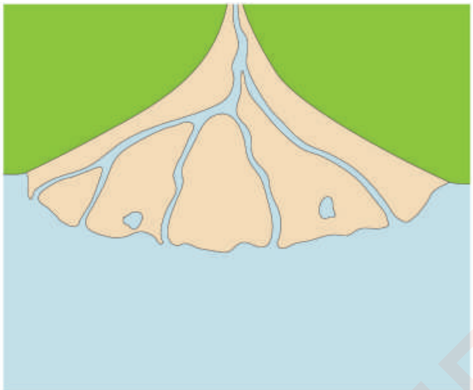


Figure 4.15: *Arcuate delta*

A digitate delta

It is a type of delta which looks like the foot of a bird, with claws. That is why it is referred to as a bird's foot delta. It is composed of very fine material called silt. This type of delta has long distributaries which are far apart and dominated by levees. Weak currents and sea waves contribute much in the formation of a digitate delta. The delta is characterized by few distributaries (Figure 4.16). Examples of such deltas are Mississippi River delta in USA and Omo River delta in Ethiopia.

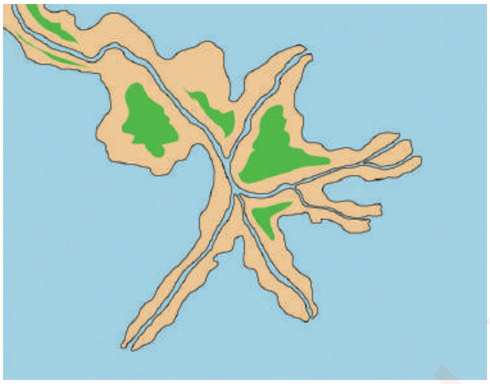


Figure 4.16: *Digitate delta*

An estuarine delta

This refers to a type of delta that develops in the submerged mouth of a river, called an estuary. Its shape is that of an estuary. Due to the presence of tides, this type of delta does not extend out to the sea. Waves and currents remove the sediments as they are deposited (Figure 4.17). Examples of estuary deltas are River Ob in Russia, River Volta in Ghana and River Congo in the Democratic Republic of Congo (DRC).

Figure 4.17: *Estuarine delta*

A cuspate delta

This is a tooth -like delta, formed where a river reaches a straight coastline with a strong wave action. There is uniform spreading of materials on either side of the river mouth (Figure 4.18). Lagoons are rarely found there. Examples include the deltas of rivers Ebro in Spain and Tiber in Italy.

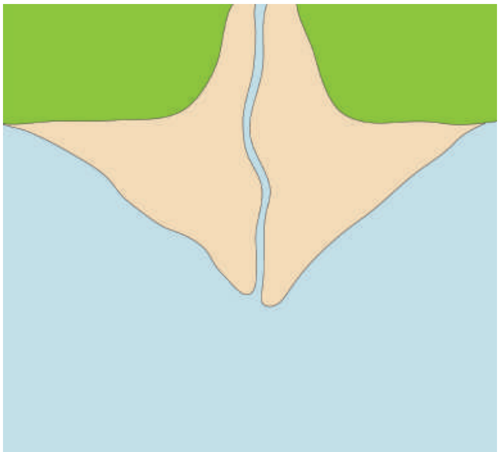


Figure 4.18: *Cuspate delta*

Exercise 4.1

Answer all questions.

1. Draw a long profile of a river and outline the characteristic features of each stage.
2. With the aid of diagrams, describe why erosion is dominant at the upper stage and deposition at the old stage of the river.
3. What are the conditions necessary for the formation of an ox-bow lake?

River rejuvenation

River rejuvenation is a renewal of the erosive power of a river. The river is characterized by vertical erosion at the upper course which deepens its valley. River rejuvenation can be caused by an uplift or fall of the land. It is also formed where a new and an old river meet and when there is increase in the river volume which can be caused by heavy rainfall or melting of ice.

Depending on the nature of the underlying rocks, river rejuvenation can lead to the formation of *knick points*, *paired terraces* and *raised meanders*.

Knick points

These are formed when there is a break of slope of the river bed due to occurrence of faults along the river. They are marked with the presence of waterfalls.

Paired terraces

These are formed when the vertical erosive power of the river undercuts the river banks to form steps or benches on the sides of the river (Figure 4.19).

Incised meanders

These are formed when vertical erosion of the river cuts the meanders deeply into the river floor. The slopes of the meanders may differ due to undercutting and lateral erosion of a river. One side may be steeper than the other side of the slope (Figure 4.19). Incised meanders can be symmetrical if the sides are equally standing or asymmetrical if one side is steeper or gentle than the other.

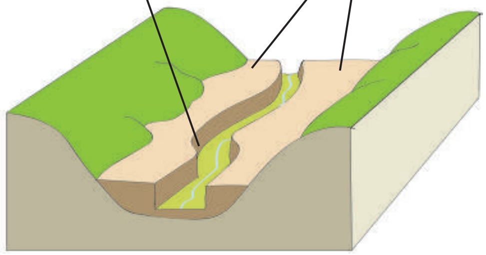


Figure 4.19: *Paired terraces and incised meanders*

Activity 4. 1

In a group:

(a) discuss and write down how the renewal process of a river can occur at the mature stage of the river.

(b) make a presentation in the classroom.

Drainage system of a river

Drainage is a natural or artificial removal of surface and sub-surface water from one area to another. The area drained by a river and its tributaries is known as a river basin. A drainage system can also be referred to as a drainage network. The main river and its tributaries form a river system. Rivers form layouts called *drainage patterns*. A drainage pattern is the spatial layout or arrangement of a river. It is a geometric shape that a river forms as a result of different geological structures, climatic condition or denudation history of the area.

There are two main systems of river drainage, which are *accordant* and *discordant* drainage systems. The types of drainage patterns are determined by rock structure, its hardness and nature of slope as well as erosive power of the river system. These factors have influence on the development of several drainage patterns. The major ones are discussed in this section.

An accordant drainage system

An accordant drainage system is one which correlates to the relief and geology of the area it flows. The drainage pattern that is largely a reflection of the geomorphological and geological structure of the place is divided into five drainage patterns, namely *trellis, rectangular, radial, dendritic* and *centripetal*.

Dendritic pattern

This is a pattern which looks like a trunk of a tree with its branches or like a leaf with its veins. A pattern has many tributaries from different directions joining the main river at an acute angle (Figure 4.20). This pattern is common in the world and generally develops in low relief areas (with gentle slopes and uniform rock structure). The direction of a river and its tributaries is determined by the slope. River Rufiji, Pangani and Ruvuma provide dendritic drainage patterns in Tanzania.

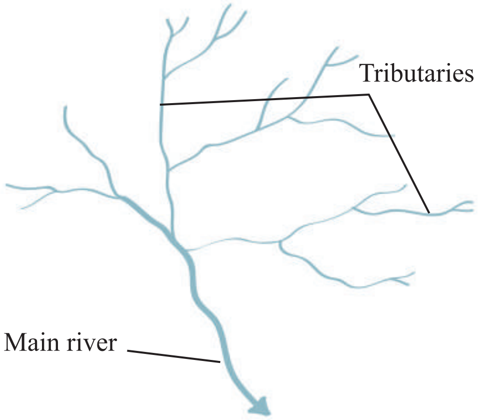


Figure 4.20: *Dendritic drainage pattern*

Trellised pattern

It is a pattern that develops in areas with alternate hard and soft rocks. The tributaries join the main river valley at almost right angle. They develop mainly in limestone regions (Figure 4.21).

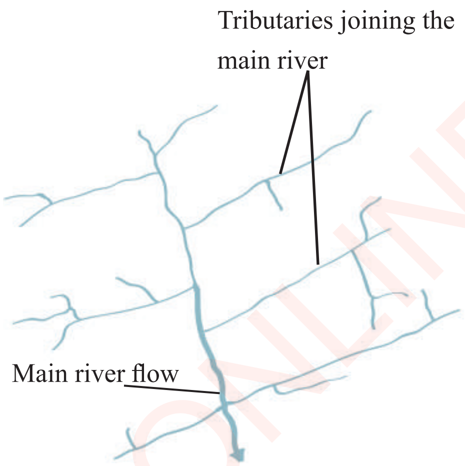


Figure 4.21: *Trellis drainage pattern*

Rectangular pattern

This is a pattern which is similar to the trellised, but it has tributaries joining the main river at a right angle (Figure 4.22). Rectangular patterns are common in areas which are faulted and a good example is the Bamenda Highlands in Cameroon. It is a result of structural control with streams following joints or fault lines.

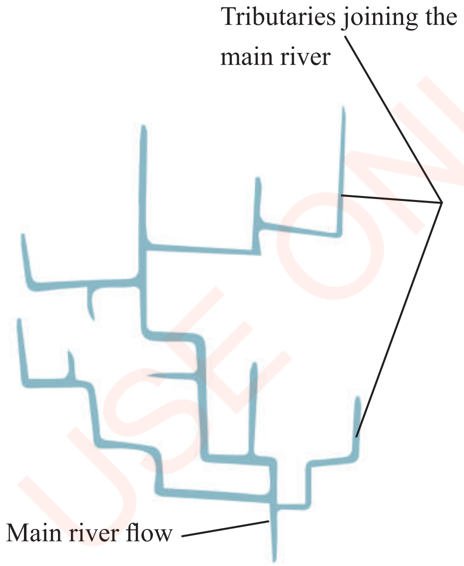


Figure 4. 22: *Rectangular drainage pattern*

Radial pattern

It is a drainage pattern or arrangement of streams flowing outwards, down the flanks or slopes of the dome or cone shaped upland, like a large volcano (Figure 4.23). The stream flows outward from the summit in all directions. Radial patterns are found in the flanks of mountain Kilimanjaro, Elgon, Cameroon and Kenya.

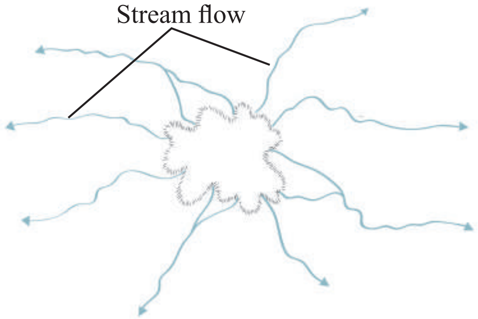


Figure 4.23: Radial drainage pattern

Centripetal pattern

This is a drainage pattern in which all streams flowing from all directions converge at the centre in the basin. The determining factor for its occurrence is slope. A centripetal pattern usually forms an inland drainage (Figure 4.24). Examples of a centripetal drainage include drainage into lakes Naivasha, Baringo, Turkana in Kenya, and Lake Chad basin in Chad. Other examples include Lake Balangida in Hanang District and Lake Haubi in Kondoa, Tanzania.

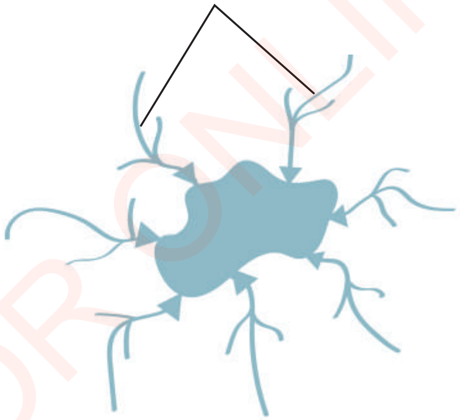


Figure 4.24: *Centripetal drainage pattern*

Discordant drainage

A discordant drainage system is one which does not follow existing relief features and geological structure of the area. It is divided into two patterns, namely *antecedent* and *superimposed drainage*.

Antecedent drainage pattern

This is a drainage system where the river maintains its course by cutting the newly uplifting relief keeping pace with uplifting process (Figure 4.25). Examples of antecedent drainage include River Ruaha in Tanzania and Brahamaputra and Indus in India.

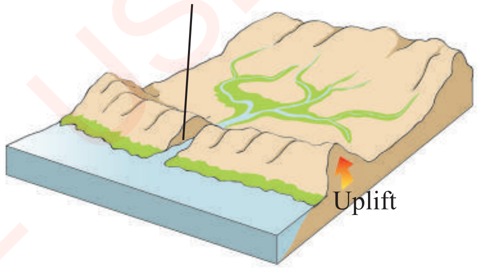


Figure 4.25: *Antecedent drainage pattern*

Superimposed drainage

A superimposed drainage pattern is a system which does not adjust with the structure of the original rock by cutting deeper through the existing landforms. It does not adjust no matter the hardness of the rock materials, but rather maintains the same path, as illustrated in Figure 4.26.

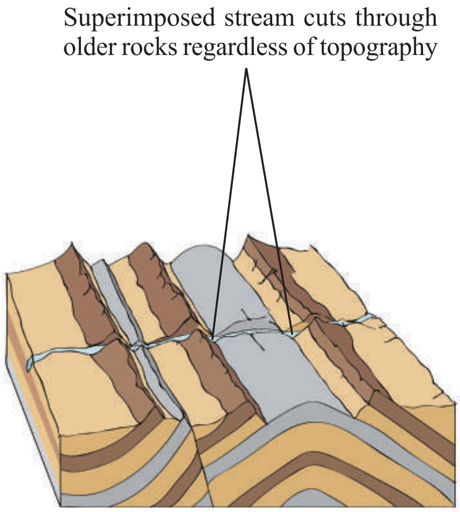


Figure 4.26: *Superimposed drainage pattern*

Figure 4.27 presents an illustration of river drainage system categories.

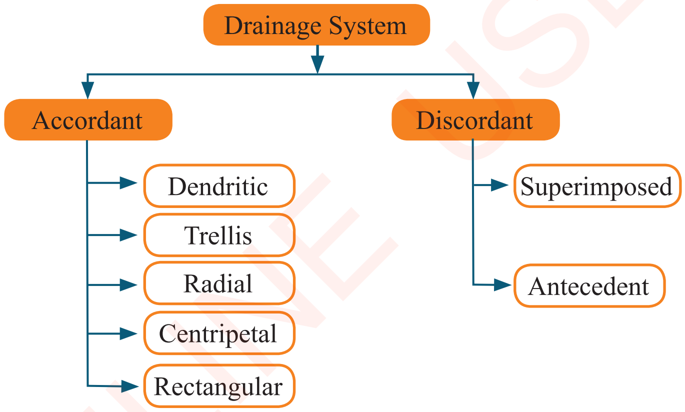


Figure 4.27: *Drainage systems and patterns of a river*

River capture

River capture also known as river piracy, is a process whereby a powerful river diverts the course of the other neighboring weak rivers into its own course (Figure 4.28). A stronger river develops a pirate stream which advances towards a weaker river until it totally captures the weaker river and diverts it to the stronger river course.

Conditions necessary for a river capture to occur

A river capture occurs due to the following conditions:

(a) The capturing river should be stronger or must have greater energy for vertical erosion than the weak river;

(b) The capturing river must be lying at a lower level and usually with a steeper gradient than its weaker river;

(c) The capturing river must be flowing over relatively softer rocks. For example, limestone rocks which are easily eroded;

(d) The two rivers must fall in the same catchment area; and

(e) The capturing river must have a pirate stream which has both powerful vertical and headward erosion.

Landforms resulting from a river capture

River capture can lead to the formation of *pirate stream, elbow of capture, misfit river* and *wind gap* as shown in Figure 4.28.

Pirate stream

This is referred to as the capturing river. It is powerful and performs headward erosion to capture the neighbouring weak river.

Elbow of capture

It is a band produced when a river has been diverted. However, not all right-angled bends in rivers are due to river capture.

Misfit river

It is a beheaded stream having lost headwaters due to river-capture and has been reduced in volume such that it becomes too small for its valley.

Wind gap

It is a valley of the beheaded stream below the point of capture or elbow and its base may be dotted with gravel or alluvium. The wind gap is also referred to as a dry valley.

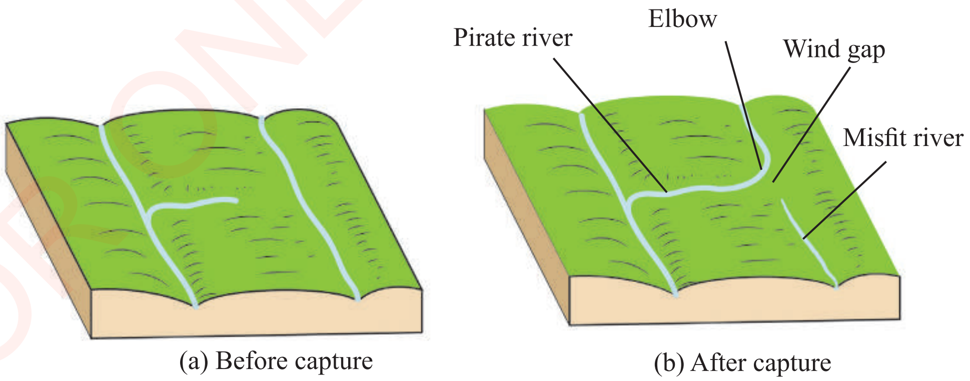


Figure 4.28: *Features formed by river capture*

River regime

River regime refers to the seasonal fluctuation of water volume in the river. The following are three major types of river regimes: *simple*, *double* and *complex* regimes.

Simple river regime

This is a regime in which there is one period of maximum volume of water on rain season and one period of minimum volume of water on dry season. Ruvuma and Ruaha rivers in Tanzania are good examples.

Double regime

Occurs where a river attains double maxima and minimum of water volume. A period of maxima volume of water occurs along the equatorial zone like Congo river. The increase of volume of water resulting from early summer snow melt and autumn-winter rains like Rhine river in Europe. Double regime also occurs in equatorial region where rivers like Congo and Amazon experience maxima on March and September.

Complex regime

It is a regime of rivers passing through various climatic regions. Such rivers have several periods of maximum volume of water since their tributaries flow through regions with different rain seasons. Examples of rivers with complex regime are Nile river in Africa and the Mississippi in U.S.A. The Mississippi river receives water from different tributaries of Tennessee and Ohio rivers.

Impacts of rivers to human life

Rivers have both positive and negative impact on human beings as discussed in the following subsections.

Positive impact of rivers

(a) Rivers provide water for domestic uses such as cooking, drinking and washing. For example, River Ruvu is a source of water for Dar es Salaam;

(b) Rivers provide ideal sites for the generation of Hydroelectric Power (H.E.P). For example, the Pangani and Kihansi falls in Tanzania and Victoria falls along Zambia-Zimbabwe border are used to generate H.E.P. The power is useful in industries and homes;

(c) Alluvial deposits provide fertile soils which are suitable for crop farming, for example, the Rufiji River Basin in Tanzania, the Nile Valley in Egypt and the Hwang-Ho River Valley in China;

(d) Rivers are sources of water for irrigation schemes. For example, the Kilombero sugarcane plantations in Tanzania are irrigated by water from Kilombero river, the Gezira irrigation scheme in Sudan gets water from the Blue Nile, also the Mwea-Tebele irrigation scheme in Kenya;

(e) Rivers provide a habitat for aquatic organisms such as fish and frogs. Such organisms are for example, Kihansi frogs which are a source of tourist attraction;

(f) Some rivers are navigable, so they can be used to transport goods and people from one place to another. Examples are Congo river in the Democratic Republic of Congo, Nile river in Egypt, the Rhine river in Europe and the Mississippi in U.S.A; and

(g) Some rivers are used to mark boundaries between territories or geographical units. For example, River Ruvuma marks the boundary between Tanzania and Mozambique.

Negative effects of rivers

Rivers can also have negative impact on human life as shown below:

(a) If polluted, rivers can spread waterborne diseases such as cholera and bilharzia;

(b) Dangerous animals such as crocodiles and hippos live in rivers. These animals attack fishermen and other people who use rivers or live nearby such areas; and

(c) During times of heavy rains, river banks can overflow and cause floods that may lead to loss of biodiversity, life, properties and destruction of important infrastructures.

Groundwater

Water which penetrates through the soil into the bedrock is called groundwater. Some water seeps through permeable rocks. Permeable rocks allow water to infiltrate through because they are porous or pervious. Porous rocks have open texture, coarse-grained constituents and loose cementation. These rocks include sand, sandstone and gravel. Pervious rocks such as carboniferous limestone, chalk and jointed granite have joints and fissures through which water passes.

Rocks which do not allow water to infiltrate are refered as impermeable rocks. If the impermeable rock underlies a permeable rock the latter becomes a water-holding rock. The water holding rock is sometimes called an *aquifer* (Figure 4.29). Examples of impermeable rocks include granite, gabbro and cliorite. The percolation of water stops when it reaches impermeable rock, forming a level of saturation or water-table. The pores of rocks at this place are always filled with water. The level of the water table fluctuates with seasonal changes in temperature and precipitation. The lowest level of water in an aquifer is called the permanent water table. Any level above it is a temporary or seasonal water table. Aquifers are important sources of water.

Groundwater may appear on the surface as springs or wells. A spring may push out water depending on the nature and relationship of the rocks in which the groundwater is held. A well differs from a spring in the sense that, the well is dug by man to extract water from the aquifer. The position of the water table is of vital importance in the sinking of wells. Wells which are sunk far down to the permanent water table contain water throughout the year while those sunk just to the temporal water-table often dry up in the dry season.

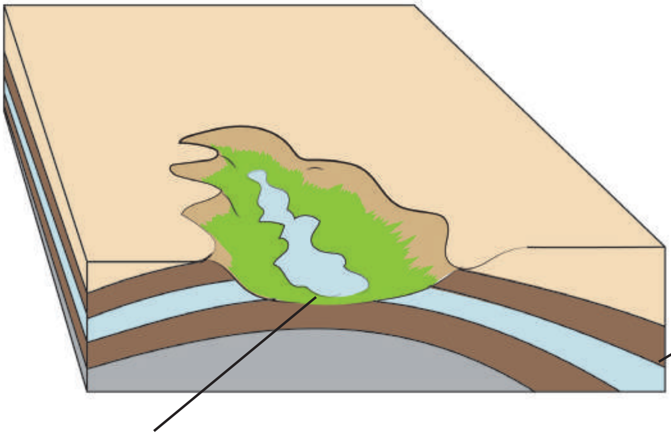


Figure 4.29: *Aquifer*

Groundwater in limestone or karst regions

Groundwater influences the formation of landforms in limestone regions. A limestone is a well jointed permeable rock of calcium carbonate. Groundwater is absorbed into the limestone rock and mostly penetrates downward through joints. There are many features that are formed on the surface of limestone regions and others are formed under the ground. Surface features include *sink holes* or *swallow holes, dolines, uvala* and *polje* (Figure 4.30).

These features are formed when water containing weak carbonic acid enters the rocks through joints and dissolves them as it seeps down the cracks. A hole through which a river enters the underground water is called a sink-hole or swallow hole. These holes may merge to form large hollows called dolines. When many dolines join together, they form uvalas and when several uvalas merge they form a very large depression known as polje. As most of the surface water disappears underground, there is an absence of surface drainage in these areas.

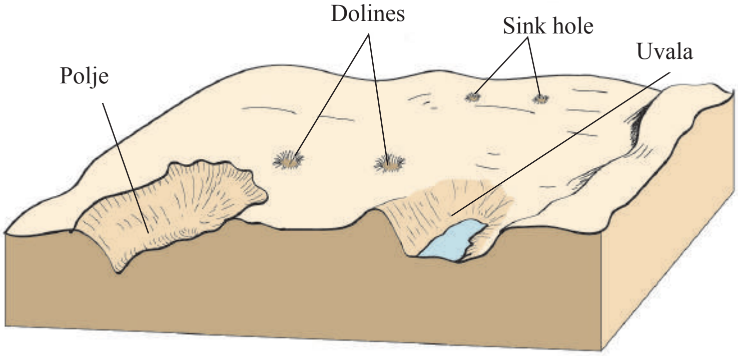


Figure 4.30: *Surface features in limestone regions*

Features that are formed underground in a limestone region include *caves, stalactites, stalagmites, natural pillars* and *resurgence rivers* (Figure 4.31). Beneath the surface, the weak acidic water continues to dissolve the rock forming caverns or caves. As the dissolved rock drops from the roof of the caverns through joints and falls to the floor, water evaporates, leaving behind rock features.

Stalactites are sharp and slender calcite features growing from the roof of the cave pointing downwards while the rock solution that drops on the floor of the cave grows slender structures of calcite that point from the floor upwards known as stalagmites. When stalactites and stalagmites join, they form natural pillars. Some examples of caverns, stalactites, stalagmites and pillars are found in Amboni Caves in Tanga, Tanzania. Some of the groundwater may flow for long distances as underground rivers before finding its way to the surface as resurgence rivers. The roofs of underground caverns and rivers may collapse to form *gorges*.

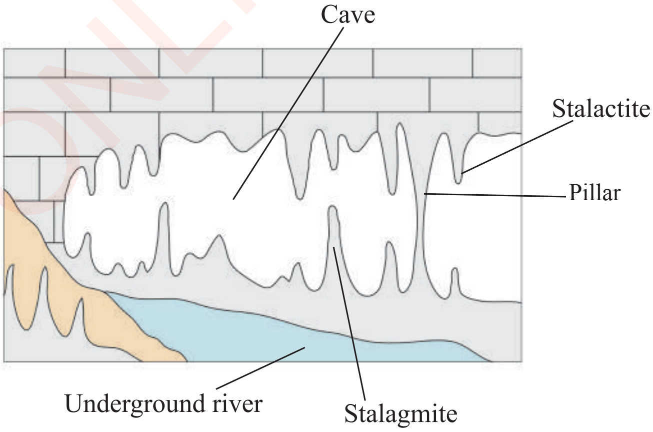


Figure 4.31: *Ground features in a limestone region*

Exercise 4.2

Answer all questions.

Choose the correct answer.

1. Which of the following is an agent of erosion, transportation and deposition of materials on the earth's surface _____.
   (a) mass wasting
   (b) running water
   (c) weathering
   (d) vulcanicity

2. Rain water which flows on the surface without following a proper channel is called?
   (a) groundwater
   (b) river
   (c) runoff
   (d) spring

3. The section of a river characterized by a sharp V-shaped valley and interlocking spurs is_____.
   (a) the old stage
   (b) the middle stage
   (c) the young stage
   (d) the mature stage

4. Meanders and ox-bow lakes are characteristic features of rivers in the _____.
   (a) young and old stage
   (b) long profile stage
   (c) middle and old stage
   (d) old and young stage

5. The young stage of a river is usually dominated by _____.
   (a) erosion and transportation
   (b) erosion and deposition
   (c) transportation and deposition
   (d) erosion only

6. Renewal of a river's power to erode its valley is called _____.
   (a) river capture
   (b) river meanders
   (c) river rejuvenation
   (d) river drainage

7. River piracy develops as a result of _____.
   (a) decrease in erosive power of a weak stream
   (b) washing away of interlocking spurs
   (c) deposition in the middle stage of a weaker stream
   (d) backward or head ward erosion into a weaker stream

8. At which stage of a river is deposition dominant?
   (a) The young stage
   (b) The old stage
   (c) The middle stage
   (d) All stages

9. One of the conditions for the formation of a delta is that, there must be _____.
   (a) enough load deposited in the middle course
   (b) active erosion in the upper and middle courses
   (c) a coast characterized by heavy tides, especially where the river enters the sea
   (d) enough load deposited in the upper and lower courses

Action of ice

When water temperature falls below freezing point, solidifies to form ice. The action of ice on the earth is referred to as *glaciation*. Tiny droplets of water (water vapour) in the atmosphere may also freeze to form white powdery flakes called *snow*. In polar and sub-polar regions, extensive areas may be covered by a permanent thick layers of ice and snow called ice sheets.

Thick accumulation of ice on a slope makes the bottom layers melt under pressure. This action triggers off the movement of ice downslope. A mass of moving ice is called a glacier. Glaciers are common in polar and subpolar regions on snowcapped mountains in temperate regions and on very high snowcapped mountains in the tropics. Examples are the glaciers on top of Mount Kilimanjaro in Tanzania.

A *snowline* is a line on a hill slope or mountain side that represents the lower limit of permanent snow. Below this line, the snow that falls during summer will melt. The elevation of the snow line varies considerably in different regions. In the tropics, the snowline is as high as 5 500 metres above sea level. Glacial erosion involves the processes of plucking, abrasion and sapping. Plucking involves the removal of blocks of bedrock which have been loosened by ice. This process is common in areas with jointed rocks. Abrasion occurs when rock debris frozen into the base of the glacier is dragged over the surface bed rock thus eroding the surface. Sapping involves wearing of rocks by alternate freezing and thawing of water at the base of cracks along the mountain sides.

Highlands glacial erosional features

Features produced by glaciations in highlands differ from those produced in lowlands. While in the highland there is erosion, in the lowlands there is deposition. The main features produced in highland glaciated areas include *arêtes, cirques, pyramidal peaks, hanging valleys, glacial lakes, truncated spurs, u-shaped valleys, ribbon lakes* and *fiords* (Figure 4.32). These features are formed through glacial erosion processes of plucking, abrasion, freezing and thawing (sapping).

A cirque

This is also known as a corrie. It is a steep sided, semi-circular basin curved on the side of a mountain by a glacier. Plucking on the back wall of the basin steepens it, while abrasion on the floor deepens it. Sometimes a cirque can be filled with water to form a corrie lake or tarn. Telek Tarn on the slope of Mount Kenya is an example of a corrie lake.

An arêtes

This is a steep-sided-knife edged ridge separating two cirques or corries in a glaciated highland area. It is formed by plucking back of the cirque. Examples of arêtes are found on the sides of mount Matterhorn in the Swiss Alps, in Switzerland.

A pyramidal peak

It is a sharp peak formed when the sides of the cirques are cut and deepened by frost action.

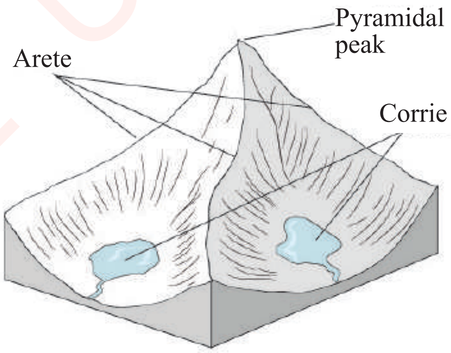


Figure 4.32: *Erosional glaciation features in highland*

A u-shaped valley

It is a steep-sided valley with a flat floor produced by vertical and lateral erosion of moving ice. Hanging valleys are produced by unequal down cutting on the tributary valleys and the main valley. Greater erosion of the main valley by the greater mass of ice will deepen the floor so that the tributary valleys hang above the main valley and form a hanging valley. When a glacier flows through interlocking spurs it straightens the valley by cutting the projecting spurs to form truncated spurs with steep ends.

Lowlands glacial erosional features

Erosional features of glaciated lowlands are roche moutonnee and crag and tail. These features are described in the section that follow.

Roche moutonnee

It is formed when a resistant residual mass of rock rises above the surrounding land surface. The upstream side is smoothed by ice abrasion but the leeside of the rock is plucked to form a steep slope (Figure 4.33)

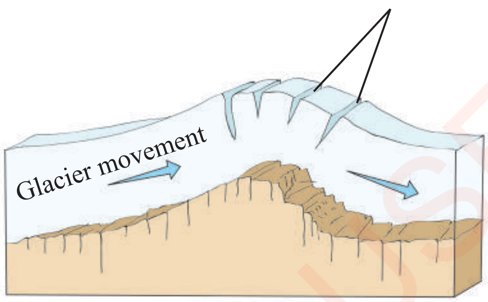


Figure 4.33: *Roche moutonnee*

Crag and tail

This is a mass of resistant rock with a steep ice smoothed rock face at one end and a gentle slope of a rock glacier drift at the other side of the rock (Figure 4.34).

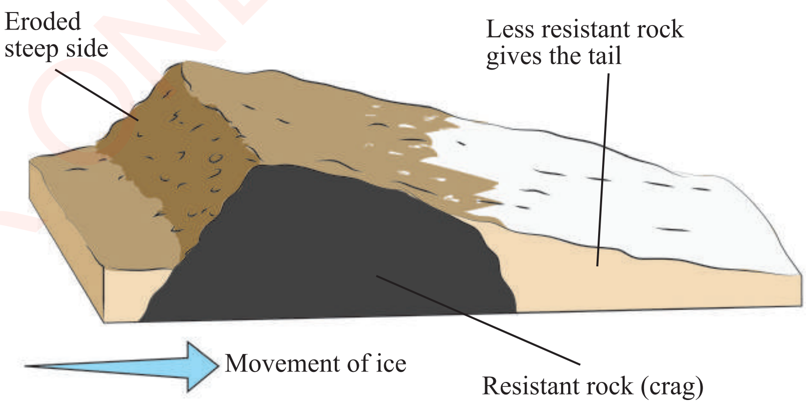


Figure 4.34: *Crag and tail*

Glacial depositional features

Depositional features produced in highland glaciation include *moraines, drumlins, eskers, outwash plains, erratic* and *boulder clay plains* as shown in Figures 4.35 and 4.36.

Moraine

These are rock particles and fragments mainly transported and deposited by glacier. There are four types of moraines namely lateral, medial, ground and terminal (Figure 4.35). A lateral moraine is the load carried along the sides of a glacier. A medial moraine is formed when adjacent lateral moraines join while a terminal moraine is a bulk of the debris transported at the front of the glacier and deposited when the glacier melts. A ground moraine is carried as load at the bottom of the glacier.

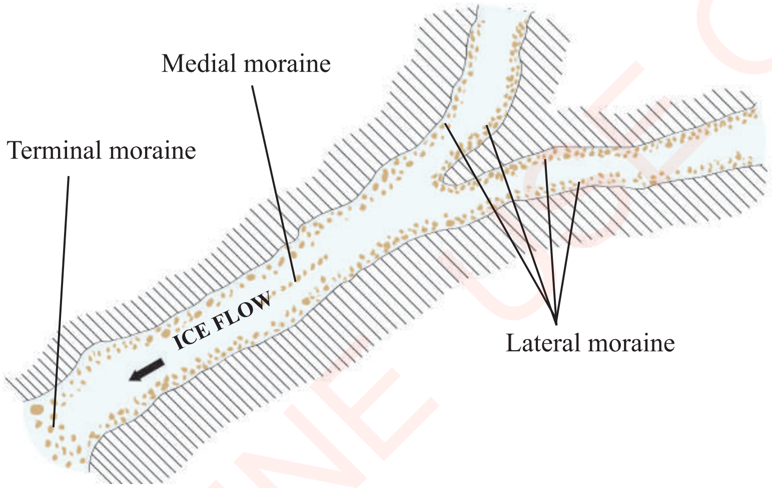


Figure 4.35: *Moraines*

Drumlins

These are elongated hills or ridges of boulder clay usually oval and half egg-like shape. They occur about 1 kilometer long and between 25 to 100 meters high. They often occur in groups giving rise to a "basket of eggs-like" topography. They are depositional features formed when materials carried by the ice exceed its capacity and get deposited.

Eskers

These are long, narrow, meandering ridges of sand and gravel. They are about 40 meters high and their materials occur in layers. They are formed when ice retreats leaving bonded materials following the pattern of the stream.

Outwash plains

These are wide, gently sloping plains of fluvial glacial deposits of sand, gravel and silt which result from massive volumes of melt water, spreading materials.

Erratics

These are boulders of varying sizes which are deposited by ice sheets and glaciers when the ice melts. Erratics help in tracing the direction of the quaternary ice flow but when they occur in large numbers, they hinder farming activities.

Boulder and clay plain

It is a uniform boulder plain resulting from deposition by ice sheets and glaciers. It is an extensive flat low-lying land consisting of boulders and clay that were randomly deposited by ice sheets.

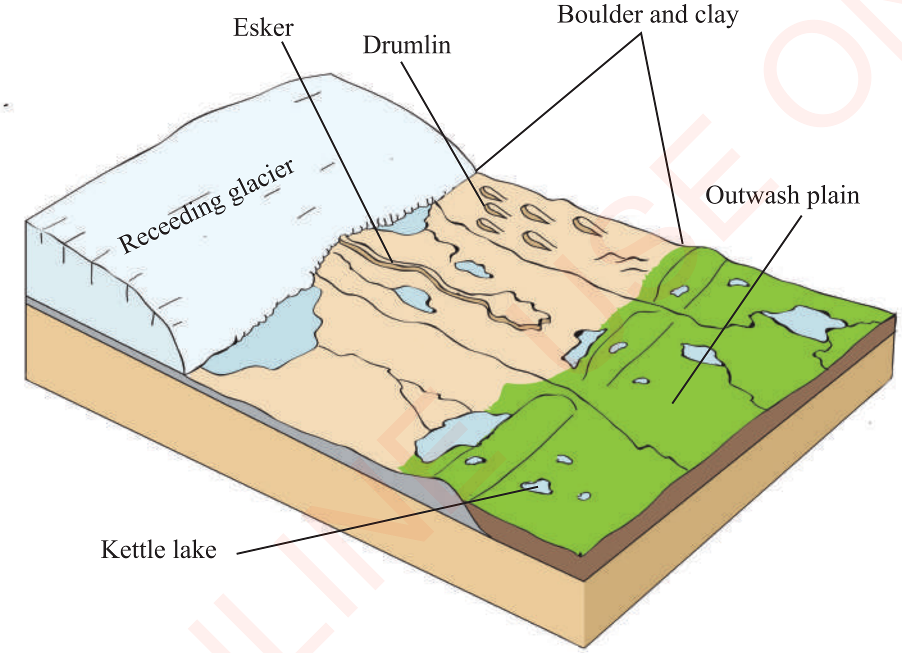


Figure 4.36: *Features of glacial deposition*

Importance of glaciation

Glaciated landforms have economic importance to human life in different ways. For example, corries may become good sites for formation of lakes. Corrie lakes in Switzerland and Canada have helped in attracting development of the countries' tourism industry. Hanging valleys may form waterfalls suitable for generating hydro-electric power, a good example is found in Switzerland. All these features create good sceneries for social recreation, study and tourism. Glaciated highland areas attract tourists because of the spectacular features they form. Such features include pyramidal peaks, arêtes and cirques. Winter sports are also possible in these areas. Materials deposited by glacial erosion like sand and gravel can be used for building. Furthermore, areas which are under glacial activities have very few diseases because the prevailing cold conditions do not favour the survival of vectors like mosquitoes and snails. Fertile soils like moraine soils are useful for agricultural activities including cultivation and pasture.

Revision exercise 4

Section A

1. Match each item in **Column A** against its corresponding item from **Column B**.

Column A	Column B
(i) Water in a solid form	(a) snow
(ii) Removal of blocks of rock due to ice action	(b) ice
(iii) Erosional features caused by action of ice in the highlands	(c) glacier
(iv) Moving mass of ice	(d) arête, corrie and pyramidal peak
(v) Glacial depositional features which may hinder cultivation if they occur in large numbers	(e) abrasion
(vi) Frozen water in a powder form	(f) plucking
(vii) Rock particles and fragments mainly transpoted by glacier	(g) moraines
	(h) roche moutonnee
	(i) erratic

2. Describe the importance of erosional and depositional features formed by the action of ice.

3. Describe the following features:
   (a) Snowline
   (b) Moraine
   (c) U- shaped valley
   (d) Glaciated landform

4. Distinguish between the following:
   (a) Sheet erosion and rill erosion
   (b) Corrasion and corrosion

5. In which ways can the physical features associated with ice and glacier be turned into economic opportunities?

Section B

Choose the appropriate answer from the box.

karst scenery, sink hole, spring, caverns, ice cap, gorges, moraines, stalagmites, glacier, basket of eggs, hydraulic action, stalactite, topography, abrasion, pyramidal peaks

6. A mass of moving ice is known as _____.
7. A thick, permanent layer of ice on an elevated plateau is termed as _____.
8. Erosion by glaciers is geographically referred to as _____.
9. Structures which grow downwards from the roof of a cavern due to evaporation are referred to as _____.
10. An opening through which a stream disappears to form underground stream is known as _____.
11. Features which are formed when the roof of a cavern collapses are known as _____.
12. A landscape of sink-holes, underground streams and caves is known as _____.
13. Groundwater appearing as an outflow on the surface is known as _____.
14. One of the erosional features of glaciers is termed as _____.
15. Scenery groups of drumlins are termed as _____.

Chapter Five

The action of wind and waves on the Earth's surface

Introduction

Forces that act on the earth's crust or close to the earth surface, through the action of wind and waves produce different features on the landscape. In this chapter, you will learn about wind processes, actions and the resultant erosional and depositional features in the arid (desert) regions. You will also learn about wave action as well as features produced by wave erosion and deposition in the ocean. The competencies developed in this chapter will enable you to identify the resulting landscape features of wind and wave actions and sustainably make use of the features for wellbeing.

The action of wind in desert areas

Wind is air in motion. The frequently blowing wind in desert and semi-desert regions normally act as a key agent of erosion, transportation and deposition. A desert is a landscape characterised by sparse or no vegetation and receives very little or no rainfall for prolonged period of time.

Due to the scarce vegetation and broad open landscape wind blows strongly compared to other areas hence contributing to the hostility of the areas to both plants and animals. In humid regions erosion by wind is less manifested. This is because rock particles in humid areas are bound together by water and plant roots. However, areas where vegetation have been cleared and the land is bare, wind erosion is more experienced.

Determinants of wind action

The action of wind could be slow or fast depending on the speed and strength of the wind, nature of the load being transported, obstacles in the path of the wind such as vegetation cover as well as weather conditions.

The speed and strength of wind determine the distance and size of the load transported. Winds with high velocity are usually stronger, and therefore transport more heavier materials than winds of lower velocity. Weather conditions associated with weak winds lower the rate of transportation while conditions associated with strong winds increase the speed and distance of transportation. Nature of the load transported also influences the distance moved. Lighter materials are moved longer distances compared to heavier ones. Also, lighter materials are carried even higher in the air compared to heavier ones.

Obstacles in the path of the wind also affect transportation by wind. For instance, large rock boulders, bushes, tall buildings and vegetation block wind thus reducing its velocity and strength to carry the load. Wind gradually drops its load by starting with heavier materials. Although vegetation cover reduces the velocity and strength of the wind in such a way that the materials cannot be transported over long distances, it binds together the materials of the earth's surface, thus reducing the impact of deflation.

Weather conditions also affect transportation rate by wind. When it rains some of the dust particles in the air are washed down by the rain, and sunny weather facilitates abrasion and deflation. Meanwhile, moist surface bound materials together by moisture. Essentially, wind action causes erosion, transportation and deposition. Wind erosion and deposition form features unlike transportation. The wind erosional and depositional features formed depend more on the type of rocks and nature and strength of the processes of wind action.

Wind erosion

The mechanism of erosion by wind involves three processes, namely deflation, abrasion and attrition.

Deflation

Deflation refers to the blowing away of rock waste that lowers the land surface and produces depressions that are sometimes very extensive. Generally, light fine material is carried over greater distances than coarse rock fragments which are carried over short distances or rolled along the ground because they are heavier.

Abrasion

This refers to the constant blasting, grinding and scratching of rock surfaces by sand and rock fragments carried by wind, which hurls these against the rock. Abrasion is most effective at the base of rocks because the load of the wind is greater here. Abrasion contributes to the formation of features like rock pedestals, zeugens, yardangs and ventifacts.

Attrition

Attrition refers to the breaking up of rock particles through collision against each other as they are transported by wind from one place to another. The outcomes of this process are the formation of rock particles which form the essential materials of extensive sand deserts. This process results into the formation of sand dunes and barchans.

Features formed by wind erosion

Features which result from wind erosion are *rock pedestals*, *yardangs*, *zeugens*, *deflation hollows*, *inselbergs* and *ventifacts*. These features are described in the following subsections.

Rock pedestals

Rock pedestals are tower-like structures or shapes composed of alternate bands of soft and hard rocks. They are also called mushroom rocks. Example of the rock pedestals is in the Gara Mountains in Saudi Arabia. They are primarily formed by wind action whereby weak band of the rock gets eroded while the hard band remains to form rock pedestals as shown in Figure 5.1.

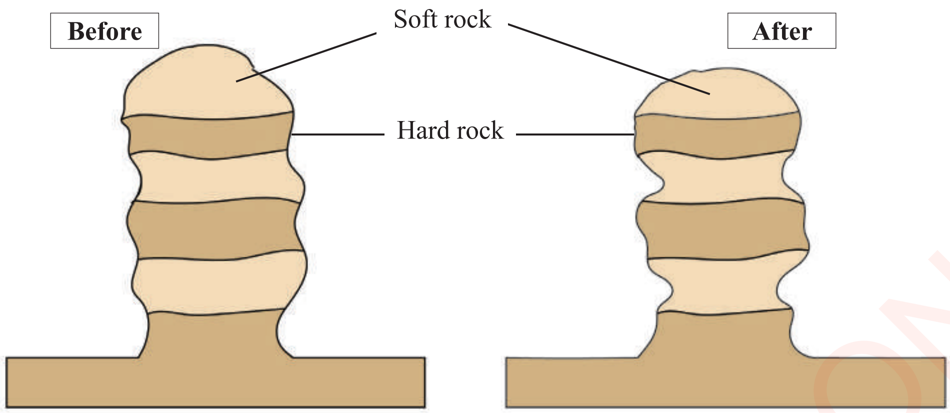


Figure 5.1: *Rock pedestals*

Yardangs

Yardangs are elongated rock ridges of about 100-500 metres long with gentle slopes separated from one another by furrows. These standing ridges are 5 to 15 meters high with lengths of up to 1000 metres. Yardangs are formed when layers of soft and hard rocks are vertically arranged one beside the other, and lie parallel to the direction of the prevailing wind. Wind abrasion erodes the softer rocks to form troughs and leaves the more resistant rocks standing as ridges. These ridges are called yardangs as shown in Figure 5.2. Examples of yardangs are found in Salah (Central Algeria) and near Kom Ombo in Egypt.

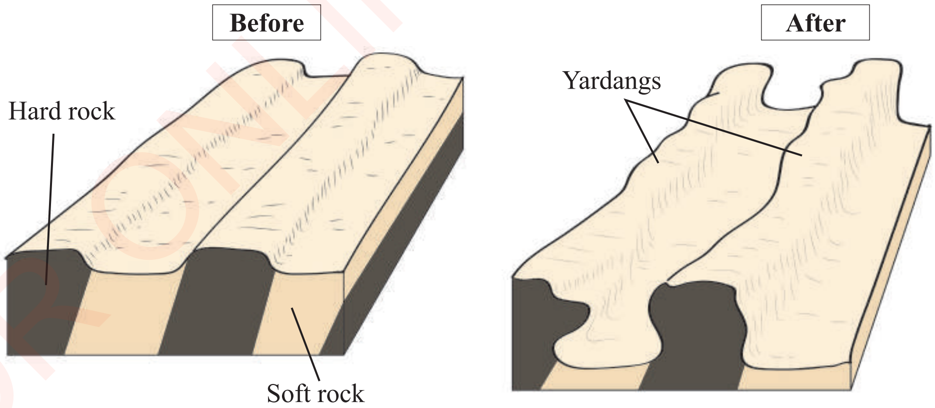


Figure 5.2: *Yardangs*

Zeugens

These are flat-topped ridges with steep slopes which are separated by grooves or furrows in desert regions. They may be up to 30 meters high. Zeugens are formed when layers of hard and soft rocks lie horizontally, one above the other. Mechanical weathering opens up joints on the surface rock, therefore enabling wind abrasion to erode the underlying softer layer. They result into the formation of a ridge and furrow landscape. The formed ridges are called zeugens, as shown in Figure 5.3.

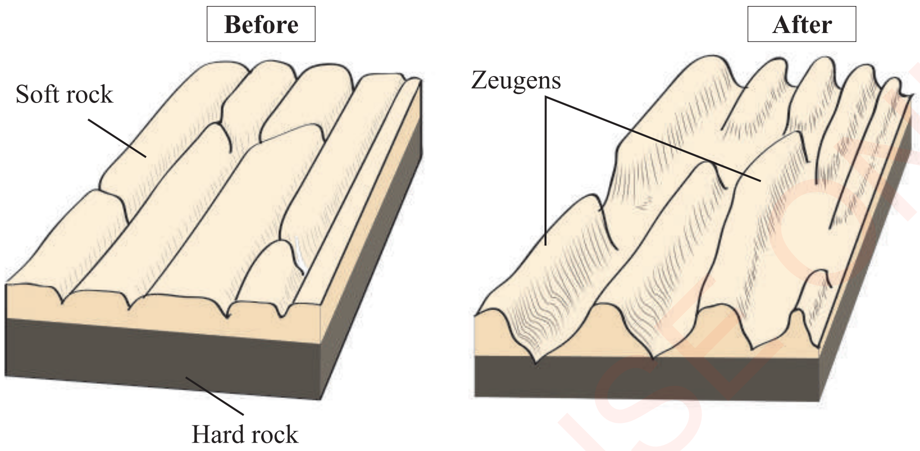


Figure 5.3: *Zeugens*

Deflation hollows

These are depressions in desert regions resulting from wind removal of loose materials from flat areas of dry-uncemented sediments normally in deserts. Small hollows called pans are common in the Kalahari Desert. Larger depressions like the Qattara depression in Egypt were formed by wind deflation. When these hollows are filled with water they form oases. Some deflation hollows may be influenced by faults as shown in Figure 5.4.

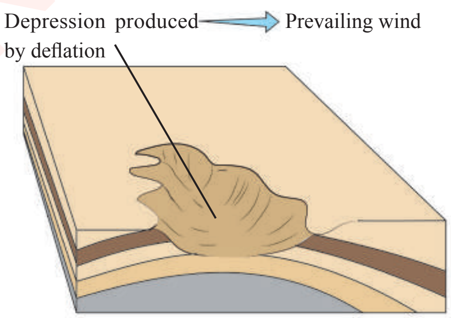


Figure 5.4: *Deflation hollow*

Inselberg

These are isolated steep-sided and round topped masses of rock that rise from flat plains. They may be formed through wind action that takes away the weathered particles leaving a mass of resistant rock standing like round topped masses (Figure 5.5). They occur due to the removal of weathered fragments by wind erosion. Inselbergs are common in the Kalahari Desert, part of Algeria, North West Nigeria, Mozambique and Western Australia.

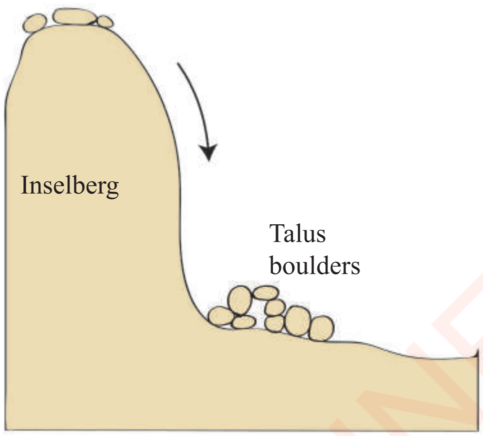


Figure 5.5: *Inselberg*

Ventifacts

Ventifacts, also known as *dreikanter,* are sharpened and flattened rocks, smoother in their wind facing sides due to sand blasting by the action of wind. The materials are too heavy to be transported by wind as shown in Figure 5.6.

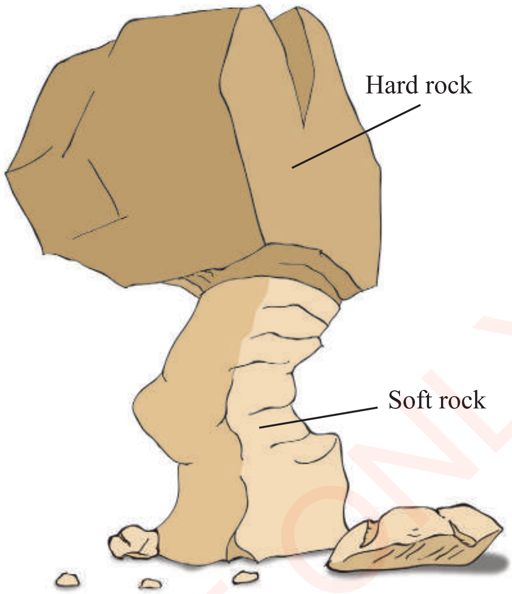


Figure 5.6: *Ventifacts (Dreikanter)*

Transportation by wind

Materials that are transported by wind could be in form of dust, silt, boulders and pebbles. Transportation by wind takes place in three processes, namely suspension, saltation and surface creep or traction. Suspension is a process of transporting fine materials held in the air above the ground. Dust and other small particles are usually transported by wind in this way. The process whereby materials are transported by bouncing on the ground as they are moved by wind is called *saltation*.

Since this process occurs in a repeated manner, the materials can be transported across a reasonable long distance. When strong winds carry much heavier materials which can neither be uplifted nor bounced, the process is called surface creep. During surface creep, materials roll on the surface from one place to another and the distance moved depends on the strength of the wind.

Activity 5.1

Read different books or visit websites to identify different wind erosional features, then do the following.

(a) draw different wind erosional features in your exercise book.

(b) Using a clay soil or modelling clay, mould a model resembling wind erosional feature.

(c) With the supervision of your subject teacher, describe the moulded feature in the classroom.

Exercise 5.1

Section A

Choose the correct answer.

1. The dominant agent of erosion, transportation and deposition in arid and semi-arid regions is called _____.
   (a) running water
   (b) ice
   (c) wind
   (d) waves

2. Erosion by wind takes place through the processes of _____.
   (a) abrasion, attrition and deflation
   (b) abrasion, collision and blowing
   (c) collision, abrasion and attrition
   (d) deflation, blowing and dust

3. The following are processes of transportation by wind _____.
   (a) abrasion, attrition and deflation
   (b) plucking, abrasion and saltation
   (c) soil creep, mudflow and jumping or bouncing
   (d) saltation, suspension and surface creep

Section B

Write TRUE for a correct statement and FALSE for an incorrect statement.

4. Saltation is a process of transporting materials by bouncing on the ground.
5. The process of removing finer grains of silt and clay from the earth's surface is called deflation.
6. Most of the desert features like yardangs, zeugens, barchans and many others are attractive to tourists.
7. Wind transports sand particles more easily than rock and stone particles.

Section C

Write short answers on the following:

8. State the differences between inselbergs and ventifacts.
9. How does the process of wind transportation occur?

Wind deposition

Many factors account for the nature and distribution of wind depositional landforms. The nature of the surfaces from which the sand is worn away, is one of the key determinants. These may consist of deep sand, bare rock or weathered rocks and pebbles. Eroded materials are transported by wind and eventually deposited to form depositional features of different types and shapes. Factors that influence the rate of wind deposition include the nature of land surface on which wind is blowing. For example, presence of obstacles like buildings, vegetation or hills influences fast deposition. Similarly, decrease in the speed of wind influences deposition.

Features formed by wind deposition

Features formed due to obstructed wind include sand dunes of two types, namely *barchans* and *seifs* or *longitudinal dunes*. Other sand depositional features include loess deposits.

Sand dunes

These are hills of sand deposited by wind in the desert. The formation of dunes is influenced by vegetation cover, size of the sand particles, relief of the desert and the velocity of wind. There are two types of sand dunes, namely barchans and seifs dunes.

(a) *Barchans*

Barchans are crescent-shaped sand dunes which occur individually or in groups. Their development can be caused by an obstruction such as a shrub or a rock. The windward side of a barchan is gently sloping and the leeward side is steep and slightly concave as Figure 5.7 shows. A barchan moves slowly forward as grains of sand are carried from the windward side to the leeward side. The migrating barchans can bury settlements and farms. Barchans are found in Western Libya, Eastern Chad, Northern Niger and Mauritania.

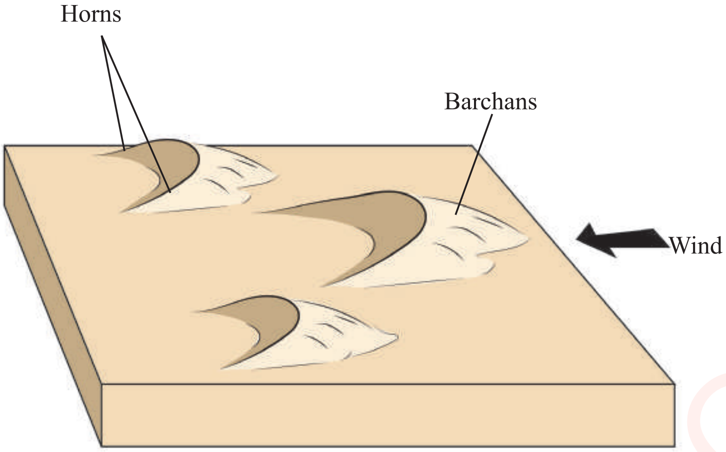


Figure 5.7: *Barchans*

(b) *Seif dunes*

Seif dunes are long narrow ridges of sand which lie parallel to the direction of the prevailing wind, as shown in Figure 5.8. The dominant wind blows straight along the depressions between the dune lines, keeping them clear of sand, while eddies help to build up the sides of the dunes. A seif dune usually develops from a small sand ridge which as it forms it slowly moves forward in the direction of the prevailing winds. Seifs are often several hundred metres high and many kilometres long.

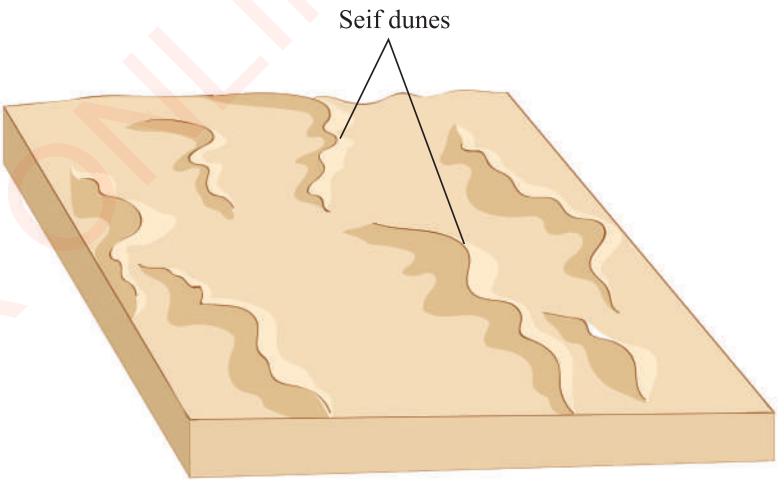


Figure 5.8: *Seif dunes*

Loess

This is an accumulation of fine particles of sand transported and deposited by wind beyond the desert limits. Some of these particles are blown into the sea while the rest are deposited in the desert margin where they accumulate to form loess. Loess occurs extensively in the loess plateaus of Northern China at Hwang Ho (Yellow River). It is also found in Central Belgium and France. Loess leads to the formation of fertile soil.

Activity 5.2

Read materials related to wind erosion and deposition, then;

(a) describe the mechanisms of wind erosion in your exercise book.

(b) with the aid of illustrations show the features formed by wind erosion.

(c) explain how features formed by wind action contribute to the economy of the country.

Exercise 5.2

Section A

Choose the correct answer.

1. These are some of the features resulting from wind erosion _____.
   (a) inselbergs, cliffs and barchans
   (b) rock pedestals, yardangs and zeugens
   (c) ventifacts, sand dunes and deflation hollows
   (d) seif dunes, barchans and transverse dunes

2. Water sources that develop in deflation hollows in the desert are called _____.
   (a) springs
   (b) oases
   (c) geysers
   (d) mudflow

3. The crescent-shaped depositional features found in desert are called _____.
   (a) seif dunes

(b) zeugens
(c) yardangs
(d) barchans

Section B

Write TRUE for a correct statement and FALSE for an incorrect statement.

4. Loess areas are not good because they constitute soils that are formed from fine-grained dust blown by wind from deserts.
5. Some of the features that are formed by wind action are barriers to transportation across deserts.
6. Human activities accelerate erosion by wind.

Importance of wind erosion and depositional features

Wind erosion and depositional features have great importance including provision of productive land and tourist attractions. Loess deposits form fertile soil which favours the growth of crops like grains, cereals, fruits and sugarcane. Water in the oases and deflation hollows can be used for irrigation, domestic and industrial purposes. In addition, such water can be a useful habitat for aquatic organisms.

Features formed due to wind erosion and deposition such as sand dunes, zeugens, yardangs and rock pedestals can attract both domestic and foreign tourists, inturn boost the countries' economies and increase foreign currency. Furthermore, wind erosion and depositional features provide sites for geographical study.

Activity 5.3

In a group, discuss with examples the significance of wind action to human life. Write this information in your exercise books.

Wave action and coastal features

The constant action of waves, currents and tides alter or modify the shape of the coastline by creating both erosional and depositional features. A coastline is a strip of land bordering the sea. In some cases, a coastline may have cliffs and beaches composed of sand and pebbles. A coastline is therefore subjected to constant effects of waves. This makes wave action a dominant agent of coastal or marine erosion and deposition.

Coastal erosion

Waves are most powerful agents of coastal (also referred as marine) erosion. They are caused by winds which set up a series of undulating water swells which flow forward and backward. The water from breakers creeps up the beach as swash and retreats as backwash. The swash wave is more powerful than the backwash wave. Therefore, swashes are termed as constructive waves because they deposit materials on the sea shores (Figure 5.9(a)). Constructive waves have stronger swash than backwash to the extent they deposit materials easily along the shore. Backwashes are termed as destructive waves because they take materials from the shore back to the sea (Figure 5.9(b)).

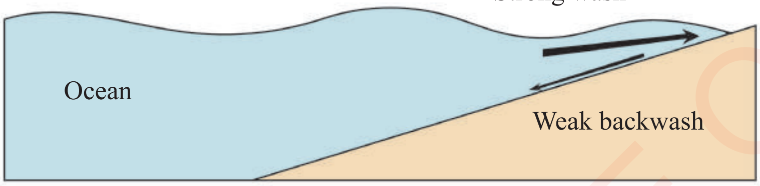


Figure 5.9(a): *Constructive waves*

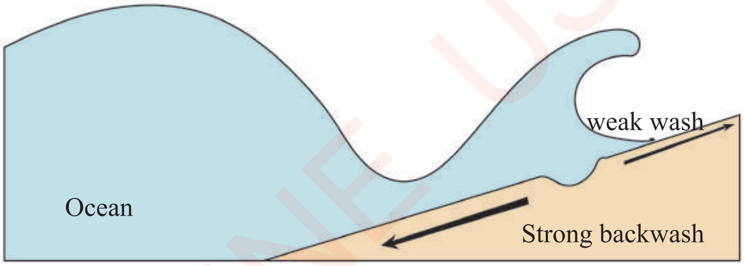


Figure 5.9(b): *Destructive waves*

The extent to which wave action shapes or modifies the coasts depends on the following factors:

(a) Strength of the wind that blows over the sea. The stronger the wind the greater the effect. Usually, strong winds generate stronger waves which lead to more destruction or construction;

(b) Depth of the sea water along the coast. Strong or weak wave formation depends on the depth of the sea. Normally, shallow water impedes waves forward movement, while deeper water encourages powerful strong waves to reach the shores. Strong waves have greater effect than weak waves;

(c) Nature of the rocks on the coast. Weaker rocks are eroded easily than stronger ones. The chemical composition of the rocks also determines the rate of erosion in the coast; and

(d) Alignment of the coast. Waves reaching an indented coastline wear back the outstanding headlands which are suitable for the development of natural harbours while waves reaching a straight coast will be refracted.

There are four main processes involved in marine erosion by waves, namely *hydraulic action*, *corrasion*, *attrition* and *solution*.

(a) *Hydraulic action*

This process takes place when water is hurled against a cliff causing air in cracks and joints to become suddenly compressed. Repeated compression and expansion eventually result in rock fragmentation. It is the ability of the moving water or wave to dislodge and transport rock particles.

(b) *Corrasion*

Corrasion also known as *abrasion* is the process whereby boulders, pebbles and sand are thrown against the base of a cliff by breaking waves and this causes undercutting and rock breaking.

(c) *Attrition*

Attrition occurs as boulders and rocks are hurled against the shore and against each other by breaking waves and they gradually break up into small pieces.

(d) *Solution*

Minerals in some rocks react chemically with sea water. For example, water can react with salt rocks and desolve it. This in turn causes the rocks to become less resistant to erosion hence, get carried away easily.

Features produced by wave erosion

Wave erosional features along the coast include *cliffs, wave-cut platforms, capes and bays, caves and arches, stacks, blow holes* and *geos*. These features are described in the sections that follows.

Cliff

A cliff is formed when wave erosion undercuts the shore to form a steep slope towards the sea or ocean (Figure 5.10).

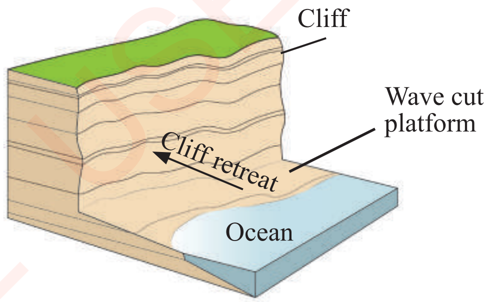


Figure 5.10: *Cliff and wave cut platform*

Wave cut platform

A wave cut platform is a fairly flat part of the shore that develops when a cliff is pushed back by waves, whereby the rock wastes form a terrace. This terrace becomes widened to form a wave-cut platform, as shown in Figure 5.10.

Caves and ledges

When a cliff consists of layers of different rocks, or rocks with joints or faults, the less resistant rocks are eroded more rapidly. Through abrassion and hydraulic action, they are turned into hollows which later become caves at sea level while the most resistant rocks project seawater as ledges (Figure 5.11).

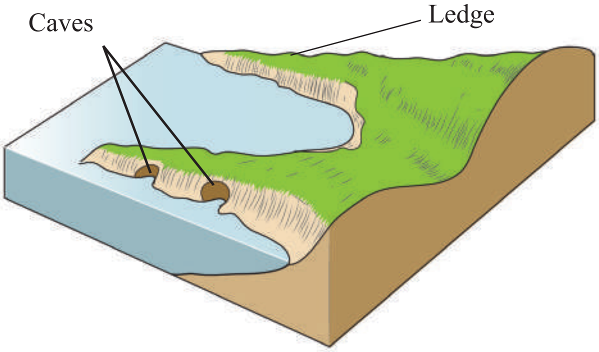


Figure 5.11: *Cave and ledge*

Blow hole

This is an opening formed when a cave tunnel becomes enlarged and extended into the top of the cliff. This opening is called a blow hole (Figure 5.12).

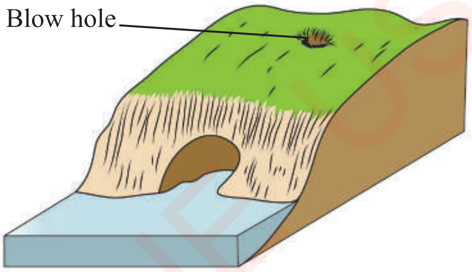


Figure 5.12: *Blow hole*

Geo

This refers to a long narrow inlet of the sea that penetrates into a cliffs. Geos are formed as a result of the collapse of the roof joining the cave and a blow hole (Figure 5.13).

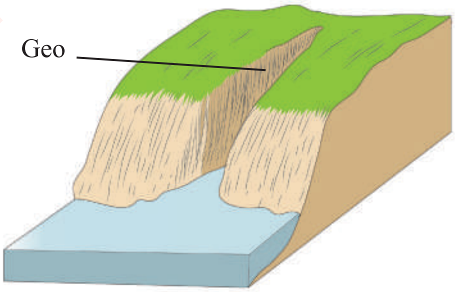


Figure 5.13: *Geo*

Natural arch

This is formed when caves develop on either sides or both sides of the headland such that they ultimately join together to form a natural arch, as shown in Figure 5.14.

Stack

This is a pillar of rock formed when natural arches collapse, separating the headland from its terminal. This terminal is called stack and is left standing on the seaward side of the cliff line, as shown in Figure 5.14.

Stump

This is an isolated mass of rock that has been formed as a result of a stack being considerably eroded and hence reduced in size, as shown in Figure 5.14

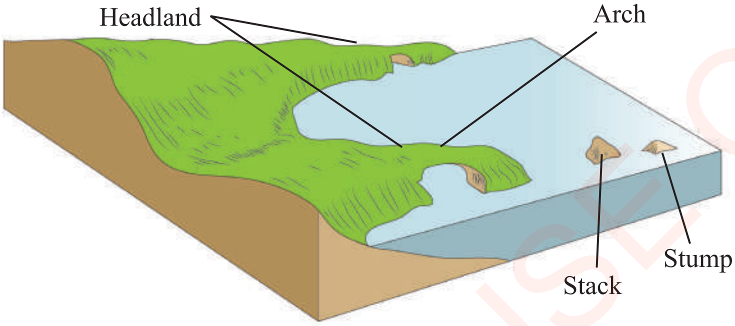


Figure 5.14: *Stack, stump and natural arch*

Waves as agents of deposition

The rate of deposition in the ocean or along the coast is influenced by the energy, frequency of breaking waves, gradient of the shore, supply of the sediment, configuration of the coastline and depth of the water. A shore with a gentle slope reduces the velocity of the backwash leading to deposition of materials. Also, abrupt changes in coastline direction lead to halting of longshore drift and hence deposition of sediments. Deposition occurs more where the swash is weaker than the backwash. The swash moves the materials up the beach and the weaker backwash is unable to return the material carried by the swash to the sea. The following sections describe features produced by waves deposition.

Beaches

These are formed when the eroded materials are transported and deposited on the sea shore. Such materials include sand, boulders or mud and shingles. A shore is the distance between the highest water tide and the lowest water level in the sea, lake or ocean. A beach may also be defined as a gently sloping platform formed when constructive waves deposit sand, shingles and pebbles upon the shore. A beach covered by sand is called a sandy beach (Figure 5.15) while the one covered by shingle is called shingle beach. Shingle beaches are also referred to as rocky or pebble beaches.

Figure 5.15: *Sandy beach in Zanzibar*

Source: tanzania-bush-and-beaches-1.jpg (1500×430) (barkingzebratours.com)

Spit

It is a low-lying narrow ridge of sand or pebbles joined to the midland or island on one end and the other end terminating into the sea. It is formed by a longshore drift. It usually lies perpendicular to the coast and it is also known as an offshore bar, as shown in Figure 5.16.

Sand bar

This is a ridge of sediments which is parallel to the coast (Figure 5.16). It is normally formed at the river mouth. A bar differs from a spit in the sense that a spit lies perpendicular to the coast while a bar lies parallel to it.

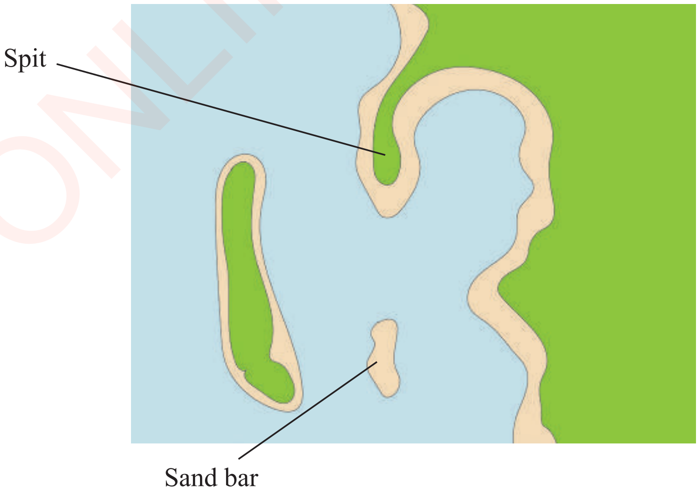


Figure 5.16: *Spit and Sand bar*

Tombolo

This occurs when one end of a spit is attached to the mainland and the other is attached to an offshore island. It is a ridge which starts as a spit then grows out into the sea and finally joins the coast and offshore island, as shown in Figure 5.17.

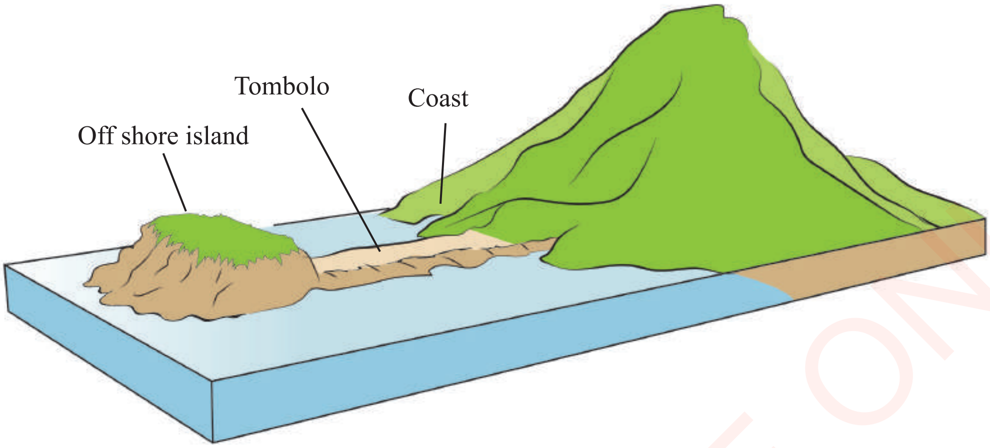


Figure 5.17: *Tombolo*

Mud flats

These are formed when tides deposit fine silt along a bay or an estuary. This silt together with alluvium result into a platform of mud called a mudflat. When these mud flats consist of vegetation like grass and mangroves, they form a swamp. The vegetation is called salt marshes because it grows in areas where water is salty (Figure 5.18).

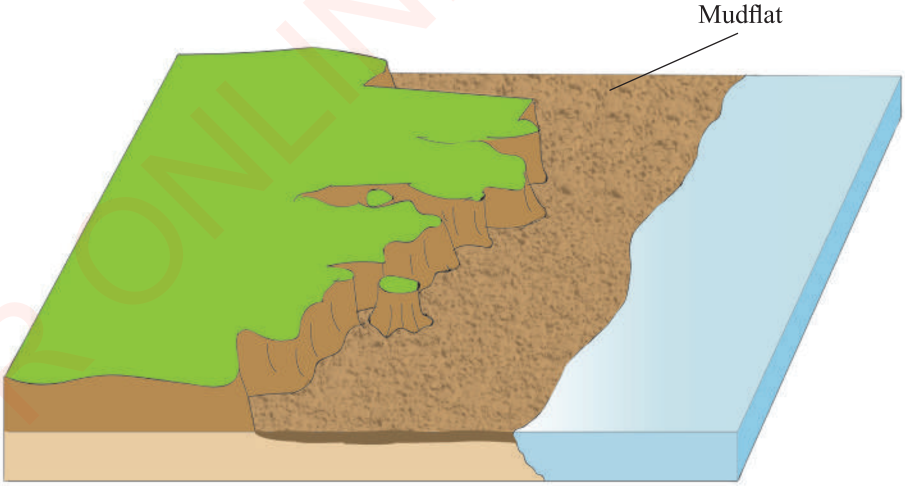


Figure 5.18: *Mudflats*

Socio-economic importance of coastal erosional and depositional features

Features resulting from coastal erosion and deposition have the following importance:

(a) Extensive coastal plains provide suitable sites for human settlement;

(b) High tides can be harnessed to produce hydroelectric power. (A good example can be cited from Northern France);

(c) Water masses and oceans at the coast modify the climate of the surrounding regions;

(d) Beaches are used for recreational activities such as jogging, swimming and playing grounds for different games; and

(e) The features create employment opportunities to the local community such as tourist guides who earn money directly from the tourists.

Exercise 5.3

Answer all questions.

1. Describe how the processes of wave erosion occur.

2. Explain the importance of coastal erosional and depositional features.

Coral reefs

A coral reef is a limestone rock which are made of calcium carbonate and calcareous algae formed when coral polyps die. Polyps are tiny sea creatures of many colours and shapes, some with sponge-like shapes, while others are smooth and rounded with a hard skeleton of calcium carbonate.

Formation of coral reef coasts

When coral polyps die, their skeleton made of calcium carbonate accumulates to form coral limestone. Calcareous algae which precipitates calcium carbonate helps to cement the space between the skeleton. Thereafter, the skeleton is compressed and compacted under its own weight to form a coral reef. The process of piling up of skeletons, compressing and compacting them by using their own weight helps to form masses of rocks called coral reef coasts. In order for the coral polyps to survive they should develop in tropical oceans on the eastern side of the continents between 30°N and 30°S of the equator where temperature is not less than 21°C. They need clear oxygenated water with plentiful supply of plankton (food for polyps). Again they need sediments, free salt water and sunlight which penetrate about 50 metres deep. They also need plentiful supply of plant food. There are three types of coral reefs namely *fringing reefs*, *barrier reefs* and *atolls*. These types are described in the sub-sections that follow.

Fringing reef

This consists of a platform of coral connected to, and built out from a coast. The seaward edge sloping down into deep water falls steeply to the sea floor. The distance of the reef from the shore ranges from 450 metres to over 1 800 metres. A fringing reef grows seaward from the land. It is separated by a shallow lagoon between the coast and the edge of the reef, as shown in Figure 5.19. It is found along the coasts of Tanzania and Kenya. Despite being evident in Tanzania and Kenya, the fringing reefs extend from Mozambique to Somalia.

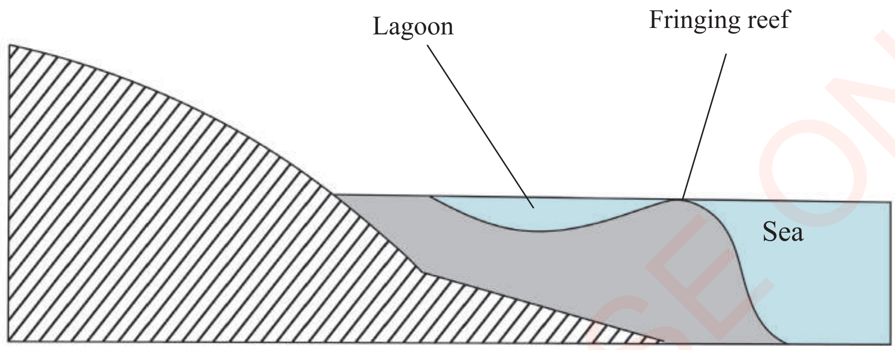


Figure 5.19: *Fringing reef*

Barrier reef

This is normally located several kilometres away from the shore, and is separated from the shore by a deep water lagoon or any other body of water, as shown in Figure 5.20. The coral of the barrier reef is often joined to the shore, although the lagoon may be too deep for coral to grow on its bed. A good example of a barrier reef is Mayotte Island located between Malakasis and Mozambique.

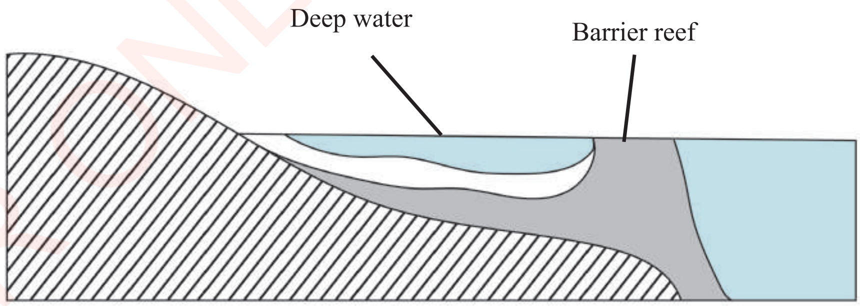


Figure 5.20: *Barrier reef*

Atoll reef

This is a circular-elliptical or horse shoe shaped coral reef enclosing a lagoon without islands in between, as shown in Figure 5.21. Atolls are common in the Pacific and Indian oceans. Some atoll reefs are very large, for example, the Suradiva in the Maldives which is 64 km long. The best example of an atoll in Africa is the Aldabra atoll that lies between Zanzibar and Madagascar about 700 km from the African coast.

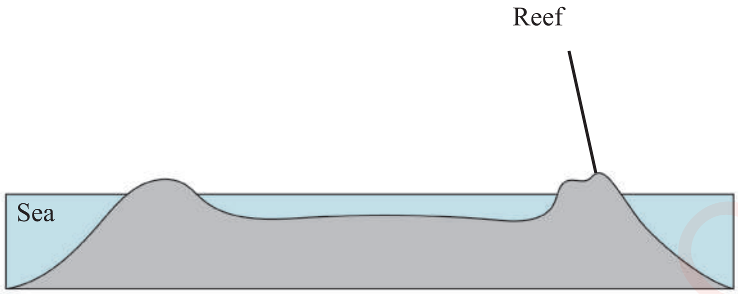


Figure 5.21: *Atoll reef*

Importance of coral reefs

(a) They provide good fish breeding grounds;

(b) They attract tourists who contribute to the national income and in turn boost the economy of the country. Mbudya Island in the Indian Ocean near Dar es Salaam and numerous coral rag sites in Zanzibar are good examples of coral islands that attract tourist;

(c) They provide habitats for sea turtles, algae and fish;

(d) They act as raw materials in pharmaceutical industries, for example, the production of Plaster of Paris (P.O.P);

(e) They are used as raw materials in manufacturing of cement and gypsum powder;

(f) They protect coastlines from erosion, flooding and storm damage; and

(g) They are used for decoration.

Disadvantages of coral reefs

(a) They hinder development or occurrence of natural harbours;

(b) They are barriers to navigation since they tend to lead to the development of shallow lagoons;

(c) They block waves hence hindering development of erosional and depositional features like beaches and curves which can be tourists attractions; and

(d) Coral masses discourage swimming in the sea or oceans. Diving in coral coasts is dangerous.

Activity 5.4

Read various textbooks and documents on actions of winds and waves, then do the following:

(a) use illustrations to describe features formed as a function of wave erosion and deposition.

(b) write a summary on the importance of coastal erosional and depositional features to human life.

(c) explain how you would apply the competencies developed after studying this chapter in your daily life.

Exercise 5.4

Answer all questions.

1. Explain the processes involved in the formation of coral reefs.

2. Categorise the features in the box below into their respective erosional, depositional or coral reef features.

   spit, bays, wave-cut platforms, lagoon, caves, beaches, cliffs, arch and stack, tombolo and mud flats

Revision exercise 5

Section A

Choose the correct answer.

1. Marine erosion is a constant action of _____.
   (a) Wind and running water
   (b) waves, currents and tides
   (c) swash and backwash
   (d) wave breaks

2. This is not a factor influencing the extent to which wave action shapes the coast _____.
   (a) the strength of wind
   (b) the depth of the sea along the coast
   (c) the type of ocean currents washing the coast
   (d) the nature of rocks on the coast

3. The most active agent of marine erosion and deposition is _____.
   (a) wave
   (b) current
   (c) tide
   (d) wind

Section B

Answer the following questions:

4. Define coral reef.
5. Describe the necessary conditions for coral formation.
6. With examples, describe the three types of coral reefs.
7. What are the advantages and disadvantages of coral reefs to human beings?
8. What will happen if dynamite fishing continues along the East zone of the Indian ocean?

Chapter Six

Soil

Introduction

Soil is an important component of life on earth. Both flora and fauna depend on the soil for their survival. In this chapter, you will learn about the meaning of soil, factors for soil formation, its composition, importance, characteristics, and simple classification of soils. You will also learn about soil erosion and ways of conserving the soil. The competencies developed from this chapter will enable you to conserve soil as an essential natural resource. This will help to increase land productivity and enhance industrial productivity for the wellbeing of the society.

Concept of soil

Soil is the thin uppermost layer of the earth's crust composed of inorganic and organic materials. Soil constitutes rock particles, mineral matter, water, air, decayed matter and living organisms. The constituents are in different proportions, thus forming different soil types. Soils are important as they support growth of useful vegetation to animals and humans. They are also used for supporting different activities such as agriculture and forestry.

Factors for soil formation

Weathering is the key process in soil formation, this is because the inorganic matter in the soils is derived from weathered materials known as regolith. This may consist of transported materials such as alluvium, colluvium and loess or it may be partially weathered materials derived from the underlying parent rock. For example, sandstone will produce a sandy soil. The important factors for soil formation are parent rock, climate, relief, living organisms and time as explained in the equation: S= f(p, c, r, l)t whereby; 'S' stands for soil, 'f' stands for factors for soil formation, 'p' stands for parent rock, 'c' for climate, 'r' for relief, 'l' for living organisms and 't' for time.

Climate

Climate is an influential factor that determines the nature of weathering in a particular area. Climate has the greatest role in soil formation through precipitation, temperature and wind. These elements of weather influence rock weathering, rate of chemical reactions and the characteristics of the soil. A place with more rain is likely to have a better developed soil than a dry area because water is necessary for chemical reaction and biological activities. The chemical reaction decomposes the parent rock to produce small particles and contributes to chemical properties of soil. Biological activities are important for the breakdown of rock materials and addition of organic materials.

Temperature affects both chemical reactions and biological activity in the soil. Relatively higher temperature accelerates the rate of chemical weathering and biochemical changes of soil organisms. Chemical reaction is generally increased by relatively higher temperature. Thus, tropical soils are likely to have parent materials which are thoroughly altered chemically, whereas soils of the frozen tundra region have parent materials which are composed largely of mechanically broken materials. High temperature also influences rock disintegration through alternate change of temperature at night and during day time.

Bacterial activities are increased by warmer soil temperature. In the humid tropics, bacteria decompose most of the dead plants that lie on the ground. However, there is little humus on the top soil of the humid tropics because much of the humus formed is leached. In forests of cold continental climates, decomposition by bacterial action is reduced and therefore the ground is covered by a layer of decomposing and partially decomposed vegetation. Wind may increase the rate of evaporation from the soil and may remove surface soil in arid regions. Wind-blown dust may accumulate and form the parent material of a soil.

Relief or topography

Steep slopes develop thin layers of soils because the weathered materials are removed easily while in gentle slopes and lowland areas deep soil is formed because of the accumulation of eroded materials from the steep slopes. Most soils on flat areas are poorly drained because infiltration rate is low. Soil at lower areas is better developed since most of the weathered and eroded material are accumulated here. Gentle slopes have deep soils while flat or lowlands soils are even deeper. Such areas are recipients of organic and inorganic materials eroded from elsewhere. This makes chemical weathering more effective. In areas of depressed lowland, the soil is always young as it is poorly drained. Thus it may become water logged, for example, peat soil.

Living organisms

Plants and animals play an important role in soil formation. Plants supply organic matter such as leaves, twigs, fruits and seeds when decomposed. Plants and dead animals are decomposed by bacteria and changed into soil. Vegetation affects soil development since it supplies most of the organic materials and minerals after decomposition. Plant roots and animal burrowing help the disintegration of rocks to produce smaller particles. In addition, organisms such as ants, worms, and mice contribute in mixing minerals. Human beings are also a part of living organisms which play an important role in the formation of soil through various activities including cultivation, construction and irrigation.

Parent materials

Parent materials are unconsolidated minerals and organic deposits in rocks from which soils develop. These materials are the key factors for soil formation which contribute to the physical and chemical characteristics of soil, for example, soil structure, colour and texture. The parent materials are weathered under the influence of climate and organisms to form soil. For example, soil developing on weathered granite will be sandy, while soils derived from basal and limestone have a fine texture. Soil fertility also depends on the nature of parent materials, for example, an infertile sandy soil may result from sial parent materials.

Time

Time refers to the duration taken in the process of soil formation from the beginning to the time it matures. This means a newly broken up rock will take time before it is changed into actual soil. The longer the time a rock is exposed to weathering agents, the more it contributes to maturity of the soil. Soil is referred to as mature if it has been acted upon by all soil-forming processes for a long period of time, to develop a permanent soil profile. Soil can take about 3 000 to 12 000 years to become sufficiently mature for farming.

Importance of soils

Soils support plant growth which includes a wide range of vegetation and crops, depending on the type of soil. Soil also determines the type of natural vegetation of a place. In addition, soil is used in the construction of buildings and making of pottery which uses well-sieved soil, for example, sand and clay. Soils are habitats for living organisms such as ants, bacteria, earthworms and snakes. Furthermore, in a battle ground, people might make tunnels in the ground for protection. Dead bodies and other rubbish are buried in the soil, which decompose and add humus to the soil, thus contributing to soil fertility. In addition, soil is a source of minerals since it is derived from parent materials of different composition. Researchers use soils to investigate mineral content, to support agricultural development. On the other hand, some soils are of cultural value in some communities. For example, red ochre and clay are used for body decoration by the Maasai. Clay is also mixed with herbs and used by some communities for medicinal purposes.

Components of soil

Soil is mainly composed of different materials which include organic matter, inorganic matter, water and air.

Organic matter and living organism

Organic matter and living organisms constitute 5% of soil components. Organic matter includes humus derived from decayed remains of organisms, fallen leaves and grasses. Plant and animal remains are the main sources of organic matter. Soil organisms such as bacteria and fungi break down the organic matter depending on the nature of the soil forming processes. They also perform weathering through burrowing. Plant roots also penetrate the soil for further breakdown. Decomposed vegetation and plants add nutrients in the soil.

Organic matter is very important because of its role in the formation of humus. Humus is important because of the following:

(a) It improves the soil structure. A soil with humus has a well-developed soil profile as the top layer will consist of enough organic content;

(b) It increases pore space, making it easier for air and water to penetrate the soil;

(c) It reduces exposure of soil to erosion. Organic matter improves soil compaction and supports vegetation cover, thus reduces soil erosion;

(d) It minimizes the leaching of nutrients; and

(e) It provides suitable medium for valuable soil organisms.

Inorganic matter

Inorganic matter constitutes 45% of the total volume of the soil. It is formed when the parent rock disintegrates into small particles. Mineral matter or inorganic particles in the soil range in size from stones (feldspar) to relatively small particles (clay), for example, feldspar to clays.

Water

Soil water or moisture accounts for 25% of the soil. Water contained in the soil is called soil water. It is derived essentially from rainfall runoff and irrigation. Water is important for regulating soil temperature, dissolving and transferring nutrients, controlling chemical reactions in the soil as well as mechanical weathering. Water also plays a significant role of washing soluble minerals such as salts from the top soil to the sub-soil. This process is known as leaching.

Air

Soil contains gases which account for 25% of soil components. Air is contained in pores (spaces between soil particles) forming what is referred to as soil atmosphere. It is this air that provides oxygen for the metabolism of soil organisms. Air accelerates oxidation and biological activity. Well-aerated soil is productive while poorly-aerated soil is less productive. Soil air facilitates plant growth as plant roots can efficiently absorb water and mineral nutrients in the presence of oxygen. Soil air may include gases like oxygen, carbon dioxide and nitrogen.

Soil properties

Soil has physical, chemical and biological properties. These are discussed in the sections that follow.

Physical properties of soil

Physical properties of the soil include *porosity, colour, texture, density* and *structure*.

Soil porosity

Porosity is the total amount of pore spaces in a soil. The total volume of available pore spaces in a soil is a result of the texture and structure of the soil. Soil with coarse materials like sand have big pore spaces while soil with fine materials (grains) has small pore spaces. Sand and clays are good examples, respectively. Pores in the soil horizons control the movement of water (intake, flow, and drainage) and air circulation.

Soil colour

This is the most obvious characteristic of soil. From soil colour it is easy to tell how a soil has been formed, its contents as well as its fertility. For example, a soil which is dark in colour is rich in humus, while red colour indicates the presence of ferrous minerals.

Soil texture

This refers to the coarseness or fineness of a soil, relative to the size of individual particles. These particles can be classified according to their size, from gravel, sand, silt to clay. Soil texture is important because it determines the capacity of the soil to retain water or release it. Table 6.1 shows soil particles and their sizes.

Soil texture can be estimated by sense of feel. This is how the soil feels (gritty, smooth, sticky) and how it responds to rubbing between the fingers and thumb. Sand particles feel gritty and can be seen individually with the necked eye. Silt particles have a smooth feel to the fingers when dry or wet and cannot be seen individually without magnification.

Table 6.1: *Soil particle size(s) and type(s)*

Particle diameter in (mm)	Name of the soil
2.00 – 0.2	Sand
0.2 – 0.02	Fine sand
0.02 – 0.002	Silt
Less than 0.002	Clay

Soil texture in relation to the types of soil is described graphically in a soil texture triangle (Figure 6.1). A soil texture triangle is drawn to show the relation of sand, silt and clay concentration in soil. Texture concentration determines the type of soil. Naming of soil depends on the textural percentage of particles. For example, if the ratio of silt is 65%, sand is 15% and clay is 20%, then the soil type will be silt-loam. In a soil texture triangle, each corner of the triangle represents a soil type consisting solely of particle sizes, as illustrated in Table 6.1.

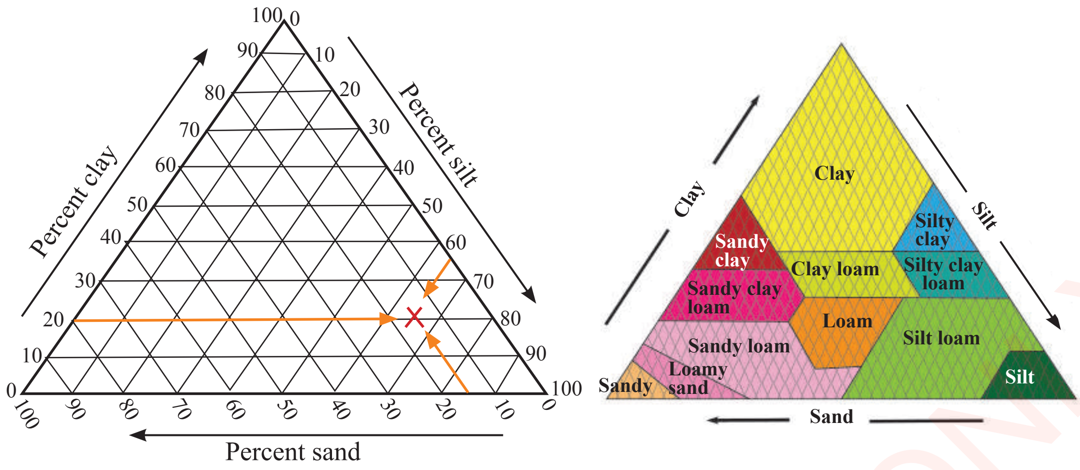


Figure 6.1: *Soil texture triangle*

Soil structure

Soil structure is the appearance of soil by arrangement of individual soil particles within the soil or the way soil grains are grouped together to form larger pieces of aggregates. The structure of the soil particles is described on the bases of shape and arrangement. That is, some soil clumps are made of vertical columns, some have platy soil structures and others have spherical, primatic, blocky structures and so on. Soil structure determines plant growth and the rate of soil erosion.

Soil density

Soil density is dry mass per unit volume. As the density of any object is measured by mass divided by its volume, soil is measured in units expressed in grams per cubic centimetre (g/cm3) or megagrams per cubic meter (Mg/m3). The two soil densities are bulk density and particle density. Bulk density represents soil density as a whole, including solid and pore spaces while particle density represents only the mass per unit volume of the soil solids. Pore spaces are not included.

Chemical properties of the soil

These are properties relating to chemical processes taking place in the soil. The major chemical properties of soil are its acidity or alkalinity. Acidity or alkalinity is determined by the amount of hydrogen ions in the soil and is commonly measured by a pH value. Soil with a pH value 7 is said to be neutral, with a value less than 7 is acidic, and that with a value greater than 7 is alkaline. Plants differ in their tolerance to acidity or alkalinity and this influences their distribution. For example, coffee does well in acidic soils while leguminous plants thrive well in alkaline soils because each of the crop is sensitive to a specific pH level. Human beings can treat the soil either to raise or lower its acidity.

Biological properties of soil

The biological properties of soil refer to the variety and concentration of living organisms in the soil. Organisms that may be contained in the soil are earthworms, bacteria and fungi. In moist areas with a lot of plant remains, such as in the tropical forests, there is a high concentration of earthworms and bacteria, whereas in arid and semi-arid areas living organisms are limited in numbers and diversity. Coniferous forests have a lot of moisture and plant remains but the concentration of living organisms is low because of the acidity of the soils. Biological soil properties include soil organisms and presence of organic matter. These organisms have various functions in the soil. They help breaking parent material to release nutrients such as magnesium, calcium and iron. They also improve soil structure and enhance water infiltration.

Soil profile

Soil profile refers to the vertical sections of soil from the surface to the bed rock, characterized by distinct layers usually of different textures and colours. Mature soil consists of four layers, called horizons. The main layers of the soil are top layer (A horizon), sub-soil (B horizon), weathered rock fragment (C horizon) and bedrock (D horizon). These layers are presented in Figure 6.2. The top layer contains the finest soil particles. Humus in a soil is usually in the upper part of the soil which is normally termed as A horizon (top soil). In this particular layer, there exists decomposed organic matter, and that is why it is dark-brown in colour. In this layer the materials are washed downward where by nutrients are taken from the topmost layer to lower layers. This process is known as eluviation. The layer below the A horizon is known as the B horizon. This is the subsoil which is poor in humus, thus has a light colour. It is also less in organic matter but rich in mineral matter as it receives mineral matter from the A horizon. The layer below the B horizon is known as the C horizon. It is characterised by weathered rock fragments. Therefore, it is a very hard rock. The layer has little or no organic matter. The last layer is the D horizon which is the bed rock. It is a rock which has not been weathered.

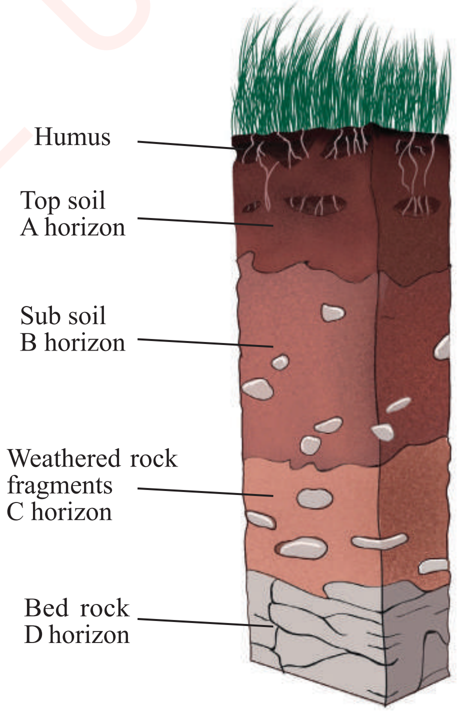


Figure 6.2: *Soil profile*

Activity 6.1

1. In a group, do the following:
   (a) choose a portion of land in your school compound then excavate the soil to two metres deep.
   (b) identify the layers of soil you observe.
   (c) compare the layers with the soil profile you have studied .
   (d) draw a well lebelled soil profile showing the layers identified in (b).
2. Use locally available materials to create a soil profile.
   (a) Describe each layer of the soil profile you have created.
   (b) Describe the importance of the uppermost layer of soil in your daily life.

Exercise 6.1

Answer all questions.

1. Why is it important to learn about soil properties?
2. Describe the importance of water in the soil.
3. Show the relationship between time factor and soil maturity.
4. Discuss factors that influence soil formation.

Types of soil

Soil can be identified on the basis of its texture. Soil types according to texture include *sandy soil, clay soil, silt soil* and *loamy soil*.

(a) Sandy soil consists mainly of sand, hence has sufficient air spaces. It is commonly referred to as light soil. This light soil allows water to pass through easily taking plant nutrients with it. Therefore, this soil type needs constant manure. It is suitable for horticulture and other root crops like carrots. In Tanzania, sandy soils are found in many places, but they are dominant in the coastal belt.

(b) Clay soil consists mainly of very fine particles, with tiny air spaces. It contains little air but can hold much water. Therefore, it is referred to as heavy soil and is difficult to cultivate. When it dries up it forms a very hard surface with many cracks. Clay soils are often rich in plant nutrients. Clay soils are found in Mwanza and Shinyanga regions in Tanzania, where they are known as mbuga soils.

(c) Silt soil consists of particles of intermediate size between sand and clay. It has more air spaces than clay soils but less than sandy soils. Therefore, it is more suitable for agriculture than both sandy and clay soils. Silt soils are commonly found in river flood plain.

(d) Loamy soil consists of particles of various sizes. The type of loamy soil depends on the proportion of sand, silt and clay in the soil. It can be a sandy-loam soil if it contains more sand; silt-loam soil if it contains more silt; and clay- loam soil if it contains more clay. Loamy soils are well-aerated and drained. Most volcanic areas have clay-loam soils such as those found on the slopes of Mount Kilimanjaro in Northern Tanzania.

Activity 6.2

Read various texts from the library or internet sources, then do the following:

(a) describe the importance of soil.

(b) visit different places with different types of soil then write down what types of soil you have observed.

Exercise 6.2

Answer all questions.

1. Define soil profile and clearly show its horizons.

2. Read various texts from library or internet sources on the types of soil suitable for crop production. Mention the best type of soil for each of the following crops and give reasons.

   (a) Coconut
   (b) Cashewnut
   (c) Coffee
   (d) Maize
   (e) Tea
   (f) Rice

Soil erosion

Soil erosion is the removal of the top soil by agents of erosion. The agents of erosion are running water, waves, ice and wind. Soil erosion is usually accelerated by human activities such as overstocking, removal of vegetation cover and cultivation on steep slopes without erosional control measures.

There are four main types of soil erosion, namely; wind erosion, running water erosion, wave erosion and ice erosion. Water erosion is one of the most common erosion types that involves splash erosion, sheet erosion, rill erosion and gully erosion. Other types of erosion include geological and accelerated erosion.

Causes of soil erosion

There are various causes of soil erosion, which include; deforestation, overgrazing, shifting cultivation, building and excavation works.

(a) Deforestation

This is a practice of cutting down trees. When trees are cut, the soil is exposed to rain droplets, sun and wind. The rain drops loosen the topsoil hence making it more vulnerable to erosion.

(b) Overgrazing

This occurs when plants are subjected to intensive grazing over a long period of time or without sufficient recovery periods thus reducing vegetation and exposing the soil to agents of erosion. The practice reduces the compaction of soil and exposes the land to erosion which may result to desertification. Similarly, animal hooves make soil particles loose, making them easy to be removed by agents of erosion.

(c) Shifting cultivation

This is a common practice in areas with a sparse population. It is a system of cultivation whereby land is cleared by slash and burn methods. A few years after the soil has lost its fertility, the land is abandoned and people move to other virgin lands. The soil is left unprotected because there is no vegetation cover.

(d) Monocropping

This is a practice of planting the same crop on the same land for many years. This kind of farming exhausts the soil. The soil then deteriorates in quality, becomes loose and it can be easily eroded by using agents like water.

(e) Building and excavation works

Works such as construction of roads and buildings, mining and quarrying are also responsible for soil erosion. These works expose the inner soil to agents of erosion. These activities involve the removal of the top soil by machines which then accelerates the rate of soil erosion.

Relationship between human population growth and rate of soil erosion

(a) As human population increases, the demand for land also rises. However, habitable and cultivable, land becomes inadequate to meet the increasing demand of human population. When the population increases, people start to cultivate on hills and valleys in order to produce enough food to feed the population. This trend accelerates the rate of soil erosion.

(b) With population increase, it becomes difficult to maintain soil conservation activities as the demand for grazing and farming becomes high, hence exposing land to agents of erosion.

(c) A large population needs more area for shelter, fuel wood and timber. Hence, people clear land to build houses, harvest building materials and firewood. All these activities expose the land to agents of erosion.

Effects of soil erosion

Soil erosion is a serious problem which has many effects on economic activities as follows:

(a) Environmental pollution. Eroded soil that is carried into rivers, lakes and oceans may contain chemical pollutants that may affect aquatic life and weaken some economic activities like fishing.

(b) Siltation. Siltation reduces the water depth in the dams or river channels hence leads to water shortage that affects some investments like hydro-electric power thus accelerate the problem of power rationing.

(c) Loss of productive soil. Soil erosion involves removal of the top fertile soil, leaving the subsoil which is less fertile. This in turn leads to low land productivity, increasing the likelihood of famine and hunger occurrences. In other words, it adversely affects agricultural activities.

(d) Destruction and loss of properties. Erosion can damage roads, houses and bridges. This is because soil erosion goes together with de-attachment of rocks which act as the foundation of these buildings, roads and bridges.

(e) Source of materials for building and construction. When eroded material is deposited in form of sand it becomes a good resource for building and construction purpose.

Ways of controlling soil erosion

People are advised to control soil erosion by applying soil conservation methods. Soil conservation is an effort made by people to prevent soil erosion and hence retain soil fertility. There are various measures for controlling soil erosion which include the following;

(a) Use of proper farming techniques

The use of proper farming techniques helps in conserving the land. These techniques are listed in the sections that follow.

(i) *Strip cropping*

This is the practice of planting alternate rows of crop plants of the same family such as beans and peas, with open growing crops such as corn. This practice prevents wind and erosion.

(ii) *Terracing*

This involves creating artificial

steps or bends on hillsides. At the front of each flat terrace, strips of grass may be grown to trap any soil that might be washed away.

(iii) *Mulching*

This is the use of plant remains such as pruned leaves to cover cultivated ground. The mulch protects the soil from direct impact of raindrops and wind. In this way, the soil is protected from splash and wind erosion.

(iv) *Intercropping*

This is a practice where two or more types of crops are grown on the same piece of land each with different benefits to the soil. For instance, one could plant maize and beans in the same farm. While beans help to improve the nitrogen content of the soil, maize draws nitrogen from the soil.

(v) *Crop rotation*

This involves growing of different crops on the same piece of land on a rotational basis. Crop rotating prevents exhaustion of particular nutrients from the soil as different crops require different nutrients to grow and mature.

Also, one could practice fallowing for one season or more so as to help the soil recover its fertility. Fallowing is a process of allowing the cultivated land to rest or uncrop for one or more seasons of shorter periods to regain from loss of fertility.

(b) *Afforestation and reforestation*

Afforestation involves planting of trees in areas where no forest existed before while reforestation is the planting of trees on land that had forests before. Trees help to hold soil particles together so that they are not easily carried away by wind or by running water.

(c) *Education*

Education on environment and population growth should be provided to all people. This will help to create awareness about conservation of the environment, hence reduce soil erosion as there will be proper environmental management and optimum population growth that will conserve the environment.

Activity 6.3

Visit a nearby area which is affected by soil erosion and there after do the following:

(a) observe the area and mention any types of soil erosion observed.

(b) with relevant examples, explain what might be the causes of the soil erosion observed.

(c) what measures do you propose to rectify the problem?

Revision exercise 6

Section A

Write TRUE for a correct statement and FALSE for an incorrect statement.

1. Soil erosion, climate change and deforestation are some of the threats facing soil maturity.
2. Soil formation is a function of wind and waves through the process of erosion and transportation of materials.
3. Soil contains both organic and inorganic materials like decomposed plants and weathered rocks.

Section B

*Match each item in **Column A** against its corresponding item in **Column B**.*

Column A	Column B
4. The way soil grains are grouped together to form soil lumps	(a) soil texture
5. A measure of alkalinity or acidity of a soil	(b) clay soil
6. Inorganic matter, organic matter, water and air	(c) soil structure
7. Vertical cross-section of a soil from the surface to the underlying rock	(d) soil pH
8. Have particles of intermediate size between sand and clay	(e) soil porosity
9. Size of individual particles composing a soil	(f) components of soil
	(g) soil profile
	(h) silty soil
	(i) soil density

Section C

Fill the blanks by selecting the correct answer from the box.

Humus, Parent rock, Soil, Water, Aeration, Time

10. _____ determines the mineral composition of soil.
11. _____ reduces the supply of oxygen in the soil.
12. _____ is derived from decaying plants and animals as well as their wastes.
13. _____ plays an important role in soil formation.

Section D

Answer the following questions

14. Briefly define the following terms:
    (a) Soil erosion
    (b) Afforestation
    (c) Porosity
15. Distinguish between soil texture and soil structure.
16. Outline four major factors which influence the formation of soil.
17. Highlight various methods you would employ to control soil erosion.
18. Discuss the socio-economic effects of soil erosion.
19. With examples explain the economic importance of soil.

Chapter Seven

Elementary Surveying

Introduction

Land survey is something we do in our everyday life at home. We do land survey when determining points to erect poles for chicken sheds, determining sites to establish vegetable gardens and erecting brick beacons to dermacate boundaries of our land or farms. In this chapter, you will learn about the meaning and types of land survey on the basis of instruments used. The competencies developed in this chapter will enable you to use survey equipment for proper land use planning.

The concept of land survey

Land survey refers to the art, science and technology of measuring and recording distances, angles, directions and elevations in order to position features on the earth's surface relatively to other features or absolutely. Features or points are fixed in reference to a particular reference datum, direction relative to cardinal points and or angles relative to the earth's core. Land survey gives us data that forms a base for planning or map production.

Types of land survey

A number of criteria exists for classifying land survey. Some of the criteria include survey purpose, survey equipment used, survey method adopted and the size of area to be surveyed. In this chapter you will learn about land survey and its classification based on the type of instruments used. Types of land survey include chain or tape survey, plain table survey, prismatic compass survey and land leveling. In this chapter however, only chain survey will be covered.

Chain or tape survey

Chain survey has its name derived from the principle instrument used (chain). It was built on the principles of the oldest method used by early surveyors when demarcation of the land used ropes (see Figure 7.1). For example, the boundary between pieces of farm lands of different owners, was marked by rope knots.

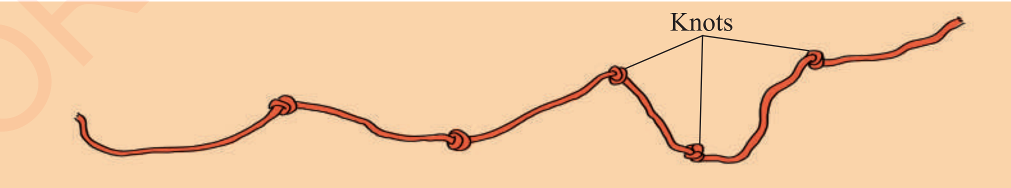


Figure 7.1: *Rope*

However, due to technological development, chains have been replaced by more accurate and sophisticated linear measuring devices like tapes and land measuring wheels (see Figure 7.2).

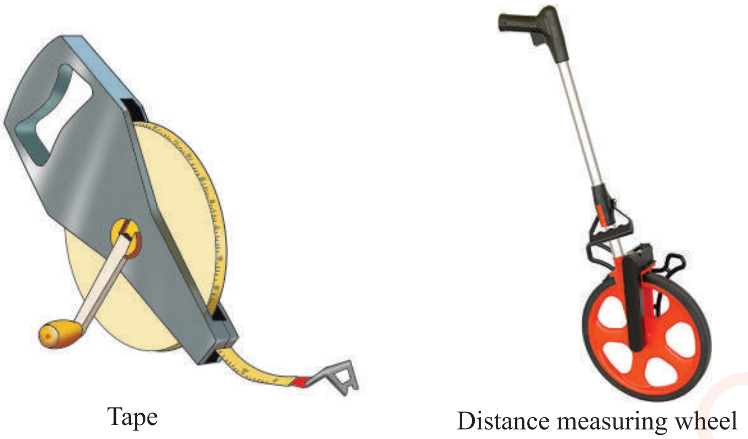


Figure 7.2: *Measuring devices*

Equipment used in chain surveying

The necessary equipment used in chain surveying include a chain or measuring tape or surveyors' band, cross staff, wooden pegs, arrows, ranging poles, note book and drawing equipment kept in a mathematical set.

A chain

A chain is used to measure short straight distances. It is made up of a tempered steel wire. At the end of the chain, there is a handle for dragging it on the ground. Chains have length ranging from 20 metres to 40 metres. They are made up of rings which are connected by links. Small links are connected by rings. The length from one ring centre to another ring centre is 200 mm counted in total to the end of handles (see Figure 7.3).

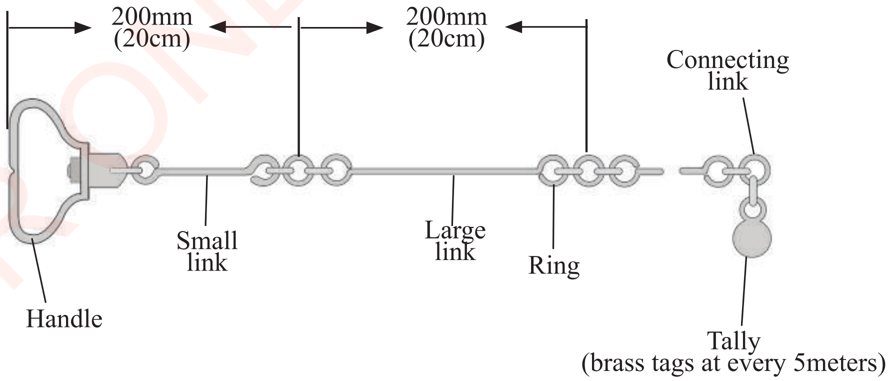


Figure7.3: *Chain*

A tape

It is made of steel, coated linen, or synthetic material. Measuring tapes are available in lengths of 20, 30, 50 and 100 metres, usually indicated on the tape. A tape is used to measure short distances (see Figure 7.2).

Ranging poles

Ranging poles are straight round rods ranging between 30 and 40 mm thick and 2 to 3 meters long. They are made of wood or light alluminium metals. Ranging poles are used to mark temporary points or stations or straight line of traverse. They are marked red and white or black and white to enhance visibility, as indicated in Figure 7.4.

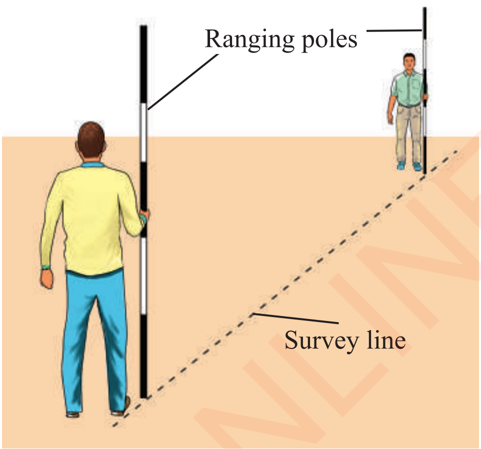


Figure 7.4: *Ranging poles*

Pegs

Pegs are short pieces of wood or metal used for marking positions permanently during survey. Wooden pegs are normally 40 mm square and 50 cm long and they can be made locally. The pegs are erected in the ground. They are used for marking permanent stations along the survey line.

Pegs are usually put at a starting point and at any point where a survey line changes its direction, as shown in Figure 7.5.

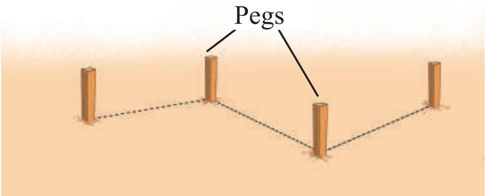


Figure 7.5: *Wooden pegs*

A cross staff

It is made of wood or metal with eye slits at right angles fitted on a stand (see Figure 7.6). It is used to establish right angles on the ground perpendicular to the survey line.

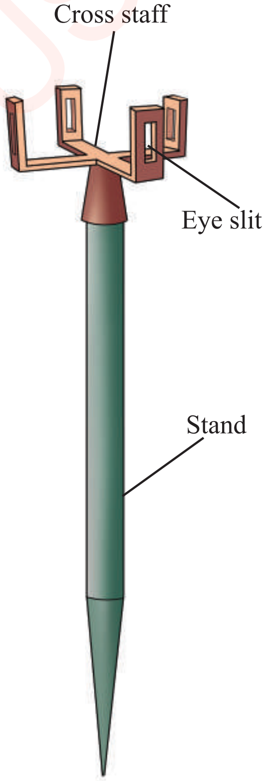


Figure 7.6: *Cross staff*

Arrows

They are made of steel wire of 35 - 40 centimetres long. The steel wire are normally bend at the top into a circle. They are sometimes tied up at cherty with red cloth to facilitate visibility. They are used to mark temporary points on the ground during survey (see Figure 7.7).

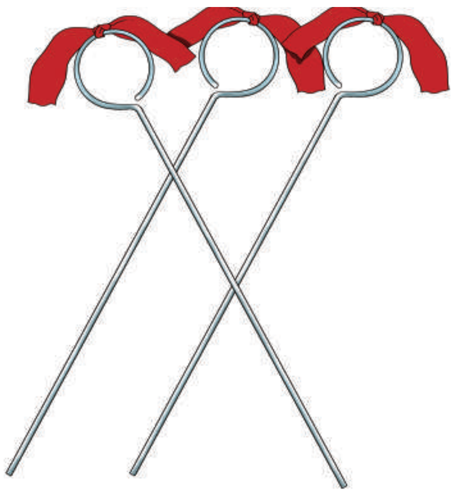


Figure 7.7: *Arrows*

A note book

All observations and measurements taken during chain surveying are to be recorded in a standard note book. Notebooks are used during fieldwork to record the data obtained. They should be spiral bound, of good quality, and 150 mm x 100 mm in size. A hard pencil is used for drawing in the field and a rubber is used to erase errors (see Figure 7.8).

Figure 7.8: *Note book, pencil and rubber*

Exercise 7.1

Answer all questions.

1. Explain how you will use the following equipment when doing a simple chain survey:
   (a) A note book, pencil and rubber
   (b) Distance measuring wheel
   (c) Ranging poles
   (d) Cross staff
   (e) Arrows
2. Mention the types of land survey.
3. Explain why chain survey is referred to as a simplest method of surveying.

Chain or tape surveying process

Chain surveying is a method of surveying in which only linear measurements are taken in the field by using a chain or tape measure. It measures a series of straight lines on the ground and all points or features are fixed relative to the line of traverse by either right angles (offsets) or tie lines.

Measuring by a chain or tape

Chain or tape survey involves measuring of a series of short straight lines on the ground with a chain or tape measure to locate points with reference to the line of traverse by using tie lines or offset method. The line of traverse is a series of straight lines on the ground measured by a chain or tape from fixed points such as trees, water taps or walls in the field of survey. Actually, it is the main line along which other lines (ties and offsets) are to be drawn.

Tie lines

Ties are lines drawn from the line of traverse at an angle ranging between 30°and 60° to a fixed point in the field, relative to the line of traverse. However, ties join the line of traverse at acute angles or obtuse angles.

Offsets

These are lateral measurements taken from an object to the chain line (survey line) at right angles (90°). Objects or details recorded can be water tap, tree, building angle or pole.

A person who conducts survey activities is known as a surveyor. The surveyor cannot work alone in the field, he or she should be accompanied by assistants who work in the field to form a survey team. Mostly a survey team is composed of three people, who include a leader, a follower and a booker.

(i) *The leading chain person(leader)*

This is the one who initiates movement along the Line of Traverse (LT) by holding the chain and arrows and moving forward.

(ii) *The follower*

This is a member of the survey team who puts the ranging pole, arrow or peg at the right point and holds the chain straight to the point. This helps the chain person to extend the chain accordingly.

The follower is also responsible in ranging as is directed by the leading chainman. Ranging refers to the process of establishing a straight line between two points and or establishing points in a straight line. It involves the use of different handy signal-codes to be followed by an assistant. For example, when a surveyor makes a rapid swap of a right hand to the right, means an assistant should move considerably to the right. Consistently when a surveyor swaps a left arm to the left, means an assistant should plumb a rod to the left. On the other hand, when a surveyor has both hands put together above the head and brings down, this means the range is correct. A surveyor can have his hands put together and extend horizontally and brings them down quickly to mean an assistant has to fix the ranging pole where he/she is.

(iii) *The booker*

A booker is a professional surveyor who works in the field as a recorder, sketcher and collector of all data obtained during the surveying process.

Objectives of chain survey

Any land survey conducted has an objective to be accomplished. Survey can be carried out to determine the size and shape of a farm, a lake, or a mountain so as to make plans and maps; to collect land details; to locate features; to determine horizontal and vertical distance and determine direction of features, among others.

Exercise 7.2

Answer all questions.

1. What do you understand by the following terms in chain survey?
   (a) Tie lines
   (b) Offset
   (c) Line of travers
2. If you are given a task to do a survey of a particular place, how many people will you need in your team and what are the tasks of each person?
3. Why do you think people do land survey?

Procedures in chain survey

Any land survey has to go through some steps before field measurements are carried out. The process involves three major steps: reconnaissance, observation and measurement.

(a) Reconnaissance

This is the first step in land surveying. It is a step which involves visiting the area to get familiar with it before the actual survey is conducted. Reconnaissance equips surveyors with general knowledge of the topography and thereafter be able to determine types of equipment required, personnel needed and other resources which can assist in the accomplishment of the survey activity. It can involve going through topographical maps of an area and any relevant documents. Reconnaissance involves the following two important considerations.

(i) *Determining the purpose or objectives of the survey:* Understanding the purpose of the survey can help the surveyor to decide on the method of the survey. The purpose can involve determining the catchment area of water discharge; setting boundaries to avoid land conflicts or planning land for settlement and electrification system.

(ii) *Preparation for site reconnaissance:*

When preparing for site reconnaissance, surveyors gather available information on the area to be surveyed, prepare equipment and methods in order to determine the accuracy needed, and identify devices according to accuracy needed.

(b) Observation and measurement

In this step, methods of measurement are determined. This step involves the establishment of suitable station that would save as control points during the surveying process. The step also involves determination of the relative positions and sizes of natural and physical features. It also includes processes of taking measurements (booking), like distances between two points, and determining right angles among others.

Methods of establishing and setting right angles during chain surveying

Several methods for setting or determining right angles during field chain surveying exists. Right angles to a detail from the survey line can be established using readymade devices like optical square, a square or a cross staff. Sometimes schools may not have the identified survey equipment. In a situation when schools are unable to afford buying those industrial survey equipment, two methods namely; 3-4-5 and rope method can be used. Those methods are easy and cheap for they do not require cost full equipment. Methods are described as follows;

(a) Setting right angle using 3-4-5 method

Requirements

Setting right angle using this method in the field requires a measuring tape, two wooden rods or ranging poles, few locally made pegs and three persons.

Steps in setting right angle are as follows;

(i) Person 1 unfolds a measuring tape and holds together the zero mark and the 12 mark of the tape (the 12 mark is a sum of 3+4+5, (Figure 7.9)). The surveyor may decide on the ratios to be used, that is, it can be 7-8-9 or 9-10-11 depending on the distance of an offset to be recorded and the length of the tape.

(ii) Person 2 stretches the tape along the survey line $\overline{AB}$ towards B to a 3 metre mark and holds it (Figure 7.9).

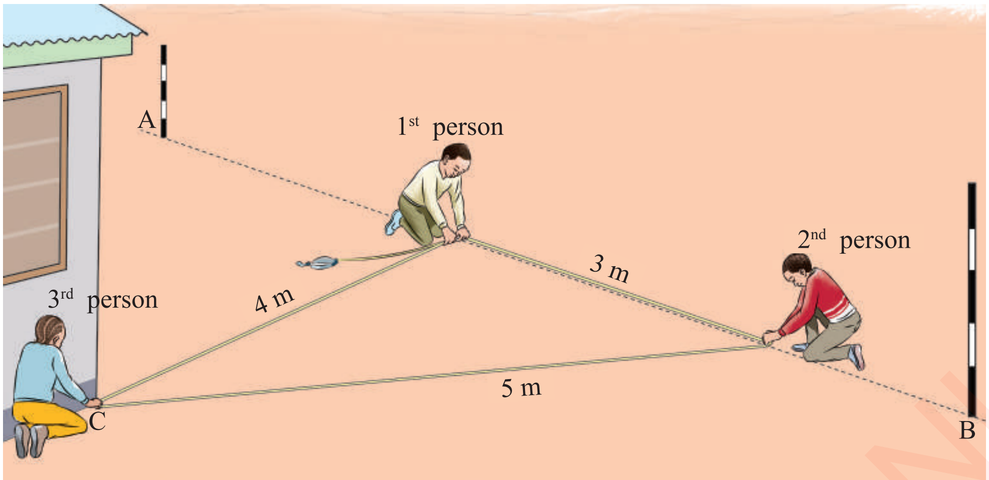


Figure 7.9 *Stretches the tape towards B and C*

Person 1 and 2 are in the same line along the same line along the survey line $\overline{AB}$

(iii) Person 3 stretches the tape to an offset to be recorded. The angle at where person 1 stands is the right angle. The third person will be holding at 8 metre mark on the tape (Figure 7.10).

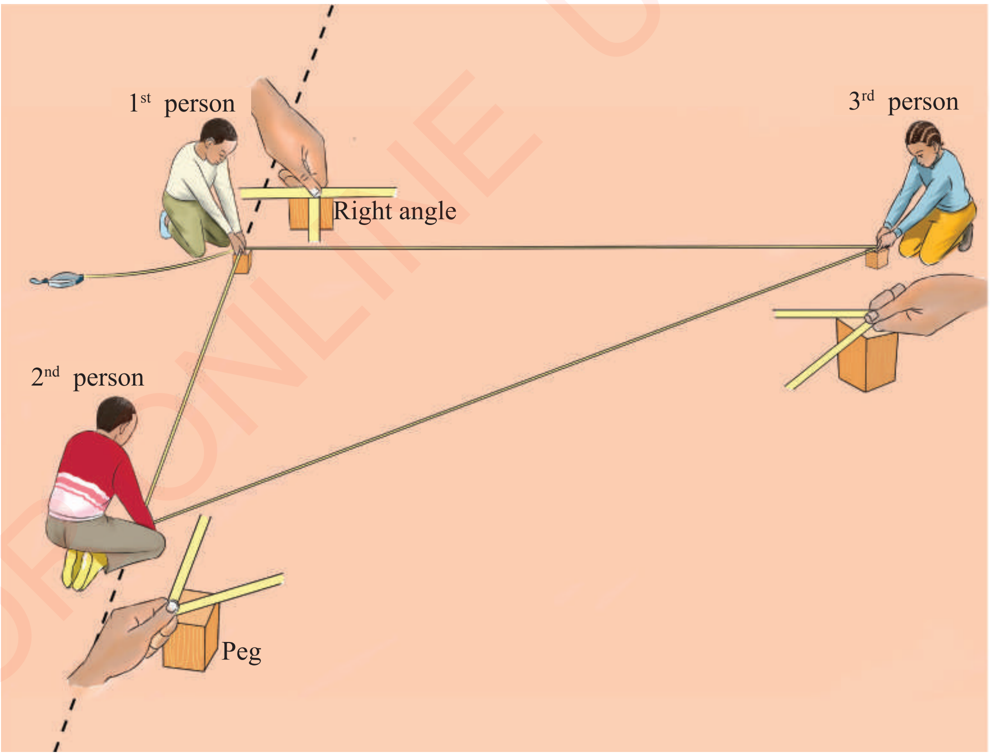


Figure 7.10 *Setting a right angle*

When all sides of the tape are stretched as described in step (i) to (iii), a triangle with lengths of 3-4-5 metres is formed.

(b) Setting a right angle by a rope method

Requirements

A rope of considerable length depending on the distance of an offset from a survey line, a peg, a ranging pole, a tape and three persons.

Steps in setting right angle by using rope method;

(i) Set a peg at a detail (offset) to be recorded (in this case, a house). Tie a rope at the peg a loop to help scratch the ground (Figure 7.11).

(ii) Stretch a rope from peg towards A along the survey line. Make sure that a loop scratches through survey line at point C then keep dragging a loop you are holding towards point D to make a semi-circle as shown in Figure 7.11. Therefore, the loop of the rope will have crossed at point C and D.

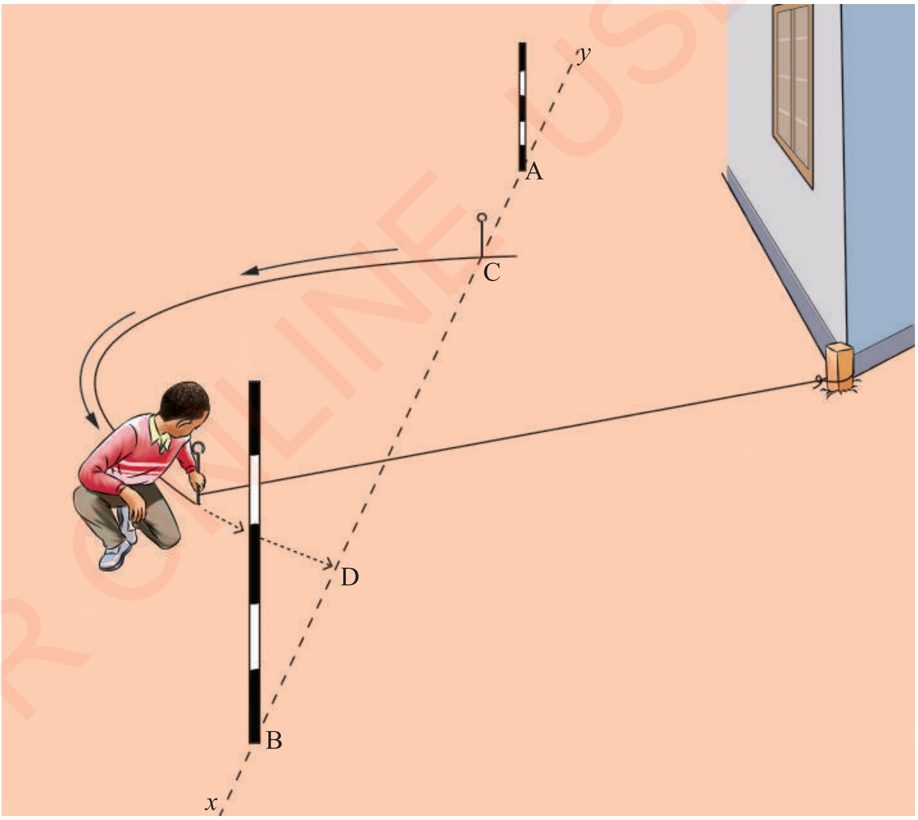


Figure 7.11 *Making a semi-circle by using a rope*

(iii) Measure the distance between point C and D along the survey line (for example, the length between point C and D is 30 metres).

(iv) Divide the distance obtained in (iii) above by two so as to get its half, that is $\frac{30}{2} = 15$.

(v) Measure 15 metres from either C towards D or from D towards C. The point from any of the points where 15m marks reads will be a right angle to an offset (Figure 7.12).

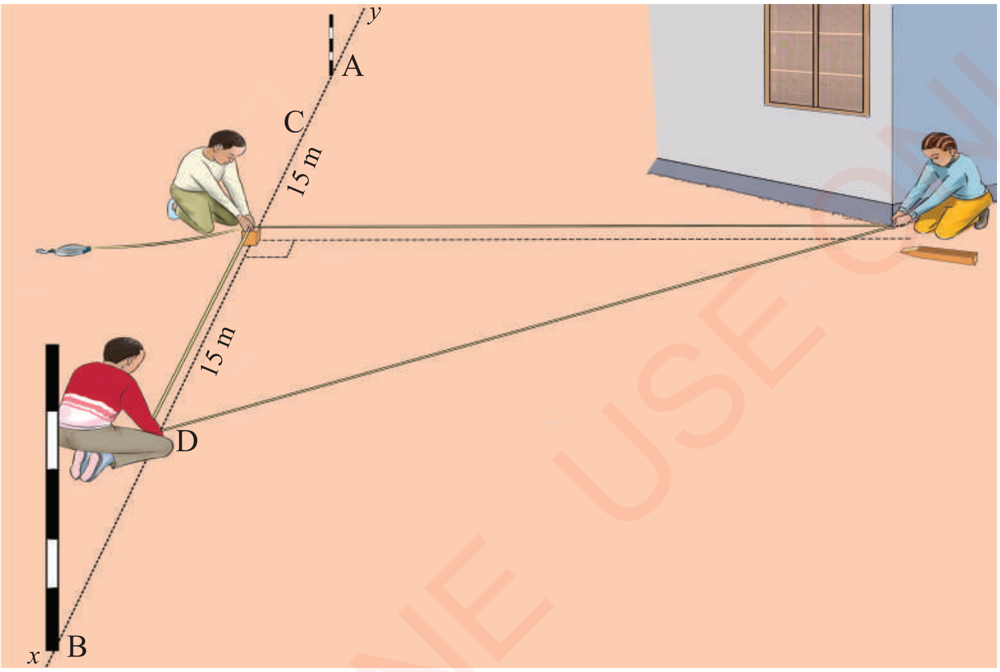


Figure 7.12 *Setting a right angle*

Procedure of measurement in chain survey

Assume the objective of your chain survey is to determine the area of the school farm. Basing on this objective, you should have to identify the appropriate equipment to be involved, including a pencil, rubber, a notebook, a scaled ruler for booking, a chain, pegs and arrows for surveying. The following are the procedures;

(a) Establish a base line AB from which all measurements are taken. A base line can be established along or across the farm where it is seen from all parts clearly. For example, the baseline between A and B in Figure 7.13 is seen clearly.

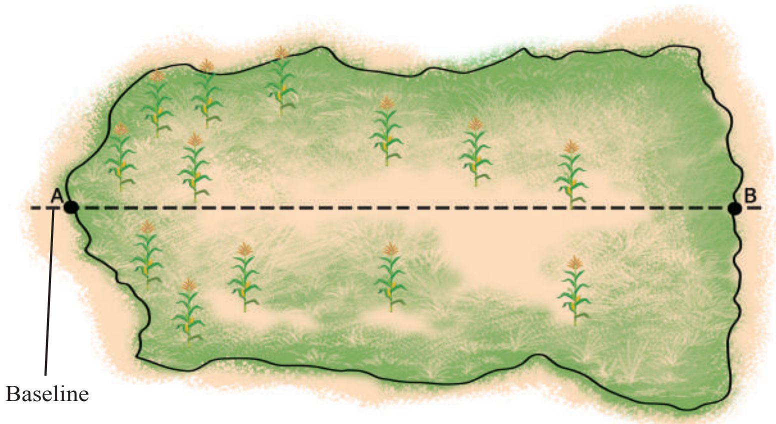


Figure 7.13: *School farm*

(b) Take measurements at right angles (90º) from the chain line (baseline) alternately on each side of the survey line (Figure 7.14). The measurements can be booked in the field during chaining.

(c) Determine the area of each trapezium and rectangles obtained from the measurements, in this case they will be areas (in m^2) of ten (10) figures (a) – (j), see Figure 7.14.

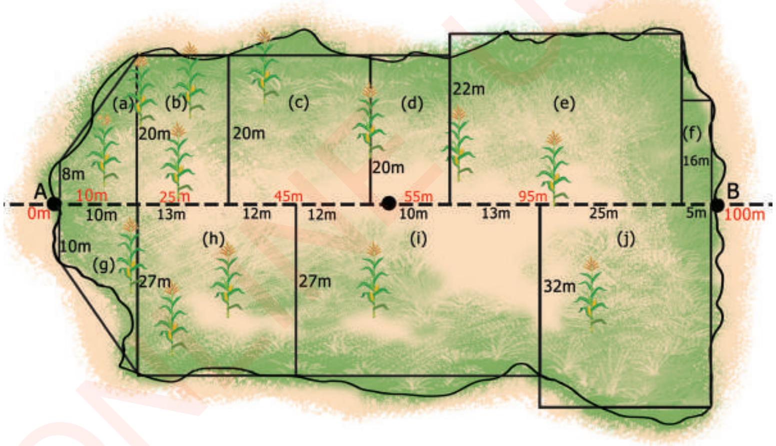


Figure 7.14: *School farm with measurements*

Area (a) $\frac{1}{2}(8\text{ m} + 20\text{ m})\ 10\text{ m}$ $\frac{1}{2} \times 28\text{ m} \times 10\text{ m}$ $\frac{1}{2} \times 280\text{ m}^2$ $= 140\text{ m}^2$	Area (b) $20\text{ m} \times 15\text{ m} = 300\text{ m}^2$ Area (c) $22\text{ m} \times 20\text{ m} = 440\text{ m}^2$ Area (d) $20\text{ m} \times 10\text{ m} = 200\text{ m}^2$

<table>
<tr><td>Area (e)
$22\text{ m} \times 40\text{ m} = 880\text{ m}^2$</td><td rowspan="3">Area (g)
$\frac{1}{2}(a + b)\,h$
$\frac{1}{2}(10\text{ m} + 27\text{ m})\,10\text{ m}$
$\frac{1}{2} \times 37\text{ m} \times 10\text{ m}$
$\frac{1}{2} \times 370\text{ m}^2$
$= 185\text{ m}^2$</td></tr>
<tr><td>Area (f)
$16\text{ m} \times 5 = 80$</td></tr>
<tr><td>Area (h)
$25\text{ m} \times 27\text{m} = 675\text{ m}^2$</td></tr>
<tr><td>Area (i)
$27\text{ m} \times 37\text{ m} = 945\text{ m}^2$</td><td>Area (j)
$30\text{ m} \times 32\text{ m} = 960\text{ m}^2$</td></tr>
<tr><td colspan="2">Therefore, total area =
$142\text{ m}^2 + 300\text{ m}^2 + 440\text{ m}^2 + 200\text{ m}^2 + 880\text{ m}^2 + 80\text{ m}^2 + 185\text{ m}^2 + 657\text{ m}^2 + 945\text{ m}^2 + 960\text{ m}^2 = 4\,805\text{ m}^2$
The size of the school farm is 4 805 square metres</td></tr>
</table>

Booking in chain survey

Booking is a process during which the measurements taken in the field are recorded in a field notebook. This is normally done by a surveyor and not by an assistant so as to avoid unnecessary errors. In booking, the following should be taken into consideration:

(i) All linear measurements should appear at the centre of the column and it has to start from the bottom upwards.

(ii) Features at the right-hand side must be recorded on the right-hand side while those at the left hand side must be recorded on the left-hand side of the column.

(iii) All offsets and ties must be shown on the side they appear along the survey line.

On your booking sheet draw parallel lines as shown in Figure 7.15.

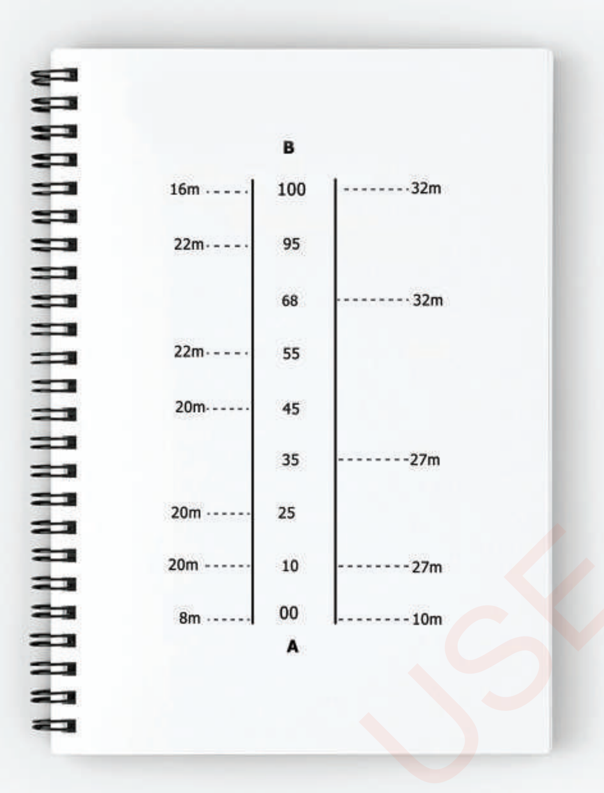


Figure 7.15: *Booking sheet or page*

(c) Presentation of the survey data collected

Survey data collected are presented in a way that can be easily interpreted and understood by the intended user. Survey data can be presented in form of maps, plans, or diagrams produced in a suitable scale and with conventional signs and symbols.

Testing and adjusting the length of a chain

Due to continuous use of a chain, its length can get altered or changed. Its length may be shortened due to the bending of links or the length may be elongated either due to stretching of links and joints or opening out of small rings. For accurate work, it is necessary to test the chain from time to time. Procedure for adjusting an elongated chain include the following:

(a) close up the joints of the rings found to be opened out;

(b) reshape the damaged rings;

(c) remove one or more small rings; and

(d) adjust the links at the end.

If the chain is found to be too short, the following procedure can be followed to correct the length:

(a) Straighten the bent links
(b) Open the joints of the rings
(c) Replace one or more small circular rings by bigger ones
(d) Insert new rings where necessary/ needed
(e) Adjust the links at the end

Folding of the chain after use

To fold the chain, the leader should move forward by pulling the chain at the middle then the two halves of the chain will come side by side. After this, commencing from the central position of the chain, two pairs of links are taken at a time with the right hand and placed on the left hand alternately in both directions. Finally, the two brass handles will come at the top. The bunch should then be fastened by the strap.

Remember to include the leader and the follower. The follower as mentioned earlier is the surveyor who holds the chain at the zero end of the chain at the station. The one who drags the chain is known as the leader and takes with him or her the ranging poles and arrows for making points on the ground.

Activity 7.1

In a group, conduct a simple chain survey around your school compound following all necessary steps to determine the area in square metres. Present it to your class.

Advantages of chain survey

Compared to other types of surveys, the chain survey is the simplest and commonest technique of surveying exercise. The equipment can be easily replaced, example tapes, and land measuring wheels. Normally, a simple chain survey does not involve complicated mathematical calculations. It does not deal with angular measurements either. It also involves only few people to conduct the exercise. The survey team may have only three people. It is thus, a cost-effective technique.

Disadvantages of chain survey

Compared to other types of survey techniques, chain survey has some limitations. It cannot be conducted in a built-up and large areas. It cannot easily be undertaken in densely wooded areas. It is mostly suitable in open ground areas. It may not be conducted in water logged areas. It is subject to several chances of accumulation of errors which may be caused by problems with the chain. Sometimes, the chain linkages may fail to stretch properly and result to inaccurate data. Also, sagging of the chain may lead to errors in chaining. Chain survey becomes a more complicated method when there are obstacles in the area to be surveyed. It is also the oldest method of surveying which involves heavy work, a lot of time and cumulative errors.

Conducting the chain survey accurately

(a) Avoid establishing many survey lines in order to avoid missing out on some of them.

(b) Avoid setting chain lines (mainline) along any obstacles that can obscure visibility or measurement.

(c) Set one major line from which other lines are developed to create triangles.

(d) Make sure that all angles of established triangles range between 30º and 120º.

(e) Keep the chain line short and take accurate measurements.

Exercise 7.3

Answer all questions.

1. Explain what you would do when preparing for a chain survey.
2. Give four 4 reasons why chain survey is important in our life.

Obstacles in conducting chain survey

Obstacles in chain surveying are objects or features that obscure visibility along the chain line or obstruct chaining. Obstacles which are common in chain survey include; obstacles which do not obscure visibility for example ponds and wells and surveyors can walk around them. Obstacles which do not obscure visibility and surveyors cannot walk around them such as rivers, and extended swamps, hills and thick forests. Obstacles which obscure visibility but which allow the surveyors to walk around include tall buildings, compound walls, and areas with extreme steep slopes.

Overcoming obstacles along the chain line

Different techniques could be used in overcoming obstacles in chain survey. Some of the techniques are described in the following sections.

(a) Using the right angle method

This method is applicable to those obstacles which do not obscure visibility but obstruct chaining across it. The barrier (for example, a pond) can however be walked around, as indicated in Figure 7.16.

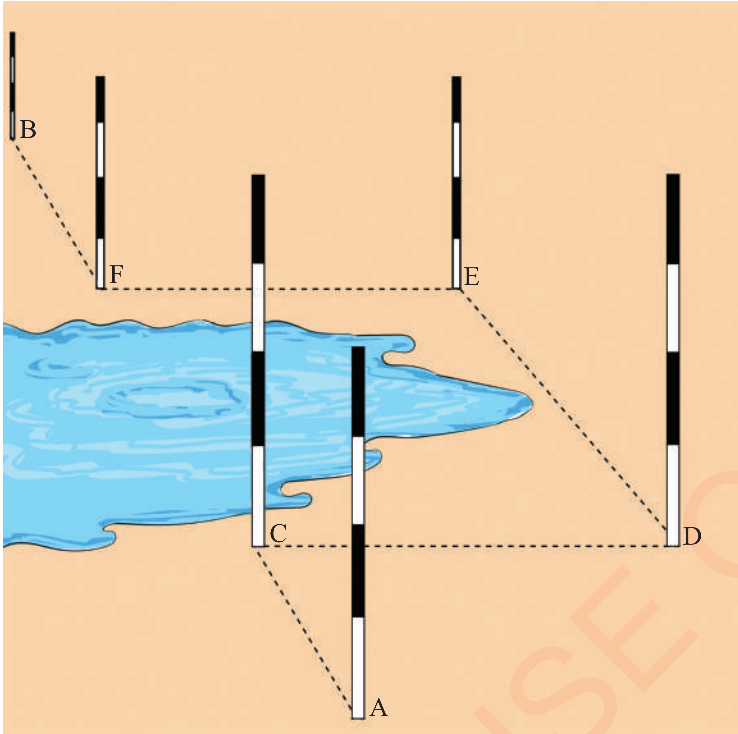


Figure 7.16: *Overcoming a pond as an obstacle*

Procedure:

(i) Fix a ranging pole at a starting point (A), then walk around and put another ranging pole at point (B) along the survey line to make a straight chain line AB;

(ii) Insert a ranging pole at C and F along the survey line AB;

(iii) From point C and F establish a perpendicular line CD and FE at right angle to avoid the obstacle;

(iv) From point D develop a line DE at right angle to avoid the obstacle;

(v) Thus, the distance of line DE =FC.

(b) Using congruent triangles or a similar triangle technique

During the process of taking measurements along the chain line (base line), one may find an obstacle which obstructs chaining but not ranging poles. If the obstacle is a river for example, one of the methods of overcoming such obstacle is to use similar triangles. See the procedure described after Figure 7.17.

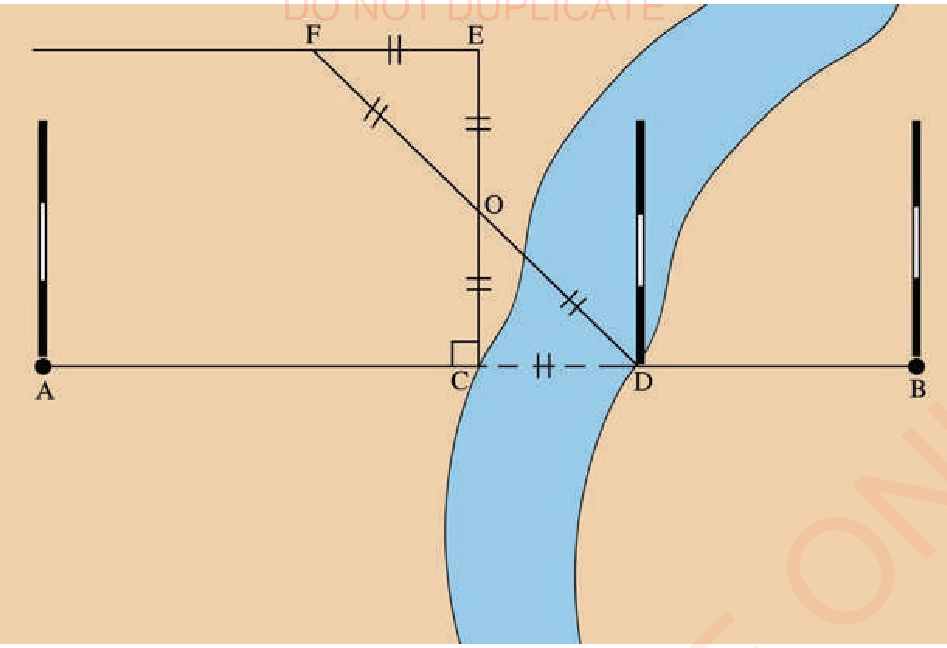


Figure 7.17: *Overcoming a small river as an obstacle by congruent triangles*

Procedure:

Suppose AB is a chain line.

(i) Fix two poles at C and D on either side of the river. Points C and D should be along line AB. At point C develop a perpendicular line CE, such that an angle ACE is equal to 90º. Bisect line CE at O to make line DF, so that CO = EO. Set another line EF parallel to the survey line AB.

(ii) Range yourself at point B in such a way that line DOF is straight (180º), thus CD = EF.

(c) *Using the pythagoras theorem*

The Pythagoras Theorem is one of the methods which can be used to calculate the dimensions of an area with obstacles such as a building, forest, rock or others. This method is used in overcoming obstacles which obscure visibility and may not be walked through easily. Consider the right-angled triangle in Figure 7.18.

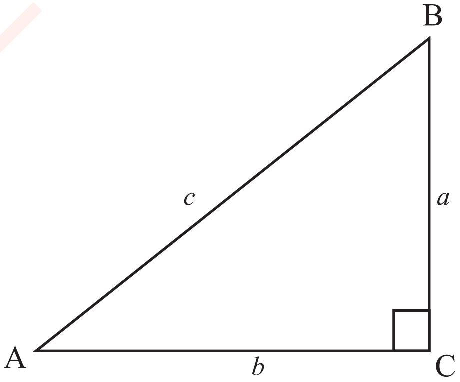


Figure 7.18: *Right-angled triangle*

If the two sides of a right-angled triangle are known, the third side can be calculated. From the Pythagoras theorem this is written as follows:

$$\left(\overline{AB}\right)^2 = \left(\overline{AC}\right)^2 + \left(\overline{BC}\right)^2$$

$$\Rightarrow c^2 = a^2 + b^2$$

$(a^2+b^2= c^2)$

Procedure:

Assume, the main line is $\overline{AB}$

(i) Erect a ranging pole at point A;

(ii) From point A, develop a straight line to point C, such that point C is at right angle to point B where it avoids the obstacle;

(iii) From point C develop a perpendicular line to point B, such that point A and B are in a straight line (Figure 7.19); and

(iv) Apply the Pythagoras Theorem to determine the distance of line AB.

Where:

CB=a

AC=b

AB=c

Formula $(a^2+b^2= c^2)$

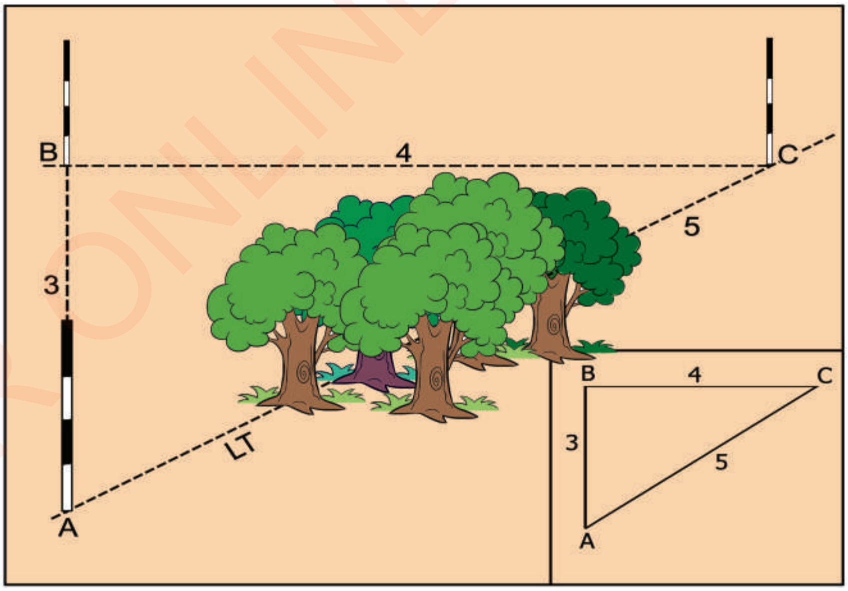


Figure 7.19: *Overcoming an obstacle a forest along LT*

(d) Using the rectangle method

This method is used to overcome any obstacle obstructing both chaining and ranging.

Suppose AB is a chain line.

Procedure:

(i) Two points A and B are aligned at one side of the building;

(ii) From both points A and B develop a perpendicular line, such that the developed line clears the object at A_1 and B_1, respectively;

(iii) Join points A_1 and B_1, such that the line clears the obstacle to make point C;

(iv) From point C develop a perpendicular line to point C_1, such that CC_1 is the same distance as AA_1;

(v) From point C_1 develop a straight line to point D, such that $C_1D=AB$; and

(vi) From point D, develop a straight line to point D_1 such that $CC_1=DD_1$ hence, $BC_1=B_1C$, (refer to Figure 7.20).

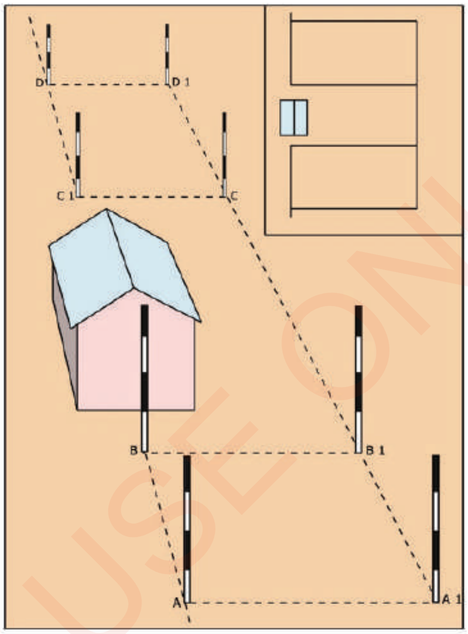


Figure 7.20: *Overcoming a building as an obstacle*

Exercise: 7. 4

Answer all questions.

1. Classify obstacles that may be encountered during a chain survey.
2. What would you do to overcome obstacles such as a pond in a chain survey?

Common errors in survey

Errors are discrepancies arising as a result of some fault and imperfection of instruments used or the human error. Errors can be grouped into three categories: systematic (cumulative) errors, accidental (compensating) errors and gross errors.

(a) Systematic errors

Systematic errors are also called cumulative errors. They are errors caused by expansion or contraction of steel band. Therefore, the steel band needs to be standardized especially in case of temperature variation whereby each band is standardized at a certain temperature. Also, systematic errors may occur and where the base line is not straight or the ranging rods are slightly in a zigzag position or in case the tape is not properly stretched.

(b) Accidental errors

Accidental errors, also called random errors or compensation. They are a result of lack of perfection of the human eye or in the methods and equipment used. They are errors which decrease with the increasing number of observations taken. In chain surveying, accidental (compensation) errors can occur due to variations in tension of stretching or improper holding of the tape. In both cases, the distance measured will roughly be longer or shorter than the actual distance. If the same distance is measured four times and an average taken, then a good approximation of the true value can be obtained.

(c) Gross errors

Gross errors have their roots in carelessness or negligence of the surveyor and are entirely attributed to human incompetence. They are also called mistake error. Examples of gross errors are misplacement of a ranging pole, miscounting of bands and/or poor spelling of numbers in words. Erroneous booking can be prevented by reading the number loudly and the booker repeating it. For example, one could read fifteen (15) instead of fifty (50). Only careful reading such as one-five for fifteen and five-zero for fifty can prevent such mistakes.

Sources of errors in chain survey

Sources of errors in chain survey can result from several factors including human error, instrumental error and environmental error. A single measurement error can be transferred to other measurements. This could include faults in the equipment such as a chain which does not stretch properly. This may be caused by lack of seriousness among the survey team when conducting the survey. The surveyors may fail to stretch the chain properly leading to differences in measurements. This happens when the arrows do not touch the outer edge of the brass handle or measuring tape. Most of the time, incorrect positioning of the arrows along the chain line leads to errors. The use of too many or too long chain lines can also cause errors in a chain survey. Consistently, unclear calling out of measurements at low voices can contribute to errors in booking.

Ways of avoiding errors or discrepancies in chain survey

There are several ways that can be used to avoid errors in chain survey. Before undertaking any survey, the chain should be checked and repaired for any damage. It is advised to avoid steep slopes and major obstacles. The idea of keeping chain lines short and measuring them accurately ensures all lines are included, also calling out measurements to a booker as clearly as possible and asking them to repeat minimize errors. The accuracy of the chain can be verified by laying it against an accurate tape. If there is any error, readings must be adjusted. A stepping method should be used when chaining along a sloping ground. This involves holding a chain or tape horizontally over short distances. The chain should not be allowed to bulge. It should be stretched and straightened properly to ensure correct positioning of arrows or poles since they must touch the outer edge of the brass handle or measuring tape and be perfectly upright. All these go along with proper booking, detailed note booking, and making neat sketches and writings.

Exercise: 7.5

Identify and explain the different sources of error in chain survey.

Development of survey techniques today

Although old techniques of land survey like chain survey, plain tables and compass surveys are being learnt today, they are being replaced by several new geomatic devices like Global Positioning System (GPS) (see Figure 7.21). Technology is changing the type and nature of surveying, and number of human power needed for each survey practice.

Figure 7.21: *GPS machine*

GPSs are advanced survey devices used to locate positions and measure distances between points, by utilizing satellite signals. The instrument is mostly preferred because it can collect information more quickly than the use of a chain or tape. The use of GPSs helps to reduce the number of equipment to be used in a survey; hence a single surveyor can accomplish the entire work. Moreover, it helps in locating positions on the earths surface and can draw a map on its own, hence reduces all hand drawing tasks.

The importance of surveying in social and economic activities

Surveying has shown a significant role in day-to-day human activities. It helps to prepare topographical maps which could show hills, valleys, rivers, villages, towns and forests of a region. Also, it helps to prepare cadastral maps showing the boundaries of a field to officiate possession of land and solve conflicts related to houses and other properties. In this case, surveying is significant for land use planning. An engineer's map which shows features like irrigation canals, railways and roads is the work of survey. Some maps showing railway communications with different parts of a country are the products of surveying. Moreover, surveying can be used to prepare a contour map to determine the best possible route for roads and railways. Geological surveys produce maps which show underground resources. Surveys also can add details to existing plans on large scale maps.

Revision exercise 7

Section A

Answer the following questions:

1. Describe the uses of the following, in chain surveying:
   (a) Coloured tie rug on arrow (b) Cross staff
   (c) Ranging poles (d) Measuring tape
2. Explain the meaning of the following terms as used in chain surveying:
   (a) Ranging (b) Chaining
3. What is the use of survey to a Geographer?
4. Describe the instruments used in chain surveying.
5. Write short notes on the following terms as applied in chain surveying.
   (a) Offsets (b) Tie lines
6. What preparation has to be done before carrying out a chain survey?
7. Describe social and economic benefits of surveying.
8. Identify the merits and demerits of a simple chain survey.
9. Identify the purpose of surveying by giving examples from your area.

Section B

*Match each item in **Column A** against its corresponding item from **Column B**.*

Column A	Column B
10. Carelessness or negligence by the surveyor.	(a) Systematic error
11. Thin steel skewers for making points on the ground.	(b) Line of traverse
12. Series of straight lines on the ground measured by a chain or tape from the fixed points.	(c) Observation
13. A step which involves visiting the area before conducting actual survey.	(d) Tie line
14. Lines marked during field survey, joining the line of traverse at right angles .	(e) Gross error
	(f) Offsets
	(g) Reconnaissance
	(h) Arrows

Chapter Eight

Map reading and interpretation

Introduction

Map reading and interpretation are important skills which a person needs to have. These skills are essential and necessary in deriving information from maps, regarding spatial distribution of phenomena, such as settlements and population, landscape, vegetation, livestock, water bodies and other natural resources. In this chapter, you will learn about the concept of map reading and interpretation, interpret topographical maps through recognizing features on a map, generate information from maps and interpret information based on daily activities. The competencies developed in this chapter will enable you to interpret and generate information from topographical maps which are important in your daily activities.

The concept of map reading and interpretation

Map reading is an act of recognizing or identifying natural and man-made features and their spatial relationship on a map. Map interpretation is about deriving information from maps in relation to particular needs. Also, it can be defined as a process of examining a given topographical map of an area for the purpose of identifying its geographical information. Map reading and map interpretation always go together. There are basic essential elements that help us to read and interpret maps. These elements are north direction, frame or margin, title, scale, grid and key or legend. Map reading and interpretation involve skills such as measuring distances, calculating areas, reading grid systems and positions, interpreting contour lines and direction.

Importance of maps

Maps provide information on the nature and distribution of geographical phenomena such as settlements, population, landscape, livestock and vegetation. From maps we can get information like distance between points or heights of landscape. Maps also provide a basis for the study of geographical problems, such as land degradation, floods and deforestation. Maps show political boundaries of different geographical units such as villages, districts, regions and countries. They also show boundaries of different land properties.

In addition, maps are essential in any field of study, as they are used to show settlements, plantations and mines. Maps that show routes may help travellers, pilots and tourists to reach their destinations. People who forecast the weather, use weather pattern maps. Also, people who study earthquakes use maps showing plates in the earth's crust. Again statistical maps provide valuable information for statistical analysis. Furthermore, maps are used in military activities such as location of military camps, military traps and bridges.

Types of maps

There are two main types of maps prepared according to purpose, namely topographical and statistical maps.

Topographical maps

These are maps which show both man-made and natural features. Man-made features are sometimes called cultural features. Topographical maps may portray man-made features like roads, buildings, and administrative boundaries. Topographical maps may also portray relief features such as mountains, valleys, and drainage features such as lakes, rivers and swamps. They also portray vegetation like woodlands and forests.

Statistical maps

These are maps which provide quantitative information. These are maps which show the value of different phenomena such as the distribution of population, rainfall, crops, minerals, temperature, and vegetation. Statistical maps are sometimes called distribution maps. Dots maps are good examples of statistical maps.

Essentials of a map

A map has key essential elements such as *title, key or legend, scale, north direction and frame* or *margin*. Maps also have lines to show position, for example, grid lines, latitudes and longitudes.

A map title

A map title is an element which tells the reader what the map is all about. A map title is important because it describes the main theme of a map.

A map scale

A map scale is the ratio between the distance measured on a map and its corresponding actual distance on the ground. Map scales enable calculation of actual ground distances from map distances. Map scales can be expressed in the following three ways.

(a) As a statement, for example, one centimetre on the map represents the distance of one kilometre on the earth's surface or ground. Sometimes this can be written as 1 cm to 1 km.

(b) As a representative fraction (RF), for example, $\frac{1}{100\,000}$ or 1:100 000. This means one centimetre on the map represents 100 000 centimetres on the ground. It should be noted that a centimetre is the basic unit used in a map scale unless guided otherwise.

(c) As a linear scale, which is a way of expressing a map scale in a straight line divided into equal intervals proportional to the actual length on the ground. A linear scale is also called a bar scale. It is divided into a primary section and a secondary section as shown in Figure 8.1.

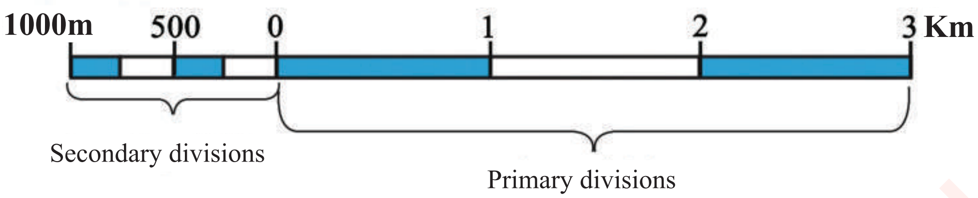


Figure 8.1: *Linear scale*

A key

Maps use symbols and signs to represent information. A map key explains the meaning of symbols and signs on the map. All signs and symbols applied in the map must be shown on the key. A key enables map readers to understand the meaning of details found on the map.

A margin

This is a line drawn around a map to show the bounded area of the map. It is also known as a border or a frame.

North direction

North direction is important in determining the bearing of a particular feature on a map. The North direction on a map is useful to identify the north bearing of mapped areas and then to locate other directions of the area such as East, North-East, South-East and South-West.

Activity 8.1

Visit the library or the Internet choose any map of your interest then do the following:

(a) identify the type of map you have chosen.

(b) mention the criteria you have used to categorize the map.

(c) mention the importance of the map you have chosen.

(d) list any five features found on that map.

(e) mention basic things which helped you to depict those features.

Reading and interpreting topographical maps

Reading a map means studying and identifying various features which are shown on the map with the help of conventional symbols and signs. Interpreting maps means observing the features shown on the map for the purpose of judging their significance. It involves translating the information by describing the features shown on the map. In order to read and interpret topographical maps you need to know how different symbols are used to represent different features shown on the map.

Ways of showing position on a map

The position of a place on a map can be given in a number of ways. These include using place name, grid reference, latitude and longitude, and bearing and distance.

Place name

A place on a map can be located by its name. For example, on the map of Africa different places can be located such as Accra in Ghana, Dodoma in Tanzania and Lake Tana in Kenya. Place names may be considered adequate where a rough idea of the location of a place is all that is required.

Grid reference

Grid reference is a network of parallel vertical and horizontal lines on a map used to fix positions. The vertical lines are referred to as the Eastings since their values increase eastwards. The horizontal lines are known as Northings since their values increase northwards. Normally, a grid reference has six digits, the first three digits are Eastings and the next three digits are Northings. For example, a grid reference of 675246, means 675 represent Eastings and 246 represent Northings.

Latitude and Longitude

Latitudes and longitudes are used for giving the position of a place. These lines are always needed in the process of map making. Nearly all maps indicate latitudes and longitudes along their edges. A latitude is measured northwards and southwards from the centre of the earth which is the equator, while a longitude is an angular measurement eastward and westward from the centre of the earth which is the Prime Meridian.

In an atlas, a list of all places shown on a map is provided at the end of the book. This is the index of the atlas. For each place, position is given by latitude and longitude. For example, Dar es Salaam on the map of Tanzania is located on latitude 7 degrees South and longitude 39 degrees East.

Bearing and distance from a place or point

Some of the problems concerning names can be resolved simply by combining description of place names with bearing and distance. For example, a dispensary could be located 5 kilometres 45 degrees from Bagamoyo town. The angle which is measured clockwise from a fixed zero line known as North is called bearing. The purpose of bearing is to give an accurate indication of the direction of one place from another through the use of angle degrees.

The following are the procedures for locating an object or place on a map by using bearing and distance:

(a) identify the point on the map by using grid reference;

(b) establish a cardinal point at the point identified;

(c) measure the forward bearing;

(d) change the map scale and use it to convert the ground distance into map distance;

(e) draw a straight line from the point along the angle of observation; and

(f) measure the distance obtained from the point along the line.

Note: Where the distance ends is where the object is located.

For example, from Figure 8.2, identify the feature located 4 km and 45 degrees from point P grid reference 100200. The map scale is 1cm represents 0.5 km.

Solution:

$$1 \text{ cm} : \tfrac{1}{2} \text{ km}$$

$$x : 4 \text{ km}$$

$$\frac{1 \text{ cm} \times 4 \text{ km}}{\tfrac{1}{2} \text{ km}}$$

$$\frac{4 \text{ cm}}{1} \times \frac{1}{2} = 8 \text{ cm}$$

Map distance = 8 cm

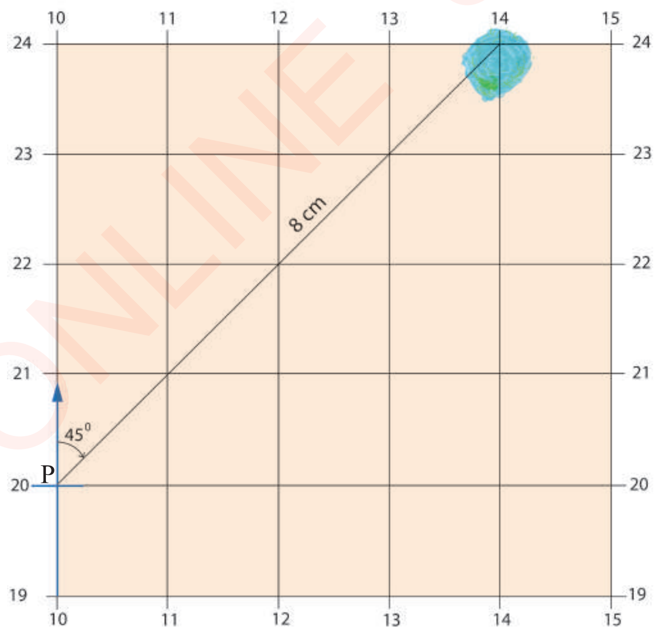


Figure 8.2: *Using bearing and distance to find a place or point on a map*

Therefore, the feature which is located 8 cm and 45° from point P is a swamp.

Exercise 8. 1

Answer all questions.

1. Suppose you have been given a map of Tanzania with grid references, place names, latitudes and longitudes, which way will you use to show the position of a place? Explain why you have chosen this method.
2. From a map of Tanzania Mainland, identify the location of Dodoma by using grid reference.
3. Calculate the ground distance between grid reference 400530 and 305551.

Regions of Tanzania Mainland

Methods of representing relief on topographic maps

Relief entails the physical shape or appearance of the surface of the earth. Cartographers (or map makers) use several methods to show relief of the landscape. These methods are explained in the sections that follow.

Trigonometric stations

These are small triangles used on maps to show the exact elevation of the highest point in given areas. The triangle has a black dot inside followed by a number showing the exact height from the sea level (Figure 8.3). Many stations could be located on the peaks of hills so that they could be seen from many directions. There are two types of trigonometric stations: primary and secondary trigonometric stations. Primary trigonometric stations show high points in the area mapped, while secondary trigonometric stations show high points in the area mapped but which are lower than primary trigonometric stations.

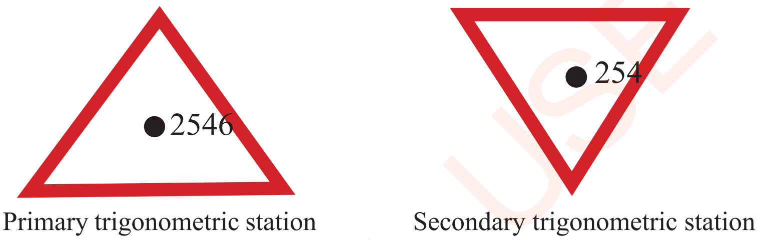


Figure 8.3: *Trigonometric stations*

Spot heights

This is a method of showing relief which uses dots to show the exact height or relief of an area. The relief is indicated by a dot followed by a number of the exact height of a place on a map. Figure 8.4 provides an example whereby •110 is a spot height.

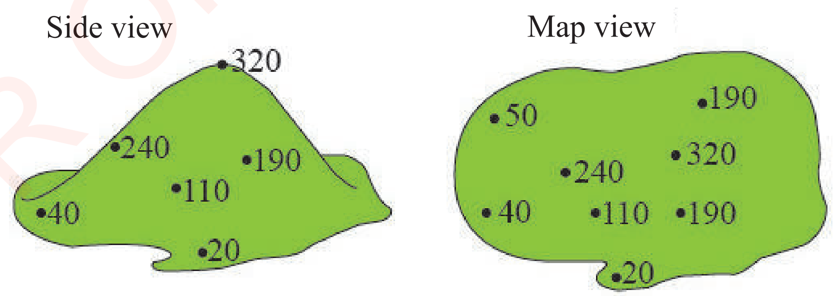


Figure 8.4: *Spot height*

Layer tinting or layer colouring

This is a method of showing relief by different colours. A specific colour is used for each band of elevation which represents a definite elevation range (Figure 8.5). For example, brown colour can be used to show the highest height above sea level and green to show the lowest height above sea level. However, a map user cannot determine the exact elevation of a specific point by using this method.

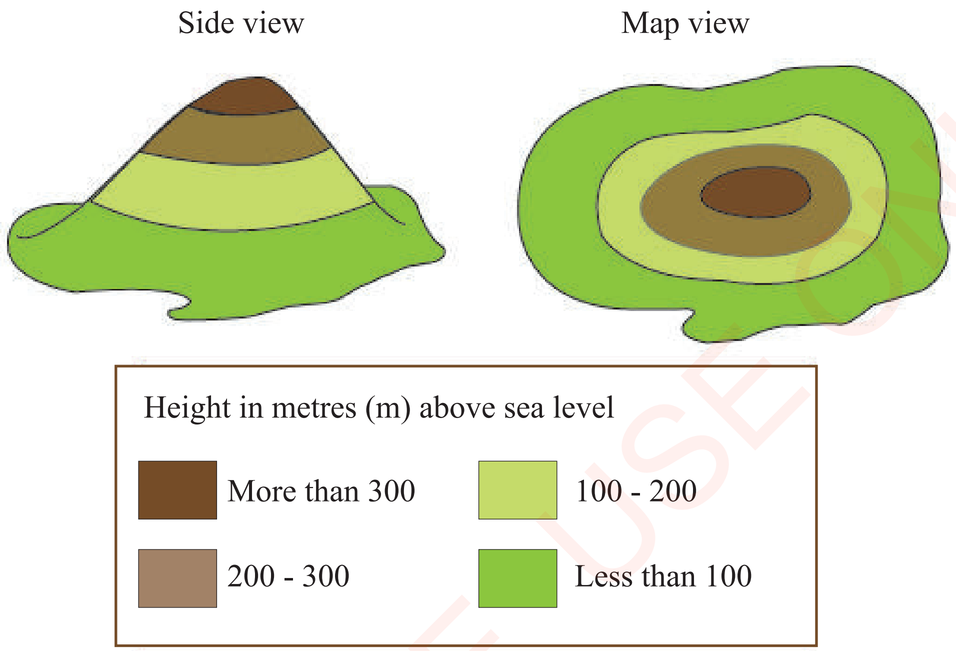


Figure 8.5: *Layer tinting or colouring*

Form lines

Form lines are not measured from any datum plane and have no standard elevation. They give only a general idea of the relief. They are represented on a map as pecked lines and are not labeled with representative elevations.

Hill shading

This indicates relief by a shadow effect achieved by tone and colour that results in the darkening of one side of terrain features such as hills and ridges. The steeper the slope the darker the shading. This sometimes is used in combination with contour lines to emphasize the features (Figure 8.6).

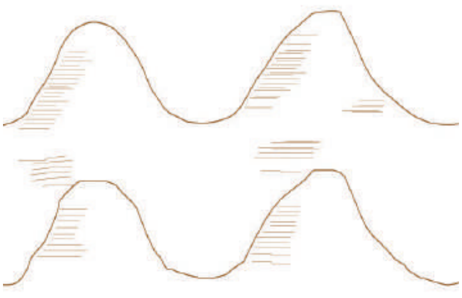


Figure 8.6: *Shaded relief or hill shading*

Hachuring

This is a method of representing relief of an area by using hachures. Hachures are short, broken lines that are used to show relief specifically showing direction and steepness of slopes. They are sometimes used with contour lines. Hachures are used extensively on small scale maps to show mountain ranges, plateaus, and mountain peaks but they do not represent exact elevations (Figure 8.7). Hachures that are close together indicate steep slopes. The degree of thickness of hachures increases with the degree of slope, and they point towards the direction of slope.

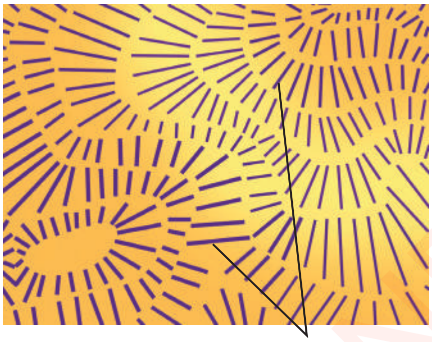


Figure 8.7: *Hachures*

Benchmark (BM)

A benchmark is a place where the exact elevation is known. It is a reference mark of a known elevation cut or set on a stone, concrete or aluminum plate or other durable material used in the determination of altitudes. Benchmarks are used as reference points from which other objects on the ground can be determined. Benchmarks on maps are indicated by symbol (x) followed by elevation values of the given points on the map together with letters BM.

Contours

Contours are lines drawn on a map to join all places of the same height above the mean sea level. The sea level is regarded as zero height.

Mean sea level is the average level between high and low tide marks. Contours are drawn on a map at intervals of the same numerical value known as the vertical interval. The vertical interval of contours is therefore the vertical difference between two successive contour lines.

Activity 8.2

In a group, do the following:

(a) Make a mound of clay of about 30 cm high to represent a hill Fig. 8.8(a).

(b) Place a ruler upright by the side of the mound.

(c) By using a straight piece of wood with a pointed end tied to the ruler at 10 cm, mark and draw a line around the mound.

(d) Move to 20 cm and then 30 cm. Mark and draw similar lines. In the end there will be many circles around the mound at intervals of 10 cm.

(e) Viewed from above, the pattern of circles formed on the mound would look as shown in Fig. 8.8(b). This represents the plan of the mound on a flat surface.

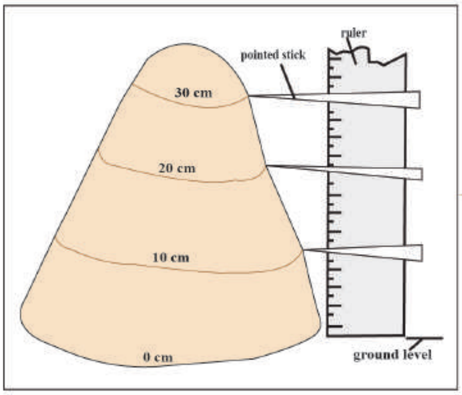


Figure 8.8(a): *Mound 30 cm high*

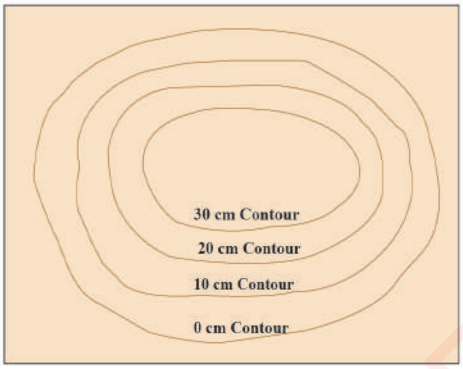


Figure 8.8(b): *Plan of the mound in contour*

Contours and associated landforms

Although contour lines basically represent heights of different places above mean sea level, they also form different patterns which depict different landforms. Contours do not cross one another. Sometimes it occurs that contours are so close that they touch each other. In certain cases, they are widely spaced. In either case, the vertical interval remains the same. In Figure 8.9, side 'A' of the hill has a steeper slope than side 'B'. Contours on side A are closely spaced while those on side B are widely spaced. This is because the horizontal distance from one contour to another on side 'A' is shorter than that on side 'B'.

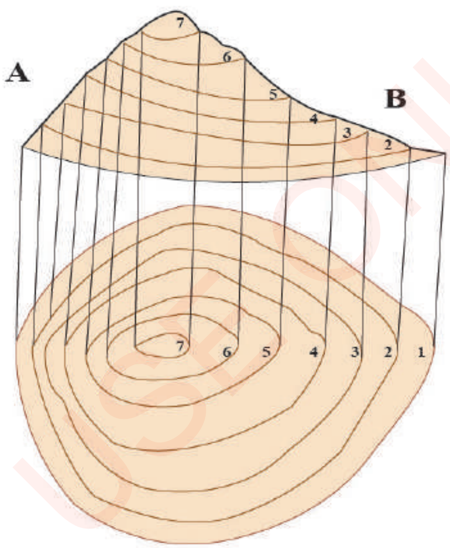


Figure 8.9: *Hill with steep and gentle slopes*

The closer the contours the steeper the slope, the farther apart the contours, the gentler the slope. Contour lines are normally presented by brown colour. The patterns of contours represent different landforms like valleys and spurs, saddles and cols, ridges, escarpments, slopes of different degrees of steepness, plateaus and plains. Landforms or relief shown on contour maps may be divided into two major categories, namely highlands and lowlands.

Highland landforms

Valleys and spurs

These often occur side by side on a hill side. The patterns of contours showing the two features are similar. Where there is a valley, contour lines resemble a V or U-shape. The pointed end of V or U points to the higher ground. This is shown by ascending order in which the contour lines are marked. In the case of a spur, the V or U bends towards the lower ground (Figure 8.10).

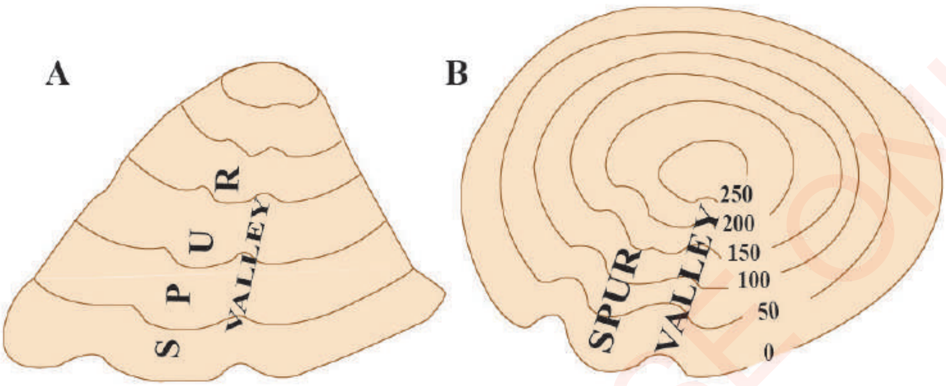


Figure 8.10: *Valley and spur on a hill side*

A saddle

The space between two peaks of a mountain or a mountain range is called a saddle or a col. A saddle is generally wider than a col. Saddles provide convenient passages across mountain ranges. Contours showing a peak are usually closer. Inner curves are at higher elevation than outer curves and the peak is within the inner most curve (Figure 8.11).

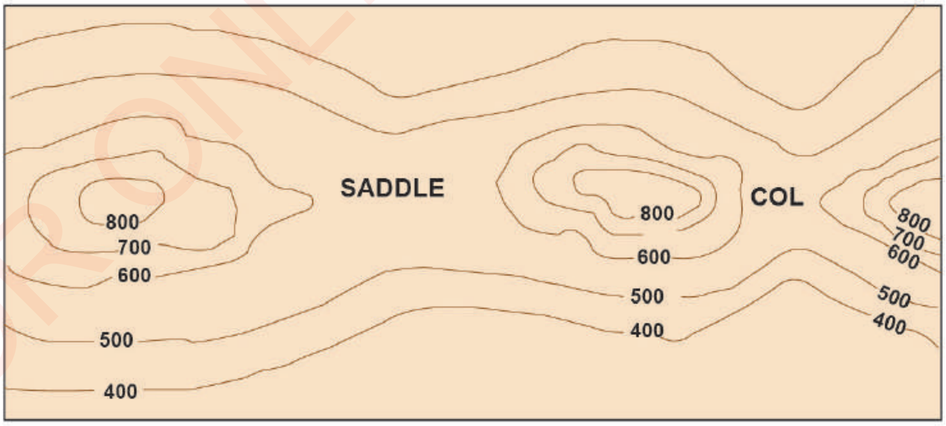


Figure 8.11: *Saddle and a col*

A ridge

This is a geographical feature consisting of a chain of mountains or hills that forms a continuous elevated crest for some distance. It can also be defined as a narrow and long relief feature with steep slopes. Contours for a ridge run almost parallel to each other (Figure 8.12).

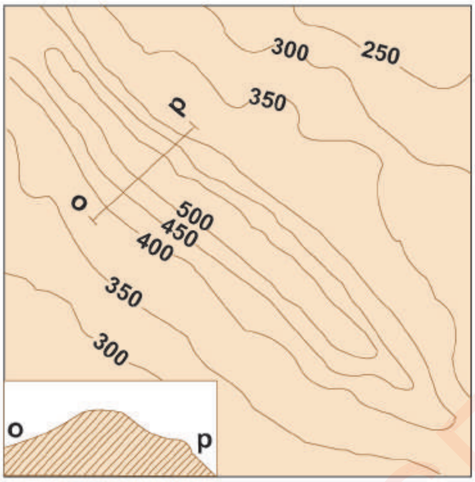


Figure 8.12: *Ridge*

Escarpment

An escarpment is an area of highland with a very steep slope on one side and a gentle slope on the other (Figure 8.13). The steep slope of an escarpment is called the scarp slope, and the gentle slope is known as the dip slope.

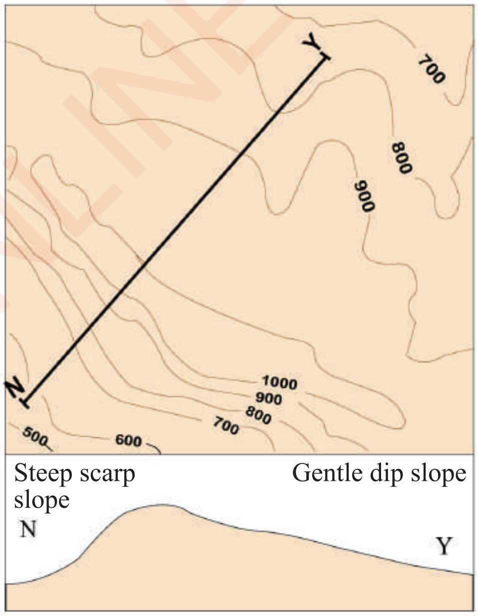


Figure 8.13: *Escarpment*

A plateau

This is an extensive highland region with an undulating surface. A plateau is easily identified on a map by the absence of contour lines on the higher land surface and with a series of contours close together on either side, (Figure 8.14). In some cases, it is possible to find contours on a plateau surface, indicating the presence of a hill or hills.

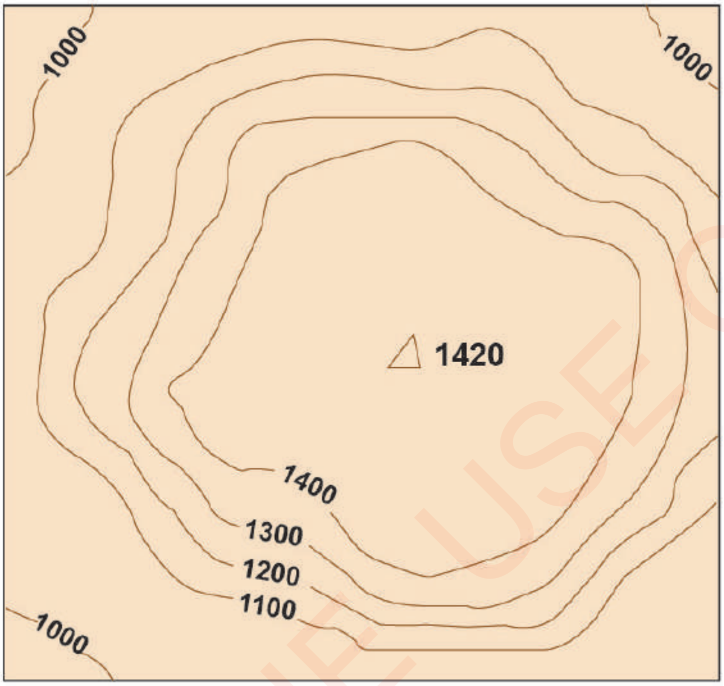


Figure 8.14: *Plateau*

Slopes

These can either be steep or gentle. Slopes which are constantly steep or gentle are usually referred to as even slopes (Figure 8.15(a)). However, some slopes bear both characteristics. For example, a concave slope is gentle at the lower elevation and gets steeper at the higher elevation. Contours of a concave slope are widely spaced at the lower elevation and closely spaced at the higher elevation (Figure 8.15(b)). A convex slope has a steep slope at the bottom and a gentle slope at the top of the ground. Contours of this slope are closely spaced at the lower ground and widely spaced at the higher ground (Figure 8.15(c)).

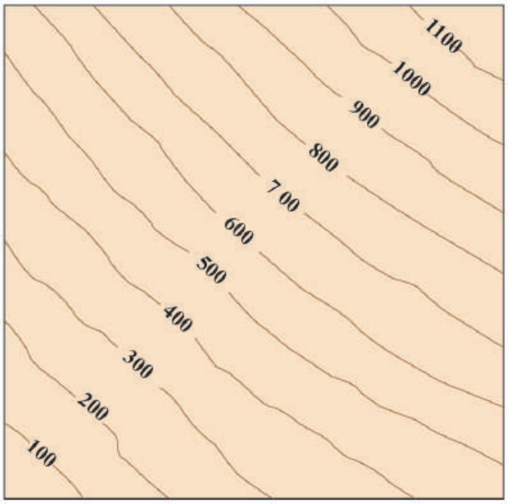


Figure 8.15(a): *Steep slope*

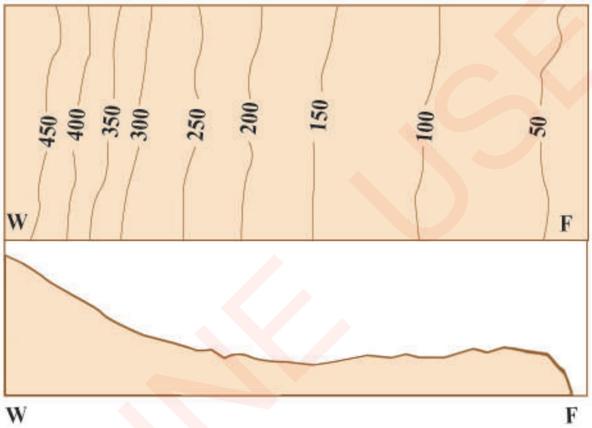


Figure 8.15(b): *Concave slope*

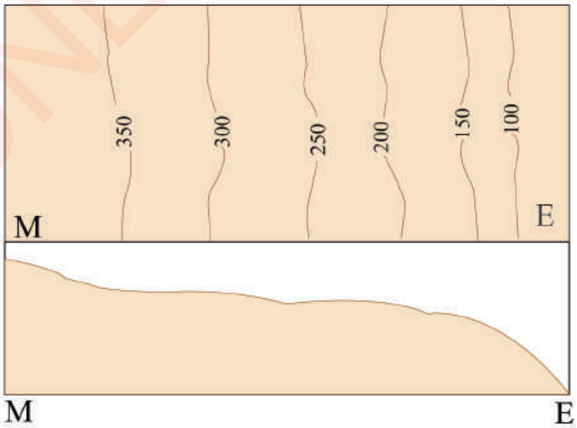


Figure 8.15(c): *Convex slope*

Exercise 8.2

Answer all questions.

1. How can you depict a plateau on a topographical map?
2. Differentiate between the following features on a topographical map;
   (a) a valley and a spur
   (b) a saddle and a col
   (c) mountains and plateaus
3. Using vivid examples explain the importance of valleys to human life.

Lowland landforms

A gorge

This is a deep narrow steep-sided river valley. The contours of a gorge are close together forming a narrow V shape pointing sharply upstream. The river in the gorge crosses each contour at the highest point of each (Figure 8.16).

A V- shaped valley

The contours portraying a V-shaped valley are V in shape and point upstream (Figure 8.16). The stream crosses each contour at its highest point when the V-shape is wide, and when the contours are further apart, it indicates a wide and less steep valley.

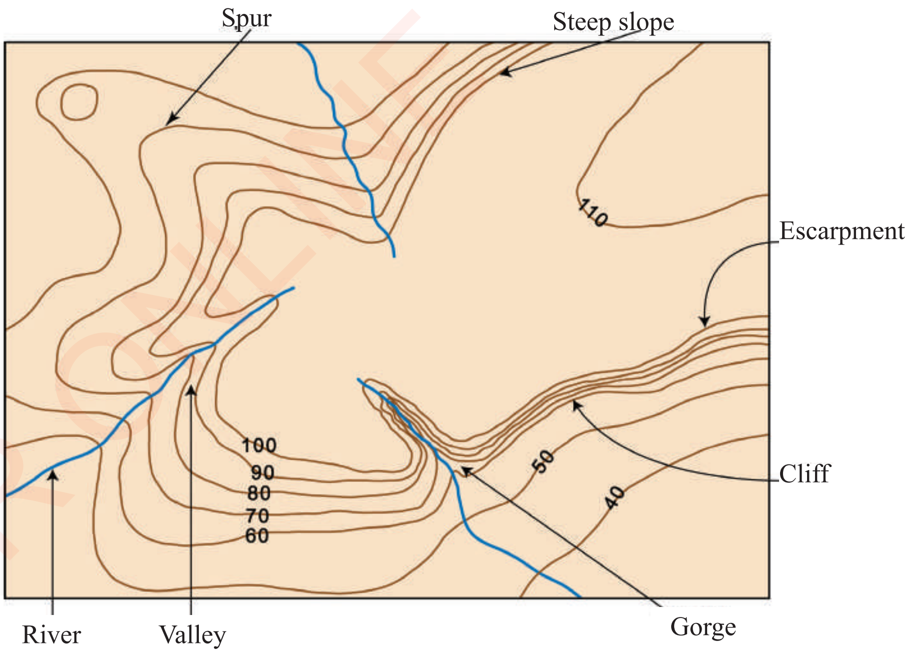


Figure 8.16: *Gorge, V- shaped valley and cliff*

Levees

These are natural ridges built up by a stream along the edges of its channel. In a contour map, the ridges are shown by pecked lines at right angles to the course of the river (Figure 8.17).

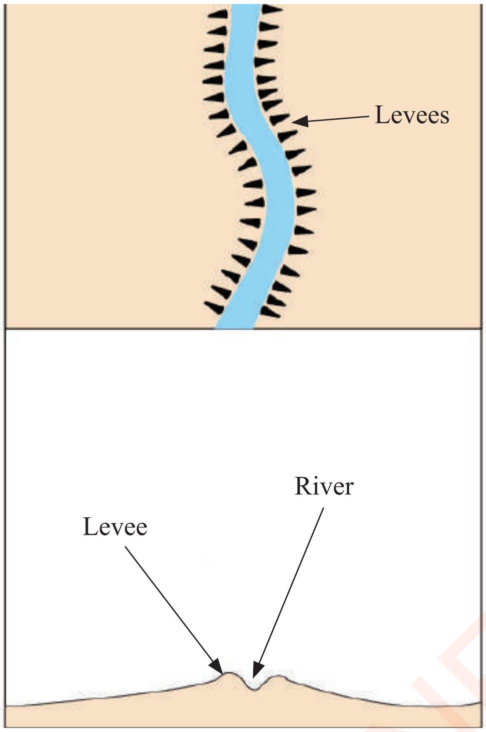


Figure 8.17: *Levees*

A flood plain

This is an area of lowland built up by the deposition of alluvium (Figure 8.18). During flooding, the river floods the lowlands and spreads a layer of silt over the flood plain. The contours are spaced in a way that they mark the general width of the flood plain. The other higher contours are evenly spaced marking the gentle slope of the banks of the flood plains.

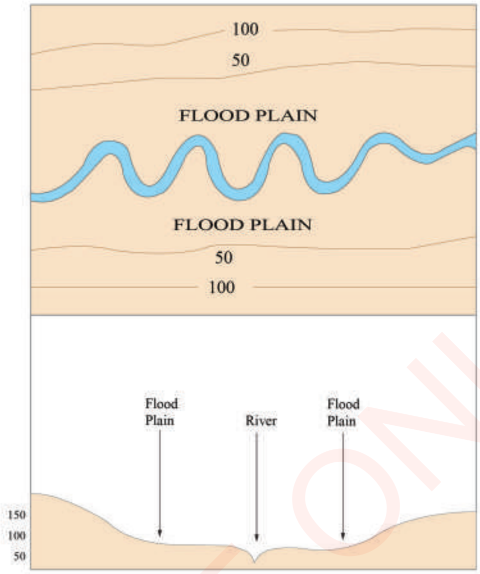


Figure 8.18: *Flood plains*

A delta

A delta is a flat area of alluvial material (clay, silt, sand, mixture) at the mouth of a river crossed by many distributaries. In a contour map, a delta is marked by many distributaries that enter a lake or sea. The lowest contour marking the delta follows roughly the outline shape of the delta (Figure 8.19).

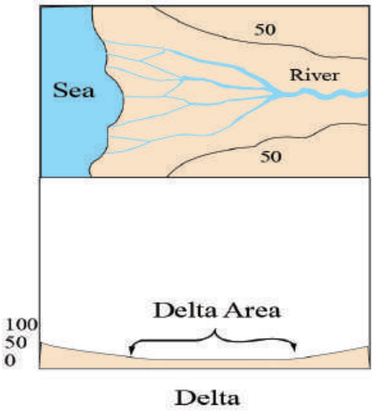


Figure 8.19: *Delta*

Coastline landforms

Estuary

An estuary is the mouth of a river where it enters a lake or sea. Also, an estuary refers to the tidal mouth of a river where the tides meet the river currents of fresh water. The contours of an estuary are widely and evenly spaced forming a wide U shape that points upstream (Figure 8.20).

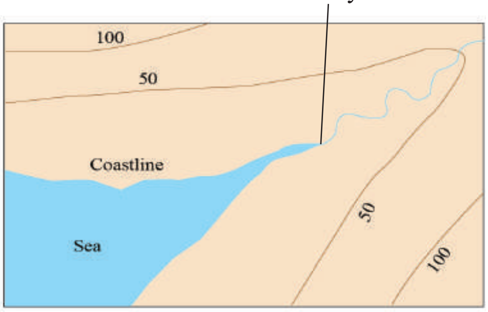


Figure 8.20: *Estuary*

Cliff

A cliff is a high steep rock face along a coast, river or lake. A cliff is a vertical or near vertical feature. In a contour map, a cliff may be indicated in two ways.

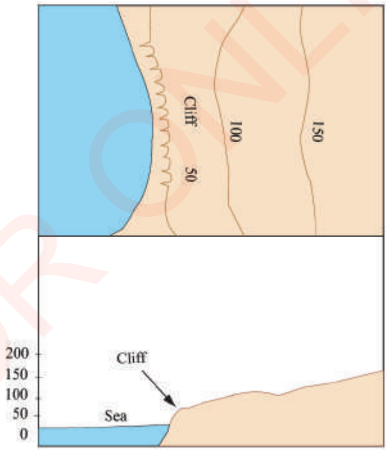


Figure 8.21: *Cliff*

A cliff may be shaded by short lines drawn at right angles to the coast, river or lake to mark the steepness of the cliff (Figure 8.21). In a contour map, when a cliff has a steep slope, the contours are closer together. When a cliff face is vertical, the contours are so close together that they overlap or join to form a single contour line (Figure 8.22).

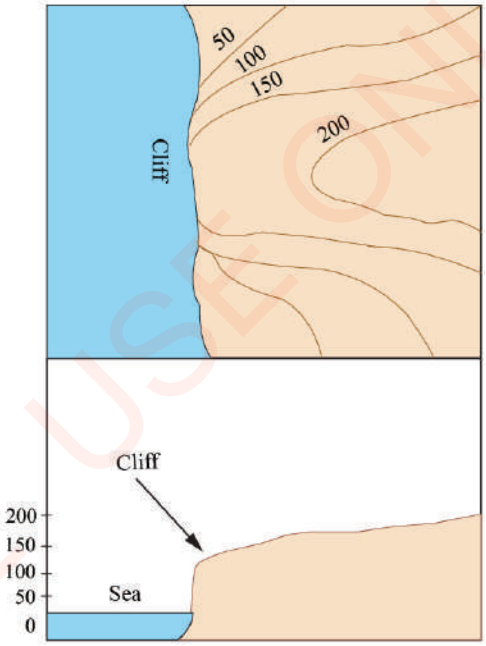


Figure 8.22: *Cliff, with overlapping contours*

Coral fringed coastline

A coral fringed coastline is formed by a coral platform which lies close to the shore. It is separated from the mainland or island by a lagoon or shallow channel. A fringing reef may be 0.5 to 2.5 kilometres in width. In a contour map, the coral fringed coastline is marked clearly by shading or by using symbols to show the areas with coral fringing reef in the sea (Figure 8.23).

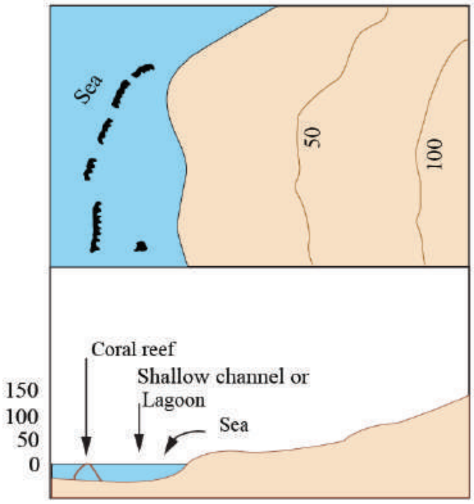


Figure 8.23: *Coral fringed coastline*

Exercise 8.3

Section A

Choose the correct answer.

1. In Figure 1, a river marked PR is shown crossing a 300-contour line. Which of the following statements is true?

    (a) The direction of flow is shown by the arrow "A"

    (b) The direction of flow is shown by the arrow "B"

    (c) The direction of flow cannot be told from this information

    (d) The river has no direction

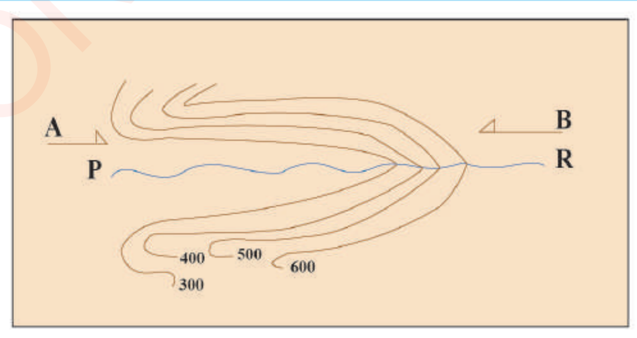


Figure 1

2. In Figure 2, what does X represent?

   (a) A ridge
   (b) A dip
   (c) A col
   (d) A hill top

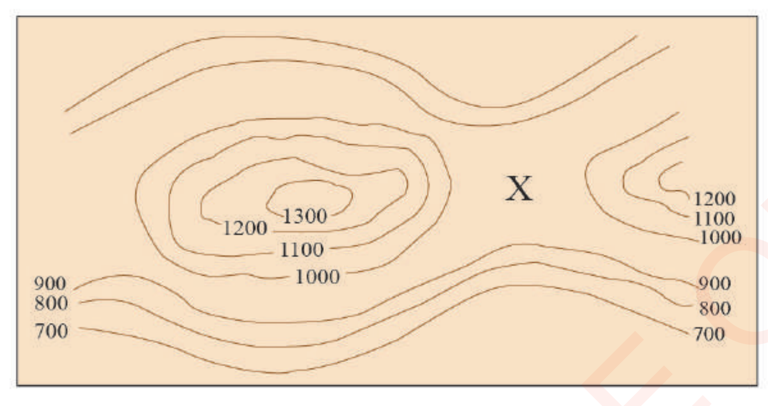


Figure 2

3. In Figure 3, what does XY represent?

   (a) A spur
   (b) A valley
   (c) A saddle
   (d) A hill

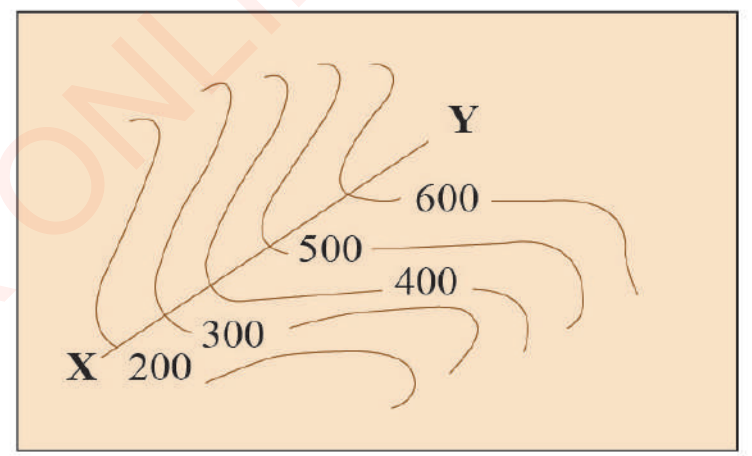


Figure 3

4. What kind of slope is represented in Figure 4?
   (a) An escarpment
   (b) A convex slope
   (c) A concave slope
   (d) A gentle slope

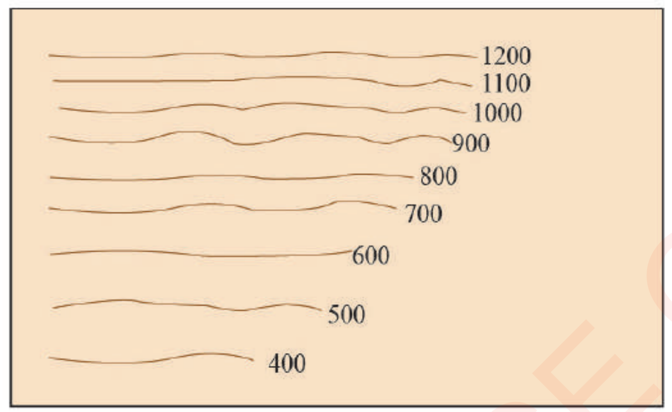


Figure 4

5. What kind of slope is represented in Figure 5?
   (a) A scarp slope
   (b) A dip slope
   (c) A convex slope
   (d) A steep sided valley

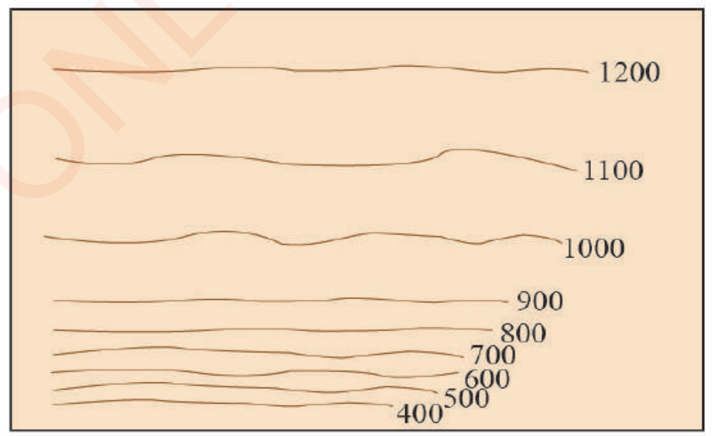


Figure 5

6. What kind of slope is represented in Figure 6?

   (a) An even slope

   (b) A convex slope

   (c) A concave slope

   (d) A very gentle slope

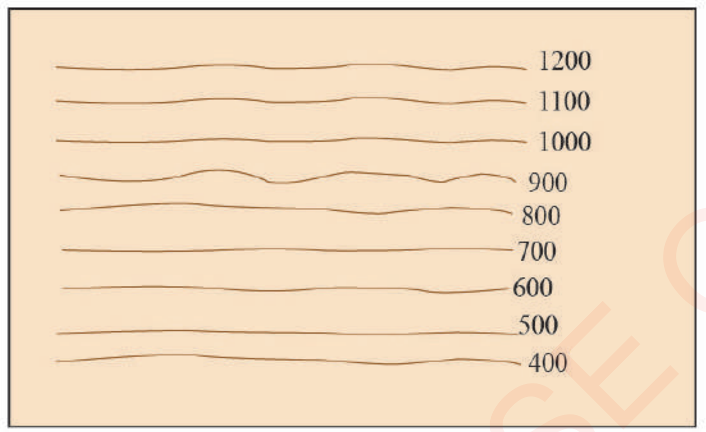


Figure 6

7. Which feature is represented by the contours in Figure 7?

   (a) A valley

   (b) A plateau

   (c) A ridge

   (d) A hill

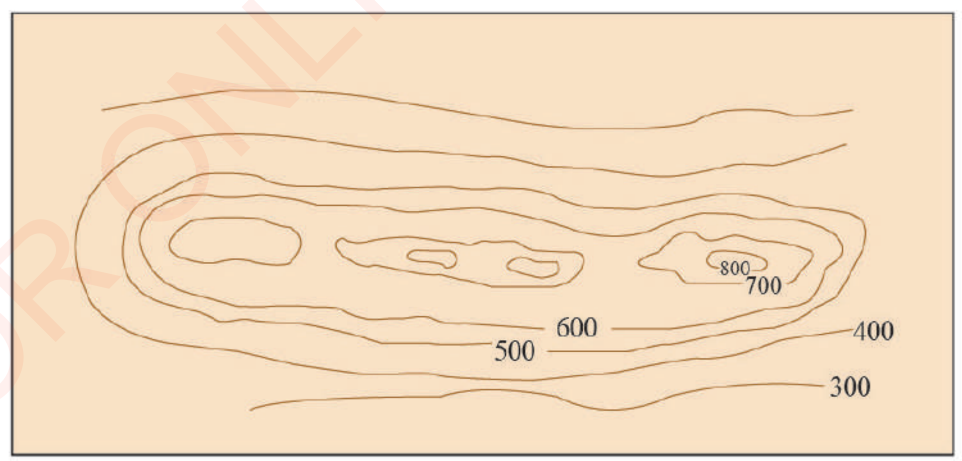


Figure 7

8. Which feature is represented by the contours in Figure 8?
   - (a) A scarp slope
   - (b) A dip slope
   - (c) A convex slope
   - (d) A steep sided valley

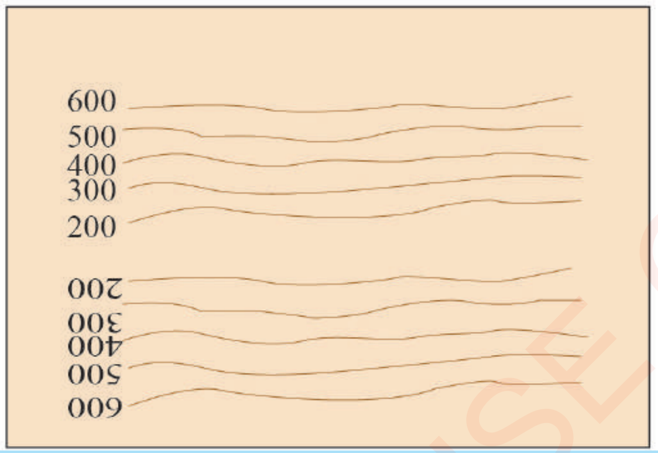


Figure 8

9. Contours marked by letter Y in Figure 9 represent ____.
   - (a) A scarp slope
   - (b) A dip slope
   - (c) A gentle valley side
   - (d) A concave slope

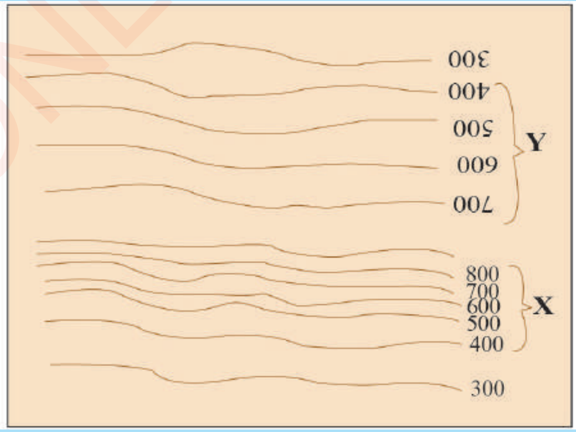


Figure 9

Section B

Match items in ***Column A*** *with their corresponding meanings in* ***Column B****.*

Column A	Column B
10. A space between two peaks of a mountain.	(a) A scale
11. Short broken lines that are used to show relief.	(b) A legend
12. A small triangle used on maps to show the exact elevation of height in a given area.	(c) Margin
13. This explains the symbols and signs used on a map.	(d) A trigonometric station
14. A ratio between the map distance and actual ground distance.	(e) Hachures
	(f) A saddle
	(g) A valley

Cross section

A cross section is used to show relief variations across a region. In drawing a cross section from a map, the following stages are followed:

(a) Mark two end points as A and B between which the cross section is desired;

(b) Draw a straight line to join the two end-points, A and B;

(c) Two end points of the area to be sketched should be marked AB (Figure 8.24).

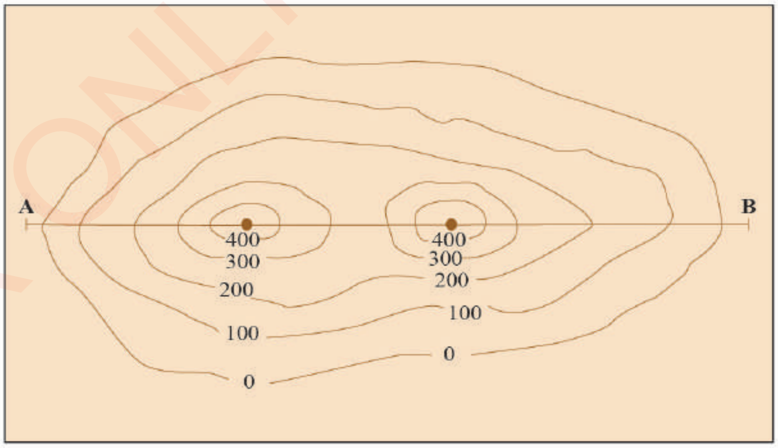


Figure 8.24: *Two end points are marked AB*

(d) Hold the edge of a piece of paper along AB, and mark on the paper where every contour cuts the paper edge. Values of contours are written and a note of any significant features (man- made or natural) is indicated on the paper, as shown in (Figure 8.25).

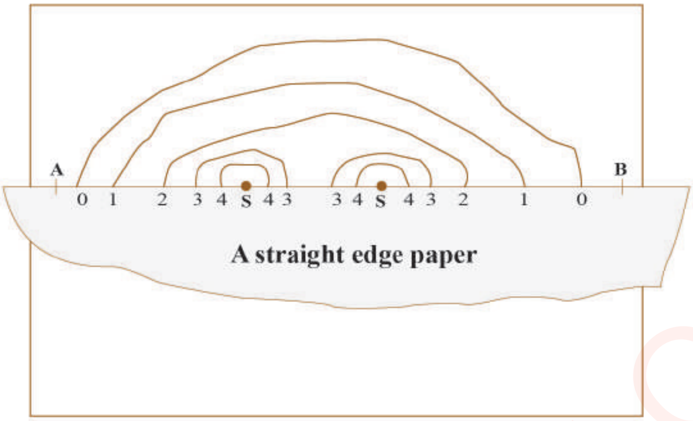


Figure 8.25: *Straight edge of paper*

(e) Prepare a vertical scale after marking the values of contours on the paper. The horizontal scale of the cross section is in the same scale as that of the map (Figure 8.26).

Figure 8.26: *Framework*

Take the highest contour line on the map to be 400 meters. In drawing, an allowance should always be given for the peak by showing the next contour (500 m contour).

(f) The horizontal base-line represents the line between two points. The marked paper is placed along the base line so that 'A' on the paper falls on 'A' on the scale. Then, each contour along the horizontal line is marked. With a pencil and a ruler vertical lines are lightly drawn up to the line which represents the contour height (Figure 8.27).

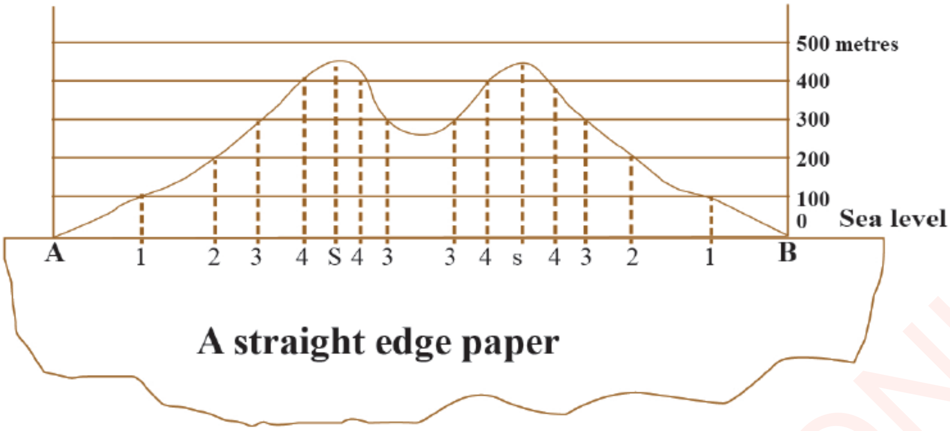


Figure 8.27: *Straight edge of paper on a scale*

(g) Prepare a frame for drawing the cross section

The first line will fall on the 100-meter contour so that the vertical line will be drawn from the base-line to the 100-meter contour line. The next vertical line will be drawn to the 200-meter contour. Note that the heights of mountain summits are not exactly known in this case but we know that they are above 400 meters but not as high as 500 meters. The approximate summits of the hills can be drawn quite easily by joining the tops of the vertical lines with a smooth curve. Write the names of other important relief and man-made features above the corresponding features on the cross section.

Intervisibility

Map makers and readers are interested in knowing from a map whether one place is visible from another place or not. This is called intervisibility. It is easy to tell whether a place is visible from another if it is known that the portion of the land surface between the two observation points is lower. But when it is not known, then it is necessary to draw a cross section between the points. If two places A and B were to represent two observation points, a cross section would make it possible to tell whether the two places are intervisible or not (Figure 8.28).

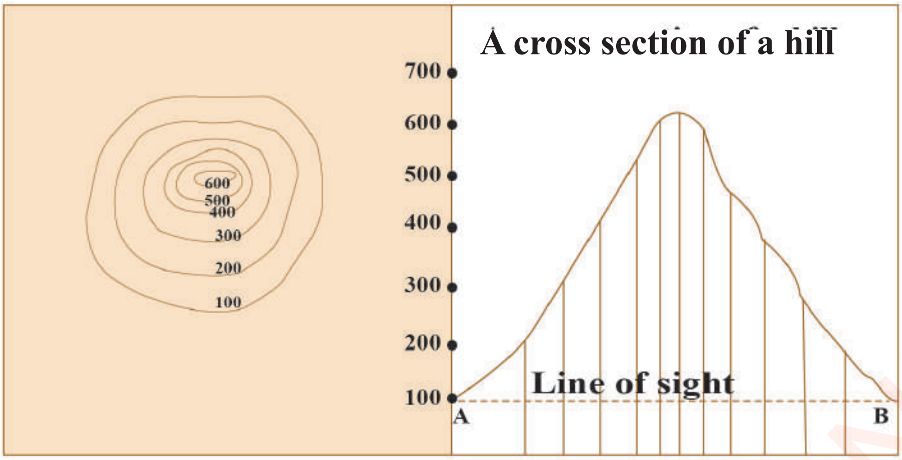


Figure 8.28: *No intervisibility between A and B*

To determine intervisibility, we draw a line of sight joining the two points in a cross section. If a mountain or a hill develops between two points A to B, the two points are not intervisible because the hill or mountain is an obstacle (Figure 8.27). When a basin or depression develops, there is intervisibility because when a line of sight is drawn it passes straight without being obstructed (Figure 8.29).

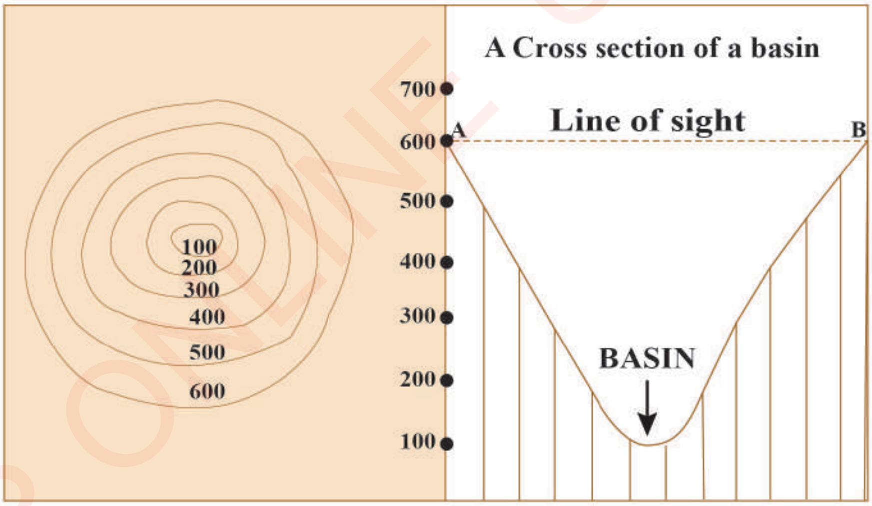
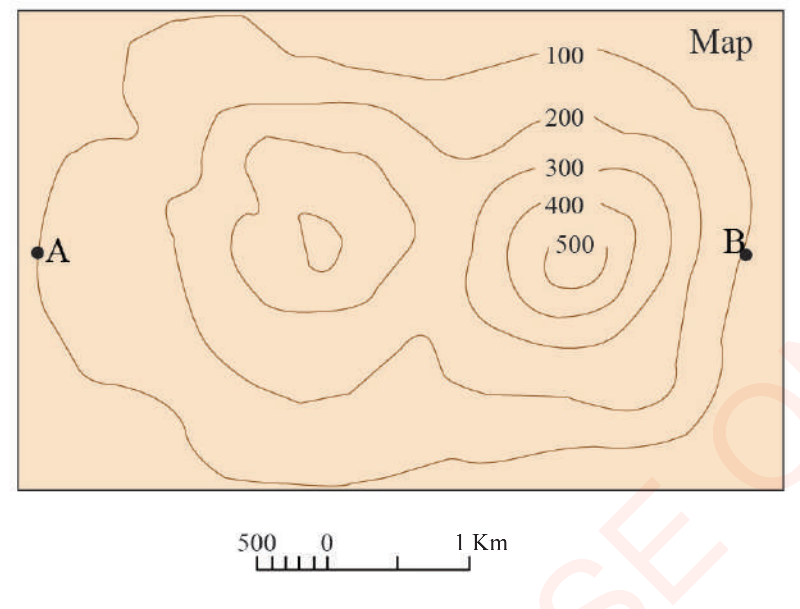


Figure 8.29: *There is intervisibility between A and B*

It is important to note that intervisibility can be affected by other factors such as presence of buildings, vegetation, hills and mountains.

Exercise: 8.4

Study the following contour map and answer the subsequent questions.



(a) Draw a cross-section between points A and B.

(b) State the intervisibility between points A and B.

(c) Give reasons for the intervisibility stated in (b) above.

Vertical Exaggeration (VE)

Vertical Exaggeration (VE) is defined as the number of times by which the vertical scale (VS) is larger than the horizontal scale (HS). It is a comparison between the horizontal and vertical scales of a cross profile. In other words, vertical exaggeration is a scale that is used in cross section perspectives in order to emphasize vertical features, which might be too small to identify, relative to the horizontal scale.

To show relief clearly, the vertical scale on a relief section is nearly exaggerated. Vertical Exaggeration (VE) must be stated after one has drawn the cross section.

Mathematically, Vertical Exaggeration could be expressed as follows:

$$VE = \frac{\text{Denominator of Horizontal Scale (DHS)}}{\text{Denominator of Vertical Scale (DVS)}} \text{ or } \frac{VS}{HS}$$

Where:

(a) Vertical scale is derived from the contour interval of the given map. It is the scale on the vertical axis of the cross section;

(b) Horizontal scale is the one given on the map from which a cross section is drawn (Example, 1: 50 000); and

(c) Both vertical scale and horizontal scale must use the same units of measurements.

For example, if a map scale is 1:100 000 and the vertical scale is one cm to 100 m then the vertical exaggeration is calculated as follows.

Solution

$$\text{Vertical Exaggeration (VE)} = \frac{\text{Vertical Scale (VS)}}{\text{Horizontal Scale (HS)}}$$

$$\text{HS} = 1:100\,000$$

$$\text{VS} = 1\,\text{cm} \quad \text{to} \quad 100\,\text{m} \quad = 1:100\,000$$

Therefore;

$$\text{VE} = \frac{1:10\,000}{1:100\,000}$$

$$\text{VE} = \frac{1}{10\,000} \times \frac{100\,000}{1}$$

$$\text{VE} = \frac{100\,000}{10\,000}$$

$$\text{VE} = 10 \text{ times}$$

OR

$$\text{Vertical Exaggeration (VE)} = \frac{\text{Denominator of Horizontal Scale (DHS)}}{\text{Denominator of Vertical Scale (DVS)}}$$

$$\text{VE} = \frac{100\,000}{10\,000}$$

$$\text{VE} = 10 \text{ times}$$

Vertical Exaggeration (VE)= 10 times

This means that the vertical scale is 10 times larger than horizontal scale.

Note: 100 m have been converted into centimetres where by 1 m =100 cm

Exercise 8.5

Answer all questions.

1. Calculate the VE of a cross section where the map scale is 1:300 000 and VS is 1:10 000
2. Find the HS when the VS is 1:100 and the VE is 4
3. Find the VE when the VS is 1:10 000 and the HS is 1:25 000

Gradient

Gradient is the measure of a slope. Slope is an important concept in Geography because it affects people's daily lives. Transportation routes such as roads, railways and airport runways avoid steep slopes because they demand more energy from both human beings and vehicles. Some farmers cultivate their fields in gentle slopes whereas steep slopes are either left to natural vegetation or they are planted with trees. When steep slopes are cleared of their vegetation cover, soil erosion by running water occurs. House builders eliminate slopes by construction of level floors.

If for any reason one wishes to measure the degree of a slope, it is important to compare vertical interval to horizontal distance. The resulting ratio is called gradient.

In map reading, the calculation of gradient is done by comparing the vertical interval between two places and the horizontal distance between them. The difference in height between two places is called the vertical interval. The vertical interval can be obtained by subtracting the altitude of the lower point from the altitude of the higher point.

The horizontal distance between the two points is measured on the map, which is then converted into ground distance by the use of the map scale. In calculating gradient, both vertical and horizontal lengths must be brought to the same unit of length. The formula for calculating gradient is:

$$\text{Gradient} = \frac{\text{Vertical Interval (VI)}}{\text{Horizontal Equivalent (HE)}} \quad \text{or Gradient} = \frac{\text{Highest} - \text{Lowest Height}}{\text{Horizontal Equivalent(HE)}}$$

Procedure

(a) Identify the points by using grid reference or any other method;

(b) Find the map distance between the points;

(c) Change the map scale, for instance 1 cm to ½ km;

(d) Use the map scale converted in (c) to change map distance into ground distance;

(e) Change the ground distance in km into metres; and

(f) Feed in the formula the distance obtained.

For example,

Using, Figure 8.30, find the gradient between point A and point B if the map scale is 1 cm to 2 km; and the points are 8.4 cm apart.

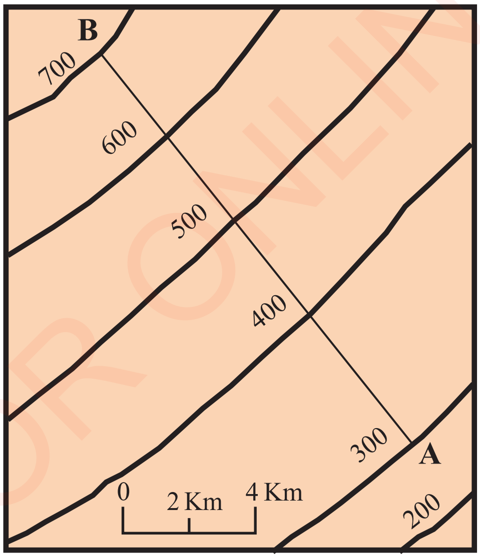


Figure 8.30: *Contour map*

Solution:

Data given;
Highest height = 700 m
Lowest height =300 m
Map distance = 8.4 cm
Horizontal equivalent=?

$$\text{Gadient} = \frac{\text{Highest-Lowest Height}}{\text{Horizantal Equivalent (HE)}}$$

Then, if 1 cm ⟶ 2 km

8.4 cm ⟶ ?

$$\frac{8.4\text{ cm} \times 2\text{ km}}{1\text{ cm}}$$

$$= 16.8 \text{ km}$$

(a) Change the ground distance obtained (16.8 km) into metres.

Then, if 1 Km ⟶ 1000 m

16.8 Km ⟶ ?

$$\frac{16.8\text{ Km} \times 1000\text{ m}}{1\text{ m}}$$

$$= 16.8 \times 1000 \text{ m}$$

$$= 16800 \text{ m}$$

(b) Feed in the formular the data obtained

$$\text{Gradient} = \frac{\text{V.I}}{\text{H.E}}$$

$$\text{Gradient} = \frac{(700 - 300)\text{ m}}{16\,800\text{ m}}$$

$$\text{Gradient} = \frac{400}{16\,800} = \frac{4}{168}$$

$$\text{Gradient} = \frac{1}{42} \text{ or } 1 \text{ in } 42$$

This means that to every 42 m of horizontal distance, there is a rise (vertical distance) of 1 m.

Where the ground is flat, the gradient is zero and it reaches 1 when the angle rises to 450. Gradient increases indefinitely to a vertical position. Gradient may be expressed as a ratio or fraction such as 1:50. In normal circumstances slope is not even, it changes over short distances. Therefore, most of the gradient calculated will be average gradient.

It should be noted that vertical interval is the difference in height between the higher elevation and the lower elevation while the contour interval is the difference between two successive contours.

Exercise 8.6

Answer all questions.

1. Calculate the gradient of a map, using the data given below:

   The highest point is marked 800 m. The lowest point is marked 600 m. Map scale is 1:50 000, Map distance is 4 cm.

2. Using Figure 8.28, calculate the gradient from point A to point B where the map scale is 1:100 000

Map interpretation

In topographic maps, information about location, landscape and cultural features is shown with the help of conventional symbols and signs. From such information, one can read and interpret the relief, drainage, climate, vegetation, settlement and economic activities of a particular location shown on a map.

Describing relief of an area

Relief refers to the physical shape of the surface of the earth which includes mountains, hills, plateaus, plains, valleys, depressions and escarpments. These physical landforms on the earth's surface differ in shape and size. The relief sometimes called topography of a map refers to the shape of the land surface. Various relief features on a topographical map can be identified by the use of contours and a number of conventional symbols.

Describing the relief of a map, several things should be considered. For example, when the contour lines on a topographical map are close together, this indicates a hill or mountainous area (highland area), while cases where contours are far apart it indicates the presence of a gentle slope or a lowland area.

The following are useful hints for interpreting relief on a map:

(a) Describe the relief of a region (highland, low land or both) by explaining its characteristics without forgetting to indicate the general altitude as shown on the map.

(b) State the major landforms shown on the map (mountains, valleys, hills and plateaus) by giving the position of each landform with the aid of direction and place names.

Describing the drainage of an area

Drainage is the outflow of water from an area through a system of natural streams such as rivers, lakes, swamps and other water bodies. To interpret drainage means to describe the distribution of water features, direction of the main rivers and types of drainage patterns, that is whether it is dendritic, radial, trellised, parallel or centripetal or fault-guided. Water features can either be natural or artificial. Drainage can tell about the surface relief and features as it is influenced by the steepness or gentleness or the hardness or softness of a rock and the amount of rainfall.

Describing the climate of an area

Climate is the average of weather conditions of a given area recorded over a very long period of time (not less than 30 years). At topographic map gives little direct evidence of climatic conditions, yet by looking at certain evidence, one is able to describe the climate of a given mapped area. The following aspects may help in describing the climatic conditions of a certain area.

(a) Latitude of an area

Areas between 0º to 5º degrees North and South of the Equator are characterized by an Equatorial climate. Areas between 5º and 15º North and South of the equator are likely to have Savanna or Tropical climatic characteristics. Deserts are located between latitude 20º and 30º North and South of the Equator.

(b) Presence of water surfaces and drainage patterns

A general high density of streams indicates that the area receives heavy rainfall while the presence of few streams, intermittent and seasonal streams, salt lakes and bore holes indicates aridity.

(c) Vegetation

(i) The presence of forests in a map indicates heavy rainfall.

(ii) Woodland vegetation indicates medium rainfall.

(iii) Shrubs, thickets and grasslands indicate dry conditions. Normally these areas experience light rainfalls.

(d) Crops

Different climatic conditions favour different crops. Areas where coffee, tea and sugar cane grow indicate that the areas receive heavy rainfall while areas where cotton and sisal grow indicate medium rainfall. Sorghum and millet grow in an arid or semi-arid climate.

Describing vegetation distribution

Vegetation refers to the total assemblage of plant cover in an area. Vegetation is usually incomplete on mapped areas. The common natural vegetation shown on maps include forests, woodlands, thickets, mangroves, scrubs and grasslands. Vegetation cover portrayed on a map may be either natural or artificial. Natural vegetation is identified by an irregular pattern while artificial ones are identified when they occupy a regular pattern on the map face. Conventional symbols are used to give hints in interpreting types and distribution of vegetation in an area.

The following hints might be useful in interpreting the distribution and type of vegetation.

(a) Read carefully the key of the map on the part of vegetation symbols and distinguish each symbol to avoid confusion.

(b) Study the whole map sheet and identify all types of vegetation represented by the symbols.

(c) Comment on the distribution and types of vegetation using direction and grid reference. For example, shrubs are widely found in the South East. It is important to give a specific location of each vegetation type.

Describing settlement in an area

Settlement is any habitable area where people can live and perform a certain economic activity such as mining, agriculture and trade. There are two common types of settlements, namely rural and urban settlements.

Rural settlement

A rural settlement is a sparsely populated community that exists in the country. Rural settlement develops in villages and the majority of people (about 80%) are engaged in agricultural activities.

Urban settlement

An urban settlement is a populated area comprising mostly man- made structures. Urban settlements are commonly found in district headquarters and regional administrative centres and along transportation routes. Approximately 80% of the urban population is engaged in non-agricultural activities.

Aspects of settlements

Any type of settlement consists of three aspects: site, situation and functions. These aspects influence the growth of any settlement. Site is the actual place where people decide to locate their settlement while situation refers to the position of the settlement in relation to the surrounding environment. Function is the reason why a settlement developed in the first place. The function of a settlement describes all main human activities taking place in the area. The functions of settlements may be for administrative purposes, trading, manufacturing, recreation as well as human residence.

Settlement patterns

A settlement pattern refers to the shape or layout of a settlement. It refers to the way buildings are distributed in an area. The common forms of settlement distribution patterns are nuclear, linear and dispersed settlements.

(a) *Nucleated settlement pattern*

In a nuclear settlement pattern, buildings are grouped around a central core such as a church, market, road junction or mining areas (Figure 8.31).

(b) *Linear settlement pattern*

This is a settlement along transport routes such as roads and river valleys. In this pattern, buildings are arranged in lines (Figure 8.31).

(c) *Dispersed settlement pattern*

A dispersed settlement pattern is where the buildings are spread out in an area and are often found in upland areas. It represents scarcity of people in a site where buildings are scattered over a wide area. Dispersed settlement patterns are often associated with agricultural activities and are frequently surrounded by farm lands (Figure 8.31).

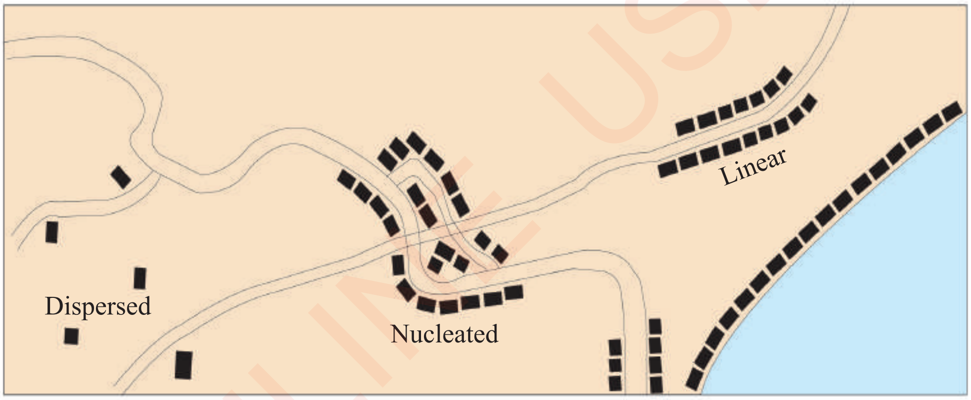


Figure 8.31: *Settlement patterns*

Describing human economic activities

On a map, various signs are used to show different types of human economic activities. The following are useful signs or indicators for describing human economic activities on a map. Pastoralism on a map can be identified by the presence of dispersed settlements, grasslands, water pans, water holes, cattle dips and cattle holding areas. Fishing can be identified by the presence of small coastal settlements along the sea shore, lakes or large rivers. Lumbering can be identified by the presence of forest, saw mills and minor roads ending in forest areas. The presence of beaches, highlands and other attractive features indicates possibilities for tourism activities.

In addition, mining and quarrying activities are shown by signs of smelting and quarrying. Manufacturing is identified by factory installations and special factories. In many urban settlements, it is usually assumed that there are various kinds of small-scale industrial establishments. A topographical map shows little direct information on trade. Communication networks and ports indicate the presence of trade, while agriculture in a topographical map can be identified by the presence of scattered cultivation for small scale agriculture, estates or plantations for large scale agriculture, and agricultural departments and centres.

Describing rocks or geological nature of an area

Rocks are not shown directly on maps, instead they may be recognized by analyzing the relationship between landforms, soils and vegetation. For example, the presence of conical hills, craters and hot springs suggest the presence of igneous rocks due to volcanic activity. The presence of rivers, seasonal swamps and valleys may indicate presence of sedimentary rocks due to erosion and deposition. If the place is characterized by stagnant water bodies like swamps, lakes or dams and rocks it can be described as having impermeable rocks. If the place is dominated by seasonal streams and rivers the rocks can be described as permeable rocks, as water passes easily from one place to another.

If the soil supports crop cultivation or is covered by plants, then the rocks can be described as igneous rocks, which are generally fertile.

Areas with little vegetation cover indicate the presence of metamorphic rocks as they are not fertile. The presence of a coral fringed coastal line indicates the area is dominated by limestone rocks.

Describing human social activities

On a map, various symbols and signs can be used to show different social activities carried out by people. For example, the presence of a school indicates there is provision of education as a social service. Also, the presence of a hospital indicates that there is provision of health services, while the presence of a church or mosque indicates that there is provision of religion services. The presence of roads, railways, telephone lines indicates that there is provision of transport and communication services. Also, the presence of a police post or military camp indicates that security services are available.

Revision exercise 8

Answer the following questions:

1. Study the Table below and fill in the blank spaces.

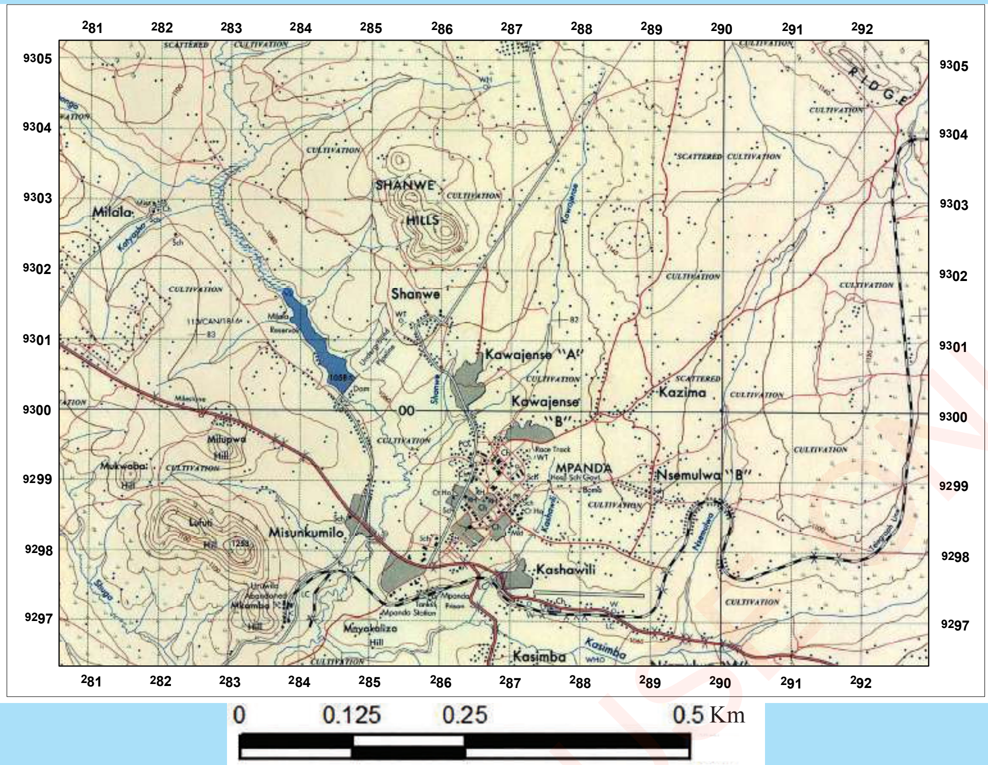
Human activity	Evidence
(a) Pastoralism	....
(b)	Presence of lakes, rivers, dams, coastal areas and rivers
(c) Trade	....
(d)	Presence of factories or industries
(e) Transportation	....
(f)	Presence of crops, farms and plantations
(g) Mining	....
(h)	Presence of highlands and beaches

2. Describe any five methods of representing relief on topographic maps.
3. Write the long form for each of the following map reading abbreviations.

   (a) VE (b) HS (c) HD (d) VS (e) DHS

2. Write short notes on the following geographical terms:
   (a) Vertical exaggeration
   (b) Intervisibility
   (c) Topographical map
4. List any five factors that may help to give evidence of the presence of settlements on a map.
5. Study the Map extract of Mpanda, then answer the questions that follow.

MPANDA



KEY

- Town or area with Permanent Buildings
- Other Populate Area, Houses
- All Weather Road: Bound Surface
- All Weather Road: Loose Surface
- Dry Weather Roads
- Main Track (Motorable)
- Other Track and Footpath
- Cut Line
- Railway, Siding, Station, Level Crossing
- Railwa Light
- Steep Slope
- Contours (V,1.20m)..................Depression
- Air Photo Principal Point with Film No.
- Water Course, Waterfall Rapids, Dams
- Water Course, (Wide), Waterfall Rapids
- Watercourse (Indefinite)
- Borehole, WaterHole, Well, Spring
- Bund, Major Fence, Hedge
- Cliff
- Forest
- Tree Swamp
- Papyrus Swamp, Marsh, Boge
- Riverine Trees
- Plantation: (Coffee C, Palm, Sisal S, Sugar Su, Wattle W
- Woodland
- Scrub
- Scattered Trees
- Palm Trees
- Seasonal Swamp

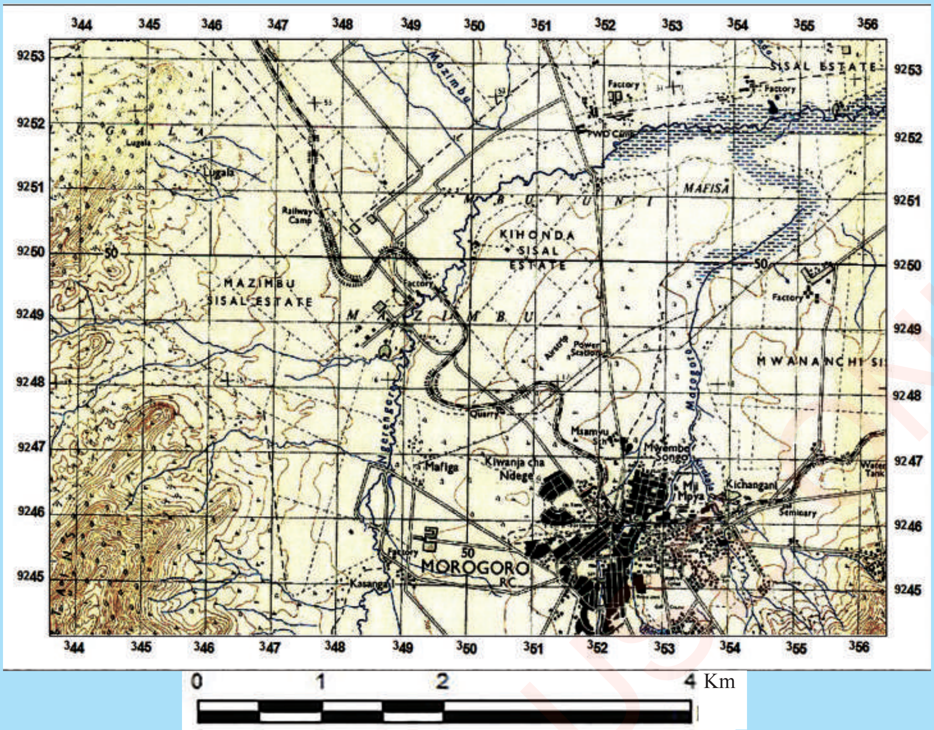
(a) With the evidence from the map, analyse the settlement patterns of the mapped area.

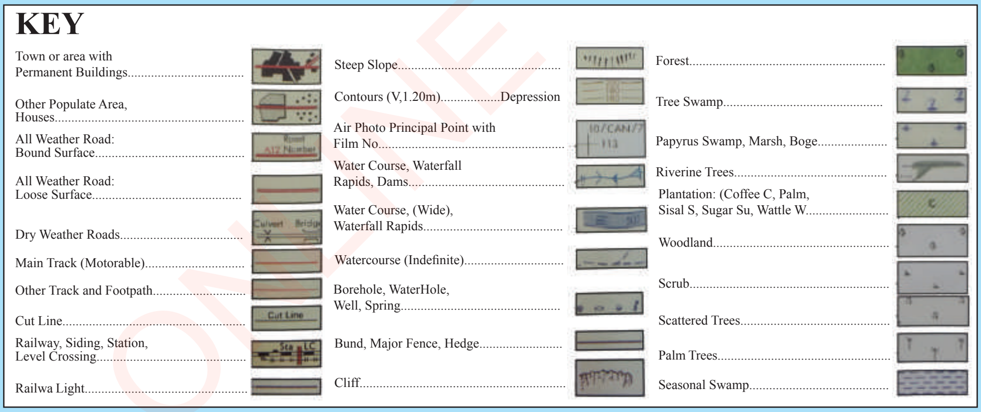
(b) With the evidence from the map, describe the nature of relief in the mapped area.

(c) With evidence from the map, describe the types of drainage patterns found in the mapped area.

6. Study the Map extract of Morogoro and answer the questions that follow.

MOROGORO





(a) With the evidence from the map, suggest economic activities that are likely to take place in the area.

(b) Calculate the distance in kilometres of the railway from grid reference 466533 to 510480.

(c) Find the bearing of Mazimbu Sisal Estate from Kiwanja cha ndege.

Chapter Nine

Photograph reading and interpretation

Introduction

Photograph reading and interpretation are important skills which help in the recognition of natural and artificial features and the assessment of the effects of human activities on the environment. In this chapter, you will learn about the concept of photograph, photograph reading and interpretation. The competencies developed in this chapter will help you to interpret and generate information from photographs in your daily activities.

Concepts of photograph reading and interpretation

A photograph is an image or picture taken by a camera on the earth's surface. These images can be stored or presented in hard or softcopy. Photographs show the visible part of the environment. Photograph reading refers to the simple recognition of both man-made and natural objects in a photograph. Photograph interpretation is the examination of a photograph or image to identify objects and judge their significance. Photograph reading and interpretation involve obtaining information about natural and man-made features portrayed in a photograph.

Types of photographs

Photographs also can be taken from different positions towards the ground. Based on the position of the photographer and alignment of the principle axis of a camera; there are three types of photographs, namely ground or horizontal photographs, oblique photographs and vertical or aerial photographs.

Horizontal photographs

Horizontal or ground photographs are pictures taken at ground level, whereby the camera and the object are at the same level (Figure 9.1). It is a picture taken when the camera axis is horizontal to the object. These type of photographs usually focus on object in front the camera. The focus of a camera towards the object may lead into close-up or general view of the object. The view of object differs from one photo to another; as a result of the distance of an object from the camera. The objects which are closer to the camera appear larger than the objects which are farther from the camera.

Figure 9.1: *Horizontal photograph of Julius Nyerere International Airport Terminal 3*

There are two types of horizontal photographs namely; panorama and close-up photograph.

(a) *Panorama horizontal photograph*: These are general view photographs which show many items on an extensive landscape (Figure 9.2(a)). They show one side of the features, with a very wide horizon in the background. Panorama photograph is also defined as the art of taking a number of pictures from the same viewpoint and combining or stitching them to make one image covering a wide view.

Figure 9.2 (a): *Panorama of Lake Manyara*

Source: https://www.google.com/search?q=panorama+lake+manyara+flamingo&tbm...

(b) *Close-up horizontal photograph*: This is a particular view photograph which focuses on one specific object that needs to be interpreted, as shown in Figure 9.2 (b).

Figure 9.2(b): *Close-up photograph*

Characteristics of a horizontal photograph

(a) It is taken when the principle axis of a camera is horizontal to the object to be captured;

(b) It is taken at about 180º;

(c) It shows only the front view of the object;

(d) It covers a small area;

(e) It has three major parts which are foreground, middle ground, and background;

(f) Objects which are closer to the camera appear larger than the objects that are farther from the camera;

(g) It does not show the top view clearly; and

(h) The scale of the photograph decreases from the foreground to the background. The camera is close to the object.

Activity 9.1

Read different sources on photograph, then:

(a) write down the uses of photographs.

(b) explain with examples how horizontal photograph is useful to our daily lives.

Oblique photographs

'Oblique' means neither parallel nor at right angle to a specified line. Oblique photographs are therefore photographs taken from an elevated angle of less than 90°. There are two main categories of oblique photographs, namely; low oblique photograph and high oblique photograph.

(a) *Low or ground oblique photographs*: These are taken when a photographer is on an elevated ground such as at the top of a hill, cliff, building or holds the camera with its principle axis at a low elevated angle of less than 60° (Figure 9.3(a)) towards the ground. A low oblique photograph (Figure 9.3(b)) is characterised by some features. It is divided into three main parts: fore view, middle view and back view. Objects at the fore ground are large and seen clearly. Objects decrease in size from the foreground outward. The low oblique photograph has no horizon. A three-dimension view is seen, that is top view, side view and front view.

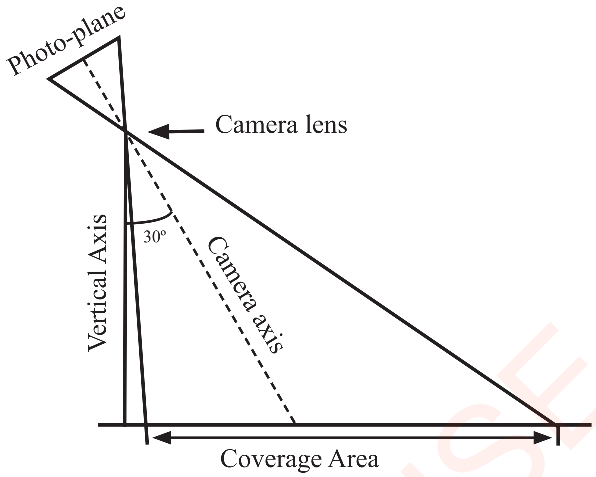


Figure 9.3(a): *Angle of a low oblique photograph*

Figure 9.3(b): *Low oblique photograph*

Source: https://dvaerialphoto.com/benefits-of-oblique-aerial-photography/

(b) *High oblique photographs*: These photographs are taken from the sky with the camera tilted at an angle of less than 90º towards the ground (Figure 9.4(a)). The photographer may take the photograph while an aircraft or drone is flying at low levels. These photographs cover quite a large area of land and are similar in many ways to the ground oblique photographs, as seen in Figure 9.4(b). Objects near the camera appear slightly larger than those far away from the camera due to diminishing scale. Such photographs include a horizon. High oblique photographs cover a larger area than horizontal photographs.

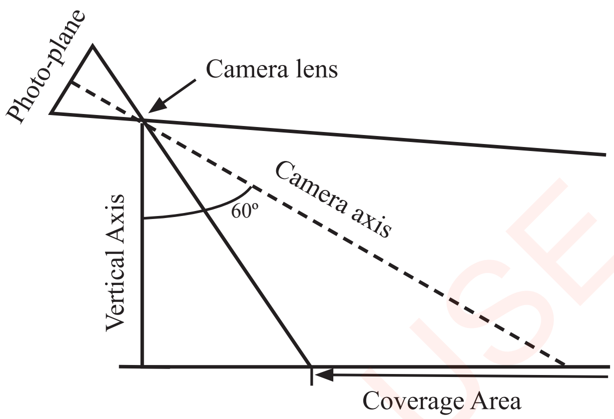


Figure 9.4(a): *Angle of a high oblique photograph*

Figure 9.4(b): *High-angle oblique photograph of Dar es Salaam harbour*

Activity 9.2

Find different photographs from books, journals or Geography past papers then do the following:

(a) study them carefully.

(b) identify horizontal and oblique photographs.

(c) analyse the characteristics of each photograph seen.

(d) write your answers in your exercise book.

(c) *Vertical or aerial photographs*: Vertical photographs are taken when the principal axis of a camera is vertical (90°) to the general ground level (Figure 9.5(a)). They are taken vertically with camera directed above an object or scenery (Figure 9.5(b)), focusing on specific area of interest on the ground.

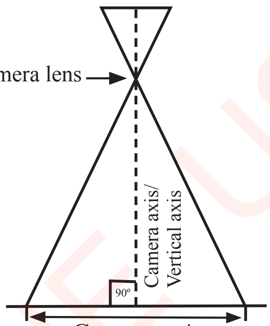


Figure 9.5(a): *Angle of a vertical or aerial photograph*

Figure 9.5(b): *Vertical or aerial photograph*

Source: https://blog.werobotics.org2018/01/17/flooding

Characteristics of vertical or aerial photographs

Aerial photographs have the following characteristics:

(a) They are taken vertically at 90° with the camera positioned above the scenery;
(b) They focus on specific features on the ground but they also show the surrounding scenery;
(c) They cover a relatively large area compared to horizontal and oblique photographs;
(d) Only the top view of features is seen;
(e) The sides of features are obscured by overhead cover; and
(f) The scale of a photograph decreases from the photograph centre.

Activity 9. 3

In a group, do the following:

(a) go to the library and read about vertical or aerial photographs, then present the information in your class.
(b) read different sources on types of photographs and differentiate between oblique, horizontal and aerial photographs.

Similarities and differences between photographs and maps

Similarities

(a) Both have scales;
(b) Both are used in planning and management activities such as in agriculture, engineering, construction and military;
(c) Both show natural and man-made features of the earth's surface; and
(d) Both are used in field works or field studies.

Differences

Table 9.1: *Differences between maps and photographs*

No.	Maps	Photographs
1.	They are selective as they show what was intended to be presented.	They are not selective. They show each and everything which appear in the lens of the camera.
2.	The scale of a map is constant throughout a map.	The scale of a photograph decreases with depth, from the foreground to the background or from a focal point outward.
3.	Features are constant all over the map since the scale is used.	Images at the foreground appear bigger than those at the the background.

Table 9.1: *Differences between maps and photographs* (continues)

No.	Maps	Photographs
4.	Maps use symbols and signs which require special skill to read and interpret.	Photographs show images or pictures of real objects.
5.	It is easy to calculate distance or area on the maps because they have a constant scale.	It is not easy to calculate distance or areas on photographs because photographs have a diminishing scale.
6	They take a lot of time to prepare, thus they are more expensive to produce. Maps are prepared from photographs.	Photographs are less expensive to produce and they are faster to take.
7.	Maps require skills on photogrammetry.	Photographs require little knowledge on using the camera.
8.	Maps bear titles.	Photographs do not have written titles.
9.	Maps have North direction.	Photographs do not show direction.

Uses of photographs

Photographs have various uses as follows:

(a) They are a source of information about human activities such as farming, mining, fishing and lumbering; and historical events such as wars and natural disasters like volcanic eruptions and floods.

(b) Photographs are used to keep record of events such as volcanic eruptions, floods, impacts of earthquakes, effects of mass wasting and other events.

(c) Photographs can accommodate many images outside the human reach. Photographs can bring information from remote areas where people cannot reach, for example, beyond the moon, in large thick forests and from the bottom of the ocean.

(d) Various experts of different fields use photographs for planning and tracking environmental changes overtime.

(e) Photographs summarize bulky verbal descriptions.

(f) Anthropologists and sociologists study photographs of various groups of people for clues on patterns of human behaviour.

(g) Cartographers use photographs in map-making. Due to advancement in science and technology, cartographers no longer draw maps manually but use computers.

(h) Photographs can be used to capture information of moving objects like moving flocks of animals, floods, landslides and lava flow.

(i) Photographs can be used in understanding weather of a place. For example, the type of clothes worn help to tell whether the weather is hot or cold.

(j) Photographs may be used for planning purposes.

(k) Photographs can be used to tell the morphology of a landscape. It tells whether a landscape is a highland or lowland. Highlands are shown by the presence of mountains and lowlands. Photographs can show the presence of such coastal features as beaches, coral reefs and plains.

Exercise 9.1

Answer all questions.

Study the following photographs and answer the questions that follow.

A

B

Source:https://www.un-ihe.org/mapping-and-remotesensing

1. Which one between photographs A and B above is;
   (a) an oblique photograph?
   (b) a vertical photograph?
2. Give reasons to your answer in (1) above.
3. What is the difference between a low oblique photograph and a high oblique photograph?
4. Suggest the captions (titles) of photographs A and B.

Reading and interpreting photographs

Photograph reading and interpretation involves translating the information by describing features shown in the photograph. Photograph reading and interpretation involves the following;

(a) Identifying and describing features in the photograph;
(b) Identifying and interpreting physical features in the photograph;
(c) Identifying and interpreting human activities in the photograph; and
(d) Associating or relating different features shown in the photograph.

Identification and description of a photograph features

Photographs especially horizontal photographs can be divided into three parts, namely foreground, middle ground and background (Figure 9.6).

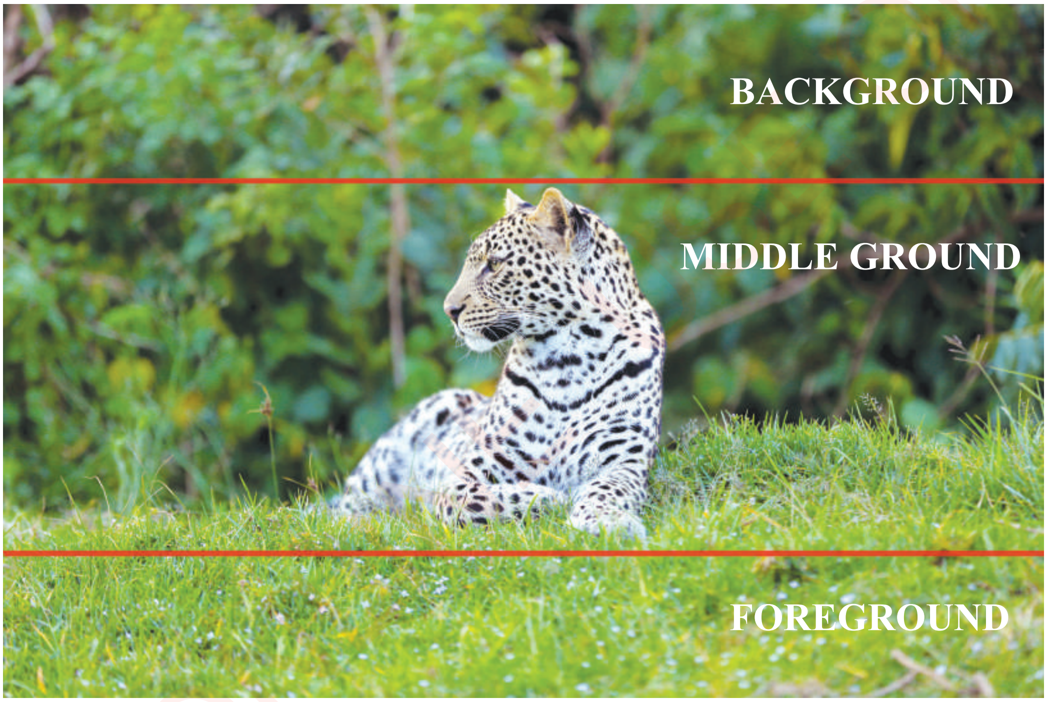


Figure 9.6: *Photograph divisions for description purposes*

The foreground refers to the part of the photograph nearest to the camera. Middle ground refers to the central part of the photograph and background refers to the part of the photograph farthest from the photographer. These grounds are obtained by dividing the photograph horizontally into three parts.

For example, the main features in the foreground in Figure 9.6 is vegetation cover (grass) while at the middle ground, a leopard and vegetation are seen. The background shows a forest.

Generally, the identification and description of features in the photograph are aided by a number of elements including; tone or hue, size of features, shape of objects, shadow, location, pattern, association, and knowledge about the area from which the photograph was taken.

(a) *Tone*

Tone refers to the colour characteristics of an object relative to other objects in a photograph. Colour of objects helps to identify objects. For example, water bodies appear blue, tarmac roads are shown by dark colour, while vegetation appears green and soil appears brownish or dark. However, the colour tones will depend on the nature of the photographs whether black and white or colored. Variation in tone or colour allows identification of shapes and pattern of objects.

(b) *Shadow*

The time of day when the photograph was taken is indicated by the shadow of the images. For example, the image of a photograph taken in the morning, has its long shadows casted to the west, as shown in Figure 9.7. A photograph taken in the evening, has its long shadows casted to the East. The photograph taken in the afternoon casts short shadows around an object. A photograph which is taken in the morning has a dull shadow, while those taken in the noon are bright.

(c) *Association*

Presence of a particular feature in a photograph may indicate the probability of having other activity, condition or features. For instance, the presence of a filling station implies the presence of automobiles, hence transportation activities. The presence of water bodies may imply presence of fishing activity. Some features are always found in association with other related features.

A photograph can also be used to tell the weather, season or even climate of the place. This can be done by looking at the activities carried out, nature of vegetation and the sky. A bright clear sky with dry vegetation implies a dry period or season. Presence of thick forests or vegetation, crops and land scenery can be used to tell about the climate of a place. For example, thick forests indicate heavy rainfall and high temperature areas. Presence of animals, like camels and horses indicate aridity. Cattle, buffaloes, elephants, lions, rhinos, giraffes, and zebras reveal a savanna type of climate with moderate rainfall.

Figure 9.7: *Photographs taken in the morning*

Source: https://www.flickr.com/photos/23985194@N06/5340775050/

The type of clothing worn by people appearing in a photograph and nature of houses might suggest the prevailing weather of the area. When people appear to be wearing heavy clothing with faces almost completely covered, it is an indication of cold weather. When people appear in light clothes it indicates that the weather is hot. Activities taking place in the area can also suggest the type of season. If people are seen planting crops, it is the planting season if they are seen harvesting crops, it is the harvesting season.

(d) *Location*

Presence of a particular object in a photograph can suggest and give clues of several information. For instance, presence of a leopard (Figure 9.6) in the photograph suggest that the area in which photo was taken is a game reserve, jungle, national park or zoo.

(e) *Prior-knowledge of the photographed geographical area*

Familiarity of the area in the photograph help to interpret and describe features, surfaces and objects presented in the photograph. Such geographical knowledge, can be used to establish the title of the photograph.

Identifying and interpreting physical features

Many physical features shown in a photograph can be identified and interpreted. These features can include relief, vegetation, drainage, rock types and waterbodies.

Relief

Before interpreting physical features, it is important to identify first relief features on a photograph. This can be done by giving a general idea about the area shown in the photograph. When describing different sceneries and landforms, it is important to go further and describe the forces and processes that are responsible for their formation and modification. Relief features in a photograph may include flat and/or mountainous forms.

(a) *Flat landscapes*

Flat landscapes occur both in lowland and highland areas. In the lowlands, they are called plains and in the highlands, they are called plateaus. Plain altitudes are less than 500 metres while plateau altitudes are more than 500 metres above sea level. It is difficult to estimate the altitude of an area directly from a photograph. However, other features appearing in the photograph and economic activities may be used. In hilly areas, ridges, escarpments and conical hills may easily be identified according to their appearance.

(b) *Mountainous areas*

Snow might be seen more often at higher levels. The type of trees growing could give a clue about the altitude of the land. If there are crops growing or animals being reared, these could also give a clue as to the altitude. Certain crops such as wheat and apples are grown on high altitude; likewise, animals such as sheep and dairy cattle are also reared in high-altitude areas within the tropics.

Drainage

Different drainage features can be identified in a photograph. These features are like rivers, lakes and seas. In these features, different aspects can be studied, for example, the shape of river valleys, and stages. Presence of certain features on the photograph can tell the nature of the rock over which a river might be flowing. For example, the presence of rapids and waterfalls is an indication that the river is flowing over steep land. River meanders suggest that the river is into its mature or old stage. Interlocking spurs indicate that the river valley is into its upper stage, and the topography is made of alternating layers of hard and soft rocks.

Rock types

This also suggest the type and nature of the bed-rock. By observing pattern of an area in the photograph, one can be able to describe nature and type of rocks. For example, a photograph shows river layout to be trellis then it also suggest that the area has a hard rock.

Climate

Through studying photographs, one can detect the weather and climate of a place. This can be done by observing different features contained in a photograph. The type of crops grown and vegetation on the photograph can be used to detect the climate of a place. Vegetation types and crops can also provide evidence about the season and climate of a place. For example, the presence of cacti signifies aridity or semi-aridity, and hence a desert or semi desert climate. Crops such as sisal are grown in hot areas that receive low rainfall while sugarcane thrives in warm to hot climates with high rainfall. The type of clothes people are wearing in a photograph can indicate the weather and possible climate. Heavy clothes indicate cold climate while light clothes indicate warm or hot climate conditions.

Vegetation

Photographs can show the type of vegetation of an area. The vegetation can either be planted or a natural forest. Natural forests would appear to be distributed unevenly while planted forests would usually appear in clear straight lines. In planted forests, trees tend to be of the same type, size and height because they were planted at the same time. The plant characteristics that may appear on the photograph can be used as a guide to the general types of vegetation.

When describing vegetation on a given photograph there are guidelines to be followed; the type of vegetation should be identified, for example, forests, thickets, grasslands, and swamp plants. The plants should be described, by giving details such as height, shape and appearance of leaves. Where possible, names of species of plants should be given, for example, eucalyptus trees and cacti. Planted vegetation should be distinguished from natural ones by their characteristics.

Settlement

A settlement is a place where people establish a community. It comprises of different buildings such as hospitals, schools, mosques, churches, and markets. However, some settlements are made up of institutional, industrial and commercial buildings most of which may not comprise living houses. There are two types of settlements: rural and urban.

In a photograph, rural settlements can be indicated by the following features:

(a) Many semi-permanent and few permanent buildings such as grass thatched houses or iron roofed houses with mud or brick walls;

(b) Presence of farming, livestock keeping or fishing activities; and

(c) Scattered houses.

Urban settlements can be identified by the following features:

(a) Permanent buildings, which dominate the area;

(b) Planned streets;

(c) Many motor vehicles on the road which may lead to traffic jams; and

(d) Many large buildings and warehouses marking industrial areas.

Identifying and interpreting human activities

To interpret land use or human activities taking place in a photographed area, the following clues can help.

(a) The natural vegetation of the area, for example, grassland or scrub vegetation may suggest grazing;

(b) Presence of estates or farms suggests crop farming and sometimes industrial work;

(c) The presence of domestic animals suggests grazing while wild animals may indicate tourism;

(d) Presence of rivers or coastal plain indicates fishing;

(e) Communication networks, markets, shops and suggest trading;

(f) Tourism may also be noted by the presence of attractive features such as beaches, caves, craters, thick forests and zoos;

(g) Mines indicate mining;

(h) Factories indicate industrial work; and

(i) Forests indicate lumbering activities.

Activity 9. 4

In a group, collect different photographs, then do the following:

(a) compare and contrast the photographs basing on their types.

(b) associate the features shown in the photographs with other activities.

(c) take the photographs and bring in class to discuss with fellow students.

Revision exercise 9

Section A

A: *Write TRUE for a correct statement and FALSE for an incorrect statement.*

1. Ground photographs are also known as horizontal photographs.
2. The other name of an aerial photograph is a close-up photograph.
3. Foreground refers to the part of the photograph nearest to the reader.
4. The key is very essential when interpreting a photograph.
5. There are two types of ground-level photographs.
6. Presence of wild animals on a photograph may suggest a grazing area.

7. Photographs can be used as a source of information about people's activities such as farming, mining, fishing and lumbering.

Section B

Answer the following questions:

8. Compare and contrast photographs and maps.
9. Explain why photographs are important to geographers

Section C

Study the photograph below and then answer the questions that follow.

10. Identify features found in the foreground, middle ground and background of the photograph.
11. Name the crop shown on the photograph.
12. List three benefits of the crop you have named in number 2 above.
13. Under what scale is the type of farming practised? Why?
14. Mention other crops which can be grown in this area.
15. Explain climatic conditions suitable for the growth of the crop mentioned in number 2.

Section D

Study the photograph below and answer the questions that follow.

16. Name the crop shown in the photograph.
17. Mention climatic conditions, which favour the growth of the crop.
18. Name at least three regions in Tanzania where this crop is grown on a commercial scale.
19. With concrete evidence, explain the possible scale of production of the crop as shown on the photograph.
20. What are economic potentials of this crop for the farmers of this region?
21. With reference from other regions, what are the possible limitations or hindrances facing the production of this crop in Tanzania?
22. Suggest the economic activities that might be carried out in the photograph.

Section E

Study the photograph below and answer the subsequent questions.

Source: https://dailynews.co.tz/news/2019-03-225c94c53044e81

23. What type of photograph is this?

24. With evidence, determine the time when the photo was taken?

Chapter Ten

Application of simple statistics

Introduction

Statistics is one of the important aspects in Geography. It gives numerical facts which are collected and analysed systematically to be used for different geographical purposes. In this chapter, you will learn about the concepts, types, application and importance of simple statistics. The competencies developed from this chapter will enable you to apply simple statistical techniques to analyse, present and use data for different purposes.

The concept of statistics

Statistics is a discipline of collecting, organising, analysing, interpreting and presenting numerical data. Statistics deals with numerical information known as data. In Geography, the numerical facts collected systematically are used for different geographical purposes. Examples of numerical information include total annual rainfall, temperature and crop production per year. A person who collects, classifies, analyses, presents and interprets data is known as statistician. Data collected provide a lot of information that may be arranged systematically for easy understanding, analysis and drawing conclusions. Statistics can be classified into two categories, namely *inferential statistics* and *descriptive statistics*. Inferential statistics deals with all procedures that enable one to draw conclusions and generalise the entire population by the use of samples. Descriptive statistics involves a broad set of data obtained from the field and summarised using statistical measures.

Statistical data

Statistical data is a body of information of a particular phenomenon given in numerical form that can be organised, summarised and presented using different statistical methods. Geographical data comprise facts and statistics collected for reference or analysis. These facts and statistics are of different types, namely primary and secondary data.

Primary data

Primary data are first-hand information about a particular phenomenon. The information can be obtained through conducting fieldwork using tools or instruments such as questionnaires, observation guides and different types of interview guides.

Secondary data

Secondary data include those obtained from published documents such as books, journals, articles and government publications. They are second hand information.

Types of statistical data according to the nature of data

(a) Discrete data

This refers to data which can only be given as whole numbers, for example, number of people, animals, houses and vehicles. This data represents things which are not divisible.

(b) Continuous data

This is data which is presented to show a range of values. It can be in the form of fraction or decimal places. It can also include data whose values can be measured such as altitude, temperature and years.

Discrete and continuous data can be presented in form of individual or grouped data.

(i) Individual data

This refers to the exact value or observation given to an individual item in a sample range, such as population in a country, number of students in a school or production of a certain commodity.

(ii) Grouped data

This refers to statistics without specific or exact figures but groups of several values. For example, age of students in a secondary school may be represented in groups, as shown in Table 10.1.

Table 10.1: *Grouped data*

Age group	No. of Students
13-14	48
15-16	70
17-18	62

Importance of statistical data to the user

Statistical data is used in land planning, resources allocation and provision of social services. Such data is also used in forecasting future trends of geographical phenomena and comparison and explanation of different geographical phenomena. For example, a study of climatic data of an area could enable one to explain the existence of certain types of vegetation. Raw and bulky data is simply summarised by statistics for easy interpretation and explanation. Moreover, statistics enables us to convert massive data into a simple and manageable form by using measures of central tendency and dispersion for study purposes. Furthermore, geographical information can be made available in a small space by summarising it in different statistical forms.

Activity 10.1

Study more sources of statistical data and write down other benefits of statistical data related to your daily activities.

Ways of presenting statistical data

Data can be presented in several ways including statistical graphs, maps, charts, diagrams and tables. This chapter focuses on how bar graphs, line graphs and pie charts can be used to present data.

Types of graphs

Graphs are among the methods commonly used by geographers to present statistical information. There are two main types of graphs used in statistical data presentation. These are line graphs and bar graphs.

Line graphs

Line graphs are graphs that use lines to connect several points which relate to each other. The graphs are used to illustrate trends over time for continuous data. They are also used to compare two different variables over time. A variable refers to a measurable characteristics of a person, group or object that varies within the sample under investigation. For example; age, weight, distance, year, rainfall, temperature and vegetation cover. There are four types of line graphs, namely *simple line graphs*, *multiple line graphs*, *divergent line graphs* and *compound line graphs*.

(a) Simple line graphs

Simple line graphs are types of graphs that are plotted by a single line. These are drawn by plotting a dependent variable against an independent variable by joining the points by lines. Simple line graphs are used to show the relationship between two variables, for example, tonnes of tea produced over time. Figure 10.1 is an example of the simple line graph demonstrating coffee production (in '000 tonnes) from 2011-2015.

Procedure to construct simple line graphs

In order to draw simple line graphs, the following are the procedure to be followed:

(i) identify the required data;

(ii) identify the independent and dependent variables;

(iii) decide on horizontal and vertical scales. The vertical scale should be selected on the basis of the largest value in relation to space available and the horizontal scale should be selected on the basis of number of years in relation to space available;

(iv) draw and divide the vertical axis (y-axis) and horizontal axis (x-axis);

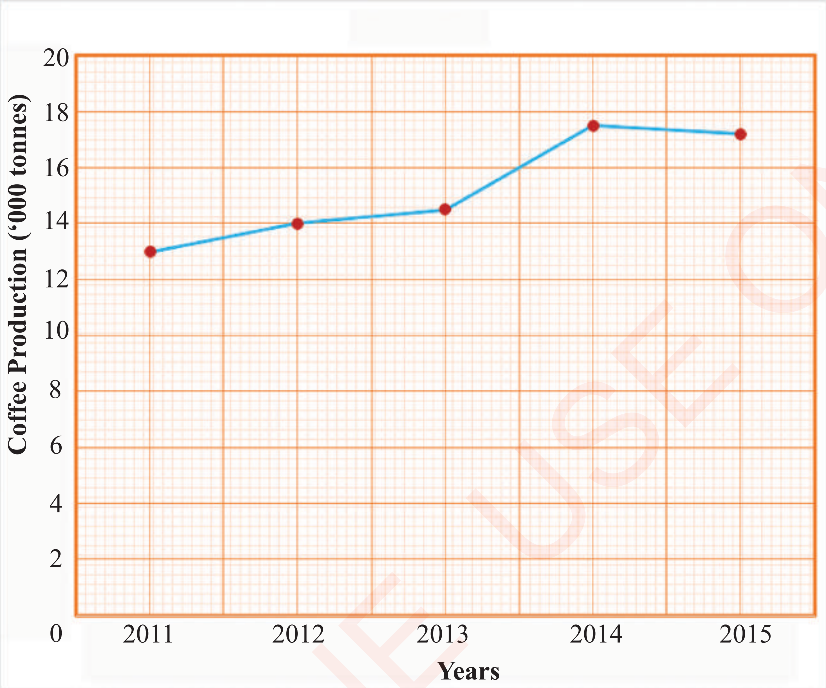
(v) join and plot the graph; and

(vi) write the title of the graph (the title of a graph is always derived from the question).

Carefully study Table 10.2 showing coffee production (‘000 tonnes) from 2011-2015 and then draw as simple line graph.

Table 10. 2: *Coffee production from 2011 to 2015*

Years	2011	2012	2013	2014	2015
Production (‘000 tonnes)	13	14	14.5	17.5	17.2



Scale: Vertical Scale: 1cm to 2 000 tonnes; Horizontal Scale: 2cm to 1 year

Figure10.1: *Coffee production from 2011 to 2015*

Advantages of a simple line graph

Construction of a simple line graph is easy since it involves little data, and a single line is drawn. It is simple to compare variations in the relationship between two variables because the trend of the relationship can easily be seen. Also, it does not involve complex mathematical calculations and exact values can easily be extracted from the graph.

Disadvantages of simple line graphs

The simple line graphs has some limitations. It gives the impression that the pattern or trend is constant. It can be difficult to determine an exact value at a given point of the graph. The graphs cannot be used to present more than two variables or data at a time.

(b) **Multiple line graph**

A multiple line graph which is also called a comparative or grouped line graph represents more than one item on the same graph, for example, production of maize, tea, coffee and sisal during a given period of time. The procedure for constructing a multiple line graph is similar to that used in a simple line graph. Table 10.3 gives statistics of crop production in tonnes from 2016 to 2019. The information is presented in a multiple line graph, in Figure 10.2.

Table 10. 3: *Crops production between 2016 to 2019*

Year / Crops	2016 ('000 tonnes)	2017 ('000 tonnes)	2018 ('000 tonnes)	2019 ('000 tonnes)
Maize	200	260	275	280
Tea	100	200	180	260
Coffee	150	220	200	170
Sisal	60	150	100	200

Scale: Vertical Scale = 1cm to 50 000 tonnes; Horizontal Scale = 2 cm to 1year

Figure 10.2: *Crops production from 2016 to 2019*

Advantages of a multiple line graph

A multiple line graph is easy to interpret and enables easy comparison of data. It is time and space saving as several dependent variables are presented in one graph. It involves simple mathematical knowledge and enables one to estimate the intermediate value between two specified periods. It provides good visual impression of the data presented.

Disadvantages of multiple line graph

It is comparatively difficult to draw a multiple line graph since many items are presented in the same period of time. This may cause confusion when many variables are illustrated and their lines intersect. It is also difficult to compare the lines since many lines are drawn in the same graph.

(c) **Divergent line graph**

This is a line graph which explains how variable values deviate from the *mean*. It shows fluctuations (rise or fall) of values from the average (Figure 10.3). It is also known as a loss and gain graph.

Procedure to construct a divergent line graph

(i) Find the total value of items;

(ii) Calculate the mean (average) of the given data;

(iii) Subtract the average from each item value to get deviations;

(iv) Put the zero line at the centre of the graph as an average (The line must be thickened for the purpose of interpretation);

(v) Choose a suitable scale; and

(vi) Draw a horizontal line and vertical line whereby positive values are shown above the zero line and negative values below the zero line.

Carefully study Table 10.4 showing sisal production (‘000 tonnes) from 2003 to 2007 and then draw a divergent line graph.

Table 10. 4: *Sisal production from 2003 to 2007*

Years	2003	2004	2005	2006	2007
Production (‘000 tonnes)	70	160	120	210	185

Solution:

(i) Find the total value of production;

Total production is 70 + 160 + 120 + 210 + 185 = 745 tonnes

(ii) Calculate the mean: This is obtained by adding the total value and dividing it by the number of occurrences.

$$\overline{X} = \frac{\sum X}{N}$$

Where: $\overline{X}$ = Mean, $\sum$ = Summation, X = Value, N = Number of values

$$\overline{X} = \frac{70 + 160 + 120 + 210 + 185}{5}$$

Therefore, $= \frac{745}{5} = 149$

(iii) Find deviations: Deviation is obtained by subtracting the average (mean) from each item.

Year	Production (x)	$X - \overline{X}$	Deviation
2003	70	70-149	-79
2004	160	160-149	11
2005	120	120-149	-29
2006	210	210-149	61
2007	185	185-149	36

(iv) Plot the deviation graph

Scale: Vertical Scale = 1cm to 20 000 tonnes; Horizontal Scale = 2 cm to 1year

Figure 10.3: *Sisal production from 2003 to 2007*

Advantages of a divergent line graph

A divergent line graph is simple to read and easy to interpret. The variation of the divergent line is seen clearly. It is therefore suitable for determining loss and profit or increase and decrease.

Disadvantages of a divergent line graph

Constructing a divergent line graph is tiresome since it involves calculations, and drawing which are time consuming. There is also the possibility of drawing a wrong graph if the calculations are not accurate. It does not show actual values, only data showing deviation from the mean is presented. The method is used to present only one item therefore it is not suitable for many items.

(d) **Compound line graphs**

Compound line graphs are types of graphs where a variety of variables is presented as subsequent lines (Figure 10.4). The graphs are also known as composite, cumulative or divided line graphs. The use of compound line graphs is a good alternative to group or comparative line graphs. A compound line graph is used to present multiple data of different items cumulatively in each year. The procedure of plotting the values is the same as for a comparative line graph. The main difference is that instead of drawing lines with different patterns or colours, they are all shown in bold but the space between one line and the next is shaded differently.

Procedure for constructing a compound line graph:

(i) Establish a cumulative table;

(ii) Select an appropriate scale for dependent and independent variables; and

(iii) Follow other steps used in the construction of a simple line graph.

Carefully study Table 10.5(a), showing the production of cash crops ('000 tonnes) from 2011 to 2016 and draw a compound line graph.

Table 10. 5(a): *Production of principal cash crops from 2011 to 2016*

Crops / Year	Sisal ('000 tonnes)	Cotton ('000 tonnes)	Coffee ('000 tonnes)	Tea ('000 tonnes)
2011	113	42	53	14
2012	104	67	45	17
2013	92	50	53	17
2014	81	56	49	18
2015	86	60	48	17
2016	74	59	67	10

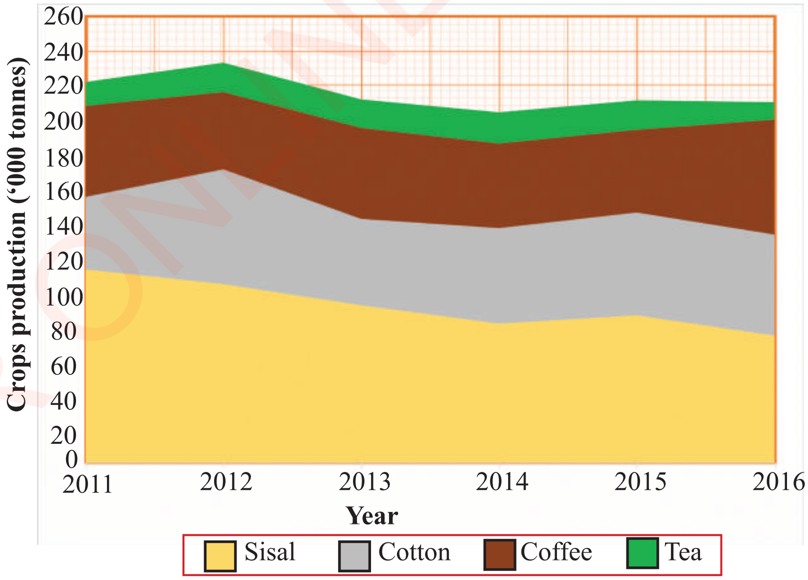
Before drawing a compound line graph, use the data provided in Table 10.5(a) to construct a compound table. Then make use of the data to draw a compound line graph. The values of the first column are used as a starting point for adding other values on the next columns, on the corresponding row.

Table 5(b): *Preparation of a compound table*

Year/Crops	Sisal	Cotton	Coffee	Tea
2011	113	113+42	113+42+53	113+42+53+14
2012	104	104+67	104+67+45	104+67+45+17
2013	92	92+50	92+50+53	92+50+53+17
2014	81	81+56	81+56+49	81+56+49+18
2015	86	86+60	86+60+48	86+60+48+17
2016	74	74+59	74+59+67	74+59+67+10

Table 5(c): *Cumulative table showing total value of each crop*

Year/Crops	Sisal	Cotton	Coffee	Tea
2011	113	155	208	222
2012	104	171	216	233
2013	92	142	195	212
2014	81	137	186	204
2015	86	146	194	211
2016	74	133	200	210



Scale: Horizontal scale 2cm to 1 year; Vertical scale 1cm to 20 000 tonnes

Figure 10.4: *Cash crops production from 2011 to 2016*

Advantages of a compound line graph

A compound line graph enables easy comparison of values. It does not consume much time because several lines representing each independent variable are combined. It does not involve long mathematical calculations hence enables one to estimate the intermediate value between two specified periods. A lot of data of different items is accommodated.

Disadvantages of a compound line graph

A compound line graph is hard to read and interpret, as well as to choose a suitable scale when data differs by a great magnitude. It can cause confusion when many variables are cumulative and not all values start from zero. The graph also cannot establish the cause of variation in the variables. The graph does not present actual data because it presents cumulative data.

Activity 10.2

Study the simple, multiple, compound and divergent line graphs presented in this chapter.

(a) With the facilitation of the teacher, find out different statistical data for two or more crops production in Tanzania for five or more consecutive years from different sources such as books, internet and reports from government or private institutions.

(b) Use the data in (a) above to draw a simple line graph, a multiple line graph and a compound line graph. Show the procedure to be followed when drawing these graphs.

Exercise 10.1

Answer all questions.

1. Mention four differences between multiple and compound line graphs.
2. Mention five advantages of interpreting statistical data in Geography.
3. Study the following data of maize production in country 'Y' ('000 tonnes) in the table below and answer the questions that follow.

Year	2012	2013	2014	2015	2016	2017	2018	2019
Tonnes	70	120	80	110	150	60	130	140

(a) Draw a divergent line graph showing maize production in country 'Y'

(b) Comment on the characteristics of the graph that you have drawn.

(c) What is the usefulness of a divergent line graph?

Bar graphs

Bar graphs are graphs that display data using rectangular bars or columns of different heights to represent such data. Bar graphs use rectangular bars to visually display each value and how it compares to other values in the graph. The greater the value, the longer the bar. They provide a simple and easy way to interpret data. They are used to graphically illustrate diverse information such as the value of a country's leading exports and imports of goods over a specified period of time, and mean monthly temperature and rainfall. There are several types of bar graphs namely *simple bar graph, multiple bar graph, divergent bar graph, compound bar graph* and *percentage compound bar graphs*.

(a) **Simple bar graph**

The construction and usage of a simple bar graph are similar to a simple line graph. However, instead of using a line, parallel bars are used. It consists of a number of bars placed side by side, the length of each bar being set according to the size of the number which it represents. Simple bar graphs may be drawn with a vertical or horizontal base.

Data in Table 10.6 shows coffee production in metric tonnes from 2010 to 2014. Study carefully data in Table 10.6 and draw a simple bar graph.

Table 10. 6: *Coffee production from 2010 to 2014*

Year	2010	2011	2012	2013	2014
Production ('000 tonnes)	105	100	140	150	130

Procedure for constructing a simple bar graph:

(i) Identify the data;

(ii) Identify the independent and dependent variables;

(iii) Choose a suitable vertical scale and horizontal scale (see Figure 10.5);

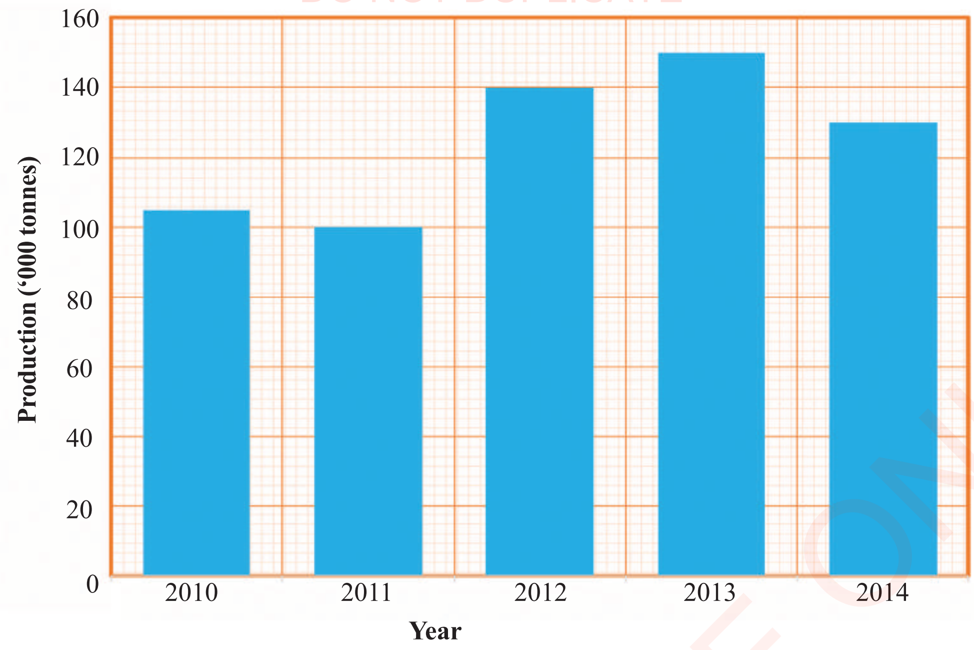
(iv) Decide on horizontal and vertical scales. The vertical scale should be selected on the basis of the largest value in relation to space available and the horizontal scale should be selected on the basis of number of years in relation to space available;

(v) Draw and divide the vertical axis (y-axis) and horizontal axis (x-axis);

(vi) Draw the bars by using the value of each bar (the values of coffee production in tonnes are shown in Table 10.6);

(vii) Shade the bars; and

(viii) Write the title of the graph (the title of the graph is always derived from the question).



Scale: Horizontal scale: 2cm to 1 year; Vertical scale: 1cm to 20 000 tonnes

Figure 10.5: *Coffee production from 2010 to 2014*

Advantages of a simple bar graph

A simple bar graph is simple to construct, read and interpret. It is also used to compare production from one year to another and it involves simple mathematical calculations.

Disadvantages of a simple bar graph

This graph is not suitable for data having more than one item. Construction of bars also may lead to accumulation of some errors. It does not offer comparison of different variables or data.

(b) **Multiple bar graph**

Multiple bar graphs are also referred to as comparative or grouped bar graphs. Sometimes there are more than two sets of data to be compared in a bar graph. In this case, a multiple bar graph is appropriate. Multiple bar graphs are essential in presenting several items in the same category of line. Different colours or shading help to portray the values of different items presented, as shown in Figure 10.6. Consider Table 10.7 and draw a multiple bar graph.

Table 10. 7: *Crop production from 2018 to 2020*

Year / Crops	2018 ('000 tonnes)	2019 ('000 tonnes)	2020 ('000 tonnes)
Maize	200	260	275
Tea	100	200	180
Coffee	150	220	200

Procedure for drawing a multiple bar graph:

(i) Identify the required data;

(ii) Identify the independent and dependent variables;

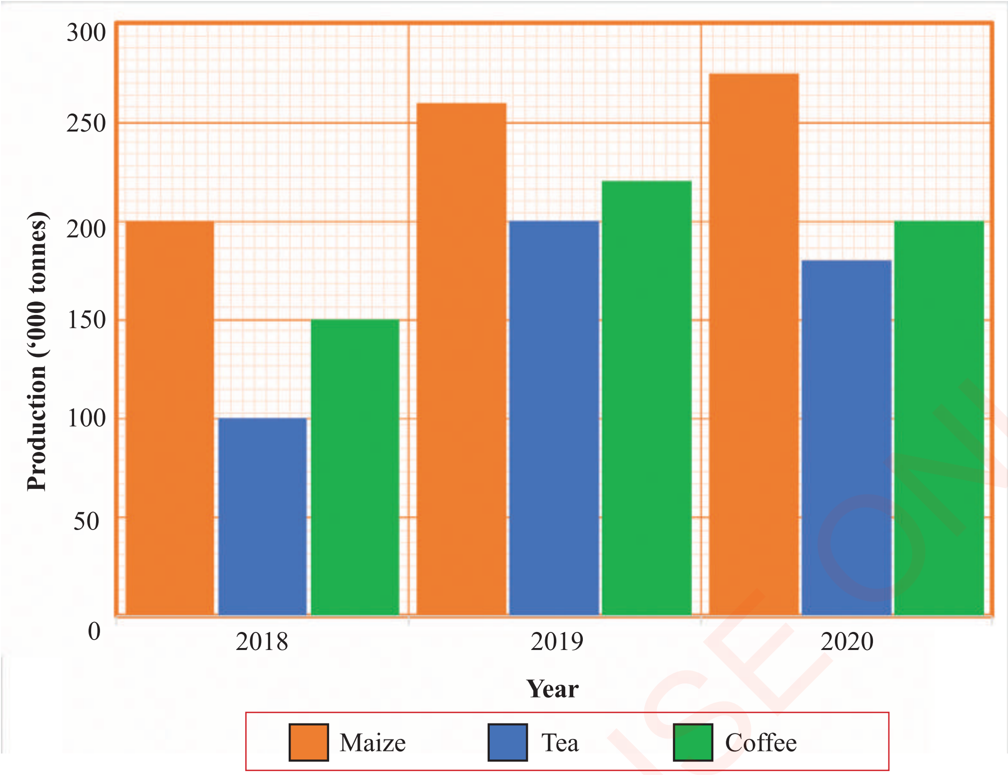
(iii) Decide on horizontal and vertical scales. The vertical scale should be selected on the basis of the largest value in relation to space available and the horizontal scale should be selected on the basis of number of years in relation to space available;

(iv) Draw and divide the vertical axis (y-axis) and horizontal axis (x-axis);

(v) Insert the values of the same year by drawing the bars;

(vi) Choose different colours to shade the bars and make sure one item is represented by the same colour in different years (figure 10.6, Brown colour represents maize, blue colour represents tea and green colour represents coffee); and

(vii) Write the caption of the graph, scale and the key.



Scale: Horizontal scale: 3 cm to 1 year; Vertical scale: 1cm to 50 000 tonnes

Figure 10.6: *Crop production from 1998 to 2000*

Advantages of a multiple bar graph

A multiple bar graph is easy to construct. It is simple to make comparisons of production in a given period and it is easy to interpret due to distinguished shading. Also, it does not involve long mathematical calculations.

Disadvantages of a multiple bar graph

More than one bar is drawn in a single year, therefore it consumes a lot of time. In case a lot of data is to be presented, this may be difficult to understand.

(c) **Divergent bar graph**

Like the divergent line graph, a divergent bar graph shows how data deviates from the mean. The procedure for drawing a divergent bar graph is similar to that of a divergent line graph. However, instead of using line graphs vertical bars are used where positive values are presented by bars pointing upwards and negative values presented by bars pointing downwards from the zero line (Figure 10.7). Consider

Table 10.8(a), then draw a divergent bar graph.

Table 10.8(a): *Sisal production from 2016 to 2020*

Year	2016	2017	2018	2019	2020
Production ('000 tonnes)	60	150	100	200	175

Procedure for constructing divergent bar graph:

(i) Determine the variables (dependent and independent variables);

(ii) Calculate the mean:

$$\bar{X} = \frac{\sum X}{N}$$

Where: $\bar{X}$ = Mean, $\sum$ = Summation, X = Value, N = Number of values

$$\bar{X} = \frac{60 + 150 + 100 + 200 + 175}{5}$$

$$= \frac{685}{5}$$

$$= 137$$

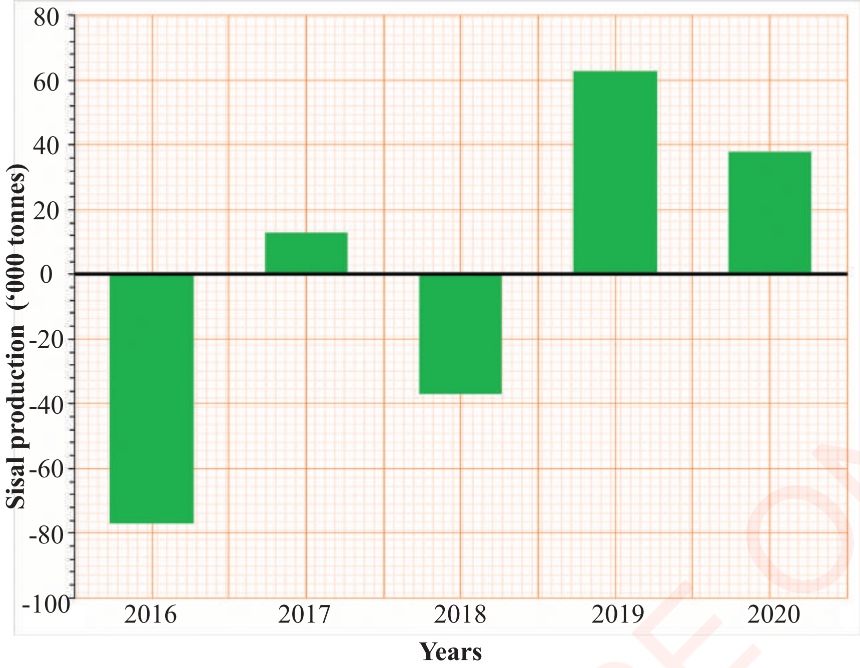
$$\therefore \bar{X} = 137 \text{ tonnes}$$

(iii) Find the deviations of values from the mean; and

Table 10.8(b): *Sisal production from 2016 to 2020*

Year	**Production (X)**	$X - \bar{X}$	**Deviation**
2016	60	60-137	-77
2017	150	150-137	13
2018	100	100-137	-37
2019	200	200-137	63
2020	175	175-137	38
TOTAL	**685**		

(iv) Plot the deviation graph



Scale: Horizontal scale: 2cm to 1 year; Vertical scale: 1cm to 20 000 tonnes

Figure 10.7: *Sisal production from 2016 to 2020*

Advantages of a divergent bar graph

A divergent bar graph is easy to read and interpret. The fluctuation of values is seen clearly, so it is easy to make comparisons. It gives good visual impression.

Disadvantages of divergent bar graph

Construction of a divergent bar graph consumes a lot of time. It does not show actual values and the method is used to present only one item. Inaccuracy on divergence may occur if the calculations are wrong.

(d) **Compound bar graph**

Compound bar graphs are drawn by dividing one bar into several components. They are also known as divided bar graphs. Instead of bars being placed side by side, the component parts are placed on top of one another. Each component is noted by the differentiated pattern or colour shading and the total length of the bar compared with the vertical scale as shown in Figure 10.8.

Procedure to construct a compound bar graph

(i) Obtain the data and arrange it starting with the highest item value;
(ii) Add the values of all components of each year, to establish a raw of totals;
(iii) Choose a suitable scale for dependent and independent variables;

(iv) Draw the graph, insert the values for each component part;

(v) Choose a pattern or colouring for each component part; and

(vi) Insert a title, key and scale.

Carefully study Table 10.9(a) showing cash crops production from 2017 to 2020 and construct a compound bar graph.

Table 10. 9(a): *Cash crops production from 2017 to 2020*

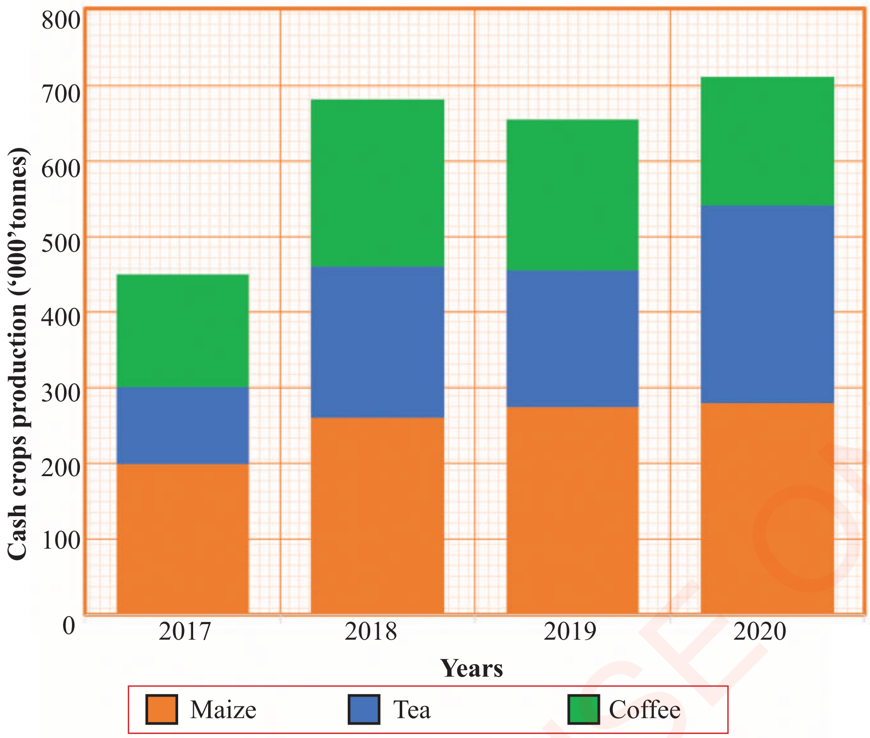
Year / Crops	2017 (tonnes)	2018 (tonnes)	2019 (tonnes)	2020 (tonnes)
Maize	200	260	275	280
Tea	100	200	180	260
Coffee	150	220	200	170
TOTAL	450	680	655	710

Table 10. 9(b): *Cumulative table*

Years	Maize (tonnes)	Tea (tonnes)	Coffee (tonnes)
2017	200	200 + 100	200 + 100 + 150
2018	260	260 + 200	260 + 200 + 220
2019	275	275 + 180	275 + 180 + 200
2020	280	280 + 260	280 + 260 + 170

Table 10.9(c): *Cumulative table showing total value of each crop*

Years	Maize (tonnes)	Tea (tonnes)	Coffee (tonnes)
2017	200	300	450
2018	260	460	680
2019	275	455	655
2020	280	540	710



Scale: Horizontal scale: 2cm to 1 year; Vertical scale: 1cm to 100 000 tonnes

Figure. 10.8: *Cash crops production from year 2017 to 2020*

Advantages of a compound bar graph

A compound bar graph facilitates easy comparison of values because it represents many items. It is easy to interpret due to different patterns and colouring, making it impressive to look at since different colours or patterns are used. It is a good method to use as it accommodates many items or data. It presents the trend of data in different years.

Disadvantages of a compound bar graph

It is difficult to compare the components since all component parts do not start upon the same base. It is due to this reason that it is recommended to write the actual value on the face of each bar. It can also cause confusion if it is not properly constructed. The method does not show rise and fall in production of an individual component or time.

(e) **Percentage compound bar graph**

This is a bisected column graph used to compare the percentage that each value contributes to a total of 100% across categories as shown in Figure 10.9. Consider data for cotton purchase changes across years as shown in Table 10.10 and construct a compound bar graph.

Procedure for constructing a percentage bar graph:

(i) Set the total of the data for each year;

(ii) Calculate the percentage of each data set for each year;

(iii) Draw the vertical axis (y-axis) to represent the dependent variables;

(iv) Draw the horizontal axis (y-axis) to represent the independent variables;

(v) Label both axes using a suitable scale;

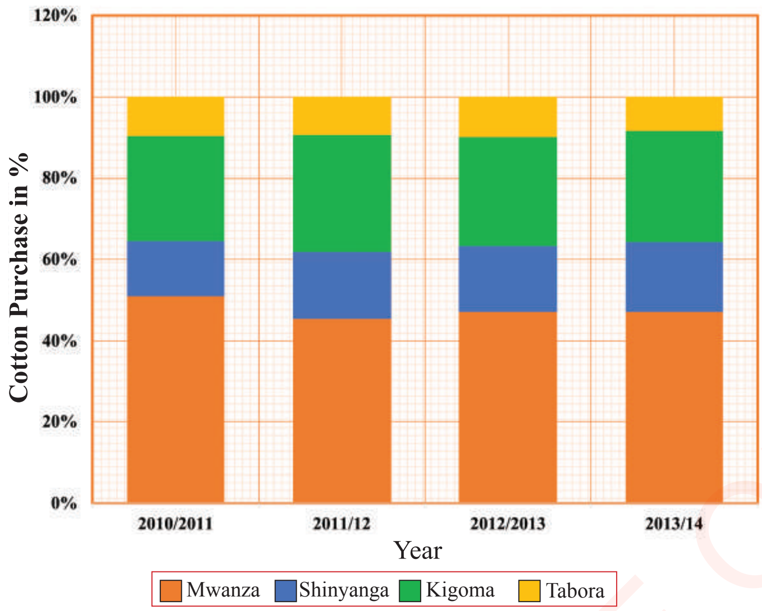
(vi) Plot the cumulative percentage values for each year; and

(vii) Use values for the compound to subdivide the cumulative.

Carefully study Table 10.10 showing cottons purchase in Tanzania from 2010/2011 to 2013/2014 and construct a compound bar graph.

Table 10.10: *Cotton purchase changes from 2010/2011 to 2013/2014*

Region/Year	2010/2011	2011/2012	2012/2013	2013/2014
Mwanza	106,000 (51%)	126,000 (45.3%)	116,000 (47%)	123,000 (47%)
Shinyanga	28,000 (13.4%)	46,000 (16.5%)	40,000 (16.2%)	45,000 (17.2%)
Kigoma	54,000 (26%)	80,000 (28.8%)	67,000 (27.1%)	72,000 (27.4%)
Tabora	20,000 (9.6%)	26,000 (9.4%)	24,000 (9.7%)	22,000 (8.4%)



Scale: Horizontal scale: 2cm to 1 year; Vertical scale: 1cm to 10%

Figure 10. 9: *Cotton purchase changes from 2010/2011 to 2013/2014*

Pie Chart

A pie chart can also be referred to as a simple divided circle or pie graph. The chart involves division of circles into segments to represent given components of the data, proportionally. The size of each segments in the circle is always proportional to the value it represents as shown in Figure 10.10.

Procedure for constructing a pie chart

(i) Add up all the totals of the values to be represented to get a grand total;

(ii) Find the percentage of each value using the grand total as it is in column c;

(iii) Get the size of the segments and find out their degrees (For example, 22.8% represents 82.08º as it is in column d);

(iv) Find the number which will give the size of the segments or divisions, multiply each percentage by 360;

(v) Draw a circle of a convenient size and divide it using a protractor into segments corresponding to the degrees of each value;

(vi) Shade the segments (Darker colours are best used for the smaller segments); and

(vii) Shade and label each segment.

(viii) Complete the pie chart by giving its heading.

Carefully study Table 10.11(a) showing food crops production in 2004 and then draw a pie chat.

Table 10.11(a): *Food crop production in 2004*

Crop	Production (tonnes)
Maize	90,000
Beans	40,000
Potatoes	50,000
Rice	65,000
Wheat	20,000
Sugar	20,000
TOTAL	285,000

Table 10.11(b): *Percentage of each food crop production*

(a) Crop	(b) Value (tonnes)	(c) Percentage for each crop	(d) Degree for each crop in a pie chart
Maize	90000	$\frac{90000}{285000} \times 100\% = 31.58\%$	$\frac{31.58}{100} \times 360° = 113.69°$
Rice	65000	$\frac{65000}{285000} \times 100\% = 22.8\%$	$\frac{22.8}{100} \times 360° = 82.08°$
Potatoes	50000	$\frac{50000}{285000} \times 100\% = 17.54\%$	$\frac{17.54}{100} \times 360° = 63.14°$
Beans	40000	$\frac{40000}{285000} \times 100\% = 14.04\%$	$\frac{14.04}{100} \times 360° = 50.54°$
Wheat	20000	$\frac{20000}{285000} \times 100\% = 7.02\%$	$\frac{7.02}{100} \times 360° = 25.27°$
Sugar	20000	$\frac{20000}{285000} \times 100\% = 7.02\%$	$\frac{7.02}{100} \times 360° = 25.27°$

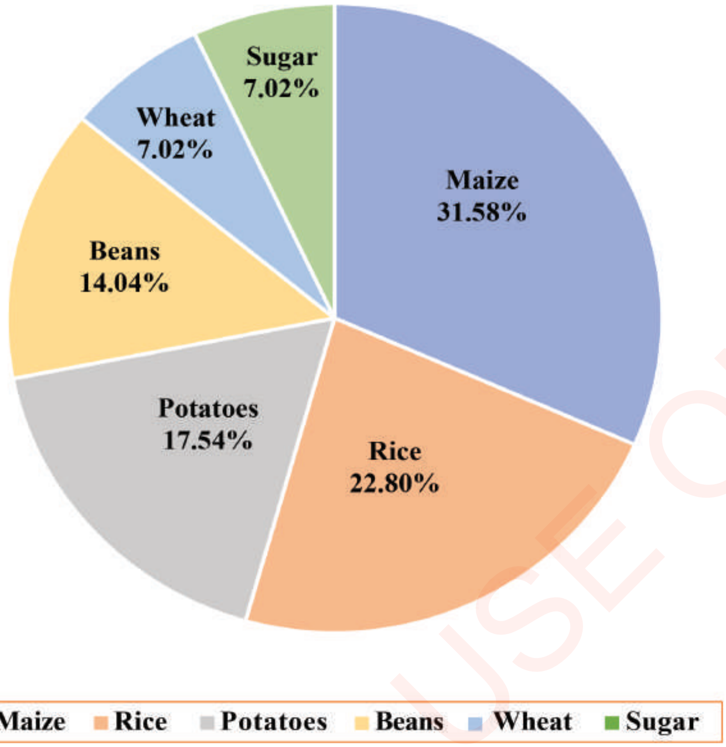


Figure 10.10: *Food crop production in 2004*

Advantages of a pie chart

A pie chart is easy to construct, read and interpret. It illustrates statistical information very accurately. It is also easy to determine the value of a component since it is indicated in each segment. Visual impression of the individual components is clear, which improves the understanding of the information. Moreover, it is easy to assess the proportion of individual components against the total. Thus, it is a good method for comparison purposes.

Disadvantages of a pie chart

The actual data is hidden as values shown on the face of the segments may be in percentage or degrees, and represented actual values remain hidden. Where the values of the data set vary slightly, it is difficult to visualize the proportional differences between values.

Activity 10.3

Study the data in the table below for regional 'S' and answer the questions that follow.

Cash crop	Tonnes
Sisal	40 000
Cotton	75 000
Cashew nut	90 000
Coffee	45 000
Tea	30 000
Pyrethrum	50 000

1. Draw a pie chart showing cash crops production in the region 'S'. Show the whole procedure to be followed when drawing it.
2. Make an interpretation of the pie chart.

Exercise 10.2

Answer all questions.

1. Explain how a multiple bar graph differs from a compound bar graph.
2. Why is statistical data presented by using graphs and charts?

Summarisation of massive data

Raw data collected from various sources can be summarised in an organized form to make sense of the scored information by using statistical measures. The statistical measures used in summarizing data include measures of central tendency. The measures of central tendency involve *arithmetic mean (mean)*, *mode* and *median*.

Presentation of massive statistical data

When data is collected in the field, it is usually in a raw form. For the data to be useful, it needs to be processed, arranged in a logical manner and presented in such a way that the information can be easy to read and draw conclusions. For this purpose, data may be arranged and presented in tables. The data from tables may be presented in graphical forms using graphs and charts.

Simple statistical measures and interpretation

These are statistical measures and techniques used to summarise and show the distribution of data. They also indicate where the centre of distribution tends to be located. They inform about the shape and nature of the distribution. Their role is to facilitate comparison between data.

Measures of central tendency

(a) **Mean**

Mean (arithmetic mean) is the same as average value of data. It can be calculated for both individual and grouped data.

Calculating the mean for individual data

The mean for individual data is obtained by adding data values and dividing the resultant total by the number of occurrences.

Arithmetic mean is represented as:

$$\overline{X} = \frac{\Sigma X}{N}$$

Where: $\overline{X}$ = Arithmetic mean, Σ = Summation, X = Individual value, N = Number of occurrences

For example, coffee production from 2011 to 2020 (‘000 tonnes) is presented in Table 10.12. Find the mean:

Table 10. 12: *Coffee production in ‘000 tonnes from 2011 to 2020*

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Production (‘000 tonnes)	80	75	70	70	70	65	65	60	40	35

Find the summation of the given data by number of variables;

Solution:

$$\overline{X} = \frac{80 + 75 + 70 + 70 + 70 + 65 + 65 + 60 + 40 + 35}{10}$$

$$\overline{X} = \frac{630}{10}$$

$$\overline{X} = 63$$

Therefore, the mean of coffee production is **63 tonnes.**

Mean for grouped data

$$\overline{X} = \frac{\sum fx}{\sum f}$$

Where: $\overline{X}$ = Mean

f = Frequency

x = Class mark (i.e. the average between lowest and highest scores of the class interval

Σ = Summation of

For example, find the mean from the following grouped data below in Table 10.13(a):

Table 10.13(a): *Height of people in Mahande Street*

Height (cm)	Frequency
60-62	5
63-65	18
66-68	42
69-71	27
72-74	8

Solution:

Table 10.13(b): *Calculation of grouped mean*

Height (cm)	Frequency (f)	Class mark(x)	fx
60-62	5	61	305
63-65	18	64	1 152
66-68	42	67	2 814
69-71	27	70	1 890
72-74	8	73	584
Total	$\sum f = 100$		$\sum fx = 6745$

(a) Find the class mark (x) of each group.

For example, the class mark of the first column at the third row is 61. This is found by adding the highest and lowest scores of the class interval then divide by 2 in the following formulae:

$$\frac{X_1 + X_2}{2}$$

$$X = \frac{60 + 62}{2}$$

$$X = 61$$

(b) Find (fx)

This is found by taking the frequency of each data times the class mark of the corresponding data.

For example, the 'fx' of the first column at the third row is 305. It is found by multiplying 61 which is the class mark with 5 which is the frequency of the corresponding data.

(c) Find the summation of fx and divide by the total number of frequency to get the mean of the grouped data.

$$\bar{X} = \frac{\sum fx}{\sum f}$$

$$\bar{X} = \frac{6745}{100}$$

$$\bar{X} = 67.45$$

Therefore, mean height is **67.45 cm**

Advantages of mean

(a) It is used to measure the centre of a numerical data set;
(b) It is used for making comparison in statistical data;
(c) It is used to summarize statistical data; and
(d) It is used to find other statistical measures in some cases.

Disadvantages of mean

(a) It is highly affected by extreme values;
(b) It is time consuming especially for grouped data; and
(c) It cannot be established in an open-ended data.

(b) **Mode**

Mode is the most frequently occuring value in data distribution. It is the score or value that appears more frequently than another score or value in a distribution.

Calculating mode for individual data

The modal value can be unimodal, bimodal or multimodal. Unimodal occurs when there is one (1) mode value in a distribution

Example 1

From the given scores below find the mode

2, 4, 5, 6, 7, 9, 11, 3, 2, 4, 5, 2, 3, 4,5, 6, 2, 3, 3, 9, 3, 11, 3. The mode in the distribution is 3, which occurs 6 times compared to others.

Bimodal occurs when the set of data has two modes. Where as data set with more than two modes is called multimodal.

Bimodal

Examples 2

3, 4, 4, 4, 5, 6, 7, 7, 7, 8, 10, 10

4 and 7 are modes of bimodal data which have occurred 3 times.

Mode becomes useful in statistics in many ways. One of the important ways is when a mode is used to describe the content of the distribution of data. But sometimes the distribution is shown in a form of grouped data. Modal frequency refers to the number of times the mode(s) have appeared in a data set.

Mode for grouped data

$$\text{Mode} = L\left(\frac{D_1}{D_1 + D_2}\right)i$$

Where:

i = class interval size or class width

D_1 = the frequency of the modal class minus the frequency of the next lower class

D_2 = the frequency of the modal class minus the frequency of the next higher class

L = lower class boundary of modal class

Example

How do we determine mode in grouped data? Consider Table 10.14 and calculate the mode of the given data.

Table 10.14: *Age of children admitted in Kidale Hospital*

Age	Frequency
0-4	1
5-9	5
10-14	2
15-19	2

Procedure for calculating mode of a grouped data:

(a) Calculate the lower class boundary of the modal class;

$$\text{Mode} = L + \left(\frac{D_1}{D_1 + D_2}\right)i$$

L (Lowest limit) 5 – 0.5 = 4.5

(b) Calculate D_1

D_1 5 – 1 = 4

(c) Calculate D2

D_2 5 – 2 = 3

(d) Calculate i

Class width = upper boundary – lower boundary

$i = 9.5 - 4.5 = 5$

(e) Therefore, substitute in the formula,

$$4.5 + \left(\frac{4}{4+3}\right)5$$

$$4.5 + \left(\frac{4}{7}\right)5$$

$$4.5 + (0.57 \times 5)$$

$$= 4.5 + 2.85$$

Therefore, **mode** is **7.35**

Advantages of mode

(a) It is useful to determine production or trend of commodities.

(b) It is not affected by the accuracy of a few extreme values. For example, in a certain examination the results are 45,55,6, 90, and 99. Then the mode is not affected in this case.

(c) It is easy to read and interpret the given area.

Disadvantages of mode

(a) It ignores other values in the distribution, taking only the value with the highest frequency.

(b) In some distribution, the modal value cannot be established.

(c) It cannot be used for further calculation.

(c) **Median**

The median value of data is the middle value of the ordered data. It is obtained by arranging the numbers in ascending or descending order of their values or descending order and then marking the number in the middle. If there are two middle numbers, the median is the average of those two numbers.

Median for individual data

Example 1

1, 3, 4, 11, 12, 3, 2, 6, 2

Solution:

1, 2, 2, 3, 3, 4, 6, 11, 12

Mid score is 3, so the median is 3

Example 2

3, 12, 7, 9,4,5,6,8,5,8

Median = arranging numbers in order of size; 3, 4, 5, 5, 6, 7, 8, 8, 9, 12

Therefore, the median is the average of 6 and 7, that is

$$\frac{6+7}{2} = 6.5$$

Therefore, the median is 6.5

Median for grouped data

Median can be calculated from grouped data.

$$\text{Median} = L + \left(\frac{N/2 - F}{f}\right)i$$

Where: L = lowest number of the median class

N = total number of frequency

f = frequency of the median class

F = cummulative frequency (also written as *cf*) before median class

i = class interval size (class width)

From the Table 10.15 find the median of the following data:

Table 10.15: *Weight of people in Mahande Street*

Weight in Kg	Frequency	Commulative frequency
60-62	5	5
63-65	18	23
66-68	42	65
69-71	27	92
72-74	8	100
Total	**N=100**	

Median class is obtained from the middle or near middle number of cumulative frequencies. For example, cumulative frequency = 100; therefore, 100/2 = 50. Hence a nearby number to 50 is 65.

L = 66 – 0.5 = 65.5

N = 100

F= 23

f = 42

i = 3

$$\text{Median} = 65.5 + \left(\frac{100/2 - 23}{42} \right) 3$$

$$= 65.5 + 1.92$$

Therefore, median is **67.42 Kilograms**

Advantages of median

(a) It can be determined for any type of data;

(b) It may be easy to understand because of being a half-way point;

(c) It is not affected by extreme values in distribution.

Disadvantages of median

(a) Other values in the distribution are not included;

(b) It is not suitable for hypothesis testing;

(c) It is somehow difficult to obtain the median when data is odd; and

(d) It cannot be used for further calculation.

Exercise 10.3

Answer all questions.

1. Elaborate how mean, mode and median are useful in daily life?
2. Find mean, mode and median from the grouped data given in the following table.

Scores	Frequency
40 – 42	5
43 – 45	10
46 – 48	42
49 – 51	35
52 - 54	27

Revision exercise 10

Section A

1. Define the term statistics.
2. What is the difference between secondary and primary data?
3. Why is statistics important in our daily life?
4. Write short notes on the following statistical terms:
   (a) mode
   (b) mean
   (c) median
5. What is the meaning of continuous data?
6. Differentiate between discrete data and continuous data.
7. Study the data in the following table then find the mean, mode and median of these workers.

Street	A	B	C	D	E	F	G	H	I	J
Number of workers	12	06	20	03	12	02	12	03	18	09

Section B

Choose the correct answer.

8. What are the four types of statistical data basing on their nature ____.
   (a) Individual data, discrete data, raw data and secondary data
   (b) Individual data, discrete data, grouped data and continuous data
   (c) Primary data, secondary data, grouped data and collective data
   (d) Individual data, grouped data, statistical data and discrete data

9. Three common types of graphs in statistics are ____.
   (a) Bar graphs, line graphs and pie charts
   (b) Line graphs, scale graphs and bar graphs
   (c) Linear graphs, line graphs and dotted graphs
   (d) Bar graphs and line graphs

10. Measures of central tendency involve ____.
   (a) Mode, mean and variables
   (b) Mode, arithmetic mean and data
   (c) Mean, mode and median
   (d) Arithmetic mean, arithmetic progression and arithmetic series

Section C

Answer the following questions.

11. Study the given table showing mark scores for form three students in Changarawe Secondary School and calculate the mean, median, mode.

Mark score	Frequency
1-10	2
11-20	6
21-30	4
31-40	8
41-50	6
51-60	4
61-70	4
71-80	2
81-90	3
91-100	1

12. The following table shows attendance of students at Pangamawe Secondary School. Draw a divided circle to present the data.

Form	Number of students
I	90
II	80
III	75
IV	86
V	69
VI	70

13. Study the table below and draw a grouped or comparative bar graph showing the export of agricultural products in tonnes from 2018 to 2020.

Year /commodity	2018	2019	2020
Maize	12000	500	10000
Fruits	900	700	12000
Coffee	3000	5000	7000

14. Rose and Othman are selling mathematical sets. Most of the time they keep records in their notebook. One day their Geography teacher told them about the simplest way of presenting data for a single variable over time. The following table indicates mathematical sets sold from 2010 to 2016.

Year	2010	2011	2012	2013	2014	2015	2016
Mathematical sets	90	100	40	50	20	70	120

(a) Name the simplest ways of presenting the data.

(b) Mention five advantages of the methods of presenting data mentioned in (a) above.

(c) Present the given statistical information by using any appropriate graph.

Glossary

Aquifer A permeable rock which stores and transfers water.

Arable A land suitable for cultivation of crops.

Assimilation The total process of plant nutrition, including photosynthesis and the absorption of raw materials.

Atoll A ring-shaped coral reef.

Barysphere The inner most part of the earth.

Bedding plane The boundary between adjacent layers or strata in a sedimentary rock.

Bench mark Is a reference mark of known elevation cut or set in stone, concrete or other durable material and used in the determination of altitudes.

Biosphere The whole of the region of the earth's surface, the sea, and the air that is inhabited by living organisms.

Cartographer A person who studies and practices the art of making maps.

Cliff A tall, vertical, or near vertical, rock face.

Climate Aggregate weather conditions of an area over a long period of time which allow for the designation of seasonal patterns and expected future weather.

Climate change Long term variations in climate, particularly related to average annual temperatures and annual rainfall.

Clint Flat-topped block that forms the 'paving stone' in a limestone pavement.

Deforestation Removal of forest covers due to cutting or burning, or a combination of the two.

Denudation	Stripping of surface cover. Can apply to both vegetation and soils.
Dip slope	A topographic (geomorphic) surface which slopes in the same direction, and often by the same amount, as the true dip or apparent dip of the underlying strata.
Distributary	Facts and statistics collected together for reference or analysis.
Escarpment	An elongated, steep slope at the edge of an upland area such as a plateau or cuesta.
Geology	The science that deals with the earth's physical structure and substance, its history, and the processes that act on it.
Geomorphology	The study of the physical features of the surface of the earth and their relation to its geological structures.
Latitude	The angular distance in degrees north or south of the equator to a point on the earth's surface.
Lithosphere	A rock layer forming the outermost part of the earth.
Loam	A soil having roughly equal proportions of clay, sand and silt.
Longitude	The angular distance in degrees east or west of the prime meridian at Greenwich to a point on the earth's surface.
Nitrogen fixation	A process carried out by certain algae and soil bacteria whereby atmospheric nitrogen is incorporated to form nitrogen-based organic compounds.
Oasis	A wet-point site in an arid area.
Pervious rocks	Rocks that allow water to flow along cracks or joints.
Plateau	An area of highland, usually consisting of relatively flat terrain that is raised significantly above the surrounding area, often with one or more sides with steep slopes.

Plucking A form of glacial erosion in which ice freezes on to rock and pulls it away when the glacier moves on.

Regolith Rock material that has been weathered from the original bedrock.

Ridge A long, narrow crest of a hill or mountain.

Scarp The steep slope of an escarpment.

Scarp slope A slope in the land that cuts across the underlying strata, especially the steeper slope of a cuesta.

Suspension The transport of load in the body of the water in a river i.e., being carried along in the flow.

Systematic error An error that, as long as conditions are unchanged, will always have the same magnitude and the same algebraic sign.

Trigonometric station A fixed surveying station, used in geodetic surveying and other surveying projects in its vicinity.

Vent A pipe-like gap in the ground which allows volcanic material to pass through to the surface.

Ventifacts A stone or pebble which has been shaped by wind-blown sand, usually in the desert, so that its surface consists of flat facets with sharp edges.

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